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Parliamentary Commissioner for the Environment

Land use modelling report: Mataura catchment in Southland/Murihiku

21 August 2023

CONFIDENTIAL

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2	Second draft with 2B results added
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4	Final draft
5	Final report
6	Additional appendices added - draft
7	Additional appendices added - final

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Glossary

Agricultural emissions levy

In June 2022, the He Waka Eke Noa partnership recommended to Government that a farm-level, split-gas levy be used to price emissions from 2025 instead of the ETS. The emissions levy refers to the price farm businesses will have to pay per kilogram of methane, nitrous oxide and carbon dioxide gas emitted from their farm systems. A pricing pathway has been provided in the Appendices.

Agricultural utilisation

Within the Nature Braid model, a measure of how the land is being used for agriculture, relative to its capacity to support agriculture based on soil and topography characteristics.

Agricultural utilisation – optimal / not optimal

If land is predicted by the model to be highly suitable for agriculture, and is also being used for agriculture, then the Nature Braid model will consider this optimal. However, if land is predicted to be marginal or less suitable for agriculture, and it is currently being used for agriculture, then the model will consider this not optimal.

Agricultural utilisation status

This output combines the current and predicted optimal output but in a different way to the relative agricultural utilisation output category. Rather than being concerned with direction of change (under or over utilisation), it considers whether the current agricultural utilisation may be worthy of preservation or change. For more information, see Appendix 2.

Average flow class

This output is a classified version of average water flow, in cumecs (m^3/s). Flow delivery to all points in the river and lake networks are classified into five categories: <1 m^3/s, 0.1-1 m^3/s, 1-10 m^3/s, 10-100 m^3/s, >100 m^3/s.

Baseline 2025

The ‘current’ year of 2025, to which the five modelled policy scenarios are compared. We assume that land use remains similar to current/recent conditions until 2025, when levies are introduced, providing a 2025 environmental baseline for all scenarios.

C-factor

The ratio of soil loss expected from a landscape under a particular land use/cover (e.g., cropping, forest, etc) to what is expected from land under clean-tilled continuous fallow. The C-factor is unitless, ranging from 0 for land cover with no soil (e.g., water bodies, bare rock) to 1.0 for bare soil. This is used within the RUSLE model.

Carbon dioxide equivalent (CO_2-eq) emission

This is defined by the IPCC (2022) as “The amount of carbon dioxide (CO2) emission that would have an equivalent effect on a specified key measure of climate change, over a specified time horizon, as an emitted amount of another greenhouse gas (GHG) or a mixture of other GHGs. For a mix of GHGs, it is obtained by summing the CO2-equivalent emissions of each gas. There are various ways and time horizons to compute such equivalent emissions (see greenhouse gas emission metric). CO2-equivalent emissions are commonly used to compare emissions of different GHGs but should not be taken to imply that these emissions have an equivalent effect across all key measures of climate change". For further information see https://www.ipcc.ch/

Clear-fell harvesting / clear-felling

A forestry practice which involves the cutting down/harvesting of an entire stand of trees within a commercial forest.

Classified Nitrogen accumulated load

This output combines the predictions of accumulated total N load with user specified thresholds, to categorise the nutrient loading into very low to very high categories.

Classified Nitrogen in-stream concentration

This output combines the predictions of N stream concentration with the user specified thresholds, to categorise the concentration into very low to very high categories.

Classified Phosphorus accumulated load

This output combines the predictions of accumulated total P load with user specified thresholds, to categorise the nutrient loading into very low to very high categories.

Classified Phosphorus in-stream concentration

This output combines the predictions of P stream concentration with the user specified thresholds, to categorise the concentration into very low to very high categories.

Current agricultural utilisation

This output shows utilisation according to current land cover/use, ignoring predicted production capacity. Uncertainty is reliant on the accuracy of land cover/land use data. Arable and improved grassland are considered to be highly productive, for example, while bare ground, or built infrastructure such as railways and roads, are considered to provide no agricultural utilisation

Discount rate

The percentage rate at which the present value of money is considered to decrease over time. For the purpose of this study a 5% discount rate has been assumed. However, this is further explored in a sensitivity analysis.

Economic Farm Surplus (EFS)

A measure of farm profitability considering revenue less farm expenses (including wages), but excluding any tax or investment costs (rent, lease, interest or return on capital).

Flood interception classification

This output shows the flood mitigation layer, which is influenced by soil, land use, topography, and climate. It identifies high-priority areas where land is not mitigated by any vegetation and where flow is either being generated or accumulated. Potential sources of error include inaccuracies in land use input data or Nature Braid classification of land cover as mitigating or not-mitigating.

Failure to account for storage capacity of deep soils in non-wetland areas, or faster runoff in urban areas with paved surface may reduce accuracy of mapping of areas of high and low flood concentration.

Flood mitigation classification

This output shows the mitigation classification of the current soil/land use and areas. Potential sources of error include inaccuracies in land use input data or Nature Braid classification of land cover as mitigating or not-mitigating, as well as failure to account for soil permeability.

Habitat connectivity

This output highlights areas of ideal habitat based on land use/cover and user-defined thresholds of minimum habitat size. It uses information about species ability to travel through hostile terrain to highlight how far it can travel from patches of ideal habitat.

He Waka Eke Noa (HWEN)

He Waka Eke Noa – the Primary Sector Climate Action Partnership was formed in 2019 to design a practical, credible, and effective system for reducing emissions at farm level, as an alternative to government policy to bring agriculture into the New Zealand Emissions Trading Scheme (NZ ETS). Refer to https://hewakaekenoa.nz/ for more information.

High levy pathway

The high emissions pricing pathway starts in 2025 at \$1.06 per kg CH_4 and \$42.50 per tCO_2-eq from N_2O/CO_2. The levy rate starts with a 50% discount in 2025, which reduces by 7.1 percent per year (pp yr-1).

Low levy pathway

The low emissions levy pathway starts in 2025 at \$0.11 per kg CH_4 and \$4.25 per tCO_2-eq from N_2O/CO_2. The levy rate starts with a 95% discount in 2025, which reduces by 1 percent per year (pp yr-1).

Medium levy pathway

The medium levy was calculated using the low levy + 40% of the difference between the low levy and the high levy. This pathway starts in 2025 at \$ 0.49 per kg CH_4 and \$19.60 per tCO_2-eq from N_2O/CO_2

N fertiliser cap

A maximum limit on the amount of synthetic nitrogen (N) fertiliser that may be applied. For both the Wairoa and Mataura catchments the limits of 85 kg N/ha/year have been applied for 2030, and 65 kg N/ha/year for 2060.

N high-risk

Areas classified as “high” within the Nitrate-Nitrite-Nitrogen (NNN) output of Land and Water Science.

Nitrogen accumulated load

This output shows the accumulated total N load (in kg/yr), considering the load not just at a point (depending on modified export coefficients which are influenced by rainfall, irrigation, fertiliser, effluent, and stock), but also that contributed from "uphill" sources. N accumulated load is estimated based on terrestrial nutrient loads combined with topographic routing and effective precipitation to route water through the landscape. High values are prime targets for mitigation or interception opportunities. Accuracy reflects that of the input data on land use and the relevant Nature Braid export coefficient, as well as the DEM and topographic routing approach used to model accumulation. The output can be used to extract total N accumulated load (kg/yr) at any point.

NZ ETS

The New Zealand Emissions Trading Scheme (NZ ETS), a key tool for meeting our domestic and international climate change targets, including the 2050 target set by the Climate Change Response Act 2002. Refer to https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/ets/ for more information.

Phosphorus accumulated load

This output shows the accumulated total P load (in g/yr), considering the load not just at a point (depending on modified export coefficients which are influenced by rainfall, irrigation, fertiliser, effluent, and stock), but also that contributed from "uphill" sources. P accumulated load is estimated based on terrestrial nutrient loads combined with topographic routing and effective precipitation to route water through the landscape. High values are prime targets for mitigation or interception opportunities. Accuracy reflects that of the input data on land use and the relevant Nature Braid export coefficient, as well as the DEM and topographic routing approach used to model accumulation.

Predicted optimal agricultural utilisation

This output ignores the input land cover and instead predicts a near-optimal utilisation based on soil water holding characteristics, fertility, elevation, slope, aspect. For more information, see Appendix 2.

Productive land

Land identified by Nature Braid with "high or very high" productive capacity based on slope, fertility, aspect, and drainage.

Relative agricultural utilisation

This output is calculated from a comparison of predicted optimal agricultural utilisation and current agricultural utilisation outputs. It flags where land appears to be over or under-utilised. For more information, see Appendix 2.

Riparian planting

Indigenous (New Zealand native) vegetation planted by streams and other waterways.

Risk of sediment delivery

This output shows sediment delivery vulnerability depending on whether the soil loss (using 'Soil loss risk') is occurring on non-mitigated land.

RUSLE

Revised Universal Soil Loss Equation

Sediment high-risk

Areas susceptible to erosion and sediment delivery based on either LWS (high Sediment and Pathogen Susceptibility) or NB (high sediment delivery)

Sequestration payment

In this report, “sequestration payment” refers to the financial payment for carbon sequestered from planting forestry, within the NZETS,

Soil loss risk

This output shows the risk of soil loss based on Terrestrial soil erosion and user-defined thresholds.

Stocking rate

An indicator of farm intensity measured in stock units per hectare (SU/ha). A stock unit in FARMAX is calculated by dividing the total intake in standard DM (10.8 MJME/kgDM) eaten by 550kgDM. This is the approximate annual feed requirement of a 55kg breeding ewe rearing a single lamb.

Terrestrial N loads

This output shows the total N load (kg/ha/yr) generated at any point within the landscape, considering the load at a point, depending on modified export coefficients which are influenced by rainfall, irrigation, fertiliser, effluent, and stock. Proportion of dissolved vs. particulate N needs to be defined by the user. The default value is 0.8. Nitrate and ammonium are treated separately as nitrate is more soluble while ammonium somewhat sorbed.

Terrestrial P loads

This output shows the total P load (g/ha/yr) generated at any point within the landscape, depending on modified export coefficients (which is influenced by rainfall, irrigation, fertiliser, effluent) together with Olsen P and topography. Proportion of dissolved vs particulate P needs to be defined. The default value is 0.3. Particulate and dissolved species are considered separately.

Terrestrial soil erosion by water

This output shows the annual soil loss by water using the RUSLE (Revised Universal Soil Loss Equation) which considers rainfall, soil, land use/cover, management, and topography. The rainfall factor uses the New Zealand constants formulated by Klik et al. (2015) and the user is referred to that article to find the constants for their study area.

Total Nitrogen in-stream concentration

This output shows total N concentration (in mg/L) at all points in-stream. High values suggest that the catchment of this point should be targeted for mitigation/interception opportunities. N in-stream concentration is influenced by N accumulated load and stream attenuation. This is subject to errors in the input (or modelled intermediate) spatial data layer for the river network, in addition to any sources of inaccuracy in the modelled accumulated terrestrial nutrient concentration.

Total Phosphorus in-stream concentration

This output shows total P concentration (in mg/L) at all points in-stream. High values suggest catchment of this point should be targeted for mitigation/interception opportunities. P in-stream concentration is influenced by P accumulated load (below) and stream attenuation. This is subject to errors in the input (or modelled intermediate) spatial data layer for the river network, in addition to any sources of inaccuracy in the modelled accumulated terrestrial nutrient concentration.

Untargeted revenue recycling

Recycling of agricultural emissions levy funds for the implementation of land management practices and farm system changes that improve freshwater quality, protect/enhance biodiversity and reduce emissions, using broad policy approaches that do not take into account the specific features of the catchment.

LAND USE TYPES

Dairy

A modelled land use type within this study (using FARMAX and Nature Braid). This is modelled in FARMAX as a dairy cow system with peak 770 Friesian cross cows milked on 250 ha with a 120 ha support block on which replacements are grazed and cows wintered on a fodder beet crop, producing 940 kgMS/ha with an EFS of $3595/ha.

Dairy Support

A modelled land use type within this study (using FARMAX and Nature Braid). This is modelled in FARMAX as a 200 ha dairy support unit, grazing 128 replacement calves from December through to 22 months; 500 mixed age cows are wintered on crop and baleage made on farm; bull beef is also finished on farm; EFS of $374/ha.

Exotic Forestry

A modelled land use type within this study (using simple economics and Nature Braid). Productive forestry based on non-native tree species. The example used within this study is pine (*Pinus radiata*).

High Country Sheep and Beef

A modelled land use type within this study (using FARMAX and Nature Braid). This is modelled in FARMAX as 8,000 effective hectares running 2 stock units per hectare at a sheep to beef ratio of 75:25. 60% of lambs are finished, 60% of beef sales are prime, also grazing mixed age dairy cows. 38 kg meat + wool/ha. EFS = $96/ha.

Hill Country Sheep and Beef

A modelled land use type within this study (using FARMAX and Nature Braid). This is modelled in FARMAX as 1500 effective hectares running 5 stock units per hectare, sheep to beef ratio is 80:20. 3200 mixed age ewes and 200 mixed age cows are wintered, finishing 70% of lambs. 40% of cattle sold are prime. 96.5 kg meat + wool/ha. EFS is $244/ha.

Horticulture (Tulips)

A modelled land use type within this study (using simple economics and Nature Braid). As tulip growing is an existing land use in the catchment, this was used as an example of a high value use in the model. A simple system was developed including the rate and timing of N and P fertiliser inputs and per hectare economic returns. To estimate GHG emissions, the HortNZ GHG calculator was used. Horticulture (Tulips) was only able to transition into very high productive capacity land.

Indigenous Vegetation

A modelled land use type within this study (using simple economics and Nature Braid). Existing or new non-productive plantings of New Zealand native species, that is not predominantly trees but may include some trees.

Lowland Sheep and Beef

A modelled land use type within this study (using FARMAX and Nature Braid). This is modelled in FARMAX as 330 ha breeding/finishing farm running 11.6 stock units per hectare. Sheep to beef ratio of 90:10% with no breeding cows on farm. 289kg meat + wool /ha. EFS is $711/ha.

Mixed Cropping

This is modelled in FARMAX as predominant income from cash cropping with 250ha in crop, and 158ha in pasture. Main crops are barley, wheat, and oilseed rape. Sheep: Beef ratio is 25:75 with 500 mixed age ewes wintered and 330 mixed age dairy cows wintered on forage crop. 200 weaner steers are purchased and finished on farm. 252 kg meat + milk/ha. EFS = $1665/ha

Sheep Dairy

A modelled land use type within this study (using simple economics and Nature Braid). A representative system has been developed for the Mataura catchment. The minimum farm size is 50 ha. The system is pasture based and milking 850 ewes at peak, producing 57.6 kgMS/ewe/season. The estimated EFS is $5000/ha. GHG emissions have been calculated manually using the FARMAX Lowland Sheep and Beef system as a proxy where information was required.

Totara Forestry

A modelled land use type within this study Productive forestry with (*Podocarpus totara*). A specific example of indigenous forestry that has been used within this study.

Wetland

Areas on top of very poorly drained soils that become covered by shallow standing water, whether seasonally/ephemerally, and are able to support flora and fauna suitable for wet conditions or in the liminal spaces between terrestrial and aquatic ecosystems (Ausseil et al., 2008)

Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for the Parliamentary Commissioner for the Environment (PCE) (**'Client'**) in relation to modelling potential land use change under different future policy scenarios ('**Purpose**') and in accordance with the contract titled 'Consultancy Contract to Perform an Assignment for the Parliamentary Commissioner for the Environment' with the Client dated 26th January 2022 ('**Contract**'). The findings in this Report are based on and are subject to the assumptions specified in the Report and the Contract. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

In preparing the Report, WSP has relied upon data, surveys, analyses, designs, plans and other information ('**Client Data'**) provided by or on behalf of the Client. Except as otherwise stated in the Report, WSP has not verified the accuracy or completeness of the Client Data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this Report are based in whole or part on the Client Data, those conclusions are contingent upon the accuracy and completeness of the Client Data. WSP will not be liable in relation to incorrect conclusions or findings in the Report should any Client Data be incorrect or have been concealed, withheld, misrepresented, or otherwise not fully disclosed to WSP.

Acknowledgements

It is important to acknowledge that this modelling exercise has taken place within the broader context of the overall Landscapes project, including wide-ranging conversations by the PCE with stakeholders both within the two catchments and more broadly, and other contracted providers. This includes work by Land and Water Science (LWS) on physiographic layers; as well as separate work to explore Māori perspectives for the Mataura catchment.

For the specific purpose of this modelling exercise, a range of expert discussions and stakeholder engagement activities were undertaken to ensure relevance, as well as informing stakeholders of progress with the project. Two workshops were carried out: One online, at the start of the project; and one in person to critique the modelling of the first three scenarios, provide lessons and promote rich discussion on the difference between an untargeted and a landscape approach. These workshops were invaluable and much gratitude is due to the participants who invested their time and expertise in supporting this though exercise.

Particular thanks is due to Thriving Southland, who kindly provided advice on multiple occasions and supported the connection with appropriate locals, including farmers. In addition, a range of industry experts have contributed their time and knowledge to this process.

While it is impossible to list here everyone who has contributed to this project to date, throughout the text we have indicated where specific advice was provided. It should be emphasised that the provision of advice in no way indicates responsibility of the provider for the way in which that advice was incorporated into the modelling. In this, as in any modelling exercise, all models are wrong. However, we are extremely grateful to all those who helped us make this particular exercise more relevant and useful.

Executive Summary

The Parliamentary Commissioner for the Environment (PCE) is investigating what an integrated landscape approach looks like in Aotearoa New Zealand and its potential to improve freshwater quality, climate change and biodiversity outcomes. Scenarios are being explored in the Mataura catchment (Southland/Murihiku) and the Wairoa catchment (Northland/Te Tai Tokerau).

This report provides an overview of the modelling approach and results of the five modelled scenarios in the Mataura catchment, intended to explore the research question:

Could an integrated landscape approach enable rural communities and tangata whenua to achieve better climate, water, soil, and biodiversity outcomes than an untargeted approach?

By assessing potential land use change under different future policy scenarios, this project aims to shed light on how some of the major policy levers under consideration might impact on land use, and hence people and their environment.

As with any future modelling scenarios, there are significant limitations on the accuracy with which both the current and future landscape can be modelled. There are a wide range of variables and uncertainties beyond the scope of this work. Multiple assumptions, simplifications and subjective choices were required in order to bring together the different disciplines, scales, and models used for this work. In all such choices, the aim has been not to propose, recommend or predict the impacts of a specific future policy, but rather to highlight the trade-offs between different policy approaches as a thought exercise. The intent is to stimulate useful, science-based, and policy-focussed conversations about some of the future pathways under consideration.

Approach

To represent the impact of policy choices in the Mataura catchment, five policy scenarios were developed to explore the research question for three timesteps; 2025, which is referred to as the ‘baseline’, 2030 and 2060. These were explored using an ensemble of models: the Nature Braid to explore spatial environmental impacts; Farmax to represent pastoral farming systems; and a broader economic analysis including a simple representation of other land use types, to explore land use change.

For each scenario, either a high or low agricultural emissions levy rate is represented. Scenarios 1A and 2A, using a low levy rate, the levy is considered to be used for national level research on reducing greenhouse gas emission, and is not directly recycled back into the catchment. For the high levy rate scenarios (1B, 2B and 2C), a proportion of the funds generated by the higher levy rate is assumed to be available for recycling back into the catchment in either an untargeted (1B) or targeted (2B and 2C) manner.

Scenarios 1A and 1B represent untargeted policy approaches. Scenario 1A is intended to represent the current trajectory, based on a low levy rate. In scenario 1B, revenue from the levy is channelled or ‘recycled’ back into the catchment in the form of a subsidy for stocking rate reductions, and support for Riparian Planting and planting of other Indigenous Vegetation. Scenario 2A, the first of the targeted or landscape-driven scenarios, is based on the low emissions levy and explores a targeted reduction in allowable synthetic fertiliser for nitrogen (N) and phosphorous (P), for areas in the catchment identified as high-risk for those nutrients. Scenario 2B, like 1B, is based on the high emissions levy and revenue from the higher levy is recycled back into the catchment. Funding is spent in a targeted manner on subsidising conversion to Sheep Dairy; converting waterlogged, marginal land to wetlands; Riparian Planting and the creation of some constructed wetlands.

Scenario 2C is based on 2B, but also investigates the option of phasing out forestry from the ETS and using the funds equivalent to what would have been paid for sequestration as a "multipurpose fund" to support environmentally beneficial initiatives – principally, subsidising Totara (*Podocarpus totara*) Forestry in place of Exotic Forestry with pine (*Pinus radiata*). Scenario 2C also uses the multipurpose fund for planting Indigenous Vegetation in gullies.

To represent land use, six representative farm 'types' were set up in the model FARMAX based on the main land use types in the Mataura catchment, covering Dairy, Dairy Support, three different Sheep and Beef systems (High Country, Hill Country, and Lowland) and one Mixed Cropping farm. These modelled farms were drawn into a broader economic analysis to explore land use changes under the different scenarios. Exotic and indigenous (Totara) Forestry, Sheep Dairy, and Horticulture (Tulips) are represented in simple economic models Indigenous Vegetation and Wetlands are considered non-economic and used generic parametrisation averaging over evidence between individual, undisturbed species.

For the purpose of this thought exercise, land use change is assumed to occur for three main reasons:

1) Loss of profitability: If profitability drops to $0/ha, the land use will change to a more profitable use;
2) Highly profitable alternative land use with short-medium term returns: In the case of the example highly profitable Horticulture alternative (Tulips) the available land is assumed to transition due to the high profitability and lack of investment required by the landowner (in this case, available land is leased by the tulip grower);
3) Where land use change is promoted and subsidised for environmental benefit, as is the case with the Sheep Dairy and Totara Forestry systems.

The broader economic analysis also included a cost for interventions (such as the cost per hectare for riparian and other native planting, or conversion to wetlands). The Nature Braid team have used the GIS information available to assess land areas available for, or affected by, each intervention. The economic assessment has provided non-spatial land use change tables, related to the "potential productivity" of the land based on categories identified in the Nature Braid model and existing land use. This information was then mapped onto the landscape and fed into the Nature Braid model to provide spatially explicit assessments of the environmental impacts of the different scenarios.

The first three scenarios and estimates of their potential impacts were presented to a group of stakeholders in the Mataura catchment at a workshop on the 21st of July 2022, forming the basis for discussion on mitigations to be implemented in the final two scenarios: 2B and 2C. Both of these scenarios (2B and 2C) are targeted/landscape-driven with a high levy rate, and the excess levy is recycled back into the catchment to support mitigations that will benefit the environment. In scenario 2C, the NZETS is be phased out, and instead, revenue available to the catchment is supplemented by central government funding for actions that recognise multiple benefits beyond carbon sequestration.

Summary of results and key observations by scenario

Scenario 1A provided a baseline under the lower emissions levy. In this scenario, the most significant land use change is an increase in Horticulture (Tulips) growing to cover most of the highly productive land but limited by the requirement for a six-year rotation. The emissions levy reduces but does not eliminate profitability of the pastoral land uses, until 2060. By 2060, the emissions levy has led to High Country Sheep and Beef farms becoming unprofitable and the land moving to another use. For the purposes of this modelled thought exercise, it is assumed that this land will change to Exotic Forestry.

Scenario 1B, under the high emissions levy, provides a more dramatic picture of change: In this scenario, Horticulture (Tulips) growing also increases significantly. By 2030, all High-Country farms have moved to Exotic Forestry or Indigenous Vegetation, and the Hill Country stocking rate is reduced by 58% (that is, to 42% of the baseline). Riparian planting has been completed for the whole catchment. By 2060, all Hill Country farms have moved to Exotic Forestry, and all Lowland Sheep and Beef farms are subsidised down to 58% of baseline. Methane emissions and *E. coli*, reduce significantly due to reductions in stocking.

The high levy rate drives significant land use change. The overall results suggest that some types of sheep and beef farm in particular may be very heavily impacted by the levy. This further validates the findings of other, more in-depth recent modelling studies such as the recent report by Beef + Lamb NZ (2022) which was based on an analysis of 452 actual farms from the B+LNZ Sheep and Beef Farm Survey.

Reducing stocking rates is not viable economically even with pressure of the levy. Unless subsidised, it is likely that most farms will simply pay the levy and become less profitable.

It is assumed that the pressure on the economic use of land will continue to lead to transitions to higher value uses. Horticulture (Tulips) have been used to illustrate this point, and although this will not be the only high value use change, it provides an example of movement in this direction. For this exercise, the transition towards these high value uses have only been constrained on the basis of land availability, however there are likely to be other constraints (market, capital, etc).

Considering the potential growth in high value horticulture/floriculture, it will be important to consider their environmental impacts. Work is already underway by Environment Southland and tulip growers to assess their environmental impact and ensure best practice. These may extend beyond nutrient issues; however, pesticide and herbicide applications were beyond the scope of the present study.

Among other secondary factors, the type of forestry utilised will have an important bearing on the broader environmental impacts. In the 1B scenario, the Riparian Planting and other Indigenous Vegetation intercepts and holds significant water and sediment flow and associated contaminants (e.g., nutrients) prior to it reaching streams. This was clearly seen in the in-stream N and P concentrations which had a small reduction in the mean concentration over the catchment, but larger reductions in high concentrations. The flow mitigation results show that although forestry and Riparian Planting only directly changed ~70,000 ha of the catchment, this planting also mitigated/benefited an additional ~150,000 ha of the catchment by slowing rapid water flow generated uphill of the planting and catching sediment and nutrients enroute to the streams. The Riparian Planting led to some “implicit” spatial landscape targeting being embedded n 1B.

In *Scenario 2A*, two levels of nutrient limits are applied to the identified high-risk areas for N and P synthetic fertiliser, respectively: For 2030, the limits are set at 85kg N/ha/yr and 25kg P/ha/yr. For 2060, this drops to 65 kg N and 20kg P/yr. At 2030 levels, Horticulture (Tulips) growing is still considered economic, however arable and forage crops are no longer grown in these areas. Pasture growth is reduced for the Dairy and Dairy Support systems for each of these steps. The restrictions on synthetic fertiliser application under scenario 2A had negligible impacts on Phosphorus fertiliser as inputs, as the high-risk areas for P already applied low rates of fertiliser. However, Nitrogen fertiliser was restricted and so benefits in-stream are seen. The interventions in

2A bring slight decreases in N and P in-stream concentrations. The significant increase in Exotic Forestry in 2A 2060 leads to higher risk of soil loss.

There is also some potential for perverse effects from this scenario when it comes to greenhouse gas emissions: The fertiliser restrictions could potentially drive land out of cropping and into pastoral systems, thereby increasing overall stocking rates and hence methane emissions.

In ***Scenario 2B***, a targeted “landscape” approach guides application of the funds generated by the higher emissions levy. The fund is applied to a) A subsidy to assist farmer transition to Sheep Dairy; b) restoration of wetlands where the land already tends to be waterlogged; c) Riparian planting including flax around the wetland areas; and d) the creation of some constructed wetlands.

Mitigation options applied in this scenario (2B) lead to significant decreases in the in-stream N and P concentrations, much more than in previous scenarios including scenario 1B and 2A. Noticeably, with wetlands, flax, and Riparian Planting in 2B by 2060, the mean in-stream N concentration is reduced by almost two times and the mean in-stream P concentration reduced by three times compared to the baseline. The interventions in 2B also bring larger benefits of flow mitigation compared to scenario 1B.

Restoring wetlands in waterlogged areas provides an efficient approach to retiring farmland - land with very poor drainage is targeted for conversion to wetlands; these areas are the cheapest to convert back to wetlands, have high impact on nutrient flows and tend to be problem areas for farmers due to the cost of maintaining drains and deterioration of productivity when not maintained. Highly productive land remains in farming either by enabling the farm to concentrate on the best land or by a subsidised a change to Sheep Dairy. This subsidy is modelled as a per hectare pay out but could equally well be implemented as a contribution to the development of infrastructure and marketing. The results from this scenario also demonstrate the value of landscape modelling for policy decisions; the interconnected nature of a catchment highlighting the flow on impacts of interventions.

In ***Scenario 2C***, newly registered forestry carbon credits are phased out of the NZ ETS from 2030. A multi-benefit fund is established to facilitate environmentally beneficial activities. The new fund is modelled to be approximately equivalent to sequestration benefits that would have been paid out under the NZ ETS. In this scenario, targeted mitigations and land use change occur as they do in Scenario 2B (funded by the levy) except that all land conversion to Exotic Forestry (pine) is instead converted to Totara Forestry with the multi-benefit fund subsidy covering the difference between totara and pine; and extra funds are used for targeted gully planting. The planting of totara instead of pine and targeted gully planting at high flow concentrations, together with Sheep Dairy, Riparian Planting, and wetland restoration in this scenario, reduces the mean in-stream nutrient concentrations and sediment delivery to a much greater extent than in all previous scenarios. The mitigations in 2C also provide significant benefits for flood mitigation and kererū habitat connectivity.

Following consultation in the Mataura, three additional scenarios were requested by the PCE after the completion of the first five scenarios. These were intended to explore: A-12: A new agroforestry systems applied to three farm systems (based on the original 2B scenario); A – 13: the impact of converting marginal land to indigenous vegetation (based on the original 1A scenario); and A – 14: the conversion of land above 600m from sheep and beef to tussock grassland (based on the original 2B scenario).

These additional scenarios are not discussed in the main report but have been included as a separate summary in Appendices A - 12, A - 13 and A – 14, respectively.

1 Introduction

The Parliamentary Commissioner for the Environment (PCE) is investigating what an integrated landscape approach looks like in Aotearoa New Zealand and its potential to improve freshwater quality, climate change and biodiversity outcomes. For this purpose, the PCE has engaged WSP, in partnership with Nature Braid, to conduct a modelling exercise in two case study catchments: the Mataura catchment in Southland/Murihiku and the Wairoa catchment in Northland/Te Tai Tokerau. This report focuses on the Mataura catchment.

The primary research question guiding this thought experiment is:

Could an integrated landscape approach enable rural communities and tangata whenua to achieve better climate, water, soil, and biodiversity outcomes than an untargeted approach?

To help answer the research question, five scenarios were developed by the PCE, WSP and Nature Braid in consultation with stakeholders at three timesteps: 2025 (referred to as the 'baseline', 2030 and 2060. These scenarios formed the basis for exploring the research question together with stakeholders in the two catchments. Further details of the scenarios are provided in Section 3 and Appendix A1 - Overview of policy scenarios for Mataura.

- **Scenario 1A:** Low levy, untargeted freshwater regulations.
- **Scenario 1B:** High levy, funds 'recycled' back into the catchment though untargeted policies.
- **Scenario 2A:** Low levy, targeted limits on synthetic fertilisers for high-risk areas.
- **Scenario 2B:** High levy, targeted revenue recycling.
- **Scenario 2C:** High levy, forestry phased out from New Zealand Emissions Trading Scheme (NZ ETS).

As part of this process, engagement with stakeholders in the Mataura catchment was undertaken. This included two workshops – one online, at the start of the project, and one in person after the first three scenarios had been completed. In addition, advice was sought from a range of local landowners and experts to help validate the modelling set ups and approach. The results of the first three scenarios (1A, 1B and 2A) were shared at the second Mataura workshop, held in person in Southland on the 21st of July 2022. Feedback from the workshop around the scenarios and the modelled impacts of the first three scenarios has been used as a basis to develop the approach and mitigations for the final two scenarios (2B and 2C).

This modelling exercise has sought to:

- Illustrate how land management practices and land uses in the two case study catchments might change in future in response to an untargeted approach to environmental policy;
- Estimate the associated changes in environmental and economic indicators that would be expected to result from these future changes in land management practices and land uses; and
- Consider how the results might differ if a targeted 'landscape' approach were taken to environmental policy interventions.

The following factors are considered to be beyond the scope of the present modelling exercise:

- The impacts of climate change on productivity and land use suitability;
- Other land uses (than those specified under Section 2.4), such as forest land planted exclusively for carbon credits (carbon forestry) and land used for multiple purposes (e.g., agroforestry);
- New technologies to reduce on-farm environmental impacts that could become available in the future (e.g., a methane vaccine);
- Non-forestry removals of greenhouse gases (e.g., by soils, marine plants); and
- Other environmental issues such as water quantity (droughts floods, etc) and heavy
- metals or synthetic chemical contaminants in the environment.

2 Approach and methodology

To explore the research question, a hybrid approach has been developed. The approach taken integrates a set of modelling tools (FARMAX, Economic analysis and Nature Braid) that when combined, can provide insights into both the environmental and economic factors under analysis.

A high level explanation of the overall process is detailed in the subsequent Section 2.1, with each of the components described in Section 2.2 to Section 2.4. Detailed scenario descriptions and assumptions of these are described in Section 3.

2.1 Overview of process

A schematic of the modelling tools used to address the research question is shown in Figure 2-1.

The combination of these tools has been used to explore the 'untargeted' and 'targeted' landscape scenarios for the present (i.e., baseline, 2025), 2030 and 2060 time steps.

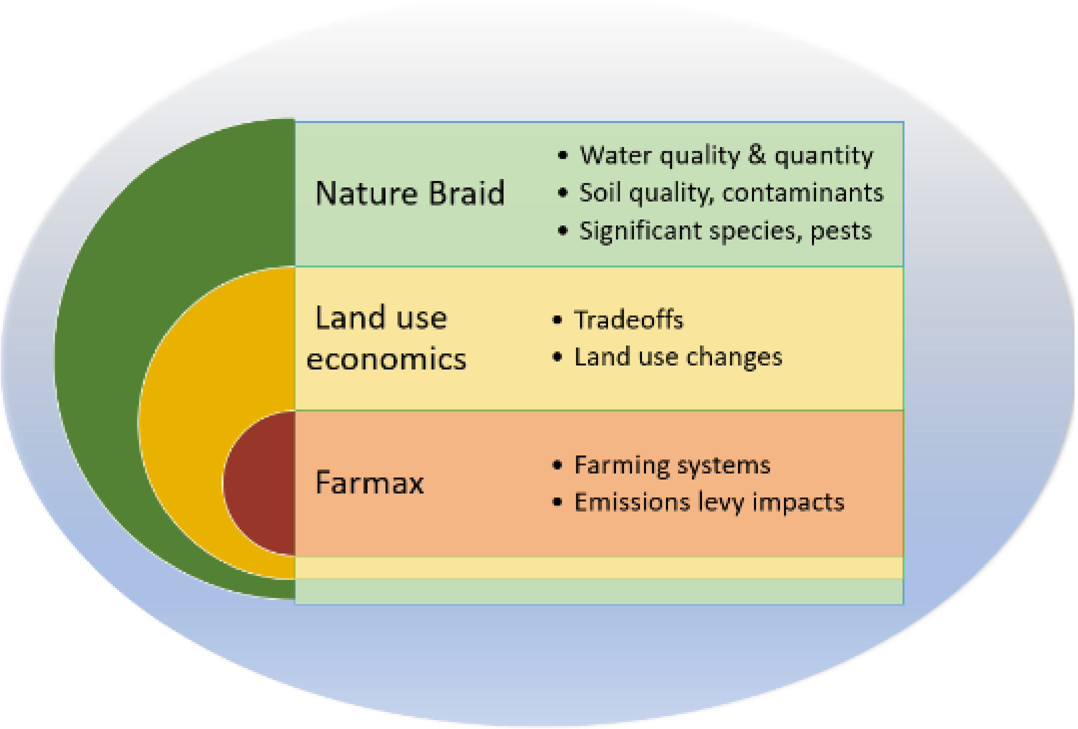

Figure 2-1. Schematic of the project approach. All three models work in conjunction to determine how policy impacts land use and subsequent economics and feasibility of a catchment.

A high-level summary of the approach is provided below.

2.1.1 FARMAX and economic analysis

To support the assessment of the economic impact and likely responses of landowners under the different scenarios, a set of land use "types" have been identified to represent the main economic land uses within the Mataura catchment (the approach to delineating these land use types is described below in section 2.3). The following types have been modelled using the FARMAX farm systems model:

- Dairy (cow);
- Dairy Support;
- High Country Sheep and Beef;
- Hill Country Sheep and Beef;
- Lowland finishing sheep and beef, and;
- Mixed Cropping.

The outputs from the farm types modelled were then included with the land use economics process, along with those types that cannot be modelled in FARMAX.

Additional land uses which were modelled outside of FARMAX in the broader economic analysis include:

- Horticulture (Tulips)
- Exotic Forestry (Pine)
- Indigenous Vegetation
- Totara Forestry
- Wetlands

FARMAX also provided GHG emissions for each farm type, which have then been used to calculate the emissions levy at farm level. These figures were then extrapolated into a per hectare estimate (by farm type) to estimate catchment-level emissions. Profitability was then reassessed under the 2030 and 2060 levy scenarios. For those land use types outside of FARMAX, separate emission calculation analyses were undertaken.

Within FARMAX, there are various libraries containing default values for production and economic parameters, which can be altered manually if required. The most significant in terms of this project are meat schedules and milk pay-outs, farm working expenses and pasture growth and quality. FARMAX financial data operates primarily on a “cash-in/cash-out” basis and does not include capital values or on-farm capital costs.

The primary financial unit of measurement for this project is **Economic Farm Surplus (EFS).** This measure excludes interest and rent, and this is appropriate as the cost of funding the farm business has not been analysed. Depreciation is included and this is considered as a proxy for the ongoing capital required to maintain the farming business. FARMAX generates economic outputs using a library of commodity prices and expenses. Estimated revenue is specific to the system established in FARMAX. Changes in commodity prices outside of the FARMAX model have not been forecasted.

The broader land use economic analysis is then used to project likely land use change resulting from different policy scenarios, based on the outputs of FARMAX and Nature Braid as well as consideration of transition costs.

The assumptions of the land use economics are discussed in Section 2.4 for each land type, where applicable.

2.1.2 Environmental analysis

To provide a spatially explicit assessment of ecosystem services and environmental indicators, the Nature Braid model (formerly Land Utilisation Capability Indicator, LUCI) is employed. For this purpose, the spatial distribution of the modelled farm types was identified and assessed against their relative productivity levels as predicted by the Nature Braid model. This provides a basis for a distributed economic assessment of land use change. The relative productivity levels also provided an additional layer of validation for pasture growth rates in the catchment for specific farm types. Further detail regarding how the Nature Braid model works can be found in Appendix A2 – Nature Braid Model.

The outputs of the FARMAX models (i.e., monthly stock numbers and weights, cultivation practices, and fertiliser inputs) and outputs from the simple economic analysis modelling were fed into Nature Braid to represent the changes in land use, and the subsequent impacts to environmental indicators. It is assumed that land use remains similar to current conditions until 2025 when levies are introduced, providing a baseline for all scenarios.

2.1.3 Combined land use economic analysis and outputs

In order to assess potential land use change, the profitability of the modelled land use types have been assessed against each other, as well as additional 'future' land use options such as Totara Forestry or Horticulture (Tulips) i.e., this is incorporating the 'land use economic modelling' as shown in Figure 2-1.

Using financial and physical parameters from the FARMAX 'base' models and feedback of spatial distribution and production capacity from Nature Braid, further economic analysis was conducted. The main purpose of the analysis is to determine how land use is likely to change in response to policy changes.

The land use change methodology is based primarily on profitability; if the revenue from the land in its current use is not covering the variable costs, it will change to another use. This represents an inertia to land change as some land will change use when it is not providing sufficient return on investment while other land will continue in its current use even when it is effectively making a loss. For the purpose of this thought exercise, land use change is assumed to occur for three main reasons:

1) Loss of profitability: If profitability drops to $0/ha, the land use will change to a more profitable use;
2) Highly profitable alternative land use with short-medium term returns: In the case of the example highly profitable Horticulture alternative (Tulips) the available land is assumed to transition due to the high profitability and lack of investment required by the landowner (in this case, available land is leased by the tulip grower);
3) Where land use change is promoted and subsidised for environmental benefit, as is the case with the Sheep Dairy and Totara Forestry systems.

Currently Exotic Forestry (pine) is significantly more profitable than indigenous alternatives, so it has been assumed to be the preferred forestry option without intervention.

The broader economic analysis also included a cost for interventions (such as the cost per hectare for riparian and other native planting, or conversion to wetlands). The Nature Braid team have used the GIS information available to assess land areas available for, or affected by, each intervention. The economic assessment has provided non-spatial land use change tables, related to the "potential productivity" of the land based on categories identified in the Nature Braid model and existing land use. This information was then mapped onto the landscape and fed into the Nature Braid model to provide spatially explicit assessments of the environmental impacts of the different scenarios. Productive capacity ("utilisation"), as provided by Nature Braid, has also been taken into account in this assessment.

The final outputs from this modelling exercise from the combined Nature Braid, FARMAX and Economic analysis approach are spatial maps demonstrating how land use could change under the five different scenarios at different time periods and spreadsheets detailing the economic impact of land use change.

2.2 Emissions levy

2.2.1 Calculation approach – farm level

An important modelling choice has been whether to calculate the emissions levy at farm level, by calculating emissions from stock and fertiliser inputs, or to calculate this at processor level, which would then be passed on to farmers via prices for meat and milk products. In practice, implementation and transaction costs may be simpler/lower at the processor level. However, the impact of this approach is less direct in terms of feedback in the modelled system. For example, calculated at processor level, no levy would then be applied directly to the Dairy Support farm type, as there is no direct product.

Importantly, the recommendation of the He Waka Eke Noa (HWEN) Primary Sector Climate Action Partnership, released on the 8th of June 2022 (HWEN, 2022), is for a farm-level levy system. In response to the HWEN recommendations, the government released its Pricing agricultural emissions consultation document on 11th of October 2022 (MfE & MPI, 2022) and has proposed a modified version of the farm-level levy system put forward by HWEN, with an interim processor-level levy if needed if the farm-level system is not ready by 2025. A farm-level levy system is considered preferable by all parties within the HWEN partnership, as opposed to agriculture entering the NZ ETS. Our modelling has been aligned to consider these recommendations, which also request a split-gas approach where farmers can calculate their own methane and nitrous oxide emissions, rather than referring to national averages.

The HWEN recommendations align well with the approaches under exploration in this project. The recommended 11c per kilo starting price for methane, held for three years, aligns with the low levy scenarios under exploration (1A and 2A) using a 2025 baseline. In these scenarios, the levy is assumed to be recycled into national-level research but the impacts of this are not directly reflected in the catchment-level modelled scenario. Scenarios 1B, 2B and 2C (high levy scenarios) will explore at a high level some of the opportunities for incentivising emissions reductions and sequestration, while supporting multiple environmental benefits such as improving water quality and biodiversity outcomes.

2.2.2 Emissions levy calculation

To calculate the expected on-farm cost of the greenhouse gas (GHG) emissions levy, physical parameters and GHG outputs from the six 'base' FARMAX models have been used. FARMAX provides a range of GHG estimations in various formats. To calculate the levy generated from each farm type, estimates in kilograms of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O)

on a per farmed hectare basis have been selected and are described in Appendix A6 - Emissions levy pricing pathway

Kilograms of CO_2-eq (carbon dioxide equivalent) on a per farmed hectare basis have also been used to determine emissions intensity (kg CO_2-eq/ha) for each farm system. Per hectare emissions have been calculated by multiplying the per kg cost of an individual gas, according to the pricing pathway by per hectare emissions of each gas for a given farm system outlined in Appendix A8 – Estimated Emissions. These are based on the price pathways published by the Climate Change Commission and agreed for the purpose of this modelling project in consultation with experts and industry representatives. The total provides the expected per hectare levy cost for each farm type in the current year. This process was repeated from years 2025 to 2060 following the timesteps, discount rates and gas pricings in the PCE pricing pathway.

The total GHG levy for the low and high price pathway, over the whole catchment has been determined using the previously established on-farm levy, multiplied by the area of that land use found within the catchment. The total area of each land use within the Mataura catchment has been determined by Nature Braid, utilising existing land use layers as described in Section 2.32.1. The crude assumption that every hectare of a particular land use, produces the same amount (kg gas/ha) of CH_4, N_2O and CO_2 was required to estimate the 'whole catchment' levy. This was used to estimate the funds to be recycled into the catchment.

2.2.3 Agricultural emission sources

For all the farm systems modelled in FARMAX, the GHG emissions are calculated within the software. The sources include both enteric and manure methane (CH_4) from livestock digestion, nitrous oxide (N_2O) from animal manure and nitrogen fertiliser and carbon dioxide (CO_2) from urea hydrolysis. Any emissions from fuel use or non-agricultural waste are not covered. FARMAX implements the calculations in *Methodology for calculation of New Zealand's agricultural greenhouse gas emissions; Version 4* (MPI, 2023)

Enteric CH_4 is calculated using animal dry matter intake, while N_2O emissions are calculated using a range of emissions factors. FARMAX also utilises the global warming potential over a 100-year time span (GWP100) from the IPCC fourth assessment report (IPCC, 2007). The GWP figures of 1, 25 and 298 have been used for CO_2, CH_4 and N_2O respectively, throughout the project where manual calculations have taken place.

Where systems were modelled outside of FARMAX, other tools or manual calculations were used: For the Horticulture (Tulips) system, proportionally N_2O emissions and the subsequent levy was assumed to be negligible compared to the overall profitability of the system and was therefore not factored into the economic analysis. Retrospectively, the total catchment GHG's were calculated and included the use of HortNZ emissions calculator (HortNZ, 2021) to determine estimated emissions from this system (from nitrogen fertiliser and lime; fuel and other sources are not included in the calculation). The same GWP100 estimate for N_2O of 298 is used within the calculator; specific emissions factors are also included within the spreadsheet. Therefore, the contribution to whole catchment emissions from the change in Horticulture (Tulips) area has been considered, but the impact of the levy on Horticulture (Tulips) economics was assumed to have no consequence on overall profitability for that system.

For the Sheep Dairy system, methane emissions were calculated manually based on estimated animal demand and dry matter intake, following methodology from Ministry for Primary Industries (2022). N_2O and CO_2 emissions from urine, manure and fertiliser were calculated using the Lowland Sheep and Beef FARMAX outputs as a proxy and calculating an emission factor per kg N applied as fertiliser and a stocking rate conversion for excreta emissions to determine total GHG emissions.

2.2.4 *Impact of levy on farm economics*

As described in section 2.1.3, the distribution land use productivity is represented in the economic assessment based on financial and physical parameters from the FARMAX 'base' models and feedback of spatial distribution and production capacity from Nature Braid.

The levy is assumed to be proportional to the revenue per hectare, which is apportioned to land based on its productive potential. Therefore, the levy affects the most productive land the most and the least productive land the least.

In the course of the project, a slightly alteration was made in the approach to calculating the viability of a particular land use. Prior to modelling scenario 1B, we had been working simply on the basis of average returns. However, after completing the calculations for scenario 1B (under the higher levy rate) it was identified that the land use change rule could better be calculated on the basis of variable returns, including the variability in levy rate. Effectively, land use would change when the existing use no longer made a contribution to fixed costs. This change in approach had no impact on the scenario 1A land use change decisions. However, the approach was applied inconsistently in scenario 1B - due to an oversight, the revised calculations were not applied in the 2030 transition table. This affected transitions only for the High Country land (for example, the land around the Glenaray station). The impact of the "average" vs "variable" approach meant that all High Country land was moved to Exotic Forestry in 2030. Had this been applied consistently, only the low-production high country land would have moved to Exotic Forestry, as occurred in Scenarios 2B and 2C.

2.3 Delineation of land use types

To delineate basic categories of land use within the catchment for representation within the model, the most recent Mataura land use map produced by Environment Southland and Land and Water Science (LWS) was used as a basis (Figure 2-2). The original Mataura land use classes (Table 2-1) were represented as six modelled (FARMAX) farm types (Dairy, Dairy Support, Lowland Sheep and Beef, Hill Country Sheep and Beef, High Country Sheep and Beef, and Mixed Cropping). Exotic Forestry and Indigenous Vegetation were also represented as land use types in the Nature Braid and economic modelling, although these were not modelled in FARMAX.

A combination of the two fields "*Land_Use*" and "*ES_LandUse*" were used within the attribute table of to delineate the farm types. The selection rules are summarised in Appendix A4 – Nature Braid Selection Rules. The preliminary results of predicted optional agricultural "utilisation" from Nature Braid were also used to corroborate the delineation of the six farm types.

Nature Braid estimates agricultural "utilisation" (or production capacity) based on soil water characteristics, fertility, slope, aspect, rainfall, and evapotranspiration. This analysis shows that Dairy, Dairy Support, and Mixed Cropping areas are primarily located in what the Nature Braid model estimates to be the most productive land within the Mataura catchment. These are followed by Lowland Sheep and Beef, Hill Country Sheep and Beef, and High Country Sheep and Beef. The reclassed land use map contains 20 classes (Table 2-1, Figure 2-2). The catchment is primarily covered by Sheep, Beef, and Dairy farms (89.5%), followed by Exotic Forestry, mainly in the upper catchment and most of the Waikopikopiko River catchment (3.3%). Arable land accounts for 2.3% and urban area covers 1.9%.

Table 2-1. Land area for each land use class within the Mataura catchment and predicted agricultural utilisation. Shaded land use classes have been modelled in FARMAX.

No.	Land use class	Area (ha)	Percentage (%)	Mean predicted production capacity (1-5) *
1	Hill Country Sheep and Beef	180,700	25.11	3.50
2	Lowland Sheep and Beef	157,873	21.93	2.52
3	Indigenous Vegetation	145,828	20.26	
4	Dairy	83,933	11.66	2.27
5	High Country Sheep and Beef	60,557	8.41	3.60
6	Dairy Support	21,619	3.00	2.41
7	Exotic Forestry	18,931	2.63	
8	Other	13,783	1.91	
9	Deer and other livestock	11,029	1.53	
10	Road	9,597	1.33	
11	Lakes and rivers	5,419	0.75	
12	Deer	2,557	0.36	
13	Mixed Cropping	2,291	0.32	2.05
14	Small land holding	1,564	0.22	
15	Public use and recreation	1,140	0.16	
16	Residential	1,098	0.15	
17	Lifestyle	718	0.10	
18	Other animals	499	0.07	
19	Industrial and airports	402	0.06	
20	Commercial use	186	0.03	

(*) Value range is 1 to 5; 1: very high production capacity; 2: High production capacity; 3: Moderate production capacity; 4: Marginal production capacity; 5 Negligible production capacity.

For this project, in consultation with experts including local farmers, six farm types were selected to be modelled in FARMAX. Other land uses that are important for the ecosystem services and economy of the catchment include deer, deer and other livestock, Indigenous Vegetation, and Exotic Forestry. Lifestyle, other animals, and small land holding land uses are also important, but they account for a very small proportion of the Mataura land (less than 0.5%). Due to project constraints as well as the marginal proportion of these land use types, local specific parameterisation of these are not included in the model.

Given the capacity of wetlands to deliver multiple ecosystem services, wetlands play an important role in Nature Braid's algorithms. Wetlands have also been identified as highly important to iwi in the region. However, it was not possible to separately identify existing wetlands as the land use map provided by Land Water Science (LWS) had combined wetlands with drier forest and scrub environments as one "Indigenous Vegetation" class.

For the purpose of identifying areas where wetlands can be restored or constructed in scenarios 2B and 2C, areas of poor drainage (and prone to waterlogging) were identified using Nature Braid based on soil, climate, and topography data. However, it was not possible to validate these areas against artificial drainage layers. Therefore, in practice it is important to validate these areas as while they are currently represented as having low productive capacity, if artificial drainage is present this may mean they are in fact highly productive areas.

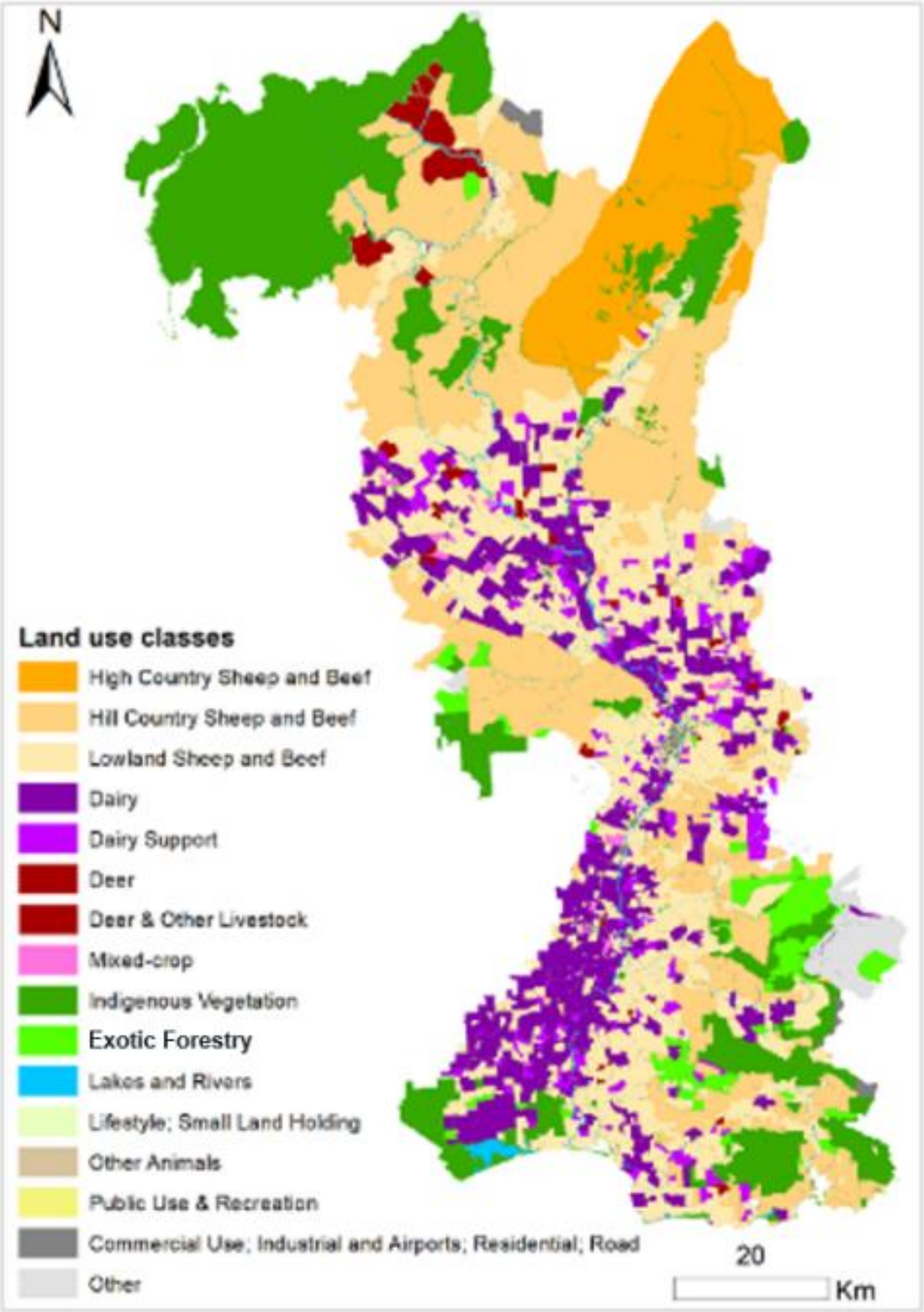

Figure 2-2. Reclassed land use map for the Mataura catchment.

2.4 Representing land use types

A brief overview and the key assumptions for each modelled land use type are provided in this Section.

Due to the uniqueness of New Zealand farms and their individual management, it is impossible to model farm systems that accurately represent all on-farm operations. To capture the diversity of farming systems within the Mataura catchment, a range of 'base models' representing various farm types were created. Selection of these representative systems was based on current land use in the Mataura catchment (see Section 2.3) and follow up engagement with industry professionals within the catchment who were familiar with the project. These were confirmed with the PCE before model development began.

Originally, six hypothetical farm systems were modelled using *FARMAX Dairy 8.1.0.55* and *FARMAX Redmeat 8.1.0.55*. The aim of each model is to broadly represent 'typical' farms for a range of farm typologies prevalent within the Mataura catchment. The model farms were generally constructed around available and relevant industry statistics. Further details of FARMAX modelling can be found in Appendix A3 including some key assumptions and limitations for this project, and information for the creation of the six FARMAX base farm setups is detailed in Appendix A5 – . The information was selected following engagement with industry professionals, online research, and the descriptions of each Beef + Lamb New Zealand (B+LNZ) data class in the B+LNZ Otago/Southland Quintile analysis report (B+LNZ, 2020); pers. comm J. McGimpsey B+LNZ, 2022). The outcomes of this project were also factored into the decision-making process, with a desire to represent farm systems that contribute significantly to the area of land used, as well as the economic and environmental footprint of farm systems within the Mataura catchment.

For the land use types which could not be modelled in FARMAX i.e., Exotic Forestry and future land use types of Tulips and Totara Forestry, have been represented in the economic models using a simple land profitability analysis. These were also developed with support and input from industry professionals, as well as available literature to verify that they were representative for modelling purposes.

Following the second workshop for the Mataura catchment, additional land use types were discussed. From the proposed selection, Sheep farming (Sheep Milk) and Flax were decided to be incorporated.

2.4.1 Dairy (cow) and Dairy Support

For the Dairy sector two 'base models' were created to represent typical cow Dairy and Dairy Support systems in the catchment. These modelled systems were based on 2020/2021 Dairybase benchmarks from 44 owner-operator farms in Southland. Refer to Appendix A5 – FARMAX Base Farm Setups.

2.4.2 High Country Sheep and Beef, Hill Country Sheep and Beef, Lowland Finishing Sheep and Beef, and Mixed Cropping

For the sheep and beef sector, four 'base models' were generated to represent a typical farm system for High Country, Hill Country, Lowland finishing and breeding, and Mixed Cropping (mixed arable) farm types within the Mataura catchment. The farm system and financial information for all typologies is based on the B+LNZ Otago/Southland benchmarking data, using mean values from the 2019/20 Economic Service: Sheep and Beef Farm Survey. Class 1, Class 2 and Class 7 and Class 8 datasets were used to base the high, hill, lowland, and Mixed Cropping systems respectively, however the high country 'class 1'data has been amended significantly following consultation with

Southland B+LNZ representatives, who confirmed that ‘high country’ in the Mataura is systematically different to ‘typical’ NZ high country observed in Central Otago and Canterbury. The Class 8 survey data is predominantly from farms in the Canterbury region (B+LNZ, 2020); therefore, the systems have also been amended to better reflect the Mixed Cropping systems in the Mataura, which required engagement with consultants (pers. comm Simon Ferguson, FarmRight 2022) and online research regrading cash crop production.

These industry available datasets helped to establish the basic size of the farm, stock numbers, average fertiliser application rates and most production and economic parameters including farm working expenses and milk production, stock sales, reproductive performance etc. The FARMAX software also filled many gaps using industry data and user feedback which is regionally specific. Many of these inputs can be manually adjusted according to the user to better reflect individual farm operation. Pre-set FARMAX meat and milk schedules/pay-outs were selected for product value, driving income, the timing of sale or the destination of meat (store sales vs prime sales) were manually set and reviewed by farmers in the catchment for each farm type.

The value of cash crops, and the establishment expense for each crop was selected using the Lincoln University Farm budget manual (Askin & Askin, 2018). The budget manual was also used to cross check other farm working expenses. Crop rotation, event timing and yield were determined through engagement with industry professionals, and from industry publications (pers. comm Simon Ferguson, FarmRight 2022; (Askin & Askin, 2018; Figure.NZ, 2012; Specialty Seeds, 2021; FAR, 2022).

Key inputs included selecting stocking rates, animals breed, classes and ratios, cropping, feed conservation and fertiliser practices, mating dates, sale and event dates, target sale weights and store stock policy. The input assumptions and base models were sense checked by farmers in catchment or industry representatives, and adjustments made, to ensure the models were representative of typical farm practices within the catchment.

The absence of deer farming from the representative farm types was noted and a deer industry representative (and farmer) engaged in a discussion on the subject on 29th March. Recognising the small scale of the sector in the region and its decline in recent years, privacy issues were also a factor to be considered. In the past many deer were run as a smaller part of larger livestock enterprises, and it was felt that they could be incorporated into those farm types.

There are significant challenges in representing the variability of impacts in this form of modelling approach. The choice to take a hybrid approach (basing each farm type on average data, and then validating the representativeness of this setup with farmers from the catchment with similar systems) was made after in-depth discussion with industry experts on the benefits and risks of modelling “real” or “average” farms, within the limitations and resources of this study.

Ensuring realistic pasture growth rates for some of the sheep and beef systems provided a particular challenge, as the FARMAX libraries in this case were considered to overestimate pasture production. These were adjusted with the kind support of David Stevens of AgResearch (pers. comm 20 June 2022) with reference to Cossens (1990) and cross-checked against the productive capacity ratios provided in Nature Braid.

Validation and review of the setup of different farm systems was also supported through personal communications with representatives from Thriving Southland, DairyNZ, B+LNZ, and farmers in the catchment.

2.4.3 Wetlands and Indigenous Vegetation

As described above, no wetlands have been separately delineated in the original land use maps. However, some areas identified as lakes and rivers in the original land use maps have been considered to provide a basis for land use changes in scenarios within the economics and Nature Braid model. Where land is restored or converted to Wetland (scenarios 2B and 2C) a capitalisation rate of 7% has been assumed. Landowners are compensated for their land use conversion to Wetland based on their lands current use type and their land production capacity adjusted by the capitalisation rate of 7% to reflect the perpetuity return of their current land use that they forgo. It has been assumed that a one-off fixed Wetland establishment cost of $80,000 per hectare and a recurring annual Wetland maintenance expense of $1100 per hectare for Dairy land conversion to Wetland and $258 per hectare for all other remaining land conversions to Wetland. Constrained by the levy funds available in the catchment each year and land identified by Nature Braid as potential areas for Wetland conversion, the area of land conversions to Wetland and the total expected costs for each relevant scenario have been modelled. Gully planting (scenario 2C) is treated the same as natural wetland restoration.

Where wetlands are also constructed (scenarios 2B and 2C), this is considered to incur an establishment cost of $155,000/ha, while other costs remain the same. The restoration and construction of wetlands is considered to include planting, which has been parameterised in the Nature Braid model as flax.

Indigenous vegetation is represented in the Nature Braid model as Riparian Planting, wetland planting, gully planting, and the additional planting of indigenous vegetation on farms in scenario 1B (indigenous reforestation). These could have a wide range of costs but for the economic assessment we simplify this to three cost models:

- Riparian Planting: the planting of an 8m strip (4m each side) beside rivers and streams uses a mixed planting model costing $4.20 per m2 to establish and $1.47 per m2 each subsequent year for maintenance.
- Wetlands, either natural or constructed: Natural wetlands cost $80k per ha to establish and constructed wetlands (needing earthworks) cost $155k per ha to establish. Both have a small cost per annum maintenance, (between $250 and $1,100 depending on the land type).
- Gully planting: The bottom of many gullies are similar to natural wetlands and can have significant environmental benefit if planted in indigenous vegetation. Nature Braid identified these areas and the cost of planting these is assumed to be the same as natural Wetlands
- Planting of indigenous vegetation on farms on areas of the farm that are no longer profitable to farm: This is assumed to be equivalent to indigenous reforestation. Indigenous reforestation is significantly cheaper than natural wetland planting mainly as the stems per ha is lower due to more of them being trees. These are assumed to cost $25k per ha.

2.4.4 Horticulture (Tulips)

Horticulture (Tulip) growing was selected as a representative high value alternative land use in the catchment. The expected costs and returns for land conversions to tulip growing have not been assessed directly: While actual returns to tulip growers are much higher, land for tulip growing is leased at approximately $5000 per hectare (pers. comm Rudi Verplancke, June 2022). For modelling purposes, we have therefore assumed a simple, conservative return for tulips of $5000 per hectare. We have assumed that only land with very high production capacity identified by Nature Braid as suitable for tulip growing in the catchment can be converted in each scenario. In addition, tulips are grown in a six-year rotation. We have therefore assumed that one sixth of suitable land can be utilised for tulip growing.

2.4.5 Exotic Forestry

This was not modelled in FARMAX. Therefore, an economic model using a simple land profitability analysis was undertaken. The key parameters to characterise Exotic Forestry for modelling have been summarised in Table 2-2 below. An assumed real cost of capital (discount rate) of 5% was used to discount future values back to present terms and to inform current decision-making.

Table 2-2: Exotic Forestry parameters assumed for this project. Values are per hectare

	Exotic Forestry
Establishment cost	$1,250
Average annual maintenance costs in years 1-10	$181
End-of-life harvest value	$33,700
End-of-life harvest year	25
Capitalisation rate (pre-tax real)	5%
Sequestration rate	24.16 t/ha/year
Return (perpetual)	$10,365
Equivalent Annual Annuity (EAA)*	$518
Subsidy to compensate	$0

*estimated using 5% of return.

The sequestration rate for Exotic Forestry in the catchment has been approximated by calculating the average annual sequestration from year 1 to year 25 (assumed harvest year) based on the MPI Lookup tables (MPI, 2017). The mean annual sequestration rate on 24.16 t/ha/year was used for the Mataura catchment.

Annual sequestration payments have been modelled starting in the planting year. As forests are harvested, they will no longer be eligible for sequestration credits hence the related sequestration payment ceases. It is assumed that sequestration payments are paid at the end of year to all eligible forestry hence no sequestration pay backs were required for harvesting during the year. It's assumed that as soon as forests mature and are harvested, new forests are being replanted in the same year such that they could still be eligible to sequestration payments. As the majority of the return is practically expected to be realised when the forestry matures and are harvested, we had modelled returns as an effective annual annuity to reflect an equal return split across the modelled period such that catchment profitability could be assessed. For all scenarios expect 2C, forestry earns sequestration payments between 2025 to 2060. For scenario 2C, sequestration payments are phased out by 2030.

2.4.6 Additional land uses – Flax and Sheep Dairy

At the second workshop, feedback was sought from participants on environmentally beneficial activities and land use alternatives for the Mataura catchment. Further information on these land uses, and related considerations are included in Appendix A9 – Other Land Use Types.

Sheep Dairy was selected as an additional high value alternative land use in the catchment, following the workshop engagement. The details of Sheep Dairy and why it was chosen are summarised in Appendix A9 – Other Land Use Types. This was not modelled in FARMAX, however parameters for this system are described in Appendix A5 – FARMAX Base Farm Setups.

It was decided that Flax should be modelled for environmental improvements only (not including economic benefits). The environmental benefits of Flax are modelled within the Nature Braid software, where wetlands are restored. It should be noted that there are potential economic benefits from Flax growing, as well as broader biodiversity and cultural benefits, although none of these were quantified for this study. This is relevant for Scenario 2B and 2C only, and not represented separately in Scenario 1A, 1B and 2A.

2.4.7 Totara Forestry

The sustainable Totara Forestry system ('Totara Forestry') modelled includes totara (*Podocarpus totara*) under continuous cover forestry. This means that the forest canopy is maintained at a certain level without clear-felling (Mason 1999). As totara are not modelled in FARMAX, the economic analysis considered a selective harvesting regime of 60 years after the initial establishment and continuous maintenance and pest control Table 2-3).

It should be noted that the assumption for establishment costs are about eleven times those of Exotic Forestry. Establishment, maintenance, and pest control costs are highly variable and severely understudied for indigenous vegetation in New Zealand (Forbes 2021). While the assumption of (tree) stocking rates for the economic analysis was 2,000 stem/ha (New Zealand Farm Forestry Association n/d.), totara could be grown at lower stocking rates (see for example Satchell 2018). This choice of stocking rate is therefore a conservative one.

Table 2-3: Totara Forestry parameters assumed for this project.

	Totara Forestry
Establishment Cost	$14,750/ha
Average annual maintenance costs in years 1-10	$2,025/ha
End-of-life harvest value	$110,000/ha
End-of-life harvest year	60
Capitalisation rate (pre-tax real)	5%
Sequestration rate	8.2tCO_2/ha/yr
Return 2025	-$946
Return 2030	-$1,294
Return 2060	-$1,294

The sequestration rate for Totara Forestry in the catchment has been approximated by calculating the average annual sequestration from year 1 to year 35 (tree age in 2060) using the data for indigenous forest from the MPI Lookup tables (MPI, 2017). The mean annual sequestration rate on 8.2tCO_2/ha/year was used. However, as Totara Forestry is only included in scenario 2C, in which the NZETS is phased out, no sequestration payments are made; this figure is only used to calculate overall sequestration for the catchment in scenario 2C.

The Nature Braid parameters for sustainable Totara Forestry implicitly assumed a continuous cover forestry system, for example, the C-factor in the RUSLE model used for totara was the same as the indicative C-factor for native forest (0.005). The Nature Braid model also assumes that the sustainable totara mitigates flow and is a good habitat for kereru.

Nature Braid has assumed that Totara Forestry is high retention for soil losses and flood as it was recommended as suitable for production plantation forestry on erodible hill country (Satchell, 2018). It has an extensive lateral root system that often spreads and can produce new root systems after flooding and roots can develop from the trunk where silt has been deposited (Bergin, 2003).

Both the Mataura and Wairoa cases used the same parameters in Nature Braid and economic assumptions for Totara Forestry.

3 Scenarios and assumptions of modelling

For each scenario, a specific set of choices and assumptions were required. This section outlines these choices and their rationale.

For all scenarios except scenario 2C, no limits are assumed for the NZ ETS. Consequently, the economic value of the NZ ETS is incorporated into eligible plantings such as Exotic Forestry. The modelling assumes the same ETS price path that applies to the Levy is available to Exotic Forestry.

As the levy is a crucial component of each scenario, refer to Appendix A6 - Emissions levy pricing pathway for the specific emissions levy pricing pathway.

3.1 Scenario 1A: Low levy, untargeted freshwater regulations

In the first scenario, the lower levy is introduced in 2025, increasing gradually over time. The impact of the lower-rate emissions levy was calculated for 2030 and 2060, and associated land use change assessed (as summarised in section 2.1). The revised proportions of land uses were then fed back into Nature Braid to assess the environmental impacts of the land use change. The option of Horticulture (Tulips) growing represents a high value alternative use for the highly productive land.

The levy revenue collected is small and is assumed to be recycled into national-level research on reducing emissions from agriculture (‘untargeted revenue recycling’). For the purpose of this scenario, it is therefore not recycled back into the catchment.

This scenario also assumes a current N fertiliser application rate limited of 190kg N/ha/year for all pastoral systems, and no control on P inputs. All farms are modelled to comply with the winter grazing regulations.

Stock exclusion regulations are assumed to be in place, with all stock excluded from waterways. However, it is assumed for modelling purposes that riparian areas have not been established.

3.2 Scenario 1B: High levy, untargeted revenue recycling

This scenario has higher levy rates that rise more rapidly than 1A. The additional levy is recycled back into central government funding programmes and spent using simple untargeted approaches (‘untargeted revenue recycling’). This enables comparison to 2B where the revenue is distributed to the catchment in a targeted, landscape-specific manner (‘targeted revenue recycling’).

The impact of the higher-rate emissions levy was calculated for 2030 and 2060, and associated land use change assessed. In this assessment, the levy funds available were first applied based on a prioritised “waterfall” available to the catchment through central government funding programmes. For the purposes of this scenario, the funding was applied to the modelled interventions as detailed below:

1) *Support for Riparian Planting.* Riparian Planting within the catchment, for farms adjacent to waterways. Planting riparian areas can provide significant benefits for water quality and biodiversity, as well as providing a carbon sink.
2) *Support for restoring Indigenous Vegetation*. We have assumed a subsidy to restore indigenous vegetation, and that this subsidy is taken up in an untargeted way by 25% of uneconomic farmland
3) *A direct subsidy for reducing stocking rates.* This was selected as initial calculations have indicated that reduced stocking rates will likely mean a significant reduction in

profit. Reducing stocking rates is recognised as the main ‘lever’ for reducing on farm greenhouse gas emissions. A subsidy for reducing stocking rates has been modelled. How this subsidy would work in practise has not been specified; It has been modelled simply as an annual payout to farmers based on reducing stock levels from those modelled in FARMAX. These are made available to farmers who would still be making a positive marginal return after the levy. When the subsidy results in zero stock for a farm type it is removed and the land use is assumed to change.

4) **National Research Programme**. The remaining levy revenue is recycled into national-level research on reducing emissions from agriculture.

The revised proportions of land uses, and Riparian Planting areas were then fed back into the Nature Braid model to assess the environmental impacts of the land use changes.

3.3 Scenario 2A: Low levy, targeted freshwater regulations

This scenario shows the effect of targeted, landscape-specific freshwater regulations. Limits (or ‘caps’) on N and P fertiliser inputs are based on landscape susceptibility to loss of freshwater contaminants.

To identify susceptible areas, the physiographic layers from LWS were used to identify the main source areas for high loading and/or high accumulations of contaminants. These were identified as areas where contaminant loads for N and P (respectively) are above ecological thresholds as identified in physiographic layers from previous research. For N, low redox potential areas were also considered as higher risk.

The High class (level 4) of the LWS NNN layer was used to identify the N high-risk areas. The LWS PP and DRP layers were used to create the TOTP (Total P) susceptibility layer (TOTP = 0.7*PP + 0.3*DRP) for identifying the P high-risk areas. The average threshold for the high class for PP and DRP was used to identify the highest quantile for TOTP. The N high-risk areas were used to allocate the changes in stock and fertiliser.

For these high-risk areas specific to N, the main farm types were then identified, and their nutrient outputs quantified. Average fertiliser inputs for these farms were then used as a basis for limit-setting. A blanket synthetic fertiliser limit (cap) was set for N and P high-risk areas, respectively.

The NES-FW (2020) sets a national standard for synthetic N fertiliser use, capping application to pastoral land at 190 kgN/ha/yr. The policy scenarios set in 2A are designed to test the potential impacts on land use change derived from a more restrictive N fertiliser limit, in conjunction with the agricultural emissions levy. Currently the NES-FW rule doesn’t apply to horticultural and arable uses but these land uses are regulated through consenting with regional council. The 2A policy surrounding fertiliser application is a targeted rule applied to areas identified as high risk for N loss, however it is applied to all land uses if they fall within a risk zone, including horticulture or orcharding within this modelling exercise.

The N limit for 2030 was set at 85 kgN/ha/year. This was determined on the basis of the impacts to the highest N using land use, being Horticulture (Tulips) in the Mataura. Personal Communication with R. Verplanke (June 2022) indicated that the minimum level of N fertiliser required to remain a viable operation was around 85kgN/ha/yr but this would involve significant changes to the current management system. Anything below that level was assumed to reduce bulb quality beyond and acceptable quality and risk the loss of supply to European markets. This rate is also close to 50% of the NES-FW limit of 190 kgN/ha/yr.

