Exploring land use change under different policy settings in two case study catchments

May 2024

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata
PO Box 10 241
Wellington 6140
Aotearoa New Zealand

Phone +64 4 495 8350
Email pce@pce.parliament.nz
Web pce.parliament.nz

May 2024

ISBN
978-0-947517-42-7 (print)
978-0-947517-43-4 (electronic)

Photography
Cover images: Southland, Greg Briner; Northern Wairoa, Jason Milich, Flickr; Southland, Ted Hodge, Flickr.

Chapter header images: *Botrychium biforme*, Dean, iNaturalist NZ; *Asplenium flabellifolium*, Rowan Hindmarsh-Walls, iNaturalist NZ; *Botrychium australe*, chris_mcgrannachan, iNaturalist NZ; *Asplenium haurakiense*, Danielle Munster, iNaturalist NZ; *Abrodictyum strictum*, Alex Fergus, iNaturalist NZ; *Cyclosorus interruptus*, Bill Campbell, iNaturalist NZ; *Trichomanes endlicherianum*, brucedc, iNaturalist NZ; *Blechnum zeelandicum*, Wendy John, iNaturalist NZ.

Exploring land use change under different policy settings in two case study catchments

May 2024

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

Acknowledgements

The Parliamentary Commissioner for the Environment, Simon Upton, is indebted to a number of people who helped him conduct this investigation. Special thanks are due to Greg Briner, who led the project, supported by Leana Barriball, Dr Robert Dykes, Richa Garg, Dr Anna Hooper, Dr Scott Kelly, Dr Geoffroy Lamarche, Dr Nora Lanari, Megan Martin, Dr Sophie Mormede, Dr James Newman, Matt Paterson, Katerina Porou, Dr Edwin Sayes and Geoff Simmons. The Commissioner would also like to acknowledge the late Dr Ed Hearnshaw, who played an important role in initiating this investigation.

The Commissioner would like to thank the following organisations for their time and assistance during the investigation:

- Environment Southland
- Hokonui Rūnanga
- Land & Water Science
- Matakohe Architecture + Urbanism
- Nature Braid
- Northland Regional Council
- Whangarei District Council
- WSP.

The Commissioner would like to particularly thank everyone who participated in the hui and workshops undertaken for this project. He would also like to thank Whangārei Terenga Paraoa Marae and Ngāraratunua Marae for hosting the hui and workshops for the Wairoa case study.

The Commissioner also wishes to thank the following individuals for reviewing earlier drafts of the report. While he has benefited hugely from their insights, any errors, omissions or opinions are entirely his own.

- Chantez Connor-Kingi, Ngāti Kahu o Torongare, Ngāti Hine o Te Iwi
- Dr Graeme Doole, AgResearch
- Dr Sandy Elliott, National Institute of Water and Atmospheric Research
- Blair Keenan, Waikato Regional Council
- Riki Parata, Dr Jane Kitson (Ngāi Tahu, Kāti Māmoe and Waitaha) and Ailsa Cain (Waitaha, Kāti Māmoe, Ngāi Tahu), Hokonui Rūnanga
- Dr Jenny Webster-Brown and Professor Rich McDowell, Our Land and Water National Science Challenge.

Simon Upton

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

Contents


Botrychium biforme

1 Introduction

Almost half of the land area of Aotearoa is currently being used for agriculture and production forestry.[1] These land uses provide employment in rural areas and account for a significant share of export revenue. But our current ways of using and managing land are interfering with the natural carbon, nitrogen and phosphorus cycles, and damaging the ecosystems that underpin our health, wellbeing, incomes and cultural identities. Tackling these environmental issues while improving the quality of life for communities and tangata whenua in rural areas is one of the biggest challenges facing the agriculture and forestry sectors.

Over the past few decades, many different policies and initiatives have been announced to deal with climate change, freshwater quality and indigenous biodiversity. The result is a mass of overlapping laws, policy instruments and funding programmes. These policies all influence land uses and land management practices. But they are not necessarily pulling in the same direction.

There has been limited consideration to date of the interactions between these policies, or the combined effect they are likely to have at a catchment or sub-catchment scale. There is a risk that opportunities to address multiple environmental objectives could be missed, or that policies aiming to achieve one environmental objective could have unintended negative consequences for another. Furthermore, article 2 of Te Tiriti o Waitangi gives Māori the right to exercise rangatiratanga over their lands and taonga, so a joined-up approach to addressing these challenges has to encompass engagement with mana whenua.

[1] MfE and Stats NZ, 2021, p.18.

To take just one example, current freshwater regulations have a farm-level focus. But while the responsibilities for losses of contaminants typically stop at property boundaries, the environmental effects of those contaminants do not. This mismatch means cumulative environmental effects are rarely factored into decisions related to land use and land management.

Further, while some property boundaries are aligned with physical features of the landscape such as waterways or ridge lines, many are not. As a result, in the absence of voluntary cooperation between landowners sharing the same catchment or enforced regulations that make collective action mandatory, there is often a limit on the impact that any individual can have on improving freshwater quality or biodiversity in their area.

Regulating on the basis of property boundaries therefore enshrines a status quo that makes no environmental sense in some places. To look beyond property boundaries is to start to see the world differently.

Freshwater regulations would ideally account for variation in landscape characteristics such as topography, spatial connectivity, climate, hydrology, geology and the physical and chemical properties of soils and the subsurface environment. Alongside land use and land management practices, these physical and chemical characteristics operating at different scales can be key drivers of spatial variability in freshwater quality outcomes in some places.

The currently fragmented approach to managing different elements of the environment can be complex and confusing for the landowners, land managers, communities and tangata whenua who live in it. Neither does it fit well with how Māori see their relationship with te taiao and how mātauranga Māori is used to illustrate this. Different ways of perceiving and understanding landscapes influence what needs to be managed, for what reason, and how to go about doing so.

In response to what I perceived to be an increasingly myopic focus on carbon sequestration in the context of climate change mitigation, in my report *Farms, forests and fossil fuels: The next great landscape transformation?* I called for a 'landscape approach' that would "integrate all that we know about environmental processes at the landscape scale with bottom-up, grass-roots knowledge".[2]

Meanwhile, in *Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways*, I highlighted the importance of advancing our understanding of the drivers of freshwater quality by "extracting extra value from existing information and data – for example, by joining up datasets across domains, rethinking existing conceptualisations and designing new ones".[3] This follow-up work aimed to explore both ideas in greater detail.

I did not begin this investigation with a fixed view of what a landscape approach is, or what a more effective approach to environmental policy might look like. I had an inkling that the current way of doing environmental policy – fragmented by domain, with a focus on farm-level regulations and emissions pricing – will not achieve the goals New Zealand has set itself for freshwater quality, biodiversity and greenhouse gas emissions. I suspected that an approach focused on integration between domains and catchment-level processes, bringing people and the landscape together, and learning from different knowledge systems might fare better. So I decided to conduct an exercise to further develop and test this idea.

---

[2] PCE, 2019, p.156.

[3] PCE, 2018, p.113.

During the course of the investigation, I was often asked for a more specific definition of what I meant by the terms 'landscape' and 'landscape approach'. I deliberately did not attempt to provide one. This was in part because different solutions will be needed at different scales in different places, and there are various ways of considering landscapes, so no single definition exists that will work everywhere. It was also because there is already an established body of academic literature around 'integrated landscape approaches' that I did not wish to wade into.

When I use the term landscape, it is the everyday idea of a landscape that I am talking about – the whenua, the wai, everything under your feet and as far as you can see – leaving nothing out and avoiding a compartmentalised and schematic view of something that is a living entity (existentially) and in our minds (culturally). Avoiding one definition also allows for other definitions to be considered. All people in Aotearoa will have a different opinion on what a landscape is. For Māori, if that landscape is connected to physical and metaphysical elements and whakapapa, then what is important to manage will be directly linked to that definition.

The aim of this work was to explore different perspectives on:

- the likely consequences for landscapes and the environment of pursuing a disconnected mix of environmental policies
- the likely outcomes relative to the status quo of implementing alternative policy mixes
- the perspectives of tangata whenua on the kaupapa of integrated landscape management and how those perspectives might be included as part of any future approach to managing land and water resources at a catchment scale.

A series of hui and workshops were held in the Mataura catchment in Murihiku Southland and the Wairoa catchment in Te Tai Tokerau Northland to capture different perspectives on the issues above. I also commissioned work on landscape susceptibility mapping, land use modelling, and mana whenua perspectives for both case study catchments to help inform the exercise.[4]

Work began on this project in 2019 after the release of *Farms, forests and fossil fuels*. It was completed in 2023, following delays caused by COVID-19. Inevitably, some of the policy settings on which the case studies were based have either been reviewed or delayed. Such is the challenge that faces anyone trying to do work at the catchment level in New Zealand's dynamic policy environment.

This exercise was exploratory and intended as a proof of concept. It raised more questions than it provided definitive answers. As a result, this document contains no recommendations. What it does contain is a summary of the findings I took from the two case studies. It is also being published alongside *Going with the grain: Changing land uses to fit a changing landscape*,[5] a report that synthesises some recurring themes that have emerged from all the work I have done on land use change and policies that change land uses.

4 Based on how mana whenua wanted to be involved, these perspectives were either reflected in the modelling exercise as discussed further in the next chapter, or outlined in a standalone piece as summarised in chapter four.

5 See https://pce.parliament.nz/publications/going-with-the-grain-changing-land-uses-to-fit-a-changing-landscape.

2

Asplenium flabellifolium

How the exercise was undertaken

To better understand the trade-offs and consequences of different policy mixes for landscapes, an integrated exercise in two case study catchments was undertaken. The exercise attempted to integrate information on the biophysical features of the landscape with land use modelling, as well as input from tangata whenua, landowners, communities and other local experts. It explored how the two landscapes might change in response to different mixes of policies for addressing climate change, freshwater quality and biodiversity, considering specific local contexts.

The aim was to explore what an integrated exercise to explore these issues might look like. If considered useful, exercises of this type could be developed further by landowners, communities and tangata whenua to assist them in making decisions relating to land uses and land management practices. They could also potentially be used by regional councils as part of formal decision-making processes. Further, they could help central government agencies to understand what the local consequences of national-level policies are likely to be.

This exercise focused on the consequences for landscapes of different policies for reducing greenhouse gas emissions, improving freshwater quality, and restoring or enhancing indigenous biodiversity. There are of course many other environmental issues related to land and water management that need to be tackled, such as freshwater quantity, biosecurity, weeds, pests, chemical contaminants and climate change adaptation. While not the focus of this exercise, it is possible that the type of process explored here could lend itself to some of these other challenges, especially if a more holistic approach is taken to managing landscapes.

Two contrasting case study areas were explored – the Mataura catchment in Murihiku Southland and the Wairoa catchment in Te Tai Tokerau Northland (Figure 2.1). Although both case studies are situated within the wider national policy context, they are characterised by very specific regional circumstances that shape what the impact of different policies would be on the ground.

The questions explored with local people in each case study were:

- How is land currently being used and managed in the catchment? What are the main environmental issues?
- How would the landscape be expected to change in the future if climate change mitigation, freshwater quality and biodiversity policies are addressed separately? What would be the environmental outcomes?
- How could things be done differently? What changes to land uses and land management practices could be made, and what can science tell us about where the best places would be to prioritise these actions? What would be the environmental outcomes?
- What can mātauranga Māori and te ao Māori frameworks and tools tell us about the landscape, and what actions would be needed to restore the mauri of the whenua and the wai from a Māori perspective?
- What would the costs and other impacts of the transition be under different scenarios?

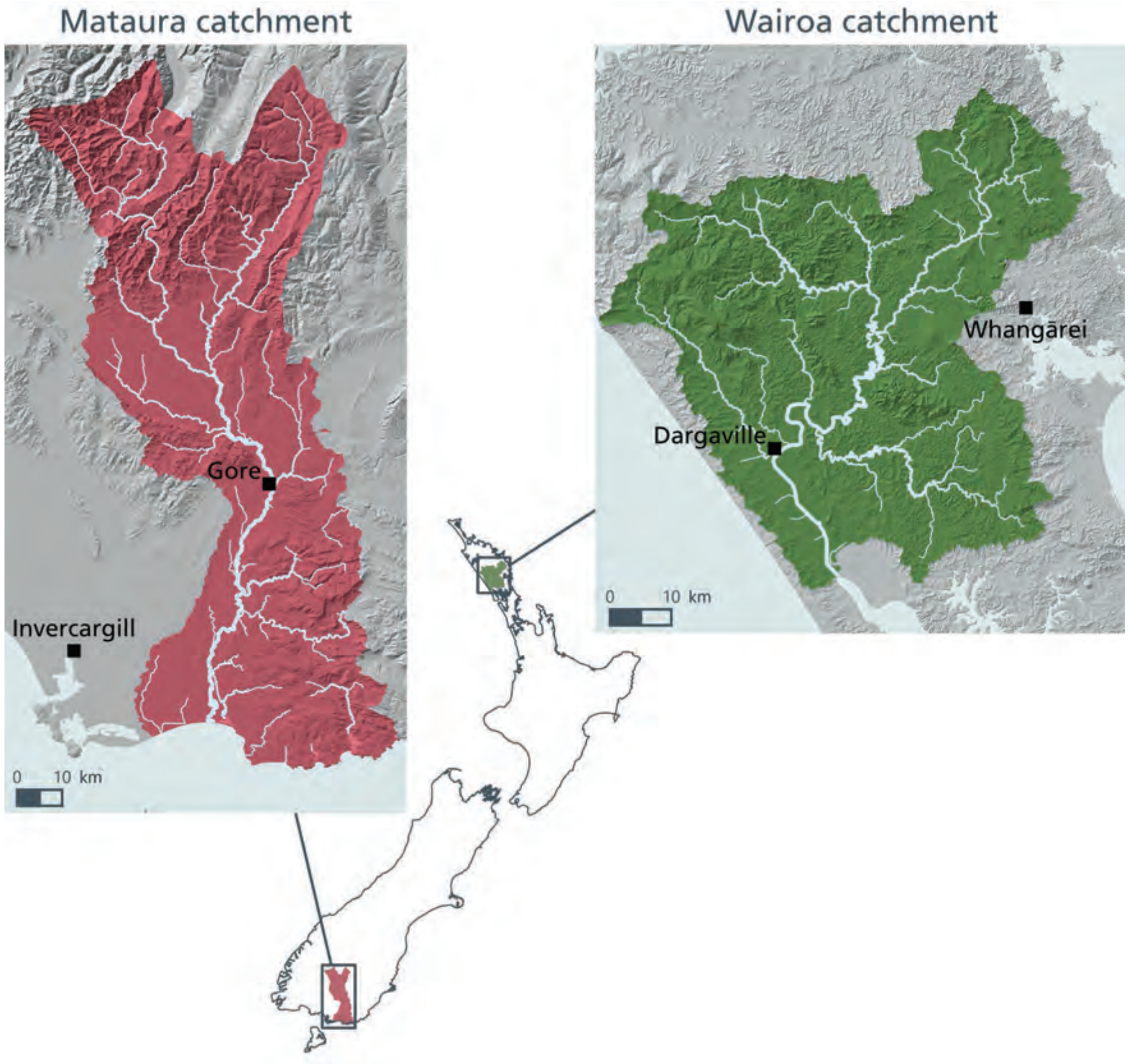


Figure 2.1: Location of the Mataura and Wairoa catchments. The boundary of Wairoa is the sea-draining catchment. For Mataura, the proposed freshwater management unit was used as the catchment boundary.

For each case study, a series of hui and workshops were organised to discuss the questions above. In addition, the following pieces of work were commissioned for each catchment.

- Landscape susceptibility mapping
- Land use modelling
- Tangata whenua perspectives

The project was designed to test whether integrating different perspectives and tools could yield useful information to inform decision making. It was not designed to lead to recommendations about what specific changes to land uses and land management practices should be made in each place. That said, the information gathered might well be useful for those living there if they decide to pursue a more bottom-up approach to managing environmental pressures in the future.

The landscape susceptibility mapping and land use modelling are discussed in more detail in the following sections. The work on tangata whenua perspectives is discussed in chapter four.

Landscape susceptibility mapping

Trying to make rules to govern the environmental impact of land use and land management runs up against the fact that landscape characteristics are often too complex to be accounted for in decisions that affect specific properties. The impacts of land uses do not stop at property boundaries. They are felt throughout the entire receiving landscape and will depend on many fine-grained factors that are very difficult to incorporate into regulatory decision making, including where within a landscape the activity occurs. Our understanding of the dynamics of contaminants moving through the landscape is limited, and we either lack or have limited data available to rely on.

It is against this backdrop of interconnected factors that Land & Water Science was commissioned to examine the landscape characteristics and landscape susceptibility to loss of seven freshwater contaminants plus nitrous oxide emissions from soil for both case study catchments.[1] The aim was to improve our understanding of the role landscape characteristics play in driving freshwater quality and soil nitrous oxide outcomes in these catchments, based on available data and expert knowledge.[2]

To do this, controlling factors within the landscape that best describe the spatial variability in water quality were identified and compared with direct measurements from the water quality monitoring networks in each catchment.[3] Controlling landscape characteristics included topography, climate, geology, hydrology, weathering and other physical and chemical processes, such as reduction and oxidation in soils, sediments, rocks and aquifers.

Once identified, these relationships were used to build maps of landscape susceptibility for each contaminant. These maps represent the relative susceptibility of the landscape within the catchment to contaminant loss, based on landscape characteristics. The aim was to develop susceptibility classifications that are independent of land use, though land use decisions do tend to be influenced by landscape characteristics, so fully untangling the effect of land use is challenging.[4] Susceptibility is represented on a 0-to-100-point scale – with 100 indicating the highest susceptibility and zero indicating no susceptibility.[5]

An example of what the landscape susceptibility maps look like is shown in Figure 2.2. The figure displays two different sources of environmental pressure: total suspended sediment, which dominates in Wairoa, and nitrate-nitrite nitrogen, which is a key pressure in Mataura. For nitrate-nitrite nitrogen in Mataura, areas of high susceptibility are associated with well-drained soils and areas with an abundance of oxygen (i.e. oxidising conditions). For total suspended sediment in Wairoa, areas of high susceptibility are associated with weak sedimentary mudstones (which are highly susceptible to weathering) and poorly drained soils on steeper slopes where slips are more likely and overland flow is more erosive.[6]

---

1 Rissmann et al., 2022. The seven freshwater contaminants modelled were nitrate-nitrite nitrogen (combining nitrate [NO_3^-] and nitrite [NO_2^-]); organic and ammoniacal nitrogen (NH_3 and NH_4^+); dissolved reactive phosphorus; particulate phosphorus; turbidity; total suspended sediment (in Wairoa only); and *Escherichia coli (E. coli).*

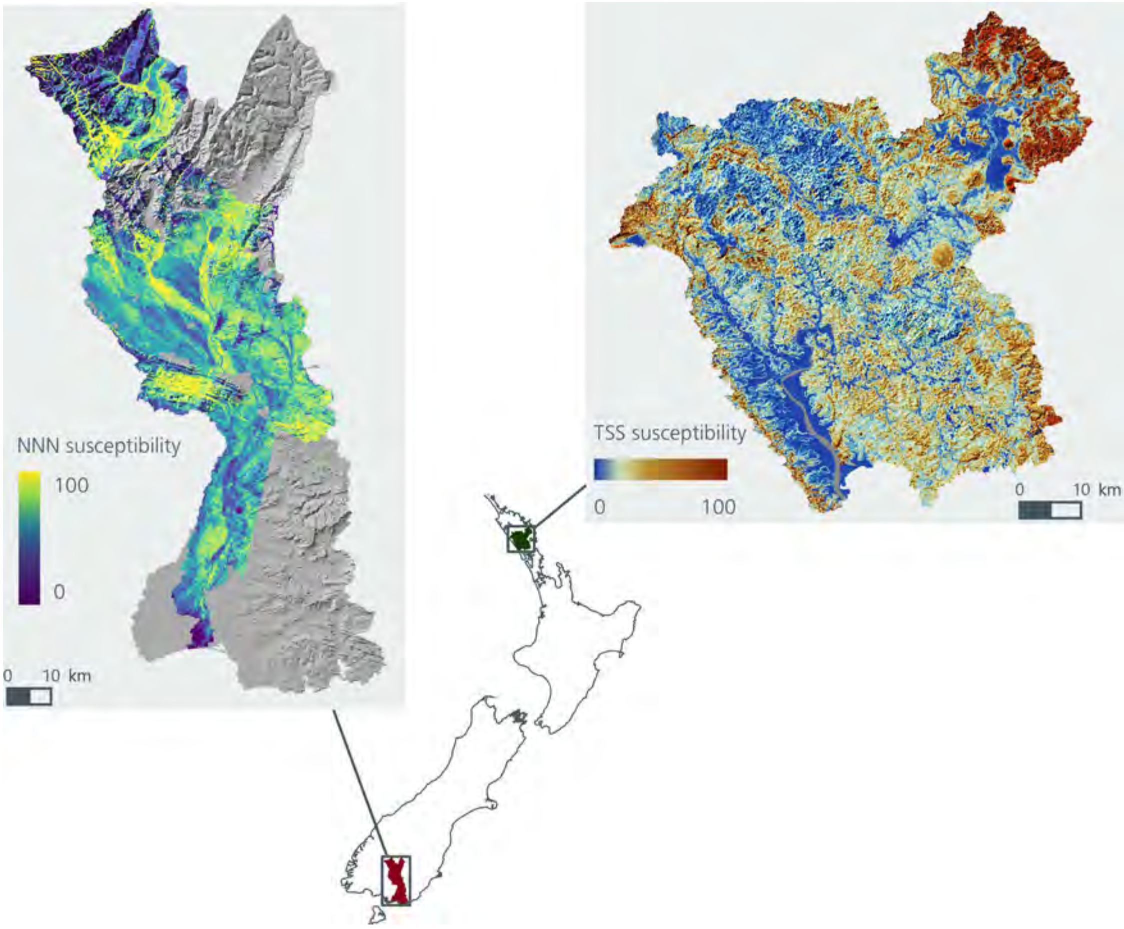
2 Landscapes' contribution to freshwater quality in New Zealand is further described in Rissmann et al. (2024). They found that climate, geomorphology and lithology are key factors that determine landscape susceptibility to loss of contaminants, particularly phosphorus, *E. coli* and turbidity.

3 For soil nitrous oxide, expert knowledge was used to identify controlling landscape factors in the absence of monitoring data.

4 The modelling team did their best to remove the effects of land use by regressing long-term average water quality measurements against land use intensity and extracting the residuals.

5 A detailed description of the approach and methods employed for the landscape susceptibility mapping can be found in Rissmann et al. (2022), available at https://pce.parliament.nz/publications/exploring-land-use-change-under-different-policy-settings-in-two-case-study-catchments.

6 Rissmann et al., 2022, pp.22–25.



Source: Adapted from Rissmann et al. (2022)

Figure 2.2: Contaminant susceptibility maps for nitrate-nitrite nitrogen (NNN) in the Mataura catchment (left) and total suspended sediment (TSS) for the Wairoa catchment (right). Areas with higher values have a higher susceptibility to the loss of the selected contaminants relative to other locations within the catchment. For some areas in the north and southeast of the Mataura catchment (representing 54% of the total catchment area), landscape susceptibility could not be estimated because radiometric survey data were unavailable. Where possible, the Nature Braid model was used to fill in these gaps for the purposes of the land use modelling exercise.

As with any modelling exercise, there are strengths and limitations to the modelling of landscape susceptibility in Wairoa and Mataura. The main strengths of this approach are its cross-disciplinary, data-driven nature, its high spatial resolution, and its potential to integrate multiple landscape characteristics. The methodology can evolve as understanding of processes improves and new datasets become available. If these datasets are updated, or better representations of landscape characteristics become available, spatial landscape susceptibility layers can be reasonably easily updated.

However, like any modelling exercise, the results are highly dependent on the input assumptions. It is a nascent discipline that suffers from the gaps that currently exist in environmental data collection and reporting. This makes it difficult to calibrate or validate the modelled relationships, though Land & Water Science did test the model outputs against existing soil and geological classifications and found statistically significant relationships in both catchments. The method works best in parts of the country that have high-resolution datasets available, such as radiometric survey data. Older records and datasets with coarser spatial resolutions tend to have higher associated uncertainty. Furthermore, in many places there are only a limited number of water quality monitoring sites and associated biases in distribution of the sites.[7] Completely removing the effects of land use from these relatively small datasets is very challenging.

Landscape susceptibility mapping provides an example of the type of spatially explicit information that can be drawn on to make better informed decisions that work with the landscape, rather than against it.[8] In this respect it represents an evolution from the use of Land Use Capability information to identify areas for protection in the National Policy Statement for Highly Productive Land 2022,[9] or identification of areas of high erosion risk in the National Environmental Standards for Commercial Forestry.[10] These are, by comparison, comparatively coarse characterisations of landscape variability, though they are relatively cheap and readily accessible.

As part of the exercise to test a more landscape-based approach to environmental policy, landscape susceptibility maps of key contaminants were used to inform some of the land use decisions in the land use modelling. This modelling is described in more detail below.

Land use modelling

WSP were commissioned to undertake catchment-scale land use and environmental modelling.[11] The modelling was designed to show how land management practices and land uses could change in the two case studies under different policy scenarios, and to estimate the associated changes in environmental and economic outcomes between now and 2060. The aim of the modelling was to provide a sense of the extent to which whole-of-landscape approaches to environmental policy could result in different landscapes and different environmental and economic outcomes compared to the current approach.

To do this, the environmental and economic impacts of a range of policy scenarios were modelled by integrating land use maps, farm system information, physical and chemical characteristics of the catchments, and economic variables. The outputs include changes in land use areas in response to policies and regulations, changes in economic indicators such as profitability, and modelled impacts on a range of environmental indicators related to freshwater quality, erosion, greenhouse gas emissions and biodiversity. The modelling did not account for the effects of climate change itself.

[7] Rissmann et al., 2024.

[8] The resolution of the landscape susceptibility maps that can be generated depends on the resolution of the underlying monitoring data and inputs.

[9] Land Use Capability is a spatial classification of land based on its rock type, soil, slope angle, erosion type and severity, and vegetation cover information. For more on the methodology see Lynn et al. (2009). For an interactive map, see the Manaaki Whenua – Landcare Research website (https://ourenvironment.scinfo.org.nz/maps-and-tools/app/Land%20 Capability/lri_luc_main).

[10] The National Environmental Standards for Plantation Forestry were amended and renamed the National Environmental Standards for Commercial Forestry in November 2023.

[11] The reports by WSP for Wairoa (WSP, 2023b) and Mataura (WSP, 2023a) are available at https://pce.parliament.nz/publications/exploring-land-use-change-under-different-policy-settings-in-two-case-study-catchments.

The outputs from this exercise are just modelled outcomes. Like any modelling exercise, simplifications had to be made to represent the complex environmental, economic and social systems that are at play within the catchments. The results provide an indication of the direction and magnitude of change that might be expected under different policy settings. They are not about what *will* or *should* happen. The results of the modelling should be read alongside the Māori perspectives work in chapter four.

The following sections describe the policy scenarios modelled and the models used by WSP to investigate the potential impacts of the policy scenarios in the Wairoa and Mataura catchments.

Policy scenarios

Six policy scenarios were developed to test and compare the outcomes of different approaches to environmental policy. The scenarios were informed by current and forthcoming climate, freshwater and biodiversity policies (as described in chapter one), as well as input from local people in both catchments, including mana whenua in Wairoa.[12] In Mataura, mana whenua chose not to participate in this process, preferring instead to provide an alternative analysis of how existing tools developed by Ngāi Tahu ki Murihiku can be used to help achieve outcomes from different environmental policies in an integrated way.

The general approach taken was to test the environmental and economic outcomes of different policy and regulatory settings that drive land use change, such as an agricultural emissions levy, the New Zealand Emissions Trading Scheme (NZ ETS) and freshwater regulations. The exercise did not evaluate the policies and regulations required to achieve a specific environmental or economic target. In other words, the environmental and economic outcomes achieved were outputs of the modelling, not inputs. This meant that existing national targets for reducing greenhouse gas emissions and improving freshwater quality were not necessarily met in the scenarios modelled.[13]

This approach was chosen for two main reasons. First, emissions reduction targets are set at a national level. No single catchment or farm is, for example, required to reach a 24–47% reduction in biogenic methane emissions as set down in the Climate Change Response Act 2002.

Second, the level of ambition for freshwater quality (i.e. the extent to which targets are more stringent than the national bottom lines in the National Policy Statement for Freshwater Management 2020) should be informed by those who live and connect to the catchment. At the time of writing, processes to determine the desired freshwater quality outcomes for the Wairoa and Mataura rivers were ongoing.[14] Naturally, national bottom lines will need to be met, but tougher limits need to be set to ensure the objective of Te Mana o te Wai is achieved and in doing so the mauri of the water is protected.[15] In the absence of freshwater quality targets to achieve Te Mana o te Wai set by communities and tangata whenua, any targets used in the modelling would have been arbitrary.

---

[12] Mana whenua in Wairoa also participated by providing information on their values and aspirations for the catchment that was supplementary to the input into the modelling.

[13] An example of a modelling exercise where climate and freshwater targets were met is McDowell et al. (2022). This national-level land use optimisation modelling exercise tested New Zealand's ability to grow a healthy diet and meet climate and freshwater objectives within two scenarios.

[14] For example, a range of draft freshwater objectives have been proposed for waterbodies in Southland. These have been developed to reflect qualities of hauora that support the health and wellbeing of waterbodies within Murihiku Southland (Bartlett et al., 2020). The final objectives and limits are expected to be in place by 2025.

[15] Te Mana o te Wai – the life-supporting capacity of freshwater – is the fundamental concept of the Essential Freshwater regulations.

What the outcomes of the modelling can tell us is how far different policies and policy approaches might take each catchment towards reducing greenhouse gas emissions, improving freshwater quality and enhancing indigenous biodiversity. If the tested policies yield an outcome that falls short of the community's expectations, that would potentially indicate the need for even more far-reaching land use change in the future.

Four main policy interventions were modelled in the scenarios.

- **A farm-level split-gas levy on agricultural emissions.** The decision to model a levy on agricultural emissions was based on the outcome from He Waka Eke Noa – Primary Sector Climate Action Partnership and the Government of the time anticipating an agricultural emissions levy of some form being implemented from 2025.[16,17] A low and a higher levy price pathway were modelled in each catchment to understand how agricultural emissions pricing may impact the profitability of different pastoral land uses.
- **Levy revenue spending.** In the low levy scenarios, the revenue was spent on national research and development for reducing agricultural emissions (the effect of this spending was not modelled). In the higher levy scenarios, some revenue was still allocated to research and development, but the rest was used to fund changes in land management practices and land uses in Mataura and Wairoa.
- **Freshwater quality regulations.** Targeted freshwater quality regulations were implemented in some scenarios to understand the potential benefit of spatially targeted (as opposed to uniform) interventions to reduce contaminant losses. The targeted regulations tested were (i) a variable cap on nitrogen fertiliser application rates, with more stringent caps in places that are highly susceptible to loss of nitrate-nitrite nitrogen; and (ii) mandatory conversion of pastoral farmland to agroforestry systems in areas at high risk of sediment loss.
- **Policies for supporting forestry.** The main forestry support policy modelled was the NZ ETS. In some scenarios, alternatives to pine production forestry were modelled,[18] such as agroforestry (spaced poplar in Wairoa and spaced red beech/tawhairaunui with a broadleaf/kāpuka nurse crop in Mataura), tōtara continuous cover forestry and unharvested native forestry. Scenario 5 assumed no new forests registered in the NZ ETS from 2030 onwards and subsidies for tōtara continuous cover forestry.

A summary of the six scenarios is presented in Table 2.1.[19]

---

[16] In this report, the term 'agricultural emissions' is used to refer to biogenic methane and nitrous oxide emissions from the agriculture sector.

[17] HWEN, 2022.

[18] In this report the term pine production forestry is used to refer to rotational clear-fell harvesting of single-age stands of monoculture pine plantations which have an average rotation age of approximately 28 years. Pine plantation forestry is used as a wider term referring to all types of pine plantation, which also includes the likes of permanent pine carbon forests and continuous cover forestry operations.

