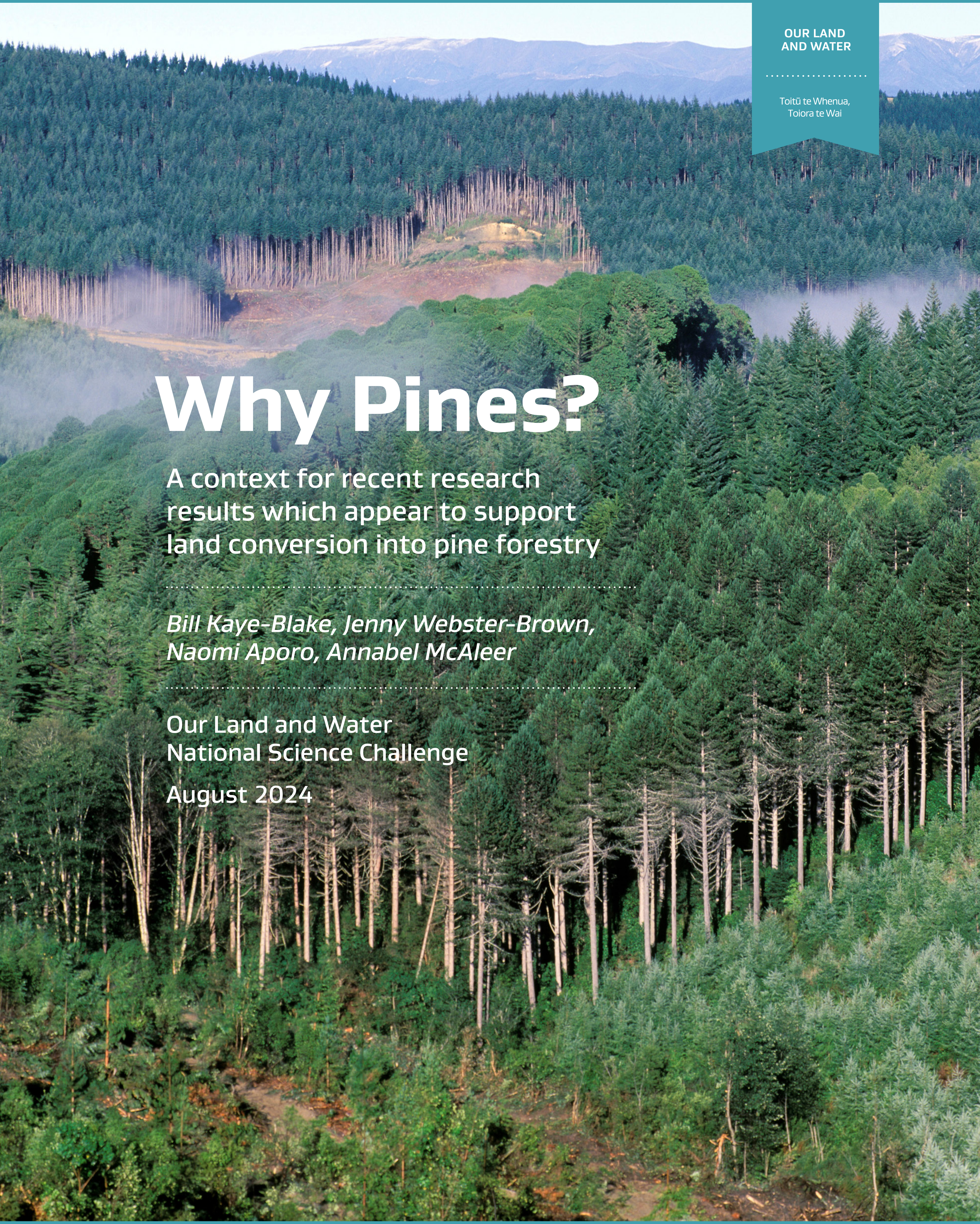
National SCIENCE Challenges

OUR LAND AND WATER

Toitū te Whenua, Toiora te Wai



Why Pines?