The 2060 Limit was set without consideration of the Horticulture (tulip) system as it was assumed any further restriction would put that system out of business. Therefore, a restriction of 50% of the next highest baseline use in the catchment (Dairy) was applied, capping N fertiliser application to 65 kgN/yr. This is a considerable reduction from the current 190 kgN/ha limit, however the purpose in the scenario was to test a more extreme scenario to identify potential impacts to catchment land use and environmental outcomes, especially freshwater quality.

In order to assess the impact of this fertiliser reduction for N, the relevant farm types were modelled in FARMAX, which provides a measure of N response for pasture. The likely impact on cropping systems and economic thresholds were broadly estimated through reference to relevant research (Moran et al, 2017; Fraser, et al., 2020) and engagement with industry professionals. For P, reductions in pasture growth could not be modelled directly. Available literature on the response of farming systems to P (e.g., Mackay, et al., 2009) suggests there is significant context-specific variation in response. In particular, the long-term impacts of reducing P inputs for the future scenarios (2030-2060) were unable to be estimated within the constraints of the present study. It was therefore decided for modelling purposes to simply reduce the fertiliser inputs for farms in the P high-risk area and address the potential impact on the relevant farm types as a narrative alongside the modelling. Detailed of the assumptions used for the FARMAX modelling for scenario 2A are provided in Appendix A7.

Where it was economically viable to do so, farming systems in N high-risk areas were optimised under the new N fertiliser limits. Land use change was then assessed for the N high-risk areas. Land use change in the N low-risk areas was assumed to occur in the same way as scenario 1A. The revised proportions of land uses were then fed back into the Nature Braid model to assess the environmental impacts of the land use change.

3.4 Scenario 2B: High levy, targeted levy recycling

This scenario shows the effect of targeted landscape mitigations on environmental outcomes, where levy revenue is recycled back into the catchment, to facilitate environmental improvement.

The levy revenue calculation for this scenario follows the same high pricing mechanism as 1B, however the fund is recycled back to support targeted actions within the landscape which include:

- Payments to implement land management practices and farm system changes that improve freshwater quality, protect/enhance biodiversity and reduce emissions.
- Payments for retiring pasture and conversion to / restoration of Indigenous Vegetation or Wetlands.
- Payments for land use change from highly intensive pastoral land uses to less intensive productive land uses with lower environmental impacts.

This scenario is designed to test environmental outcomes by funding targeted mitigations through the levy generated by emissions. The high emission levy is still in effect (as for scenario 1B); therefore, we expect farmers will seek higher value land uses. Horticulture (Tulips) and Sheep Dairy are used as examples of a high value uses on suitable land for the 2B scenario. We expect significant investigations into high value uses will continue to be undertaken though it is difficult to make any predictions as to what they might be. Existing research suggests that there are higher value uses available now and suggests some inertia in land use change – hence the assumption that a subsidy for changing to Sheep Dairy could be required. Exotic Forestry remains an alternative use for transition on lower productivity land classes.

The emission fund is distributed in four 'funding allocation' tranches, which each contain one type of mitigation. In parallel, land is converting to other uses as profitability is affected by emission levy increases. These are detailed as follows:

1. Tranche one assumes that the levy fund will contribute to nation-wide research and development, using the same monetary amount as scenarios 1A and 2A. While the scenario is designed to be independent of central government administration, feedback from the second Mataura workshop concluded that there is good reason to maintain a national research fund for nationwide benefit.
2. Tranche two funds targeted restoration of Wetlands (non-constructed) on land that is classed as having negligible production capacity and is identified as naturally waterlogged by the Nature Braid model. This included planting flax in these areas.
3. Tranche three provides payments for riparian planting.
4. Tranche four funds Wetland construction, on land that is currently in production. Construction of wetlands was prioritised on areas identified in Nature Braid as 1) poor drainage, susceptible to waterlogging; and 2) seasonally drained/imperfectly drained areas.

These tranches are modelled using a waterfall methodology that prioritises these uses in order. The final tranche (4) is very large and funds do not cover conversion of all the areas to wetland. Therefore, transition was prioritised by land use, with lowest cost land use prioritised.

In parallel to the tranche mitigation spending, incentivising alternative land use from the levy fund was applied in 2030 and 2060. The fund contributed to a 50% subsidy for the upfront conversion cost from an existing land use to Sheep Dairy. Conversion cost for Sheep Dairy was assumed at $10,000 per hectare with a minimum farm size of 50 hectares, on any land classified as 'very high' or 'high' production capacity in the Nature Braid model.

As targeted mitigations replace current productive land in some instances, that land is assumed to be purchased or leased in perpetuity, from the landowner as an upfront cost. Land is paid for based on its current productivity with the following hierarchy in the cost of land proportion to emissions from that land:

Dairy Support > Dairy > Lowland Sheep and Beef > Mixed Cropping > Hill Country S & B > High Country S & B

This is to achieve the greatest reduction in emissions per dollars spent on land procurement.

3.5 Scenario 2C: High levy, forestry phased out from NZ ETS

This scenario follows the same emissions levy and targeted mitigations as 2B; however, it is designed to show the effect of phasing out newly registered forestry from the NZ ETS, removing the incentive to plant forest primarily for carbon credits. A new multi-benefit fund would be established in replacement of the NZ ETS fund to facilitate targeted forest planting with a focus on multiple benefits, not just carbon sequestration. The multi-benefit fund is based on the amount of sequestration payments that the ETS would have provided based on actual planting.

Agricultural emission pricing continues to follow the high pricing pathway, and non-forest land use transitions and mitigations are the same as the 2B scenario.

For the targeted afforestation to have multiple benefits regarding climate, water quality and biodiversity as well as financial benefit for landowners, the assumption was that production forestry (Exotic or Totara Forestry) for timber was required. Totara Forestry, with additional funding for fencing and pest control to protect understory development, was modelled to replace the more profitable Exotic Forestry that would otherwise be planted. Totara Forestry is incentivised on the basis of potential co-benefits for biodiversity, climate, water quality and economic outcomes compared to Exotic Forestry.

The “multiple benefit” fund subsidy is calculated as the difference between the economic value of using the land for Exotic Forestry and Totara Forestry. As reduced profitability due to the agricultural emission levy was the fundamental driver for land transition to forest in other scenarios, it is assumed forest will still be planted on farmland as the emission levy increases. As a result, the incentive from the multiple benefit fund is designed to compensate the loss in opportunity from planting Totara Forestry vs Exotic Forestry, as the financial return is greater for pine when compared to totara establishment. Targeted mitigations and land use change occur as they do in scenario 2B.

It is assumed that all existing Exotic Forestry (15,999 ha) in the baseline 2025 is registered in the ETS and will remain so until 2030, with an expectation that they would all take up the subsidy and convert to Totara Forestry at their next harvest cycle. This will all be completed by 2060.

Land identified in 2C as likely to move to Exotic Forestry between 2025 and 2030 is not moved from its current land use until after 2030, when it will move to Totara Forestry. This is assumed on the basis that initial uncertainty around the ETS will slow this change. However, it should be noted that in practice, uncertainty could potentially also drive a change in the opposite direction.

The total value of the multi-benefit fund is calculated as the value of the sequestration from Totara Forestry that would have been paid out if forestry had remained in the NZ ETS, so reflects the planting of Totara Forestry rather than Exotic Forestry. Even so, the model suggests multi-benefit funds available of $80.3M per year from 2030, increasing to $565.6M by 2060. The majority of this is used to subsidise Totara Forestry in all areas that would have been planted in Exotic Forestry in scenario 2B.

The model indicates that the establishment of Totara Forestry does not exhaust the funding available. By 2060, a total of $2.5B is available to implement environmentally beneficial activities.

As an example of further uses of this fund, for environmental objectives, funds were then directed to plant Indigenous Vegetation in gully areas at high flow concentration locations where it will have a direct effect on environmental outcomes. These extra plantings would be inconvenient for forestry and minimal pasture growth so are assumed to have no harvesting potential and no effect on surrounding land productivity. Using the Nature Braid model, 14,394 locations were identified with a total area of 6,306 ha. These were selected in areas with topographic convergence, where analysis of the flow mitigation layer, the accumulated sediment, nitrogen, and phosphorus layers suggested that significant nitrogen, phosphorus, and sediment could potentially be retained in the landscape by slowing water flows. Further uses of the remaining funding have not been modelled.

4 Results

4.1 Baseline 2025 results description

4.1.1 Environmental analysis

Nature Braid uses the land cover data to assess both the current agricultural utilisation and the environmental impact of not just the agricultural utilisation, but also the underpinning geoclimatic and topographic factors underpinning environmental outcomes. Highly productive land which is under intensive agricultural activities e.g., Dairy, Sheep and Beef systems, and Mixed Cropping, covers 79.74% of the catchment (Figure 4-1, top right). Approximately 15.51% of the catchment is considered to have no/negligible agricultural production value but it may be important for other non-agricultural uses.

The predicted optimal agricultural utilisation map is based on soil water characteristics, fertility, slope, and aspect (Figure 4-1, top left). Areas that are flat with a slope less than 5 degrees and under Brown soils with well-draining, and fertile are considered to have high agricultural production potential. In Mataura, 30.8% of the catchment has high to very high agricultural potential. Areas that are susceptible to waterlogging or very hilly are considered to have low agricultural production potential as these areas require further management interventions to become suitable for agricultural use. 64.6% of the catchment is considered to have marginal productivity and 3.74% to have negligible production value, mostly found in the northern hill country.

The relative agricultural utilisation combines the current and predicted agricultural productivity to identify whether current agricultural utilisation is suitable for the associated agricultural productivity potential (Figure 4-1, bottom right). An area of 28.43% of the catchment is flagged as significantly over-utilised while 24.24% is somewhat over-utilised. These areas are under Sheep and Beef systems in hill countries (Hill Country Sheep and Beef) of Mataura and considered over-utilised due to the hilly topography.

The utilisation status map provides an assessment of whether the current agricultural utilisation may be worthy of preservation or change (Figure 4-1, bottom left). If the current agricultural utilisation of land is appropriate with associated agricultural production potential, Nature Braid marks the land as typical/usual utilisation. Typical agricultural production areas account for 38.47% of the catchment, extending across Dairy farms on low slopes (<5 degrees). Agricultural production results highlight large unusually utilised areas in the upper part of Mataura. These areas are under Sheep and Beef farms on steep slopes (>20 degrees) which the model highlights as having negligible/marginal agricultural productivity and unable to support production. The areas include large parts of the High Country Sheep and Beef around Glenaray station, as well as other areas under High- and Hill Country Sheep and Beef systems.

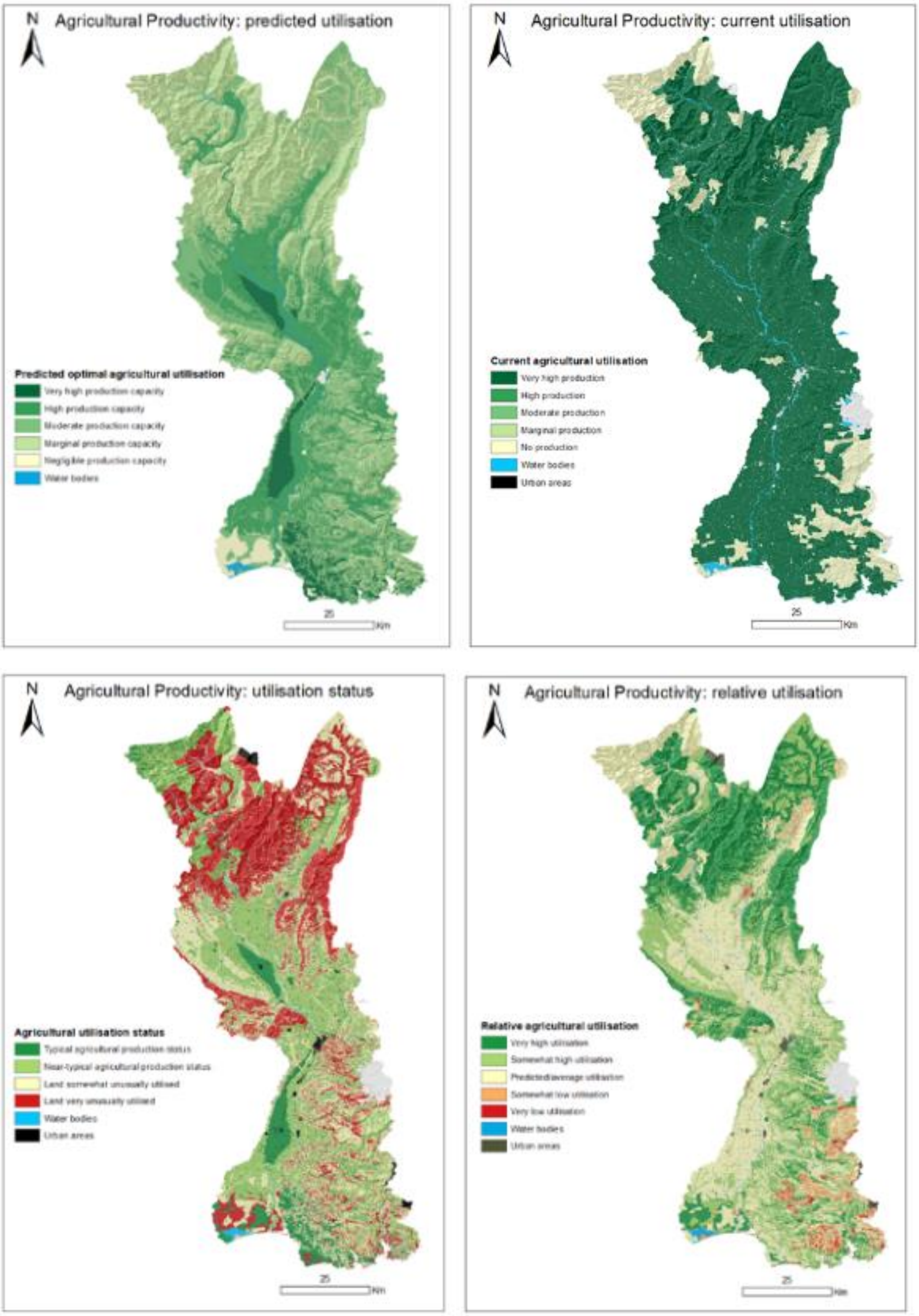

Figure 4-1. Results of agricultural productivity: predicted agricultural utilisation, current agricultural utilisation, agricultural utilisation status and relative agricultural utilisation (explanations of the classifications are in table 23).

In Mataura, the mean N (total N) in-stream concentration is ~0.76 mg/L, reaching a maximum of 341.46 mg/L. The reaches with generally higher average in-stream N concentration are identified in Mataura River at the Lower Mataura catchment and stream around Gore and Mataura townships (Figure 4-2; bottom). The model results (Table 4-1) align with total nitrogen concentrations (LAWA) monitored in the Waimea stream at Mandeville and in Longridge Stream, both with a median of 4.3 mg/L, and the Oteramika stream with a concentration of 3 mg/L.

Table 4-1. Classified in-stream N concentrations for the baseline 2025.

In-stream N concentration	Number of reaches	Percent of total (%)
<1 mg/L	39,847	77.06
1 to 3 mg/L	11,094	21.35
3 to 5 mg/L	628	1.2
5 to 10 mg/L	172	0.33
>10 mg/L	19	0.037

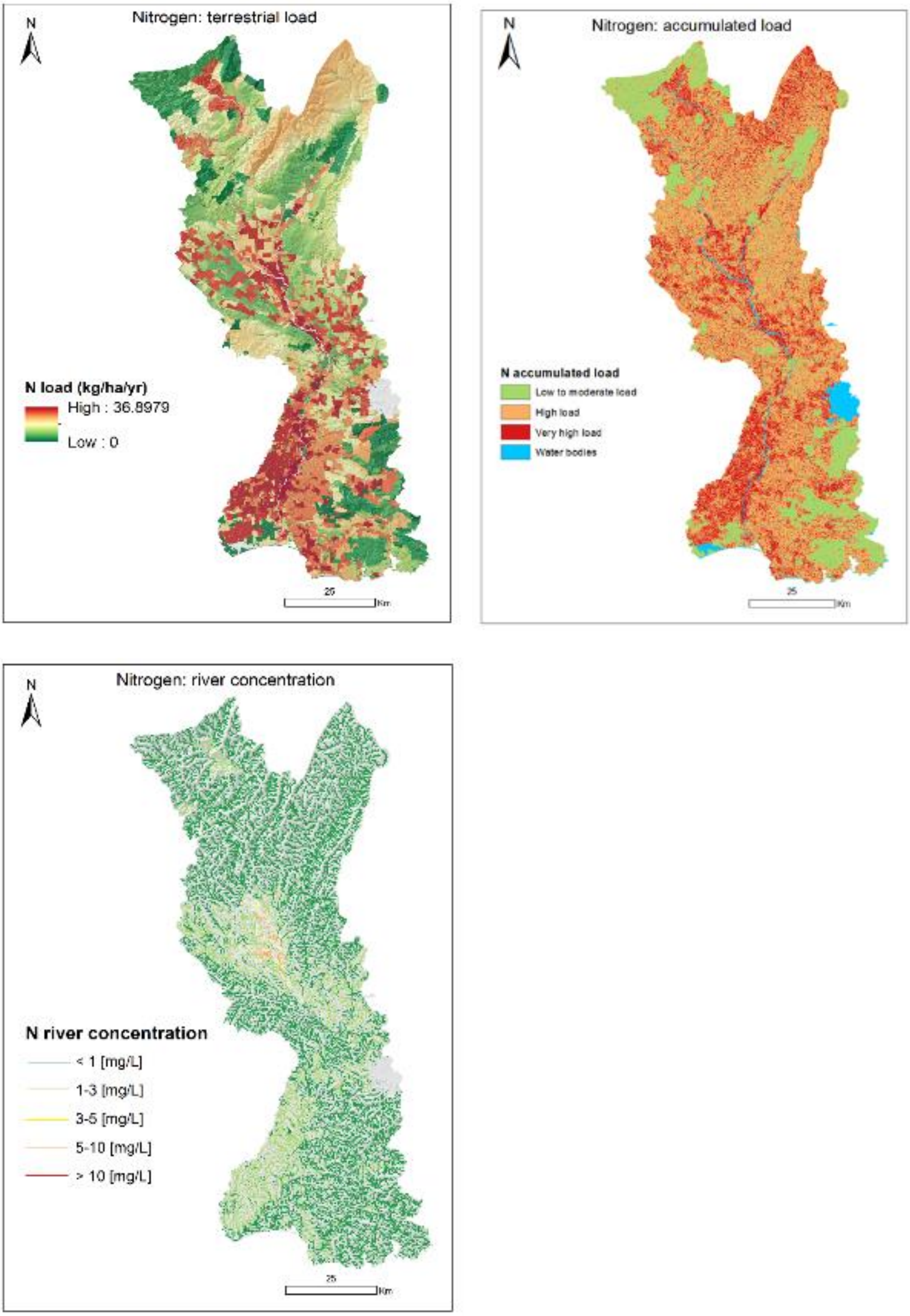

Figure 4-2. Results of nitrogen: Nitrogen terrestrial load, Nitrogen accumulated load classification and Nitrogen in-stream concentration

Nature Braid estimates the terrestrial nutrient load (kg/ha/yr) through a modified export coefficient approach that uses spatially explicit information on land, soil, topography, and rainfall in addition to regional information on fertiliser, stocking, and irrigation to generate accumulated load at a point. The estimated maximum nitrogen load in Mataura is 36.89 kg/ha/yr and the mean value is 8.72 kg/ha/year (Table 4-2).

Table 4-2. Summary statistics of nitrogen terrestrial loads for the farm types within the Mataura catchment.

	Nitrogen terrestrial load (kg/ha/yr)
Min	0
Mean	8.72
Max	36.89

The highest mean nitrogen terrestrial loads occur on Dairy and Dairy Support areas (Table 4-3). Nature Braid also estimates accumulated load (kg/yr) based on terrestrial nutrient loads combined with topographic routing and effective precipitation to route water through the landscape. Large areas of high nitrogen terrestrial loads (total N loads) (Figure 4-2; top left) and accumulated loads (Figure 4-2; top right) are identified in Dairy farms along the Mataura River and the Seaward Down domain.

Table 4-3. Mean nitrogen terrestrial loads for the farm types within the Mataura catchment.

Farm types	Mean nitrogen terrestrial load (kg/ha/yr)
Dairy	26.74
Dairy Support	15.12
Lowland Sheep and Beef	7.50
Hill Country Sheep and Beef	6.23
High Country Sheep and Beef	6.53
Mixed Cropping	9.41

Most of the streams in within the Mataura catchment have in-stream total P concentrations less than 0.01 mg/L (Table 4-4) with an average concentration of ~0.02 mg/L and maximum concentration of ~23.07 mg/L. Like the nitrogen results, streams with a concentration greater than 0.05 mg/L are mostly found at the Lower Mataura catchment and streams around Gore and Mataura townships (Figure 4-3, bottom). From measurement data published by LAWA, high total phosphorus is also found at Mimihau Stream at Wyndham (5-year median of 0.035 mg/L), Mokoreta River at Wyndham River Road (5-year median of 0.026 mg/L), Mataura River at Mataura Island Bridge (5-year median of 0.024 mg/L) and Waikaka Stream at Gore (5-year median of 0.06 mg/L).

Table 4-4. Classified in-stream P concentrations for the baseline 2025.

In-stream P concentration	Number of reaches	Percent of total (%)
<0.01 mg/L	31,595	57.64
0.01 to 0.025 mg/L	9,826	17.92
0.025 to 0.05 mg/L	7,697	14.4
0.05 to 0.075 mg/L	2,711	4.94
>0.075 mg/L	2,979	5.43

High phosphorus loads are also identified in Dairy farms along the Mataura River. Large areas of high phosphorus terrestrial loads (Figure 4-3, top left) and accumulated loads (Figure 4-3, top right) are located in Whiterigg and Wendon. The maximum phosphorus load in Mataura is 2179.30 g/ha/yr with a mean value of 369.13 g/ha/yr (Table 4-5). Dairy, Dairy Support, Lowland Sheep and Beef, and Mixed Cropping farms have higher mean phosphorus terrestrial loads compared to the catchment mean (Table 4-6).

Table 4-5. Summary statistics for phosphorus load for the baseline 2025.

	Phosphorus load (g/ha/yr)
Min	0
Mean	369.13
Max	2,179.29

Table 4-6. Mean phosphorus terrestrial loads for the farm types within the Mataura catchment.

Farm types	Mean phosphorus terrestrial load (g/ha/yr)
Dairy	1,306.00
Dairy Support	805.34
Lowland Sheep and Beef	429.04
Hill Country Sheep and Beef	159.27
High Country Sheep and Beef	86.71
Mixed Cropping	442.95

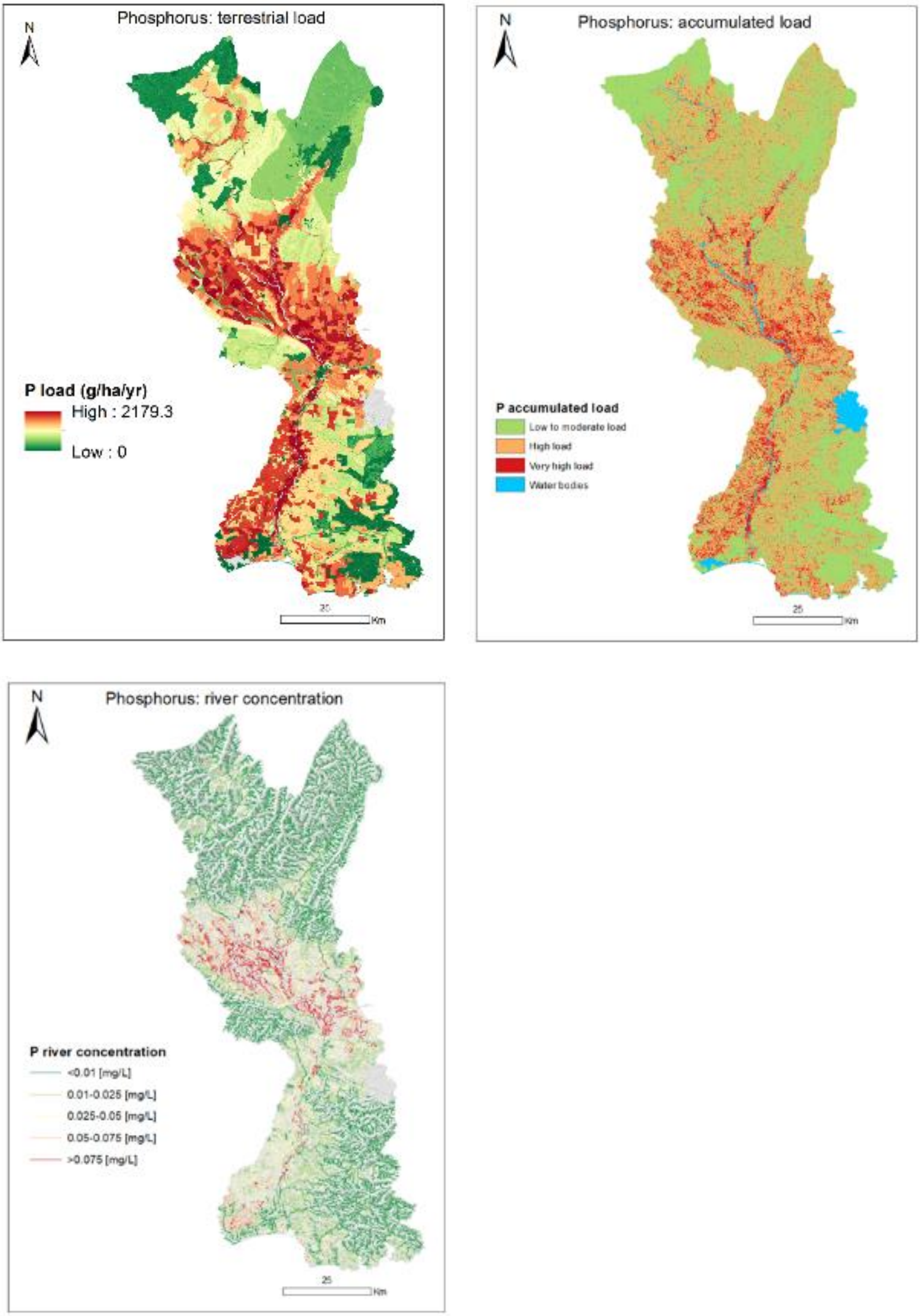

Figure 4-3. Results of phosphorus: Phosphorus terrestrial load, Phosphorus accumulated load classification, P in-stream concentration.

The flood mitigation output uses information on water movement and landscape hydrology to delineate areas that are mitigating movement of flow, areas that are mitigated, and non-mitigated features. With large areas of intensive farming, 77.9% of the catchment is identified as non-flood mitigated features. 18.44% of high flood concentrations are in places of high flow concentration and have large contributing areas with no mitigation. These unmitigated areas have the potential to carry flow and associated contaminants (e.g., nutrients and sediments) directly to streams, affecting flooding events and water quality.

High flood concentration areas are located along with the riparian areas of the Mataura River, particularly around Gore and Mataura townships and farmland in Sandstone and Ardlussa (Figure 4-4, top right). Large clusters of high flood concentration pixels are in the lowlands and valleys of the Old Man Range northeast part of Mataura. High flood concentration also occurs on flat areas in small clusters of pixels across the catchment. These areas of high flood concentration and unmitigated land (Figure 4-4, top left) are potential areas of opportunity to consider management changes. The average flow map shows where higher flows can generally be expected for the Mataura, which consist of two main tributaries from the north-west and north-east sections joining to flow southward to the outlet (Figure 4-4, bottom).

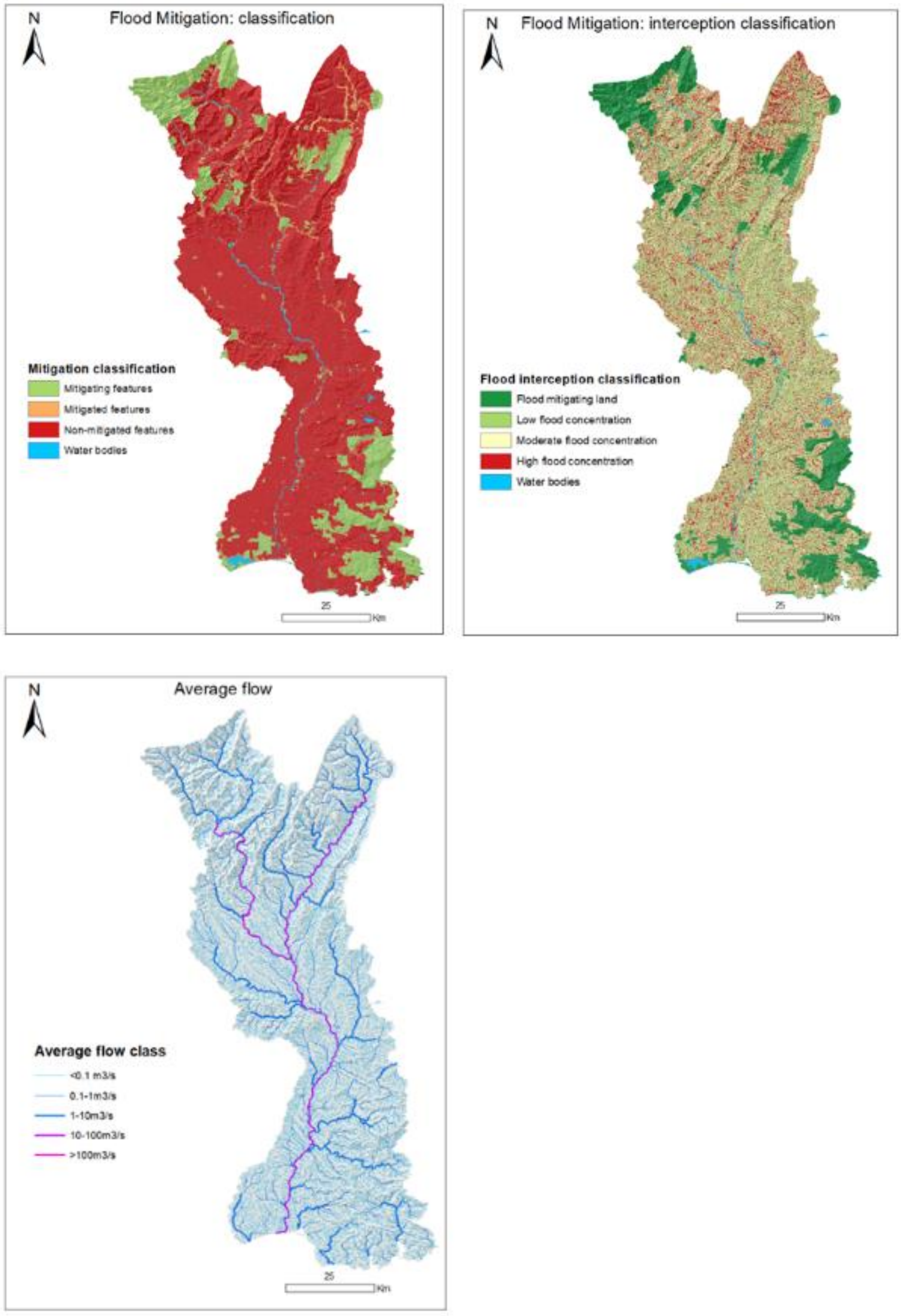

Figure 4-4. Results of flood mitigation: flood mitigation, flow mitigation and average flow

The mean soil loss for the Mataura catchment was about 10.6 tonnes/ha/yr for the baseline 2025. The areas of high soil losses were around the north end and southeast corner of the catchment (Figure 4-5, top left). The soil loss over small time scales is mainly driven by rainfall and topography, along with soil type and cover/management. Over longer time scales, the broader climatic and geological influences have affected these shorter-term drivers of vulnerability. The north end and southeast corner of the catchment corresponded to higher volumes of rain which have higher rainfall erosivity, and combined with the steep topography, make these areas vulnerable to soil loss. The classified soil loss risk shows that the agricultural areas on hilly topography are at risk of extreme soil losses (>10 tonnes/ha/yr; Figure 4-5, top right). The sediment delivery map is useful for narrowing down the areas for potential management interventions because it considers whether the soil losses generated are being intercepted by mitigating features or not (Figure 4-5, bottom). Areas of high sediment delivery risk that are not being mitigated have the potential to produce sediment-rich flows that affect water quality.

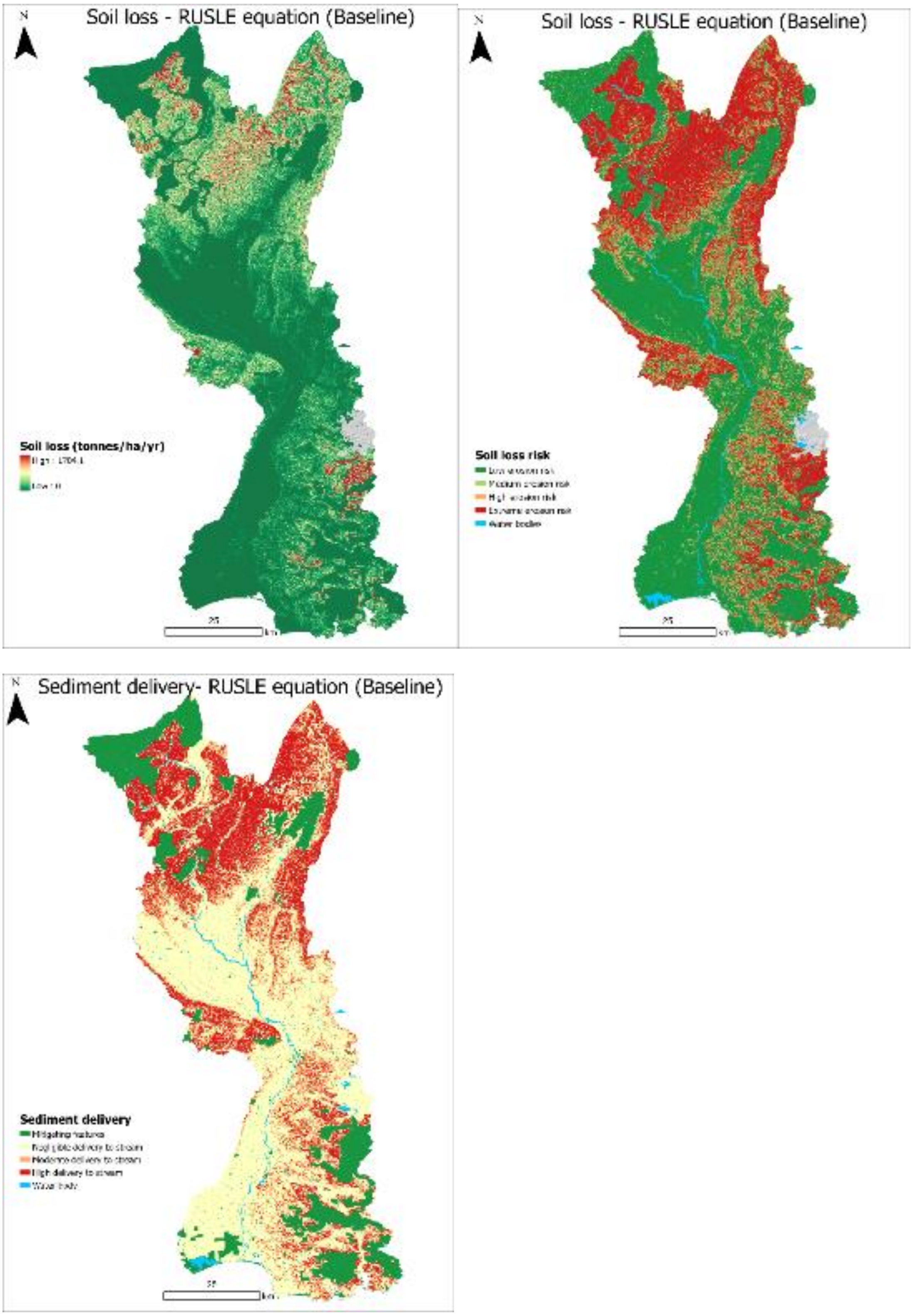

Figure 4-5. Results relating to both "point"-scale soil loss: (soil loss (tonnes/ha/yr and a categorisation of risk), and risk of this soil being delivered to water ways ("sediment delivery").

Habitat connectivity classes for kererū are presented in Figure 4-6. The parameterisation used was obtained from a previous study in Christchurch (Nguyen, et al., 2021). Based on this study, the minimum area for kererū to make a habitat is 0.05ha. However, the current land use map does not well present small native bushes which can provide habitat for kererū. To better map the habitat connectivity of kererū, information on small patches of native vegetation or vegetation suitable as corridors for kererū should be added to the current land use data. Parameterisation should also be improved to reflect the habitat condition for preferred kererū in the catchment as this affects species' survival and movement.

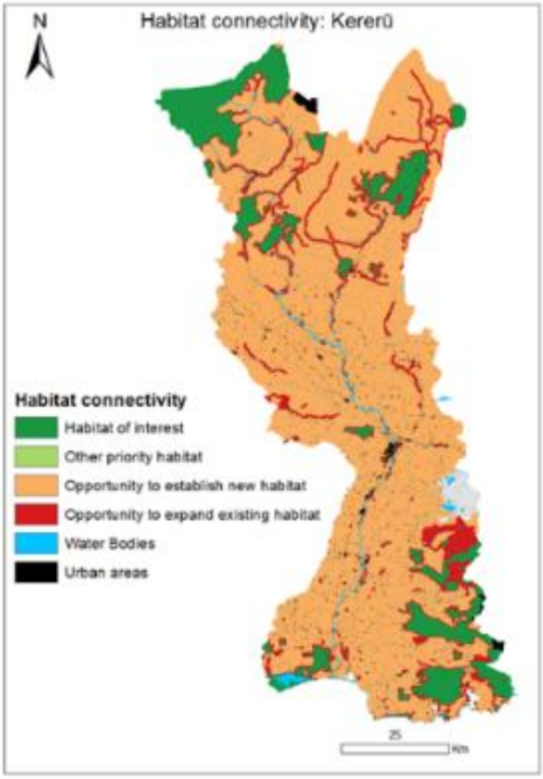

Figure 4-6. Results of habitat connectivity for kererū.

4.2 Scenario 1A

It is estimated that the catchment profitability in 2025 will be $463.78M. This will increase to $480.03M in 2030 due to Dairy, Dairy Support and Lowland transitioning to a better modelled land use (Horticulture – Tulips). By 2060, the catchment profitability would increase to $810.90M as all the unprofitable High Country Sheep and Beef converts to Exotic Forestry.

4.2.1 Economic analysis

Changes in profitability of farming is shown in Table 4-7. As the levy rate increases over time, all farming land use becomes less profitable; in particular by 2060 High Country Sheep and Beef farming has become unprofitable and Hill Country Sheep and Beef is barely making any profit.

Table 4-7. Profitability of farm types under Scenario 1A for 2025, 2030 and 2060.

EFS per ha	Baseline (2025)	Scenario 1A (2030)	Scenario 1A (2060)
Dairy	$3,474	$3,388	$2,370
Dairy Support	$348	$293	($358)
Lowland Sheep and Beef	$695	$658	$626
Hill Country Sheep and Beef	$230	$213	$17
High Country Sheep and Beef	$64	$58	($18)
Mixed Cropping	$1,253	$1,219	$811
Horticulture (Tulips)	$5,000	$5,000	$5,000

The resulting change in land area is shown in Table 4-8. Highly productive land is immediately used for the high value Horticulture (Tulips). Horticulture (Tulips) require a six-year rotation cycle, so change is limited to 1/6th of highly productive land.

By 2060 it is assumed that all High Country Sheep and Beef land moves out of the current land use, as it becomes unprofitable. This transition occurring to Exotic Forestry has been modelled. However, in practice, this land has very low productivity potential. Particularly for high altitudes (above 600m) this may be more likely to move to Indigenous Vegetation. For this reason, these areas have been shaded in the land use maps provided in Appendix A11 – Additional Nature Braid Maps

Land use maps and N high risk areas map

Table 4-8. Change in land area for each farm type under scenario 1A, for 2025, 2030 and 2060.

	Baseline (2025)		Scenario 1A (2030)		Scenario 1A (2060)	
	Area	%	Area	%	Area	%
Dairy	80,520	13.6%	78,163	13.2%	78,163	13.2%
Dairy Support	21,425	3.6%	20,977	3.5%	20,977	3.5%
Lowland Sheep and Beef	156,652	26.5%	153,926	26.0%	153,926	26.0%
Hill Country Sheep and Beef	170,597	28.8%	170,597	28.8%	170,597	28.8%
High Country Sheep and Beef	60,554	10.2%	60,554	10.2%	0	0.0%
Mixed Cropping	2,268	0.4%	2,268	0.4%	2,268	0.4%
Indigenous Vegetation	83,363	14.1%	83,363	14.1%	83,363	14.1%
Wetland	2,992	0.5%	2,992	0.5%	2,992	0.5%
Exotic Forestry	15,999	2.7%	15,999	2.7%	76,553	12.9%
Horticulture (Tulips)	0	0.0%	5,533	0.9%	5,533	0.9%

A total levy revenue of $2.87B will be collected by 2060 and this has been modelled to be recycled back into the catchment as financial support for national level research.

4.2.2 Impact on overall emissions

Figure 4-7 shows the overall impact of land use changes for 1A on the total emissions by CO_2-eq. Total emissions are reduced from 724,238 in 2025, to 706,429 in 2030, and -796,885 in 2060. Negative emissions indicate catchment sequestration exceeds catchment emissions.

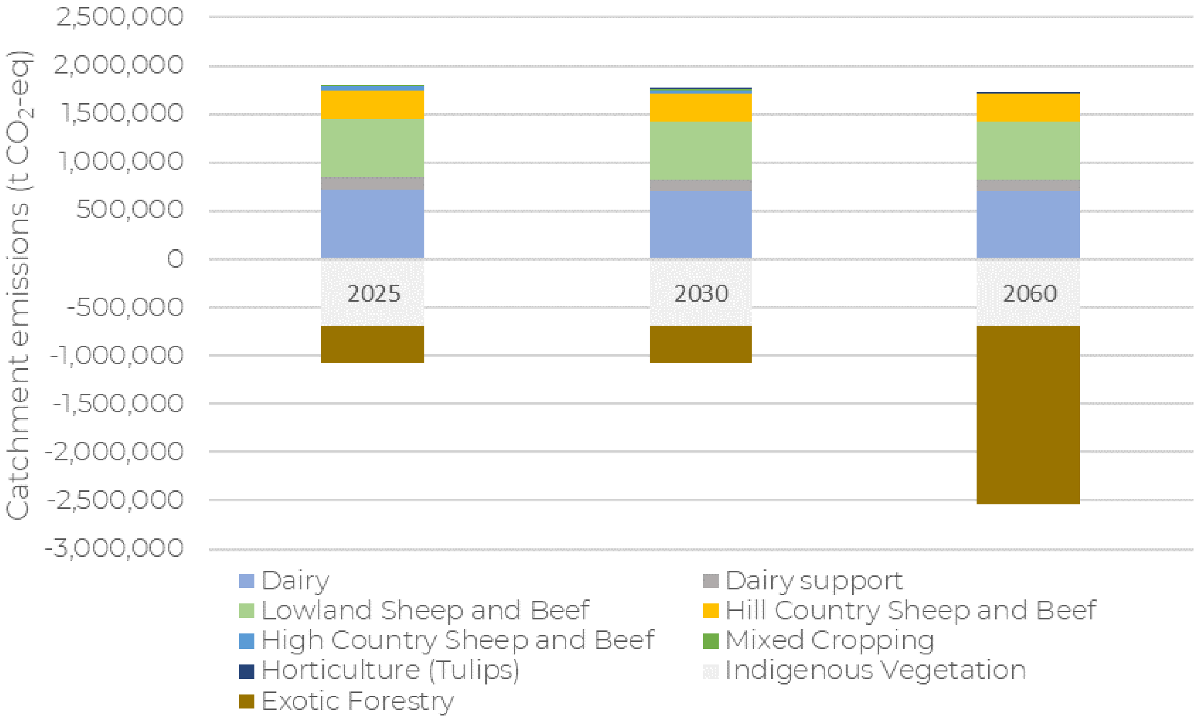

Figure 4-7. Tonnes CO2-eq per farm type for Scenario 1A.

4.2.3 Environmental analysis

The results for agricultural productivity in 2030 do not change significantly with the move of Dairy, Dairy Support, and Lowland Sheep and Beef to Horticulture (Tulips), as Nature Braid still considers horticulture as agriculturally productive land. In 2060, with the move of High Country Sheep and Beef farming to Exotic Forestry and Indigenous Vegetation, the overall agricultural utilisation of the Mataura is considered to have decreased. Although Indigenous Vegetation is important for other ecosystem services (e.g., nutrients, habitat), Nature Braid does not consider this land to have agricultural production value. Exotic Forestry is also not considered agricultural usage as Nature Braid's agricultural productivity tools mainly consider stocking and arable land as productive compared to forestry.

The move from High Country Sheep and Beef to Exotic Forestry in 2060 appears in the maps for the 2030 and 2060 scenarios below (Figure 4-8) in the northeast end of the Mataura catchment. In terms of mean nitrogen terrestrial loads (Table 4-9) and stream concentrations (Table 4-10), the 2030 scenario presented a slight decrease with the move of some areas under Dairy, Dairy Support, and Lowland Sheep and Beef to the less intensive land use of Horticulture (Tulips). The 2060 scenario presented a larger decrease in mean due to the move of intensive High Country Sheep and Beef to Exotic Forestry, removing stock. Although Exotic Forestry would have fertiliser inputs at particular stages of tree growth, this was not considered in this analysis.

Table 4-9. Statistics for nitrogen terrestrial load for the baseline and scenarios.

Nitrogen terrestrial load (kg/ha/yr)	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Min	0	0	0
Mean	8.72	8.72	7.98
Max	36.89	36.89	36.89

Table 4-10. Statistics of in-stream nitrogen concentration for the baseline and scenarios.

Nitrogen stream concentration (mg/L)	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Min	0	0	0
Mean	0.76	0.75	0.71
Max	341.45	278.52	278.52

For mean nitrogen terrestrial loads per farm type, the average values for Dairy, Dairy Support, and Lowland Sheep and Beef have decreased compared to the baseline 2025 scenario with the move from these farm types to Horticulture (Tulips) (Table 4-11).

Table 4-11. Mean N terrestrial loads for baseline 2025, Scenario 1A 2030 and 2060 for farm types in the Mataura.

Farm types	Mean nitrogen terrestrial load (kg/ha/yr)		
	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Dairy	26.74	26.64	26.64
Dairy Support	15.12	15.10	15.10
Lowland Sheep and Beef	7.50	7.48	7.48
Hill Country Sheep and Beef	6.23	6.23	6.23
High Country Sheep and Beef	6.53	6.53	N/a (All High Country moved to Exotic Forestry)
Mixed Cropping	9.41	9.41	9.41
Horticulture (Tulips)	N/a	4.55	4.55

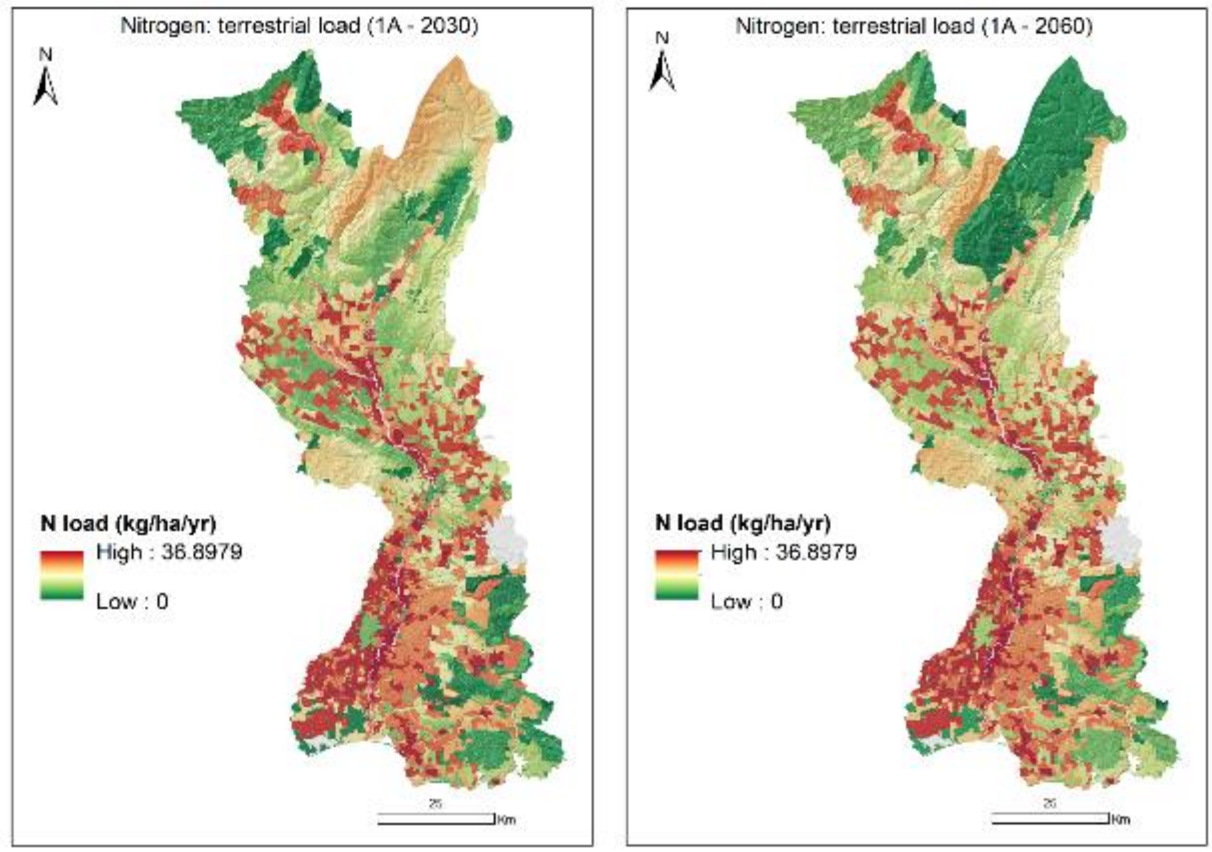

Figure 4-8. Nitrogen terrestrial load results for Scenario 1A 2030 and 2060.

Similar to the nitrogen load maps, the 2030 and 2060 maps below (Figure 4-9) illustrate how the move from High Country Sheep and Beef to Exotic Forestry showed lower terrestrial phosphorus loading for the northeast of the catchment.

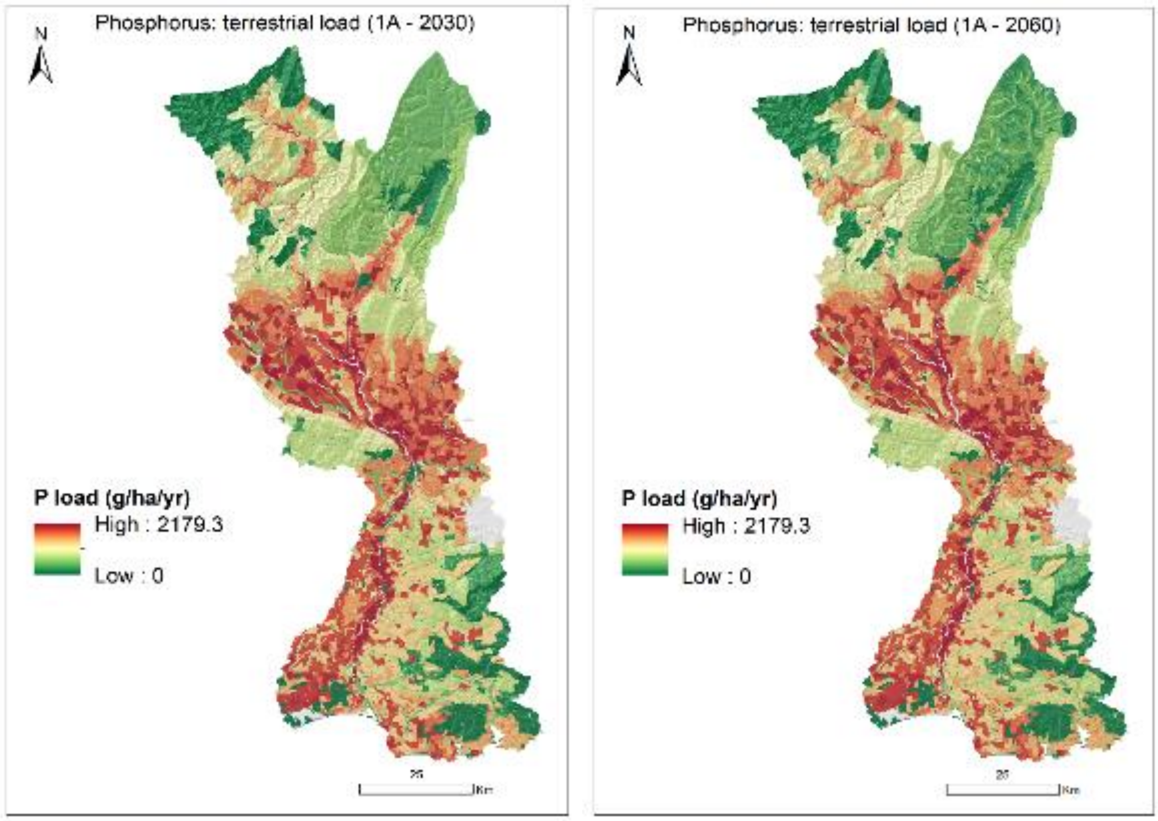

Figure 4-9. Phosphorus load results for Scenario 1A 2030 and 2060.

The results for phosphorus statistics (Table 4-12, Table 4-13) were similar to nitrogen. The changes in 2060 contributed to slightly lower mean loads and in-stream concentrations.

Table 4-12. Statistics for phosphorus terrestrial load for the baseline 2025 and scenarios.

Phosphorus load (g/ha/yr)	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Min	0	0	0
Mean	369.13	369.37	362.05
Max	2,179.29	2,179.29	2,179.29

Table 4-13. Statistics for in-stream phosphorus concentrations for the baseline and scenarios.

Phosphorus stream concentration (mg/L)	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Min	0	0	0
Mean	0.02	0.02	0.019
Max	23.07	21.71	21.71

There are slight increases in mean phosphorus terrestrial load in this scenario because Exotic Forestry has replaced some extensively (i.e., not intensively stocked) land on steep slopes and so more sediment overall is generated, which carries the particulate P along with it (Table 4-14).

Table 4-14. Mean P terrestrial loads for baseline 2025, Scenario 1A 2030 and 2060 for farm types in the Mataura.

Farm types	Mean phosphorus terrestrial load (g/ha/yr)		
	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Dairy	1,306.00	1,323.90	1,323.90
Dairy Support	805.34	813.71	813.71
Lowland Sheep and Beef	429.04	431.36	431.36
Hill Country Sheep and Beef	159.27	159.27	159.27
High Country Sheep and Beef	86.71	86.71	N/a (All High Country moved to Exotic Forestry)
Mixed Cropping	442.95	442.97	442.97
Horticulture (Tulips)	n/a	511.61	511.61

The flood mitigation results (Table 4-15) indicate a large increase in mitigating features in 2060 compared to the baseline 2025 and 2030 due to the move to Exotic Forestry. The assumption in Nature Braid for Exotic Forestry is that it is capable of intercepting water flow and associated nutrients and sediments. However, it also generates large amounts of sediment within Nature Braid, particularly on steep slopes as an average load including consideration of loss around harvest time is included.

Table 4-15. Results of the flood mitigation tool for the baseline 2025 and scenarios.

Flood characteristics	Area of the catchment (ha)		
	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Mitigating features	99,056	99,056	158,893
Mitigated features	23,976	23,976	16,841
Non-mitigated features	498,245	498,245	445,439
Water bodies	17,315	17,315	17,315

For soil loss by water, 2030 did not show a large change due to the relatively small area that became Horticulture (Tulips) (Figure 4-10, top left). However, the mean soil loss for 2060 increased due to the presence of plantation forestry on the northeast corner of the Mataura which interacts with the high rainfall and hilly topography (Figure 4-10, top right). Exotic Forestry harvesting is associated with erosive practices, causing the mean to be much higher. Prior to harvest, Exotic Forestry is considered capable of mitigating flow, hence the flow mitigation results above (Table 4-15) and sediment delivery results below (Figure 4-10, bottom maps), but the harvesting makes this land use vulnerable to erosion.

Table 4-16. Summary statistics for terrestrial soil loss for the baseline 2025 and scenarios.

Soil loss (tonnes/ha/yr)	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Min	0	0	0
Mean	10.6	10.6	18.1
Max	1,704.1	1,704.1	1,760.5

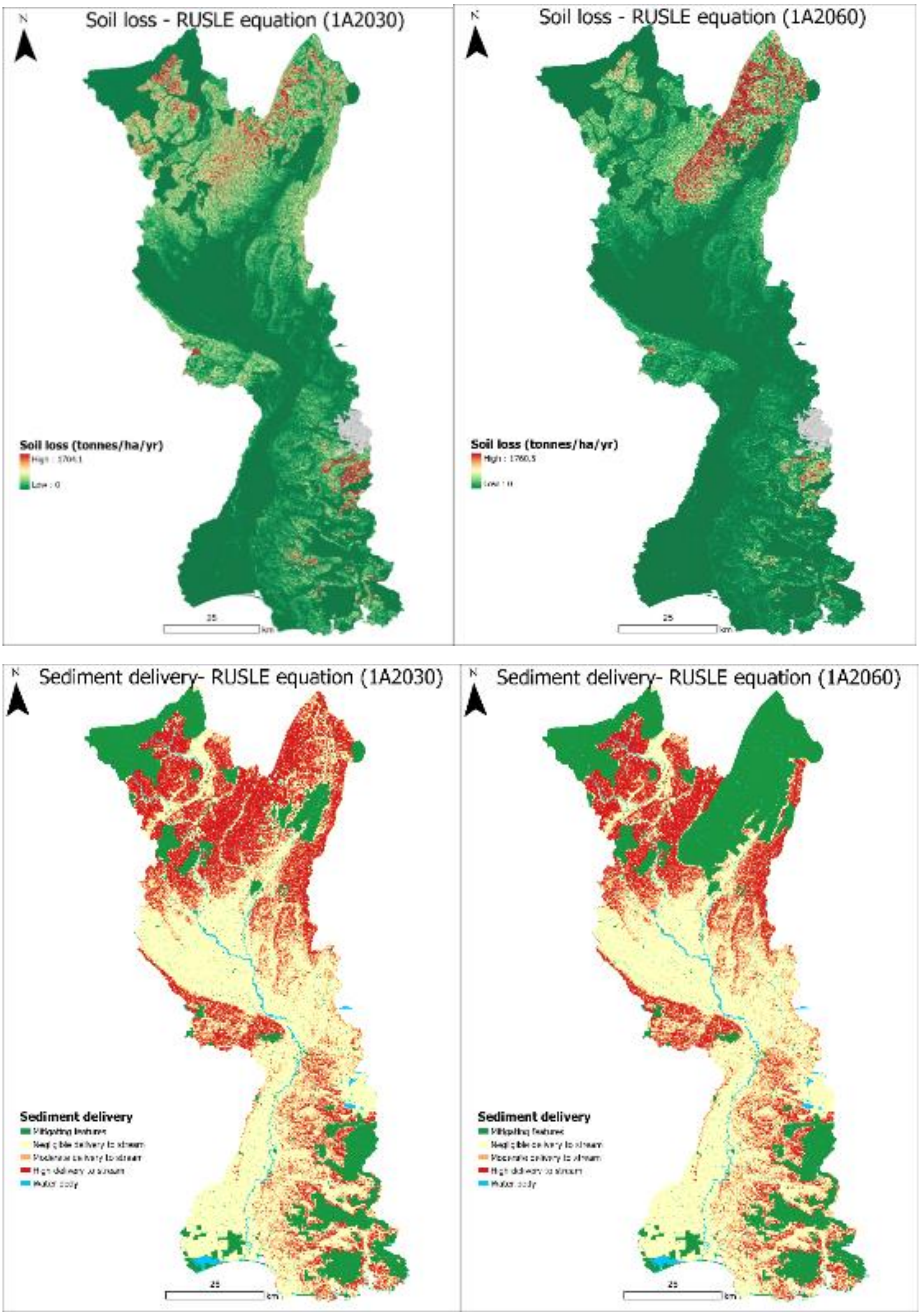

Figure 4-10. Erosion results for Scenario 1A 2030 and 2060.

In the 2060 scenario, the areas of opportunity to expand existing habitat as the move to Exotic Forestry resulted in vegetated areas adjacent to Indigenous Vegetation, the ideal habitat for kererū (Figure 4-11). Since Exotic Forestry is relatively easy for kererū to move through, this addition may create corridors for kererū to reach their ideal habitat (Indigenous Vegetation).

Table 4-17. Results of the habitat connectivity tool for kererū for the baseline 2025 and scenarios (changes compared to baseline are presented in brackets).

Habitat classification	Area of the catchment (ha)		
	Baseline 2025	Scenario 1A 2030	Scenario 1A 2060
Habitat of interest	82,253	82,253 (0)	82,253 (0)
Other priority habitat	0	0	0
Opportunity to establish new habitat	460,450	459,105 (-1,345)	420,342 (-40,108)
Opportunity to expand existing habitat	60,066	61,416 (+1,350)	100,179 (+40,113)

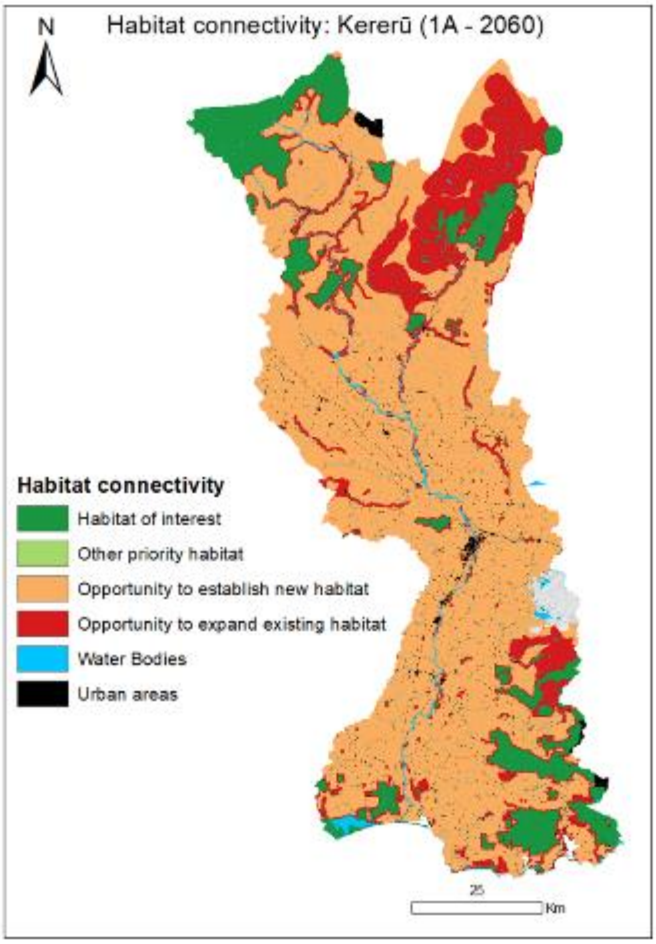

Figure 4-11. Habitat connectivity results for kererū for 2060.

4.3 Scenario 1B

It is estimated that the catchment profitability in 2025 will be $395.12M. This is lower than scenario 1A as under the high levy pathway, returns on Dairy, Dairy Support, Lowland Sheep and Beef, Hill Country Sheep and Beef, and High Country Sheep and Beef are lower. Similar to scenario 1A, catchment profitability will increase to $431.72M in 2030 mainly due to Dairy, Dairy Support and Lowland transitioning to a better modelled land use (Horticulture – Tulips) and all High Country Sheep and Beef converting to Exotic Forestry. By 2060, the catchment profitability would increase to $1.21B as all Hill Country Sheep and Beef converts to Exotic Forestry.

4.3.1 Economic analysis

Changes in profitability of farming is shown in Table 4-18. In this scenario the levy rate increases significantly over time, and all farming land use becomes less profitable. By 2060 all three Sheep and Beef systems and Dairy Support become unprofitable and are making a loss.

Table 4-18. Profitability of farm types under Scenario 1B for 2030 and 2060 compared with the baseline 2025.

EFS per ha	Baseline (2025)	Scenario 1B (2030)	Scenario 1B (2060)
Dairy	$3,131	$2,806	$657
Dairy Support	$129	($80)	($1,453)
Lowland Sheep and Beef	$546	$406	($523)
Hill Country Sheep and Beef	$164	$101	($312)
High Country Sheep and Beef	$39	$15	($145)
Mixed Cropping	$1,116	$985	$125
Horticulture (Tulips)	$5,000	$5,000	$5,000

The resulting change in land area is shown in Table 4-19. Highly productive land (as identified in Nature Braid) is immediately used for the high value Horticulture (Tulips). Tulips need a six-year cycle, so the change is limited to 1/6th of highly productive land.

Note that High Country Sheep and Beef shows an overall profitability of $15 per ha in 2030. This represents the average of the five productivity classes according to the revised “variable” assessment approach. Under this approach, only the lowest productivity land should have transitioned to Exotic Forestry. However, due to the change in approach described in section 2.2.4, all of the High Country Sheep and Beef land has been shown as transitioning to Exotic Forestry for this scenario.

This scenario assumes that the revenue from the levy is returned to the catchment in the form of:

- Payment for Riparian Planting. All land suitable for planting is planted by 2030.
- Subsidy for planting Indigenous Vegetation. It is assumed 25% of land that becomes uneconomic for High Country Sheep and Beef or Hill Country Sheep and Beef takes up this subsidy.
- Stock reduction subsidy for Hill Country Sheep and Beef farming. This begins in 2030 and all stock is removed from the land prior to 2060 – so it assumed that the subsidy stops, and the land is converted to Exotic Forestry.

- Stock reduction subsidy for Lowland Sheep and Beef farming. This begins when Hill Country Sheep and Beef farming is reduced to zero and reduces lowland stocking rate levels to about 58%, based on the funds available up to 2060.
- The remaining levy is used for national level research.

By 2060, all High Country Sheep and Beef and Hill Country Sheep and Beef land moves to Exotic Forestry or Indigenous Vegetation. Lowland Sheep and Beef remains at low stock levels.

Table 4-19. Change in land area for each farm type under Scenario 1B, for 2025, 2030 and 2060.

	Baseline (2025)		Scenario 1B (2030)		Scenario 1B (2060)	
	Area	%	Area	%	Area	%
Dairy	80,520	13.6%	78,163	13.2%	78,163	13.2%
Dairy Support	21,425	3.6%	20,977	3.5%	20,977	3.5%
Lowland Sheep and Beef	156,652	26.5%	153,926	26.0%	153,926	26.0%
Hill Country Sheep and Beef	170,597	28.8%	170,597	28.8%	0	0.0%
High Country Sheep and Beef	60,554	10.2%	0	0.0%	0	0.0%
Mixed Cropping	2,268	0.4%	2,268	0.4%	2,268	0.4%
Wetlands	2,992	0.5%	2,992	0.5%	2,992	0.5%
Indigenous Vegetation	83,363	14.1%	98,501	16.6%	141,151	23.7%
Exotic Forestry	15,999	2.7%	61,415	10.3%	189,362	31.9%
Horticulture (Tulips)	0	0.0%	5,533	0.9%	5,533	0.9%

A total levy revenue of $9.80B will be collected by 2060 under the high levy pathway. A total of $2.72B will be spent towards planting and maintaining riparian plants along the river streams in the catchment. A further $1.44B is spent to support the planting of Indigenous Vegetation on farmland that has become uneconomic. Next, levy revenue is returned to the catchment as subsidy payments for stock reduction, where a total of $2.22B would be spent towards subsidising Hill Country farming stock reduction and $2.21B would be spent towards subsidising Lowland farming stock reduction (Figure 4-12). In this scenario, $1.20B remains to support national level research.

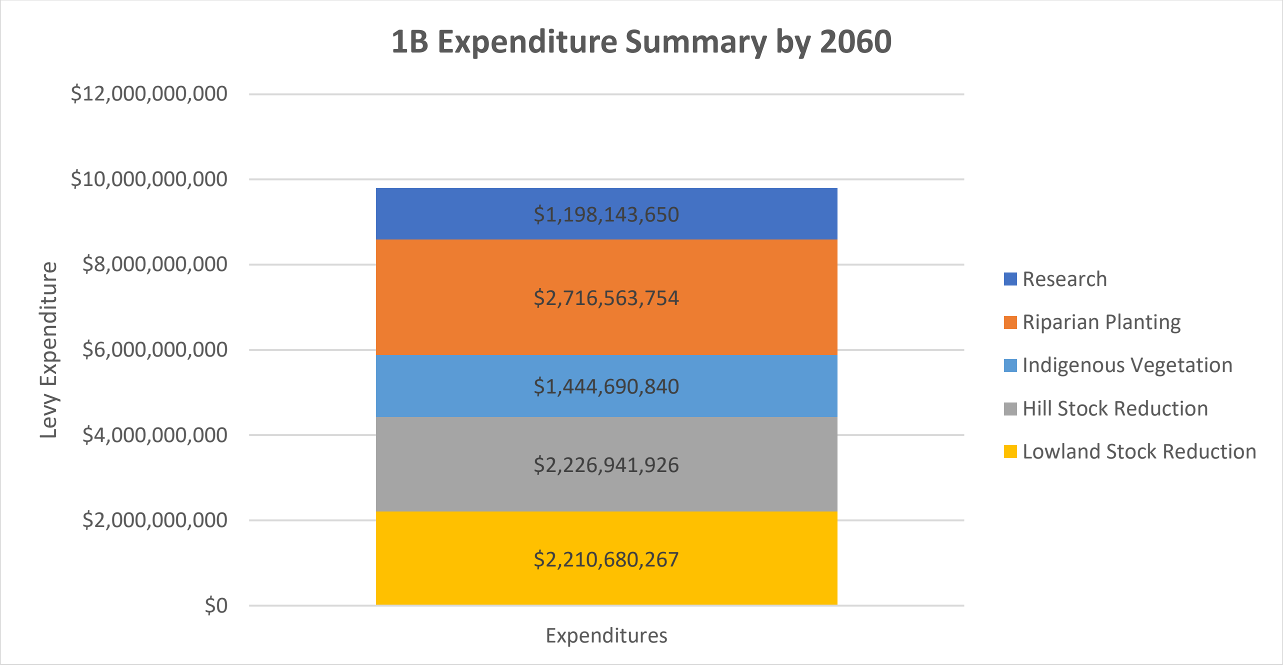

Figure 4-12. Levy Revenue Collected and Expenditure Summary for scenario 1B

4.3.2 Impact on overall emissions

Figure 4-13 shows the overall impact of land use changes for 1B on the total emissions by CO_2-eq. Total emissions are reduced from 724,238 in 2025, to -474,444 in 2030, and -4,231,128 in 2060. Negative emissions indicate catchment sequestration exceeds catchment emissions.

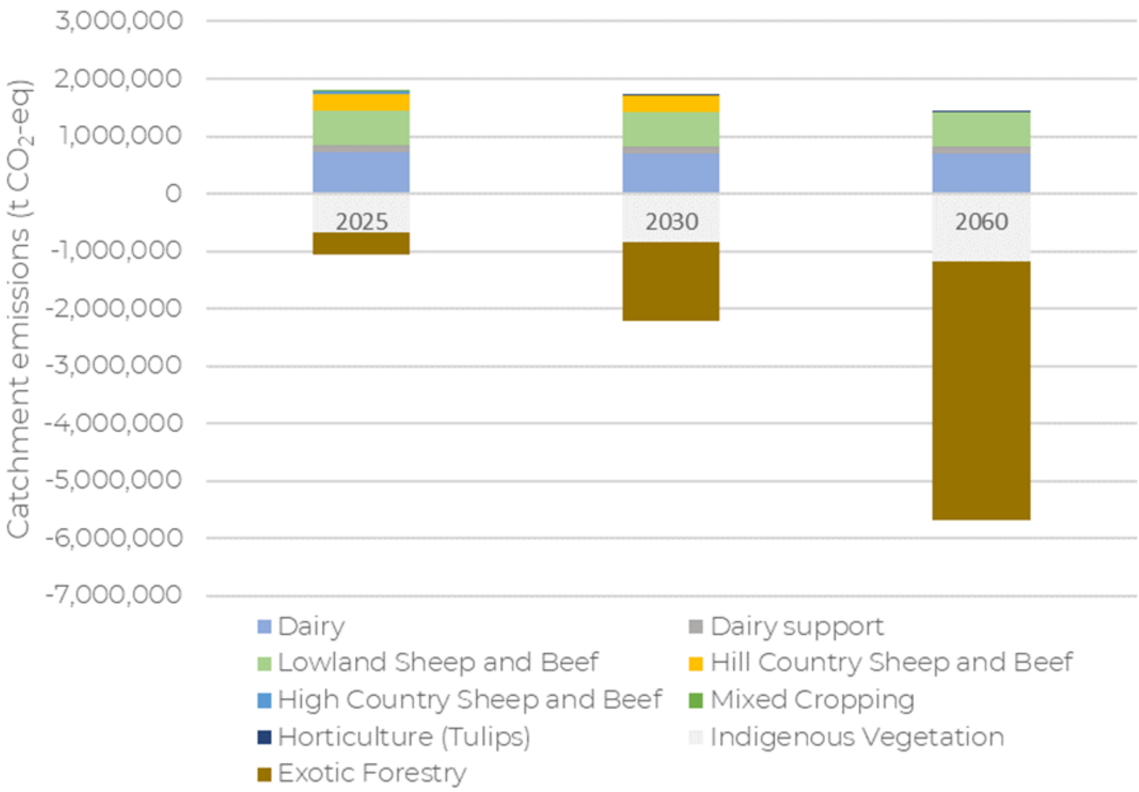

Figure 4-13: Tonnes CO2-eq per farm type: Scenario 1B.

4.3.3 Environmental analysis

For agricultural productivity, the change to Horticulture (Tulips) (2030) and change to Exotic Forestry (2060) had the same effect as Scenario 1A. The addition of Riparian Planting on flat and fertile land is considered unusual utilisation by Nature Braid as it reduces agricultural productivity, but this land use will benefit the nutrients and flood mitigation services.

The effect of adding in Riparian Planting is illustrated in the statistics for in-stream N concentration (Table 4-20) where the mean is reduced by ~0.16 mg/L and the maximum is reduced by over 300 mg/L. The Riparian Planting is able to intercept and mitigate the effects of nutrient on water quality.