[19] These policy scenarios have different labels in the WSP reports for Wairoa (WSP, 2023b) and Mataura (WSP, 2023a). They correspond as follows: scenario 1 = 1A, scenario 2 = 1B, scenario 3 = 2A, scenario 4 = 2B, scenario 5 = 2C, and scenario 6 = Variation: Conversion of marginal pastoral land to native forest.

Table 2.1: Summary of the six policy scenarios. Differences in how the scenarios were applied in the two catchments are noted in the descriptions.

Scenario	Description
Scenario 1. **Low levy, no revenue recycling back to catchment**	**Levy:** Low farm-level levy on agricultural emissions that increases gradually over time. • Biogenic methane: \$0.11 per kilogramme of methane ($kgCH_4$) in 2025, rising to \$3.19 per $kgCH_4$ in 2060. • Nitrous oxide: \$4.25 per tonne of carbon dioxide equivalent (tCO_2e) in 2025, rising to \$127.48 per tCO_2e in 2060. **Use of levy revenue:** Levy revenue is spent on national-level research on reducing emissions from agriculture (the effect of this spending was not modelled). **Freshwater quality regulations:** All farms comply with the freshwater quality regulations (nitrogen fertiliser cap, winter grazing, stock exclusion) current at 2022. **Biodiversity regulations:** No loss of existing native forests or wetlands. **Forestry:** Pine production forests remain eligible for registration in the NZ ETS.
Scenario 2. **Higher levy, untargeted revenue recycling back to catchment**	**Levy:** Higher farm-level levy on agricultural emissions that rises more rapidly over time. • Mataura: Biogenic methane \$1.06 per $kgCH_4$ in 2025, rising to \$7.97 per $kgCH_4$ in 2060; nitrous oxide \$42.50 per tCO_2e in 2025, rising to \$318.70 per tCO_2e in 2060. • Wairoa: Biogenic methane \$0.49 per $kgCH_4$ in 2025, rising to \$5.10 per $kgCH_4$ in 2060; nitrous oxide \$19.55 per tCO_2e in 2025, rising to \$203.96 per tCO_2e in 2060.[20] **Use of levy revenue:** Revenue from the levy is recycled back into central government funding programmes and spent on national-level research (the effect of this spending was not modelled) and funding the costs of riparian planting along all waterways in each catchment. In Mataura, some levy revenue was also spent on untargeted subsidies to reduce stocking rates and to restore indigenous forests. **Freshwater quality regulations:** All farms comply with the freshwater quality regulations (nitrogen fertiliser cap, winter grazing, stock exclusion) current at 2022. **Biodiversity regulations:** No loss of existing native forests or wetlands. **Forestry:** Pine production forests remain eligible for registration in the NZ ETS.

[20] The levy price for Wairoa in scenario 2 was lower than the price used for Mataura. This was because if the same high price pathway had been used for Wairoa, it would have led to all pastoral farming becoming economically unviable by 2060, which would have defeated the purpose of the modelling.

Scenario 3. **Low levy, tailored freshwater regulations**	**Levy:** Low farm-level levy on agricultural emissions that increases gradually over time (same as scenario 1). **Use of levy revenue:** Levy revenue is spent on national-level research on reducing emissions from agriculture (the effect of this spending was not modelled). **Freshwater quality regulations:** All farms comply with the winter grazing and stock exclusion regulations current at 2022. In addition, the following tailored caps on fertiliser application rates are applied: • Both catchments: A more stringent cap on nitrogen fertiliser application rates of 85 kilograms of nitrogen per hectare per year (kgN/ha/yr) in 2030 and 65 kgN/ha/yr in 2060 applies in areas with high susceptibility to loss of nitrate-nitrite nitrogen. • Wairoa: Livestock farms in high-sediment-risk areas (based on landscape susceptibility mapping and Nature Braid modelling) must convert to agroforestry systems, which are eligible for registration in the NZ ETS. • Mataura: A limit on phosphorus fertiliser application rates applies in areas with high susceptibility to loss of phosphorus. **Biodiversity regulations:** No loss of existing native forests or wetlands. **Forestry:** Pine production forests remain eligible for registration in the NZ ETS.
Scenario 4. **Higher levy, targeted revenue recycling back to catchment**	**Levy:** Higher farm-level levy on agricultural emissions that rises rapidly over time (same as scenario 2). **Use of levy revenue:** Some revenue from the emissions levy is spent on national-level research (the effect of this spending was not modelled); the rest is recycled back to the catchment and used to support targeted actions aimed at achieving multiple environmental objectives. The actions are: • Wairoa: riparian planting, loans for converting dairy land to macadamia orchards, restoring one pocket of the Hikurangi Repo (Otonga pocket) back to wetlands • Mataura: riparian planting, subsidies for converting dairy land to sheep dairying, restoring and constructing wetlands. In addition, unprofitable hill country and lowland sheep and beef farms on moderate to high production capacity land convert to agroforestry systems, which are eligible for registration in the NZ ETS.[21] **Freshwater quality regulations:** All farms comply with the freshwater quality regulations (nitrogen fertiliser cap, winter grazing, stock exclusion) current at 2022. **Biodiversity regulations:** No loss of existing native forests or wetlands. **Forestry:** Pine production forests remain eligible for registration in the NZ ETS.

[21] In the supporting WSP report for Mataura, this scenario is referred to as 'Scenario 2B Variation: New agroforestry systems applied to three farm systems'. The assumptions and results for this scenario are in Appendix 12 of the WSP report (WSP, 2023a, pp.188–213).

Scenario 5. **Higher levy, targeted revenue recycling back to catchment, forestry phased out of NZ ETS**	**Levy:** Higher farm-level levy on agricultural emissions that rises more rapidly over time (same as scenario 2). **Use of levy revenue:** Some of the revenue from the emissions levy is spent on national-level research (the effect of this spending was not modelled); the rest is recycled back to the catchment and used to support targeted actions aimed at achieving multiple environmental objectives. The actions are: • Wairoa: riparian planting, loans for converting dairy land to macadamia orchards, restoring all seven pockets of the Hikurangi Repo back to wetlands • Mataura: riparian planting, subsidies for converting dairy land to sheep dairying, restoring and constructing wetlands. **Freshwater quality regulations:** All farms comply with the freshwater quality regulations (nitrogen fertiliser cap, winter grazing, stock exclusion) current at 2022. **Biodiversity regulations:** No loss of existing native forests or wetlands. **Forestry:** No new forests are allowed to be registered in the NZ ETS after 2030. Subsidies are provided for planting alternative forestry types with significant biodiversity and/or erosion control benefits, such as tōtara continuous cover forests and gully planting with native species in Mataura.
Scenario 6. **Low levy, no revenue recycling back to catchment, trees integrated into farms (farm–forestry)**	**Levy:** Low farm-level levy on agricultural emissions that increases gradually over time (same as scenario 1). **Use of levy revenue:** Levy revenue is spent on national-level research on reducing emissions from agriculture (the effect of this spending was not modelled). **Freshwater quality regulations:** All farms comply with the freshwater quality regulations (nitrogen fertiliser cap, winter grazing, stock exclusion) current at 2022. **Biodiversity regulations:** No loss of existing native forests or wetlands. **Forestry:** All livestock farming on moderate, high, or very high production capacity land with low erosion risk remains in its current land use. Livestock farming on marginal land with low erosion risk is converted to pine production forestry. Livestock farming on high-sediment-risk land and/or negligible production capacity land is converted to permanent native forest. All new forests are eligible for registration in the NZ ETS.

Modelling approach

To illustrate changes through to 2060 under each policy scenario, three modelling tools were combined: FARMAX, Nature Braid and additional economic modelling. These modelling tools are described in Box 2.1. More detailed information on how these models work and the method used by the modelling team is available in the supporting WSP reports.[22]

The general approach to modelling the land use change and environmental impacts of the different policy scenarios is shown in Figure 2.3.

Box 2.1: Overview of models used in land use modelling

FARMAX

FARMAX is a farm system modelling and decision support tool. It was used to estimate production and profitability for a set of representative farm systems in each case study catchment. The inputs include physical farm parameters (e.g. farm size, regional location, livestock numbers, fertiliser application), economic data and farm performance information.

For Wairoa, the farm systems modelled in FARMAX were dairy, hill country sheep and beef, lowland beef finishing, and mixed cropping (kūmara cropping and lamb finishing). For Mataura, the systems modelled were dairy, dairy support, high country sheep and beef, hill country sheep and beef, lowland sheep and beef finishing and breeding, and mixed cropping (beef, sheep, barley, wheat and oilseed rape).

Nature Braid

Nature Braid is a spatially explicit ecosystem services model that was used to estimate the impact of land use change on ecosystem services and environmental indicators.[23] The input data includes a digital elevation model, soil information, river and stream networks, and climate data (rainfall and evapotranspiration). Nature Braid runs at fine spatial scales (5–10 metres). The output indicators from Nature Braid were:

- agricultural productivity
- terrestrial loads and instream concentrations for total nitrogen and total phosphorus
- terrestrial soil loss and sediment delivery[24]
- habitat connectivity for kererū
- flood mitigation.

Additional economic analysis

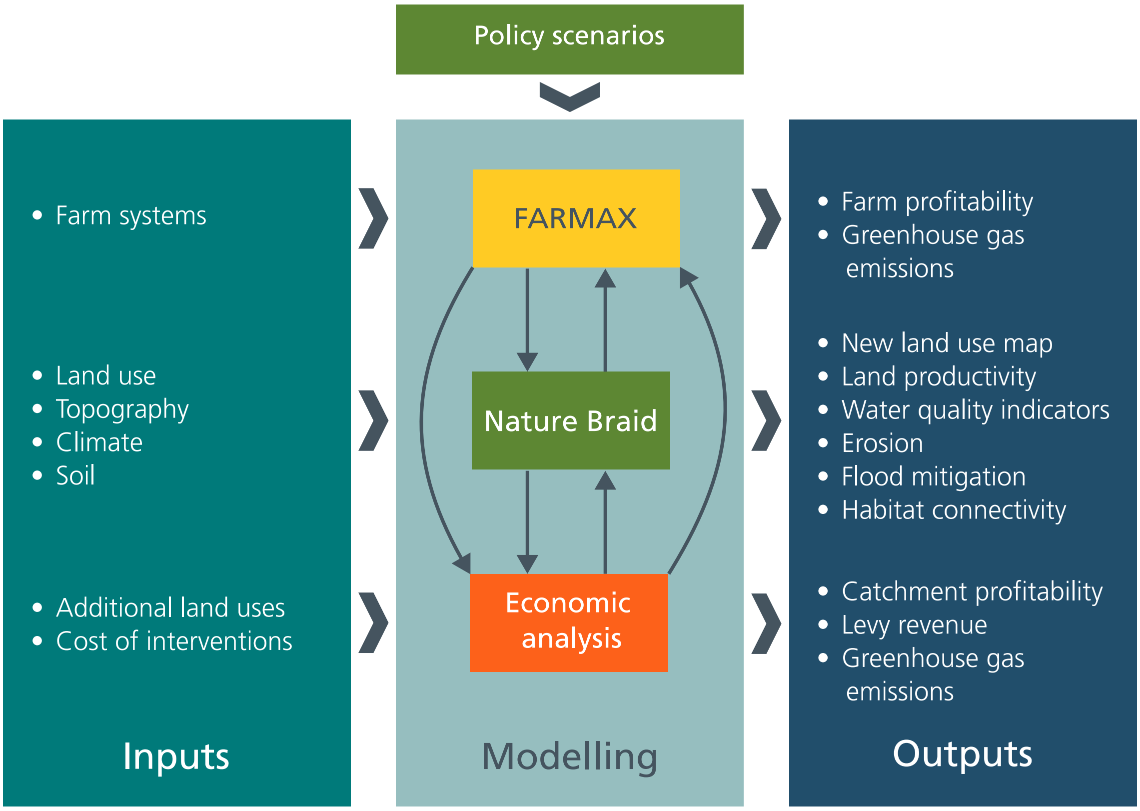
Additional economic analysis was undertaken to determine how land use would be likely to change in each scenario, and to integrate the outputs from FARMAX and Nature Braid. It considered the likely responses of landowners and land managers to policies such as agricultural emissions pricing, the NZ ETS, and freshwater regulations. It estimated how much levy revenue would be collected and how it would be spent in each scenario. It also estimated the profitability of land uses not able to be modelled in FARMAX, such as forestry and horticulture.

---

22 WSP, 2023a, b.

23 Nature Braid was formerly known as the Land Utilisation Capability Indicator (LUCI) framework.

24 These were calculated using the Revised Universal Soil Loss Equation, which uses information about rainfall erosivity, soil erodibility, topography, land use/cover, and management to estimate soil erosion by water (i.e. rainfall and runoff). It mainly accounts for terrestrial soil losses by water, but not explicitly for soil losses from landslides or mass wasting.



Source: Adapted from WSP (2023a)

Figure 2.3: Simplified workflow showing the inputs, modelling and outputs undertaken in the land use modelling.

The first step of the land use modelling process was to gather information on current land uses, types of farm systems, and the physical makeup of each catchment (which was used to determine the productive potential of the land). The modelling team worked with local industry experts to ensure the representative farm systems modelled in FARMAX reflected the unique characteristics of farms within each catchment.

Information on farm systems and the existing spatial distribution of land uses within each catchment were fed into the Nature Braid model, which assessed the impact of existing land uses on water quality, erosion, flood mitigation and biodiversity. Greenhouse gas emissions were estimated by combining emissions outputs from FARMAX for pastoral systems with additional analysis of emissions and removals from land uses modelled outside FARMAX. Collectively, the existing land use information, profitability and environmental indicators represented a modelled ‘present’ state for each of the case study catchments.

The modelling team then estimated how the catchments would be likely to change under each scenario for two future time steps (2030 and 2060), and calculated what the environmental and economic impacts of these changes would be. Major points in the analysis included assessment of the impact of an agricultural emissions levy on the profitability of pastoral farm systems, the likely response of farmers to increasing cost pressures and freshwater regulations, and the impact of the actions funded by the recycled levy revenue. The analysis assumed fixed commodity prices and no new technologies to reduce ruminant methane emissions.[25] The impact of climate change on the catchments was also not modelled.

In most cases, land use changes in the model were triggered by decreases in profitability due to the agricultural emissions levy. The modelling assumed that farmers would decide to change land use if the profitability of their farms turned negative. In general, farms with low but positive profitability did not automatically switch to a more profitable land use in the model.[26] This is because in the real world there is often inertia in land-related decision making due to a range of barriers such as debt, lack of information and limited access to expertise.

In some cases, changes in land uses and/or land management practices in the model were driven by freshwater regulations. Areas subject to more stringent regulations were identified using a combination of the Land & Water Science susceptibility maps and Nature Braid outputs. Farms within high-risk areas were remodelled in FARMAX to ensure compliance with the new rules.

For farms that were no longer profitable, the modelling assumed the land use would change to the most profitable alternative. In most scenarios, this was pine production forestry for hill country and high country sheep and beef farms, and some lowland sheep and beef farms. For dairying and some lowland sheep and beef farms, it was high-value alternative land uses such as tulips and sheep milking in Mataura, and macadamia orchards in Wairoa. These were simply used as examples of high-value alternative land uses for modelling purposes – in reality, there are no doubt other options that could be considered in each catchment.[27] Climate and soil limitations were considered, but other barriers to scaling up alternative land uses – such as supporting infrastructure needs and labour market constraints – were not modelled.

Further changes to farm systems and land use were also initiated in some scenarios through the recycling of the agricultural emissions levy revenue. Actions funded via the levy included riparian planting, loans or subsidies for land use changes that bring environmental benefits, and restoring or constructing wetlands.

In all cases, the revised farm systems (e.g. with new fertiliser application rates and stocking rates) and land uses were then fed back into the Nature Braid model to determine the environmental consequences of the policies in 2030 and 2060.

[25] If new technologies to reduce on-farm emissions become widely available, this would reduce the amount of land use change expected to occur in response to an agricultural emissions levy.

[26] Though in some cases, land use change was assumed to occur where a much higher profitable land use was available that complemented the existing farm system (e.g. tulips in Mataura, agroforestry in Wairoa).

[27] The Southland Food and Fibre Investment Acceleration Project led by Thriving Southland aims to identify key opportunities for growth in the food and fibre sector in Southland through community engagement (Thriving Southland, 2023b).

Involving local people in the exercise

Engagement with local people in each catchment was an important part of the exercise.

The choice of modelling tools used and the general framing of the policy scenarios were determined by the Parliamentary Commissioner for the Environment (PCE), WSP and the Nature Braid team at the start of the project. Additionally, local authorities, mana whenua (in Wairoa), landowners, industry groups and other local experts were involved in the process, providing advice on appropriate parameters for representing land uses in the modelling, identifying locally appropriate mitigation actions for scenarios 4 and 5, and interpreting the modelling results and key conclusions. This engagement took the form of a series of hui and workshops (in-person and online) at different stages of the project.[28]

In Mataura, the events were attended by farmers, catchment groups, the regional council and representatives of the wider agriculture and forestry sectors. The purpose of the initial engagement and first workshop was to introduce the investigation, understand perspectives and concerns with current and forthcoming environmental policies, and identify key environmental concerns, barriers to change, and land use opportunities in the catchment. In the second workshop, interim modelling results were shared, and participants were asked to identify issues and opportunities.

Mana whenua in the Mataura catchment shared their perspectives separately by outlining mana whenua led frameworks and tools. These pre-existing tools were developed to assist mana whenua in the management of various portfolios and help them in their decision making across environmental regulations and policies.

In Wairoa, the kōrero began with an online whanaungatanga event for tangata whenua. The purpose of the online whanaungatanga event was to introduce the investigation and the project team. Following this initial engagement, a series of in-person and online hui were held with tangata whenua and other local stakeholders to understand the local context, issues and potential mitigation options, and to share and discuss the modelling results.

Once the land use modelling and other aspects of the project were completed, the findings were shared in a final hui in each of the catchments. Participants were asked to share their perspectives on the findings, highlight the problems they see with current climate, freshwater and biodiversity policies and the consequences for their catchment if they continue, and provide their feedback on how things could be done differently.

[28] To ensure that the modelling inputs and parameters used to represent farms and other land uses were locally appropriate, WSP also engaged directly with experts from the agriculture and forestry sectors in the Wairoa and Mataura catchments.

Limitations of this exercise

An exercise of this nature will be inherently complex. Each aspect of it has so many variables. The landscape has multiple biophysical parameters, some of which vary at the sub-paddock scale. Most catchments have multiple land uses, and the spatial distribution of these land uses is determined by history, what the current land managers and kaitiaki want to do with that land, and the economic feasibility of different land use options.

Central government and local authorities have multiple and often overlapping policies in place to achieve certain outcomes and avoid other outcomes. Integrating them all gets very messy very quickly, especially as the regulatory landscape is often subject to change. It would be nearly impossible to factor all of these variables into a modelling exercise. Doing so was certainly well beyond the resources available for this exercise. Choices had to be made. Each choice introduced limitations.

To understand where the riskiest parts of the case study landscapes are and where the best places for interventions would be, physiographic modelling by Land & Water Science and outputs from the Nature Braid model were used. Other environmental models could have been used. Regardless of which models were used, the paucity of environmental data, especially at a granular level, would have introduced errors and limitations.

Likewise, a number of different economic models for modelling farm systems are available in New Zealand. FARMAX was used for this project. Others could have been chosen. Each one would deliver different results because they are designed differently, use different algorithms and have different underlying assumptions. Even with a single model, there are multiple different input assumptions that could be used, all of which will affect the results. Many other scenarios could have been modelled, but the number of times the models could be run was limited.

There are multiple environmental and economic policies that influence land uses and land management practices, and the resulting state of the environment. Some policies work together, some potentially undermine each other. Modelling the impact of interacting environmental policies is complex enough for the existing set of policies. It is much harder and more uncertain to test different mixes of future policies. This exercise focused on the impact of a potential levy on agricultural emissions (and the impact of recycling levy revenue back to the catchment), the NZ ETS and selected freshwater quality regulations. Other policy mixes could have been chosen.

More rigorous testing of the robustness of the assumptions and other choices used for this exercise would have been necessary if the point of this exercise had been to feed into the formal decision-making processes of government, businesses, land managers, communities and tangata whenua. But it was not. The point of this exercise was to test whether the concept of integrating spatial susceptibility mapping, land use and economic modelling with input from local people could deliver useful insights into the potential alternative futures arising from different mixes of policy. If the approach is determined to be useful, the tools would need to be developed further so they are fit to be used to inform decision making. It would be at that point that the appropriateness of the models and the robustness of their assumptions would need to be rigorously tested and debated.

Botrychium australe

3 Case study catchments today

Some of the most rapid and widespread changes in New Zealand's landscapes have been due to the expansion and intensification of pastoral farming. This was made possible by draining wetlands, straightening and channelling rivers, deforestation and clearing other vegetation. The legacy of these past actions shapes, in some cases literally, the catchments we see today.

The following sections outline the land uses and state of the environment in the Wairoa and Mataura catchments today.

Mataura River catchment

The Mataura River is the heart of the catchment. It is important culturally, socially and economically.

For mana whenua, the Mataura River is an important source of mahinga kai. The practice of mahinga kai is central to mana whenua identity, ways of knowing, social cohesion and overall wellbeing.[1] In particular, the harvest of kanakana (pouched lamprey, *Geotria australis*) during their migration is a very important activity that maintains mana whenua connection to the area and their responsibility as kaitiaki to harvest the resource in a sustainable way. This responsibility includes understanding land-based and other impacts that affect the ecosystem and migratory pathway of mahinga kai species.

Te Au Nui Pihapiha Kanakana (Mataura Falls) is a culturally significant site for mahinga kai of kanakana (Figure 3.1). The falls were heavily modified in the late nineteenth century to provide water for a freezing works, a paper mill and a hydropower station. Today there is still a meat processing plant on one side of the awa and a hydropower scheme on the other. In 2006, Te Au Nui Pihapiha Kanakana became part of a wider mātaitai reserve covering ten kilometres of the Mataura River, established by Hokonui Rūnanga.[2]

1 Kitson and Cain, 2023, p.13.

2 Thriving Southland, 2021, p.40; Kitson and Cain, 2023, p.2. As part of the mātaitai reserve rules there is to be no take of lamprey, shortfin or longfin eel allowed except on the authority of Tangata Tiaki/Kaitiaki (Fisheries (Mataura River Mataitai Reserve Bylaws) Notice 2009 (No. F485)).

Source: Alexander Turnbull Library, Mataura River, original photographic prints and postcards from the file print collection, Box 16, ref: PAColl-7344-81, records/23077784

Figure 3.1a: Te Au Nui Pihapiha Kanakana (Mataura Falls) before it was heavily modified in the 1890s to provide water for a freezing works, a paper mill and a hydropower station.

Source: PCE

Figure 3.1b: The Mataura River downstream of Te Au Nui Pihapiha Kanakana in 2021. There is still a meat processing plant on one side of the awa and a hydropower scheme on the other.

The Mataura River catchment (Box 3.1) is dominated by sheep and beef farming, dairying and pockets of pine production forestry (Figure 3.2). While agricultural expansion into undeveloped areas has largely ceased since the mid-1980s, changes are still occurring. The main change is a shift from sheep and beef farming to more intensive dairying.[3] There are also some high-value crops grown within the catchment, including tulips, which are exported in various forms to international markets.

Current land use activities and increasing intensification of agriculture are key contributors to the degradation of water quality in the Mataura catchment.[4] Water quality is particularly degraded in the middle and lower reaches of the catchment where the most intensive farming occurs.[5] The levels of *E. coli* and dissolved inorganic nitrogen are particularly concerning. Water clarity also decreases markedly between the upper and lower reaches of the Mataura River.

Box 3.1: Mataura catchment physical setting

Flowing south from the Eyre Mountains, the Mataura River dissects the Garvie Mountains before flowing across the Waimea plains and being joined by the Waikaia River. The Mataura continues to flow south through Gore and the Hokonui Ranges before entering the sea at Toetoes (Fortrose) Estuary.

The Mataura River traverses a variety of geologies, shaped most recently by Quaternary glacial activity. There is a complex array of soil types within the catchment that vary in their physical, chemical and biological components.[6] Under the surface, much of the catchment has accessible groundwater aquifers. The connection between surface water and aquifers in some regions plays an important role in how and when nutrients flow through the catchment.

Relatively cool and wet overall, the climate varies along the length of the Mataura catchment, transitioning from subalpine conditions in the north to marine-dominated in the south. In the future, temperatures are expected to rise. Rainfall will generally increase in intensity but become less frequent as the number of dry days increases.[7]

Today, little indigenous cover remains over large parts of the Mataura catchment. Wetlands in particular have been degraded. Close to 90% have been drained for agriculture since European settlement. This has resulted in the loss of important habitat as well as other ecosystem services, such as the processing of nutrients and sediment.[8]

The Mataura River is also subject to a Water Conservation Order (promulgated in 1997) that stipulates that at any point, 95% of the natural flow in the Mataura River must remain. While the primary goal of the order is to protect the trout fishery, its terms inevitably protect other species to some degree.

---

3 Ledgard, 2013, p.1; Freeman et al., 2020, p.10.

4 Thriving Southland, 2021, p.21.

5 LAWA, 2023a. Point source discharges also contribute to degraded water quality, particularly in and around Gore, but improvements have been made in recent times (Thriving Southland, 2021, p.21).

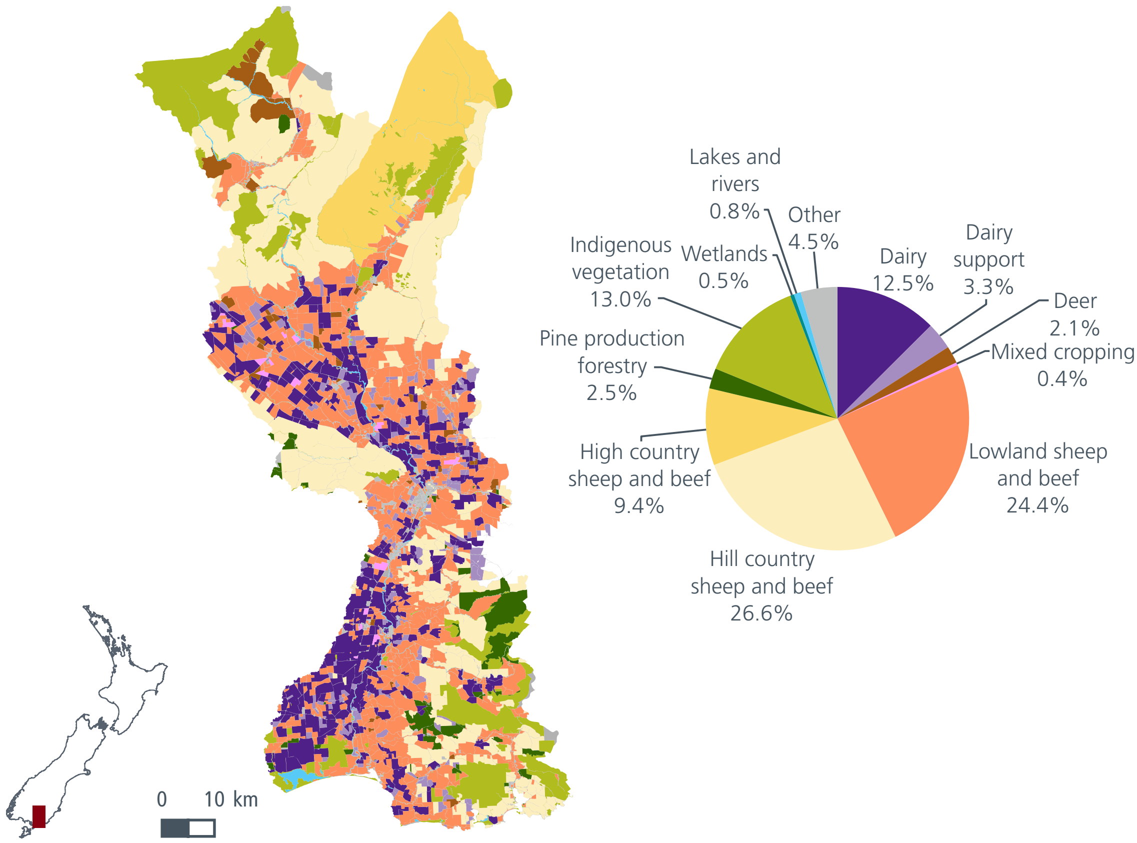
6 Freeman et al., 2020.

7 Zammit et al., 2018.

8 Freeman et al., 2020; Clarkson et al., 2013.

Intensification of land use in the Mataura catchment has come with land management practices that have the potential to significantly degrade water quality. For example, if managed poorly or too widespread, intensive winter grazing can have detrimental effects on freshwater quality (as well as animal welfare).[9] It is, therefore, not only the *type* of land use that is important, but the associated management *practices* that will determine freshwater quality outcomes.

Actions are being taken to improve land management practices within the Mataura catchment. This includes the work of catchment groups and Thriving Southland to target interventions based on the physiographic approach and landscape susceptibility (Box 3.2).[10] The Whakamana te Waituna initiative has also delivered projects aimed at improving the health of Waituna Lagoon, which is located to the west of Toetoes Estuary.[11]



Source: Adapted from WSP (2023a)

Figure 3.2: Land use in the Mataura catchment.

9 Environment Southland, 2020; MfE, 2022.

10 For example, see the Thriving Southland Beyond Regulation Mataura Catchment Project (https://www.thrivingsouthland.co.nz/beyond-regulation-mataura-catchment-project/). Rissmann et al. (2023) provide an example of the use of susceptibility mapping to prioritise interventions to reduce contaminant losses from a dairy farm in the Mataura catchment.

11 Whakamana te Waituna (https://www.waituna.org.nz/) is a partnership between Te Rūnanga o Awarua/Te Rūnanga o Ngāi Tahu, Department of Conservation, Environment Southland, Southland District Council and Fonterra (through the Fonterra–DOC Living Water partnership).

However, changes in land management practices can only achieve so much. For example, modelling undertaken as part of setting freshwater objectives in Murihiku Southland suggests that a 79% load reduction in total nitrogen and 58% load reduction in total phosphorus would be needed in the Mataura catchment to meet draft objectives.[12] Research suggests that even if the use of existing best management practices were universally undertaken, they would be insufficient to achieve desired outcomes.[13] De-intensifying existing land uses in some parts of the catchment and shifting to alternative land uses in others will be needed to achieve the desired environmental outcomes.[14]

Intensification has also led to significant pressure on the quantity of water remaining in the Mataura River. Despite the requirements to retain flows under the Mataura Water Conservation Order, a 2020 review found that the river has been overallocated north of Gore.[15]

Box 3.2: Southland's catchment groups and Thriving Southland

A large number of catchment groups have been established in Southland – 35 as of August 2023.[16] Many of these are voluntary, bottom-up groups that were formed by farmers in response to the freshwater regulations being introduced as part of the Essential Freshwater programme. The activities being undertaken vary from group to group. Examples include field days, talks by guest speakers, freshwater monitoring, education and outreach activities, and piloting alternative land management practices.[17]

Thriving Southland was set up in 2020 to support and connect Southland's catchment groups. The projects undertaken or supported by Thriving Southland include a study of Southland's food and fibre opportunities, a wetland development project, a winter crop establishment trial, and a project to develop and trial the use of physiographic modelling to better understand spatial variation in freshwater and soil nitrous oxide emissions. It also provides free resources, supports events, and has a team of catchment group coordinators to assist with setting up and supporting catchment groups in Southland.[18]

The loss of native ecosystems in the catchment generally reflects changes nationally, with upland and mountain ecosystems remaining the most intact while lowland and coastal ecosystems have suffered widespread clearance and modification. For example, podocarp forest formerly covered most of the lowland plains, but now only small fragments remain scattered across the catchment. Intensification over the past 30 years has led to the further loss of shrubland, red tussock and wetlands.[19] As a result, there has been a continued loss of connectivity between larger areas of indigenous vegetation and wetlands.[20]

---

[12] Snelder, 2021, pp.98–99.

[13] McDowell et al., 2021, p.399; Southland Regional Forum, 2022, p.21.

[14] Southland Regional Forum, 2022.

[15] Water Conservation (Mataura River) Order 1997; PDP, 2020.

[16] Thriving Southland, 2023c.

