Options for improving water quality within the Otago region:

Development of GMP & GMP+ scenarios project report

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Executive Summary

The purpose of this project is to develop a series of representative Overseer models that can be used to characterise the majority of farming systems found within Otago. Typology data provided by Otago Regional Council (ORC) was used to inform decisions around the setup of these models, with the models then used to assess the impact of a series of mitigation options to reduce nitrogen (N) and phosphorus (P) loss within the farm system. The management mitigations were categorised as being GMP or GMP+, where GMP activities were expected to be either already undertaken or to be implemented within individual farm environmental plans over the next 2-5 years and GMP+ options were considered more difficult/expensive or longer time frames to implement.

Seven Overseer models were created to represent the different typologies identified from data provided by ORC for Otago FMU's/Rohe, with four dry stock farming systems (breeding sheep/beef & deer and trading stock) and three dairy farm systems were selected for model development. The base models developed for each farm system were assumed to represent indicative status quo operations. Each of the mitigations were applied to the relevant base model and "stacked" one scenario at a time to quantify the cumulative impact of increasing numbers of mitigations. The order of applying mitigations was based on likely adoption from farmers, with the base assumption being that farmers would initially apply mitigations of low cost/high impact, and then transition into considering implementation of more expensive/low impact mitigations based on their ability to impact N & P loss within a farm system. This enabled estimation of the percentage reductions that could be achieved through implementing GMP/GMP reductions, with these estimates then used to quantify potential reductions for the Otago FMU/Rohe.

Modelling outcomes suggest that implementation of relevant GMP mitigation options could result in a 9% reduction in N leaching, and 6% reduction in P loss. If farmers then went on to also implement a range of GMP+ mitigation activities, total reductions could double to 20% and 11% respectively, with dairy farming systems having the capacity to achieve greater reductions than the sheep/ beef dry stock farming systems, but only accounting for 8% of total land usage.

When evaluating these results, it is very important to recognise that the final impact and cost of adopting mitigations to reduce N and P loss will depend on the current farm system (how intensive it is currently and type of infrastructure present), where it is located (soil types and climate), what mitigations are used, and secondary actions taken (farmer values and priorities).

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Adoption is also a key factor to consider, and there is likely to be considerable variation in the rate of uptake of the different mitigation options. Many farms are likely to first adopt mitigations that provide meaningful impact with least cost or disruption to their business (e.g., Optimising soil Olsen P levels), however, adoption rate of more complex mitigations (e.g., stand-off facilities) which require significant capital input would require a strong business case prior to implementation.

GMP outcomes

- The models demonstrated that reducing shoulder season nitrogen fertiliser had the largest impact on N loss for dairy farming systems (6-11%), with smaller reductions (1-5%) observed through on/off crop grazing and catch crops for dry stock.
- Although, well facilitated wetlands had a significant impact on N loss in some models, this was more evident on more intensively farmed sloping land where reductions of approximately 10% could be achieved across both dairy and dry stock farming systems, although with only 1% of dry stock farms reported as irrigated, the overall impact was very small.
- Optimisation of Olsen P soil levels and using low soluble P fertiliser provided the largest impact across all systems, with other GMP mitigations had negligible impact on P loss.

GMP+ mitigations

GMP+ mitigations which are considered more expensive or take longer to implement provided larger nutrient loss reductions across all models.

- This was particularly evident where irrigation is present resulting in 43-65% reductions in N loss and 36-55% reductions in P loss when irrigation is upgraded to efficient (pivot/fixed grid) and well monitored (soil meter scheduling) systems. The main reason for the large reduction in N loss is minimising the volume of water flowing through the soil profile and leaching nutrients into ground water, similarly, reducing overland flow of irrigation water will have a large impact on sediment/P loss.
- Stand-off facilities provided moderate reductions in N loss, particularly when used to replace wintering on crop (Dairy 3), but the value proposition for this mitigation would need to be validated with FARMAX or similar impact modelling.

GMP++ mitigations

A number of additional "outside of the box" mitigations were also, considered but classified as "GMP++" due to expected delays in adoption (technology, cost, time etc), and potentially limited uptake if the potential environmental benefits don't outweigh the impediment to mitigation implementation.

- Incorporating plantain into dairy pastures was the only mitigation used in GMP++ for dairy and provided a 3- 12% reduction in N loss with no impact on P loss. Barriers to implementing this option would be ease of management and persistency of plantain within a pasture sward.
- Stand-off facilities for beef animals through winter provided 19% reduction in N loss and 4.5% reduction in P loss, similarly with dairy, there would need to be a strong business proposition for this to be implemented.
- Retiring productive land to plant in forestry provided only modest reductions in N and P loss over and above what could be achieved through other GMP/GMP+ interventions.

Contents

Background

This project builds on work undertaken in 2021[1] where an excel model framework was developed to assess the impact of a range of mitigation activities on nitrogen leaching (N) and phosphorus losses (P) within the Otago region. Outcomes from the 2021 project were then used to inform discussions around the potential levels of reduction, with this project focused on development of realistic farm Overseer models that could be used to effectively "map" the impacts of changing management practices to water quality outcomes according to farm type and description.

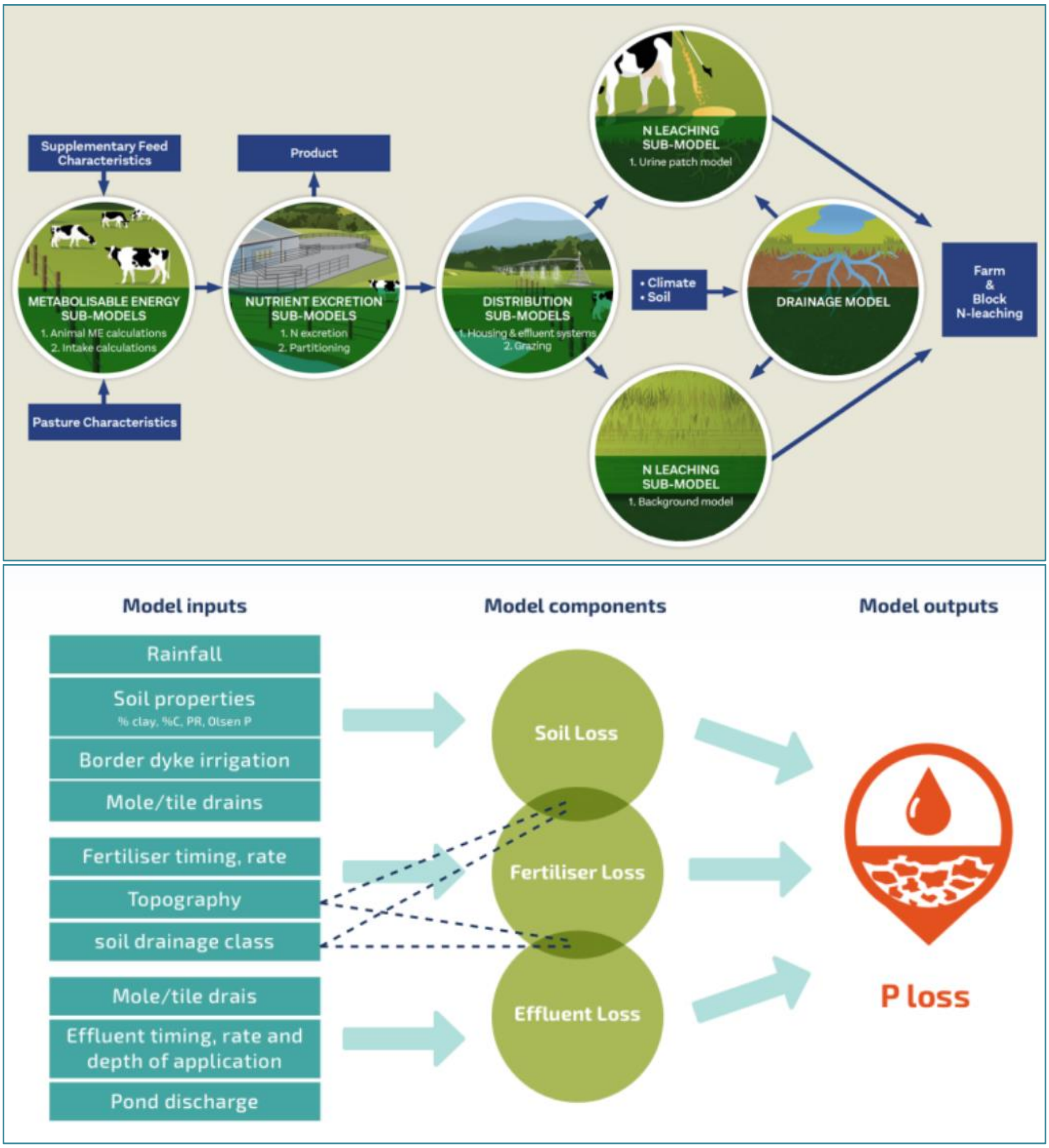
OverseerFM[2] (Overseer) is an online software tool that can be used to assess the impact of changing management practices on environmental outcomes. Figure 1 shows a high-level overview of some of the factors impacting on N leaching and P losses from Otago farm systems, which include land usage (e.g., dairy versus sheep & beef farm types), and then within each of the farm types, differences in soil type and drainage, moisture levels, and gradient. Overseer can be used to provide an accurate representation of likely N leaching and P losses on any given type of farm, and then provide an assessment of the impact of one or more management practices being implemented to reduce N leaching and/or P losses on farm over time.

It is important to note, that within any given farm, there is often considerable variation in rainfall, soil types, (both impacting on soil moisture) and slope gradients, and that these factors impact on the types of management practices that may be implemented within any given area of the farm. The cost and practicality of implementation also vary, with mitigation activities identified in the earlier 2021 report classified into 3 separate groups for assessment.

- **Base**: The current state of mitigation management being implemented on farm. This will include some GMP's across the base models. For example, dairy currently exhibit over 95% stock exclusion in the base model.
- **Good Management Practice (GMP):** which includes the mitigation activities expected to be either already undertaken or to be implemented within individual farm environmental plans over the next 2-5 years.
- **Good Management Practice Plus (GMP+):** which includes additional mitigation activities that could be applied by individual farmers to improve overall water quality outcomes for their farm/region. Generally, GMP+ options are more difficult/expensive to implement.

[1] ORC mitigation framework project report (November 2021).
[2] https://www.overseer.org.nz/
[3] https://www.overseer.org.nz/our-model

Figure 1. OverseerFM overview of Nitrogen loss and Phosphorus loss [3] .



Purpose

The purpose of this report is to develop a series of representative Overseer models that can be used to characterise the majority of farming systems found within Otago. These models were then used to assess the impact that implementation of GMP and GMP+ mitigations on N leaching and P losses compared to current estimates (as reported to ORC).

Note the models used within this report are **not** based on actual farms and should not be used to determine or defend nutrient limit thresholds for the agricultural sector within Otago.
Instead, the models have used been generated to provide a "broad understanding" of how N and P loss could be impacted by management change, with farm specific modelling required to assess both financial and environmental outcomes for any individual farm enterprise within the Otago region.

Report overview

This report is broken into 3 sections, with further technical detail provided within the Appendices:

1. **Typological data**: includes a description of the data used to define the range of Overseer farm system models required.
2. **Modelling approach**: includes a detailed description of the assumptions used within each of the base farm system models developed, and mitigation measures applied.
3. **Results:** provides a high-level summary of both GMP and GMP + outcomes for N and P reductions for each of the dry stock and dairy farming systems, and the estimated impact of applying these reductions across the Otago region.
4. **Appendices**
    I. Detailed typological information for each of the differing farm systems across the Otago FMU/Rohe.
    II. Detailed descriptions of the mitigation applied and outcomes for each of the individual farming systems.
    III. Expected reductions by FMU/Rohe, and typology.

Section 1: Typology data

Typology data (provided by ORC) was used to identify major land uses and evaluate the primary sources of N leaching and P loss within the Otago region. Landscape characteristics such as topography, soil and climate influence the vulnerability risk of contaminant transport to water, while a diverse set of farm inputs, feedstock and soil management practices influence land use pressures that determine contaminant pathways. Aligning landscape characteristics (topography, soil and climate) with land use pressures (land use activity/farm type) provides 'typologies' (Monaghan et al., 2021[3]; Srinivasan et al., 2021[4]) to which contaminant (N & P) discharges can be benchmarked.

The typology data provided for use in this analysis included information on land use, soil type, moisture levels, slope, and N & P losses per annum, with these typologies developed by ORC through combination of datasets including: i) spatial datasets (rainfall and soil temperature); ii) topography datasets (slope layer that combines LiDAR and elevation data available for Otago); iii) soil data (e.g., drainage class); Iv) Otago irrigation data; and v) land use data (e.g., sheep, dairy, forestry, deer and others).

Land use

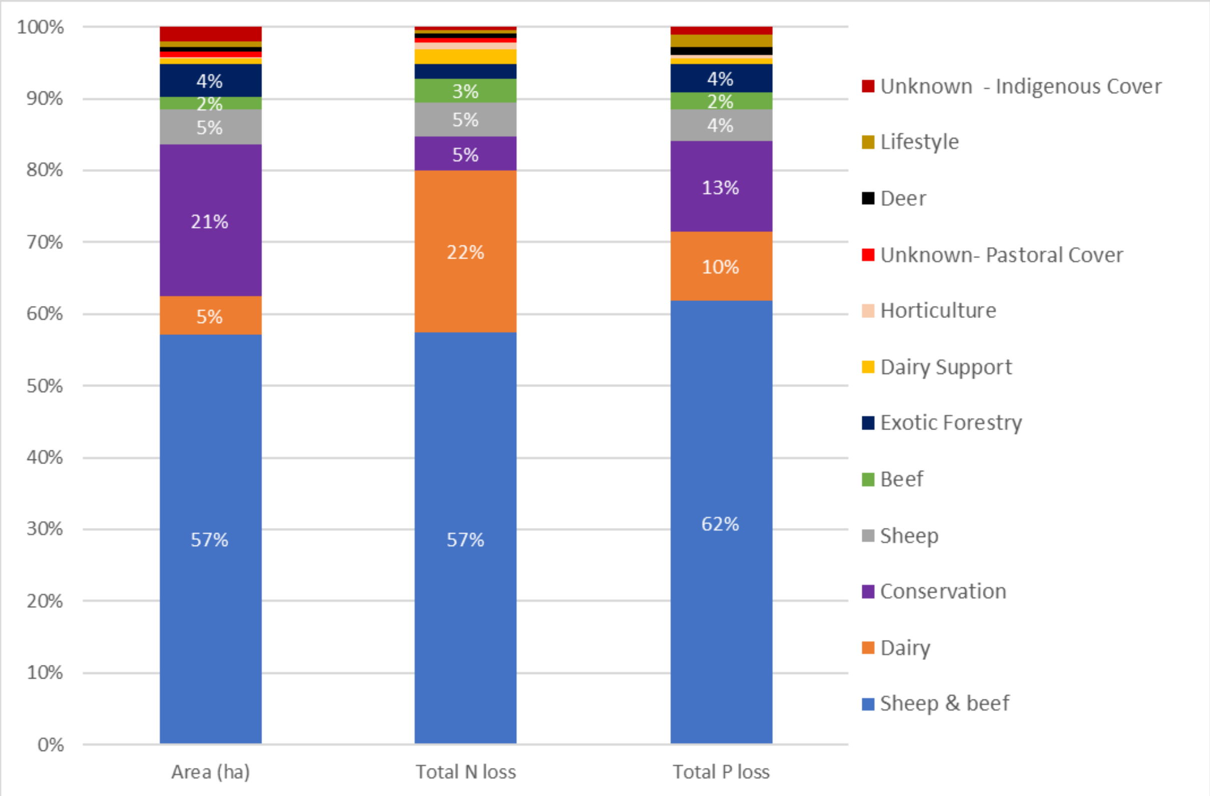
Information on land use was initially used to evaluate the impacts of N and P losses by farm type, with Figure 2 showing a comparison of land usage data with respect to N and P loss as a percentage of total land area, N and P loss. At a regional level, this data shows that sheep and beef farming account for more 57% of total land use, compared to 5% for dairy farms. At this level, the bulk of the remaining land includes both conservation area and forestry, with less than 5% of total land area attributed to the other dry stock farming uses including dairy support, beef, and deer farming enterprises combined.

From an environmental perspective, the primary sources of N & P losses are from sheep & beef farming and dairy, with the proportional impact of dairy being higher for both N and P loss relative to other land uses. Similarly, whilst deer farming only accounts for less than 1% of total land area, the enterprise shows a disproportionate impact for P losses, whilst the overall impacts of both beef and dairy support are relatively consistent (area versus P loss). Conversely, conservation land which accounts for 21% of total land, had substantially lower rates of N and P loss than the livestock farming enterprises.

[3] Monaghan et.al, 2021: Quantifying contaminant losses to water from pastoral landuses in New Zealand I. Development of a spatial framework for assessing losses at a farm scale, New Zealand Journal of Agricultural Research, 64:3, 344-364, DOI: 10.1080/00288233.2021.1936572

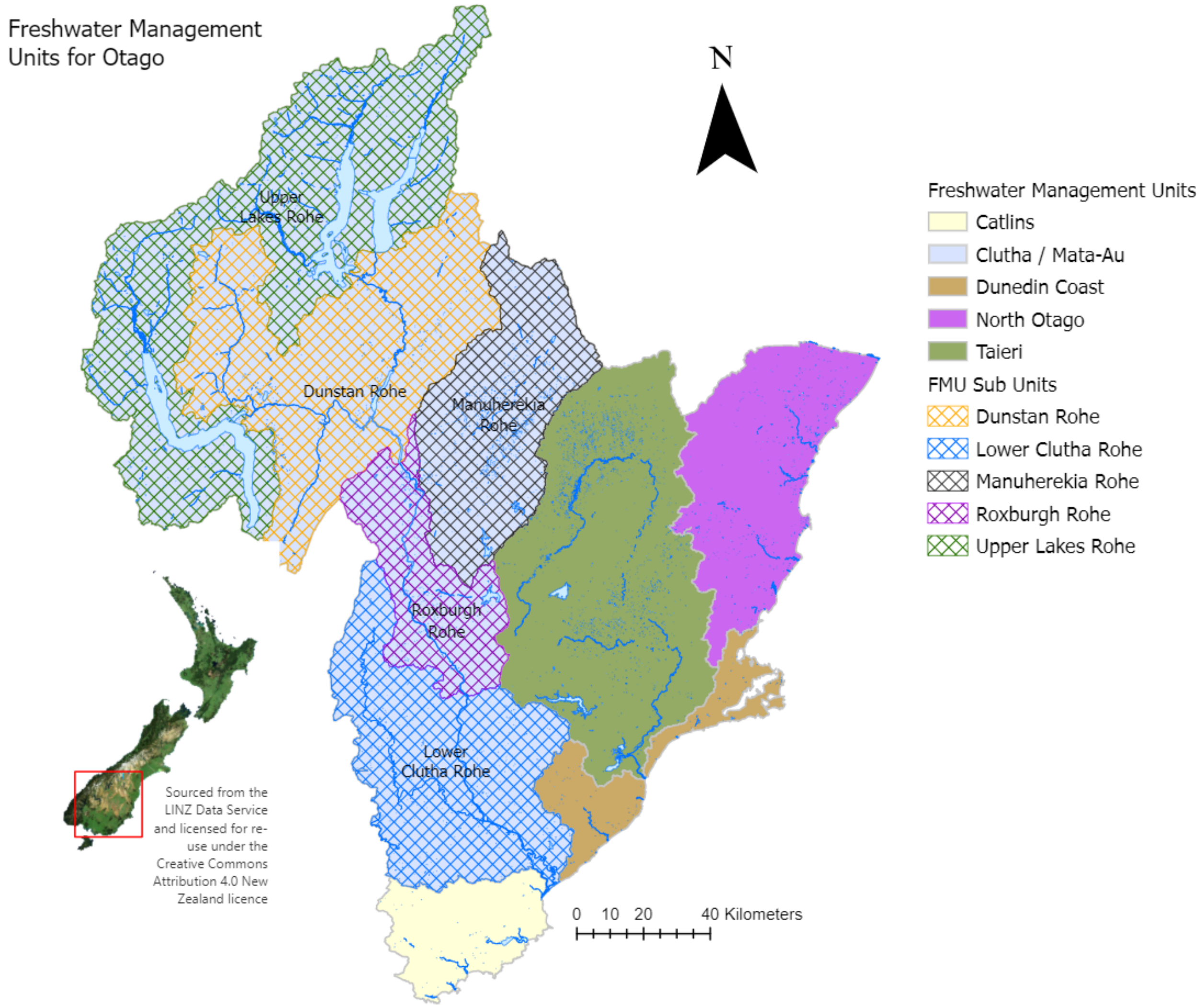
[4] Srinivasan et.al, 2021: Development of a national-scale framework to characterise transfers of N, P and *Escherichia coli* from land to water, New Zealand Journal of Agricultural Research, 64:3, 286-313, DOI: 10.1080/00288233.2020.1713822

Figure 2. Comparison of land use data with respect to total land area, Nitrogen leaching and P losses within the Otago region.



It is important to note that there is considerable variation in land use across the different individual Freshwater Management Units (FMU)/Rohe. Figure 3 provides an overview of land area within each of the 5 FMU's, with the Clutha/Mata-Au FMU further compartmentalised into 5 different subunits (Rohe), and typology classifications for each of these Rohe included within the analysis.

Figure 3: Overview of the Freshwater Management Units for the Otago region.



Error! Reference source not found. shows a comparison of land use data for the Lower Clutha and Upper Lakes Rohe, with 17% of land in the Lower Clutha attributed to dairy farming, and 9% beef. In contrast, no land has been attributed to dairy farming in the Upper Lakes region, which has 45% of total land classified as being part of conservation estates. Total land area also varies within the different FMU/Rohe, with the Taieri FMU being the largest, and Dunedin and Coast the smallest (Figure 5.) Further information on land use is provided within Appendix 1.

Figure 4. Comparison of land use data with respect to total land area, Nitrogen leaching and P losses for the lower Clutha and Upper Lakes Rohe.