A context for recent research results which appear to support land conversion into pine forestry

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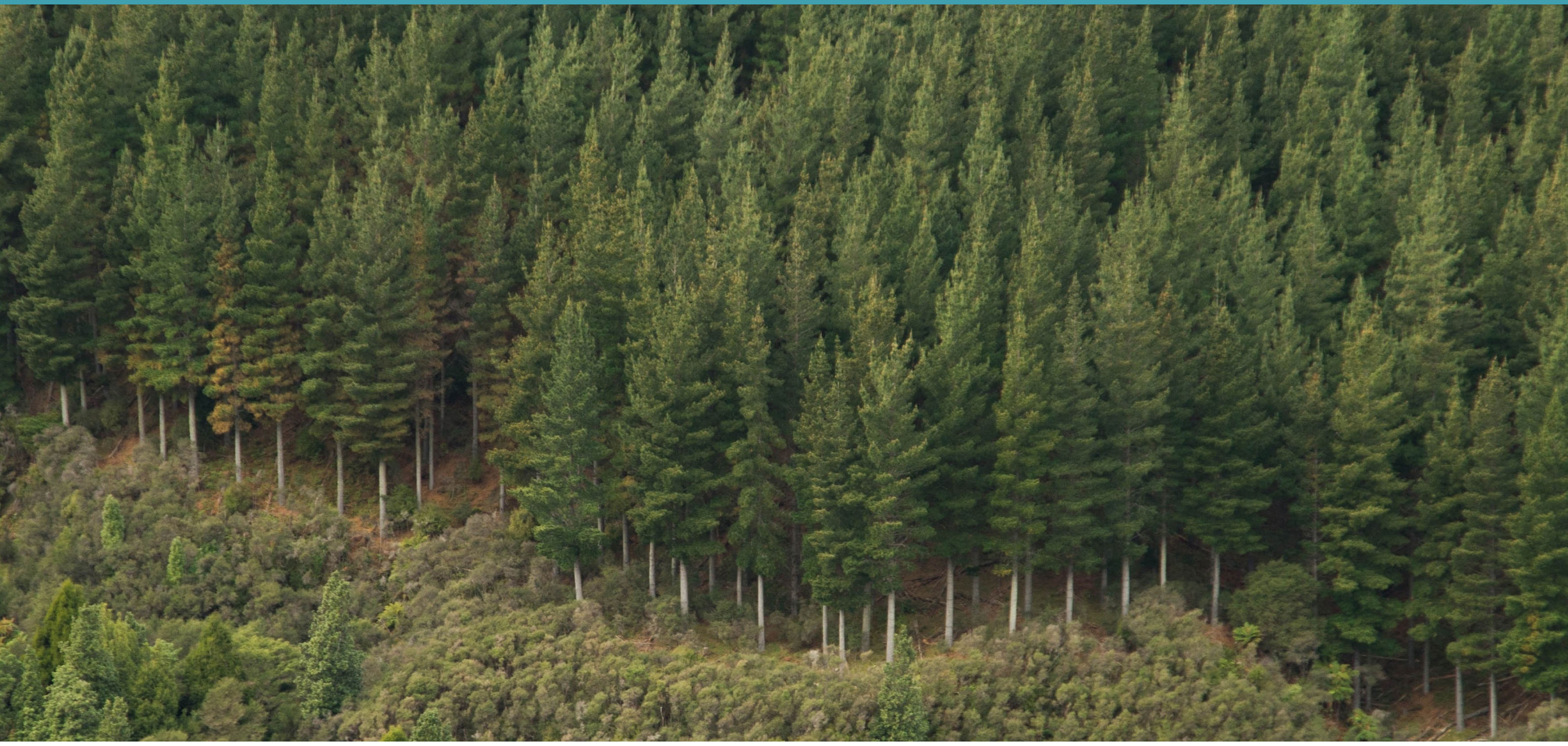

Summary

Four research programmes funded by the Our Land and Water (Toitū te Whenua, Toiora te Wai) National Science Challenge (OLW) and completed in autumn 2024 each considered how land uses might change in the future to meet environmental goals, assuming current policies and economic incentives remain unchanged. Despite using different techniques and perspectives, all suggest a likely increase in pine plantations in Aotearoa New Zealand, on land currently used for sheep and beef farming. A recent report from the Parliamentary Commissioner for the Environment (2024), '<u>Going with the grain: Changing land uses to fit a changing landscape</u>', yielded similar results.

Because the results of these research programmes reinforce each other, OLW has written this short article to provide a wider context for the results, highlight the limitations and constraints of this modelling, and recommend possible next steps.

These research results certainly raise concerns. Rural and Māori communities have expressed concern about intergenerational equity with the conversion of productive sheep and beef land to pine forestry. They foresee that it will remove families and jobs from communities, leading to future depopulation and the loss of rural schools and community organisations. Other concerns include the lower biodiversity value of pine forest compared to native vegetation, and the potential impacts of forestry waste on freshwater systems, estuaries and infrastructure.

However, these results can also act as a catalyst for a much-needed conversation about what communities want for their lifestyles, land and landscapes in this country, and whether our current economic, agricultural and environmental policies can deliver this. The research also highlights a need for more quantitative information on more land uses than those currently dominant (dairy, sheep and beef, and exotic forestry). We need to be able to model the economic and non-economic value, and scalable potential, of arable and horticulture land uses, and other less common and potential alternative land uses.