[17] Thriving Southland, 2023a.

[18] Thriving Southland, 2022.

[19] There was a 45% decline in the extent of wetlands on private land in Southland between 1990 and 2012, with the majority shifting to pasture (Robertson et al., 2019, p.6).

[20] Wildland Consultants, 2008, p.16.

Wairoa River catchment

From the top of the ranges to the entrance of the Kaipara Moana (Kaipara Harbour), mana whenua of the Wairoa catchment are deeply embedded in the landscape. As kaitiaki their responsibility is to ensure a prosperous environment for the future, where their connection to the area is unsevered and enduring. Historical settlement sites, mahinga kai sites and wāhi tapu are found all along the awa. Many hapū relied heavily on their taonga resource, tuna (eel), as sustenance.

The decline of the mauri of natural resources is a significant issue in the Wairoa catchment. Degraded water quality negatively affects kai moana harvesting sites and the ability for tangata whenua to mahinga kai and feed their whānau. The loss of indigenous biodiversity has also negatively impacted the ability of tangata whenua to carry out traditional cultural activities.[21]

The Wairoa catchment (Box 3.3) is dominated by pastoral farming (dairy, sheep and beef) with some exotic pine production forestry (Figure 3.3). High-value horticulture crops, such as avocado and kiwifruit, are increasingly grown in the catchment due to its favourable climate and soils. The lower reaches of the Wairoa River near Dargaville are also one of the main kūmara production areas in New Zealand. This arrangement of land uses is the product of significant land use change over a long period of time, resulting in environmental degradation throughout the catchment.

Box 3.3: Wairoa catchment physical setting

The Wairoa River (also known as the Northern Wairoa River) begins where the Mangakāhia and Wairua rivers meet, near Tangiterōria. It reaches the sea in what is now known as the northern branch of the Kaipara Moana.

The largest catchment in Te Tai Tokerau, it is characterised by a mild, humid and windy climate due to its northern location, low elevation and close proximity to the sea.[22] Rainfall varies substantially between years, with some years punctuated by erratic, heavy events. Ex-tropical cyclones occasionally bring heavy rain and strong winds to the region, but droughts are common. Northland is predicted to become significantly drier and hotter by the end of the century. Projections for the coming century show a decrease in the frequency of very heavy rainfall in Northland, though extreme rainfall from tropical cyclones was likely to be underestimated in these results.[23]

The geology of the Wairoa River catchment is a mixture of volcanics, alluvium and sands, and sedimentary rocks (sandstones and mudstones). The latter are highly erodible, increasing the potential for sediment loss to rivers and streams. Much of the original land cover has been lost, with remnants of indigenous vegetation scattered throughout the catchment, on both public and private land.

The catchment is home to a diverse range of aquatic species. Many, such as tuna (longfin eels, *Anguilla dieffenbachii*), are a valued source of kai for tangata whenua. It is also one of the main tributaries of the Kaipara Moana, an important nursery for juvenile fish such as snapper (*Chrysophrys auratus*).[24]

---

21 Northland Regional Council, 2017; Royal, 2022.

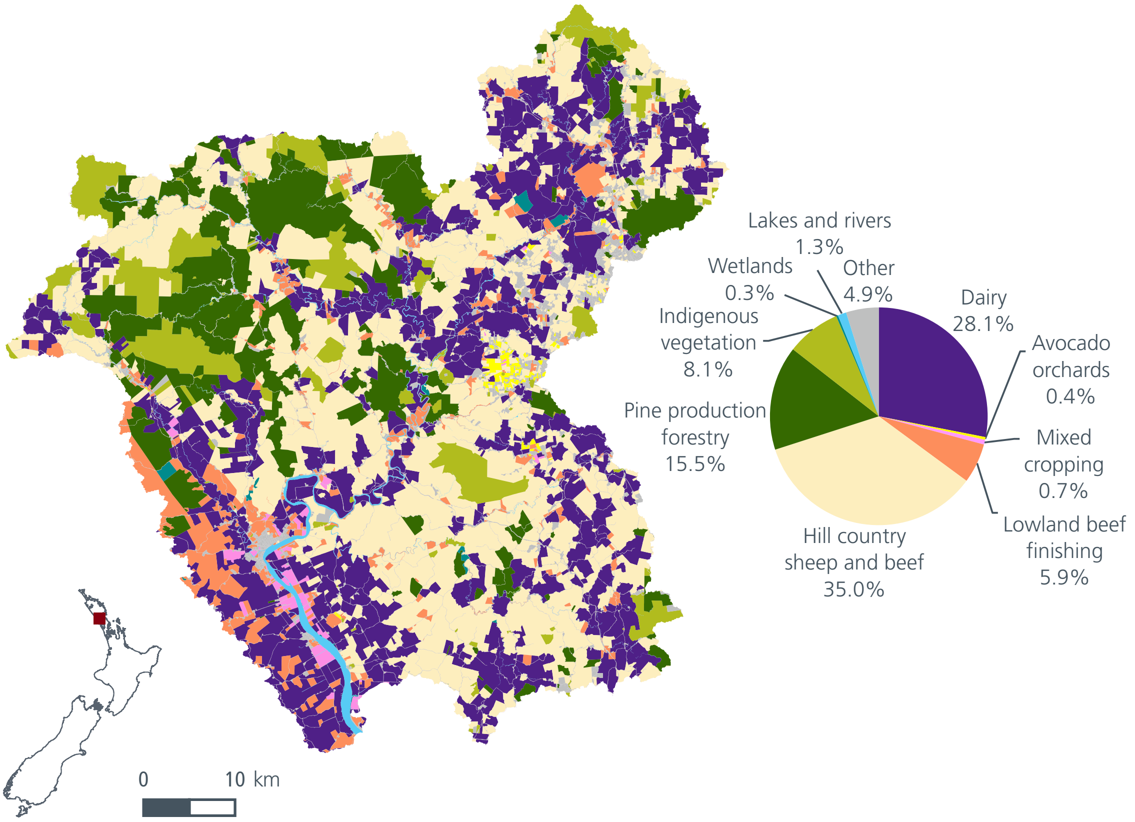
22 Chappell, 2013.

23 Pearce et al., 2016, p.74.

24 For example, the majority of snapper found on the west coast of the North Island come from the Kaipara Moana (Morrison et al., 2009, p.68).

Sediment is the main freshwater quality concern in the Wairoa River, although there are elevated nutrient levels across many indicators in most of the catchment.[25] The causes of high sediment loss can be attributed to the highly erodible geology in some parts of the Wairoa catchment exacerbated by pastoral farming and forestry.[26]

Sediment lost from the Wairoa catchment is ultimately deposited in the Kaipara Moana, degrading its mauri and the harbour's ecological health and wellbeing.[27] To combat sedimentation in the harbour, the Kaipara Moana Remediation Programme (Box 3.4) has been established to coordinate and implement changes in land management to reduce sediment loss in the wider catchment.



Source: Adapted from WSP (2023b)

Figure 3.3: Land use in the Wairoa catchment today.

[25] NRC, 2019, pp.40–41; LAWA, 2023b.

[26] Green and Daigneault, 2018, p.10; Rissmann et al., 2022, p.109.

[27] Swales et al., 2011, p.12; KMR, 2020.

Box 3.4: Kaipara Moana Remediation Programme

Kaipara Moana is the largest estuarine body in Aotearoa. Containing a range of rare and significant ecosystems, it is of profound importance for hapū, with great spiritual, cultural and economic value. It is facing severe environmental degradation primarily due to sedimentation, with an estimated 700,000 tonnes deposited into the harbour each year. This is about six times the amount before human settlement.[28]

In October 2020, the Crown signed a memorandum of understanding with project partners (Kaipara Uri,[29] Northland Regional Council and Auckland Council) to launch the Kaipara Moana Remediation Programme. The agreement built on years of work by hapū who were concerned that Kaipara Moana was in poor health and, if left unchecked, would be at risk of degrading beyond repair.[30]

The Government is contributing $100 million towards the total project cost of $200 million for the first six years (of an anticipated ten-year programme). Co-funding is being provided by councils, landowners, industry and others.

The remediation programme's key focus areas include the restoration of wetlands, fencing and riparian planting around waterways, and stabilising highly erodible land.[31] Given that the Wairoa River catchment makes up over half of the entire Kaipara Moana catchment, it features prominently in the scheme.

Land clearance has meant that native ecosystems have been lost or restricted to a fraction of their original extent in the Wairoa catchment. Prior to the arrival of humans, the catchment was a mixture of broadleaf-podocarp-kauri forests, alluvial forests and wetlands.[32] Currently, less than 10% of the catchment is covered in indigenous vegetation. Taonga species, such as tuna whakaheke (migrating eel), have been adversely impacted by drainage and land use changes. Draining and development of the Hikurangi Repo (Hikurangi Swamp) provides a particularly marked example of this. Once a large wetland consisting of marsh, swamp, fen and bog, it has been mostly drained for agriculture since in the early twentieth century (Box 3.5).[33] In addition to land clearance, introduced species and predators are putting native species, such as North Island brown kiwi (*Apteryx mantelli*), under pressure.

---

[28] KMR, 2020, p.2; Green and Daigneault, 2018, p.16.

[29] Kaipara Uri include the following iwi/hapū: Ngā Maunga Whakahī o Kaipara, Te Rūnanga o Ngāti Whātua and Te Uri o Hau.

[30] KMR, 2020.

[31] KMR, 2022, p.6.

[32] Conning, 2001, pp.52, 65, 67.

[33] Conning, 2001, p.52; Clarkson et al., 2015.

Box 3.5: The Hikurangi Repo and Hikurangi Flood Management Scheme

The Hikurangi Repo lies at the heart of the Wairua sub-catchment, in the upper reaches of the Wairoa River catchment. The repo (swamp) is of cultural significance to many local hapū. It is an important source of mahinga kai, a source of healing and a place for burial and baptismal practices.

Originally covering most of the floodplain, the repo has been progressively drained since 1919 to develop the area for agriculture. Only the Otakairangi and Wairua River wetlands remain relatively intact. Other smaller fragments are scattered across the Hikurangi floodplain, mostly on private or conservation land.[34]

Ongoing flooding issues throughout the mid-twentieth century led to development of the so-called 'Hikurangi Swamp Major Scheme'. The purpose of the scheme was to limit the frequency and extent of flooding on drained farmland.[35] Stopbanks and floodways were constructed, dissecting the scheme's 5,670 hectares into seven pockets. Each pocket has large pumps to limit the extent and duration of flooding of the surrounding farmland (which is primarily used for dairying). Whangarei District Council is currently the owner and consent holder for what is now known as the Hikurangi Flood Management Scheme.[36]

Freshwater quality, biodiversity and climate change issues converge in the Hikurangi Repo, with competing stakeholder interests. These issues include:

- **Protecting biodiversity:** The remaining fragments of undrained land are home to remnants of a rare type of fen wetland and remain threatened by the ongoing impacts of drainage, habitat loss and elevated nutrients from farms. The drains in and surrounding the Otakairangi remnant in particular contribute to a lowering of its water table, accelerating peat decomposition, and an ecological shift in favour of mānuka, accompanied by biodiversity loss. Drains are also conduits for weeds.[37]
- **Sediment and freshwater quality:** Sediment and other nutrients are no longer filtered through the Hikurangi Repo due to the channelisation of the river and loss of wetland extent. As a result, there has been increased degradation of the Wairoa River and ultimately the Kaipara Moana. Improving the Wairoa River and the Kaipara Moana (see Box 3.4) will require addressing the issue of the Hikurangi floodplain to some degree.[38]

---

[34] Conning, 2001, p.52; Clarkson et al., 2015.

[35] WDC, 2012b, p.12.

[36] WDC, 2012b, p.15

[37] Clarkson et al., 2015, p.vi.

[38] Royal, 2021, p.3. Modelling also suggests that the majority of sediment delivered to the Kaipara Moana comes from the Wairua and Mangakāhia catchments in the upper Northern Wairoa, highlighting the importance of restoration initiatives in these areas (Daigneault et al., 2017, p.48).

- **Tuna whakaheke:** A significant concern for mana whenua is the scheme's impact on tuna whakaheke. Hikurangi Repo is an important habitat for tuna.[39] Tuna whakaheke begin their autumn journey from the repo into the Kaipara Moana and on to the Pacific Ocean after the first rains. The pump stations within the scheme represent significant barriers to fish passage and can kill tuna if the pumps are switched on during heavy rainfall.[40] While management actions are in place, these have failed in the past.[41]
- **Increasing flood frequency and magnitude:** The scheme was originally designed to prevent flooding from a one-in-five-year flooding event. With the intensity of rainfall expected to increase in the future, the scheme will come under further pressure and maintenance costs are likely to increase.[42]

---

[39] WDC, 2012a, p.9.

[40] For example, tuna were chopped up by the scheme's pump stations in 2021 after autumn rain. The pumps switched on automatically to reduce river levels and to stop surrounding farmland getting flooded. At the same time, the rain triggered the start of the tuna migration (Botting, 2021).

[41] For example, pumps are not to be turned on within the first eight hours of rain to allow the tuna whakaheke to successfully start their migration (WDC, 2022, p.3).

[42] WDC, 2012b, p.12; WDC, 2021, p.78.

Asplenium haurakiense

4 Tangata whenua frameworks, tools and knowledge

Any approach to landscape management has to include mana whenua, the people who have a spiritual and cultural connection to the land they have lived on for many generations. It was therefore important to understand the perspectives of tangata whenua in both case studies on the kaupapa of integrated landscape management and how Māori perspectives might be included as part of any future approach to managing land and water resources at a catchment scale.

We were guided by mana whenua groups from each case study catchment as to how they would like their mātauranga Māori represented within this investigation. They also provided advice on what a good process of inclusion would look like, based on their views of Treaty partnership and data and resource equity.

The two mana whenua groups chose to provide their input into this investigation and to express their tino rangatiratanga within this process in different ways, reflecting different local contexts. Although they took different approaches and expressed themselves in different ways, what was similar was that any input provided was underpinned by their values and concepts of landscapes and integrated management from a te ao Māori perspective.

For the Murihiku Southland case study, we worked with Hokonui Rūnanga, who developed a report reflecting the collective mātauranga of Ngāi Tahu ki Murihiku. The view of Ngāi Tahu ki Murihiku was that because the land use modelling did not include parameters pertaining to te ao Māori, their mātauranga could not be integrated into it. At the same time, they perceived a risk that having no representation of mana whenua values and pre-existing methods in the exercise could mislead the reader to assume that there were no mana whenua led tools or perspectives that could support this kaupapa, or that Ngāi Tahu ki Murihiku implicitly approved of the investigation's process and outputs. To avoid that outcome, they chose to develop a separate piece of work to sit alongside the land use modelling.[1] The report outlined:

- related mana whenua frameworks and tools that have been developed by iwi and mana whenua for the Mataura catchment (including a summary of the methodology and results of the tools for two sites within the catchment)
- commentary and questions on the framing of the PCE investigation
- discussion of the integrated landscape approaches being explored by the PCE and a mana whenua approach.

---

[1] Kitson and Cain, 2023.

In Te Tai Tokerau Northland, a facilitator was contracted to lead the engagement with mana whenua and coordinate input from hapū into the exercise, including ways that mātauranga might either be included within the modelling framework or aligned with it. Ngā mana whenua o Wairoa – Te Tai Tokerau provided some input directly into the land use modelling. They also shared generalised views about what was important to them in their rohe that must also feed into any catchment-scale decision-making process.

The different approaches, tools employed and outcomes for each mana whenua group are summarised below.

Ngā mana whenua o Mataura

Ngāi Tahu ki Murihiku represent the shared interest areas of Hokonui, Awarua, Ōraka-Aparima and Waihōpai Papatipu Rūnanga (Ngāi Tahu). The Mataura catchment is a part of their rohe. The input provided into this investigation was led and reviewed by Hokonui Rūnanga. It reflects the collective mātauranga of Ngāi Tahu ki Murihiku.

Understanding landscapes from a Ngāi Tahu ki Murihiku perspective is founded in their principles, epistemology and ontology, and is firmly placed in te ao Māori. Ngāi Tahu have centuries of customary associations, rights and interests in the Gore District (including the Mataura catchment) and its resources. These associations are historical and contemporary, and include whakapapa, place names, mahinga kai, tribal economic development, and landholdings."[2]

Whakapapa connects them to the landscape and carries responsibility for looking after the environment and their connection to it.

Te Tiriti o Waitangi and the Ngāi Tahu Claims Settlement Act 1998 (signed in 1997) created a "binding legal relationship between the Crown and Ngāi Tahu, however, this is much broader than simply a contract and includes aspects of beneficial/fiduciary relationship".[3] For Ngāi Tahu, this means applying their environmental philosophy in their takiwā (area) as a management right guaranteed to them through this relationship.[4]

Ki uta ki tai and integrated landscape approaches

Ngāi Tahu ki Murihiku define integrated landscape approaches through the concept of ki uta ki tai. This means all things are connected, and mana whenua belong to the environment and are only borrowing resources from future generations. A key component to this concept is the importance of mahinga kai and the role it plays in understanding the connections of resources, people and landscapes. Ki uta ki tai is used to:

> "analyse the interconnected effects across a region. For example, if an estuary is degraded, what is the extent of that state and where, if anywhere, along the contributing waterbodies does the state change from degraded to hauora."[5]

---

[2] Kitson and Cain, 2023, p.1.

[3] Kitson and Cain, 2023, p.11.

[4] Kitson and Cain, 2023, p.12.

[5] Kitson and Cain, 2023, p.11.

Ngāi Tahu ki Murihiku have developed frameworks and tools for integrated landscape approaches drawing on Te Tiriti o Waitangi and a localised understanding of the principles, deed of settlement arrangements and policy frameworks for iwi environmental management – for example, their iwi management plan and Te Mana o te Wai (under the National Policy Statement for Freshwater Management).

Te Tangi a Tauira, the Ngāi Tahu ki Murihiku Natural Resource and Environmental Iwi Management Plan 2008, assists them to effectively participate in environmental policy and planning as it allows for the articulation of their values and their expression of kaitiakitanga. It also aids in the council's statutory obligations to provide for their issues and policies in planning documents.

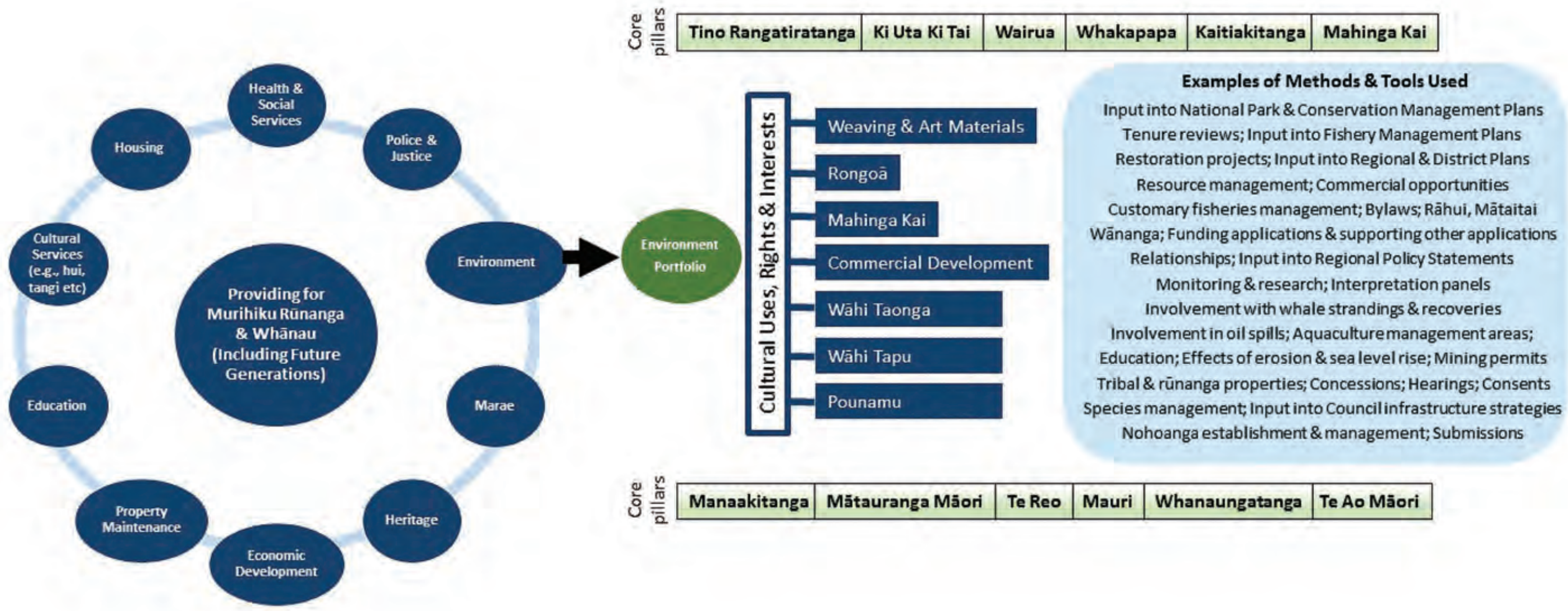
Te Kawa o te Taiao is a strategic document that Hokonui Rūnanga developed to bring together various strands and relevant information for a clear purpose and is often referred back to when conducting environmental kaupapa.

Te Mana o te Wai has been included in the proposed Southland Water and Land Plan as it centres on the health of the water and land itself rather than human use. Ki uta ki tai is then used to bind and integrate all of the elements together. Ngāi Tahu indicators work with the attributes in the National Policy Statement for Freshwater Management and Te Mana o te Wai to maintain and improve water quality and quantity in a culturally relevant manner across the Murihiku takiwā.[6]

The policies and approaches above direct how engagement between local authorities and mana whenua must be conducted and express the needs and expectations of mana whenua. For Ngāi Tahu ki Murihiku, this has shaped regional and district plans to date and should be applied in any attempt to conduct integrated landscape management in the Mataura catchment.

The integrated landscape management approach taken by Ngāi Tahu ki Murihiku encapsulates more than policies related to freshwater, climate change and biodiversity and goes beyond economic impacts. It includes social, health and wellbeing impacts. In their view, these cannot be excluded from an approach that looks at landscapes. Figure 4.1 illustrates the multiple policies, plans and government processes that Ngāi Tahu ki Murihiku need to consider when developing tools to manage the environment and inform policy development.

[6] Kitson and Cain, 2023, p.17.



Source: Kitson and Cain (2023, p.23)

Figure 4.1: The multiple portfolios operated by Murihiku Papatipu Rūnanga (left), and the core pillars guiding the implementation of the environment portfolio and some examples of the services facilitated by Papatipu Rūnanga on behalf of, and in collaboration with, Murihiku whānau (right).

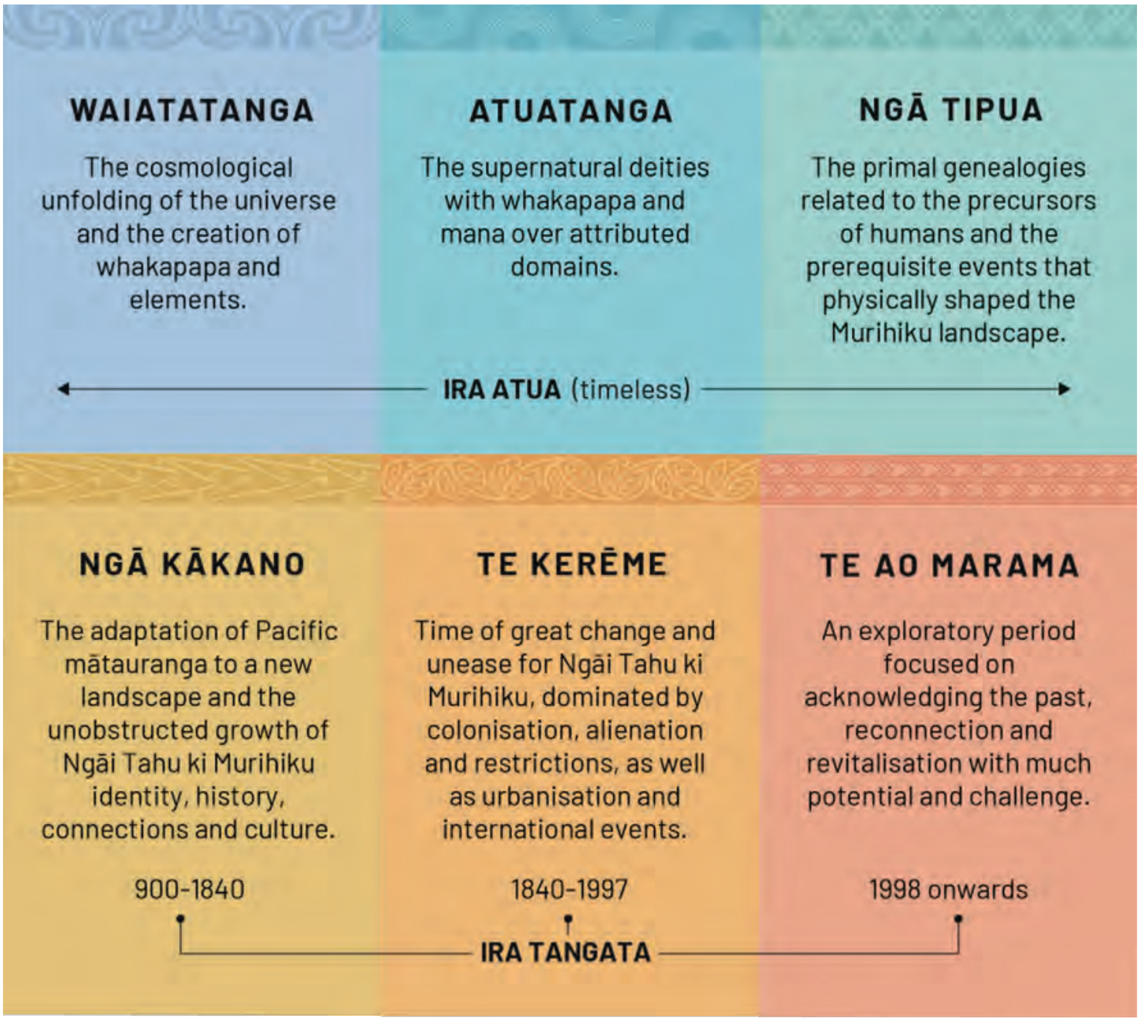
Ngāi Tahu ki Murihiku have developed two tools from these frameworks:

- Āpiti Hono Tātai Hono, which enables a comprehensive understanding of landscapes as known to Ngāi Tahu ki Murihiku and what is appropriate at place
- Murihiku Cultural Water Classification System, which assesses the state and thresholds around particular cultural uses (e.g. wai noho and wai tuna).

Both tools can incorporate different knowledge systems within their te ao Māori frameworks. Both provide information and data relevant to their environmental management needs within a ki uta ki tai integrated approach.

Āpiti Hono Tātai Hono

Āpiti Hono Tātai Hono is ordered by whakapapa and centred on ira atua and ira tangata. It is categorised into six layers representing the relationships between people and atua as pertaining to landscapes (Figure 4.2).



Source: Kitson and Cain (2023, p.19)

Figure 4.2: Summary of ira atua and ira tangata layers.

Ira atua recognises the metaphysical elements of culture and landscape that have always been there, and always will be.[7] The ontological understanding of the world as seen from a Ngāi Tahu ki Murihiku perspective is held in this category. This includes the creation of the universe and the atua who hold mana over certain environmental domains and events that physically shaped the landscape. Ira tangata includes the connections that people have with the landscape over time, including into the future.

In this framework, Ngāi Tahu ki Murihiku are able to recognise, assess and manage fundamental components of their culture and identity (ira atua) and safeguard their historical connections to the landscape, while also evolving their own mātauranga (ira tangata).

Assessing the landscape using these layers is iterative, evolving and collectively agreed. No single practitioner or source of information is emphasised. Layers are collectively interpreted, and whakapapa is used as a tool to resolve conflict. The tool can be used across all of the landscape or for parts of it (air, water, soil). It takes a holistic view by integrating the humanistic and environmental components of the landscape.

As part of their input into this investigation, two sites were assessed by Hokonui Rūnanga and the whānau within the Mataura catchment. The sites were Te Au Nui Pihapiha Kanakana (Mataura Falls) and Waikākahi (Waikaka Stream – Maitland). Through a desktop review, hui and site visits, Hokonui Rūnanga determined that in order for the mauri of the falls to improve and for whānau to reconnect to the area for mahinga kai and other cultural purposes, changes such as safer access to the site, improved migratory pathways, and improved water and air quality are needed.[8]

An aspiration for the Waikākahi site is to naturalise the site and its wider ecosystem by planting, weeding and improving water quality. This would allow for mana whenua to engage with the area in similar ways to their tīpuna while also improving the ecological health of the stream, including mahinga kai species.

Murihiku Cultural Water Classification System

Ngāi Tahu ki Murihiku developed the Murihiku Cultural Water Classification System as a response to multiple pieces of legislation with overlapping impacts, which in their view were impeding the protection of mahinga kai species and practices of Ngāi Tahu ki Murihiku. It is a system that allows them to express their uses, values, aspirations and expectations of freshwater, and to monitor for better management in an integrated way and at a landscape scale.

The classification system currently centres on the following cultural uses:[9]

- wai pounamu (waters for the movement, collection and working of pounamu)
- wai nohoanga (seasonal camping areas across the landscape)
- wai tuna (waters that sustain the intergenerational harvest of tuna).

---

[7] Kitson and Cain, 2023, p.19.

[8] Other actions needed were also identified that would contribute to the improvement of mauri at that site (Kitson and Cain, 2023, p.50).

[9] Kitson and Cain, 2023, p.21. Others are in development.

Each cultural use has a set of themes, attributes and indicators/measures that reflect the needs of the resource itself, the user and the supporting environment. The system uses various knowledge systems and sources of information (including mātauranga Māori, social science, science and cultural heritage) to determine the state of each attribute. For example, for the cultural use of Wai Tuna, some examples of attributes that would reflect sustainable harvest include the abundance of tuna, the quality of tuna for consumption and their ability to migrate.

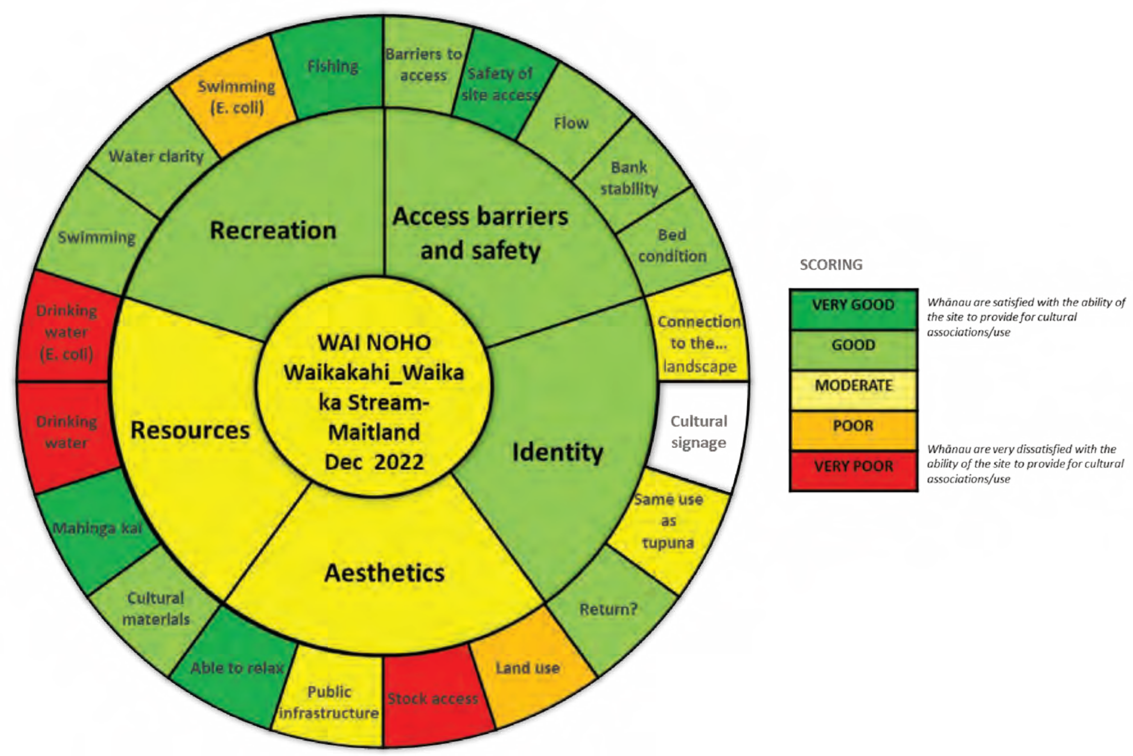
The same two sites in the Mataura catchment were assessed as for the Āpiti Hono Tātai Hono assessments. Data were captured by mana whenua using a cultural health assessment (cultural health index), science measures (Stream Health Monitoring and Assessment Kits) and monitoring assessments (fyke nets for tuna population assessments). Targets were also developed for analysis and interpretation of the data. A collective understanding of the individual assessments was reached by mana whenua after the site assessments.