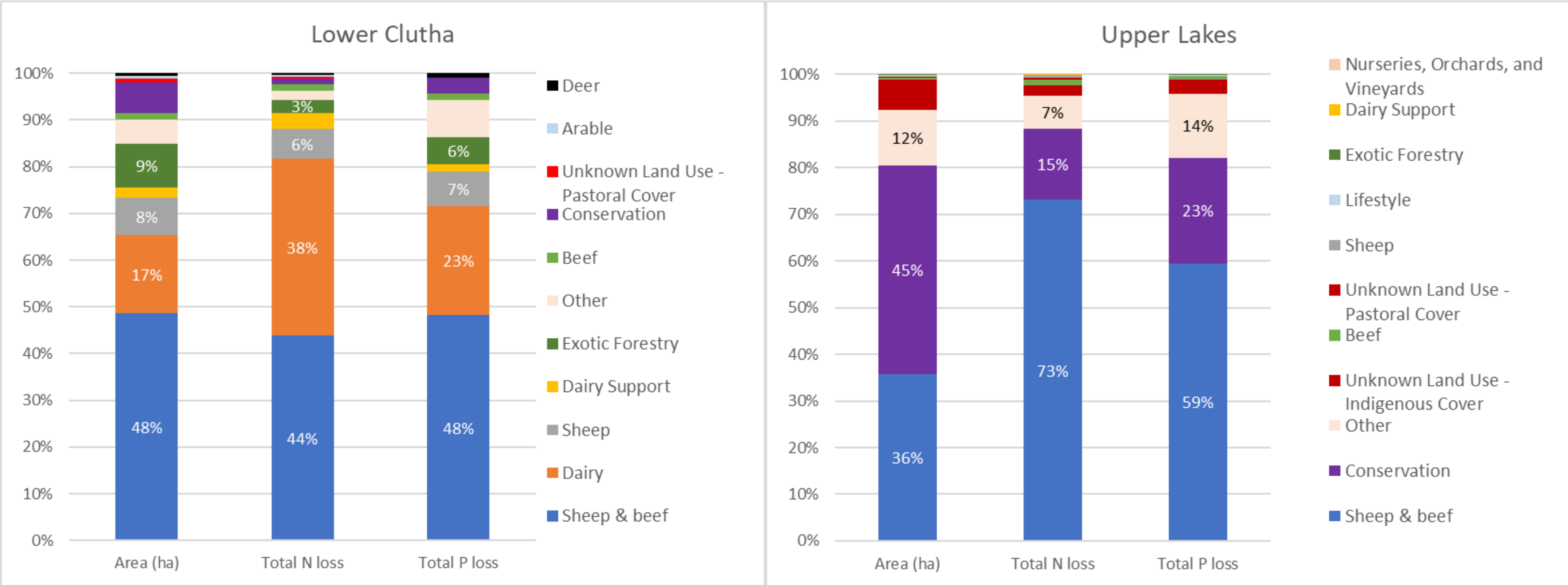
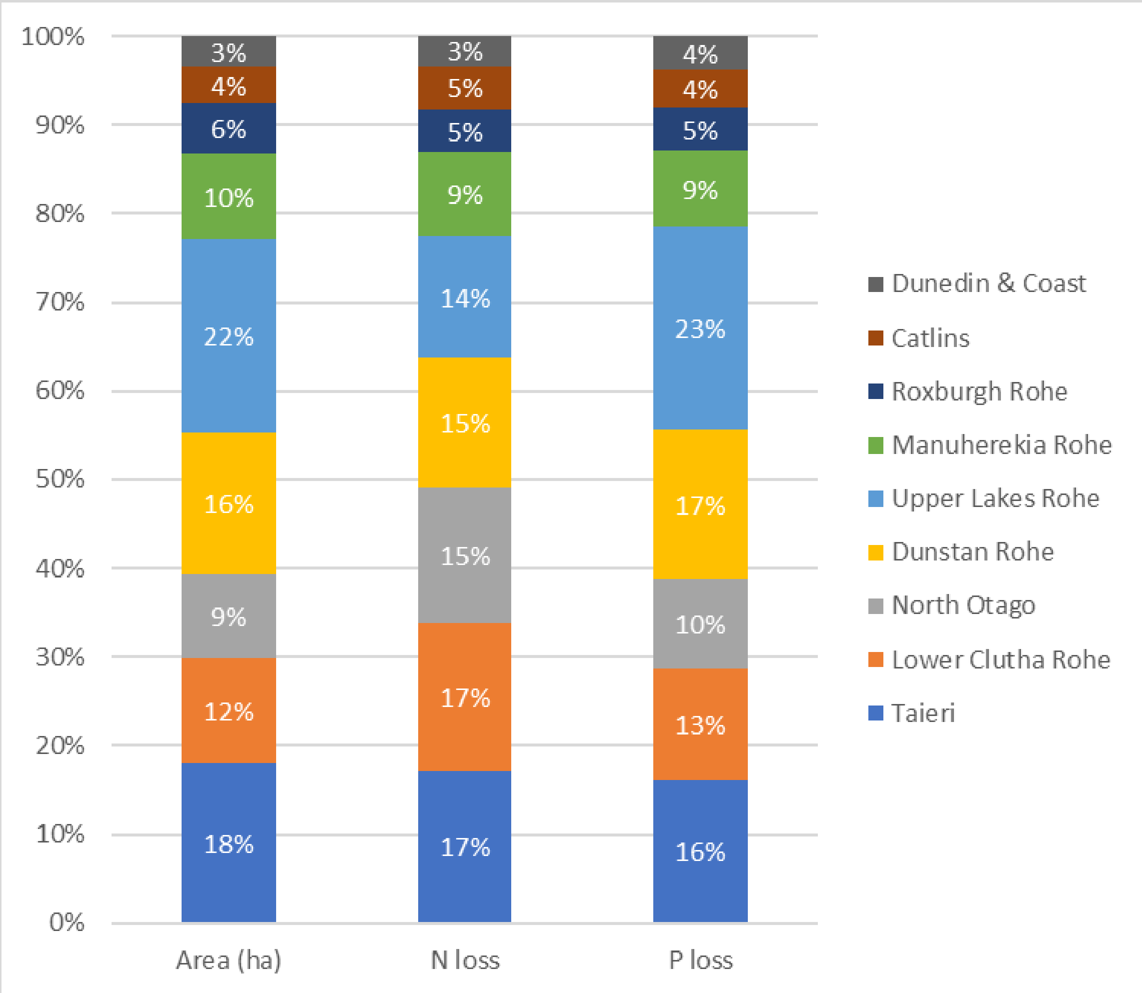


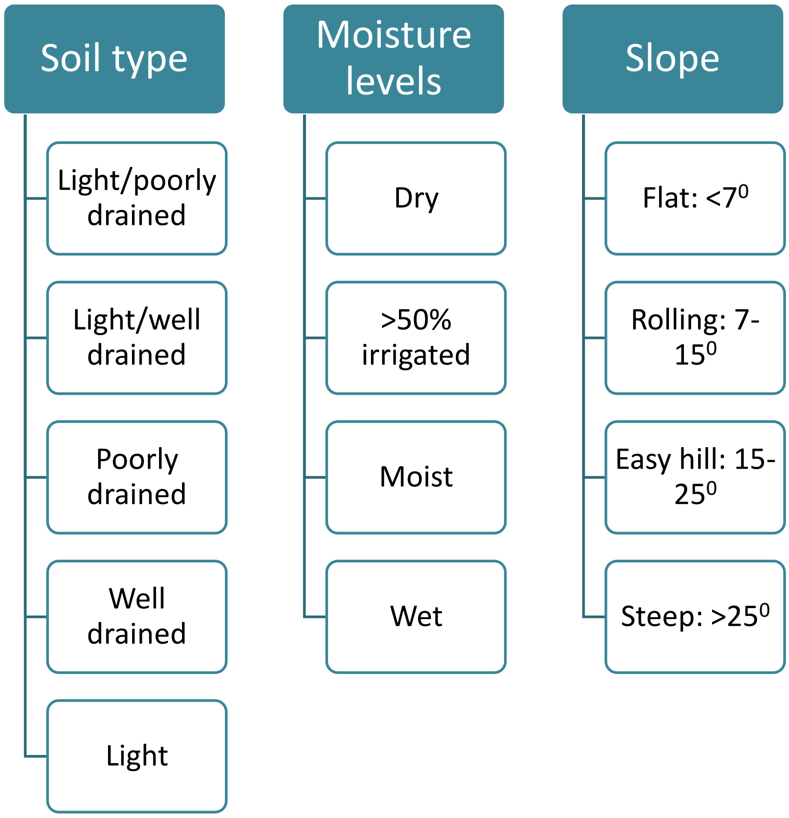
Figure 5. Comparison of land use data with respect to total land area, Nitrogen leaching and P losses within each of the individual FMU/Rohe.



Land types

In order to develop an accurate representation of the differing farming systems operating within each of the FMU/Rohe, the typology data has also been used to evaluate farms by land use type, soil type and drainage, moisture content, and slope. Figure 6 shows the matrix of potential typology classifications across the regions, with N and P loss data available for 80 different combinations for each of the land use types. These 80 typologies are a factorial of the 5 different soil types, 4 moisture classifications, and 4 slope classifications provided within the ORC typology data sets, with the average N and P losses calculated according to reported values for each of the different farm types within type typology classifications.

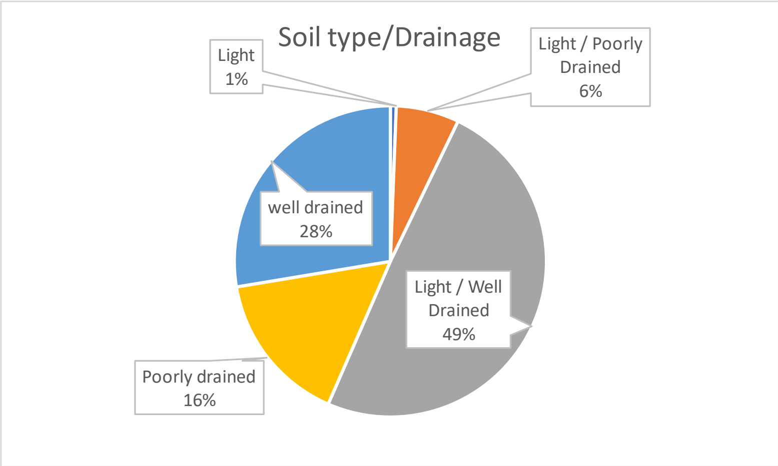
Figure 6. Matrix of typology combinations used to evaluate the different farm typologies within the Otago region.

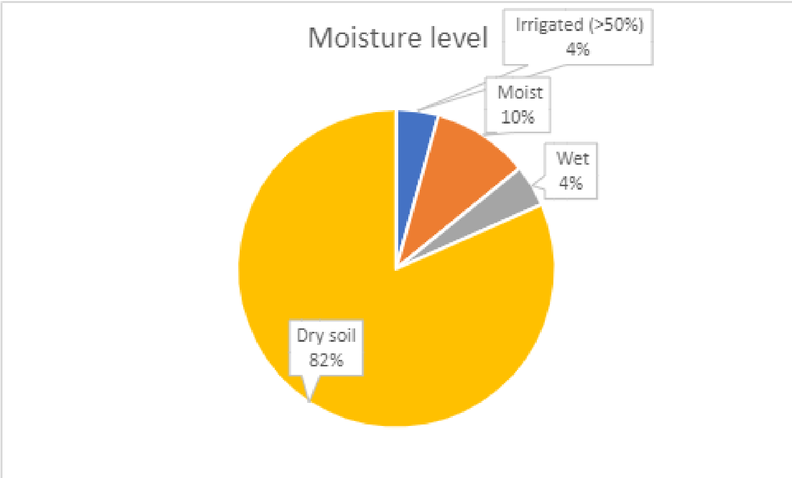


With this project focused on livestock farming enterprises, pivot tables were used to analyse the data according to regional estimates of land use by soil/moisture/slope typology. Figure 7 provides an overview of each of the different typology groups for livestock farming including dairy, dairy support, sheep, beef, sheep & beef, and deer, with approximately half of the land classified as light/well drained soil types, and 82% classified as dry for moisture levels. These results are then further classified below by farm enterprise type with dairy farming enterprises predominantly grouped as either dry or irrigated (Figure 8), whilst sheep & beef producers also included land types classified as moist or wet (Figure 9).

This data was then used to inform decisions around the types of Overseer models required to represent the majority of farm typologies, with a full description of the model used provided in the following section and a more detailed breakdown of the typology data included within Appendix 1.

Figure 7. Overview of the proportions of land within each of the typology groups for (a) soil type/drainage, (b) moisture levels and (c) slope.





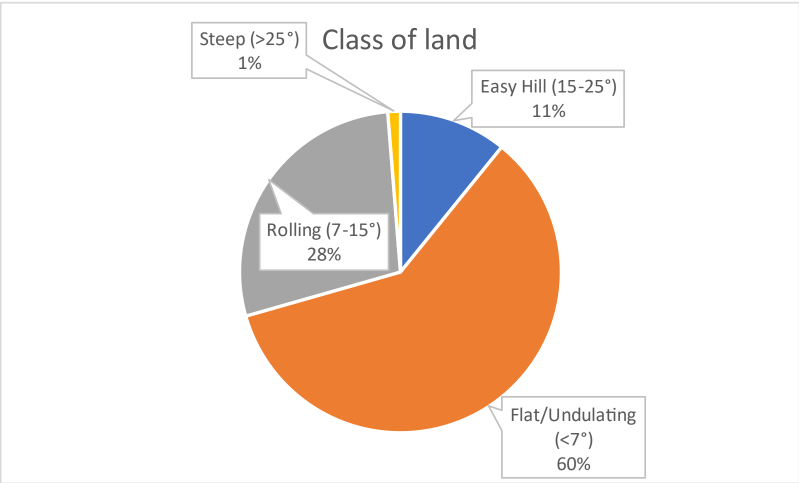
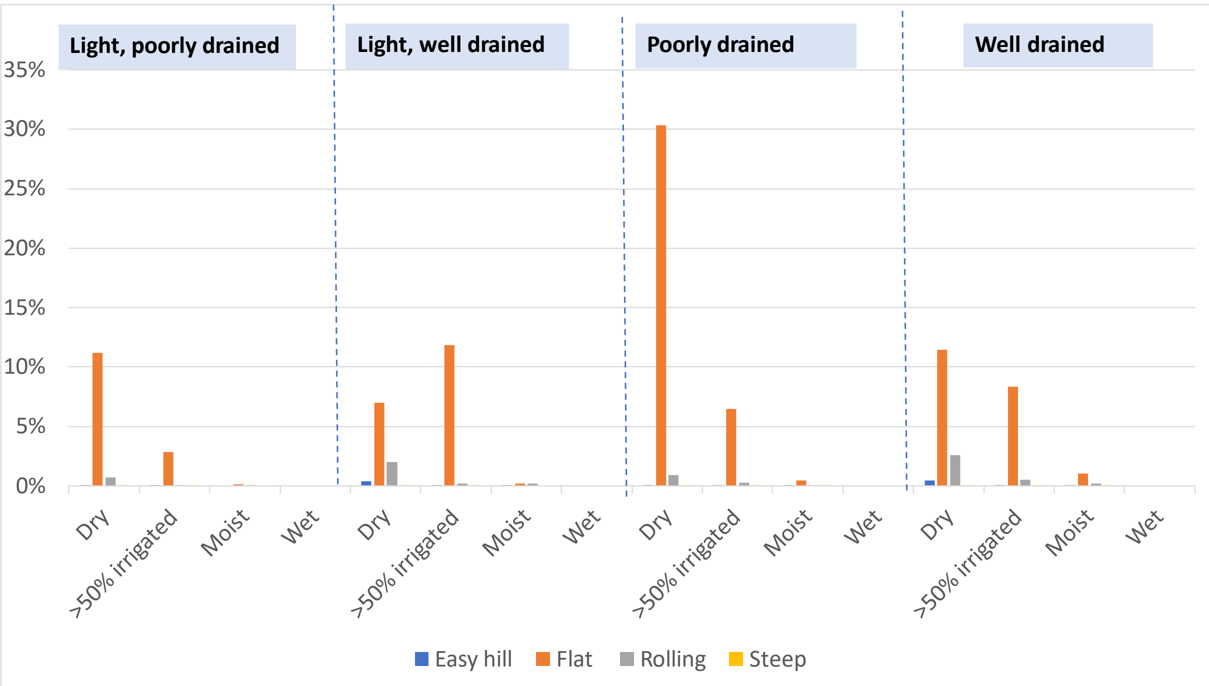


Figure 8. Proportion of land within each of the different land typologies for dairy, and dairy grazing farming systems.

(a) Dairy farming systems



(b) Dairy grazing farming systems

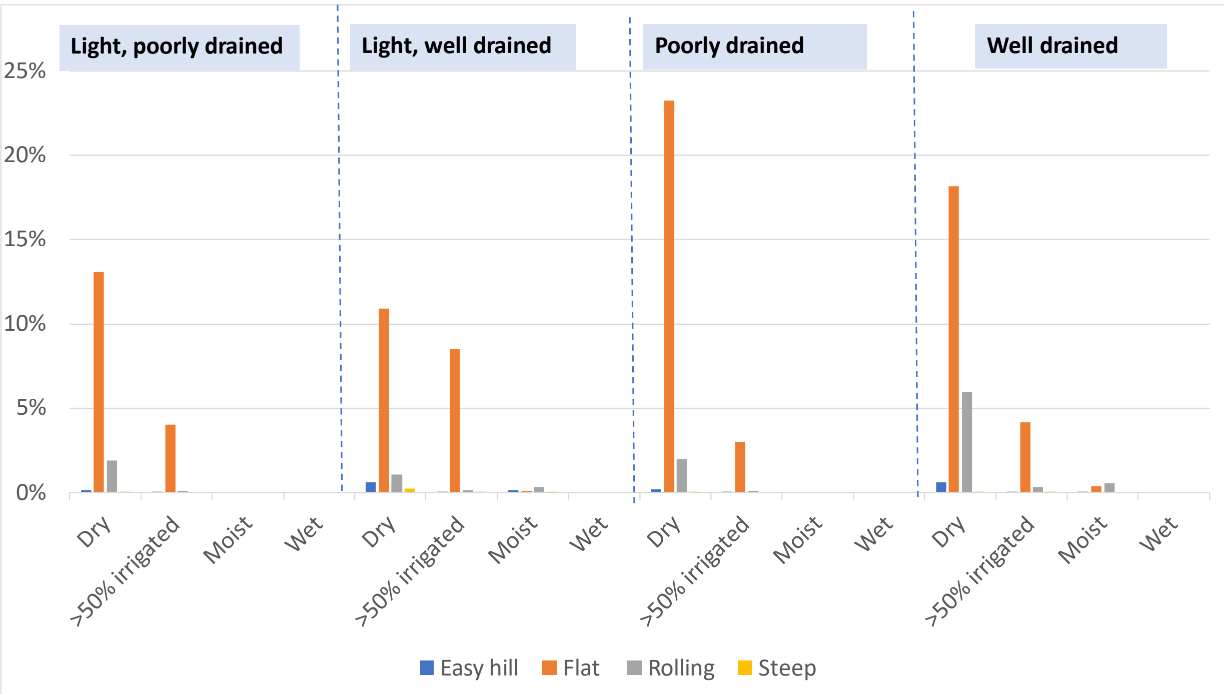
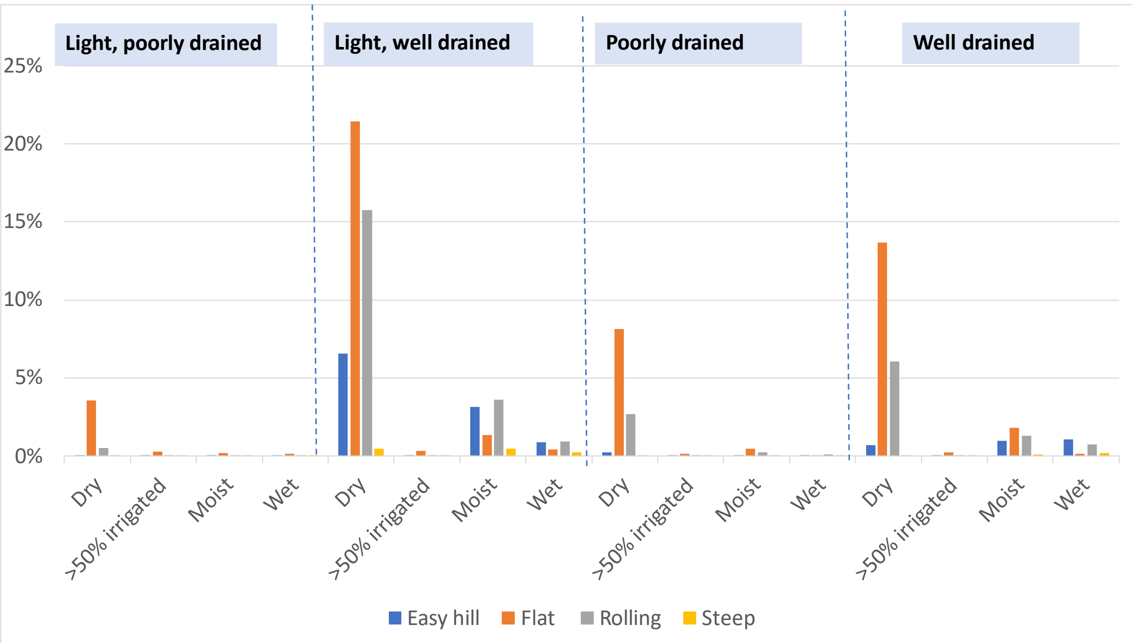
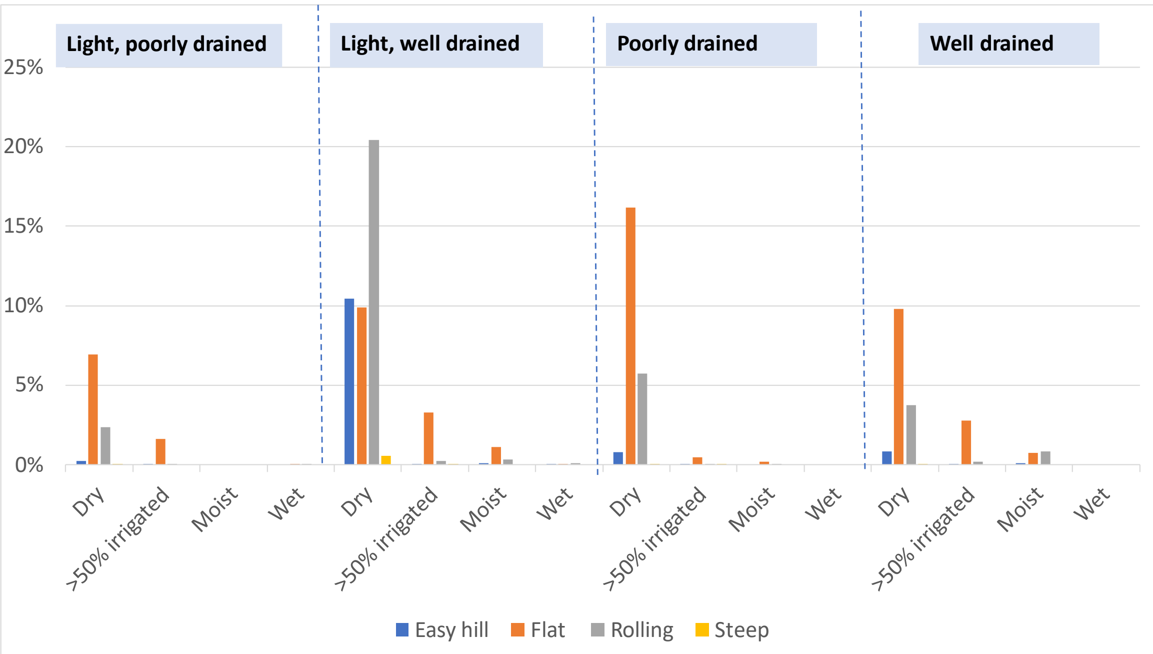


Figure 9. Proportion of land within each of the different land typologies for dry stock farming systems.

(a) Sheep & beef farming systems



(b) Deer farming systems



Section 2: Modelling approach

Overseer was used to model the impact of different mitigations on N and P loss from selected farm systems. Base farm models were developed to represent the majority of farm typologies represented within Otago FMU/Rohe, with 4 dry stock farming systems (sheep/beef & deer) and 3 dairy farm systems selected for model development.

The base models developed for each farm system were assumed to represent indicative status quo operations, with mitigations then selected based on their ability to impact N & P loss within a farm system. It is important to note that these mitigations have also been selected according to alignment with existing industry research (DNZ[5], OLW[6]), with mitigations categorised by type into 6 different groups including fertiliser, farm dairy effluent (FDE), crop management, riparian management, irrigation, and infrastructure (animal stand-off facilities).

Within Overseer, each of the mitigations were applied to the relevant base model and "stacked" one scenario at a time to quantify the cumulative impact of increasing numbers of mitigations. The order of applying mitigations was based on likely adoption from farmers, with the base assumption being that farmers would initially apply mitigations of low cost/high impact, and then transition into considering implementation of more expensive/low impact mitigations if required. Additional mitigations were also applied at the end of the modelling process to assess options which were deemed unlikely to be adopted immediately due to higher uncertainty, complexity, or cost (retiring large areas of land, sowing out farm with plantain/pasture mix etc).

It should be noted that every mitigation modelled within this report will have a physical and economic impact on the farm system which has not been quantified as part of this analysis. In some cases, this impact could be uneconomic and result in fundamental farm system changes. Farmax is the best tool to establish the physical and financial impact of many of these mitigations. Some practices to reduce contaminant loss may only be considered outside of the models - for example, for wetland or sediment trap implementation.

Farm system models

Dry stock

In the case of sheep, beef and deer, the challenge was to sufficiently represent the wide variety of systems and typologies so that the impacts of mitigation can be modelled and matched as well as possible in 4 farm models. With more time, additional systems and typologies would have been modelled. As a compromise, aspects of the models such as soil

[5] https://www.dairynz.co.nz/environment/on-farm-actions/reducing-phosphorus-p-loss/

[6] https://ourlandandwater.nz/download-effective-farm-mitigation-actions/

type and drainage were adjusted to assess the impact on N and P losses, if additional models containing a wider array of soils been included[7].