These results are not a prediction of an unavoidable future. They are, instead, an indication of what could happen if current policies and economic signals do not change to accommodate different ways of thinking about our land use.

There are three factors influencing the research findings: real and true physical and economic reasons; constraints and choices related to modelling the future; and the current policy settings and incentives that are included in the modelling.

These results are not a prediction of an unavoidable future. They are, instead, an indication of what could happen if current policies and economic signals do not change to accommodate different ways of thinking about our land use.

OLW believes the results point to the need for more of the type of grounded, collaborative information generation and decision-making the National Science Challenges have championed. The issue of agricultural land conversion has many dimensions and is influenced by factors other than economic returns. It involves value judgments as well as different cultural perspectives and perceptions of wellbeing, so it calls for inclusive participation and representation.

Introduction

The Our Land and Water (Toitū te Whenua, Toiora te Wai) National Science Challenge (OLW) operated as a mission-led research funding entity from 2016 to 2024. It supported research to assess the impacts of agricultural land use on water quality, as well as approaches to improve water quality while maintaining the economic viability of farming and forestry.

Towards the end of OLW, several pieces of research were commissioned to synthesise previous research to answer a major question: Can we achieve national bottom lines for water quality attributes through land-use change, and what does that land use look like?

Four research programmes addressed different aspects of this question through land-use modelling. In each of these programmes, the modelling indicated that increasing areas of exotic pine forestry and decreasing areas of sheep and beef farming would be the most viable way to improve environmental performance, while ensuring an acceptable economic return from use of the land. These results were produced by different teams working with different models, so we can trust that it is a genuine outcome rather than an artefact arising from a specific modelling technique.

These unanticipated outcomes raise several concerns about our future landscapes and rural community wellbeing and prosperity. This article seeks to provide some context for these results, looking at the factors which have influenced the researchers and the modelling. The aim is to understand the implications of the findings and what might be required to achieve more socially and economically resilient outcomes.

Summary of the research results

Healthy Estuaries

Healthy Estuaries research modelled the water contaminants entering estuaries from different land uses. Existing information on farmland and farming practices was used to create a data set of how land is used around most of the country's estuaries. This was used to estimate the degree of water contamination arising from current land use, and how much this could be reduced by choosing the best land-use options to improve water quality outcomes.

Modelling indicated that for most estuaries it is only possible to meet National Policy Statement for Freshwater Management (NPS-FM) (2020) "bottom line" water quality targets for nitrogen concentrations with some land-use changes as well as widespread adoption of mitigation strategies on farms. In the three estuary catchments modelled in more detail, meeting those targets required a combination of mitigation practices and land-use change from arable and many sheep and beef farms into exotic forestry and natural vegetation (retirement of farmland).

Read more about these results at:
ourlandandwater.nz/estuariessummary

Stronger Signals

The Stronger Signals research modelled the impact of policy tools on farmer choices and farming practices, and the consequences for water quality and greenhouse gases. An agent-based microsimulation model was developed to investigate how different interventions, such as policies or prices, affected farmer behaviour and farming decisions. These decisions were then linked to production, profitability, and environmental outcomes assessed against both the NPS-FM (2020) and the Climate Change Response Act targets. A dataset of 72,000 virtual farms was used to simulate the actual farm population of Aotearoa New Zealand, including spatial data about production and profit, rules to govern specific behaviours, and learning processes so virtual farmers could improve.

Modelling indicated that, within the current economic and policy framework, a large amount of land would be converted to exotic carbon forestry within 30 years, to meet greenhouse gas emission targets. An improvement in freshwater quality would result, but additional pollutant pricing mechanisms would be needed before NPS-FM water quality targets could be met. Even if the carbon price dropped to zero, about one-fifth of sheep and beef land was still predicted to be converted to other uses, including a majority to forestry. Current economic conditions therefore favour converting sheep and beef farms into forestry, even without the extra revenue from carbon credits.

Read more about these results at:
ourlandandwater.nz/strongersignals

Synthesis Scenarios for Future Land Use

The Synthesis Scenarios for Future Land Use research modelled three catchments with poor water quality, to see if mitigation and land-use change could achieve water quality targets, while not comprising profitability. A model of land uses and their environmental impacts was developed, based on land-use data for Aotearoa New Zealand, to indicate the types of farming and management practices that would be needed. A prioritised list of the mitigation practices that farmers preferred was used to model their impacts on profitability and water contamination.