Table 4-20. Summary statistics of in-stream nitrogen concentration for the baseline 2025 and scenarios.

Nitrogen stream concentration (mg/L)	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Min	0	0	0
Mean	0.76	0.6	0.48
Max	341.45	7.17	7.17

When looking at the statistics for N load (Table 4-21), the combination of land use change and reductions in stocking brings down the mean nitrogen load across the Mataura catchment.

Table 4-21. Summary statistics for nitrogen terrestrial load for the baseline 2025 and scenarios.

Nitrogen terrestrial load (kg/ha/yr)	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Min	0	0	0
Mean	8.72	7.59	5.92
Max	36.89	36.89	36.89

The land use changes had the same effects as Scenario 1A. For 2030, the decrease in mean N load for Hill Country Sheep and Beef was influenced by the 42% reduction of stocking units compared to the baseline 2025 (Table 4-22). Similarly, the reduction of Lowland Sheep and Beef stocking units to 58% of the baseline 2025 caused a decrease in the mean N load for that farm type. These reductions are reflected in difference between the 2030 and 2060 terrestrial N load (Figure 4-14).

Table 4-22. Mean N terrestrial loads for the baseline 2025, Scenario 1B 2030 and 2060 for farm types in the Mataura catchment.

Farm types	Mean nitrogen terrestrial load (kg/ha/yr)		
	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Dairy	26.74	26.63	26.65
Dairy Support	15.12	15.09	15.11
Lowland Sheep and Beef	7.5	7.47	6.23
Hill Country Sheep and Beef	6.23	5.41	N/a (All Hill Country Sheep and Beef moved to Exotic Forestry)
High Country Sheep and Beef	6.53	N/a (All High Country Sheep and Beef moved to Exotic Forestry)	
Mixed Cropping	9.41	9.41	9.42
Horticulture (Tulips)	N/a	4.55	4.55

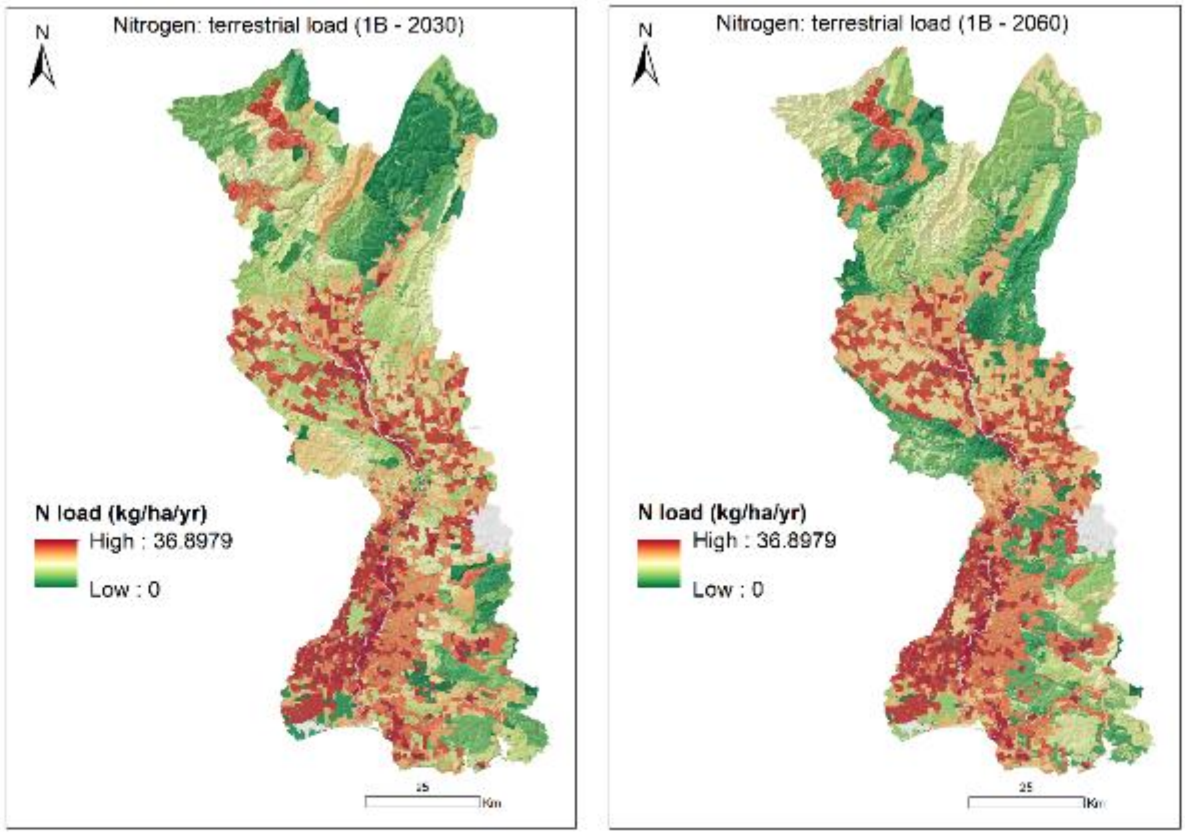

Figure 4-14. Nitrogen terrestrial load results for Scenario 1B 2030 and 2060.

Like the N results, the in-stream P concentrations show a decrease in the mean and a larger decrease in the maximum concentrations, relating to the Riparian Planting intercepting flow with nutrients (Table 4-23).

Table 4-23. Summary statistics for the phosphorus concentration for the baseline 2025 and scenarios.

Phosphorus stream concentration (mg/L)	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Min	0	0	0
Mean	0.02	0.01	0.01
Max	23.07	0.66	0.66

The reductions in 2060 are reflected in the terrestrial P load maps (*Figure 4-15*). The statistics for phosphorus load show decreases in the mean for both 2030 and 2060, relating to the reduction of stock (*Table 4-24*, *Table 4-25*).

Table 4-24. Summary statistics for the phosphorus terrestrial load for the baseline 2025 and scenarios.

Phosphorus terrestrial load (g/ha/yr)	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Min	0	0	0
Mean	369.13	352.7	312.23
Max	2,179.29	2,179.3	2,179.3

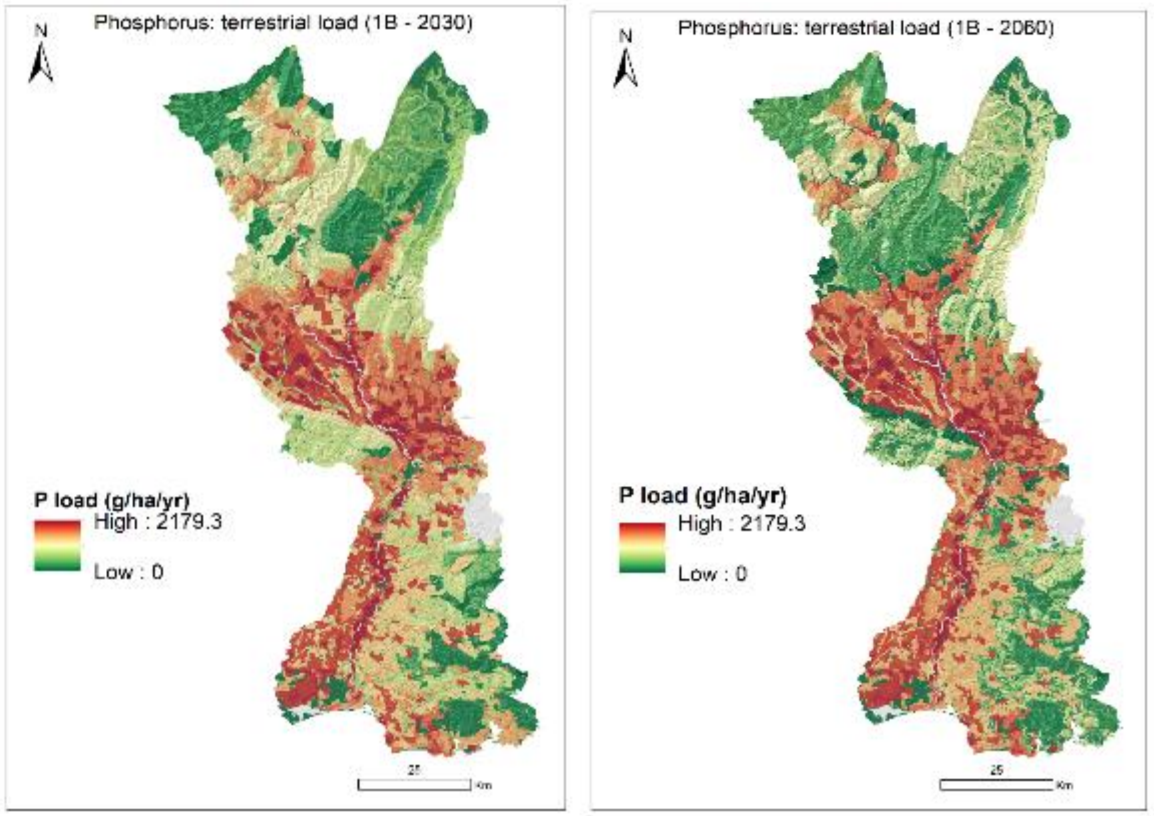

Figure 4-15. Phosphorus terrestrial load results for Scenario 1B 2030 and 2060.

Table 4-25. Mean P terrestrial loads for baseline 2025, Scenario 1B 2030 and 2060 for farm types in the Mataura.

Farm types	Mean phosphorus terrestrial load (g/ha/yr)		
	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Dairy	1,306.00	1,323.36	1,324.28
Dairy Support	805.34	814.09	614.73
Lowland Sheep and Beef	429.04	431.35	431.66
Hill Country Sheep and Beef	159.27	159.08	N/a (All Hill Country Sheep and Beef moved to Exotic Forestry)
High Country Sheep and Beef	86.71	N/a (All High Country Sheep and Beef moved to Exotic Forestry)	
Mixed Cropping	442.95	442.70	442.71
Horticulture (Tulips)	N/a	511.45	511.45

The addition of Exotic Forestry and Riparian Planting created a large increase in the mitigating features in 2030 (+ 70,468 ha) and features considered mitigated or receiving the benefit from the additional planting (+ 158,325 ha). This shows that the area changed for Exotic Forestry and Riparian Planting and other planting benefits uphill areas approximately 2.2 times its size. The change in 2060 was not as dramatic as the Exotic Forestry changes were already located on uphill areas, which are also reflected in the soil loss (Figure 4-16).

Table 4-26. Results of the flood mitigation tool for the baseline 2025 and scenarios.

Flood characteristics	Area of the catchment (ha)		
	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Mitigating features	99,056	169,524	333,806
Mitigated features	23,976	182,301	118,932
Non-mitigated features	498,245	269,990	169,121
Water bodies	17,315	17,080	17,034

Similar to Scenario 1A, the move to Exotic Forestry on hilly topography causes increases in the mean and maximum values for terrestrial soil loss in the Mataura. However, due to the addition of Riparian Planting and other Indigenous planting, more of the Mataura experiences less sediment delivery risk (Figure 4-16, bottom). Like nutrients, understanding the effects of interventions should consider both what is produced at a point (load) and what is eventually delivered to streams.

Table 4-27. Statistics for terrestrial soil loss for the baseline 2025 and scenarios.

Soil loss (tonnes/ha/yr)	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Min	0	0	0
Mean	10.6	15.1	23.4
Max	1704.1	1760.5	1771.6

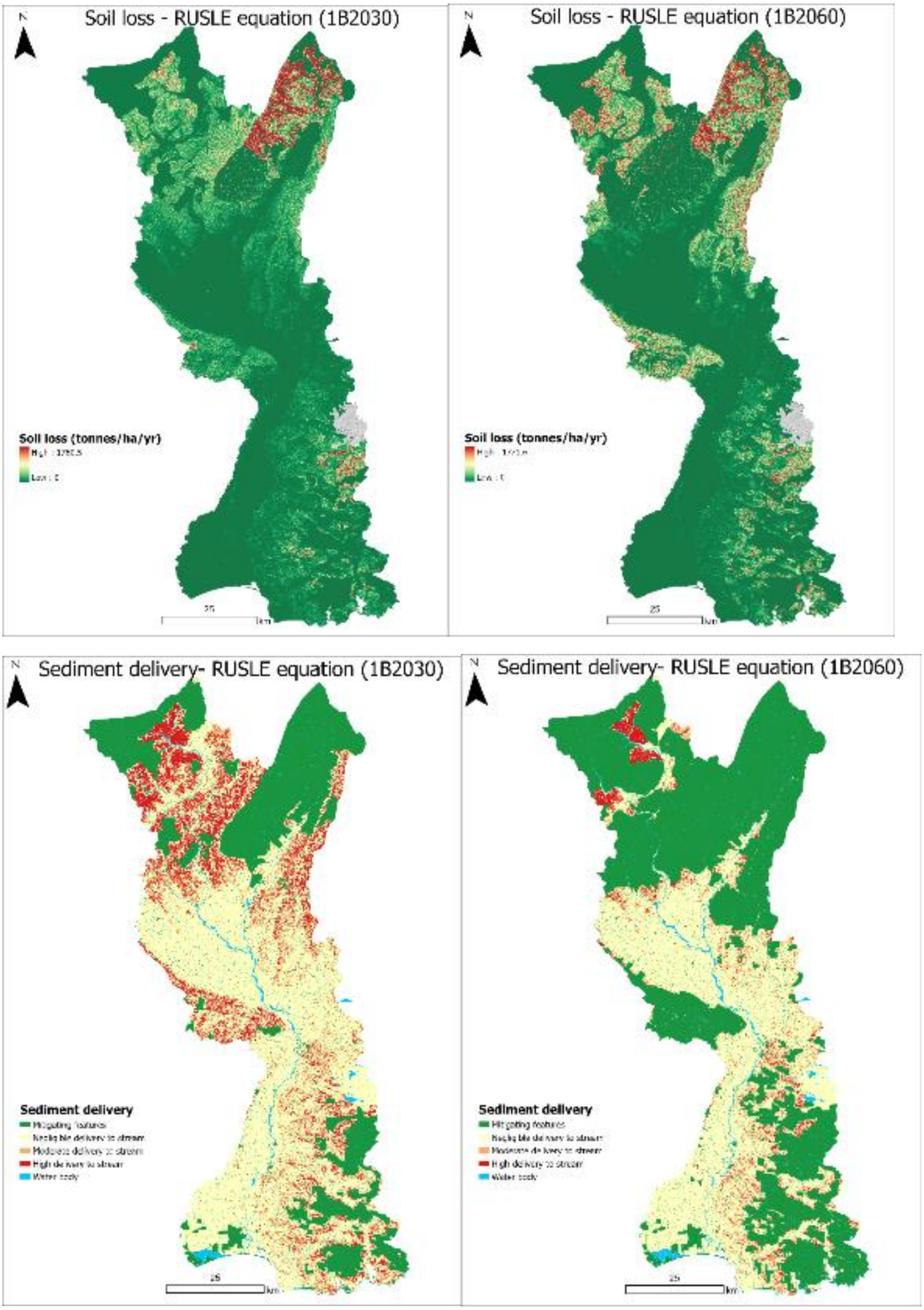

Figure 4-16. Erosion results for Scenario 1B 2030 and 2060.

The addition of Riparian Planting in 2030 and 2060 increased the amount of habitat available for the kererū (Figure 4-17). Including native tree species favourable for kererū within the Riparian Planting can potentially create corridors for the birds to connect habitat patches. This planting on streams may also benefit ground-dwelling waterfowl.

Table 4-28. Results of the habitat connectivity tool for kererū for the baseline 2025 and scenarios (changes compared to baseline 2025 are presented in brackets).

Habitat classification	Area of the catchment (ha)		
	Baseline 2025	Scenario 1B 2030	Scenario 1B 2060
Habitat of interest	82,253	113,754 (+ 31,501)	153,114 (+70,862)
Other priority habitat	0	0	0
Opportunity to establish new habitat	60,066	121,457 (+61,391)	69,428 (+9,362)
Opportunity to expand existing habitat	460,450	367,563 (-92,887)	380,350 (-80,100)

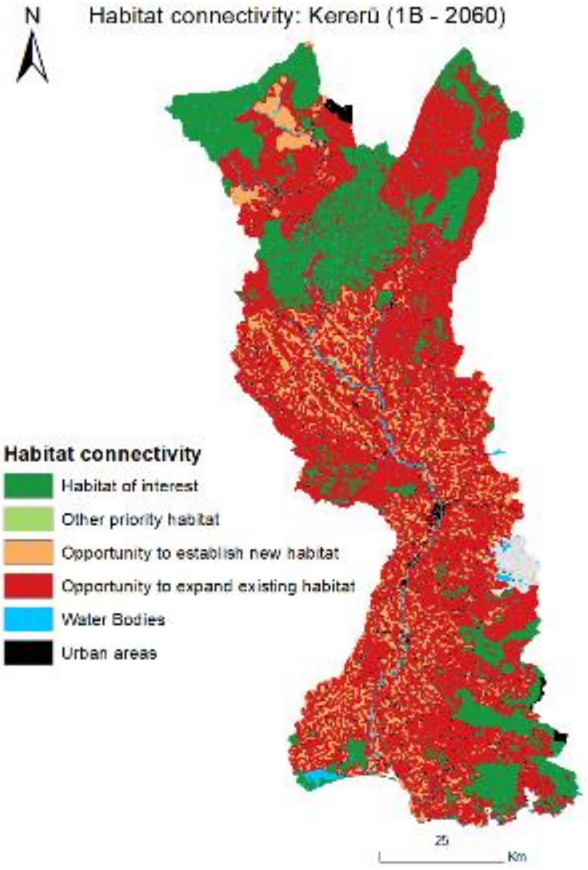

Figure 4-17. Habitat connectivity results for kererū for Scenario 1B 2060.

4.4 Scenario 2A

It is estimated that the catchment profitability in 2025 will be $463.78M. Similar to scenario 1A, this will increase to $480.03M in 2030 due to Dairy, Dairy Support and Lowland Sheep and Beef transitioning to a more profitable modelled land use (Horticulture – Tulips). By 2060, the catchment profitability would increase to $810.90M as all High Country Sheep and Beef converts to Exotic Forestry.

4.4.1 Economic analysis

Changes in profitability of farming is shown in Table 4-29. For 2030 and 2060 we show two values, the “normal/business as usual” land and the N high-risk areas of land (see Section 3.3 for a description of N high-risk land). Some of these show increases in returns for farming that is optimised for lower N use, an area for investigation is whether any “normal” land would invest in switching the farming methodology to achieve this return.

As in scenario 1A, as the levy rate increases over time, all farming land use becomes less profitable, by 2060 High Country Sheep and Beef farming has become unprofitable and Hill Country Sheep and Beef is barely making a profit.

Table 4-29. Profitability of farm types under Scenario 2A for 2025, 2030 and 2060.

EFS per ha	Baseline (2025)	Scenario 2A (2030)	At Risk	Scenario 2A (2060)	At Risk
Dairy	$3,474	$3,388	$2,663	$2,370	$2,005
Dairy Support	$348	$293	$469	($358)	$143
Lowland Sheep and Beef	$695	$658	$860	$626	$501
Hill Country Sheep and Beef	$230	$213	$230	$17	$68
High Country Sheep and Beef	$64	$58	$82	($18)	$31
Mixed Cropping	$1,253	$1,219	$818	$811	$300
Horticulture (Tulips)	$5,000	$5,000		$5,000	

The resulting change in land area is shown in Table 4-30. As in scenario 1A, suitable highly productive land is transitioned the high value Horticulture (Tulips). Tulips need a six-year rotation, so it is limited to 1/6th of suitable highly productive land. However, by 2060 the lower nitrogen cap on N high-risk land (65kg N/ha) make Horticulture (Tulips) untenable and returns to its previous use. As in scenario 1A we assume all High Country Sheep and Beef land moves to Exotic Forestry.

Table 4-30. Change in land area for each farm type under Scenario 2A, for 2025, 2030 and 2060.

	Baseline (2025)		Scenario 2A (2030)		Scenario 2A (2060)	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Dairy	80,520	13.6%	78,163	13.2%	78,163	13.2%
Dairy Support	21,425	3.6%	20,977	3.5%	20,977	3.5%
Lowland Sheep and Beef	156,652	26.5%	153,926	26.0%	153,926	26.0%
Hill Country Sheep and Beef	170,597	28.8%	170,597	28.8%	170,597	28.8%
High Country Sheep and Beef	60,554	10.2%	60,554	10.2%	0	0.0%
Mixed Cropping	2,268	0.4%	2,268	0.4%	2,268	0.4%
Indigenous Vegetation	83,363	14.1%	83,363	14.1%	83,363	14.1%
Wetlands	2,992	0.5%	2,992	0.5%	2,992	0.5%
Exotic Forestry	15,999	2.7%	15,999	2.7%	76,553	12.9%
Horticulture (Tulips)	0	0.0%	5,533	0.9%	5,533	0.9%

A total levy revenue of $2.87B will be collected by 2060 where this has been modelled to be recycled back into the catchment as financial support for national level research as consistent with scenario 1A (Figure 4-18).

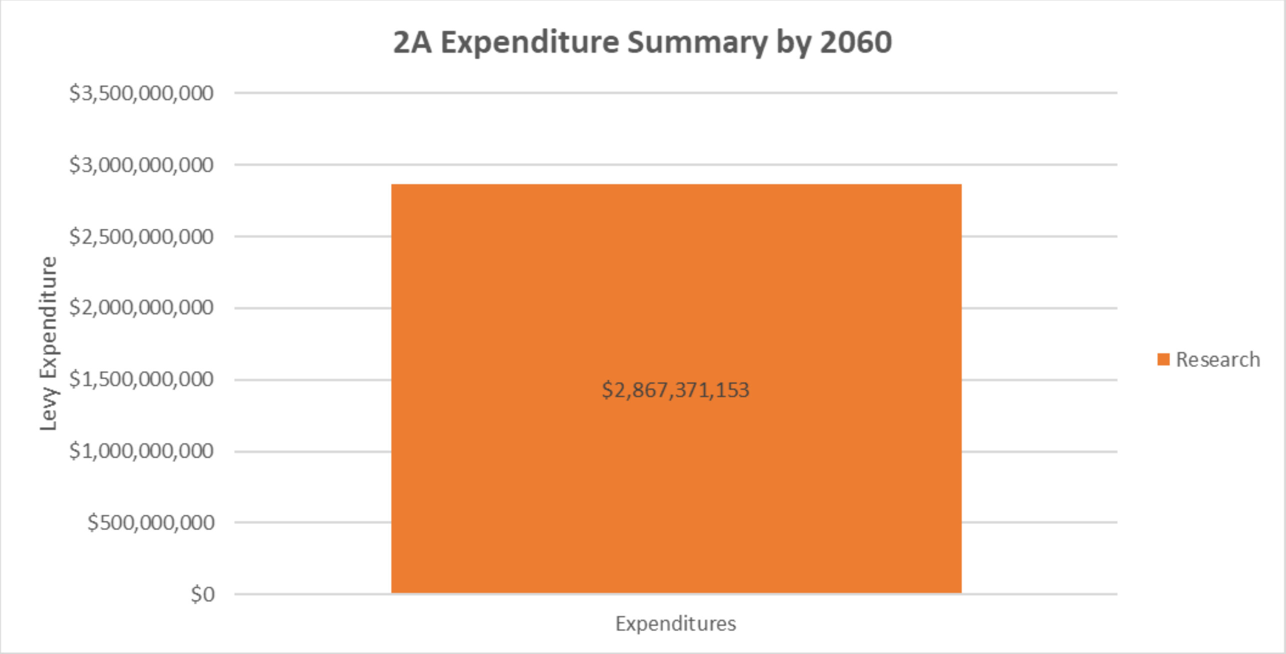

Figure 4-18. Levy Revenue Collected and Expenditure Summary for scenario 2A

4.4.2 Impact on overall emissions

Figure 4-19 shows the overall impact of land use changes for 2A on the total emissions in tCO_2-eq. Total emissions are reduced from 724,239 tCO_2-eq in 2025, to 688,927 tCO_2-eq in 2030, and -980,956 tCO_2-eq in 2060. Negative emissions indicate catchment sequestration exceeds catchment emissions.

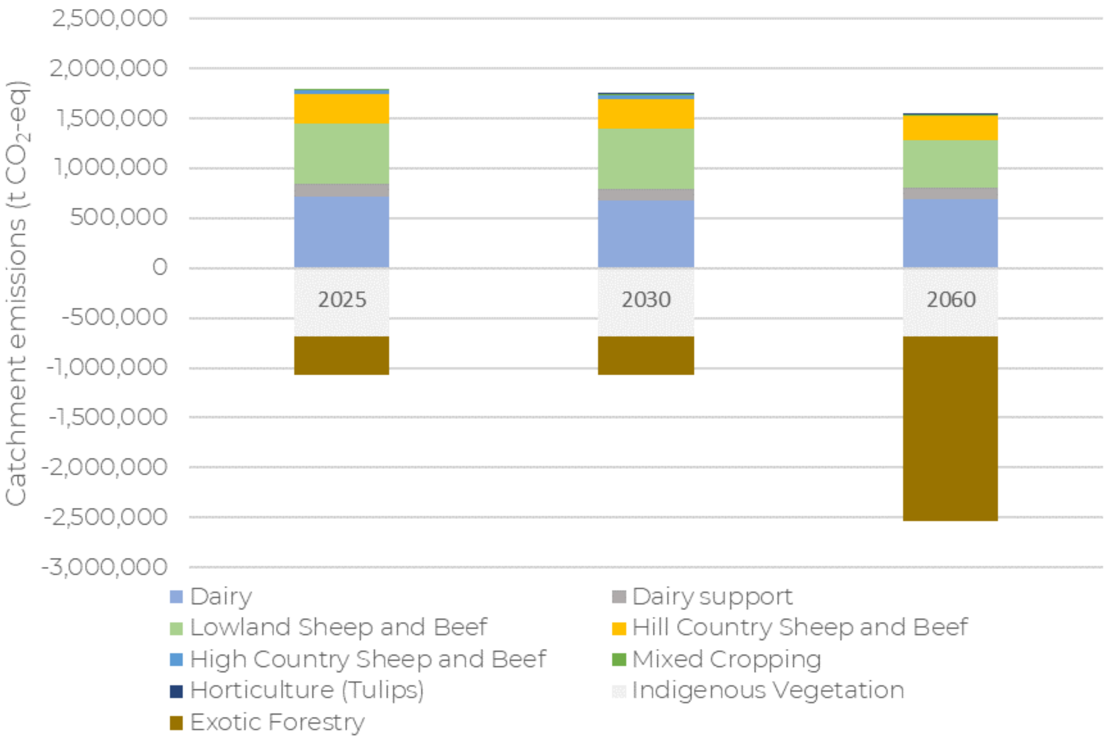

Figure 4-19: Tonnes CO2-eq per farm type for scenario 2A.

4.4.3 Environmental analysis

Across almost all farm types, the changes to land use and stocking, and limits on fertiliser inputs caused decreases in the mean nitrogen load. The biggest decreases were for Dairy, Dairy Support, and Mixed Cropping (Table 4-33). Across almost all farm types, the changes to land use and stocking, and limits on fertiliser inputs caused decreases in the mean nitrogen load. The biggest decreases were for Dairy, Dairy Support, and Mixed Cropping. The changes in mean nitrogen load of the six farm types between 2030 (N cap limit of 85 kg/ha) and 2060 (N cap limit of 65 kg/ha) were small.

The effect of N caps in this scenario can be seen in the decrease of the mean N load of the whole catchment and in-stream N concentrations (Table 4-32). Compared to the baseline 2025, mean N load decreased by 0.27 (kg/ha/yr) in 2030 and by 0.9 (kg/ha/yr) in 2060. The mean N stream concentrations decreased from 0.76 mg/L in the baseline 2025 to 0.73 mg mg/L and 0.70 mg/L respectively in 2030 and 2060. In this scenario, the max in-stream concentrations decreased significantly, 63.57 mg/L in 2030 and 59.12 mg/L in 2060 compared to the baseline 2025 (Table 4-31).

Table 4-31. Summary statistics for nitrogen load for the baseline 2025 and scenarios.

Nitrogen terrestrial load (kg/ha/yr)	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Min	0	0	0
Mean	8.72	8.45	7.82
Max	36.89	36.89	36.89

Table 4-32. Summary statistics of in-stream nitrogen concentration for the baseline 2025 and scenarios.

Nitrogen stream concentration (mg/L)	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Min	0	0	0
Mean	0.76	0.73	0.70
Max	341.45	277.88	282.33

In 2060, 798ha of Horticulture (Tulips) land within the N high-risk areas identified by the physiographic nitrite-nitrate-nitrogen (NNN) susceptibility layer was moved back to Dairy, Dairy Support, and Mixed Cropping. Differences in model resolution and methods between Nature Braid and physiographic layers led to some differences in what areas were considered as nitrogen high-risk. For example, Nature Braid identifies some areas of the catchment to be low to medium risk, but the physiographic layer indicates high risk N load, and sometimes the reverse can be seen (high Nature Braid, low-medium physiographic). Therefore, the mean nitrogen load of Horticulture (Tulips) in 2060 is a little bit higher than that of 2030 due to N cap limits not being applied to the remaining Horticulture (Tulips) land in 2060. The effect of conversions from High Country Sheep and Beef farming to Exotic Forestry in reducing terrestrial N loads are clearly seen in the difference between the 2030 and 2060 maps (Figure 4-20).

Table 4-33. Mean N terrestrial loads for baseline 2025, 2A 2030 and 2A 2060 scenarios for farm types in the Mataura.

Farm types	Mean nitrogen terrestrial load (kg/ha/yr)		
	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Dairy	26.74	25.64	25.47
Dairy Support	15.12	14.86	14.72
Lowland Sheep and Beef	7.5	7.42	7.42
Hill Country Sheep and Beef	6.23	6.21	6.21
High Country Sheep and Beef	6.53	6.53	All High Country Sheep and Beef moved to Exotic Forestry
Mixed Cropping	9.41	8.77	8.77
Horticulture (Tulips)	N/a	4.35	4.58

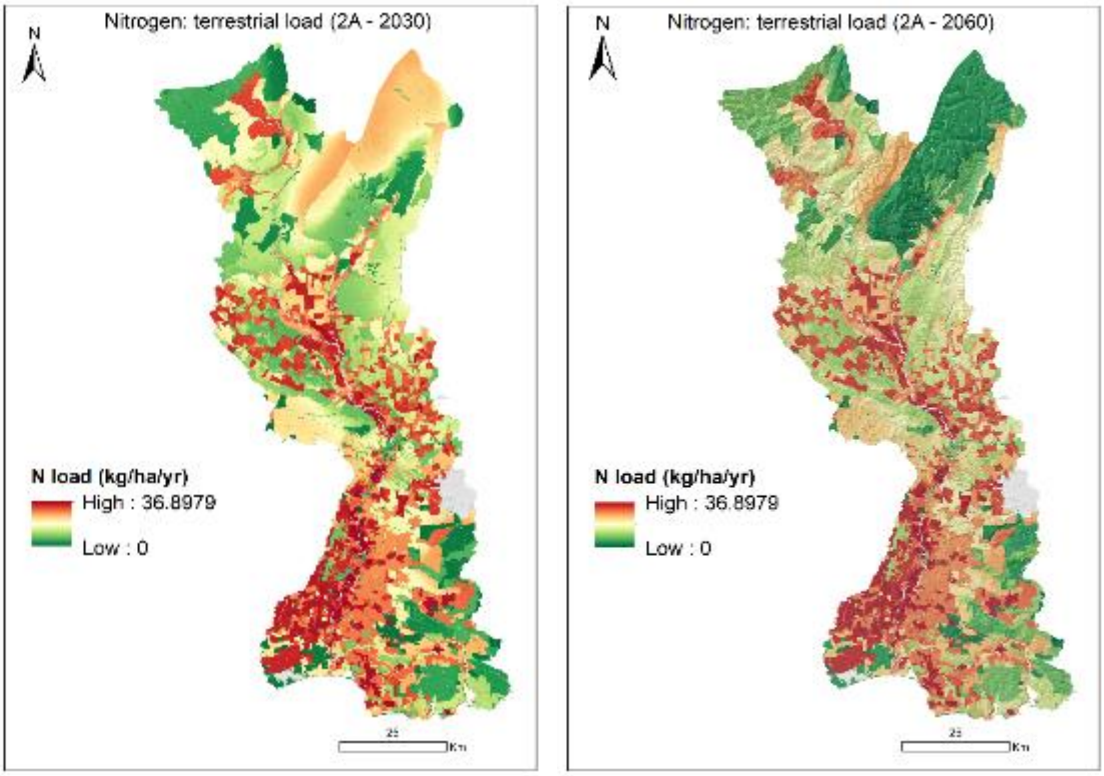

Figure 4-20. Nitrogen terrestrial load results for Scenario 2A 2030 and 2060.

There is a decrease in the maximum P in-stream concentration from the baseline 2025 to 2030 and 2060 (Table 4-34).

Table 4-34. Summary statistics for the phosphorus concentration for the baseline 2025 and scenarios.

Phosphorus stream concentration (mg/L)	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Min	0	0	0
Mean	0.02	0.02	0.019
Max	23.07	22.45	22.06

The mean phosphorus load for each farm type (*Table 4-35*) shows decreases in the load between 2030 and 2060 in Dairy, Dairy Support, Lowland Sheep and Beef. The mean phosphorus load in Mixed Cropping and Horticulture (Tulips) slightly increased in the period of 2030 to 2060. This is due to the P high-risk areas identified by the physiographic layers not being within high producing farmlands identified by Nature Braid, which were the basis of setting P caps. Therefore, it is difficult to identify the impacts when applying P caps to these P high-risk areas on the map. However, the conversions to Exotic Forestry in 2060 showed a decrease in terrestrial P load (Figure 4-21).

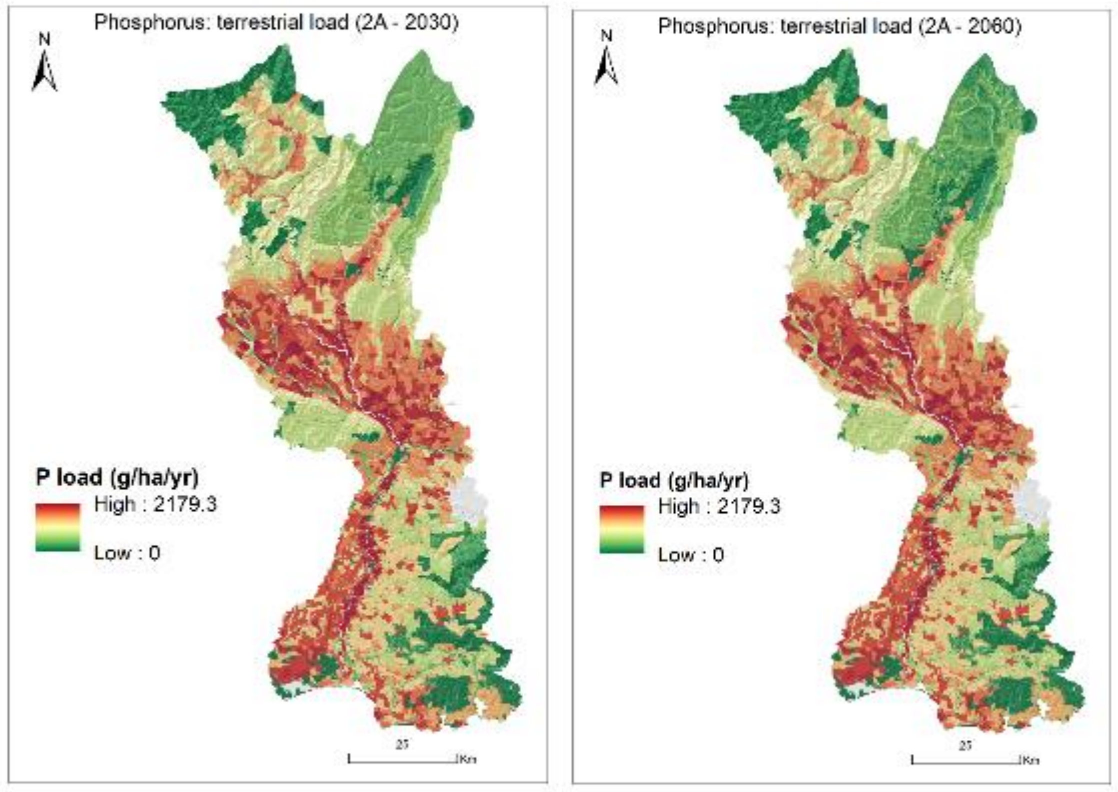

Figure 4-21. Phosphorus terrestrial load results for Scenario 2A 2030 and 2060.

Table 4-35. Mean P terrestrial loads for baseline 2025 and scenarios for farm types in the Mataura.

Farm types	Mean phosphorus terrestrial load (g/ha/yr)		
	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Dairy	1,306.00	1,322.20	1,317.60
Dairy Support	805.34	809.11	809.04
Lowland Sheep and Beef	429.04	431.37	430.60
Hill Country Sheep and Beef	159.27	158.90	158.91
High Country Sheep and Beef	86.71	86.72	N/a (All high country moved to plantation forestry)
Mixed Cropping	442.95	442.97	481.44
Horticulture (Tulips)	N/a	640.037	652.37

In scenario 2A – 2030, mean of P terrestrial load across the catchment is lower than the baseline 2025 (Table 4-36) however, the value returns closely to the baseline in 2060. As mentioned above, the areas where P cap limits were set are not within highly productive farmland. Therefore, the effect of the P cap limit could not be clearly seen in the P loading result.

Table 4-36. Summary statistics for the phosphorus terrestrial load for the baseline 2025 and scenarios.

Phosphorus terrestrial load (g/ha/yr)	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Min	0	0	0
Mean	369.13	362.71	370.0
Max	2,179.29	2,179.29	2,179.29

The flood mitigation capacity does not change with the 2A 2030 scenario, but the mitigating features increase in 2060 with the significant increase of Exotic Forestry (Table 4-37).

Table 4-37. Results of the flood mitigation tool for the baseline 2025 and scenarios.

Flood characteristics	Area of the catchment (ha)		
	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Mitigating features	99,056	99,056	158,898
Mitigated features	23,976	23,976	16,942
Non-mitigated features	498,245	498,245	445,439
Water bodies	17,315	17,315	17,315

With the small change of Dairy, Dairy Support and Lowland Sheep and Beef to Horticulture (Tulips) in 2030, there is very small change in mean soil loss. However, with the significant conversions to Exotic Forestry like Scenario 1A 2060, mean soil loss in 2060 is nearly double the baseline value (Table 4-38, Figure 4-22, top right). Exotic Forestry in high slopes (high country area) is highly susceptible to erosion due to the erosive practices associated with harvesting.

Table 4-38. Summary statistics for terrestrial soil loss for the baseline 2025 and scenarios.

Soil loss (tonnes/ha/yr)	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Min	0	0	0
Mean	10.6	10.6	18.1
Max	1704.1	1704.1	1760.5

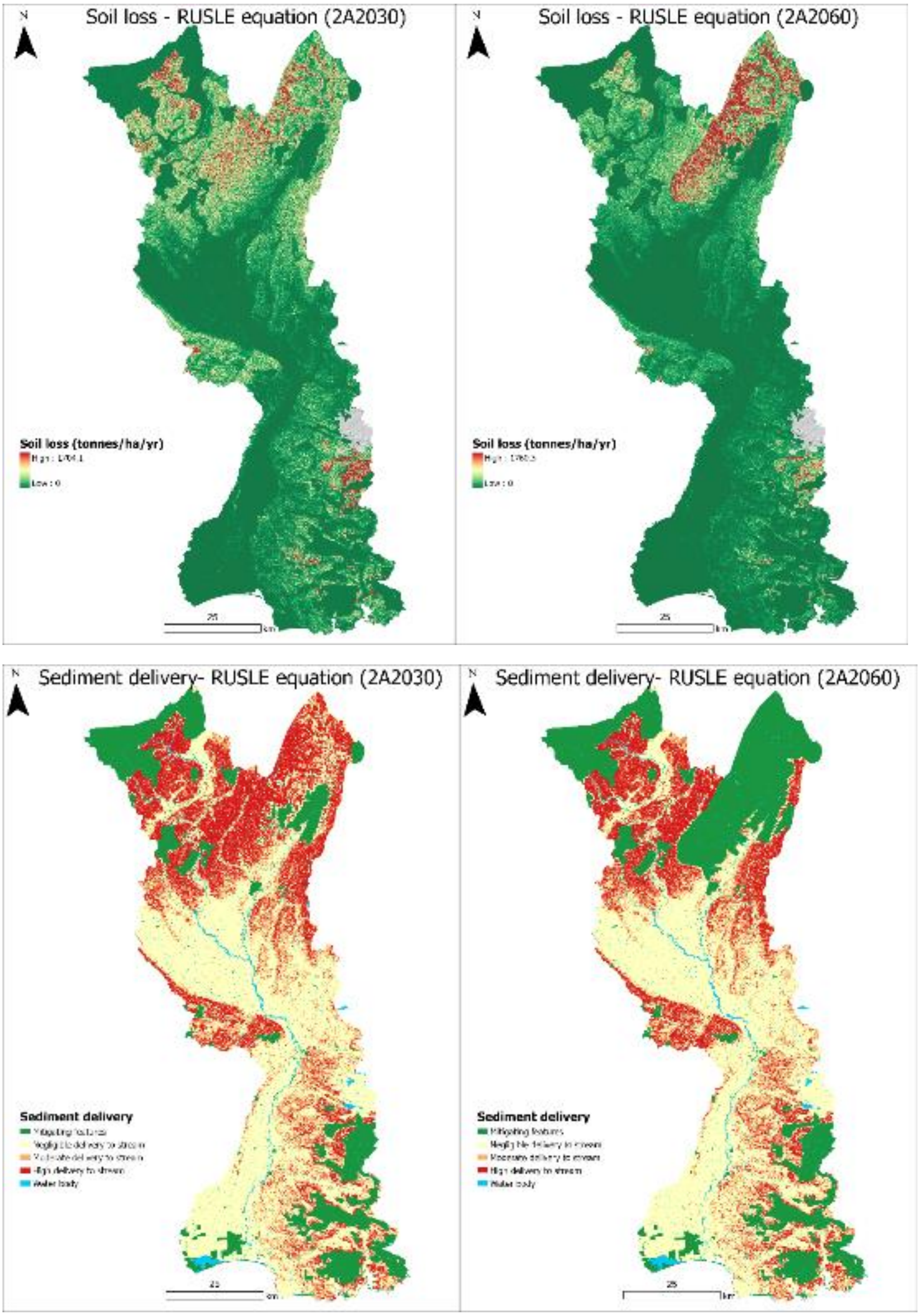

Figure 4-22. Erosion results for Scenario 2A 2030 and 2060.

The addition of Exotic Forestry in northeast Mataura can improve habitat connectivity for kererū (Table 4-39). Vegetated areas of Exotic Forestry adjacent to Indigenous Vegetation can create corridors for kererū to reach Indigenous Vegetation which is their ideal habitat (Figure 4-23).

Table 4-39. Results of the habitat connectivity tool for kererū for the baseline 2025 and scenarios (changes compared to baseline are presented in brackets).

Habitat classification	Area of the catchment (ha)		
	Baseline 2025	Scenario 2A 2030	Scenario 2A 2060
Habitat of interest	82,253	82,253 (0)	82,253 (0)
Other priority habitat	0	0	0
Opportunity to establish new habitat	460,450	458,287 (-2,163)	420,081 (-40,369)
Opportunity to expand existing habitat	60,066	62,234 (+2,168)	100,441 (+40,375)

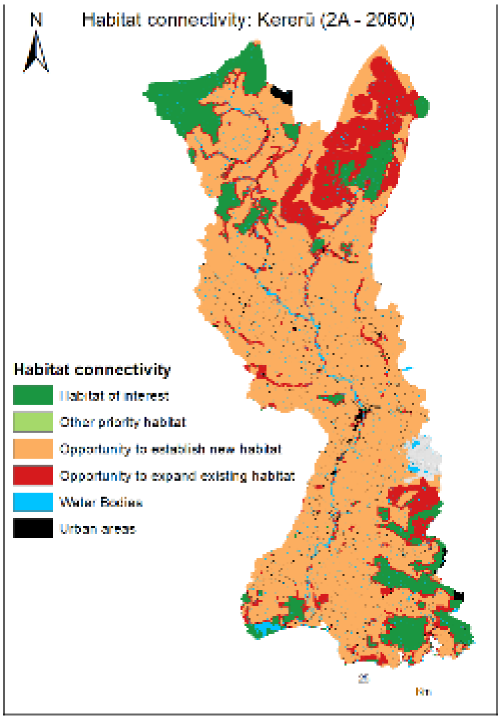

Figure 4-23. Habitat connectivity results for kererū for 2060.

However, it is likely that environmental improvements are more directly related to the system and land use changes than the reduction in fertiliser inputs. There is very little cross over between land that is susceptible to nitrogen loss, and land which is susceptible to phosphorus loss, although there are some similar drivers of nutrient loss for both N and P (i.e., slope, rainfall, nutrient loading, soil characteristics).

P high-risk areas fall on the higher altitude areas with increased slope. The analysis in Table 4-35 shows a significant area of high and hill country land falls within the P high-risk category, Lowland Sheep and Beef systems also contribute significantly to the area. In order to achieve large improvements in P loss to water, the extensive Sheep and Beef properties will require mitigation, however under current 'typical' systems the average P loading (kg P/ha/yr) from artificial fertiliser is already well below the 25 kg P and 20 kg P hypothetical restrictions set for the 2A scenario.

While the intensive Dairy systems will be impacted by P application restrictions, needing to decrease fertiliser application by 13.5 kg P/ha/yr to year 2030, and a further 5 kg P/ha/yr by 2060, there will be very little gain on a catchment level due to the limited area of Dairy and Dairy Support land which falls under the high-risk category for P. Under the current 2025 scenario, Lowland Sheep and Beef systems apply 21.6 kg P/ha/yr as artificial fertiliser which is only 1.6kg/ha beyond the most severe restriction observed in 2060. While nearly 3800 ha of lowland systems in the Mataura are considered high risk for P loss, a 1.6 kg P/ha reduction is miniscule when looking at the catchment wide effect and the concentration of P loading observed on the extensive land currently used for Hill and High Country Sheep and Beef production. Setting policy to restrict phosphorus fertiliser application may therefore have only a minor direct effect on reducing the P loading in at risk areas.

Nitrogen risk follows a different pattern, with the majority of total N loading within N high-risk areas, being generated from intensive lowland uses, namely Dairy and Lowland Sheep and Beef. Dairy is the clear outlier with mean N loading of high-risk areas at 24 kg N/ha/yr, followed by Dairy Support. By proportion Lowland Sheep and Beef and Hill Country Sheep and Beef have the two largest areas of high-risk land for N loss. However, these two systems combined only just exceed Dairy when considering the catchment wide N loading within high-risk areas (344 616 for Dairy vs 375 876 kg N for Lowland and Hill Country Sheep and Beef).

N fertiliser restriction of 85 kg N in 2030, and 65 kg N in 2060, have large implications on most systems due to the prevalence of winter cropping in the Mataura. The use of forage crops provides essential feed for winter feed deficit and restricted pasture growth but requires high N inputs to reach economic yields. The severe restrictions in input N for the 2A 2030 and 2060 scenarios result in the removal of forage cropping from all systems, and the full-scale conversion of Mixed Cropping properties into livestock finishing units. Dairy and Dairy Support fertiliser applications were also cut back significantly resulting in destocking and the purchase or conservation of feed. After 2030, only the Dairy Support and Dairy systems would require further reduction in N input.

4.5 Scenario 2B

It is estimated that the catchment profitability in 2025 will be 395.12M. This will decrease to $366.54M in 2030 mainly due to all negligible production capacity Lowland Sheep and Beef, Hill Country Sheep and Beef, and High Country Sheep being converted to wetland. By 2060, the catchment profitability would increase to $2.25B mainly due to all Dairy Support, Hill Country Sheep and Beef, and High Country Sheep and Beef converting to Exotic Forestry.

This scenario assumes that revenue from the levy is returned to the catchment for environmental beneficial activities, including a subsidy to shift to Sheep Dairy; wetland restoration and construction, and riparian planting, as described above.

4.5.1 Economic analysis

Changes in profitability of farming are presented in Table 4-40. In this scenario, levy rates increase significantly over time. To enhance decision making, we have separated variable cost and fixed costs to show the profitability difference of the five land productivity levels.

Table 4-40. Profitability per ha of farm types under Scenario 2B for 2025, 2030 and 2060.

EFS per ha	Baseline (2025)	Scenario 2B (2030)	Scenario 2B (2060)
Dairy	$3,131	$2,806	$657
Dairy Support	$129	($80)	($1,453)
Lowland Sheep and Beef	$546	$406	($523)
Hill Country Sheep and Beef	$164	$101	($312)
High Country Sheep and Beef	$39	$15	($145)
Mixed Cropping	$1,116	$985	$125
Wetland	$0	$0	$0
Horticulture (Tulips)	$5,000	$5,000	$5,000
Sheep Dairy	$3,635	$3,495	$2,566

Changes in profitability of farming for each land productivity class in 2060 are presented in Table 3-41. In this scenario, the weighted average profitability of Dairy and mixed land use is positive, but negative returns for low productivity levels.

Table 4-41. Profitability per ha of the original farm types under Scenario 2B for each level of land productivity, for 2060.

Variable return per ha	Very high	High	Moderate	Marginal	Negligible
Dairy	$1,390	$1,166	$6	-$876	-$3,140
Dairy Support	-$1,522	-$1,503	-$1,404	-$1,329	-$1,137
Lowland Sheep and Beef	-$519	-$520	-$526	-$530	-$541
Hill Country Sheep and Beef	-$368	-$361	-$326	-$299	-$230
High Country Sheep and Beef	-$193	-$188	-$160	-$138	-$83
Mixed Cropping	$220	$170	-$85	-$278	-$776

The resulting changes in land area are shown in Table 4-42. As for scenario 1B, highly productive land is converted to Horticulture (Tulips) by 2030, on the same 6-year cycle as in 1B. Conversion to Sheep Dairy also occurs on very high production capacity land by 2030. By 2060, large scale conversion of predominantly lowland farms, occurs to Sheep Dairy. Farming land with negative variable returns which are not suitable for Wetlands are assumed to transition to Exotic Forestry. By 2060, 43.7% of farmland has transitioned to Exotic Forestry.

For the sake of this modelling exercise, it has been assumed that Riparian Planting can occur without impacting land use, and no change is shown in the area of Indigenous Vegetation. This has been modelled only as an environmental effect in the Nature Braid.

Table 4-42. Land area distribution for each farm type under Scenario 2B, for 2025, 2030 and 2060.

	Baseline (2025)		Scenario 2B (2030)		Scenario 2B (2060)	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Dairy	80,520	13.5%	72,064	12.1%	16,677	2.8%
Dairy Support	21,425	3.6%	10,891	1.8%	0	0.0%
Lowland Sheep and Beef	156,652	26.4%	162,686	27.4%	77,743	13.1%
Hill Country Sheep and Beef	170,597	28.7%	167,549	28.2%	0	0.0%
High Country Sheep and Beef	60,554	10.2%	59,175	10.0%	0	0.0%
Mixed Cropping	2,268	0.4%	2,268	0.4%	1,798	0.3%
Wetlands	2,992	0.5%	9,289	1.6%	26,074	4.4%
Indigenous Vegetation	83,363	14.0%	83,363	14.0%	83,363	14.0%
Exotic Forestry	15,999	2.7%	20,426	3.4%	275,907	46.4%
Horticulture (Tulips)	0	0.0%	5,533	0.9%	5,533	0.9%
Sheep Dairy	0	0.0%	1,127	0.2%	107,276	18.0%

A total levy revenue of $6.71B will be collected by 2060. We have modelled the same value as in scenario 1A to be recycled back into the catchment as financial support for national level research ($2.87B). A total of $1.28B will be spent towards planting and maintaining riparian plants along the river streams in the catchment. Another $536M will be used to subsidise Sheep Dairying. Remaining levy revenue has been modelled to be spent towards Wetland restoration, with $776M to be spent towards restoring natural Wetlands within the catchment and $1.25B to be spent towards targeted, constructed Wetlands creation within the catchment (Figure 4-24).

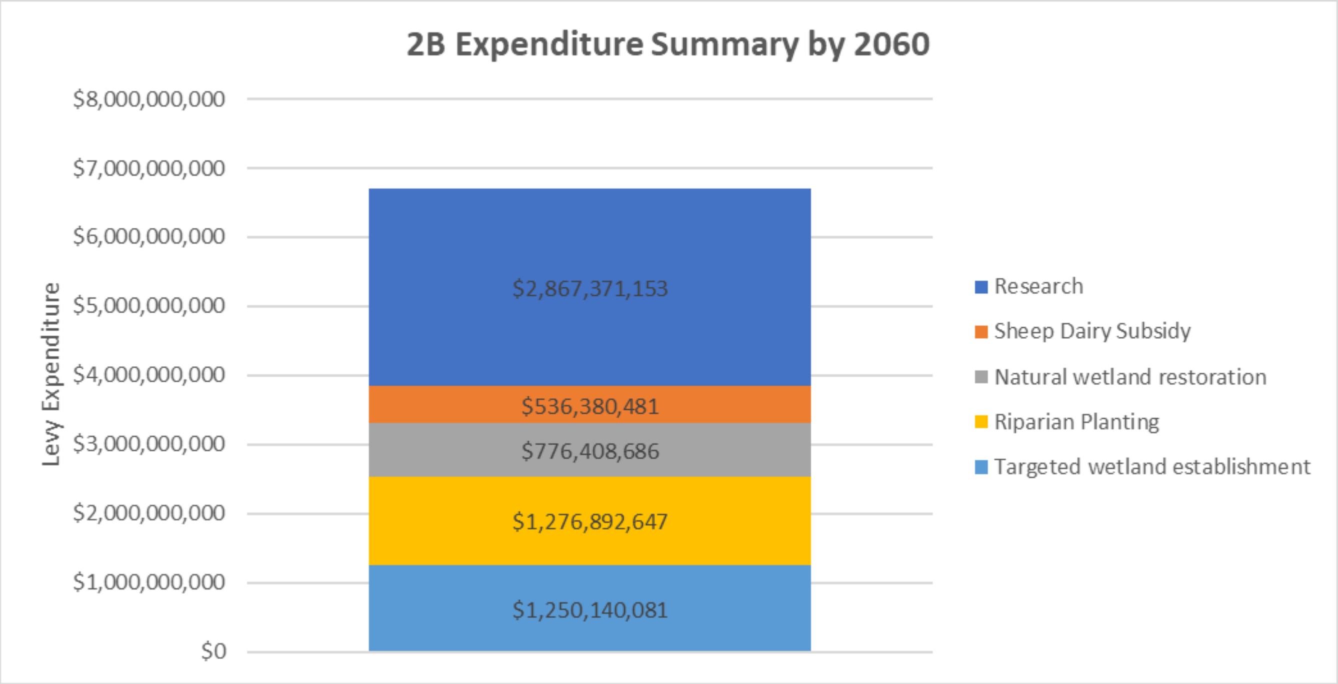

Figure 4-24. Levy Revenue Collected and Expenditure Summary for scenario 2B.

4.5.2 Impact on overall emissions

Figure 4-25 shows the overall impact of land use changes for 2B on the total emissions in CO_2-eq. Total emissions are reduced from 724,238 in 2025, to 525,958 in 2030, and -5,815,66 in 2060. Negative emissions indicate catchment sequestration exceeds catchment emissions.

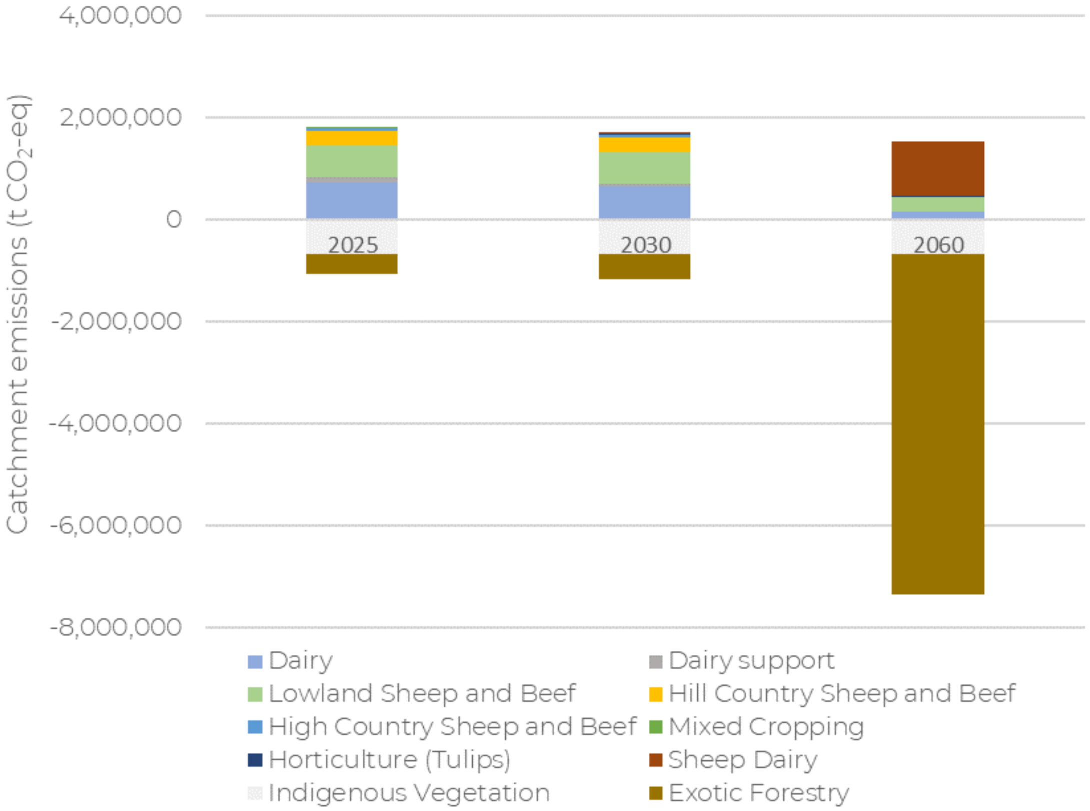

Figure 4-25. Tonnes CO2-eq per farm type for scenario 2B.

4.5.3 Environmental analysis

For scenario 2B in 2030, 2,357 ha of Dairy farms, 1,193 ha of Dairy Support, and 3,108 of Lowland Sheep and Beef with very high production capacity are changed to 5,533 ha of Horticulture (Tulips) and 1,127 ha of Sheep Dairy farms. 7,455 ha of Dairy farms with moderate production capacity are changed to Lowland Sheep and Beef. In the marginal production land, 2,057 ha of Dairy and 1,553 of Dairy Support are also converted to Lowland Sheep and Beef. An area of 6,297 ha of very poor drainage area within Dairy (4,042 ha), Dairy Support (342), and Lowland Sheep and Beef (1,913), which has a negligible production capacity, is used for Wetland restoration. The poor drainage area was identified using Nature Braid based on soil, climate, and topography data. Flax is planted around Wetlands. All remaining negligible productivity land, 3,047 ha of Hill Country Sheep and Beef and 1,379 ha of High Country Sheep and Beef are converted to Exotic Forestry.

Between 2030 – 2060, a large percentage (~84%) of Dairy farms within very high and high production capacity areas, and all Dairy Support and Lowland Sheep and Beef land having very high and high production capacity are transitioned to Exotic Forestry and Sheep Dairy. It is assumed that each Sheep Dairy farm is required to be at least 50ha. In addition, the rate of conversion to Sheep Dairy is considered to be constrained by the need to breed appropriate ewes (a population growth rate of 16.6% per year has been assumed). In moderate and marginal agricultural productivity land, all of Hill and High Country Sheep and Beef changes to Exotic Forestry (69,874 ha). 11,284 ha of Dairy and 3,260 ha of Lowland Sheep and Beef with poor drainage in moderated production land are moved to Wetlands. An area of 2,088 ha with poor drainage and negligible production capacity within Lowland, Hill Country, and High Country Sheep and Beef, and 151 ha of marginal productivity poor drainage land is used to restore Wetlands, with Flax planted 16m around these. Riparian planting is implemented for all streams, such as is the case for scenario 1B.

The effect of mitigation options for the whole catchment can be seen in the decrease of mean N load and in-stream N concentration by 2060. The mean terrestrial N load decreases from 8.72 to 7.98 kg/ha/yr in 2B 2030, and 4.52 kg/ha/yr in 2B 2060 (Table 4-44, Figure 4-26). The mean in-stream N concentration also decreases from 0.76 mg/L to 0.685 mg/L and 0.36 mg/L in 2B 2030 and 2B 2060 respectively (Table 4-43). In 2B 2060, the maximum in-stream N concentration reduces by 336.46 mg/L compared to the baseline 2025 value.

Significant improvements in N retention can be seen when the interventions are applied between 2030 and 2060. Although adding Riparian Planting can affect agricultural productivity, this land use will benefit the nutrients and flood mitigation services.

Table 4-43. Summary statistics for in-stream nitrogen concentration for the baseline 2025 and Scenario 2B 2030 and 2060.

Nitrogen stream concentration (mg/L)	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Min	0	0	0
Mean	0.76	0.685	0.36
Max	341.45	275.438	4.808

Table 4-44. Summary statistics for nitrogen load for the baseline 2025 and Scenario 2B 2030 and 2060.

Nitrogen load (kg/ha/yr)	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Min	0	0	0
Mean	8.72	7.98	4.52
Max	36.89	36.89	37.37

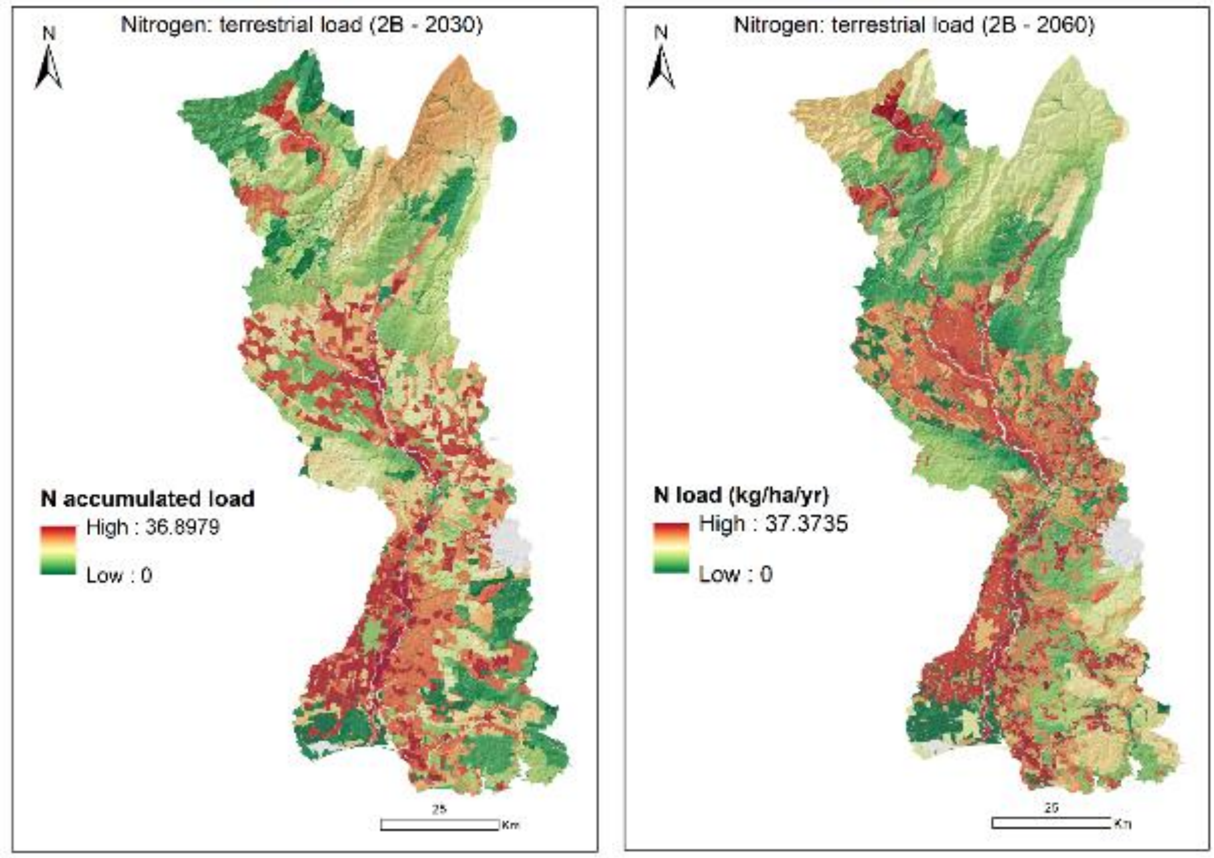

Figure 4-26. Nitrogen load results for Scenario 2B 2030 and 2060.

Decreases in mean nitrogen load are also seen in Lowland, Hill Country, and High Country Sheep and Beef farms (Table 4-45). The slight increases in N load in 2030 in Dairy Support are due to slightly intensified use of the remaining Dairy Support land.

Table 4-45. Mean N terrestrial loads for the baseline 2025, Scenario 2B 2030 and 2060 for farm types in the Mataura.

Farm types	Mean nitrogen terrestrial load (kg/ha/yr)		
	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Dairy	26.74	26.87	26.49
Dairy Support	15.12	15.78	N/a (No Dairy Support land remains)
Lowland Sheep and Beef	7.5	7.46	7.42
Hill Country Sheep and Beef	6.23	5.31	N/a (No Hill Country Sheep and Beef land remains)
High Country Sheep and Beef	6.53	6.38	N/a (No High Country Sheep and Beef land remains)
Mixed Cropping	9.41	9.41	9.88
Horticulture (Tulips)	N/a	4.55	4.54
Sheep Dairy	N/a	15.03	14.24

Similar to the nitrogen results, the reductions in 2060 are reflected in the mean in-stream P concentration, terrestrial P load, and P accumulated load. Mean and max in-stream P concentrations for 2030 show a slight decrease compared to the baseline 2025 (Table 4-46). The mean in-stream P value in 2060 reduces three times compared with the baseline. Mean phosphorus load in the whole catchment is decreased for both 2030 and 2060 (Table 4-47, Figure 4-27).

Table 4-46. Summary statistics for the phosphorus concentration for the baseline 2025 and Scenario 2B 2030 and 2060.

Phosphorus stream concentration (mg/L)	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Min	0	0	0
Mean	0.02	0.019	0.00476
Max	23.07	21.58	0.4348

Table 4-47. Summary statistics for the phosphorus terrestrial load for the baseline 2025 and Scenario 2B 2030 and 2060.

Phosphorus load (g/ha/yr)	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Min	0	0	0
Mean	369.13	353.35	169.8
Max	2179.29	2179.29	2179.29

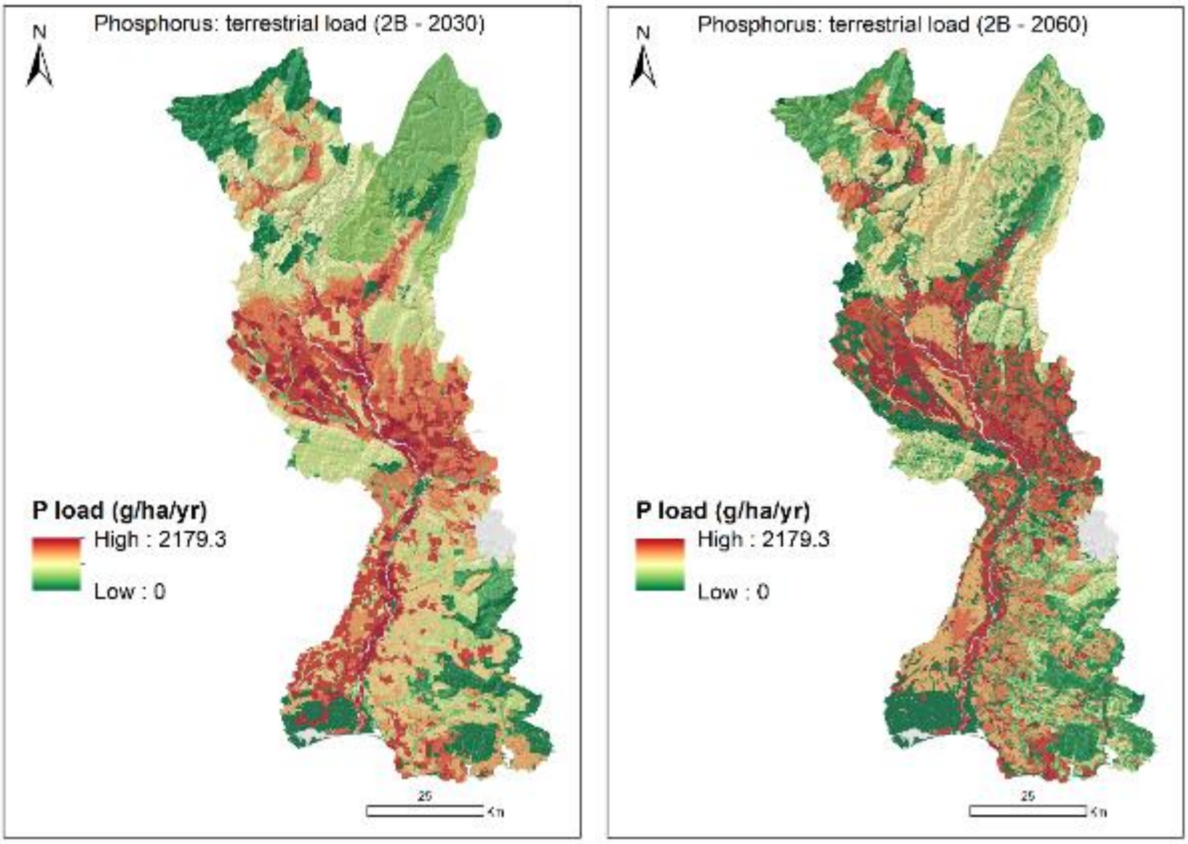

Figure 4-27. Phosphorus terrestrial load results for Scenario 2B 2030 and 2060.

As for mean P loads per farm type (Table 4-48), interventions in B 2030 lead to slight decreases in Hill and High Country Sheep and Beef farms. The mitigation options in 2B 2060 can bring the mean P loads in Dairy land down to 50.58 g/yr (less than one fifth of the baseline value). In scenario 2B 2060, mean P loads also significantly decrease in Lowland Sheep and Beef, Mixed Cropping, and Horticulture (Tulips).

The increases in P load in 2030 in Dairy and Dairy Support are due to the increase in area and high P use for Horticulture (Tulips).

Table 4-48. Mean P terrestrial loads for baseline 2025, Scenario 2B 2030 and 2060 for farm types in the Mataura.

Farm types	Mean phosphorus load (g/ha/yr)		
	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Dairy	1306.00	1356.49	1209.22
Dairy Support	805.34	891.49	N/a (No Dairy Support land remains)
Lowland Sheep and Beef	429.04	430.74	393.00
Hill Country Sheep and Beef	159.27	157.28	N/a (No Hill Country Sheep and Beef land remains)
High Country Sheep and Beef	86.71	85.32	N/a (No High Country Sheep and Beef land remains)
Mixed Cropping	442.95	442.97	453.08
Horticulture (Tulips)	N/a	511.61	511.73
Sheep Dairy	N/a	217.37	440.15

The addition of Wetlands in 2030 and 2060 and Riparian Planting in 2060 creates a large increase in the area of mitigating features in 2030 (+ 10,885 ha) and 2060 (+ 286,527 ha) and features considered mitigated or receiving the benefit from the additional planting (+ 10,720 ha in 2030 and + 102,172 ha in 2060). This shows that the area changed for Wetlands and Riparian Planting in 2060 benefits uphill areas approximately 2.8 times its size.

Table 4-49. Results of the flood mitigation tool for the baseline 2025, Scenario 2B 2030 and 2060.

Flood characteristics	Area of the catchment (ha)		
	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Mitigating features	99,056	109,941	385,583
Mitigated features	23,976	34,696	126,148
Non-mitigated features	498,245	476,653	110,490

The changes in 2030 and 2060 lead to increases in mean soil loss from point to point in the catchment because of the expansions of Exotic Forestry (Table 4-50). However, due to the addition of Riparian Planting and Wetlands, the Mataura catchment experiences less sediment delivery risk to waterways in 2B 2060 (*Figure 4-28*).

Table 4-50. Summary statistics for terrestrial soil loss for the baseline 2025 and Scenario 2B 2030 and 2060.