He Puna Whakaata o Mātauranga visualisation tool was developed to illustrate the current state of cultural uses at each site. It shows the current state as a circle with the cultural use being considered at its centre. A segmented inner circle represents the themes of that cultural use, and an outer segmented circle represents the attributes. The colours represent the collective scores given during the assessment of the sites, ranging from very poor (red) to very good (green).

For the Murihiku Cultural Water Classification System assessment at the Waikākahi (Waikaka Stream – Maitland) site, wai noho and wai tuna were assessed. Only the wai noho assessment is summarised here. Examples of the targets for this site and assessment include:

- water is safe to swim in
- site can be used for mahinga kai
- stock are unable to access the site
- public infrastructure does not impact access for whānau to cultural sites.

The whānau scored each indicator individually on a five-step scale from very poor to very good. These scores were then combined to give a total score for each attribute. Five themes were identified with 21 attributes. Most themes scored good to moderate (inner circle). The overall state for this cultural use was scored as moderate (centre circle) (Figure 4.3).



Source: Kitson and Cain (2023, p.56)

Figure 4.3: Murihiku Cultural Water Classification System assessment for wai noho: He Puna Whakaata o Mātauranga at Waikākahi (Waikaka Stream – Maitland) site.

For the Te Au Nui Pihapiha Kanakana – Mataura Falls site, only wai noho was assessed. Five themes were identified, with various targets, attributes and indicators/measures determined for each theme. Examples of the targets that whānau identified at this site included:

- having safe access to the site
- to reconnect as mana whenua of the site
- to access the site for resource use.

Most attributes were moderate to very poor, with only 3 out of 21 being good or very good. All five themes were determined to be moderate to very poor.

Commentary on the PCE's investigation

Ngāi Tahu ki Murihiku were clear on their definition of a landscape approach, and thus the tools needed to inform catchment-scale decision making. Their position on this kaupapa was clearly articulated in their report and is summarised here.[10]

[10] Kitson and Cain, 2023, pp.26–27.

The way Māori view and therefore manage the environment is holistic. This view has been used to develop tools that join up the siloed nature of the environmental management system. Ngāi Tahu ki Murihiku landscape values include social, cultural and economic parameters that have been used to develop their targeted approach to integrated landscape management – ki uta ki tai. This understanding of the importance of landscapes is largely invisible within the current system, but is necessary.[11] A relevant question then is, why have Māori frameworks and tools not been used in targeted responses regionally and locally? What are the barriers to a ki uta ki tai landscape approach?

Ngāi Tahu ki Murihiku acknowledge that integrated landscape approaches are perhaps the only way we can tackle complex environmental issues. However, in their view, an approach like this needs to ensure and recognise different paradigms at the outset to accommodate a more diverse understanding of landscapes.

Ngāi Tahu ki Murihiku considered that the approach taken by the PCE was unable to incorporate regional expressions of mātauranga Māori and tikanga because they were not used in the framing of the questions for the problem definition and model selection. As a result, any findings from the project were divorced from the inherent meanings, social norms and epistemological traditions of each iwi/hapū. Ngāi Tahu ki Murihiku consider that the inclusion of a fragment of a culture or its mātauranga divorced from its paradigm is not a sustainable or ethical approach to integrated landscape approaches, nor is it useful or relevant to Māori.

The full commentary of Ngāi Tahu ki Murihiku on the PCE's investigation is available on the PCE website.[12]

Ngā mana whenua o Wairoa – Te Tai Tokerau

The Māori perspectives component of this exercise for the Wairoa catchment included a desktop review and co-facilitation of local hui and workshops to collate whānau narratives on landscapes and integrated landscape approaches. Due to the diversity of these narratives, the summary below is only a snapshot of mana whenua views. The initial intention was to determine whether these narratives could inform the land use modelling and to discuss how hapū whakaaro and narratives could inform integrated management at a catchment scale. The content of the rest of this section is based on commentary from mana whenua at the hui and workshops, as well as additional input from hapū representatives.

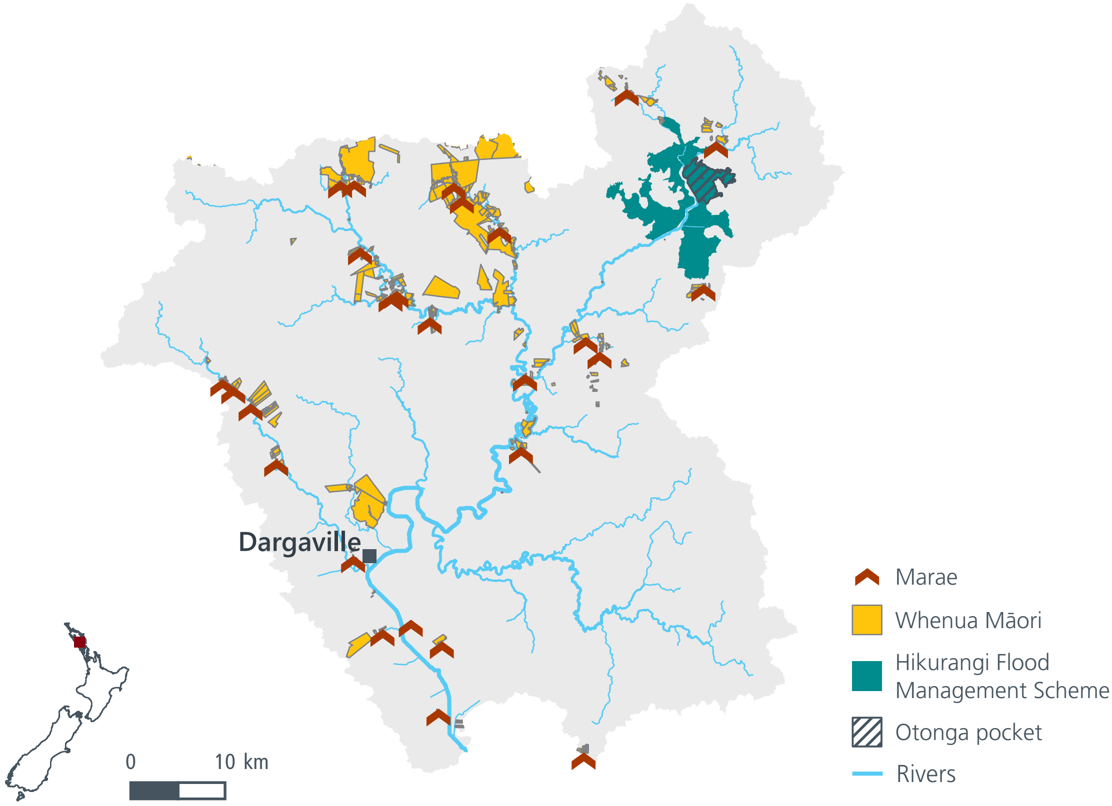
Traditional Māori philosophy has shaped the way mana whenua see the Wairoa catchment. Through whakapapa and principles derived from te ao Māori ways of understanding, important aspects of landscapes are understood. These include the physical parameters of the landscape and how mana whenua connect to them, historical impacts, kaitiakitanga and mana. When thinking about integrated landscape management, these all need to be considered.

The cultural landscape of the Wairoa catchment is rich and diverse. It contains 310 parcels of ancestral Māori land, more than 24 marae, and is part of the identity of 43 hapū and 6 iwi (Figure 4.4). The mountains and ranges of Huruiki, Ruapekapeka, Mangōnui and Tūtāmoe are part of the physical representation of their cultural connection.

---

[11] Ki uta ki tai is recognised in the National Policy Statement for Freshwater Management, which requires every regional council to "give effect to Te Mana o te Wai, and in doing so must … adopt an integrated approach, ki uta ki tai, to the management of freshwater" (Clause 3.2).

[12] See https://pce.parliament.nz/publications/exploring-land-use-change-under-different-policy-settings-in-two-case-study-catchments; Kitson and Cain, 2023, pp.26–27.



Sources: Ministry of Justice (2017); Te Puni Kōkiri (2017); Whangarei District Council (pers. comm., 2023)

Figure 4.4: Map of the Wairoa River catchment showing marae (red arrows), whenua Māori (yellow areas) and the extent of the Hikurangi Flood Management Scheme (teal area).

The cultural landscape of the Wairoa catchment is about connection and is not purely economic. Some local farmers also whakapapa to the catchment. They work on land that has been passed down through the generations, or play an important part in local and Māori communities. These relationships are important. Any attempt at managing landscapes in an integrated way requires a good understanding of the diversity of relationships that are held within the landscape: the relationship that mana whenua have with the land; the relationship that farmers and other landowners have with the land; and the relationships between people.

The landscape represents the history of settlement by people, from the various waka arriving from the Pacific over many generations, to new settlement today. Hapū lost tino rangatiratanga through colonisation, and attempted to retain it through the signing of He Whakaputanga o te Rangatiratanga o Nu Tireni (the Declaration of the Independence of New Zealand) and Te Tiriti o Waitangi. The hapū of the Wairoa catchment emphasise that this is a part of history that must not be forgotten. They state that they never ceded sovereignty over their lands, fisheries, water, taonga, culture and resources, yet their authority has been superseded by the Crown. The current approach taken by mana whenua is the progression towards a Treaty-based future where authority to govern is shared between those the Treaty represents.

The catchment encompasses both iwi who have settled some of their grievances with the Crown and others who have not. This diversity of hapū adds complexity. The approach that most hapū take in the Wairoa catchment is one of independently addressing local matters while acknowledging that whānau and hapū within the catchment and beyond are also interdependent and engaging on matters of shared importance. As one hapū member noted, "What we do impacts on other hapū, so it makes sense to do some things together. We are stronger together." This approach has challenges but also brings opportunities. For example, at least five hapū in the upper catchment are monitoring the wai in their rohe as a collective, using innovative techniques and tools to demonstrate Te Mana o te Wai.[13]

Hikurangi Repo

The Hikurangi Repo is a very important area for many hapū in the Wairoa catchment. Identified as a wāhi tapu, the repo was a source of healing, and resources like harakeke and tuna were traditionally harvested there. Kaitiaki and different hapū from the surrounding area would come to harvest from the repo. It belonged to everyone; it was the kai cupboard for all and trade would go on between coastal hapū and hapū at the repo. Because of this, everyone had to agree on how they would protect and collect from it.

The repo was also used to bury bones, for baptismal practices, and in recent times has been a focus of activism concerning the decline of tuna and rongoā plants. The development of a flood management scheme to permit and protect farming has seen the repo significantly modified and drained. What was previously around 6,000 hectares of fen and wetland has been reduced to only 200 hectares (see Box 3.5). In the early 2000s, one of the hapū (Ngāti Hau) voiced concern about the killing of tuna by the large pump stations that were installed in the repo to pump floodwater from agricultural land during heavy rainfall events (see Figure 4.5).[14]

Following the loss of tuna, peatlands and natural habitat, mana whenua have mobilised to prevent further degradation and make clear their aspirations to restore the mauri of the repo and the surrounding area. A business case is currently being developed to retire an area of the repo called the Otonga pocket (Figure 4.4). It is an important peat site that could potentially be developed into a natural water retention area, which could play a significant role in holding water and cleaning it. Restoring some of the repo back to a healthy functioning wetland would also assist the local hapū to reclaim their rangatiratanga and improve economic and socio-cultural outcomes for the community.[15]

As part of the scenario development phase of the modelling exercise, the importance of the repo was emphasised by mana whenua at the workshops. In response to this input, the scenarios were modified to include the retirement of one part of the repo (the Otonga pocket) by 2060 in scenario 4, and all seven pockets of the repo by 2060 in scenario 5. It is possible to use current land values to estimate the cost of purchasing the land required. However, given there are no local precedents for returning an area of this size from farmland to wetland it is very difficult to estimate the total cost of restoration and maintenance.[16]

---

[13] Hapū member at PCE integrated landscapes hui, pers. comm., September 2023.

[14] Armstrong-Read, 2016, p.4.

[15] Hapū member at PCE integrated landscapes hui, pers. comm., July 2023.

[16] The cost of remediation and restoration will depend on a range of factors, including earthworks required, planting costs and fencing requirements (Tanner et al., 2022).

The land use modelling estimated the cost of purchasing the Otonga pocket to be around $19 million, with a *maximum* total restoration cost of $128 million. Economies of scale and the use of volunteer labour for planting natives are likely to substantially reduce the total cost. For all seven pockets the respective figures were $243 million and $908 million. The modelling assumed that the restoration was funded by recycling revenue collected from the agricultural emissions levy (refer to chapter two for more detail on each of the scenarios).

Source: PCE

Figure 4.5: The Hikurangi Repo after heavy rainfall. Most of the Hikurangi Repo has been drained for agriculture since the early twentieth century. Pump stations are used to control the flooding of farmland after heavy rainfall events, but their operation can endanger migrating tuna.

Additional commentary from ngā mana whenua o Wairoa – Te Tai Tokerau

Commentary from ngā mana whenua o Wairoa was broad, ranging from highlighting the fractured way that science deals with environmental problems to the lip service paid to mātauranga Māori as a robust evidence base. Key points are listed below.

- A more holistic, integrated view to the problem is needed – for example, by including spiritual and social parameters into the thinking.
- Innovative ways of managing land were highlighted, such as alternative native forestry options and harvesting methods, and diverse pastures using deep-rooting species that can have positive impacts on soil health. The view of ngā mana whenua o Wairoa is that clear-felled pine forestry diminishes the mauri of the whenua and increases the risk of erosion. They also highlighted that in many cases the profits do not stay within the community, nor are they put back into cleaning up the environment.

- Making decisions on land use requires a more balanced view than just considering economic factors alone. For example, the principle of kaitiakitanga must be considered when making land use change decisions, and an intergenerational view of the land must be taken as opposed to maximising the profitability of the land in the short term. Mana whenua questioned why the New Zealand Emissions Trading Scheme does not currently provide rewards for restoring or constructing wetlands, which can sequester carbon from the atmosphere and store it as peat.
- The Hikurangi Repo was not the only important site for mana whenua. All waterways in the catchment are in some way important, and mana whenua would like them to be restored for their children and their grandchildren.[17]
- Understanding and including all forms of relationships is also important. Connectivity across hapū, cultures, land uses and relationships between people and the environment would need to be considered in any exercise attempting to develop integrated management approaches with the mana whenua of the Wairoa catchment. As noted by one hapū member, "The wellbeing of our waterways is reflective of the wellbeing of our people."[18]
- Taonga species that are important to mana whenua would also need to be considered in modelling. For the Wairoa catchment, this includes tuna as a potential indicator species and kahikātoa as a potential preferred species for future forestry.[19]

The hapū of Wairoa catchment identified the following themes as being important to consider in any catchment-scale approach to land management.

- Te Tiriti o Waitangi and He Whakaputanga o te Rangatiratanga o Nu Tireni need to underpin decision making.
- Te Mana o te Wai and the environment must be prioritised over short-term economic needs and must be factored into all land use decisions.
- Understanding historical impacts is essential if decisions are to enhance the wellbeing of the landscape and the people of the area.
- The hapū in Wairoa are already working in an integrated way across many important kaupapa. For example, the hapū are not just concerned about rural land use change but also the expansion of urban areas and conversion of rural land to housing and other urban land uses, which place different strains on the landscape. These kaupapa, as well as other social, health and economic issues, should be considered in any integrated approach.

---

[17] Hapū member at PCE integrated landscapes hui, pers. comm., July 2023.

[18] Hapū member at PCE integrated landscapes hui, pers. comm., July 2023.

[19] Kahikātoa is the Northland name for mānuka (*Leptospermum scoparium*).

Whakapapa and landscapes

In both catchments, mana whenua provided valuable insights and information on how to include their views in an approach like this. Mana whenua in both catchments define and understand landscapes through their whakapapa (their connection). This influenced the way they approached this exercise as well as the input they chose to provide.

Te Tiriti o Waitangi and other founding documents and current policies that embed te ao Māori concepts set the foundation for how relationships are forged and reinforced. But they are not the only driving force behind mana whenua actively engaging in environmental management. Their whakapapa – their connection to the landscape – means they are responsible for the health of the environment.

This active role is multi-faceted as many kaitiaki have responsibilities as both mana whenua and landowners. Any attempt to manage landscapes in an integrated way must consider how to ensure mana whenua and their rangatiratanga are acknowledged within a process that provides for different definitions of landscapes.

Abrodictyum strictum

5

Consequences of disconnected environmental policies in Mataura and Wairoa

Environmental policy is currently characterised by policies that have been developed separately and are focused on achieving domain-specific outcomes at different spatial scales. For example, climate change mitigation policy is concerned with managing greenhouse gas emissions at the national and global level. By contrast, freshwater policy is mainly concerned with local and catchment-based outcomes.[1] While each of these policies may have been the subject of careful development, the way they interact with one another seems to have been less well considered. As a result, the way the policies operate can be disconnected.

The disconnected nature of the goals of different environmental policies was a recurring theme in conversations with people in the Wairoa and Mataura catchments. Improving the health and wellbeing of the awa came through time and again as a critical concern. Climate change mitigation was often a less urgent priority at the local level. The conversations also highlighted that not enough attention is given to the potential consequences of policies for Māori, and that there is limited support available for iwi, hapū and whānau to fulfil their role as kaitiaki of the whenua, as discussed in the previous chapter.

The previous government proposed introducing a levy on agricultural emissions. If one is implemented in future, an agricultural emissions levy – combined with the price signals from the New Zealand Emissions Trading Scheme (NZ ETS) – would be likely to have a significant impact on the landscapes of Aotearoa.[2] There could be some co-benefits for freshwater quality and biodiversity, though these would depend on the policy settings (e.g. the levy rate) and catchment circumstances.

Two key themes are discussed in this chapter regarding the consequences (intended or otherwise) and trade-offs that may arise from current and forthcoming environmental policies. Modelling results from scenarios 1 and 2 are used to illustrate these potential consequences (see Table 2.1 for descriptions of the scenarios).

The first theme is how the current policy trajectory could have significantly different outcomes depending on the context of the catchment and the farm systems located there. It draws on the contrasting impacts of the low agricultural emissions levy price on land use in the Wairoa and Mataura catchments, using the modelling results from scenario 1.

1 McDowell and Kaye-Blake, 2023, p.2.

2 For more information, see NZPC, 2018; PCE, 2019; He Pou a Rangi, 2021; HWEN, 2022.

The second theme is the consequences and trade-offs that may need to be dealt with if environmental policies are not considered in a joined-up way. In particular, the impact of a medium agricultural emissions levy driving wholesale land use change and the flow-on environmental and non-environmental effects in the Wairoa catchment are illustrated, drawing on the modelling results from scenario 2 in Wairoa.

The uneven effect of a low agricultural emissions levy in different catchments

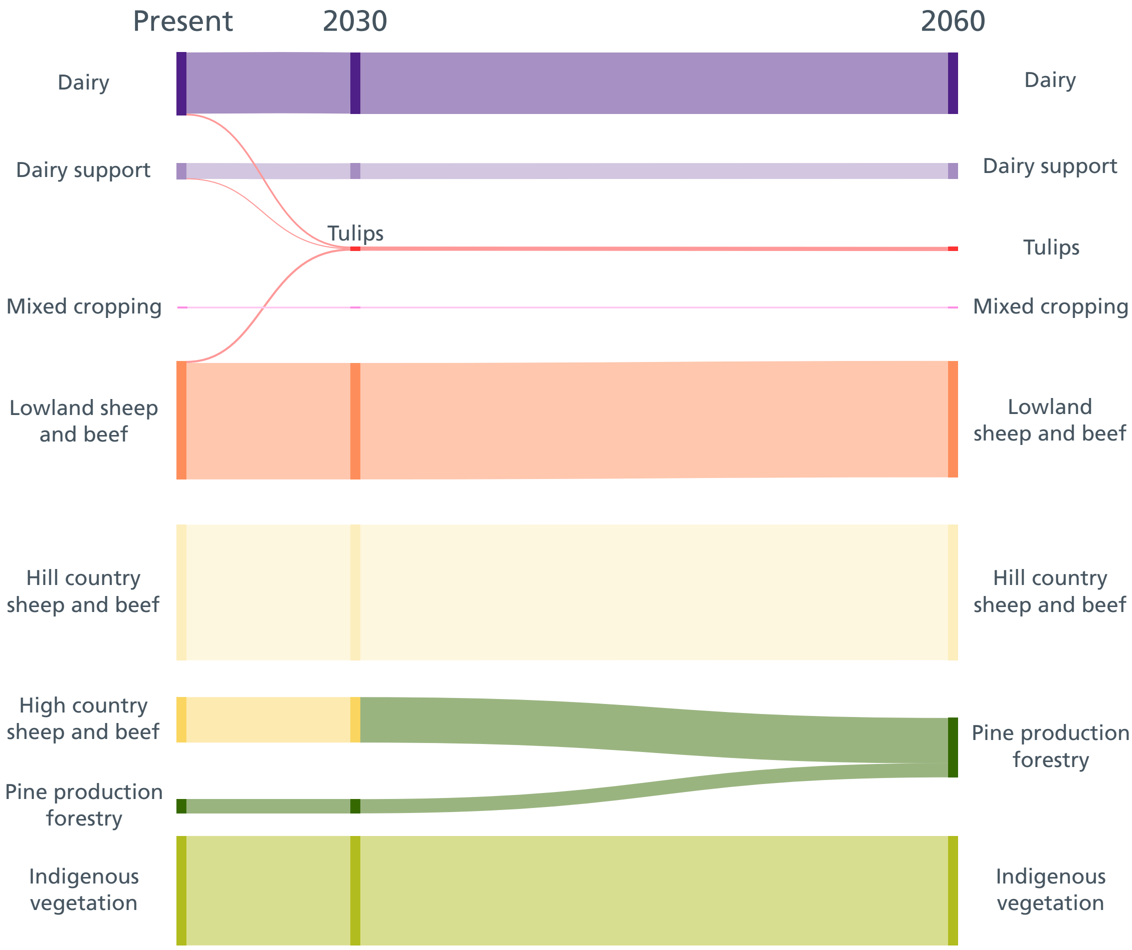
To meet New Zealand's national emissions reduction targets, the previous government suggested the introduction of a price on agricultural emissions at a farm level from 2025. The exact price (and scope) is still to be finalised, but when a price is imposed, it will impact some farms, sectors and catchments more than others. When added to the impact of the NZ ETS and existing freshwater rules and regulations, the introduction of a levy has the potential to drive significant land use change.

The price at which the levy is set will play an important part in how and where land use change occurs. The land use modelling conducted as part of this exercise (scenario 1) clearly demonstrated that, even under a relatively low price pathway, there will be very uneven impacts on different sectors and catchments.

For example, with a low agricultural emissions levy there would likely be minimal impact on land use in the Mataura catchment, although all livestock farms become less profitable. The modelling indicated that the only major land use change would be the transition of areas of high country sheep and beef out of pastoral farming (Figure 5.1).[3] Whether pine production forestry would be established in these areas would depend on site-specific factors such as climate, elevation and slope, along with logistic factors affecting the ability to harvest and distance to the nearest port or processing plant. For example, it was noted by workshop participants that some areas of high country sheep and beef in the Mataura catchment would not be suitable for pine production forestry due to elevation, biodiversity values and tenure type.[4]

[3] WSP, 2023a, pp.60–68. This increases the area of pine production forestry from 3% of the catchment area in 2025 to 13% in 2060. Dairy support also becomes unprofitable in 2060 but is retained to ensure that a functioning dairy sector is maintained. Hill country sheep and beef are also very close to becoming unprofitable by 2060.

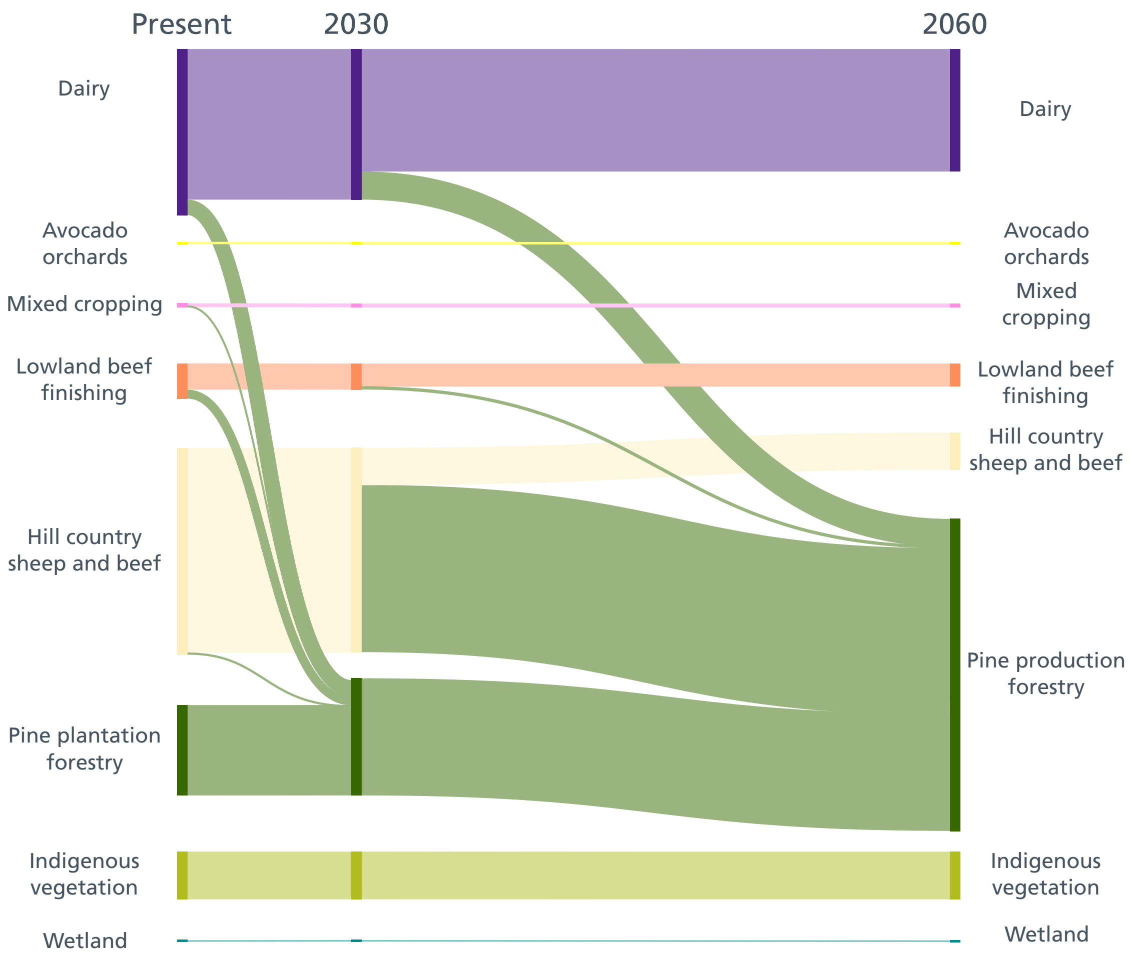
[4] See WSP (2023a, pp.232–249) for information on how the economic and environmental outcomes would change if high country sheep and beef land above 600 metres in Mataura were to transition to tussock instead of pine production forestry. Note that some of the land categorised as 'high country sheep and beef' in the baseline land use map is in fact high altitude tussock with high biodiversity values.



Source: Adapted from WSP (2023a) modelling

Figure 5.1: Modelled land use change in the Mataura catchment under a low agricultural emissions levy and untargeted freshwater policies (scenario 1). Flows between timesteps represent land transitioning to a new land use. Tulips are included as an example of a higher-value, lower-intensity land use, though the area of land suitable for tulips in Mataura is small. In this scenario, the modelling assumed that all high country sheep and beef land transitioned to pine production forestry by 2060; in reality, some of this land may be unsuitable for pine production forestry.

In stark contrast, even a low levy price resulted in significant land use change in the modelling for Wairoa (Figure 5.2).



Source: Adapted from WSP (2023b) modelling

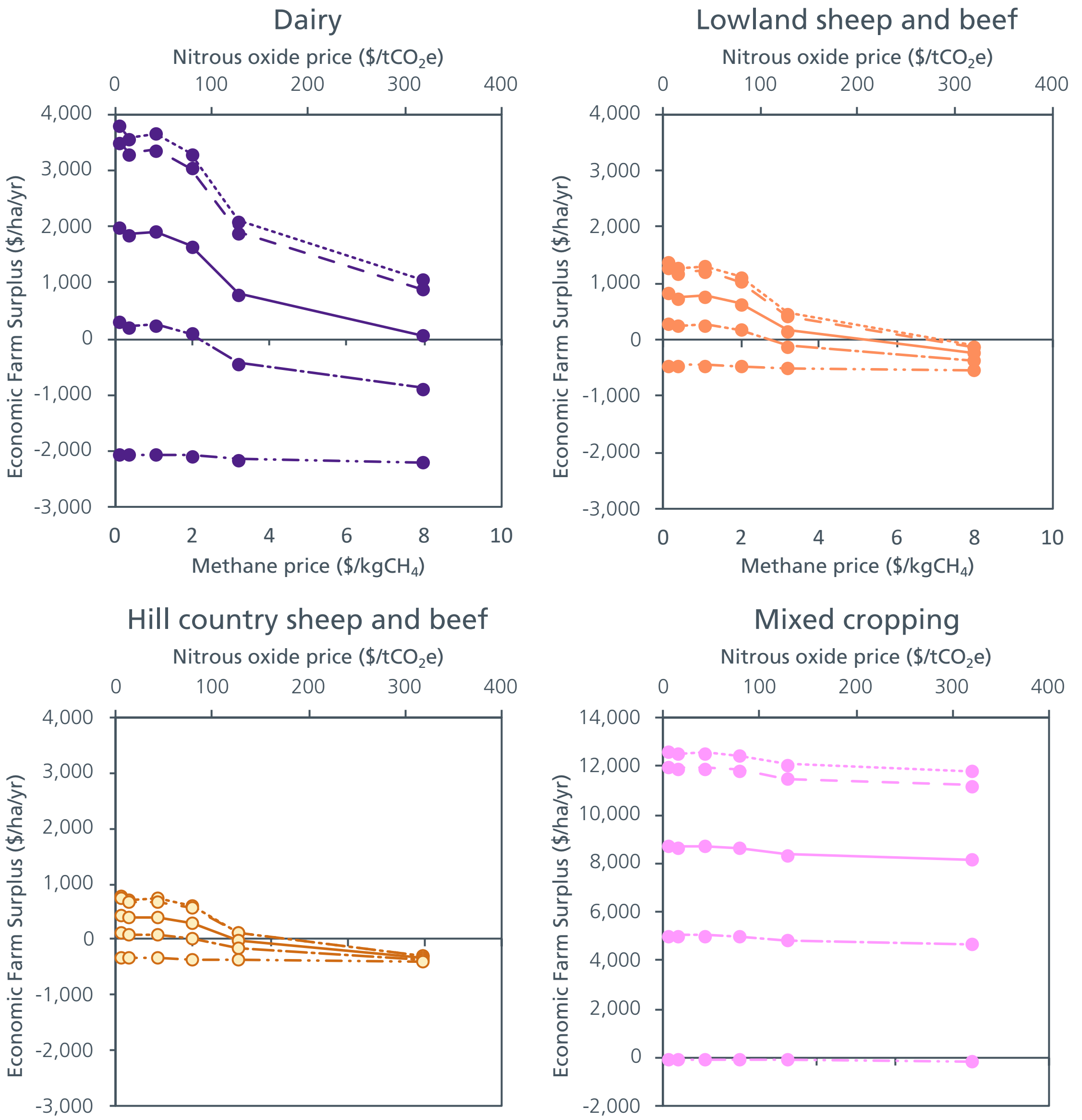
Figure 5.2: Modelled land use change in the Wairoa catchment under a low agricultural emissions levy and untargeted freshwater policies (scenario 1). Flows between timesteps represent land transitioning to a new land use.