Table 1 shows an overview of the 4 dry stock farm system models, where elements of each Rohe are included in model farms, but each farm is not necessarily representative of a particular Rohe.

Beef + Lamb New Zealand generate a series of farm benchmarking information based on typical farm classes, with farms within any given FMU or Rohe, ranging from extensive breeding properties to intensive finishing systems. The B+LNZ Class 6 and Class 7 models[8] best represent the systems typical of Otago farms and formed the basis of 3 of the farms systems built for the analysis. A further model was included with irrigation and a component of beef finishing. A deer component has been included in two of the models based on typical farm practices and production.

The base models were populated using a combination of industry data (eg. stock numbers, production, and fertiliser use etc, and industry expertise (farmer and consultant knowledge) to represent farm operations containing the various typologies. The base models were then validated by checking that the inputs and outputs were representative for the relative land use types. Once the models were validated, the mitigations were stacked in sequence and the impact on the farm outputs recorded.

Dairy

Three dairy models were developed to best represent the wide variety of systems and typologies identified within ORC data. Table 6 shows an overview of the 3 dairy models, where elements of each Rohe are included in the model farms, but each farm is not necessarily representative of a particular Rohe.

The typology data for dairy farming show dryland farms are predominantly farmed on flat imperfectly drained land and irrigated farms on predominantly flat land with a mixture of imperfectly and well drained soils. About 15% of dairy support land is irrigated but this is not represented within the model as it would have minimal impact on overall outcomes given dairy support is only 1% of overall land area within the Otago region.

> It is important to note that when setting up the base models for both the dry stock and dairy systems some practices were included as current best practice. While this will vary amongst individual farms, some practices have already been broadly adopted and hence have become a part of current best practice. One example is fencing off waterways on dairy farms and another is cattle exclusion on flat, easy contour land.

[7] Results documented as “sensitivity analyses” within descriptions provided within Appendix 2: Detailed modelling outcomes

[8] https://beeflambnz.com/data-tools/farm-classes

Table 1. ***Dry stock models used to represent ORC typology data.***

Name	S&B 1	S&B 2	S&B 3	S&B 4
Farm description				
High level description	B+LNZ Class 6 type - mix of cultivated and non-cultivated areas	B+LNZ Class 6 - more extensive breeding with a higher portion of steeper land and unfertilised area	B+LNZ Class 6 - intensive flat with irrigation and low rainfall dryland	B+LNZ Class 7 - includes finishing
Relevant Rohe/area	Taieri - big % of stock and area and similar to Lower Clutha extensive edge	Upper Lakes + extensive central Otago	North Otago and Manuherekia part irrigated and lower rainfall	South/West Otago – intensive edge of lower Clutha and Catlins
Typography				
Contour	Flat/rolling/easy hill	Rolling/Steep	Flat/Rolling	Flat/Rolling
Soil type	Brown/Pallic	Brown/Pallic	Brown/Gley	Brown/Pallic
Drainage	Poor 20%	Poor 20%	Poor 20%	Poor 20%
% Irrigated	0%	0%	37%	0%
Livestock				
Stocking rate (per ha)	6.5	3	6 (Dryland=low; irr=high)	15
% Sheep	75%	72%	79%	90%
% Beef	25%	15%	3%	10%
% Dairy	0%	0%	0%	0%
% Deer	0%	12%	18%	0%
Supplementary feed (cropping)				
Cropping area	5%	3%	7%	5%
Crop type	Swedes and kale	Swedes, Rye-corn, Silage	Swedes and kale, with balance converted to silage	Swedes with baleage used as a top up
Yield (t/ha)	10	8	10	12
Crop use	Heifers, hoggets, and ewes	Sheep Beef and deer breeding	Sheep breeding finishing and Deer finishing + summer crop for lamb finishing	Cattle and hoggets, and also ewes in late winter
Kg crop/SU wintered	55	60	30	70

Table 2. Dairy models used to represent the ORC typology data.

Name	Dairy 1	Dairy 2	Dairy 3
Farm description			
High level description	Dairy Platform - 550 cows on 220 ha flat dryland, imperfectly drained, moderate rainfall (830mm) Producing 427 kgMS/cow or 1085 kg/ha	Dairy Platform - 842 cows on 240 ha flat irrigated, well drained, low rainfall (563mm). Producing 483 kgMS/cow or 1749 kg/ha	120 ha Dairy support - dryland flat/rolling, imperfectly drained, moderate rainfall (847mm). Rearing 135 R1's, 135 R2's and wintering 441 cows
Relevant Rohe/area	Dairy - Lower Clutha, Dunedin, Catlins, Taieri, Manuherekia	Dairy - Upper Clutha, Upper lakes, North Otago, Dunstan, Roxburgh	All dairy support (including irrigated)
Typography			
Contour	Flat	Flat	Flat 50%/rolling 50%
Soil type	Pallic	Pallic/Brown	Pallic
Drainage	Imperfect	Imperfect/well drained	Imperfect
SR/Ha	2.7 cows/ha	3.4 cows/ha	
Irrigation area	0	Fully irrigated	0
Cropping/feed assumptions (cows gazed on support block through June/July)			
Crop type	Milking fodder beet (4 ha) Dry cow fodder beet (2ha) Turnips (13 ha)	Fodder beet (10 ha)	Fodder beet (8.8 ha) Kale (3 ha)
Yield (t/ha)	FB - 22 TDM/ha Turnips – 10 TDM/ha	FB - 28 TDM/ha	FB - 22 TDM/ha Kale – 12 TDM/ha
Usage	Milking	Milking	Cows – fodder beet- winter Calves – kale - winter
Supplement harvested (TDM)	120 TDM pasture silage	120 TDM pasture baleage	60 TDM baleage,60 TDM baleage, 55TDM hay 55TDM hay
Supplement imported (TDM)	150 TDM PKE 200 TDM cereal silage	300 TDM barley grain	Nil

Mitigation options

As outlined in the modelling approach, Overseer has been used to assess the impact of a range of mitigation options within each of the dry stock and dairy farming systems. While the Overseer model has become the main industry tool for assessing nutrient loss estimates on farm, there are limitations. Individual farm management practices vary widely and impacts on N and P loss are difficult to quantify. While stocking rates are typical for the region, the degree to which pastures are grazed or critical source areas are protected are not easily quantified within the model.

Table 3 provides a high-level description of the mitigation options evaluated, with options grouped according to GMP/GMP+ status, and type, including:

- Fertiliser usage, including application rates and type.
- Dairy effluent management, including farm dairy effluent (FDE) area and application rate.
- Wintering systems, including crop systems (on/off grazing, catch crops, plantain) and barns.
- Riparian management, including buffer strips, stock exclusion and wetlands.

- Irrigation improvements, including reduced flood irrigation outwash, and changes to more efficient irrigation systems (example, border dyke to k-line to pivot to fixed grid).
- Land use change, resulting in reductions in grazing area and introduction of radiata pine plantation forestry blocks.

Table 3. Mitigation options identified as suitable for inclusion in the GMP & GMP+ models.

GMP: Fertiliser options	
Optimal Olsen P	Phosphate fertiliser applications were adjusted to maintain Olsen P soil levels within optimal range for each land use (Dairy-30, Dairy support 25, S&B easy contour –20, S&B steep contour 16).
Less soluble fertiliser	Superphosphate fertiliser is replaced with low soluble Reactive Phosphate Rock (RPR). RPR is much less soluble than Superphosphate with approximately 1/3 of the total phosphate contained being available in the year it is applied.
Reduce nitrogen fertiliser	Nitrogen fertiliser is considered to be a significant contributor to deterioration of water quality. This mitigation assesses the impact of shoulder season (spring/autumn) reductions in nitrogen fertiliser applications to pasture (not crops). Note: this is more suited as a dairy strategy due the high reliance on N fertiliser.
GMP: Farm dairy effluent (FDE)	
Increase FDE area	The area available for dispersing FDE to land is increased by approximately 100% to reduce potential loading of nutrient to soil.
Defer and apply low rate DFE application to land	FDE applications are deferred to low-risk times through the year (Nov – March) and applied through low-rate sprinklers (<12mm), however, this would require additional effluent storage holding capacity in order to implement.
GMP: Winter crop options	
On/off grazing	Animals are modelled as being on winter crop (grazing) for 10hrs (vs 24 hrs) to reduce the time available for urine (primarily) to be deposited on crop ground. When stock are not on crop, they are assumed to be on grazing pasture.
Catch crops	Crop rotations are altered to mimic the practice of sowing an annual crop (Oats) after grazing to utilise surplus nitrogen within the soil root zone. In each situation, an Oat crop is sown in the month following final defoliation and is either grazed in situ or harvested for silage (dairy -Autumn sown, dry stock – spring sown).
GMP: Riparian options	
Buffer strips	Buffer strips are used to mimic fenced riparian areas which filter overland water flow from critical source areas. Dairy/dairy support areas are predominately flat land, therefore, we have assumed that each buffer strip in the model filter overland flow from a 30ha catchment. The buffer strips are considerably larger for S&B land especially where rolling/steep land types form a significant area of the model farm.
Wetland	A wetland is included in the model and settings in Overseer adjusted to reflect a small wetland of Class 1-3 condition with moderate convergence and an aquitard depth of 0-1m. The catchment area is set to a moderate level in proportion to the farm area.
Stock Exclusion	Base dairy models assume 100% stock exclusion. Dry stock model 3 did not exclude cattle from water in the base model so that the impact could be modelled. The base dry stock models 1,2 and 3 assumes cattle and deer are excluded from water on flat and easy contour blocks. On rolling and steep hill blocks, cattle and deer are not excluded from waterways, with the stock exclusion mitigation for dry stock assuming that cattle are excluded from access to water across all contours. Deer are assumed to have wallows present in all models but only pace fences in intensive blocks.
GMP: Irrigation	
Reduce flood irrigation outwash (dry stock only)	There is currently a mandate for all border dyke and flood wash irrigation to be superseded with spray irrigation by 2030, therefore, this mitigation is already being addressed through current regulation and has not modelled as a mitigation within the dairy models.

GMP+: Fertiliser options	
Reduce seasonal and crop fertiliser rates	Seasonal use of nitrogen fertiliser is further reduced to limit synthetic N inputs to pasture (October – February). Crop N applications are also reduced for dairy and dairy support models.
GMP+: Winter crop options	
On/off grazing	Animals are modelled as being on winter crop (grazing) for 4hrs (vs 24 hrs) to reduce the time available for urine (primarily) to be deposited on crop ground. Stock are removed from crop to pasture land.
GMP+: Riparian options	
Constructed Wetlands	Additional class 1 S&B wetland included with high convergence. For GMP+ applications, the wetland area and catchment areas are increased. In the case of S&B farm 4 the tile and mole drainage was treated through an artificial wetland prior to discharge to waterway. No GMP+ option for dairy or dairy support.
GMP+: Wintering barn/stand off	
Wintering barn	All dairy and dairy support animals are wintered within a covered wintering barn. No winter crops are grown on the dairy or support blocks. Silage made on farm or purchased used to support animal intakes in the barns.
GMP+: Irrigation	
Efficient irrigation	All k-line and lateral spray irrigation converted to variable rate pivot and solid set irrigation with soil moisture sensors for irrigation scheduling. This reduces excessive water flowing through the root zone and reduces nutrient contamination risk of ground water.
GMP++: Technology	
Incorporate plantain into pasture mix	Research shows that plantain has the ability to reduce urinary nitrogen excreted from grazing ruminants, therefore reducing N leaching to ground water. This mitigation would take many years to implement as farms generally take 15+ years to complete a pasture renewal cycle. This mitigation assumes the pasture renewal cycle is complete and the entire farm has 15% plantain mix in the pasture sward.
GMP++: Land use change/land retirement	
Forestry	Where applied, the mitigation includes reducing the pasture area of steep land and changing that land to plantation forest (*Pinus radiata*). Stock numbers are adjusted to account for land loss assuming that the poorest areas were converted to forest.
Grass filter strips	Grass filter strips were not routinely used as there is a high degree of variation in how it could be modelled (strip width, length and area of catchment). Where modelled (sheep and beef 2) the strip length, width and catchment area were all standardised to 3000m X 10m at 300Ha, respectively. Standard of vegetation was set at good quality grass in intensive blocks and average in extensive areas.

Comments

Not all mitigation options identified with the OLW report and assessed within the 2021 project were suitable for inclusion within Overseer, with a description of mitigations judged as not suitable for Overseer modelling provided below;

- Critical Source Area (CSA) management – CSAs are considered high risk for transporting sediment and nutrients (especially when ploughed, cropped or grazed during high rainfall events). They are found where runoff accumulates in high concentration, they are usually small, low-lying areas, for example, gullies and swales. Managing these areas well is a great way to reduce sediment and nutrient loss from your farm[9].

[9] https://www.dairynz.co.nz/environment/on-farm-actions/land-management/critical-source-areas

- Options to mitigate against soil losses, such as sediment traps, are not available within Overseer, and wetlands are assumed to capture no P. Wetlands have a role in nitrogen reduction and have been included in the models. It might be expected that wetland construction would allow for the management and removal of trapped sediments as a part of best management practice, but this is not the case. Indeed, sediment often accumulates in wetlands and can impair their function for N mitigation until flood events can re-mobilise the sediment and push it downstream. Where mitigations are applied within the model, there are multiple areas for user interpretation such as area, percentages of flow captured or quality of wetland. Wetland type and area were included in models but the actual ability to include a wetland (suitable site) was not assessed. At a catchment level, farms will vary in the topography and ability to include wetlands and the degree to which wetlands can mitigate against nutrient loss.
- Variable rate applications of fertiliser or applying fertiliser at different rates to each paddock is not easily modelled. However, this is considered an active management option for farmers when distributing applied nutrients on farm. Fertiliser nutrients can be altered between blocks within Overseer but generally, management blocks are determined by broad categorisation relating to contour, crops, or soil type. Subtleties of management such as differential fertiliser applications by paddocks are very difficult (and time consuming) to apply within Overseer.

Other key pieces of information pertaining to the use of Overseer include:

- Irrigation mitigations were included in the models with a combination of upgrades allowing controlled applications based on soil moisture. Where contour is undulating, the ability to control water application is limited. If pivots are not able to be used, fixed grid can allow the fine control required but few options exist for this. As border dykes are phased out, less by-wash will be available to mitigate against, and Overseer has limited options in this respect.
- Fertiliser rates are easily adjusted, and applications are reduced to hold an Olsen P level in line with an agronomic optimum. Changing the fertiliser type is simple on an individual farm basis but will pose a logistical issue if large number of farms change practice based on environmental outcomes. For example, If RPR (Imported Reactive phosphate rock – low soluble P) is adopted as the preferred form of phosphate fertiliser to replace superphosphate (manufactured locally).
- Reductions in nitrogen use will result in lower pasture mass grown on farm. To compensate for less available feed, the farm system would normally be adjusted, for example, reduce stocking rate, purchase additional feed, or simply feed animals less and produce less animal product (milk, meat, fibre etc). Within our models Overseer has assumed that less feed is produced with no other management options included. Further modelling of economic impacts utilising tools such as FARMAX in combination with Overseer would be required to explore these financial impacts.
- Crops are considered a significant 'hot spot' on farms for N loss, particularly winter crops which often have N loss in the range of 60-300 kgN/ha. Overseer recognises the N loss risk of crops but does not have a function which can demonstrate the impact of good management practices such as increasing buffer zones or improving grazing management.
- Stock exclusion of beef from water ways is not complete on sheep and beef farms, however, anecdotal evidence suggests that a high portion of intensive S&B farms have fenced off water

ways. While exclusion of cattle on more extensive areas was modelled, there is a large variation in the situations where cattle have access to streams. Overseer applies a combination of base load loss and a second loss category that can be mitigated by fencing[10]. These two categories are adjusted in the model depending on contour.

- Wetlands are highly variable in aspects such as catchment area, area of wetland and the degree of channelling through the wetland. Wetlands applied in GMP modelling were of a lower standard than those included in the GMP+ models. The reason for the lower standard was that farmer and industry awareness around the requirements for high functioning wetlands will improve over time allowing a higher standard to be attained.
- Grass filter strips have been included in 2 of the dry stock models. We have assumed that dairy farms have 100% stock exclusion from water ways, therefore, this option was not included as a mitigation.
- Where pine forests have been included in S&B models, no account has been made of the tracking required to access the forest or the soil disturbance during deforestation, or bare fallow land between tree rotations.

[10] Review of the Phosphorus sub model in OVERSEER – September 2016

Section 3: Results

Using the base models as a starting point, a series of metrics have been used to evaluate the potential impacts of implementing a sequential series of GMP and GMP+ mitigation options of each of the dry stock and dairy farm system models. Key metrics evaluated are shown below, with a detailed description of the mitigation applied and results outcomes provided within Appendix 2: Detailed modelling outcomes:

- Changes in Total N and P losses for each farm system.
- Changes in N and P per hectare.
- Percentage reductions relative to base.

In order to assess the impact of the ‘bundling’ of individual mitigations within each of the GMP and GMP+ groupings, a “Heat plot” has been used to show the sequential reductions achieved for each mitigation. Table 4 shows results for N leaching, where the % changes have been highlighted according to impact and calculated as the proportional impacts of the additional mitigation relative to base. It is important to note that not all mitigations have been modelled for all farm systems, with “0” results showing mitigations that had little or no impact versus missing results for those not included within the models. Note that the total reductions achieved by GMP+ also include those gains achieved through the prior implementation of the GMP package. Similarly, those gains arising from additional options are inclusive of those achieved by GMP and GMP+.

These results clearly show that reducing N application rates and wetlands are the most effective forms of mitigation for reducing nitrogen leaching, with irrigation improvements also recognised as highly effective for both dry stock and dairy farming systems. Total GMP reduction ranges from 4-9% for non-irrigated dry stock farming systems and 9-18% for dairy systems.

Reducing flood irrigation outwash (from border dyke systems) may have a substantive impact on N leaching on irrigated sheep and beef farms, however, it is important to note that this is only partly under farmer control, and dependent on location within catchment, and practices on neighbouring farms. Implementation of this mitigation can be variable across farm, and care must be taken in interpreting results.

Table 5 shows a similar set of results for P loss with the biggest impacts being from use of lower soluble phosphorus fertilisers and improving irrigation efficiency. Land use change has also been identified as potentially having a substantive impact on the extensive sheep and beef farming system, with conversion of steep hill land to forestry resulting in reducing sheep and cattle numbers.

Table 4. Scale of reduction (%) of GMP/GMP+ and other mitigation options on N leaching within each of the dry stock and dairy farming systems. Note that the total reductions achieved by one package include those gains achieved through the prior implementation of the packages listed above it in the table.

	S&B1	S&B2	S&B3	S&B4	Dairy 1	Dairy 2	Dairy 3
GMP mitigation options							
Optimum Olsen P	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Low soluble P fertiliser	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Reduced N inputs stage 1		0.8			**11.1**	6.0	5.6
Enlarged FDE area					-0.1	5.5	
Limiting fertiliser to effluent area							
Deferred and low rate FDE					1.1	-4.9	
On-off grazing in autumn/winter	3.8	1.0	2.9	0.6	0.4	0.9	1.5
Catch crop	2.1	2.0	-1.7		3.7	1.0	
Stock exclusion	0.5	0.2		0.9			
Reduced flood irrigation out wash			9.3				
Constructed or facilitated natural wetlands	2.9	0.4	9.2	6.3	0.2	1.0	**10.6**
GMP Total (% reduction in N leaching)	**9**	**4**	**20**	**8**	**17**	**10**	**18**
GMP+ mitigation options							
Optimum Olsen P							
Increasing plantation forestry area	1.1	0.8					
On-off grazing in autumn/winter				0.3	0.2	4.8	0.0
Constructed or facilitated natural wetlands	3.3	1.0	**24.5**	0.0			
Reduced N inputs stage 2					1.0	7.7	5.0
Controlled release P fertiliser							
Variable rate fertiliser							
Wintering in barn or standoff					3.0	3.9	**17.3**
Variable rate irrigation and fertigation			**43.1**			**64.7**	
Strategic grazing of pasture in CSA							
Strategic grazing of crop in CSA							
Edge of field attenuation (buffer zones)							
GMP + Total (% reduction in N leaching)	**14**	**6**	**87**	**8**	**21**	**85**	**40**
Additional GMP++ options							
Land use change (forestry)	2.5	5.6					
Grass Filter strips	2.5	5.6					
Plantain 15% (with standoff)					**11.8**	2.0	5.1
Wintering barn (dry stock)				**19.2**			
Replace winter crop with Plantain				**18.5**			
Total including additional options (max % reduction)	**16**	**12**	**87**	**27**	**33**	**88**	**45**

Table 5. Scale of reduction (%) of GMP/GMP+ and other mitigation options on P loss within each of the dry stock and dairy farming systems (%). Note that the total reductions achieved by one package include those gains achieved through the prior implementation of the packages listed above it in the table.

	S&B1	S&B2	S&B3	S&B4	Dairy 1	Dairy 2	Dairy 3
GMP mitigation options							
Optimum Olsen P	1.7	0.0	5.9	0.0	**11.4**	**15.0**	**14.3**
Low soluble P fertiliser	5.2	0.4	7.0	5.5	3.2	7.1	3.6
Reduced N inputs stage 1		0.0			0.0	0.0	0.0
Enlarged FDE area					-0.6	0.2	0.0
Limiting fertiliser to effluent area							
Deferred and low rate FDE					0.0	-0.6	
On-off grazing in autumn/winter	-0.4	0.0	0.0	0.0	0.0	0.0	1.8
Catch crop	0.4	0.0	-3.1		0.0	0.2	
Stock exclusion	4.8	0.3		0.9			
Reduced flood irrigation out wash			0.0				
Constructed or facilitated natural wetlands	0.0	0.0	**18.4**	0.0	0.0	0.0	0.0
GMP Total (% reduction in P loss)	**12**	**1**	**28**	**6**	**14**	**22**	**20**
GMP + mitigation options							
Optimum Olsen P							
Increasing plantation forestry area	3.5	3.5					
On-off grazing in autumn/winter				0.0	0.0	0.0	
Constructed or facilitated natural wetlands	0.0	0.0	0.0	0.0			
Reduced N inputs stage 2					0.6	0.0	0.0
Controlled release P fertiliser							
Variable rate fertiliser							
Wintering in barn or standoff					0.0	1.0	8.9
Variable rate irrigation and fertigation			**55.4**			**35.7**	
Strategic grazing of pasture in CSA							
Strategic grazing of crop in CSA							
Edge of field attenuation (buffer zones)							
GMP+Total (% reduction in P loss)	**15**	**4**	**84**	**6**	**15**	**58**	**29**
Additional GMP++ options							
Land use change (forestry)	4.8	**11.7**					
Grass Filter strips	7.8	**15.5**					
Plantain 15% (with standoff)					0.0	0.0	0.0
Wintering barn (dry stock)				4.5			
Replace winter crop with Plantain				4.5			
Total including additional options (max % reduction)	**23**	**20**	**84**	**11**	**15**	**58**	**29**

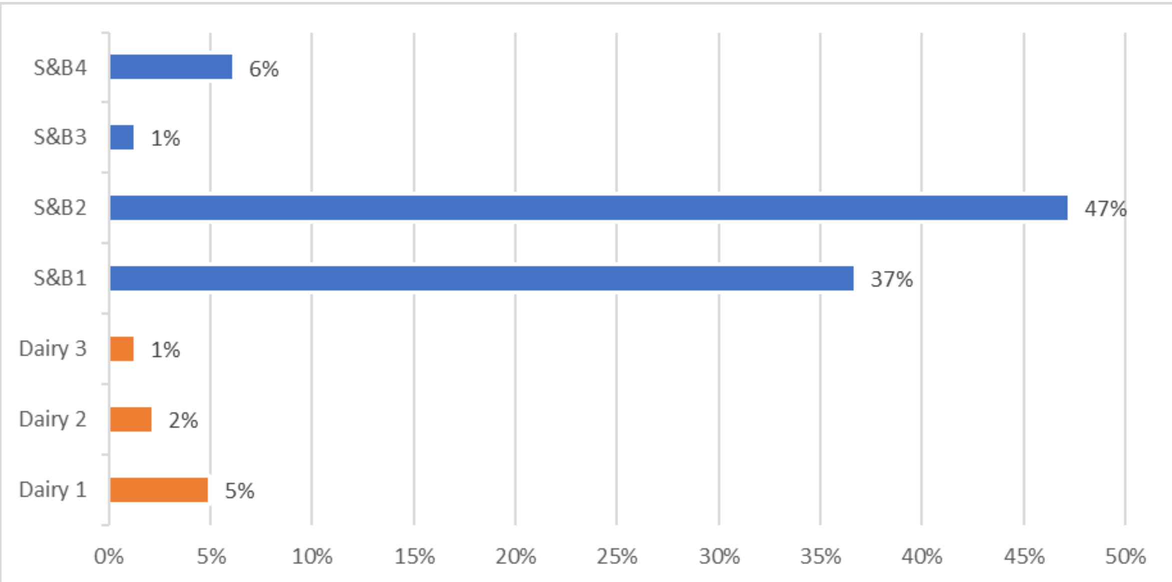
Application

With results for each of the farm system models now known, the next step in the process is to align each of the different typology groups with one of the farm system models, and apply the percentage reductions achieved within the model to reported estimates of N and P loss.