Soil loss (tonnes/ha/yr)	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Min	0	0	0
Mean	10.6	11.3	32.1
Max	1704.1	1725.4	1760.5

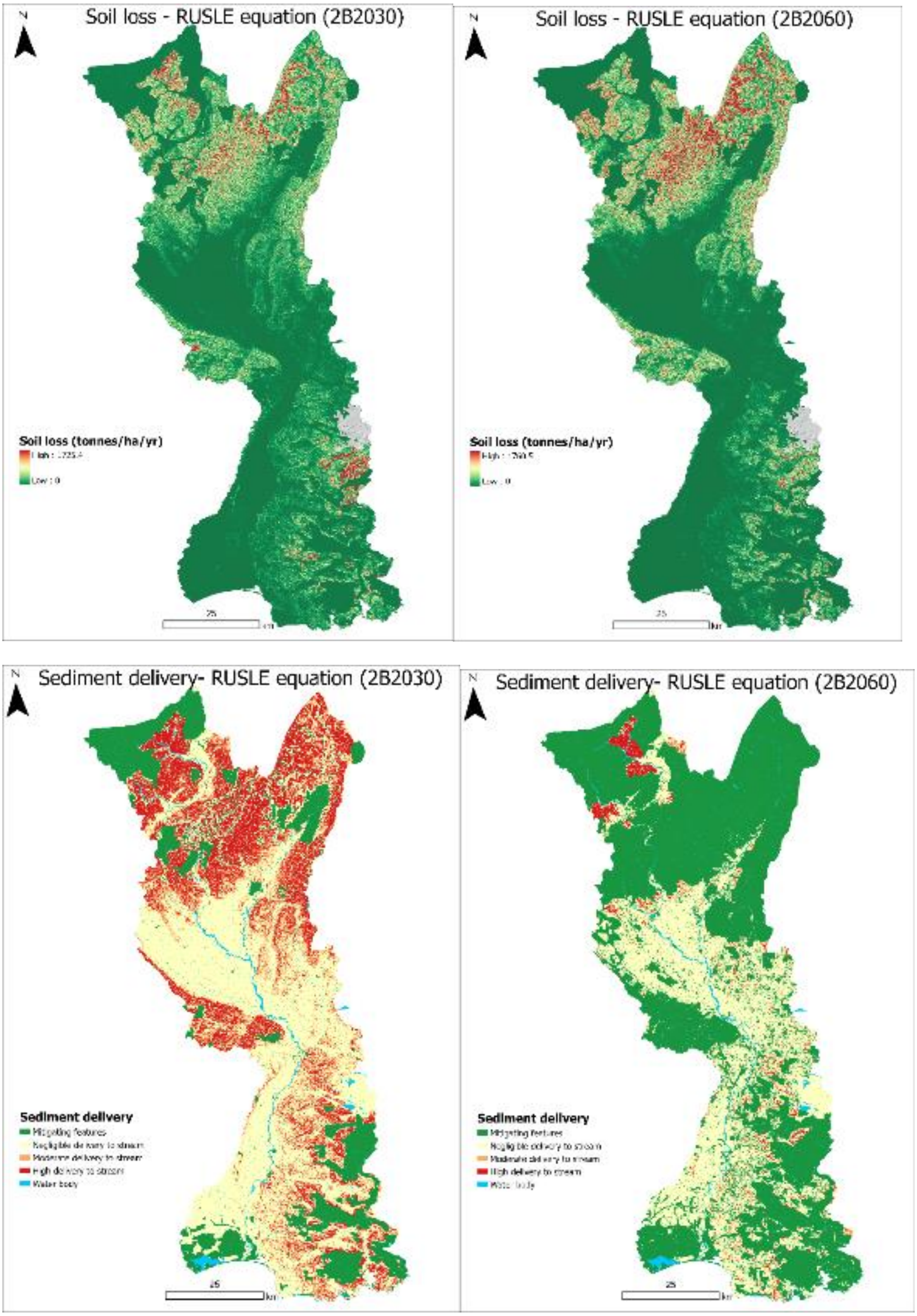

Figure 4-28. Erosion results – soil loss and sediment delivery for Scenario 2B 2030 and 2060.

The addition of Riparian Planting in 2060 increases the amount of habitat available for kererū (Figure 4-29, Table 4-51). Having the Riparian Planting as native species favourable for kererū can potentially create corridors for birds to connect habitat patches. This planting on streams may also benefit ground-dwelling waterfowl.

Table 4-51. Results of the habitat connectivity tool for kererū, for the baseline 2025 and Scenario 2B 2030 and 2060 (changes compared to baseline are presented in brackets).

Habitat classification	Area of the catchment (ha)		
	Baseline 2025	Scenario 2B 2030	Scenario 2B 2060
Habitat of interest	82,253	82,183 (-70)	86,995 (+4,742)
Other priority habitat	0	6,197 (+6,197)	22,212 (+22,212)
Opportunity to establish new habitat	460,450	449,643 (-10,807)	65,410 (-395,040)
Opportunity to expand existing habitat	60,066	64,826 (+4,760)	429,028 (+368,962)

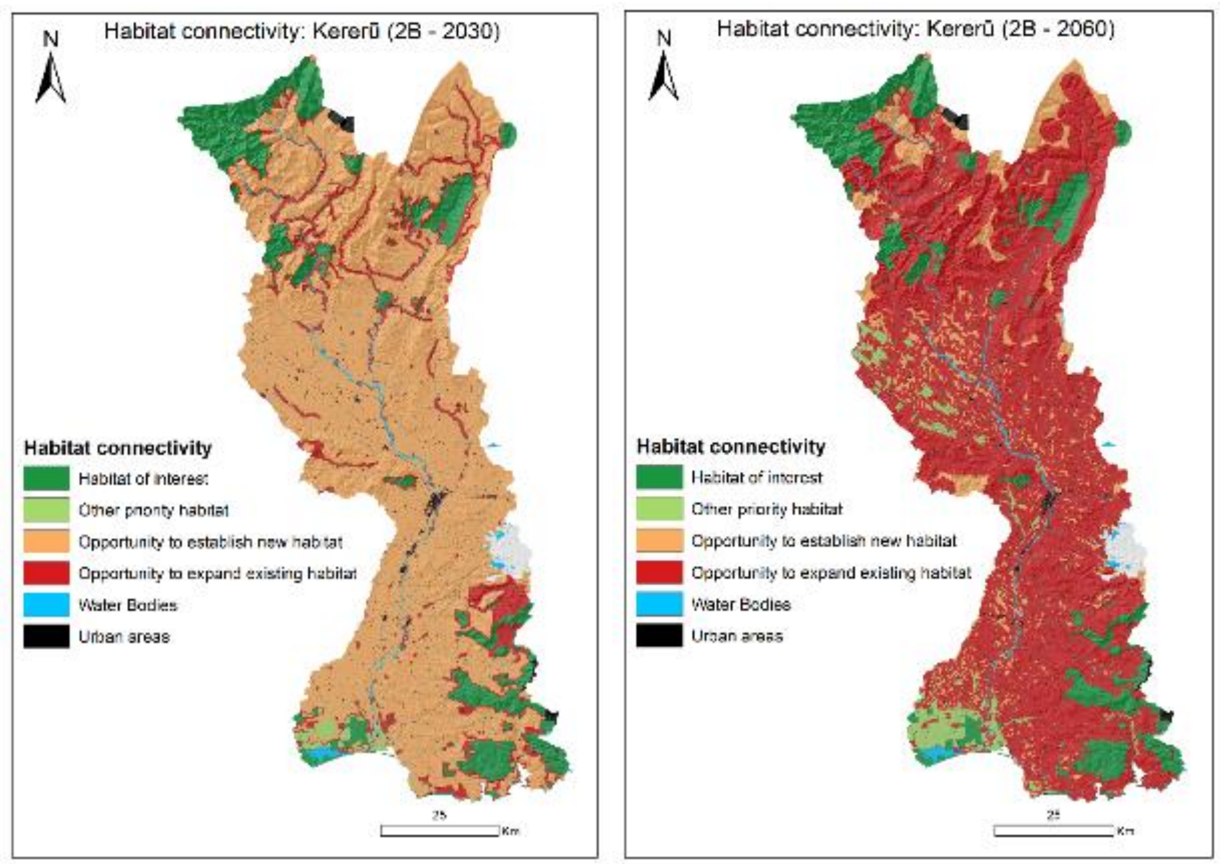

Figure 4-29. Habitat connectivity results for kererū for Scenario 2B 2030 and 2060.

4.6 Scenario 2C

It is estimated that the catchment profitability in 2025 will be $395.12M. This will decrease to $327.56M in 2030 mainly due to negligible production capacity Dairy, Dairy Support and Lowland Sheep and Beef being converted to wetland. By 2060, the catchment profitability would decrease to $416.35M mainly due to Dairy Support, Lowland Sheep and Beef, Hill Country Sheep and Beef, and High Country Sheep and Beef converting to Totara Forestry.

4.6.1 Economic analysis

Changes in average profitability of farming are presented in Table 4-40. In this scenario levy rates increase significantly over time.

Table 4-52: Profitability per ha of farm types under Scenario 2C for 2025, 2030 and 2060.

EFS per ha	Baseline (2025)	Scenario 2C (2030)	Scenario 2C (2060)
Dairy	$3,131	$2,806	$657
Dairy Support	$129	($80)	($1,453)
Lowland Sheep and Beef	$546	$406	($523)
Hill Country Sheep and Beef	$164	$101	($312)
High Country Sheep and Beef	$39	$15	($145)
Mixed Cropping	$1,116	$985	$125
Wetland	$0	$0	$0
Horticulture (Tulips)	$5,000	$5,000	$5,000
Sheep Dairy	$3,635	$3,495	$2,566
Exotic Forestry*	$518	$518	$518
Totara Forestry*	($1,294)	($1,294)	($1,294)

*Equivalent Annual Annuity (EAA) estimated using 5% of return.

To enhance decision making, we have separated variable cost and fixed cost to show the profitability difference of the five land productivity levels.

This scenario assumes, as in Scenario 2B, that revenue from the levy is returned to the catchment for environmental beneficial activities including:

a. Subsidies for Sheep Dairy
b. Restoration of natural Wetlands
c. Riparian planting
d. Targeted Wetlands establishment

Additionally, in this scenario, instead of ETS sequestration payments, an additional multipurpose fund is available to support environmentally beneficial activities. These funds are used to subsidise Totara Forestry so that it is the highest best use for land that would otherwise change to Exotic Forestry (pine). In addition, this fund is used for targeted planting in in gullies.

The resulting changes in land use are shown in Table 4-53. As for scenario 2B, highly productive land is converted to Horticulture (Tulips) by 2030, on the same 6-year cycle as in 1B. Some conversion to Sheep Dairy also occurs on very high production capacity land by 2030. In addition, some very low production capacity land will convert to Wetland by 2030. By 2060, large scale conversion of predominantly lowland farms transitions to Sheep Dairy (with the same constraints as outlined under scenario 2B). Farming land with negative variable returns that is unsuitable for Wetland conversion are assumed to transition to Totara Forestry using the subsidy from the multi-purpose fund. Furthermore, all Exotic Forestry converts to Totara Forestry (assumed to occur at the next scheduled pine harvest), 46.4% of farmland has transitioned to Totara Forestry by 2060. Gully planting, also funded by the multipurpose fund, covers a total of 6,306 ha in general native/indigenous plants to manage water flows. This area consists of small, generally unusable spots spread over a very wide area. For modelling purposes, we do not count this as a land use change but rather assume that this planting has no benefit / disbenefit on the productivity of the land for its current use.

This scenario indicates that by 2060, assuming an equivalent size to payments under the NZETS, there will be a $4.5B surplus in the “multipurpose fund” that could still be spent on environmentally beneficial activities.

Table 4-53. Land area distribution for each farm type under Scenario 2C, for 2025, 2030 and 2060.

	Baseline (2025)		Scenario 2C (2030)		Scenario 2C (2060)	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Dairy	80,520	13.5%	72,064	12.1%	16,677	2.8%
Dairy Support	21,425	3.6%	10,891	1.8%	0	0.0%
Lowland Sheep and Beef	156,652	26.4%	162,686	27.4%	77,744	13.1%
Hill Country Sheep and Beef	170,597	28.7%	170,597	28.7%	0	0.0%
High Country Sheep and Beef	60,554	10.2%	60,554	10.2%	0	0.0%
Mixed Cropping	2,268	0.4%	2,268	0.4%	1,798	0.3%
Wetlands	2,992	0.5%	9,289	1.6%	26,072	4.4%
Indigenous Vegetation	83,363	14.0%	83,363	14.0%	83,363	14.0%
Totara Forestry	0	0%	0	0%	275,907	46.4%
Exotic Forestry	15,999	2.7%	15,999	2.7%	0	0.0%
Horticulture (Tulips)	0	0.0%	5,533	0.9%	5,533	0.9%
Sheep Dairy	0	0.0%	1,127	0.2%	107,276	18.0%

A total levy revenue of $6.71B will be collected by 2060. We have modelled the same value as in scenario 1A to be recycled back into the catchment as financial support for national level research ($2.87B). A total of $776M will be spent towards planting and maintaining riparian plants along the river streams in the catchment. Another $536M will be used to subsidise Sheep Dairying. Remaining levy revenue has been modelled to be spent towards Wetland restoration, with $1.25B to be spent towards restoring natural Wetlands within the catchment and $1.28B to be spent towards targeted constructed Wetland creation within the catchment (Figure 4-30).

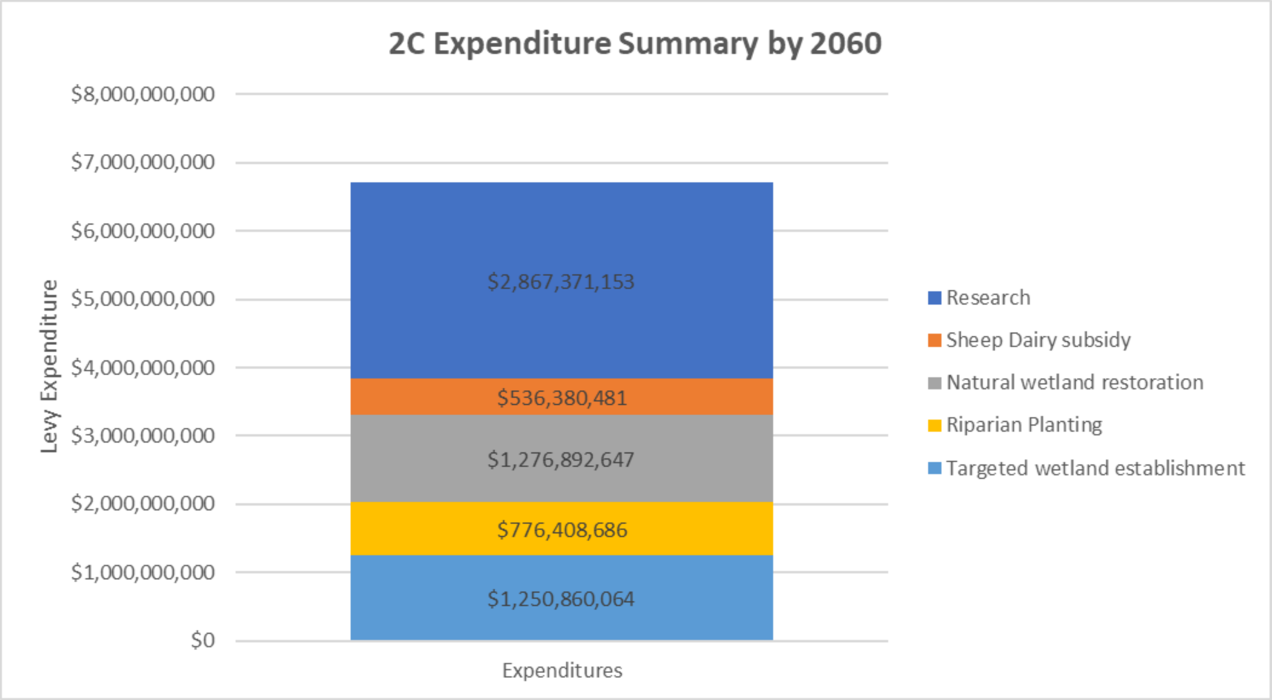

Figure 4-30. Levy Revenue Collected and Expenditure Summary for scenario 2C.

4.6.2 Impact on overall emissions

Figure 4-31 the overall impact of land use changes for 2C on the total emissions in tCO_2-eq. Total emissions are reduced from 724,238 tCO_2-eq in 2025, to 639,081 tCO_2-eq in 2030, and -1,408,245 tCO_2-eq in 2060. Negative emissions indicate catchment sequestration exceeds catchment emissions.

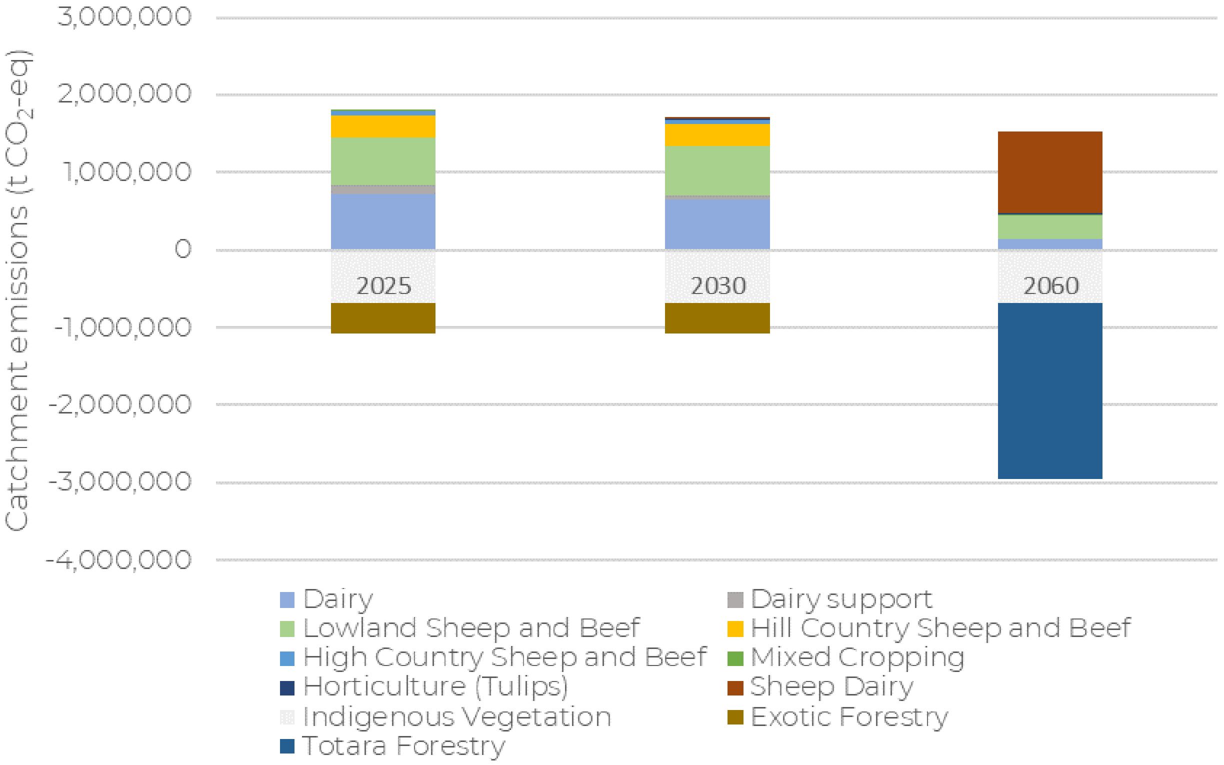

Figure 4-31. Tonnes CO2-eq per farm type for scenario 2C.

4.6.3 Environmental analysis

In scenario 2C (2030), 2,357 ha of Dairy farms, 1,193 ha of Dairy Support and 3,108 of Lowland Sheep and Beef with very high production capacity are changed to 5,533 ha of Horticulture (Tulips) and 1,127 ha of Sheep Dairy farms. 7,455 ha of Dairy farms with moderate production capacity are converted to Lowland Sheep and Beef. In the marginal production land, 2,057 ha of Dairy and 1,553 of Dairy Support are also converted to Lowland Sheep and Beef. An area of 6,297ha with very poor drainage within Dairy (4,042 ha), Dairy Support (342ha), and Lowland Sheep and Beef (1,913ha), which has a negligible production capacity, is used for Wetland restoration. The poor drainage area was identified using Nature Braid based on soil, climate, and topography data. Flax is planted buffer around Wetlands.

Between 2030 – 2060, the changes for Lowland Sheep and Beef, Sheep Dairy, and Wetlands are the same as in scenario 2B. The differences are that Totara Forestry is planted instead of Exotic Forestry, and gully planting (assuming generic native/indigenous vegetation parameters) is planted at locations with high flow concentration. A large percentage (~84%) of Dairy farms within very high and high production capacity areas, and all Dairy Support and Lowland Sheep and Beef land having very high and high production capacity are transitioned to Totara Forestry and Sheep Dairy (each Sheep Dairy farm is at least 50ha). All Exotic Forestry left in 2030 is converted to Totara Forestry in 2060. An area of 2,088 ha with poor drainage and negligible production capacity within Lowland, Hill Country, and High Country Sheep and Beef, 14,545ha of poor drainage area with moderate production capacity, and 151 ha of marginal productivity poor drainage land is used to restore Wetlands, with Flax planted 16m around these. Riparian planting is implemented for all streams, such as is the case for scenarios 1B and 2B.

The effect of mitigation options for the whole catchment can be seen in the decrease of mean N load and in-stream nitrogen concentration in 2030 and 2060. The mean in-stream N concentration decreases from 0.76 mg/L in the baseline to 0.69 mg/L in 2030 and to 0.36 mg/L in 2060 (Table 4-54). The maximum n-stream N concentration reduces slightly by 65.57 mg/L in 2030. The maximum in-stream N concentration is significantly decreased in 2060 to 3.58 mg/L, a reduction of 337.87 mg/L. The mean terrestrial N load decreases from 8.72 to 8.02 kg/ha/yr in 2C 2030, and 4.67 kg/ha/yr in 2C 2060 (Table 4-55, Figure 4-32). The reduction in N load and stream concentration in 2C 2060 is larger than in any other scenario. The planting of Totara Forestry and targeted gully planting show significant improvements in N retention.

Table 4-54. Summary statistics for in-stream nitrogen concentration for the baseline 2025 and Scenario 2C 2030 and 2060.

Nitrogen stream concentration (mg/L)	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Min	0	0	0
Mean	0.76	0.69	0.36
Max	341.45	275.43	3.58

Table 4-55. Summary statistics for nitrogen load for the baseline 2025 and Scenario 2C 2030 and 2060.

Nitrogen load (kg/ha/yr)	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Min	0	0	0
Mean	8.72	8.02	4.67
Max	36.89	36.89	37.37

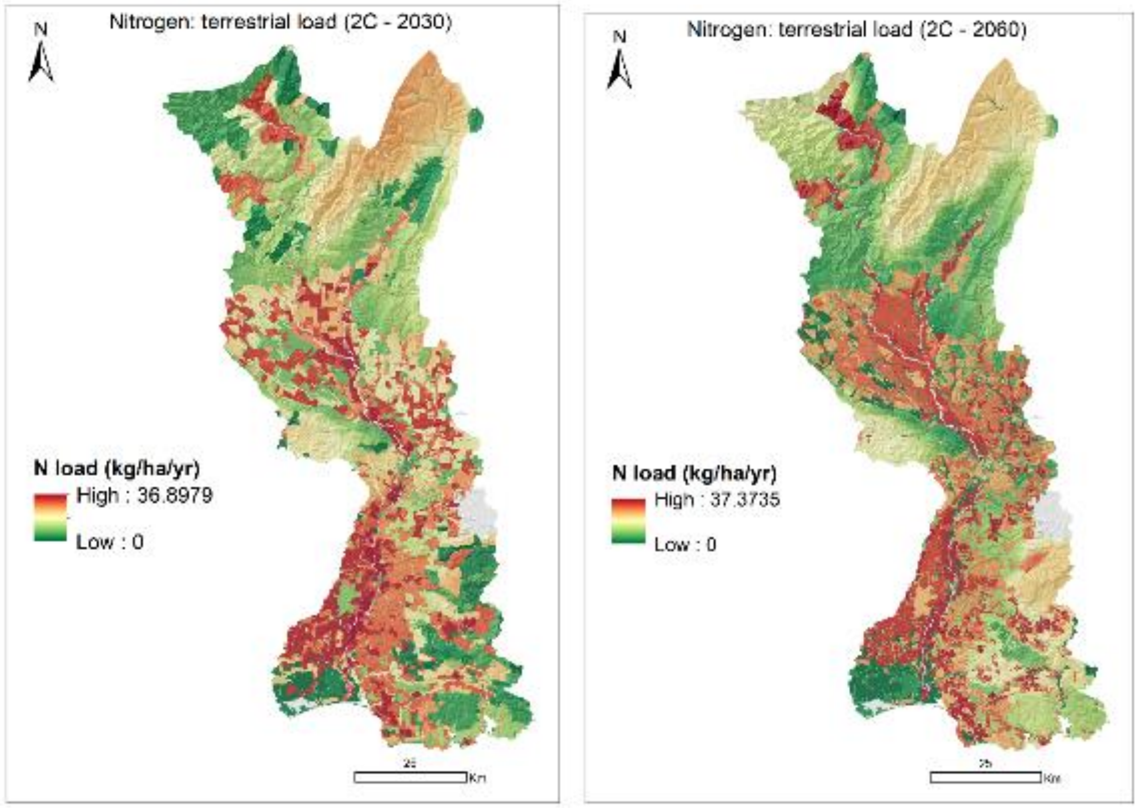

Figure 4-32. Nitrogen load results for Scenario 2B 2030 and 2060.

As for the mean N load per farm type, 2030 mean nitrogen load decreases in Lowland Sheep and Beef and Hill Country Sheep and Beef farms. In 2060, there is no Dairy Support, Hill Country Sheep and Beef, and High Country Sheep and Beef. 2060 N load is decreased in Dairy, Horticulture (Tulips), and Sheep Dairy (Table 4-56).

Table 4-56. Mean N terrestrial loads for baseline 2025, Scenario 2C 2030 and 2060 for farm types in the Mataura.

Farm types	Mean nitrogen terrestrial load (kg/ha/yr)		
	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Dairy	26.74	26.87	26.49
Dairy Support	15.12	15.78	N/a (all Dairy Support land is converted to other land uses)
Lowland Sheep and Beef	7.5	7.46	7.73
Hill Country Sheep and Beef	6.23	5.41	N/a (all Hill Country Sheep and Beef land is converted to other land uses)
High Country Sheep and Beef	6.53	6.53	N/a (all High Country Sheep and Beef land is converted to other land uses)
Mixed Cropping	9.41	9.41	9.88
Horticulture (Tulips)	N/a	4.55	4.54
Sheep Dairy	N/a	14.35	14.24

The mean in-stream P concentration, terrestrial P load, and P accumulated load also reduce significantly in 2030 and especially in 2060 compared to the baseline 2025. The mean in-stream P concentration reduces more than five times from 0.2 to 0.0038 mg/L and the maximum reduces 95.7 times in 2060. This reflects the great impacts of Totara Forestry and targeted gully planting for P retention (Table 4-57). The mean P terrestrial load also decreases slightly in 2030 and significantly in 2060 (Table 4-58, Figure 4-33).

Table 4-57. Summary statistics for the phosphorus concentration for the baseline 2025 and Scenario 2C 2030 and 2060.

Phosphorus stream concentration (mg/L)	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Min	0	0	0
Mean	0.02	0.019	0.0038
Max	23.07	21.58	0.241

Table 4-58. Summary statistics for the phosphorus terrestrial load for the baseline 2025 and Scenario 2C 2030 and 2060.

Phosphorus load (g/ha/yr)	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Min	0	0	0
Mean	369.13	354.05	166.85
Max	2179.29	2179.29	2179.29

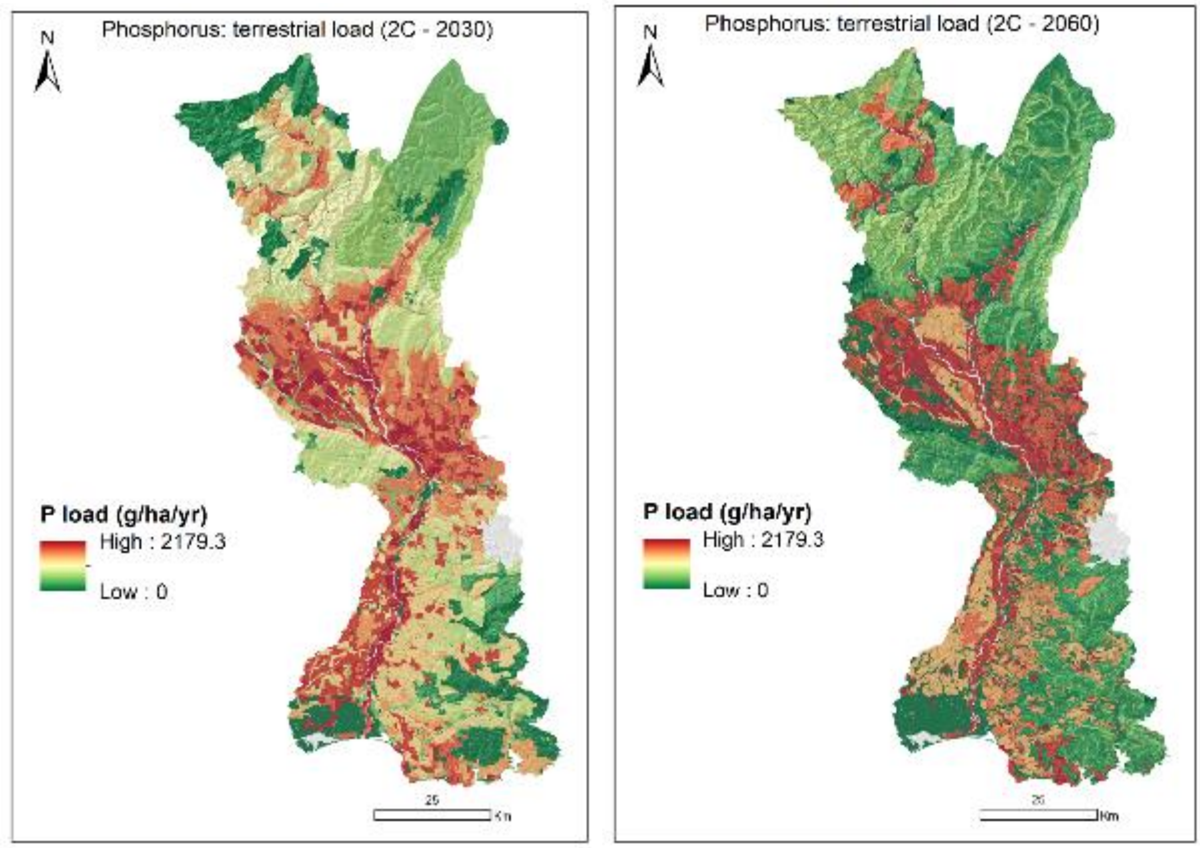

Figure 4-33. Phosphorus terrestrial load results for Scenario 2C 2030 and 2060.

The value of mean P loads in different farm types also decreases (Table 4-59). The mitigations applied in 2C 2030 slightly bring down the men P load in Hill Country Sheep and Beef farms. In 2060, the mean P loads in Dairy reduces to 1209.23 g/ha/yr (reduces nearly 1000 g/ha/yr compared with the baseline 2025 value), and Lowland Sheep and Beef reduces to 407.175 g/ha/yr. The value also decreases in Mixed Cropping, Horticulture (Tulips) and Sheep Dairy.

Similar to 2B, the increases in P load in 2030 in Dairy Support and Dairy Support is due to intensified use of the remaining Dairy and Dairy Support land combined with high P use for Horticulture (Tulips). With large areas of land moved to Sheep Dairy in 2060, the mean P load in this land use increases.

Table 4-59. Mean P terrestrial loads for baseline 2025, Scenario 2C 2030 and 2060 for farm types in the Mataura.

Farm types	Mean phosphorus terrestrial load (g/ha/yr)		
	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Dairy	1306.00	1356.49	1209.23
Dairy Support	805.34	891.49	N/a (all Dairy Support land is converted to other land uses
Lowland Sheep and Beef	429.04	430.74	407.176
Hill Country Sheep and Beef	159.27	159.26	N/a (all Hill country land is converted to other land uses)
High Country Sheep and Beef	86.71	86.71	N/a (all High country land is converted to other land uses)
Mixed Cropping	442.95	442.97	453.3
Horticulture (Tulips)	N/a	511.61	511.94
Sheep Dairy	N/a	217.37	440.224

The changes to Totara Forestry, Wetlands, and gully and Riparian Planting bring a large increase in the area of mitigating features in 2030 (+ 105,533 ha) and 2060 (+ 387,294 ha) and features considered mitigated or receiving the benefit from the additional planting (+ 24,612 ha in 2030 and 152,586 ha in 2060) (Table 4-60). This shows that the area changed for Wetlands and Riparian Planting together with gully planting and Totara Forestry largely benefits uphill areas.

Table 4-60. Results of the flood mitigation tool for the baseline 2025 and Scenario 2C 2030 and 2060.

Flood characteristics	Area of the catchment (ha)		
	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Mitigating features	99,056	105,533	387,294
Mitigated features	23,976	24,612	152,586
Non-mitigated features	498,245	491,143	82,452

The changes in 2060 lead to a large decrease in mean soil loss from 10.6 to 2.6 tonnes/ha/year and in the maximum soil loss value (Table 4-61). Due to the addition of Riparian Planting (similar to scenarios 1B and 2B), Wetlands, gully planting, and Totara Forestry, a greater area within the Mataura catchment experiences less sediment delivery risk compared to other scenarios (Figure 4-34).

Table 4-61. Summary statistics for terrestrial soil loss for the baseline 2025 and Scenario 2C 2030 and 2060.

Soil loss (tonnes/ha/yr)	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Min	0	0	0
Mean	10.6	10.6	2.6
Max	1704.1	1704.1	684.8

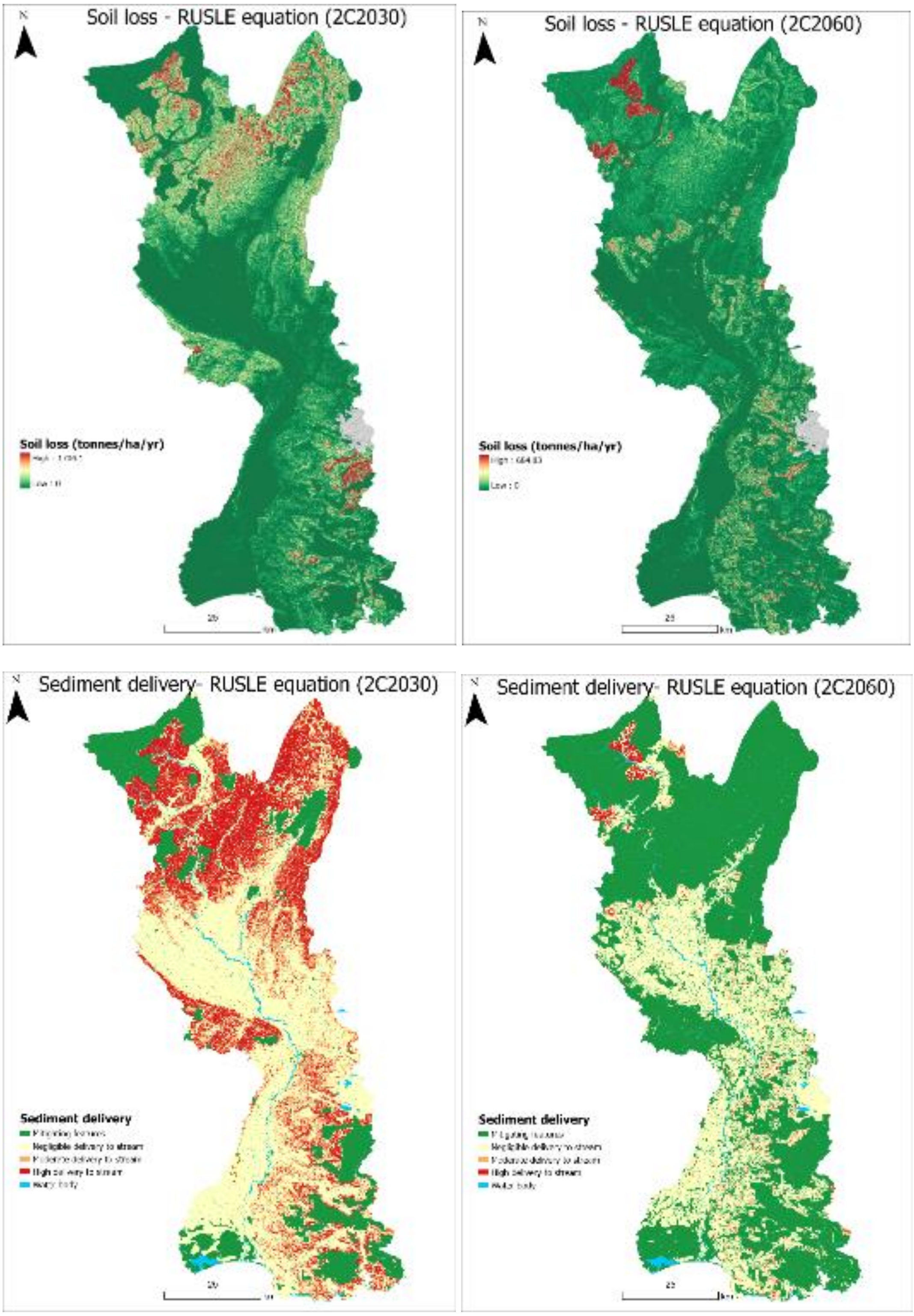

Figure 4-34. Erosion results – soil loss and sediment delivery for Scenario 2C 2030 and 2060.

The changes to Totara Forestry and the additions of riparian and gully planting in 2060 increase the amount of habitat available for kererū (Figure 4-35; Table 4-62). The riparian, gully, and Totara Forestry planting all include native trees favourable for kererū. The habitat of interest in 2060 increases approximately 4.3 times compared to the baseline 2025.

Table 4-62. Results of the habitat connectivity tool for kererū, for the baseline 2025 and Scenario 2C 2030 and 2060 (changes compared to baseline are presented in brackets).

Habitat classification	Area of the catchment (ha)		
	Baseline 2025	Scenario 2C 2030	Scenario 2C 2060
Habitat of interest	82,253	82,185 (-68)	361,752 (+279,499)
Other priority habitat	0	6,197 (+6,197)	22,263 (+22,263)
Opportunity to establish new habitat	460,450	453,191 (-7,259)	5,162 (-455,288)
Opportunity to expand existing habitat	60,066	61,275 (+1,209)	214,507 (+154,441)

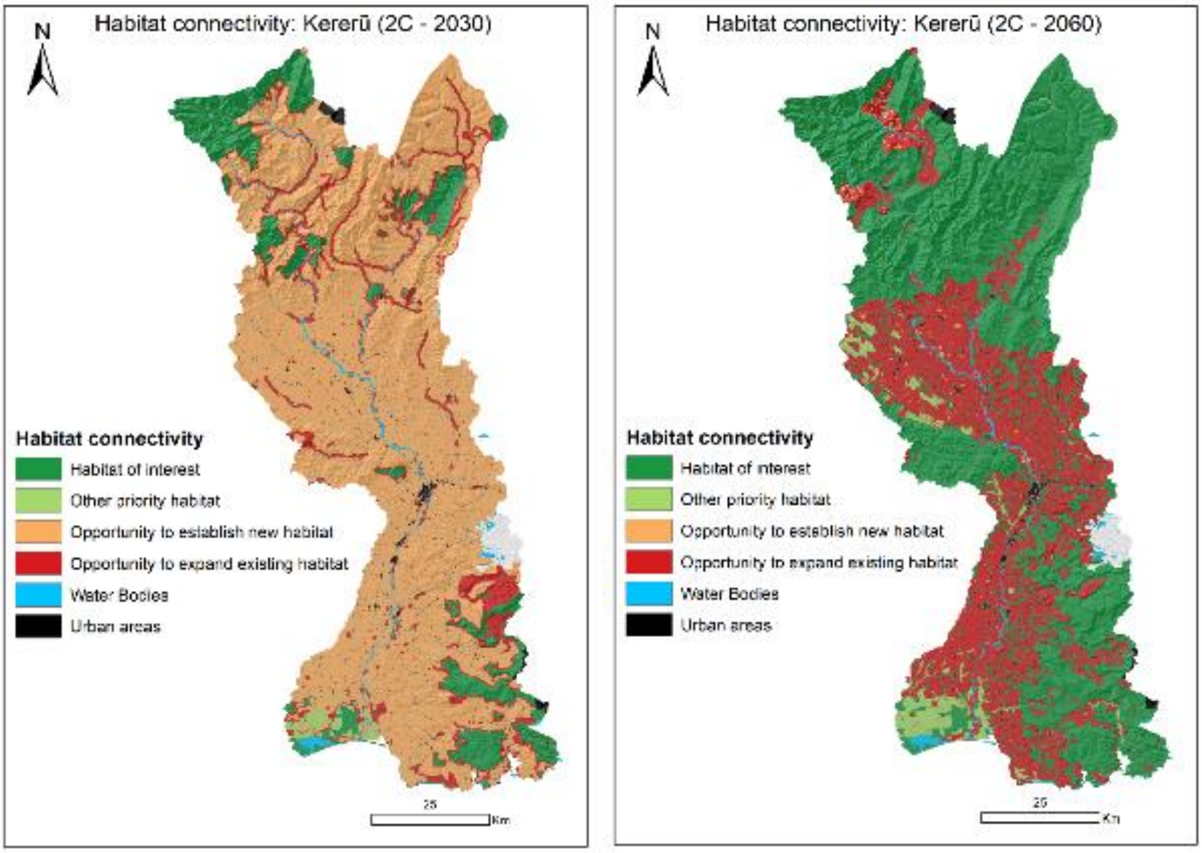

Figure 4-35. Habitat connectivity results for kererū for Scenario 2C 2030 and 2060.

Table 4-63: A and B Changes in P and N fertiliser rates by land use in relation to load for the respective high-risk areas.

A) Land use	Baseline 2025 P fertiliser (kg/ha/y)	2030 (25kg P/ha/y limit)	2060 (20kg P/ha/y limit)	Area (ha) in P high risk class (DRP and PP)	Mean P load (g/ha/yr) in high-risk area	Total estimated load	Notes
Dairy	38.5	25	20	400	1,080	451,865	Most of the land with P high-risk is in marginal production capacity zone
Dairy Support	20	20	20	224	723	182,071	Most land in moderate or marginal production capacity zone
Lowland Sheep and Beef	21.6	21.6	20	3,769	140	410,994	Most land (3511ha) in marginal production capacity zone
Hill Country Sheep and Beef	5.7	5.7	5.7	41,443	163	6,041,033	Most land (38285ha) in marginal production capacity zone
High Country Sheep and Beef	1.9	1.9	1.9	4,020	414	1,662,586	Most land (3094ha) in marginal production capacity zone
Mixed Cropping	13	13	13	0	387	207	Less than 1ha total in P high-risk areas

B) Land use	Baseline 2025 N fertiliser (kg/ha/y)	2030 (85kg N/ha/y limit)	2060 (65kg N/ha/y limit)	Area (ha) in N high risk class (NNN-Q3-Q4)	Mean N load (kg/ha/yr) in high-risk area	Total estimated load	Notes
Dairy	130.2	73.8	59	12,918	24	344,616	Most land in high or very high production capacity areas
Dairy Support	99.2	84.6	64.7	3,535	14	49,246	Most land in high or moderate production capacity areas
Lowland Sheep and Beef	31.6	17.8	17.8	30,122	7	217,952	Most land (15,564ha) in high production capability areas
Hill Country Sheep and Beef	7.9	2.7	2.7	26,483	6	157,924	Most land in moderate or marginal production capacity areas
High Country Sheep and Beef	3.2	1.2	1.2	1,247	5	5,980	Most land in moderate or marginal production capacity areas
Mixed Cropping	117.6	52.3	52.3	944	10	9,270	Most land in high or very high production capacity areas

4.7 Sensitivity analysis

To assess the robustness of modelled results, a sensitivity analysis was conducted to examine the extent to which results are affected by changes in assumptions. The sensitivity analysis focusses on the assessment of whether altering a limited number of key assumptions may lead to different conclusions.

4.7.1 Input Variables

The sensitivity analysis has been conducted by setting the current assumptions and methods as the base case of our model scenarios. Changes to the following assumptions were then tested, while leaving all other assumptions and methods in the base case unchanged:

- Discount rate.
- Land productivity distribution.
- Threshold at which land use changes.

4.7.2 Detailed scenario sensitivity testing

An annual real discount rate of 5% has been assumed in scenario 2C. This is based on the estimation of farmers' weighted average cost of capital, which aligns with the discount rate proposed by The Treasury (Te Tai Ohanga - The Treasury, 2020). In the base model, in scenario 2C, by 2060, 60.4% of modelled land will be used for Totara Forestry with the support of the multi-purpose fund. Both Exotic Forestry and Totara Forestry require a long time to maturity, but this is particularly important for Totara Forestry, with at least 60 years to harvest. Thus, returns depend heavily on the assumed discount rate. Given the importance of the cost of subsidy required to compensate for Totara Forestry, it is crucial that the effects of varying the discount rate assumption is examined.

This sensitivity analysis modelled the impact of varying the real discount rate between -4% to 15%. Although negative discount rates or extreme discount rates like 15% are unlikely and could only be short-lived, these have been included for the purpose of assessing the reliability of findings. The results from the sensitivity analysis suggest that for all positive discount rates assessed, the findings in the base model will not change as the multi-purpose fund will cover all the required subsidy compensations. As the discount rate turns negative, the multi-purpose fund will not be sufficient to cover all the required compensation, where less Totara Forestry would be planted with the difference in land use being planted in Exotic Forestry instead. This model would not be appropriate when the discount rate is close to 0% as there will be formula errors.

Given the model complexity, there are mixed implications for subsidy cost as the discount rate changes. As the discount rate increases from 4% onwards, the cost of subsidy falls as Exotic Forestry become relatively less profitable. The cost of subsidy decreases to zero as the discount rate gets closer to 0.88%, as Totara Forestry becomes relatively more profitable. As the discount rate falls below zero, the cost of subsidy increases making Totara Forestry less viable.

Supported by the sensitivity analysis, this provides confidence in the findings presented even if the actual discount rate differs from the original assumption, as the long-term discount rate should be above 1%. The sensitivity analysis is detailed in Table 4-64 below.

Table 4-64. Implication of changing discount rate on key outputs in Scenario 2C.

Discount rate (real)	Totara Forestry covered (ha)	Subsidy Compensation Required (per ha)	Exotic Forestry return (per ha)	Totara Forestry return (per ha)
-4%	162,890	$71,140	($50,699)	($121,839)
-3%	161,671	$71,676	($60,247)	($131,923)
-2%	154,046	$75,224	($80,000)	($155,224)
-1%	126,156	$91,854	($140,604)	($232,458)
0.878%	N/A	$0	$122,809	$122,854
1%	275,907	$5,092	$105,861	$100,769
2%	275,907	$21,781	$45,241	$23,461
3%	275,907	$25,406	$25,462	$56
4%	275,907	$26,017	$15,880	($10,136)
5%	275,907	$25,636	$10,365	($15,272)
6%	275,907	$24,927	$6,871	($18,056)
7%	275,907	$24,148	$4,521	($19,627)
8%	275,907	$23,407	$2,876	($20,531)
9%	275,907	$22,743	$1,693	($21,050)
10%	275,907	$22,165	$824	($21,340)
11%	275,907	$21,668	$178	($21,490)
12%	275,907	$21,243	($308)	($21,552)
13%	275,907	$20,879	($677)	($21,556)
14%	275,907	$20,565	($957)	($21,522)
15%	275,907	$20,293	($1,170)	($21,463)

Land productivity distribution

The Nature Braid model provides a five-class scale of production capacity. Land is classified by its physical characteristics in these classes that range across these classes:

- Very high production capacity
- High production capacity
- Moderate production capacity
- Marginal production capacity
- Negligible production capacity

To assess the relative returns of these classes according to the productivity of the land use, a land productivity distribution is applied. There is very limited information available on the likely shape of this distribution and our approach evolved as further information became available through our research.

Consequently, in scenario 1A a very simple form of distribution was used, where 100% productivity was used for land identified as very high or high production capacity, 70% for land identified as moderate or marginal production capacity and 10% for land identified as negligible production capacity. These were scaled so that the weighted average return for each land use was equal to the return calculated for that land use by FARMAX.

In developing Scenario 2B following consultation, further information became available on the dry matter production distribution for pasture growth. While not precisely analogous, this gave a better estimate of the Land Productivity Distribution, and the model was altered to incorporate this information. While this was not expected to significantly alter results, a sensitivity analysis was performed to check this.

For scenario 1A, changing land productivity distribution from the base model to a linear distribution or the distribution assumed for 2B, farming profitability by land productivity changed slightly but not sufficiently to change the findings from those of the base case. This is in line with expectations. Regardless of which productivity distribution, land with positive returns is still making positive returns and similarly for land with negative returns. Changes in land productivity returns are consistent between different land types, keeping the relative profitability of different farm types the same as in the base model.

A similar process was replicated for scenario 2B to test whether findings would change if different land productivity distributions were adopted. As expected, adopting the land productivity distribution in 1A for 2B has made more productive land relatively less profitable and less productive land relatively more profitable but did not change these significantly enough to change the expected land use changes. The results from changing the productivity distribution assumption are consistent with the base model as any changes in returns happens at the productivity level, making the relative profitability between farm types the same.

The sensitivity analysis provides greater assurance to the model findings. The sensitivity analysis is detailed in Table 4-65, Table 4-66, Table 4-67, and Table 4-68 below.

Table 4-65. 2030 land profitability in Scenario 1A of base model.

Profitability of farm types - 2030	Very high production capacity	High production capacity	Moderate production capacity	Marginal production capacity	Negligible production capacity	2030 Return
Dairy	$3,873	$3,873	$2,711	$2,711	$387	$3,388
Dairy Support	$341	$341	$239	$239	$34	$293
Lowland	$779	$779	$545	$545	$78	$658
Hill	$217	$217	$217	$217	$22	$213
High	$89	$59	$59	$59	$6	$58
Mixed	$1,299	$1,299	$910	$910	$0	$1,219

Table 4-66. 2030 land profitability in Scenario 1A with 2B land productivity distribution.

Profitability of farm types - 2030	Very high production capacity	High production capacity	Moderate production capacity	Marginal production capacity	Negligible production capacity	2030 Return
Dairy	$4,013	$3,825	$2,852	$1,749	$200	$3,388
Dairy Support	$356	$339	$253	$155	$18	$293
Lowland	$1,239	$1,181	$881	$540	$62	$658
Hill	$380	$362	$270	$166	$19	$213
High	$122	$116	$87	$53	$6	$58
Mixed	$1,425	$1,358	$1,013	$621	$71	$1,219

Table 4-67. 2060 land profitability in Scenario 1A of base model.

Profitability of farm types - 2030	Very high production capacity	High production capacity	Moderate production capacity	Marginal production capacity	Negligible production capacity	2030 Return
Dairy	$2,709.12	$2,709.12	$1,896.38	$1,896.38	$270.91	$2,370
Dairy Support	($416.39)	($416.39)	($291.47)	($291.47)	($41.64)	($358)
Lowland	$741.91	$741.91	$519.34	$519.34	$74.19	$626
Hill	$17.77	$17.77	$17.77	$17.77	$1.78	$17
High	($27.28)	($18.19)	($18.19)	($18.19)	($1.82)	($18)
Mixed	$864.57	$864.57	$605.20	$605.20	$0.00	$811

Table 4-68. 2060 land profitability in Scenario 1A with 2B land productivity distribution.

Profitability of farm types - 2030	Very high production capacity	High production capacity	Moderate production capacity	Marginal production capacity	Negligible production capacity	2030 Return
Dairy	$2,806.97	$2,675.33	$1,994.76	$1,223.59	$140.16	$2,370
Dairy Support	($435.02)	($414.62)	($309.14)	($189.63)	($21.72)	($358)
Lowland	$1,179.95	$1,124.61	$838.52	$514.35	$58.92	$626
Hill	$31.12	$29.66	$22.11	$13.56	$1.55	$17
High	($37.56)	($35.80)	($26.69)	($16.37)	($1.88)	($18)
Mixed	$948.42	$903.94	$673.99	$413.42	$0.00	$811

Threshold at which land use changes

The final assumption assessed in our sensitivity analysis was the threshold at which land use changes. This analysis focussed on scenario 1A as the base scenario as it is the scenario that relies most on this assumption. Findings from scenario 1A can be extrapolated for the other modelled scenarios.

The current threshold at which land use changes is assumed to be $0, the minimum return required per hectare of land. This was based on the logical expectation that, at the least, farmers will change land use just before getting negative returns. This sensitivity analysis examined the impact of changing the assumed profitability threshold from $0 to $100. Surprisingly, this did not change the 2060 results. Compared to the base model, more farming land will transition to forestry by 2030 as land transition to forestry happens quicker. Although land transition has occurred faster, by 2060, land use remains the same as in the base model. This is because by 2060, the higher threshold doesn't impact the transition of land with negative returns. For land that remains in farming, their competition has decreased dramatically such that their profitability was already significantly above the higher threshold.

5 Discussion

By assessing potential land use change under different future policy scenarios, this project aims to shed light on how some of the major policy levers under consideration might impact on land use, and hence people and their environment.

The scenarios provided considerable food for thought on some of the challenges under consideration. In particular, the high level of land use change driven by the emissions levy, particularly at the high levy rate and with a particularly heavy impact on sheep and beef farming systems. This further validates the findings of other, more in-depth recent modelling studies such as the recent report by Beef + Lamb NZ (2022), which was based on an analysis of 452 actual farms from the B+LNZ Sheep and Beef Farm Survey. The extensive increase in Exotic Forestry under most scenarios, also provides a significant challenge to consideration of future trajectories. While the results do not show a large change in the area under Dairy farming, these farms do show a significant drop in profit under the high levy scenarios. In this exercise, Dairy farmer's capital structure has not been considered, however this is likely to have a significant financial impact on some farmers.

For all farm types, the variable return per stock unit is significantly higher than the emissions levy that would be saved by reducing stock units. Therefore, there is no economic benefit from reducing stock units and we assume that, without a subsidy, farms will not reduce stock numbers. It has been assumed that stock levels will remain the same per hectare until the land has a higher best use. It is also worth considering the risk that the reduced profitability could drive farmers to increase intensity.

The results also highlight the potential for some of the alternative land uses explored, as well as important considerations if they were to increase. Workshop participants highlighted the potential for a collaborative approach to land use change, which can be supported by subsidies. This would enable the creation of a shared pathway and the critical mass required to successfully develop new pathways to market. One example is Sheep Dairy. The subsidy for transition to this system is modelled as a per hectare pay out but could equally be implemented as a contribution to the development of infrastructure and marketing.

New and/or expanding land uses will each bring with them a specific set of challenges and trade-offs. For example, Sheep Dairy, while high value and with significant potential in Mataura, may still contribute significantly to greenhouse gas emissions and nutrient loading in waterways. With the potential growth in high value horticulture, it will be important to consider their environmental impacts. Tulip growing provides one example of such a high value land use, and work is already underway by Environment Southland and tulip growers to assess their environmental impact and ensure best practice. It also highlights some of the trade-offs, such as the potential for such high value, low emissions uses to be limited by nutrient-focussed regulations (as tulips were in Scenario 2A).

Sustainable Totara Forestry systems, while environmentally beneficial, are not currently economic in comparison with Exotic Forestry. It should be noted that for this exercise, the transition towards higher value uses have primarily been constrained on the basis of land availability, however there are likely to be other constraints (market, capital, etc).

There is also some potential for perverse effects when it comes to greenhouse gas emissions: The fertiliser restrictions could potentially drive land out of cropping and into pastoral systems, thereby increasing overall stocking rates and hence methane emissions.

The scenarios provided a useful thought exercise to spark conversation, particularly on the feasibility and barriers to implementing certain interventions. It spoke to the importance of place, where spatially explicit and targeted interventions may offer better outcomes, but also the importance of involving communities in scenario generation for modelling.

Local knowledge is an essential element of any future thinking exercise on land use change. A good example of this was the conversion of the Glenaray high country station to pine plantation. This was modelled as converting to Exotic Forestry but considered by the workshop participants as unrealistic. The land use maps show the location of the Glenaray high country station and its conversion to Exotic Forestry in some of the scenarios as a shaded area, for this reason. Future sensitivity analysis of retiring the land to other types of vegetation (e.g., indigenous vegetation, tussock, etc.) may be required to understand the potential outcomes of conversion to other land uses.

Environmental benefits

For all scenarios, environmental benefits were observed. This was particularly marked, however, for Scenarios 2B and 2C, the landscape scenarios which recycled levy money back into the catchment for targeted actions; and in the case of 2C, provided an additional fund for multipurpose environmental outcomes.

As the emissions levy increases over time, it is expected that agricultural land use will transition to lower emission uses and forestry, capitalising on the ETS. When considering whole catchment emissions and sequestration, there is a clear reduction in emissions for all scenarios between 2025 and 2030. As the prices of emissions increases over time, the rate of land transitioning from agriculture to forestry is accelerated, resulting in significant carbon sequestration. By 2060, sequestration from Exotic Forestry and Indigenous Vegetation is significantly greater than net agricultural emissions for all five scenarios.

The significant environmental benefits in Scenario 1B illustrate the capability of planting interventions to benefit uphill areas much larger than the actual area they are planted in. Although this was in principle an untargeted policy scenario, it further illustrates the importance of both "what" and "where" in management interventions and planning. The Riparian Planting intercepts and holds significant water and sediment flow and associated contaminants (e.g., nutrients) prior to it reaching waterways. This was clearly seen in the in-stream N and P concentrations which had a small reduction in the mean concentration over the catchment, but larger reductions in high concentrations. The flow mitigation results show that although forestry and Riparian Planting only directly changed ~70,000 ha of the catchment, this planting also mitigated/benefited an additional ~150,000 ha of the catchment by slowing rapid water flow generated uphill of the planting and catching sediment and nutrients enroute to waterways. The Riparian Planting led to some “implicit” spatial landscape targeting being embedded in Scenario 1B.

Restoring wetlands in waterlogged areas provides an efficient approach to retiring farmland - land with very poor drainage is targeted for conversion to wetlands; these areas are the cheapest to convert back to wetlands, have high impact on nutrient flows and tend to be problem areas for farmers due to the cost of maintaining drains and deterioration of productivity when not maintained.

The scenarios that involved Riparian Planting and reductions in stock generally had better environmental outcomes. The conversions to Forestry and Riparian Planting, and targeted gully planting, also benefitted uphill/upslope areas much larger than their extent, especially in Scenario 1B. The addition of these features also led to decreases in terrestrial nutrient loads and in-stream nutrient concentrations. However, the additions of pine plantation Scenario 2C 2030 and 2B 2060 led to higher potential mean soil losses due to the interactions of high rainfall and steep topography with the vulnerable periods of soil erosion in forestry parcels (e.g., first few years when establishing and during harvesting). Scenario 2C 2060 had the biggest gains for kererū habitat due to the addition of Totara Forestry.

When compared to the national bottom lines for NO_3-N (Ministry for the Environment, 2020), the changes in Scenario 2C 2060 increased the percentage of stream reaches within the Mataura catchment to a mean below 2.4 mg NO_3-N/L. The percentage of reaches within Band A ($\leq$1.0 mg NO_3-N/L) increased to 94% in Scenario 2C 2060 compared to 80% in the baseline 2025. For ammonia (NH_4-N), percentage of reaches within Band A ($\leq$ 0.03 mg NH_4-N/L annual median) and Band B (>0.03 and $\leq$ 0.24 mg NH_4-N/L annual median) increased to 93% in Scenario 2C 2060 compared to 83% in the baseline. Note the bands are set using medians from monthly sampling while the daily hydrology and mean annual estimates of N and P load were used. However, the changes are still indicative of movement between the bands.

Scenario 2C, in particular, showed dramatic environmental benefits: The mean in-stream N concentration decreases from 0.76 mg/L in the baseline to 0.69 mg/L in 2030 and to 0.36 mg/L in 2060. The mean in-stream P concentration decreases from 0.02 mg/L in the baseline to 0.019 mg/L in 2030 and to 0.0038 mg/L in 2060. In addition, a more than four-fold increase in habitat of interest for kererū (*Hemiphaga novaseelandiae*) indicates significant biodiversity benefits. While we did not model changes in pest species such as wilding pines and feral ungulates, it is highly likely that replacing all Exotic Forestry (pine) with a more carefully managed, sustainable Totara Forestry system will have a positive impact on these issues. In addition, there was still significant funding remaining in the multipurpose fund. It would be interesting to model the 2C scenario with the lower levy rate, to examine whether a similar level of environmental benefits could be achieved with a multipurpose fund the size of the ETS and voluntary land use change, without such a negative impact on farmers.

Limitations of the methodology

As with any future modelling scenarios, there are significant limitations on the accuracy with which both the current and future landscape can be modelled. There are a wide range of variables and uncertainties beyond the scope of this work. Significant limitations arise from both data uncertainty and modelling assumptions. Multiple assumptions, simplifications and subjective choices were required in order to bring together the different disciplines, scales, and models used for this work. In all such choices, the aim has been not to propose, recommend or predict the impacts of a specific future policy, but rather to highlight the trade-offs between different policy approaches as a thought exercise. The intent is to stimulate useful, science-based, and policy-focussed conversations about some of the future pathways under consideration.

A number of specific limitations have been identified and mentioned throughout the report, as the approach has been described. In particular, modelling the economics and environmental outcomes of land use was limited in the kinds of farm and management systems that could be represented, due to limited spatial delineation of the different farming systems and broad-brush estimates of typical management characteristics. Similarly, the lack of data regarding point sources of nutrients in the Mataura such as wastewater treatment plants and septic tanks means that the modelled estimates for nutrients (P in particular) may be an under-estimation of actual conditions. If this information was available, it could be incorporated into the Nature Braid, but only diffuse sources are represented in the current report. The soil loss modelling within the Nature Braid mainly accounts for terrestrial soil losses by water, but not explicitly for soil losses from landslides or mass wasting. This means it underestimates sediment delivery and hence particulate P losses from steep unconsolidated soils and is likely the main reason why estimated P concentrations under high country Exotic Forestry are lower than expected. For harvesting, clear-felling was assumed for Exotic Forestry, but future work and more data could enable modelling more sustainable harvesting regimes.

There were also issues with reconciling differences between the spatial datasets used as model input. For example, polygons in the Mataura land use map that were identified as lakes and rivers are not always consistent with the soil map, which can cause issues in spatial modelling. Any uncertainties present in the input datasets compound and propagate through to the modelling results, so it is important to be aware of these. In the Mataura, one of these uncertainties was the extent of wetland areas in the Baseline 2025 as they were not explicitly delineated in the original land use map and thus assumptions had to be made in the scenario modelling regarding potential placement of constructed wetlands, wetland restoration, etc.

Finally, for modelling simplicity, riparian planting and gully planting were not modelled economically as a change in land use. While this was kept consistently simple across the scenarios that included riparian planting (1B, 2B and 2C), enabling comparison; in practice the removal of this land from production is also likely to have an economic impact. In addition, this was modelled for all scenarios as occurring to a consistent distance from each waterway. In order to target model targeted riparian planting more effectively, further work would be required to analyse the optimal areas for increasing or decreasing riparian buffer areas.

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Appendices

A1 - Overview of policy scenarios for Mataura

Scenario	1. Untargeted approach		2. Targeted landscape approach		
Variation	1A. Low levy, untargeted freshwater regulations	1B. High levy, untargeted revenue recycling	2A. Low levy, targeted freshwater regulations	2B. High levy, targeted revenue recycling	2C. High levy, forestry phased out from NZ ETS
Purpose	This scenario is based on the processor-level hybrid levy option that has been proposed by He Waka Eke Noa. The initial levy rate is relatively low and increases gradually over time. The levy revenue collected is small and is recycled into research on reducing emissions from agriculture.	This scenario has higher levy rates that rise more rapidly than 1A. All of the revenue from the levy is recycled back into central government funding programmes and spent using a simple untargeted approach. This enables comparison to 2B where the revenue is distributed to the catchment in a targeted, landscape-specific manner.	This scenario shows the effect of targeted, landscape-specific freshwater regulations. Caps on nitrogen and phosphorus are based on landscape susceptibility to loss of freshwater contaminants. In all other features it is the same as 1A.	This scenario shows the effect of targeted revenue recycling. It is the same as 1B except that the revenue from the emissions levy is recycled back into a community fund, which is used to support targeted actions (land management practices, farm system changes and/or land use change) that produce multiple environmental outcomes. The community (including tangata whenua), local government and iwi/hapu decide together how the community fund is spent. They have access to tools such as Nature Braid and landscape susceptibility mapping to help inform their decision-making.	This scenario shows the effect of phasing out forestry from the NZ ETS. It is the same as 2B except that the price for forestry NZUs from newly registered forests decreases to zero by 2030. The lost revenue from NZU sales is compensated by additional central government funding for forestry, which is used to support targeted forest planting with a focus on multiple benefits.
Biological emissions pricing	• Levy introduced in 2025 based on He Waka Eke Noa processor-level hybrid levy option • Split-gas approach with separate prices for methane and long-lived gases (N_2O and CO_2) • Levy rate set at a relatively low in 2025, increasing gradually over time	• Same as 1A, except with higher levy rates that rise more rapidly over time	Same as 1A	Same as 1B	Same as 1B

Use of levy revenue	None (for modelling purposes) (The assumption is that revenue collected from the levy will be small, and likely to be channelled mainly to research at the national level. Accounting for this is beyond the scope of this study.)	Levy revenue is recycled back into central government funding programmes and spent on: • Payments to implement land management practices and farm system changes that reduce emissions. • Payments for planting trees that are not eligible for the NZ ETS. For modelling purposes and to make the scenario comparable to 2B, the amount of levy revenue spent in the catchment is set equal to the amount raised in the catchment. The central government funding is allocated to farms in an untargeted manner based on land use type, farm area and/or output. Some funding is still channelled back to national level research.	Same as 1A	Levy revenue is recycled back into a community fund. The community, tangata whenua and local government decide how the revenue is spent. This could include: • Payments to implement land management practices and farm system changes that improve freshwater quality, protect/enhance biodiversity and reduce emissions. • Payments for retiring pasture and conversion to / restoration of indigenous/native gully planting or Riparian Planting or wetlands. • Payments for land use change from highly intensive pastoral land uses to less intensive productive land uses with lower environmental impacts. The payments are allocated in a targeted manner by using tools such as landscape susceptibility mapping and Nature Braid to identify the best locations to undertake actions. Part of the levy revenue fund could be allocated to projects that benefit Māori, iwi and hapu.	Same as 2B except the levy revenue is supplemented by central government funding for forestry (similar to the One Billion Trees programme) that recognises multiple benefits beyond carbon sequestration. Allocation of funding for forestry could be determined based on landscape susceptibility/ecological needs, etc.

NZ ETS	- No limits on forestry in the NZ ETS	Same as 1A	Same as 1A	Same as 1A	- The price for forestry NZUs from newly registered forests decreases to zero by 2030, reflecting a phase out of incentives for new forests (all types) under the NZ ETS
Freshwater regulations	- Current nitrogen fertiliser application rate limited (for pastoral land use only) - No controls on phosphorous inputs - Stock exclusion regulations - Intensive winter grazing regulations	Same as 1A	- Nitrogen fertiliser application rate limits based on landscape susceptibility to loss of nitrogen - Tailored controls on phosphorous inputs based on landscape susceptibility to loss of phosphorous - Stock exclusion regulations: same as 1A - Intensive winter grazing regulations: same as 1A	Same as 2A	Same as 2A

A2 – Nature Braid Model

Biophysical modelling was carried out using the Nature Braid model. The Nature Braid framework is a land management and decision support tool that uses landscape information to create quantitative and qualitative spatial outputs (Jackson, et al., 2013). These outputs show areas providing ecosystem services (agricultural productivity, flood mitigation), hotspots for management interventions (nutrient loads and delivery, soil erosion and sedimentation), and areas of trade-offs/synergies between services. Nature Braid runs at fine spatial scales (~5m to 10m; field to catchment to national scales) and is spatially explicit as its algorithms maintain biophysical principles and spatial configuration.

In this project, Nature Braid was used to provide maps of agricultural productivity, nitrogen, phosphorus, flood mitigation, erosion, and habitat connectivity of kererū (*Hemiphaga novaseelandiae*). With the majority of the Mataura catchment used for agricultural land (Table 2-1), assessing the agricultural productivity and nutrient delivery under current conditions was important for building scenarios. Flood mitigation and erosion are services that have synergies with nutrient delivery, meaning that management interventions that address nutrient delivery are likely to provide benefits for flooding and erosion too. Kererū are species of interest in Southland due to their ability to disperse seeds of large-fruited tree species over long distances, providing benefits to populations of fleshy-fruited trees in fragmented landscapes such as the Mataura catchment (Powlesland, et al., 2011).

The inputs used for the Nature Braid model are listed in Table A - 1. The specific parameterisation for the six FARMAX farm types was done based on FARMAX outputs on stocking rate and fertiliser uses under baseline 2025 and different scenarios.

Table A - 1. Summary of input datasets used for this application of Nature Braid.

Model input	Information	Source
Digital elevation model	8-metre resolution raster	(Land Information New Zealand, 2012)
Land use map	Southland land use layer	Environment Southland
Soil	Fundamental Soils Layer (FSL)-polygon	(Landcare Research NZ, 2010)
Rivers and streams	River Environment Classification (REC2)	(NIWA, 2019)
Rainfall and evapotranspiration	500 metre resolution raster	(NIWA, 2012)

As described in Jackson et al. (2013) the agricultural valuation tools within the Nature Braid model provide screening methods to categorise land by its productivity value (production capacity) for farmers. This serves an important purpose when it comes to considering trade-offs and synergies between ecosystem services (including production), which is particularly critical to this project.

Nature Braid's agricultural productivity tool evaluates production potential, utilisation, and status (Table A - 2). Areas that are flat, well-draining, and fertile are considered to have high agricultural production potential while areas that are susceptible to waterlogging or very hilly are considered to have low agricultural production potential. The relative agricultural "utilisation" identifies areas that are over-utilised which may be indicative of farming that requires more management activities to make it productive/sustainable. Areas that are under-utilised indicate where opportunities to increase agricultural productivity may be present. Agricultural utilisation status combines the current and predicted optimal output in a different way to the relative utilisation described previously. Land with appropriate utilisation is considered worthy of protection, and areas where land is over or under-utilised are flagged for consideration of management change.

Additionally, the current land use regime is considered in order to examine the degree to which this value is currently utilised. In the calculation of perceived agricultural value (i.e., the value of the land independent of its current land management utilisation), each element in the landscape is categorised as one of: very high value, high value, marginal, low value, or no value according to (a) slope and aspect, (b) soil drainage characteristics and (c) fertility information with soil organic matter/organic carbon as the proxy (where available). It should be noted that this valuation layer ignores existing land use (except implicitly, insofar as land use may have modified soil characteristics, etc.); it is an indication of potential rather than current value. Further valuation layers consider the current utilisation of the land and how this compares to its predicted utility for agricultural production

Table A - 2. Overview of output from the agricultural productivity tool.

Output layer from agricultural productivity tool	Influenced by	Indicates
Predicted optimal agricultural utilisation	Soil type, using assigned values of fertility, waterlogging (permanent, seasonal, or negligible) and topographic data (aspect, slope, and elevation)	Low to very high agricultural potential
Current agricultural utilisation	Land cover/management data	Ranks areas from highest agricultural productivity to lowest
Relative agricultural utilisation	Combines predicted optimal agricultural utilisation and current agricultural utilisation outputs above	Delineates where land appears to have very high utilisation, potentially being over-utilised, or have very low utilisation, potentially being under-utilised - very high utilisation and potentially being over-utilised when current utilisation category is higher than predicted optimal agricultural utilisation - predicted average utilisation when current utilisation and predicted optimal agricultural utilisation are in the same category - very low utilisation and potentially being under-utilised when current utilisation category is lower than predicted optimal agricultural utilisation
Agricultural utilisation status		Considers whether the current agricultural utilisation may be worthy of preservation or change: - typical/usual utilisation: current utilisation and predicted optimal productivity are in the same category or current utilisation is appropriate for predicted optimal productivity - unusually utilised: current utilisation and predicted optimal productivity are in different categories or current utilisation is appropriate for predicted optimal productivity

Predicted optimal agricultural utilisation

This output ignores the input land cover and instead predicts a near-optimal utilisation based on:

1. Soil water holding characteristics: permanent, seasonal, or negligible.
2. Fertility: organic carbon is used as a proxy, OC is divided in 5 ranges: 0-2%, 2-6%, 6-15%, 15-30% and >30%
3. Topography: elevation (based on elevation thresholds in meters above sea level (masl) set by user including elevation threshold of productive agricultural land and elevation threshold of all agricultural land), slope (based on slope thresholds in degrees set by user including slope threshold for very productive land and slope threshold for somewhat productive land) and aspect (varying according to hemisphere and with zero effect near the equator)

Flat, well-draining, and fertile areas are predicted to have a high potential for agricultural production for example, more waterlogged areas or steeper areas have less potential. This model output is dependent on the accuracy of user set thresholds and weightings, as well as the soil data layer supplied as input to the scenario pre-processing tool.

Uncertainty may also be introduced through model processing since values for soil fertility and waterlogging are based on estimates or national averages for the soil type and may not reflect site conditions accurately.

Categories	Meaning
Very high production capacity	Well-drained soil, very high fertility and slope is less than or equal to slope threshold for very productive land and elevation are less than the elevation threshold for productive land
High production capacity	Well-drained soil. high fertility, and slope is less than or equal to slope threshold for very productive land and elevation are less than the elevation threshold for productive land
Moderate production capacity	Well-drained soil, moderate fertility, slope is less than or equal to slope threshold for somewhat productive land and elevation are less than the elevation threshold of all agricultural land
Marginal production capacity	Seasonal waterlogged soil, low fertility, slope, slope is less than or equal to slope threshold for somewhat productive land and elevation are less than the elevation threshold of all agricultural land
Negligible production capacity	Permanent water-logged soil, low fertility and slope is more than the slope threshold for somewhat productive land and elevation are more than the elevation threshold of all agricultural land

Current agricultural utilisation

This output shows utilisation according to current land cover/use, ignoring predicted production capacity. Uncertainty is reliant on the accuracy of land cover/land use data. Arable and improved grassland are considered to be highly productive, for example, while bare ground, or built infrastructure such as railways and roads, are considered to provide no agricultural utilisation.

Categories	Meaning
Very high production	Well-drained soil, very high fertility and slope is less than or equal to slope threshold for very productive land and elevation are less than the elevation threshold for productive land
High production	The current land use is medium producing grassland
Moderate production	The current land use is low producing grassland
Marginal production	The current land use is marginally productive, such as woodland and/or heath, vegetation that is not used for agricultural production
No production	The current land use is bog or wetlands, sand and/or rock

Relative agricultural utilisation

This output is calculated from a comparison of predicted optimal agricultural utilisation and current agricultural utilisation outputs. It flags where land appears to be over or under-utilised. If both current and predicted utilisation are within one category of each other, land is considered to be appropriately utilised. If they differ by more than one category, Nature Braid flags where current production appears to be over utilising the land (so may be inefficient farming, or not sustainable), and also where opportunities to increase agricultural production may be present. Any errors in the model output for current and predicted agricultural utilisation will propagate through to this data layer.

Categories	Meaning
Very high utilisation Somewhat high utilisation	Current utilisation category is higher than predicted optimal agricultural utilisation (i.e., land is potentially over-utilised).
Predicted/average utilisation	Current utilisation and predicted optimal agricultural utilisation are in the same category.
Somewhat low utilisation Very low utilisation	Current utilisation category is lower than predicted optimal agricultural utilisation (i.e., land is potentially being under-utilised).

Agricultural utilisation status

This output combines the current and predicted optimal output but in a different way to the relative agricultural utilisation output category. Rather than being concerned with direction of change (under or over utilisation), it considers whether the current agricultural utilisation may be worthy of preservation or change. Land in appropriate utilisation (predicted/average utilisation class in the relative agricultural utilisation map) is considered worthy of protection, areas where land is over or under-utilised are flagged for consideration of change to management. Errors in model output for current and predicted agricultural utilisation will propagate through to this data layer.