Hill country sheep and beef farms were significantly affected by emissions pricing in the modelling. The modelling indicated that once the levy is introduced, most hill country farms would become unprofitable and transition to the most profitable alternative use for that land, which in most cases would be pine production forestry. Lowland beef finishing farms would also be impacted, with a high proportion barely making a profit by 2060 (Figure 5.3).[5] This result is in line with modelling commissioned by Beef + Lamb New Zealand, which found that the profitability of some sheep and beef farms will be significantly impacted by the introduction of an agricultural emissions levy, even at a low level.[6]

---

[5] WSP, 2023b, pp.57–58.

[6] Beef + Lamb New Zealand, 2022, p.19.



Source: Adapted from WSP (2023b).

Figure 5.3: Profitability per hectare at different emissions prices for dairy, lowland sheep and beef, hill country sheep and beef, and mixed cropping farms in Wairoa. For each farm type, farms on land with high production capacity have greater profitability than farms on low production capacity land. As the price on biogenic methane and nitrous oxide emissions increases, the profitability of farm systems decreases, all else being equal. These calculations assumed a 5% discount rate and no changes in commodity prices.

Ultimately, 82% of hill country sheep and beef land in Wairoa transitions to pine plantation forestry by 2060 in this low levy scenario. The proportion of the catchment in pine production forest increases from 17% at present to 57% in 2060. Whether such a significant shift would occur in practice depends on a range of factors, including landowner preferences. For example, some hill country sheep and beef farmers may forgo the higher profitability of pine production forest for other less profitable, but preferred, land uses.

There are smaller reductions in lowland beef finishing and dairy farming because the productive capacity of the land used for these land uses is higher and the profitability per hectare is greater.

The impact on greenhouse gas emissions follows a similar pattern to the modelled land use change in both catchments. In Mataura, there is a negligible reduction (~5%) in biogenic methane emissions between now and 2060. For Wairoa, there are greater modelled reductions in biogenic methane emissions (~44% reduction). The increase in pine plantation forestry also increases carbon dioxide removals in Wairoa substantially, though future carbon dioxide removals from forestry are difficult to estimate accurately in the absence of catchment-specific data on age classes and sequestration rates.[7]

Given the limited impact on land use in Mataura, minor changes in modelled freshwater quality and biodiversity indicators occur.[8] Changes in land management practices were not modelled in scenario 1, meaning that where a land use persisted, greenhouse gas emissions and loss of freshwater contaminants were largely unchanged.

The limited impact on freshwater quality also highlights that untargeted national freshwater policies such as the current cap on synthetic nitrogen fertiliser (which permits a maximum fertiliser application rate of 190 kilograms per hectare per year for pastoral land uses) are unlikely to be enough to achieve catchment freshwater quality goals in Mataura. Given that good farm management practices are also unlikely to achieve draft catchment freshwater objectives even if fully achieved,[9] catchment-specific rules and regulations enabled through the National Policy Statement for Freshwater Management, and its linking of Te Mana o te Wai and ki uta ki tai, are likely to be needed.

In Wairoa, greater improvements in freshwater outcomes occur under scenario 1 due to the shift from pastoral farm systems to forestry. For example, the modelling indicated that instream concentrations of total nitrogen would be reduced considerably in some areas of the catchment.[10]

[7] WSP, 2023b, p.142.
[8] WSP, 2023a, pp.58–64.
[9] Southland Regional Forum, 2022, p.21.
[10] WSP, 2023b, p.59–60.

The uneven effect of pricing agricultural emissions highlights the need for the Government to be clear on the desired outcomes of its policies and to be upfront about the likely consequences for landscapes of pursuing those outcomes. The indication that introducing even a relatively low levy on agricultural emissions may lead to substantial land use change in some locations emphasises the role that catchment context plays on the impact of national policies. Complementary policies alongside emissions pricing could be considered to help mitigate the impacts on individuals, communities and tangata whenua who may be negatively affected by the introduction of an agricultural emissions levy.

The wider environmental trade-offs between climate change mitigation and other environmental and economic outcomes are thrown into stark relief when a higher emissions price is introduced. This is discussed in the next section.

Consequences and trade-offs of a higher agricultural emissions levy

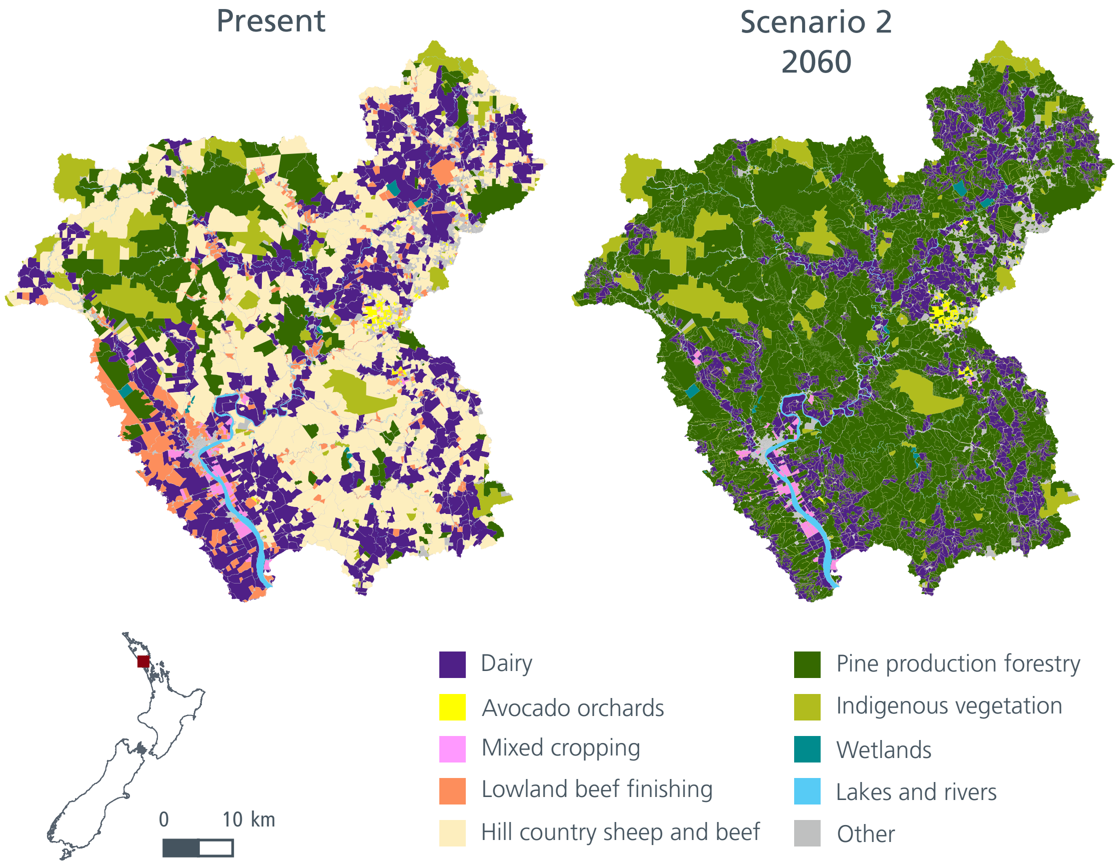
The combination of a levy on agricultural emissions and the attractiveness of tree planting under the NZ ETS would see a shift in the relative profitability of pine plantation forestry compared to pastoral farming. As a result, large-scale land use change can be expected. The likelihood of this occurring increases as the level of any price on agricultural emissions increases. The effect of a relatively high price on agricultural emissions on the Wairoa and Mataura catchments (modelled in scenario 2) demonstrates how this might play out and what the consequences might be for the environment and for the people living in these catchments.

Similar to the low levy scenario, the greatest changes to land use would be expected to occur in the Wairoa catchment. If a high levy price pathway had been applied in the modelling for Wairoa, all pastoral farming in the catchment would have become unprofitable and transitioned to pine production forestry.[11] Rather than model such an extreme outcome, a medium levy was modelled instead of a high levy in scenario 2 for Wairoa.

Even with the levy rate set at a medium level,[12] significant land use change would still be expected to occur in the Wairoa catchment under this scenario (Figure 5.4 and Figure 5.5). In the model, all sheep and beef farms transitioned to pine production forestry with only dairy farms in the most productive areas surviving.

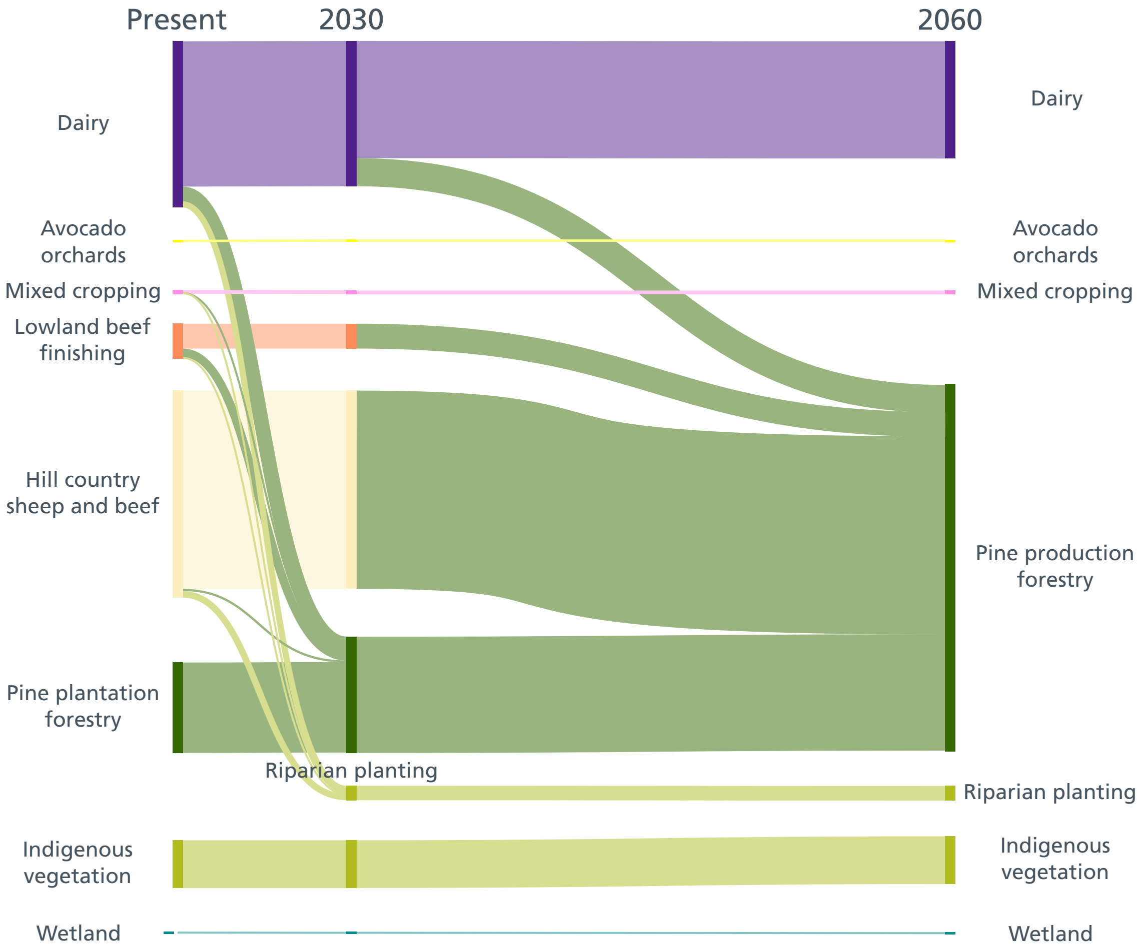
[11] WSP, 2023b, p.32. Transitions to other high-value crops were not modelled to occur due to limited water availability (e.g. in the case of avocados) and/or the high costs of establishment and processing infrastructure required.

[12] See WSP (2023b, p.32) for more details.



Source: Adapted from WSP (2023b) modelling

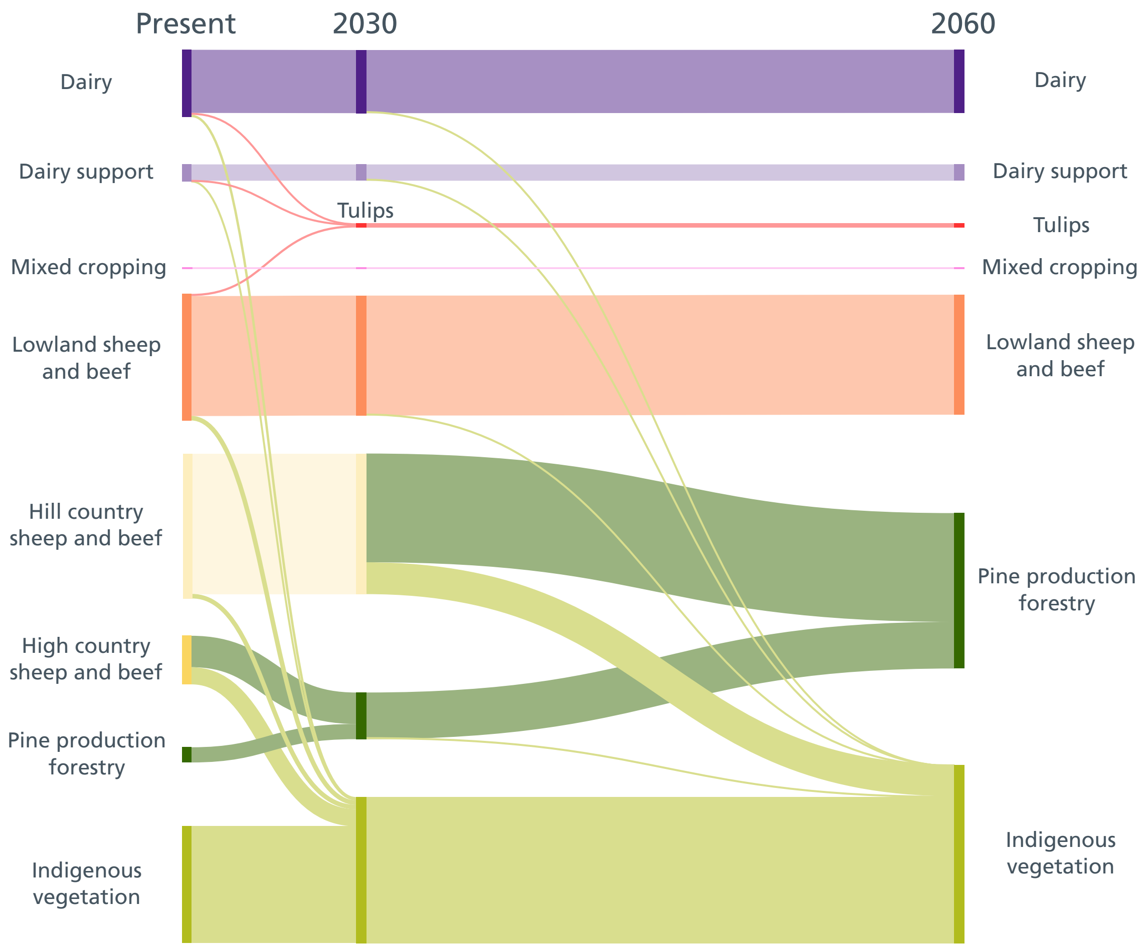
Figure 5.4: Map of the modelled change in land use between the present and 2060 in the Wairoa catchment under scenario 2 – medium agricultural emissions levy and untargeted freshwater policies. 'Indigenous vegetation' includes riparian planting. 'Other' includes all other land uses.



Source: Adapted from WSP (2023b) modelling

Figure 5.5: Modelled land use change in the Wairoa catchment under scenario 2.

In Mataura, a high levy would also be expected to result in a significant change in land use, with all high and hill country sheep and beef farms becoming unprofitable by 2060 (Figure 5.6). Dairy farming is the only land use that continues relatively unchanged under the assumptions in this scenario, although profitability is reduced by around 79%.



Source: Adapted from WSP (2023a) modelling

Figure 5.6: Modelled land use change in the Mataura catchment under scenario 2.

The following discussion focuses on the Wairoa catchment, given the significant transition in land use that may occur under this scenario.

Transitioning to what is in effect a binary pine-and-dairy landscape in the Wairoa catchment would have a range of economic, social and environmental consequences.

A large-scale expansion of pine production forestry driven by the NZ ETS could increase profitability at the catchment scale due to the combined income from wood production and carbon credits. However, pine production forestry operations differ from sheep and beef farms significantly in their scale and type of operation. For example, pine production forestry jobs are largely tied to the harvest cycle, with gaps in employment demand between planting and harvesting periods. This variability can be smoothed to some degree by larger planted areas and staggered planting.

Nationally, pine production forestry is estimated to provide greater employment per hectare then sheep and beef farming.[13] However, a local analysis of employment rates in the Wairoa district in Hawke's Bay suggested that sheep and beef farming has greater direct employment on a per hectare basis compared to pine production forestry.[14] One explanation for the difference between national and local estimates is that forestry workers, and forestry-related processing jobs, are often located in larger regional centres. The result is that although changes in employment may not be large nationally, the type and location of those employed are likely to change, having flow-on effects.[15]

Economically, the catchment's economy would be tied to the NZ ETS price to a much greater extent. Volatility in the price due to regulatory uncertainty and potential oversupply of forestry units could leave the catchment exposed to rapid shifts in fortune. This is something that He Pou a Rangi Climate Change Commission has highlighted.[16]

Further, if the transition to pine in the Wairoa and Mataura catchments were to be reproduced in other parts of the country,[17] the increasing reliance on funding from the NZ ETS (which ultimately comes from emitters in the transport, energy and industry sectors) as the main source of rural income becomes increasingly problematic nationally for a range of economic, social and environmental reasons.[18]

The loss of most pastoral farming in the catchment would also have distributional and social impacts on the community. What these social impacts are and how they might affect those in the catchment were not quantified in the modelling. However, the feedback at the workshops from people in the case study catchments was that the impact of large-scale land use change on individuals and the community is a key concern. They highlighted that land use change does not happen in a vacuum. It affects people, their livelihoods and the wider community, most obviously in terms of employment. Other potential negative social impacts include a reduction of business services in the catchment, the ongoing viability of health and education services, and an undermining of social cohesion and a sense of community.[19] Social issues are likely to disproportionally affect Māori.[20]

In reality, other barriers to the establishment of pine production forestry would likely delay any large-scale transitions. Barriers include volatility in the carbon market price, uncertainty around future climate change mitigation policy, technological advancements, commodity prices, landowner preferences and skills, and land banking to increase land value and retain future flexibility.[21] Given the significant impact on profitability modelled for a range of land uses, these factors would likely only delay rather than halt land use change in this scenario.[22]

---

[13] PwC, 2020, p.5. In comparison, permanent carbon forestry would significantly reduce employment compared to both sheep and beef and pine production forestry (PwC, 2020, pp.6–7).

[14] Harrison and Bruce, 2019, p.17.

[15] ICCC, 2019, p.81; PCE, 2019, p.151.

[16] He Pou a Rangi, 2023, p.60.

[17] As indicated in, for example, modelling of the Hurunui catchment in PCE, 2019, pp.144–145.

[18] PCE, 2019, pp.149–154.

[19] ICCC, 2019, p.81; PCE, 2019, p.150.

[20] Forestry Reference Group, 2018, p.4.

[21] NZPC, 2018, p.305.

[22] Though regulatory intervention through national direction or regional rule setting could directly limit the area of land converted to forestry.

The stark transitions in land use in scenario 2 are, of course, partly a function of the assumptions that were used in the land use modelling. For example, no new technologies to reduce agricultural emissions were assumed to come into effect during the modelling period. If viable technologies such as a methane vaccine become widely available at low cost, agricultural emissions pricing might not have such a significant effect on farm profitability. Similarly, commodity prices are assumed to be static over time. Any increase in commodity prices would improve farm profitability, potentially mitigating some of the impact of the agricultural emissions levy (though of course the reverse would also be true).

Environmentally, the large-scale transition to pine production forestry modelled for the Wairoa catchment highlights the complex trade-offs present between competing environmental policy domains.

On the climate change mitigation side, emissions are significantly reduced in this scenario due to the decrease in livestock numbers in the catchment. In Wairoa, modelled biogenic methane emissions were reduced by 54% by 2060 relative to the current level. This is the largest change in greenhouse gas emissions across all the scenarios modelled. At the same time, the expansion of fast-growing pine forests would be expected to remove significant quantities of carbon dioxide from the atmosphere.

Biodiversity conservation would also improve in the Wairoa catchment under scenario 2. Pine forests can provide habitat for some native species, representing an improvement over pasture.[23] For example, pine production forests can provide habitat for native species such as the North Island brown kiwi (*Apteryx mantelli*).[24] The expansion of forested area would also increase connectivity between indigenous vegetation remnants scattered through the landscape, providing easier passage for native bird species – although it could also provide avenues for pest species to move more easily. Riparian planting across the catchment in this scenario, funded by revenue from the agricultural emissions levy, would also provide additional habitat for terrestrial and aquatic native species.

There would also be co-benefits for freshwater quality. For example, the removal of livestock from large areas of the catchment would eliminate the primary source of nitrogen and pathogens from many rivers and streams (Figure 5.7). Riparian planting can also intercept nutrient runoff, further reducing potential nutrient loss.[25] In addition, as pine production forest transitions through mid-rotation to mature forest stages, erosion risk is reduced compared to pasture.[26] Canopy closure also contributes to freshwater quality improvements by restricting unwanted aquatic plant growth.[27] However, benefits may be offset during and after the harvest phase when the land is left exposed, leaving it vulnerable to erosion (see below). Other ongoing issues for freshwater ecosystems that were not modelled, such as fish passage barriers, will also continue to be an issue in the Wairoa River catchment.

---

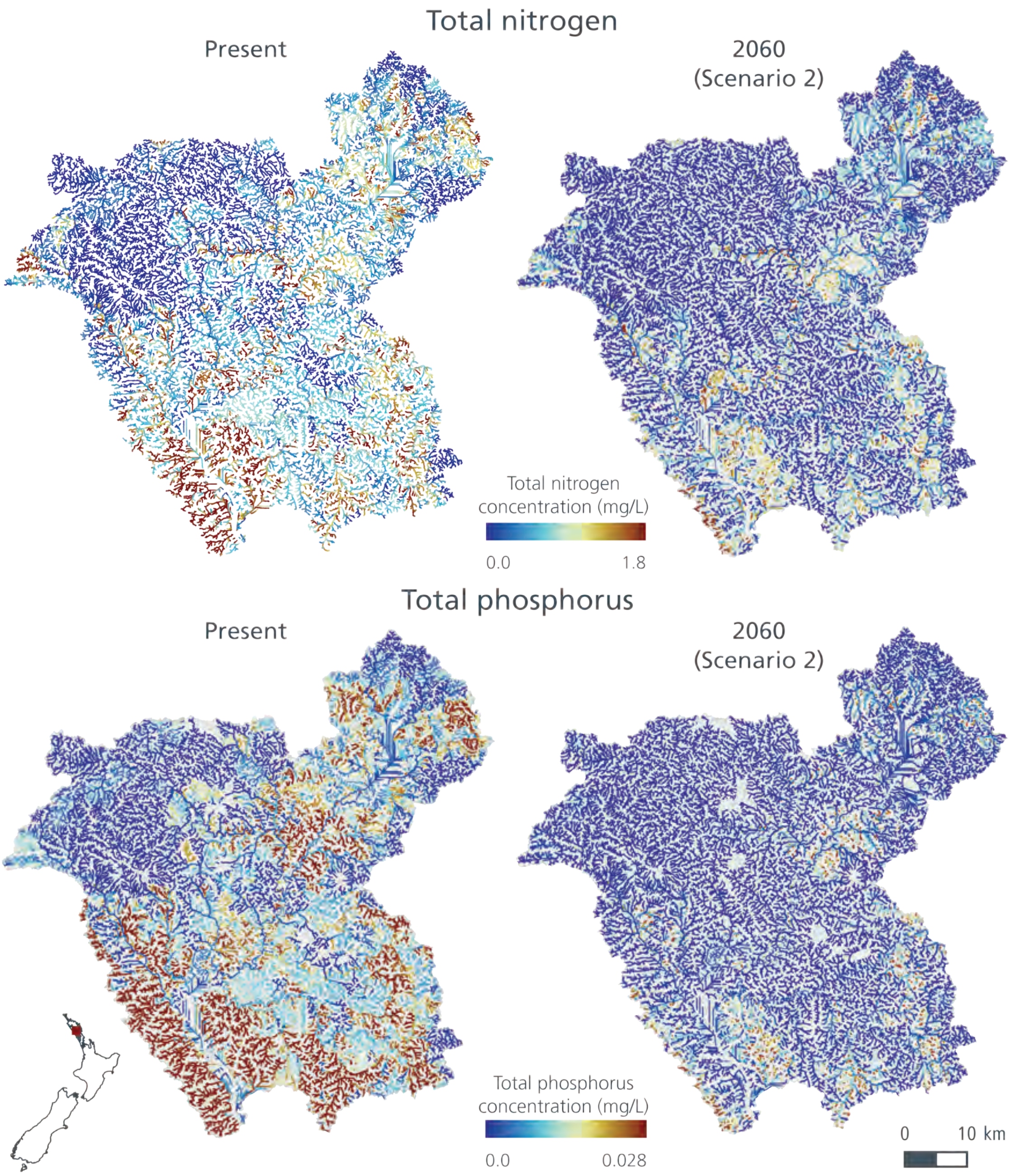
[23] Norton, 1998; Brockerhoff et al., 2008; Pawson et al., 2010.

[24] Sporle, 2016. Another example is the kārearea (New Zealand falcon, *Falco novaeseelandiae*), although they are not found within Northland (Seaton and Hyde, 2013).

[25] For example, the area of the catchment whose flow is intercepted prior to reaching a waterbody increased 201% between 2025 and 2060 in scenario 2 (WSP, 2023b).

[26] Fahey and Marden, 2006.

[27] Baillie and Neary, 2015.



Source: Adapted from WSP (2023b) modelling

Figure 5.7: Change in modelled total nitrogen and total phosphorus concentrations in the Wairoa River catchment between the present and 2060 under scenario 2. Improvements in freshwater quality indicators is due to a combination of the loss of large areas of pastoral farming and livestock and the interception of contaminants by forested and riparian areas. Note that total nitrogen concentrations in the Wairoa River are generally low compared to other waterways in New Zealand.

One of the trade-offs in environmental outcomes modelled for Wairoa is the potential increase of post-harvest erosion risk in the catchment. The modelling undertaken for this project highlighted that erosion and soil loss from clear-felled pine production forests can be very high in the period after harvesting.

Prior to harvesting, soil losses from pine production forests are generally lower than losses from pasture.[28] This has been demonstrated in empirical studies of instream sediment concentrations in forested and unforested sub-catchments in New Zealand.[29] However, disturbances caused by clear-fell harvesting (the most common type of harvesting in New Zealand; Figure 5.8) and replanting will intermittently impact on water quality. There is a window of around eight years between harvesting and when newly planted pine trees are established, during which the land is more susceptible to erosion, particularly during periods of heavy rainfall.[30] As a result, large amounts of sediment and nutrients can be deposited into waterbodies during this time. Heavy rainfall events can also lead to large amounts of harvest debris (commonly known as slash) being washed into waterways and out to the coast.[31]

Source: PCE

Figure 5.8: Clear-fell harvesting of a production forest in Southland. The risk of erosion increases in the years after production forests are clear-felled.

28 Established pine trees can reduce erosion by improving soil strength and reducing soil moisture due to their roots and canopy intercepting rainfall (Lambie et al., 2018, pp.10–11).

29 Fahey and Marden, 2006.

30 Ritchie, 2012, pp.9–14; Lambie et al., 2018.

31 A fact that has been made all too clear in the aftermath of repeated heavy rainfall events in Tairāwhiti in recent years (Ministerial Inquiry into Land Uses in Tairawhiti and Wairoa, 2023).

Management practice and regulations under the National Environmental Standard for Commercial Forestry go some way to reducing erosion risk and issues associated with harvest debris. However, with such large areas modelled to transition to pine production forests there is a high likelihood of harvesting coinciding with heavy rainfall events. This is compounded by the expected increase in frequency of heavy rainfall events predicted as a result of climate change. In short, we do not yet know what the overall net effect on erosion and sediment would be from converting large areas of pasture to pine production forestry.

Although not modelled, a large-scale transition to plantation forestry could have other negative environmental effects depending on site characteristics. For example, large-scale forest planting can change catchment water flows, which can be a problem in drought-prone, highly modified landscapes.[32] Forests also absorb more heat because they are typically darker than pasture.[33] Therefore, while planting forests has a cooling effect globally, the local temperature effects are more uncertain.[34]

There are also inherent issues with relying on pine plantation forestry to remove and store carbon. For example, carbon stored in forests can be rapidly released back to the atmosphere in the event of fires, pests, droughts, storms and other disturbances. Climate change is expected to exacerbate these risks in the future. It also locks up land in forestry in perpetuity, forever changing the landscape of our case study catchments – or at least until a cheap and effective way to remove carbon dioxide from the atmosphere and store it permanently underground becomes widely available.[35]

Alternative forestry approaches such as continuous cover forests, native production forests and agroforestry systems can ameliorate some of these issues. However, they come with their own set of barriers and concerns. The use of alternative forestry types is explored in the following chapter.[36]

The results presented here highlight how broad-brush national policies can significantly impact catchments – and the consequences may be exacerbated by not joining up environmental policies. Trade-offs (intended or otherwise) between environmental, economic, social and cultural outcomes need to be considered together to avoid changes that may later be regretted but are locked in for decades to come.[37] The outcome of not doing so will be suboptimal in many regards.

---

32 Harnett, 2019, p.18.

33 Kirschbaum et al., 2011. The change in heat absorption between colours is known as the albedo effect.

34 The soils under pine forests may also help to remove methane from the atmosphere. Scion is undertaking research to better understand this effect (Scion, 2023).

35 PCE, 2019, p.103; He Pou a Rangi, 2021, p.316.

36 Permanent exotic forests are another alternative forestry option but were not modelled.

37 He Pou a Rangi, 2021, p.316.

6

Cyclosorus interruptus

How could things be done differently?

The previous chapter explored what the various consequences of disconnected environmental policies could be in the Mataura and the Wairoa catchments. This chapter explores what alternative mixes of policies could look like and what the outcomes might be. It draws on discussions with and input from local people and mana whenua (Wairoa catchment only), as well as the results of the physiographic susceptibility mapping and scenarios 3–6 of the land use modelling (see Table 2.1 for descriptions of the scenarios).