> Within this process, it is important to note that with up to 80 potential combinations of different land types (soil, moisture, and slope), a degree of compromise has been required to 'match' each of the different land use types and typologies, and care should be taken in interpreting the results.

Figure 10 shows a breakdown of land areas assigned to each of the different farming systems within the Otago region. Whilst there may be a level of inaccuracy within the assignments used, it clearly demonstrates that the majority of land has been classified as falling into the "B+LNZ class 6 type" farming systems and assumed to be best represented by the S&B 1, and S&B 2 Overseer models.

Figure 10. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models.



The farm model assignments have then been used to assess the range of variation in N & P loss, with Table 6 showing a comparison of the typology data for N leaching relative to the model farm estimates, and Table 7 the same results for P losses. Weighted averages have been used to assess the impact of differences in average N & P loss relative to total area across the typologies, with the minimum and maximum values depicting the variability within individual typologies assigned to each of the dry stock and dairy farm model systems.

Table 6. Comparison of typology data versus modelled farm system for N losses.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	14.9	19.3	2.5	26.0	43	36	34	29
Dairy 2	28.5	36.5	2.5	37.0	112	101	16	14
Dairy 3	13.1	13.7	2.5	27.3	23	19	14	13
S&B1	6.6	7.6	0.0	21.3	9.7	8.8	8.4	8.1
S&B2	6.5	7.4	2.3	23.0	7.2	6.9	6.7	6.3
S&B3	9.9	14.4	0.0	23.0	13.7	11.0	1.7	1.7
S&B4	8.1	10.1	2.0	18.0	12.8	11.8	11.8	9.3

Table 7. Comparison of typology data versus modelled farm system for P losses.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.31	0.57	0.18	0.67	0.73	0.63	0.62	0.62
Dairy 2	0.68	0.63	0.48	0.87	2.0	1.56	0.83	0.83
Dairy 3	0.31	0.31	0.18	0.67	0.5	0.41	0.36	0.36
S&B1	0.42	0.40	0.00	1.60	0.23	0.20	0.20	0.18
S&B2	0.58	0.51	0.18	1.93	0.94	0.93	0.90	0.79
S&B3	0.61	0.49	0.00	1.52	1.26	0.90	0.21	0.21
S&B4	0.48	0.47	0.20	1.07	0.43	0.41	0.41	0.39

Whilst modelled outcomes for N and P loss are relativity well aligned for the dry stock farm system models, modelled outcomes for dairy are consistently higher than those reported within the typology data. This arises from several sources:

- With Overseer being highly sensitive to synthetic nitrogen fertiliser use, irrigation type/management, and soil types, we have incorporated relatively high base loads of nitrogen within all the base models to ensure they were representative of current farming practices[11]. This could result in elevated levels of potential N loss, and care needs to be taken in interpretation of the results.
- The irrigation base model (dairy model 2) consists of inefficient k-line/sprinkler technology which significantly elevates N loss. Well drained soils are very sensitive to leaking excess nutrients through the soil profile, especially when surplus irrigation water is applied to heavily fertilised paddocks.

It is important to consider the material impacts of these differences in modelled outcomes, particularly given their magnitude. These are:

- The scale of reductions when defined in percentage terms will not be impacted. Thus, the differences in base N and P losses will have little to no deleterious impact when linking farm modelling to catchment-level outcomes for water quality if percentage changes are relied upon.

[11] Note that this was done after discussion with ORC technical advisory group, including input from Ross Monaghan

- The scale of reductions defined in load form accruing to mitigation (e.g. in terms of kg N/ha or kg P/ha) will be widely different because of the differences in baseline losses. These will degrade the validity of forecast impacts in waterways, if load changes are used instead of percentage changes when translating farm-level changes to the catchment scale.
- The cost of achieving percentage reductions in a given nutrient vary widely according to the baseline load. Indeed, it is typically cheaper to abate nutrients on farms with a higher baseline leaching load, given the presence of inefficient nutrient use (Doole, 2012[12]). Farms with higher leaching loads potentially have more mitigation options available to them. For example, an irrigated dairy farm on light soils with high levels of imported feed will often have N loss levels above 100 kg N/ha. The high levels of imported feed and inefficient irrigation offer tangible targets for improving nutrient use efficiency.

Impact analysis

Table 8 shows the estimated impact within the Otago region[13], when the % reductions for N and P loss for each of the GMP, GMP+ and GMP++ are used to estimate total reductions in each of the different farm systems.

Table 8. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Otago FMU/Rohe.

	Nitrogen			**Phosphorous**		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	10%	85%	87%	22%	58%	58%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	**14%**	**50%**	**58%**	**17%**	**29%**	**29%**
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	23%
S&B2	4%	6%	12%	1%	4%	20%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	8%	8%	27%	6%	6%	11%
Total reductions: dry stock	**7%**	**13%**	**17%**	**5%**	**9%**	**21%**
Total reductions: All	**9%**	**20%**	**26%**	**6%**	**11%**	**19%**

The levels of reduction in N and P loss from the model farms are lower than that reported by an Our Land and Water (OLW) project[14] where at a national level, potential load reductions for N & P by 2035 estimated at 34 and 39% respectively, compared to GMP++ estimates of 26 and 19% from this analysis. However, it is important to recognise that reported outcomes are based on regional as opposed to national data, and that not all mitigations included in the OLW study could be included within the mitigations modelled within the synthetic Overseer models used. Further, though mitigation impacts on dairy

[12] Doole, G.J. (2012). Cost-effective policies for improving water quality by reducing nitrate emissions from diverse dairy farms: an abatement-cost perspective, *Agricultural Water Management* 104, 10-20.
[13] Results for individual FMU/Rohe, are provided within Appendix 3.
[14] https://www.tandfonline.com/doi/full/10.1080/00288233.2020.1844763

farms are substantial, these are watered down by the dominance of the sheep and beef land use in the region. Indeed, if more dairy land were present, these large (potential) reductions would be available more widely. Differences between the dry stock and dairy farms system modelled relative to those reported by OLW were:

- **Dry stock**: OLW predicted up to 13 and 36% reductions for N and P by 2035 respectively, compared to estimates of 17 and 21% from this analysis with no allowance for inclusion of detainment bunds, sediment traps or the on-farm management of critical source areas.

- **Dairy:** OLW projected reductions of up to 59% for N and 51% for P by 2035. Our models predicted very similar results for potential N reduction (58%) but were considerably lower for P at up to 29% reductions. This is attributed to an inability to account for additional mitigations such as CSA grazing management, variable rate fertiliser applications and sediment traps within the Overseer model framework used. The OLW project also included additional mitigations such as in stream sorbents and controlled release fertilisers which were not included in GMP+ mitigations.

Discussion and Next Steps

The ability of individual farms to mitigate against N and P loss will vary greatly with a key example being the shift to efficient irrigation which is only valid for a small cohort of farmers. The model farms represent average typologies to help inform the likely scale of mitigations overall but there will be a lot of variation at individual farm levels as farm resources, farmer skill, topography and soil type influence outcomes.

More detailed farm models representing actual farms for specific typologies would provide more accurate data regarding mitigation impacts. Farmax modelling supports the identification of more accurate physical and financial information regarding farm system changes and would better inform the value proposition of implementing each mitigation for a farm business. For example, it is unlikely that dairy farmers would inject capital infrastructure for a stand-off facility to reduce N loss by 1% due to its high cost but are more likely to optimise Olsen P levels to reduce P loss by 11% given that this is likely to be cost neutral or even increase profit.

We would recommend accompanying each Overseer model outcome with estimation of the physical and financial impact resulting from each change, drawing on Farmax as appropriate. This would provide further insight around the likely adoption rate (and sequencing) of individual mitigation options and hence enable a more accurate assessment of potential reductions over time. Alternatively, a similar approach could be used to estimate the aggregate mitigation cost associated with different bundles. This could draw from literature available around the cost of alternate mitigations, with examples of this approach provided below[15].

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[15] Doole, G.J. (2016). Description of mitigation options defined within the economic model for the Healthy Rivers Wai Ora Project, Waikato Regional Council report HR/TLG/2015-2016/4.6, Hamilton.

Matheson, L., Djanibekov, U., Bird, B., and Greenhalgh, S. (2018). *Economic and contaminant loss impacts on farm and orchard systems of mitigation bundles to address sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui water management areas*, Ministry for the Environment, Wellington.

Monaghan, R.M. (2009). The BMP Toolbox—selecting the right best management practice for mitigating farming impacts on water quality, In: Currie, L.D. and Yates, L.J. (eds.), *Nutrient management in a rapidly changing world*, Massey University, Palmerston North, 328-334.

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Monaghan, R., McDowell, R., and Muirhead, R. (2012). *Generalised estimation of mitigation performance and costs*, Ministry for the Environment, Wellington.

Monaghan, R., McDowell, R., and Muirhead, R. (2016). *Generalised estimation of mitigation performance and costs*, Ministry for the Environment, Wellington.

Appendix 1 – Land typology and Land Use data

Land type data

In order to get an assessment of the range of potential variation in N and P losses across the Otago region, data has been assessed according to average, minimum and maximum N and P losses for each farm enterprise type of 10 ha or more within any individual FMU/Rohe

- Table 9. Soil moisture content: N and P losses by farm type enterprise type
- Table 10. Soil type/drainage: N and P losses by farm type enterprise type.
- Table 11. Gradient: N and P losses by farm type enterprise type.

Note that these estimates are based on the typology data provided by ORC, and external review has suggested that some estimates are lower than expected.

Table 9. Soil moisture content: N and P losses by farm type enterprise type.

	Average N	Min N	Max N	Average P	Min P	Max P
Dry						
Beef	7.7	4.0	9.8	0.4	0.3	0.7
Dairy	17.2	3.3	22.1	0.6	0.4	0.8
Dairy support	11.8	8.5	13.6	0.3	0.2	0.3
Deer	5.0	3.5	5.6	0.5	0.4	0.6
Sheep	6.2	2.5	7.5	0.4	0.2	0.6
Sheep & beef	5.9	3.3	7.5	0.4	0.2	0.6
Irrigated						
	Average N	Min N	Max N	Average P	Min P	Max P
Beef	18.0	10.3	23.0	0.6	0.4	1.0
Dairy	32.7	2.5	37.0	0.7	0.5	0.9
Dairy support	19.2	17.5	24.0	0.4	0.4	0.5
Deer	8.4	6.0	9.6	1.3	1.0	1.5
Sheep	10.1	3.3	13.3	0.4	0.3	0.7
Sheep & beef	10.6	5.5	15.2	0.5	0.3	0.7
Moist						
	Average N	Min N	Max N	Average P	Min P	Max P
Beef	14.6	7.8	21.3	0.5	0.4	1.0
Dairy	20.8	16.0	26.0	0.7	0.5	1.0
Dairy support	21.2	16.5	27.3	0.4	0.4	0.5
Deer	7.1	6.0	8.0	1.1	1.0	1.3
Sheep	8.5	2.8	18.0	0.5	0.2	1.1
Sheep & beef	10.0	4.5	18.0	0.8	0.3	1.6
Wet						
	Average N	Min N	Max N	Average P	Min P	Max P
Beef	17.2	13.5	19.0	0.6	0.6	0.6
Dairy	-	-	-	-	-	-
Dairy support	-	-	-	-	-	-
Deer	9.0	9.0	9.0	0.4	0.4	0.4
Sheep	5.8	5.8	5.8	0.3	0.3	0.3
Sheep & beef	10.1	3.3	18.0	0.9	0.4	1.9

Table 10. Soil type/drainage: N and P losses by farm type enterprise type.

	Average N	Min N	Max N	Average P	Min P	Max P
Light						
Beef	22.2	21.3	23.0	0.5	0.5	0.5
Dairy	25.9	14.8	37.0	0.5	0.4	0.6
Dairy support	-	-	-	-	-	-
Deer	-	-	-	-	-	-
Sheep	5.1	4.7	5.6	0.3	0.3	0.3
Sheep & beef	7.5	3.3	18.0	0.6	0.3	1.9
Light/Poorly drained						
Beef	11.8	4.5	23.0	0.4	0.3	0.8
Dairy	20.6	13.5	37.0	0.6	0.4	0.9
Dairy support	13.6	11.3	21.2	0.3	0.3	0.5
Deer	5.6	4.7	9.0	0.7	0.5	1.4
Sheep	6.6	2.5	13.3	0.3	0.2	0.5
Sheep & beef	7.1	3.3	15.2	0.4	0.2	1.4
Light/Well drained						
Beef	10.7	4.0	23.0	0.5	0.3	1.0
Dairy	23.2	14.0	37.0	0.7	0.4	1.0
Dairy support	15.6	8.5	27.3	0.3	0.2	0.5
Deer	6.5	4.7	9.6	0.8	0.4	1.5
Sheep	6.5	2.8	13.3	0.4	0.2	1.1
Sheep & beef	8.4	4.5	18.0	0.6	0.3	1.9
Poorly drained						
Beef	10.3	6.0	23.0	0.5	0.3	1.0
Dairy	21.2	13.5	37.0	0.7	0.4	1.0
Dairy support	13.5	11.3	18.0	0.3	0.2	0.5
Deer	5.4	3.5	8.0	0.7	0.4	1.4
Sheep	7.2	4.5	13.3	0.5	0.2	1.0
Sheep & beef	8.3	4.5	16.8	0.6	0.3	1.9
Well drained						
Beef	10.6	4.5	23.0	0.5	0.3	1.0
Dairy	21.7	2.5	37.0	0.7	0.4	1.0
Dairy support	14.0	8.5	27.3	0.3	0.2	0.5
Deer	5.6	3.5	9.0	0.7	0.4	1.4
Sheep	7.8	4.3	18.0	0.5	0.2	1.0
Sheep & beef	8.2	4.0	18.0	0.6	0.3	1.9

Table 11. Gradient: N and P losses by farm type enterprise type.

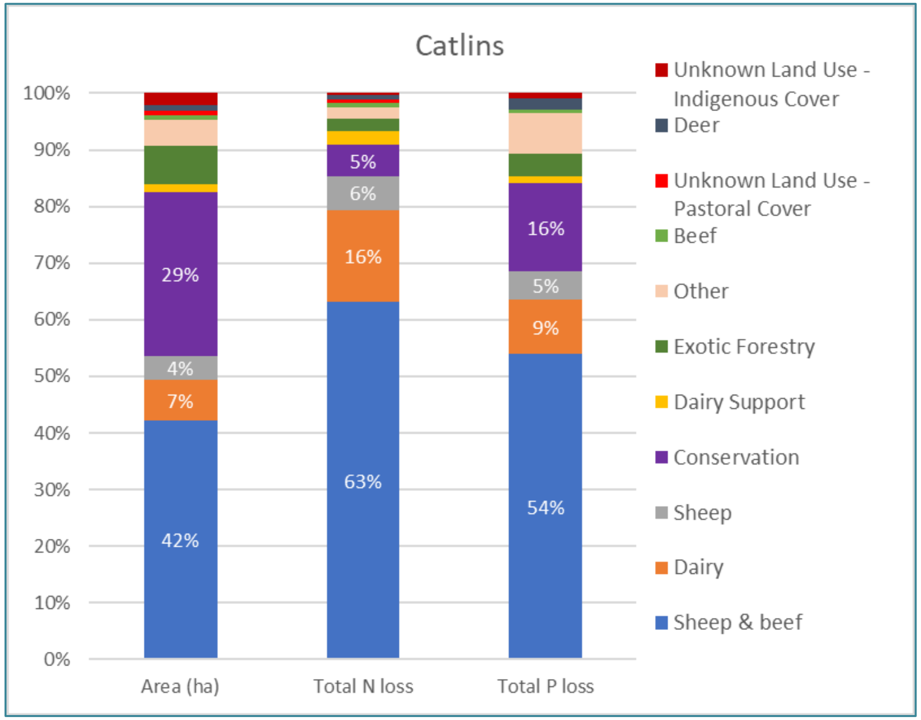
	Average N	Min N	Max N	Average P	Min P	Max P
Easy hill						
Beef	6.7	4.5	10.3	0.6	0.4	1.0
Dairy	18.7	14.0	34.7	0.6	0.5	0.9
Dairy support	12.7	8.5	17.5	0.3	0.2	0.4
Deer	5.2	4.7	6.0	0.6	0.5	1.0
Sheep	5.0	2.5	8.5	0.5	0.3	1.0
Sheep & beef	5.8	3.3	8.8	0.6	0.3	1.1
Flat/Undulating (<7°)						
Beef	13.7	6.5	23.0	0.4	0.3	0.6
Dairy	24.2	14.8	37.0	0.6	0.4	0.7
Dairy support	14.8	8.5	27.3	0.3	0.2	0.5
Deer	6.1	3.5	9.6	0.8	0.4	1.5
Sheep	8.7	3.5	18.0	0.4	0.2	0.6
Sheep & beef	10.8	4.7	18.0	0.4	0.3	0.6
Rolling (7-15°)						
Beef	9.5	6.5	13.7	0.4	0.3	0.8
Dairy	21.2	13.5	34.7	0.7	0.5	1.0
Dairy support	14.4	11.3	23.3	0.3	0.3	0.5
Deer	5.8	3.5	9.0	0.7	0.4	1.4
Sheep	7.2	2.9	11.5	0.4	0.2	0.7
Sheep & beef	8.3	4.5	12.8	0.5	0.2	0.7
Steep(>15°)						
Beef	4.9	4.0	5.3	0.6	0.5	0.7
Dairy	2.9	2.5	3.3	0.6	0.5	0.7
Dairy support	11.3	11.3	11.3	0.3	0.3	0.3
Deer	5.6	5.6	5.6	0.6	0.6	0.6
Sheep	4.2	3.0	6.0	0.6	0.4	1.1
Sheep & beef	4.7	3.3	6.0	1.0	0.5	1.9

Land use

Comparisons of land use data with respect to total land area, N leaching and P losses for each FMU/Rohe are provided below.