Categories	Meaning
Typical/usual agricultural production status	Current utilisation and predicted optimal productivity are in the same category or current utilisation is appropriate for predicted optimal productivity.
Near-typical agricultural production status	Current utilisation and predicted optimal productivity differ by one category
Land on somewhat unusually utilised Land very unusually utilised	Current utilisation and predicted optimal productivity are in different categories or current utilisation is not appropriate for predicted optimal productivity. Land somewhat unusually utilised has current utilisation and predicted optimal productivity are different in two categories. Land very unusually utilised has current utilisation and predicted optimal productivity are different in three categories or more.

Flood Mitigation

The flood mitigation tool considers spatially explicit hydrological and topographical routing with connectivity and configuration details (Table A - 3). It uses information on the storage and permeability capacity of elements within the landscape from soil and land use data. Flow accumulation determined using GIS is then modified according to permeability and storage of the landscape. This tool maps areas where overland and near-surface flow may accumulate as well as "mitigating features" with the capacity to help mitigate floods and high stream flow which may follow high-intensity precipitation events. Areas with high water storage capacity and/or high infiltration capacity can help to mitigate downstream flood risk by acting as a sink for fast-moving overland flow and near-surface subsurface flow; either storing this or routing the water more slowly through subsurface routes.

Table A - 3. Overview of output from the flood mitigation tool.

Output layer from flood mitigation tool	Influenced by	Indicates
Flood/flow mitigation	Soil, land use, topography	Mitigation classification of current soil/land use
Flood interception	Soil, land use, topography, climate	Identifies high-priority areas where land is not mitigated by any vegetation and where flow is either being generated or accumulated
Average flow in cumecs (m^3/s)		Flow delivery to all points in the river and lake networks, to estimate water supply services

Flood interception classification

This output shows the flood mitigation layer, which is influenced by soil, land use, topography, and climate. It identifies high-priority areas where land is not mitigated by any vegetation and where flow is either being generated or accumulated. Potential sources of error include inaccuracies in land use input data or Nature Braid classification of land cover as mitigating or not-mitigating. Failure to account for storage capacity of deep soils in non-wetland areas, or faster runoff in urban areas with paved surface may reduce accuracy of mapping of areas of high and low flood concentration.

Category	Meaning
Flood mitigating land	Areas that are providing mitigation of flow (e.g., trees, ponds, deep permeable soils or other flow sinks) and can intercept flows (and their associated mass, nutrients, sediments, contaminants etc) before reaching streams.
Low flood concentration	Areas with low flow concentration based on a threshold set by the user.
Moderate flood concentration	Areas with moderate flood concentration based on a threshold set by the user.
High flood concentration	Areas of high flood concentration (large contributing area with no mitigation) and where the landscape could benefit from mitigation based on a threshold set by the user.

Flood mitigation classification

This output maps the mitigation classification of the current soil/land use and areas. Potential sources of error include inaccuracies in land use input data or Nature Braid classification of land cover as mitigating or not-mitigating, as well as failure to account for soil permeability.

Category	Meaning
Mitigating features	Areas that are providing mitigation of flow by slowing down flow or having high storage capacity (e.g., trees, ponds, deep permeable soils or other flow sinks).
Mitigated features	Areas that receive mitigation benefits as water and other mass originating in these areas are intercepted by mitigating features before reaching a stream, lake or river.
Non-mitigated features	Areas with low permeability and/or storage that do not flow through mitigating features. Any flows from these areas are going directly into water bodies without any features to buffer them.

Habitat

The habitat connectivity tool can be applied for identification of suitable areas for habitat expansion and protection. The tool follows a cost-distance approach to evaluating habitat connectivity, following the approach outlined by Forest Research's BEETLE project (Biological and Environmental Evaluation Tools for Landscape Ecology). Given the importance of kererū in Mataura and to fragmented landscapes more generally due to the species' ability to disperse the seeds of fleshy-fruited trees over long distances, the preliminary habitat connectivity map was produced for kererū in the catchment. Habitat connectivity parameterisation for kererū by Nguyen et. al (2021) was used to provide the preliminary habitat connectivity map of kererū in Mataura.

Habitat connectivity

This output highlights areas of ideal habitat based on land use/cover and user-defined thresholds of minimum habitat size. It uses information about species ability to travel through hostile terrain to highlight how far it can travel from patches of ideal habitat.

Category	Meaning
Habitat of interest	Native vegetation patches meet the habitat threshold of 0.05 ha which is the minimum foraging habitat size for bush and water birds. The habitat threshold for kererū is 0.05 ha.
Other priority habitat	Not the habitat of interest but being conserved for other purposes, for example, herbaceous freshwater and saline vegetation.
Opportunity to establish new habitat	Within these areas, habitat establishment is possible but exceeds the maximum cost-distance travelled, meaning that any new habitat established here would not be connected to existing habitat of interest.
Opportunity to expand existing habitat	New habitat in this area would act to extend the existing habitat. This does not suggest that the entire area in this category needs to be established with the habitat of interest; rather this shows the maximal extent within which new habitat would be connected to existing habitat. Establishing habitat at this edge of this extent will improve connectivity because the distance travelled across 'hostile' terrain to get to this patch is within the maximum cost-distance through 'hostile' terrain threshold. Outside of this extent, too much 'hostile' terrain would need to be traversed and therefore would not improve connectivity.

Nutrients

Nature Braid estimates the terrestrial nutrient load through a modified export coefficients which consider biophysical and climate characteristics, nutrient inputs, irrigation, stock, Olsen P, and topography (Trodahl (2018); Table A - 4). The accumulated load (classified) map combines the predictions of accumulated nutrient load with user-specified thresholds, to categorise the nutrient loading into very low to very high categories. It is influenced by the load contributed from "uphill" sources, topographic routing, and effective precipitation to consider delivery to streams. In-stream nutrient concentrations and loads are also estimated, with the concentrations used to classify stream reaches into having low to very high concentrations based on user-defined thresholds.

Table A - 4. Overview of output from the nutrient tools.

Output layer from flood mitigation tool	Influenced by	Indicates
Terrestrial nutrient loads	Modified export coefficients, rainfall, irrigation, fertiliser, effluent, stock units, topography Water movement; sediment movement Additionally, phosphorus loading is also influenced by Olsen P levels where data is available and assumes best practice where not	Total nutrient load generated at any point within the landscape Nitrogen: kg/ha/yr (Nitrate, Ammonium are treated separately as nitrate is more soluble while ammonium somewhat sorbed) Phosphorus: g/ha/yr (particulate and dissolved species considered separately)
Accumulated load (kg/yr and classified)	Estimates of accumulated nutrient loads based on terrestrial nutrient loads combined with topographic routing and effective precipitation to route water through the landscape	Estimates delivery of nutrients to water bodies Thresholds (user-defined): Nitrogen: • High: 0.1 kg/yr • Very high: 1 kg/yr Phosphorus: • High: 10 g/yr Very high: 100 g/yr
Nutrient in-stream concentration (mg/L and classified)	Based on accumulated load (above), sediment and nutrients (above) and stream/groundwater attenuation (lags and variable residence times in groundwater can be input where quality information exists)	Concentration of nutrients in-stream for each pixel (mg/L) and reach (classified) Thresholds (user-defined): Total Nitrogen*: • High: 5 mg/L • Very high: 10 mg/L Total Phosphorus: • High: 0.025 mg/L Very high: 0.075 mg/L

* These thresholds are based on the World Health Organisation's recommendation of a maximum concentration of 11.3mg/L nitrate-N for drinking water and the New Zealand College of Midwives recommendation for pregnant women to avoid water with ≥ 5mg/L nitrate-N (WHO, 2022).

Nitrogen

Classified Nitrogen accumulated load

This output combines the predictions of accumulated total N load with user specified thresholds, to categorise the nutrient loading into very low to very high categories.

Thresholds:

- N critical load threshold 1 (kg/yr): below which accumulated N load is considered of no concern, the default value is 0.1 kg/yr
- N critical load threshold 2 (kg/yr): above which accumulated N load is considered of significant concern, the default value is 1 kg/yr

Category	Meaning
Low to moderate load	Total N accumulated is less than N critical load threshold 1 defined by user
High load	Total N accumulated load is between N critical load threshold 1 and 2
Very high load	Total N accumulated load is higher than N critical load threshold 2

Classified Nitrogen in-stream concentration

This output combines the predictions of N stream concentration with the user specified thresholds, to categorise the concentration into very low to very high categories.

Thresholds:

- Threshold of high N concentration (mg/L): below which accumulated N concentration is to be considered of no concern, the default value is 5 mg/L based on World Health Organisation recommendation of maximum concentration of 11.3mg/L for drinking water
- Threshold for very high concentration (mg/L): above which accumulated N concentration is to be considered of significant concern, the default value is 10 mg/L based on World Health Organisation recommendation of maximum concentration of 11.3mg/L N for drinking water

Nitrogen accumulated load

This output shows the accumulated total N load (in kg/yr), considering the load not just at a point (depending on modified export coefficients which are influenced by rainfall, irrigation, fertiliser, effluent, and stock), but also that contributed from “uphill” sources. N accumulated load is estimated based on terrestrial nutrient loads combined with topographic routing and effective precipitation to route water through the landscape. High values are prime targets for mitigation or interception opportunities. Accuracy reflects that of the input data on land use and the relevant Nature Braid export coefficient, as well as the DEM and topographic routing approach used to model accumulation. The output can be used to extract total N accumulated load (kg/yr) at any point.

Total Nitrogen in-stream concentration

This output shows total N concentration (in mg/L) at all points in-stream. High values suggest that the catchment of this point should be targeted for mitigation/interception opportunities. N in-stream concentration is influenced by N accumulated load and stream attenuation. This is subject to errors in the input (or modelled intermediate) spatial data layer for the river network, in addition to any sources of inaccuracy in the modelled accumulated terrestrial nutrient concentration.

Phosphorus

Classified Phosphorus accumulated load

This output combines the predictions of accumulated total P load with user specified thresholds, to categorise the nutrient loading into very low to very high categories.

Thresholds:

- P critical load threshold 1 (kg/yr): below which accumulated P load is considered of no concern, the default value is 0.01 kg/yr
- P critical load threshold 2 (kg/yr): above which accumulated P load is considered of significant concern, the default value is 0.1 kg/yr

Category	Meaning
Low to moderate load	Total P accumulated is less than P critical load threshold 1 defined by user.
High load	Total P accumulated load is between P critical load threshold 1 and 2.
Very high load	Total P accumulated load is higher than P critical load threshold 2.

Classified Phosphorus in-stream concentration

This output combines the predictions of P stream concentration with the user specified thresholds, to categorise the concentration into very low to very high categories.

Thresholds:

- Threshold of high P concentration (mg/L): below which accumulated P concentration is to be considered of no concern (oligotrophic). The default value is 0.025 mg/L, based on guidance from Dodds et al. (1998).
- Threshold for very high concentration (mg/L): above which accumulated P concentration is to be considered of significant concern, the default value is 0.075 mg/L based on guidance from Dodds et al. (1998)

Phosphorus accumulated load

This output shows the accumulated total P load (in g/yr), considering the load not just at a point (depending on modified export coefficients which are influenced by rainfall, irrigation, fertiliser, effluent, and stock), but also that contributed from “uphill” sources. P accumulated load is estimated based on terrestrial nutrient loads combined with topographic routing and effective precipitation to route water through the landscape. High values are prime targets for mitigation or interception opportunities. Accuracy reflects that of the input data on land use and the relevant Nature Braid export coefficient, as well as the DEM and topographic routing approach used to model accumulation.

Total Phosphorus in-stream concentration

This output shows total P concentration (in mg/L) at all points in-stream. High values suggest catchment of this point should be targeted for mitigation/interception opportunities. P in-stream concentration is influenced by P accumulated load (below) and stream attenuation. This is subject to errors in the input (or modelled intermediate) spatial data layer for the river network, in addition to any sources of inaccuracy in the modelled accumulated terrestrial nutrient concentration.

RUSLE

The RUSLE (Revised Universal Soil Loss Equation) uses methods initially applied to agricultural land in the United States of America which have been further developed and applied in various contexts around the world (Wischmeier & Smith, 1978; Renard, et al., 1997; Benavidez, et al., 2018). It uses information about rainfall erosivity, soil erodibility, topography, land use/cover, and management to estimate soil erosion by water (i.e., rainfall and runoff). The effect of rainfall on erosion is calculated based on coefficients produced by (Klik, et al., 2015). The RUSLE mainly accounts for terrestrial soil losses by water, but not explicitly for soil losses from landslides or mass wasting.

Nature Braid extends this by examining which areas have high susceptibility to soil loss and do not have any land use downhill that can intercept sediments, making the receiving streams vulnerable to sediment delivery (Table A - 5). The methods and data we use are more highly resolved and updated versus the “USLE” component of NZ Sednet, although we are not routing sediment through the river network in detail as this requires more information on bank form and characteristics than was available.

Table A - 5. Overview of output from the RUSLE.

Output layer from flood mitigation tool	Influenced by	Indicates
Terrestrial soil erosion by water	Rainfall, soil, land use/cover, management, topography	Estimates of soil erosion (tonnes/ha/yr)
Soil loss risk	Terrestrial soil erosion (above) and user-defined thresholds	Risk of soil loss based on thresholds (by default, any soil loss beyond 5 tonnes/ha/yr is considered high)
Risk of sediment delivery	Soil loss risk (above) and mitigating vs non-mitigating features	Whether land use is mitigating (intercepts flow and sediment) or risk of sediment delivery (negligible to high)

Risk of sediment delivery

This output shows sediment delivery vulnerability depending on whether the soil loss (using ‘Soil loss risk’) is occurring on non-mitigated land.

Category	Meaning
Mitigating features	Areas that are providing mitigation of sediment delivery (e.g., trees, ponds, deep permeable soils, or other flow sinks.
Negligible delivery to stream	Areas where soil loss is occurring, but this is being intercepted by mitigating features before reaching water bodies.
Moderate delivery to stream	Areas of high soil erosion risk which are not being mitigated before reaching water bodies.
High delivery to stream	Areas of extreme soil erosion risk which are not being mitigated before reaching water bodies.

Soil loss risk

This output shows the risk of soil loss based on Terrestrial soil erosion and user-defined thresholds.

Thresholds:

- Lower threshold for medium erosion risk (2.5 tonnes/ha/yr)
- Lower threshold for high erosion risk (5 tonnes/ha/yr)
- Lower threshold for extreme erosion risk (10 tonnes/ha/yr)

Terrestrial soil erosion by water

This output shows the annual soil loss by water using the RUSLE which considers rainfall, soil, land use/cover, management, and topography. The rainfall factor uses the New Zealand constants formulated by Klik et al. (2015) and the user is referred to that article to find the constants for their study area.

A3 – FARMAX

FARMAX is a decision support tool designed to help pastoral farmers to monitor, review and analyse their farming businesses, in order to optimise their profits and farming systems. Developed by AgResearch and commercially launched in 1993, the FARMAX engine utilises AgResearch published science and expertise to ensure all information feeding into the model is relevant and up to date. The engine is designed to model both the biological systems and economic outcomes of various farming systems, with individual Dairy and Redmeat software packages.

The software allows for actual physical farm parameters to be inputted including farm size, regional location, livestock stock numbers by class, breed, mating and reproductive performance and production information as well as timing of product sale along with product statistics. The model calculates the required feed demand for a modelled livestock system within the constraints of user-defined pasture growth rates and animal performance data. It uses feed demand data for different livestock classes and feed supply information from an extensive database of pasture growth and crop yields. This is integrated with economic information so that complex farm systems can be modelled. However, it does not consider spatial aspects and only models nitrogen fertiliser inputs in relation to pasture growth. It can be used to predict physical and financial outcomes of a farm so is a useful tool for optimising a farm system given different scenarios.

For economic analysis, up to date meat and milk schedules are built into the FARMAX model but these can be adjusted to reflect farm actuals. Nitrogen fertiliser inputs, cropping and conservation areas and pasture production can all be manually input in the model. Where information is unavailable, FARMAX libraries provide industry average information. Farm expenses are also built into the model and are either from a library of information or can be manually corrected for increased accuracy for an individual user.

Assumptions and limitations of FARMAX for this project

All scenarios were run in ‘long-term’ mode. This provides checks and balances to ensure that the model is balanced for factors such as pasture covers, stock reconciliations, animal liveweight gains, for example prompting checks on opening and closing stock numbers to ensure that the system is stable over multiple years.

Modelling hypothetical farms was a limitation of the farm system modelling as financial results and farm management decisions are not real for any specific farm types. Taking an average approach was preferred over identifying a real farm in the catchment, to prevent the selection of a farm business which would not be considered average in the catchment. The non-spatial nature of the FARMAX model was also a limitation when feeding physical farm information into the Nature Braid model which has a spatial element.

It is important to note that during this project, FARMAX software underwent an update. WSP has not investigated whether this update has affected any calculations or processes within the model. This does not affect results within catchment, however when comparing results between the Mataura and Wairoa catchments, care will need to be taken as these are modelled in two different versions of FARMAX.

A4 – Nature Braid Selection Rules

The six farm types modelled in FARMAX were delineated using the two fields “Land_Use” and “ES_LandUse” within the attribute table of the Mataura land use map. Both fields were used as the land use field specified by PCE did not distinguish between Dairy and Dairy Support. The selection rules are detailed below:

Dairy

"ES_LandUse" = 'Dairy'

Dairy Support

"ES_LandUse" IN('Dairy Support', 'Dairy Support and Other Livestock', 'Livestock Support')

Note from the Southland LU layer report (page 44: Table 1 identifies two classifications for support properties, Dairy Support and other livestock. It is likely that both these categories are used primarily for Dairy Support; however, the properties which are identified as livestock support (LIVSUP) contain none or limited stock type information. In the AgribaseTM dataset, the farm type for identifying Dairy dry stock is DRY. This category was classified as Dairy Support (DAISUP) by RULE3a. Agribase Grazing (GRA) category, defined as grazing other people’s stock, will be classified as Livestock Support (Rule 6b). Other planted types (OPL) with fodder crops (fodd_ha) identified as greater than 50 % of the farm area, are classified as Livestock Support (LIVSUP) (RULE 6c).)

Lowland Sheep and Beef

"Land_Use" IN('Lowland Livestock' , 'Lowland Livestock and Arable') AND "ES_LandUse" IN('Beef' , 'Sheep' , 'Sheep and Beef', 'Mixed Livestock', 'Mixed Livestock and Arable')

Note: the definition of “Mixed Livestock” is Sheep, Beef and Deer

Hill Country Sheep and Beef

"Land_Use" IN ('Hill Country Livestock', 'Hill Country Livestock and Arable') AND "ES_LandUse" IN ('Beef' , 'Sheep', 'Sheep and Beef', 'Mixed Livestock', 'Mixed Livestock and Arable')

High Country Sheep and Beef

"Land_Use" = 'High Country Livestock' AND

"ES_LandUse" IN ('Beef' , 'Sheep', 'Sheep and Beef', 'Mixed Livestock', 'Mixed Livestock and Arable')

Mixed Cropping

"Land_Use" IN ('Arable', 'Horticulture')

Other land use classes were based on the "Land_Use" column.

The polygons within land use classes of Mataura_LU_farmtypes.shp were dissolved to a create multipart polygons layer Mataura_LU_farmtypes_Dissolv.shp

A5 – FARMAX Base Farm Setups

Dairy			
770 Friesian cross cows are milked on 250 hectares with a 120ha support block on which replacements are grazed and cows wintered on a fodder beet crop. Replacement rate is 20%	Key Performance Indicators	2025	
	Milking area (ha)	250	
	Support block area (ha)	120	
	Peak cows milked	770	
	Stocking rate (cows/ha)	3	
	Liveweight (kg/cow)	500	
	liveweight/ha (kg/ha)	1260	
	Nitrogen fertiliser use (kgN/ha/yr)	140	
	Production Summary		
	Milk (kgMS /ha)	940	
	Meat (kg/ha)	132	
	Emissions	kg/ha	Total (tonne)
	Methane	268	99.2
	Nitrous Oxide	7.0	2.6
	CO_2-eq	8959	3315
	Financial		
	Milk price ($/kgMS)	9.76	
	EFS ($/ha)	3625	

Dairy Support			
128 Dairy replacements calves are grazed from December through to 22 months of age. 500 Dairy cows are wintered on a fodder beet crop supplemented with baleage made on the farm. 450 bulls are purchased in August and September, then sold to works from January through to April	Key Performance Indicators	2025	
	Effective area (ha)	200	
	Cows wintered	500	
	R2 heifers grazed	126	
	R1 heifers grazed	128	
	Bull beef	450, 100% prime	
	Nitrogen fertiliser use (kgN/ha/yr)	79	
	Production Summary		
	Milk (kgMS /ha)	0	
	Meat (Kg/ha)	677	
	Emissions	kg/ha	Total (tonne)
	Methane	167	33.4
	Nitrous Oxide	4.8	.96
	CO_2-eq	5727	1145
	Financial		
	Cow by month grazing ($/hd/wk)	$40	
	Heifers by month ($/hd/wk)	4-9 mth-$8.00 10-22mth $15.00	
	EFS ($/ha)	$374	

Hill Country Sheep and Beef

Predominantly a steep to moderate hill farm, with 400ha of easy country for winter cropping and finishing youngstock.

Pasture grows at an average of 4,396 kgDM/ha and is medium quality ryegrass and clover pasture, with a 39ha swede crop grown for winter forage.

3200 MA Romdale ewes are wintered, with a 25% replacement rate. All hogget's are mated and 70% of lambs are finished on farm.

200 MA beef-type cows are wintered at a 20% replacement rate. Heifers are over mated, and excess sold in the spring store market. 70% of steers born are sold as weaners, the remainder are finished.

Key Performance Indicators	2025	
Effective area (ha)	1500	
Species ratio (sheep:beef)	79:21	
Stocking rate (SU/ha)	5.0	
Nitrogen fertiliser summary (kgN/ha/yr)	10.1 kgN/ha on 400 ha	
Crop area (ha)	40 ha swedes	
Production Summary		
Product per effective ha (kg)	96.37	
Opening MA ewes	3168	
Opening MA cows	200	
Lambs sold	3404, 71% prime	
Cattle sold	229, 41% prime	
Emissions	kg/ha	Total (tonne)
Methane	55.9	83.8
Nitrous Oxide	1.1	1.6
CO$_2$-eq	1397	2583
Financial		
Gross margin per kg product	$4.69	
Gross margin (per effective ha)	$451.9	
EFS ($/ha)	$239	

High Country Sheep and Beef

An 8400 ha property, with 40% low production high country, 21% and 26% is unimproved and improved hill respectively, 8% is flatter finishing country and the remaining 5% in ineffective. Average potential pasture growth is 2780 kgDM/ha/yr. 100ha of winter crop is grown and used to winter 600 MA Dairy cows.

8300 MA Romdale ewes are wintered, with a 25% replacement rate. The top 40% of hoggets are mated. 57% of lambs are finished and the rest sold store before the end of May. 270 MA beef cows are wintered, with excess heifers sold as weaners. All steers are aimed to finish beyond 250 kgCW.

Key Performance Indicators	2025	
Effective area (ha)	8000	
Species ratio (sheep:beef)	76.24	
Stocking rate (SU/ha)	2.0	
Nitrogen fertiliser summary (kgN/ha/yr)	18 kgN/ha on 350ha	
Crop area (ha)	100 swede/kale	
Production Summary		
Product per effective ha (kg)	37.7	
Opening MA ewes	8290	
Opening MA cows	270	
Lambs sold	6973, 57% prime	
Beef sold	271, 61% prime	
Emissions	kg/ha	Total (tonne)
Methane	21.6	173
Nitrous Oxide	0.4	3.3
CO_2-eq	541	4327
Financial		
Gross margin per kg product	$4.57	
Gross margin (per effective ha)	$172.5	
EFS ($/ha)	$95	

Lowland Sheep and Beef

Predominantly the farm is a breeding/finishing unit, with 1950 MA high performing Romney ewes wintered, weaning 145%.

A terminal Suffolk ram is crossed over 1500 ewes and all replacements for improved lamb finishing. There is no breeding cows but 80 head of weaner steers, heifers or Dairy bull beef is purchased for finishing. 99% of lambs and beef is finished at high carcass weights.

A small area of winter crop is grown for winter grazing, with a small area of barley grown for whole crop silage.

The farm grows an average of 8809 kgDM of high quality pasture.

Key Performance Indicators	2025	
Effective area (ha)	330	
Species ratio (sheep:beef)	89:11	
Stocking rate (SU/ha)	11.6	
Nitrogen fertiliser summary (kgN/ha/yr)	19.4 kgN/ha on 151ha	
Crop area (ha)	20 swede/kale, 7 barley silage	
Production Summary		
Product per effective ha (kg)	289	
Opening MA ewes	1939	
Opening MA cows	0	
Lambs sold	3198, 100% prime	
Beef sold	80, 99% prime	
Emissions	kg/ha	Total (tonne)
Methane	123	40.7
Nitrous Oxide	2.6	.84
CO_2-eq	3873	1278
Financial		
Gross margin per kg product	$4.41	
Gross margin (per effective ha)	$1273	
EFS ($/ha)	$711	

Mixed Cropping

The farms predominant venture is cereal cropping, with wheat, barley and oilseed rape the key crops. Peas and kale are also included in the rotation. 63% of gross far revenue is from the cropping enterprise.

40% of the farm is in pasture, where 500 MA Romney ewes are wintered, with a 25% replacement rate. All lambs are finished. 200 steers are purchased as weaners and finished at 300 kg carcass weights.

280 diary heifers are grazed from May to may, and a further 330 MA Dairy cows are wintered.

Key Performance Indicators	2025	
Effective area (ha)	408 (250 ha crop)	
Species ratio (sheep:beef)	25:75	
Stocking rate (SU/ha)	9.7 (whole farm)	
Nitrogen fertiliser summary (kgN/ha/yr)	118 kg N/ha over 408ha	
Crop area (ha)	236	
Production Summary		
Product per effective ha (kg)	252.5	
Opening MA ewes	500	
Opening MA cows	0	
Lambs sold	1033, 100% prime	
Beef sold	200 (100%)	
Emissions	**kg/ha**	**Total (tonne)**
Methane	113	16.1
Nitrous Oxide	2.4	.96
CO_2 -eq	3583	1462
Financial		
Gross margin per kg product	$9.98	
Gross margin (per effective ha)	$2521	
EFS ($/ha)	$1655	

Sheep Dairy (Not modelled in FARMAX)

850 ewes are milked on flat to rolling terrain, assuming 'very high or high' productive capacity as defined by Nature braid. Farms are a minimum land area of 50 hectares.

Mob replacement rate is 20%, and hoggets remain on farm. Sire rams also remain on farm.

All lambs are assumed to be barn raised, with male lambs sold off farm as early as possible.

All systems are pasture based, with in-shed feeding in place to maintain production.

Key Performance Indicators	2025	
Milking area (ha)	50	
Peak ewes milked	850	
Stocking rate (milking ewe's/ha)	17	
Liveweight (kg/ewe)	80	
liveweight/ farmed ha (kg/ha)	1570	
Nitrogen fertiliser use (kgN/ha/yr)	18	
Production Summary		
Milk (kgMS /ewe)	57.6	
Lambing %	175	
Emissions*	kg/ha	Total (tonne)
Methane	316.5	15.8
Nitrous Oxide	6.5	.33
CO_2-eq	9874	494
Financial		
Milk price ($/kgMS)	$13.80	
EFS ($/ha)	$5000	

FARMAX was not used to model the Sheep Dairy system. Methane emissions were estimated according to farm system and liveweight assumptions as described above, based on the methodology outlined in (Ministry for Primary Industries, 2022).

Nitrous oxide and carbon dioxide was estimated using FARMAX outputs for the Lowland Sheep and Beef system as a proxy and adjusting for stocking rate changes.

Modelling presented in Venture Taranaki (2022) and Griffiths, L. (2015), wider research and personal communication with industry professionals was used to inform decision making regarding the Sheep Dairy system.

A6 - Emissions levy pricing pathway

Parameter	Unit	2025	2030	2035	2040	2045	2050	2055	2060
CH_4, low (95% discount in 2025, reduced by 1 pp yr-1)	\$ per kgCH_4	0.11	0.35	0.60	0.93	1.35	1.88	2.49	3.19
CH_4, high (50% discount in 2025, reduced by 7.1 pp yr-1)	\$ per kgCH_4	1.06	1.97	2.58	3.32	4.24	5.36	6.60	7.97
N_2O/CO_2, low (95% discount in 2025, reduced by 1 pp yr-1)	\$ per tCO_2-eq	4.25	13.80	24.07	37.20	53.91	75.00	99.52	127.48
N_2O/CO_2, high (50% discount in 2025, reduced by 7.1 pp yr-1)	\$ per tCO_2-eq	42.50	78.86	103.16	132.87	169.44	214.29	264.04	318.70

Per hectare levy calculation equation: kgGas/farmed ha x \$/kgGas = \$/ha in levy

A7 – Scenario 2A assumptions

Baseline with no fertiliser cap, except current limit of 190 kg N/ha	
Dairy	
Effluent area	Effluent block at 30 ha, at an N loading rate of 50 kgN/ha/yr from effluent. Best practice assumed and area compliant. Receiving 140kg N/ha as artificial urea.
Fertiliser (N&P)	140 kgN/ha/yr applied in 3 dressing August to April on area in pasture. 38.5 kgP/ha applied November and March
Forage crop	30 ha of fodder beet grown 174.4 kgN/ha/yr & 37.2 kgP/ha/yr applied as synthetic fertiliser
Stock numbers	770 Friesian cows wintered and 173 heifers reared
Dairy support	
Fertiliser (N&P)	90 kgN/ha/yr of urea applied in two applications & 20 kgP/ha /yr
Forage crop	23 ha of fodder beet grown. 174.4 kgN/ha/yr & 37.2kg P/ha/yr applied as fertiliser
Stock numbers	500 winter dairy grazers; 126 dairy replacements grazed; 450 trade beef
High country sheep and beef	
Fertiliser (N&P)	9 kgN/ha/yr applied to 700 ha of finishing country
Crop	50ha swedes and 50ha of kale grown. 194 kgN/ha/yr & 39 kgP/ha/yr applied as fertiliser.
Conserved feed	No pasture conserved
Livestock policy	An extensive breeding/finishing farm with an effective 8000 ha farmed. 100 ha of winter forage grown for dairy grazing. 65% of sheep sales are prime, while 61% of beef sales are prime.

Hill country sheep and beef	
Fertiliser (N&P)	5.6 kgN/ha/yr applied to finishing country; 4.7 kgP/ha/yr
Crop	40ha swedes grown with 194 kgN/ha/yr & 39 kgP/ha/y applied from fertiliser
Conserved feed	No pasture conserved
Livestock policy	An extensive hill country farm, that runs 5.0 SU/ha, wintering 3200 MA ewes and 270 MA cows. Of all sheep sales 73% are sold prime, while 41% of beef sales are prime.
Lowland sheep and beef	
Fertiliser (N&P)	Pasture receives 17.8 kgN/ha/yr applied in two applications (spring and autumn) applied to 303 ha. A total of 18.3 kgP/ha/yr is applied in split applications (Oct, March)
Crop	20ha swedes (194 kgN/ha/yr & 39 kgP/ha/yr) and 7ha barley for silage. (156.4 kgN/ha/yr & 28 kgP/ha/yr)
Conserved feed	No pasture conserved
Livestock policy	An intensive finishing and breeding unit, wintering 1940 high performing ewes and no breeding cows. 98% of all sales are prime.
Mixed cropping	
Fertiliser (N&P)	Pastoral area receives 80 kgN/ha/yr applied in two applications in early spring and autumn. 5 kgP/ha/yr applied to whole farm
Crop	61% of farm area in crop rotation: field peas, wheat, oil seed rape, barley, oats, rape. Total 141 kgN/ha/yr & 13 kgP/ha/yr fertiliser added to crop area.
Conserved feed	56ha made into pasture baleage
Livestock policy	60% of the farm is for cropping, the remaining 40% for pasture. The farm is stocked at 9.7 Su/ha, with 500 MA ewes wintered, 330 MA dairy cows are wintered grazed with 280 heifers grazing from May to May. 200 steers and all lambs are finished on farm.

Scenario 2A 2030 Assumptions – 85 kg N/ha limit	
Dairy	
Effluent area	Effluent block maintained at 30 ha, at a rate of 50 kgN/ha/yr from effluent. Synthetic N fertiliser reduced to 35 kgN/ha/yr as urea (total area receiving 85kgN/ha/yr)
Fertiliser (N and P)	The milking platform (excluding effluent block) receives two applications of urea, totalling 85 kgN/ha/yr. All pasture receives split applications of phosphorus in November and March, totalling 38.5 kgP/ha/yr.
Forager crop	Due to N fert beyond 85 kgN/ha/yr no fodder beet crop is grown, and energy demand replaced with baleage and pasture. All baleage made on farm.
Stock Number	Cow numbers and replacements reared reduced by 15%. Milk production per cow similar to the base farm
Dairy support	
Fertiliser (N and P)	Pasture N fertiliser reduced to a total of 84.6 kgN/ha/yr over the whole farm
Forage crop	No forage crop due to N requirement above 85 kgN/ha/yr, feed requirement replaced by feeding baleage and pasture.
Stock numbers	Cows wintered reduced by 44% to 280. Replacement heifers grazed reduced by 17% to 304, Trade beef reduced by 33% to 300 bulls.
High country sheep and beef	
Fertiliser (N and P)	9 kgN/ha/yr applied to 700 ha of finishing country.
Crop	No forage cropping due to N fert requirements above 85 kgN/ha/yr. Fertiliser removed
Conserved feed	To meet feed requirements of winter grazing dairy cows, 134 ha of baleage (at 15 bales per ha) is conserved and cut on farm. An additional 25 kgN/ha/ha applied to pasture before conservation.
Livestock policy	No change to the current policy, with conserved feed used to replace requirement of gazing dairy cows. Assumed that all other livestock are raised on pasture.

Hill country sheep and beef	
Fertiliser (N and P)	N application remains constant averaging 2.7 kgN/ha/yr, applied to 360 ha of finishing country at 5.6 kgN/ha/yr
Crop	All forage crop removed, resulting in a feed shortage in late august/early spring. Crop fertiliser removed.
Conserved feed	Feed deficit met by feeding out hay in winter early spring. 765 big bales purchased in February for $ 85/bale
Livestock policy	No change to livestock policy, winter feed deficit met with supplement.
Lowland sheep and beef	
Fertiliser (N and P)	Pasture fertiliser remains as 2025, applying an average of 17.8 kgN/ha/yr over the whole farm.
Crop	No forage crop or whole crop barley for silage, due to N fertiliser limit.
Conserved feed	102 ha of pasture conserved for baleage, at $47 per bale. Fed during winter deficit
Livestock policy	No change in stock from 2025. Conserved feed in October and fed during winter deficit, pasture covers lower in winter than 2025.
Mixed cropping	
Fertiliser (N and P)	All cropping area returned to pasture. P fertiliser rates for this area are adjusted to the equivalent of lowland systems at 18.6 kg P/ha/yr. N fertiliser applied to the whole farm, at an average of 50 kg N/ha/yr. Pasture growth rate of the ex-cropping block reduced to 10.5 t DM/ha to match rest of farm.
Crop	All cash and forage crops are removed from the system. An economic optimum of 8t/ha for wheat in Southland was determined in previous research (Pers.comm D. Mathers, June 2022). This is taken as a broad proxy for the crops grown on farm. Below economic yields, its assumed farmers would switch to livestock finishing and trade.
Conserved feed	An addition 150 ha of pasture is conserved for baleage and fed in May to August, with excess feed (279 tonnes) sold off farm. Its assumed that cropping equipment is exchanged for machinery suited for making baleage and it is made by the farmer at a cost of $20 /bale (pers. comm P. Hawk, June 2022)
Livestock policy	All dairy grazing is removed from the system, and replaced with 400 Friesian bulls, purchased in early summer, and killed above 550 kg LW at 18 to 21 months old. Winter trade lambs increased by 100% to 1000 lambs, and all other stock classes increased by the same proportion as pasture area increased (61%). 98% of livestock sold, is sold prime.

Scenario 2A 2060 Assumptions – 65 kg N/ha limit	
Dairy	
Effluent area	Effluent block remains at 30ha.
N fertiliser	Milking platform and support area receiving a maximum of 65 kgN/ha/yr as urea, in split applications.
Forage crop	No forage crop grown, baleage cut on farm and fed over winter
Stock numbers	Stock numbers and cow performance remains the same as 2030, assumed improved farm management and better pasture utilisation.
Dairy support	
N fertiliser	Split applications of urea, totalling 64.7 kgN/ha/yr.
Forage crop	No forage crops grown. Feed requirement met with baleage conserved on farm.
Stock numbers	No change from the 2030 (85kgN limit) scenario.
High country sheep and beef	
	N application is already under 65 kg N/ha/yr, unchanged from 2030
Hill country sheep and beef	
	N application is already under 65 kg N/ha/yr, unchanged from 2030
Lowland sheep and beef	
	N application is already under 65 kg N/ha/yr, unchanged from 2030
Mixed cropping	
	N application is already under 65 kg N/ha/yr, unchanged from 2030

A8 – Estimated Emissions

Total catchment emissions by land use (tonnes CO2-eq)

	1A			1B			2A			2B			2C		
	2025	2030	2060	2025	2030	2060	2025	2030	2060	2025	2030	2060	2025	2030	2060
Dairy	721,379	700,262	700,262	721,379	700,262	700,262	721,380	683,970	686,667	721,379	645,621	149,409	721,379	645,621	149,409
Dairy support	122,714	120,148	120,148	122,714	120,148	120,148	122,715	115,597	115,349	122,714	62,379	-	122,714	62,379	-
Lowland Sheep and Beef	606,839	596,279	596,279	606,839	596,279	596,279	606,840	597,819	479,590	606,839	630,213	301,161	606,839	630,213	301,165
Hill Country Sheep and Beef	293,768	293,768	293,768	293,768	293,768	-	293,767	294,376	248,163	293,768	288,519	-	293,768	293,768	-
High Country Sheep and Beef	40,329	40,329	-	40,329	-	-	40,329	39,499	-	40,329	39,411	-	40,329	40,329	-
Mixed Cropping	8,131	8,131	8,131	8,131	8,131	8,131	8,130	10,153	4,748	8,131	8,131	6,446	8,131	8,131	6,446
Indigenous Vegetation	-682,386	-682,386	-682,386	-682,386	-847,614	-1,185,144	-682,386	-682,386	-682,386	-682,386	-682,386	-682,386	-682,386	-682,386	-682,386
Exotic Forestry	-386,536	-386,536	-1,849,520	-386,536	-1,361,851	-4,487,237	-386,536	-386,536	-1,849,520	-386,536	-493,492	-6,665,913	-386,536	-386,536	-
Totara Forestry													-	-	-2,258,496
Horticulture (Tulips)	-	16,433	16,433	-	16,433	16,433	-	16,433	16,433	-	16,433	16,433	-	16,433	16,433
Sheep Dairy	-	-	-	-	-	-	-	-	-	-	11,127	1,059,183	-	11,127	1,059,183
Net Emissions	724,238	706,429	-796,885	724,238	-474,444	-4,231,128	724,239	688,927	-980,956	724,238	525,958	-5,815,666	724,238	639,081	-1,408,245

Negative (red) values indicate carbon sequestration in tonnes CO_2-eq.

A9 – Other Land Use Types

At the second workshop for the Mataura catchment, the following question was proposed:

> *If you had an unlimited budget and could make it happen, what are the three things you would do to improve environmental outcomes in the Mataura catchment?*

Three areas of improvements were discussed:

1. Looking into the hydrology of the catchment and how water can be strategically slowed down.
2. Looking into the connectivity of the land to water and also connectivity within the waterways, in particular the use of fish passages, biodiversity, and Mahinga Kai values.
3. Looking at diverse farm systems and landscape planning - re-imagining the landscape and considering how best to utilise the land based on susceptibility or resilience. A range of pastoral, arable and horticultural options were discussed which could potentially provide the appropriate outcomes within the catchment:
    - Sheep or goat dairy (we have focused on Sheep Dairy)
    - Oats for milk
    - Flax
    - Wine grapes

Due to project constraints, it has not been possible to model all four of the above options. Therefore, Sheep Dairy has been modeled in full for both environmental and economic impact. In addition, Flax is being planted for its environmental impact only, and although economic and cultural benefits are not being quantified, they are likely to exist. A summary as to why these land uses have been chosen as options to model is outlined below.

Sheep Dairy

Although Dairy farming has remained profitable in the previous scenarios (1A, 1B and 2A), profit has still significantly decreased. As milk payout varies, the frequency of non-profitable seasons may increase over time. Also, we have not included the capital in use in our modelling and the extent of leverage will mean different financial imperatives for different farmers. With Dairy having the greatest environmental risk, improvements can still be gained. The transfer of Dairy operations to Sheep Dairy may be an achievable land use change for Dairy farmers while remaining true to their livestock farming roots. Anecdotally, within the Waikato region, a number of Dairy farmers have converted to sheep milking (Sheep Dairy) for the financial gain as well as because this farming operation has many similarities to Dairy cow milking. Sheep Dairy may also be a viable option for some sheep and beef farmers.

Due to altitude, temperature, and topography of the land, it will not be a suitable land use for conversion of High Country Sheep and Beef farms (which became unprofitable relatively quickly in scenarios 1A, 1B and 2A).

There is the potential for Sheep Dairy to be a suitable conversion from Hill Country Sheep and Beef operations, but only on part of the operation (i.e., on land that is flat to rolling and the layout of the property would be as such that walking distances for sheep are short). This is because the greater the sheep maintenance energy requirements are, the lower the milk production is. These requirements will likely restrict the number of hill country properties that are suitable for Sheep Dairy. For properties that are suitable, large areas of land may become unproductive because sheep cannot graze due to the location and the topography making the slope of the land too steep for supplementary feed making.

Conversion from Lowland Sheep and Beef looks to be the most suitable option for a land use change to Sheep Dairy, given the topography, productivity and farm infrastructure suited to farming sheep. It is worth considering Sheep Dairy systems usually operate on an area less than 100 ha, while lowland finishing farms are modelled as 330 ha units. There is potential to convert the best of a Lowland Sheep and Beef farm to a Sheep Dairy platform and continue breeding and finishing on the rest. A conversion would also require the addition of a milking parlour and associated infrastructure, as well as lamb rearing barns.

Although Sheep Dairy is labour intensive and would require investment in on-farm infrastructure, per hectare returns from Sheep Dairy are relatively high compared to other land used in this study. As a result, there is potential for a large range of existing land use to transition to Sheep Dairy in the Mataura catchment.

Flax

Flax has been chosen to be modelled for environmental improvements only (not economic impacts). When used as an environmental mitigation, flax can offer a range of different benefits (McGruddy, 2006). The benefits include the following:

- Plays a role within a riparian setting to slow the flow of surface runoff and absorb nutrients. Flax may also assist with nitrate uptake at deeper levels within the soil not available to grasses (rooting down to 3m).
- Connecting corridors and providing a natural habitat along waterways and wetlands. Dense plants create habitats for insects, birds, lizards, seed, and flowers provide food for native geckos, birds, bats.
- Flax is relatively cheap and easy to source plants, easy to establish, fast growing, low growing, has minimum maintenance and inputs, and is robust. It is a permanent, evergreen planting that is long-lived. It is resistant to drought, waterlogging and flood, frost, heat and cold. It is also tolerant of a range of soil types, sites, and conditions. It is herbicide resistant to Triclopyr (which is used for blackberry and gorse).
- Deep rooting – roots may be as wide and deep as the bush height (3m+).
- Stabilising riverbanks – flax has potential here, however *more assessments are needed.*
- Close-spaced plantings create inter-locking root systems which assist with flood control. Closer spacings (approx. 2m x 2m) also prevent weed invasion.
- Providing extended buffers (floodplain plantings).
- Acts as a nursery plant to allow more sensitive species to establish.
- Can be grown as a monoculture or within a mixed planting.
- Different species *Phormium cookanium* (wharariki) vs. *P. tenax* (harakeke) have different properties. Wharariki is more frost/cold tolerant and more drought tolerant than harakeke.
- Has use as a shelterbelt species (used extensively in Southland)
- Fits within existing farm systems. On Dairy farms, can co-exist with pivot irrigation systems.
- Offers shelter for lambing.
- Cattle may feed on it and there is evidence to suggest beneficial effects from this (healthier calves and less bloat). Flax green strippings (a byproduct of processing) may have potential as a supplement for livestock.

Oats for milk

Growing oats as a catch crop to improve environmental outcomes has been practiced in Southland for many years. Oats have been commonly grown in Dairy and Sheep and Beef operations following winter forage crops to take up excess nitrogen from the system. Oats have a similar role within arable systems; however, they are also commonly planted after summer crops.

Although the demand for alternative ‘milk’ products has increased in recent years and Southland provides suitable growing conditions, there are several considerations that make it challenging for a land use change out of the primary land uses to growing oats.

- Most oats currently grown in Southland are not for grain, but rather for livestock forage or as a catch crop. Oat milk requires the grain for processing, meaning additional farmer skill and machinery may be required to obtain economic grain yields.
- Oats are planted in systems as an environmental consideration rather than for profit. The money and therefore effort is placed into the primary farming operation. Typically, the cultivar of oats grown isn’t the highest quality and becomes stock feed.
- Oats are a short rotation crop growing 4-6 t/DM /ha and cover only a small proportion of the farm. Therefore, very little money is made from the crops. A recent study on the potential for oat milk in Southland also confirmed that the margins for oat milk were relatively small right across the value chain (Campbell et al., 2022).
- Oats are not grown year-round but rather in spring and autumn therefore there are questions around supply across the year.
- When looking at carbon emissions the current New Zealand model (used for some brands, but not all) is to ship oat grain to Sweden for milk production. There may be significant ‘food mile’ emissions that need to be factored in when making direct comparisons between the other land uses.

There will always be the need for oats as part of Dairy, sheep and beef and arable systems due to their ability to capture and remove nitrogen from the soil profile before it is leached. There is also a market for oat grain, however large system changes are required to convert to significant grain-oat production. There may be an appetite for this in the arable sector, however livestock farmers are likely to favour a switch to another livestock system if a land use change is required.

Wine grapes

Growing grapes for wine has been suggested as a possible land use change option within the Mataura catchment. In Central Otago, wine country has proved to be highly suited to the soils and climate. However, the current landscape within the Mataura catchment is significantly different to that of Central Otago. The option of growing grapes in Mataura was proposed at the second workshop with specific mention to climate change resulting in Southland becoming warmer and drier (similar to the current Central Otago climate), and therefore suitable for grapes. However, there is likely to be challenges with finding suitable soils for grape production. Southland soils are typically poorly drained, wet soils, while grapes are commonly grown on well-drained gravels. Soil type is extremely important for grapes used for wine as this influences the flavour profile of the wine. Because of these reasons, and that the opportunity for grape growing is dependent on the degree of climate change occurring. For these reasons, and because climate change adaptation is beyond the scope of the present study, grapes have not been chosen to be investigated further.

Forestry

The application of a levy which prices agricultural GHG emissions subsequently reduces the profitability of livestock farming businesses. As the discount rate decreases with time, farm profitability is further impacted assuming no optimisation of current systems. Alternatively, plantation forestry sequesters carbon dioxide as trees grow. If registered in the ETS, foresters can earn carbon credit while not being exposed to the agricultural GHG levy to the extent of livestock farms. As a result, the profitability of plantation forestry outcompetes agricultural uses.

Comparatively the gap widens as time goes on, due to the reducing discount rate/ increasing levy cost of GHG emitted.

We consider two forestry types, Exotic Forestry (*Pinus radiata* - pine) and Totara Forestry (*Podocarpus totara* - totara). Without further intervention, the highest best use is Exotic Forestry. This is the case with or without including sequestration revenue from the ETS. Strong feedback from the workshop concluded that the non-GHG environmental impacts of pine plantations were significantly negative. The emphasis of Scenario 2C was to use any ETS sequestration revenue to subsidise Totara Forestry so that any land that would otherwise be planted in pine would be planted in totara.

The decision to use totara as a plantation forest species was due to the amount of data available, with existing research surrounding plantation establishment, production, and harvest. Targeted landscape mitigation to improve biodiversity outcomes was a question proposed as part of this project, incorporating pest control, and fencing in the model costs allowed the assumption that within the Totara Forestry understory species can develop, with habitat corridors tested by Nature Braid.

It is important to note the on-farm profitability has driven the level of forestry conversion modelled. The wider social and cultural impacts of significant forestry conversion have not been modelled, nor have the infrastructure requirements of increased timber volumes and any changes to future log markets. Due to time and resource constraints, it was not possible to model the optimisation of current agricultural systems and the inclusion of forestation as part of existing farm businesses to off-set losses in profitability because of an agricultural gas levy.

Summary

For the purposes of modelling for 2B and 2C, it was necessary to select a limited number of options. Two land use options, Sheep Dairy and Totara Forestry, were selected:

- Sheep and goat milking may have similar economic benefits; and although goats may be better able to range over steep slopes, more interest in Sheep Dairy was expressed at the workshop. Additionally, data and other evidence to support modelling predictions, particularly within the catchment, is stronger for Sheep Dairy.
- The environmental benefits of Flax are clear and some of these able to be relatively robustly modelled within the Nature Braid software. These environmental impacts are quantified and although we do not have the evidence or resources to model economic benefits, these most likely exist and there are also often clear, broader biodiversity and cultural benefits when they are planted “in the right place”.

A10 – Comparison of Nature Braid versus River Observation Concentration Data

This appendix presents:

1) A comparison of Nature Braid results for the Mataura versus LAWA river observation measurements;
2) A breakout of Nature Braid NH_4-N, NO_3-N, particulate P and dissolved reactive P results for the baseline 2025 Mataura scenario versus the most extreme scenario of environmental change (2C 2060).

Note that although the Nature Braid on average “underpredicts” total N and P compared to observed values, this is expected, especially when it comes to total P. This is because although the Nature Braid represents the impact of land management in detail and can infill missing localised parameters from more general regional, national, or international datasets where necessary, it needs explicit information on industrial discharge, sewage, number, and approximate locations of septic tanks etc to fully account for point source data inputs. Trends between observed and modelled predictions match well.

Thresholds for NO_3-N were based on NOF guidelines around toxicity (Ministry for the Environment, 2020); influenced by ANZG (2018) and various NIWA client reports, including Whitehead et al. (2021). Similarly thresholds for NH_4-N were influenced by these guidelines, although the NOF guidelines on NH_4-N are less clear and based on quantile information; the information from ANZG (2018) was primarily used to consider thresholds at which NH_4-N has chronic to extreme toxicity effects on a range of aquatic species (Table A - 6).

Table A - 6. Thresholds used to classify potential toxicity to ammonium and nitrate species in river

NO_3-N thresholds for stream concentration (mg/L)	Meaning
<1	Negligible toxicity
<2.4	Low chronic toxicity
<3.8	Some chronic toxicity
<6.9	High chronic toxicity as concerning chronic toxicity
<20	Some acute toxicity
>20	Highly acute toxicity
NH_4-N thresholds for stream concentration (mg/L)	Meaning
<0.01	Negligible toxicity
<0.05	Low toxicity
<0.1	Some toxicity
<0.5	Somewhat concerning toxicity
>0.5	High toxicity

As both dissolved reactive phosphorus and particulate phosphorus are generally not directly toxic to aquatic species, rather indirectly harmful when combined with other environmental factors contributing to eutrophication, thresholds for these remained as documented in the Nature Braid, based on internationally accepted thresholds for where P contributes to eutrophication.

Table A - 7. Comparing total N results between Nature Braid and LAWA annual average.

LAWA site	Location	total N (mg/L) LAWA 5 year median	total N (mg/L) LAWA annual average 2006 - 2020	total N (mg/L) Nature Braid value
es-00021	Rural-Lowland-Pasture	1.18	1.27	0.76
es-00022	Rural-Lowland-Pasture	1.20	1.25	1.03
es-00024	Rural-Upland-Pasture	0.48	0.49	0.31
es-00025	Rural-Lowland-Pasture	0.81	0.69	0.97
es-00026	Rural-Upland-Native vegetation	0.11	0.15	0.25
es-00027	Rural-Lowland-Pasture	1.19	1.48	0.79
es-00028	Rural-Lowland-Pasture	1.36	1.47	0.45
es-00029	Rural-Upland-Plantation forest	0.28	0.40	0.03
es-00030	Rural-Lowland-Pasture	1.09	1.17	0.33
es-00033	Rural-Lowland-Native vegetation	0.34	0.39	0.04
es-00034	Rural-Lowland-Pasture	0.91	1.01	0.24
es-00036	Rural-Lowland-Pasture	3.00	2.84	2.26
es-00037	Urban-Lowland Pasture	1.12	1.10	0.23
es-00042	Rural-Upland-Native vegetation	0.28	0.31	0.29
es-00044	Rural-Lowland-Pasture	1.18	1.17	0.41
es-00057	Rural-Lowland-Pasture	1.25	1.45	0.97
es-00064	Rural-Lowland-Pasture	1.39	1.54	0.48
es-00065	Rural-Upland-Pasture	4.3	4.3	1.2
es-00067	Rural-Lowland-Pasture	0.65	1.0	0.67
es-00068	Rural-Lowland-Pasture	2.5	2.85	1.87
es-00106	Rural-Lowland-Pasture	1.6	1.66	2.17
es-00130	Rural-Lowland-Pasture	4.3	3.73	0.91
es-00135	Rural-Lowland-Pasture	2.2	2.35	1.3
nrwqn-00033	Rural-Lowland-Pasture	1.48	1.48	1.16

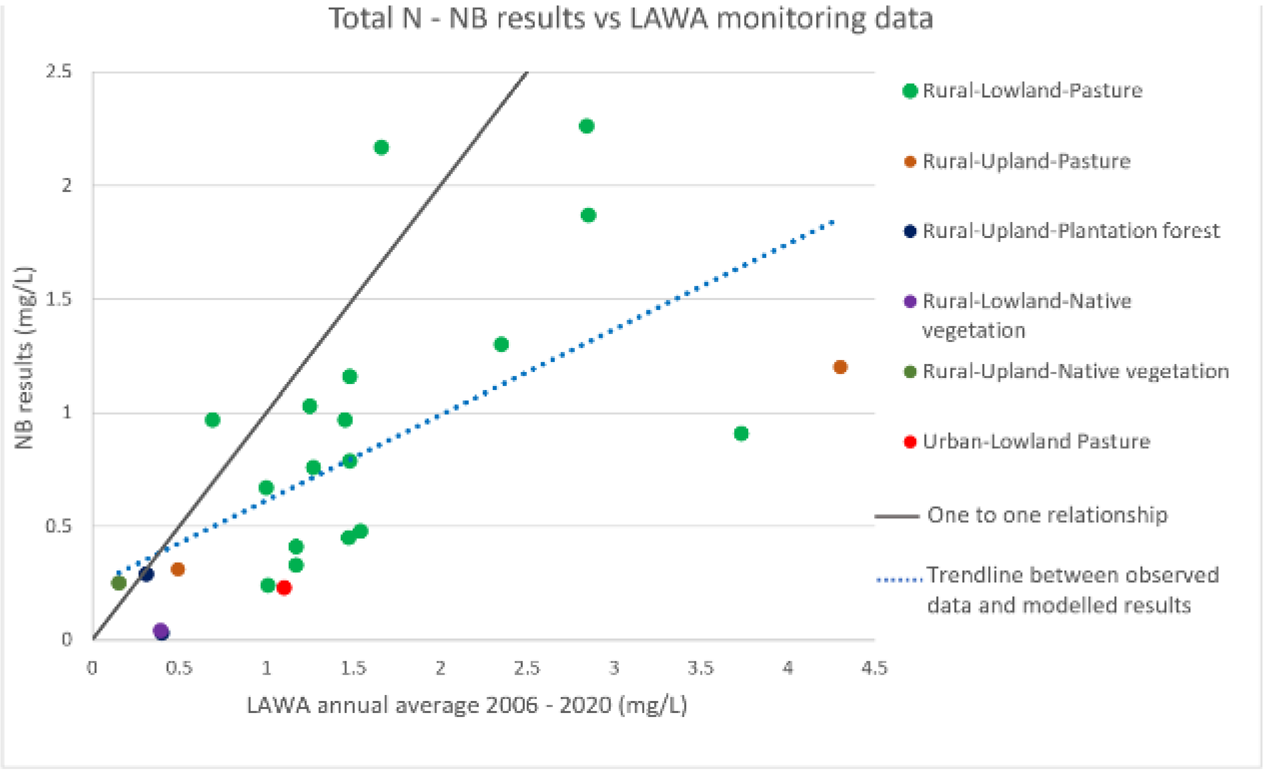


Figure A - 1. Total N results between Nature Braid and LAWA annual averages.

(note underprediction is expected as data on sewage, septic tanks, industrial discharge was not available and not included, also driving rainfall and potential evaporation were on different)

Table A - 8. Comparing total P results between Nature Braid and LAWA annual average.

LAWA site	Location	total P (mg/L) LAWA 5 year median	total P (mg/L) LAWA annual average 2006 - 2020	total P (mg/L) Nature Braid value
es-00021	Rural-Lowland-Pasture	0.024	0.03698	0.00794
es-00022	Rural-Lowland-Pasture	0.0235	0.04918	0.01594
es-00024	Rural-Upland-Pasture	0.009	0.01718	0.00194
es-00025	Rural-Lowland-Pasture	0.014	0.02743	0.02862
es-00026	Rural-Upland-Native vegetation	0.009	0.01442	0.000598
es-00027	Rural-Lowland-Pasture	0.06	0.07871	0.011833
es-00028	Rural-Lowland-Pasture	0.026	0.04683	0.00257
es-00029	Rural-Upland-Plantation forest	0.0195	0.02384	0.000126
es-00030	Rural-Lowland-Pasture	0.03	0.03951	0.001597
es-00033	Rural-Lowland-Native vegetation	0.02	0.03550	0.000369
es-00034	Rural-Lowland-Pasture	0.037	0.05627	0.00165
es-00036	Rural-Lowland-Pasture	0.0875	0.10635	0.030052
es-00037	Urban-Lowland Pasture	0.016	0.03840	0.003122
es-00042	Rural-Upland-Native vegetation	0.014	0.03004	0.00135
es-00044	Rural-Lowland-Pasture	0.035	0.04849	0.003079
es-00057	Rural-Lowland-Pasture	0.128	0.15391	0.0216
es-00064	Rural-Lowland-Pasture	0.057	0.07837	0.004032
es-00065	Rural-Upland-Pasture	0.06	0.08661	0.071077
es-00067	Rural-Lowland-Pasture	0.04	0.06180	0.023653
es-00068	Rural-Lowland-Pasture	0.0695	0.09658	0.107407
es-00106	Rural-Lowland-Pasture	0.158	0.190497	0.06125
es-00130	Rural-Lowland-Pasture	0.046	0.06554	0.026153
es-00135	Rural-Lowland-Pasture	0.04	0.062961	0.009327
nrwqn-00033	Rural-Lowland-Pasture	0.03	0.051911	0.043363

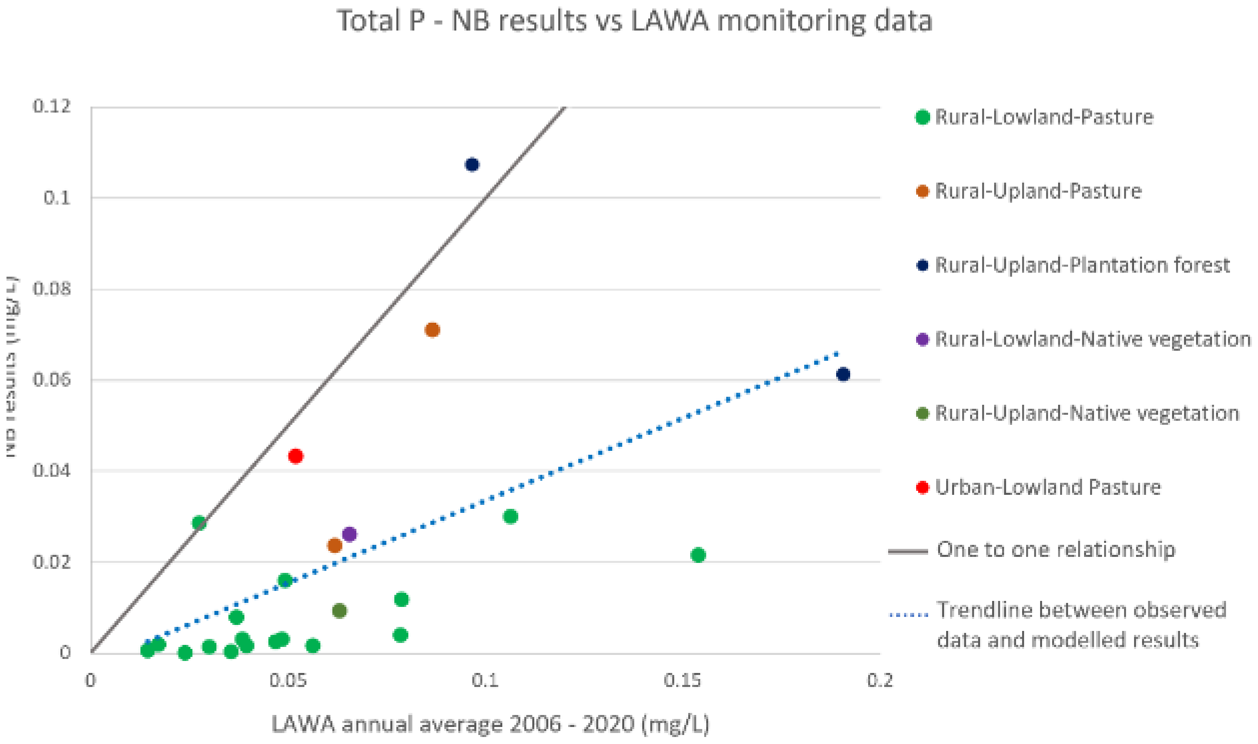


Figure A - 2. Total N results between Nature Braid and LAWA annual averages.

(note underprediction is expected as data on sewage, septic tanks, industrial discharge was not available and not included, also driving rainfall and potential evaporation were on different.)

The proportion of NO_3-N and NH_4-N was assumed to be 0.8:0.2 and the proportion of dissolved reactive phosphorus (DRP) and particulate phosphorus (PP) was assumed to be 0.3:0.7. The results of NH_4-N, NO_3-N, particulate P and dissolved reactive P, however, are not simply obtained from multiplying the total N and total P using the assumed proportions. The proportion is just one of the input parameters for Nature Braid's N and P model and N and P species separation. The separation also considers other factors including topography, soil type, climate, land use and land management, requiring the Nature Braid nutrient models to be rerun to ensure impact of these factors and spatial configuration is maintained.

As both dissolved reactive phosphorus and particulate phosphorus are generally not directly toxic to aquatic species, rather indirectly harmful when combined with other environmental factors contributing to eutrophication, thresholds for these remained as documented in the Nature Braid, based on internationally accepted thresholds for where P contributes to eutrophication.

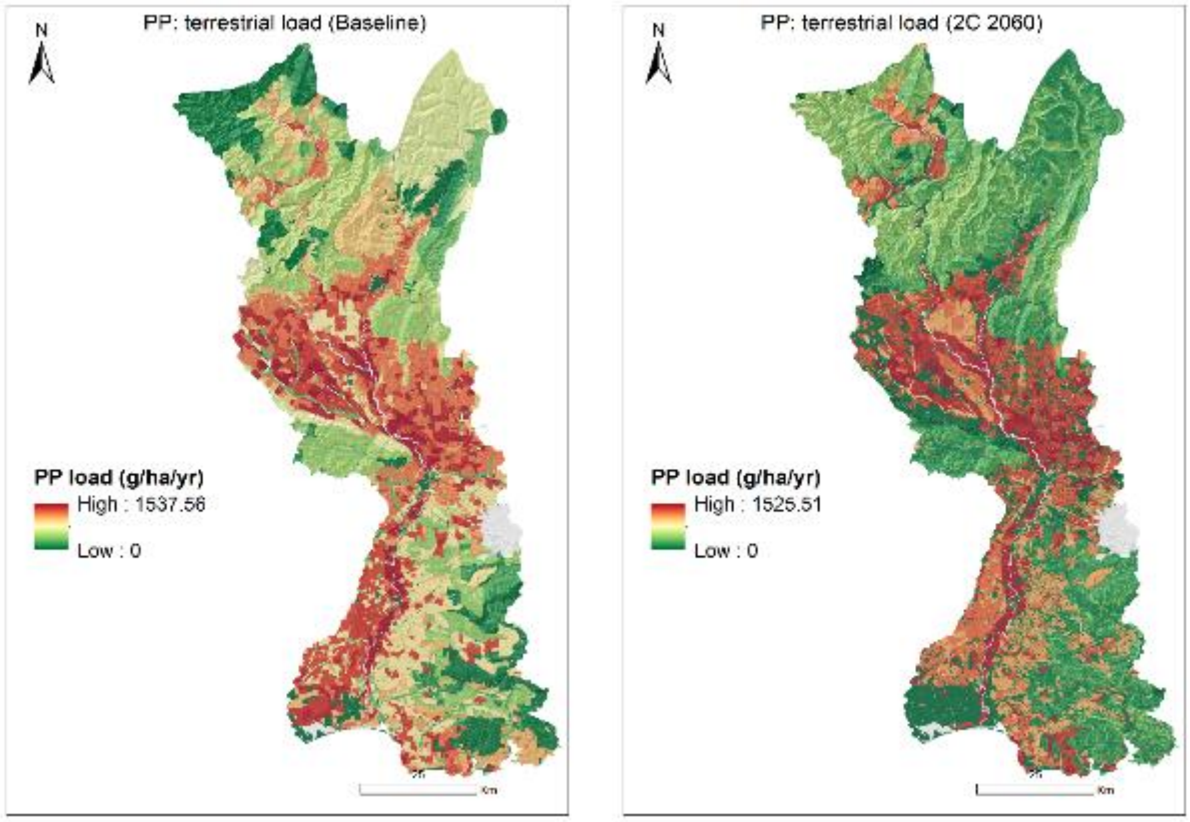


Figure A - 3. Particulate P terrestrial load changes between Baseline 2025 and Scenario 2C 2060.

Table A - 9. Summary statistics for particulate P terrestrial load for the baseline 2025 and scenario 2C 2060.

PP load (g/ha/yr)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	267.0	132.6
Max	1,537.6	1,526.5

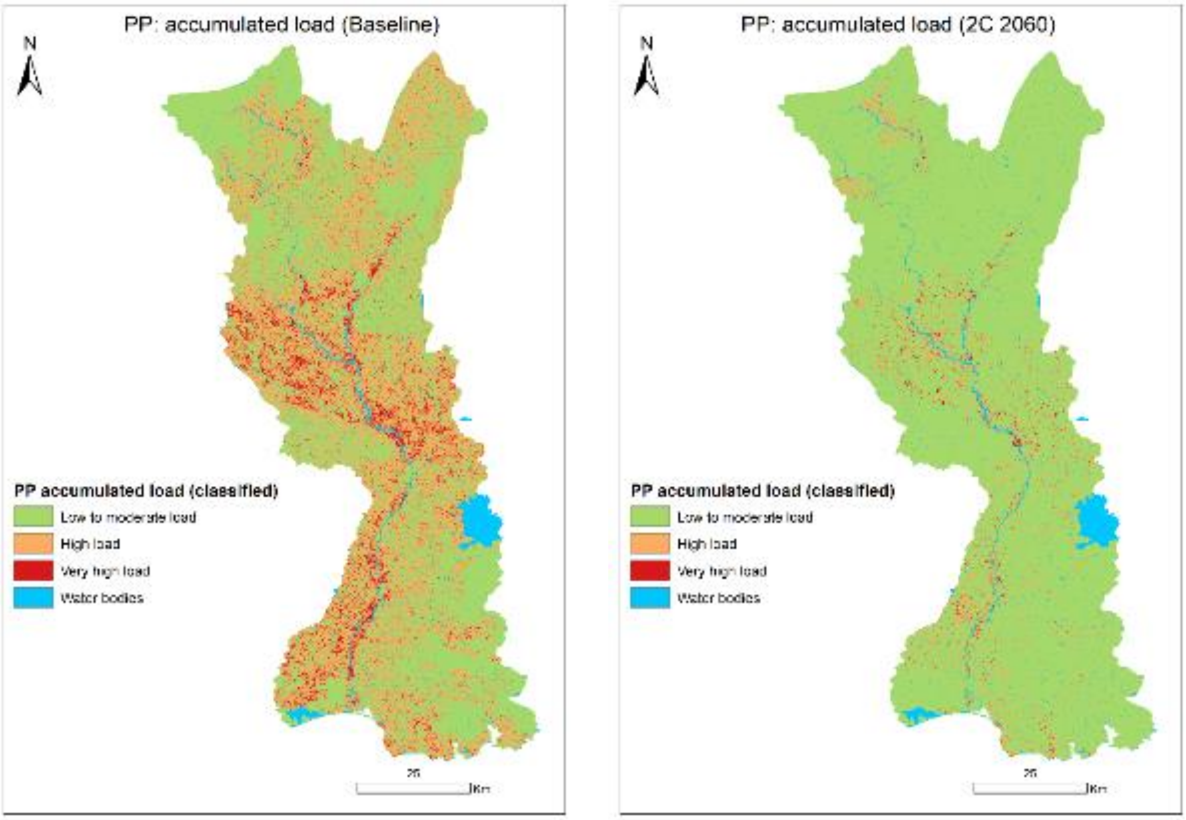


Figure A - 4. Particulate P accumulated load changes between the baseline 2025 and Scenario 2C 2060.

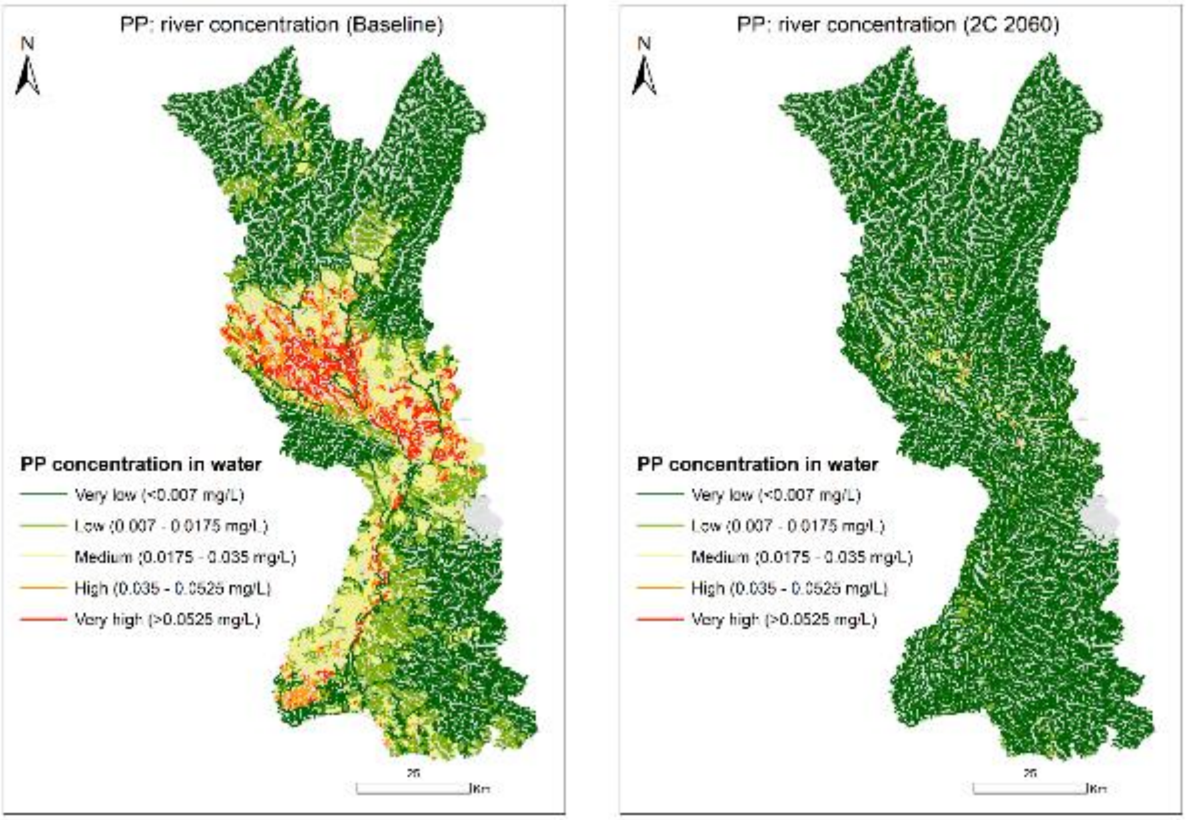


Figure A - 5. Particulate river concentration changes between Baseline and Scenario 2C 2060.

Table A - 10. Summary statistics for Particulate P stream concentration for the baseline 2025 and scenario 2C 2060.