The catchments were the Tukituki catchment in Hawkes Bay, the Waihao catchment in South Canterbury and Te Hoiere (the Rai Valley) in the Marlborough region. In each catchment, mitigation practices reduced profitability but did not meet water quality targets, especially for nitrogen. However, if modelling focused on land-use change this was up to 98 percent effective in reaching nitrogen targets and could increase profitability up to 20 percent. Notably this result could only be achieved by converting existing farmland to exotic forestry. In the case of the Tukituki catchment, most of the existing sheep and beef farmland (about 75% of the catchment) would need to be replaced by pine forest.

Read more about these results at:
ourlandandwater.nz/synthesisscenarios

Mosaics vs Monocultures

To test the overall premise that mosaics of diverse land-use would provide better environmental outcomes, a fourth research programme, Mosaics vs Monocultures, integrated two existing models: one containing water quality and quantity information for catchments (NWEM), which can be used to assess the effects of NPS-FM (2020) implementation, and the other (LUMASS) containing spatial data on farmland and farm types, which can be used to optimise land-use decisions.

This modelling indicated that while mosaics of land uses (smaller blocks of different land uses distributed over a landscape) produced minor economic and environmental benefits, those benefits could be outweighed by the kind of improvements land managers could make when operating at larger scale and with more specialisation. Similar land uses tend to cluster together, driven by characteristics of land and climate and access to specialised support services and infrastructure.

Read more about these results at:
ourlandandwater.nz/mosaics

Implications of these results

These findings, together with national-level modelling of the primary sector which indicates around half of sheep and beef farm area will be replaced by forestry by 2050, raise significant concerns.

The models are forecasting a very different sort of rural landscape for Aotearoa New Zealand, if we seek to achieve good freshwater quality as well as greenhouse gas emissions targets and ongoing agricultural profitability. The modelling has not included a public and conscious assessment of the impacts.

Rural communities have already raised the alarm about potential impacts on wellbeing. They are seeing individual landowners carefully and rationally weighing the options, and determining that converting to forestry, or selling to someone who will, is best for them and their families. Some sheep and beef farmers feel a threat to their identity and their intergenerational connection to their land due to a lack of financially feasible options, with serious consequences for their mental health. The potential flow-on impacts for rural communities include decreasing employment, population, support industries, schools, clubs and infrastructure. They foresee a "hollowing out" of smaller rural communities and consequent reduction in the health and wellbeing of those left behind.

There are also implications for food security and food access. After the experience of Covid-19 and worldwide supply disruptions, people are more aware of the importance of having and maintaining secure access to locally grown food. Incentives or subsidies may be needed to promote locally grown food and maintain some level of production capabilities, particularly for those commodities that are not economically profitable at farm scale. Given that this country's agricultural production tends to be export-focused, with the overwhelming percentage of milk and meat being sent offshore, ensuring sufficient local food production would require a deliberate strategy by industry and government.

Another concern is the environmental effects of pine forests, and the possibility that we may be swapping one environmental problem for another. While standing pine forests are acknowledged to generate generally better water quality than pasture over their lifecycle, during harvesting and early regrowth the impacts of sediment and debris on waterways can be catastrophic. Pine forests pose wildfire risk and can impact terrestrial water flow.

Much of the indigenous vegetation that still exists at lower elevations in Aotearoa New Zealand is in small pockets on sheep and beef farms, providing an important biodiversity refuge.These could be degraded if pine plantations replaced farms that maintain these pockets of native forest. However, pine forests provide better habitat for native birds than pasture and potentially can support native understory if managed to do so. On the other hand, pine trees can invade many native landscapes across farm boundaries. The net effects of pine forests on biodiversity are complex and require careful consideration.

Photo: Kieren Scott

What is influencing these results?

OLW discussed the convergence of these modelling results with the researchers, who have a nuanced understanding of the constraints on their modelling processes. Taking this into account, as well as considering other research within and external to OLW (e.g., PCE 2024), it is clear that while the results are correct in terms of a modelled outcome, they are also the product of assumptions, processes and datasets used by the models.

The results are projections rather than predictions: they show what-could-happen-if, rather than what-will-happen-regardless.

We see three groups of factors influencing the outcomes:

- 'Real' reasons: Physical and economic aspects of the situation that are true for farming and forestry, independent of opinion or research methods used.
- Modelling reasons: Choices about modelling techniques as well as simplification methods and data type and quality.
- Policy reasons: The models include the incentives provided by current policy, which represent choices made through policy and political processes.

‘Real’ reasons

Sheep and beef farming, particularly on poorer land, has generated moderately low profit for some time, relative to other land uses. Income from strong wool is only break-even at best and red meat is currently generating low returns. As a result, farmers do not have money to invest in improving farming practices, mitigation or land-use change. Also, sheep and cattle do create environmental impacts, including greenhouse gas emissions, *E. coli* and, depending on farming practices and location, nitrogen, phosphorus and sediment in runoff. Therefore, some sheep and beef farming continues to cause environmental damage for relatively low economic gains. To improve this situation, more effective, low-cost mitigation measures and an increase in the economic return on wool and red meat is needed.

By contrast, **pine forestry** in Aotearoa New Zealand can be more profitable with lower environmental impact. Radiata pine grows well and quickly across the country and there is strong international demand for this timber. Forestry companies can efficiently harvest trees, load logs on trucks and trains, and export those logs to international markets. Trees and logs can also be stored in a way that milk and meat cannot, allowing foresters to manage price fluctuations and market risks to some extent.

Also, under the New Zealand Emissions Trading Scheme (NZ ETS), foresters can sell carbon credits to get revenue for plantation forests that are harvested. The first rotation captures carbon and subsequent rotations maintain it (if not harvested, they eventually reach a steady state in which carbon captured equals carbon released). Rules about selling and accounting for carbon credits are set by the Ministry for Primary Industries, and prices for carbon credits are set in carbon markets (although they are also influenced by government policy).

Pine forestry has a range of social and environmental impacts. Standing forests produce less nitrogen, phosphorus, and *E. coli* contamination of waterways than pastoral farming. However, harvested areas can produce a large amount of sediment contamination and woody debris. In heavy rain, woody debris can damage the waterways and infrastructure.

Carbon forestry using permanent pine forests avoids some of the problems of harvested forests. With no harvest, they do not have the same problems with sediment and woody debris. They produce more carbon credits and can be a better option financially. However, they also support less ongoing employment, which is one of the concerns of rural communities.

Another option for landowners and managers would be to establish **native or indigenous forests**. They produce less sediment loss than exotic forests because they are harvested less frequently or not at all, support native species of flora and fauna, and have additional environmental, recreational, social, and cultural benefits, particularly for Māori. However, indigenous forestry cannot currently compete commercially with exotic pine forestry. It is more expensive to establish, although the cost-saving Tīmata Method, tested by OLW research, is now available. Native trees are slower growing than exotics and so carbon credits are produced more slowly generating a lower revenue per hectare. Other options for monetising indigenous vegetation, such as through mānuka honey or tourism, require diversifying a farm business and may involve uncertain costs and revenues.

OLW research to explore

- OLW science has evidenced effective low-cost mitigation measures, such as slow-release fertiliser targeted to critical source areas (McDowell et al 2020).
- The Value Project (thevalueproject.nz) collates a selection of OLW research findings and case studies to demonstrate how Aotearoa New Zealand food companies can generate greater returns from sustainable production.
- Novel land uses such as agrivoltaics (on-farm solar energy production) have been shown by OLW research to offer potential to increase net profit on sheep and beef farms (Vaughan et al 2019).
- OLW research developed a ‘Value Chain Compass’ that offers a guide for enterprises wanting to create a new value chain or transform an existing supply chain into a value chain (McIntyre et al 2022).
- Additional OLW research outputs related to increasing value can be explored via ourlandandwater.nz/topic/increasing-value.
- The Tīmata Method initiates natural processes known to restore ngahere, reducing the cost of establishing native trees by over two-thirds or around $20,000 per hectare (Dewes 2023).
- Native silvopastoral systems plant native trees at wide spacings within fields on sheep and beef farms, with livestock grazing beneath, reducing soil erosion, adding resilience to the impacts of climate change, and improving biodiversity outcomes (Mackay-Smith 2024).
- Native forest can be established using pine trees as a nurse crop and ETS payments to help pay for initial costs, showed an OLW-funded pilot study (AgFirst 2023).

Modelling reasons

Modelling simplifies reality by focusing on the role of a few key factors in defining an outcome. By their very nature, models are prone to error if those factors are not the only ones influencing an outcome, or the process by which the factors operate is poorly understood. Consequently, they are sometimes dismissed as too simple and dependent on the quality of their inputs (data) and assumptions made. However, they remain a useful tool for understanding possible futures, and there are few alternative methods for making such projections.

Data quality is key to ensuring a realistic modelling result. In Aotearoa New Zealand, there are only a few sources of robust data on the economic and environmental performance of farming and forestry. The same datasets therefore tend to support many different models, which may reduce any differences in modelling outcomes. The data is incomplete for many land uses, particularly for newer, alternative land uses that we might seek to include in a land use change scenario, such as native silvopastoral systems. Even for sheep and beef and forestry, there are social and environmental impacts that are not considered, and neither are different farming practices and mitigations. The modelling results are therefore based on a limited picture of the future.

Modelling processes are complex for land and water modelling, and building and maintaining a reliable model takes time. As a result, there are only a few land-use models in use in Aotearoa New Zealand at any one time. With limited funding, there is always a trade-off between focusing resources on a few models, to allow them to be developed further, or maintaining several models with different approaches, which enables differences to be explored. At least three of the programmes considered here (*Mosaics vs Monocultures*, *Synthesis Scenarios for Future Land Use*, and *Healthy Estuaries*) used the same model (LUMASS – Land Use Management Support System), which means that the outcomes are not independent.

One **assumption** made in all modelling was the future price of carbon paid to support pine forests, which is one factor driving a modelled shift from sheep and beef to forestry. The market price has fluctuated considerably over recent years, and there are many estimates of its future price. Modelling results depend in part on the modeller's choice of the future carbon price.

Another assumption involves the funding of sheep and beef conversion to forestry. There are (at least) two ways to consider the cost of conversion: on a cashflow basis or by using annual averages. For cashflow (e.g., in a business case) the conversion is funded as an upfront cost, other costs are incurred for managing the forest, then cash comes in later years from the sale of carbon and, eventually, timber. For modelling purposes, however, using annual averages for the costs is simpler: the ability to borrow and finance is assumed, and costs and revenue are smoothed out. Sheep and beef farmers would not typically have the capital to convert to forestry, so their decisions are based on cashflow, not annual averages. They are long-term investment decisions.

Simplification of the decision-making process is necessary in modelling but is not always a good reflection of a more complex reality.

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For example, converting sheep and beef land to forestry may require selling the land or getting outside investors, possibly from overseas. Complexities include who is doing and funding the conversions, and who maintains control of the property. Also, farmers, landowners and land managers vary in the priority they place on financial outcomes, with research showing profit is usually one of several considerations. They will also consider other factors, such as their wellbeing or intergenerational equity in the land. Models, on the other hand, are usually seeking to optimise an option, by weighing alternatives according to some (often economic) criteria.

The *Stronger Signals* research used an agent-based optimisation model that incorporated environmental concern and tolerance for risk. Synthesis Scenarios for Future Land Use also considered farmer preferences when developing the mitigation cost curves used in its modelling. However, these models are still limited by information available about farmer behaviours as observed in the past (or assumed for the future), simplifying the actual judgments made by people.

Another important **simplification** is considering only individual decision-making by farmers, applied at farm-scale and choosing from the most common current land-use options. Community-, catchment- and industry-level preferences or decisions are poorly represented (if at all) in all except the Mosaics vs Monocultures modelling, which tested decision-making at different geographic scales. The importance of supply chains and value chains in creating opportunities for new products and rewarding farmers is not considered, and nor is the infrastructure required to reach scale for new primary commodities. In reality, land-use-change decision-making involves systems as well as individuals, including community and commercial interests, and ideally extends beyond BAU land-use options.

OLW research to explore

- The Land Use Opportunities: Whitiwhiti Ora project brought farmers and researchers together to co-design a process to assess land-use opportunities within the Waimakariri catchment in Canterbury (Roberts 2024).
- The Pohewa Pae Tawhiti (Visualising Horizons) research programme developed a decision-support framework for Māori landowners where decisions are made by a board or committee, to develop scenarios with different options that are consistent with their vision and priorities (whakaarotau) for their land and water resources (Kingi et al 2023).
- The Next Generation Systems project held workshops where they aimed to develop future-ready farm systems. Understanding consumer demand for products was an important feature of these workshops (Leftfield Innovation Limited 2022).
- None of the models used in the four research programmes used a Māori framework. Kaitiaki Intelligence Platforms research has designed an environmental sensor network that uses advanced technology and local indigenous knowledge to provide environmental intelligence, framed from Māori worldview (Reid et al, 2024). Data from such a network could inform and improve land-use decisions in Aotearoa New Zealand.

Policy reasons

All the models used were driven by the same set of policy targets, or lack thereof, which has likely contributed to the convergence in modelling outcomes. The implications of the choices made in setting policy therefore need to be examined.

The **ETS** provides support for forestry, increasing the revenue to forestry beyond the income from timber alone and making it a more attractive land-use compared to sheep and beef farming. However, this is something of an artefact with at least three choices embedded in this policy that are subject to change. The first is creating carbon credits from forests and rules for accounting for them. The second is not accounting for carbon sequestration on sheep and beef farms by failing to recognise soil carbon, shelterbelts and other stores of carbon. The third is the focus on net emissions rather than decarbonising the economy, which would reduce the value of carbon credits. Therefore, attaching carbon credits to forestry is a choice, which raises questions about whether this is a choice the country wants to make.

Similar choices underpin our other **environmental policies**. Policy that prioritises the heath of freshwater and meeting GHG targets, while good for the long-term welfare of the country, do have consequences for community and culture. There has been not yet been a thorough national-scale assessment of the value to communities of meeting these environmental targets. While the NPS-FM (2020) water quality national bottom lines do provide modellers with clear, measurable targets to be achieved, these targets are based on water quality monitoring data and cannot take account of socioeconomic costs and consequences of meeting them.

The development of **biodiversity** incentives and markets is lagging well behind that of carbon credits and the ETS. Credits for actions to support improved biodiversity on farms might provide sheep and beef farmers with a way to earn extra income for the pockets of biodiversity on their properties. Markets for biodiversity, especially biodiversity funds, could provide capital for investing in mitigation actions to reduce water quality impacts. Biodiversity incentives could also support planting indigenous forests rather than pine forests.

OLW research to explore

- OLW research provided the first national-scale assessment of the current state compared to 'bottom lines' for all four contaminants across the whole country and found substantial reductions of at least one contaminant are required in almost all regions (Snelder 2023).
- A market for biodiversity credits is one financing option that could help New Zealand farmers fund land-use change to meet environmental targets, found an OLW study (Muller et al, 2023).

Conclusion and where to from here?

In conclusion, OLW's multiple attempts to synthesise research results to address whether it is possible to achieve national bottom lines for water quality attributes through land-use change and if so, what would the resulting land use look like, have yielded surprisingly consistent results. Different land-use modelling exercises indicated that current policy and economic drivers generate an outcome of significantly less sheep and beef farming and more exotic forestry.

This projected outcome is unlikely to be acceptable to many New Zealanders.

This prediction is largely driven by ongoing economic weaknesses in the sheep and beef industry, the policy-driven economic strengths of forestry, and the relative environmental footprints of both land uses. It is constrained by limitations in the input land-use data and modelling processes, as well as by policy decisions embedded in the models.

By understanding the factors that have influenced this outcome, we can now explore the next steps that can be taken to support land-use change decisions that do reflect the collective aspirations of our farmers, their communities and the agri-food and -fibre sector in Aotearoa New Zealand. These next steps could include:

1. **Wool and red meat exporters can continue to improve the economic performance of their value chains**, building on the efforts of the sector, sharing added value with producers to invest in mitigation activities. OLW research shows how the industry can become more profitable by developing relationship-based value chains that connect producers with consumers willing to pay a premium for this country's products and approaches to farming. OLW research also provides evidence that overseas consumers are willing to pay more for these products and why. This information can be used to support profitable commercial actions, with continued investment in agricultural research and development, more consumer and market research, and better industry collaboration to invest in the right systems.
2. **Collaborative research between scientists and producers can develop lower cost, more effective mitigation options** for sheep and beef farms, improving on-farm mitigation of contaminant leaching and runoff. There is a need for continued investment in innovative methods for reducing contaminant loss.
3. **Policymakers, producers, financial institutions and researchers could recognise other benefits associated with non-forestry land uses.** For example, in places where the land is suitable, a small amount of horticulture could replace some of the jobs lost from sheep and beef farms. Developing these options would be part of an integrated strategy that looks more holistically at land use and its impacts.
4. **Policymakers could take into account the wider benefits of sheep and beef farming.** There are social, cultural, and wider environmental issues to consider beyond addressing poor water quality. Sheep and beef farming also has cultural value in Aotearoa New Zealand, for rural communities, for the wider population, and particularly for Māori. Farm-level decisions have ramifications for rural communities, especially for employment and community resources such as schools and clubs. Sheep and beef farms also contribute environmental services, such as their low elevation native vegetation supporting and restoring biodiversity.
5. **Researchers and policymakers can quantify the risks and benefits of pine forestry** that have not been included in the modelling so far. These include the risk of fire affecting both community safety and forest value, of forestry debris and sediment erosion impacting on waterways, infrastructure, land and communities, of forest species invading native landscapes, and of reduced water availability following large-scale afforestation. The potential benefits of pine forestry for supporting native bird species and native understory should also be considered. There are also risks inherent in how the carbon price is set and how future carbon markets are managed. This would provide a more informed perspective on pine forestry.

OLW research to explore

- Nine key elements of successful relationship-based agri-food value chains have been identified and organised into the Value Chain Compass, providing a guide for enterprises wanting to create a premium value chain (McIntyre et al 2023).
- Consumer 'willingness-to-pay' research provides evidence that overseas food customers will pay a price premium for many product attributes already produced widely in New Zealand, such as meeting high standards for animal welfare and food safety, hormone/antibiotic-free, grass-based, and simply 'made in New Zealand' (Yang and Renwick 2019).
- Adoption of new on-farm mitigation innovations can be improved by employing a co-innovation approach, including stakeholders in their design and development. Empirical data from OLW indicates that this approach increased the adoption of innovations from 20% to 53%, on average, and reduced the complexity for farmers in evaluating agri-environmental benefits, leading to significant improvements in both environmental and economic outcomes (McDowell et al, 2024).

6. **Policymakers can recognise the benefits of native forestry.** Converting highly erodible pasture to native forests should be prioritised to reduce erosion across Aotearoa New Zealand. Permanent native forests sequester carbon indefinitely, support diversity of life including taonga species, provide significant cultural benefits to tangata whenua, and provide many other environmental and social benefits. Native forests could become profitable long-term enterprises if recognised with 'premium credits' on carbon markets, or through production of high-value timber and other natural products, creating jobs in nurseries, planting, pest control, eco-tourism, selective timber harvesting, bioactive extracts and other industries. Most people in Aotearoa support the idea of more native forestry, and farmers are interested in the potential of native forest cover on their land.
7. **Policymakers can re-assess the influence of climate change policy** on land-use change and its impacts on communities and the sheep and beef sector. The relative economic strength of exotic forestry in this modelling is in a large part due to the ETS and its use of carbon credits. By not decarbonising other parts of the economy and by making the planting of indigenous forests less economically viable, Aotearoa New Zealand is encouraging the growth of pine forestry. In the ETS a higher price for carbon sequestration could be applied to incentivise the planting of native forest on erosion-prone land. MPI look-up tables could be updated to better represent carbon sequestration in pines and native trees. Further, by developing a carbon credit system but not a biodiversity incentive system, there is a mechanism to support one land use over another. Decisions need to be made with a more balanced understanding of the environmental consequences.
8. **All New Zealanders have an interest in the wider implications and consequences** of land use change to achieve healthy waterways. The modelling results are strongly driven by the need to achieve NPS-FM (2020) national bottom lines for water quality attributes. The NPS-FM is the best instrument we currently have to ensure the health of our freshwater ecosystems, but that doesn't mean the concerns raised by farming groups about the wellbeing of rural people and communities should be dismissed. We now have more evidence about the size of the gap between the current state of freshwater and the NPS-FM national bottom lines, and better understanding of the societal impacts and costs of achieving these bottom lines. The next update to the NPS-FM could consider this new evidence, and include provisions for more flexibility in their application in catchments where land-use change to forestry appears to be the only viable option. This would require robust discussions with affected community groups and mana whenua, informed by both socioeconomic and freshwater research, to establish a more acceptable, viable land-use change scenario.

All modelling is a simplification of reality. In the land-use modelling discussed in this article, economic considerations have been prioritised over other aspects of land-use change decisions, and alternative land-use scenarios were limited by the lack of data. As a consequence, we urge readers to consider the conversion to exotic forestry projected by these research programmes in this wider context.

OLW research to explore

- The required labour needs for different land uses, including different crops at varying stages of development, can be assessed with an OLW-funded digital tool, which also provides complementary land-use diversification options that can smooth workforce requirements over a year (Barker & Bell, 2023; Bell et al, 2024)
- Research from OLW and the Healthier Lives National Science Challenges found it is theoretically possible to design a 'win-win-win' plan for future food production – one that feeds all New Zealanders a healthy diet, while reducing greenhouse gas emissions or freshwater contamination, and minimising the financial impact on families and farmers (McDowell, et al., 2022).
- While the economics of actions to improve water quality are an important part of farmer preferences and decision-making, environmental benefit and personal preference are also primary motivations for farmers. OLW research combined existing land-use models with farmer surveys and catchment mitigation cost curves to develop a unique catchment-level model (Stone et al, 2024).
- Sheep and beef farmers in the Tukituki catchment scored indigenous forest their highest preference from a range of land uses when asked to indicate their willingness to undertake some form of land use change (Stone et al, 2024).
- Converting pasture on highly erodible land to native forest would decrease average annual sediment loads delivered to the stream network by 50 Mt/yr at the national scale (Lambie et al, 2023).
- MPI look-up tables currently overestimate pine carbon sequestration and underestimate native carbon sequestration when trees are 30 years old (Lambie et al, 2023).

OLW research to explore

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