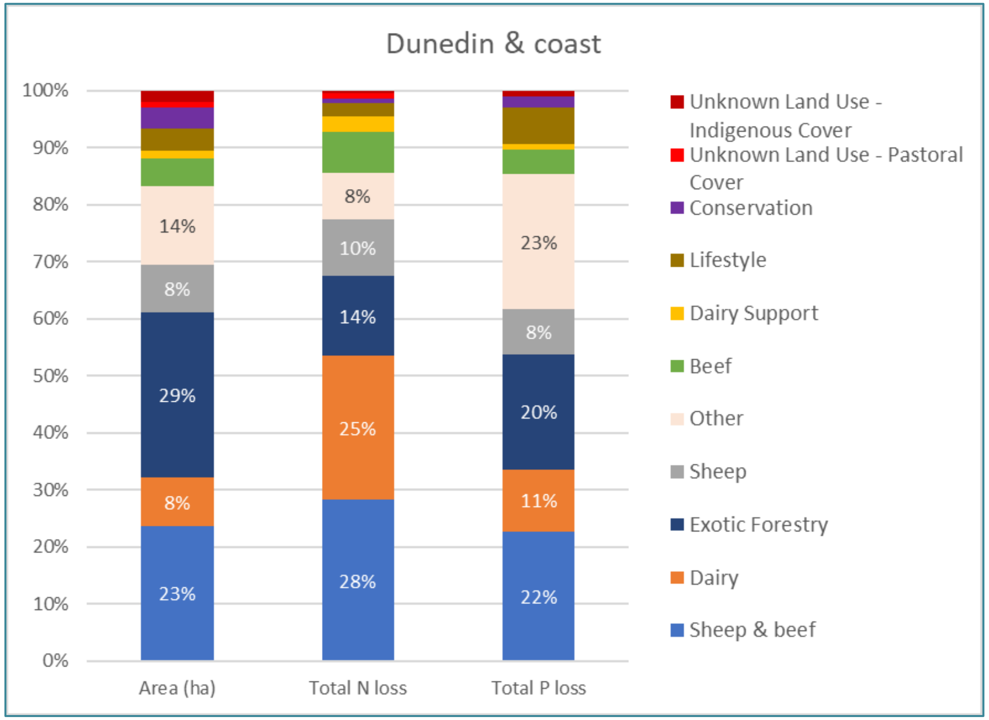
Catlins FMU

- Total Land area: 129,693 ha



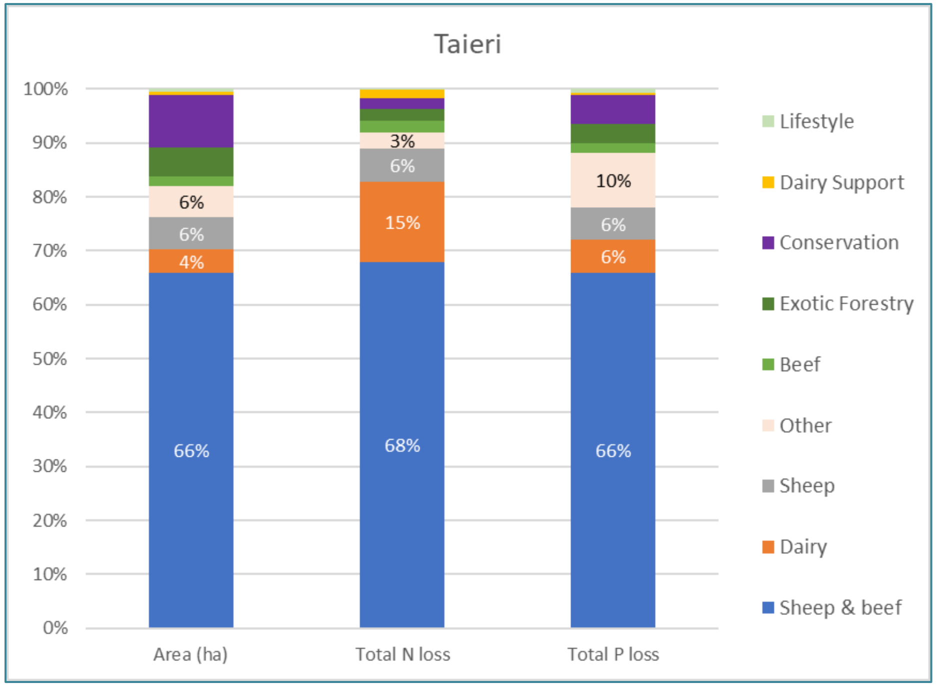
Dunedin & coast FMU

- Total Land area: 110,726 ha



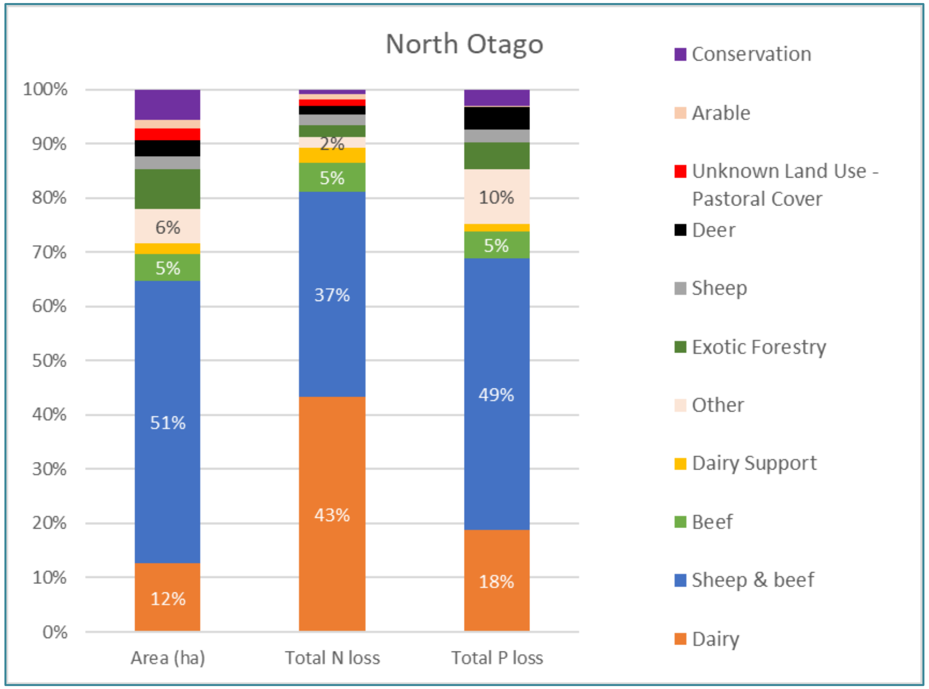
Taieri FMU

- Total Land area: 570,546 ha



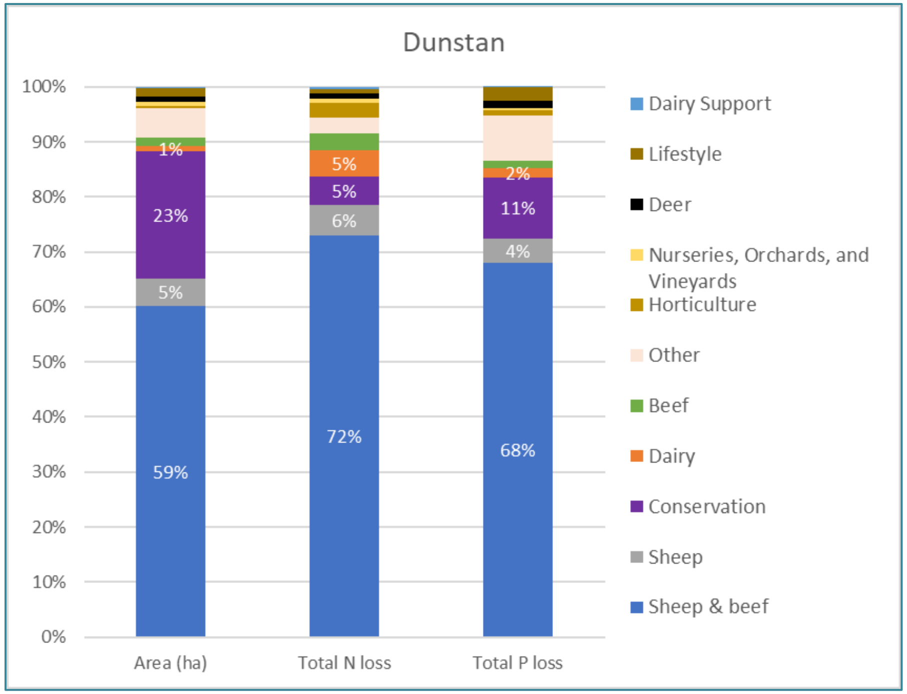
North Otago FMU

- Total Land area: 297,918 ha



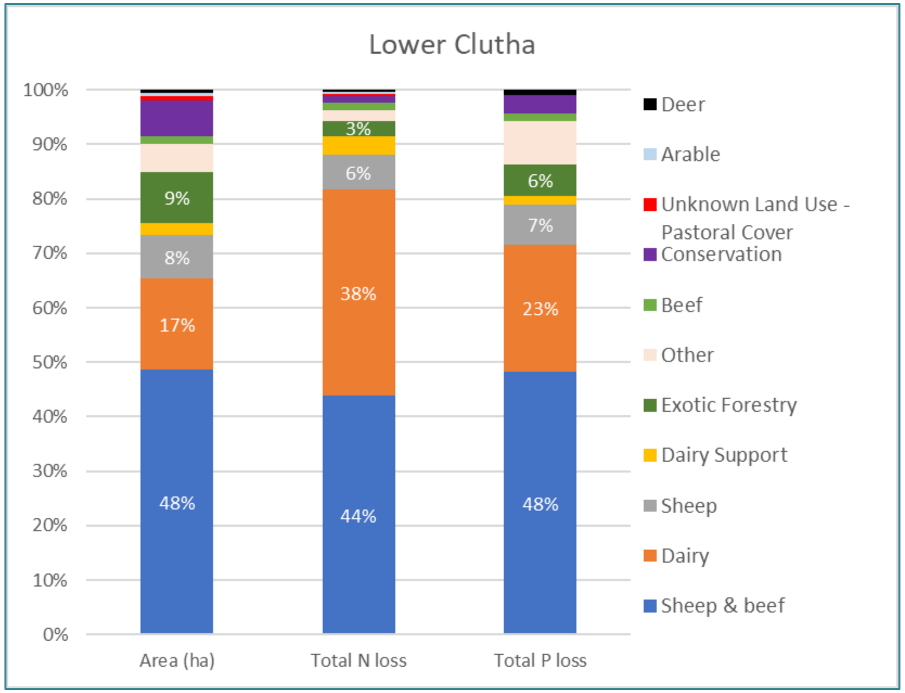
Dunstan Rohe

- Total Land area: 508,535 ha



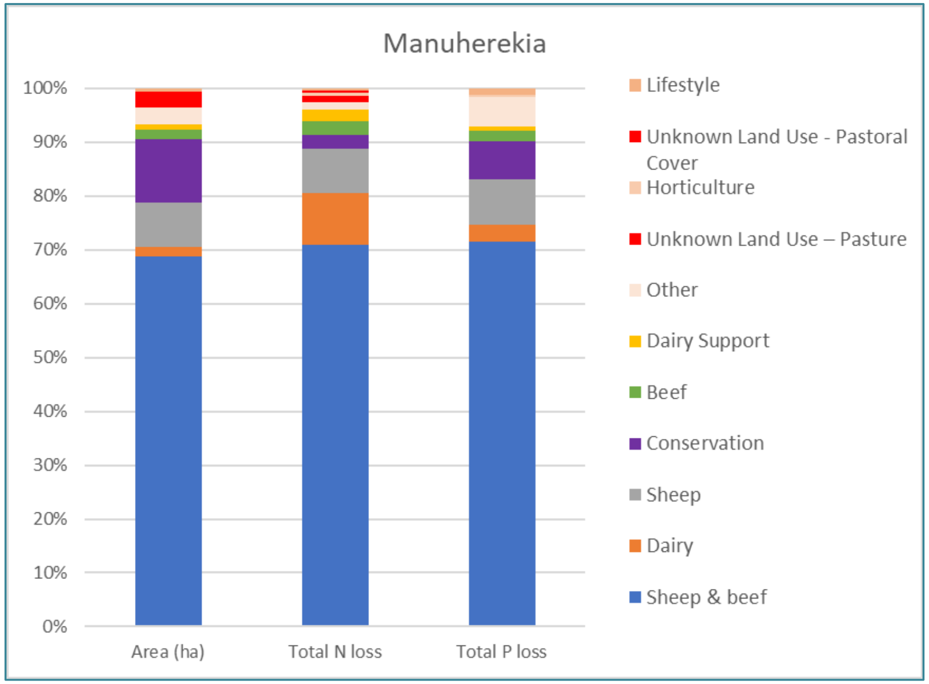
Lower Clutha Rohe

- Total Land area: 380,627 ha



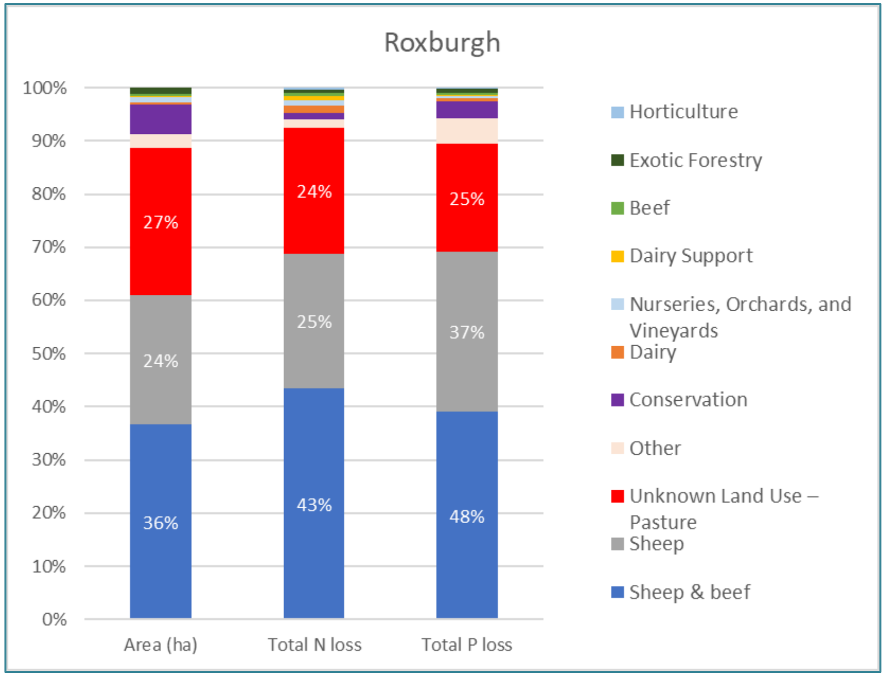
Manuherekia Rohe

- Total Land area: 303,043 ha



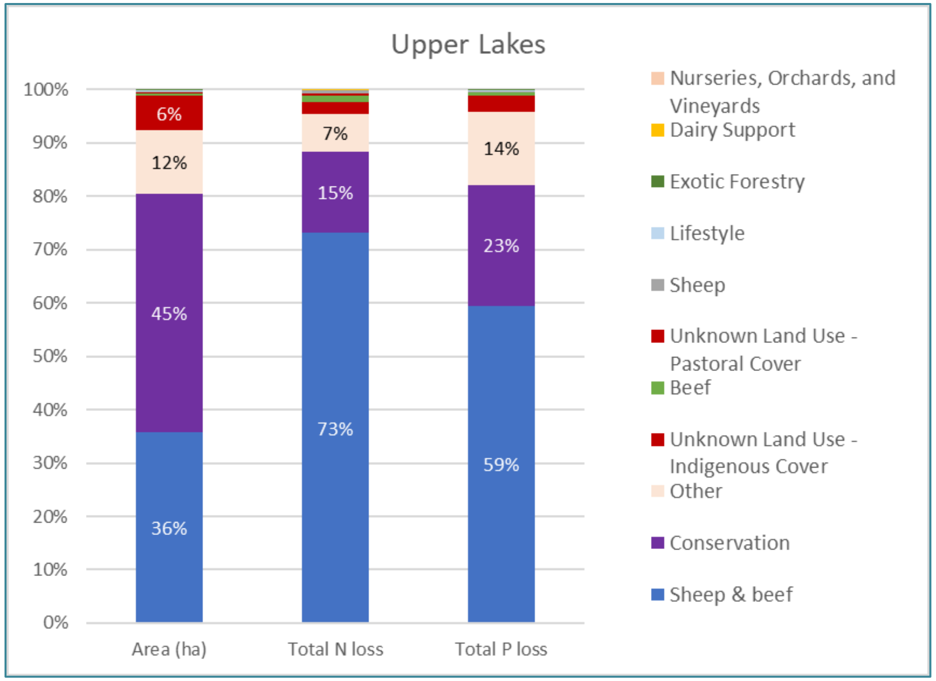
Roxburgh Rohe

- Total Land area: 182,075 ha



Upper Lakes Rohe

- Total Land area: 698,810 ha



Appendix 2: Detailed modelling outcomes

S&B 1: Class 6 (sheep and beef)

The stock systems and practices modelled for this 999 ha farm is based very closely on Beef and Lamb New Zealand class 6 with a sheep dominant system on rolling contour. Stocking rate in Overseer is 6.5su/Ha with a combination of cultivated rolling area and steep uncultivated hill supported by a more intensive flat area. Soil types were adjusted to reflect 80% free draining across the property.

Default Olsen P levels were set to 20 across the property and fertiliser application was set to 250Kg/Ha of superphosphate on the flat and easy rolling areas of the property. Nitrogen use was limited to crop areas where it was applied in the form of DAP at sowing. Table 12 shows the impact of GMP and GMP+ mitigations within the S&B1 model, with further comments below.

GMP outcomes

The combination of GMP mitigations (excluding land use change) resulted in a 9.4% reduction in farm nitrogen losses with winter crop management and inclusion of a wetland having the biggest single impacts. Farm phosphate losses were lowered by 11.7% overall with a 5.3% through change to fertiliser type having the largest single impact.

- **Fertiliser usage:** Changes in fertiliser usage resulted in up to 7% reductions in phosphorus losses, but with low usage of nitrogen based fertiliser, N loss remained constant. While Olsen P levels have been modelled at 20, typical fertiliser rates in the base model are above the level required for maintenance. Both reduction to maintenance and change to less soluble forms of phosphate have an impact on phosphate loss. While RPR use is modelled, availability is likely to be constrained and some use cases will be difficult through spread ballistics and low rainfall/ high soil pH combinations.
- **Winter crops:** In the base model stock are wintered on brassica crops shows a N loss of 83.6Kg/Ha on the winter crop areas relative to the pasture areas ranging from 5-8Kg/Ha of N loss. The first mitigation included in the GMP bundle for winter crop areas was on off grazing where stock was removed from the area for a portion of the day (8 hours grazing). This action reduces the urine deposition onto the crop area where it is exposed to leaching during the winter and spring months. As a result of the mitigation, total farm N loss reduced from 9.7KgN/Ha to 9.3KgN/Ha.
- **Catch crops**: Catch crops were included in the GMP model where a cereal crop (oats) was sown in spring immediately following the winter crop. Nitrogen loss on farm is reduced from 9.3 to 9.1 Kg/Ha as the oat crop is able to utilise a portion of the nitrogen that would have otherwise leached from the root zone prior to re-grassing in late spring.
- **Stock exclusion**: Cattle were excluded from water on the extensive uncultivated hill block reducing P losses by a further 4.7%. It is modelled that cow's winter on this block, but the relative stocking rate of the block is much lower than others and cattle make up 26% of total stock numbers. N loss is reduced by 0.6% by excluding cattle from waterways.
- **Overland flow/riparian**: Inclusion of a class 1 wetland capturing 200Ha of catchment at moderate convergence reduced nitrogen loss to 8.8Kg/Ha. P loss remained at 214Kg for the farm or 0.2Kg/ha. Exclusion of cattle from access to waterways reduced total P losses by 5.1%.

GMP + outcomes

Conversion of 50 ha of steep land from pasture grazing to plantation forestry, and increasing wetland area to 500 ha, resulting in an additional 4.4% reduction in N leaching and 3.5% in P losses.

- **Fertiliser usage:** Farm fertiliser was left unchanged as the fertiliser type had already been adjusted along with optimal rates. However, variable rate application may offer advantages, particularly to steeper contour areas.
- **Winter crops:** Winter crop mitigations were already implemented as part of the GMP mitigations, but the grazing period was further reduced to 4hrs on crop. There was no impact on either nitrogen or phosphate losses due to this change.
- **Plantation forestry:** 50 ha of steep land was converted from pasture grazing to radiata pine forest, resulting in a 1.5% reduction in N leaching, and 4.5% reduction in P losses.
- **Overland flow/riparian**: A further wetland area was included in the model extending the catchment by 500Ha. The wetland was a 6Ha class 1 fenced wetland with high convergence, and N losses reducing from 8.8Kg/Ha to 8.5Kg/Ha or a reduction of 3.3%. Phosphate loss was reduced by 1Kg over the farm or a 0.5% reduction. Increasing wetland area had no impact on P levels, however active management of sediment traps (trapped sediments are periodically removed) are likely to lead to better reductions for phosphorus.

Other options (GMP ++)

Land use change (increase forest area to 100 ha of steep land) resulted in reduced synthetic phosphate usage and reduced erosion, increasing cumulative P reduction to 20%. However, relative stocking rates for the remaining (productive) area increased from 6.26/Ha to 6.4/Ha. Grass filter strips were also included with no impact on N leaching but increasing total P reductions by a further 3%.

- **Land use change:** Plantation forestry was included on 100Ha of steep land with a reduction in ewe numbers and beef cows estimated. The change to the model reduced synthetic phosphate application by 5% with no change to N use. Nitrogen loss increased relative to base by 5% while Phosphate losses were lower by 16%. Relative stocking rate increased from 6.26/Ha to 6.4/Ha over the productive area reflecting the loss of the poorest land to trees. The significant lowering of the phosphate loss is likely to be a combination of less phosphate applied and the phosphate that is applied is directed to relatively flatter land.
- **Grass filter strips:** Grass filter strips were included and modelled as approximately 1/3 of the rolling and steeper blocks being treated through a 6m strip.

Sensitivity analysis:

Altering the soils in the base model to light soils increased N loss by 37%. When mitigations were applied the N loss was able to be reduced by 21% compared to 16% for the original model. P loss was not increased relative to base model and ability to reduce P loss through mitigations was increased from 21% to 23%.

Application of the S&B 1 model:

S&B 1 was the most generic model and as such has been mapped to more of the typologies than any other single model. The farm system itself is the most typical of Otago farms as is the wintering system and mix of contour. Where a typology indicated that modest gains could be possible for both N and P losses, this model was often chosen.

Table 12. Summary of changes, including cumulative reductions in N and P losses for Sheep and Beef farming system 1.

Mitigation	Action	Nitrogen leaching			Phosphoros losses		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg)	P (kg/ha)	% Change
Base		**9,708**	**9.72**	**-**	**230**	**0.230**	**-**
Optimal Olsen P	Fertiliser applications were reduced to 150Kg/Ha on the flat and easy rolling areas to hold Olsen P near 20.	9,708	9.72	0%	226	0.226	-1.7%
Less soluble fertiliser	Fertiliser type was changed to RPR at a rate of 100Kg/Ha on cultivated and easy paddock areas.	9,708	9.72	0%	214	0.214	-7.0%
On off grazing	Stock was removed from winter feed crop area for a portion of the day (8 hours grazing). This action reduces the urine deposition onto the crop area where it is exposed to leaching during the winter and spring months.	9,335	9.34	-3.8%	215	0.215	-6.5%
Catch crops	Greenfeed cereal crop sown in the month following final defoliation and grazed in situ prior to sowing in grass pasture.	9,127	9.14	-6.0%	214	0.214	-7.0%
Stock exclusion	Cattle excluded from accessing water on the extensive (uncultivated) hill block.	9,076	9.09	-6.5%	203	0.203	-11.7%
Wetland	Inclusion of a class 1 wetland capturing nutrient losses from 200Ha of catchment at moderate convergence.	8,796	8.80	-9.4%	203	0.203	-11.7%
GMP	**All mitigations GMP**	**8,796**	**8.80**	**-9.4%**	**203**	**0.203**	**-11.7%**
Increasing plantation forestry area	50 Ha of steep pasture grazing converted to plantation forestry (100 ha total).	8,691	8.70	-10.5%	195	0.195	-15.2%
Additional Wetlands	Added highly effective class 1 wetland to address 500H.	8,569	8.38	-13.8%	195	0.195	-15.2%
GMP+	**All mitigations GMP+**	**8,569**	**8.38**	**-13.8%**	**195**	**0.195**	**-15.2%**
Additional options that could be considered (GMP++)							
Grass filter strips	Approximately 1/3 of the rolling and steeper blocks being treated through a 6m strip.	8,162	8.14	-16.3%	184	0.184	-20.0%

S&B 2: Class 6 extensive (sheep, beef, and deer)

This model is broadly based on the class 6 B+LNZ system, and with a total land area of 3,000 ha is reflective of more extensive management where are larger portion of the winter feed requirements are met by saved pasture on hill blocks.

Table 13 shows the impact of the GMP, GMP+ and GMP++ mitigations for dry stock system 2, with the steeper contour being a significant factor for P losses, and the most significant mitigation being a land use change. Winter crop management offered some benefit for N loss, but this is more challenging to achieve on extensive properties, with further commentary on individual mitigations provided below.

GMP outcomes

The combination of GMP mitigations resulted in a 4.4% reduction in farm nitrogen losses with catch crops having the biggest impact (2%). Total Phosphate losses were much lower at 0.7%, with changes in fertiliser type to a less soluble form only having a minor effect (0.4%).

- **Fertiliser use:** The base farm was altered to have an Olsen P of 20 on cultivated areas (rolling) and 16 on all other areas including 1000Ha of steep uncultivated hill. No fertiliser was applied to a further 1000Ha of Native hill. Phosphate applications to cultivated hill were dropped to 210Kg/ha of S Super 30 with no change to farm losses of nitrogen. Phosphorus loss was reduced by 1.7%. Fertiliser choice was also changed to 150Kg/Ha of RPR on cultivated area and 100Kg/Ha of RPR on uncultivated hill with total P loss reduced from 2812Kg/Ha to 2801Kg/Ha which is a further improvement of 0.4%. Nitrogen application to ryecorn was delayed from September to October, resulting in a 168kg reduction (0.8% of total nitrogen leached).
- **Winter crops:** Animals were grazed on brassica crops for 8hr per day, with N losses reducing by 1% and P losses remaining unchanged. Note that while ryecorn serves as a winter crop, it was not subjected to on-off grazing. In many cases the crop is grazed similarly to grass where recovery is expected between grazing's. In dryland situations where this model is a match, the expectation is that ryecorn is multi graze and capable of taking up soil nitrogen deposited by wintering stock.
- **Catch Crops**: Brassica crops were sown out in oats in Spring, with a further 21% reduction in N loss, and no change to P.
- **Stock exclusion:** Beef were restricted from gaining access to waterways (fencing), resulting in a 0.6% and 5.1% reduction in both N and P losses.
- **Overland flow/riparian**: Introduction of natural wetlands (Class 3 unfenced wetland including 100Ha catchment – Type C) resulting in a further 0.4% reduction in N.

GMP + outcomes:

All fertiliser and winter crop mitigation measures were included within the GMP options already modelled, with the introduction of 100ha of plantation forestry and additional wetlands resulting in further reductions in both N and P loss.

- **Plantation forestry:** 100 ha of steep land was converted from pasture grazing to radiata pine forest, resulting in a 0.8% reduction in N leaching, and 3.7% reduction in P losses.

- **Overland flow:** Inclusion of a high-quality class 1 fenced wetland results in a further 5.3% reduction in N loss.
- **Other considerations:** All fertiliser and winter crop mitigation measures were included in GMP mitigations, but variable rate fertiliser application would have merit on this model farm. Alternative wintering options possibly including lower stocking rates would be worth considering on this land type.

Other options (GMP ++)

Land use change (400 ha of steep land converted to forestry) resulted in reduced fertiliser phosphate usage, increasing cumulative P reduction to 16%. Plantation forestry was not modelled on the most extensive native land at higher altitude, but filter strips could also be applied, to gain further reductions in P loss.

- **Land use change:** retirement of 400Ha of steep land results in further reduction in sheep and cattle numbers, with N and P reductions increasing to 11.6 and 18.0% respectively.
- **Well managed filter strips**: Inclusion of 9 ha of 10 m width filter strips enabling filtering of 900 ha of catchments, results in a further 1% drop in P loss.

Sensitivity analysis

Shifting the soils to 80% lighter well drained soils and 20% less well drained light soils increased the N loss in the base model by 1.5% and when GMP+ mitigations were applied the reduction in N was very similar. P losses were 18% higher than the original base and the mitigations had a greater effect with an extra 8% of reduction for the GMP+ relative to the base model.