PP stream concentration (mg/L)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	0.014	0.003
Max	22.9	0.2

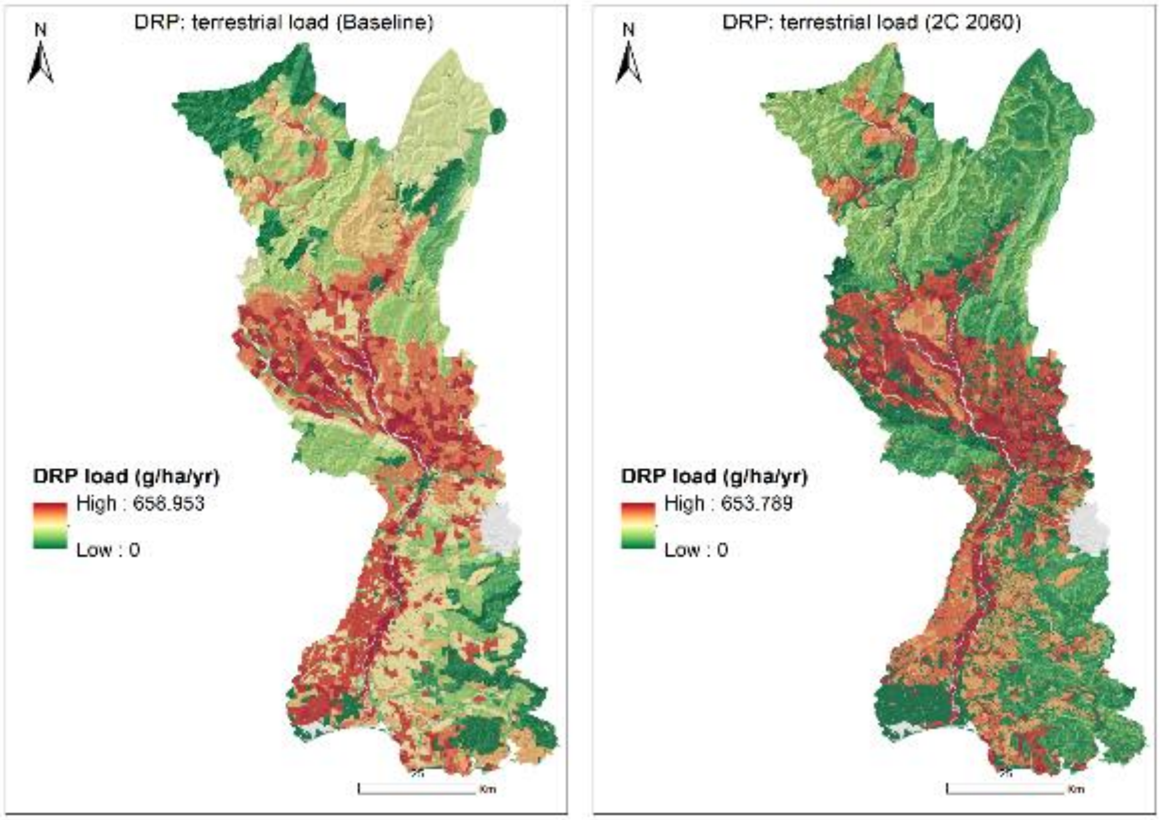


Figure A - 6. Dissolved P terrestrial load changes between Baseline and Scenario 2C 2060.

Table A - 11. Summary statistics for DRP terrestrial load for the baseline 2025 and scenario 2C 2060.

DRP load (g/ha/yr)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	114,4	56.8
Max	659	653.8

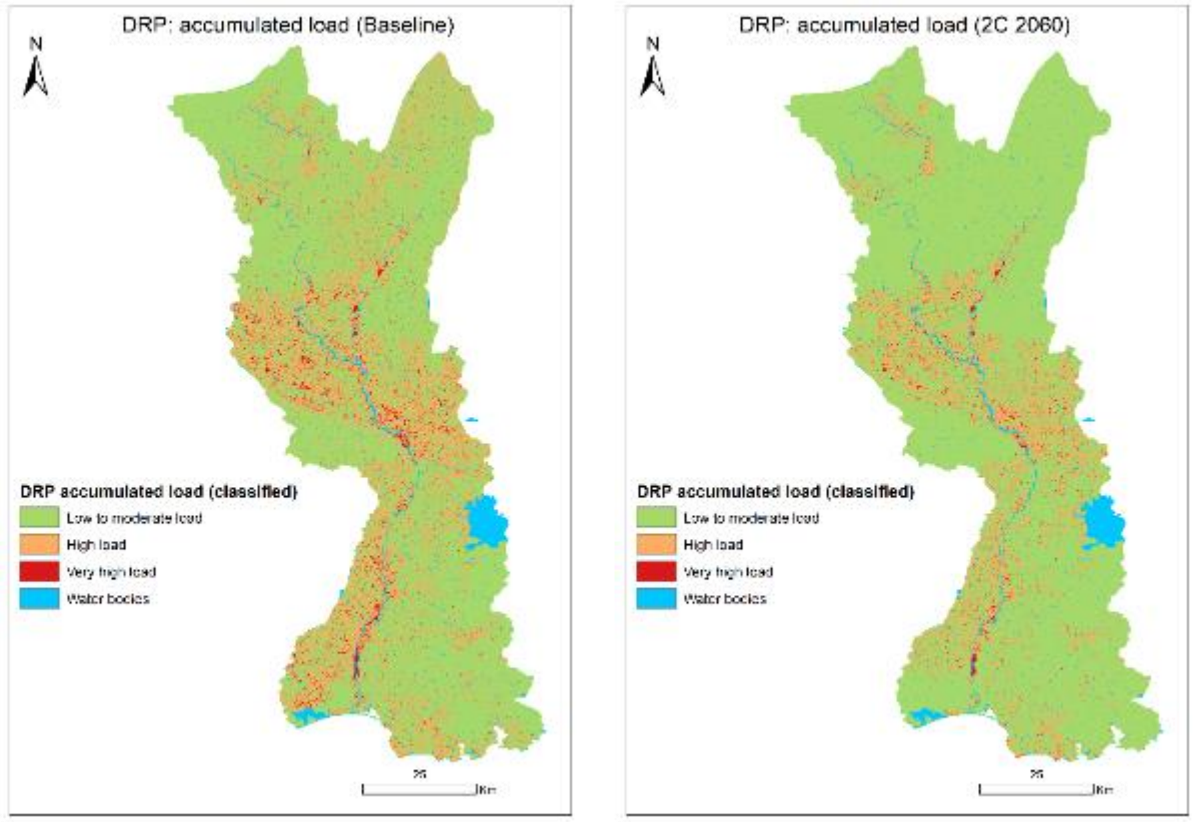


Figure A - 7. Dissolved P accumulated load changes between Baseline and Scenario 2C 2060.

Table A - 12. Summary statistics for DRP stream concentration for the baseline 2025 and scenario 2C 2060.

DRP stream concentration (mg/L)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	0.006	0.001
Max	6.9	0.07

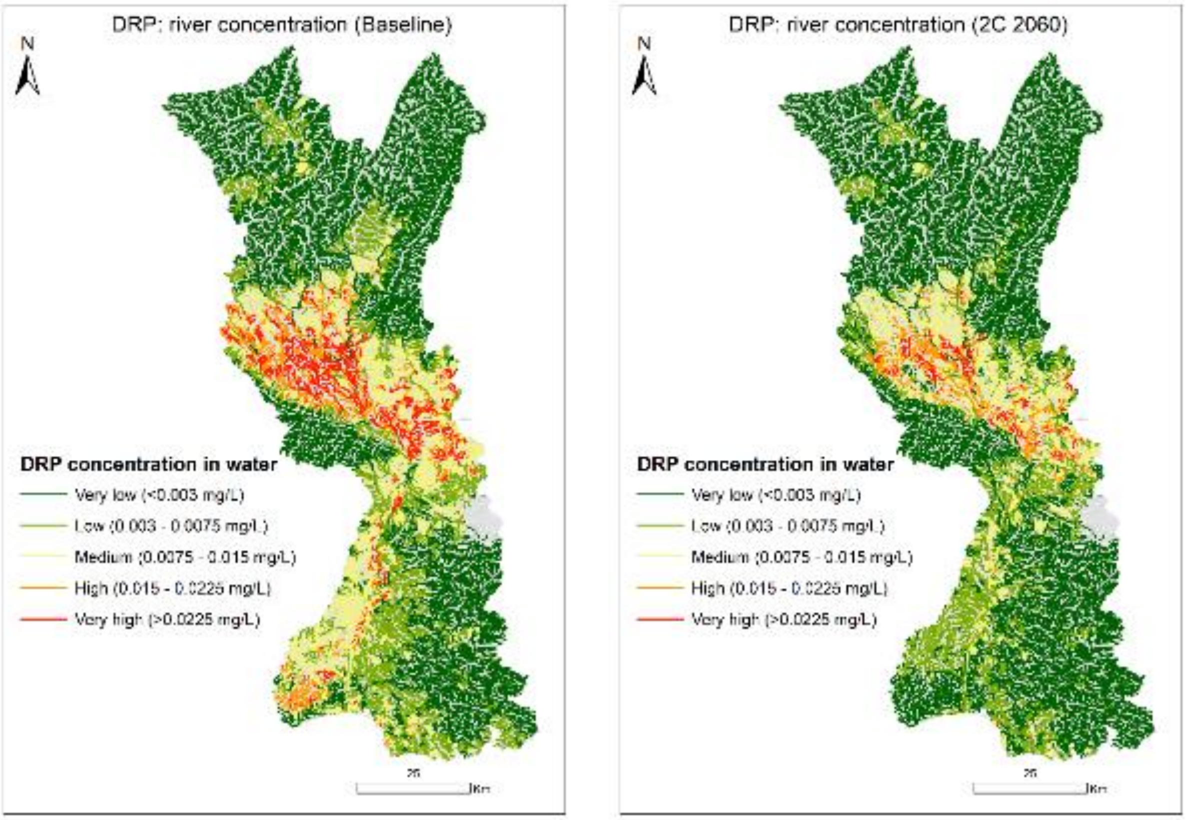


Figure A - 8. Dissolved P river concentration changes between the baseline 2025 and Scenario 2C 2060.

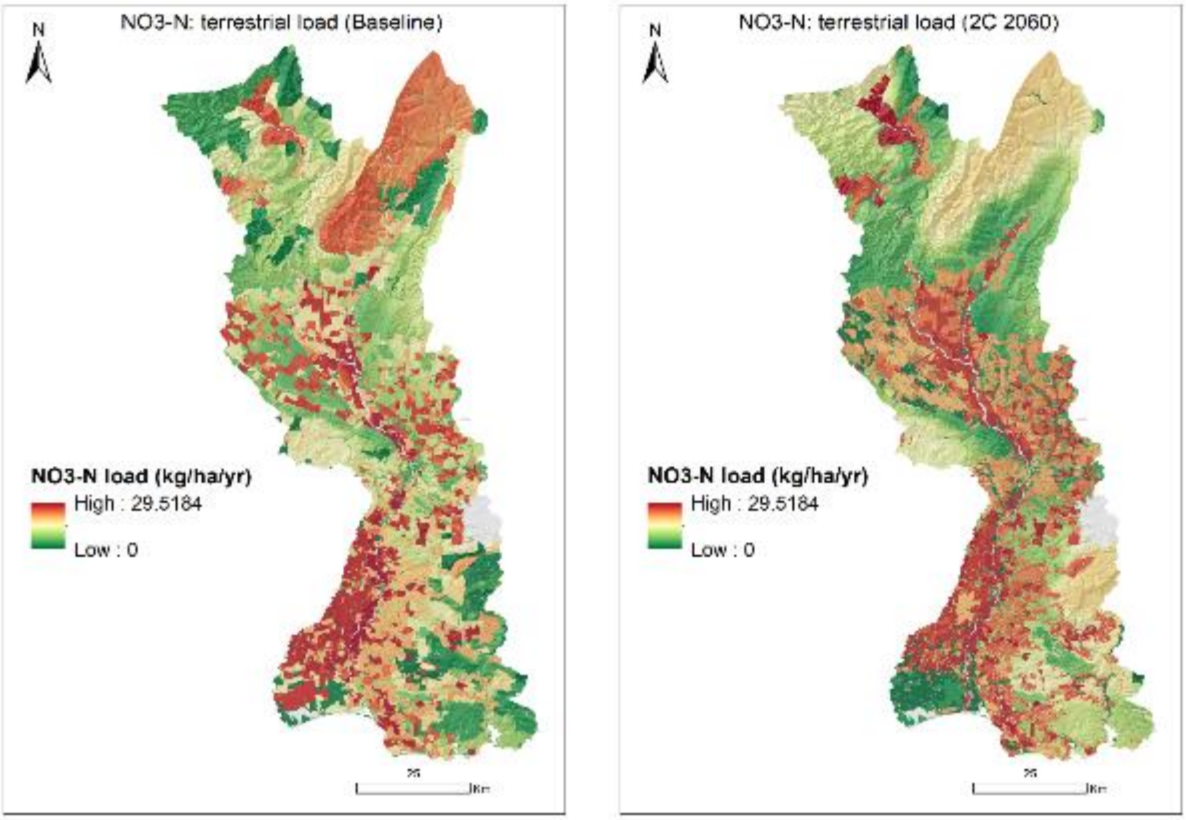


Figure A - 9. NO3-N terrestrial load changes between the baseline 2025 and Scenario 2C 2060

Table A - 13. Summary statistics for NO3-N terrestrial load for the baseline 2025 and scenario 2C 2060.

NO_3-N load (kg/ha/yr)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	7.4	3.3
Max	29.5	29.5

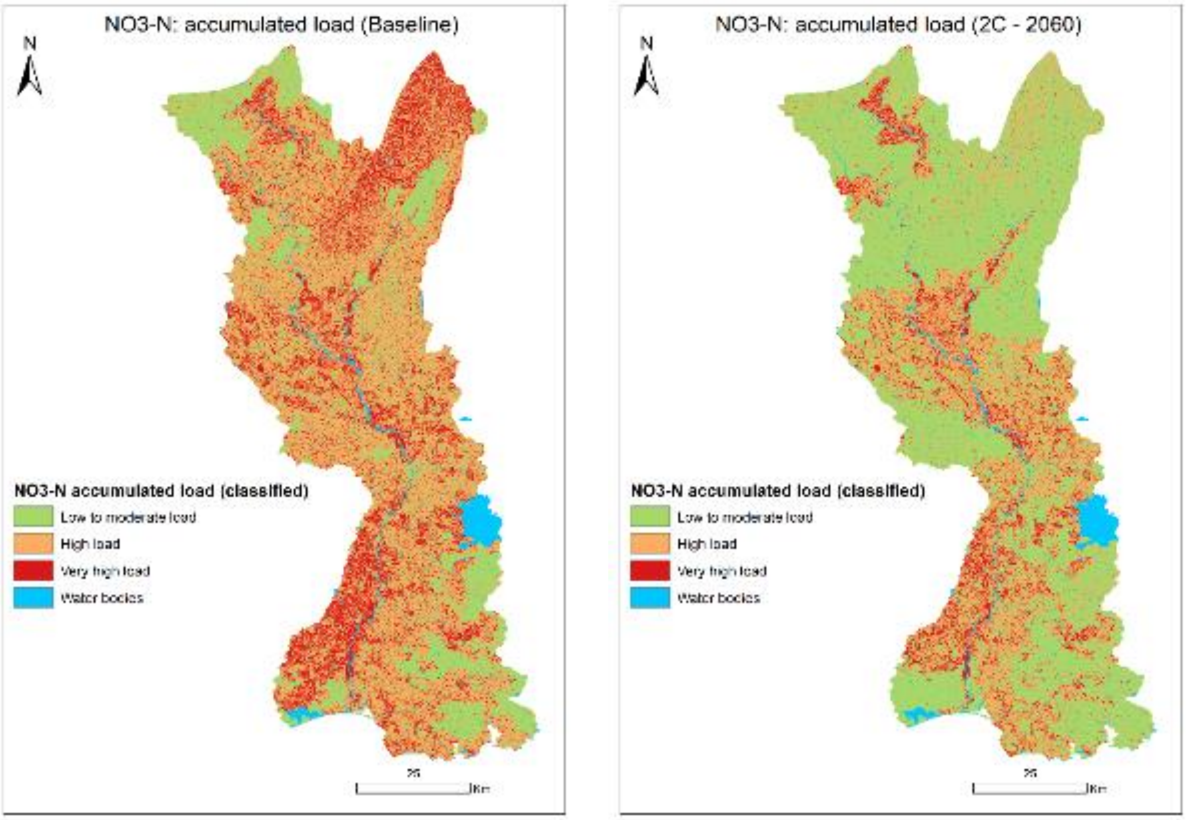


Figure A - 10. NO3-N accumulated load changes between the baseline 2025 and Scenario 2C 2060.

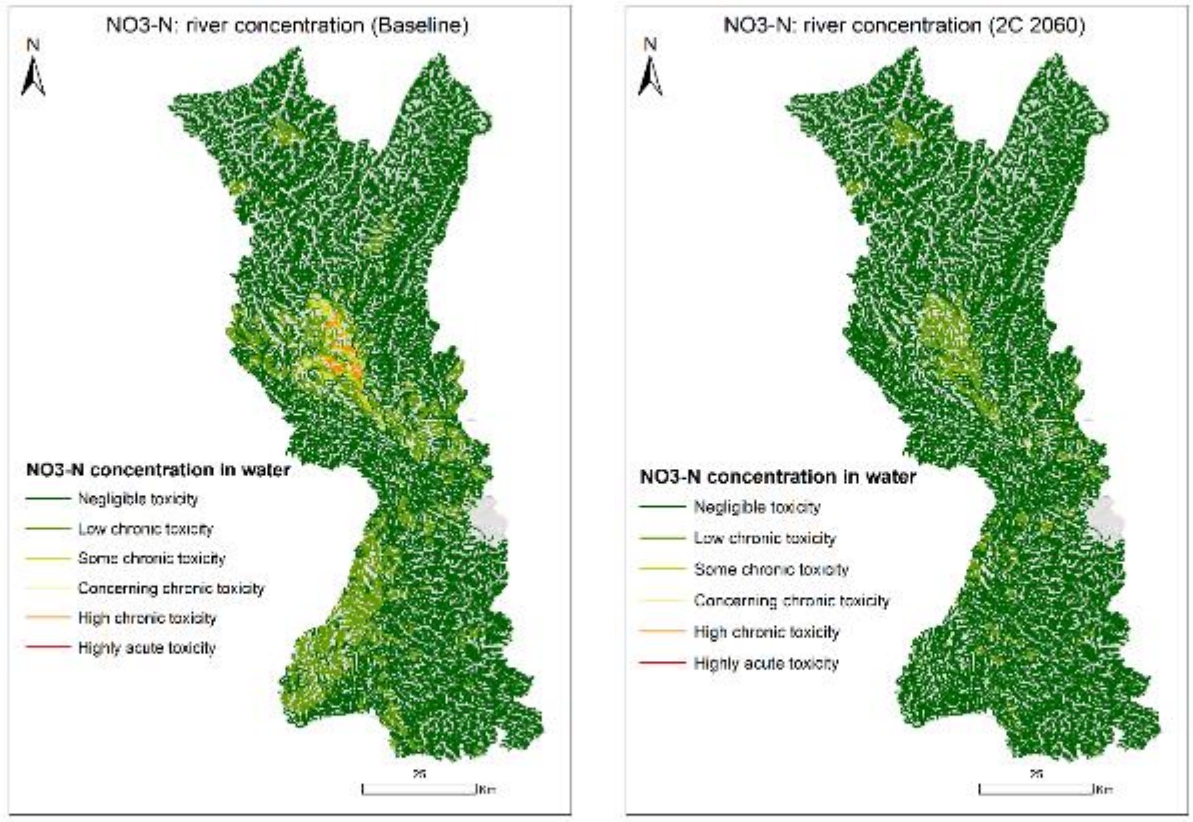


Figure A - 11. NO_3-N river concentration changes between the baseline 2025 and Scenario 2C 2060.

Table A - 14. Summary statistics for NO_3-N stream concentration for the baseline 2025 and scenario 2C 2060.

NO_3-N stream concentration (mg/L)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	0.3	0.3
Max	2.8	2.8

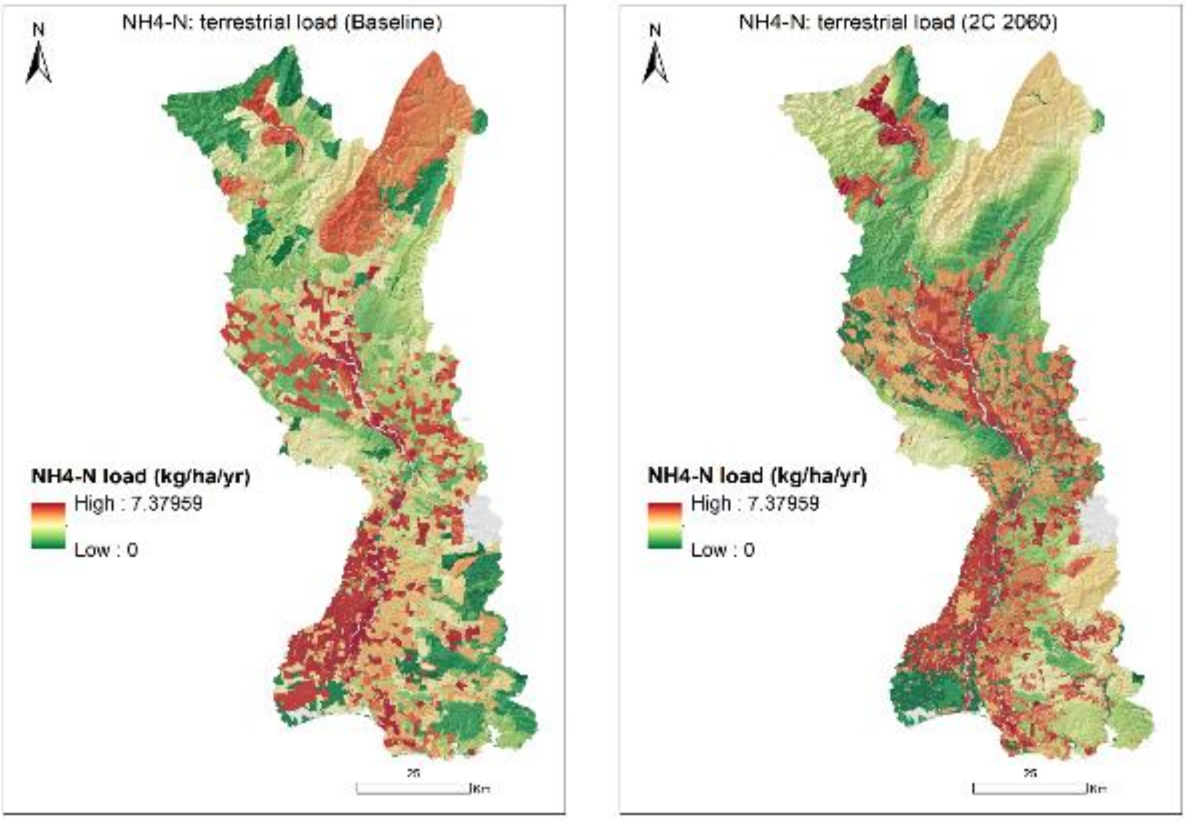


Figure A - 12. NH4-N terrestrial load changes between the baseline 2025 and Scenario 2C 2060.

Table A - 15. Summary Statistics for NH4-N terrestrial load for the baseline 2025 and scenario 2C 2060.

NH_4-N load (kg/ha/yr)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	1.8	0.8
Max	7.4	7.4

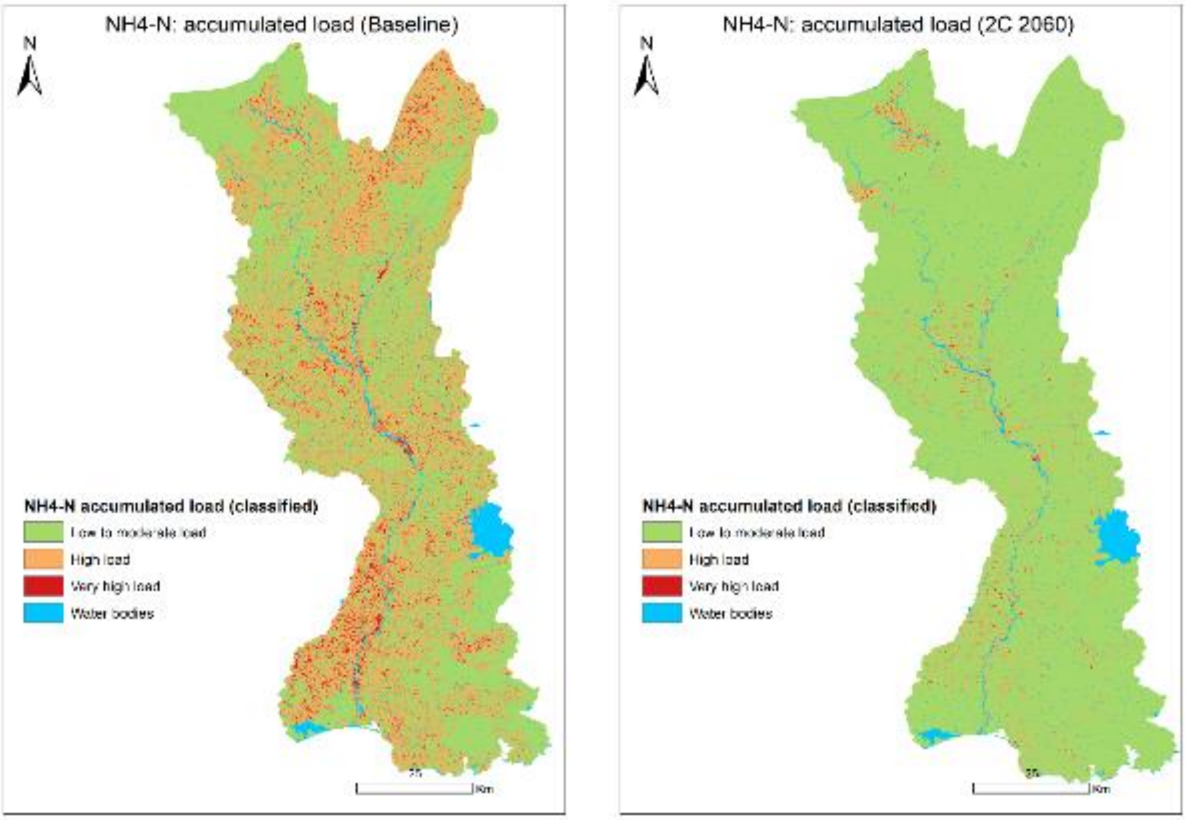


Figure A - 13. NH4-N accumulated load changes between the baseline 2025 and Scenario 2C 2060.

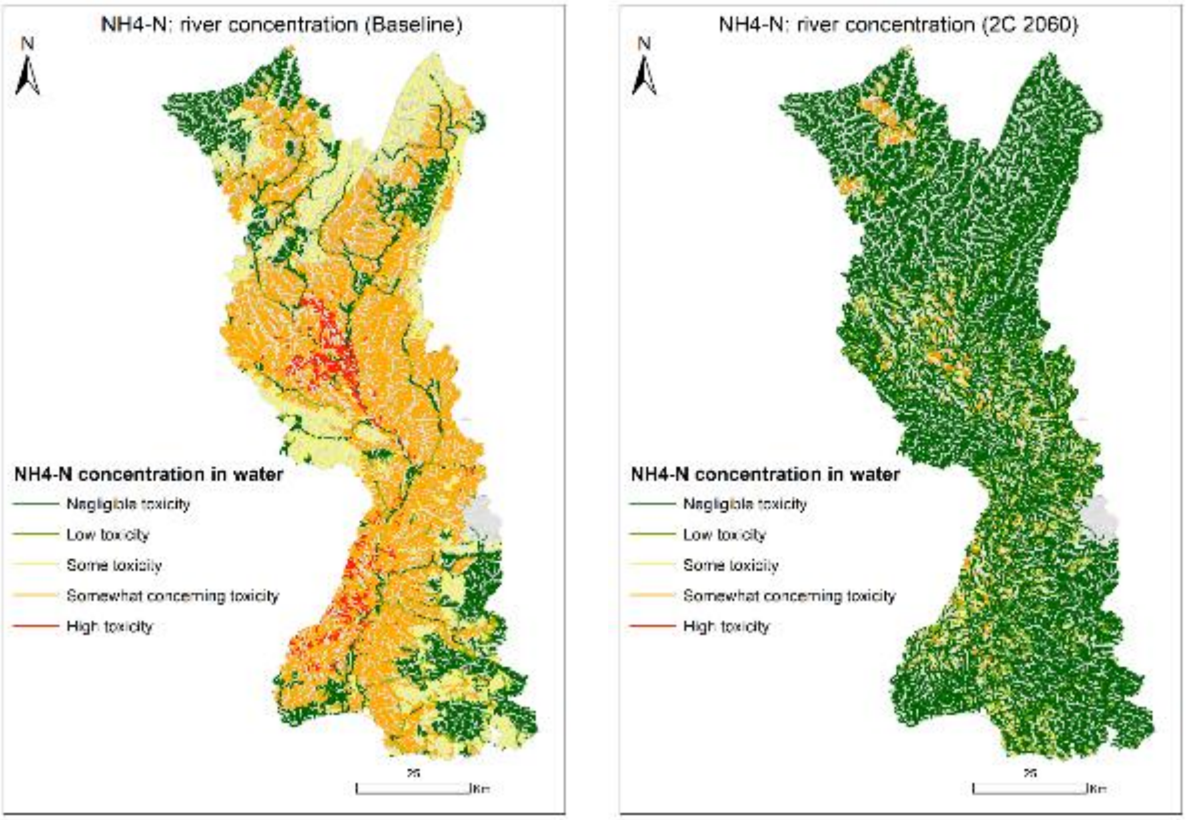


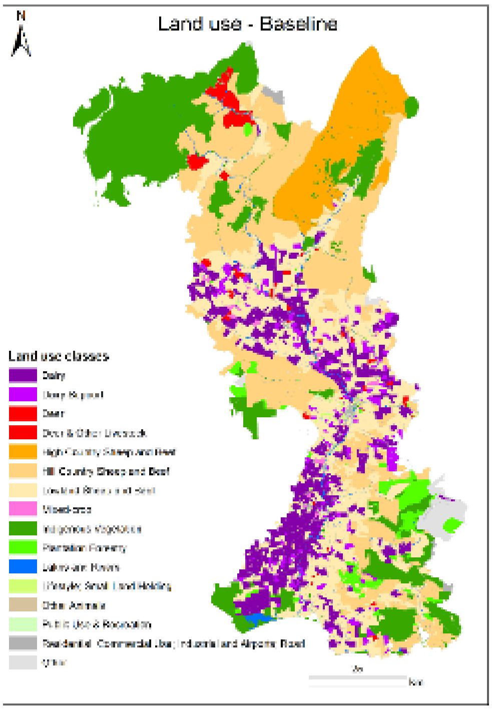
Figure A - 14. NH4-N river concentration changes between the baseline 2025 and Scenario 2C 2060.

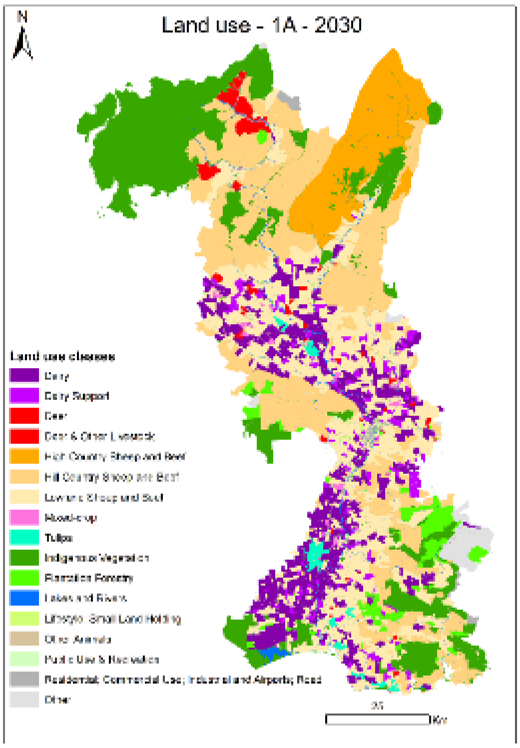
Table A - 16. Summary statistics for NH4-N stream concentration for the baseline 2025 and scenario 2C 2060.

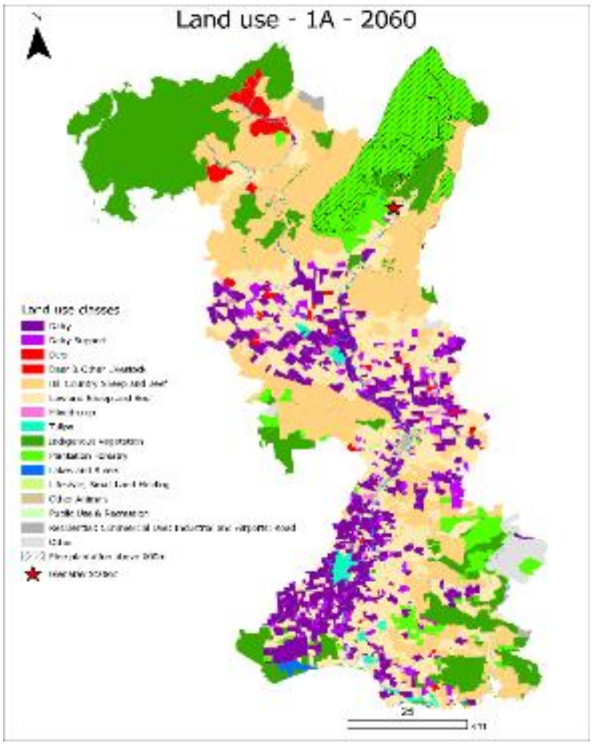
NH_4-N stream concentration (mg/L)	Baseline 2025	Scenario 2C 2060
Min	0	0
Mean	0.15	0.1
Max	333	0.7

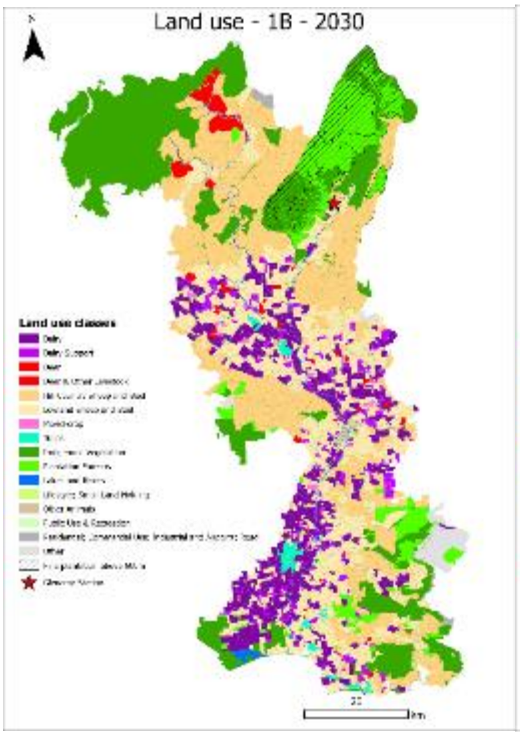
A11 – Additional Nature Braid Maps

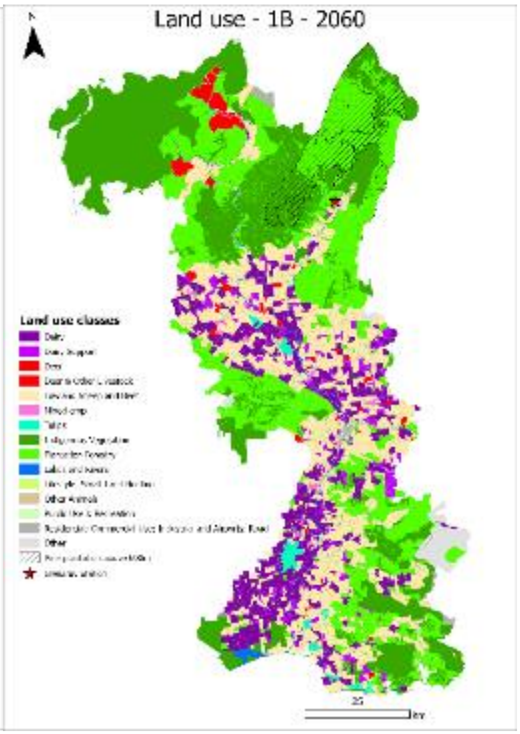
Land use maps and N high risk areas map

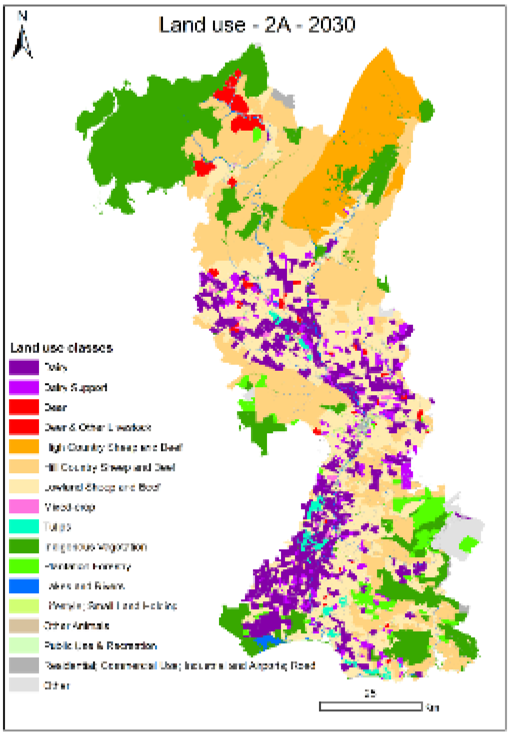


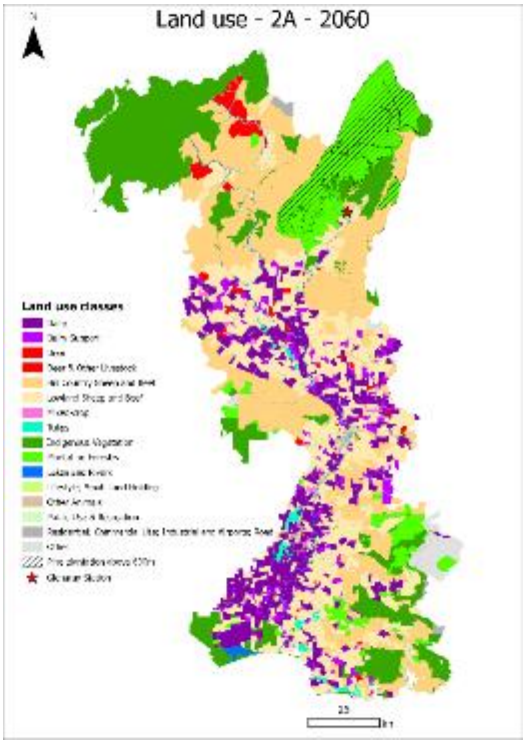


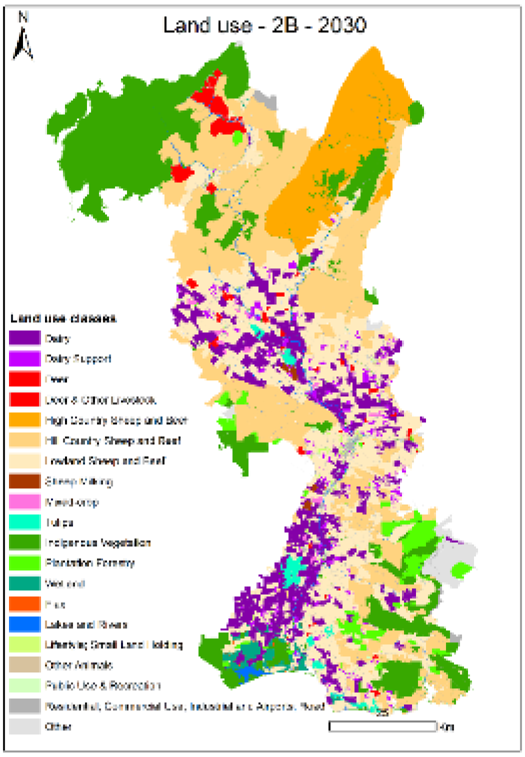


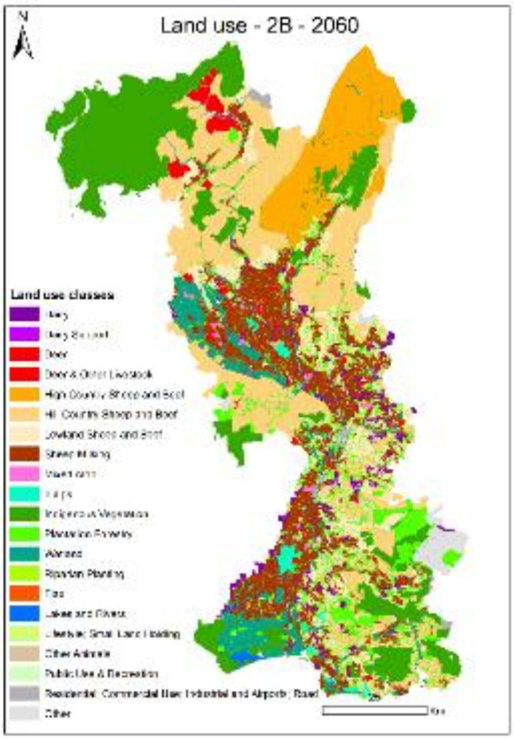

Land use - 1B - 2030
N
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
Hill Country Sheep and Beef
Lowland Sheep and Beef
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Lakes and Rivers
Lifestyle; Small Land Holding
Other Animals
Public Use & Recreation
Residential; Commercial Use; Industrial and Airports; Road
Other
Pine plantation above 600m
Glenaray Station
25
km

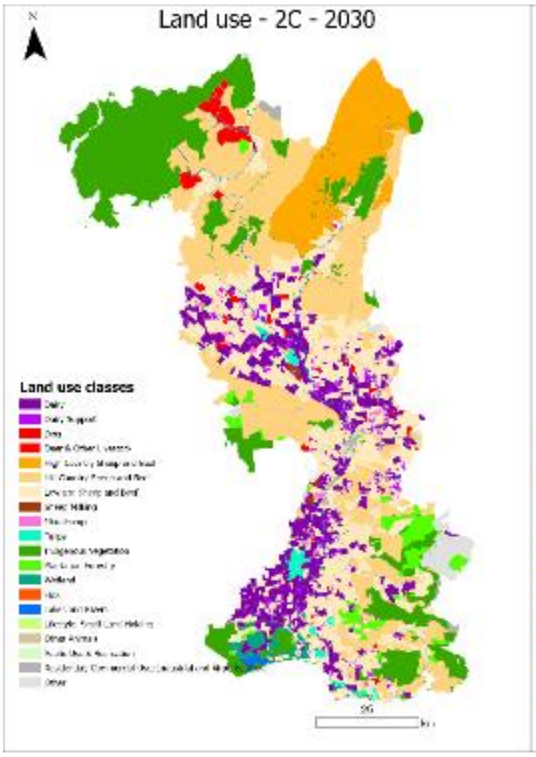

Land use - 1B - 2060
N
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
Lowland Sheep and Beef
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Lakes and Rivers
Lifestyle; Small Land Holding
Other Animals
Public Use & Recreation
Residential; Commercial Use; Industrial and Airports; Road
Other
Pine plantation above 600m
Glenaray Station
25
km

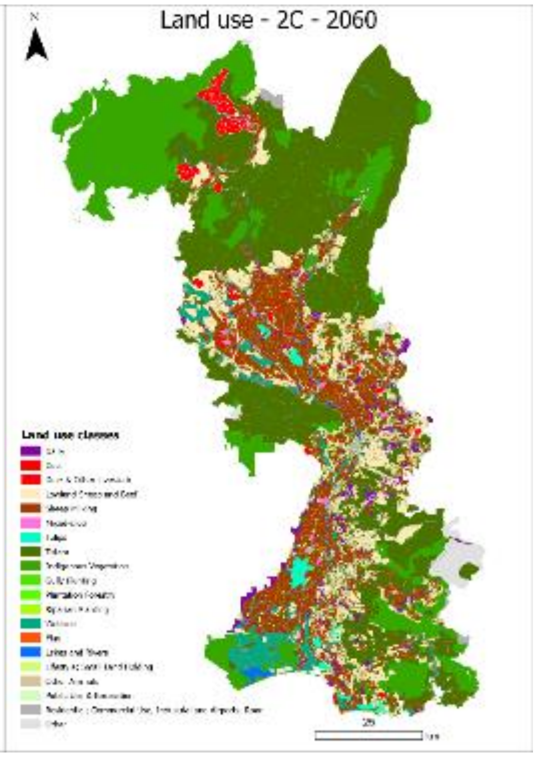

Land use - 2A - 2030
N
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
High Country Sheep and Beef
Hill Country Sheep and Beef
Lowland Sheep and Beef
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Lakes and Rivers
Lifestyle; Small Land Holding
Other Animals
Public Use & Recreation
Residential; Commercial Use; Industrial and Airports; Road
Other
25
km

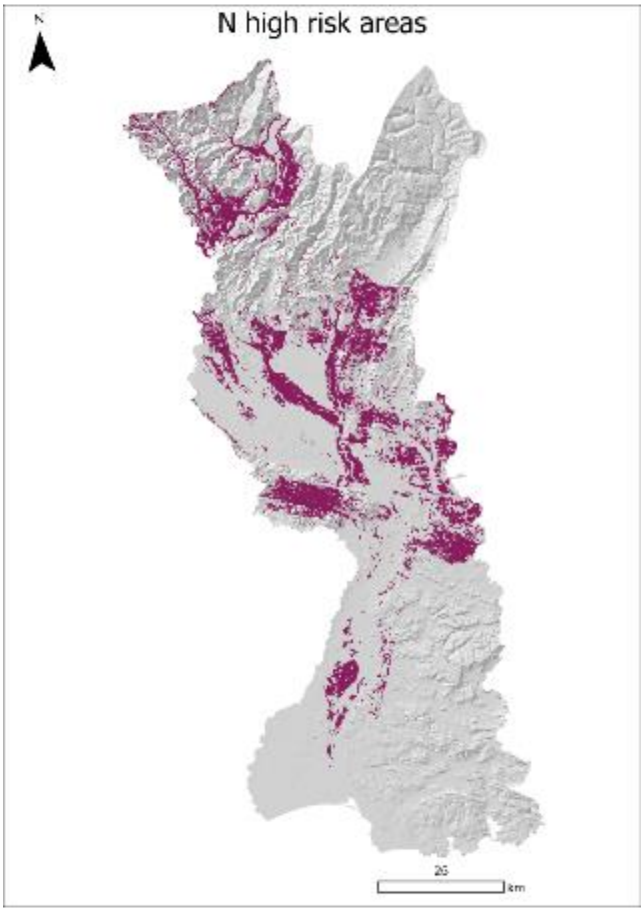

Land use - 2A - 2060
N
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
Hill Country Sheep and Beef
Lowland Sheep and Beef
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Lakes and Rivers
Lifestyle; Small Land Holding
Other Animals
Public Use & Recreation
Residential; Commercial Use; Industrial and Airports; Road
Other
Pine plantation above 600m
Glenaray Station
25
km


N
Land use - 2B - 2030
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
High Country Sheep and Beef
Hill Country Sheep and Beef
Lowland Sheep and Beef
Sheep Milking
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Wetland
Fish
Lakes and Rivers
Lifestyle Small Land Holding
Other Animals
Public Use & Recreation
Residential, Commercial Use, Industrial and Airports, Road
Other
25
Km


N
Land use - 2B - 2060
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
High Country Sheep and Beef
Hill Country Sheep and Beef
Lowland Sheep and Beef
Sheep Milking
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Wetland
Riparian Planting
Fish
Lakes and Rivers
Lifestyle Small Land Holding
Other Animals
Public Use & Recreation
Residential, Commercial Use, Industrial and Airports, Road
Other
25
Km


N
Land use - 2C - 2030
Land use classes
Dairy
Dairy Support
Deer
Deer & Other Livestock
High Country Sheep and Beef
Hill Country Sheep and Beef
Lowland Sheep and Beef
Sheep Milking
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Wetland
Fish
Lakes and Rivers
Lifestyle Small Land Holding
Other Animals
Public Use & Recreation
Residential, Commercial Use, Industrial and Airports, Road
Other
25
Km


N
Land use - 2C - 2060
Land use classes
Dairy
Deer
Deer & Other Livestock
Lowland Sheep and Beef
Sheep Milking
Mixed crop
Tulips
Indigenous Vegetation
Plantation Forestry
Riparian Planting
Wetland
Fish
Lakes and Rivers
Lifestyle Small Land Holding
Other Animals
Public Use & Recreation
Residential, Commercial Use, Industrial and Airports, Road
Other
25
Km


N
N high risk areas
25
km

A12 – Scenario 2B (2030 and 2060) – Variation: New agroforestry systems applied to three farm systems

Following consultation in the Mataura, an additional scenario was requested by the Parliamentary Commissioner for the Environment to model the impact of applying a new Agroforestry system, based on the 2B scenario (high levy, targeted levy recycling). We explore the effect of applying a new Agroforestry system to three farm systems simultaneously (Sheep Dairy, Lowland Sheep and Beef and Hill Country Sheep and Beef), for two time-steps: 2030 and 2060.

The forestry component of the Agroforestry systems will be composed of native species along with grassland, with the mix of forest species assumed to be red beech/ tawhairaunui (*Nothofagus fusca*), and broadleaf/ kapuka (*Griselinia littoralis*) as a nurse crop. The pastoral component is based on the original pastoral systems (Sheep Dairy, Lowland Sheep and Beef and Hill Country Sheep and Beef). All Agroforestry systems are envisioned to have a continuous forest cover for red beech, targeting 40% crown cover. The pastoral component is assumed to be equivalent to 50% of the original agricultural use.

Following is the description of the new Agroforestry systems and assumptions made, parameterisation of the system in Nature Braid and the results of the land use transitions, economic and environmental analysis. Economic spreadsheets, GIS layers (rasters, shapefiles) in .zip file and PNG maps were provided separately to the PCE.

Methodology and assumptions

Agroforestry systems description

For the purpose of this thought exercise (Task 1), three new Agroforestry systems were created for the Mataura catchment. Each system has two components, a pastoral and a forestry component. For the pastoral component, existing FARMAX outputs were adjusted from Phase 1 for three land uses: Hill Country Sheep and Beef, Lowland Sheep and Beef, and Sheep Dairy in 2030 to create each of the new Agroforestry systems.

For the ***pastoral component*** of each Agroforestry system, it is assumed that pasture production would reduce by 50%. Correspondingly, animal stocking rates were also reduced by 50% from the respective baseline FARMAX model. This estimate was obtained from a study on the effect of shade on pasture yield reduction (Power et al. 2001). We used the yield/shade relationship of *Eucalyptus nitens* as a proxy evergreen tree species and an assumed canopy cover of 40%. The reduction in pasture growth depends on factors such as tree species, site, tree stocking rate, forest age, and canopy cover. Further details on the assumptions for the pastoral component are provided at the end of this section.

The ***forestry component*** was designed through literature review and expert knowledge. A shortlist of species[1] was obtained from literature (Paul, 2021; New Zealand Plant Conservation Network, 1999) and discussed with a farm forestry expert (Neil Cullen, President of the New Zealand Farm Forestry Association, pers. comm. 29 May 2023) who suggested other potential tree species that could grow in the Mataura catchment.[2] A draft design was tested with staff at Environment Southland (Ewen Rodway, Senior Environmental Scientist, pers. comm. 9 June 2023) who provided feedback related

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1 Remnants of the following species in the Mataura catchment: Silver beech, Tōtara, Miro, Kahikatea, Rimu, Mānuka/kanuka. Poplars and willow are also widely present.
2 Red beech and mountain beech: Both species stand cold weather have better form than Silver beech and have a market for wood. Other traditional species available in the catchment are poplar and willow.

to the economic feasibility of the system. The final design of the forestry component of the system was completed by WSP forestry specialists.

The agroforestry system assumes red beech/ tawhairaunui (*Nothofagus fusca*[3]) as the tree species and broadleaf/ kapuka (*Griselinia littoralis*) as nurse crop. Red beech has an existing timber market, is available from nurseries in Southland, the species resists low temperatures and wind (NZ Farm Forestry Association 2023 a,b), has good form, rapid growth, and dimensional stability once dry when compared to other native tree species (Thorneycroft, 1994). Broadleaf presents rapid growth and high palatability to livestock. While the economics and growth information for both species is limited, as it is the case of most native trees in New Zealand, this exercise was used as an opportunity to explore an alternative to the poplar agroforestry system introduced for the Wairoa catchment in Phase 1.

In this thought experiment, red beech trees are initially planted at 5x30m and a final spacing of 10x30m. The initial spacing and nurse crops allow for encouraging vertical trunk growth for timber quality, and root expansion for erosion control. The system is managed so that a continuous forest cover regime (40% crown cover) is maintained and includes thinning under selective logging every 25 years. The system is set up in 2025 and registered in the ETS under the Permanent Forest category and stock change accounting, this means the participants gain NZUs as the forest grows but need to surrender NZUs when harvested. The wood volume and carbon dioxide sequestered for red beech were obtained from Tane’s Tree Trust growth and yield and carbon calculators, respectively (Tane’s Tree Trust, 2023a, b). Assumptions for the ETS price pathway were provided by PCE. The production forestry component and assumptions of the Agroforestry system are described in Table A - 17.

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[3] Synonym: *Fuscospora fusca.*

Table A - 17: Forestry component for each of the Agroforestry systems.

Timeline (years)	Activities	Cost	Benefit
0	Planting: 66 Red beech/ha and 132 Griselinia/ha Grass spot spraying Temporary fencing	Planting: $3.85 per seedling $0.80 labour per plant $0.80 grass spot spraying per plant $1.50 plant protector per plant	N/A
1-3	Weed control: Year 1 x 2 operations Year 2-3 x 1 operation Grazing stock off farm	Fencing: $0 Seedlings, planting, and release: $replace w/value Weed control: $0.3 per plant per operation Grazing: Lease	N/A
4-10	General maintenance	Maintenance cost: $1.01 per tree	NZ ETS
25	Thinning 33 trees of 25 years for form and strength, replant 33	Harvest cost: $40/t of wood	NZ ETS Wood harvest: $150/t
50	Thinning sixteen trees of 25 years, seven trees of 50 years, replant 24	As above	NZ ETS Wood harvest: $212/t
75	Thinning six trees of 25 years, four trees of 50 years, 15 trees of 75 years, replant 24	As above	NZ ETS Wood harvest: $301/t
100+	Thinning six trees of 25 years, five trees of 50 years, 2 trees of 75 years and 11 trees of 100 years, replant 24	As above	NZ ETS Wood harvest: $426/t

Specific assumptions for the pastoral component of the Agroforestry systems

Further detail of the assumptions of how the pasture components of the systems have been modelled are below.

General Agroforestry (pastoral component) assumptions compared to the baseline modelling:

- 50% of pasture production
- 50% of stocking rate
- 50% of income
- 50% of greenhouse gas emissions and subsequent levy
- 50% of all costs (fixed costs are assumed to be changed by long term changes to farming operations)
- Forage crops removed from the system, 50% of the cost to produce the forage crop is added as bought in feed (50% to represent ½ the stock so ½ the crop required)
- N and P fertiliser is still applied to the Agroforestry system, at the same timings as the base for pasture N but at 50% of the rate (due to the 50% reduction in pasture grown). Where crop has been removed, crop fertiliser has been removed.
- No other system modifications, with same animal production timing and growth rates.

Nature Braid assumptions

- To model the Agroforestry system in the Nature Braid, we assumed that:
  By 2030 (5 years in):
    - Broadleaf (nurse crop) is established.
    - Red beech is not yet well established.

  By 2060 (45 years in):
    - Red beech is established.
    - Broadleaf is no longer part of the system.
- Animal stocking units will reduce by 50% from the original land uses.
- The parameterisation for other land use conversions (Exotic Forestry, Wetlands, Riparian Planting) remain the same as in Phase 1.
- Changes in animal behaviour due to the presence of woody biomass (e.g. stock grazing, sitting under trees) is not explicitly considered in the biophysical modelling.
- Parameterisation of the forestry component of the system is for an equilibrium state, which implicitly includes all forest management activities (e.g. thinning, harvesting, replanting, pest control).
- Erosion vulnerability under the Agroforestry systems were based on a weighted average of factors for grassland (nurse crop) and planted forest (red beech) from Donovan (2022). The productivity of the land was also considered.
- A spreadsheet of physical and economic information was used by the Nature Braid and economics teams to determine the impact on the environment and economic returns respectively. Each farm system has been modelled as converting fully to an Agroforestry system.

Parametrising agroforestry scenario in Nature Braid

Parameterisation for the Agroforestry systems was based on previous literature and previous parameterisation of similar land covers within Nature Braid. Table A - 18 below shows an overview of these values, followed by justification.

Table A - 18: Parameterisation within Nature Braid for Agroforestry systems.

Land use	Flow Mitigating ability (classified)	Agricultural production (classified)	C-factor	Ideal habitat for kererū?	Resistance to kererū (classified)	Nitrogen multiplier (1 = arable land, conventional agriculture, deer, beef)	Phosphorus multiplier (1 = arable land, conventional agriculture, deer, beef)
Hill country Sheep and Beef Agroforestry (LUcode = 151)	2	1	0.02375	Yes	0	0.73	0.73
Lowland Sheep and Beef Agroforestry (LUcode = 152)							
Sheep Dairy Agroforestry (LUcode = 153)							

- Flow mitigating ability = 2 as these land uses (when established) can mitigate flow.
- Agricultural production = 1 as these are considered productive.
- C-factor = 0.02375
  - Based on annual average C-factors from Donovan (2022) for “planted forest, post-89” and “grassland grazed, non-dairy”. For the grassland, C-factor values for both high production and low production were calculated. Then for the weighted average, it was assumed that 50% of the system ground cover would be planted forest and 50% would be grazed grassland.
- Ideal habitat for kererū = yes
  - Studies of kererū diet showed evidence of the species eating *Griselinia* (Kererū Discovery, 2023), and another *Nothofagus* species (silver beech) (McEwen, 1978).
- Resistance to kererū = 0
  - The proposed Agroforestry incorporates woody biomass which would be ideal for kererū habitat and movement and would have no resistance. This value is different from the Wairoa report (Phase 1) that was deemed too conservative in hindsight.
- Nutrients:
  - In the Mataura, the nutrient multiplier values for Sheep Dairy, Hill Country Sheep and Beef, and Lowland Sheep and Beef are presented below were all 1 and a 27% reduction would bring it down to 0.73. For comparison, in the Wairoa catchment, the nutrient multiplier values for agroforestry had a 20% to 30% reduction (mean = 27%) compared to conventional livestock systems.

Land use assumptions

The land use changes were driven by the specifications for Sheep Dairy Agroforestry, Lowland Sheep and Beef Agroforestry, and Hill Country Sheep and Beef Agroforestry described in the introduction.

In general, the Agroforestry systems form an overlay to the original 2B scenario (high levy, targeted levy recycling). Specific implementation of Sheep Dairy Agroforestry and Wetlands are explained below.

Sheep Dairy Agroforestry

Land suitable for Sheep Dairy was previously identified as being land segments greater than 50ha with Very High or High Production Capacity. Table A -19 below details this land by usage in 2025.

Table A - 19: Land by usage (2025).

Original Use	Very high production capacity	High production capacity
Dairy	8,983	35,120
Dairy Support	745	4,873
Lowland Sheep and Beef	6,386	45,760
Hill Country Sheep and Beef	598	4,812
Total	16,711	90,565

In the original 2B Scenario, a small amount of this land would transition to Sheep Dairy in 2030, constrained by building up the total flock of dairy ewes. This constraint saw the land area converted to Sheep Dairy in 2030 limited to 1,127ha – assumed to all be very high production capacity land used for Dairy in 2025. This constraint was continued in this scenario, but the land immediately transitions to Sheep Dairy Agroforestry.

The rest of the Sheep Dairy land transitioned by 2060. We have assumed that all this land will transition to Sheep Dairy Agroforestry. This means that some land transitions to another form of Agroforestry (e.g., Lowland Agroforestry) in 2030 and then into Sheep Dairy Agroforestry by 2060. The forestry component is the same across the three Agroforestry systems.

Wetlands

There are two types of Wetlands in the original 2B scenario, natural Wetlands and constructed Wetlands. We assume no change to the land use change to natural Wetlands. However, any land that would have transitioned to constructed Wetlands but has already been transitioned to an Agroforestry system will remain in the Agroforestry system. Specifically, these were the transitions related to both types of Wetlands:

- Restoration of Wetlands on land prone to waterlogging and having negligible production capacity as identified by Nature Braid based on soil, topography, elevation, and aspect. The same land as in the original 2B scenario is assumed to make this transition in this scenario.

- Riparian planting (~11.3m) along streams on farmland, and inclusion of a flax buffer (~16m) around Wetlands (this is the same treatment as in the original 2B scenario).
- Creation of constructed Wetlands based on areas currently in production that are prone to waterlogging, or otherwise have poor drainage/are imperfectly drained which are identified by Nature Braid based on soil, climate and topography. Land with these characteristics is transitioned between 2030 and 2060 in the original 2B scenario. In this scenario, some of this land has already transitioned to an Agroforestry system in 2030 and remains in that system rather than converting to a constructed Wetland.

Tulips

Tulips require six times the nominal land area to allow for crop rotation. Much of the land that would have been used for Tulips has transitioned to Agroforestry which wouldn't be suitable for Tulip rotations, so Tulips are not considered as a land use option for this scenario.

Results

Land use transitions

The land use maps for 2030 and 2060 are shown in Figure A - 15 and Figure A - *16*, respectively. The next section introduces the specific transitions (as per spreadsheets provided separate to this report).

The summary of land use transitions is shown in Table A - 20.

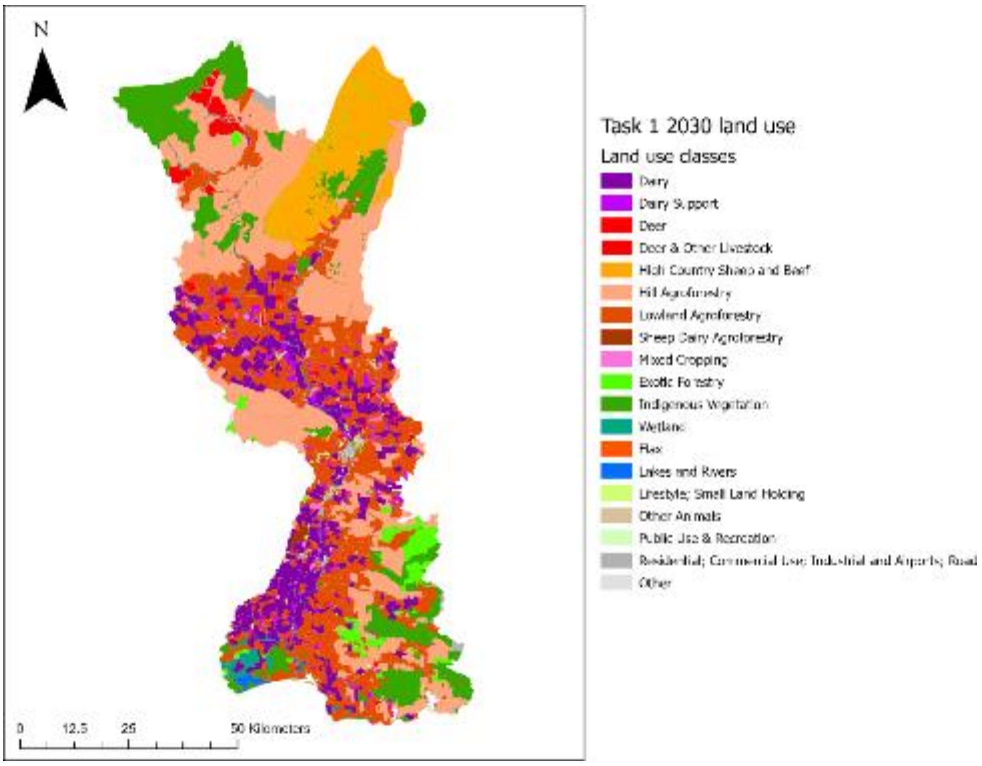


Figure A - 15: Land use map for Task 1 2030.

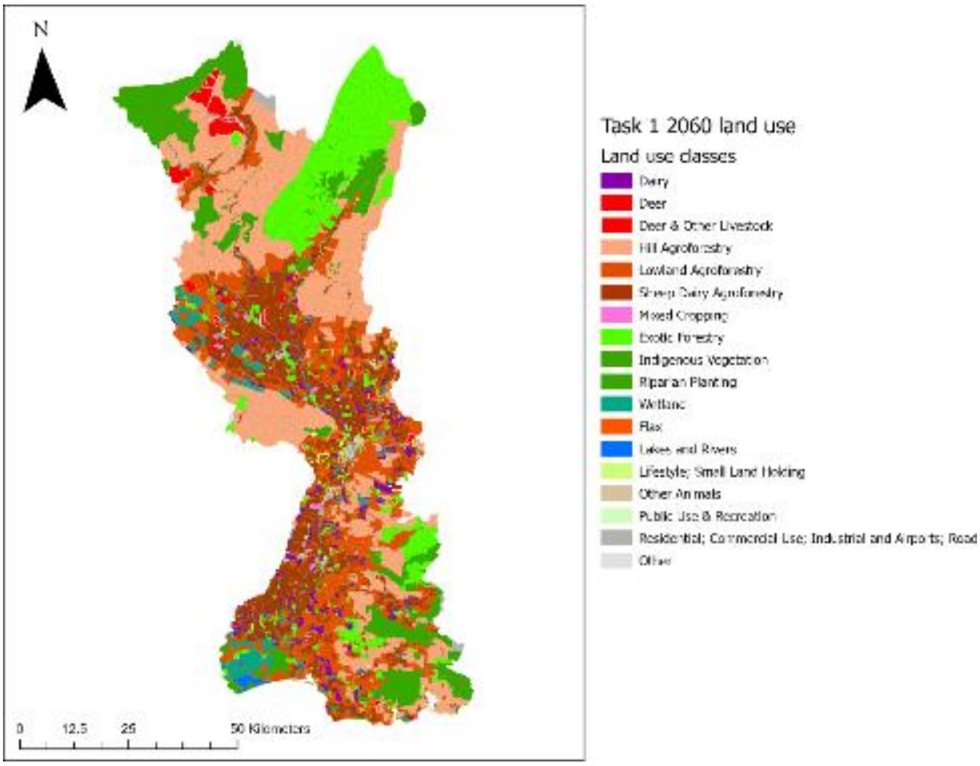


Figure A - 16: Land use map for Task 1 2060.

2030 Transitions from 2025

- Dairy: 1,127 ha of Dairy land (of the land identified above as suitable for Sheep Dairy) is converted to Sheep Dairy Agroforestry and 4,043ha (all of Negligible Production Capacity) transitions to natural Wetlands.
- Dairy Support: 342ha (all of Negligible Production Capacity) transitions to natural Wetlands. All Moderate and Marginal land originally transitioned to Lowland Sheep and Beef; this now transitions to Lowland Agroforestry.
- Lowland Sheep and Beef: 3,754ha of Negligible Production Capacity land moves to natural Wetlands. The rest of the Lowland Sheep and Beef land will convert to Lowland Agroforestry.
- Hill Country Sheep and Beef: 114ha of Negligible Production Capacity land moves to natural Wetlands. The rest of the Hill Country Sheep and Beef land will convert to Hill Country Agroforestry.
- High Country Sheep and Beef: 132ha of Negligible Production Capacity land moves to natural Wetlands. The rest of the Negligible Production Capacity land will convert to Exotic Forestry.

2060 Transitions from 2030

- Dairy: 42,976ha of Dairy land (identified as suitable for Sheep Dairy above) is converted to Sheep Dairy Agroforestry and 11,284ha of Moderate Production Capacity land transitions to constructed Wetlands.
- Dairy Support: the remaining 12,085ha transitions to Exotic Forestry.
- High Country Sheep and Beef: 132ha of Negligible Production Capacity land moves to natural Wetlands. The rest of the Negligible Production Capacity land will convert to Exotic Forestry.
- Mixed: All Moderate and Marginal Production Capacity land transitions to Exotic Forestry.
- Lowland Agroforestry: 52,146ha of Lowland Agroforestry land (identified as suitable for Sheep Dairy above) transitions to Sheep Dairy Agroforestry.

- Hill Country Agroforestry: 5,410ha of Hill Country Agroforestry land (identified as suitable for Sheep Dairy above) transitions to Sheep Dairy Agroforestry.

Table A - 20 and Figure A - 17 below summarise these land use changes. Most of the regular agricultural land has transitioned to Agroforestry with significant increases in Wetlands and Exotic Forestry.

Table A - 20: Task 1 catchment land use change.

Land use (ha)	Baseline 2025	Change between 2025 and 2030	2030	Change from 2030	2060	Change between 2025 and 2060
Dairy	80,520	-5,170	75,350	-54,261	21,090	-59,431
Dairy Support	21,425	-9,341	12,085	-12,085	0	-21,425
Lowland Sheep and Beef	156,652	-156,652	0	0	0	-156,652
Hill Country Sheep and Beef	170,597	-170,597	0	0	0	-170,597
High Country Sheep and Beef	60,554	-1,512	59,042	-59,042	0	-60,554
Mixed Cropping	2,268	0	2,268	-470	1,798	-470
Wetlands	2,992	8,384	11,376	11,284	22,661	19,669
Indigenous Vegetation	83,363	0	83,363	0	83,363	0
Exotic Forestry	15,999	1,379	17,378	65,979	83,358	67,359
Tulips	0	0	0	0	0	0
Sheep Dairy	0	0	0	0	0	0
Sheep Dairy Agroforestry	0	1,128	1,128	106,149	107,278	107,278
Lowland Agroforestry	0	161,896	161,896	-52,146	109,750	109,750
Hill Country Agroforestry	0	170,482	170,482	-5,410	165,073	165,073
Total	594,370	0	594,370	0	594,370	0

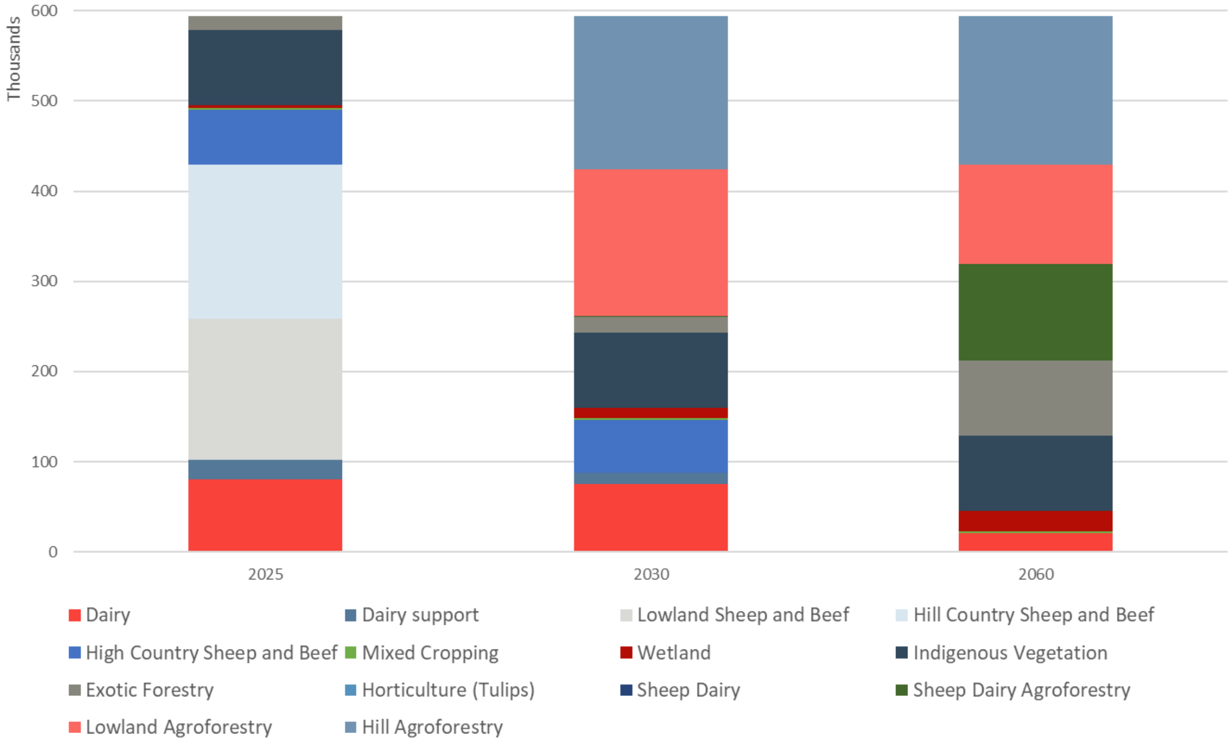


Figure A - 17: Mataura catchment land use in 2025, 2030 and 2060 for Scenario 2B-Variation

Economic impact summary

Table A - 21 and Figure A - *18* below show the scenario's changes in profitability from 2025 through to 2060. Profitability of all agricultural systems declines significantly with Sheep Dairy Agroforestry and Exotic Forestry being the only profitable activities.

Table A - 21. Task 1 catchment profitability change.

	Baseline 2025	Change between 2025 and 2030	2030	Change from 2030	2060	Total change between 2025 and 2060
Dairy	$225,905,889	$7,727,514	$233,633,403	-$221,515,422	$12,117,981	-$213,787,908
Dairy Support	-$1,704,072	$2,766,340	$1,062,268	-$1,062,268	$0	$1,704,072
Lowland Sheep and Beef	$119,894,977	-$119,894,977	$0	$0	$0	-$119,894,977
Hill Country Sheep and Beef	$17,264,386	-$17,264,386	$0	$0	$0	-$17,264,386
High Country Sheep and Beef	$1,439,203	$102,603	$1,541,805	-$1,541,805	$0	-$1,439,203
Mixed Cropping	$2,485,588	$0	$2,485,588	-$2,050,348	$435,240	-$2,050,348
Wetlands	$0	$0	$0	$0	$0	$0
Indigenous Vegetation	$0	$0	$0	$0	$0	$0
Exotic Forestry	$8,291,366	$31,852,776	$40,144,142	$506,713,394	$546,857,536	$538,566,170
Tulips	$0	$0	$0	$0	$0	$0
Sheep Dairy	$0	$0	$0	$0	$0	$0
Sheep Dairy Agroforestry	$0	$2,219,175	$2,219,175	$143,644,091	$145,863,266	$145,863,266
Lowland Agroforestry	$0	$77,667,077	$77,667,077	-$96,369,486	-$18,702,409	-$18,702,409
Hill Country Agroforestry	$0	$23,767,756	$23,767,756	-$34,729,407	-$10,961,651	-$10,961,651
Total	$373,577,336	$8,943,878	$382,521,214	$293,088,749	$675,609,963	$302,032,627

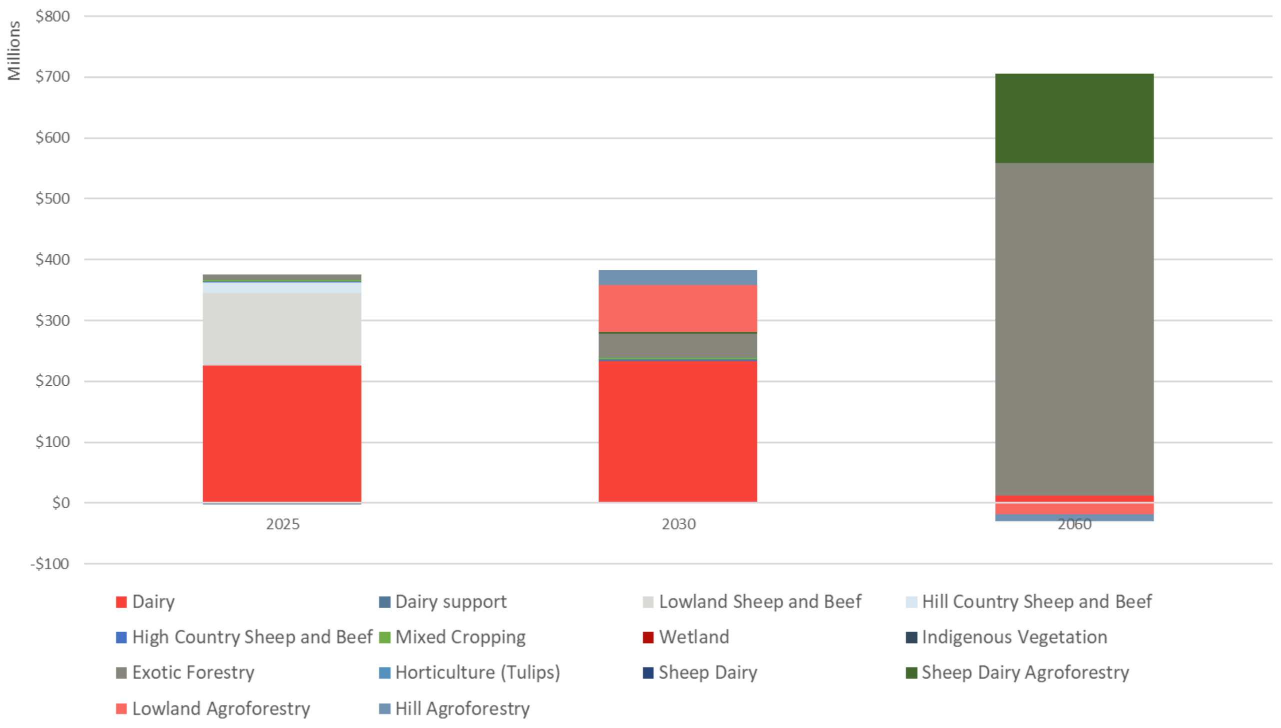


Figure A - 18: Mataura catchment profitability change in year 2025, 2030 and 2060 for Scenario 2B – Variation.