More diverse landscapes

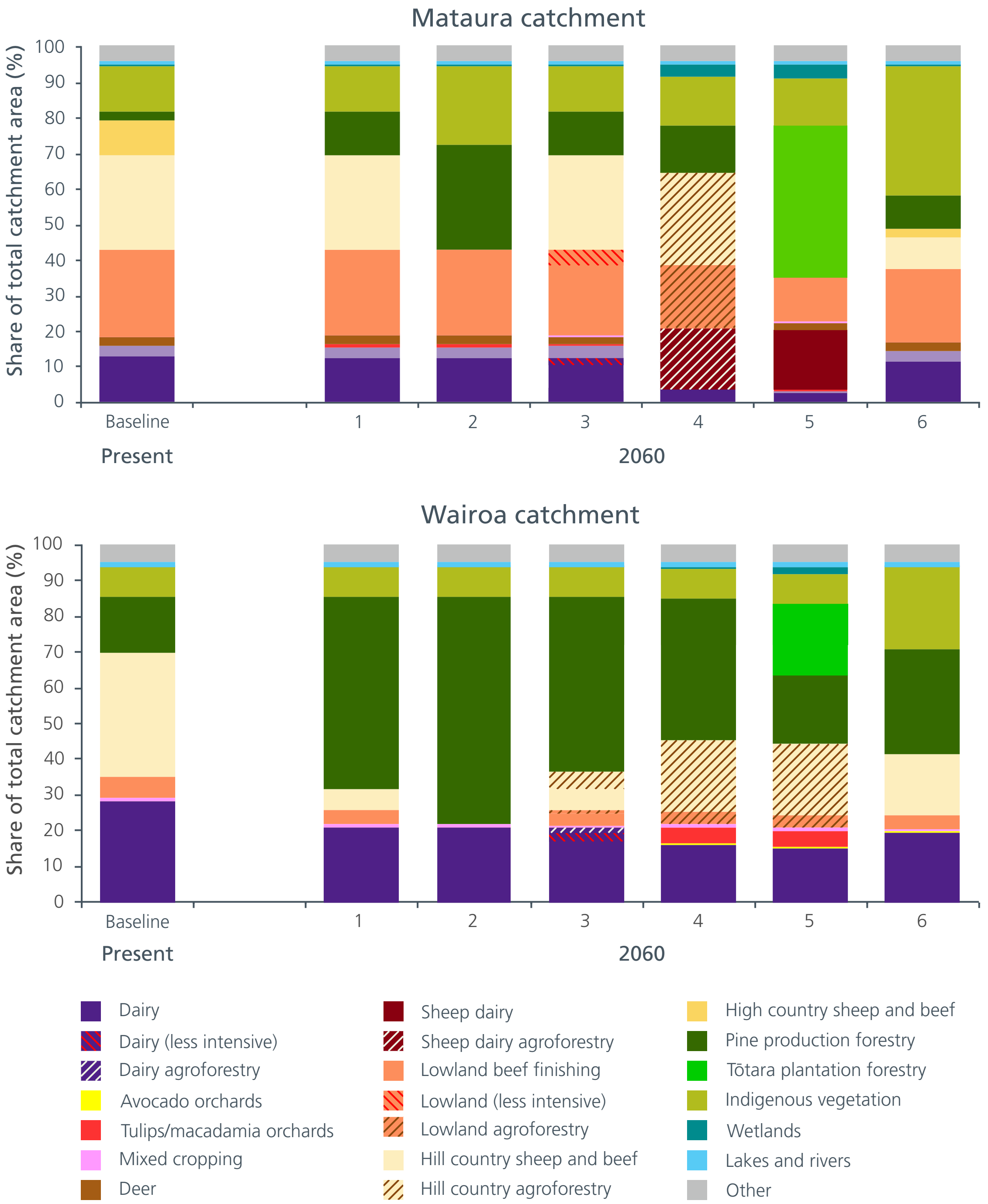
Moving to more diverse landscapes has been proposed as a way to mitigate environmental pressures and enhance resilience.[1] As part of the exercise, alternative land uses were discussed with local people in the hui and workshops in each catchment, and some representative examples of alternative land uses were selected for inclusion in the land use modelling (Figure 6.1).

In the Mataura catchment, some of the relatively low, flat, highly productive areas could be suitable for alternative land uses (Figure 6.2). The alternative land uses modelled for these areas were sheep dairying and tulip growing. These are relatively high-intensity land uses, but if located in the right areas they could be part of the mix. Sheep are lighter and produce smaller urine patches than dairy cattle, so soil compaction and nitrogen losses tend to be lower. Tulip farms do not emit biogenic methane and have lower greenhouse gas emissions than dairy farms, though they still use nitrogen fertilisers and produce nitrous oxide emissions.

In Wairoa, macadamia orchards and lowland agroforestry systems were included as examples of alternative land uses for modelling purposes (Figure 6.3). Other land use opportunities will obviously exist in both catchments, and the options available may well shift as the climate changes.[2] The alternative land uses used in this exercise should be thought of as plausible placeholders for what will, in reality, always be driven by access to capital, skills, technologies and markets.

1 Hall, 2018.

2 A comprehensive analysis of land use opportunities nationwide, and how these are likely to change as the climate changes, is being undertaken by the Our Land and Water Whitiwhiti Ora programme (OLW, 2023).



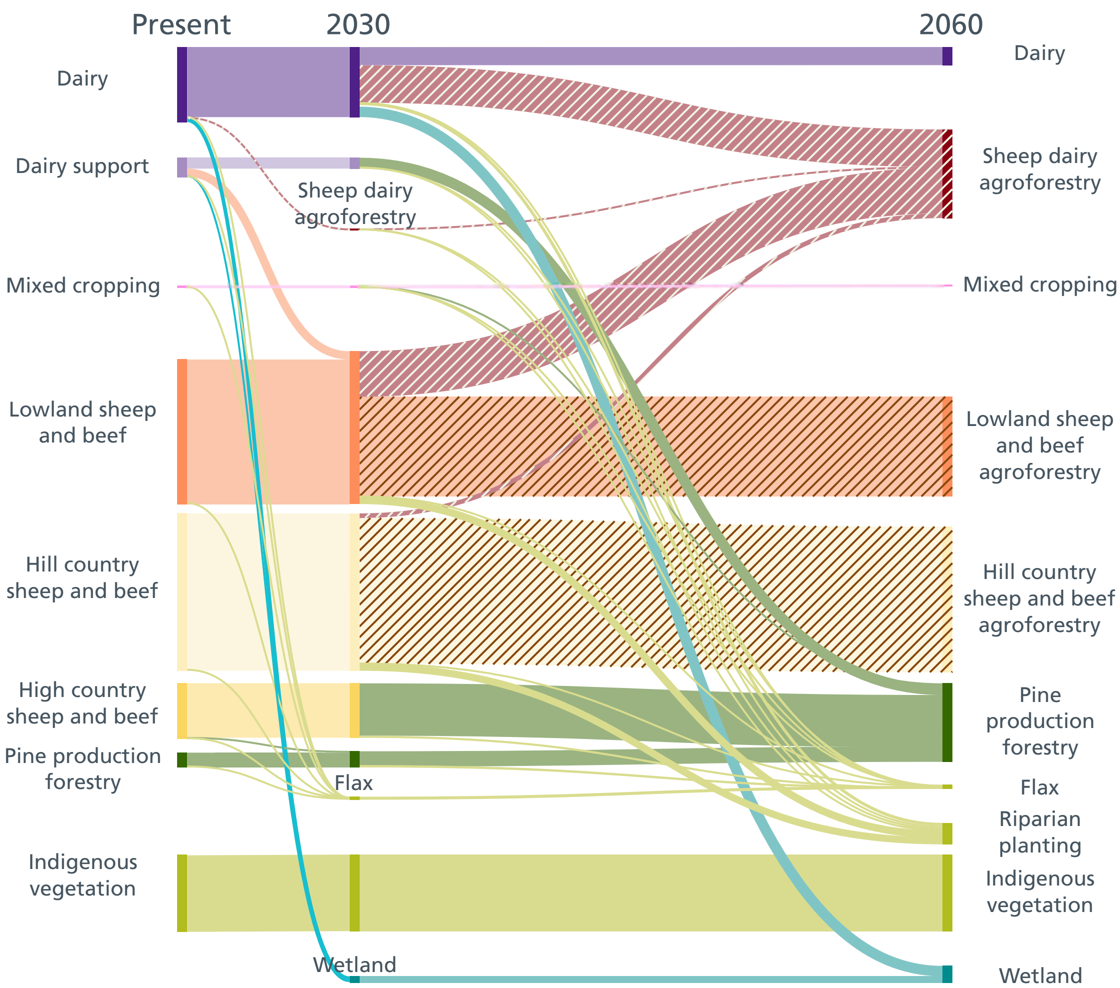
Source: Adapted from WSP (2023a, 2023b) modelling

Figure 6.1: Land uses in Mataura and Wairoa under the six policy scenarios. 'Indigenous vegetation' includes riparian planting. 'Other' includes all other land uses.

When considering alternative land uses, there are often trade-offs to be managed between different environmental objectives. No land use is without environmental impacts. Crops such as tulips, oats and avocados may have low greenhouse gas emissions per hectare compared to dairying, but they can require significant amounts of water and fertilisers and entail the use of chemical herbicides and pesticides.

In Wairoa, for example, an average avocado orchard uses around 26 times more water than a typical dairy farm.[3] For this reason, the area of avocado orchards in Wairoa was not expanded in any of the modelling scenarios.

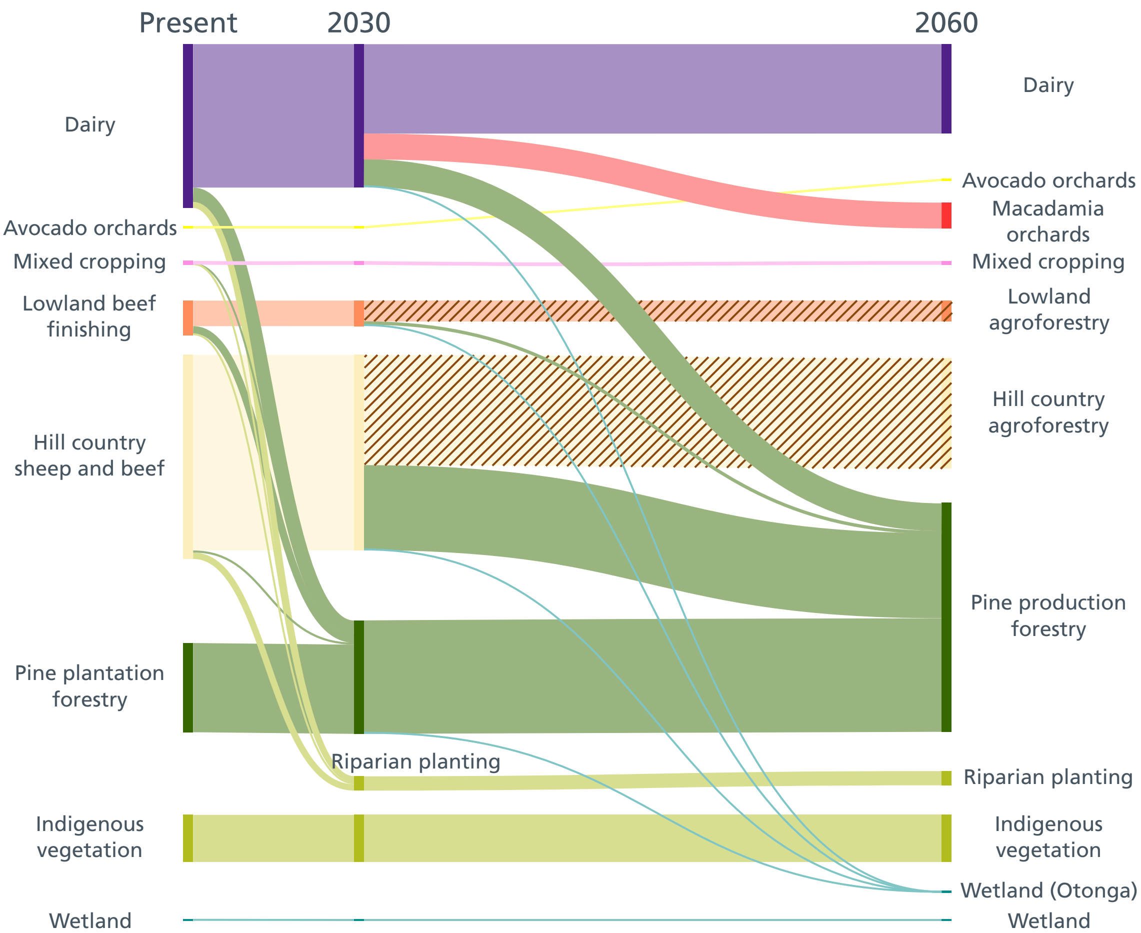
Converting some areas from intensive pastoral farming to less emissions-intensive land uses can increase profitability and reduce emissions, and it may also improve freshwater quality in some cases. For example, in a scenario where more land in the Mataura catchment was used for sheep dairying, tulip growing and pine production forestry (scenario 5, Figure 6.6), biogenic methane emissions were reduced by 14% by 2060 and nitrous oxide emissions were reduced by 21% by 2060 relative to the current level, while overall profitability at the catchment scale increased (Figure 6.4). Freshwater quality was also improved, with a 46% reduction in mean nitrogen terrestrial load (Figure 6.5) and a 55% reduction in mean phosphorus terrestrial load over the same period.



Source: Adapted from WSP (2023a) modelling

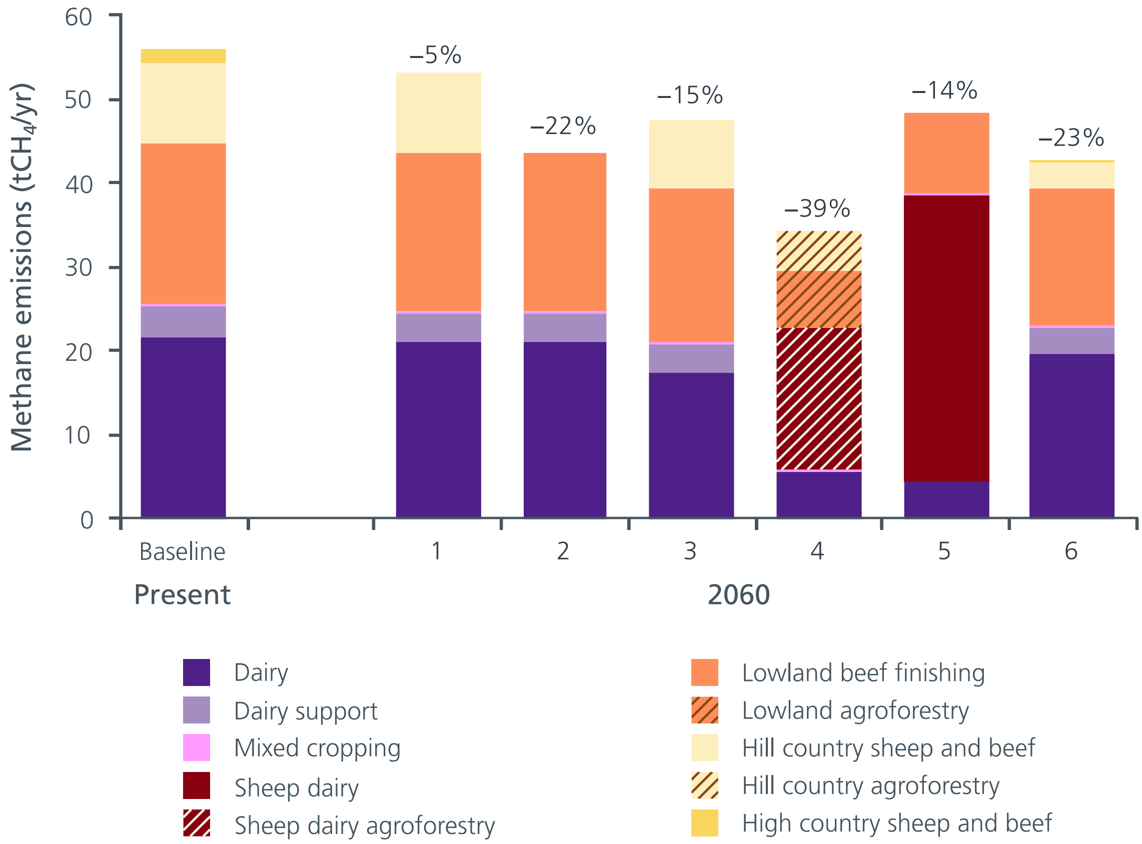
Figure 6.2: Modelled land use change in the Mataura catchment under scenario 4.

[3] WSP, 2023b, p.38.



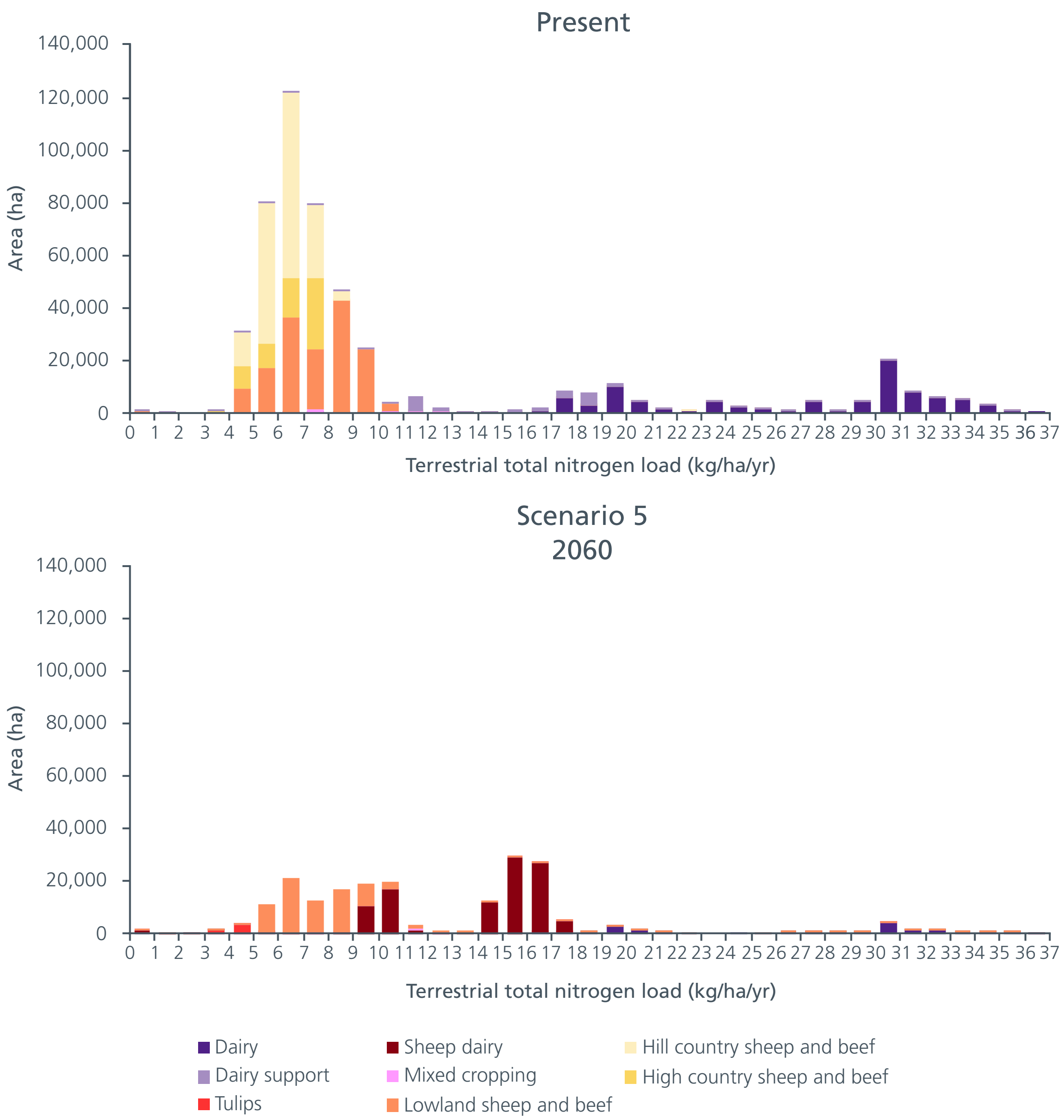
Source: Adapted from WSP (2023b) modelling

Figure 6.3: Modelled land use change in the Wairoa catchment under scenario 4.



Source: Adapted from WSP (2023a) modelling

Figure 6.4: Biogenic methane emissions in Mataura (present and 2060) under the six policy scenarios. The percentages above the bars are the reductions in biogenic methane emissions by 2060 under each scenario relative to the present level.

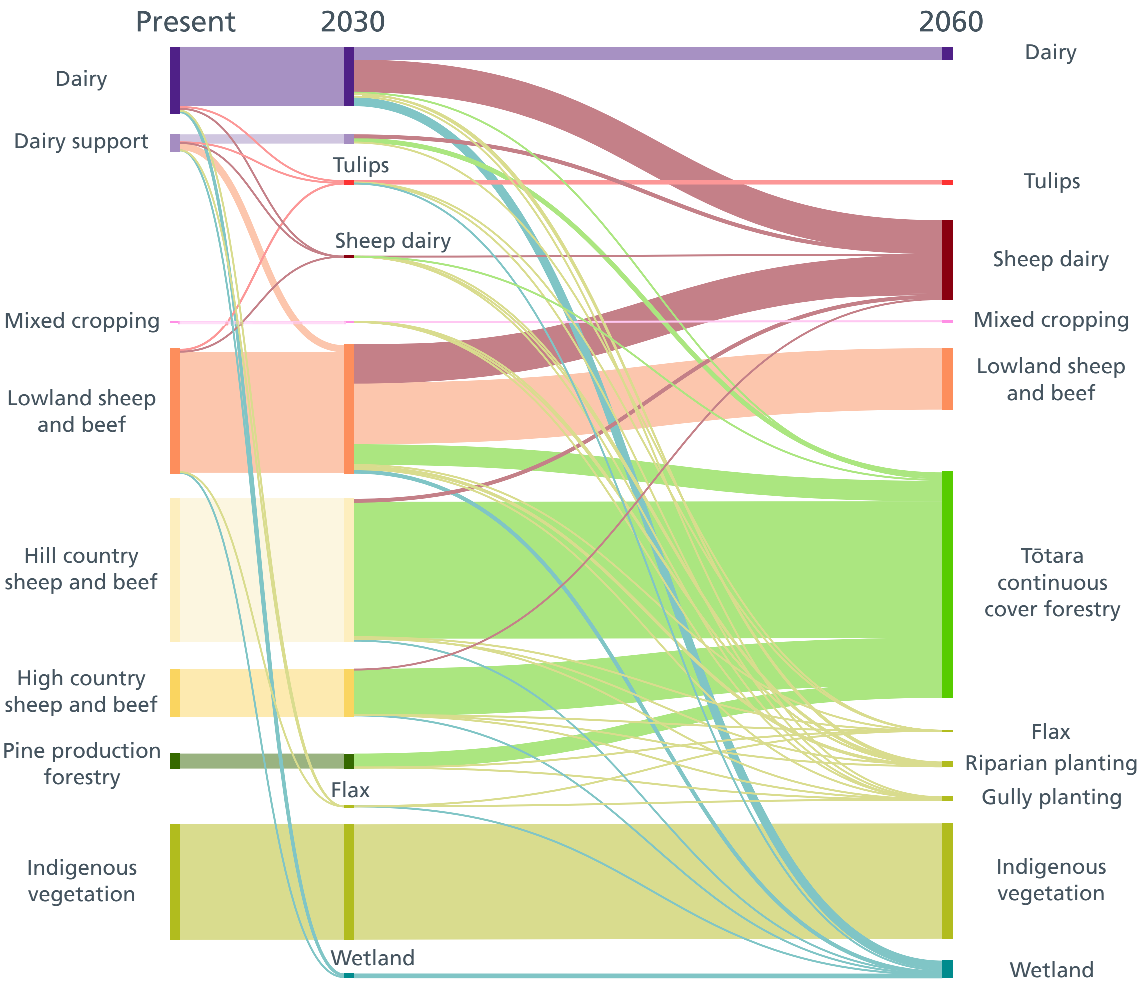


Source: Adapted from WSP (2023a) modelling

Figure 6.5: Change in total nitrogen load by land use in Mataura catchment between the present and 2060 under scenario 5 (estimates from the Nature Braid model).

Alternative forestry

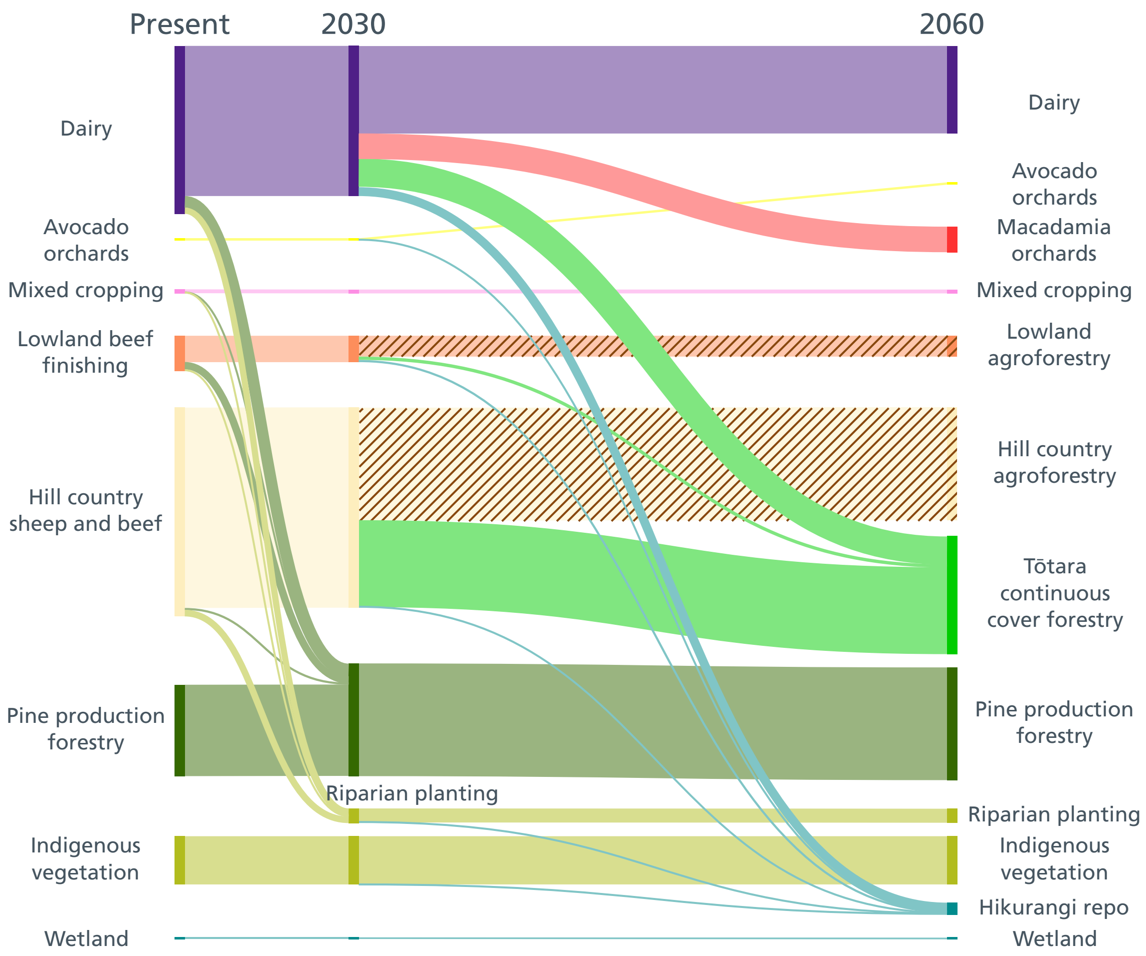
Most of the forests in Aotearoa are currently either native forests that are not harvested or *Pinus radiata* plantation forests that are clear-felled.[4] The modelling exercise considered the potential co-benefits (and costs) that might come from encouraging greater diversification of the forestry estate in Mataura and Wairoa (for example, see Figure 6.6 and Figure 6.7).



Source: Adapted from WSP (2023a) modelling

Figure 6.6: Modelled land use change in the Mataura catchment under scenario 5.

[4] Unharvested forests are sometimes referred to as 'permanent' forests. In the context of the New Zealand Emissions Trading Scheme (NZ ETS), for example, a 'permanent' forest is a forest that will not be clear-felled for at least 50 years. However, using the term 'permanent' in this way is potentially confusing because harvested forests can also be permanent, in the sense that land can be used for plantation forestry indefinitely.



Source: Adapted from WSP (2023b) modelling

Figure 6.7: Modelled land use change in the Wairoa catchment under scenario 5.

Alternative forestry types such as agroforestry systems, native continuous cover production forests, and unharvested native forests typically have lower carbon sequestration rates than fast-growing pine plantation forests.[5] On the other hand, they can offer benefits in terms of biodiversity and potentially erosion control (depending on the spacing of the plantings). The magnitude of these benefits is highly dependent on what species is planted and where. The 'right' forest to plant depends on the relative priorities of these different environmental objectives for the landscape concerned.[6] The PCE is currently undertaking further work on the topic of alternative forestry options to better understand the potential trade-offs they imply.

[5] For modelling purposes, the sequestration rates for tōtara were assumed to follow the default rates for indigenous vegetation from the NZ ETS lookup tables. These were likely underestimates because the lookup tables are based on naturally regenerating shrubland dominated by mānuka and kānuka and are undifferentiated by species or region (MPI, 2017, p.5; Aotearoa Circle, 2020, pp.14–15). A guide published by Thriving Southland shows how the carbon sequestration rates of tōtara forests in Southland can vary depending on the assumptions used (Thriving Southland et al., 2023).

[6] The benefits of integrating diverse tree clusters into landscapes are being assessed in Manaaki Whenua – Landcare Research's Trees in Landscapes (Te Kapunipunitanga a Tāne Mahuta) work programme (MWLR, 2023).

Improved forestry, climate, freshwater and biodiversity outcomes could be achieved through forestry policies that recognise the broader benefits that forests can provide beyond carbon sequestration. In the current approach, the main incentive for planting forests is provided by the NZ ETS. The financial reward from the NZ ETS depends only on the quantity of carbon sequestered by the forest. This incentivises the planting of fast-growing exotic tree species.

One way to recognise the broader benefits of forests would be to phase forestry out of the NZ ETS.[7] This would decouple incentives for forest planting from demand for offsets from fossil carbon dioxide emitters. If new forest planting were no longer funded by fossil emitters with unit surrender obligations under the NZ ETS, an alternative source of funding would need to be found to support new forest planting that could contribute to multiple environmental, social and cultural benefits.

Relying on funding from taxpayers alone to fill this gap is unlikely to be a realistic or durable solution. Removing forestry from the NZ ETS would likely boost auction revenues from the ETS. Some of that money could be reinvested in forestry. Other options to incentivise forest planting that delivers a wider range of benefits will be explored in forthcoming work.

Tailored actions to improve freshwater quality based on landscape characteristics

In addition to land use, landscape characteristics such as elevation, slope, climate, soil type, geology and hydrology are likely to be a significant driver of freshwater quality outcomes in some places. However, existing freshwater quality regulations such as the synthetic nitrogen fertiliser cap treat all pastoral land the same way. As part of the land use modelling undertaken for this investigation, tailored actions to improve freshwater quality based on landscape characteristics were considered as an alternative to uniform regulations.