Application of the S&B 2 model

More extensive, dryer and steeper typologies were often matched to this farm system and as a result, a reasonable area has been mapped as such. As there is a greater loss of phosphorus on this system, deer only typologies were more often mapped to this model.

Table 13. Summary of changes, including cumulative reductions in N and P losses for Sheep and Beef farming system 2.

Mitigation	Action	Nitrogen leaching			Phosphorus loss		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg)	P (kg/ha)	% Change
Base		**21,547**	**7.18**	**-**	**2,812**	**0.937**	**-**
Optimal Olsen P	Fertiliser applications were reduced to 210Kg/Ha Sulphur Super on the cultivated easy rolling areas to hold Olsen P near 20. Uncultivated hill set to Olsen P 16.	21,547	7.18	0%	2,812	0.937	0%
Less soluble fertiliser	Fertiliser choice was changed to 150Kg/Ha of RPR on cultivated area and 100Kg/Ha of RPR on uncultivated hill.	21,547	7.18	0%	2,801	0.934	0.4%
Nitrogen timing	Nitrogen application to ryecorn was delayed from September to October.	21,379	7.13	-0.8%	2,801	0.934	0.4%
On off grazing	Stock was removed from winter feed brassica crop area for a portion of the day (8 hours grazing). This action reduces the urine deposition onto the crop area where it is exposed to leaching during the winter and spring months.	21,162	7.05	-1.8%	2,801	0.934	0.4%
Catch crops	Greenfeed cereal crop sown in the month following final defoliation and grazed in situ prior to sowing in grass pasture.	20,721	6.91	-3.8%	2,802	0.934	0.4%
Stock exclusion	Beef cattle were excluded from accessing water on all areas.	20,677	6.89	-4.0%	2,793	0.931	0.7%
Wetland	Inclusion of a class 1 wetland capturing 200Ha of catchment at moderate convergence.	20,599	6.87	-4.4%	2,793	0.931	0.7%
GMP	**All mitigations GMP**	**20,599**	**6.87**	**-4.4%**	**2,793**	**0.931**	**0.7%**
Including plantation forestry area	100 Ha of steep pasture grazing converted to plantation forestry.	20,437	6.81	-5.2%	2,964	0.898	4.2%
Additional Wetlands	Added highly effective class 1 wetland to address 500H.	20,228	6.74	-6.1%	2,964	0.898	4.2%
GMP+	**All mitigations GMP+**	**20,228**	**6.74**	**-6.1%**	**2,964**	**0.898**	**4.2%**
Additional options that could be considered (GMP++)							
Land use change	400ha of steep land retired from livestock and into Pinus Radiata.	19,031	6.34	-11.7%	2,365	0.788	15.9%
Filter strips	9 ha of grass filter strips enabling filtering of 900 ha.	19,031	6.34	-11.7%	2,259	0.753	19.7%

S&B 3: Irrigated Class 6 intensive (sheep, beef & deer)

Baseline nutrient loss for this irrigated farm on flat to easy contour 565 ha farm is 13Kg/Ha for nitrogen and 1.2Kg/Ha for phosphorus. Nitrogen losses and use levels are relatively low as the stock system is still dominated by sheep. Phosphorus losses are high due to the high water use and by wash of the border dyke system. A riparian area was included in the base and the beef cattle and deer were not able to access streams in the model. Soils were adjusted to represent 80% free draining types as per typology estimates.

Table 14 shows a summary of GMP and GMP+ mitigation outcomes with further commentary provided below.

GMP outcomes

The combination of GMP mitigations resulted in a 20% reduction in farm nitrogen losses, and a 28% reduction in P losses, with the biggest N impacts coming from inclusion of a class 1 wetland capturing 200Ha of catchment at moderate convergence. In this model, with low rainfall, there is a low risk of loss through the leaching pathway in later winter so limited use for catch-crops to take up surplus nitrogen.

- **Fertiliser use:** Fertiliser rates were reduced to maintain an Olsen P of 20 on irrigated areas and 16 on dryland areas, with RPR used at 300 and 150 kg/ha respectively. This reduced P losses from 1.26 to 1.10 kg P/ha (13.9 %).
- **ON/off grazing:** Stock was removed from winter feed crop area for a portion of the day (4 hours grazing). This action reduces the urine deposition onto the crop area where it is exposed to leaching during the winter and spring months, resulting N leaching reducing from 13.73 to 13.33 kg N/ha.
- **Catch Crops**: With low rainfall, there is a low risk of loss through the leaching pathway in later winter so limited use for catch crops to take up surplus N. Oats were sown out in Spring but both N and P losses increased as a result of the additional dry matter grown and eaten. As a part of the winter feed block was on border dyke irrigation, the final grazing coincides with water applications increasing losses.
- **Irrigation:** Reducing border-dyke by-wash had a substantive impact on N leaching (9.2%) where the nutrient content of the water used in the irrigation is not subject to continual recycling and accumulation of nutrients. However, the nutrient content of border dyke-wash is only partly under farmer control, and dependent on location within catchment, and practices on neighbouring farms, this mitigation can be variable in its ability to be implemented.
- **Overland flow/riparian**: Introduction of an artificial wetland (type 1, 350 ha catchment) also provide substantive improvements with N leaching reducing from 12.28 to 11.03 kg/ha.

GMP+ outcomes

Two GMP+ mitigations were evaluated including inclusion of a second high grade wetland, and a switch from border dyke to spay irrigations systems, with both of these mitigations showing substantive increases in the potential for N and P loss reductions.

- **Overland flow/riparian**: Inclusion of a second high grade wetland (250 ha fenced), resulted in a further 25% reduction in N leaching, however because all water is deemed to be treated through relatively high-grade wetlands, pulsing of overland flow due to irrigation rosters makes this difficult in practice.
- **Irrigation:** A change from border dyke to efficient spray irrigation systems, resulted in total GMP+ reductions for N and P losses of 87% and 84% respectively. Factors involved include light free draining soils with less efficient spray options leading to leaching as well as the even less efficient border dyke irrigation where leaching on any free draining areas and overland flow where drainage is poor contribute to increased losses. However, the cost of implementation is very high and almost always requires bank funding to implement.

Other options (GMP ++)

No additional mitigation options were considered for the S&B 3 farm system. Due to the high value of the irrigated platform, alternative land use options were not likely and all reasonable fertiliser options have been taken into consideration. Once irrigation system is changed, overland flow is greatly reduced and as a result, further mitigations will have minimal impact on nutrient losses.

Sensitivity Analysis

The soil types modelled reflected soils available in the location but were adjusted to reflect the regional drainage typology with 80% free draining. In this case, soil types were adjusted to light soils with similar (80% free draining). N losses were 9.7% greater with light soils in the base model scenario due to more leaching from irrigation. P losses were 3% lower in the base model due to lighter soils and less overland flow. With all GMP+ mitigations applied there is a 1% increase in the ability to reduce N loss but ability to mitigate P loss is reduced by 5%.

Application of the S&B 3 model

Due to flat contour and low rainfall, potential losses to overland flow or leaching are relatively low. The considerable reductions possible through change to irrigation system are specific to farms where border dyke irrigation is utilised. For this reason, typology categories with irrigation above 50% on flat land were chosen as a match. Easy rolling areas in some situations have been included also as application method is important on rolling country as well. In the block report for the model, improving from a basic K-line system to efficient spray reduced N loss from 18Kg/Ha to 1.5Kg/Ha where soils were free draining and light particularly.

Table 14. Summary of changes, including cumulative reductions in N and P losses for Sheep and Beef farming system 3.

Mitigation	Action	Nitrogen leaching			Phosphorus loss		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg)	P (kg/ha)	% Change
Base		**7,759**	**13.73**		**711**	**1.258**	
Optimal Olsen P	Fertiliser rates were reduced on irrigated areas to retain an Olsen P of 20. An Olsen P of 16 was targeted for dryland areas.	7,759	13.73	0%	669	1.184	-5.3%
Less soluble fertiliser	Fertiliser type was changed to RPR at a rate of 300Kg/Ha on irrigated paddock and 150Kg/Ha on dryland areas.	7,759	13.73	0%	619	1.096	-13.9%
On off grazing	Stock was removed from winter feed crop area for a portion of the day (4 hours grazing).	7,532	13.33	-2.9%	619	1.096	-13.9%
Catch crops	Oats sown after winter feed crops and fed out in situ prior to resowing in pasture.	7,661	13.56	-1.3%	641	1.135	-9.8%
Irrigation	Reduce flood irrigation outwash.	6,941	12.28	-10.5%	641	1.135	-9.8%
Wetland	Include wetland (Artificial type one with 350Ha catchment).	6,230	11.03	-19.7%	510	0.903	-28.3%
GMP	**All mitigations GMP**	**6,230**	**11.03**	**-19.7%**	**510**	**0.903**	**-28.3%**
Additional Wetlands	Added 2nd high grade wetland (250 ha fenced) and improved fencing to the first wetland.	4,328	7.66	-44.2%	510	0.903	-28.3%
Variable rate irrigation	Change the irrigation systems to efficient spray.	983	1.74	-87.3%	116	0.205	-83.7%
GMP+	**All mitigations GMP+**	**983**	**1.74**	**-87.3%**	**116**	**0.205**	**-83.7%**

S&B 4: Class 7 intensive (sheep and beef)

This 250ha farm model is broadly based on Beef + Lamb NZ economic class 7 and reflects flat, intensive mostly sheep farming systems. The average stocking rate for this farm is 15 stock units/ha based on 90% sheep, and 10% beef, with both swedes and baleage used as supplementary feeds in winter. Soil type includes 80% well drained and 20% poorly drained soils to reflect Rohe and typologies in lower Clutha, and Catlins. Nitrogen is applied to 100Ha of pasture blocks in the form of Urea at a rate at 50 kg/ha in September, and other fertiliser applied to winter crops at sowing. Phosphate is applied in March in the form of Super Phosphate to all paddock areas at 250Kg/Ha.

Table 15 shows a summary of GMP and GMP+ mitigation outcomes with further commentary provided below.

GMP outcomes

The combination of GMP mitigations resulted in an 8% reduction in farm Nitrogen losses, and a 6% reduction in P losses, with the biggest N impacts coming from inclusion of a class 1 wetland capturing 63Ha of catchment at moderate convergence.

- **Fertiliser use:** Fertiliser type was changed to RPR 15S at a rate of 240Kg/Ha on cultivated and easy paddock areas. This resulted in total P loss reducing from 110 to 104kg/Ha (5.5% reduction).
- **Winter crops:** The base model where stock are wintered on brassica crops shows a N loss of 70Kg/Ha on the winter crop areas relative to the pasture areas ranging 9Kg/Ha of N loss. The first mitigation included in the GMP bundle for winter crop areas was on off grazing where stocks were removed from the area for a portion of the day (16 hours grazing). This action reduces the urine deposition onto the crop area where it is exposed to leaching during the winter and spring months. As a result of the mitigation, total farm N loss reduced from 12.83 to12.75 kg/ha (0.6% decrease).
- **Stock exclusion:** Additional fencing to ensure all stock are restricted from access to streams, results in 0.9% and 1.0% reductions in both N and P losses respectively.
- **Overland flow/riparian**: GMP unconstructed wetland is applied in GMP where 25% (63Ha) of tile drainage is channelled through a natural wetland resulting in N leaching reducing from 12.64 to 11.83 kg/ha.

GMP+ outcomes

In this model, application of GMP+ mitigations result in only minor impacts on N loss nutrient losses.

- **On off grazing:** Restricting crop grazing to 4 hours/day resulted in a 0.4% reduction in a 0.3% reduction in N leaching with no impact of P loss.
- **Overland flow/riparian**: No impacts were observed when increasing the amount of mole/tile drainage system channelled through a wetland as most of the possible mitigation was captured in GMP. This system could benefit from sediment traps in appropriate locations on the farm, however, Overseer cannot model this impact.

Other options (GMP ++)

The impact of using both winter barns and substitution of winter crops were modelled independently, with both mitigations showing substantive reductions in N loss.

- **Winter barns:** Addition of a wintering barn for cattle stock in winter months, reduced N loss by 11% and phosphorus by 4.5%. Beef margins don't usually support construction and operation of wintering barns and effluent management is variable in practice.
- **Crop substitution:** Removing winter crops from the model and adding in plantain over double the area reduced nitrogen by 10.4% and phosphorus by 4.5% due to increased area for urine spots with lower N content over winter and lower stocking rate during winter. While plantain area is assumed to recover post grazing, this is not a given in winter months and some area of pugging is likely to occur.

Sensitivity analysis:

Impact of changing soil type had only a small effect of N and P loss on the base model and during mitigations. The base model has 80% well drained soils and 20% poorly drained soils to reflect majority of soils in Otago. For sensitivity, a model was created with 80% poorly drained soils and 20% well drained soils, from base model changes were seen in total nitrogen loss and phosphorus loss. Total N increased by 10.4% and total P increased 1.4%. When GMP mitigations were applied to changed soils, total N loss decreased by 8.1% and P loss by 8.4%. GMP+ mitigations were applied to changed soils base and a further 0.4% decrease was observed in total N loss. No change was seen in P loss. Change to light soils were not considered as they would not hold the high production levels modelled without irrigation. No light soils were present in the area surrounding the farm.

Application of the S&B 4 model

Many flat contours, intensive farming systems were mapped to this farming system. Relatively low nutrient losses as baseline reduce the impact of mitigations. All GMP+ mitigations saw an 8.1% reduction in nitrogen and 6.5% reduction in phosphorus. CSA management and sediment traps have potential to be more impactful, however, are not able to be modelled effectively in Overseer.

Table 15. Summary of changes including cumulative reductions in N and P losses for Sheep and Beef farming system 4.

Mitigation	Action	Nitrogen leaching			Phosphorus loss		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg)	P (kg/ha)	% Change
Base		**3259**	**12.83**		**110**	**0.433**	
Less soluble fertiliser	Fertiliser type was changed to RPR at a rate of 300Kg/Ha on irrigated paddock and 150Kg/Ha on dryland areas.	3259	12.83	0%	104	0.409	-5.5%
On off grazing	Stock was removed from winter feed crop area for a portion of the day (16 hours grazing). This action reduces the urine deposition onto the crop area where it is exposed to leaching during the winter and spring months.	3238	12.75	-0.6%	104	0.409	-5.5%
Stock exclusion	Animals not allowed access to streams.	3210	12.64	-1.5%	103	0.406	-6.4%
Wetland	Include wetland (Artificial type one with 25% of catchment filtering through 63Ha catchment).	3005	11.83	-7.8%	103	0.406	-6.4%
GMP	**All mitigations GMP**	**3005**	**11.83**	**-7.8%**	**103**	**0.406**	**-6.4%**
On off grazing	Reduced to 4 hours of grazing.	2994	11.79	-8.1%	103	0.406	-6.4%
Additional Wetlands	Increased Artificial type one with 75% of catchment filtering through 115Ha catchment.	2994	11.79	-8.1%	103	0.406	-6.4%
GMP+	**All mitigations GMP+**	**2994**	**11.79**	**-8.1%**	**103**	**0.406**	**-6.4%**
Additional options that could be considered (GMP++)							
Winter barn for cattle	Added a winter barn to house cattle numbers over 3 months of winter.	2368	9.32	-19.2%	98	0.386	-10.9%
Plantain substituted for winter crop	Substituted winter crop for plantain and double the area due to less yield.	2391	9.41	-18.5%	98	0.386	-10.9%
GMP++	**Additional mitigations considered (max)**	**2368**	**9.41**	**-27.2%**	**98**	**0.386**	**-10.9%**

Dairy system 1: Dry land dairy farm on imperfectly drained soils

The stock systems and practices modelled for this farm are based on a typical dryland South Otago dairy farm, with a stocking rate of 2.5 cows/ha producing 1085 kg of milk solids per hectare (kgMS/ha). Soil types were based on imperfectly drained Pallic soils (classified as Timu_30a.1 within Overseer). Synthetic fertiliser including both Potassium (K) and Sulphur (S) was applied with application rates of 152 kg N/ha, 29 kg P/ha, 28 kg K/ha and 38 kg S/ha.

The majority of feed imported (150T PKE & 200 TDM cereal silage) is used for milk production with all cows sent off the platform through June & July for winter grazing (see Dairy system 3 for winter grazing impact).

Table 16 shows the impact of GMP and GMP+ mitigations within the dairy system 1 model, with further comments provided below.

GMP outcomes:

- **Optimising Olsen P:** Optimising Olsen P levels (at 30) and using low soluble P fertiliser (RPR) resulted in 5.5% reduction in P loss and no significant reduction in N loss.
- **Reducing N fertiliser** during spring and autumn. Pasture N applications through spring (Aug – Oct) and autumn (March – May) were reduced by 50%, this resulted in 11% reductions in N loss with no impact on P loss. Total pasture N applications dropped from 160 kgN/ha to 108 kgN/ha (33% reduction), no change in crop applications.
- **Farm Dairy Effluent (FDE)** Enlarging FDE area by 100% had no impact on N loss and a reduce P loss by 0.5%. Changing effluent application to from moderate (12-22mm) to low rate (<12mm) also had a negligible impact on N & P loss.
- **Crops:** Summer turnips and fodder beet are both used for milking cow fodder with animals only remaining on the crop for 1.5 hours per day. For this reason, on/off grazing of crops is not a viable mitigation for reducing nutrient loss. There is about 2 ha fodder beet used for dry cows through August which we have applied on/off grazing principles but due to such a small area there is negligible impact on the overall outcomes.
- **Catch crops**: Catch crops were included in the GMP model where a cereal crop (Oats) was sown in late autumn (May) once the crop has been grazed through March – May to support autumn milk production. The catch crop is ensiled in summer for silage then planted into permanent pasture. Nitrogen loss on farm reduced 3.7%.
- **Overland flow/riparian**: A well fenced/managed wetland area was included in the model. The wetland filtered 15ha of runoff and resulted in no reduction in N or P loss. Only small catchment areas can be used due to the flat nature of the farms.

GMP + outcomes:

- **Crops**: Due to such a small area of effective winter crop (1ha) there is a small reduction in N reduction when cows are stood off for 20 hours/day – 0.3% reduction.
- **Reducing N fertiliser:** Pasture nitrogen fertiliser is reduced through Nov-Feb by 50% and crop nitrogen fertiliser applications are reduced by 33%. This reduced N and P loss by 1% and 0.5% respectively. Total pasture N applications dropped from 108 kgN/ha to 67 kgN/ha (37% reduction), total crop N applications dropped from 95 to 64 kgN/ha (33% reduction).

- **Animal shelter**: Animal shelter used to stand milking cows off pasture through April/May for 14 hours/day and feed supplements, remaining time on grazing pasture. Crops eliminated from the farm system and replaced with 200T purchased silage to feed through the animal shelter.

GMP++ outcomes:

Incorporating Plantain into the pasture mix at 15% reduced N leaching by 11.8%. However, further investigation would be required to better understand management challenges with this level of adoption (persistence, cost, ease of management etc) and weather this could be considered a pragmatic option for farmers in the future.

Sensitivity Analysis:

The base model was changed from imperfectly drained pallic soils to well drained silt soils to understand the potential variation of nutrient loss across different soil types. Changing 90% of the soils to well drained resulted in N and P loss reductions of 41% and 28% respectively. This highlights the large variation in potential nutrient loss across different soil types which could have a significant impact when applied across the different FMU's. For more accurate information of nutrient loss on farm there should be more models completed to represent the changing typologies in each FMU.

Application of Dairy 1 model:

This generic model would best be used to compare mitigation impact on all dryland dairy farms within the Otago region. The sensitivity analysis could be used to gain a more accurate indication of the impact of mitigations for a dryland dairy farm on free draining soils.

Table 16. Summary of changes including cumulative reductions in N and P losses for Dairy farming system 1.

Mitigation	Action	Nitrogen leaching			Phosphorus losses		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg)	P (kg/ha)	% Change
Base		**9,285**	**42.7**		**158**	**0.726**	
Optimal Olsen P	Maintenance P fertiliser applications reduced to align with Olsen P 30 soil test.	9,285	42.7	0%	140	0.643	11.4%
Low soluble P fertiliser	Change P fertiliser from superphosphate to RPR for all maintenance P requirements.	9,275	42.6	0.1%	135	0.620	14.6%
Reduce shoulder N application rates	All shoulder season nitrogen applications applied at 50% of base rate (Aug – Oct and March – May). No change in crop applications.	8,241	37.9	11.2%	135	0.620	14.6%
Enlarge FDE area	FDE area increased by 100%.	8,247	37.9	11.2%	136	0.625	13.9%
Low rate FDE application	FDE application rates reduced to represent best management practice (<12mm).	8,141	37.4	12.3%	136	0.625	13.9%
On off grazing	Crop winter grazing intervals reduced from 24 hours/ day to 10 hours/day. However, stock still retained on pasture for remaining 14 hours.	8,100	37.2	12.8%	136	0.625	13.9%
Catch crops	Autumn fodder beet area sown in winter oats during month of May.	7,753	35.6	16.5%	136	0.625	13.9%
Constructed wetlands	Wet land area constructed to intercept 30% of surface water runoff.	7,732	35.5	16.7%	136	0.625	13.9%
GMP	**Combines GMP mitigations**	**7,732**	**35.5**	**16.7%**	**136**	**0.625**	**13.9%**
On/off winter crop grazing	Crop winter grazing intervals reduced from 24 hours/ day to 4 hours/day. However, stock still retained on pasture for remaining 20 hours.	7,715	35.5	16.9%	136	0.625	13.9%
Reduce total N application	All shoulder season nitrogen applications applied at 25% of base rate (Aug – Oct and March – May). All mid-season pasture applications reduced by 50% and all crop applications reduce by 35%.	7,623	33.8	17.9%	135	0.620	14.6%
Wintering barn without crops	All milking animals stood off paddock for on farm wintered in barn from June – August. No crops grown. Whole crop grown on platform and harvested as silage to feed to cows in barn over winter. Purchased silage required to replace winter crops for wintering barn.	7,348	33.8	20.9%	135	0.620	14.6%
GMP+	**Combines GMP+ mitigations**	**7,348**	**33.8**	**20.9%**	**135**	**0.620**	**14.6%**
Additional options that could be considered							
Plantain – 15%	15% of total pasture composition consisting of Plantain.	6,257	28.8	32.6%	135	0.620	14.6%

Dairy system 2: Fully irrigated dairy farm

The stock systems and practices modelled for this farm are based on a typical irrigated North Otago farm with a stocking rate of 3.4 cows/ha producing 1749 kgMS/ha. Soil types were a combination of imperfectly (Paha_16a.1) and well drained (Ngap_11a.1) soils found in the North Otago region. Synthetic fertiliser application rates of 182 kg N/ha, 39 kg P/ha, 25 kg K/ha and 60 kg S/ha.

300 ton of imported grain is used for milk production with all cows sent off the platform through June & July for winter grazing (see Dairy system 3 for winter grazing impact).

Table 17 shows the impact of GMP and GMP+ mitigations within the dairy system 2 model, with further comments provided below.

GMP outcomes:

- **Optimising Olsen P:** Optimising Olsen P levels (at 30) and using low soluble P fertiliser (RPR) resulted in 22% reduction in P loss and no significant reduction in N loss.
- **Reducing N fertiliser** during spring and autumn. Pasture N applications through spring (Aug – Oct) and autumn (March – May) were reduced by 50%, this resulted in 6% reductions in N loss with no impact on P loss. Total pasture N applications dropped from 182 kgN/ha to 127 kgN/ha (30% reduction), no change in crop applications.
- **Farm Dairy Effluent (FDE)** Enlarging FDE area by 100% reduced N loss by 5.5% with negligible impact on P loss. Changing effluent application from moderate (12-22mm) to low rate (<12mm) increased N loss by 4.9% which is not consistent with other results.
- **Crops – On/off grazing:** Summer turnips and fodder beet are both used for milking cow fodder, with animals grazing on crop for 1.5 hours per day. For this reason, on/off grazing of crops is not a viable mitigation for reducing nutrient loss. There is about 3 ha fodder beet used for dry cows through August which we have applied on/off grazing principles, but due to such a small area there is negligible impact on overall outcome N and P loss outcomes.
- **Catch crops**: Catch crops were included in the GMP model where a cereal crop (oats) was sown in late autumn (May) once the crop has been grazed. The crop is ensiled in summer for silage and planted into permanent pasture. Nitrogen loss on farm reduced 1.0%.
- **Overland flow/riparian**: A well fenced/managed wetland area was included in the model. The wetland filtered 15ha of runoff and resulted in 1% reduction in N loss. Only small catchment areas can be used due to the flat nature of the dairy farms.

GMP + outcomes:

- **Crops**: Due to such a small area of effective winter crop (3ha) there is a small reduction in N reduction when cows are stood off for 20 hours/day – 0.9% reduction.
- **Reducing N fertiliser:** Pasture nitrogen fertiliser is reduced through Nov-Feb by 50% and crop nitrogen fertiliser applications are reduced by 33%. This reduced N and P loss by 1% and 0.5% respectively. Total pasture N applications dropped from 127 kgN/ha to 76 kgN/ha (40% reduction), crop N applications dropped from 138 to 80 kgN/ha (42% reduction).
- **Animal shelter**: Animal shelter used to stand milking cows off pasture through April/May for 14 hours/day and feed supplements, remaining time on grazing pasture. Crops eliminated

from the farm system and replaced with 200T purchased silage to feed through the animal shelter. This resulted in 10.6% N loss.

- **Irrigation efficiency –** improving irrigation infrastructure to variable rate centre pivot and fixed grid provided the greatest reduction in nutrient loss. N and P loss reduce by 64.7% and 35.7% respectively. Advanced soil moisture monitoring allows for optimal irrigation applications to minimise loss of water through the soil profile and associated nutrients.

GMP++ Outcomes:

Incorporating Plantain into the pasture mix at 15% reduced N leaching by 2%. However, further investigation would be required to better understand management challenges with this level of adoption (persistence, cost, ease of management etc) and weather this could be considered a pragmatic option for farmers in the future.

Sensitivity analysis:

The base model was changed from imperfectly drained pallic soils to well drained silt soils to understand the potential variation of nutrient loss across different soil types. Changing 90% of the soils to well drained resulted in N and P loss reductions of 41% and 28% respectively. This highlights the large variation in potential nutrient loss across different soil types which could have a significant impact when applied across the different FMU's. For more accurate information of nutrient loss on farm there should be more models completed to represent the changing typologies in each FMU.

Application of Dairy 2 model:

This generic model would best be used to compare mitigation impact on all dryland dairy farms within the Otago region. The sensitivity analysis could be used to gain a more accurate indication of the impact of mitigations for a dryland dairy farm on free draining soils.

Table 17. Summary of changes including cumulative reductions in N and P losses for Dairy farming system 2.

Mitigation	Action	Nitrogen leaching			Phosphorus losses		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg)	P kg/ha	% Change
Base		**29,627**	**112.3**		**479**	**2.015**	
Optimal Olsen P	Maintenance fertiliser rates reduced to align with Olsen P 30 test.	28,876	112.1	0.2%	407	1.698	15.0%
Low soluble P fertiliser	Change P fertiliser from superphosphate to RPR for all maintenance P requirements.	28,876	112.1	0.2%	373	1.556	22.1%
Reduce shoulder N application rates	All shoulder season nitrogen applications applied at 50% of base rate (Aug – Oct and March – May). No change in crop applications.	25,248	105.3	6.2%	373	1.556	22.1%
Enlarge FDE are	FDE area increased by 100%.	23,757	99.1	11.8%	373	1.556	22.1%
Low rate FDE application	FDE application rates reduced to represent best management practice (<12mm).	25,081	104.6	6.9%	375	1.564	21.7%
On off grazing	Crop winter grazing intervals reduced from 24 hours/ day to 10 hours/day, and stock retained on pasture for remaining 14 hours.	24,841	103.6	7.7%	375	1.564	21.7%
Catch crops	Autumn fodder beet area sown in winter oats during month of May.	24,562	102.5	8.8%	374	1.560	21.9%
Constructed wetlands	Wetland area constructed to intercept 30% of surface water runoff.	25,772	101.4	9.8%	374	1.560	21.9%
GMP Total	**Combines GMP mitigations**	**25,772**	**101.4**	**9.8%**	**374**	**1.560**	**21.9%**
On/off winter crop grazing	Crop winter grazing intervals reduced from 24 hr/day to 4 hr/day. However, stock still retained on pasture for remaining 20 hours.	24,482	102.1	9.8%	374	1.560	21.9%
Reduce total N application	All shoulder season nitrogen applications applied at 25% of base rate (Aug – Oct and March – May). All mid-season pasture applications reduced by 50% and all crop applications reduce by 35%.	22,407	101	10.1%	374	1.560	21.9%
Wintering barn without crops	All animals on farm wintered in barn from June – August. No winter crops grown. Whole crops grown on platform to feed to cows in barn over winter.	21,357	89.1	20.7%	369	1.539	23.0%
Efficient irrigation	Change all K-line and travelling irrigation to pivot irrigation. All pivot irrigation supported by electronic soil moisture monitoring to assist irrigation scheduling.	3,926	16.4	85.4%	198	0.826	58.7%
GMP+	**Combines GMP+ mitigations**	**3,926**	**16.4**	**85.4%**	**198**	**0.826**	**58.7%**
Additional options that could be considered							
Plantain – 15%	15% of total pasture composition consisting of Plantain.	3,378	14.1	87.5%	198	0.826	58.7%

Dairy system 3: Dairy support farm grazing all young stock and wintering all dairy cows

The stock systems and practices modelled for this farm are based on a typical dryland South Otago dairy support farm, where all young stock are grazed from 3 months old to 24 months old, and all mixed age cows are winter grazed on crops for 9 weeks. Soil types were based on imperfectly drained Pallic soils (classified as Timu_30a.1 within Overseer) with 50% of the farm having rolling contour and 50% flat.
Base load synthetic fertiliser applied include 149 kg N/ha, 24 kg P/ha, 25 kg K/ha and 25 kg S/ha.
There is no imported feed in this system.

GMP outcomes:

- **Optimising Olsen P:** Optimising Olsen P levels (at 25) and using low soluble P fertiliser (RPR) resulted in 14.3% reduction in P loss and no reduction in N loss.
- **Reducing N fertiliser** during spring and autumn. Pasture N applications through spring (Aug – Oct) and autumn (March – May) were reduced by 50%, this resulted in 5.6% reductions in N loss with no impact on P loss. Total pasture N applications dropped from 150 kgN/ha to 93 kgN/ha (38% reduction), no change in crop applications.
- **Farm Dairy Effluent (FDE)** No FDE captured on the dairy support block.
- **Crops:** Winter fodder beet (8.8ha) and Kale (3.2ha) are used for winter grazing of replacement dairy stock and mixed aged cows through June/July. Removing all animals from winter crop to pasture for 10 hours per day reduced N and P loss by 1.5% and 1.8% respectively.
- **Catch crops**: Catch crops were not modelled in this farm system as all crops are planted back into permanent pasture immediately after grazing.
- **Overland flow/riparian**: A well fenced/managed wetland area was included in the model. The wetland filtered 50ha of sloping runoff land and resulted in 10.6% reduction in N loss. Wetlands do not capture P loss within Overseer.

GMP + outcomes:

- **Crops**: N-reduction when cows are stood off for 20 hours/day – 0% reduction.
- **Reducing N fertiliser:** Pasture nitrogen fertiliser is reduced through Nov-Feb by 50% and crop nitrogen fertiliser applications are reduced by 33%. This reduced N and P loss by 5% and 0% respectively. Total pasture N applications dropped from 93 kgN/ha to 48 kgN/ha (48% reduction), crop N applications dropped from 134 to 94 kgN/ha (30% reduction).
- **Animal shelter**: Animal shelter used to stand all animals off pasture 24/7 through June/July/Aug and feed supplements made from farm (235 TDM). 8.8ha FB and 3.2 ha Kale eliminated from the farm system as not required for wintering. Use of a wintering barn reduced N and P loss by 17.3% and 8.9% respectively.

GMP++ outcomes:

Incorporating Plantain into the pasture mix at 15% reduced N leaching by 5%. Note; further investigation would be required to better understand management challenges with this level of adoption (persistence, cost, ease of management etc) and weather this could be considered a pragmatic option for farmers in the future.

Sensitivity analysis:

The base model was changed from imperfectly drained pallic soils to well drained silt soils, to understand the potential variation of nutrient loss across different soil types. Changing 90% of the soils to well drained resulted in N and P loss reductions of 22% and 61% respectively. This highlights the large variation in potential nutrient loss across different soil types which could have a significant impact when applied across the different FMU's. This highlights the unique nature of individual farms and why a generic modelling approach can only provide a guide to impacts of nutrient loss.

Application of Dairy 3 model:

This generic model would best be used to compare mitigation impact on all dryland dairy support farms where cows are wintered on fodder beet within the Otago region.

Table 18. Summary of changes including cumulative reductions in N and P losses for Dairy farming system 3.

Mitigation	Modelling change	Nitrogen leaching			Phosphorus losses		
		Total N (kg)	N (kg/ha)	% Change	Total P (kg/ha)	P kg/ha	% Change
Base		**2543**	**22.9**		**56**	**0.505**	
Optimal Olsen P	Maintenance fertiliser rates reduced to align with Olsen P 30 test.	2543	22.9	0.0%	48	0.432	14.3%
Low soluble P fertiliser	Change P fertiliser from superphosphate to RPR for all maintenance P requirements.	2543	22.9	0.0%	46	0.414	17.9%
Reduce shoulder N application rates	All shoulder season nitrogen applications applied at 50% of base rate (Aug – Oct and March – May). No change in crop applications.	2401	21.6	5.6%	46	0.414	17.9%
On off grazing	Crop winter grazing intervals reduced from 24 hours/ day to 10 hours/day. However, stock still retained on pasture for remaining 14 hours.	2,363	21.3	7.1%	45	0.405	19.6%
Constructed wetlands	Wetland area constructed to intercept 30% of surface water runoff.	2,094	18.9	17.7%	45	0.405	19.6%
GMP	**Combines GMP mitigations**	**2,094**	**18.9**	**17.7%**	**45**	**0.405**	**19.6%**
Reduce total N application	All shoulder season nitrogen applications applied at 25% of base rate (Aug – Oct and March – May). All mid-season pasture applications reduced by 50% and all crop applications reduce by 35%.	1,967	17.7	16.3%	45	0.405	19.6%
Wintering barn without crops	All animals on farm wintered in barn from June – August. No winter crops grown. Whole crops grown on platform to feed to cows in barn over winter.	1,527	13.8	40.0%	40	0.360	28.6%
GMP+ total	**Combines GMP+ mitigations**	**1,527**	**13.8**	**40.0%**	**40**	**0.360**	**28.6%**
Additional options that could be considered							
Plantain – 15%	15% of total pasture composition consisting of Plantain.	1,398	12.6	45.0%	40	0.360	28.6%

Appendix 3: Expected reductions for individual FMU/Rohe

Expected reductions for each of the FMU/Rohe are shown below, with results presented according to:

I. Percentage of land area assigned to each of the dry stock and dairy farming systems.
II. Comparisons of typology data for each FMU/Rohe, compared to modelled outcomes for N and P losses.
III. Estimated GMP, GMP+ and GMP++ reductions for N and P loss in each of the farm systems and FMU/Rohe.

Catlins FMU

Figure 11. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Catlins FMU.

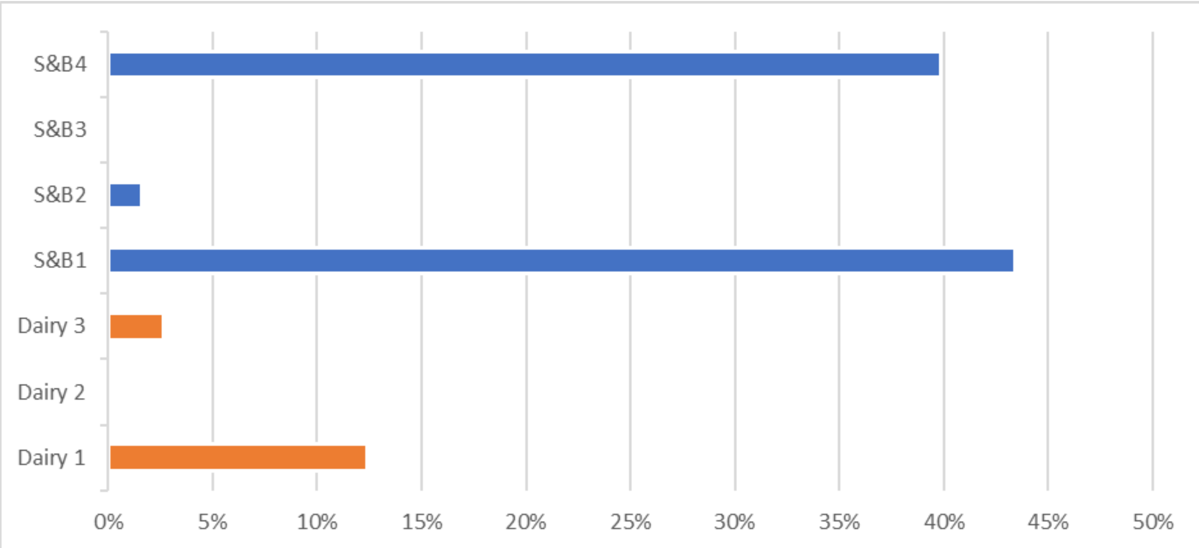


Table 19. Comparison of typology data versus modelled farm system for N losses within the Catlins FMU.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	14.8	18.1	2.5	26.0	43	36	34	29
Dairy 2	0.0	0.0	0.0	0.0	112	101	16	14
Dairy 3	14.0	13.5	8.5	27.3	23	19	14	13
S&B1	6.7	7.6	2.3	16.0	9.7	8.8	8.4	8.1
S&B2	5.6	5.9	3.5	8.0	7.2	6.9	6.7	6.3
S&B3	0.0	0.0	0.0	0.0	13.7	11.0	1.7	1.7
S&B4	13.9	16.1	8.5	18.0	12.8	11.8	11.8	9.3

Table 20. Comparison of typology data versus modelled farm system for P losses within the Catlins FMU.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.58	0.55	0.43	1.00	0.73	0.63	0.62	0.62
Dairy 2	0.00	0.00	0.00	0.00	2.0	1.56	0.83	0.83
Dairy 3	0.31	0.30	0.18	0.53	0.5	0.41	0.36	0.36
S&B1	0.48	0.44	0.18	1.60	0.23	0.20	0.20	0.18
S&B2	0.79	0.85	0.35	1.27	0.94	0.93	0.90	0.79
S&B3	0.00	0.00	0.00	0.00	1.26	0.90	0.21	0.21
S&B4	0.63	0.61	0.30	1.00	0.43	0.41	0.41	0.39

Table 21. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Catlins FMU.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	15%	21%	33%	14%	15%	15%
Dairy 2	0%	0%	0%	0%	0%	0%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	15%	23%	34%	15%	16%	16%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	23%
S&B2	4%	6%	12%	1%	4%	20%
S&B3	0%	0%	0%	0%	0%	0%
S&B4	8%	8%	27%	6%	6%	11%
Total reductions: dry stock	8%	10%	23%	8%	10%	16%
Total reductions: All	10%	13%	26%	9%	11%	15%

Dunedin & coast FMU

Figure 12. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Dunedin & Coast FMU.

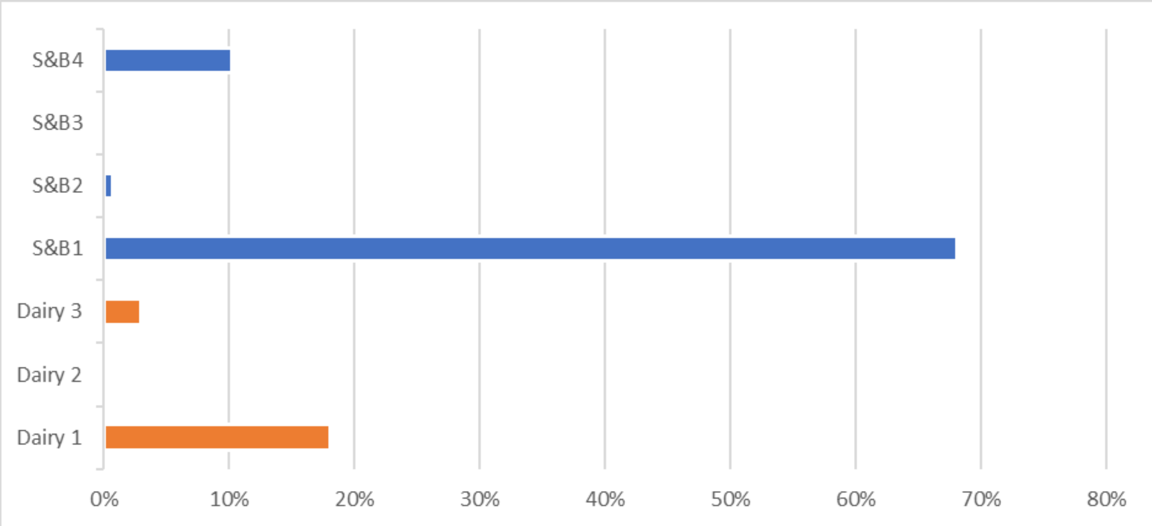


Table 22. Comparison of typology data versus modelled farm system for N losses within the Dunedin & Coast FMU.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	14.1	17.9	2.5	19.7	43	36	34	29
Dairy 2	0.0	0.0	0.0	0.0	112	101	16	14
Dairy 3	10.7	11.7	8.5	12.8	23	19	14	13
S&B1	7.1	7.4	2.1	18.0	9.7	8.8	8.4	8.1
S&B2	4.3	4.7	3.5	5.3	7.2	6.9	6.7	6.3
S&B3	0.0	0.0	0.0	0.0	13.7	11.0	1.7	1.7
S&B4	7.0	7.0	7.0	7.0	12.8	11.8	11.8	9.3

Table 23. Comparison of typology data versus modelled farm system for P losses within the Dunedin & Coast FMU.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.61	0.54	0.43	0.75	0.73	0.63	0.62	0.62
Dairy 2	0.00	0.00	0.00	0.00	2.0	1.56	0.83	0.83
Dairy 3	0.25	0.26	0.20	0.30	0.5	0.41	0.36	0.36
S&B1	0.49	0.39	0.15	1.60	0.23	0.20	0.20	0.18
S&B2	0.46	0.50	0.38	0.56	0.94	0.93	0.90	0.79
S&B3	0.00	0.00	0.00	0.00	1.26	0.90	0.21	0.21
S&B4	0.40	0.40	0.40	0.40	0.43	0.41	0.41	0.39

Table 24. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Dunedin & Coast FMU.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	0%	0%	0%	0%	0%	0%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	17%	23%	34%	14%	16%	16%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	23%
S&B2	4%	6%	12%	1%	4%	20%
S&B3	0%	0%	0%	0%	0%	0%
S&B4	8%	8%	27%	6%	6%	11%
Total reductions: dry stock	9%	13%	18%	11%	14%	21%
Total reductions: All	12%	17%	24%	12%	14%	20%

Taieri FMU

Figure 13. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Taieri FMU.

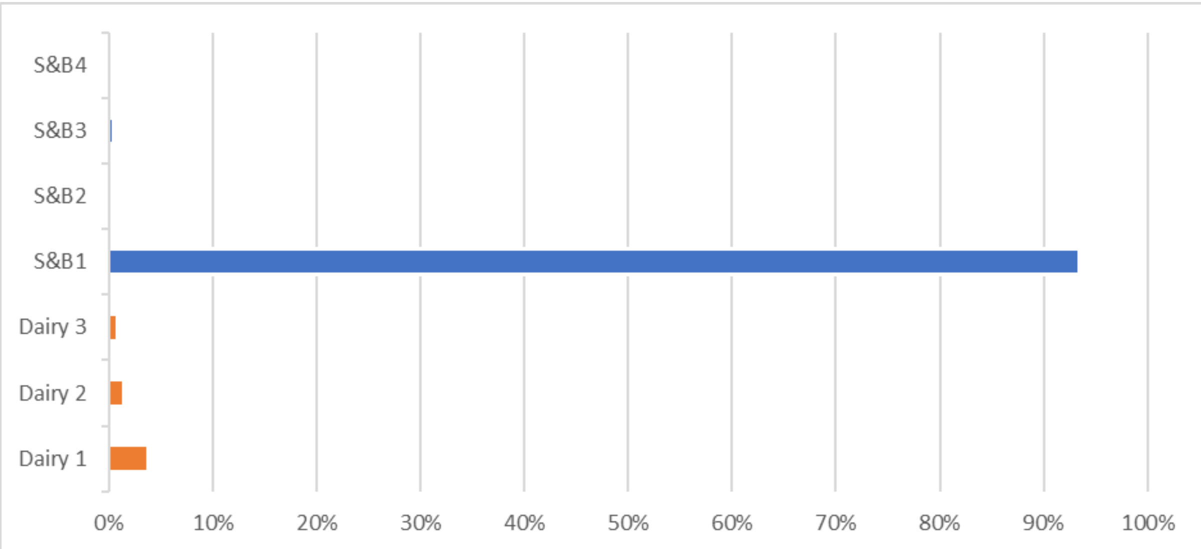


Table 25. Comparison of typology data versus modelled farm system for N losses within the Taieri FMU.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	13.1	19.4	2.5	19.7	43	36	34	29
Dairy 2	29.8	35.3	26.0	37.0	112	101	16	14
Dairy 3	12.7	16.2	8.5	22.3	23	19	14	13
S&B1	5.8	7.0	1.5	15.2	9.7	8.8	8.4	8.1
S&B2	4.7	4.7	4.7	4.7	7.2	6.9	6.7	6.3
S&B3	12.2	13.3	6.0	17.3	13.7	11.0	1.7	1.7
S&B4	0.0	0.0	0.0	0.0	12.8	11.8	11.8	9.3

Table 26. Comparison of typology data versus modelled farm system for P losses within the Taieri FMU.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.53	0.57	0.43	0.67	0.73	0.63	0.62	0.62
Dairy 2	0.63	0.61	0.48	0.87	2.0	1.56	0.83	0.83
Dairy 3	0.28	0.34	0.20	0.45	0.5	0.41	0.36	0.36
S&B1	0.44	0.39	0.20	0.95	0.23	0.20	0.20	0.18
S&B2	0.50	0.50	0.50	0.50	0.94	0.93	0.90	0.79
S&B3	0.59	0.51	0.30	1.27	1.26	0.90	0.21	0.21
S&B4	0.00	0.00	0.00	0.00	0.43	0.41	0.41	0.39

Table 27. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Taieri FMU.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	10%	85%	87%	22%	59%	59%
Dairy 3	17%	21%	33%	20%	29%	29%
Total reductions: dairy	14%	47%	55%	17%	28%	28%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	23%
S&B2	4%	6%	12%	1%	4%	20%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	0%	0%	0%	0%	0%	0%
Total reductions: dry stock	9%	14%	17%	12%	16%	20%
Total reductions: All	10%	20%	24%	12%	17%	21%

North Otago FMU

Figure 14. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the North Otago FMU.

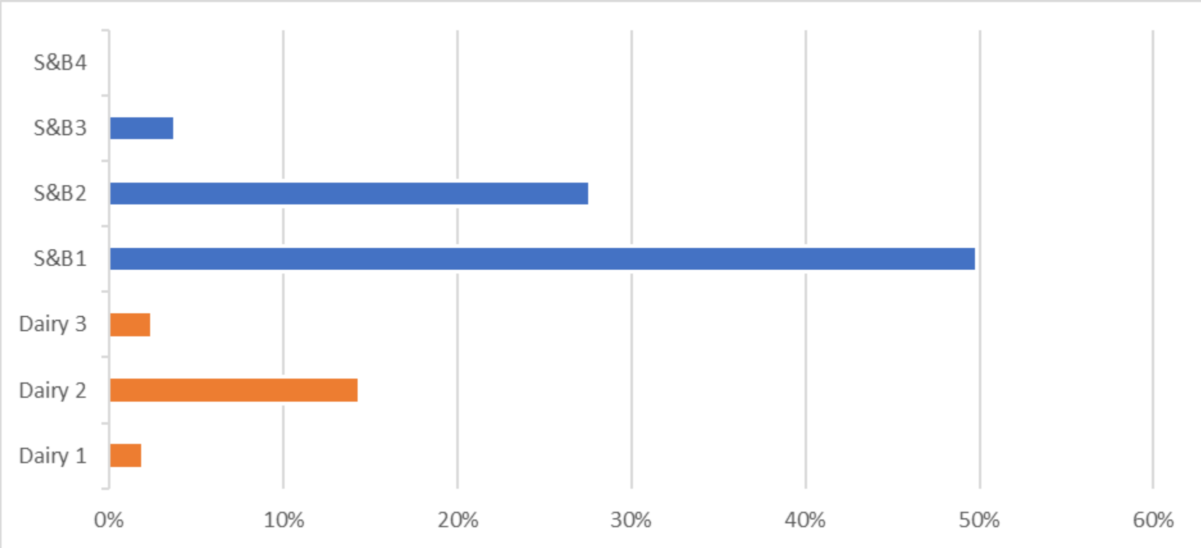


Table 28. Comparison of typology data versus modelled farm system for N losses within the North Otago FMU.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	13.5	14.6	2.5	19.7	43	36	34	29
Dairy 2	26.3	36.6	2.5	37.0	112	101	16	14
Dairy 3	14.0	13.8	2.5	18.0	23	19	14	13
S&B1	5.9	7.0	0.0	13.7	9.7	8.8	8.4	8.1
S&B2	5.8	7.3	4.5	7.5	7.2	6.9	6.7	6.3
S&B3	8.1	13.0	0.0	23.0	13.7	11.0	1.7	1.7
S&B4	0.0	0.0	0.0	0.0	12.8	11.8	11.8	9.3

Table 29. Comparison of typology data versus modelled farm system for P losses within the North Otago FMU.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.51	0.44	0.43	0.67	0.73	0.63	0.62	0.62
Dairy 2	0.69	0.64	0.48	0.87	2.0	1.56	0.83	0.83
Dairy 3	0.33	0.29	0.20	0.50	0.5	0.41	0.36	0.36
S&B1	0.44	0.41	0.00	1.00	0.23	0.20	0.20	0.18
S&B2	0.57	0.40	0.37	0.95	0.94	0.93	0.90	0.79
S&B3	0.48	0.42	0.00	1.27	1.26	0.90	0.21	0.21
S&B4	0.00	0.00	0.00	0.00	0.43	0.41	0.41	0.39

Table 30. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the North Otago FMU.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	10%	85%	87%	22%	59%	59%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	11%	80%	82%	21%	53%	53%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	23%
S&B2	4%	6%	12%	1%	4%	20%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	0%	0%	0%	0%	0%	0%
Total reductions: dry stock	9%	17%	21%	9%	15%	25%
Total reductions: All	10%	48%	51%	12%	24%	29%

Dunstan Rohe

Figure 15. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Dunstan FMU.

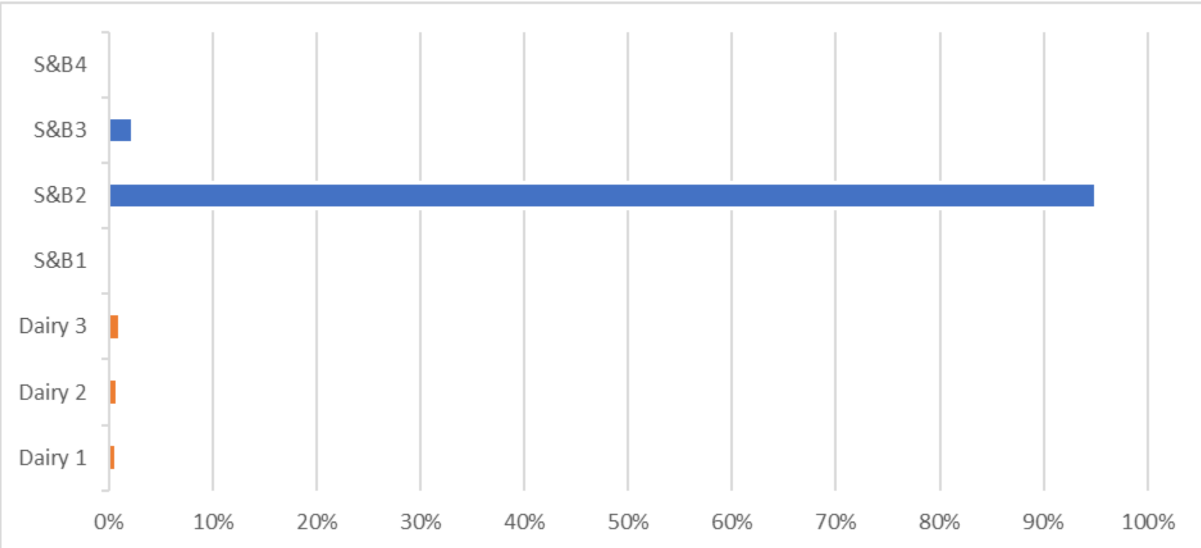


Table 31. Comparison of typology data versus modelled farm system for N losses within the Dunstan FMU.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	15.8	18.3	2.5	19.7	43	36	34	29
Dairy 2	33.9	36.7	27.8	37.0	112	101	16	14
Dairy 3	13.2	10.2	5.3	24.0	23	19	14	13
S&B1	4.8	10.6	0.0	12.0	9.7	8.8	8.4	8.1
S&B2	6.9	7.6	2.3	18.0	7.2	6.9	6.7	6.3
S&B3	10.4	16.1	3.0	23.0	13.7	11.0	1.7	1.7
S&B4	0.0	0.0	0.0	0.0	12.8	11.8	11.8	9.3

Table 32. Comparison of typology data versus modelled farm system for P losses within the Dunstan FMU.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.56	0.64	0.43	0.67	0.73	0.63	0.62	0.62
Dairy 2	0.70	0.64	0.48	0.87	2.0	1.56	0.83	0.83
Dairy 3	0.34	0.35	0.20	0.67	0.5	0.41	0.36	0.36
S&B1	0.44	0.41	0.00	1.40	0.23	0.20	0.20	0.18
S&B2	0.61	0.49	0.20	1.87	0.94	0.93	0.90	0.79
S&B3	0.75	0.56	0.30	1.43	1.26	0.90	0.21	0.21
S&B4	0.00	0.00	0.00	0.00	0.43	0.41	0.41	0.39

Table 33. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Dunstan FMU.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	10%	85%	87%	22%	59%	59%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	13%	62%	67%	19%	37%	37%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	20%
S&B2	4%	6%	12%	1%	4%	16%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	0%	0%	0%	0%	0%	0%
Total reductions: dry stock	5%	10%	15%	1%	6%	18%
Total reductions: All	6%	14%	19%	2%	7%	18%

Lower Clutha Rohe

Figure 16. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Lower Clutha Rohe.

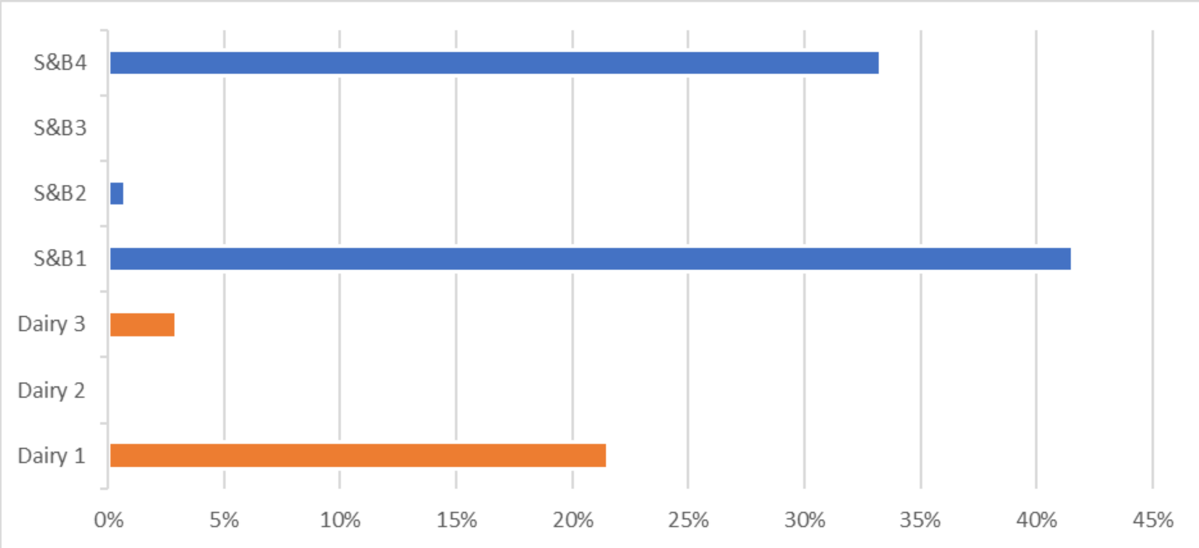


Table 34. Comparison of typology data versus modelled farm system for N losses within the Lower Clutha Rohe..

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	16.2	20.1	2.5	26.0	43	36	34	29
Dairy 2	0.0	0.0	0.0	0.0	112	101	16	14
Dairy 3	12.3	13.4	11.3	13.6	23	19	14	13
S&B1	6.1	7.5	2.3	16.0	9.7	8.8	8.4	8.1
S&B2	4.6	5.4	3.5	5.6	7.2	6.9	6.7	6.3
S&B3	0.0	0.0	0.0	0.0	13.7	11.0	1.7	1.7
S&B4	7.2	8.5	2.0	18.0	12.8	11.8	11.8	9.3

Table 35. Comparison of typology data versus modelled farm system for P losses within the Lower Clutha Rohe..

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.68	0.59	0.43	1.00	0.73	0.63	0.62	0.62
Dairy 2	0.00	0.00	0.00	0.00	2.0	1.56	0.83	0.83
Dairy 3	0.28	0.30	0.25	0.32	0.5	0.41	0.36	0.36
S&B1	0.48	0.41	0.18	1.60	0.23	0.20	0.20	0.18
S&B2	0.49	0.57	0.38	0.60	0.94	0.93	0.90	0.79
S&B3	0.00	0.00	0.00	0.00	1.26	0.90	0.21	0.21
S&B4	0.45	0.42	0.20	1.07	0.43	0.41	0.41	0.39

Table 36. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Lower Clutha Rohe.

	Nitrogen			**Phosphorus**		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	0%	0%	0%	0%	0%	0%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	**17%**	**22%**	**34%**	**14%**	**15%**	**15%**
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	23%
S&B2	4%	6%	12%	1%	4%	20%
S&B3	0%	0%	0%	0%	0%	0%
S&B4	8%	8%	27%	6%	6%	11%
Total reductions: dry stock	9%	11%	21%	**9%**	**11%**	**18%**
Total reductions: All	12%	16%	27%	**11%**	**12%**	**16%**

Manuherekia Rohe

Figure 17. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Manuherekia Rohe.

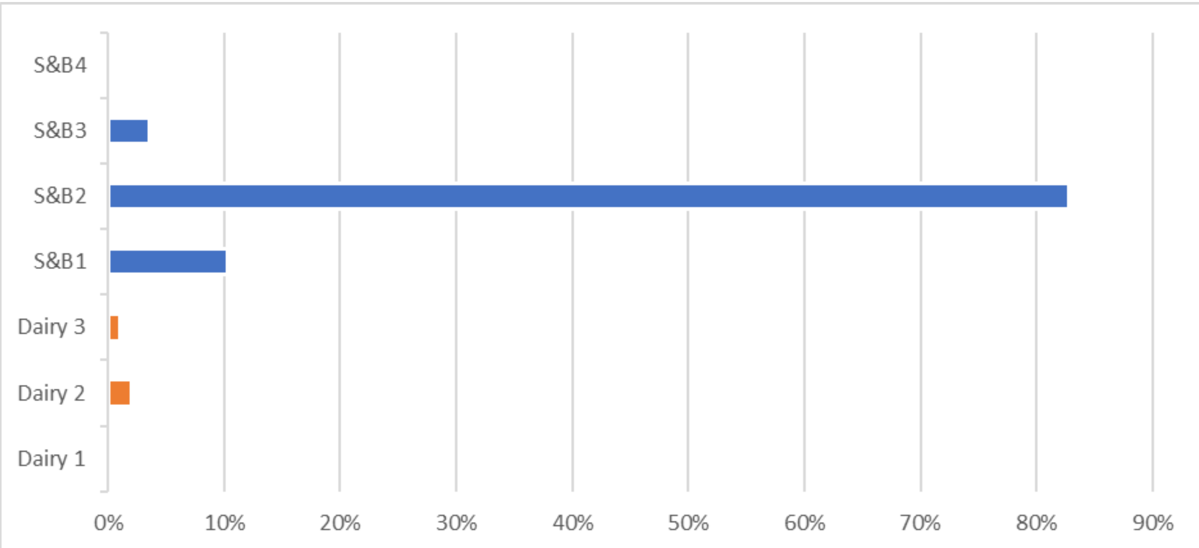


Table 37. Comparison of typology data versus modelled farm system for N losses within the Manuherekia Rohe.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	15.6	19.3	2.5	19.7	43	36	34	29
Dairy 2	29.5	37.0	2.5	37.0	112	101	16	14
Dairy 3	14.3	17.4	8.5	21.2	23	19	14	13
S&B1	6.1	6.4	0.0	8.7	9.7	8.8	8.4	8.1
S&B2	5.5	6.9	2.3	13.3	7.2	6.9	6.7	6.3
S&B3	9.3	14.8	0.0	23.0	13.7	11.0	1.7	1.7
S&B4	0.0	0.0	0.0	0.0	12.8	11.8	11.8	9.3

Table 38. Comparison of typology data versus modelled farm system for P losses within the Manuherekia Rohe.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.62	0.59	0.50	0.67	0.73	0.63	0.62	0.62
Dairy 2	0.72	0.64	0.50	0.87	2.0	1.56	0.83	0.83
Dairy 3	0.32	0.37	0.20	0.48	0.5	0.41	0.36	0.36
S&B1	0.44	0.34	0.00	0.95	0.23	0.20	0.20	0.18
S&B2	0.43	0.40	0.18	1.43	0.94	0.93	0.90	0.79
S&B3	0.60	0.51	0.00	1.43	1.26	0.90	0.21	0.21
S&B4	0.00	0.00	0.00	0.00	0.43	0.41	0.41	0.39

Table 39. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Manuherekia Rohe.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	10%	85%	87%	22%	59%	59%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	12%	74%	77%	21%	48%	48%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	20%
S&B2	4%	6%	12%	1%	4%	16%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	0%	0%	0%	0%	0%	0%
Total reductions: dry stock	6%	13%	18%	3%	9%	19%
Total reductions: All	7%	21%	25%	4%	11%	21%

Roxburgh Rohe

Figure 18. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Roxburgh Rohe.

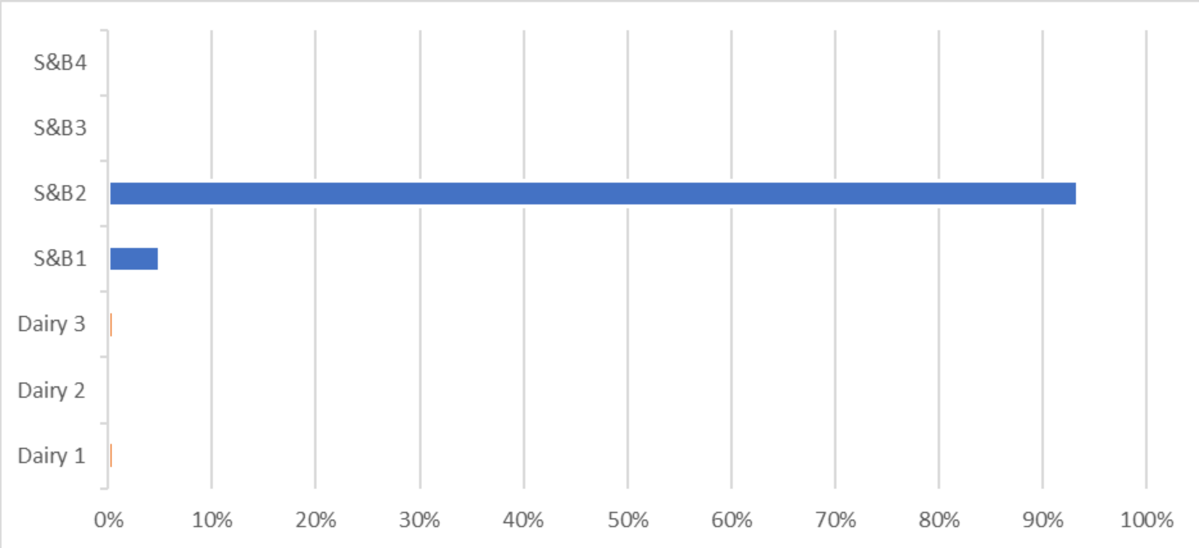


Table 40. Comparison of typology data versus modelled farm system for N losses within the Roxburgh Rohe.

Farm system	Typology data (kg N/ha)				Modelled outcomes (kg N/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	16.6	19.2	3.3	19.7	43	36	34	29
Dairy 2	20.6	27.6	2.5	27.8	112	101	16	14
Dairy 3	13.4	13.3	2.5	18.0	23	19	14	13
S&B1	5.1	5.9	2.3	7.7	9.7	8.8	8.4	8.1
S&B2	6.5	6.8	2.3	23.0	7.2	6.9	6.7	6.3
S&B3	12.6	12.5	8.0	23.0	13.7	11.0	1.7	1.7
S&B4	11.2	8.8	8.7	13.7	12.8	11.8	11.8	9.3

Table 41. Comparison of typology data versus modelled farm system for P losses within the Roxburgh Rohe.

Farm system	Typology data (kg P/ha)				Modelled outcomes (kg P/ha)			
	Average	Weighted average	Min	Max	Base	GMP	GMP+	GMP++
Dairy 1	0.61	0.59	0.43	0.67	0.73	0.63	0.62	0.62
Dairy 2	0.57	0.49	0.48	0.65	2.0	1.56	0.83	0.83
Dairy 3	0.32	0.30	0.18	0.50	0.5	0.41	0.36	0.36
S&B1	0.37	0.44	0.18	0.60	0.23	0.20	0.20	0.18
S&B2	0.46	0.42	0.18	1.27	0.94	0.93	0.90	0.79
S&B3	0.54	0.51	0.30	1.52	1.26	0.90	0.21	0.21
S&B4	0.60	0.41	0.40	0.80	0.43	0.41	0.41	0.39

Table 42. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Roxburgh Rohe.

	Nitrogen			Phosphorus		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	17%	21%	33%	14%	15%	15%
Dairy 2	10%	85%	87%	22%	59%	59%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	16%	36%	44%	16%	23%	23%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	20%
S&B2	4%	6%	12%	1%	4%	16%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	8%	8%	27%	6%	6%	11%
Total reductions: dry stock	5%	7%	12%	1%	5%	20%
Total reductions: All	5%	8%	13%	2%	5%	17%

Upper lakes Rohe

Figure 19. Proportion of land area assigned to each of the dry stock (blue) and dairy (orange) farm system models within the Upper Lakes Rohe.

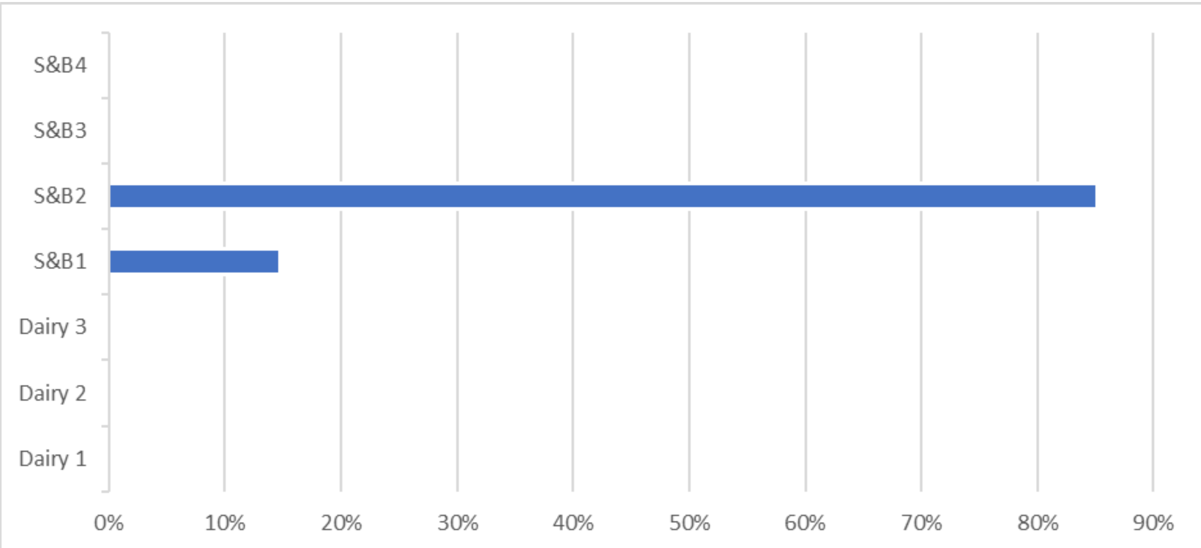


Table 43. Comparison of typology data versus modelled farm system for N losses within the Upper Lakes Rohe.

Farm system	**Typology data (kg N/ha)**				**Modelled outcomes (kg N/ha)**			
	Average	**Weighted average**	**Min**	**Max**	**Base**	**GMP**	**GMP+**	**GMP++**
Dairy 1	0.0	0.0	0.0	0.0	43	36	34	29
Dairy 2	0.0	0.0	0.0	0.0	112	101	16	14
Dairy 3	11.3	11.9	2.5	20.5	23	19	14	13
S&B1	10.4	13.5	0.0	21.3	9.7	8.8	8.4	8.1
S&B2	7.5	8.0	3.0	19.0	7.2	6.9	6.7	6.3
S&B3	9.0	9.0	9.0	9.0	13.7	11.0	1.7	1.7
S&B4	4.7	4.7	4.7	4.7	12.8	11.8	11.8	9.3

Table 44. Comparison of typology data versus modelled farm system for P losses within the Upper Lakes Rohe.

Farm system	**Typology data (kg P/ha)**				**Modelled outcomes (kg P/ha)**			
	Average	**Weighted average**	**Min**	**Max**	**Base**	**GMP**	**GMP+**	**GMP++**
Dairy 1	0.00	0.00	0.00	0.00	0.73	0.63	0.62	0.62
Dairy 2	0.00	0.00	0.00	0.00	2.0	1.56	0.83	0.83
Dairy 3	0.29	0.28	0.18	0.50	0.5	0.41	0.36	0.36
S&B1	0.46	0.49	0.00	1.20	0.23	0.20	0.20	0.18
S&B2	0.70	0.76	0.25	1.93	0.94	0.93	0.90	0.79
S&B3	0.30	0.30	0.30	0.30	1.26	0.90	0.21	0.21
S&B4	0.50	0.50	0.50	0.50	0.43	0.41	0.41	0.39

Table 45. Estimated reductions from application of GMP, GMP+ and GMP++ mitigation activities for dry stock and dairy farming systems within the Upper Lakes Rohe.

	Nitrogen			**Phosphorus**		
	GMP	GMP+	GMP++	GMP	GMP+	GMP++
Dairy systems						
Dairy 1	0%	0%	0%	0%	0%	0%
Dairy 2	0%	0%	0%	0%	0%	0%
Dairy 3	18%	40%	45%	20%	29%	29%
Total reductions: dairy	18%	40%	45%	20%	29%	29%
Dry stock systems						
S&B1	9%	14%	16%	12%	15%	20%
S&B2	4%	6%	12%	1%	4%	16%
S&B3	20%	87%	87%	28%	84%	84%
S&B4	8%	8%	27%	6%	6%	11%
Total reductions: dry stock	6%	8%	13%	2%	5%	16%
Total reductions: All	6%	8%	13%	2%	5%	16%