Environmental results

In general, most of the environmental outcomes improved in 2030 and 2060.

- By 2060, there are decreases in mean terrestrial nitrogen (8.7 kg N/ha/yr to 5.1 kg N/ha/yr) and phosphorus (369.1 g P/ha/yr to 139.4 g P/ha/yr) loads. The addition of riparian planting in 2060 also affects the in-stream nutrients, with decreases in mean values (0.8 mg N/L to 0.4 mg N/L; 0.02 mg P/L to 0.003 mg P/L) and significant decreases in maximum values (341.5 mg N/L to 5.76 mg N/L; 23.08 mg P/L to 0.097 mg P/L).

- The conversions to Agroforestry with native species also sees increases in the amount of flood mitigating features (+468,146ha) and habitat for kererū (+376,175ha) by 2060.

- In 2030, the mean terrestrial soil loss decreases (10.6 tonnes/ha/yr to 7.7 tonnes/ha/yr). However, conversions to Exotic Forestry in 2060 see an increase in mean terrestrial soil loss (10.6 tonnes/ha/yr to 14.5 tonnes/ha/yr).

Agricultural productivity

The predicted optimal agricultural utilisation is the same as the baseline, as this is driven by the underlying soil, climate, topography, and other factors (Figure A - 19). By 2060, the area of land considered to have very high production decreases to 63.59% compared to 79.74% at the baseline 2025 due to the retiring of land on what is considered more marginal productivity areas (Figure A - 20 and Table A - 22). Similarly, the area of the catchment where the predicted utilisation matches what the land is being used for increases to 43.63% compared to 38.57% at the baseline 2025 (Figure A - 21, Figure A - 22, and Table A - 23).

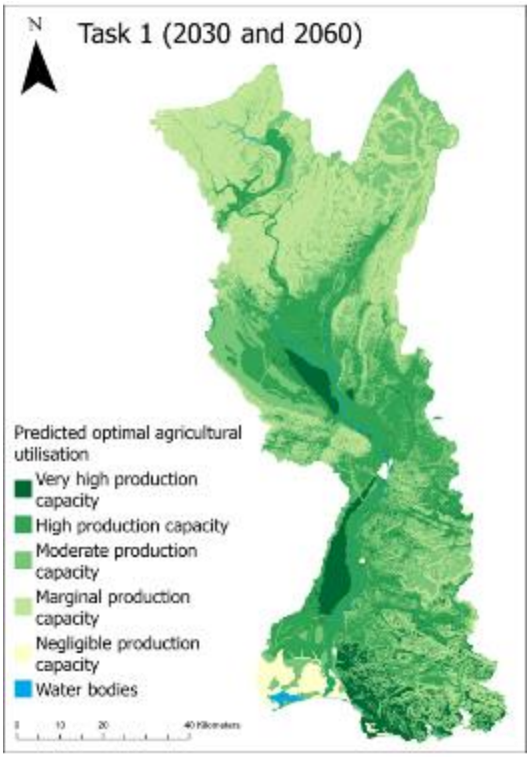


Figure A - 19: Predicted optimal agricultural utilisation for both 2030 and 2060.

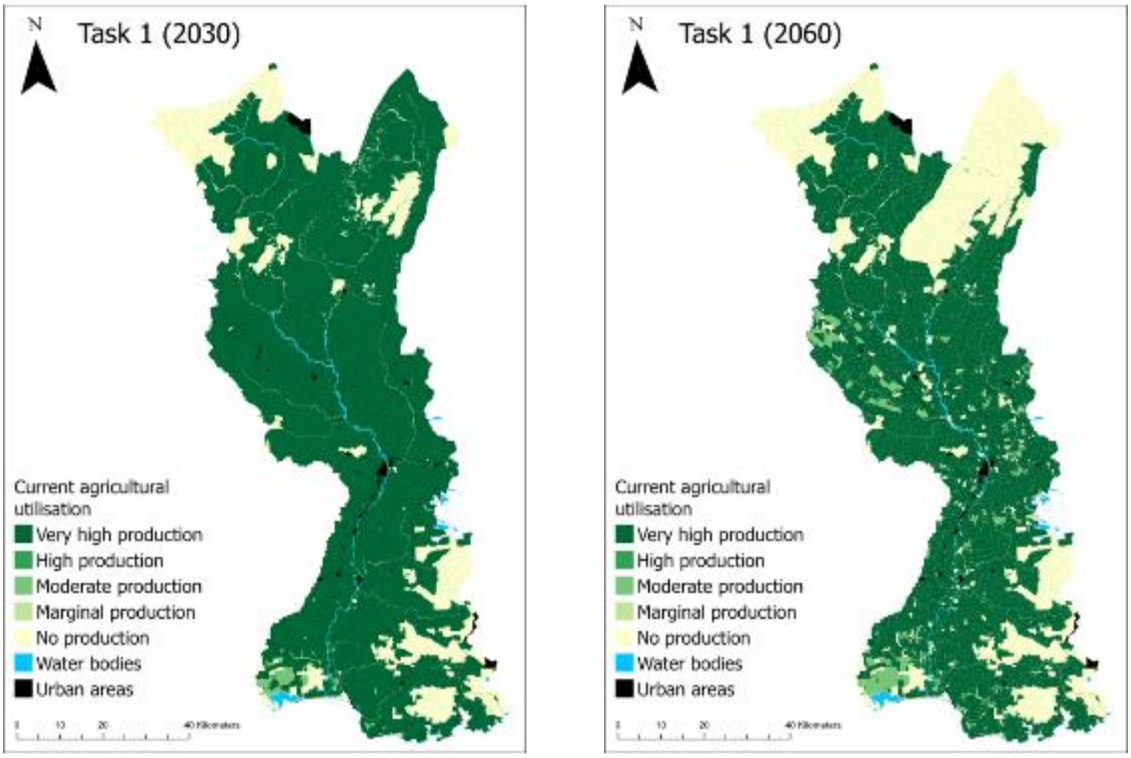


Figure A - 20. Current agricultural utilisation for 2030 and 2060.

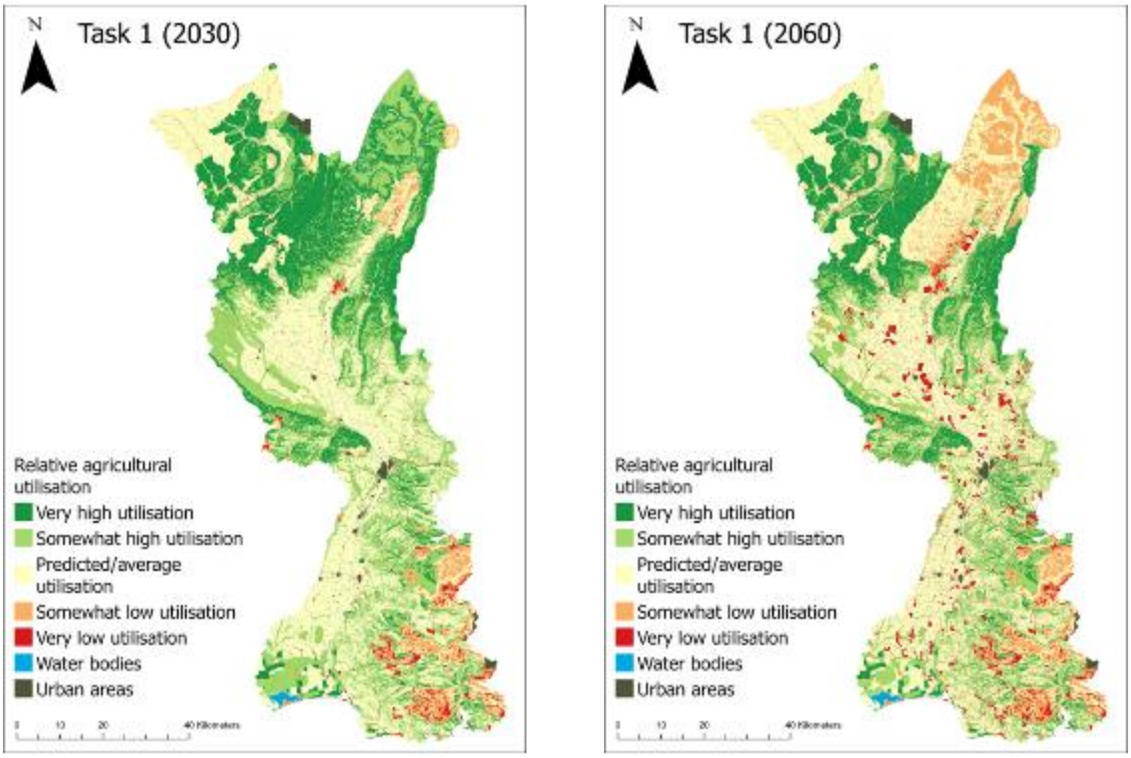


Figure A - 21: Relative agricultural utilisation for 2030 and 2060.

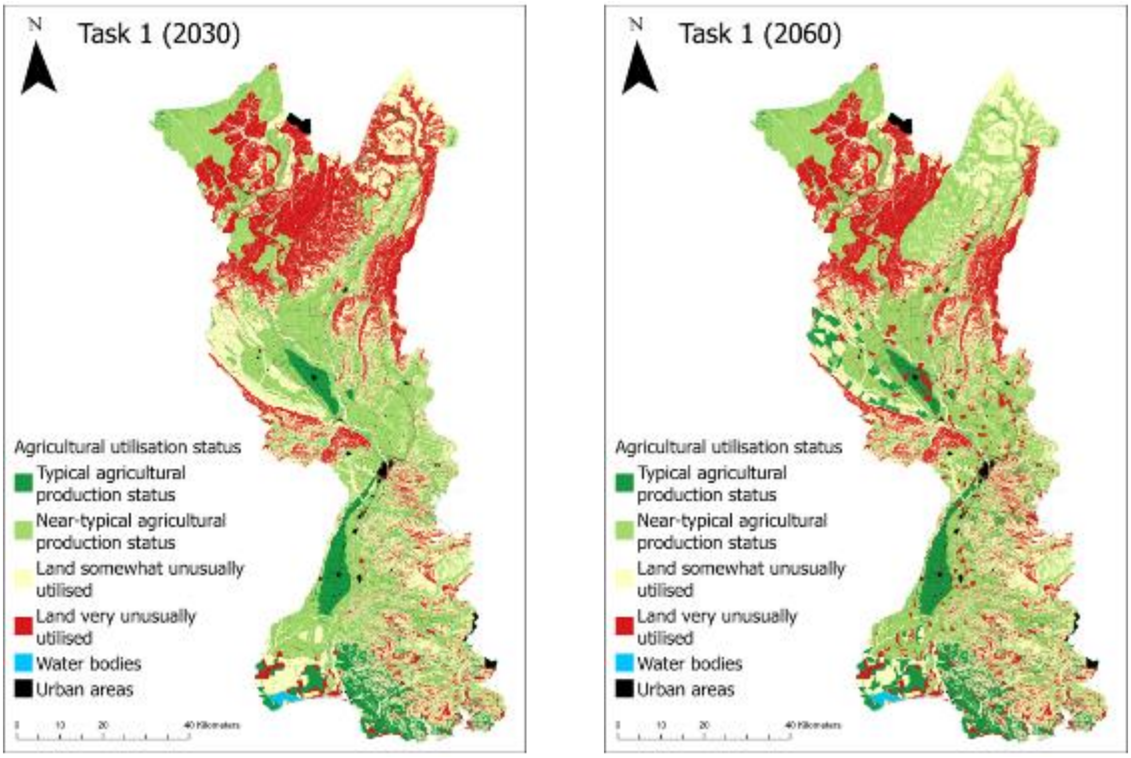


Figure A - 22: Agricultural utilisation status.

Table A - 22. Current agricultural utilisation percentages for baseline 2025, 2030, and 2060.

Current agricultural utilisation (%)	Baseline 2025	Task 1 2030	Task 1 2060
Very high production	79.74	78.55	63.59
High production	0.00	0.00	0.00
Moderate production	0.00	1.12	2.88
Marginal production	0.00	0.00	0.00
No production	15.51	16.07	29.30
Water bodies	2.89	2.46	2.46
Urban areas	1.86	1.80	1.77

Table A - 23. Relative agricultural utilisation percentages for baseline 2025, 2030, and 2060.

Relative agricultural utilisation (%)	Baseline 2025	Task 1 2030	Task 1 2060
Very high utilisation	28.43	21.45	16.6
Somewhat high utilisation	24.24	28.20	21.2
Predicted/average utilisation	38.57	40.24	43.63
Somewhat low utilisation	3.64	4.93	10.27
Very low utilisation	1.08	1.63	4.78
Water bodies	2.11	1.69	1.69
Urban areas	1.91	1.85	1.82

Nitrogen

This scenario had positive outcomes for nitrogen in 2030 and 2060 for both terrestrial load (Figure A - 23, Figure A - 24 and Table A - 24) and in-stream concentration (Figure A - 25 and Table A - 25). By 2060, the mean terrestrial load had decreased by 41.3% and the mean in-stream concentration had decreased by 51.3% relative to the baseline 2025. The addition of riparian planting in 2060 also saw a 98.3% relative decrease in the maximum in-stream concentration as the fencing/planting up of streams on livestock land limits stock access and deliveries of mass and associated nutrients to streams.

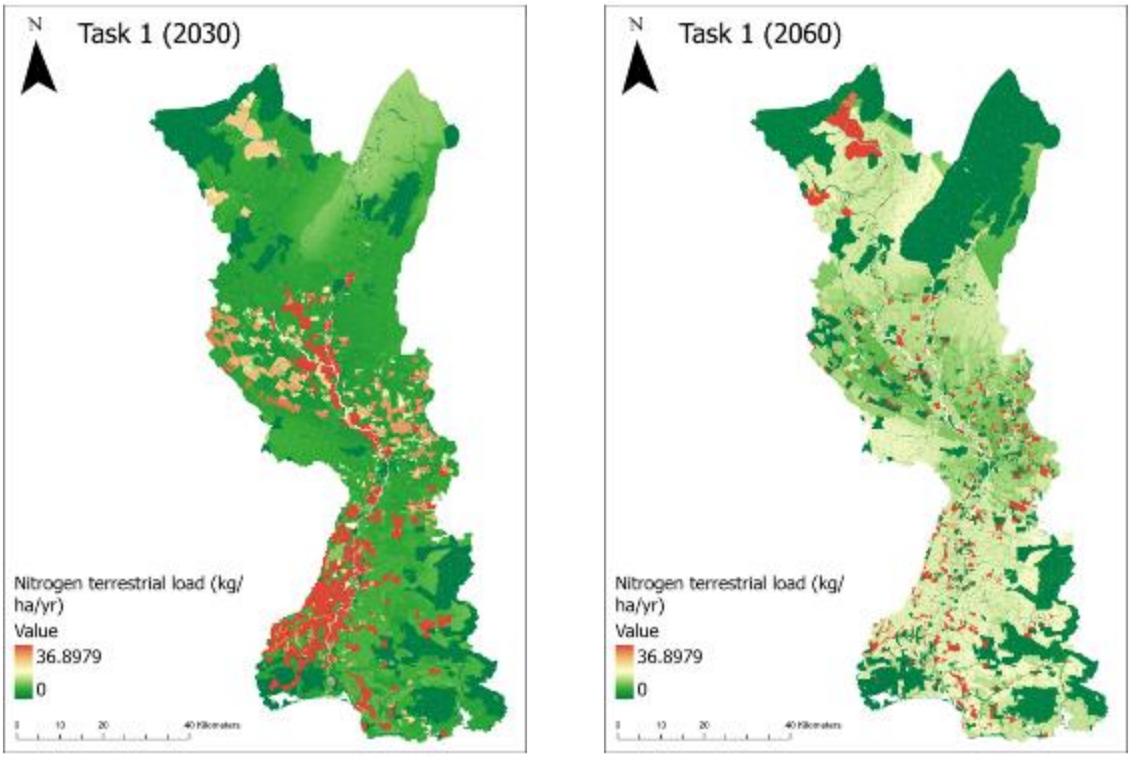


Figure A - 23: Nitrogen terrestrial load (kg/ha/yr) for 2030 and 2060.

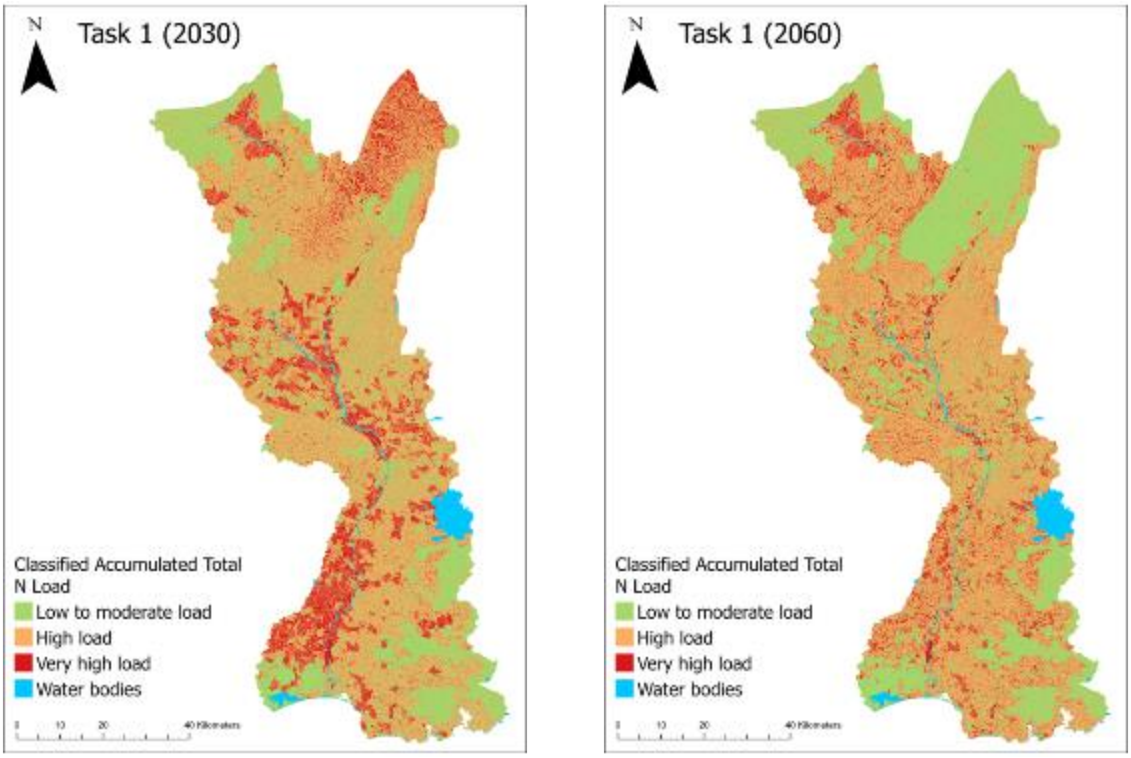


Figure A - 24: Classified accumulated total nitrogen load for 2030 and 2060.

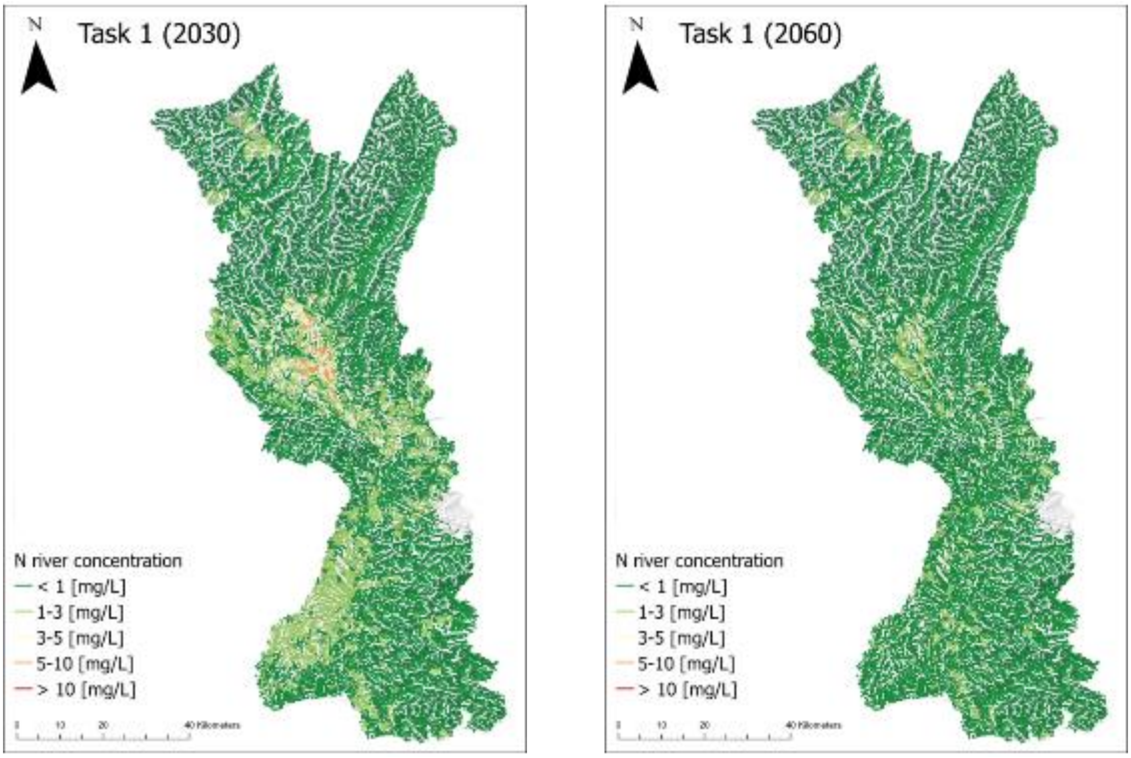


Figure A - 25: Nitrogen river concentration (mg/L) for 2030 and 2060.

Table A - 24. Summary statistics of nitrogen terrestrial loads for the baseline 2025, 2030, and 2060.

Nitrogen terrestrial load (kg/ha/yr)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Min	0.0	0.0	0.0	0.00	0.0
Median	6.6	4.0	5.7	-0.90	-13.7
Mean	8.7	6.8	5.1	-3.60	-41.3
95th percentile	30.3	30.3	11.0	-19.37	-63.9
Max	36.9	36.9	36.9	0.00	0.0

Table A - 25: Summary statistics of nitrogen stream concentration for the baseline 2025, 2030, and 2060.

Nitrogen stream concentration (mg/L)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Min	0.00	0.00	0.00	0.00	0.00
Median	0.52	0.28	0.37	-0.15	-29.2
Mean	0.76	0.54	0.37	-0.39	-51.3
95th percentile	2.38	2.26	0.96	-1.42	-59.7
Max	341.46	151.81	5.76	-335.70	-98.3

Phosphorus

Similar to nitrogen, this scenario had positive outcomes for phosphorus in 2030 and 2060 for both terrestrial load (Figure A - 26, Figure A - 27 and Table A - 26) and in-stream concentration (Figure A - 28 and Table A - 27) with greater relative changes compared to the baseline 2025. By 2060, the mean terrestrial load had decreased by 62.24% and the mean in-stream concentration decreased by 87.01% relative to the baseline 2025.

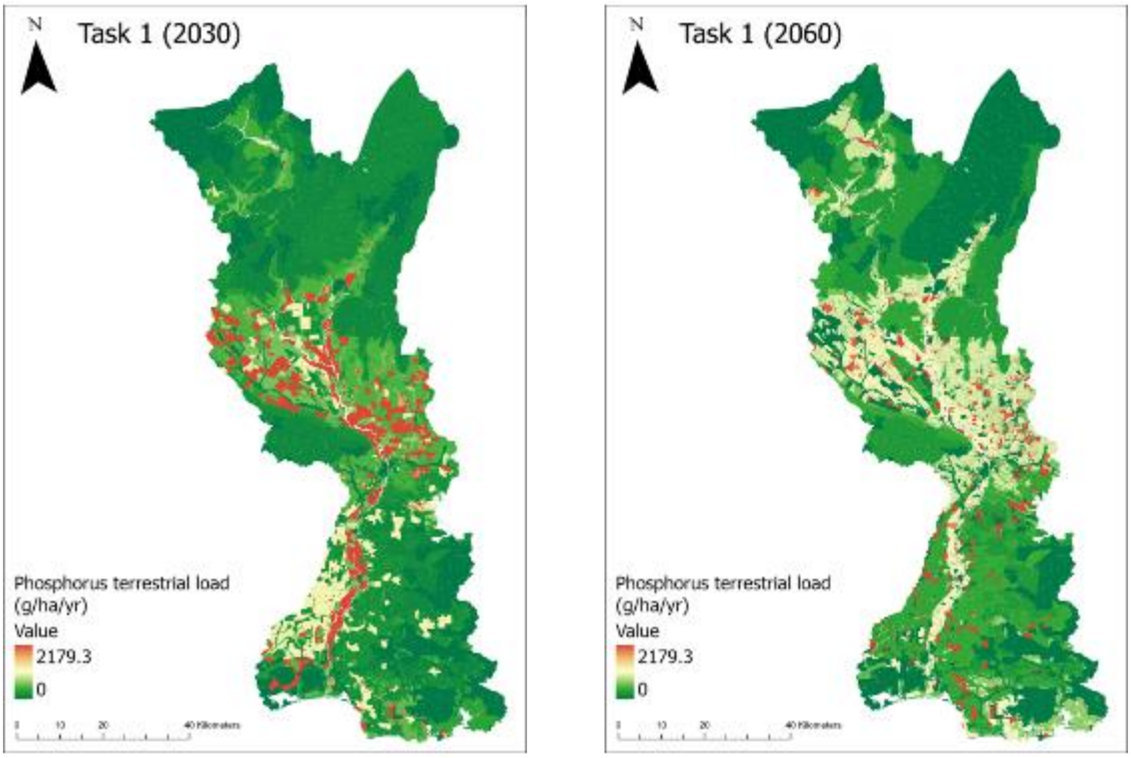


Figure A - 26: Phosphorus terrestrial load (g/ha/yr) for 2030 and 2060.

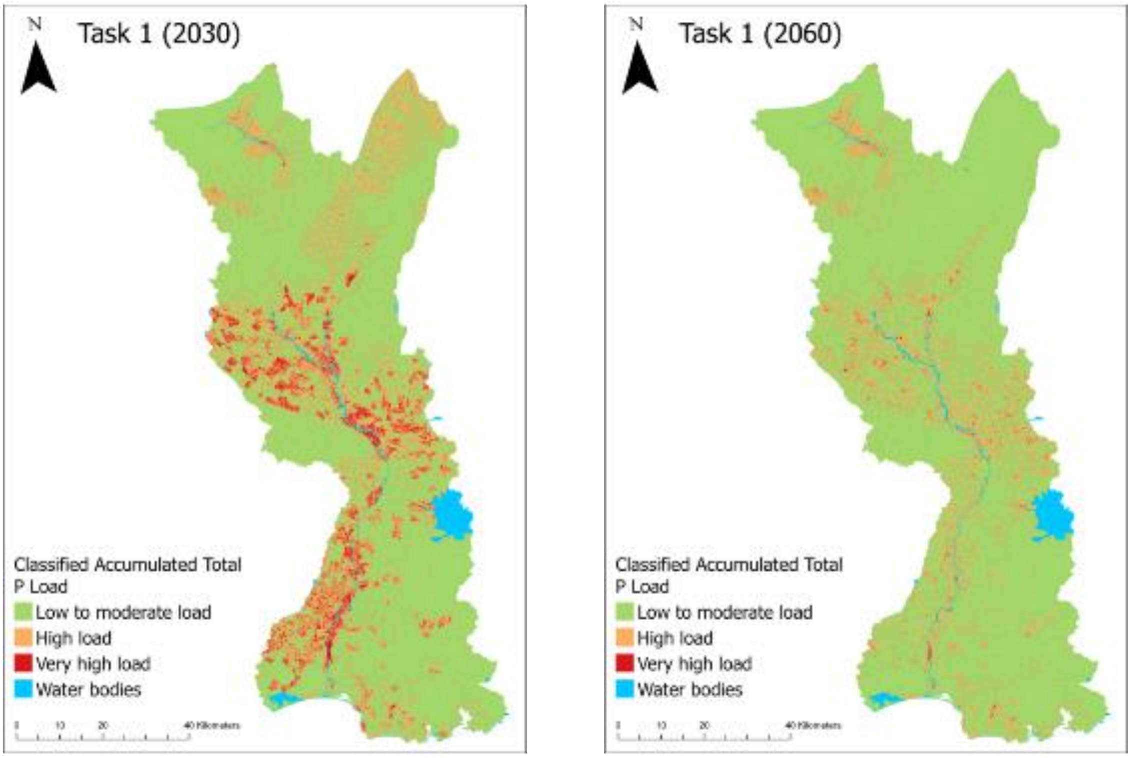


Figure A - 27: Classified accumulated total phosphorus load for 2030 and 2060.

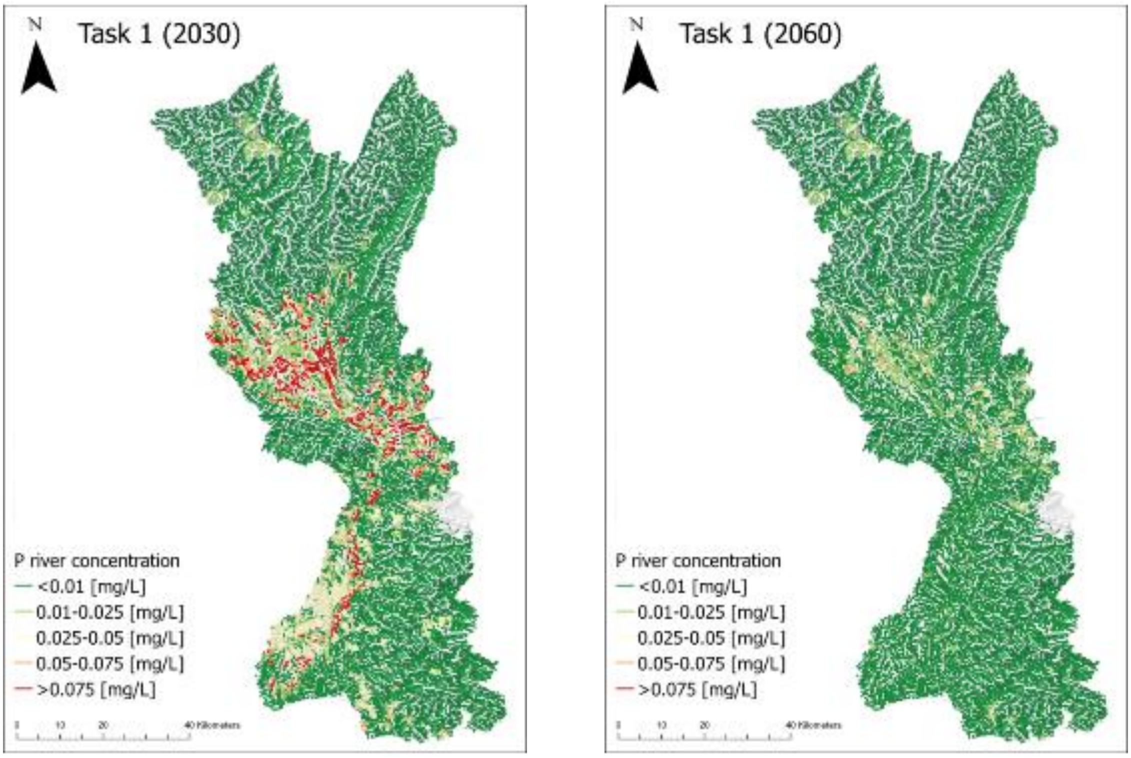


Figure A - 28: Phosphorus river concentration (mg/L) for 2030 and 2060.

Table A - 26. Summary statistics of phosphorus terrestrial loads for the baseline 2025, 2030, and 2060.

Phosphorus terrestrial load (g/ha/yr)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Min	0.00	0.00	0.00	0.00	0.00
Median	137.68	102.05	79.91	-57.77	-41.96
Mean	369.15	280.26	139.40	-229.75	-62.24
95th percentile	1,664.89	1,664.89	347.73	-1317.16	-79.11
Max	2,179.30	2,179.30	2,179.30	0.00	0.00

Table A - 27: Summary statistics of phosphorus stream concentration for the baseline 2025, 2030, and 2060.

Phosphorus stream concentration (mg/L)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Min	0.000	0.000	0.000	0.000	0.000
Median	0.008	0.0019	0.0013	-0.006	-83.37
Mean	0.020	0.010	0.003	-0.018	-87.01
95th percentile	0.082	0.048	0.010	-0.072	-87.76
Max	23.080	9.914	0.097	-22.983	-99.58

Flood mitigation

By 2030, the area of the catchment considered mitigating or having the capability to intercept flows of water, mass, sediments, and nutrients before reaching the streams increases by 342,415ha (Figure A - 30). The woody biomass associated with the new Agroforestry systems are assumed to have a greater capability of mitigating flows compared to conventional pasture. In 2060, the area taken up by mitigating features increases by 468,146ha or 472.61% relative to the baseline 2025 (Figure A - 29 and Table A - 28).

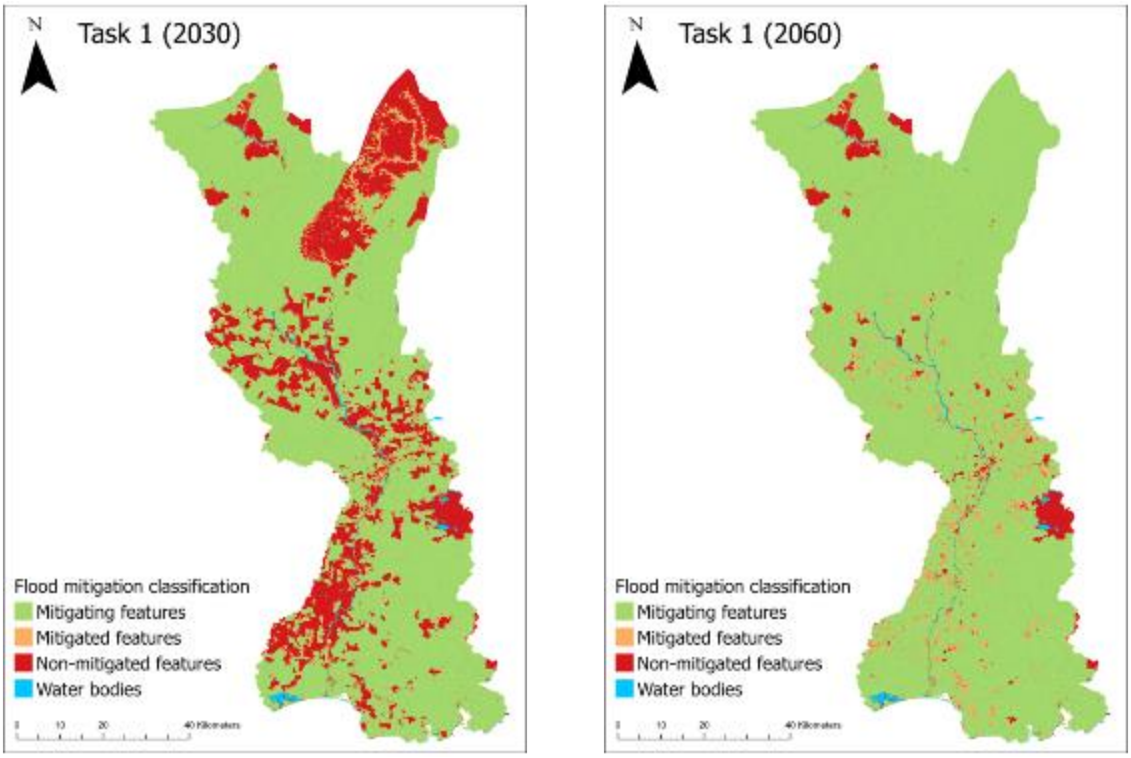


Figure A - 29. Flood mitigation classification for 2030 and 2060.

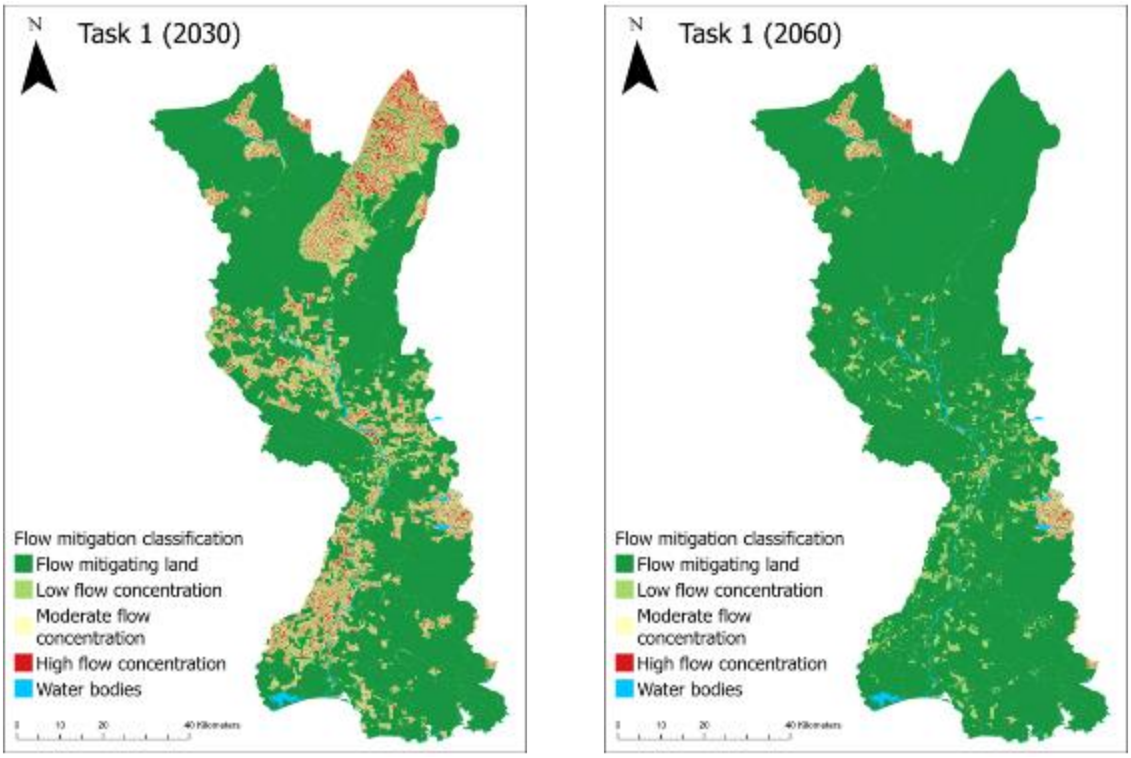


Figure A - 30. Flow mitigation classification.

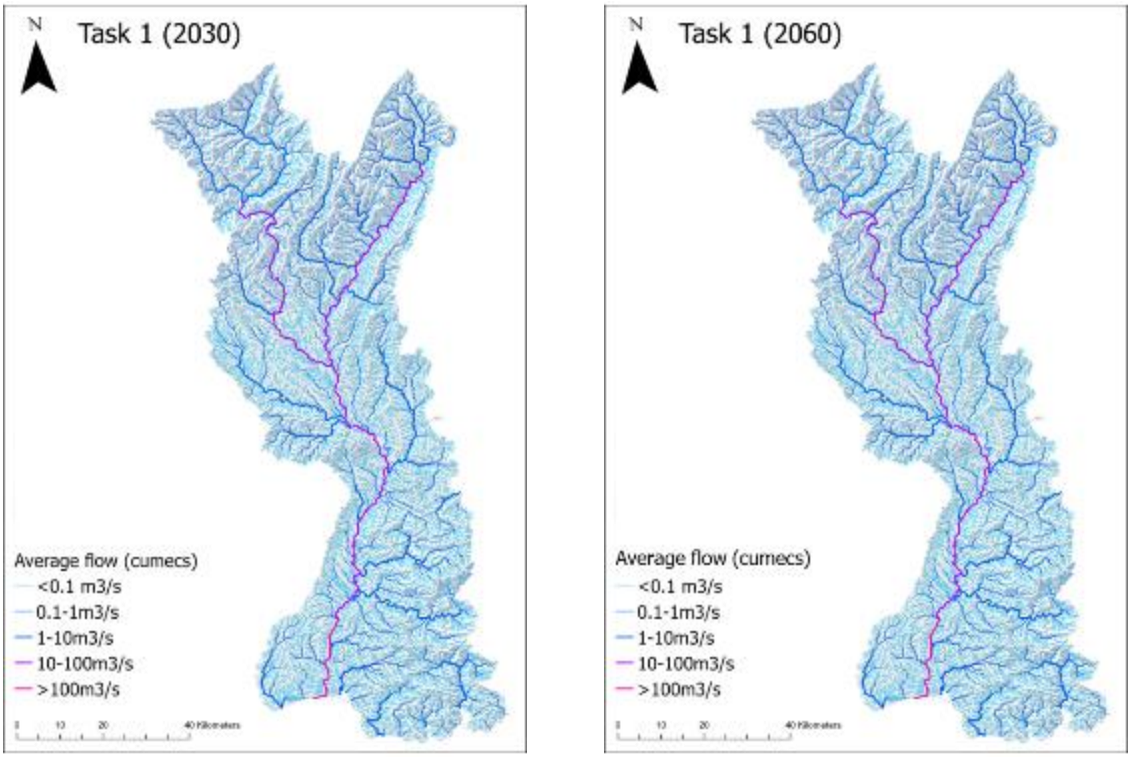


Figure A - 31. Average flow (cumecs) for 2030 and 2060.

Table A - 28. Flood mitigation classification (ha) for baseline 2025, 2030, and 2060.

Flood mitigation classification (ha)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Mitigating features	99,056	441,471	567,202	468,146	472.61
Mitigated features	23,976	33,385	30,415	6,439	26.85
Non-mitigated features	498,245	149,458	27,094	-471,151	-94.56
Water bodies	17,315	14,578	14,182	-3,134	-18.10

RUSLE

With conversions to Agroforestry less vulnerable to erosion, the areas of the Mataura catchment vulnerable to soil loss are mainly in the northern end of the catchment by both 2030 and 2060 (Figure A - 33). However, by 2060, the conversion to Exotic Forestry sees an increase in the mean (37.10%), 95th percentile (75.76%), and maximum (2%) soil losses relative to the baseline 2025 (Figure A - 32 and Table A - 29).

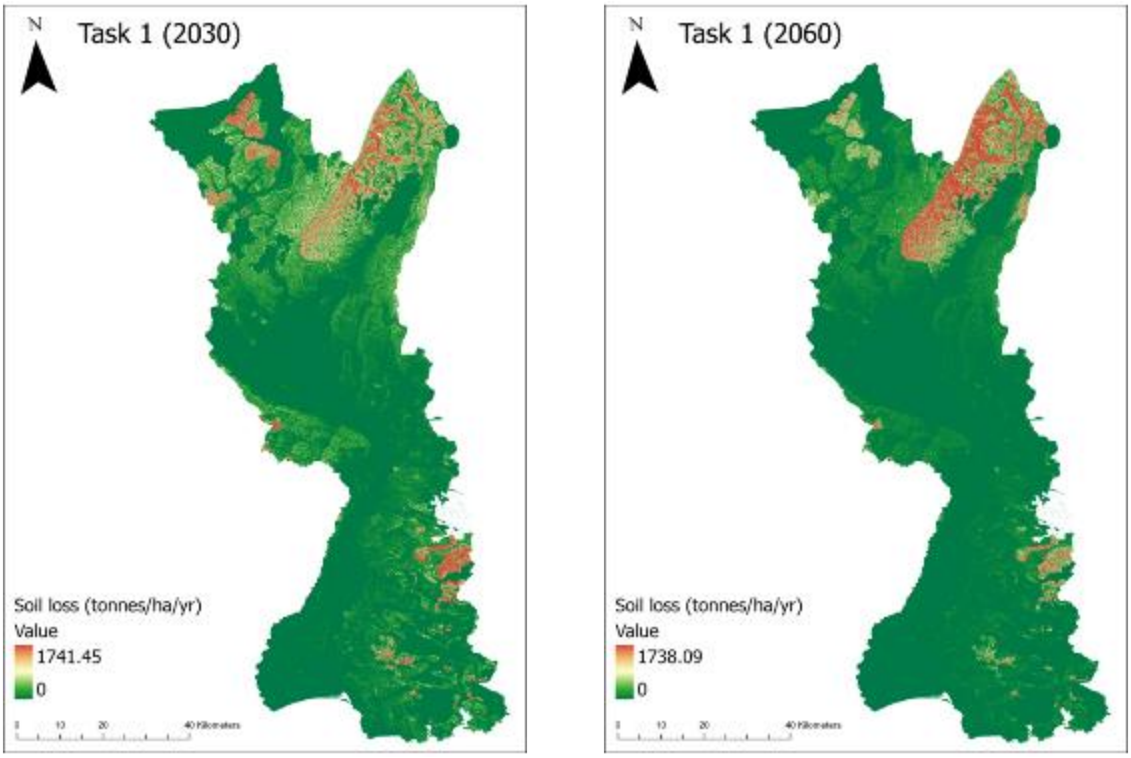


Figure A - 32. Soil loss (tonnes/ha/yr) for 2030 and 2060.

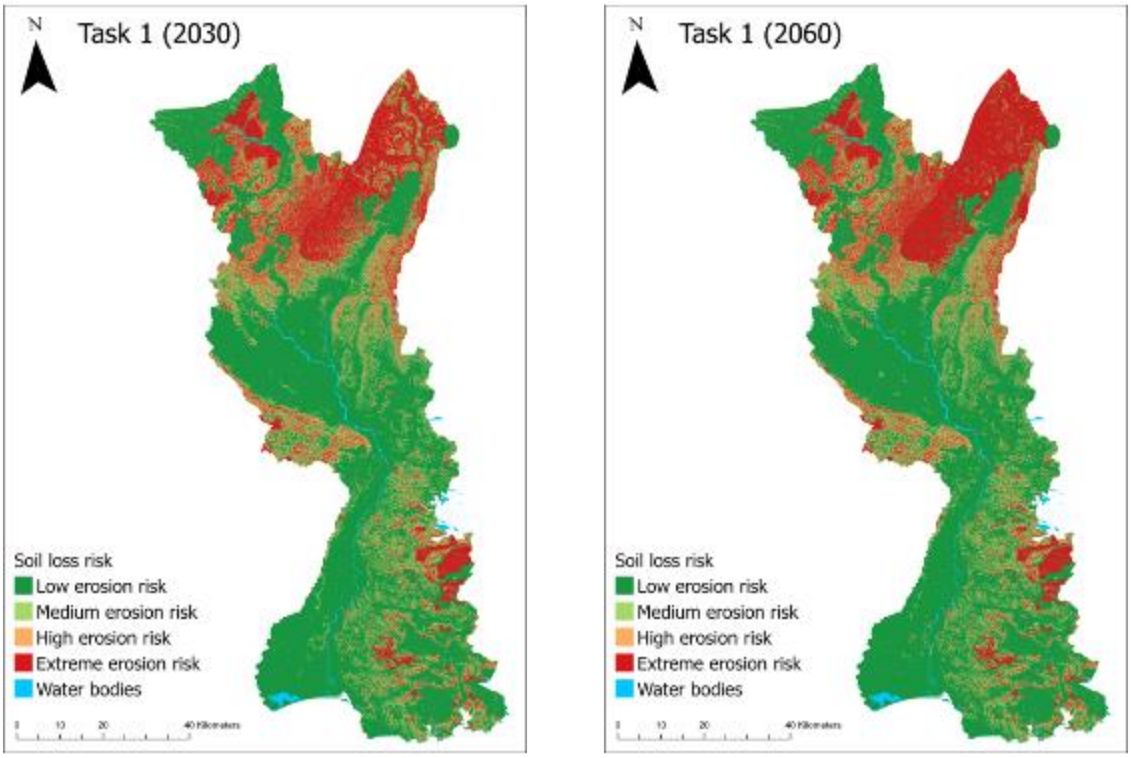


Figure A - 33. Soil loss risk for 2030 and 2060.

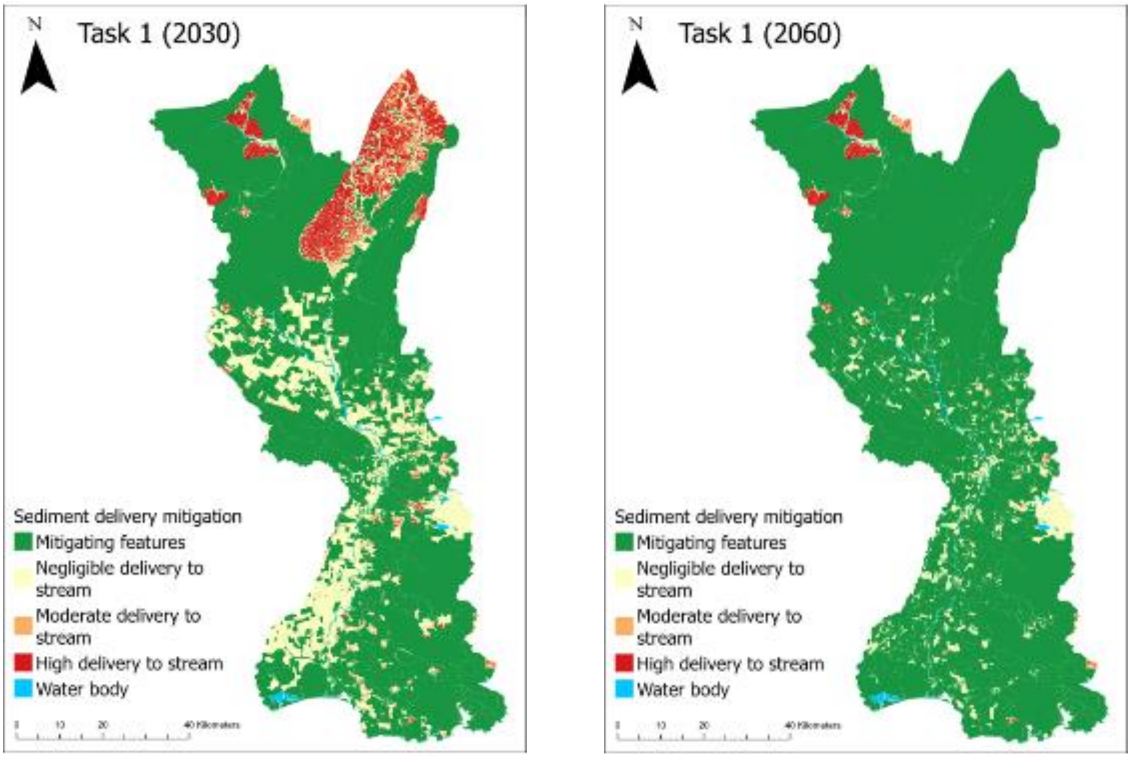


Figure A - 34. Sediment delivery mitigation for 2030 and 2060.

Table A - 29. Summary statistics for soil loss for the baseline 2025, 2030, and 2060.

Soil loss (tonnes/ha/yr)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Min	0.0	0.0	0.0	0.00	0.00
Median	1.7	1.2	1.1	-0.65	-37.00
Mean	10.6	7.7	14.5	3.92	37.10
95th percentile	46.7	35.1	82.1	35.39	75.76
Max	1,704.1	1,741.4	1,738.1	34.03	2.00

Habitat connectivity

The combination of native tree species in the Agroforestry systems are understood to be ideal for kererū based on previous literature describing their diet. By 2060, the amount of ideal habitat for kererū increased by 376,175ha or 457.34% relative to the baseline 2025 (Figure A - 35 and Table A - 30).

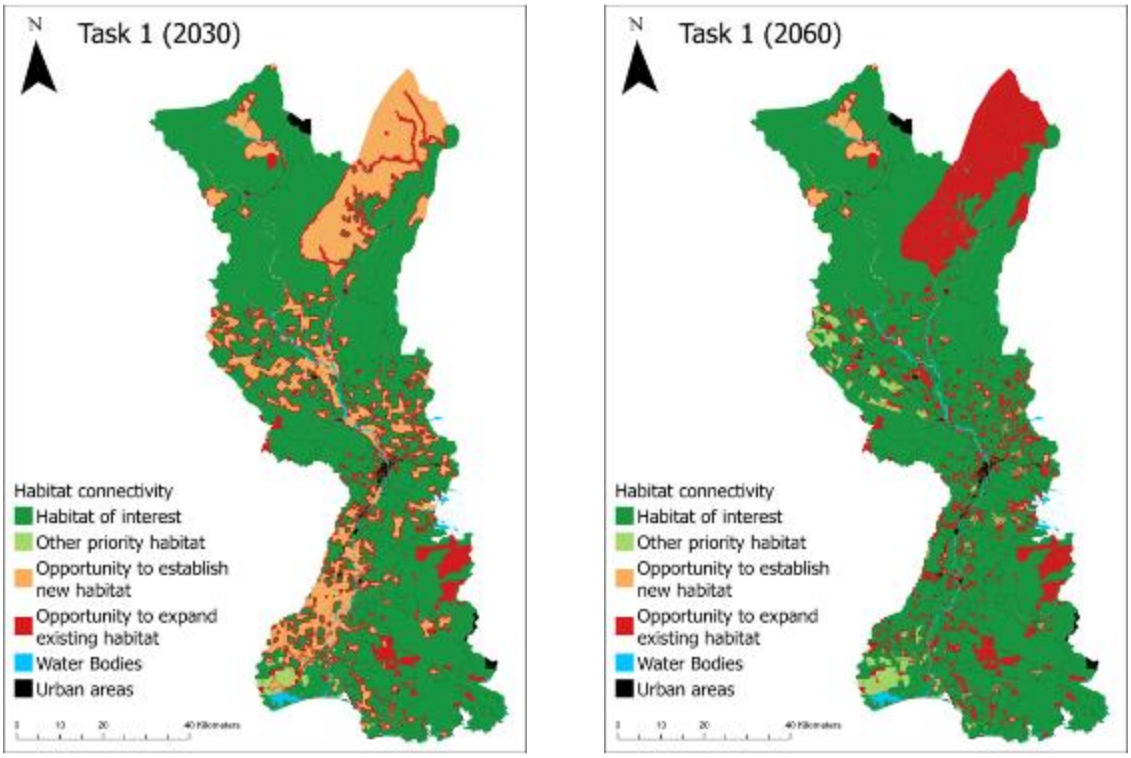


Figure A - 35. Habitat connectivity for 2030 and 2060.

Table A - 30. Habitat classification for baseline 2025, 2030, and 2060.

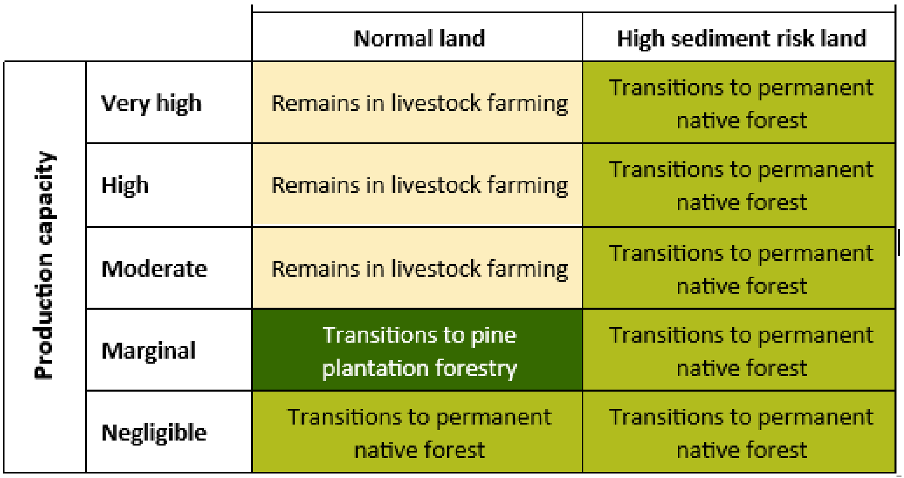
Habitat classification (ha)	Baseline 2025	Task 1 2030	Task 1 2060	Absolute change in 2060	Change in 2060 relative to baseline 2025 (%)
Habitat of interest	82,253	413,381	458,428	376,175	457.34
Other priority habitat	0	7,066	18,190	18,190	-
Opportunity to establish new habitat	460,450	103,781	8,450	-452,000	-98.16
Opportunity to expand existing habitat	60,060	81,559	120,899	60,839	101.30

A13 – Scenario 1A (2060) - Variation: Conversion of marginal pastoral land to permanent native forest

Following consultation in the Mataura, an additional scenario was requested by the Parliamentary Commissioner for the Environment to explore the impact of converting marginal land to indigenous vegetation.

This appendix describes the additional modelled scenario: *A scenario where marginal pastoral land is converted to permanent native forest instead of plantation forest in Mataura for 2060.*

This scenario explores the effect of retiring livestock farming land to permanent native forest or pine plantation forestry depending on sediment risk and production capacity according to Figure A - 36. For Mataura, the areas of high sediment risk land were identified using the Nature Braid erosion output showing areas of high sediment delivery. The predicted agricultural production capacity layer from Nature Braid was used to identify production capacity as per Figure A - 36. For modelling purposes, we have interpreted pine plantation forestry as 'Exotic forestry' and permanent native forest as 'Indigenous Vegetation' in the Nature Braid model.



		Normal land	High sediment risk land
Production capacity	**Very high**	Remains in livestock farming	Transitions to permanent native forest
	High	Remains in livestock farming	Transitions to permanent native forest
	Moderate	Remains in livestock farming	Transitions to permanent native forest
	Marginal	Transitions to pine plantation forestry	Transitions to permanent native forest
	Negligible	Transitions to permanent native forest	Transitions to permanent native forest

Figure A - 36. Land transition rules for the mixed farm-forestry scenario as requested by PCE.

Following are the methods and assumptions made in this new scenario including parameterisation of Exotic forestry and Indigenous Vegetation in Nature Braid (which are the same across the report but the parameters are explicitly presented here), the results of the economic analysis and environmental analysis.

Methods and Assumptions

- For the purpose of this scenario (Task 2), the land use changes will only occur on the livestock land use classes specified in the introduction. No other changes in land use or management are occurring on any other land use classes in the Mataura. In the Mataura, the land use classes changing are:
  - Dairy
  - Dairy Support
  - High Country Sheep and Beef
  - Hill Country Sheep and Beef
  - Lowland Beef Finishing

- For the areas that remain in livestock farming under land that has normal sediment risk and very high to moderate production capacity, there are no changes in management (e.g. stocking rate, fertiliser, etc).
- Erosion under Exotic Forestry (pine plantation) is modelled assuming a 28-year rotation wherein 6 years are considered "vulnerable" to soil erosion under extreme events such as landslides or heavy rainfall events (Baillie et al., 2015).
- The Indigenous Vegetation (permanent native forest) is not harvested after planting and is assumed to be established and have continuous cover by 2060.
- Biophysical modelling is done for one timestamp (2060) where the Indigenous Vegetation is already established, not considering the period of early growth and establishment after the land has been retired and grazing has stopped.

Parameterisation of Exotic Forestry and Indigenous Vegetation within Nature Braid

Parameterisation was based on previous literature, previous parameterisation of similar land covers within Nature Braid, and consultation with experts. Table A - 31 below shows an overview of these values, followed by justification in the bullet points below.

Table A - 31. Parameterisation table within Nature Braid for Exotic Forestry and Indigenous Vegetation

Land use	Flow Mitigating ability (classified)	Agricultural production (classified)	C-factor	Ideal habitat for kererū?	Resistance to kererū (classified)	Nitrogen multiplier (1 = arable land, conventional agriculture, deer, beef)	Phosphorus multiplier (1 = arable land, conventional agriculture, deer, beef)
Exotic Forestry (LUcode = 200)	2	5	0.218	0 (No)	1	0.054545	1.692308
Indigenous Vegetation (LUcode = 203)	2	5	0.002	1 (Yes)	1	0.131818	0.2115385

- Flow mitigating ability = 2 as these land uses (when established) can mitigate flow
- Agricultural production = 5
  - Considered non-productive (i.e. cannot support stock grazing)
- C-factor:
  - Exotic Forestry value based on weighted average of values the same as Indigenous Vegetation (0.002 to represent established vegetation) and extreme value (1)
  - Indigenous Vegetation value is based on previous literature around established native forests
- Ideal habitat for kererū:
  - No for Exotic Forestry
  - Yes for Indigenous Vegetation
- Resistance to kererū = 1
  - Both land uses are assumed to be easy for kererū to fly through.

- Nutrient parameterisation:
    - Since we are assuming no grazing, we have assumed the nitrogen and phosphorus parameterisation value to be the national average used in the default Nature Braid for Indigenous Vegetation and Exotic Forestry.

Results

Economics results

For the economic analysis in this Scenario 1A - Variation:

1. All land exposed to high sediment risk and all negligible production capacity livestock land has been prioritised to transition to Indigenous Vegetation, and all marginal production capacity livestock land has transitioned to Exotic Forestry.
2. All moderate, high, and very high production capacity livestock land that has normal or low sediment risk remains in the existing use.

The following table (A – 32) shows the land areas exposed to high sediment risk. As described in point 1 above, all of this land is transitioned to Indigenous Vegetation.

Table A - 32. Land exposed to high sediment risk in the Mataura to transition to Indigenous Vegetation.

Land Area exposed to high sediment risk 2060 (ha)	Very high production capacity	High production capacity	Moderate production capacity	Marginal production capacity	Negligible production capacity	Total
Dairy	24	62	904	1,253	2	2,245
Dairy Support	13	31	615	942	1	1,602
Lowland Sheep and Beef	90	227	5,011	10,120	36	15,484
Hill Country Sheep and Beef	72	116	9,372	74,490	2,557	86,606
High Country Sheep and Beef	2	3	7,022	27,014	1,098	35,139
Mixed Cropping	0	1	2	3	0	6
Total	202	439	22,926	113,821	3,694	141,083

Land that is not exposed to high sediment risk but has marginal or negligible production capacity will also be transitioned per the scenario rules (point 1 above) is set out in Table A - 33. A comparison of the land use change under Scenario 1A – Variation compared to Scenario 1A is provided in Table A - 34.

Table A - 33. Other land transitions in the Mataura by 2060.

Other transitions (ha)	Marginal production capacity	Negligible production capacity	Total
Dairy	804	4,041	4,845
Dairy Support	611	342	953
Lowland Sheep and Beef	6,292	3,760	10,052
Hill Country Sheep and Beef	26,971	605	27,576
High Country Sheep and Beef	9,911	414	10,325
Mixed Cropping	2	0	2
Total	**44,591**	**9,161**	**53,752**

Table A - 34: Land use change in the Mataura under Scenario 1A - Variation compared to Scenario 1A.

Land use change (ha)	Baseline 1A (2025)	Change	2060
Dairy	80,520	-7,090	73,430
Dairy Support	21,425	-2,555	18,870
Lowland Sheep and Beef	156,652	-25,536	131,117
Hill Country Sheep and Beef	170,597	-114,182	56,414
High Country Sheep and Beef	60,554	-45,464	15,090
Mixed Cropping	2,268	-7	2,260
Wetlands	2,992	0	2,992
Indigenous Vegetation	83,363	150,244	233,607
Exotic Forestry	15,999	44,591	60,590
Total	**594,370**	0	**594,370**

- The results show all agriculture land uses decline in profitability as a result of reduced land use and the increase in the emissions levy over time.
- The move to more plantation of Exotic Forestry increases overall catchment profitability (Table A - 35).

Table A - 35: Profitability change in the Mataura under Scenario 1A - Variation compared with the baseline.

	Baseline (2025)	Catchment profitability change	Scenario 1A (2060) - Variation
Dairy	$279,721,188	-$95,830,885	$183,890,303
Dairy support	$7,448,769	-$14,452,950	-$7,004,181
Lowland Sheep and Beef	$108,800,846	-$22,349,091	$86,451,755
Hill Country Sheep and Beef	$39,182,789	-$38,180,530	$1,002,259
High Country Sheep and Beef	$3,885,902	-$4,162,290	-$276,388
Mixed Cropping	$2,840,870	-$1,006,813	$1,834,057
Wetlands	$74,803	$2,168,901	$2,243,703
Indigenous Vegetation	$0	$0	$0
Exotic Forestry	$21,820,149	$375,902,074	$397,722,223
Total	$463,775,315	$202,088,416	$665,863,732

Environmental results

- By 2060, the mixed farm-forestry scenario had decreases in the mean terrestrial nitrogen (8.7 kg N/ha/yr to 6.6 kg N/ha/yr) and phosphorus (369.1 g P/ha/yr to 306.8 g P/ha/yr) loads. Both nitrogen and phosphorus in-stream concentration decreased in terms of the mean values (0.8 mg N/L to 0.5 mg N/L; 0.02 mg P/L to 0.014 mg/L) and greatly decreased in maximum values (341.5 mg N/L to 96.2 mg N/L; 23.08 mg P/L to 14.7 mg/L).
- The addition of Indigenous Vegetation and Exotic Forestry presented large increases in the amount of flood mitigating features (+193,273ha), potential habitat for kererū (+149,659ha), and connectivity throughout the catchment (+186,375ha).
- The mean terrestrial soil loss decreased with the transitions to Indigenous Vegetation in the steeper areas of the catchment from livestock farming (10.6 tonnes/ha/yr to 6.8 tonnes/ha/yr).

The updated land use map is shown in Figure A - 37, showing large transitions to Indigenous Vegetation and Exotic Forestry around the catchment.

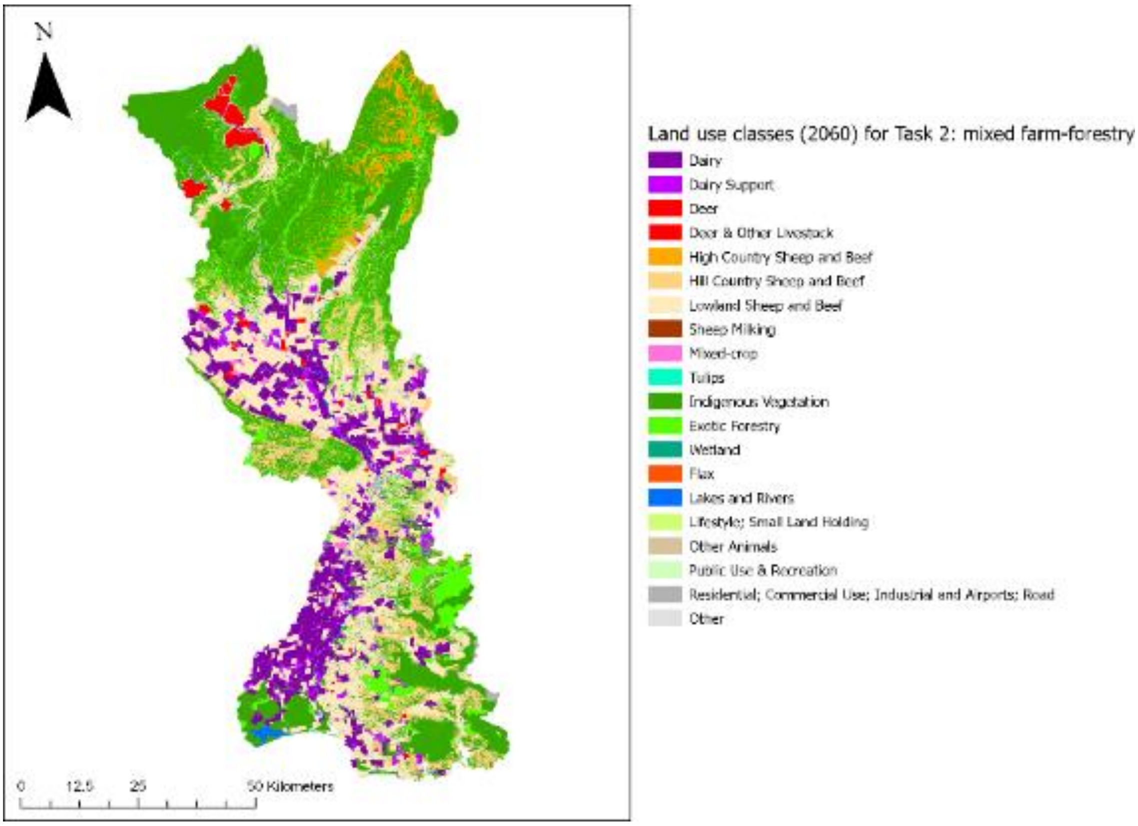


Figure A - 37. Land use map for 2060 under Scenario 1A – Variation .

Agricultural productivity

The predicted optimal agricultural utilisation is the same as the baseline, as this is driven by underlying soil, climate, topography, etc. Retiring livestock farming to Indigenous Vegetation and Exotic Forestry reduced the amount of land considered to have high production (79.74% to 49.13%; Figure A - 38 and Table A - 36) and land considered to have very high utilisation that is potentially over-utilised (28.43% to 1.14%; Figure A - 38 and Table A - 37). The area of the catchment where the actual use is appropriate for its agricultural capacity increased from 38.57% in the baseline 2025 to 60.77% in the 2060 scenario (Figure A - 38 and Table A - 37).

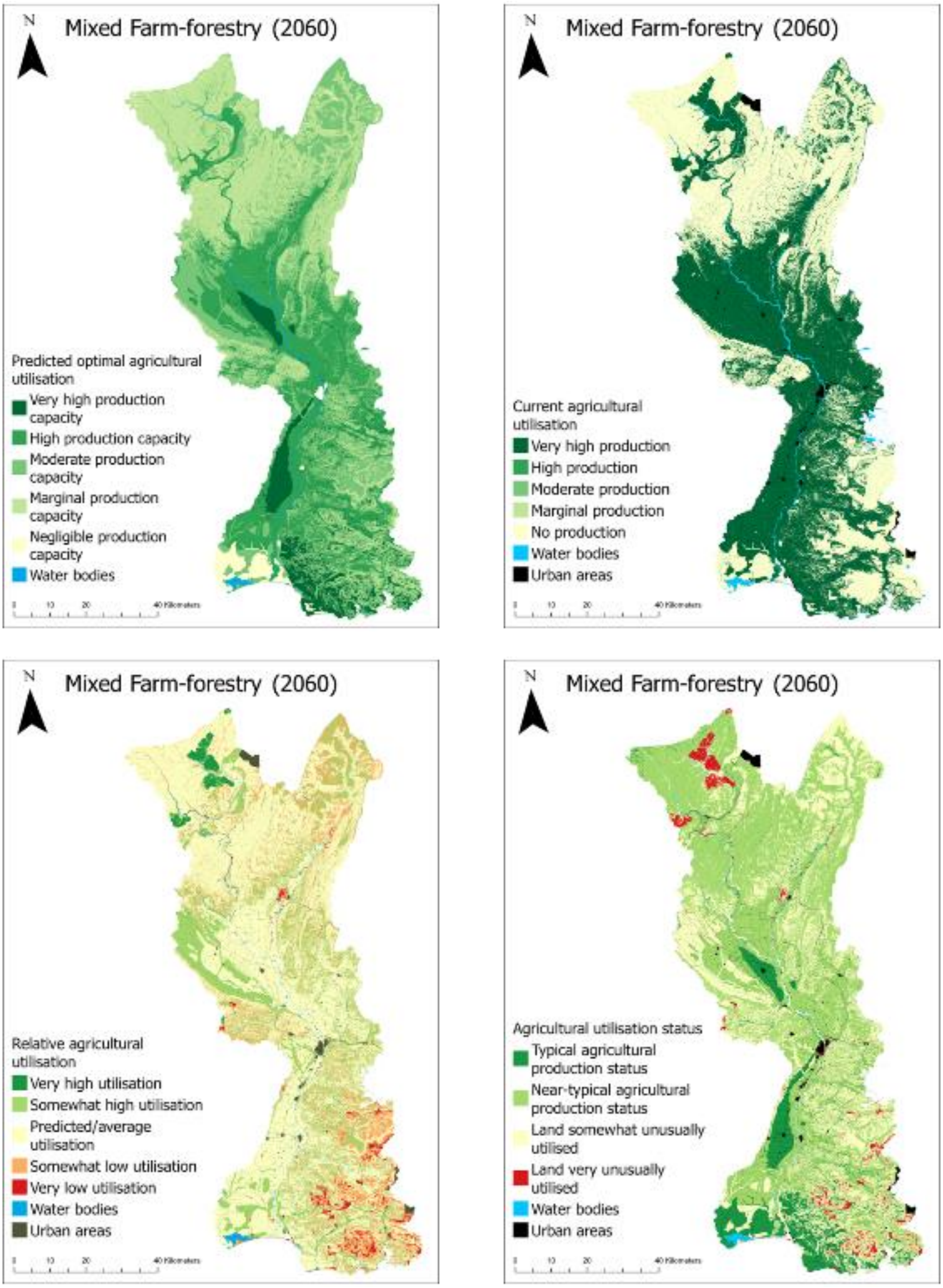


Figure A - 38. Results of agricultural productivity: predicted agricultural utilisation, current agricultural utilisation, agricultural utilisation status and relative agricultural utilisation.

Table A - 36: Current agricultural utilisation percentages for the baseline 2025 and 2060 scenario.

Current agricultural utilisation	Baseline 2025 (%)	Mixed farm-forestry 2060 (%)
Very high production	79.74	49.13
High production	0.00	0.00
Moderate production	0.00	0.00
Marginal production	0.00	0.00
No production	15.51	46.11
Water bodies	2.89	2.90
Urban areas	1.86	1.86

Table A - 37: Relative agricultural utilisation percentages for the baseline 2025 and 2060 scenario.

Relative agricultural utilisation	Baseline 2025 (%)	Mixed farm-forestry 2060 (%)
Very high utilisation	28.43	1.14
Somewhat high utilisation	24.24	18.22
Predicted/average utilisation	38.57	60.77
Somewhat low utilisation	3.64	14.18
Very low utilisation	1.08	1.65
Water bodies	2.11	2.13
Urban areas	1.91	1.92

Nitrogen

Retiring livestock farming showed decreases in the mean terrestrial nitrogen load (-2.2 kg N/ha/yr) compared to the baseline 2025 (Figure A - 39 and Table A - 38). The additional effect of these changes can be seen in the in-stream nitrogen concentrations, with the mean concentration decreasing by over a quarter (-0.2 mg/L) and the maximum concentration being 28% of the baseline 2025 value (Figure A – 39 and Table A - 39).

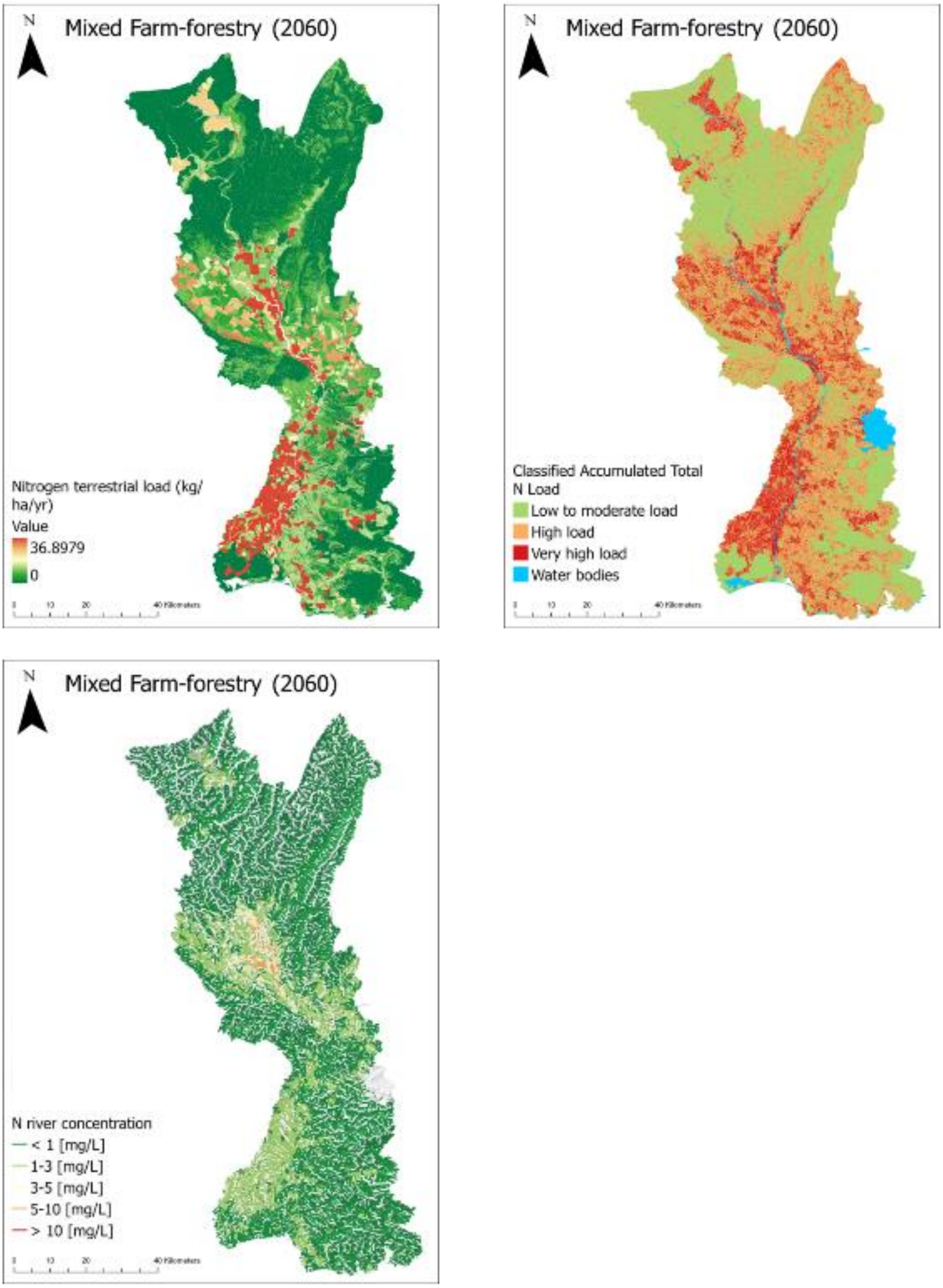


Figure A - 39. Results of nitrogen (N): terrestrial load, accumulated load classification and in-stream concentration for 2060.

Table A - 38: Summary statistics of nitrogen terrestrial loads for the baseline 2025 and 2060 scenario.

Nitrogen terrestrial load (kg/ha/yr)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Min	0.0	0.0	0.0	0.0
Median	6.6	4.1	-2.5	-37.7
Mean	8.7	6.6	-2.2	-24.7
95th percentile	30.3	30.3	0.0	-0.1
Max	36.9	36.9	0.0	0.0

Table A - 39: Summary statistics of in-stream nitrogen concentration for the baseline 2025 and 2060 scenario.

Nitrogen stream concentration (mg/L)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Min	0.0	0.0	0.0	0.0
Median	0.5	0.2	-0.3	-58.9
Mean	0.8	0.5	-0.2	-27.7
95th percentile	2.4	2.2	-0.1	-6.0
Max	341.5	96.2	-245.3	-71.8

Phosphorus

The results for phosphorus are similar to the nitrogen outcomes, with mean terrestrial load (-62.4 g/ha/yr) and mean in-stream phosphorus concentration (-0.0063 mg/L) decreasing from the baseline 2025 values (Figure A - 40, Table A - 40 and Table A - 41). The maximum value of in-stream phosphorus concentration decreased to 63% of the baseline 2025 value.

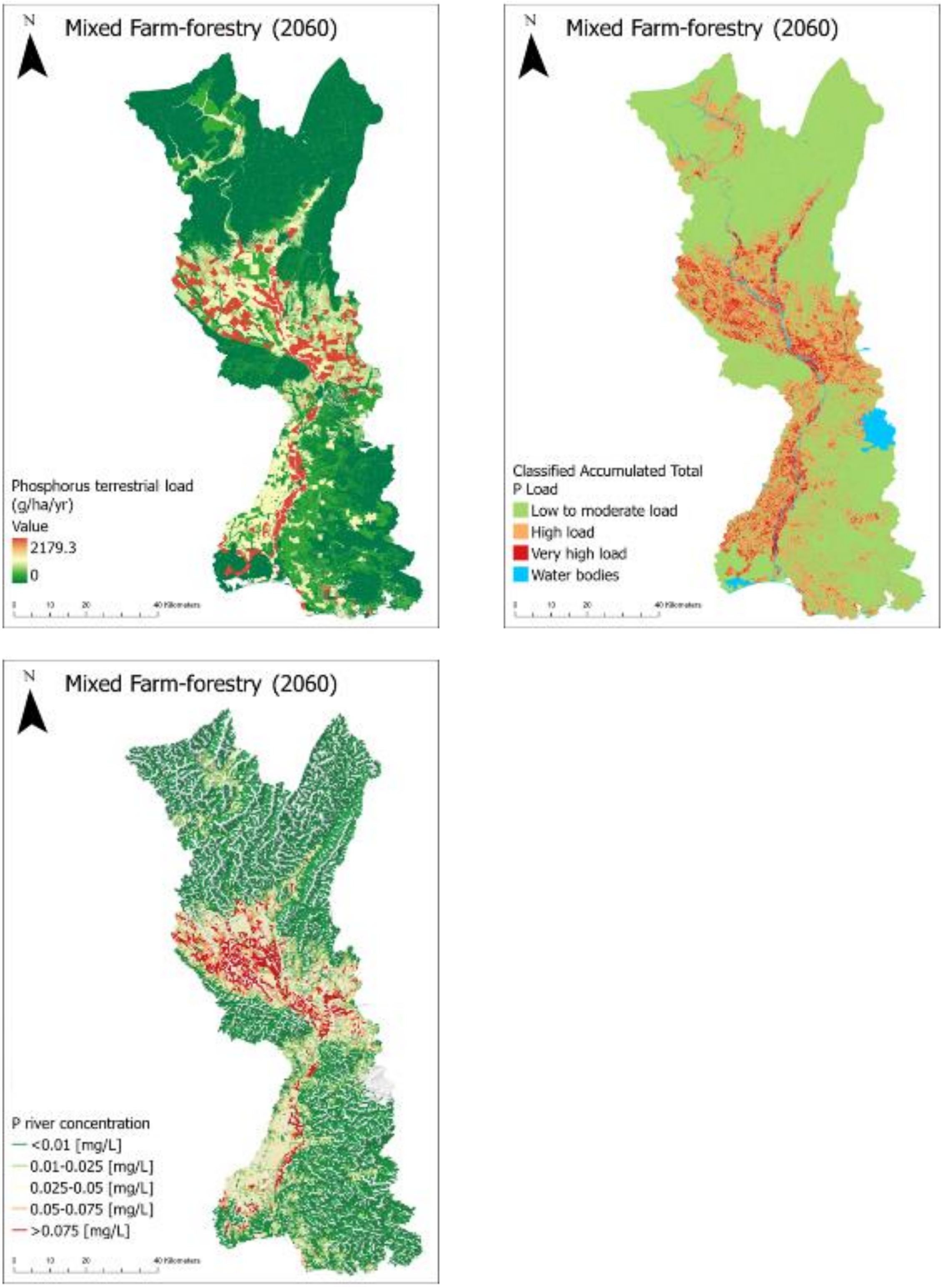


Figure A - 40. Results of phosphorus (P): terrestrial load, accumulated load classification and in-stream concentration for 2060.

Table A - 40: Summary statistics of phosphorus terrestrial loads for the baseline 2025 and 2060 scenario.

Phosphorus terrestrial load (g/ha/yr)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Min	0.00	0.00	0.0	0.0
Median	137.68	64.53	-73.2	-53.1
Mean	369.15	306.76	-62.4	-16.9
95th percentile	1664.89	1664.89	0.0	0.0
Max	2179.30	2179.30	0.0	0.0

Table A - 41. Summary statistics of in-stream phosphorus concentration for the baseline 2025 and 2060 scenario.

Phosphorus stream concentration (mg/L)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Min	0.000	0.000	0.000	0.0
Median	0.008	0.002	-0.006	-78.2
Mean	0.020	0.014	-0.006	-32.2
95th percentile	0.082	0.071	-0.011	-13.6
Max	23.080	14.711	-8.368	-36.3

Flood mitigation

The addition of Indigenous Vegetation and Exotic Forestry increases the area considered mitigating in 2060 by ~193,000ha (Figure A - 41 and Table A - 32), meaning that more of the Mataura catchment is able to capture flows of mass, water, associated sediments, and nutrients when it is under mature and established Indigenous Vegetation and Exotic Forestry.

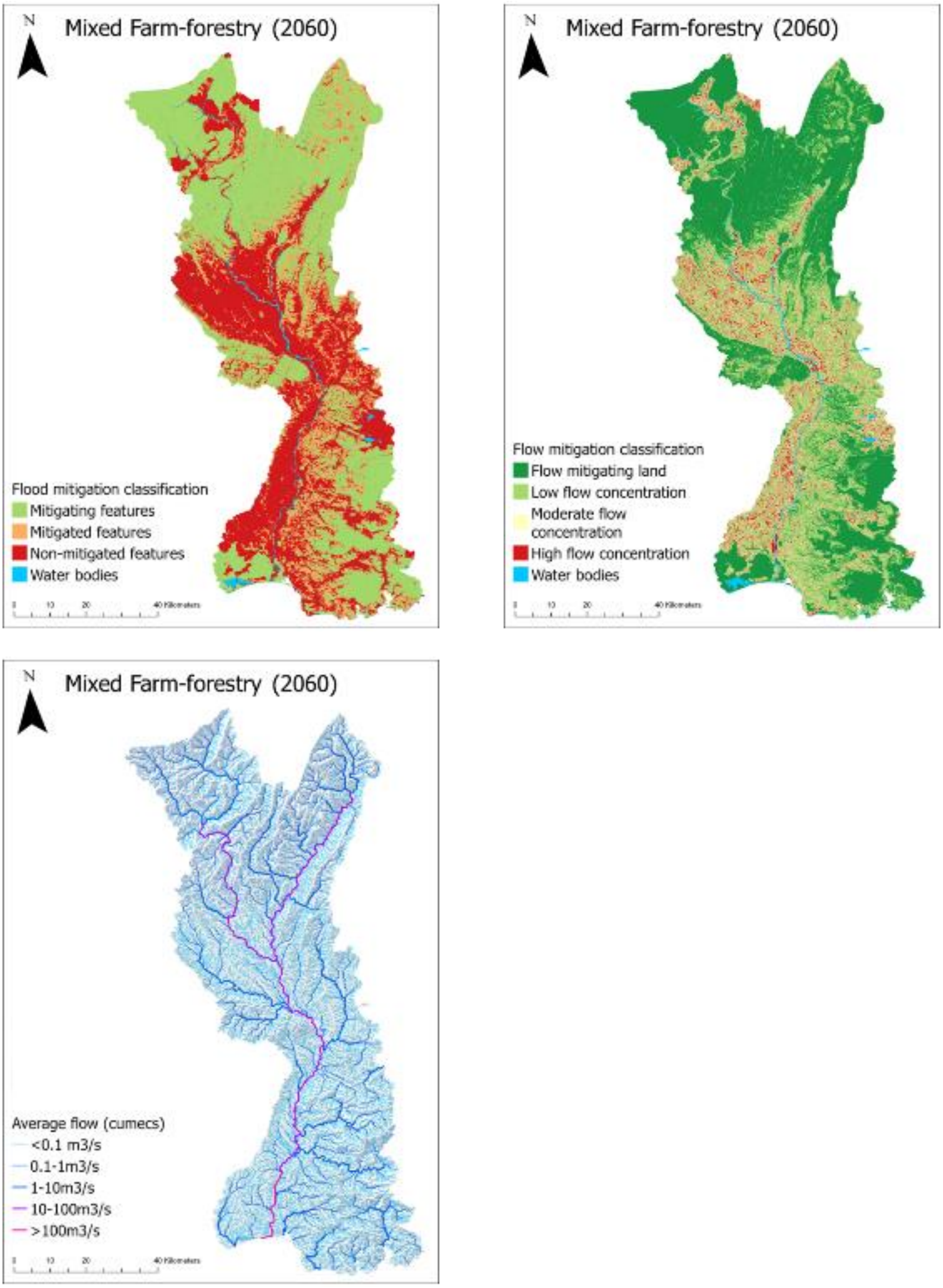


Figure A - 41. Results of flood mitigation: flood mitigation, flow mitigation and average flow for 2060.

Table A - 42: Results of the flood mitigation tool for the baseline 2025 and 2060 scenario.

Flood mitigation classification (ha)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Mitigating features	99,056	292,329	193,273	182
Mitigated features	23,976	99,828	75,852	0
Non-mitigated features	498,245	229,190	-269,055	-73
Water bodies	17,315	17,546	231	310

RUSLE

The mean soil loss decreases by 3.7 tonnes/ha/yr with the retirement of livestock grazing on the steeper slopes of the Mataura to Indigenous Vegetation (Table A - 43). The sediment delivery map (Figure A - 42) shows other areas of the catchment vulnerable to soil losses that are potential hotspots for management interventions.

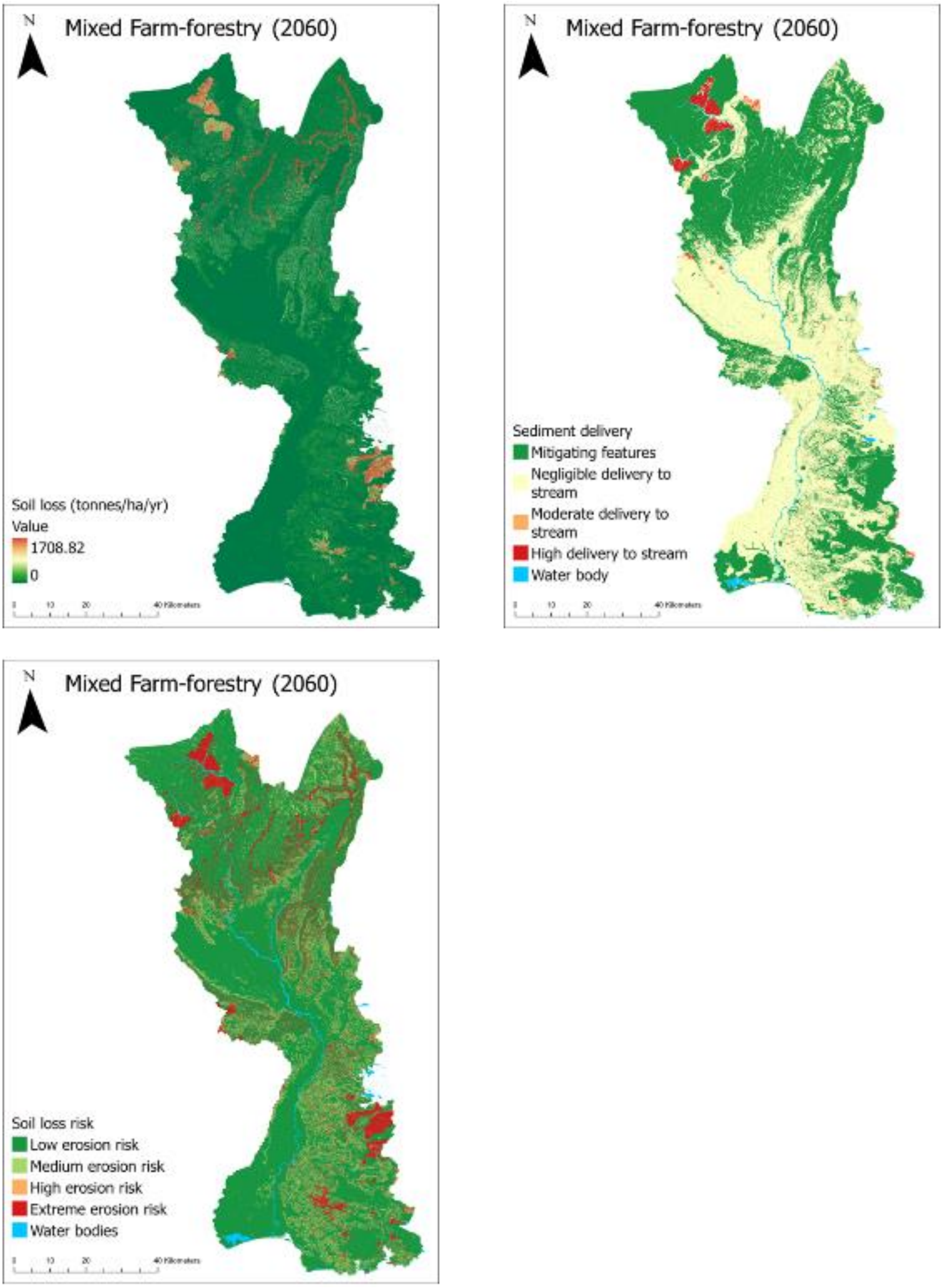


Figure A - 42: Results relating to both "point"-scale soil loss: (soil loss (tonnes/ha/yr and a categorisation of risk), and risk of this soil being delivered to waterways ("sediment delivery").

Table A - 43: Summary statistics for terrestrial soil loss for the baseline 2025 and 2060 scenario.

Soil loss (tonnes/ha/yr)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Min	0.0	0.0	0.00	0.0
Median	1.7	0.8	-0.97	-55.8
Mean	10.6	6.8	-3.74	-35.4
95th percentile	46.7	33.3	-13.38	-28.6
Max	1,704.1	1,708.8	4.75	0.3

Habitat connectivity

The addition of Indigenous Vegetation across the Mataura catchment increases the amount of ideal habitat for kererū by 149,659ha mainly in the northernmost part of the catchments, but also in small patches on the eastern side of the catchment (Figure A - 43 and Table A - 44). In-between these patches, the red areas in Figure A - 43 show the corridors that kererū can fly through as it moves between ideal habitat patches, which increases 186,375ha from the baseline 2025. The woody biomass of established Exotic Forestry allows kererū to utilise these areas as stepping-stones despite this land use not being the ideal habitat for them.

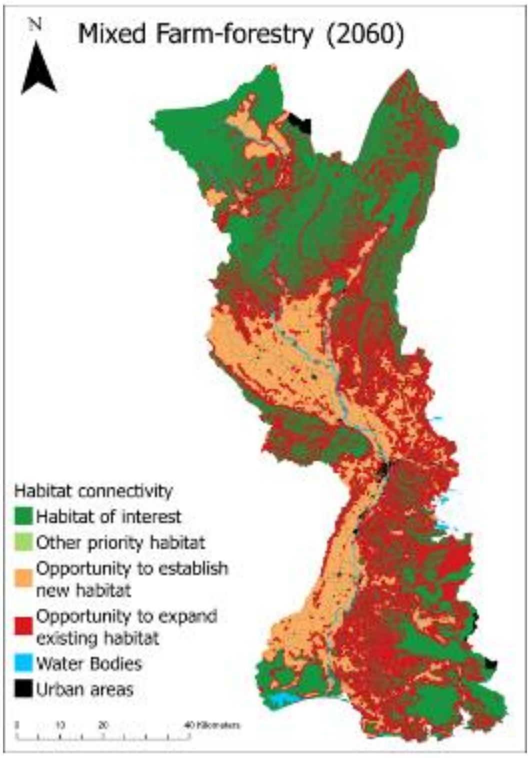


Figure A - 43. Results of habitat connectivity for kererū.

Table A - 44: Results of the habitat connectivity tool for kererū for the baseline 2025 and 2060 scenario.

Habitat classification (ha)	Baseline 2025	Mixed farm-forestry 2060	Change in 2060	Change relative to baseline 2025 (%)
Habitat of interest	82,253	231,912	149,659	182
Other priority habitat	0	0	0	0
Opportunity to establish new habitat	460,450	124,321	-336,130	-73
Opportunity to expand existing habitat (areas where kererū can easily fly through)	60,060	246,435	186,375	310

A14 – Scenario 2B (2060) – Variation: Conversion of land above 600m from sheep and beef to tussock

Following consultation in the Mataura, an additional scenario was requested by the Parliamentary Commissioner for the Environment to explore the impact of converting land above 600m from sheep and beef to tussock instead of pines.

To explore this scenario, the changes specified in Table A - 45 below were made to sheep and beef land. All other land uses, including interventions, were consistent with the original Scenario 2B 2060.

Table A - 45: Land use changes to sheep and beef land outlined by the PCE.

Baseline land use	Elevation	Land use change
High Country Sheep and Beef	≥ 600m	Converts to tussock
High Country Sheep and Beef	< 600m	Converts to pine plantation forestry (i.e. no change from 2B 2060)
Hill Country Sheep and Beef	≥ 600m	Converts to tussock
Hill Country Sheep and Beef	< 600m	Converts to pine plantation forestry (i.e. no change from 2B 2060)
Lowland Sheep and Beef	≥ 600m	Converts to tussock
Lowland Sheep and Beef	< 600m	Does whatever lowland normally does in 2B 2060

The areas above 600m (Figure A - 44) were identified using the 8m Digital Elevation Model (DEM) retrieved from the LINZ Data Service (Land Information New Zealand, 2012).

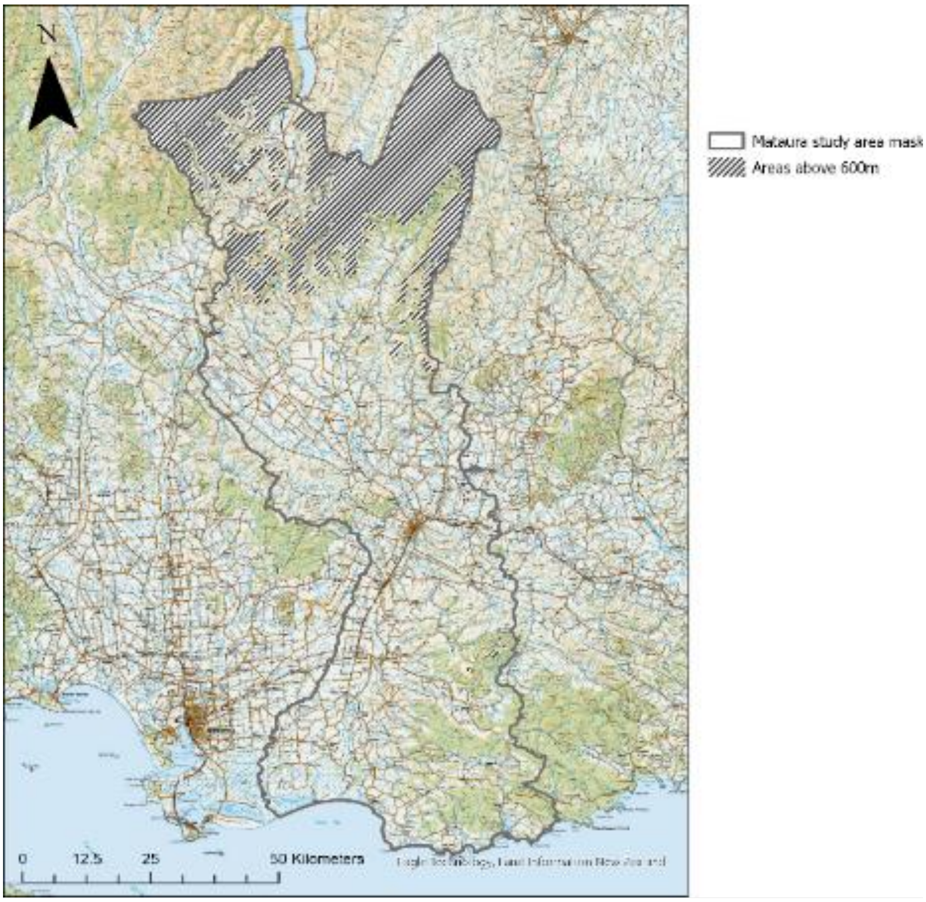


Figure A - 44. Areas of the Mataura catchment above 600m.

Methods and assumptions

- In this scenario (Task 3), the land use changes were driven by a combination of the table of interventions specified above and the environmental outcomes and economic transitions as specified for the original scenario 2B 2060. This was done by:
  1) Nature Braid first identifying the land use areas (ha) for Sheep and Beef land (Hill, High, Lowland) by the five different agricultural productivity levels for areas above and below 600m;
  2) the economics team at WSP applying the land use change rules as specified in Table A - 45 (above), and;
  3) the economics team applying the previous economic and environmental assumptions of Scenario 2B 2060.

- Within this scenario, the following land use changes were driven by biophysical characteristics:
  - Restoration of Wetlands on land prone to waterlogging and having negligible production capacity as identified by Nature Braid based on soil, topography, elevation, and aspect.
  - Riparian planting (~11.3m) along streams on farmland, including a flax buffer (16m) around wetlands.
  - Creation of constructed Wetlands based on areas currently in production that are prone to waterlogging, have poor drainage, or imperfectly drained which are identified by Nature Braid based on soil and topography.

- Within the Nature Braid model, erosion under Exotic Forestry is modelled assuming a 28-year rotation wherein six years are considered "particularly vulnerable" to soil erosion under extreme events such heavy rainfall events and landslides (Baillie et al., 2015).
- Erosion under Tussock Grassland uses a C-factor from Donovan (2022) within the Revised Universal Soil Loss Equation (RUSLE) model.
- Regeneration to tussock has a "shut the gate" approach wherein grazing is halted, and the land is allowed to regenerate on its own. By 2060, the tussock is assumed to have already established.
    - According to experts (Budha-Magar, pers. comm. 25 May 2023; C. Meurk, pers. comm. 1 June 2023) and literature (Mark et al., 2013), the likely species of tussock that will regenerate in this area are narrow-leaved snow tussock (*Chionochloa rigida*) slim snow tussock (*Chionochloa macra*) and red tussock (*Chionochloa rubra*).
    - Expert knowledge (E. Rodway, pers. comm. 9 June 2023) also indicated that there are quite a number of tussock patches in the Mataura catchment.
    - For Nature Braid runs, whether this is through passive or active restoration does not affect modelling, but active restoration (removal of weeds, etc.) may incur costs.
- From Young et al. (2012), kea (*Nestor notabilis*) were indicated as a keystone species for tussock grassland. With more time and resources setting the Nature Braid model up to include kea instead of or alongside kererū in its habit modelling would be desirable. This would require an extensive literature review of kea habitat requirements and discussions with experts to obtain reasonable parameters to set this up in Nature Braid. Therefore, due to time limitations to maintain comparability with other scenarios in this study and since the modelling considered the whole catchment, not just tussock grassland, the habitat connectivity for kererū remains the primary species modelled to look at scenario implications on biodiversity.
- The parameterisation for other land use conversions (Wetlands, Sheep Dairy, Riparian Planting, and Tulips) remain the same as in the original scenario 2B.

Parameterisation of tussock within Nature Braid

The parameterisation for tussock within the Nature Braid was created based on available literature on tussock in New Zealand and conversations/expert knowledge and input from tussock experts. We note there is very little direct information on nutrient export to rivers from tussock. Expert knowledge based on physiological properties, sediment loss and nutrient levels in soils were the main basis informing these parameters. Table A - 46 below shows an overview of these values, followed by justification.

Table A - 46: Parameterisation table within Nature Braid for tussock.

Land use	Flow Mitigating ability (classified)	Agricultural production (classified)	C-factor	Ideal habitat for kererū?	Resistance to kererū (classified)	Nitrogen multiplier (1 = arable land, conventional agriculture, deer, beef)	Phosphorus multiplier (1 = arable land, conventional agriculture, deer, beef)
Tussock (LUcode = 250)	2	4	0.0275	0	7	0.131818	0.2115385

- Flow mitigating ability = 2 as tussock can mitigate flow
- Agricultural production = 4
  - This is not 5 (non-productive land) because "agricultural production" is a measure of the land's capability/capacity for production. Tussock could support limited agricultural production (e.g. grazing) if used, hence a value of 4. However, this scenario assumes that it will not be used for agricultural production.
- C-factor = 0.0275
  - Based on an annual average of Donovan (2022) seasonal C-factors, and other studies support this as a sensible C-factor (lower than the pine weighted average, higher than permanent indigenous vegetation)
- Ideal habitat for kererū = 0 (no)
  - Colin Meurk, landscape ecologist, indicated that kererū cannot eat the tussock, so it would not be ideal for them. However, tussock is ideal habitat for kea.
- Resistance to kererū = 7
  - From previous literature and discussion, kererū can fly far and they can use woody biomass in the landscape to "hop" between patches.
  - This is not 10 (roads, residential areas) as we assume there are no roads or tall buildings in the tussock for kererū to fly into.
  - This is also not 1 (native vegetation) because of the lack of taller woody biomass ideal for the species to perch on and use as a roost as it hops between patches.
  - We therefore are suggesting a value of 7 which lines up with open public parks, areas used for outdoor recreation, etc.
- Nutrient parameterisation:
  - There is very little literature providing data-driven evidence of direct N and P exports from tussock grassland. However grey literature suggests soil nutrient levels where measured are generally low and foliage analyses indicate availability of N, P and other key nutrients are higher in pine catchments than in adjacent tussock catchments (Davis, 1994) and more generally in pine versus generic planted, ungrazed grassland (Davis and Lang, 1991).
  - Since we have assumed no grazing, the nitrogen parametrisation value is assumed to be the national average used in the Nature Braid for Indigenous Vegetation, which is indeed lower than pine or grazed grassland. 'Targeted grazing' could be considered as a weed control measure within tussock (Brown 2018, Ledgard 2009) however this was not modelled in this study.
  - The P parameterisation draws on this data for support but also includes an adjustment to lower P due to the very low rates of particulate sediment observed in tussock catchments (see e.g. O'Loughlin et al. (1984) and Bright and Magar (2016)), although note tussock may have high organic P exports (Bright and Magar, 2016)).

Results

Economic analysis

Table A – 47 below shows the land area over 600m in altitude within the Mataura catchment.

Table A – 47: Land above 600m in Mataura.

Land area representing Sheep and Beef above 600m (ha)	Moderate production capacity	Marginal production capacity	Negligible production capacity	Total
Hill	4,328	36,204	1,808	42,340
High	18,745	30,137	1,348	50,230
Lowland	35	206	1	242
Total	23,108	66,547	3,157	92,812

This land all transitions to Tussock while the rest of the transitions are as per Scenario 2B. This results in the following land uses in 2060 (Figure A - 45 and Table A - 48).

Table A - 48: Land use changes in the Mataura catchment.

	Baseline 2025	Change	2060
Dairy	80,520	-63,845	16,676
Dairy Support	21,425	-21,425	0
Lowland Sheep and Beef	156,652	-156,652	0
Hill Country Sheep and Beef	170,597	-170,597	0
High Country Sheep and Beef	60,554	-60,554	0
Mixed Cropping	2,268	-470	1,798
Wetlands	2,992	23,082	26,074
Indigenous Vegetation	83,363	0	83,363
Exotic Forestry	15,999	244,840	260,839
Tulips	0	5,533	5,533
Tussock	0	92,812	92,812
Sheep Dairy	0	107,276	107,276
Total	594,370	0	594,370

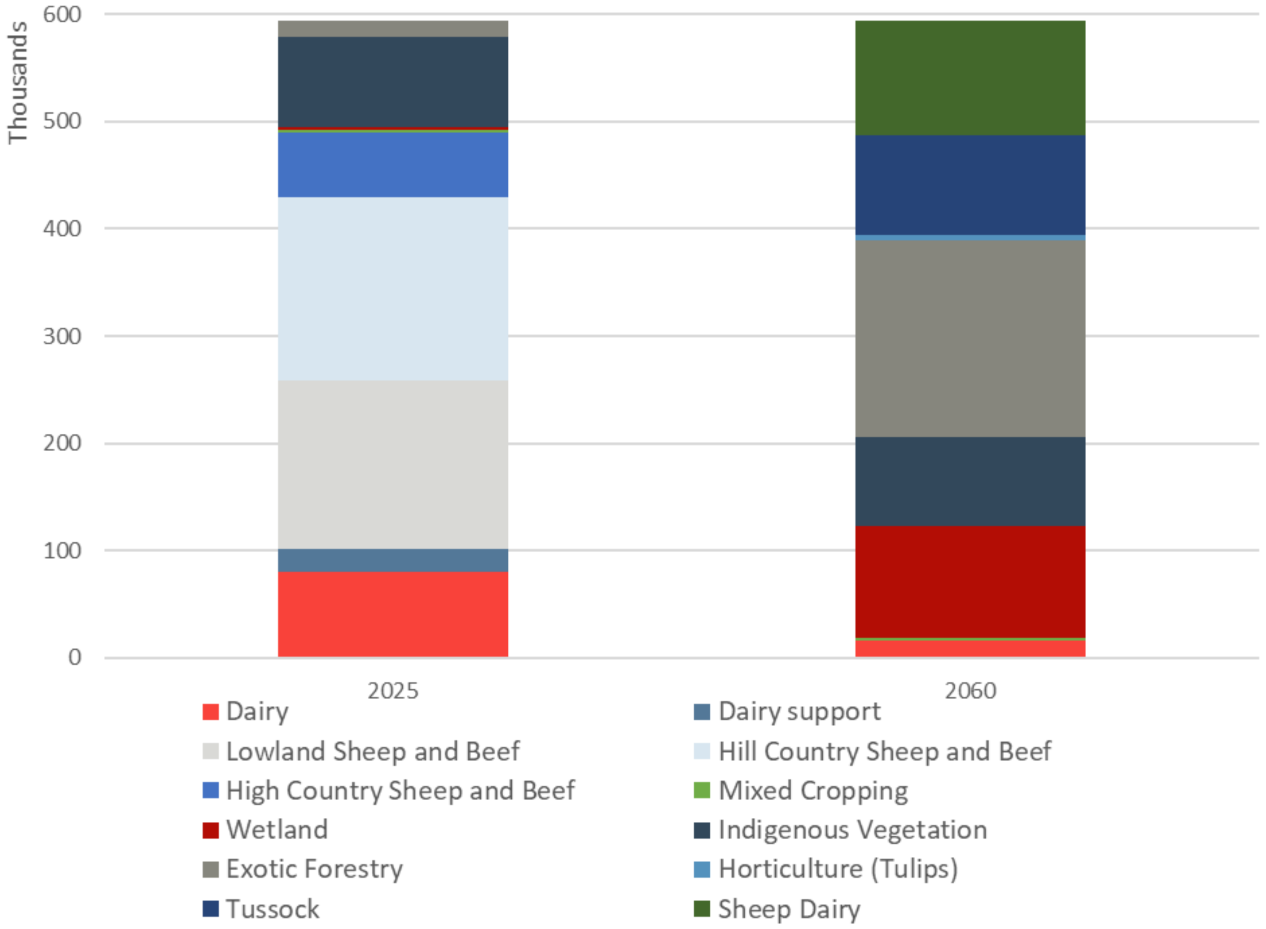


Figure A - 45: Land use in the Mataura catchment in 2025 and 2060.

The 92,812ha identified as transitioning to Tussock would have otherwise transitioned to Exotic Forestry.

This results in the following economic performance (Figure A - 46 and Table A - 49). The increased performance is solely due to the transition to Exotic Forestry.

Table A - 49: Catchment profitability change in the Mataura catchment.

	Baseline 2025	Change	2060
Dairy	$252,130,865	-$241,488,314	$10,642,551
Dairy Support	$2,756,240	-$2,756,240	$0
Lowland Sheep and Beef	$85,590,427	-$85,590,427	$0
Hill Country Sheep and Beef	$27,945,542	-$27,945,542	$0
High Country Sheep and Beef	$2,344,940	-$2,344,940	$0
Mixed Cropping	$2,529,788	-$2,205,611	$324,177
Wetlands	$0	$0	$0
Indigenous Vegetation	$0	$0	$0
Exotic Forestry	$21,820,149	$1,690,438,613	$1,712,258,762
Tulips	$0	$27,662,699	$27,662,699
Tussock	$0	$0	$0
Sheep Dairy	$0	$272,692,357	$272,692,357
Total	**$395,117,951**	**$1,628,462,595**	**$2,023,580,546**

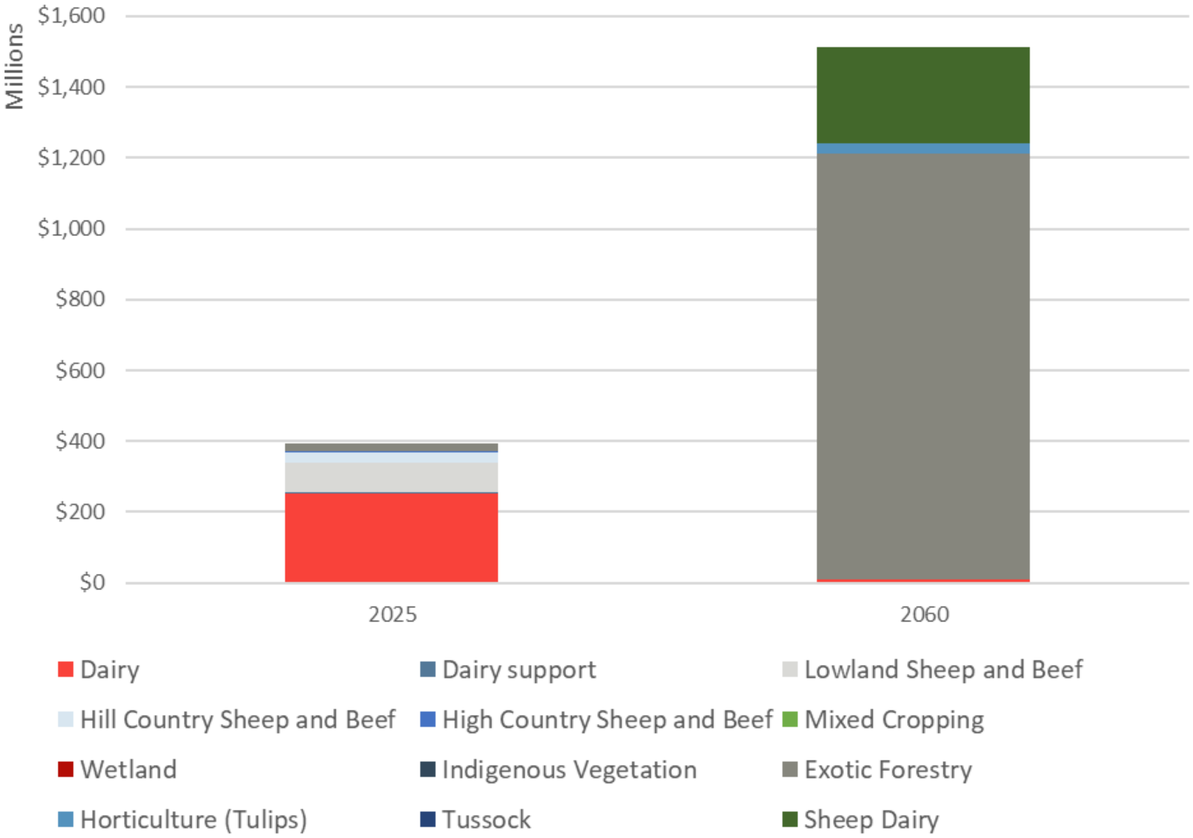


Figure A - 46: Catchment profitability in the Mataura in 2025 and 2060.

Environmental results

By 2060, this scenario has decreases in the mean terrestrial nitrogen (8.7 kg N/ha/yr to 4.2 kg N/ha/yr) and phosphorus (369.1 g P/ha/yr to 192.08 g P/ha/yr) loads. Both nitrogen and phosphorus in-stream concentration see a decrease in mean values (0.76 mg N/L to 0.32 mg N/L; 0.02 mg P/L to 0.004 mg P/L) and a significant decrease in maximum values (341.5 mg N/L to 6.0 mg N/L; 23.08 mg P/L to 0.225 mg P/L). The addition of Riparian Planting on all of the streams on farmland in this scenario helps to mitigate nutrient delivery to streams. The addition of Riparian Planting, Tussock, and Exotic Forestry presents large increases in the amount of flood mitigating features (+347,895ha), and potential habitat for kererū (+8,167ha). However, mean terrestrial soil loss increases with conversions to Exotic Forestry around the catchment (10.6 tonnes/ha/yr to 17.8 tonnes/ha/yr).

The updated land use map is shown in Figure A - 47, showing large transitions to Tussock and Exotic Forestry around the catchment as assumed in this scenario.

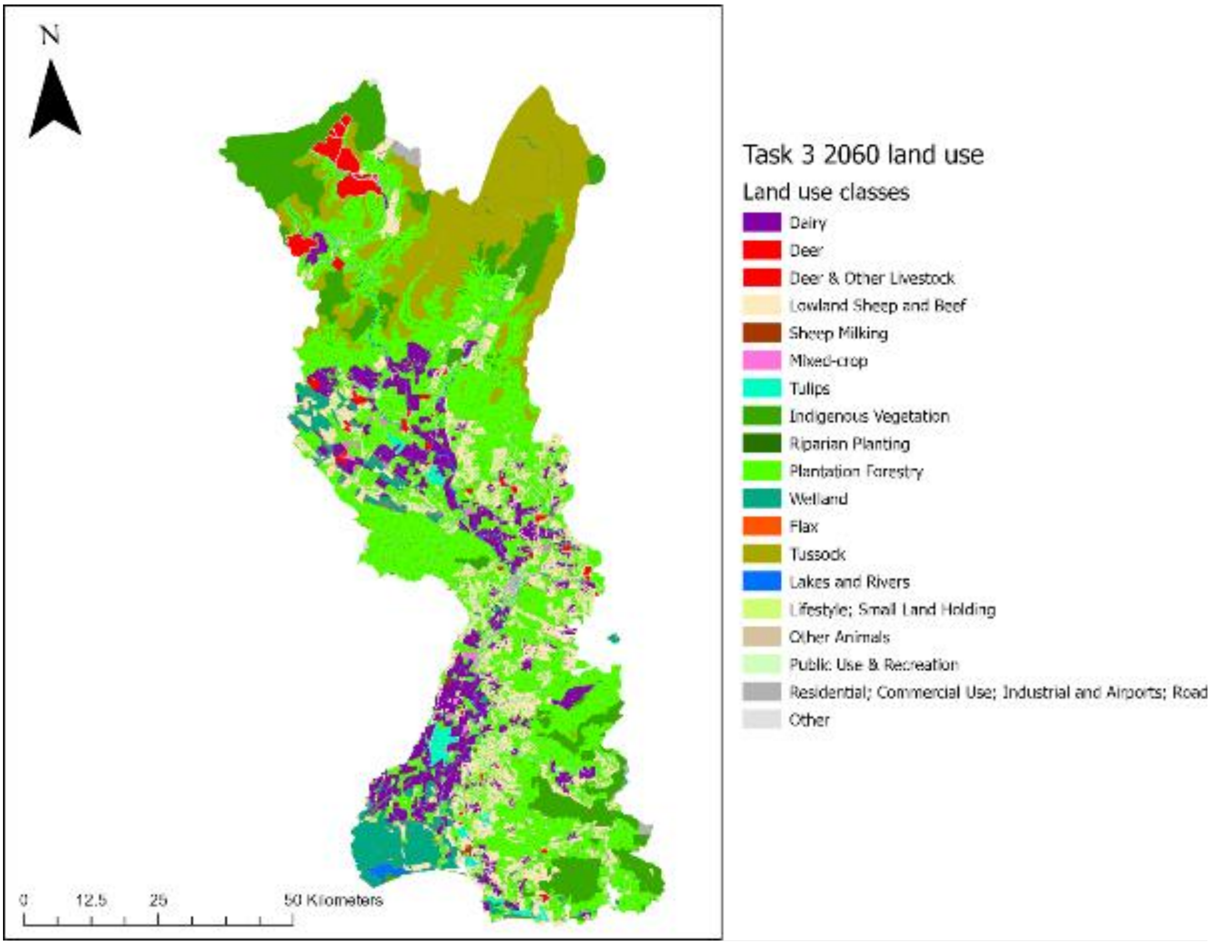


Figure A - 47: Land use map for 2060 in this scenario.

Agricultural productivity

The predicted optimal agricultural utilisation is the same as the baseline 2025, as this is driven by the underlying soil, climate, topography, and other factors. Retiring livestock farming to Indigenous Vegetation and Exotic Forestry reduces the amount of land considered to have high production (79.74% to 24.80%; Figure A - 48 and Table A - 50) and very high utilisation that is potentially over-utilised (28.43% to 2.52%; Figure A - 48 and Table A - 51). The area of the Mataura catchment where the actual use is appropriate for its agricultural capacity increases from 38.57% in the baseline 2025 to 47.66% in the 2060 scenario (Figure A - 48 and Table A - 51).

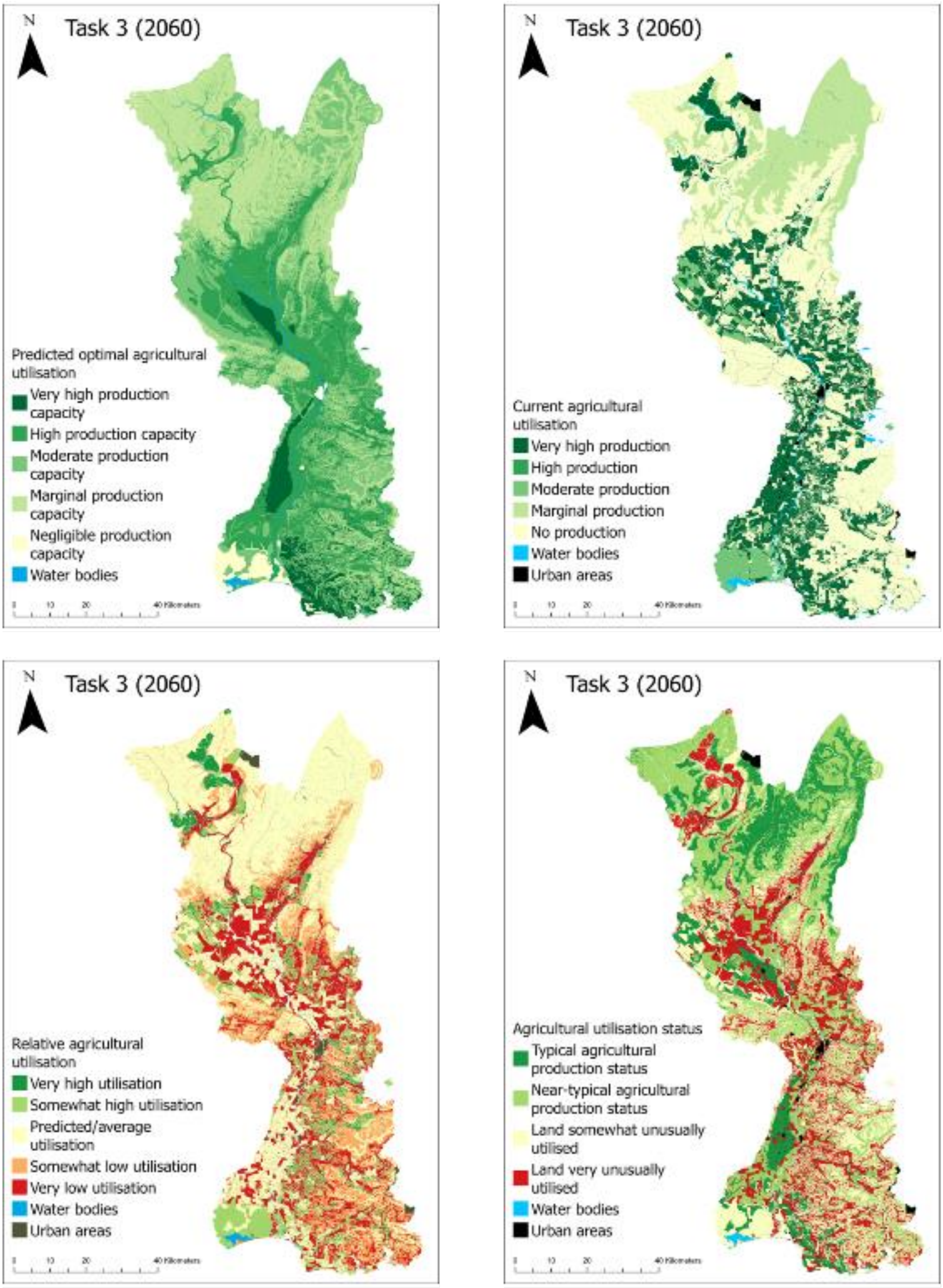


Figure A - 48: Results of agricultural productivity: predicted agricultural utilisation, current agricultural utilisation, agricultural utilisation status and relative agricultural utilisation.

Table A - 50: Current agricultural utilisation percentages for the baseline 2025 and 2060.

Current agricultural utilisation	Baseline 2025 (%)	Task 3 2060 (%)
Very high production	79.74	24.80
High production	0.00	0.00
Moderate production	0.00	4.38
Marginal production	0.00	14.52
No production	15.51	51.66
Water bodies	2.89	2.88
Urban areas	1.86	1.77

Table A - 51: Relative agricultural utilisation percentages for the baseline 2025 and 2060.

Relative agricultural utilisation	Baseline 2025 (%)	Task 3 2060 (%)
Very high utilisation	28.43	2.52
Somewhat high utilisation	24.24	11.64
Predicted/average utilisation	38.57	47.66
Somewhat low utilisation	3.64	15.44
Very low utilisation	1.08	18.82
Water bodies	2.11	2.11
Urban areas	1.91	1.82

Nitrogen

Retiring Sheep and Beef farming to Tussock, and the addition of other interventions (Wetlands, Riparian Planting) shows decreases in the mean terrestrial nitrogen load (-4.5 kg/ha/yr) and mean in-stream nitrogen concentrations (-0.4 mg/L) compared to the baseline 2025 (Figure A - 49 and Table A - 52). The effect of these changes can be further seen in the in-stream nitrogen concentrations, with the maximum concentration being 1.8% of the baseline 2025 value (Figure A - 49 and Table A - 53).

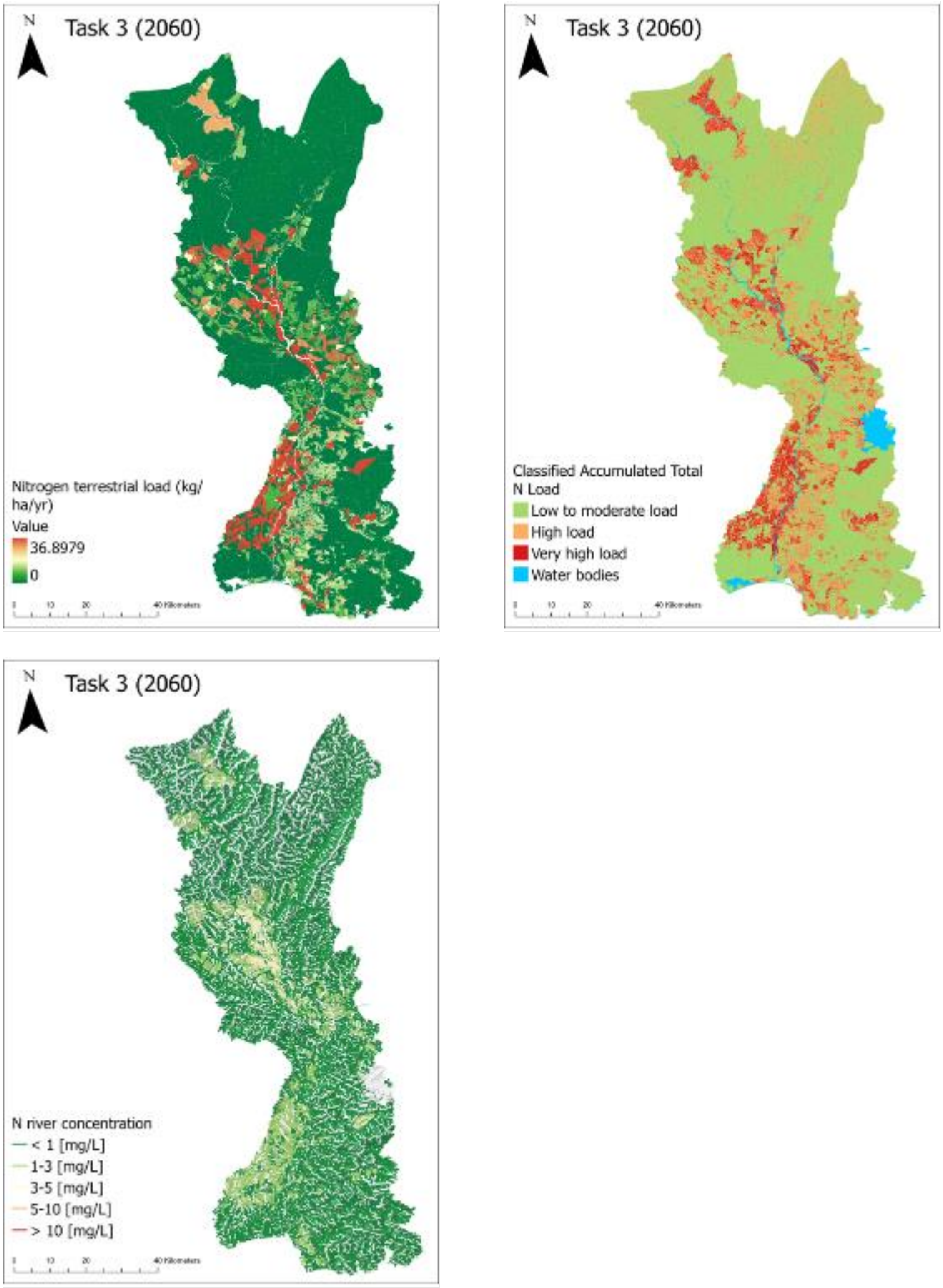


Figure A - 49: Results of nitrogen (N): terrestrial load, accumulated load classification and in-stream concentration for 2060.

Table A - 52: Summary statistics of nitrogen terrestrial loads for the baseline 2025 and 2060.

Nitrogen terrestrial load (kg/ha/yr)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Min	0.0	0.0	0.00	0.0
Median	6.6	0.5	-0.49	-93.0
Mean	8.7	4.2	-0.44	-51.8
95th percentile	30.3	30.1	-0.83	-0.7
Max	36.9	36.9	-335.45	0.0

Table A - 53. Summary statistics of in-stream nitrogen concentration for the baseline 2025 and 2060 scenario.

Nitrogen stream concentration (mg/L)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Min	0.00	0.00	0.00	0.0
Median	0.52	0.03	-6.11	-94.1
Mean	0.76	0.32	-4.52	-58.3
95th percentile	2.38	1.55	-0.21	-34.8
Max	341.46	6.01	0.00	-98.2

Phosphorus

The results for phosphorus are similar to the nitrogen outcomes, with mean terrestrial load (-177.05 g/ha/yr) and mean in-stream phosphorus concentrations (-0.016 mg/L) seeing a decrease from the baseline 2025 value (Figure A - 50, Table A - 54 and Table A - 55). The maximum value of in-stream phosphorus concentration decreases to 0.98% of the baseline 2025 value (Figure A - 50 and Table A - 55).

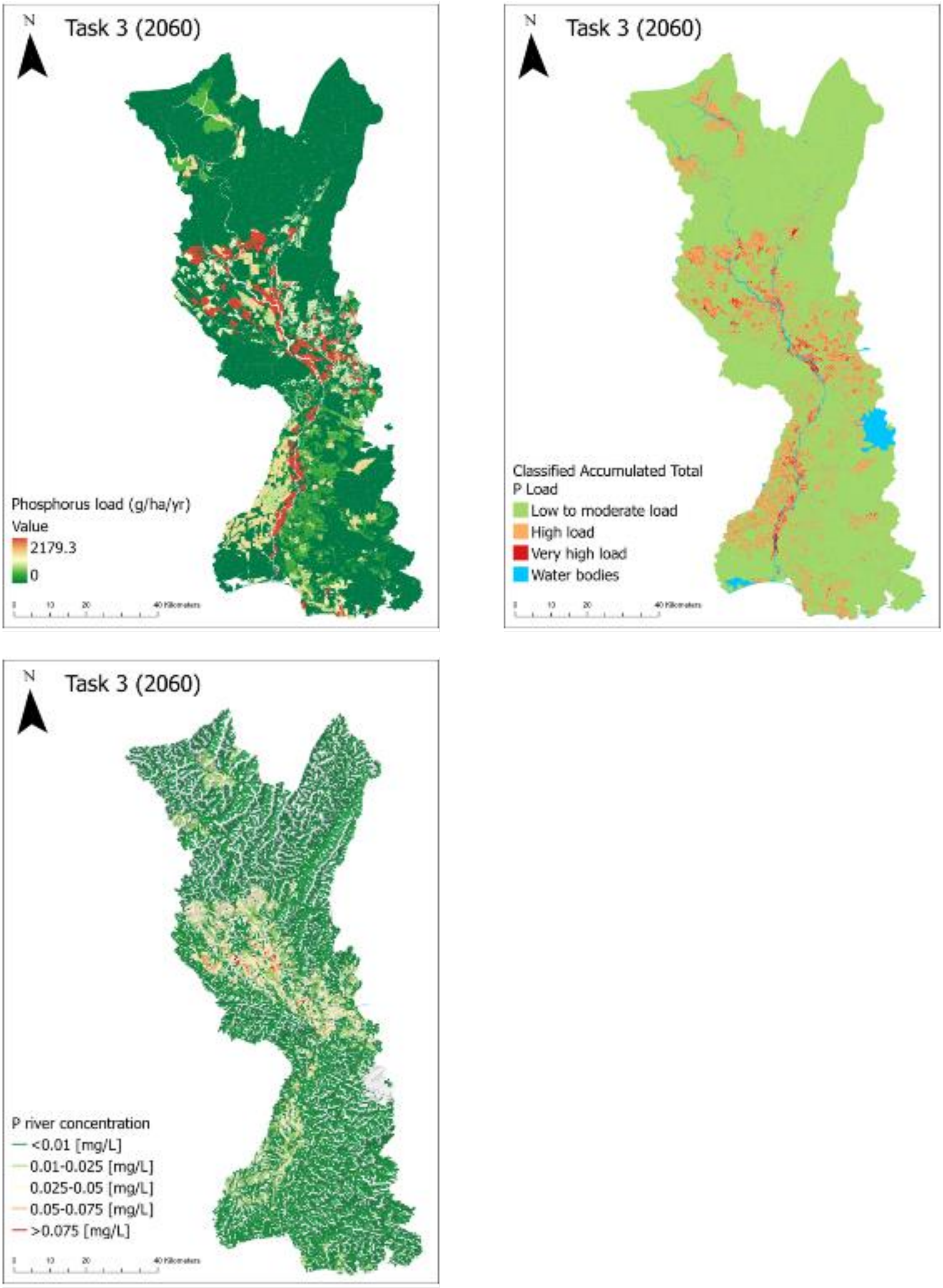


Figure A - 50: Results of phosphorus (P): terrestrial load, accumulated load classification and in-stream concentration for 2060.

Table A - 54: Summary statistics of phosphorus terrestrial loads for the baseline 2025 and 2060.

Phosphorus terrestrial load (g/ha/yr)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Min	0.00	0.00	0.00	0.0
Median	137.68	5.11	-132.57	-96.3
Mean	369.15	192.08	-177.08	-48.0
95th percentile	1664.89	735.96	-928.93	-55.8
Max	2,179.30	2,179.29	-0.01	0.0

Table A - 55: Summary statistics of in-stream phosphorus concentration for the baseline 2025 and 2060.

Phosphorus stream concentration (mg/L)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Min	0.000	0.000	0.000	0.0
Median	0.008	0.0002	-0.008	-97.7
Mean	0.020	0.004	-0.016	-81.5
95th percentile	0.082	0.011	-0.071	-87.1
Max	23.080	0.225	-22.855	-99.0

Flood mitigation

The additions of Riparian Planting, Tussock, and Exotic Forestry increases the area considered mitigating in 2060 by 347,895ha (Figure A - 51 and Table A - 56), meaning that more of the Mataura catchment is able to capture flows of mass, water, associated sediments, and nutrients when it is under mature and established Riparian Planting, Tussock, and Exotic Forestry.

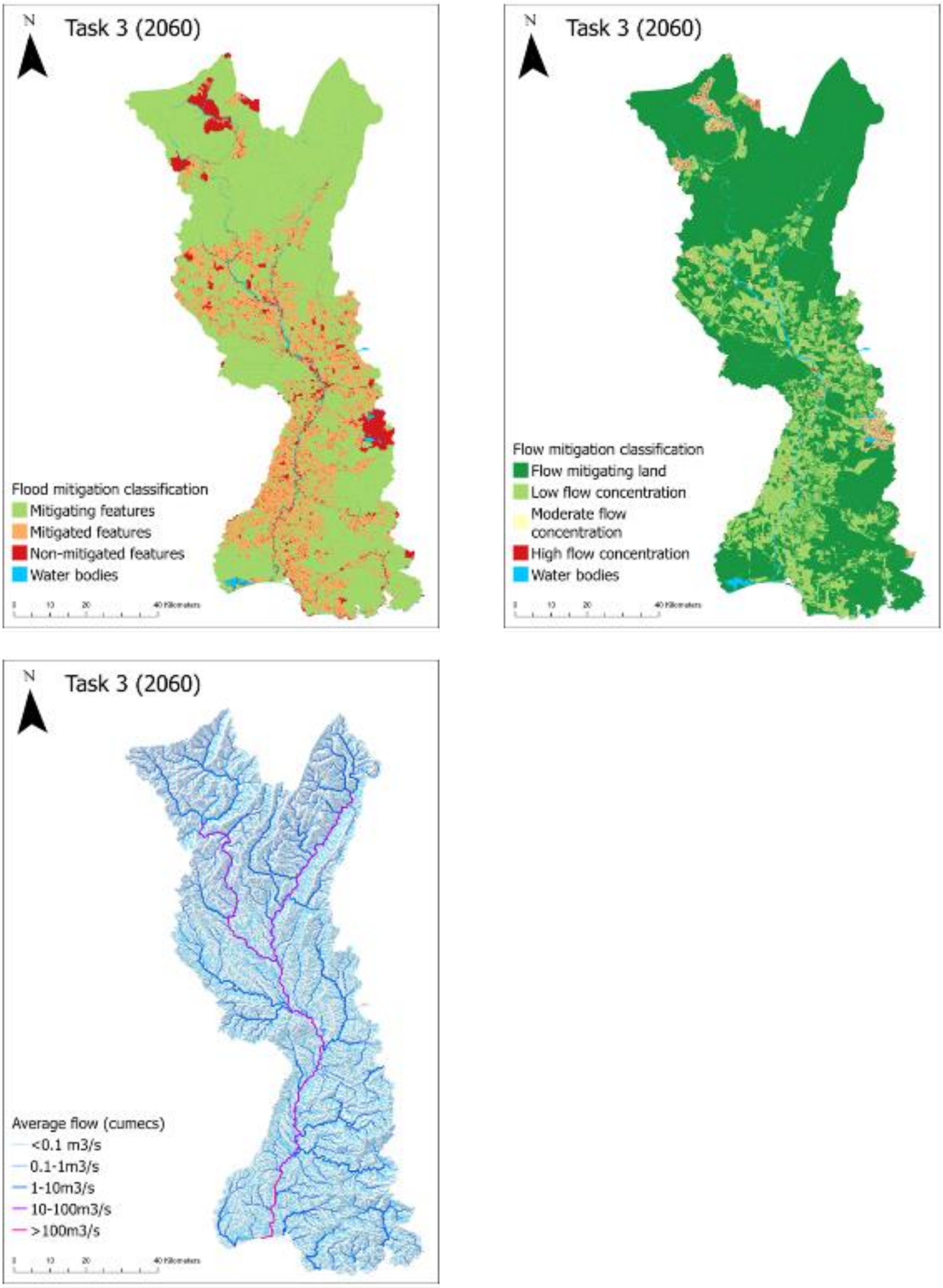


Figure A - 51: Results of flood mitigation: flood mitigation, flow mitigation and average flow for 2060.

Table A - 56: Results of the flood mitigation tool for the baseline 2025 and 2060.

Flood mitigation classification (ha)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Mitigating features	99,056	446,951	347,895	351
Mitigated features	23,976	135,009	111,033	463
Non-mitigated features	498,245	40,605	-457,640	-92
Water bodies	17,315	16,328	-987	-6

RUSLE

The mean soil loss increases with the addition of Exotic Forestry in various parts of the catchment (Figure A - 52 and Table A - 57). The sediment delivery map (Figure A - 52) shows other areas of the catchment vulnerable to soil losses that are potential hotspots for management interventions, mainly in the upper part of the catchment and other areas lacking Riparian Planting.

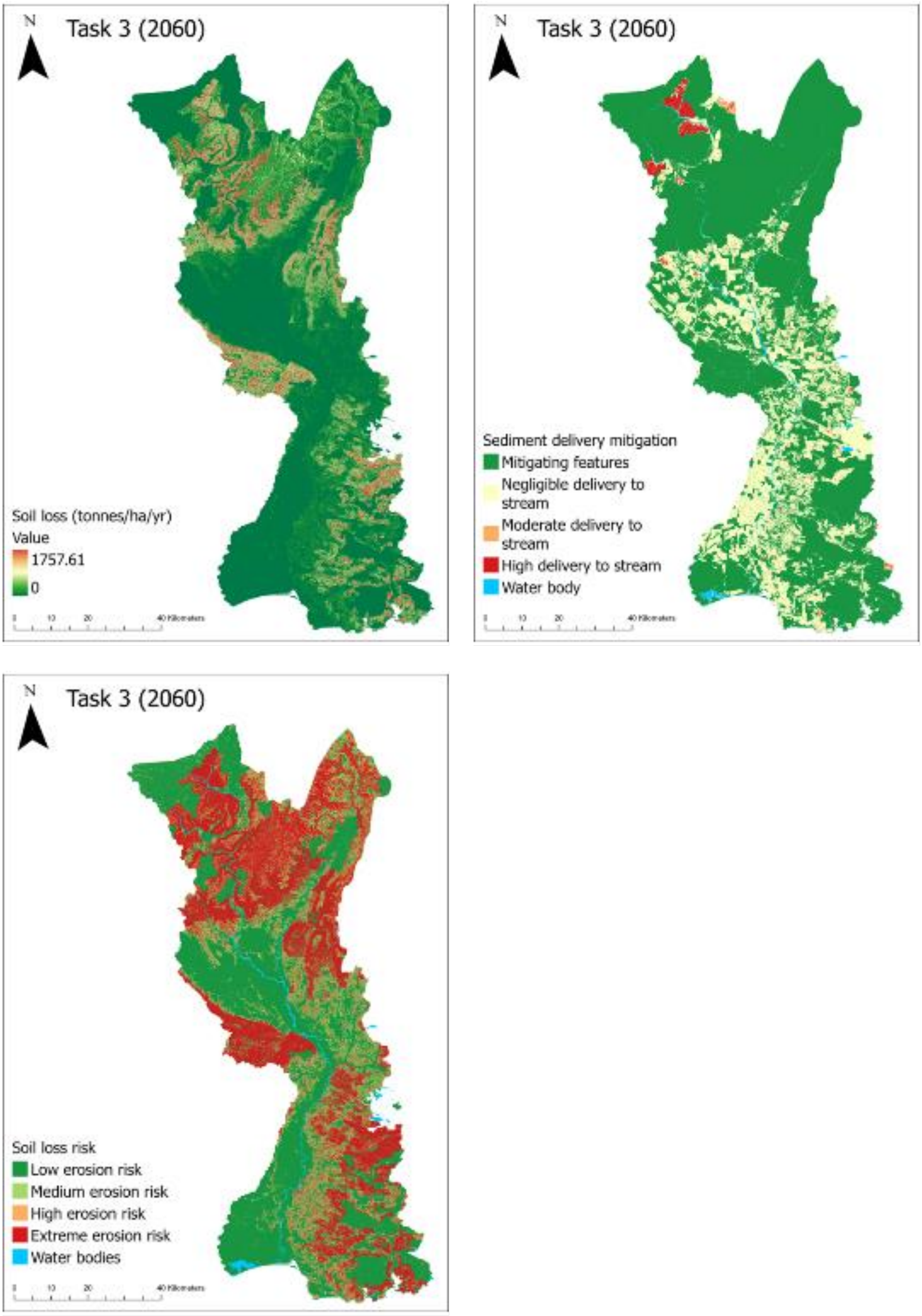


Figure A - 52: Results relating to both "point"-scale soil loss: (soil loss (tonnes/ha/yr and a categorisation of risk), and risk of this soil being delivered to waterways ("sediment delivery").

Table A - 57: Summary statistics for terrestrial soil loss for the baseline 2025 and 2060.

Soil loss (tonnes/ha/yr)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Min	0.0	0.0	0.00	0.0
Median	1.7	2.5	0.74	42.3
Mean	10.6	17.8	7.23	68.4
95th percentile	46.7	89.9	43.22	92.5
Max	1,704.1	1,757.6	53.55	3.1

Habitat connectivity

The addition of Riparian Planting in the catchment increases the amount of ideal habitat for kererū by 8,167ha (Figure A - 53 and Table A - 58) and increases the connectivity throughout the catchment as seen in the increase in opportunity to expand existing habitat which is found next to patches of ideal habitat (+349,814ha). The addition of Tussock does not expand the ideal habitat for kererū, but kea (*Nestor notabilis*) were indicated as a keystone species for tussock grassland (Young et al., 2012). With more time and resources setting the Nature Braid model up to include kea instead of or alongside kererū in its habit modelling would be desirable. This would require an extensive literature review of kea habitat requirements and discussions with experts to obtain reasonable parameters to set this up in Nature Braid.

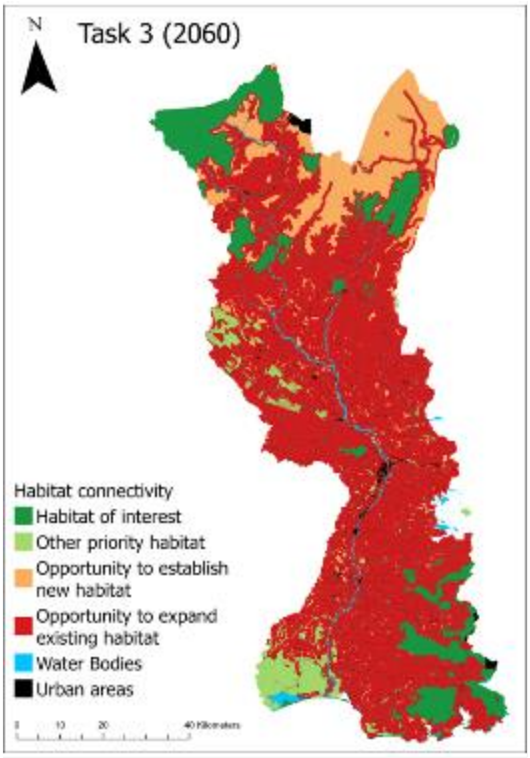


Figure A - 53: Results of habitat connectivity for kererū.

Table A - 58: Results of the habitat connectivity tool for kererū for the baseline 2025 and 2060.

Habitat classification (ha)	Baseline 2025	Task 3 2060	Absolute change in 2060	Change relative to baseline 2025 (%)
Habitat of interest	82,253	90,420	8,167	10
Other priority habitat	0	27,701	27,701	-
Opportunity to establish new habitat	460,450	75,687	-384,763	-84
Opportunity to expand existing habitat	60,060	409,874	349,814	582

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