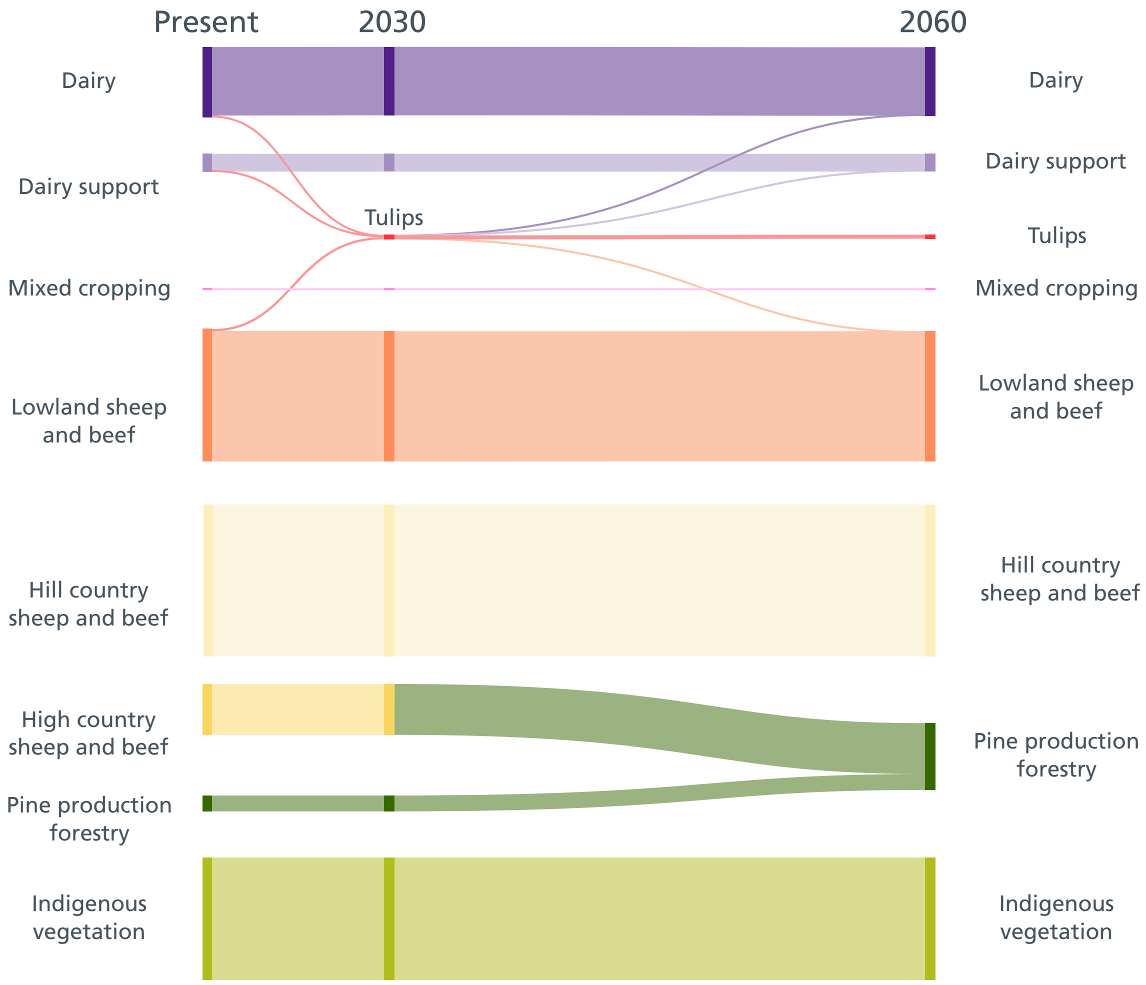
Some landscape characteristics can be quantified using a combination of direct measurements and modelling of characteristics that cannot be measured directly. For this exercise, the tools used to quantify the characteristics of the landscape and identify priority areas for interventions were the landscape susceptibility mapping work undertaken by Land & Water Science and the modelling of hotspots for management interventions by Nature Braid.

However, much of the knowledge and understanding that tangata whenua hold about the characteristics of the landscape cannot be quantified. There is therefore a risk of this information being ignored or undervalued in the policymaking process. While quantitative spatial information on landscape characteristics can be a useful resource for landowners, communities and tangata whenua when deciding what to do where within the landscape, any numerical information from models should be considered alongside (not at the expense of) qualitative forms of local and indigenous knowledge.

[7] Removing forestry from the NZ ETS was one of the options proposed in the Government's review of the NZ ETS that took place between June and August 2023 (MfE et al., 2023). In July 2023, the Government also released a discussion document exploring a biodiversity credit system as a potential funding mechanism for forestry (MfE, 2023).

One way that spatial information on landscape characteristics could be used would be to prioritise actions in areas that are highly susceptible to loss of freshwater contaminants such as nitrogen, phosphorus, sediment and *E. coli*. This idea was tested in one of the land use modelling scenarios (scenario 3). In Mataura, the maps from Land & Water Science were used to identify areas of high susceptibility to loss of nitrate-nitrite nitrogen. The modelling then assumed that the maximum amount of synthetic nitrogen fertiliser applied in highly susceptible areas was reduced from the current limit of 190 kilograms of nitrogen per hectare per year (kgN/ha/yr) to a maximum of 85 kgN/ha/yr in 2030 and 65 kgN/ha/yr in 2060. In other areas, the limit remained unchanged. Figure 6.8 shows the land use changes under this scenario.

The resulting environmental benefits were modest – a 5% reduction in mean nitrogen terrestrial load and a 7% reduction in mean phosphorus terrestrial load from dairy farming in Mataura by 2060 relative to the current level.[8]



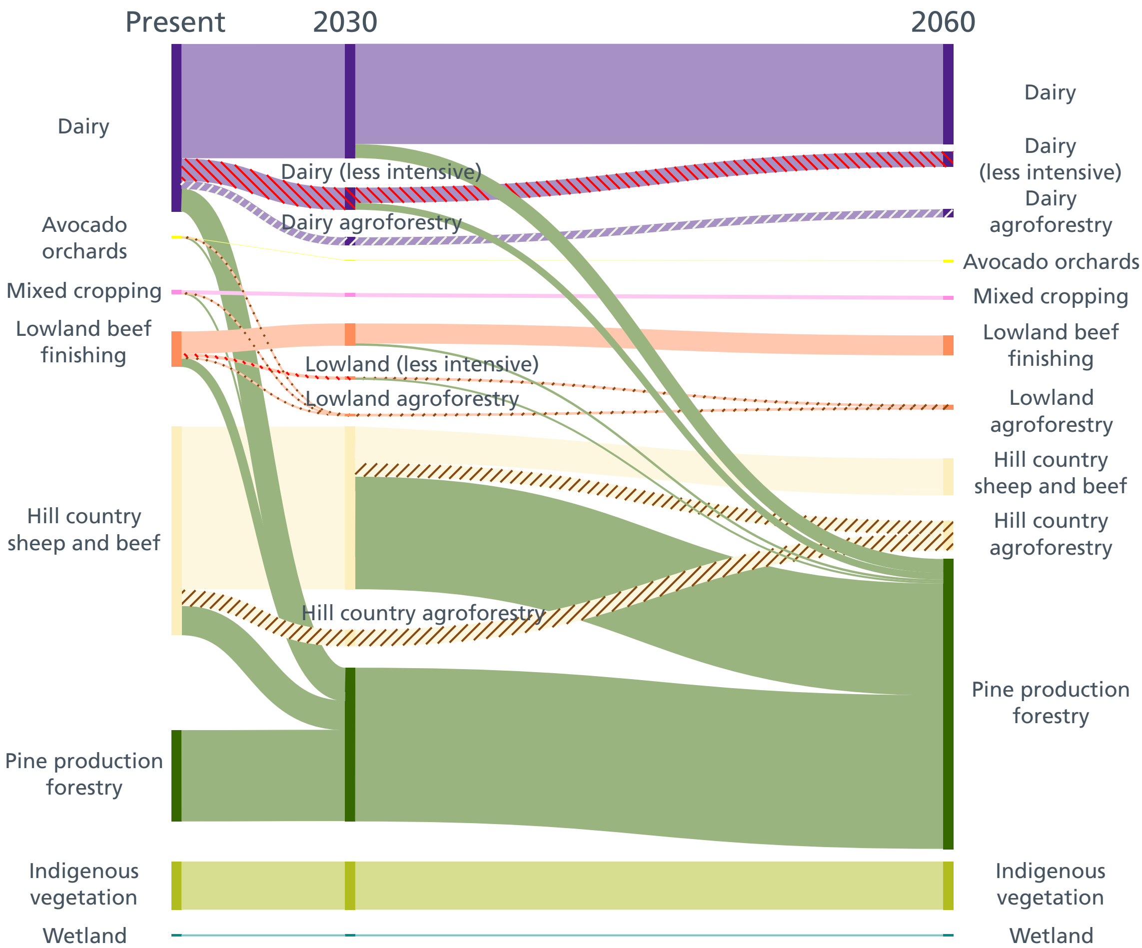
Source: Adapted from WSP (2023a) modelling

Figure 6.8: Modelled land use change in the Mataura catchment under scenario 3.

[8] Around 17% of land currently used for dairying in Mataura was identified as high-nitrogen-risk land. This means it was identified by Land & Water Science as being highly susceptible to loss of nitrate-nitrite nitrogen.

Reducing synthetic fertiliser use was one of the land management practices highlighted in a white paper published in 2019 outlining priorities for regenerative agriculture research in New Zealand.[9] Other examples included using diverse crops and pastures, minimising soil disturbance, maintaining soil cover, minimising chemical inputs and using adaptive grazing management. Projects to investigate the impacts of regenerative farming practices are being funded by the Ministry for Primary Industries through the Sustainable Food and Fibre Futures fund.[10]

In Wairoa, estimates of susceptibility to loss of sediment and pathogens from Land & Water Science as well as estimates of sediment delivery from Nature Braid were used to identify high-risk areas (Figure 6.9). The modelling indicated that integrating spaced poplars into hill country sheep and beef farms in high-sediment-risk areas at a minimum density of 100 stems per hectare could roughly halve soil losses per hectare. The modelling also assumed the poplars were registered in the NZ ETS and harvested for timber, adding an additional source of revenue for the farm.



Source: Adapted from WSP (2023b) modelling

Figure 6.9: Modelled land use change in the Wairoa catchment under scenario 3.

9 Grelet et al., 2021, p.20.

10 MPI, 2022a.

In addition to erosion control, poplars can provide shade for stock and can also be used as stock fodder. The light-coloured wood has a fine texture and can be used for furniture, toys, paper and plywood. The New Zealand Poplar & Willow Research Trust is supporting a breeding programme for poplar, and the New Zealand Farm Forestry Association established a Poplar Action Group in April 2023 to develop poplar as a commercial timber species in New Zealand.[11]

In Mataura, an agroforestry system using a mix of red beech/tawhairaunui with broadleaf/kāpuka as a nurse crop was modelled. Poplar is another promising option for agroforestry in Mataura, offering biodiversity enhancement, carbon sequestration, soil conservation and timber production benefits.[12]

While the wood yield and economics of agroforestry are highly site-specific and dependent on the demand for timber, the economic analysis suggested that planting widely spaced tree species such as poplar or red beech on livestock farms could be an opportunity for some farmers to increase their profitability while reducing their greenhouse gas emissions and mitigating soil erosion. The agroforestry systems in both Mataura and Wairoa were designed to reach crown cover of more than 30% and therefore be eligible for registration in the NZ ETS.[13] However, there are significant set-up costs for this sort of farm system change, including education and training. Further, cattle must be excluded during the transition period until the young trees are robust enough to withstand being knocked into and grazed by livestock.

The modelling also explored the impact of livestock farms converting to mixed farm–forestry systems instead of whole-farm conversions to pine production forestry only. The farm–forestry systems integrated blocks of permanent native forests and pine production forests into the parts of the landscape that were least suitable for livestock farming. Under this scenario, some land was still being used for hill country sheep and beef farming in both catchments in 2060, though the area of land used for this purpose was reduced by two thirds in Mataura and halved in Wairoa relative to the present level (Figure 6.10 and Figure 6.11). The planting of pine production forests on marginal farmland provided an additional source of income for farmers, while the conversion of high-sediment-risk and/or negligible production capacity land to permanent native forest delivered benefits in terms of erosion control, flood mitigation and improved habitat connectivity for kererū.[14]

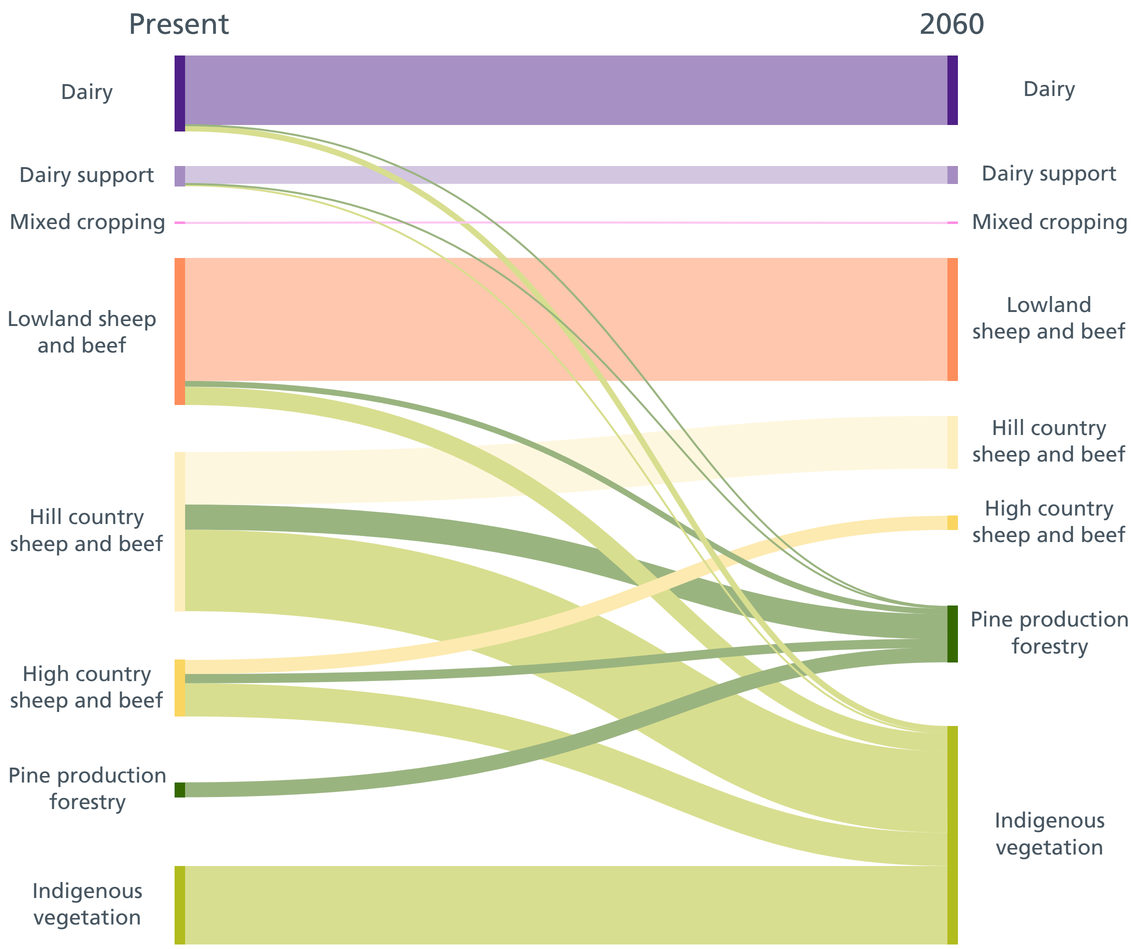
---

[11] New Zealand Poplar & Willow Research Trust, 2023.

[12] PCE integrated landscapes hui, pers. comm., August 2023.

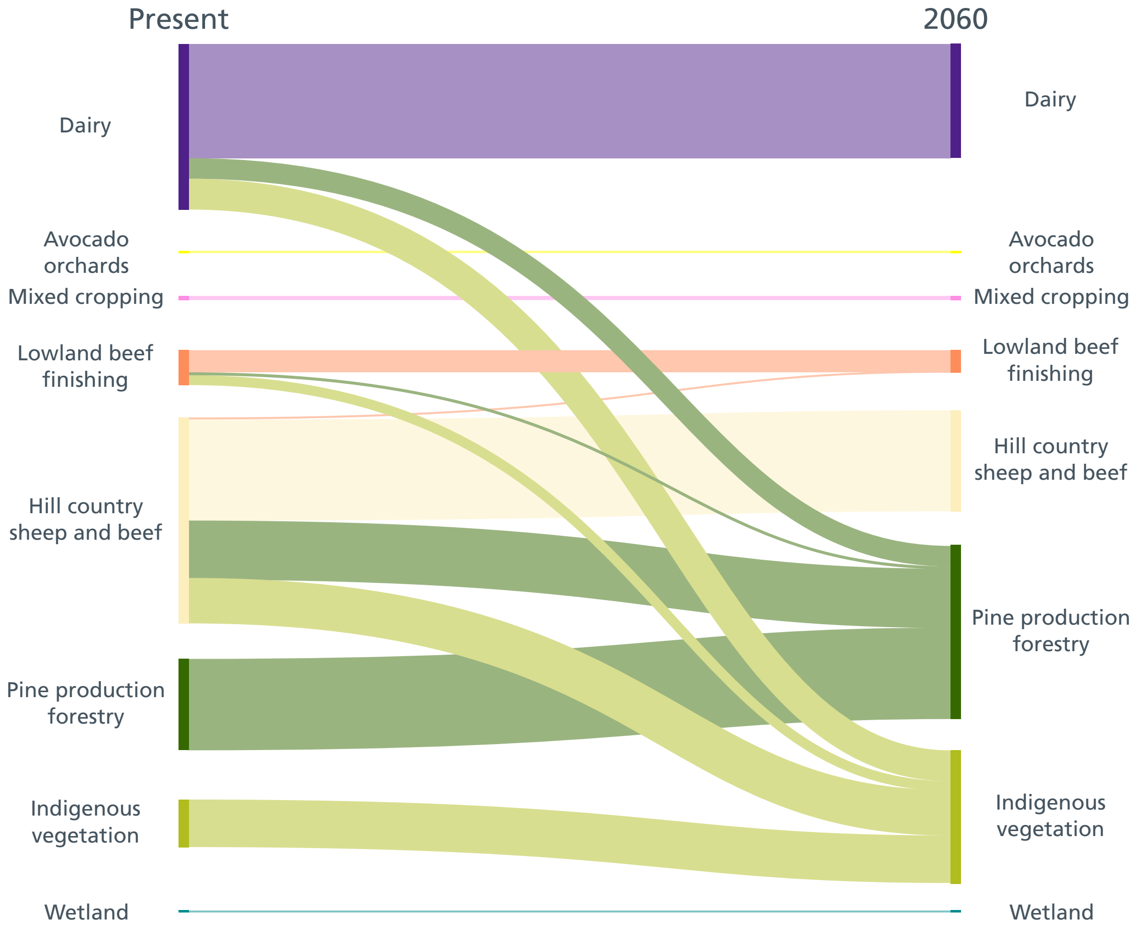
[13] A consultation on what the default carbon tables should be for space-placed poplars and willows in the NZ ETS was undertaken by the Government in September–October 2023 (Te Uru Rākau – New Zealand Forest Service, 2023).

[14] WSP, 2023a, pp.214–230; WSP, 2023b, pp.160–172.



Source: Adapted from WSP (2023a) modelling

Figure 6.10: Modelled land use change in the Mataura catchment under scenario 6. The impact of policies on land use in 2030 was not modelled in this scenario.



Source: Adapted from WSP (2023b) modelling

Figure 6.11: Modelled land use change in the Wairoa catchment under scenario 6. The impact of policies on land use in 2030 was not modelled in this scenario.

Using levy revenue recycling to connect climate, freshwater and biodiversity policies

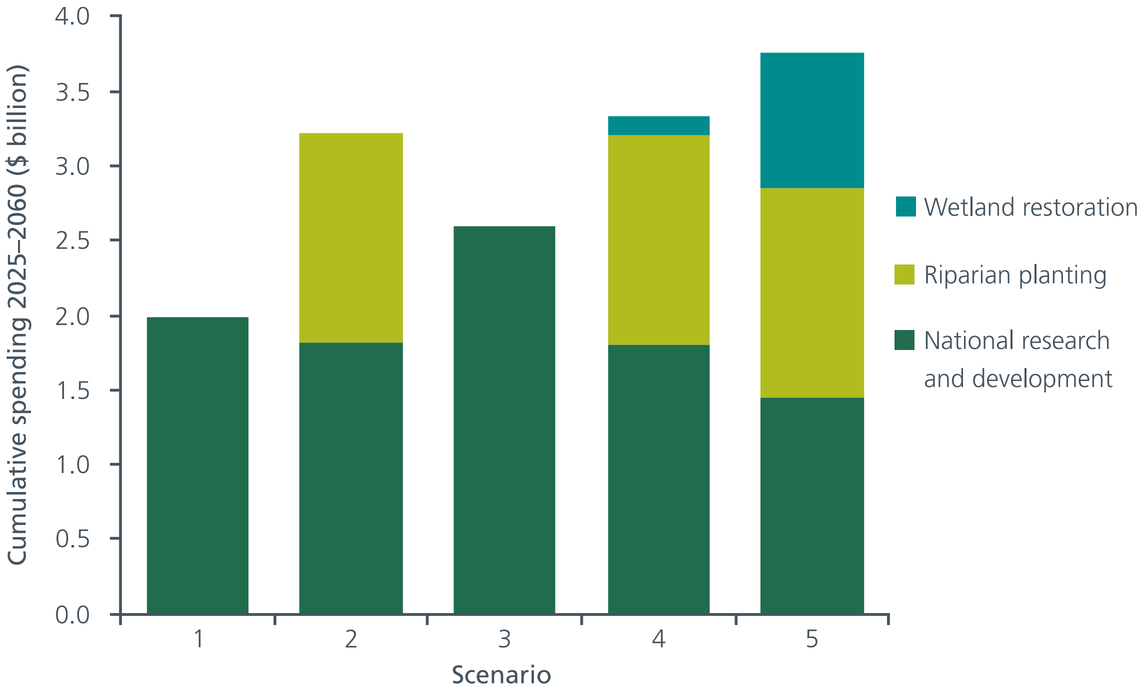
The investigation explored how different mixes of climate change, freshwater quality and biodiversity policies could be developed and implemented. In particular, with help from local people from each catchment, it considered what could be achieved if the revenue from a levy on biological greenhouse gas emissions were recycled back to the catchment it came from and used to fund actions that reduce emissions, improve freshwater quality and/or enhance biodiversity.

How the revenue will be used is an important aspect of the design of any agricultural emissions pricing policy. This modelling exercise assumed some of the levy revenue was used to fund national innovation policies and research and development of new technologies to reduce emissions (though the impacts of this spending were not modelled). He Waka Eke Noa recommended this as one of the ways to use the revenue from an agricultural emissions levy.[15]

[15] HWEN, 2022, pp.66–67.

This exercise also explored what might be achieved if the rest of the revenue from the levy were recycled back to the catchment it came from and used to enable landowners and kaitiaki to undertake actions within the catchment to reduce emissions, improve freshwater quality and/or enhance biodiversity. These actions included changes in land management practices and land uses, with interventions prioritised in the riskiest areas, as discussed above. If recycled in this way, the magnitude of funding coming back into each catchment could be significant. For example, in Wairoa the cumulative levy revenue collected during the period 2025–2060 varied from a low of $2.0 billion in scenario 1 to a high of $3.8 billion in scenario 5. Figure 6.12 summarises how this levy revenue was spent in five of the scenarios modelled for Wairoa.

There are some potential disadvantages to ring-fencing the levy revenue for specific activities in this way. For example, it risks precluding the allocation of the revenue to higher value public goods. Also, in the absence of additional sources of funding from elsewhere, the funding available for mitigation actions would be limited to the amount raised through the levy. To address this, other funding mechanisms such as government-backed loans or subsidies could be considered in addition to recycled levy revenue.



Source: Based on modelling by WSP and Nature Braid (WSP, 2023b)

Figure 6.12: Cumulative levy revenue spending in Wairoa for the period 2025–2060. Excludes subsidies for tōtara and loans for converting dairy land to macadamia orchards because these were not funded by levy revenue in the modelling. Excludes scenario 6 because levy revenue recycling was not modelled in that scenario.[16]

---

[16] Note that wetland restoration cost is a rough, high-end estimate. Actual costs would likely be lower than indicated due to economies of scale (Muller, 2020).

Trichomanes endlicherianum

7 Findings and lessons learned

This report offers no recommendations for policy settings. In part this is because the modelling was experimental and those engaged in the two catchments were asked to take part on the basis that the aim was to learn from the exercise rather than to apply it. Furthermore, given the highly place-based nature of the exercise, it seemed prudent to avoid the temptation to extrapolate any learnings from Wairoa and Mataura to other places. Below is a summary of some learnings from the two case studies that may inform future work in this area.

Current land uses and main environmental issues

Significant land use change has already occurred in the Mataura and Wairoa catchments. Prior to human arrival, both catchments were mainly covered by indigenous forests and wetland ecosystems that provided habitats for a highly diverse range of plant and animal species. Returning to that world is beyond reach. Only fragments of these native ecosystems remain. Most of the land is now being used for dairying, sheep and beef farming, and exotic production forestry. Other existing land uses include deer farming in Mataura and horticultural crops such as avocado, kiwifruit and kūmara in Wairoa.

But it is not as though some new equilibrium has been reached. The way land is currently being used and managed in both catchments continues to degrade the environment. In the Mataura catchment, the biggest freshwater quality issues are associated with nitrate and *E. coli*. The amount of organic waste discharged from point sources such as factories and meat processing plants into the Mataura River has decreased since the 1970s. This has improved the appearance of the river. However, the level of nutrients and bacteria in the river remains elevated, largely due to diffuse sources within the catchment, such as pastoral livestock farming.

The biggest freshwater quality issue in the Wairoa catchment is sediment from pastoral farming and production forestry. Sediment from the Wairoa River is deposited in the Kaipara Moana, where it degrades the mauri of the harbour and damages its ecological health. For example, fine sediment can smother sea grass and overwhelm filter-feeding shellfish.[1]

[1] Increased sedimentation in Kaipara Moana has been attributed to reductions in the abundance of scallops (*Pecten novaezelandiae*), toheroa (*Paphies ventricosa*), tuatua (*Paphies subtriangulata*), cockles (*Austrovenus stutchburyi*) and pipi (*Paphies australis*) (Gibbs et al., 2012; Morrison et al., 2014).

Historical deforestation and draining of wetlands in Mataura and Wairoa transferred significant quantities of carbon dioxide from the terrestrial biosphere to the atmosphere. In addition to this contribution to warming from historical land use change, the ruminants that have been added to these landscapes are producing biogenic methane and soil nitrous oxide emissions. New forests are also being planted in these catchments. By removing carbon dioxide from the atmosphere, these forests are returning a small fraction of the carbon previously lost from past forest clearance back to the land.

What did we learn from the physiographic mapping of landscape susceptibility?

The physiographic mapping undertaken for this project indicated that there is significant spatial variation in the susceptibility of land to loss of nutrients and soil nitrous oxide within the Mataura and Wairoa catchments.[2] It also showed that in many parts of these catchments, the susceptibility can be high for one pollutant (e.g. nitrate) but low for another (e.g. nitrous oxide), and vice versa. In other words, there are often trade-offs that need to be managed between different environmental objectives. This underlines that solutions need to be place-specific. The best actions people can take in each place to improve the environment (and the best places to undertake them) also depend on what they are trying to achieve on the land.

The type of physiographic approach used for this modelling and mapping exercise was novel and remains at a relatively early stage of development. However, with further improvements (such as more comprehensive validation, quantification of uncertainties and wider ground-truthing of the results), tools such as this have the potential to be used to aid land-related decision making at scales ranging from whole-of-catchment down to sub-paddock.

The primary purpose of this model is to provide a pragmatic tool to help landowners, land managers and catchment groups to better understand their landscape and identify the best locations for making changes to land management practices and land uses. It remains unclear what formal role, if any, spatial modelling tools like this should play in a regulatory context. The PCE is currently undertaking a review of the use of freshwater models for regulatory purposes and intends to publish the findings on this topic in 2024.

The susceptibility modelling undertaken for this exercise was based on high-resolution spatial datasets coupled with scientific understanding of the physical and chemical processes driving freshwater and soil emissions outcomes. From a Ngāi Tahu ki Murihiku perspective, such a model cannot incorporate those metaphysical elements of culture and landscapes that are central to their world view. Therefore, any insights from landscape susceptibility mapping must be set alongside the insights from tangata whenua led frameworks and tools when making decisions related to land use and land management practices in the Mataura catchment.

[2] Rissmann et al., 2022. See also Rissmann et al. (2024) who showed that landscape factors (climate, geomorphology and lithology) accounted for as much, if not more, of the spatial variation in water quality in parts of New Zealand.

What did we learn from the land use modelling?

The land use modelling provided insights into how different environmental policy mixes might shape the Mataura and Wairoa catchments over the coming decades. It revealed how the impact on livestock farms of an agricultural emissions levy would likely be different in the two catchments studied.

At a low levy rate, the modelling indicated that all hill country sheep and beef land in Mataura would remain profitable in 2060 (though profit margins would be reduced). By contrast, only around one fifth of hill country sheep and beef land in Wairoa would remain profitable. This reflects the difference in the current profitability of hill country sheep and beef farming in these two catchments, with farms in Mataura generally having a higher profitability than farms in Wairoa. At medium or high levy rates, all sheep and beef land in both catchments would become unprofitable. In most locations, the model assumed that unprofitable sheep and beef land would be converted to pine production forestry registered in the New Zealand Emissions Trading Scheme (NZ ETS). In reality, what the best alternative use would be depends on the objectives and values of the landowner.

In general, an agricultural emissions levy would be expected to result in less land use change away from dairying than sheep and beef farming because most dairy farms are more profitable than sheep and beef farms – but again, the expected impacts would be highly place-specific. The modelling suggested that even at a high levy rate, all dairy land in the Mataura would remain profitable in 2060. By contrast, in Wairoa a high levy would make all dairy land unprofitable, while at a medium levy rate, dairy farms on moderate, high and very high production capacity land (around three quarters of current dairy land) would remain profitable.

A medium to high agricultural emissions levy – in combination with increasing rewards from the NZ ETS for planting fast-growing forests – would be expected to transform both catchments into largely binary landscapes of exotic forests and dairy farms by 2060. These potential impacts should be key considerations in the design of any levy on agricultural emissions or changes to the role of forestry in the NZ ETS.

The modelling suggested that the type of price-driven transition described above could bring some environmental benefits. For example, it would reduce flows of diffuse pollutants such as nitrate and *E. coli* into waterways, reduce agricultural emissions and increase carbon dioxide removals (though keeping this carbon safely stored in the terrestrial biosphere as the climate warms would become increasingly challenging). The sediment outcomes would depend on how the pine production forests are managed and harvested. The sediment loads from unharvested forests are generally lower than those from pasture, all else being equal. However, if pine production forests are clear-felled, there is a period of around eight years after harvest during which elevated levels of sediment and harvest debris can be lost from the land, particularly when extreme weather events occur.

The modelling also highlighted that the scenario outlined above would be expected to result in a decrease in revenue from sheep and beef farming and an increase in revenue from selling carbon credits from forests into the NZ ETS market in both catchments. The extent to which the increased revenue from forestry would benefit the people living in these catchments would depend on who owns the forests. Also, tying a significant share of people's income to the price of forestry units in the NZ ETS is risky.

The future role of forests in the NZ ETS (and the associated value of the units they generate) is uncertain. Registering forests planted after 1989 in the NZ ETS is not mandatory – it is a voluntary decision that involves weighing up the financial reward of revenue from future unit sales against the opportunity cost of locking up land indefinitely in forest. Significantly, even without revenue from the NZ ETS or a levy on agricultural emissions, producing timber (and potentially other wood-based products such as bioenergy) is likely to be a more profitable use of land than hill country sheep and beef farming in most parts of the Mataura and Wairoa catchments.

Unsurprisingly, introducing a more nuanced, place-based mix of policies produced different insights. The modelling demonstrated how spending the revenue from an agricultural emissions levy on actions such as fencing off waterways, planting up riparian buffers and restoring wetlands in Mataura and Wairoa could help to reduce the quantities of nitrogen and phosphorus entering waterways, provide habitat and biodiversity corridors for indigenous species such as kererū, and help to mitigate the risk of flooding. It also demonstrated how planting tōtara continuous cover forests instead of clear-felled pine production forests would be likely to reduce erosion and soil losses.

Using some of the revenue from an agricultural emissions levy to assist the scaling up of less emissions-intensive land uses could help to reduce greenhouse gas emissions. Macadamia orchards in Wairoa and tulips in Mataura were used as examples of high-value, low-emissions land uses for the purposes of this modelling exercise. However, these alternative land uses may have other environmental effects that need to be considered, such as demand for water or the use of chemical herbicides and pesticides that are potentially harmful to ecosystem and human health. No productive land use is entirely environmentally benign.

There are several different ways that trees could be integrated into farm systems. Options explored in the modelling included mixed farm–forestry systems (with permanent native forests planted on high-sediment-risk land, exotic production forestry planted on marginal but not high-sediment-risk land, and livestock farming retained on the best land) and agroforestry systems that combine wide-spaced poplars or red beech trees with pasture.

The modelling indicated that integrating trees on farms has the potential to increase the profitability of farms in Mataura and Wairoa while reducing emissions, increasing carbon dioxide removals, and providing erosion control and biodiversity benefits. However, there is limited experience with agroforestry in New Zealand. Further research and pilot projects are needed to investigate the potential economic and environmental benefits of agroforestry systems and how these are likely to vary in different parts of the country.

The land use modelling exercise did not assess the social or cultural impacts of the hypothetical land use transitions outlined above. Some commentary from other sources on these aspects is provided in the sections below.

Wider social and economic considerations

Land uses will need to change in some places if their environmental impacts are to be reduced and the mauri of the wai and the whenua is to be protected and restored. The social and economic impacts of any transition will vary depending on how it is managed and the policies put in place to support the people affected.

Agriculture and forestry are significant contributors to the local economies of Mataura and Wairoa. In 2021, agriculture accounted for 7.8% of Northland's gross domestic product, while forestry, fishing and mining accounted for 3.7%. In Southland, the shares were 18.3% and 4.7%, respectively.[3] In terms of employment, the dairy sector employed 2.7% of the workforce in Northland and 7.6% of the workforce in Southland in 2023.[4] Many forestry-related jobs are part-time and/or seasonal, which makes measuring and estimating regional employment in the forestry sector difficult.

Estimates of the economic impacts of large-scale land use change are uncertain and highly dependent on the assumptions used. The modelling undertaken for this investigation indicated that the introduction of a levy on biological greenhouse gas emissions would decrease the profitability of livestock farming, making less emissions-intensive land uses such as forestry and horticulture more attractive. Alternative income streams such as tourism, bioenergy, wind power and solar power could also help farmers and tangata whenua to maintain viable businesses while reducing their emissions.[5]

Like any large-scale economic transition, significant land use change is likely to result in winners and losers – as there are under the status quo. Exploring the possible consequences for landscapes of different policy mixes could help the Government to design targeted support policies for people negatively affected by any transition. A just transition is needed in the agriculture sector, not just in the energy sector.[6]

Having a variety of income streams would help to improve the resilience of the community and tangata whenua to external economic shocks. This is because if one source of income suddenly decreases, at least some income is likely to continue from other sources. By contrast, if there is high reliance on only one or two sources of income, communities and tangata whenua are at greater risk of significant income losses in the event of external shocks.

---

3 StatsNZ, 2023.

4 Sense Partners, 2023, p.6.

5 A regional energy strategy for Southland for 2022–2050 prepared by Beca Ltd identified over 100 potential sites for wind farms and concluded that embedded solar farms close to electricity loads could also contribute to electricity generation in Southland (Beca, 2023). Further, a 2023 study funded by the Our Land and Water Rural Professionals Fund found that a significant area of Canterbury is suitable for integrating solar energy production with livestock farming (known as 'agrivoltaics') and indicated this could be a significant opportunity for some sheep and beef farmers to increase their profitability (Vaughan et al., 2023).

6 A guide to just transitions in any sector was developed by a team of contributors led by Motu and published in 2023 (Allen et al., 2023).

The economic and social benefits of production forests partly depend on their proximity to wood processing facilities and ports, as well as demand for timber and other wood products. The greater the capacity of wood processing facilities within a region, the greater the share of the economic benefits that can be captured locally. Of all the logs produced in 2021, 39% were processed in New Zealand.[7] A Forestry and Wood Processing Industry Transformation Plan was released by the Government in 2022. One of the key objectives of this plan is to modernise and expand domestic wood processing.[8]

While there is potential to expand the forest industry in Northland, realising this potential could be challenging.[9] For example, without a rapid upskilling of the local workforce, there may be limits to the amount of land in a region like Northland that can be converted to production forestry. Incentives for land use change therefore need to be accompanied by policies to enhance the skills and training (as well as infrastructure) needed to expand alternative land uses and supply chains. The rate of expansion of alternative land uses such as forestry also needs to be acceptable to the community and tangata whenua.

What did we learn from Māori perspectives on this kaupapa?

Māori have a deep connection to landscapes reinforced over many generations. The knowledge that was gained from fine-grained observations has not been lost but now needs to be embedded and truly acknowledged. Unsurprisingly, the scale of environmental upheaval caused by the large-scale changes in land use that have occurred in the Mataura and Wairoa catchments since the arrival of Europeans is felt most intensely by Māori. Much of what was of greatest value to them has been destroyed or severely diminished. A lot of the land they do still hold or act as kaitiaki of has relatively low productive potential and remains under-developed. Māori should not be penalised for this.

Restoring parts of the native ecosystems that have been lost (such as the Hikurangi Repo) by retiring land from farming would undoubtedly provide significant environmental and cultural benefits. However, it would be expensive. If this option were to be pursued, an inclusive and carefully designed process involving mana whenua, local authorities and farmers would be needed to work through thorny issues such as who pays.

Mana whenua are actively expressing their rangatiratanga by developing their own frameworks and tools that illustrate their understanding and connection to their landscapes. These include, but are not limited to, economics, biodiversity and freshwater, and also encapsulate concepts beyond what was modelled here or can be modelled. Both mana whenua groups provided us with a description of these concepts.

Engagement with mana whenua needs to start early and be sustained and adequately resourced. Ensuring all mana whenua are able to assert their rangatiratanga as kaitiaki and contribute their mātauranga will take time. This will be time well spent if it secures involvement and a clear idea of what the outcomes of the exercise might be.

---

7 Of the 37.2 million tonnes of logs produced in the year ended December 2021, 14.5 million tonnes were processed in New Zealand (FOA, 2023, p.23).

8 MPI, 2022b, p.28.

9 Martin Jenkins, 2015, p.1.

Any collaborative approach going forward would need to consider how to ensure mana whenua and their role as kaitiaki are acknowledged and how to co-develop solutions using different knowledge systems and ontologies. Taking a more joined-up approach to addressing environmental challenges at the landscape level requires getting inside what the landscape as a whole signifies to Māori and the community, while also ensuring that the voices of mana whenua as kaitiaki can express that and see it reflected in regulatory decisions. What is essential is understanding the values and aspirations of Māori for landscapes in their rohe and ensuring that these are taken into account in land use decisions.

The multiple overlapping policies and plans that tangata whenua are currently requested to contribute to in a disjointed way creates fatigue and adds complexity to deciding how they might like to participate. Spreading themselves too thinly across too many projects results in fewer people involved in important work. Any such complex and collaborative process is likely to be resource-heavy due to the need for endorsement by the appropriate people of the hapū. This may come from mandated organisations, marae, whenua Māori trusts, or individual kaumātua, hapū or whānau members. For this reason, early engagement to enable mana whenua to identify capability and capacity needs is essential – something this project failed to achieve.

Mana whenua are a part of environmental decision making and many whānau, hapū and iwi are kaitiaki of whenua in Aotearoa. Most are already using their definitions of landscapes to better manage and restore degraded landscapes within their rohe. The long-held connection that tangata whenua have with the land means they have a deep understanding of their landscapes and knowledge that can provide an essential perspective for decision making in their catchments.

What else did we learn from our conversations with people in these two catchments?

Landowners and tangata whenua in both catchments are under increasing pressure from current and forthcoming climate change, freshwater quality and biodiversity policies (not to mention the effects of extreme weather events themselves). There is also pressure on people to respond to the large number of consultations and policy announcements that emanate from different government agencies. It is difficult to see how these all fit together.

It was clear from our conversations that people fear that, in the absence of complementary policies or support, large-scale land use change driven by price-based mechanisms for dealing with greenhouse gases could result in negative impacts on low-income households, rural communities and tangata whenua in the Mataura and Wairoa catchments. These impacts include loss of employment in the pastoral agriculture sector and related industries, reduced viability of local businesses and services, and a decline in social cohesion and sense of community. On the other hand, improved freshwater quality (in terms of instream concentrations of nitrogen, phosphorus and *E. coli*) could provide better opportunities for mahinga kai, while people with interests in exotic forestry would stand to benefit economically under such a scenario.

Another recurring theme in our conversations with people was that climate change is likely to exacerbate many of the problems outlined above. An increased frequency of extreme weather events is already being experienced – this project spanned several heavy rainfall events in Northland. In Wairoa, events like these are likely to become more frequent and intense in the future, which could increase the risk of sediment loss from pasture and clear-felled plantation forests. Droughts could increase the risk of forests being lost through fire, thereby re-releasing their carbon back into the atmosphere. Heatwave days are expected to increase for most of the Mataura.[10] There will also be changes in the crops that can be grown in both catchments. Communities are coming to terms with the need to build their resilience in the face of a changing climate. For example, nearly all of Wairoa's kūmara production is currently located in one low-lying area near Dargaville, which is risky from a flooding perspective.

While promising alternative land uses exist in both catchments, communities are aware that these cannot be scaled up overnight. Joined-up investment in infrastructure, skills and market analysis would be needed for them to succeed.

There is an understanding that setting freshwater quality targets for the whole of these catchments makes sense because all the waterways within each catchment are connected. However, these catchments are probably too large for people to coordinate and work together effectively. Building trust and relationships is key to the success of networks such as catchment groups, but this will be hard to do if the members are far apart.[11] Any bottom-up approach to meet catchment-wide goals may therefore need to be implemented through networks of smaller groups at the sub-catchment scale.

---

[10] Zammit et al., 2018, p.12.

[11] Sinner et al., 2023, p.18.

Conclusion

This project originated in an earlier modelling exercise to determine what continued reliance on afforestation to meet New Zealand's climate change mitigation targets might mean for catchments and the people who live in them. By extending the analysis to include policies designed to address freshwater quality and biodiversity, as well as the economic costs of implementing them, the complexity of the task was increased significantly. With the resources available, the output was never going to be more than illustrative of the scale and nature of the task – both technically and in human terms. Nevertheless, the exercise demonstrated that integrating landscape susceptibility mapping, land use and economic modelling, and community and Māori input at a catchment level can generate insights into what the future of a landscape might look like under various policy mixes.

My hope is that others find the approach useful and interesting and will take the work forward. However, the concept would need substantially more development before being used to inform decision making by regulators, mana whenua, businesses, land managers or communities. The work needed includes rigorous testing and debate about which models to use, the appropriateness and the robustness of their assumptions, and how to integrate or not integrate Māori perspectives in different places.

What seems clear is that the scale of environmental pressures (of which climate change is only one) will make significant land use change increasingly likely. Whether and how such change is managed is a matter for both the market and policymakers. But whatever choices are made, they will be fraught with environmental consequences.

Blechnum zeelandicum

References

Allen, W., Baisden, T., Burgess, J., Crawford, S., Ellis, L., Hall, D., Hall, T., Jayasuriya, U., Kawharu, M., Kotula, H., Leining, C., Maher, S., Montes de Oca, O., Pueyo, A., Stephenson, J., Walton, S. and Watene, K., 2023. A guide to just transitions for communities in Aotearoa New Zealand: He puka arataki whakawhitinga tika mō ngā hapori i Aotearoa. Wellington: Motu Economic and Public Policy Research.

Aotearoa Circle, 2020. Native forests: Resetting the balance. Aotearoa Circle.

Armstrong-Read, A., 2016. Te Huarahi hei whakahokia te Māuri o nga Awa.

Baillie, B.R. and Neary, D.G., 2015. Water quality in New Zealand's planted forests: a review. New Zealand Journal of Forestry Science, 45(7): 1–18.

Bartlett, M., Kitson, J., Norton, N. and Wilson, K., 2020. Draft Murihiku Southland freshwater objectives: Providing for hauora, the health and well-being of waterbodies in Murihiku Southland. Environment Southland and Te Ao Marama Incorporated.

Beca, 2023. Southland Murihiku Regional Energy Strategy 2022–2050: Summary. Prepared for Great South Southland Regional Development Agency. Beca Ltd.

Beef + Lamb New Zealand, 2022. B+LNZ summary analysis of the potential pricing impacts on sheep and beef farms from He Waka Eke Noa levy. Wellington: Beef + Lamb New Zealand.

Botting, S., 2021. Eels minced by Hikurangi Swamp pumps dumped at council offices. The Northern Advocate, 5 March 2021. https://www.nzherald.co.nz/northern-advocate/news/eels-minced-by-hikurangi-swamp-pumps-dumped-at-council-offices/HIFOC2IWYHNGTM7ZV6E7MXFX4Y/.

Brockerhoff, E.G., Jactel, H., Parrotta, J.A., Quine, C.P. and Sayer, J., 2008. Plantation forests and biodiversity: Oxymoron or opportunity? Biodiversity and Conservation, 17(5): 925–951.

Chappell, P.R., 2013. The climate and weather of Northland. 3rd ed. Wellington: National Institute of Water and Atmospheric Research.

Clarkson, B., Ausseil, A. and Gerbeaux, P., 2013. Wetland ecosystem services. In: J.R. Dymond (ed). Ecosystem services in New Zealand – conditions and trends. Lincoln: Manaaki Whenua Press.

Clarkson, B., Bartlam, S. and Price, R., 2015. Living water – Opportunities for restoration: Hikurangi Floodplain. Hamilton: Landcare Research.

Conning, L., 2001. Northland protection strategy: A report to the Nature Heritage Fund committee. Wellington: Nature Heritage Fund.

Daigneault, A., Dymond, J. and Basher, L., 2017. Kaipara Harbour sediment mitigation study: Catchment economic modelling. Prepared for Streamlined Environmental Ltd. Auckland: Landcare Research.

Environment Southland, 2020. Southland Intensive Winter Grazing NES Advisory Group. Invercargill: Environment Southland.

Fahey, B. and Marden, M., 2006. Forestry effects on sediment yield and erosion. In: G. Eyles and B. Fahey (eds). Pakuratahi – Tamingimingi land use study report. Napier: Hawke's Bay Regional Council: 51–62.

Forest Owners Association (FOA), 2023. Facts and figures 2021/22: New Zealand plantation forest industry. Jointly released by FOA and MPI. Wellington: Forest Owners Association.

Forestry Reference Group, 2018. Forestry Reference Group final report. Wellington: Ministry for Primary Industries.

Freeman, M., Boyens, N., Costello, B. and Ballinger, M., 2020. Southland science report: Southland freshwater quality implications for rural communities. Prepared for Thriving Southland. Cromwell: Landpro Ltd.

Gibbs, M., Olsen, G., Swales, A., Shaoneng, H., 2012. Kaipara Harbour sediment tracing: Sediment dispersion across the harbour. Prepared for Integrated Kaipara Harbour Management Group. Hamilton: National Institute of Water and Atmospheric Research.

Green, M.O. and Daigneault, A., 2018. Kaipara Harbour sediment mitigation study: Summary. Report NRC1701–1 (minor revision). Hamilton: Streamlined Environmental.

Grelet, G., Lang, S., Merfield, C., Calhoun, N., Robson-Williams, M., Horrocks, A., Dewes, A., Clifford, A., Stevenson, B., Saunders, C., Lister, C., Perley, C., Maslen, D., Norton, D., Selbie, D., Chan, D., Burns, E., Le Heron, E., Crampton, E., Curran-Cournane, F., Doolan-Noble, F., Griffin, F., Good, H., Pinxterhuis, I., Todd, J., Su, J., Vernon, J., Cavanagh, J., Laubach, J., King, J., Jones, J., Orwin, K., MacMillan, K., Minor, M., Anderson, M., Buckley, M., Harcombe, M., McGlone, M., Davidson, M., Barry, M., Taitoko, M., Kirschbaum, M., Donovan, M., Conland, N., Stanley-Clarke, N., Masters, N., Schon, N., Mason, N., Gregorini, P., Mudge, P., Tapsell, P., Bruce-Iri, P., Tait, P., Roudier, P., Mellor, R., Teague, R., Gregory, R., Price, R., Holdaway, R., Dynes, R., Lavorel, S., O'Connell, S., Letica, S., Belliss, S., McNeill, S., Apfelbaum, S., Driver, T., Fraser, T., Baisden, T. and Kerner, W., 2021. Regenerative agriculture in Aotearoa New Zealand – research pathways to build science-based evidence and national narratives. Our Land and Water, Manaaki Whenua – Landcare Research and the NEXT Foundation.

Hall, D., 2018. The interwoven world – Te ao i whiria: Toward an integrated landscape approach in Aotearoa New Zealand. Auckland: The Policy Observatory, Auckland University of Technology.

Harnett, M., 2019. Myth conceptions: Are planted forests really the Devil? New Zealand Tree Grower, May 2019.

Harrison, E. and Bruce, H., 2019. Case study: Socio-economic impacts of large-scale afforestation on rural communities in the Wairoa District. Report for Beef + Lamb NZ. Masterton: BakerAg.

He Pou a Rangi Climate Change Commission, 2021. Ināia tonu nei: A low emissions future for Aotearoa. Advice to the New Zealand Government on its first three emission budgets and direction for its emissions reduction plan 2021–2024. Wellington: He Pou a Rangi.

He Pou a Rangi Climate Change Commission, 2023. 2023 draft advice to inform the strategic direction of the Government's second emissions reduction plan. Wellington: He Pou a Rangi.

He Waka Eke Noa (HWEN), 2022. Recommendations for pricing agricultural emissions – Report to Ministers. Wellington: He Waka Eke Noa Primary Sector Climate Action Partnership.

Interim Climate Change Committee (ICCC), 2019. Action on agricultural emissions. Wellington: Interim Climate Change Committee.

Kaipara Moana Remediation (KMR), 2020. Kaipara Moana Remediation memorandum of understanding. Kaipara Moana Remediation Programme.

Kaipara Moana Remediation (KMR), 2022. Pūrongo ā-tau | Annual report 2021–2022. Whangārei: Kaipara Moana Remediation.

Kirschbaum, M.U.F., Whitehead, D., Dean, S.M., Beets, P.N., Shepherd, J.D. and Ausseil, A.G.E., 2011. Implications of albedo changes following afforestation on the benefits of forests as carbon sinks. Biogeosciences, 8(12): 3687–3696.

Kitson, J. and Cain, A., 2023. Integrated landscape approaches from a Ngāi Tahu ki Murihiku perspective. Report to the Parliamentary Commissioner for the Environment. Gore: Hokonui Rūnanga.

Lambie, S., Marden, M., Kirschbaum, M., Soliman, T. and Walsh, P., 2018. Best options for land use following radiata harvest in the Gisborne District under climate change: Literature review. MPI Technical Paper No: 2018/46. Wellington: Ministry for Primary Industries.

Land, Air, Water Aotearoa (LAWA), 2023a. Mataura River. https://www.lawa.org.nz/explore-data/southland-region/river-quality/mataura-river/ [accessed 20 June 2023].

Land, Air, Water Aotearoa (LAWA), 2023b. Northern Wairoa River. https://www.lawa.org.nz/explore-data/northland-region/river-quality/northern-wairoa-river/ [accessed 20 June 2022].

Ledgard, G., 2013. Land use change in the Southland region: Technical report. Publication No 2013–13. Invercargill: Environment Southland.

Lynn, I., Manderson, A., Page, M., Harmsworth, G., Eyles, G., Douglas, G., Mackay, A. and Newsome, P., 2009. Land use capability survey handbook – A New Zealand handbook for the classification of land. 3rd ed. Hamilton: AgResearch. Lincoln: Landcare Research. Lower Hutt: GNS Science.

Manaaki Whenua – Landcare Research (MWLR), 2023. Trees in landscapes/Te Kapunipunitanga a Tāne Mahuta. Manaaki Whenua – Landcare Research. https://www.landcareresearch.co.nz/trees-in-landscapes/ [accessed 27 June 2023].

Martin Jenkins, 2015. Tai Tokerau Northland growth study: Opportunities report. Wellington: Ministry for Primary Industries.

McDowell, R.W., Herzig, A., van der Weerden, T.J., Cleghorn, C. and Kaye-Blake, W., 2022. Growing for good: Producing a healthy, low greenhouse gas and water quality footprint diet in Aotearoa, New Zealand. Journal of the Royal Society of New Zealand: 1–25.

McDowell, R.W. and Kaye-Blake, W., 2023. Viewpoint: Act local, effect global: Integrating farm plans to solve water quality and climate change problems. Land Use Policy, 129: 106670.

McDowell, R.W., Monaghan, R.M., Smith, C., Manderson, A., Basher, L., Burger, D.F., Laurenson, S., Pletnyakov, P., Spiekermann, R. and Depree, C., 2021. Quantifying contaminant losses to water from pastoral land uses in New Zealand III. What could be achieved by 2035? New Zealand Journal of Agricultural Research, 64(3): 390–410.

Ministerial Inquiry into Land Uses in Tairawhiti and Wairoa, 2023. Outrage to optimism. Report of the Ministerial Inquiry into land uses associated with the mobilisation of woody debris (including forestry slash) and sediment in Tairawhiti/Gisborne District and Wairoa District. Ministerial Inquiry into Land Uses in Tairawhiti and Wairoa.

Ministry for Primary Industries (MPI), 2017. A guide to carbon look-up tables for forestry in the Emissions Trading Scheme. Wellington: Ministry for Primary Industries.

Ministry for Primary Industries (MPI), 2022a. Regenerating Aotearoa: Investigating the impacts of regenerative farming practices. Wellington: Ministry for Primary Industries.

Ministry for Primary Industries (MPI), 2022b. Te Ara Whakahou – Ahumahi Ngahere: Forestry and Wood Processing Industry Transformation Plan. Wellington: Ministry for Primary Industries.

Ministry for the Environment (MfE), 2022. Report and recommendations on intensive winter grazing amendments. Wellington: Ministry for the Environment.

Ministry for the Environment (MfE), 2023. Helping nature and people thrive: Exploring a biodiversity credit system for Aotearoa New Zealand – Discussion document. Wellington: Ministry for the Environment.

Ministry for the Environment (MfE), Ministry for Primary Industries (MPI) and Ministry of Business, Innovation and Employment (MBIE), 2023. Te Arotake Mahere Hokohoko Tukunga – Review of the New Zealand Emissions Trading Scheme: Discussion document. Wellington: Ministry for the Environment, Ministry for Primary Industries and Ministry of Business, Innovation and Employment.

Ministry for the Environment (MfE) and Stats NZ, 2021. New Zealand's environmental reporting series: Our land 2021. Wellington: Ministry for the Environment.

Ministry of Justice, 2017. Māori Land Spatial Dataset. Ministry of Justice. https://catalogue.data.govt.nz/dataset/maori-land-spatial-dataset [accessed 6 October 2023].

Morrison, M.A., Lowe, M.L., Parsons, D.M., Usmar, N.R. and McLeod, I.M., 2009. A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 37. Wellington: Ministry of Fisheries.

Morrison, M.A., Lowe, M.L., Jones, E.G., Makey, L., Shankar, U., Usmar, N., Miller, A., Smith, M., and Middleton, C., 2014. Habitats of particular significance for fisheries management: the Kaipara Harbour. New Zealand Aquatic Environment and Biodiversity Report No. 129. Wellington: Ministry for Primary Industries.

Muller, C., 2020. Estimated on-farm economic impacts of selected mitigation options. Prepared for the Ministry for the Environment, Rotorua: Perrin Ag Consultants Ltd.

New Zealand Poplar & Willow Research Trust, 2023. NZFFA 'Poplar Action Group'. New Zealand Poplar & Willow Research Trust. https://www.poplarandwillow.org.nz/news/2023/nzffa-poplar-action-group [accessed 15 June 2023].

New Zealand Productivity Commission (NZPC), 2018. Low-emissions economy: Final report. Wellington: New Zealand Productivity Commission.

Northland Regional Council (NRC), 2017. Section 32 analysis report: Proposed Regional Plan for Northland. Whangārei: Northland Regional Council.

Northland Regional Council (NRC), 2019. River water quality and ecology in Northland. State and trends 2012–2016. Whangārei: Northland Regional Council.

Norton, D., 1998. Indigenous biodiversity conservation and plantation forestry: Options for the future. New Zealand Journal of Forestry, 43(2): 34–39.

Our Land and Water (OLW), 2023. Land use opportunities: Whitiwhiti ora. Our land and water. https://ourlandandwater.nz/project/land-use-opportunities/ [accessed 2 June 2023].

Parliamentary Commissioner for the Environment (PCE), 2018. Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways. Wellington: Parliamentary Commissioner for the Environment.

Parliamentary Commissioner for the Environment (PCE), 2019. Farms, forests and fossil fuels: The next great landscape transformation? Wellington: Parliamentary Commissioner for the Environment.

Pattle Delamore Partners (PDP), 2020. Review of consent application decision making for abstractions affecting Mataura River flows upstream of Gore. Report prepared for Environment Southland. Christchurch: Pattle Delamore Partners Ltd.

Pawson, S.M., Ecroyd, C.E., Seaton, R., Shaw, W.B. and Brockerhoff, E.G., 2010. New Zealand's exotic plantation forests as habitats for threatened indigenous species. New Zealand Journal of Ecology, 34(3): 342–355.

Pearce, P., Paul, V., Mullan, B., Zammit, C., Sood, A., Collins, D., Bell, R. and Law, C., 2016. Climate change projections and implications for Northland. Report prepared for Northland Regional Council. Auckland: National Institute of Water and Atmospheric Research Ltd.

PwC, 2020. Economic impact of forestry in New Zealand. Wellington: PricewaterhouseCoopers.

Rissmann, C., Boyce, A., Hunter, M., Kyte, R., Pearson, L. and Prebble, L., 2023. Understanding your landscape's resilience: Beyond regulation. Case study 1. Farm type: Dairy. Location: Brydone (Mid Mataura). Report prepared for the Agricultural and Marketing Research and Development Trust (AGMARDT). Invercargill: Thriving Southland and Land & Water Science.

Rissmann, C., Pearson, L., Robson, B. and Rahimi, S., 2022. Exploring a high-resolution landscape approach for managing water quality and soil greenhouse gases. Land and Water Science Report 2022/03. Invercargill: Land Water Science Ltd.

Rissmann, C., Pearson, L., and Snelder, T., 2024. Physiographic Environment Classification: a controlling factor classification of landscape susceptibility to waterborne contaminant loss. Environmental Management.

Ritchie, H., 2012. Diffuse sediment in Waikato waterways – sources, practices for reduction, and policy options. Waikato Regional Council Technical Report 2012/02. Hamilton: Waikato Regional Council.

Robertson, H.A., Ausseil, A.G., Rance, B., Betts, H. and Pomeroy, E., 2019. Loss of wetlands since 1990 in Southland, New Zealand. New Zealand Journal of Ecology, 43(1): 1–9.

Royal, C., 2021. Te Kawa Waiora Hui Wānanga Report: Whakapara Marae, Whakapara. Report prepared on behalf of Reconnecting Northland for Waimā, Waitai, Waiora. Whangārei: Reconnecting Northland.

Royal, C., 2022. Te Kawa Waiora Report 2020–2021: A tāngata whenua inspired research project concerning the health, wellbeing and mauri of the Wairoa River, its tributaries and environs. Whangārei: Reconnecting Northland.

Scion, 2023. Forest soils to the rescue. Scion Connections, 43: 37.

Seaton, R. and Hyde, N., 2013. New Zealand falcon | kārearea. In: C.M. Miskelly (ed). New Zealand Birds Online [updated 2022]. https://nzbirdsonline.org.nz/species/new-zealand-falcon [accessed 21 June 2023].

Sense Partners, 2023. Solid foundations: Dairy's economic contribution to New Zealand. Sense Partners.

Sinner, J., Robb, C., Kilvington, M., Tane, P., Tadaki, M. and Challies, E., 2023. Where next for catchment groups? Lifting ambition and gearing up for the long game. Prepared for Our Land and Water National Science Challenge. Nelson: Cawthron Institute.

Snelder, T., 2021. Assessment of nutrient load reductions to achieve freshwater objectives in the rivers, lakes and estuaries of Southland including uncertainties: To inform the Southland Regional Forum process. Lyttelton: Land Water People Ltd.

Southland Regional Forum, 2022. Achieving the community's aspirations for freshwater. Regional Forum recommendations report to Environment Southland and Te Ao Mārama Inc. Board. Invercargill: Environment Southland.

Sporle, W., 2016. Forestry management guidelines: North Island brown kiwi in exotic plantation forests. Kiwis for Kiwi.

Stats NZ, 2023. Regional gross domestic product: Year ended March 2022. Stats NZ. https://www.stats.govt.nz/information-releases/regional-gross-domestic-product-year-ended-march-2022/ [accessed 4 October 2023].

Swales, A., Gibbs, M., Ovenden, R., Costley, K., Hermanspahn, N., Budd, R., Rendle, D., Hart, C. and Wadhwa, S., 2011. Patterns and rates of recent sedimentation and intertidal vegetation changes in the Kaipara Harbour. Prepared for Auckland Council and Northland Regional Council. Hamilton: National Institute of Water and Atmospheric Research.

Tanner, C.C., Depree, C.V., Sukias, J.P.S., Wright-Stow, A. E., Burger, D.F., Goeller, B.C., 2022. Constructed Wetland Practitioners Guide: Design and Performance Estimates. Hamilton: DairyNZ/NIWA.

Te Puni Kōkiri, 2017. Marae of Aotearoa. Te Puni Kōkiri. https://hub.arcgis.com/maps/TPK::map-marae/about [accessed 6 October 2023].

Te Uru Rākau – New Zealand Forest Service, 2023. Maximising Forest Carbon Programme: Recognising space plantings and exotic hardwoods in the New Zealand Emissions Trading Scheme. Wellington: Te Uru Rākau – New Zealand Forest Service.

Thriving Southland, 2021. Southland's environmental cultural history. Invercargill: Thriving Southland.

Thriving Southland, 2022. Annual report 2021–22. Invercargill: Thriving Southland.

Thriving Southland, 2023a. Southland's catchment groups 2023. Invercargill: Thriving Southland.

Thriving Southland, 2023b. Thriving Southland launches exciting new project to boost food and fibre sector in the region. Press release, June 2023. https://thrivingsouthland.rocketspark.co.nz/site_files/24893/upload_files/blog/Mediarelease-SF+Flaunches-26June2023.pdf [accessed 3 November 2023].

Thriving Southland, 2023c. Southland catchment groups. Thriving Southland. https://www.thrivingsouthland.co.nz/catchment-groups/ [accessed 30 October 2023].

Thriving Southland, Ministry of Business, Innovation and Employment (MBIE), Agri Intel and Te Tapu o Tāne, 2023. Rural landowners guide: Capturing the value of carbon sequestration for tōtara forests 2023. Thriving Southland, Ministry of Business, Innovation and Employment, Agri Intel and Te Tapu o Tāne.

Vaughan, A., Brent, A., Fitzgerald, M. and Kueppers, J., 2023. Agrivoltaics: Integrating solar energy generation with livestock farming in Canterbury. Our Land and Water National Science Challenge.

Whangarei District Council (WDC), 2012a. Hikurangi swamp scheme fishery management plan. Whangārei: Whangarei District Council.

Whangarei District Council (WDC), 2012b. Hikurangi swamp scheme management plan. Whangārei: Whangarei District Council.

Whangarei District Council (WDC), 2021. Long term plan 2021–2031: Volume one. Whangārei: Whangarei District Council.

Whangarei District Council (WDC), 2022. Storm readiness – Procedures pre- and post a storm event. Whangārei: Whangarei District Council.

Wildland Consultants, 2008. Review of biodiversity policy in the Southland regional policy statement. Report prepared for Environment Southland (report number 2072). Dunedin: Wildland Consultants.

WSP, 2023a. Land use modelling report: Mataura catchment in Southland/Murihiku. Report prepared for the Parliamentary Commissioner for the Environment. Hamilton: WSP.

WSP, 2023b. Land use modelling report: Wairoa catchment in Northland/Te Tai Tokerau. Report prepared for the Parliamentary Commissioner for the Environment. Hamilton: WSP.

Zammit, C., Pearce, P., Mullan, B., Sood, A., Collins, D., Stephens, S., Woolley, J.M., Bell, R. and Wadhwa, S., 2018. Southland climate change impact assessment. Prepared for Environment Southland, Invercargill City Council, Southland District Council and Gore District Council. Christchurch: National Institute of Water and Atmospheric Research (NIWA).

This report has been produced pursuant to subsections 16(1)(a) to (c) of the Environment Act 1986. The Parliamentary Commissioner for the Environment is an independent Officer of Parliament, with functions and powers set out in the Environment Act 1986. His role allows an opportunity to provide Members of Parliament with independent advice in their consideration of matters that may have impacts on the environment.

This report and other publications by the Parliamentary Commissioner for the Environment are available at pce.parliament.nz.

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata
PO Box 10 241
Wellington 6140
Aotearoa New Zealand

Phone +64 4 495 8350
Email pce@pce.parliament.nz
Web pce.parliament.nz

May 2024

ISBN
978-0-947517-42-7 (print)
978-0-947517-43-4 (electronic)

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata