Situational analysis of New Zealand's bioeconomy

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Research to improve decisions and outcomes in business, resource and environmental issues.

The Agribusiness and Economics Research Unit (AERU) operates at Lincoln University, providing research expertise for a wide range of international, national and local organisations. AERU research focuses on business, resource and environmental issues.

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Disclaimer

The Ministry of Business, Innovation & Employment (MBIE) has commissioned a series of research papers looking at how Aotearoa New Zealand can increase the value generated from our biological resources and how these resources can be used more efficiently to reduce emissions. These papers have supported work under the First Emissions Reduction Plan to assess how Aotearoa New Zealand could transition to a sustainable and high value bioeconomy. The papers explore potential pathways and opportunities available to New Zealand, but they do not represent policy advice; and the views, opinions, and conclusions expressed in these papers are strictly those of the author(s).

Limitations of Scenario Modelling

The Agribusiness and Economics Research Unit (AERU) at Lincoln University was commissioned to prepare a situational analysis of New Zealand's bioeconomy, which looked at the current uses of New Zealand's biological resources and examined six land use change and export premium scenarios. The scenarios were developed to examine the land use, community, and environmental impacts of following specific pathways to meet bioeconomy and economic targets. For a number of these scenarios, the level of land use change (and associated community and environmental impacts) would rule them out as feasible pathways to support New Zealand's transition to a bioeconomy.

The modelling frame employed by the AERU measures the economic, social, and environmental consequences of land use change but should be seen primarily as a high-level assessment tool. More granular tools would be required to fully assess the implications associated with each of the scenarios, from the capital investment required to grow dairy production, through to the research and marketing development required to build export premiums and the detailed energy analysis needed to assess the biomass requirements to meet the expected primary and final energy supply requirements.

The AERU modelling had limited ability to incorporate off-setting actions (such as integrating forestry more fully into farming operations), or how improvements in livestock and land use productivity would affect the scenario outcomes. With high-level modelling of this nature the results are assessed against the status quo, rather than against a range of feasible land use and production alternatives. This limits the opportunity to assess alternative pathways, which may have lower environmental costs or offer higher economic returns (such as the utilisation of new forest production for engineered timber in construction rather than biomass for energy.

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Executive Summary

New Zealand is highly dependent on its biological resources to thrive

New Zealand's biological resources contribute to around three quarters of our exports. More broadly, biological resources and the ecosystems that underpin them are fundamental for New Zealand's wellbeing, providing carbon sequestration, water, food and material along with other ecosystem services.

Decarbonising the economy will put greater demand on New Zealand's productive land use and biological resources

New Zealand will need significantly more biomass for bioenergy production while biological resources will play a critical role in increasing the value of our exports to support the Government's goal of doubling exports. We are not currently self-sufficient in biomass, with New Zealand importing significant quantities of biomass to support the economy, the majority of which is used for animal feed[1]. At the same time New Zealand's use of biological resources has exceeded environmental limits on several measures, of which greenhouse gases (GHG) emissions is one.

New Zealand has strategic choices on what our biological resources are used for in the future

It is important therefore that New Zealand leverages the greatest value from our limited bioresources while reducing emissions and while ensuring the sustainable use of those resources and the ecosystems that underpin them. This report provides an evidence base to support decision-making on New Zealand's future bioeconomy. It was undertaken by the Agribusiness and Economics Research Unit (AERU) for the Ministry of Business, Innovation and Employment (MBIE). It supports MBIE's Circular Economy and Bioeconomy (CEBE) programme which explores how to sustainably leverage greater value from New Zealand's biological resources whilst reducing emissions.

Chapter 1; Current use of New Zealand's biological resources

Chapter 1 provides trends in land use and primary sector production (including seafood) are provided along with its contribution to GDP, exports, imports, employment and GHG emissions.

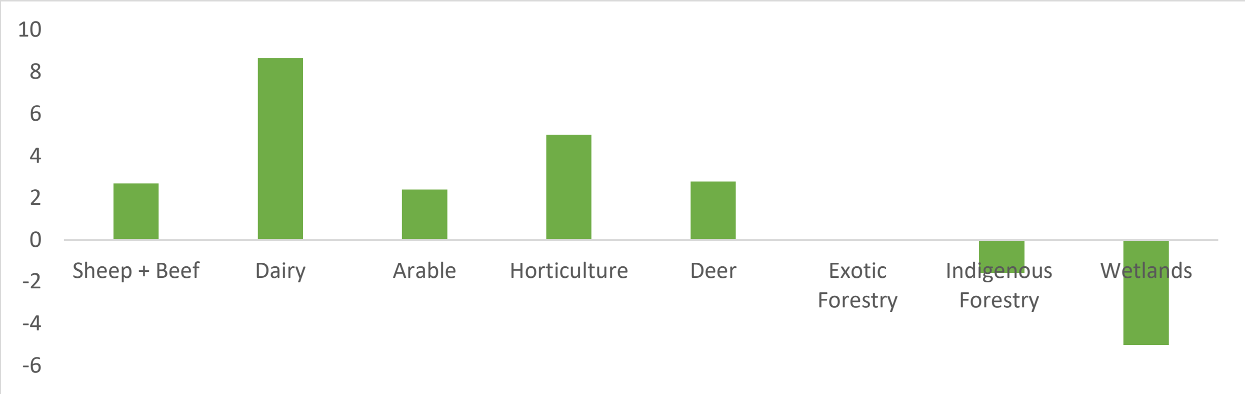
New Zealand's current land use comprises 39 per cent exotic grassland, 9 per cent tussock grassland, 26 per cent indigenous forest and 8 per cent exotic forest. A third of the land area is in the conservation estate. New Zealand has one of word largest economic excusive zones at 4 million square kilometres and 15,000 – 18,000 kilometres of coastline. There are 44 marine protected areas covering 1.7 million hectares.

For the period 2011 to 2021 the bioeconomy sectors contributed between 10.5-12.5 per cent to national GDP each year. In 2022, exports from the bioeconomy were $53 billion (80 per cent of total merchandise exports) comprising dairy (41%), then meat and wool (23%), horticulture (13%) and forestry (15%) of which 55% were logs. Seafood provided $1.98 billion in exports in 2022. The conservation estate provides additional value to the economy through its contribution particularly to tourism but also through electricity generation, provision of water and harvesting of fish and game. Agricultural land use has changed markedly. Dairy area increased by a million hectares between 2002 and 2019 while sheep and beef area decreased by 3 million hectares. The area of exotic forest has essentially not changed in the same time period.

Agriculture accounts for 49 per cent of New Zealand's emissions. Agricultural emissions grew by 13 per cent from 1990 to 2021.

1 Coriolis. 2023. Emerging and future platforms in New Zealand's bioeconomy
Circular Economy and Bioeconomy | Ministry of Business, Innovation & Employment (mbie.govt.nz)

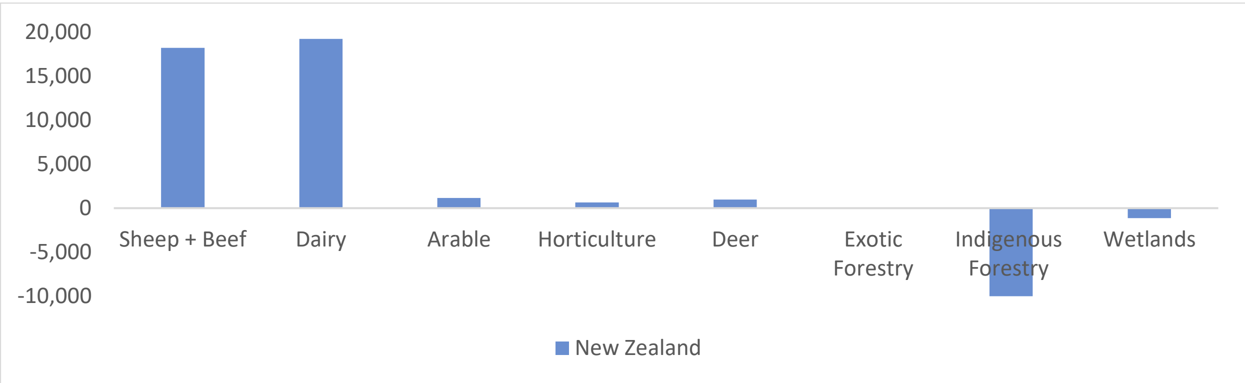
Chapter 2; Comparative emission profiles of current major land uses in the 16 regions



Emissions profiles of eight different land uses per hectare and in aggregate are provided nationally and by region. Dairy is by far the greatest emitter of the land uses at over 8 tonnes of CO_2 equivalent, followed by horticulture at around 5 tonnes CO_2 equivalent, with deer, arable, sheep and beef at around 2 to 3 tonnes CO_2 eq. This reflects the intensity of land use. In contrast exotic forest, indigenous forest and wetlands all sequester CO_2 providing NZ with carbon sinks. Exotic forestry is a major contributor to New Zealand's greenhouse gas sequestration; however, it has been assumed to be neutral in this analysis as sequestration throughout the growing cycle is potentially negated by log and wood-use post-harvest. In aggregate the main emitting land uses are dairy and sheep and beef at around 17 million tonnes CO_2 eq. In aggregate the main carbon sequestration land use is indigenous forest.

Biological emissions of land use by hectare (Average t CO_2 eq / ha per annum).

The biological emission profile of New Zealand land use in aggregate (kt CO_2 eq / ha per annum).



Chapter 3; Impacts of land use change scenarios

Chapter 3 introduces AERU's Integrated Assessment Framework (IAF) which measures the economic, social, environmental and economic consequences of land use change. Six land use change scenarios are developed based on meeting bioenergy and export targets. Scenarios 1 and 4 are the most feasible while the others are unlikely due, for example, to the amount of change required or the degree of environmental impact. However, they provide insights into the potential consequences of specific bioeconomy pathways to meet bioenergy and export targets.

Increasing forestry land use to meet bioenergy targets

The first two scenarios examine the consequences of land use change to meet a feasible and a stretch bioenergy target from wood and wood waste. Two bioenergy demand targets of 75PJ and 150PJ annually were set by MBIE in the RFP, based on modelling by ECCA on future demand requirements in New Zealand. Both scenarios assume that new forestry production is needed to meet biomass demand. The model does not consider a number of variables that could influence the supply of forest biomass. For example, the availability and collection of in-forest residues depend upon several factors including distance from market and cost of recovery and there are time lags until residues supply become available. Conversely biomass supply might be increased with a more limited impact on current sheep and beef outputs by utilising residues from existing forestry (noting that economically recoverable residues are currently well utilised for other purposes) and converting the least productive parts of farms to forestry (versus whole farm conversions).

To meet the Peta Joule (PJ) target the area each region would need to convert to exotic forestry for bioenergy was calculated. *Pinus radiata* was modelled on a 28-year harvest rotation for the scenarios, but in reality there would be the potential for short-rotation forestry with alternative exotic species, especially to meet the initial period of demand. In the case of the 75PJ scenario, an area of just over 974 000 hectares would need to be transitioned to bioenergy forests. On a 28-year rotation, this provides for a harvestable area of around 34 800 hectares annually and a sustainable harvest of 21 305 850 cubic metres of woody biomass for energy production. Appendix B provides flow chart of the method used here.

Scenarios 1 and 2; Conversion of sheep and beef lower class land into exotic unpruned forestry for 75PJ and then 150PJ bioenergy production.

Based on the IAF model the shift in land use to produce 75PJ of bioenergy would increase gross output by $470 million (assuming current prices of forestry). Forestry revenue is assumed to rise by $1.3 billion and sheep and beef revenue to fall by $840 million. The shift in land use to produce 150PJ of bioenergy increases gross output by $930 million (assuming current prices of forestry). Forestry output is assumed to rise by $2.6 billion and sheep and beef revenue to fall by $1.7 billion. In both scenarios, employment falls in sheep and beef and gains in forestry with an overall net loss of jobs. The fall in employment in the sheep and beef sector is concentrated on direct employment whereas the rise in employment in forestry is mainly in indirect employment. This may well have consequences for local rural populations with fewer being employed in these areas and lead to depopulation. Also, there are downstream impacts on the processing industries with a fall of 2,885 FTEs and 5,824 FTEs in sheep and beef processing.

The impact on the environment is generally positive with an 86 per cent reduction of greenhouse gas emissions from the baseline levels for the 75PJ scenario and 173 per cent reduction for the 150PJ scenario. However, the amount of forest residues increases by 281,767m^3 p.a. for the 75PJ scenario and by 565,737 for the 150PJ scenario. There are significant increases in the Bay of Plenty and Gisborne which already have issues with forest residues after Cyclone Gabrielle. This assumes that these residues cannot be used for bioenergy. However, if it is possible to reclaim this, the bioenergy produced would be higher.

Increasing the value of exports though land use change and leveraging higher premiums for products

Increasing the value of exports from biological resources can be achieved through several pathways including increasing high export value primary production, leveraging additional export premiums from current production, and increasing the manufacturing of high value complex biobased products. Four export scenarios examine the first two pathways while Chapter 4 examines the third.

Scenario 3 – A significant land use change to dairy

Scenario 3 models a large shift of 50 per cent lowland sheep and beef and 50 per cent arable land into dairy. This is extremely unlikely to be a viable scenario, as past conversions will have taken the most suitable land and this scenario shows an overwhelmingly negative impact on the environment, including an increase in greenhouse gas emissions of 9,392 CO_2 eq (32 per cent increase) and decreases in water and soil quality. This scenario has positive impact on output with a net increase of $17.1 billion, an increase of +$22.5 billion in dairy output – a fall in $3.3 million in sheep and beef output and $2 million drop in arable output. Employment grows by 50,907 FTEs. This scenario creates a 32.7 per cent increase on current exports.

Scenarios 4 and 5 - Gaining higher premiums on exports from current land use

Research has shown that overseas consumers are willing to pay for credence attributes such as animal welfare, food safety, and carbon neutrality. Scenarios 4 and 5 assumes a 20 and 50 per cent premium for our exports based on their various attributes. A 20 per cent premium is considered by many as achievable across the range of our existing exports however the 50 per cent would require significant change in some sector strategy, R&D, production methods and marketing.

These scenarios see an increase in output of $8.2 and $23 billion, respectively. The largest increase was in dairy at $5 billion and $12.6 billion, respectively, while sheep and beef increased by $1.7 billion and $4.4 billion respectively, followed by horticulture and arable at around $1 and $2 billion. Employment increases by 20% and 50% respectively. This scenario creates a 20.6 per cent and 42.9 per cent increase respectively on current exports.

Scenario 6 – combination of land use change to dairy and higher premium on exports

This scenario combines the large shift to dairy (scenario 3) and a 50 per cent premium for our exports (scenario 5). This is not a realistic scenario, as the very reason why we may gain premiums for our products is contradicted here as the environmental attributes plummet. This represents a 97.6 per cent increase in exports. The modelling shows a net increase of $49 billion in output. Primary sector exports increase by 100 per cent in this scenario. There is overwhelmingly negative impact on the environment, including an increase in greenhouse gas emissions of 9,392 CO_2 eq (32 per cent increase).

These scenarios were developed to assess the impacts of producing more bioenergy and attempting to double primary sector exports. However, for these to be achieved barriers to change must be addressed. In the case of the bioenergy scenarios, incentives for uptake and infrastructural development would be necessary. The conversion of sheep and beef and arable into dairy may well be infeasible and certainly not within environmental limits.

In the case of premiums in market, again incentives for change would be needed. The supply chain has served New Zealand exporters, especially through preferential access into the UK and Europe, followed by first mover advantage into China. However, other competitors are gaining market access and major firms such as Nestlé and Tesco are demanding a move to carbon-zero supply by 2050 with Nestlé aiming for emissions to be reduced by 20 per cent by 2025. For change to occur, it often requires disruption. Two of our most successful industries kiwifruit and wine faced serious disruptions in the 1980’s and therefore had to change. They developed new products but also changed to a value chain model which was market- led. This has led to kiwifruit obtaining 100% premium in market and our wine industry obtains considerable premiums. Over time attributes tend to lose their premiums and become market access requirements. For this reason, there is a need for New Zealand to keep testing new market demands and keep innovating to meet them.

Chapter 4. Case studies of increasing value while lowering environmental impact

There are other ways in which we can help meet export and environmental targets from our biological resources. A range of case studies in Chapter 4 highlight these opportunities, including:

- *Improvements in productivity whilst reducing the environmental impact through technologies* (e.g. precision agriculture, AI, drones, and use of satellite imagery), improved skills and/or investment.
- *Diversifying and concentrating on new higher-value more complex biobased products* e.g. high-value nutraceuticals. The marine environment provides considerable untapped potential. For example, algae could be used for energy, food, clothing, building, pharmaceuticals, agriculture (as a fertiliser) and plastics. There is growing interest in algae as a stock feed as it has the potential to reduce

methane emissions. The MBIE commissioned Coriolis report provides a comprehensive selection of high value low emissions opportunities.[2]

- *Leveraging higher premiums from existing products*. As modelled in scenarios 4 and 5 above, leveraging higher premiums can provide overall benefits to a range of values.
- *Developing new areas of carbon sequestration including the potential of the coastal and marine environment* This could reduce reliance on planting exotic forests or buying international carbon credits to sequester more carbon. Our marine environment has unique oceanographic features for CO_2 removal that are attracting international attention. One case study highlights the potential of the Fjords to sequestrate carbon with potential to sequestrate between 10 and 20 per cent of New Zealand's greenhouse gas emissions.

The potential of all these approaches is significant, but requires different approaches and business models, requiring investment at various stages, sophisticated marketing, and different support from government.

Chapter 5. The Māori Bioeconomy

Māori enterprises, particularly in agriculture, forestry, and fisheries, play a pivotal role in the nation's economy, contributing substantially to GDP and exports. Māori enterprises own over $23 billion in food and fibre assets. These businesses have seen constant growth in exports, production, and employment. New uses within the Māori bioeconomy include sustainable aquaculture and the development of high-value products from indigenous flora.

The Māori approach to biological resources and their allocation is deeply rooted in traditional values, notably Tauutuutu, emphasising reciprocity and the interdependence of economic, social, and environmental wellbeing. These values guide Māori enterprises in their decisions and interactions, fostering a unique economic model that balances profit with the principles of guardianship (kaitiakitanga) and sustainability.

To conclude, the biological sector is essential to New Zealand's economy, wellbeing and quality of life. It accounts for more than three-quarters of the country's merchandise exports but also contributes over half of New Zealand's GHG emissions. New Zealand will soon be asking even more of our biological resources in order to grow the value of our exports and to transition to bio-based energy and materials. For New Zealand to prosper we need to increase the economic, social, environmental, and cultural outcomes from our limited biological resources and manage the trade-offs arising from increased demand. This report examined the existing uses of biological resources and their impact on economic, social, environmental, and cultural outcomes. It modelled the trade-offs arising from bioenergy demand and identifies there are considerable opportunities to enhance the value and outcomes derived from the bioeconomy but significant change is required.

1.1.1 [2] Coriolis. 2023. Emerging and future platforms in New Zealand's bioeconomy Circular Economy and Bioeconomy | Ministry of Business, Innovation & Employment (mbie.govt.nz)

Chapter 1
Situational Analysis of New Zealand Renewable Biological Resources

Biological resources are of significant importance to New Zealand. The country uses a lot of its biological resources for storing carbon and the provision of water and food and materials and other ecosystem services. Also, biological resources are a key driver of New Zealand's economy. Therefore, the current use of biological resources is vital to the economy and New Zealanders standard of living and quality of life.

In October 2023, the Agribusiness and Economics Research Unit (AERU) at Lincoln University was commissioned by the Ministry of Business, Innovation and Employment (MBIE) to inform a policy framework on the best use of New Zealand renewable biological resources and to support the development of a Circular Economy and Bioeconomy (CEBE) strategy. Hence, the aim of this project is to inform the sustainable uses of biological resources and a reduction on waste and pollutants whilst transitioning away from dependence on fossil fuel resources to achieve economic, environmental, cultural and social outcomes.

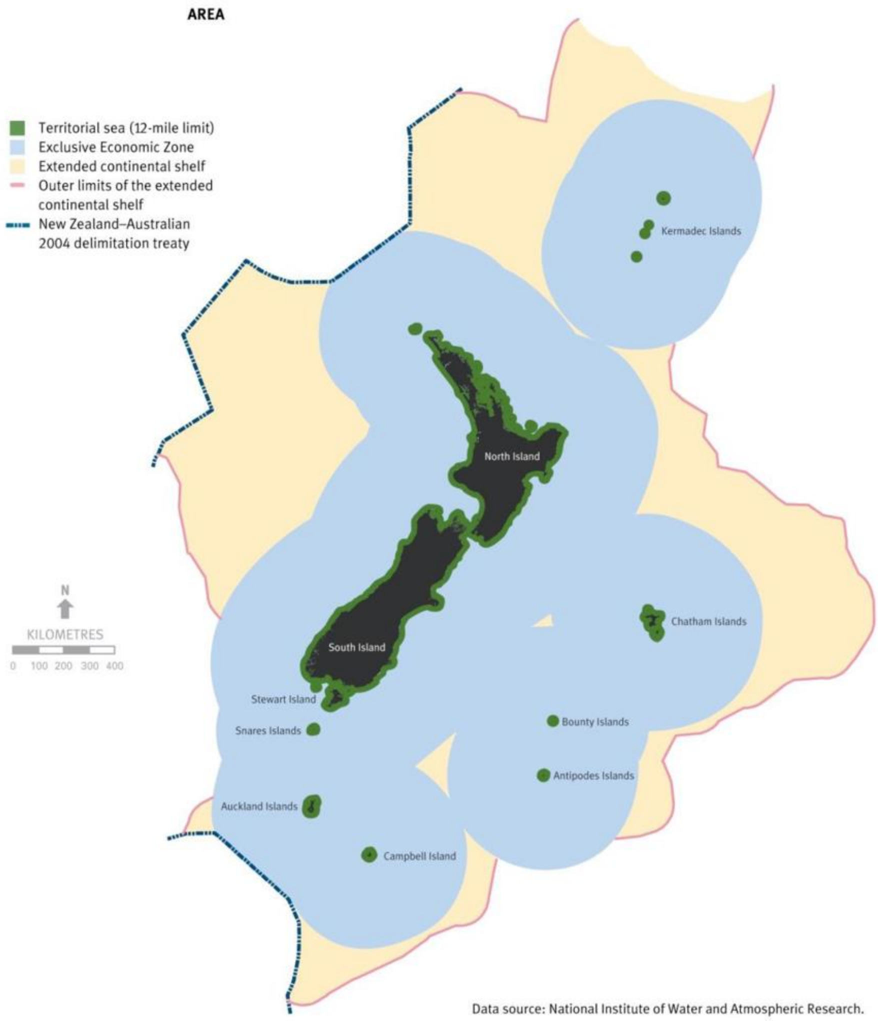
Bioeconomy: The sustainable use of natural (biomass) resource and a reduction on waste and pollutants (Wreford et al., 2019): coupled with transitioning away from dependence on fossil fuel resources to achieve economic, environmental, cultural and social outcomes.

This report is structured as follows. In Chapter 1, the current use of New Zealand's key biological resources is outlined (excluding urban areas). Chapter 2 outlines comparative emission profiles of current major land uses in each of the 16 regions in New Zealand. In Chapter 3 an integrated assessment framework is used to assess the economic, social, environmental and cultural implications of six land-use change scenarios. In Chapter 4, several case studies are presented to explore other uses of the country's biological resources and how New Zealand can achieve higher economic, social, environmental outcomes from its resources. Finally, Chapter 5 will provide a detailed description of the Māori bioeconomy. The report will finish with a conclusion in Chapter 6.

1.1 Total New Zealand – Economic zone/marine/land

New Zealand's land area is 267,021 km^2, with a total coastline of 15,134 km^2. This is shown in Figure 1-1 which depicts at a very high level the geography of New Zealand's biological resources. The territorial boundary extends 12 nautical miles offshore, and the Exclusive Economic Zone includes the sea, seabed and subsoil that are between 12 and 200 nautical miles from the coast.

Figure 1-1: New Zealand land and marine areas.



Source: Environment Foundation, 2017.

The bioeconomy (BE) concept focuses on a specific area of the economy: those activities, processes and products that involve a biological component. The aim of a BE strategy is to encourage economic growth while replacing fossil fuels used in industrial production and energy supplies with bio-based feedstocks (alternative biomass or organic matter fuels) (Diakosavvas & Frezal, 2019). The New Zealand view of this takes a broader approach to consider societal outcomes:

This report pays attention to some specific elements in a bioeconomy. ***Renewable biological resources*** includes terrestrial and marine, fauna and flora, soils, water, microorganisms. ***Biomass*** refers to the total mass of living matter in a given unit area. It is important to note that this is broader than some contexts where biomass is considered the amount of living or dead plant and animal material that can be used as a source of fuel. ***Wellbeing*** is considered broadly in terms of economic, cultural, environmental, and social flourishing. **Value** derived from the bioeconomy include economic, social, environmental and cultural benefits. **Ecosystem services** include 'provisioning services', such as food, timber and freshwater; 'regulating services', such as air quality, and climate; 'cultural services' such as recreation and sense of belonging; and 'supporting services', such as soil quality. All underpin NZ’s quality of life.

The following sections outline land-use statistics and agriculture, forestry and seafood statistics in New Zealand in order to describe the country's bioeconomy as a whole but also its individual sectors. These sections show the significant changes the different sectors of the bioeconomy have experienced in the past. There are multiple reasons for this; however, the reasons for those changes are beyond the scope of this project. Overall, it shows how land use can change in a short period of time and that it could change again in the future.

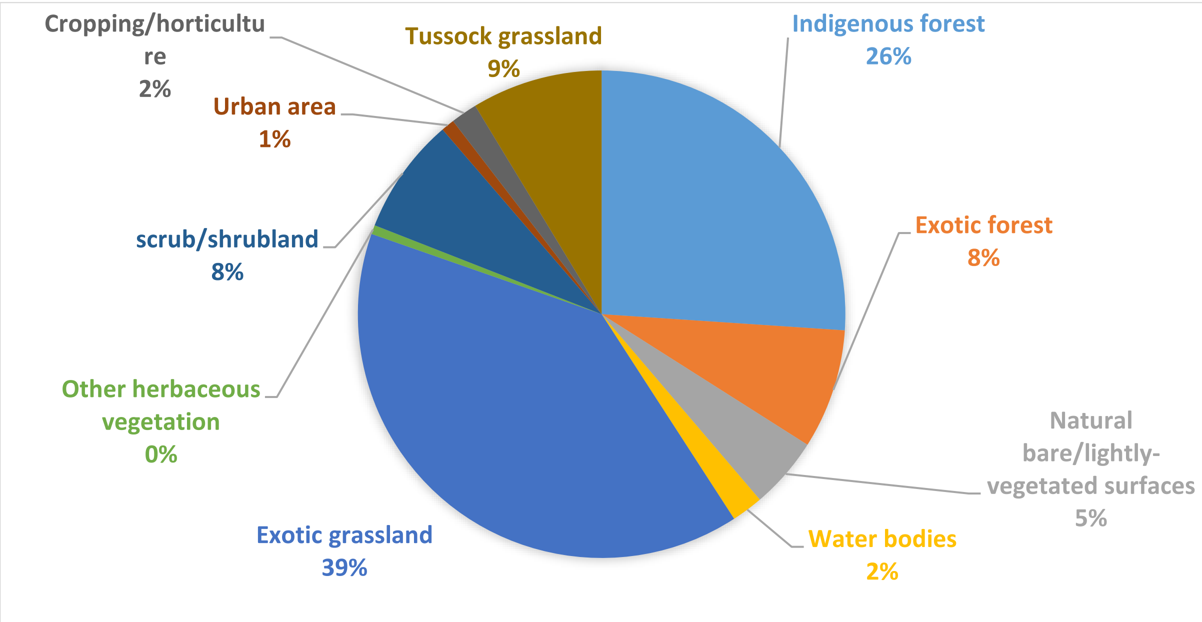
1.2 Total land-use by type

This section describes total land-use by type. The data are mostly drawn from the Land Cover Database Version 5.0 (LCDB5) provided by Manaaki Whenua Landcare Research. The database uses 2018 satellite imagery to map land cover in New Zealand, excluding the conservation estate.

New Zealand has a total area of 107.8 million hectares, including water bodies (LCDB5, 2018). Figure 1-2 below shows the percentage of land by land cover class in 2018. Collectively, grassland, growing crops and plantation forestry cover more than half of the country's available land area. Cropping and horticulture land uses occur on about 2 per cent (2 million hectares) of New Zealand's land. These land uses consist primarily of seasonal crops, for example, vegetables, cereal crops or maize. Forests represent 34 per cent of New Zealand's land cover, comprised of 26 per cent (28 million hectares) indigenous forest and 8 per cent (8.5 million hectares) exotic forest. Water bodies represent 2 per cent (2.2 million hectares). Human settlements represent only about 1 per cent (948,497 hectares) of New Zealand's land area with over 70 per cent of New Zealanders living in major urban areas.

While land-use by land cover has not changed largely over time, agricultural land-use has changed significantly. There has been a decrease in overall size of agricultural land and conversion of farming systems. This is described in detail in Section 1.7; Figure 1-15 and 1-16.

Figure 1-2: Percentage of land by land cover class, 2018.



Source: LCDB5, 2018.

1.3 Conservation areas

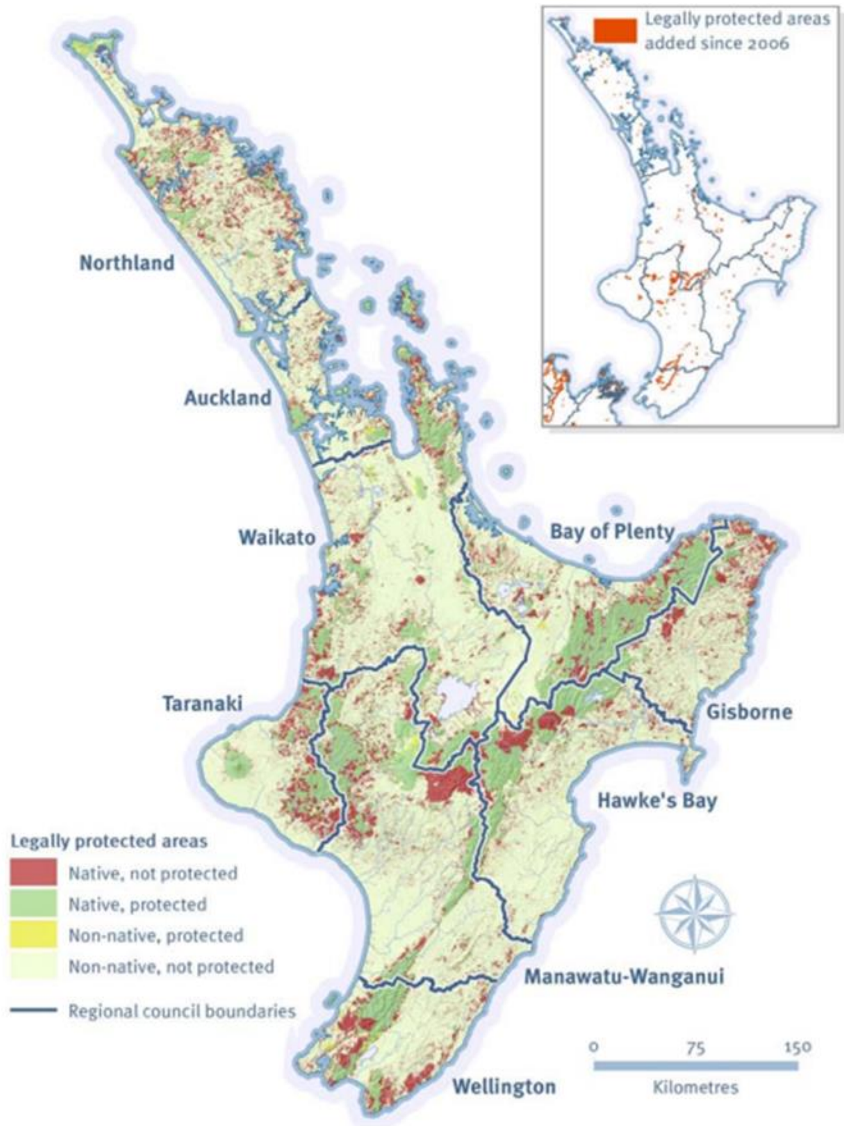
As of July 2009, an area of 8.8 million hectares (around 30 per cent) of New Zealand's land was legally protected for the purpose of biodiversity conservation and/or recreation. This protected land is dominated by native land cover. Conservation land in New Zealand is managed by a number of agencies (MfE, 2010a).

(1) The Department of Conservation (DOC) is the central government organisation charged with conserving the natural and historic heritage of the country. The agency is responsible for protecting and preserving most of the legally protected public land in New Zealand.
(2) Regional councils are responsible for managing the natural and physical resources in the regions. Some regional councils have regional parks that are legally protected.
(3) The QEII Trust works with private landowners who wish to have some or all of their land legally protected. A covenant is registered on the title to the land, providing legal protection that binds the current and all subsequent landowners. The Trust generally contributes to the establishment of the covenant and regularly monitors the land to ensure it is managed in accordance with the covenant conditions.
(4) Ngā Whenua Rāhui is a contestable fund that was established to promote the protection of native ecosystems on Māori land through kawenata (covenants). The fund contributes to the initial protection of the land and can contribute to the management of the land.

The conservation estate, waterways and other landscapes, provide a wide range of ecosystem services which enhance environmental, social, cultural and economic benefits. Ecosystem services can be categorised as 'provisioning', such as food, timber and freshwater; 'regulating', such as air quality, climate and pest regulation; 'cultural' such as recreation and sense of belonging; and 'supporting', such as soil quality and natural habitat resistance to weeds (Dymond, J. Ed, 2014). Whist some of these provide direct monetary values many of these do not and therefore are difficult to quantify in monetary terms but nonetheless are essential for functioning of our economy, society and environment.

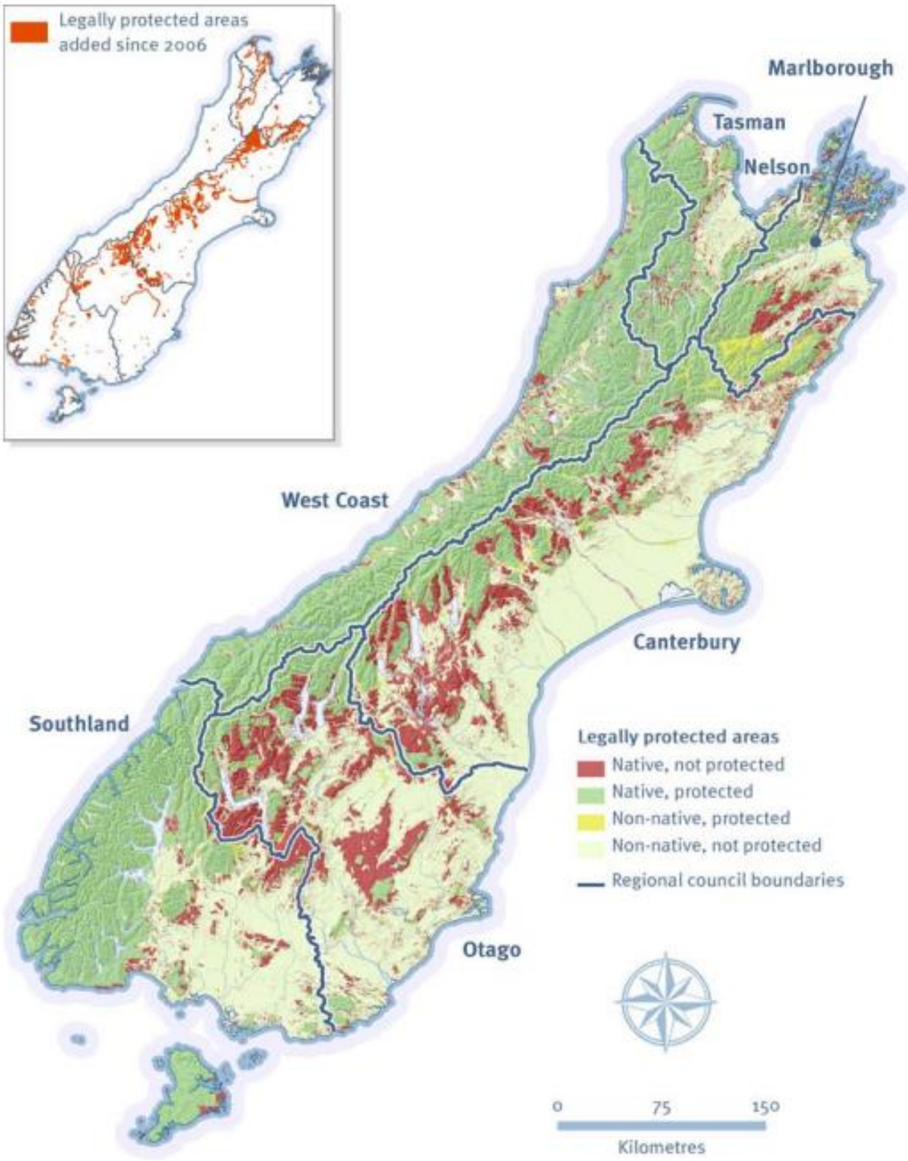
Figures 1-3 and 1-4 show the legally protected areas in the North and South Island of New Zealand in 2009.

Figure 1-3: Legally protected areas in New Zealand, North Island, 2009.



Source: MfE, 2010a.

Figure 1-4: Legally protected areas in New Zealand, South Island, 2009.

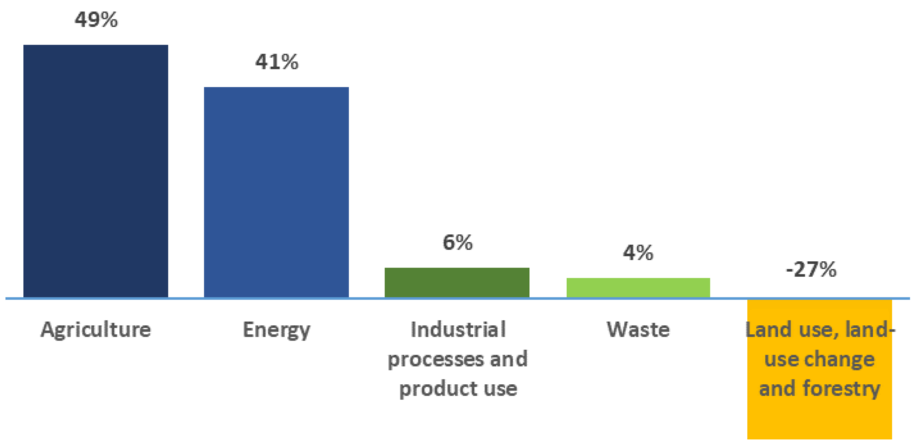


Source: MfE, 2010a.

1.4 GHG emissions

GHG emissions in New Zealand are categorised into five sectors: (1) agriculture; (2) energy; (3) industrial processes and product use; (4) waste; and (5) land-use, land-use change and forestry. In 2021, New Zealand's gross GHG were 76.8 million tonnes of CO_2 eq and net emissions were 55.7 million tonnes of CO_2 eq. Net emissions are gross emissions combined with emissions and removals from land use, land-use change and forestry. The emissions profile by sector can be seen in Figure 1-5.

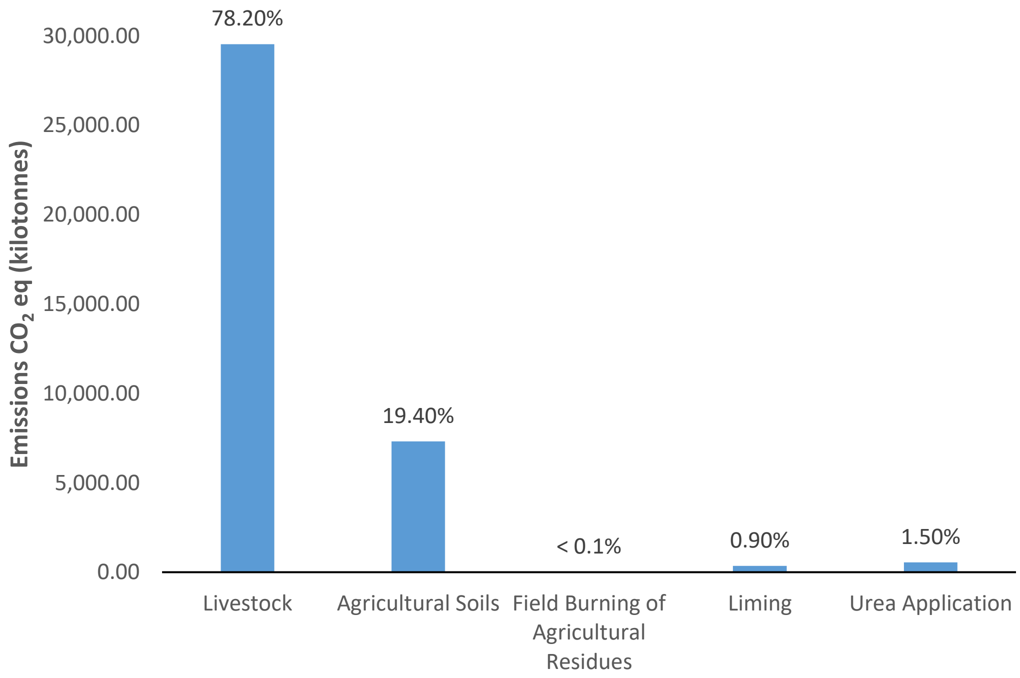
Figure 1-5: New Zealand emissions by sector, 2021.



Source: MfE, 2023.

Within the agricultural sector, emissions are measured in five categories: livestock, soils, field burning of residues, liming, and urea application. A summary of 2021 figures may be seen in Figure 1-6. Considering agricultural emissions in 2021, 78.2 per cent of emissions were from livestock with 51.1 per cent of these from cattle, 21.2 per cent from sheep and 1.5 per cent from other animals.

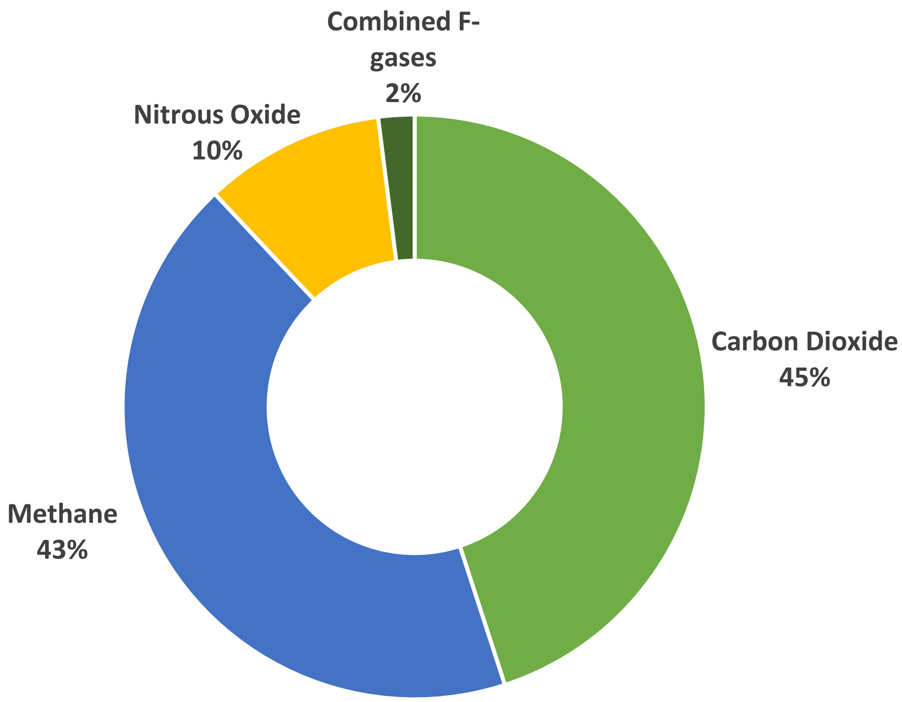
Figure 1-6: Agriculture emissions by category, 2021.



Source: MfE, 2022a.

Considering New Zealand's GHG profile is important given the climate challenges the world is and will continue to experience. Carbon dioxide (CO_2) and methane account for (CH_4) 88 per cent of emissions and the profile of these can be seen in Figure 1-7. The country has a relatively large methane profile due to its land-based economy, a unique position for a small advanced economy. This is highlighted in New Zealand being the 10th highest emitter of methane (OECD, 2023a), despite being the 31st most populated nation of the OECD (OECD, 2023b). This is of note as methane has a greater warming effect than carbon dioxide in the short term.

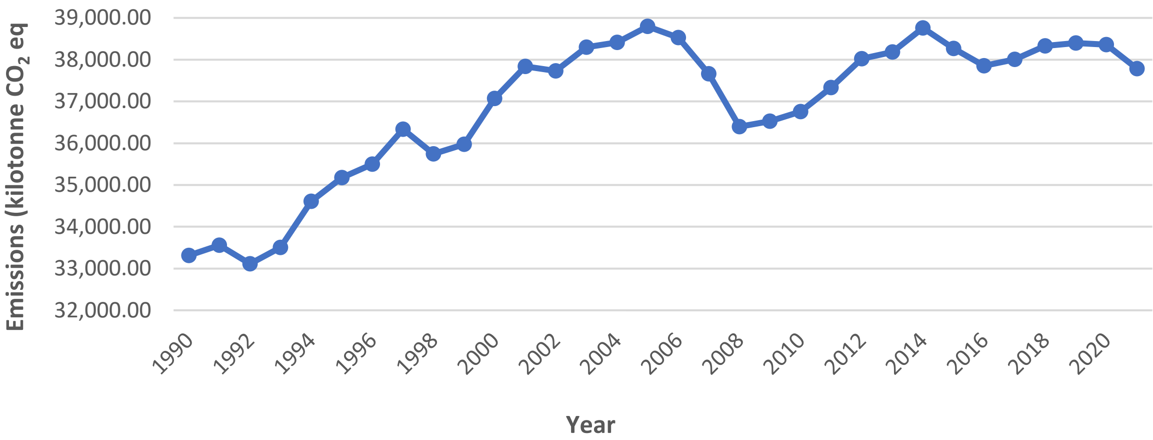
Figure 1-7: GHG profile by type, 2021.



Source: MfE, 2023.

Figure 1-8 highlights the 13 per cent increase in agricultural emissions between 1990 and 2021. Despite the country's overall emissions peaking in 2005, agricultural emissions have continued to increase. As a large contributor to the bioeconomy, agricultural emissions are a central consideration of any bioeconomy strategy plan.

Figure 1-8: New Zealand's agricultural emissions, 1990 – 2021.



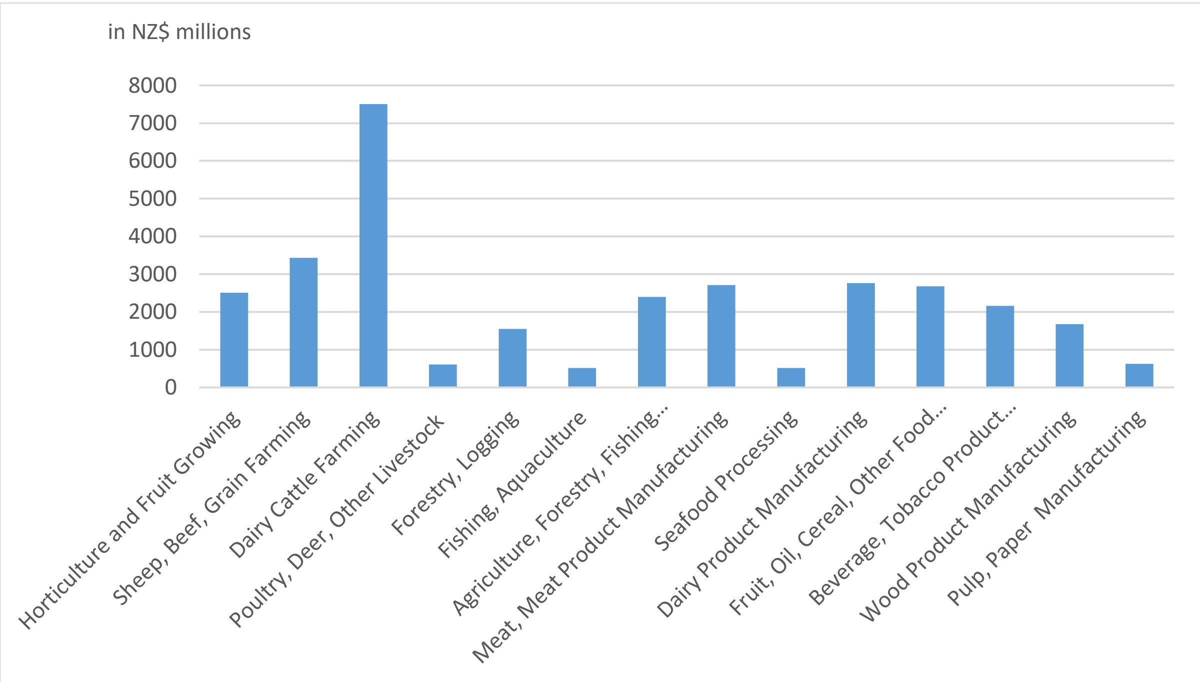
Source: StatsNZ 2022a; MfE, 2023.

1.5 Bioeconomy contribution to GDP, exports, imports and employment

New Zealand's bioeconomy plays an important role in the New Zealand economy. Figure 1-9 presents the contribution of the bioeconomy by sector to real Gross Domestic Product (GDP) in 2021. The total GDP from the bioeconomy sectors contributed NZ$32 billion in 2021; this represents a share 10.5 per cent from the total national GDP of NZ$301 billion in 2021. For the period 2011 to 2021 the bioeconomy sectors contributed between 10.5 and 12.5 per cent to national GDP each year.

In 2021, the sector with the largest share of GDP from New Zealand's bioeconomy was dairy cattle farming (24 per cent; NZ$7.5 billion) followed by sheep, beef and grain farming (11 per cent, NZ$3.4 billion), then dairy product manufacturing (9 per cent; NZ$2.7 billion).

Figure 1-9: Bioeconomy, Real Gross Domestic Product (GDP), in per cent, 2021.



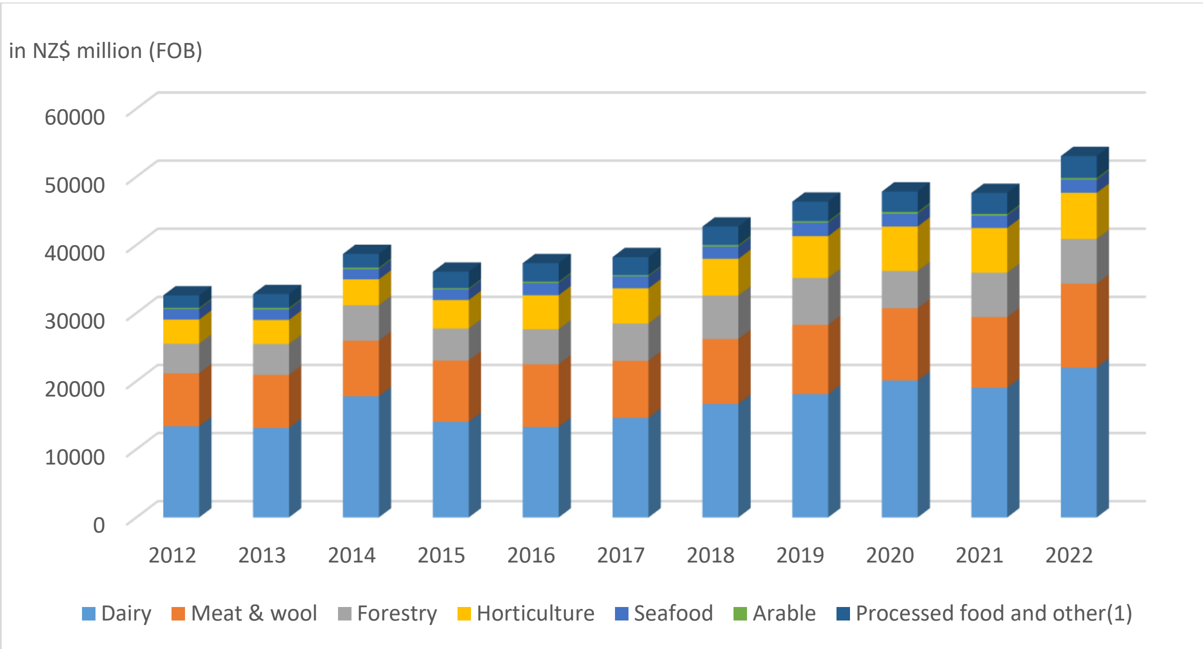
Source: Statistics New Zealand, 2022b.

The bioeconomy (and in particular the conservation estate) also contributes to the economy in addition to that shown in Figure 1-8. In particular is its contribution to tourism due to the attractions of the natural environment and the activities associated with that. In the March 2022 year (prior to COVID) tourism contributed around $26.5 billion, or 3 per cent, to GDP (Statistics New Zealand, 2023c). This was 5 per cent of direct employment and a further 3.5 per cent of indirect employment. Overseas tourism accounted for $11.9 billion or 18.7 per cent of our exports in 2022, making the industry one of New Zealand's largest foreign exchange earner. The tourism figures show the potential economic benefit derived from public conservation estate. However, there are also other economic values including electricity generation and the harvesting of fish and game.

Figure 1-10 shows value of exports by bioeconomy sector between 2012 and 2022. The total value of exports from the bioeconomy shipped from New Zealand in 2022 was $53 billion; this is 80 per cent of total goods exports in 2022 (NZ$72.2 million). As shown in Figure 1-10, the largest share in 2022 was dairy produce (41.5 per cent), followed by meat and wool (23 per cent), then horticultural products (12.8 per cent). Arable exports presented the smallest share of 0.5 per cent of all bioeconomy exports.

For the period 2012 and 2022, dairy products represented New Zealand's largest export commodity from the bioeconomy, accounting between 36 and 46 per cent of total bioeconomy exports. The second largest export commodity was sheep & wool accounting between 21 and 24 per cent of total bioeconomy exports, followed by forestry exports accounting between 11 and 15 per cent of total bioeconomy exports. Main exports destinations are China, Australia and the United States (USA).

Figure 1-10: Exports by commodity from bioeconomy sectors, in NZ$ million, 2012 – 2022.

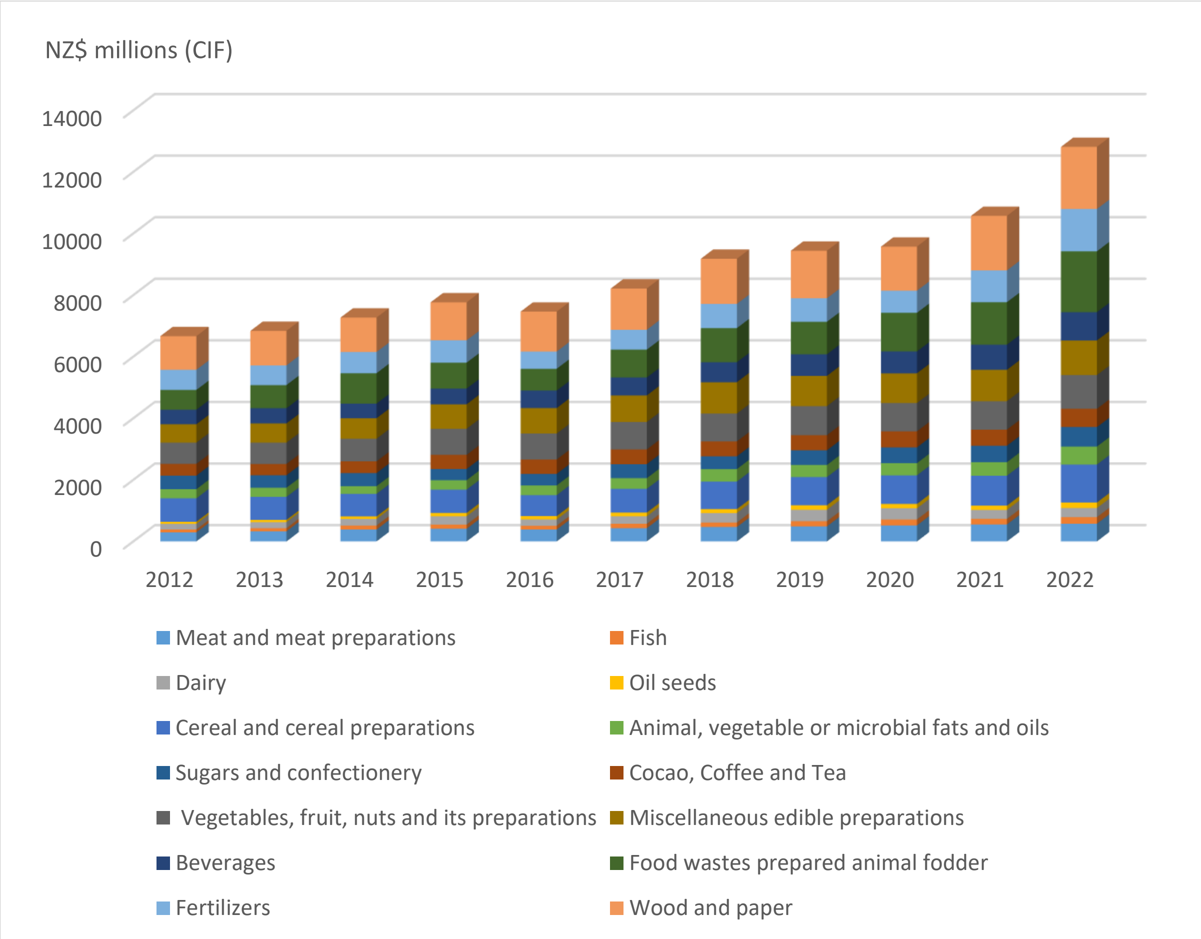


Note (1): includes live animals, honey and processed food.
Source: MPI, 2023a.

Figure 1-11 shows selected imports to New Zealand between 2012 and 2022. In 2022, the largest share was wood and paper (NZ$ 2 billion, followed by fertilizers (NZ$ 1.3 billion, then food wastes for animal feed (NZ$ 1.9 billion). Not shown in this is figure are imports of mineral fuels and oils; these were valued at NZ$ 9.9 billion in 2022, up 76 per cent from the previous year.

Imports have grown steadily between 2012 - 2022 (except 2016); for those categories presented in the figure a growth of 92 per cent between 2012 and 2022 was recorded. The category with the largest growth was recorded for food wastes (+207 per cent); followed by oil seed imports (+158 per cent), then fish imports (+128 per cent) over the 10- year period.

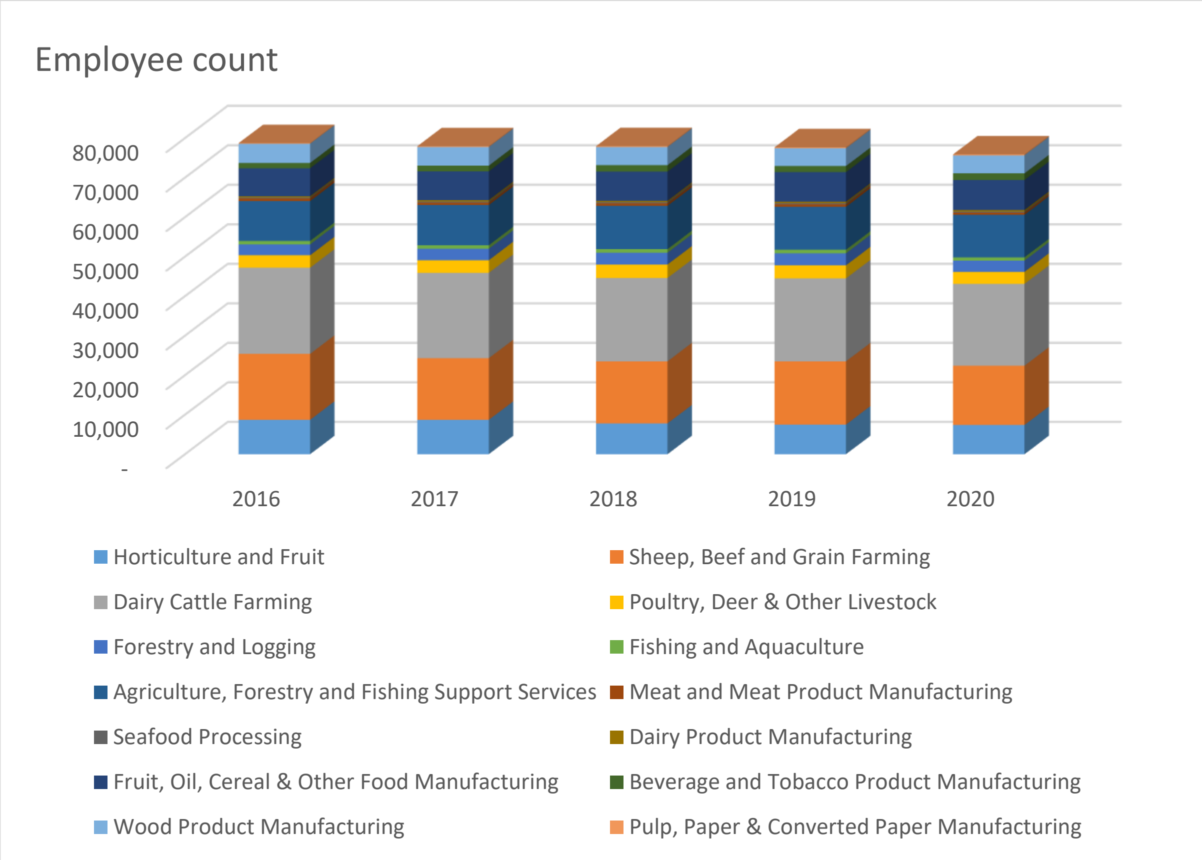
Figure 1-11: Imports by commodity from bioeconomy sectors, in NZ$ million, 2012 – 2022.



Source: StatsNZ, 2023d.

Figure 1-12 shows the number of employees in different sectors of the bioeconomy between 2016 and 2020. In 2020, the sector with the highest employment in the bioeconomy was dairy farming (20,700 employees), followed by sheep, beef and grain farming (15,000 employees), then agriculture, forestry and fishing support services (10,775 employees). Between 2016 and 2020 the sector with the largest increase in employees was pulp, paper & converted paper manufacturing which grew by 60 per cent of the period. In contrast, the number of employees in meat and meat product manufacturing decreased by 18 per cent over the same period.

Figure 1-12: Employee count by bioeconomy sector, 2016 – 2020.



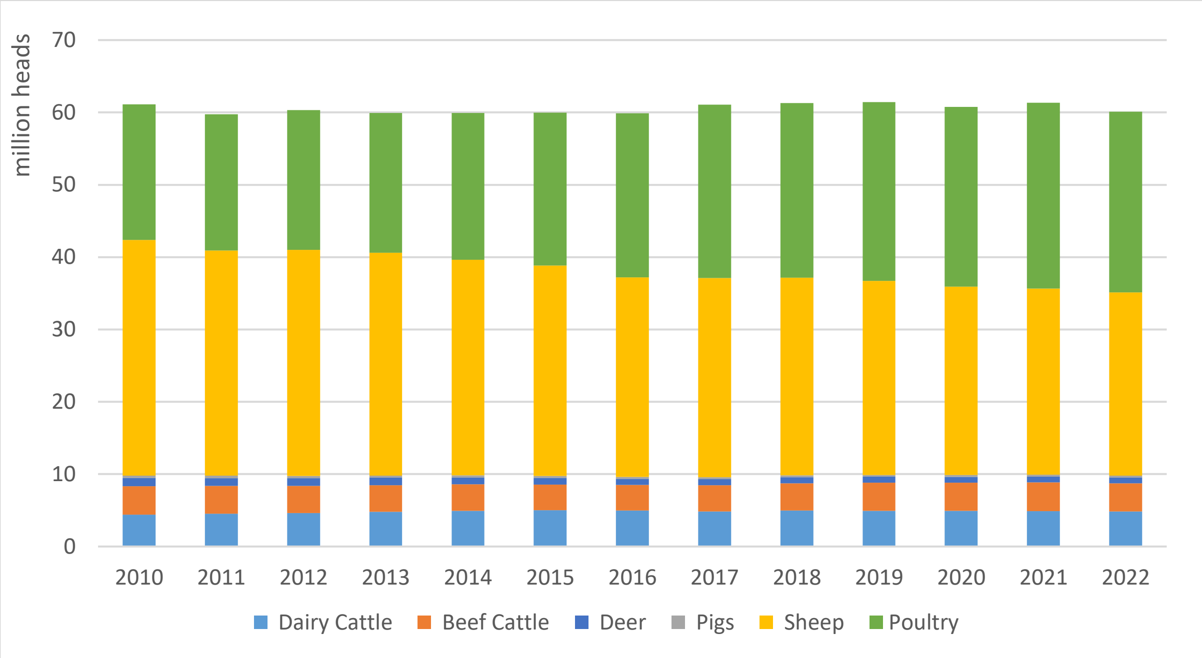
Note: Employee count (EC) refers to paid employees. It is a head count of salary and wage earners sourced from tax data.
Source: StatsNZ, 2023e.

1.6 Bioeconomy sectors

This section presents data describing New Zealand's sectors of the bioeconomy. Data are drawn from several sources, including FAOSTAT, Statistics New Zealand and industry specific data sources. It further includes data from Coriolis (2023a).

New Zealand livestock numbers have changed significantly over the past ten years. Livestock numbers by type between 2010 and 2022 are shown in Figure 1-13. In 2022, sheep, poultry, dairy cattle and beef cattle were the main livestock. While dairy and poultry numbers increased between 2010 and 2022 by 10 per cent and 33 per cent respectively, deer and sheep numbers dropped by 29 and 22 per cent in the same period. Figure 1-14 shows the relative change in time using an index.

Figure 1-13: **Livestock numbers by type, in million heads, 2010 -2022.**



Source: Stats NZ, 2023a; LIC, 2023.

Figure 1-14: **Livestock numbers by type, index, 2010 – 2022.**

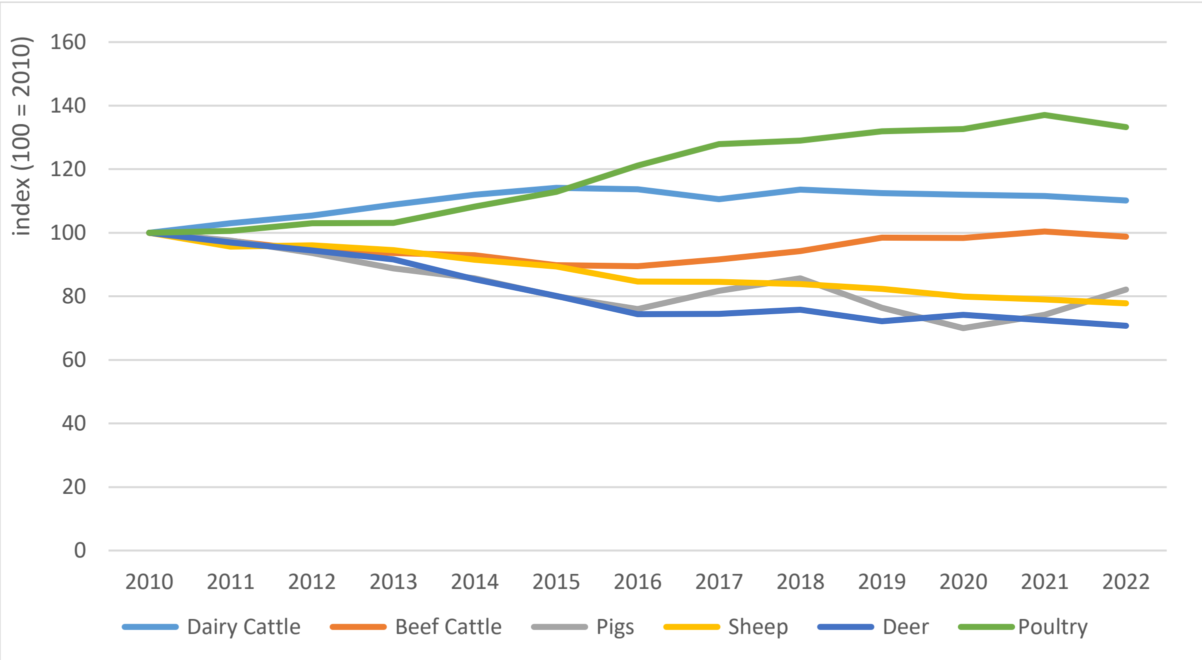
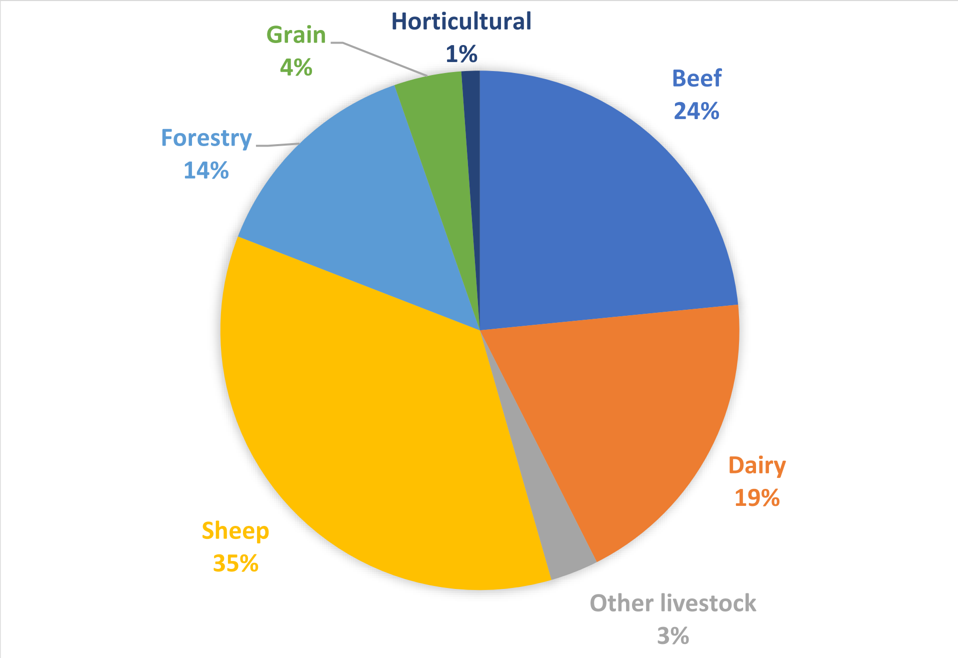


Figure 1-15 shows agricultural land-use by type in 2019 provided by Statistics New Zealand's agricultural census. The total agricultural area in New Zealand was 11.6 million hectares. In 2019, sheep farming accounted for the largest share of 35 per cent of total agricultural land, followed by 24 per cent for beef farming, then 19 per cent for dairy farming.

Figure 1-15: Agricultural land-use by type, in per cent, 2019.



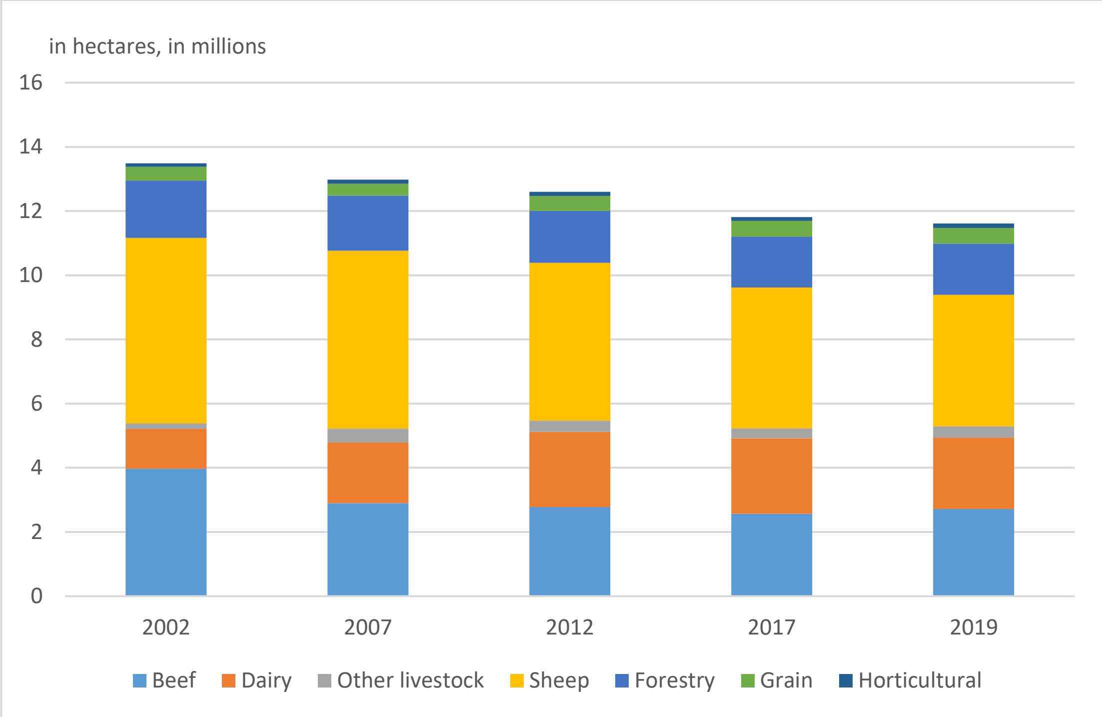
Source: Statistics New Zealand (2023b).

Figure 1-16 shows agricultural land-use over after 2002. Overall, agricultural land-use area decreased by 14 per cent, from 13.5 million hectares in 2002 to 11.6 million hectares in 2019. This is an overall reduction of 1.9 million hectares. However, despite land area decreases, agricultural export values increase. While urban land cover makes up one per cent of total land area in New Zealand (as shown in Figure 1 above), urban and residential areas expand further onto productive land, which creates tension between the use of land for housing and agriculture (MfE, 2022b). The subdivision of rural land for urban development is driven by economic factors (Agfirst, 2017).

Figure 1-16 further shows that the largest gain in land-use between 2002 and 2019 was for dairy farming, which almost doubled from 1.2 million hectares (2002) to 2.2 million hectares (2019). In the same period, the areas used for sheep farming and beef farming dropped by 1.7 million hectares (32 per cent) and 1.3 million hectares (29 per cent) respectively.

A high proportion of the changes in land-use happened in areas such as Canterbury because the region had the ability and type of land that could convert to dairy farming.

Figure 1-16: Overall land-use by agricultural sector, in hectares, millions, selected years.

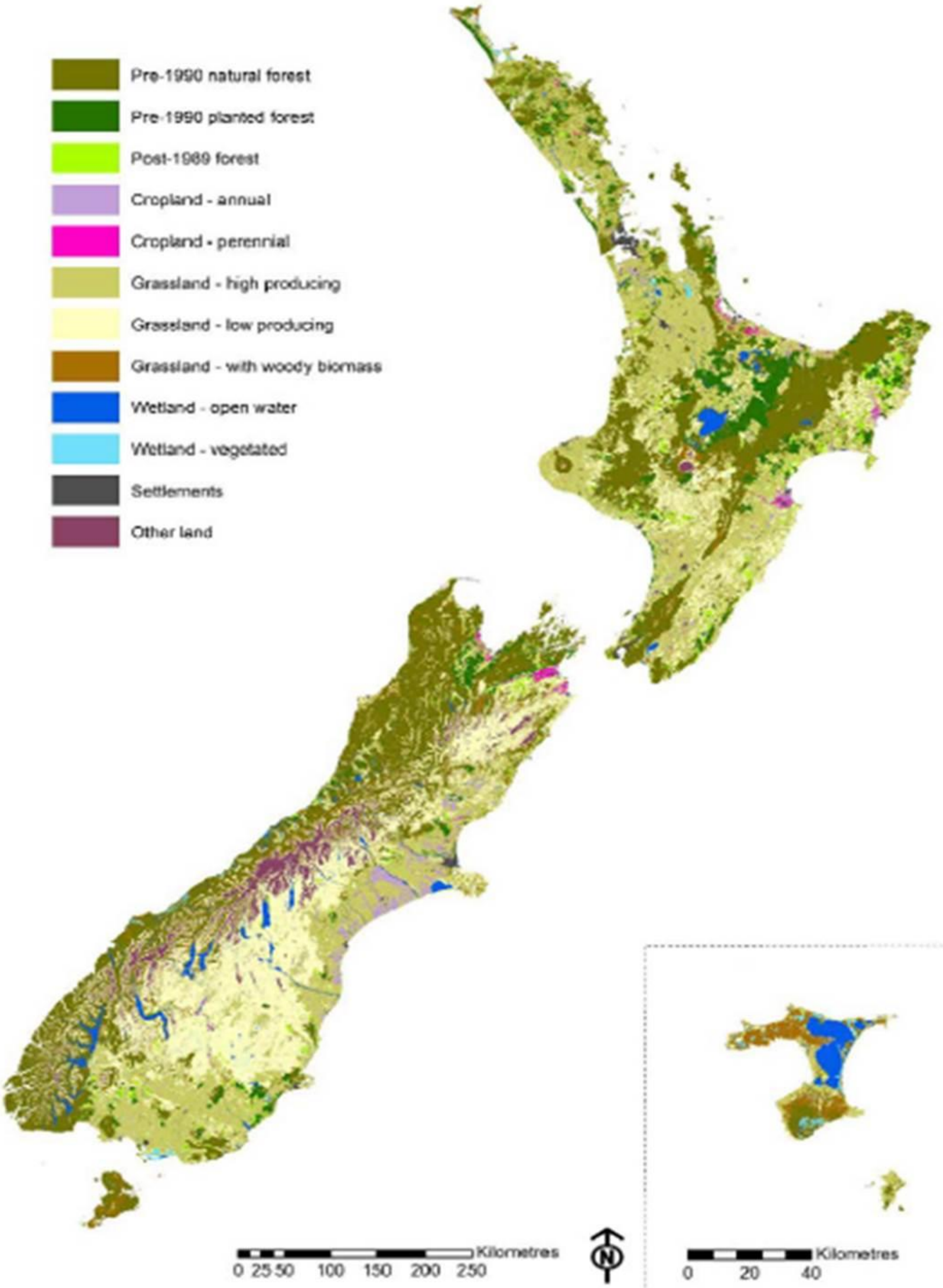


Source: StatsNZ, 2023b.

1.6.1 Forestry

New Zealand's plantation forest is an important part of the country's bioeconomy. In 2021, New Zealand had a net stocked area of planted forest of 1.7 million hectares with a standing volume of 531,395 cubic metres. Figure 1-17 shows the areas of natural and planted forests in New Zealand.

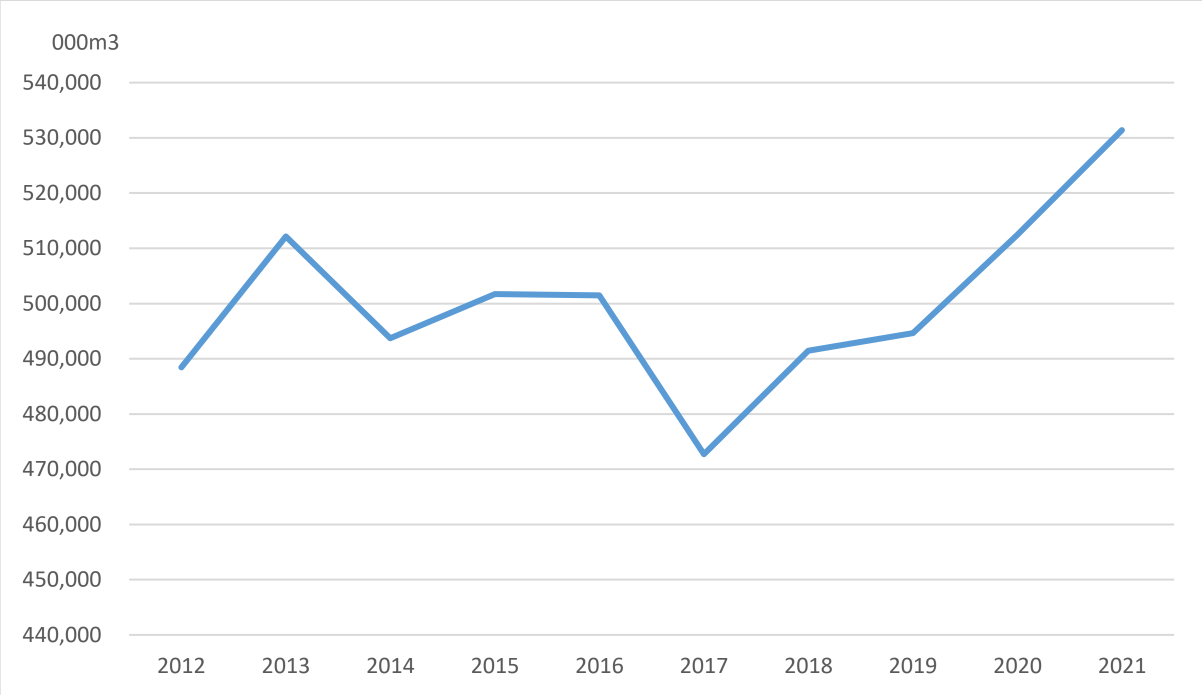
Figure 1-17: Land cover in New Zealand including natural and planted forests.



Source: MfE, 2010b

Figure 1-18 below shows the standing volume between 2012 and 2021, which fluctuated between 2012 and 2017, decreasing by 1 per cent overall. Between 2017 and 2021, there has been steady growth totally 12 per cent in 2021 compared to 2017.

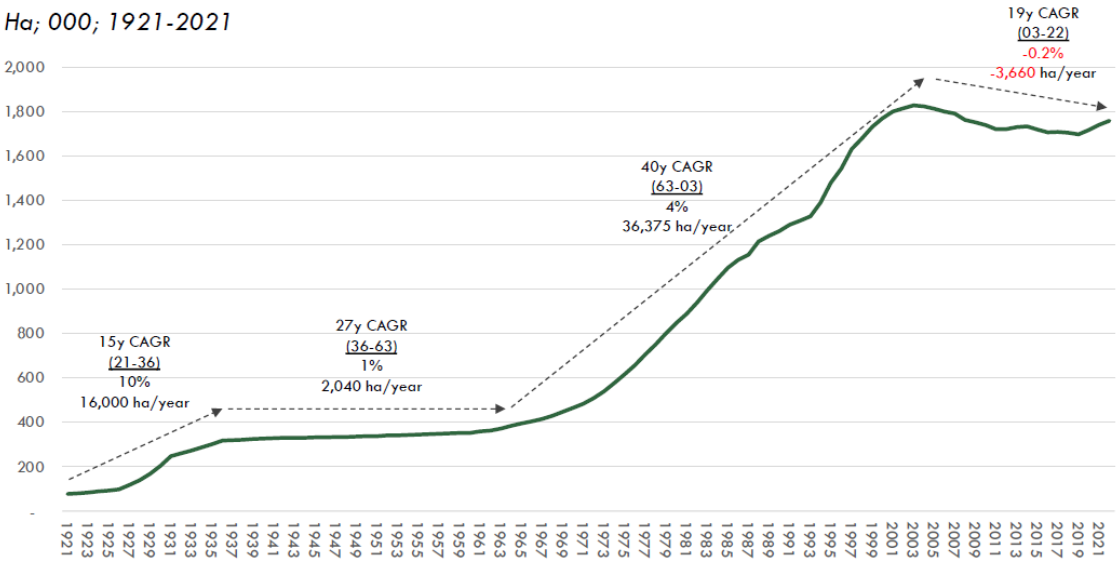
Figure 1-18: Standing volume, exotic forest, 2012-2021.



Source: NZFAO, 2023.

Figure 1-19 shows a time series over last hundred years of forestry plantation area in New Zealand. This shows that plantation forestry area started to grow considerably in the mid 1960's and peaked in 2003 and decreased since then, with a modest recovery in last two years.

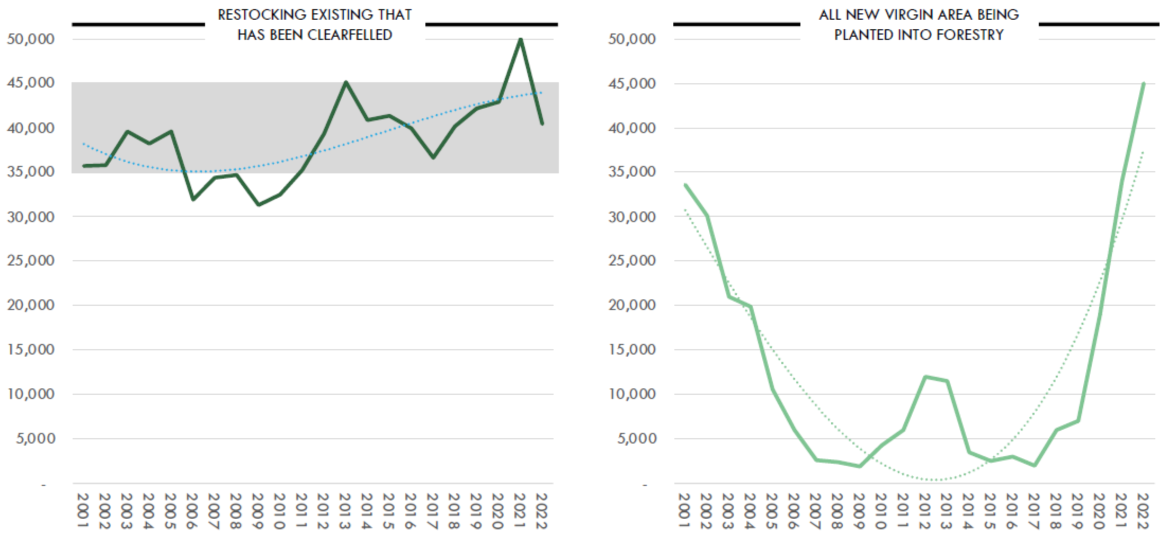
Figure 1-19: NZ plantation forest area; in hectares; 000; 1921-2021.



Source: Coriolis, 2023a.

Figure 1-20 below shows the area planted per year over the last twenty years, including virgin planting and restocking. The restocking of existing forestry lands has been at around 10,000 hectares per year. However, the new area entering forestry declined considerably from around 35,000 hectares per year in 2001 to lows of around 5,000 hectares per year but has risen since 2017 to 45,000 hectares per year in 2022.

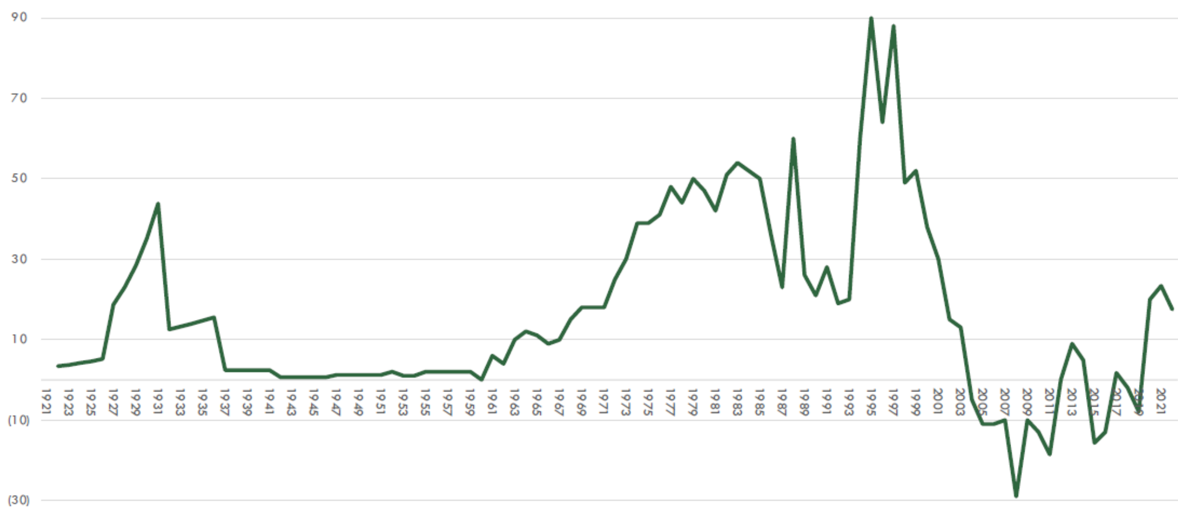
Figure 1-20: How much area is being planted annually into forestry in NZ, in hectares, 2001 – 2022.



Source: Coriolis, 2023a.

These changes above are reflected in Figure 1-21 showing the annual net change in forestry plantation area. This shows after a period of grow in the 1920's and 1930's the area remained fairly constant until 1960's when the area grew until the mid 1980's. Then, there was peak in grow in the early 1990's, after which of harvesting was greater than replanting until 2019.

Figure 1-21: Annual net change in total NZ plantation forestry area, in hectares, 000, 1921 – 2022.



Source: Coriolis, 2023a.

Figure 1-22 below shows the standing volume of forestry by region in 2022, illustrating that around 70 per cent of New Zealand plantation forestry area is in the North Island, with the Central North Island alone accounting for a third.

Figure 1-22: NZ Regional Standing Volume, in hectares, 000; 2022.

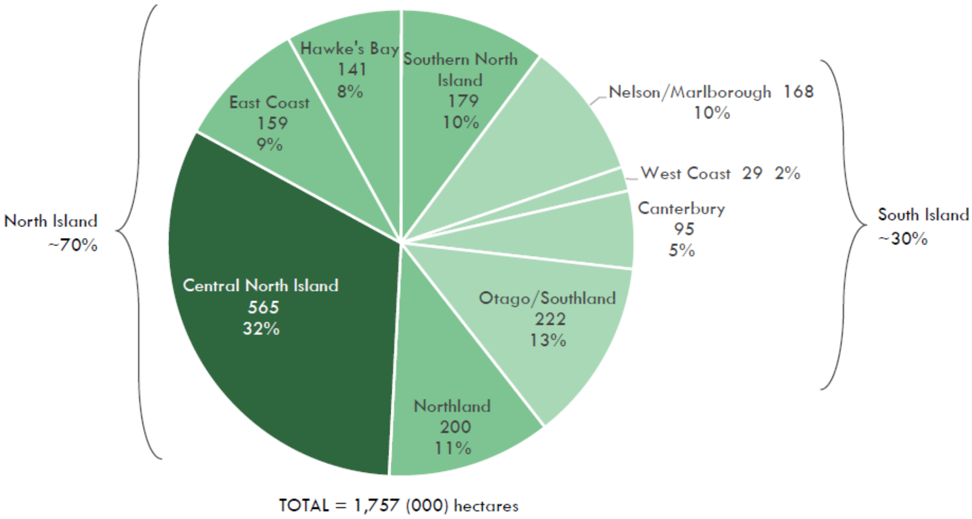
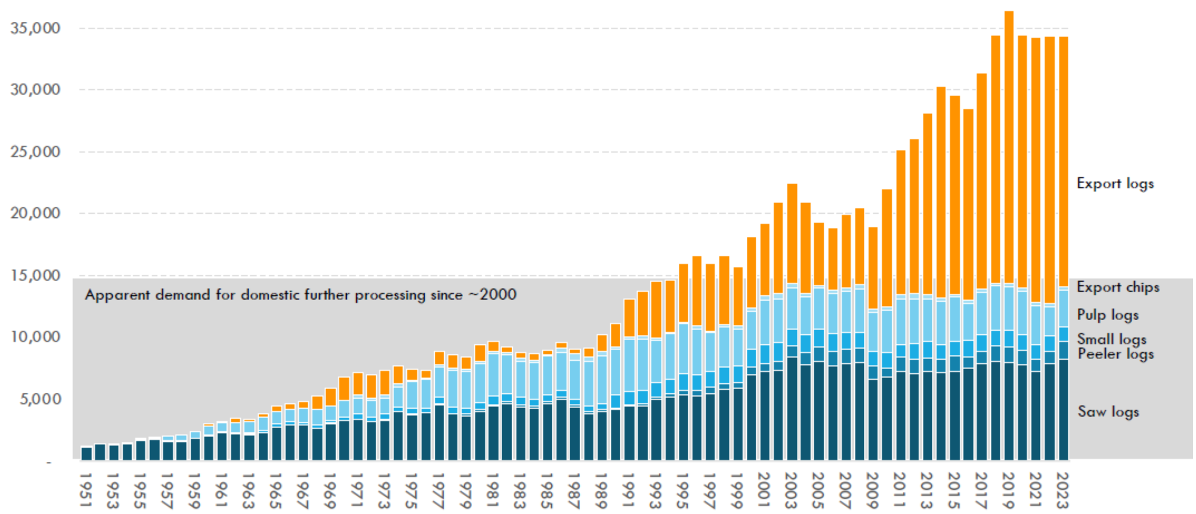


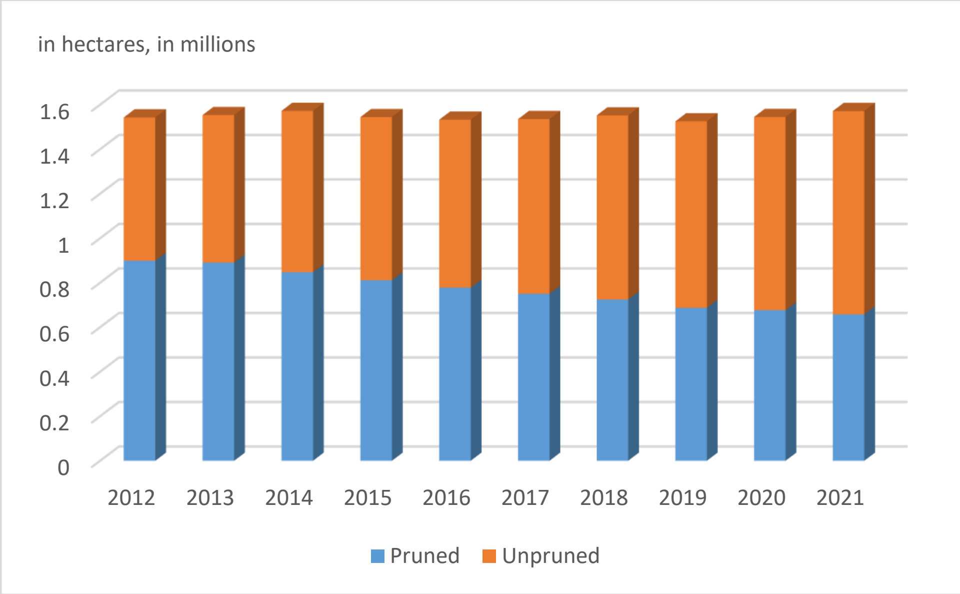
Figure 1-23 shows the estimated removals from 1951 to 2023. Most removals were for domestic consumption and/or processing until 1990. Since 1990 the export of logs grew considerably to account for well over half of production.

Figure 1-23: Estimated roundwood removals from NZ forests, in m^3; 000, 1951-2023.



Source: Coriolis, 2023a.

Figure 1-24: Area of radiata pine, pruned and unpruned, in hectares, 2010 – 2021.



Source: NZFAO, 2023; MPI 2023b.

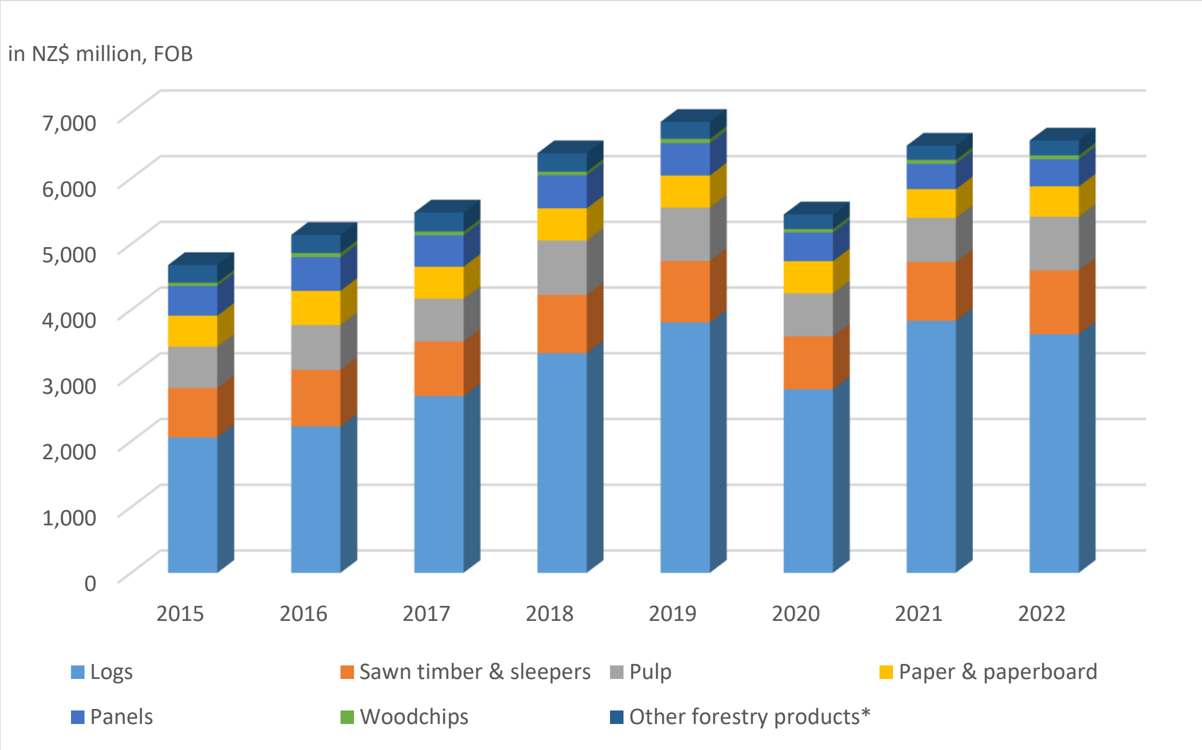
The dominant species in New Zealand's planted forest is radiata pine (1.5 million hectares in 2021). Figure 1-24 shows that in 2021 of radiata pine planted forest estate more than half of the area was unpruned (913,723 hectares unpruned compared to 657,850 hectares pruned). A general trend away from pruning can be observed between 2012 and 2021. The area of unpruned one has grown by 42 per cent between 2021 and 2021. Hence, there is a trend towards minimally tended forests. The margin between pruned and unpruned logs has been declining, and when you do the investment analysis, more often than not, an unpruned regime has a higher net present value. There is also more cash flow required for a pruned regime which is a disincentive for some owners. Some forest owners will prune anyway for strategic or risk mitigation reasons.

Figure 1-25 shows forestry exports by category between 2015 and 2022. In 2022, forestry exports were valued at NZ$6.7 billion. Main destinations were China (NZ$3.8 billion), Australia (NZ$574 million), and South Korea (NZ$420 million) (NZFAO, 2023).

By commodity, log exports represented the largest share of forestry exports accounting for 55 per cent of all forestry exports in 2022. This was followed by sawn timber (15 per cent), then pulp products (12 per cent).

Between 2015 and 2022 the value of forestry exports fluctuated. There was an increase of exports of 47 per cent between 2015 and 2019; followed by a drop of 20.8 per cent in 2020. Since then, an upwards trend can be observed with forestry exports increasing by 20.6 per cent between 2020 and 2022.

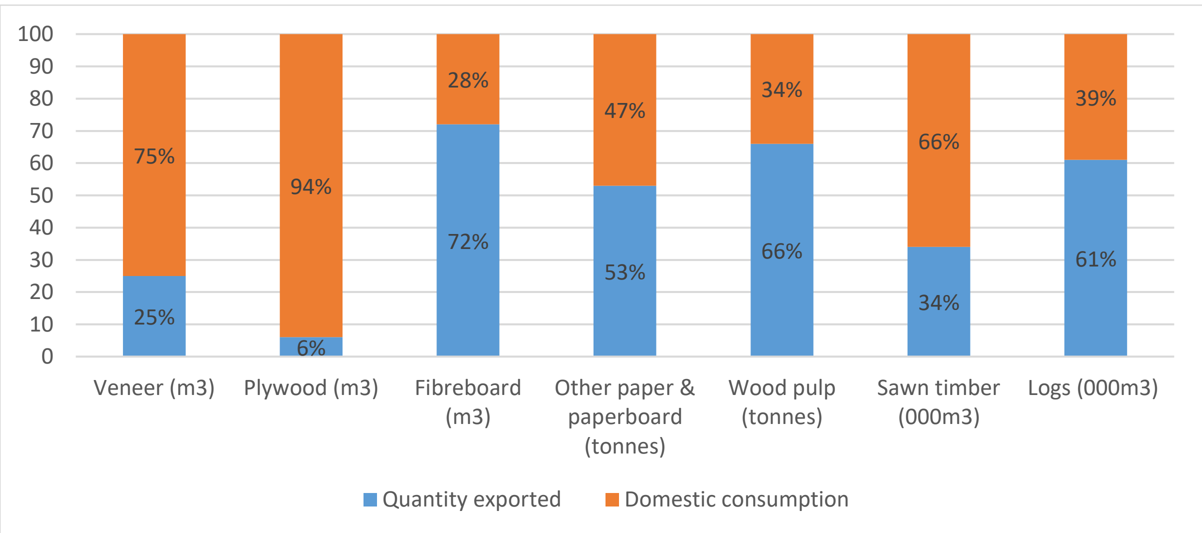
Figure 1-25: Forestry exports by category, in NZ$ million (FOB), 2015 – 2022.



Note: * Other forest products include: structural or moulded wood, furniture, and prefabricated buildings.
Source: MPI, 2019a; 2023a.

Most of New Zealand's forestry products are exported, as shown in Figure 1-26. In 2021, 72 per cent of fibreboard production was exported (the remaining 28 per cent was used for domestic consumption). Similarly, 66 per cent of wood pulp and 61 per cent of produced logs were exported. In contrast, plywood production is mainly for domestic market, only 6 per cent of production was exported in 2021. Similarly, 75 per cent of veneer production is used for the domestic market.

Figure 1-26: Production and exports of selected forestry products, in per cent, 2021.

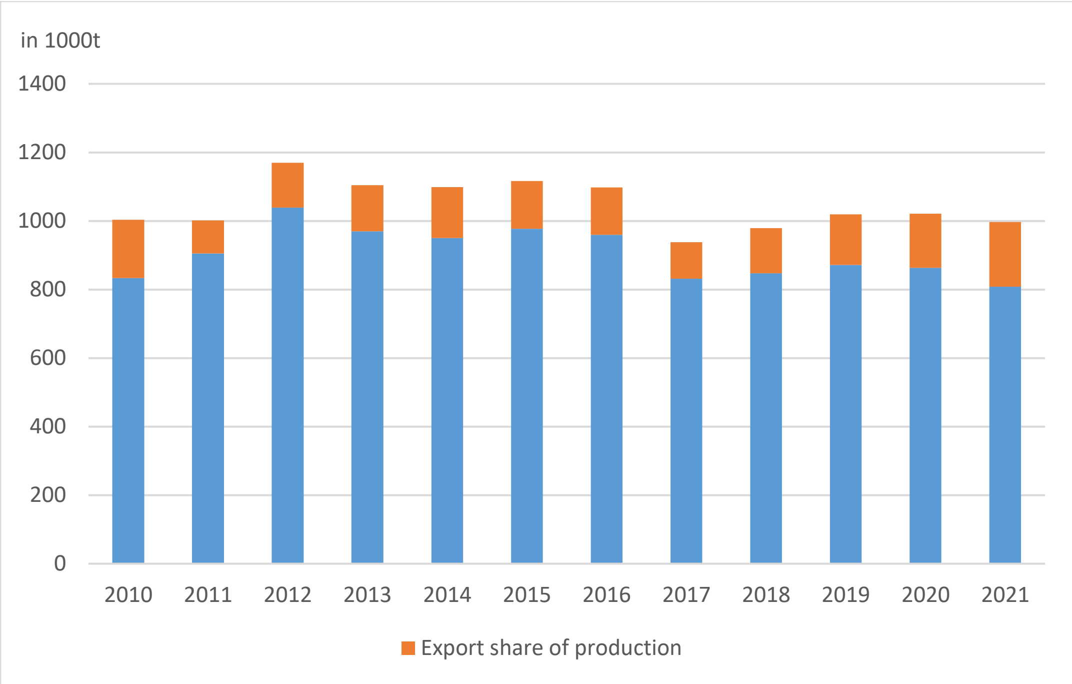


Source: NZFAO, 2023.

1.6.2 Arable

There are a range of arable crops produced in New Zealand. Wheat and barley are the dominant crops in terms of tonnes harvested. Figure 1-27 shows total cereal production and the share of export volumes between 2010 and 2021. In 2021, an amount of 997,000 tonnes of cereals were harvested, of which 170,000 tonnes were exported. This represents a share of 17 per cent.

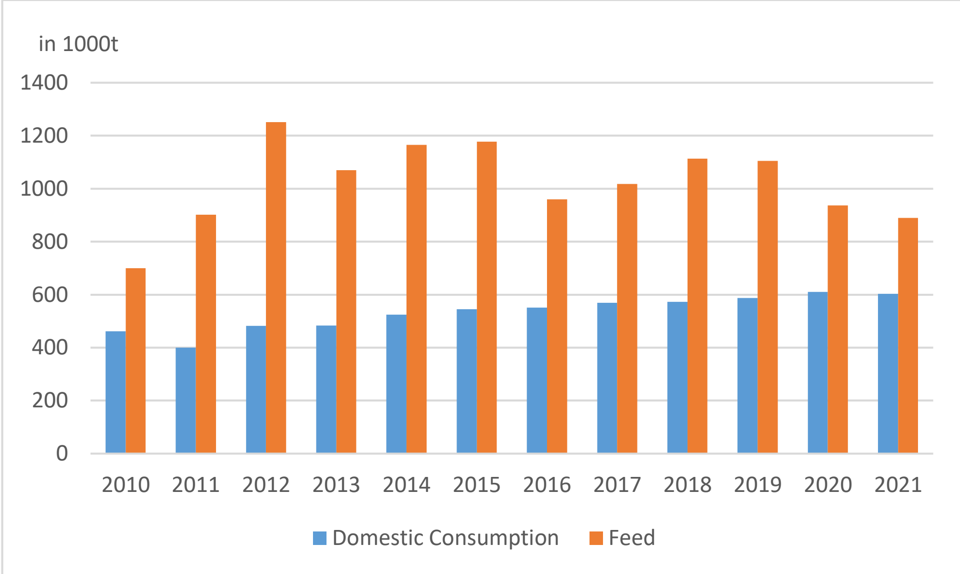
Figure 1-27: New Zealand total cereal production volumes and export share, in 1000t, 2010 – 2021.



Note: Cereal (excl. beer) includes wheat; rice; barley; maize; rye; millet; oats; sorghum; other cereals.
Source: FAO, 2023.

As shown in Figure 1-27 only small amounts of production volumes are exported (orange part of the bar). Hence, the largest share of New Zealand cereal production is for domestic consumption and animal feed. Figure 1-28 shows that in 2021 an amount of 603,000 tonnes were for domestic consumption and 890,000 tonnes were used for animal feed. While cereal consumption has grown steadily over time, the use of cereal for animal feed has fluctuated.

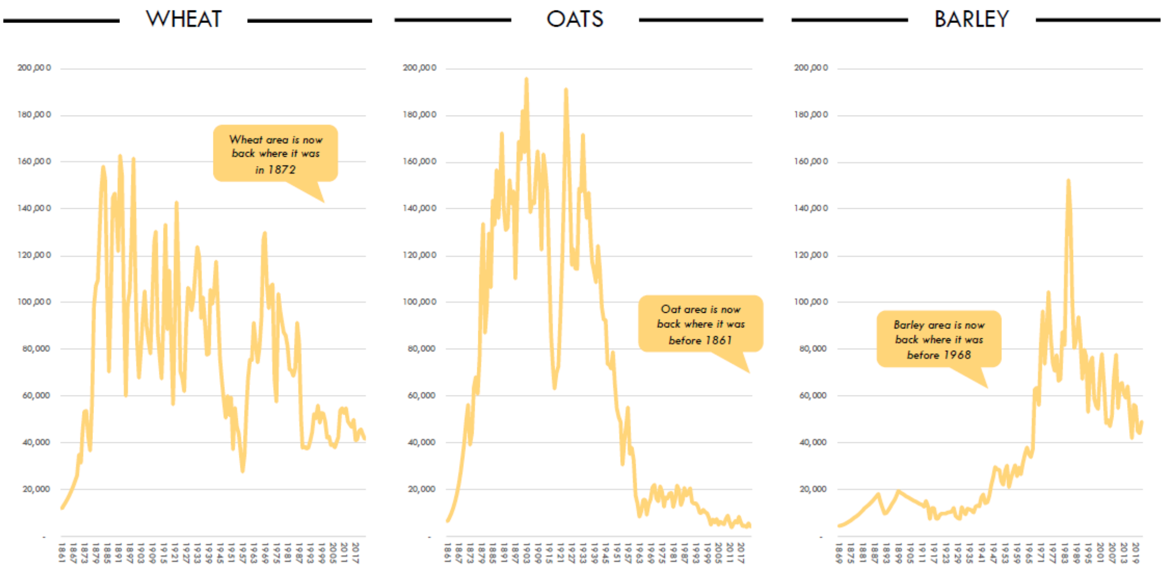
Figure 1-28: New Zealand cereal domestic consumption and animal feed, in 1000t, 2010 – 2021.



Note: Cereal (excl. beer) includes wheat; rice; barley; maize; rye; millet; oats; sorghum; other cereals.
Source: FAO, 2023.

Figure 1-29 shows the area of arable land by key crops in New Zealand from 1861 to 2022. This shows considerable grow from 1861 to the early 1990's in wheat and oats. Since then wheat and oat areas fluctuated with wheat areas falling from the mid 1980's and oat areas after the second world war with mechanisation. The barley area remained relatively low until early 1969's when it grew and then peaked around 1990 and falling since then.

Figure 1-29: NZ area in selected crops, in hectares; 1861-2022.

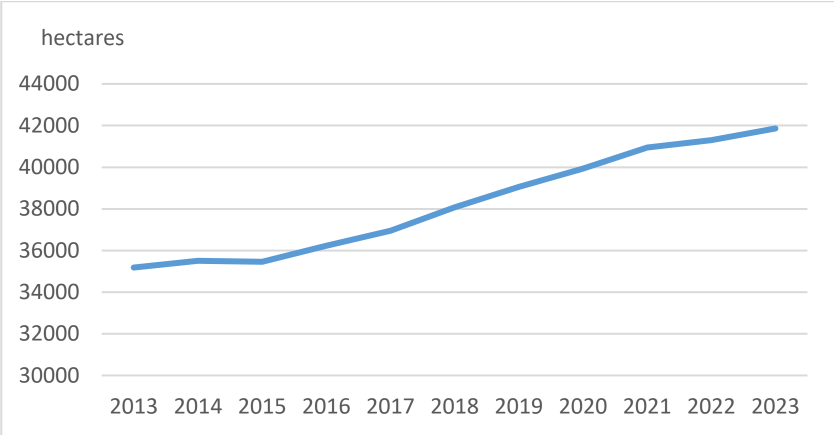


Source: Coriolis, 2023a.

1.6.3 Wine

Wine production has become an important sector for the New Zealand bioeconomy during the past ten years, particularly through exports. The current production area for viticulture in New Zealand was 41,860 hectares in 2023. Figure 1-30 shows that New Zealand's wine producing area grew consistently between 2013 and 2023, with an overall increase of 19 per cent in area used for viticulture during that period. The most widely planted grapes are Sauvignon blanc, Pinot noir, and Chardonnay.

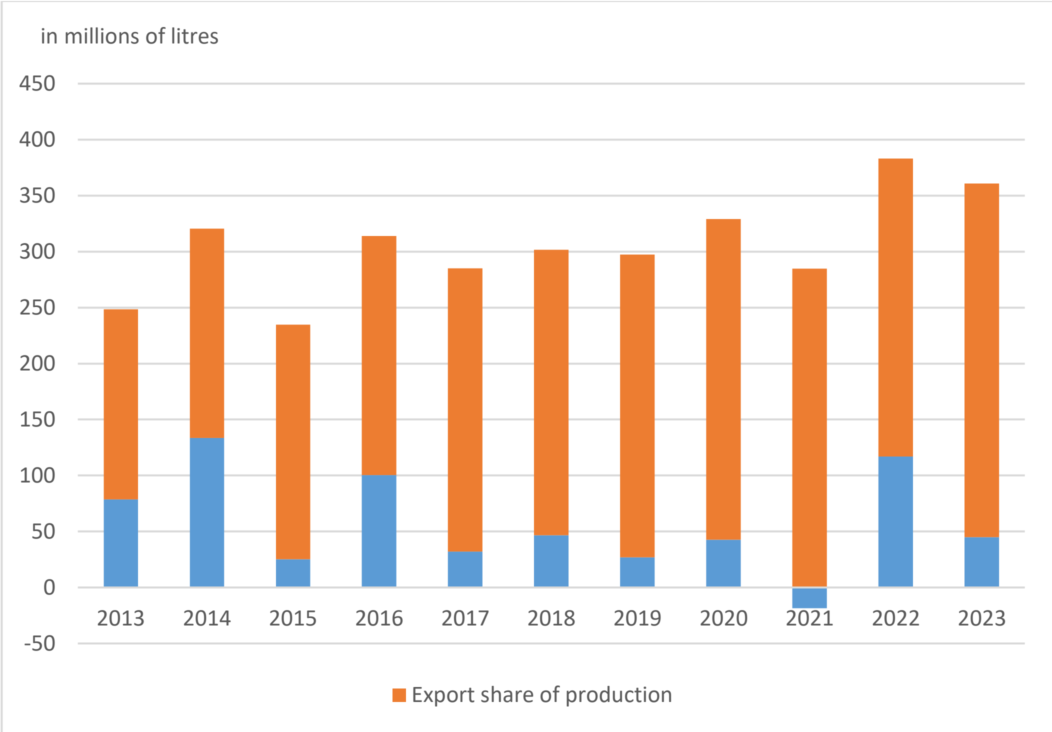
Figure 1-30: Wine producing area, in hectares, 2013 – 2023.



Source: NZ Wine, 2023.

Figure 1-31 shows volumes of wine production and exports between 2013 and 2023. In 2023, an amount of 360.7 million litres of wine were produced; this is an increase of 45 per cent during the ten years from 2013. A large share of wine production is exported. In 2023, 68 per cent (315.8 million litres) of wine was exported. Wine exports have also increased significantly over the past ten years; recording an increase of 86 per cent between 2013 and 2023. Further, total domestic sales of wine in 2023 was 85.8 million litres, this dropped by 7 per cent to 2013.

Figure 1-31: Wine production volumes and export share, in millions of litres, 2013-2023.

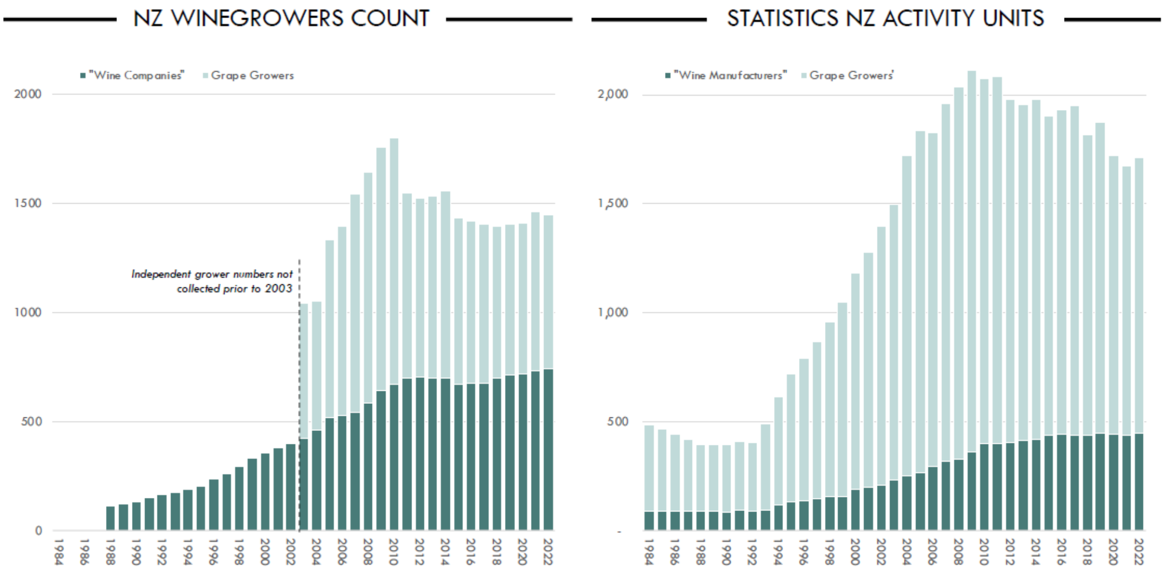


Source: NZ Wine, 2023.

Figure 1-32 below shows the number of wineries from 1984 to 2022. This shows steady rise in the number of wine companies over the period from 1984 to the early 2000's. However, according to the NZ Winegrowers count the number of grape growers grew considerable from 2002 to 2010 and then fell slightly and stabilised. According to Statistics New Zealand the number of wine growers grew considerably from 500 in 1994 to a peak of 2000 in 2010; and then has fallen since.

Figure 1-32: Number of wine industry business units in NZ, 1984-2022.

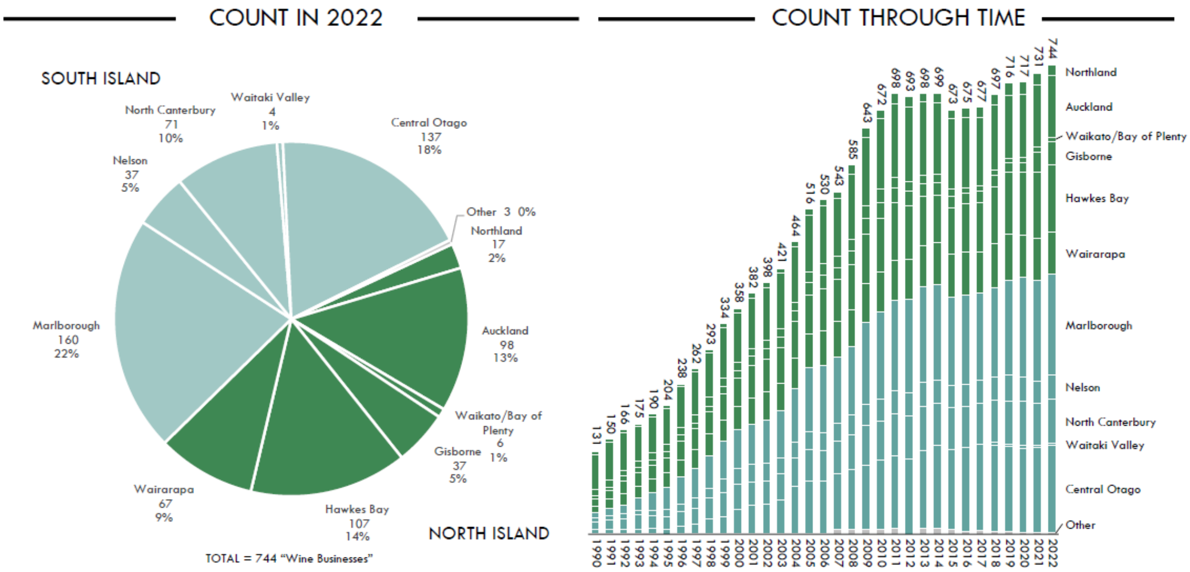
2010 grew considerable from 2002to 2012 then fell slightly.



Source: Coriolis, 2023a.

Figure 1-33 shows the number of wine businesses by region in New Zealand. The areas with greatest number are Marlborough (160), Central Otago (137), Hawke's Bay (107) followed by Auckland (98). Figure 1-33 also shows the growth in wine businesses especially areas such as Marlborough and Central Otago.

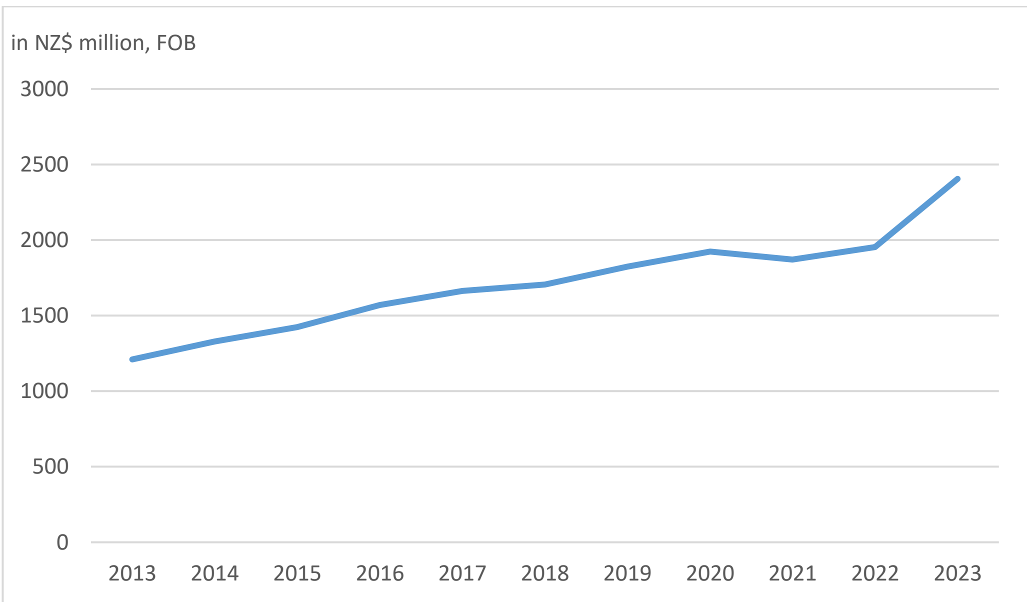
Figure 1-33: Number of wine businesses by size class in NZ, units; 1984-2022.



Source: Coriolis, 2023a.

The value of wine exports by value increased significantly between 2013 and 2023, as shown in Figure 1-34. The value of wine exports doubled between 2013 and 2023, growing from NZ$1.3 billion to NZ$2.4 billion. Main export destinations are USA, UK and Australia.

Figure 1-34: Wine exports, NZ$ million (FOB), 2013 – 2023.

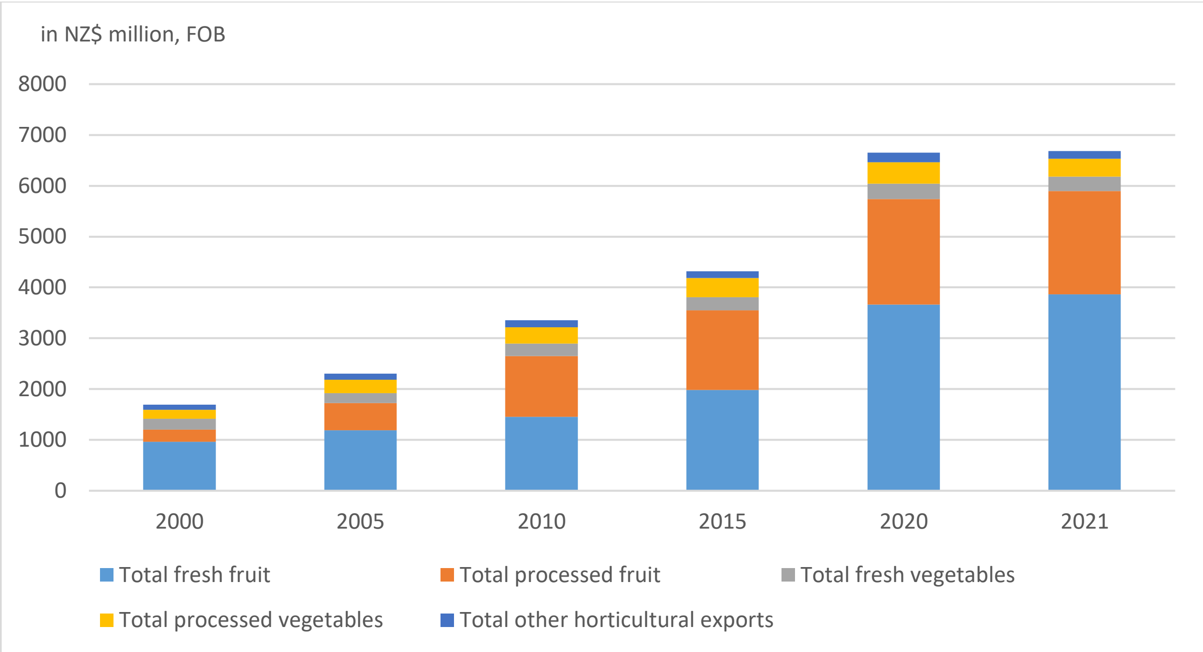


Source: NZ Wine, 2023.

1.6.4 Horticulture – Fruit and Vegetable growing

Figure 1-35 shows horticultural exports by value for selected years between 2000 and 2021. New Zealand's fresh and processed horticultural exports totalled NZ$6.7 billion in 2021, up by 0.4 per cent from the previous year. With regards to fruit exports, the main commodities shipped overseas are kiwifruit, grape wine, apples and avocados. At 40 per cent by value, kiwifruit was the highest value horticultural export crop in 2021. With regards to vegetable exports, the main commodities shipped overseas are onions, potatoes, peas and squash. Main export destinations for horticultural exports in 2021 were Continental Europe, Australia, China, USA and Japan.

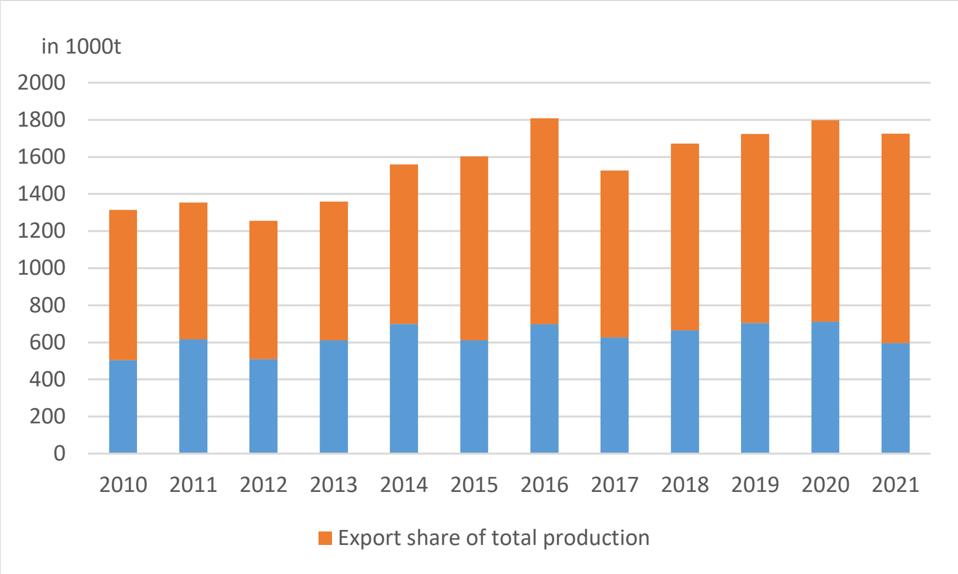
Figure 1-35: **Horticultural exports, NZ$ million (FOB), selected years.**



Note: This includes grape wine/ wine production.
Source: Fresh Facts, 2021.

Focussing on fruit (excluding wine), Figure 1-36 shows volumes of production and exports between 2010 and 2021. In 2021, a total of yield of 1.7 million tonnes was recorded; this is an increase of 31 per cent between 2010 and 2021. Export quantities have increased as well over time, growing by 40 per cent between 2010 and 2021. Most of fruit produced in New Zealand is exported. In 2021, of the 1.7 million tonnes produced, 1.1 million tonnes were exported; this is a share of 66 per cent from total production. With regards to domestic consumption, New Zealanders consumed 389,000 tonnes of fruits in 2021, this was up from 372,000 tonnes (+5 per cent) in 2010.

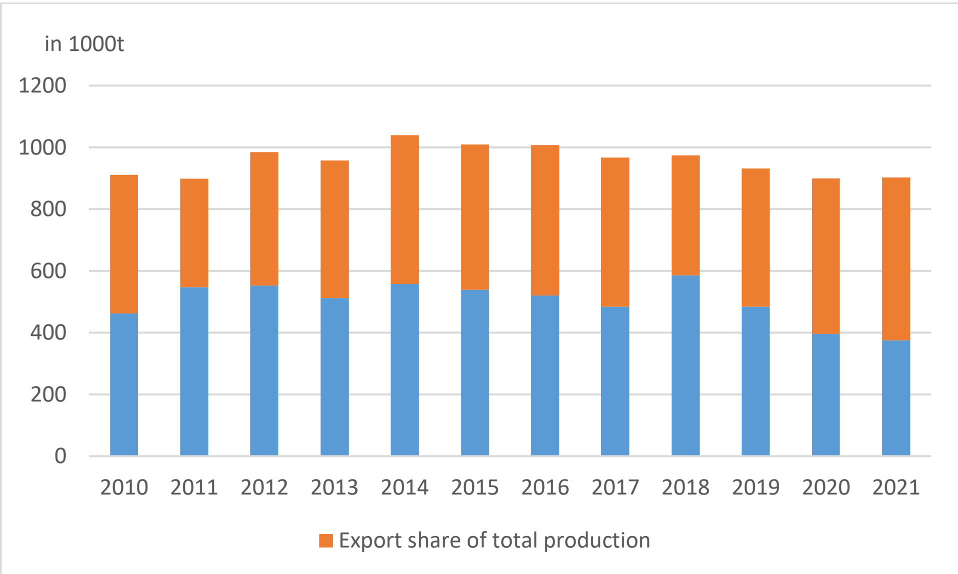
Figure 1-36: Fruit production volumes and export share, in 1000t, 2010 – 2021.



Source: FAO, 2023.

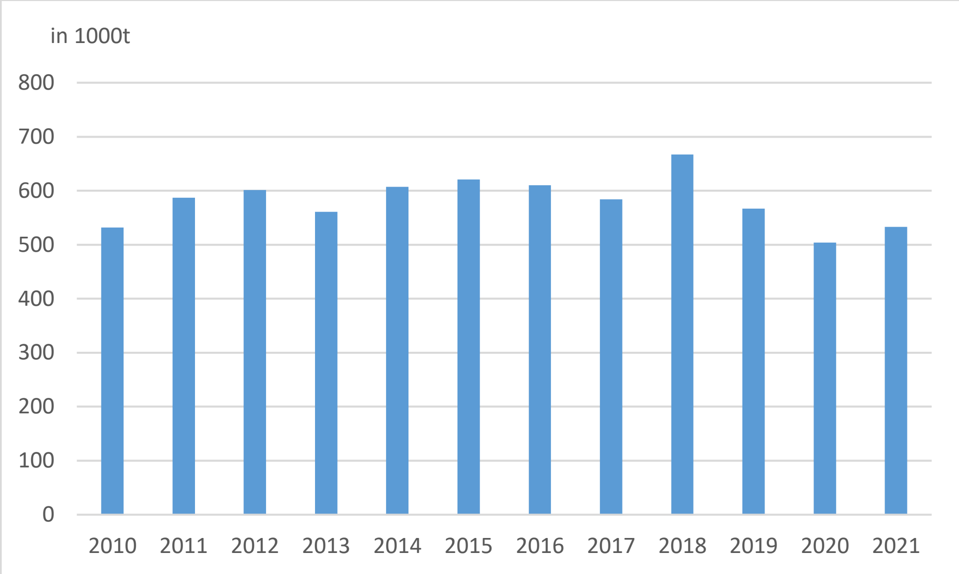
Vegetable production and export volumes between 2010 and 2021 are shown in Figure 1-37. In 2021, a total yield of 903,000 tonnes was recorded, this is a drop of 1 per cent from 2010. In contrast, export quantities have increased during that period, growing by 18 per cent between 2010 and 2021. A large amount of vegetables produced in New Zealand was exported in 2021. Of the 903,000 tonnes produced, 528,000 tonnes were exported; this is a share of 58 per cent. Domestically, New Zealanders consumed 533,000 tonnes of vegetables in 2021, unchanged from 2010 (see Figure 1-38).

Figure 1-37: Vegetable production volumes and export share, in 1000t, 2010 – 2021.



Source: FAO, 2023.

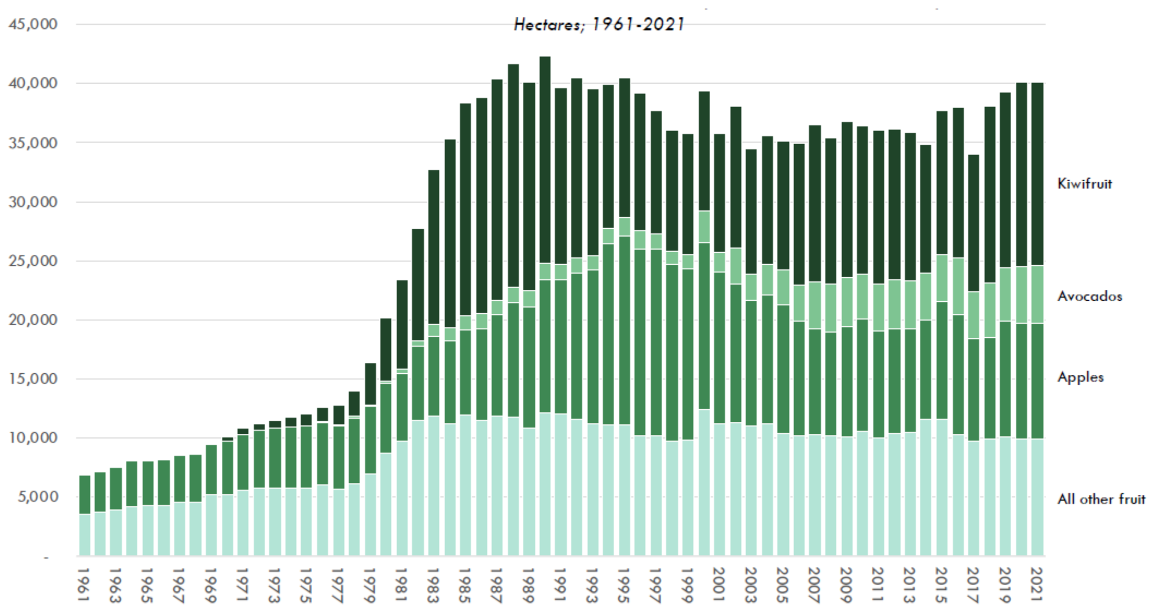
Figure 1-38: Vegetable domestic consumption, in 1000t, 2010 – 2021.



Source: FAO, 2023.

Figure 1-39 shows the area in fruit by type in New Zealand 1961 to 2021. The area for fruit grew slightly from 1961 to the early 1980's. The area then grew considerable mainly due to the growth in kiwifruit but also apples until the late 1980's when it stabilised.

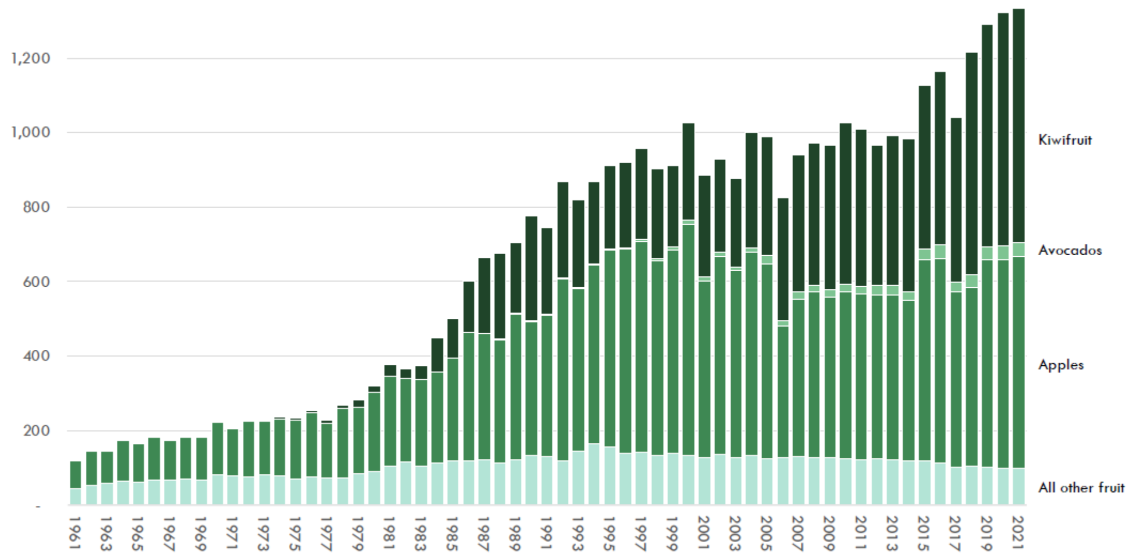
Figure 1-39: Total area in fruit in NZ (excl. grapes), in hectares, 1961 – 2021.



Source: Coriolis, 2023a.

Figure 1-40 shows that total volume of fruit produced in New Zealand from 1961 to 2021. This shows the growth from the mid 1980's especially in both kiwifruit and apple production.

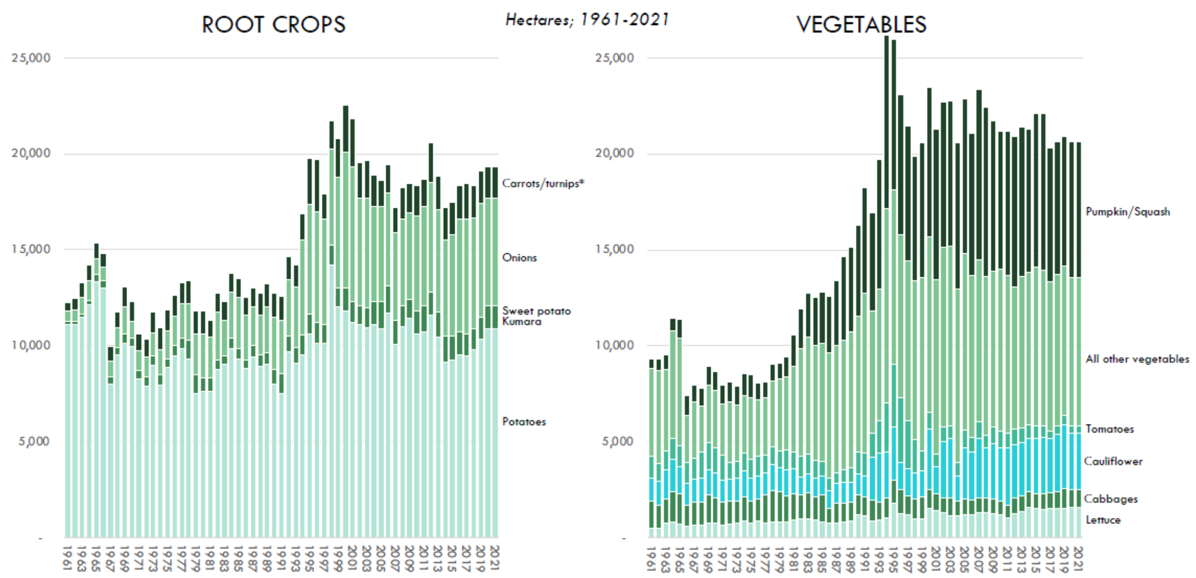
Figure 1-40 Total fruit production in NZ (excl. grapes), in 1000t, 1961 – 2021.



Source: Coriolis, 2023a.

Figure 1-41 shows that the area in root crops fluctuated from 1961 to the early 1990's then grew peaking in the early 2000's then falling slightly, mainly due to the change in area of onions. The area of vegetables was relatively stable until the mid 1980's when it grew especially due to the increase in pumpkin/squash area.

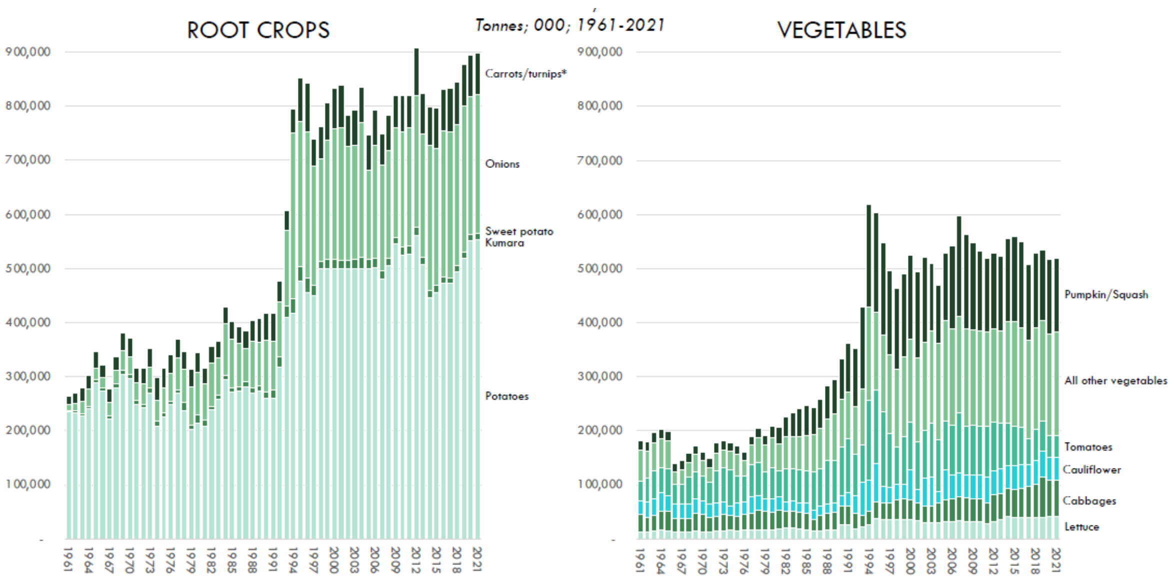
Figure 1-41: Total area in vegetables/ root crops in NZ, in hectares, 1961 – 2021.



Source: Coriolis, 2023a.

Figure 1-42 shows the total production of root crops and vegetables in New Zealand. This reflects the changes in area and shows the impact of the growth in onion production since the early 1990's. It also shows the growth in vegetable production from 1961 to the early 1990's and since then stabilised.

Figure 1-42: Total production of vegetables/ root crops in NZ, in tonnes, 1961 – 2021.

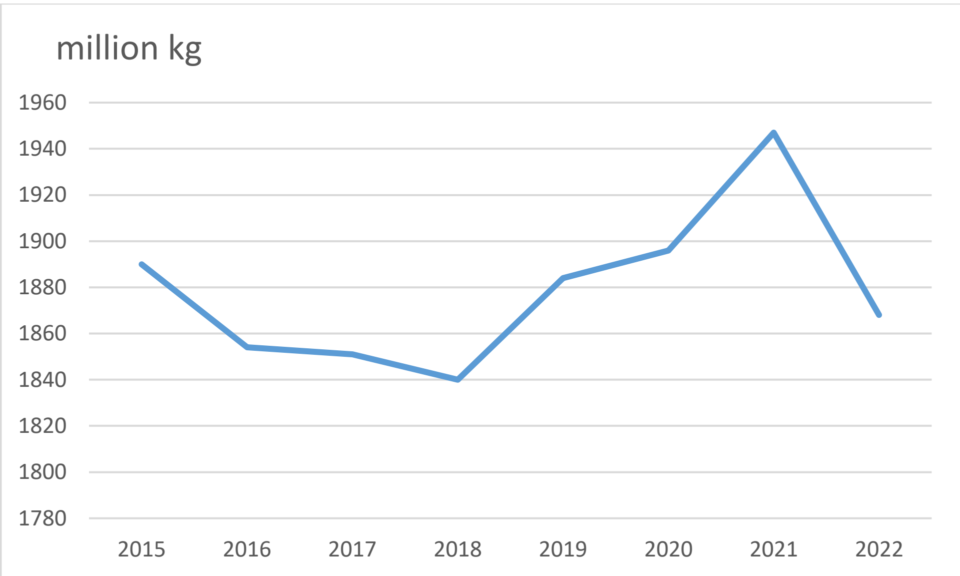


Source: Coriolis, 2023a.

1.6.5 Dairy

The dairy sector is the most important industry for New Zealand's bioeconomy. Figure 1-43 gives an analysis of milksolids production in New Zealand between 2015 and 2022. In 2022, an amount of 1.86 billion kilo milksolids were produced, dropping by 4 per cent from the previous year. Over time, production of milksolids fluctuated slightly between 1.84 billion kilo milksolids (lowest volume produced in 2018) and 1.95 billion kilo milksolids (highest volume produced in 2021) during this period. The spike in 2021 was due to favourable weather conditions.

Figure 1-43: Milk solids production, in million kg, 2015 – 2022.



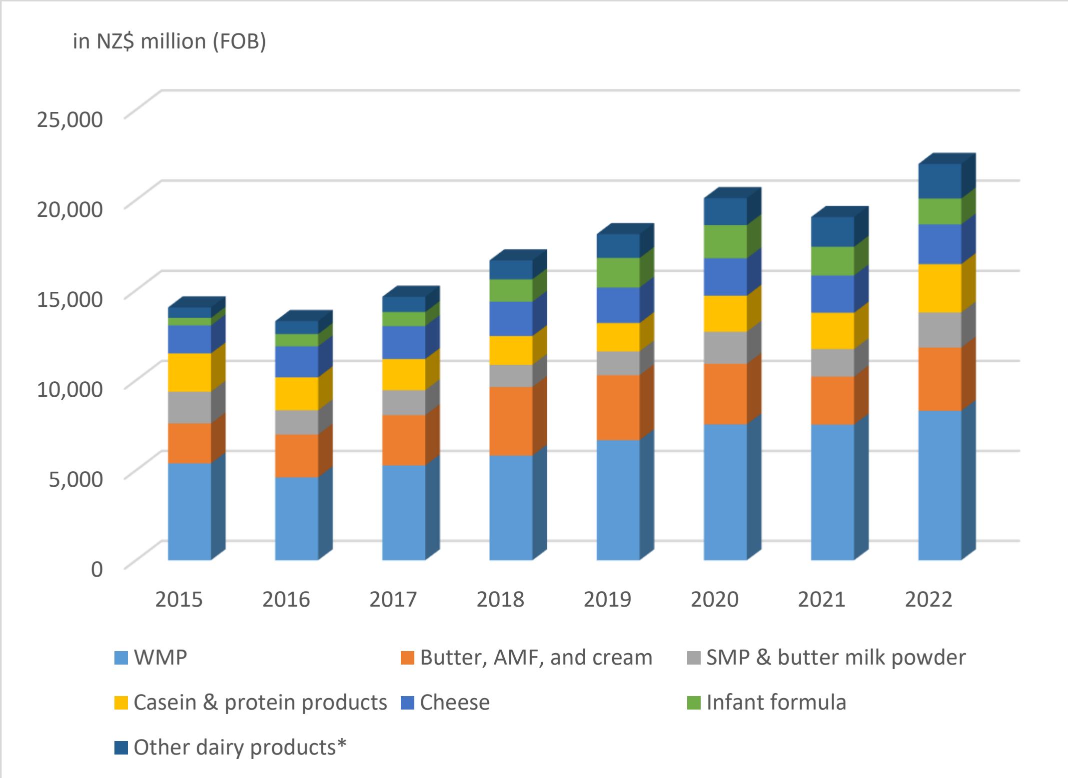
Source: LIC, 2023.

Dairy products are the highest income earner for the New Zealand bioeconomy. Unlike most countries, around 95 per cent of New Zealand's dairy produce is exported, including 95 per cent of butter, 80 per cent of skim milk power and 99 per cent of whole milk powder.

Figure 1-44 shows dairy exports by commodity between 2015 and 2022. In 2022, the total value of dairy exports was NZ$22 billion, this is an increase of 15 per cent from the previous year. In 2022, the largest share of dairy commodities was whole milk powder (WMP), representing 38 per cent of the total, followed by butter, animal fats (AMF) and cream representing 16 per cent of total, then casein and protein products, accounting for 12 per cent of the total.

Dairy exports have increased steadily over time. Figure 1-44 shows that between 2015 and 2022, dairy exports grew by 57 per cent, from NZ$14 billion to NZ$22 billion in 2022. Main export destinations are China, United States of America (USA) and Australia.

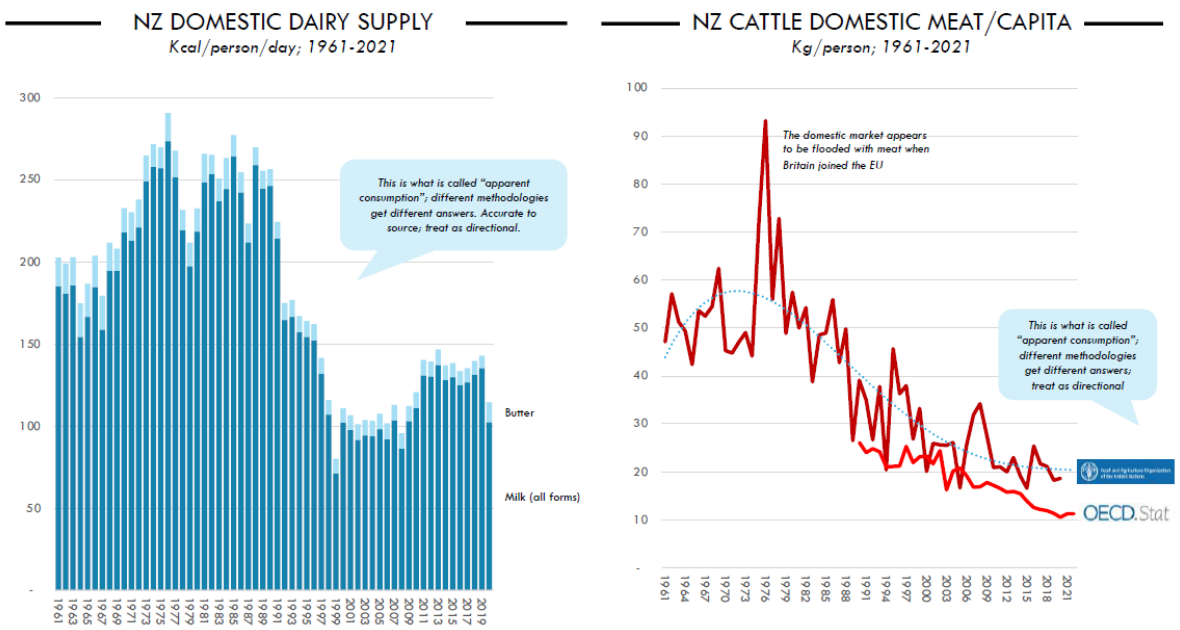
Figure 1-44: Dairy exports by commodity, in NZ$ million (FOB), 2015 – 2022.



Source: MPI, 2019a; 2023a.

Figure 1-45 shows the equivalent of dairy and beef consumption in New Zealand from 1961 to 2021. This shows that dairy consumption grew until the mid-1980's, then fluctuated and declined until the 2000's after which it remains stable. In the case of beef consumption, this grew from 1961 peaking in 1976, then has fallen consistently ever since.

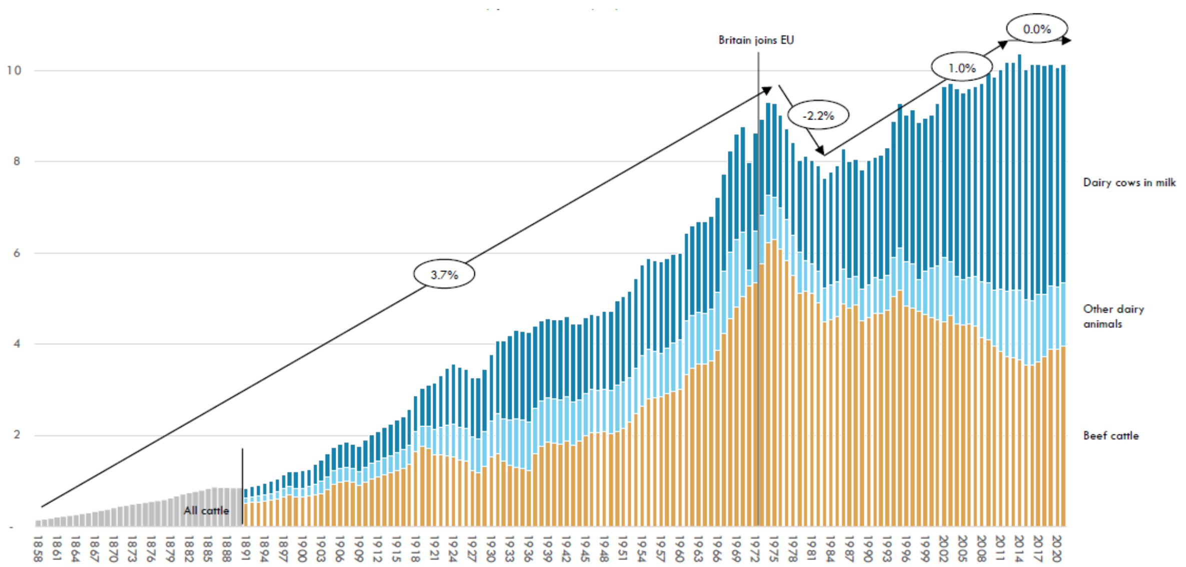
Figure 1-45: Dairy supply and beef consumption in NZ, 1961 – 2021.



Source: Coriolis, 2023a.

Figure 1-46 shows the number of cattle by type from 1858 to 2020. This shows the growth in cattle over this period until the early 1970's especially in beef cattle. Cattle numbers declined over the 1970's especially beef cattle. However, cattle numbers started to increase again in early 1980's, especially the number of dairy cattle until the early 2000's. Growth appears to have plateaued at around 2014.

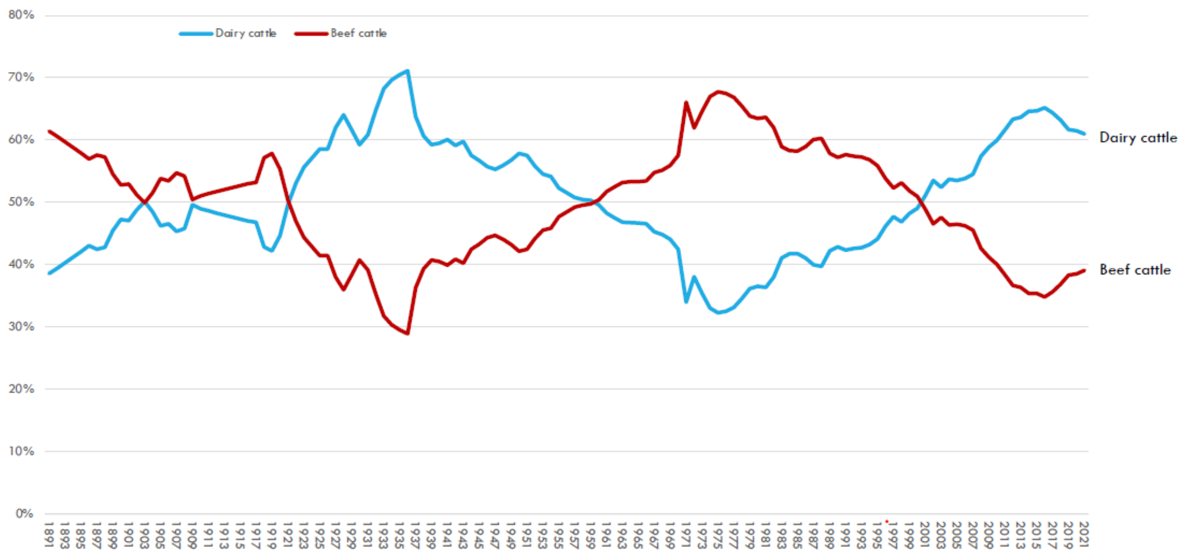
Figure 1-46: Cattle inventory, NZ, per head, 1958 – 2020.



Source: Coriolis, 2023a.

Figure 1-47 shows that the New Zealand cattle system has shifted between a meat and a dairy focus multiple times in its history.

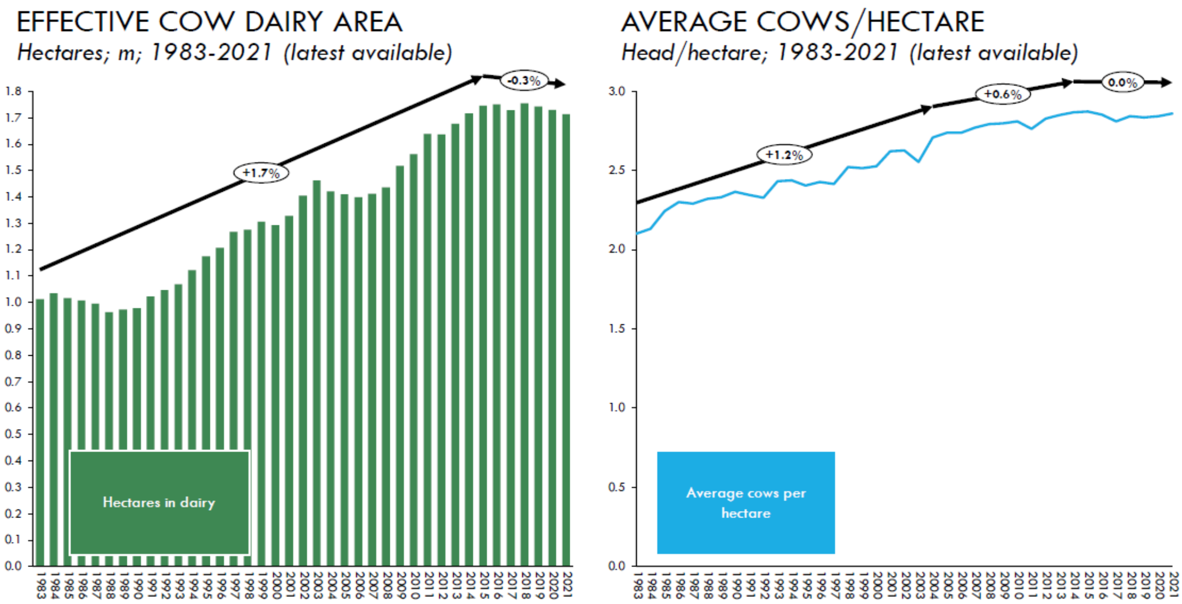
Figure 1-47: Percentage of NZ cattle inventory by sector focus, 1891-2021.



Source: Coriolis, 2023a.

Figure 1-48 shows the area focussed on dairy production and the average stocking rate. This shows the increase in dairy area from 1983 to the mid 2010's, and then stabilises. The stocking rate also grew to the mid 2010's, then has remained constant.

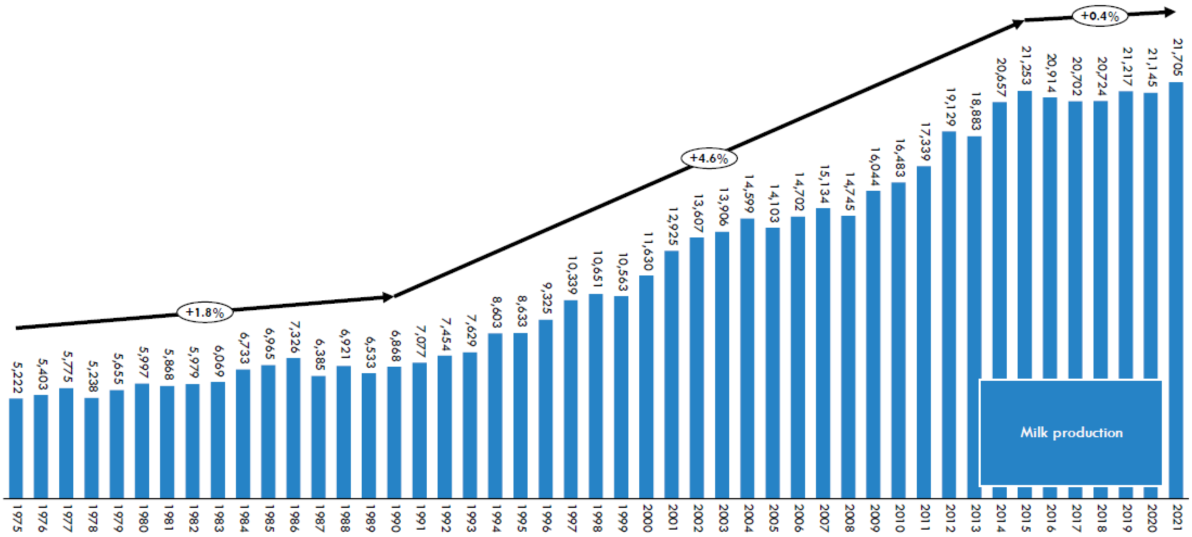
Figure 1-48: Dairy statistics, 1983 - 2021.



Source: Coriolis, 2023a.

Figure 1-49 shows that milk production rose only slightly from 1975 to 1990, then it grew considerably until the mid-2010's and has not stabilised.

Figure 1-49: Dairy cow milk production, million litres, 1975 – 2021.



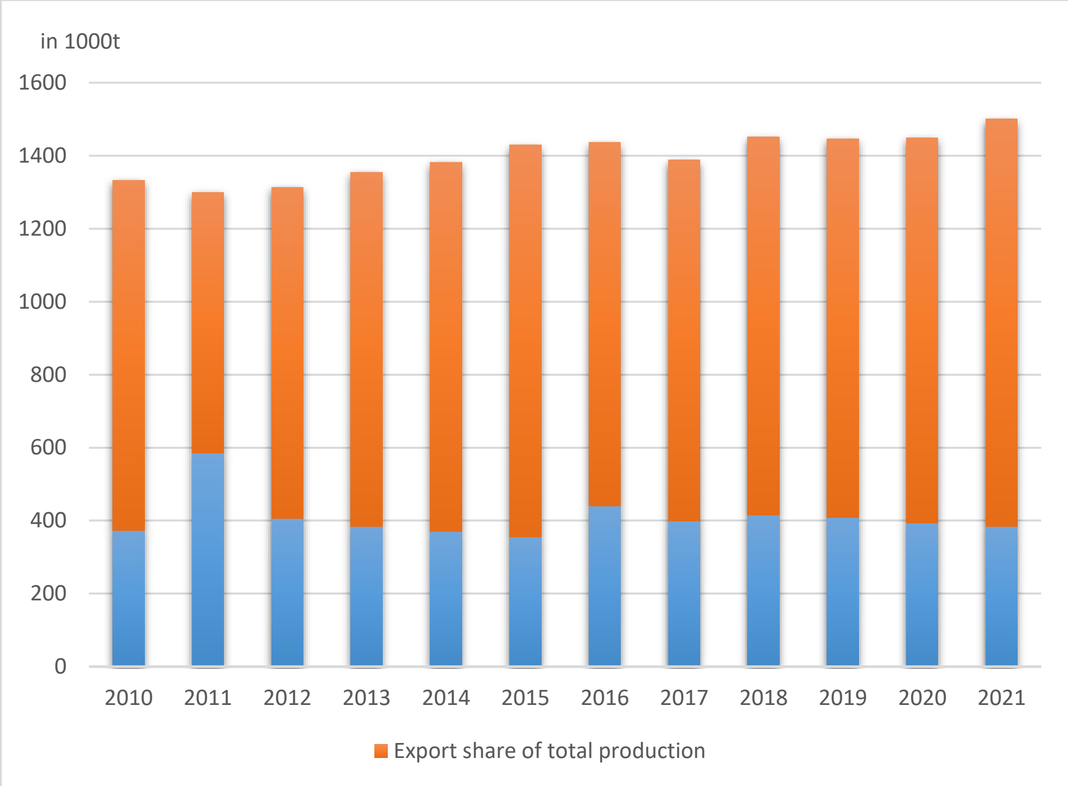
Source: Coriolis, 2023a.

1.6.6 Beef

Figure 1-50 shows the volume of total beef production, including export volumes, between 2010 and 2021. In 2021, 1.5 million tonnes of beef were produced in New Zealand, this was an increase of 4 per cent to the previous year. Of total beef production in 2021, 74 per cent (1.1 million tonnes) were exported.

Between 2010 and 2021, beef production increased by 13 per cent. Each year, more than 70 per cent of beef produced is exported. Main export countries are the United States (USA), China and the United Kingdom (UK). Further, in 2021 417,000 tonnes were used for domestic consumption which was an increase of 3 per cent from the previous year.

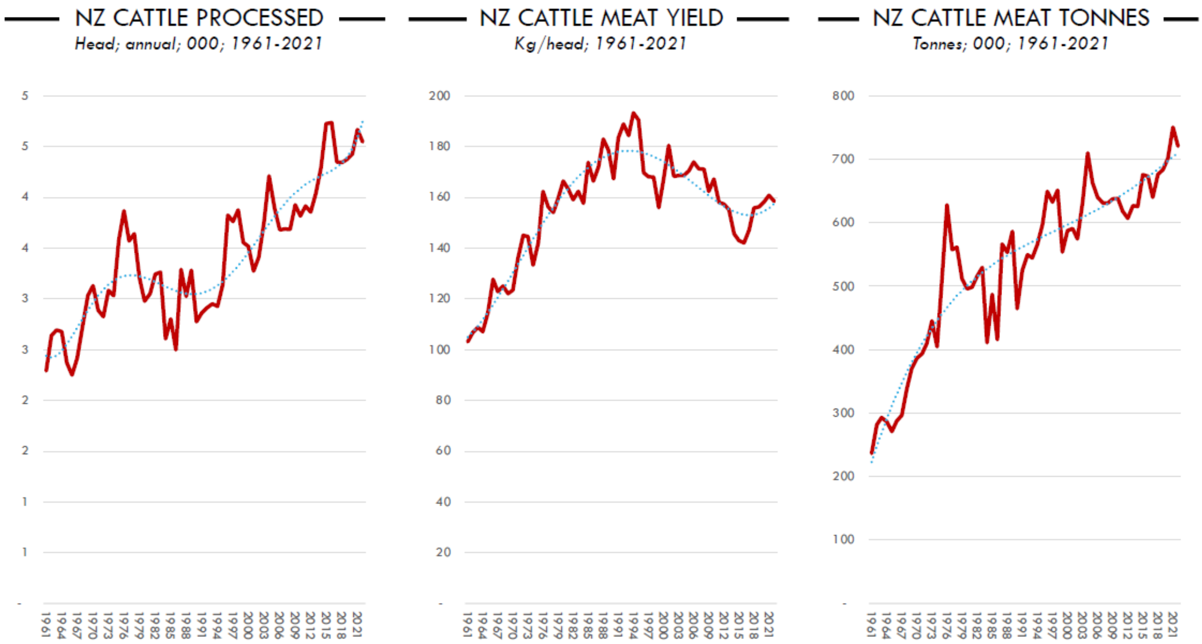
Figure 1-50: Beef production volumes and export share, in 1000t, 2010 – 2021.



Note: (1) Bovine Meat: Meat, cattle, Meat, cattle, boneless (beef & veal), Meat, beef, dried, salted, smoked, Meat, extracts, Meat, beef and veal sausages, Meat, beef, preparations, Meat, beef, canned, Meat, homogenised preparations, Meat, buffalo.
Source: FAO, 2023.

Figure 1-51 shows the number of cattle processed, the yield in Kg per head and then the tonnes of meat produced. This shows the growth numbers of cattle processed over the period with peaks, especially in the mid 1970's. Yield increased from 1961 to the late 1990's when it fell and recovered from the mid-2010's. Therefore, total production in tonnes has increased over the period with again a peak in the mid-1970's.

Figure 1-51: Beef production and yield, 1961 to 2021.

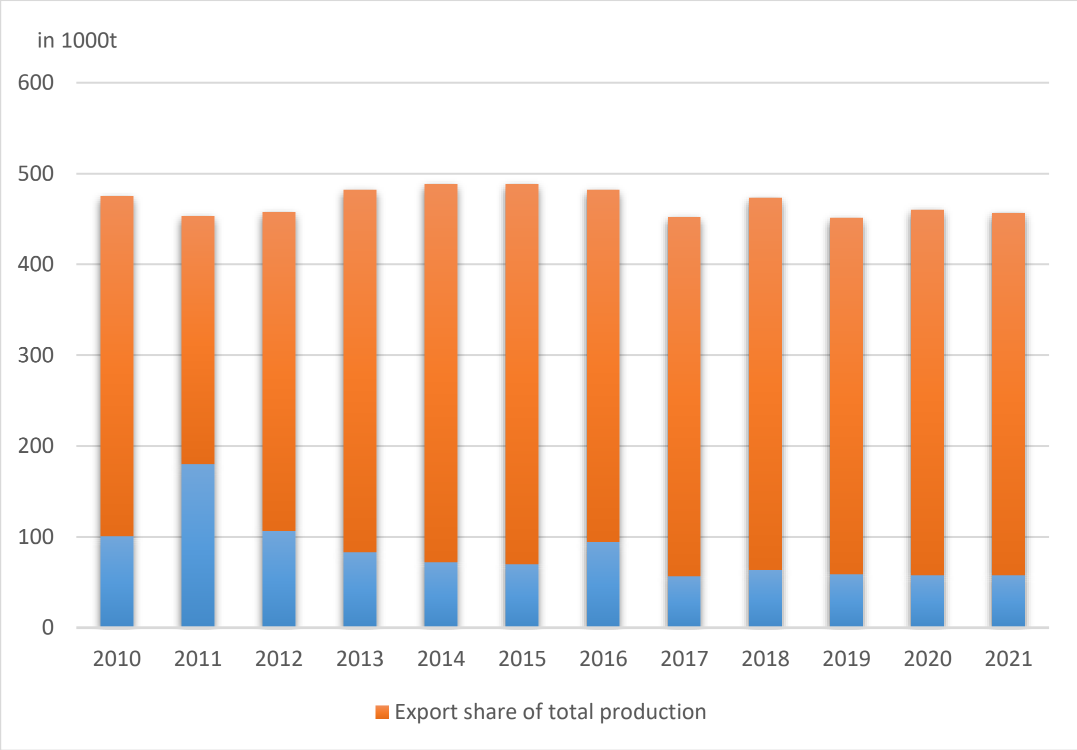


Source: Coriolis, 2023a.

1.6.7 Sheep

Figure 1-52 shows the volume of sheepmeat production, including exported volumes, in New Zealand between 2010 and 2021. In 2021, 456,000 tonnes of sheepmeat were produced in New Zealand, which was a slight decrease of 1 per cent compared to the previous year. Of total sheepmeat production in 2021, 87 per cent (398,000 tonnes) was exported. Between 2010 and 2021, sheep production decreased by 4 per cent. Each year, more than 80 per cent of sheepmeat produced is exported. Main export countries are China, the United States (USA) and the United Kingdom (UK). Similar to production, domestic consumption dropped in the past ten years. Sheepmeat consumption in New Zealand decreased by 40 per cent between 2010 and 2021 from 475,000 in 2010 to 62,000 tonnes in 2021.

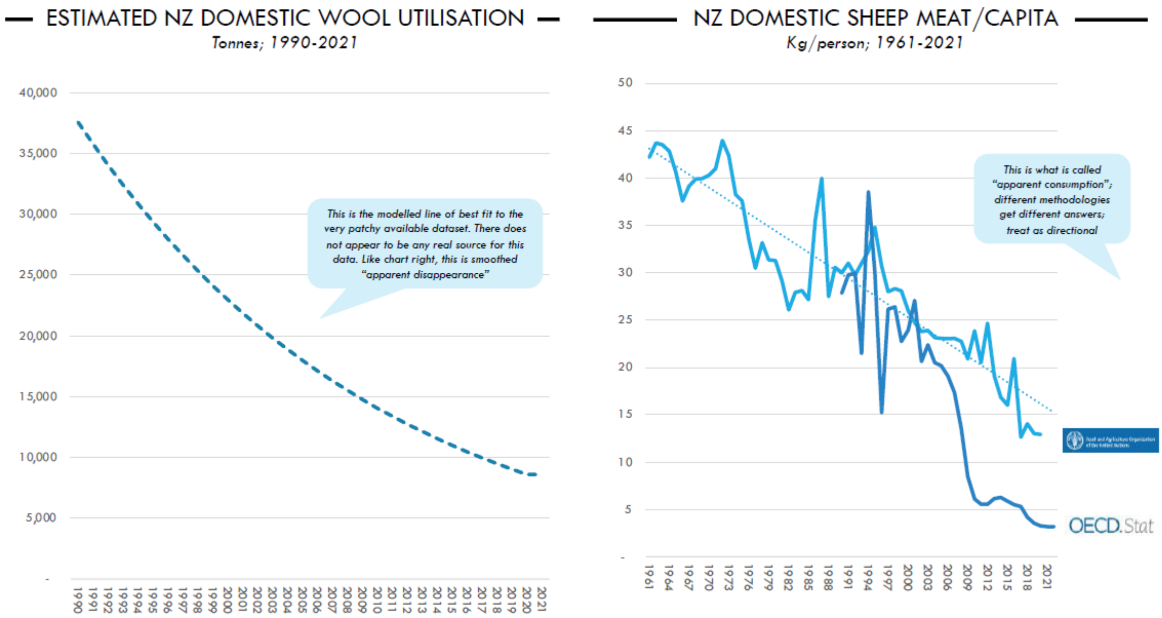
Figure 1-52: Sheepmeat production volumes and export share, in 1000t, 2010 – 2021.



Note: Definition Sheep: Mutton & Goat.
Source: FAO, 2023.

Figure 1-53 shows New Zealand domestic consumption for wool and sheepmeat from 1990 to 2021. The estimated consumption of wool has declined considerably over the period from around 37,500 tonnes in 1990 to under 10,000 in 2021. Sheep meat consumption has declined considerably also over the period from a peak of 45kg per person in 1973 to around 12kg per person in 2021.

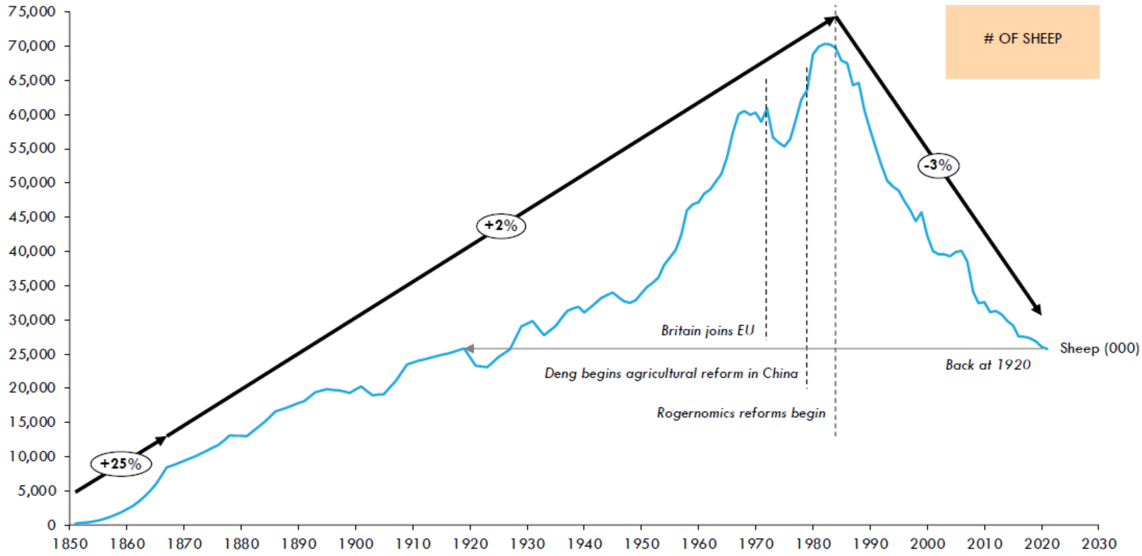
Figure 1-53: Sheepmeat and wool statistics in New Zealand.



Source: Coriolis, 2023a.

Figure 1-54 shows the number of sheep in New Zealand from 1851 to 2021. The number of sheep increased in the late 1980's. It continued to increase considerably after the second world war peaking in the early 1980's, especially after the subsides were removed. Sheep numbers have declined considerably since then. However, despite this fall in numbers, sheep production (as shown earlier) has remained constant.

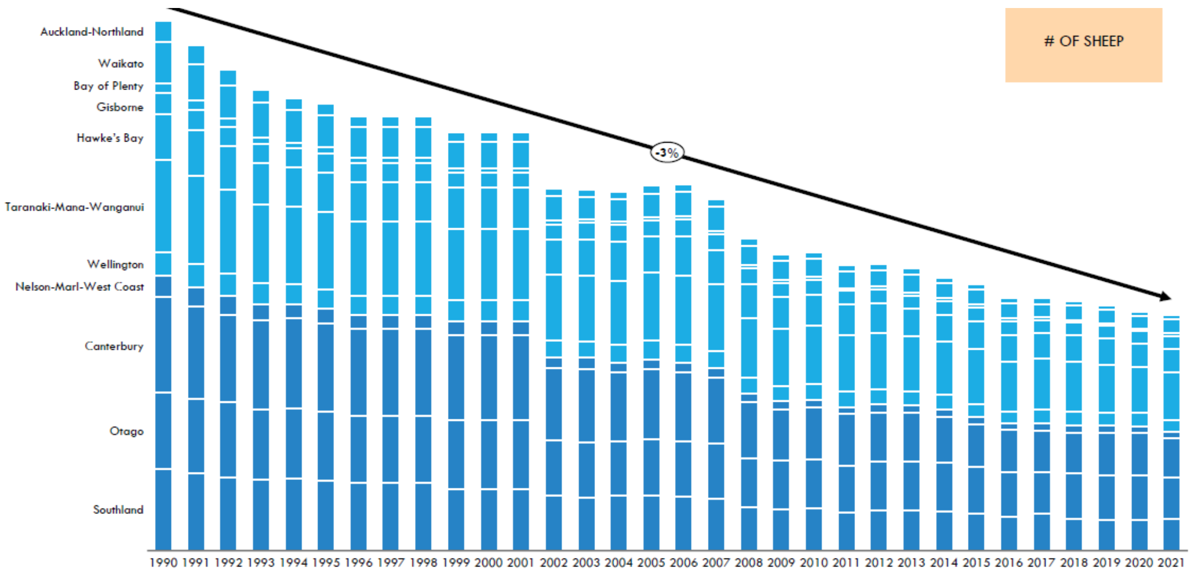
Figure 1-54: Number of sheep in NZ, head, 000, 1851 – 2021.



Source: Coriolis, 2023a.

Figure 1-55 shows that the sheep numbers decline is across all regions but particularly in regions such as Canterbury with changing land use.

Figure 1-55: Sheep in NZ by region, head; 000; 1990-2021.



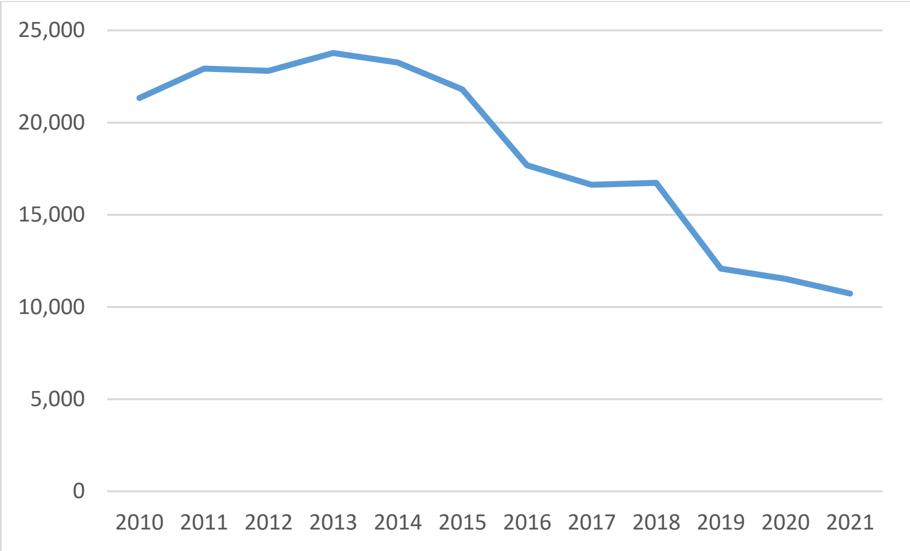
Source: Coriolis, 2023a.

1.6.8 Deer

Figure 1-56 shows the volume of venison produced between 2010 and 2021. In 2021, 10,725 tonnes of venison were produced in New Zealand, this was a decrease of 7 per cent to the previous year. Between 2010 and 2021, venison production decreased significantly by 50 per cent, from 21,339 tonnes in 2010 to 10,725 tonnes in 2021.

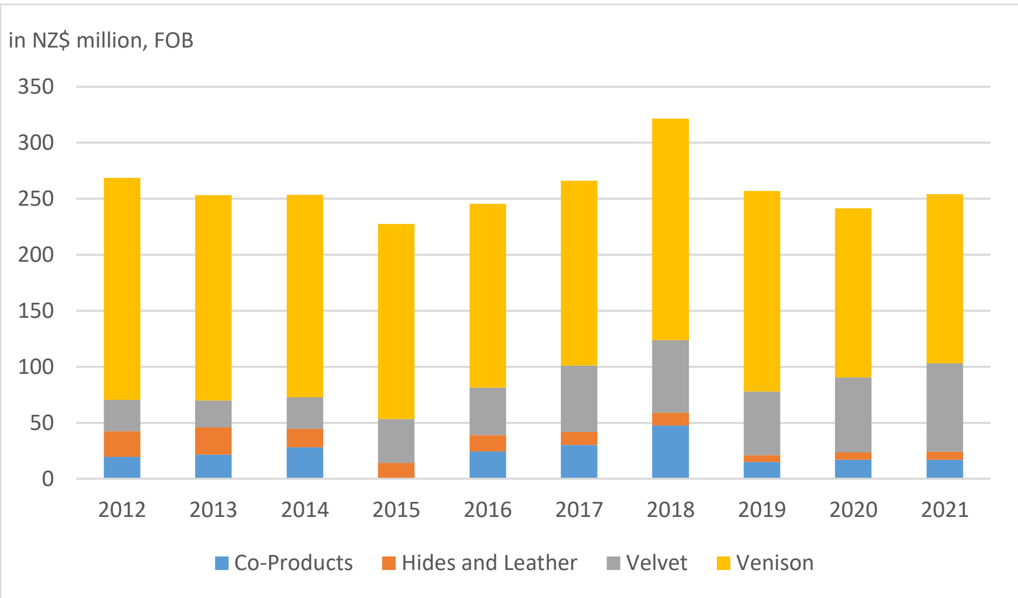
Figure 1-57 shows deer exports between 2012 and 2021. In 2021, deer commodity exports recorded NZ$254 million, this was a slight increase of 10 per cent from the previous year. In 2021, the largest share of deer commodities was venison, representing 59 per cent (NZ$151 million) of the total, followed by velvet exports (31 per cent, or NZ$79 million). Main export destinations are USA, Germany and Belgium.

Figure 1-56: Farmed venison production in tonnes (CWE), 2010 - 2021.



Source: Deer Industry New Zealand, 2023.

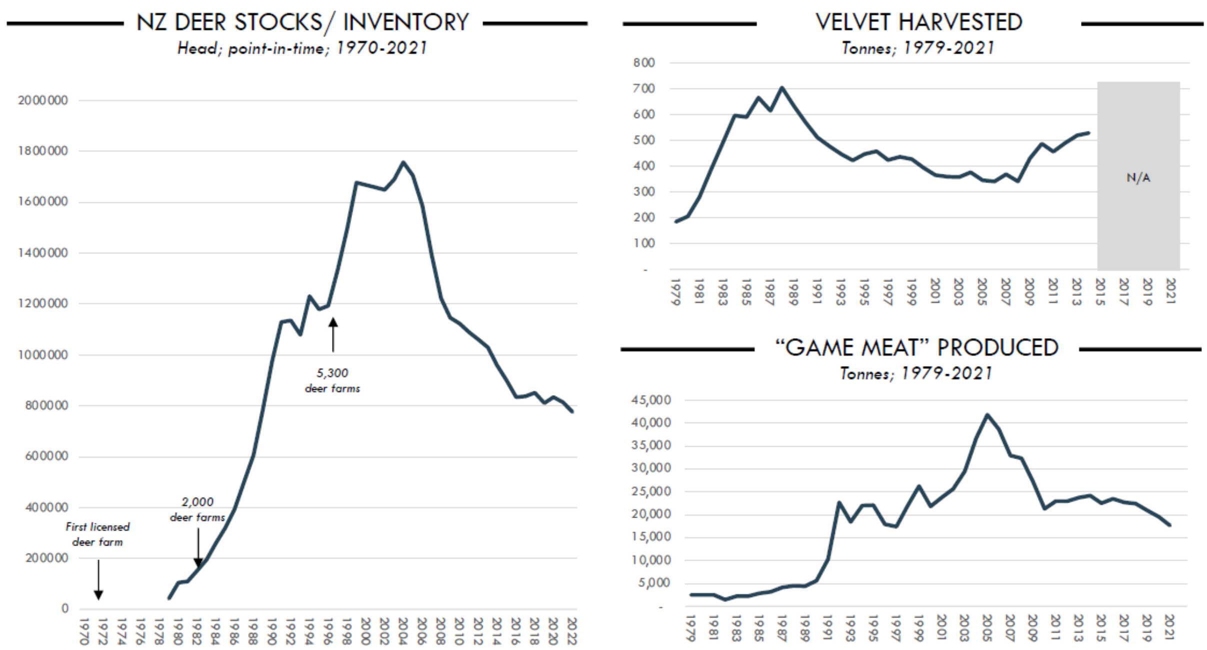
Figure 1-57: Deer exports by commodity, NZ$ million (FOB), 2012 – 2021.



Source: Deer Industry New Zealand (2023).

Figure 1-58 shows the number of deer and the production of velvet and venison from 1970 to 2021. This shows the rapid increase from 1978 to the mid-2000's in the number of deer, from nearly zero to nearly 1.8 million. Since then, numbers have declined to around 800,000 in 2021.

Figure 1-58: Deer stocks and production, 1970 -2021.



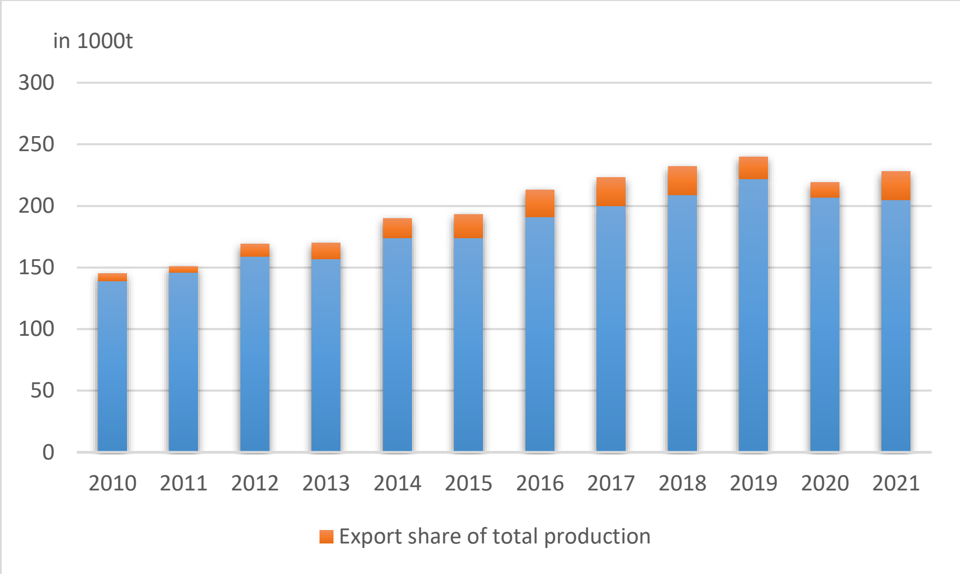
Source: Coriolis, 2023a.

1.6.9 Poultry

Figure 1-59 shows the volume of poultry production, including exports, in New Zealand between 2010 and 2021. In 2021, 238,000 tonnes of poultry were produced in New Zealand; an increase of 4 per cent from the previous year. Between 2010 and 2021, poultry production increased significantly by 57 per cent, from 145,000 tonnes in 2010 to 238,000 tonnes in 2021.

In New Zealand, poultry is predominantly produced for the domestic market. Only small amounts are exported as shown in Figure 1-59. In 2021, only 10 per cent of total poultry production was exported. However, between 2010 and 2021 poultry exports have increased by 283 per cent, from 6,000 tonnes in 2010 to 23,000 tonnes in 2021. These are still small amounts compared to other export commodities such as dairy, beef and sheepmeat.

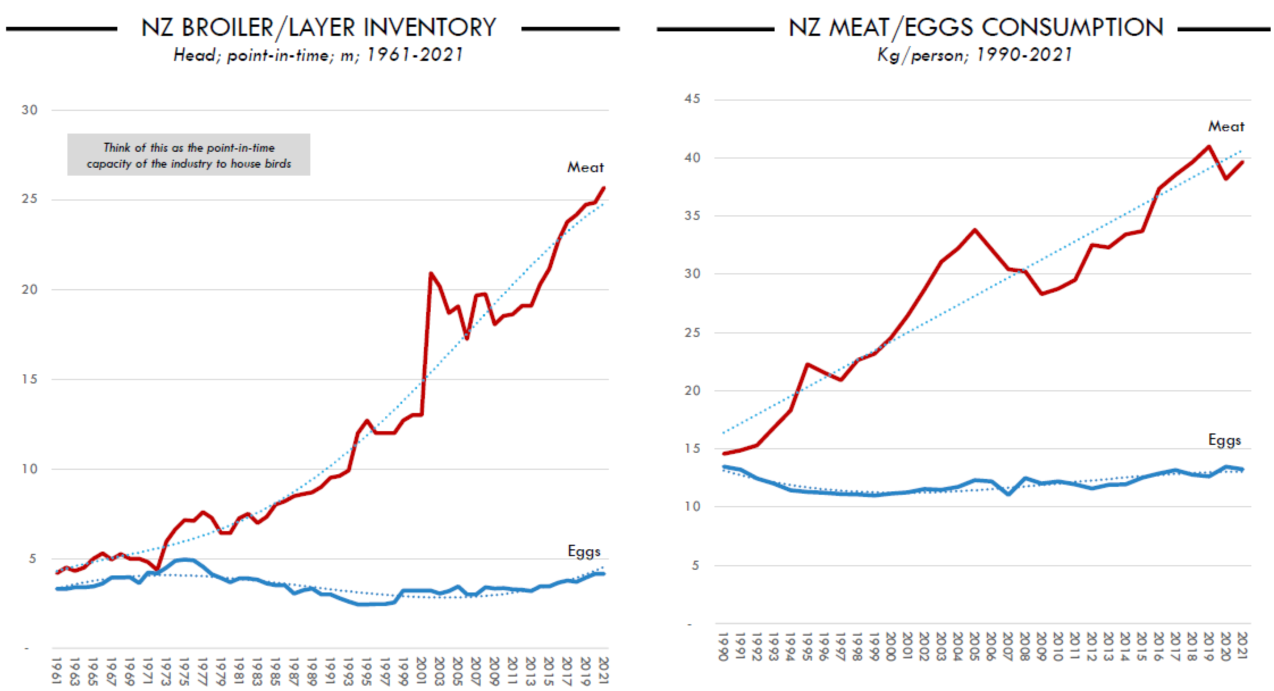
Figure 1-59: Poultry production volumes and export share, in 1000t, 2010 – 2021.



Note: Definition poultry: Meat, chicken, Fat, liver prepared (foie gras), Meat, chicken, canned, Meat, duck, Meat, goose and guinea fowl, Meat, turkey.
Source: FAO, 2023.

Figure 1-60 shows the number of chickens by broiler and layers and the domestic consumption of chicken and eggs from 1960 to 2021. This shows the rapid increase in broiler chicken and chicken consumption in New Zealand over the period; whereas, layers and egg consumption has remained constant.

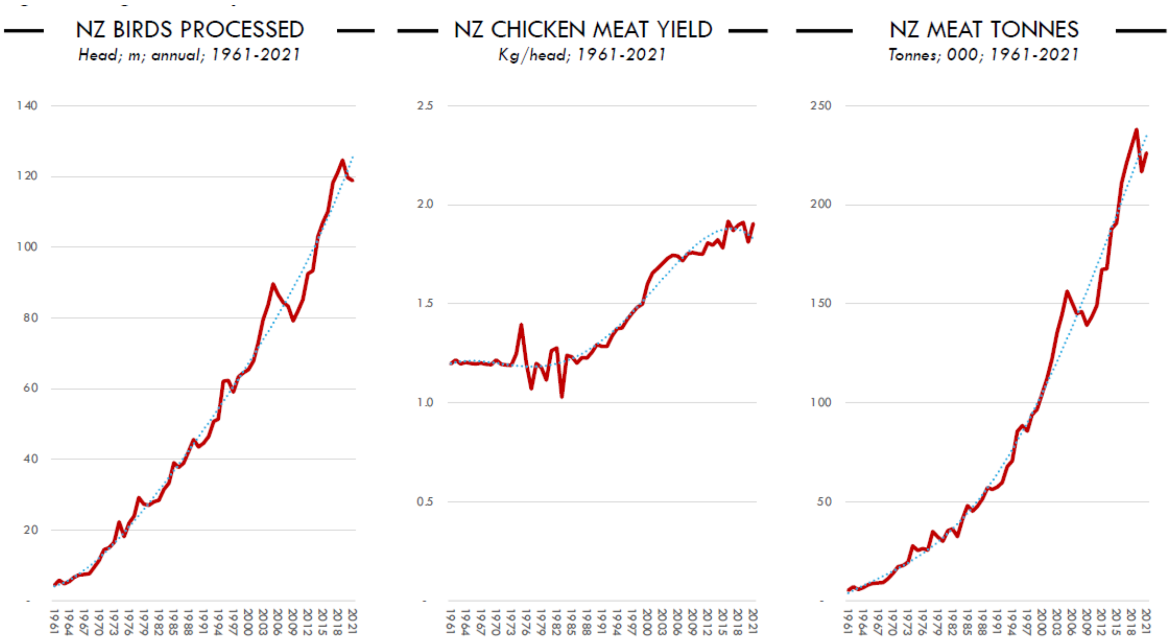
Figure 1-60: Poultry and egg statistics.



Source: Coriolis, 2023a.

Figure 1-61 shows the number of broilers, yield and thus the total meat produced in tonnes from 1961 to 2021. The growth in birds processed has been considerable from under 10 million in 1961 to 120 million in 2020. Yield, Kg per head, has also grown especially from the mid 1980's. Therefore, the production of chicken in New Zealand increased significantly from low levels in 1961 to around 220,000 in the early 2020's.

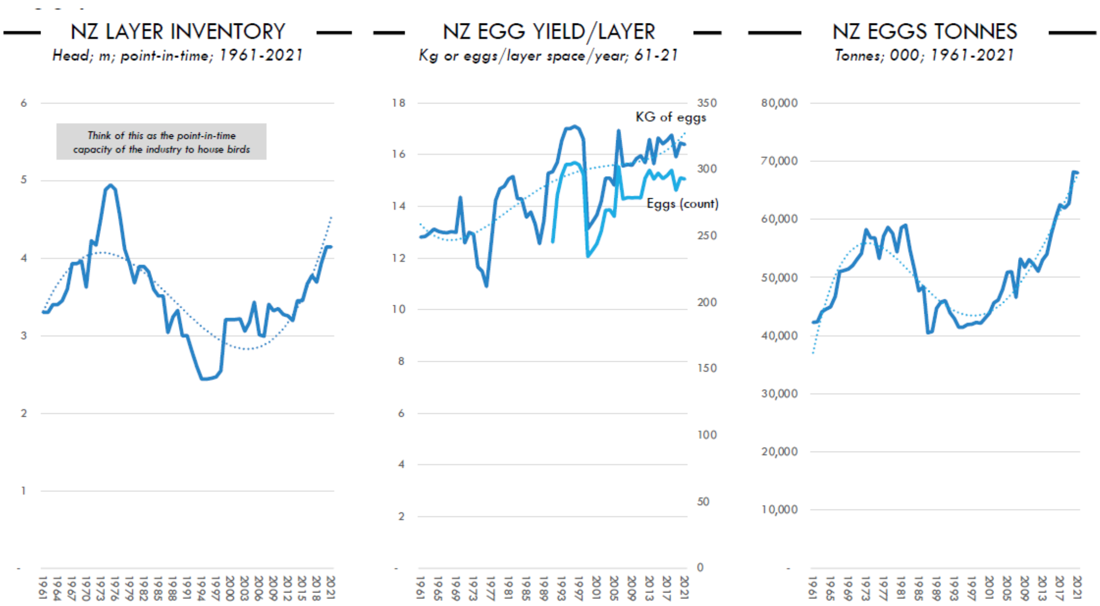
Figure 1-61: Chicken production in New Zealand, 1961-2021.



Source: Coriolis, 2023a.

Figure 1-63 shows that New Zealand egg production including the number of laying hens, yield of eggs per hen and the tonnage of eggs from 1961 to 2021. This shows the number of layers have fluctuated, yield has also fluctuated but on an upward trend. Overall production increased but then fell in the 1980's rising since then to nearly 70,000 tonnes in 2021.

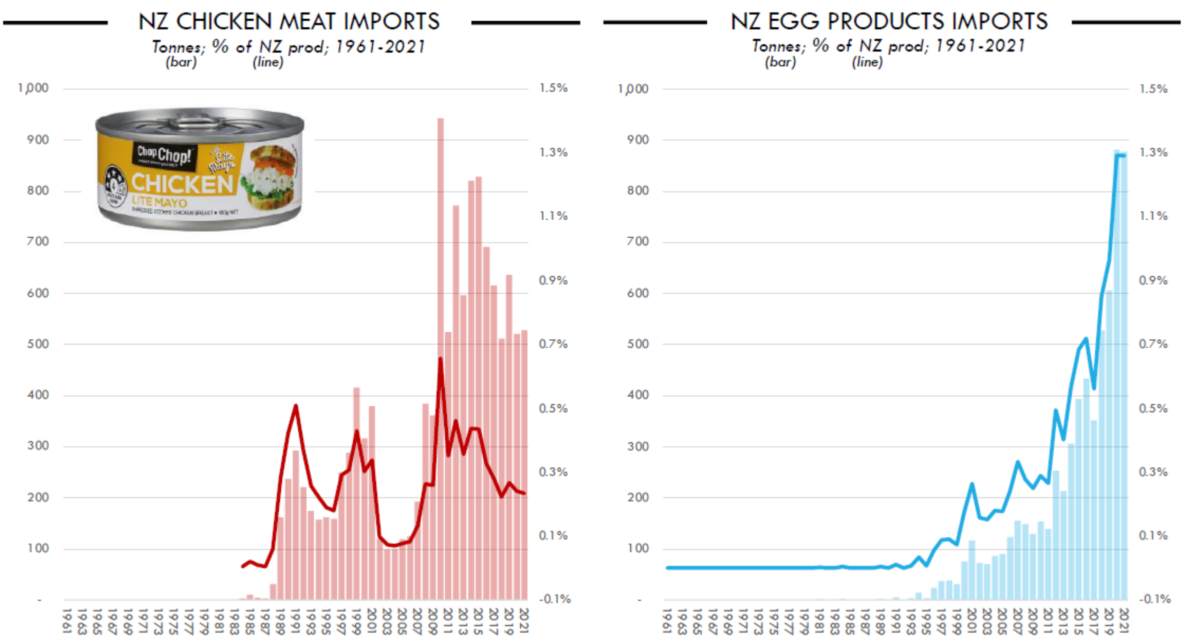
Figure 1-62: Egg production in New Zealand, 1961-2021.



Source: Coriolis, 2023a.

New Zealand imports of chicken and eggs are shown in Figure 1-63. This shows minimal imports of chicken until the mid-1980's and of eggs until the mid-1990's. New Zealand has strict biosecurity around imports and only extremely processed products can enter and volumes are close to immaterial currently.

Figure 1-63: Chicken meat and egg product imports, 1961 - 2021.



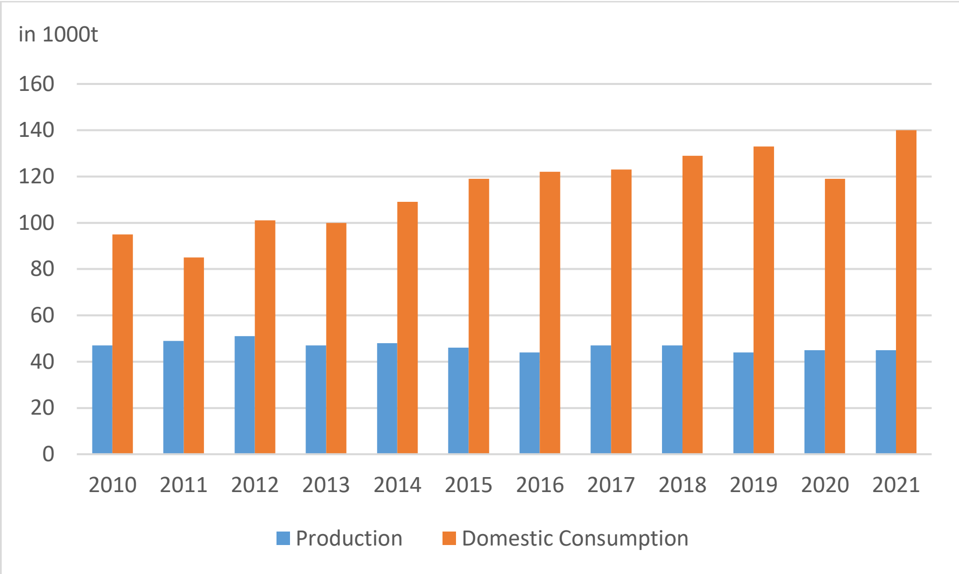
Source: Coriolis, 2023a.

1.6.10 Pork

Volumes of pigmeat production and consumption between 2010 and 2021 are presented in Figure 1-64. In 2021, 45,000 tonnes of pigmeat were produced in New Zealand; this remained unchanged from the previous year. Between 2010 and 2021, pigmeat production decreased slightly by 4 per cent, from 47,000 tonnes in 2010 to 45,000 tonnes in 2021.

In New Zealand, pigmeat is predominantly produced for the domestic market. In 2021, domestic consumption of pigmeat was 140,000 tonnes. In contrast to production, domestic consumption of pigmeat increased between 2010 and 2021, growing by 47 per cent during that period.

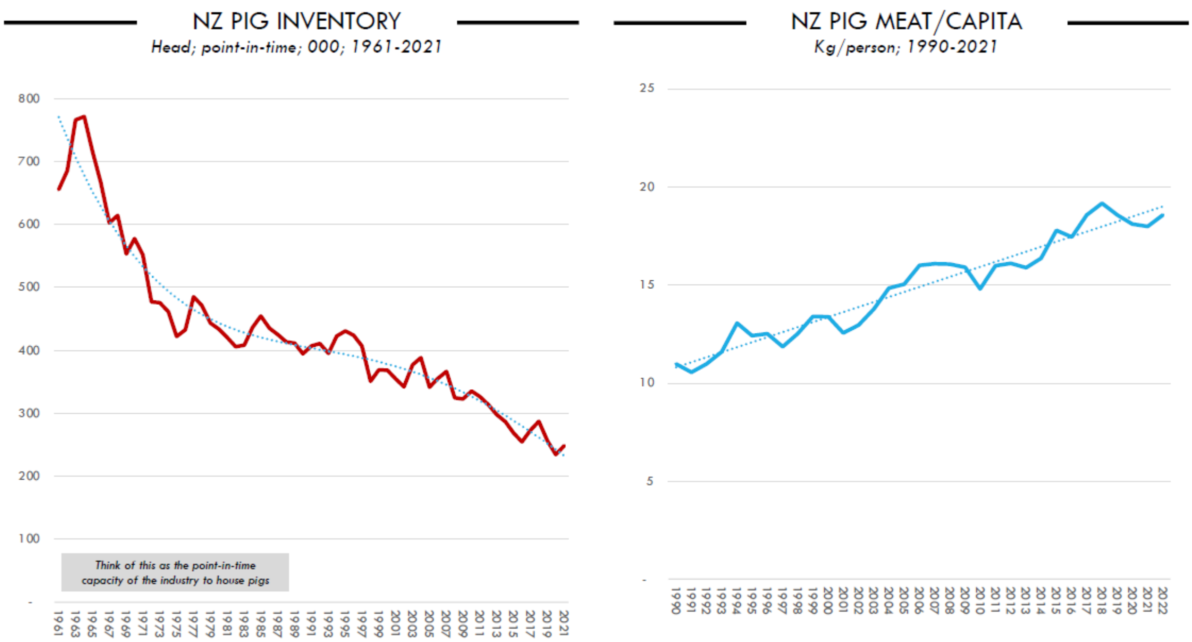
Figure 1-64: Pigmeat production and domestic consumption quantities, in 1000t, 2010 – 2021.



Note: Definition pigmeat: Meat, pig, Meat, pork, Bacon and ham, Meat, pig sausages, Meat, pig, preparations.
Source: FAO, 2023.

Figure 1-65 below shows the number of pigs in New Zealand, and their decline over the period. It also shows growing pork consumption with the gap being filled by imports as biosecurity restrictions have been eased.

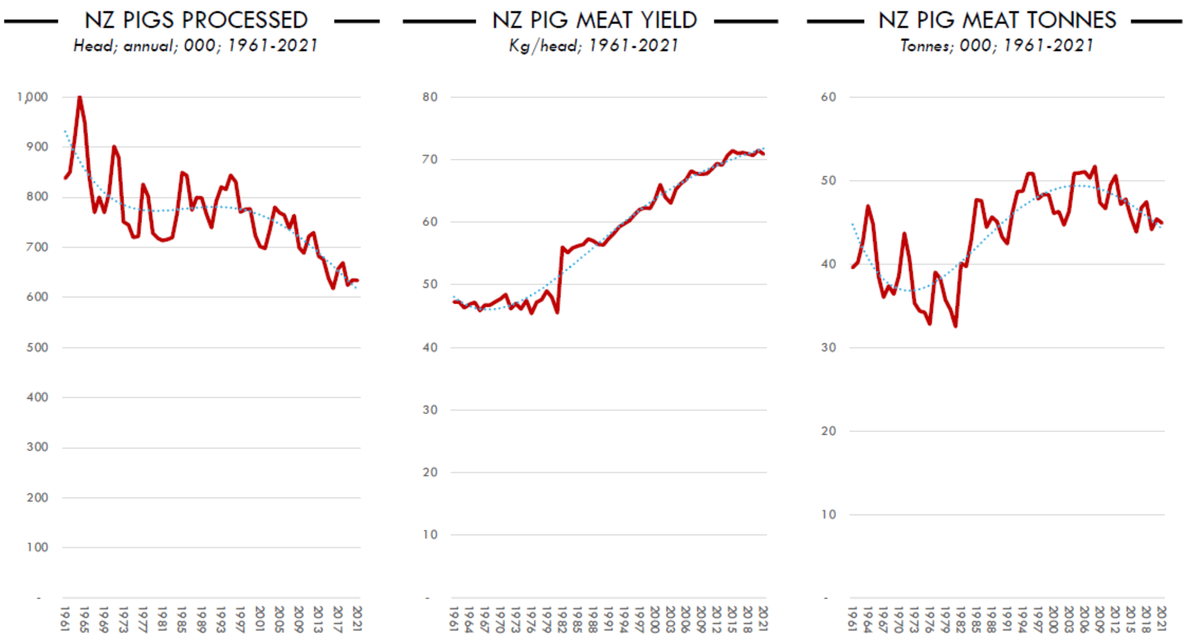
Figure 1-65: Pig numbers and domestic consumption per head, 1961 - 2021.



Source: Coriolis, 2023a.

Figure 1-66 shows the number of pigs, the average yield of meat per pig and then total domestic production from 1961 to 2021. This shows New Zealand has had falling pig numbers but stable-to-growing pig meat yields and as a consequence production has fluctuated and declined slightly since the mid 2000's.

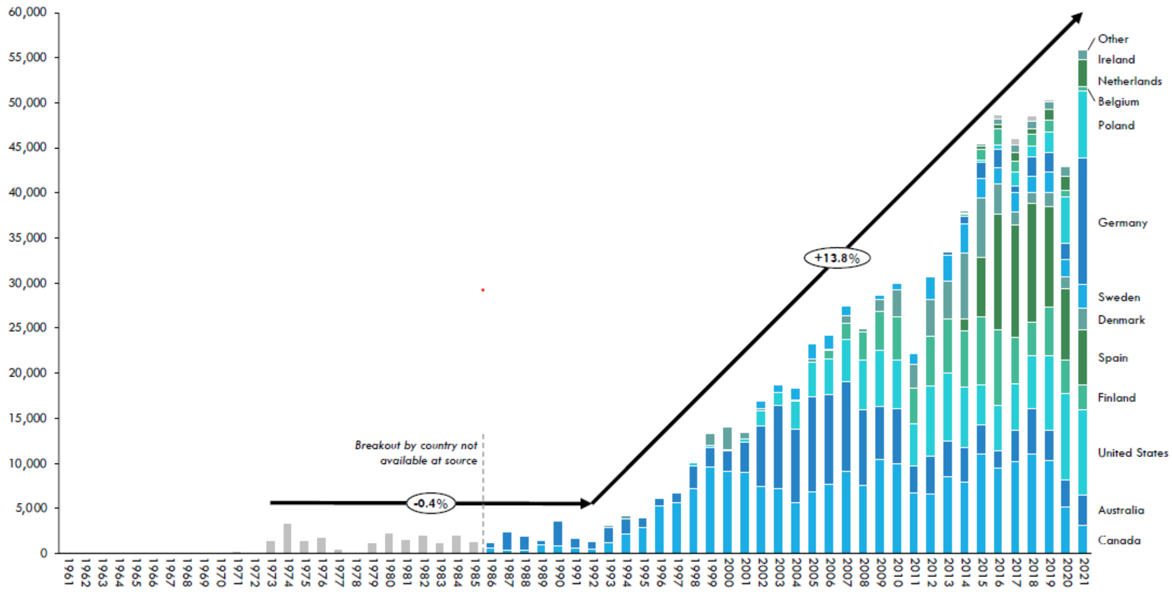
Figure 1-66: Pig and pigmeat statistics, 1991-2021.



Source: Coriolis, 2023a.

Figure 1-67 shows that New Zealand has rapidly growing pig meat imports. This has been facilitated by the relaxation in biosecurity import requirements.

Figure 1-67: NZ pigmeat imports, 1961 – 2021.



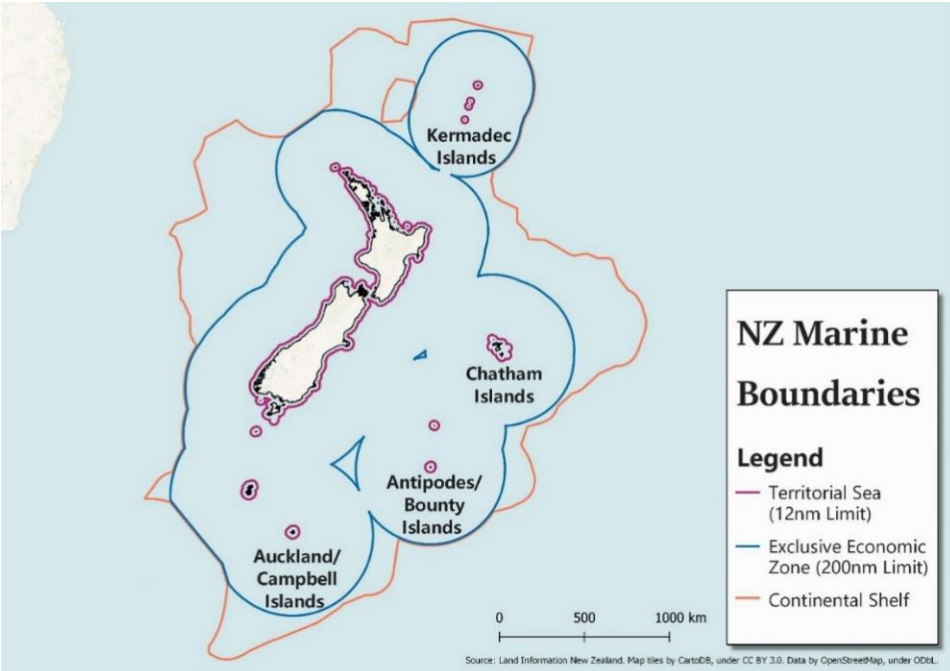
Source: Coriolis, 2023a.

1.6.11 Seafood

Seafood is New Zealand's seventh largest export earner, totalling $1.98 billion in 2022, and employing more than 16,500 people (Seafood New Zealand, 2023b). There is significant Māori ownership within the industry, with approximately 27 per cent of all quota by volume and value owned by Māori (Seafood New Zealand, 2023b).

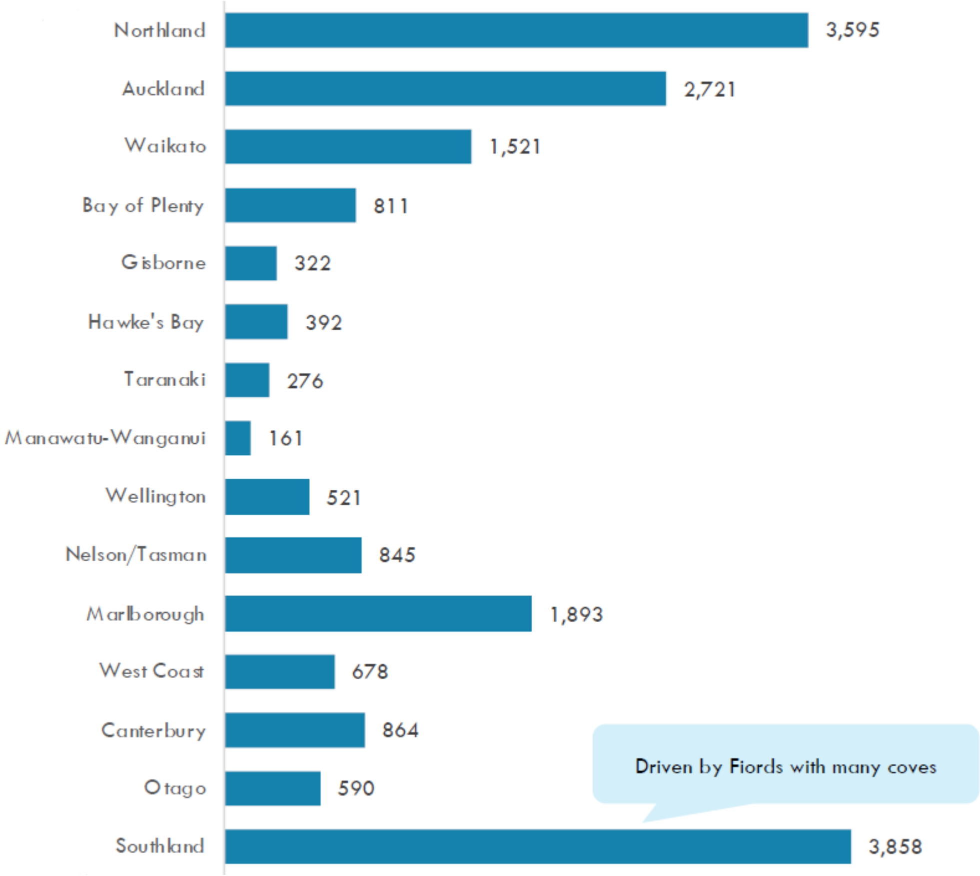
The size of the industry is unsurprising given New Zealand's coastline is estimated to be 15,000 to 18,000 kilometres, the ninth largest in the world (Coriolis, 2023a). New Zealand's marine waters measure around 4 million square kilometres (within New Zealand's exclusive economic zone) as shown in Figure 1-68. The length of the coastline by region can be seen in Figure 1-69.

Figure 1-68: New Zealand's marine boundaries.



Source: Yeoman, Fairgray & Lin; 2019, p. 12.

Figure 1-69: New Zealand coastline by region (km).



Source: Coriolis, 2023a.

Considering the industry as a whole, Table 1-1 highlights New Zealand's production and consumption of seafood, imports, exports, and non-food uses in terms of live weight tonnes. These FAO values consider the following seafood categories:

- Cephalopods
- Crustaceans
- Demersal fish
- Freshwater & diadromous fish
- Marine fish not elsewhere indicated
- Molluscs excluding cephalopods
- Pelagic fish

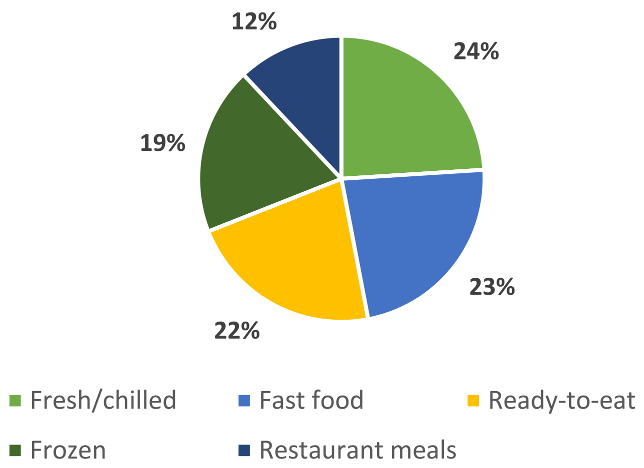
Table 1-1: New Zealand's seafood industry by volume (tonnes live weight), 2015-2019.

	Production	Exports	Imports	Non-food uses	Domestic Consumption
2015	551,962	424,940	424,940	60,016	112,690
2016	523,935	406,165	406,165	70,017	112,630
2017	532,139	424,248	424,248	45,018	111,662
2018	545,461	435,315	435,315	45,016	117,452
2019	511,644	385,210	385,210	60,016	124,160

Source: FAO, 2023.

Considering New Zealand consumption preferences, a survey by MPI (2019b) highlighted that saltwater fish and shellfish are most commonly consumed by new Zealanders, likely reflecting the range of seafood available to purchase commercially. In terms of seafood consumption, Figure 1-70 highlights domestic product preferences.

Figure 1-70: New Zealand's seafood product preferences.



Source: MPI, 2019b.

In terms of exports, fish is New Zealand's eighth largest export category (MFAT, 2022). In 2022, fish exports were NZ$1.98 billion. Table 1-2 shows a breakdown of these product by category.

Table 1-2: New Zealand seafood exports, 2022.

		Tonnes	NZ$ FOB
Finfish	Fresh	12,754.5	211,165,164
	Frozen	136,647	666,707,621
	Processed	23,349.9	125,464,533
	Total	**172,751.4**	**1,003,337,318**
Other Crustacea	Frozen	1,535.4	73,250,953
	Other forms	32.0	2,629,333
	Processed	172.5	13,453,845
	Whole	2.6	50,663
	Total	**1742.4**	**89,384,794**
Rock Lobster	Live	2,659	368,944,514
	Other forms	0.1	3,484
	Tails	9.3	676,221
	Whole	70.2	6,465,948
	Total	**2,738.7**	**376,090,167**
Shellfish	Fresh	3639,7	40,108,838
	Fresh or frozen	610.4	8,786,689
	Frozen	53,346.2	390,679,512
	Processed	1,964.8	76,413,791
	Total	**59,561.1**	**515,988,830**
Grand Total		**236,793.7**	**1,984,801,109**

Source: Seafood (2023a).

A further breakdown of exports by the top 10 species highlights that Rock Lobster, Mussels, and Hoki are New Zealand's highest value seafood exports (see Table 1-3).

Table 1-3: New Zealand top 10 seafood species exports, 2021.

Species	2021 (NZ$ million)
Rock Lobster	329
Mussels	299
Hoki	192
Salmon	139
Squid	126
Mackerel, Jack	81
Ling	64
Orange Roughy	54
Paua	33
Barracouta	32

Source: Seafood New Zealand, 2022.

New Zealand exports seafood to around 80 countries, with China, the United States, and Australia being the largest markets by value in 2021, shown in Table 1-4.

Table 1-4: Value of New Zealand seafood exports by destination, in NZ$ million, 2021.

Export Destination	Export Value (NZ$ Million)
China	636
United States of America	287
Australia	238
Japan	78
Spain	51
Poland	51
Hong Kong	42
South Korea	40
Canada	39
South Africa	31

Source: Seafood New Zealand, 2022.

1.6.11.1 Marine reserves and fresh water resources

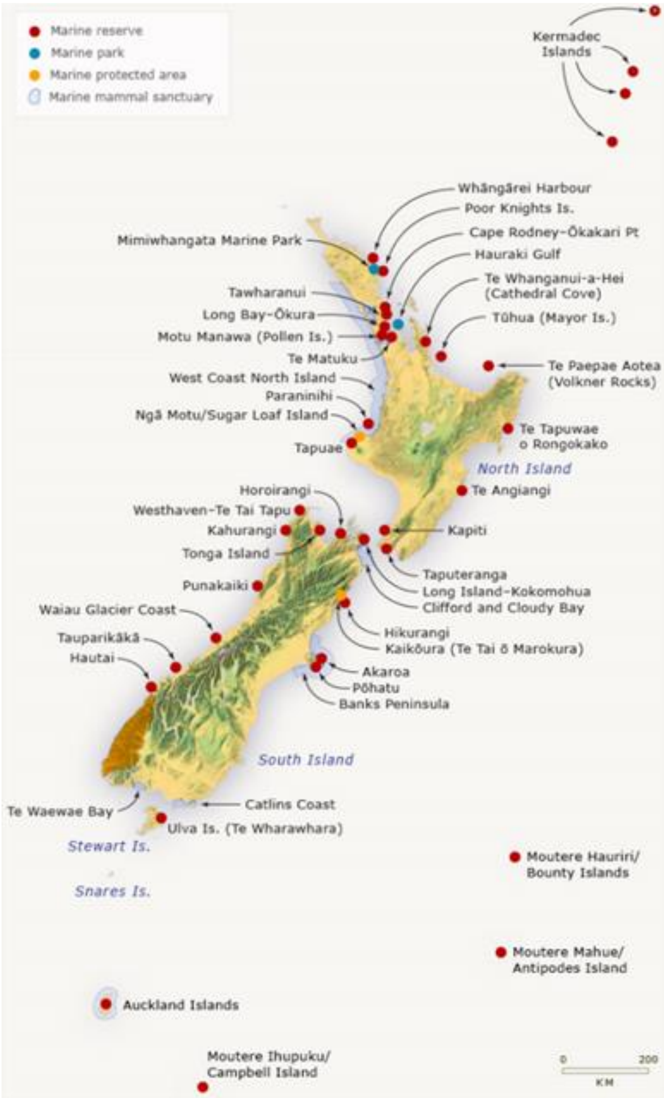
Figure 1-71 presents a map of 44 marine reserves covering just over 1.7 million hectares (within 12 nautical miles of the coast) (Te Ara, 2015). There are currently plans to introduce a further six South Island marine reserves covering 407 square kilometres in mid-2024 (RNZ, 2023).

Considering fresh water resources, lakes cover about 1.3per cent of land area in New Zealand. There are 775 lakes that are at least 0.5km long. The largest lake is Lake Taupō with an area of 623 square kilometres (Te Ara 2007).

The country has over 60 human-made lakes developed to generate electricity and supply water, with the largest of these, Lake Benmore, on the Waitaki River in the South Island supplying hydroelectricity to the grid (Te Ara, 2007).

There are around 70 major river catchments throughout the country with over 425,000km of rivers and streams (Environment Foundation, 2021). These catchments are used for recreational fishing and also for commercial aquaculture.

Figure 1-71: New Zealand marine protected areas.

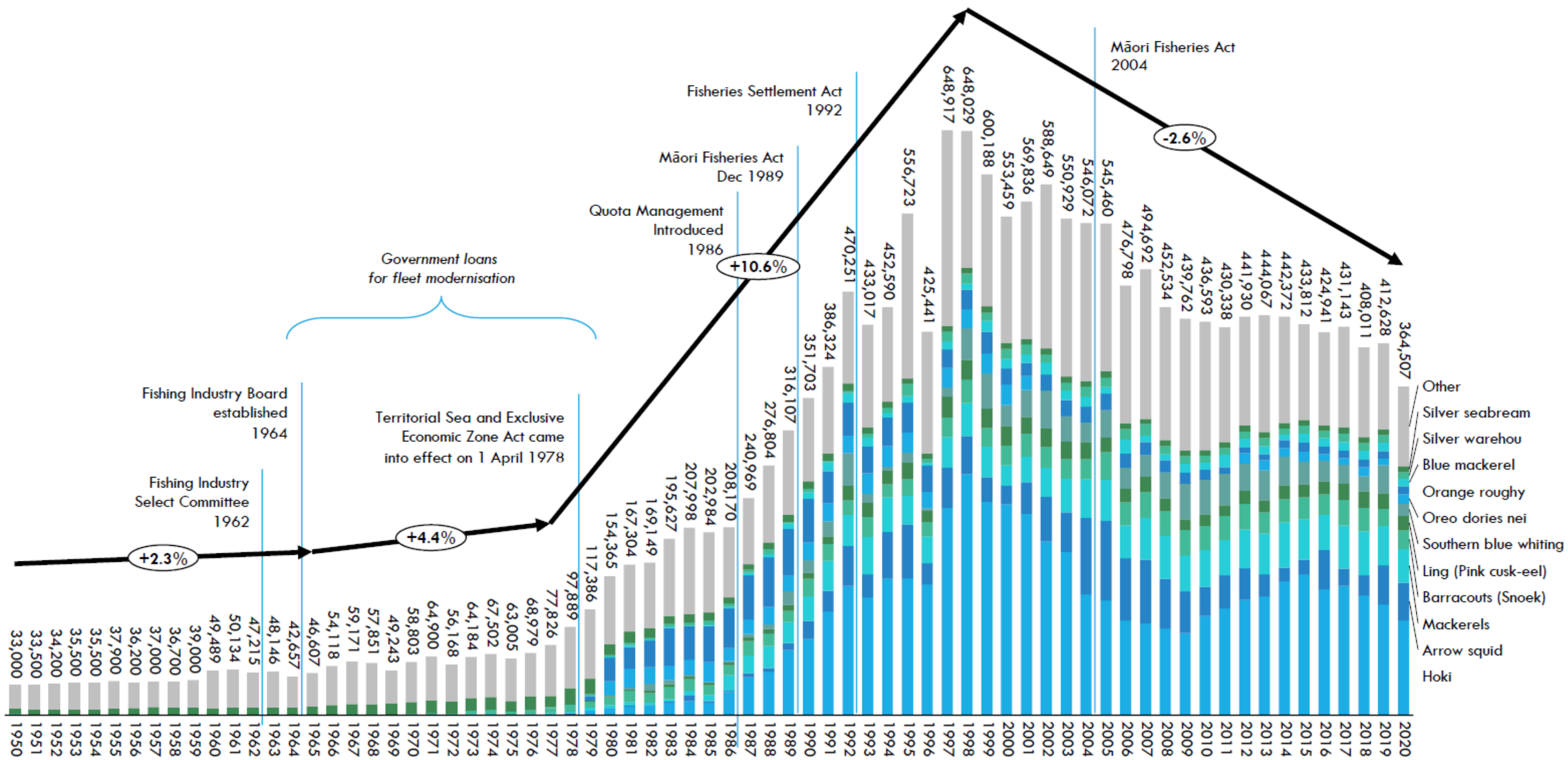


Source: Te Ara, 2015.

1.6.11.2 Commercial seafood

New Zealand's commercial seafood activities are highlighted in this section. The country utilises a mix of wild capture and aquaculture techniques. In terms of wild capture, New Zealand operates a quota management system (QMS) whereby an annual limit on total allowable catch is divided among commercial fishers, recreational fishers, and customary fishers. This is to ensure sustainable fishing based on stock levels. Figure 1-72 shows New Zealand's wild capture since 1950.

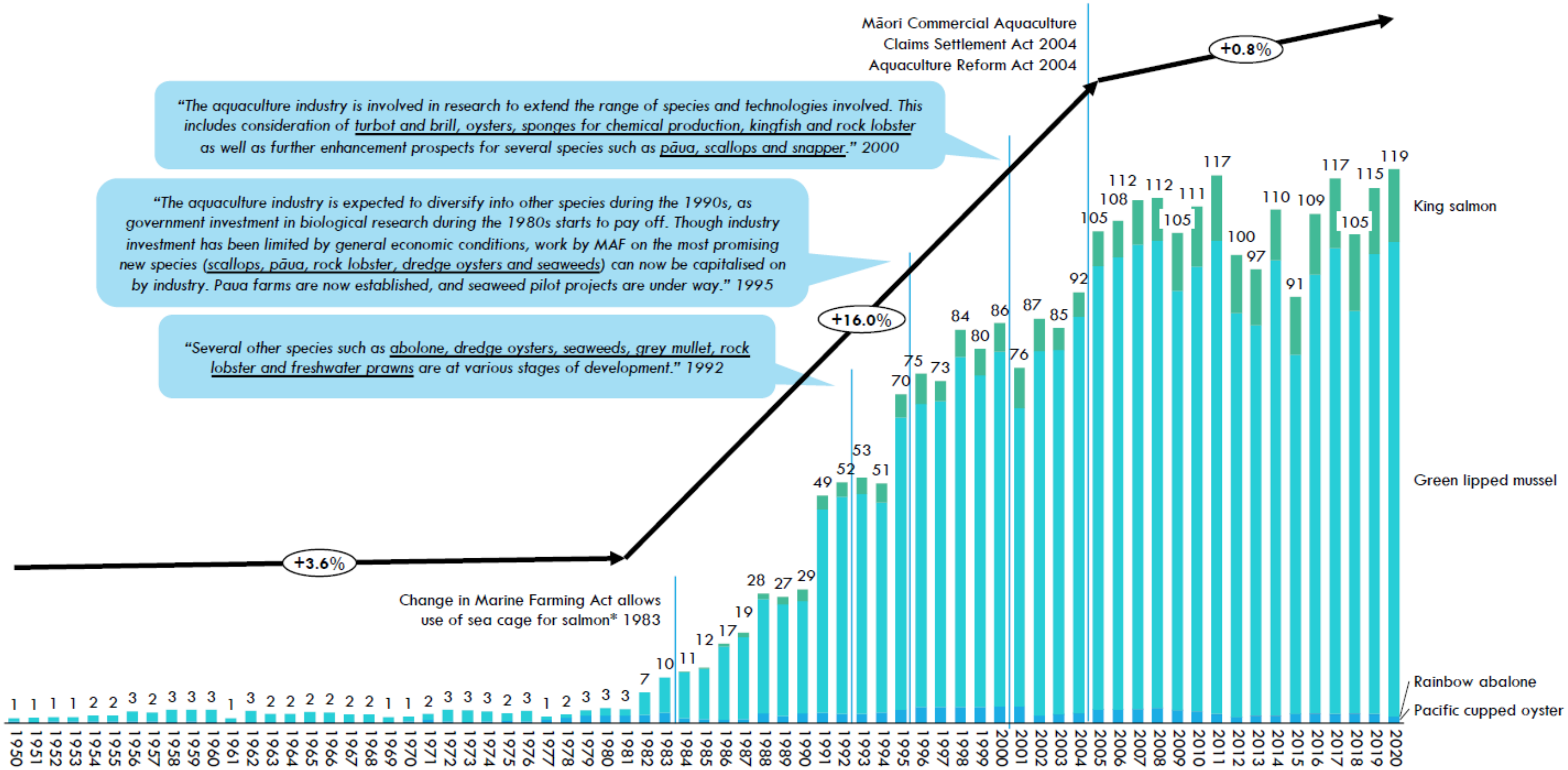
Figure 1-72: New Zealand's wild harvest from wild capture, tonnes, 1950-2020.



Source: Coriolis, 2023a.

In terms of aquaculture, the industry has experienced significant growth since 1950. However, this has since stalled from around 2004 and may be seen in Figure 1-73.

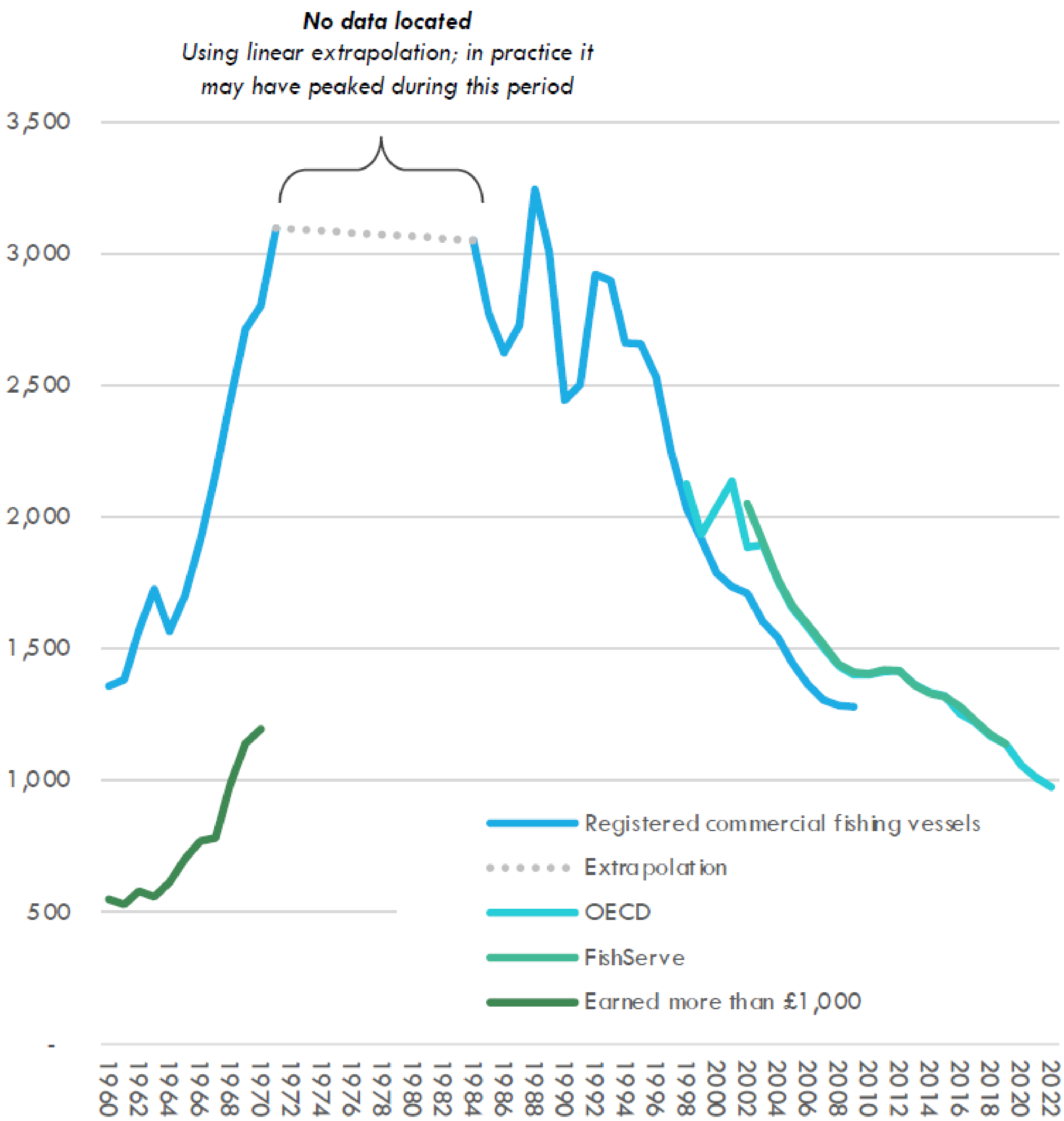
Figure 1-73: New Zealand's aquaculture harvest, in kilotonnes, 1950-2020.



Source: Coriolis, 2023a.

In addition to declining harvest numbers, the industry is also experiencing less harvest volume per employee and vessel consolidation as seen in Figure 1-74. The remainder of this section investigates these in more depth in the categories of aquaculture, deepwater fisheries and inshore fisheries.

Figure 1-74: Registered fishing vessels in New Zealand waters, 1960- 2022.

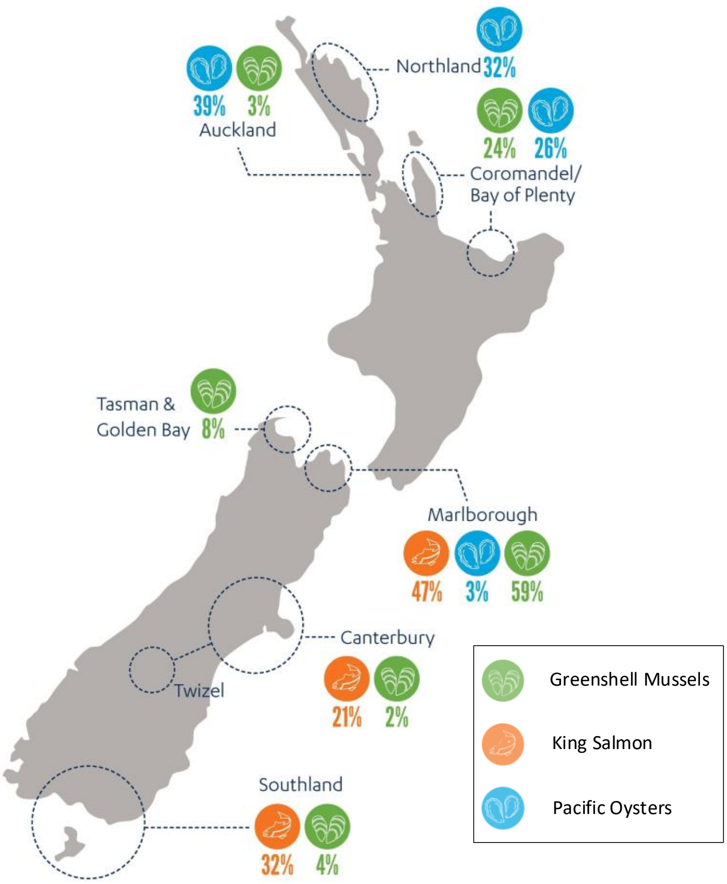


Source: Coriolis, 2023a.

Aquaculture

Aquaculture is the farming of aquatic plants and animals. In New Zealand, aquaculture largely encompasses mussel, oyster, and salmon production. While aquatic plants such as seaweed and phytoplankton are beginning to be commercialised in New Zealand, this is still an emerging industry and not considered here (see the futures section below). A map of aquaculture production areas is shown in Figure 1-75.

Figure 1-75: New Zealand's aquaculture production.



Source: Aquaculture New Zealand, 2022.

New Zealand aquaculture products are exported to 76 countries with total sector income of around NZ$671 million for the year ending 31 July 2022. This is shown below in Table 1-5. Table 1-6 highlights the top value export destinations by product category of New Zealand aquaculture products.

Table 1-5: Production and revenue of aquaculture, 2022.

	Mussels	Salmon	Oysters
Harvested product (greenweight tonnage)	82,792	16,258	1,520
Export revenue (NZ$ millions)	302	150	16
Est. domestic revenue (NZ$ millions)	45	150	8
Est. total revenue (NZ$ millions)	347	300	24
Est. total sector revenue (NZ$ million)		671	

Source: Aquaculture New Zealand, 2022.

Table 1-6: Aquaculture export destinations by product category, 2022.

	Export Destination	Value (NZ$ millions)
Mussels	United States of America	98.2
	China	32.6
	Korea	19.6
	Australia	17.4
	Spain	15.3
	Hong Kong	11.6
	Germany	11.5
	Thailand	9.2
Salmon	United States of America	79.6
	Australia	16.2
	China	15.7
	Japan	9.3
	Canada	6.3
	Singapore	4.7
	Thailand	3.7
	The Netherlands	2.9
Oysters	Australia	4.8
	China	2
	Hong Kong	1.9
	French Polynesia	1.9
	New Caledonia	1.8
	United States of America	1.3
	Russia	0.8
	Singapore	0.4

Source: Aquaculture New Zealand, 2022.

Deepwater fisheries

Deepwater fisheries are fisheries between 12 and 200 nautical miles offshore (reaching the EEZ limit). MPI estimates that over 200,000 tonnes of fish are caught by deepwater fisheries annually and in 2019 accounted for approximately NZ$870 million in export earnings (MPI, 2020a).

Under the QMS there are currently 98 fish species or groups of species divided into 642 fish stocks across different areas, with each fish stock having its own QMS boundary (MPI, 2020b). Within the deepwater fisheries portfolio, fish species have been placed into three tiers depending on their commercial importance and these may be seen below in Table 1-7.

Table 1-7: Deepwater fish stocks.

Deepwater Species[3]		
Tier 1 stocks	Hake: all Hoki: all Jack Mackerel: JMA 3 & JMA 7 Ling: LIN 3 – LIN 7 Orange Roughy: all	Oreo: all Southern blue whiting: all Scampi: all Squid: all
Tier 2 stocks	Alfonsino: all Black cardinalfish: all Barracouta: BAR 4, BAR 5 % BAR 7 Blue (English) mackerel: EMA 3 & EMA 7 Dark ghost shark: GSH 4-6 Deepwater crabs (KIC/GSC/CHC): all Frostfish: FRO 3- FRO 9 Gemfish: SKI 3 & SKI 7 Lookdown dory: all Pale ghost shark: all	Patagonian toothfish: all Prawn killer: all Redbait: all Ribaldo: RIB 3-RIB 8 Rubyfish: all Sea perch: SPE 3-SPE 7 Silver warehou: all Spiny dogfish: SPD 4 & SPD 5 White warehou: all
Tier 3 stocks	Non-QMS species	

Source: Fisheries New Zealand, 2022.

New Zealand's most commonly caught finfish categories are the Jack Mackeral and Hoki, which account for just over 40 per cent of New Zealand's fish harvest (Seafood New Zealand, 2023a). Jack Mackerel is New Zealand's highest volume catch, and include three species: *Trachurus declivis, T. novaezelandiae*, and *T. murphyi*. These are most commonly harvested off the west, north and east coasts of the North Island (Fisheries New Zealand, 2023a). Hoki (*Macruronus novaezelandiae)* are found across New Zealand waters at depths of 200-600 metres. These are most commonly harvested off the west coast of the South Island and Cook Strait (MPI, 2023d). Table 1-8 highlights the top six Deepwater exports by volume in 2022, accounting for just under 73 per cent of total finfish exports.

[3] For some species (eg Ling and Jack Mackerel), management of some stocks falls under the national deepwater plan while the remainder are managed under the national inshore finfish fisheries plan.

Table 1-8: New Zealand's top deepwater fisheries exports by volume, net weight volume (kgs), 2022.

Species	Frozen whole	Frozen fillets	Chilled fillets	Frozen H&G	Species total	% of finfish
Mackerel, Jack	18,992,340			6,761,481	25,753,821	22.94
Hoki	33,660	12,478,394	12,262	10,606,171	23,130,487	20.61
Barracouta	163,943	766,500		9,895,016	10,825,459	9.64
Mackerel, Blue	8,476,248			224,141	8,700,389	7.75
Southern Blue Whiting		4,627		7,779,831	7,784,458	6.94
Ling	24,976	3,159,210	630,477	1,849,672	5,664,335	5.05

Source: Seafood New Zealand (2023a).

Interestingly, in terms of export value, these same fish species only account for around 57.1 per cent of finfish exports, with Orange Roughy contributing an additional 5.16 per cent of value, despite being only 2.68 per cent of total export by volume. This is shown in Table 1-9.

Table 1-9: New Zealand's top deepwater fisheries exports by value, in NZ$, 2022.

Species	Frozen whole	Frozen fillets	Chilled fillets	Frozen H&G	Species total	% of finfish
Hoki		11,794,500		1,783,741	13,578,241	22.90
Mackerel, Jack	5,857,238			1,222,180	7,079,418	11.94
Ling		4,769,381	25,235	1,529,528	6,324,144	10.67
Barracouta	163,943	314,477		2,947,672	3,262,149	5.50
Orange Roughy	98,625	2,932,428	26,690		3,057,743	5.16
Mackerel, Blue	2,276,621				2,276,621	3.84
Southern Blue Whiting		445		1,335,001	1,335,446	2.25

Source: Seafood New Zealand, 2023a.

Inshore fisheries

Inshore fisheries cover waterways within New Zealand and ocean fisheries within 12 nautical miles. Important species found in these fisheries, highlighted by MPI (2022), include:

- Finfish: snapper, blue cod, flatfish, gurnard, terakihi, and trevally;
- Shellfish: cockles, pipi, pāua, and rock lobster;
- Freshwater – mostly longfin and shortfin eels; and
- Other aquatic life (e.g. seaweeds).

Inshore fishers catch around 95,000 tonnes of fish a year, largely destined for the local market (75 per cent). Export receipts are $400-500 million annually (Fisheries inshore New Zealand, n.d.).

For the Inshore fisheries (Finfish, Rock Lobster and Shellfish), in 2020 the greatest value contribution came from Finfish at 25 per cent of the total fishing value, followed by Rock Lobster with 12 per cent, and Shellfish with nine per cent (Dixon & McIndoe, 2022).

The spiny rock lobster is one of the seafood industry's top export earners. It is included in the quota management system. For the 2019/20 catch season, it is estimated that rock lobster landings totalled 2750 tonnes, with most destined for the Asian live market and around 100 tonne for the domestic market (NZRLIC, n.d).

Pāua exports were worth NZ$50 million in 2019, including shell, by-product and nutraceutical sales. The most common export product was canned pāua largely destined for Asian markets (Pāua Industry Council, 2023). Under the quota management system, fishers are able to catch up to 919 tonnes each year, though this is often lower due to voluntary reductions, with the 2019 catch being 720 tonnes of wild harvest. More than a quarter of the catch was in the Chatham Islands pāua fishery area (Pāua Industry Council, 2023).

Freshwater eels is a relatively small harvest with an estimated export value of NZ$6 million, equating to around 830 tonne (NIWA, n.d.). Nearly all caught eel is exported, with a small domestic market largely sold to ethnic groups with a history of eating eels (Māori, western Europe, Pasifika) and restaurants (Jellyman, 2012).

Chapter 2
Comparative Emissions Profile

This chapter will present comparative emission profiles of current major land uses in each of the 16 regions in New Zealand. These profiles are developed using an integrated assessment model (the AERU Integrated Assessment Framework) which measures the economic, social, environmental and economic consequences of land use changes, excluding urban areas.

2.1 Integrated Impact Assessment and the Bioeconomy

This section will introduce the Integrated Assessment Framework which will measure the impact of economic, social, cultural and environmental wellbeing from current uses of biological resources. This chapter concentrates on the greenhouse gas emissions profiles and absorption. The consideration of the wider impacts of policy were introduced in New Zealand with the Local Government Act 2002 and have since been expanded and reviewed in particular with the development of the Living Standards Framework developed by Treasury as reviewed in Dalziel et al. (2018) which has been used as a basis of the impacts included here.

The assessment will be in two parts: (1) impact of land use on greenhouse gas emissions using the Integrated Assessment Framework; and (2) marine emissions using a case study approach.

The comparative emission profile of current land uses is calculated using a modified version of the AERU Integrated Assessment Framework. Integrated Assessment Frameworks have a long history and were developed in the 1960s in the USA under the National Environmental Policy Act 1969. They have been used extensively both internationally and in New Zealand since then, their use is reviewed in Mackay, M. and Taylor, N. (2020): Integrated Assessment a review, Our land and water National Science Challenge 2022. It is important to note that while productive exotic forestry plays an important role in current and mid-term greenhouse gas removals, this modelling exercise is examining the long-term implications and thus treats exotic forestry as neutral in the baseline.

Integrated Assessment Models are one type of framework to assess impact of policy decisions. There are a wide range of models and frameworks that have been developed. These wellbeing models/frameworks guide policymakers on policy impacts across different dimensions of wellbeing, as well as the long-term and distributional issues and implications of policies (New Zealand Treasury, 2022). A review of these frameworks can be found in Saunders, C.M., Whitehead, J., and Duff S. (2022) Measuring the True (integrated) Effects of Land Use Systems: Review of Current Frameworks, Report for Our Land and Water National Science Challenge.

One of the key differences across the range of frameworks and models is their complexity. Models have the capability to show impacts of policy decisions across a wide range of dimensions using various techniques. However, they require considerable resource to develop and maintain. Whereas frameworks tend to be simpler but also easier to understand, modify and transparent.

The term *integrated impact assessment* (IIA) is used in various ways to describe efforts to consider to multiple impacts– social, health, economic, environmental, social, and so on – within one impact assessment (Morgan, 2022). Impact assessment is the process of identifying the consequences of a proposed action – project, programme, plan, or policy – to avoid or minimise negative effects and strengthen positive outcomes (Morgan, 2012; Taylor & Mackay, 2022). Impact assessment draws on multiple data sources and methods to predict social, environmental, and economic effects, including comparative case study material, quantitative modelling, trend projections, qualitative information – including local and indigenous knowledge (Jolly & Thompson-Fawcett, 2021) – and expert judgements (Taylor et al., 2004). Impact assessment may also includes the identification of mitigations to avoid or minimise major negative effects, measures to promote enhanced social, environmental and economic wellbeing, and the management of (social, environmental, and economic) change, commonly known as impact assessment follow-up (Morrison-Saunders et al., 2007).

The AERU Integrated Assessment Framework is a tool for showing economic, social, environmental and cultural impacts of land use change. Developed with funding from Our Land and Water National Science Challenge, this tool was co designed with regional councils, district council and the Treasury[4] and has been shared with a wider range of end users. The Framework is based on a mixed methods approach. This includes using Input/Output modelling to show economic impacts of land use change. This includes value-added impacts on secondary industries. It also analyses direct and indirect employment changes. Environmental impacts include greenhouse gas emissions, as well as other variables such as nitrate leaching, air pollution, biodiversity, E. Coli, macro-invertebrate index and river water quality.

The cultural variables in the framework have been selected in consultation with Māori stakeholders, including some environmental and social indicators. Currently, it includes mahinga kai and sense of belonging. Social indicators include life satisfaction, self-rated health status and connection to nature.

The Framework has been modified from its current prototype structure to meet the requirements of this project. The Framework has been extended to provide separate modules for all regions. The variables in the framework have also been modified in consultation with MBIE and MPI.

Types of land use was selected in consultation with MBIE and stakeholders. The current key agricultural land uses by type in the framework were included and expanded to include further Indigenous Forestry types as well as other land uses such as Wetlands.

Environmental impacts such as greenhouse gas emissions have been quantified using relevant emission factors. Where data is available, the impact on nitrate leaching was included. Where quantitative data is not available, qualitative data was used based upon expert opinion and literature reviews.

2.2 Modification of the Integrated Assessment Framework

The land uses and indicators in the modified Integrated Assessment Framework were chosen by the stakeholders. Where possible the information on which the indicators have been selected is from secondary sources or based on literature. This is especially the case with economic indicators and some environmental indicators. However, many of the social and some environmental indicators are scales which where possible have been informed by literature and consultation. This identifies the key gaps in data and informs the development of new information on the impact of land use change. It must also be stressed that whilst many indicators are interrelated, this has not been captured directly in the modified Integrated Assessment Framework but is highlighted in the results.

The modified framework has been assessed using an Excel workbook.

The modified framework is constructed with two main axes:

- Region of New Zealand, and
- Land Use within that region.

[4] https://ourlandandwater.nz/project/measuring-full-impacts-of-land-use-change/

The sixteen regions of New Zealand are represented within the framework.

Land Use within the modified Integrated Assessment Framework is concerned with:

- Sheep & Beef
  - 1 South Island High Country
  - 2 South Island Hill Country
  - 3 North Island Hard Hill Country
  - 4 North Island Hill Country
  - 5 North Island Intensive Finishing Farms
  - 6 South Island Finishing-Breeding Farms
  - 7 South Island Intensive Finishing Farms
  - 8 South Island Mixed Finishing Farms
- Dairy
  - Low Input (Class 1+ 2)
  - Medium Input (Class 3)
  - High Input (Class 4 + 5)
- Deer
- Arable
- Horticulture
- Exotic Forestry
  - Pruned for Logs
  - Unpruned for Logs
  - Unpruned for Bioenergy
- Indigenous Forestry
- Wetlands

The inclusion of Sheep & Beef classes enables a more accurate calculation of the impacts of the different farm classes.

Exotic Forestry has been separated into four Land Uses to account for differences between the impacts of pruned and unpruned forests, and to allow for the modelling of forestry for bioenergy.

The Wetlands Land Use Group is primarily herbaceous freshwater vegetation and includes areas of mangroves, herbaceous saline vegetation, and swamps.

These Land Use Groups were selected as they were seen to have the most impact on the scenarios to be explored using the framework.

2.2.1 Assessing land use

Current land use was assessed using data from:

- Stats NZ Agricultural and Horticultural Land Use data
- Land Cover Database v5.0
- National Exotic Forest Description (NEFD, 2019)

These data were used to determine land use by region in hectares based on the year 2019.

Stats NZ Agricultural and Horticultural Land use data

This dataset is an estimate of land use for the 16 regions of New Zealand for the categories of Dairy cattle, Beef cattle, Sheep, Forestry, Grain and Horticultural. The data set provides data points for the years 2002, 2007, 2012, 2017 and 2019. The data is modelled by Stat NZ using data from their Agricultural Production Survey and is considered by Stats NZ to be medium quality.

This dataset informed the Sheep & Beef, Dairy, Deer, Arable and Horticultural land use groups in the modified Integrated Assessment Framework. The Sheep & Beef land uses were further disaggregated using regional data from Beef and Lamb.

Land Cover Database (LCDB)

This dataset is prepared by Manaaki Whenua and is a geospatial assessment of the land cover across the whole of New Zealand. It includes the classification of 33 land cover classes, including Exotic Forestry, Indigenous Forest of different compositions, and Grassland across different production levels. Land areas were identified as Wetlands in the dataset using a flag. Land cover is captured at five time points: 1996, 2001, 2008, 2012, and 2018.

These land cover classes were mapped to the Land Use Groups used within the modified Integrated Assessment Framework and aggregated by region, particularly informing the areas of Indigenous Forest and Wetlands land uses.

National Exotic Forest Description (NEFD 2019)

This report is prepared by the Ministry for Primary Industries and provides data on planted production forestry by territorial authority across New Zealand as at 1 April 2019.

This data was used to calculate the proportion of exotic forest that is pruned and unpruned for each region and the ratio used within the framework and informed the area of Exotic Forest land use.

2.2.2 Variables included in the modified Integrated Assessment Framework

The variables included in the modified Integrated Assessment Framework are listed below:

Economic

- Revenue per hectare by land use
- Gross Output: direct, indirect and induced
- Employment: direct, indirect and induced
- Value added: direct, indirect and induced

Environmental

- Air Pollution
- Biodiversity
- E. coli
- GHG Emissions
- Ground Water Quality
- Macro-Invertebrate Index
- Mahinga Kai
- River Water Quality
- Soil Quality
- Swimming Index
- Residual Woody Biomass

Social

- Access to Basic Amenities
- Life Satisfaction (Current)
- Life Satisfaction (Future)
- Public Transport
- Self-rated Health
- Voting status

2.2.3 Calculation of impacts

Economic impacts were assessed using multipliers from Regional Input-Output tables produced by Geoff Butcher for each region for the year ended March 2020.

In the case of Emissions, Residual Biomass and Nitrates, data was used to assess the impact of each land use as described below.

For the remainder of the impacts, a Likert scale was used to assess the impact of that land use, using scores based on literature and expert judgment.

Emissions factors

Emissions factors were taken from MfE (2022d). Total emissions per hectare (by region and farm-classes) were then calculated using Beef and Lamb benchmarking reports (2019a:f) in the case of sheep, non-dairy cattle, and Deer. While DairyBase financial benchmarking statistics for owner-operators (2021) were used to quantify figures for Dairy cattle.

Calculated head per hectare by the regional groupings in Beef and Lamb's benchmarking, and specific to these farm classes. Estimates of the average head per stocking unit for non-dairy cattle by regional grouping was performed by aligned the stocking units reported in the Beef and Lamb benchmarks with StatsNZ data (2021) on animal numbers by region. Averages of head per stocking unit for sheep were calculated from the Beef and Lamb benchmarking data alone.

The assumptions around greenhouse gas emissions for productive forestry are that sequestration gained from planting and growing trees are negated by the uses of forest products post-harvest. Thus, the ongoing emissions profile of rotation forestry is neutral.

In the case of Indigenous Forestry we have assumed that it is regenerating forest pre1990 with emission factors of -1,567 kg CO_2 eq/unit per hectare, MFE (2022d).

Residual biomass

The residual woody biomass estimates were calculated from tables found in Hall, P. (2022). This is given as gross supply of residues by region in m^3 and also GJ. This has been taken as a proportion of forest in 2021 to indicate the percentage of forest residue to area.

2.3 Biological emissions profile by land use and region

The following section presents the emission profile by land use for New Zealand and for the regions.

Figure 2-1: Biological emissions of land use by hectare (Average t CO_2 eq / ha per annum).

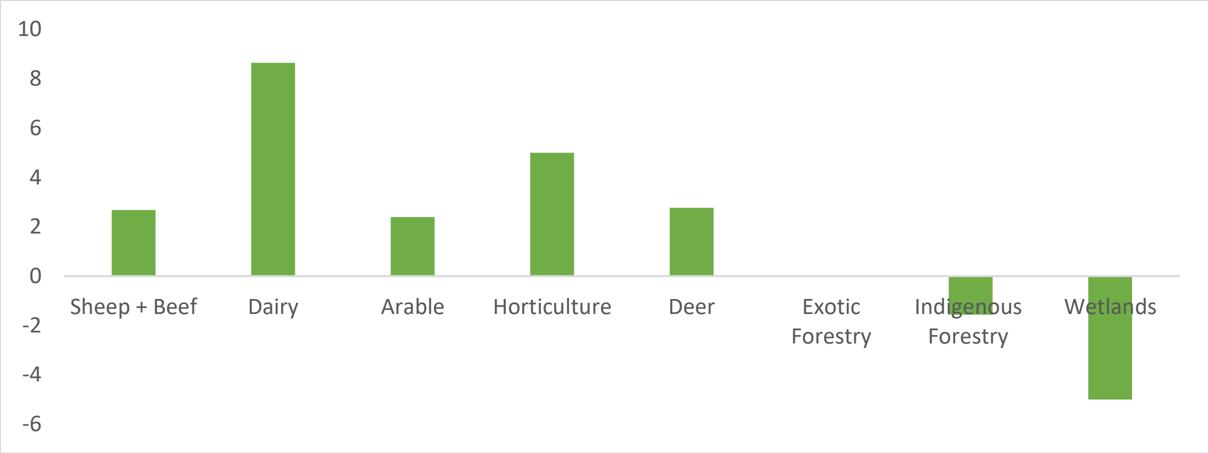


Figure 2-2 shows the emission profile for New Zealand. This illustrates the main emitting land uses are Sheep & Beef and Dairy, and sequestration by Indigenous Forestry and Wetlands. Deer, Arable, and Horticulture have a relatively low emissions.

Figure 2-2: The biological emission profile of New Zealand land use (kt CO_2 eq per annum).

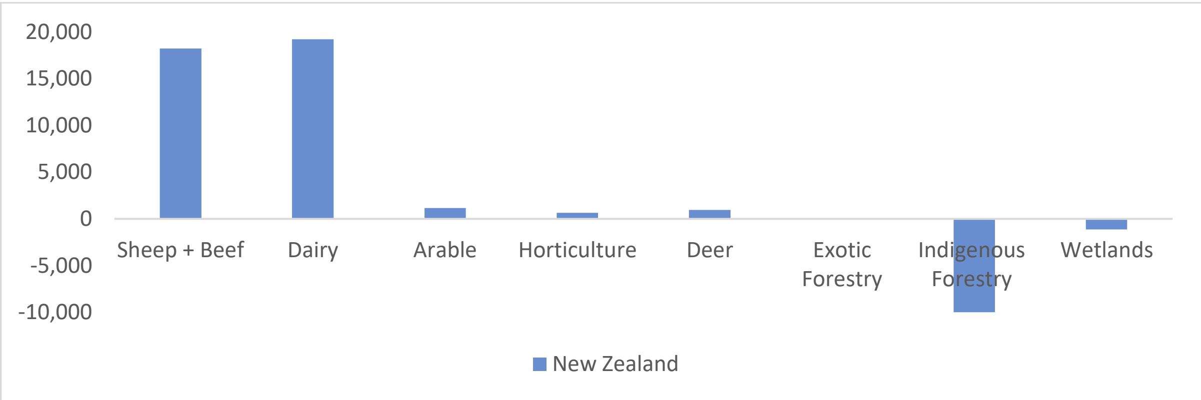


Figure 2-3 shows emission profile for Northland, again showing Sheep & Beef and Dairy the main emitters and the main sequestration of emissions by Indigenous Forestry.

Figure 2-3: The biological emission profile of Northland land use (kt CO_2 eq per annum).

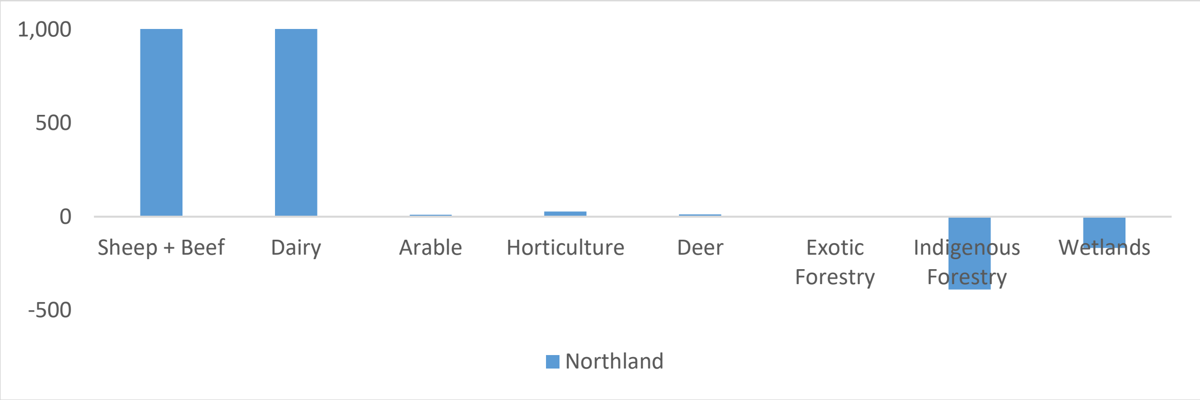


Figure 2-4 shows emission profile for Auckland, again showing Sheep & Beef and Dairy the main emitters and the main sequestration of emissions by Indigenous Forestry.

Figure 2-4: The biological emission profile of Auckland land use (kt CO_2 eq per annum).

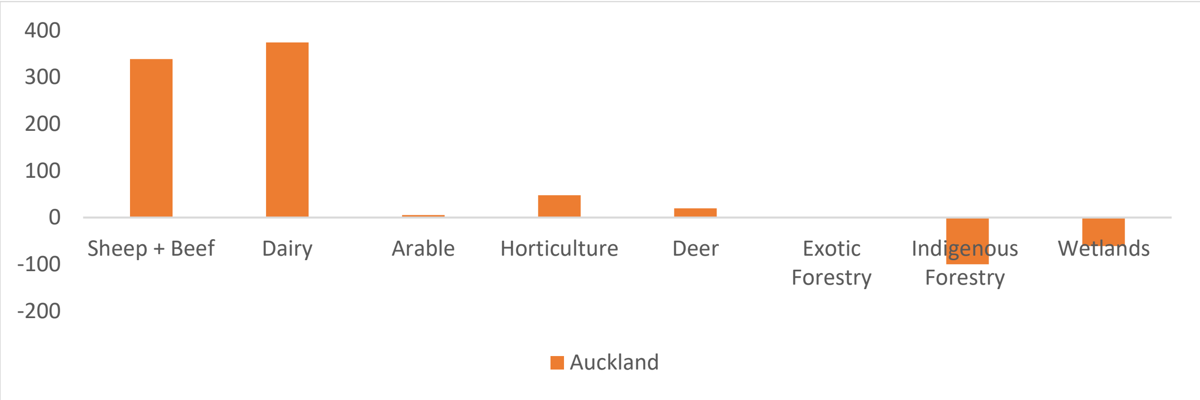


Figure 2-5 shows emission profile for Waikato, showing Dairy by far the greatest emitter followed by Sheep & Beef and the main sequestration of emissions by Indigenous Forestry.

Figure 2-5: The biological emission profile of Waikato land use (kt CO_2 eq per annum).

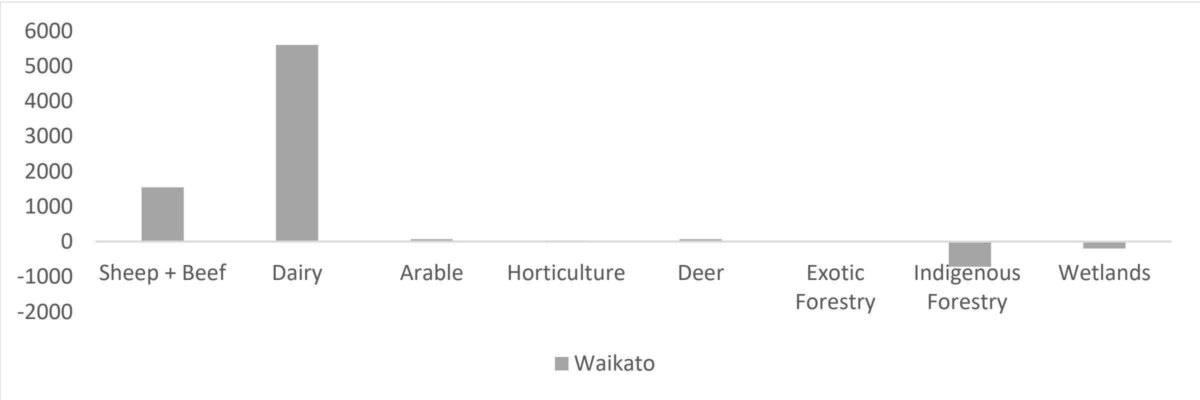


Figure 2-6 shows emission profile for Bay of Plenty, showing Dairy as the main emitter followed by Sheep & Beef and the main sequestration of emissions by Indigenous Forestry.

Figure 2-6: The biological emission profile of the Bay of Plenty land use (kt CO_2 eq per annum).

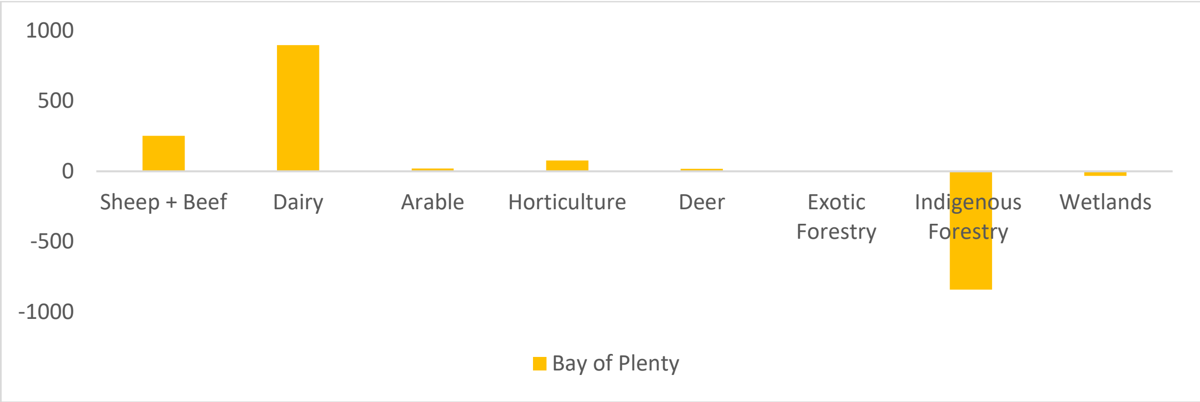


Figure 2-7 shows emission profile for Gisborne, Sheep & Beef as the main emitter and Indigenous Forestry the main sequester of emissions.

Figure 2-7: The biological emission profile of Gisborne land use (kt CO_2 eq per annum).

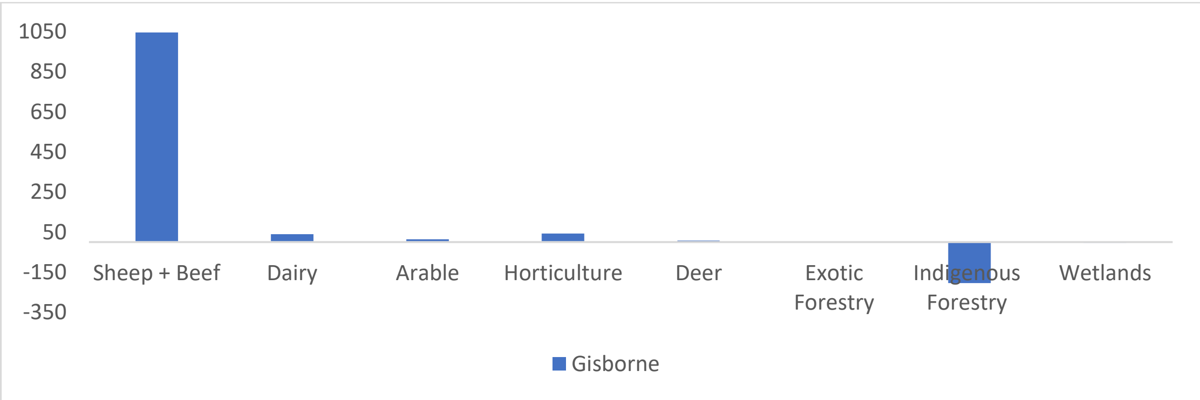


Figure 2-8 shows emission profile for Hawkes Bay, again Sheep & Beef are the main emitters and the main sequestration of emission by Indigenous Forestry.

Figure 2-8: The biological emission profile of Hawkes Bay land use (kt CO_2 eq per annum).

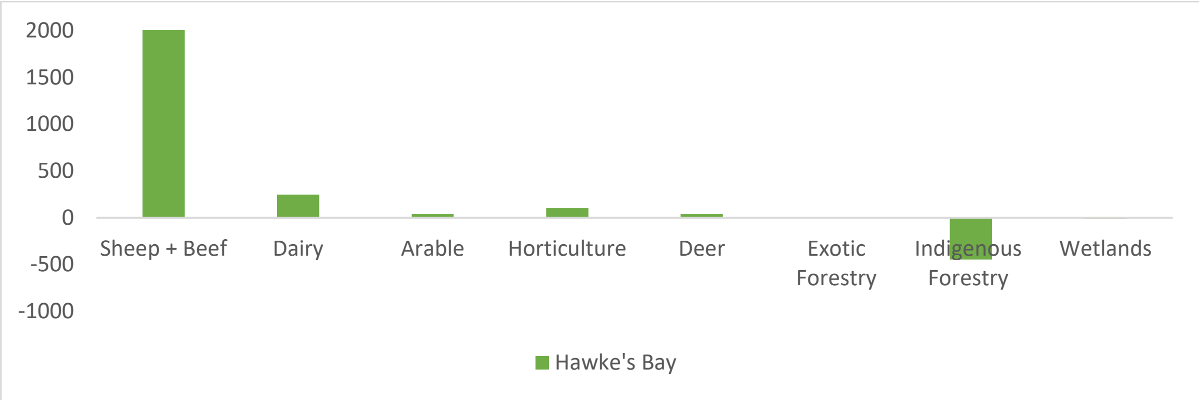


Figure 2-9 shows emission profile for Taranaki, where Dairy is by far the main emitter and relatively low levels of sequestration.

Figure 2-9: The biological emission profile of Taranaki land use (kt CO_2 eq per annum).

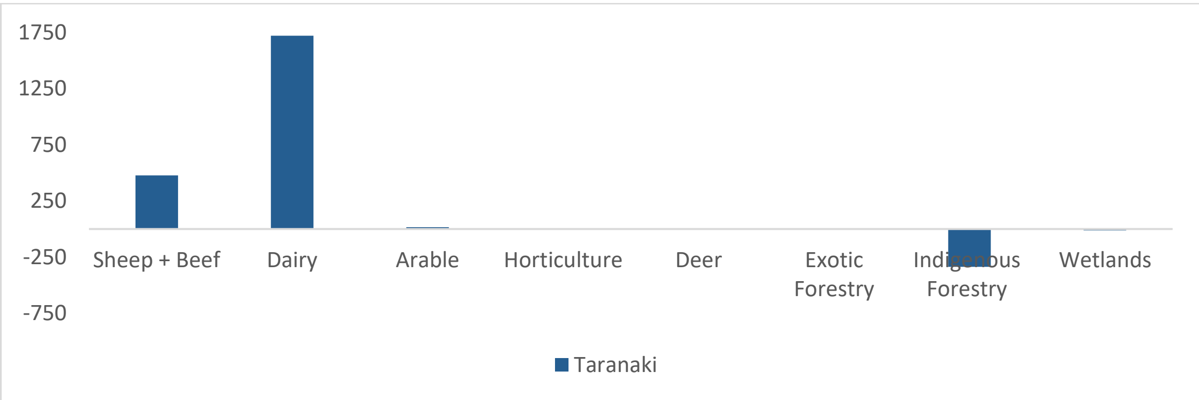


Figure 2-10 shows emission profile for Manawatū-Whanganui, again showing Sheep & Beef and Dairy the main emitters and Indigenous Forestry the main sequestrator of emissions.

Figure 2-10: The emission biological profile of Manawatū-Whanganui land use (kt CO_2 eq per annum).

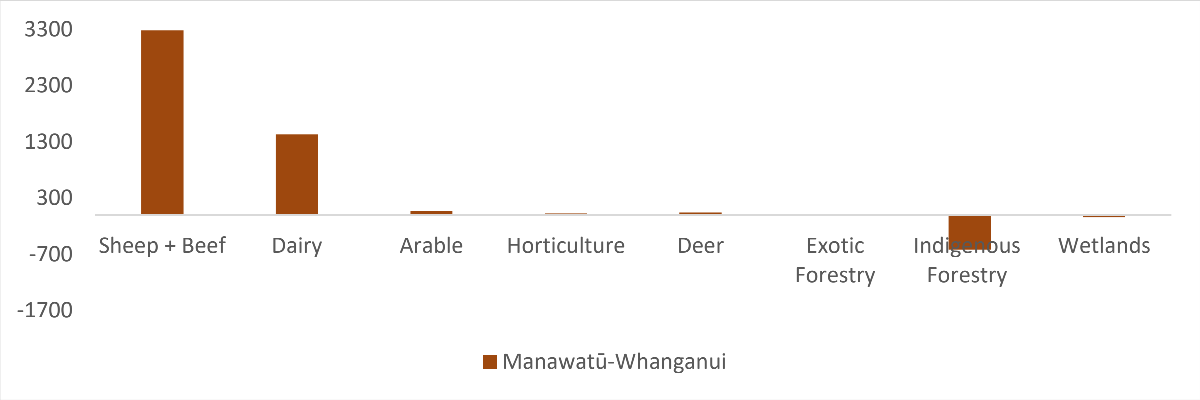


Figure 2-11 shows emission profile for Wellington, again showing Sheep & Beef the main emitter followed by Dairy, and the main sequestration of emissions by Indigenous Forestry.

Figure 2-11: The biological emission profile of Wellington land use (kt CO_2 eq per annum).

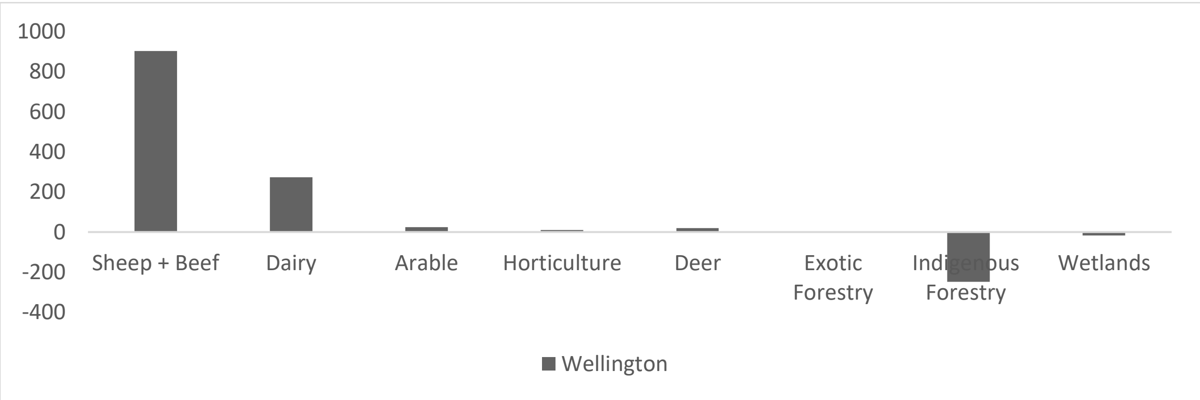


Figure 2-12 shows emission profile for Tasman, where emissions from Sheep & Beef and Dairy are relatively low compared to other regions but sequestration higher especially for Indigenous Forestry.

Figure 2-12: The biological emission profile of Tasman land use (kt CO_2 eq per annum)

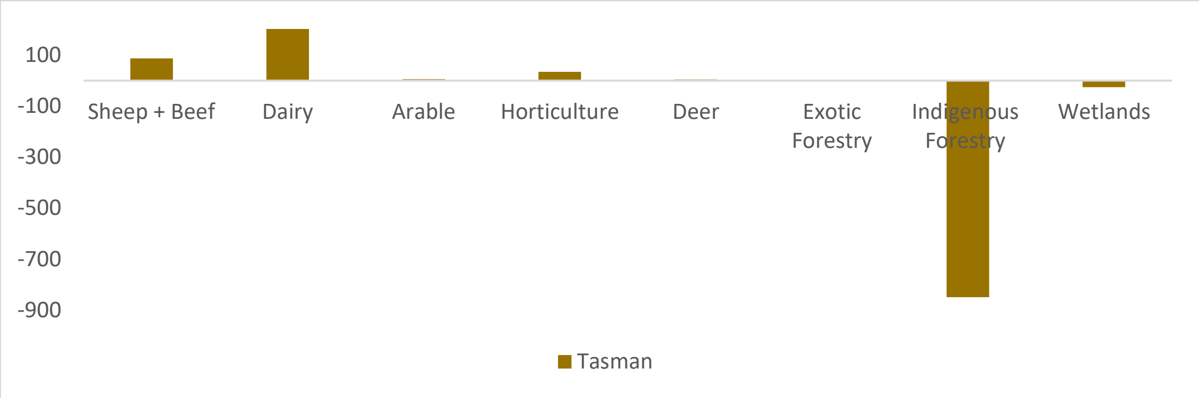


Figure 2-13 shows emission profile for Nelson, where emissions from Sheep & Beef and Dairy are relatively low compared to other regions and sequestration relatively high for Indigenous Forest.

Figure 2-13: The biological emission profile of Nelson land use (kt CO_2 eq per annum).

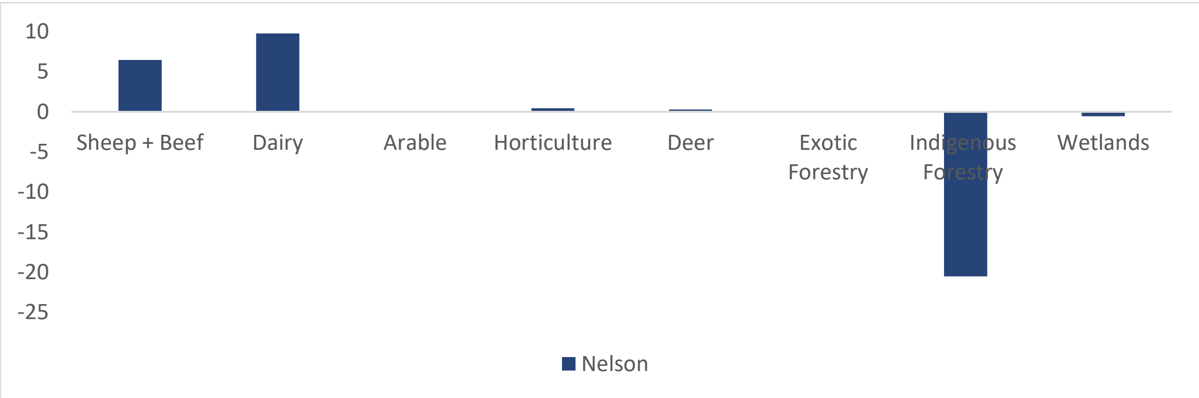


Figure 2-14 shows emission profile for Marlborough, showing Sheep & Beef the main emitter followed by lower emissions for Dairy and emissions from Horticulture. Indigenous forest is main sequestrator.

Figure 2-14: The biological emission profile of Marlborough land use (kt CO_2 eq per annum).

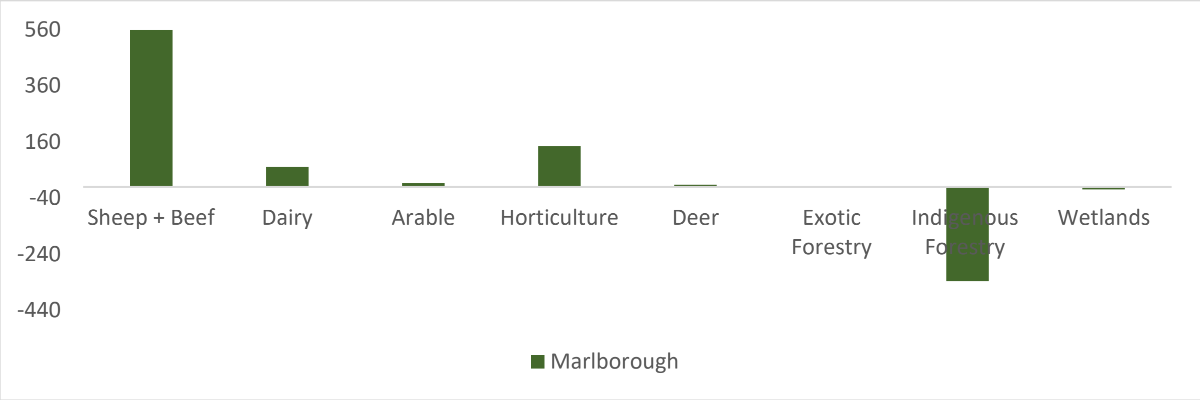


Figure 2-15 shows emission profile for the West Coast, which has relatively low emissions which is mainly from Dairy. The West Coast has considerable emissions sequestrated by Indigenous Forest.

Figure 2-15: The biological emission profile of the West Coast land use (kt CO_2 eq per annum).

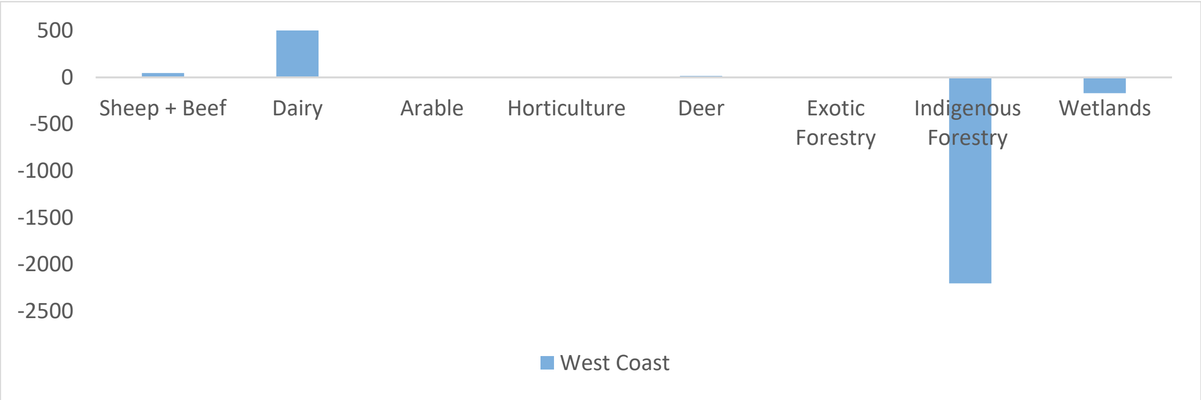


Figure 2-16 shows emission profile for Canterbury, again this shows Dairy and then Sheep & Beef the main emitters followed by Arable, and relatively low sequestration from Indigenous Forestry.

Figure 2-16: The biological emission profile of Canterbury land use (kt CO_2 eq per annum).

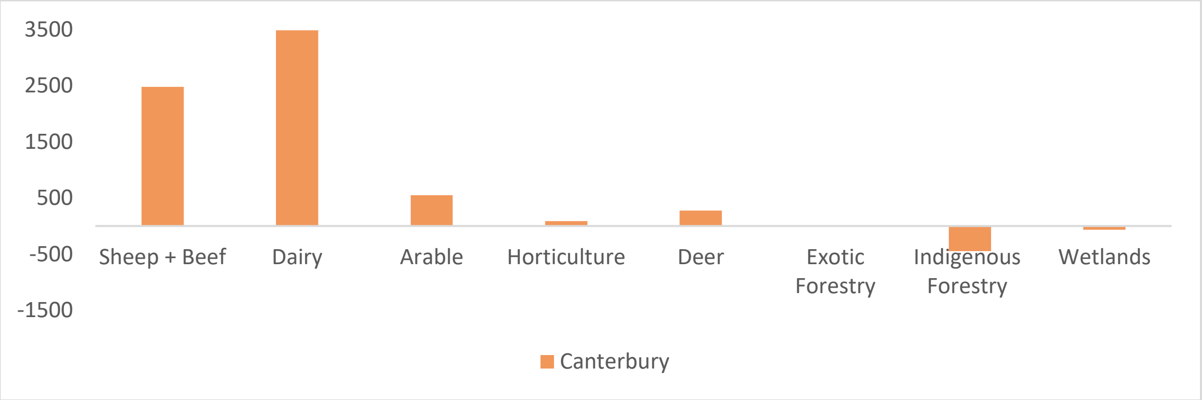


Figure 2-17 shows emission profile for Otago, this shows Sheep & Beef are the main emitter followed by Dairy, and the main sequestration of emissions by Indigenous Forestry.

Figure 2-17: The biological emission profile of Otago land use (kt CO_2 eq per annum).

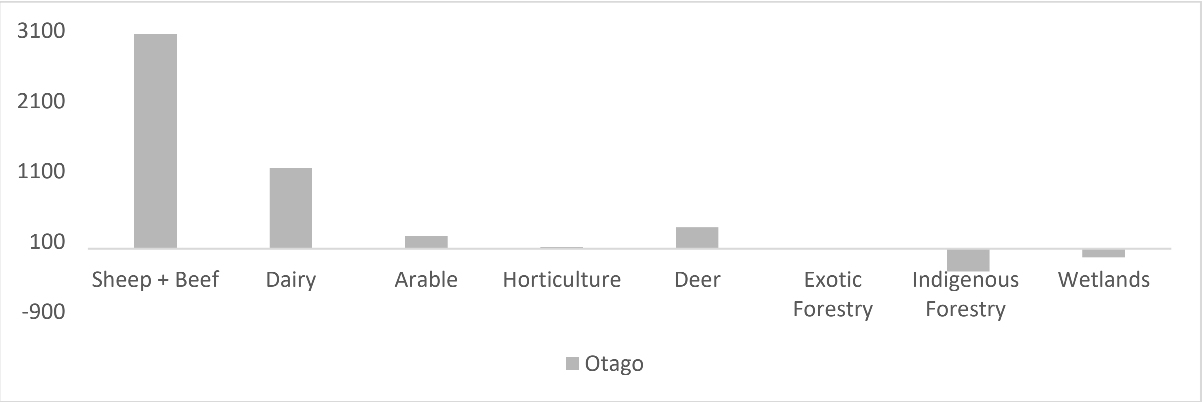


Figure 2-18 shows emission profile for Southland, showing Dairy the main emitter followed by Sheep & Beef, and the considerable sequestration of emissions by Indigenous Forestry.

Figure 2-18: The biological emission profile of Southland land use (kt CO_2 eq per annum).

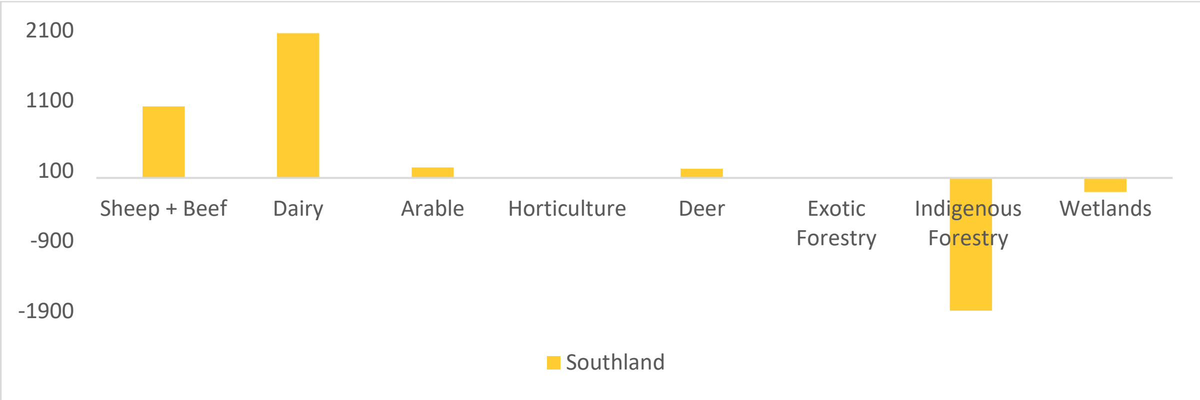
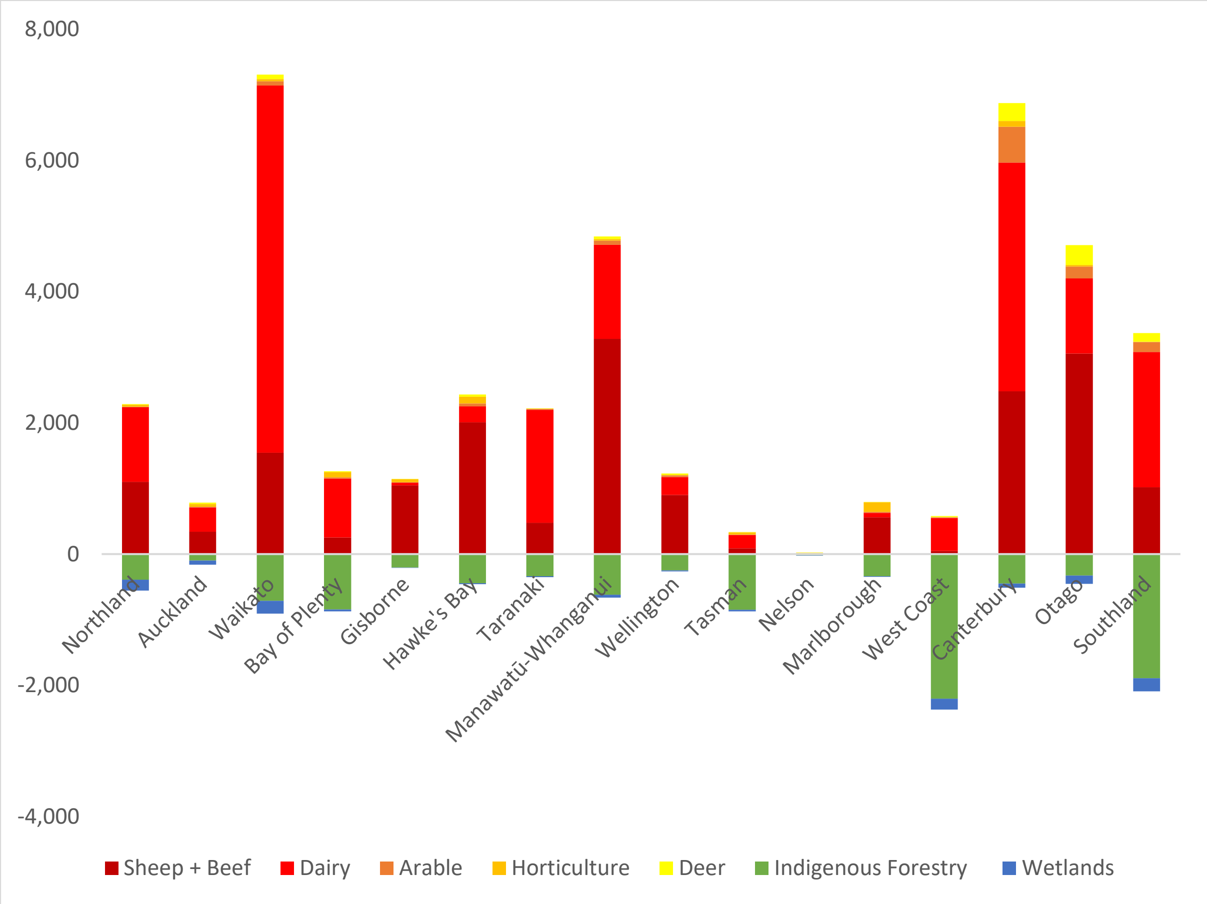


Figure 2-19 summaries the emissions by land use by region. This shows clearly the difference between the regions. Emissions from Dairy are the greatest in Waikato, followed by Canterbury, Southland and Taranaki, which is not surprising given dominance of Dairy in those regions. The emission from Sheep & Beef are relatively lower with main regions being Manawatū-Whanganui, followed by Canterbury, Otago and then Hawkes Bay. The emission sequestration from indigenous is greatest in the West Coast and Southland.

Figure 2-19: Biological emissions by land use by region



Chapter 3
Economic, Social, Cultural and Environmental Impacts from Current and Future use of Biological Resources

In this chapter, six scenarios are developed to show the economic, social, and environmental impact of land use change to meet either bioenergy targets or increases in export revenue. The scenarios vary as to their practicability but show the impacts of feasible and extreme scenarios. The AERU Integrated Assessment Framework was deployed for the analysis.

3.1 Introduction

New Zealand already asks a lot of our biological resources; they are critical for our economy contributing to our exports, for storing carbon and the provision of water and food and materials and other ecosystem services we rely on. However, our biological resources are limited, and New Zealand already imports significant quantities of 'fresh' biomass, the majority of which is used for animal feed (Coriolis, 2023b). In addition, the historic use of our biological resources has exceeded environmental limits on several measures, of which greenhouse gas (GHG) emissions is one. Despite the country's overall emissions peaking in 2005, agricultural emissions have continued to increase as shown in Chapter 1. Hence, it's not just the change in the scenarios that are of concern, it's the change on top of the current situation.

It is likely that New Zealand will be asking even more of its biological resources in the future. NZ needs significantly more biomass for bioenergy production and New Zealand's biological resources will play a critical role in growing the country's economy and increasing the value of its exports. Therefore, it is important that New Zealand can leverage the greatest value from our bioresources while ensuring the sustainable use of those resources and the ecosystems that underpin them. This will make sure that we are growing and not diminishing our ability to extract value from them in future.

For the purposes of this research, we are defining value in terms of a set of interdependent economic, environmental, and social outcomes from changes in pastoral land use excluding urban and other land uses. The other land uses in particular our conservation estate, wetlands, reserves and recreational land provide important services. These are both productive and of high value to New Zealand acting as ecosystems services.

This chapter uses the AERU framework to explore how future primary sector land use change could affect those values in response to bioenergy demand for biomass and options for increasing economic production, especially meeting the target of doubling exports. This chapter focusses on existing land uses whereas doubling exports can be achieved by higher productivity, technological change and high value processed exports. Six scenarios are considered which will be presented in more detail later.

- *Scenario 1* is producing 75PJ energy from exotic forestry – a target set by EECA;
- *Scenario 2* is producing 150PJ energy from exotic forestry;
- *Scenario 3* is converting 80% of sheep and beef lowland production and 50% of arable into dairy; this is to assess the impact on exports for New Zealand and whilst not realistic will show the stretch needed from existing land uses;
- *Scenario 4* is assuming a 20 % premium for our existing exports; as outlined in more detail below this is a realistic target;

- *Scenario 5* is assuming a 50% premium from our existing exports; as outlined below this is a considerable stretch target but possible given some exports will obtain more than 50% and others less;
- *Scenario 6* is assuming a combination of the conversion if sheep and beef and arable into dairy (Scenario 3) and the 50 % premium (Scenario 5). This is not a realistic scenario; as stated above the conversion is certainly not feasible under current conditions and the 50% premium is certainly a stretch. However, this scenario does show the difficulty of meeting the export target from existing land uses.

This chapter assesses impacts on measures of economic, social, cultural and environmental wellbeing from current uses of biological resources. The wellbeing framework comes from Dalziel et al. (2018). To assess these impacts, the AERU Integrated Assessment Framework was deployed for the analysis.

The AERU Integrated Assessment Framework is a tool for showing economic, social, environmental and cultural impacts of land use change. Developed with funding from *Our Land and Water National Science Challenge*, this tool has been co-designed with regional councils, district councils and the Treasury. The Framework is based on a mixed methods approach. This includes using Input/Output modelling to show economic impacts of land use change. It also includes value-added impacts on secondary industries. It also analyses direct, indirect and induced employment changes. Environmental impacts include greenhouse gas emissions, as well as other variables such as air pollution, biodiversity, E. Coli, macro-invertebrate index and river water quality.

The best use of the bioeconomy is to look at different ways to meet targets. When land-use changes, this has economic, social and environmental impacts. For economic impacts also wider flow-on effects for the community can be observed. For example, with an increase in dairy farming direct effect is simply the change in the revenue or output from farms and/or employment levels. However, indirect effects are the output and/or employment generated by other firms servicing the farms in the area, such as input suppliers. So, as production increases, further specialist expertise is needed by a farm such as: transport services, refrigeration specialisation, farm management consultancy. The induced effect is the impact on output and employment resulting from the changes in household expenditure in the area, flowing from direct and indirect effects. Farmers and their suppliers who now have more disposable incomes to spend on local businesses.

The cultural variables in the framework have been selected in consultation with Māori stakeholders, including some environmental and social indicators. Currently, it includes mahinga kai and sense of belonging. Social indicators include life satisfaction, self-rated health status and connection to nature.

The Framework has been developed from its prototype structure to meet the requirements of this project. It has been extended to provide separate modules for all regions. The variables in the framework were modified in consultation with MBIE and stakeholders.

The variables included in the framework are listed below:

Economic

- Revenue per hectare by land use
- Gross Output: direct, indirect and induced
- Employment: direct, indirect and induced
- Value added: direct, indirect and induced

Environmental

- Air Pollution
- Biodiversity

- E. coli
- GHG Emissions
- Ground Water Quality
- Macro-Invertebrate Index
- Mahinga Kai
- River Water Quality
- Soil Quality
- Swimming Index
- Residual Woody Biomass

Social

- Access to Basic Amenities
- Life Satisfaction (Current)
- Life Satisfaction (Future)
- Public Transport
- Self-rated Health

Types of land use were selected in consultation with MBIE and stakeholders. This includes the key agricultural land uses by type, forestry and other land uses such as wetlands.

- Sheep & Beef
    - 1 South Island High Country
    - 2 South Island Hill Country
    - 3 North Island Hard Hill Country
    - 4 North Island Hill Country
    - 5 North Island Intensive Finishing Farms
    - 6 South Island Finishing-Breeding Farms
    - 7 South Island Intensive Finishing Farms
    - 8 South Island Mixed Finishing Farms
- Dairy
    - Low Input (Class 1+ 2)
    - Medium Input (Class 3)
    - High Input (Class 4 + 5)
- Deer
- Arable
- Horticulture
- Exotic Forestry
    - Pruned for Logs
    - Unpruned for Logs
    - Unpruned for Bioenergy
- Indigenous Forestry
- Wetlands

Environmental impacts such as greenhouse gas emissions were quantified using relevant emission factors. Where quantitative data is not available, qualitative data is used based upon expert opinion and literature reviews.

The following assumptions for the framework were:

- It is a static model, therefore the changes are assumed to be seamless;
- No technological improvements;
- Existing business models are able to lever the change;
- No limitations for factors such as labour or capital e.g. immigration, housing etc.;
- The model is based on 6 land-use categories, hence urban / transport is excluded;
- For the baseline/ business as usual case no conversion costs and no tipping points were included.

As mentioned above, scenarios on potential significant new demand to the use of biological resources were developed in consultation with MBIE and other stakeholders. The analysis included possible land use changes to decarbonise the economy. Future demands will include the potential demand for bioenergy using the two scenarios identified in the RFP (75PJ of bioenergy per annum for 2030; and 150 PJ of energy per annum for 2050). These were calculated by determining the area each region would need to convert to exotic forestry for bioenergy to meet the Peta Joule (PJ) target. Exotic Forestry was modelled as *Pinus radiata* on a 28-year harvest rotation. This also implies the required biomass would not be available until the end of the first rotation (representing at least a 28-year lag). In actuality, there would be the potential for short-rotation forestry with alternative exotic species to be used, especially for the initial cohorts required with less lag; however, this would likely encounter other constraints as short rotation forestry requires flat land which being more productive may be economically unviable. Areas were allocated proportional to the size of each region and yield of Exotic Forestry in that region. That area would then be proportionally deducted from the hill country Sheep & Beef classes (Classes 1-4).

Other scenarios will include different levels of premiums for New Zealand products and a change in land use from Sheep & Beef and Arable into Dairy. These scenarios are export focused, particularly through adding premiums to New Zealand products in order to receive higher value in overseas markets. The scenarios were modelled assuming 20 per cent and 50 per cent premium for exports. These will be described in more detail in the respective section.

It needs to be mentioned that these are not realistic scenarios. The scenarios have been developed to show what it needs to achieve the target of doubling exports.

It is important to understand the range of different effects associated with the scenarios. It is especially relevant because different groups in society may bear the costs of the impact, while other groups may gain in terms of the benefits. The distribution of the costs and benefits across society can have important implications for policy makers and may not be apparent if a policy is assessed only for its aggregate, district level outcomes.

Table 3-1 presents an overview of the scenarios assessed in this chapter.

Table 3-1: Scenario overview.

	No.	Scenario Name	Description
Bioenergy Scenarios	1	Bioenergy 75PJ	Creating 75PJ (Peta Joules) per year, transferring Sheep & Beef hill land to Exotic Forestry for Bioenergy production.
	2	Bioenergy 150PJ	Creating 150PJ (Peta Joules) per year, transferring Sheep & Beef land to Exotic Forestry for Bioenergy production
Export Scenarios	3	Export 1, Land use change	80% of flatland Sheep & Beef farming and 50% of arable farming is transitioned to intensive dairy farming
	4	Export 2, 20% premium	A 20% premium is received for all products
	5	Export 3, 50% premium	A 50% premium is received for all products
	6	Export 4, Land use change & 50% premium	Combine 'Export 1' and 'Export 3' Scenarios

The AERU Integrated Assessment Framework, as stated above, was used to show the economic, environmental, social and cultural impacts from future uses of biological resources and allows a clear comparison with the current situation. The Framework is designed to evaluate scenarios affecting land use. The Framework allows for land uses to alter as required, constrained by total land availability in the region. It calculates impacts of this on direct, indirect and induced economic returns through Input-Output tables and also impacts on direct, indirect and induced employment. It also recalculates the impact on greenhouse gas emissions using the relevant emission factors as well as the impact on the other variables in the framework.

3.1.1 Economic Impact Analysis

For the economic impact analysis (EIA), a regional level Input-Output (IO) model the 16 regions and a national IO model for New Zealand (Base year 2019) were used (Butcher, 2022). The use of IO models is a standard methodology for EIA of industry sectors, and the IO models have been developed using standard methodologies.

One of the core strengths of IO analysis is that it captures the complex interactions and interdependencies which take place between different sectors within an economy. This means that it is possible to consider a number of the indirect or flow-on effects that occur throughout an economy as a result of any type of economic change. IO analysis also enables economic impacts to be evaluated at the level of individual sectors or industries, thus providing a disaggregated picture of the nature of economic impacts.

At the core of any IO analysis is a set of data that measures, for a given year, the flows of money among various sectors or industrial groups within an economy. These flows are recorded in a matrix or 'IO table' by arrays that summarise the purchases made by each industry (its inputs) and the sales of each industry (its outputs) from and to all other industries. By using the information contained within such a matrix, mathematical relationships are calculated for the economy in question.

These relationships describe the interactions between industries, specifically, the way in which each industry's production requirements depend on the supply of goods and services from other industries. With this information it is then possible to calculate, given a proposed alteration to a selected industry (a scenario), all of the changes in production that are likely to occur in the supporting industries to assess the impact on the wider economy.

Using this methodology, it is possible to calculate multipliers in order to estimate three effects of climate change related events to the district, regional and national economy:

(1) Direct effect: The direct effect is simply the change in gross output. It is accepted that secondary processing of the product (such as conversion of milk to milk powder) may occur but these additional economic costs have not been incorporated into the study.

(2) Indirect effect: The indirect effects are the value added generated by other firms servicing the farms in the relevant area, such as input suppliers. An example may be that as production changes, further specialist expertise is needed by a farm such as: transport services, refrigeration specialisation, farm management consultancy, which for example, will be affected as well i.e. as a consequence of land use change.

(3) Induced effect: The induced effect is the impact on value added resulting from the changes in household expenditure, in the relevant area, flowing from the estimated direct and indirect effects. The electrician who does not purchase goods from the local supermarket is an example of induced effects arising from land use change scenarios modelled in this study.

Multipliers for indirect and induced expenditure flows were obtained from output multiplier tables in Butcher (2022).

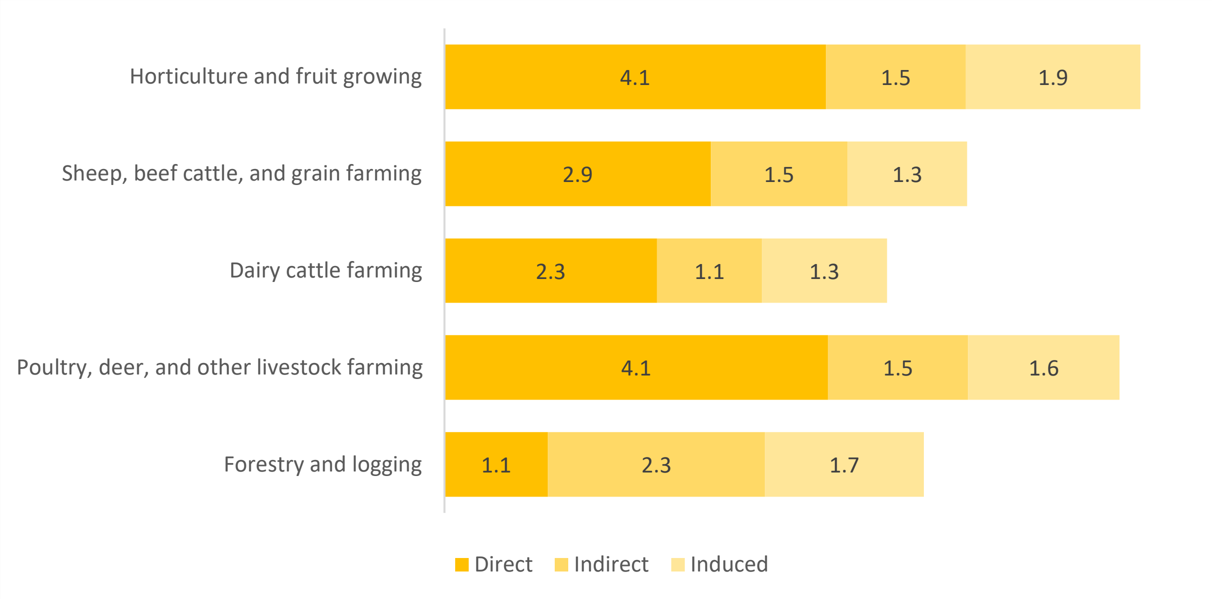
Employment effects

Employment estimates associated with the total expenditure – including the direct, indirect and induced impacts – were calculated for the different categories using relevant multipliers obtained from Butcher (2022) The multiplier tables estimate the average number of employees required to produce a million dollars of output by industry. These multipliers were applied to the direct, indirect and induced impacts of land-use changes to obtain estimates of employment for firms supplying or servicing these sectors.

The employment multipliers are averages and are a coarse measure of the impact on employment. If there is a change in land use from sheep & beef to dairying they are likely to underestimate the impact on employment. Also, individual farmers will be making decisions regarding their employment levels perhaps increasing their workloads as financial constraints arise, and this is not reflected here.

Figure 3-1 shows that investment in Horticulture and fruit growing has a higher impact on employment, in terms of direct, indirect and induced effects. Forestry and logging has the lowest direct impact on employment of these industries.

Figure 3-1: Employment effects of investment in industry.



3.2 Environmental impacts

In the case of emissions and residual biomass, data was used to assess the impact of each land use as described below.

For the remainder of the impacts, a Likert scale was used to assess the impact of that land use, using scores based on literature and expert judgment.

Emissions factors

Emissions factors were taken from MfE (2022d). Total emissions per hectare (by region and farm-classes) were then calculated using Beef and Lamb benchmarking reports (2019a:f) in the case of sheep, non-dairy cattle, and deer. While DairyBase financial benchmarking statistics for owner-operators (2021) were used to quantify figures for dairy cattle.

Calculated head per hectare by the regional groupings in Beef and Lamb's benchmarking, and specific to these farm classes were used. Estimates of the average head per stocking unit for non-dairy cattle by regional grouping was performed by aligned the stocking units reported in the Beef and Lamb benchmarks with StatsNZ data (2021) on animal numbers by region. Averages of head per stocking unit for sheep were calculated from the Beef and Lamb benchmarking data alone.

In the case of indigenous forestry, it was assumed that it is regenerating forest pre1990 with emission factors of -1,567 kg CO_2 eq/unit per hectare (MFE, 2022d).

Residual biomass

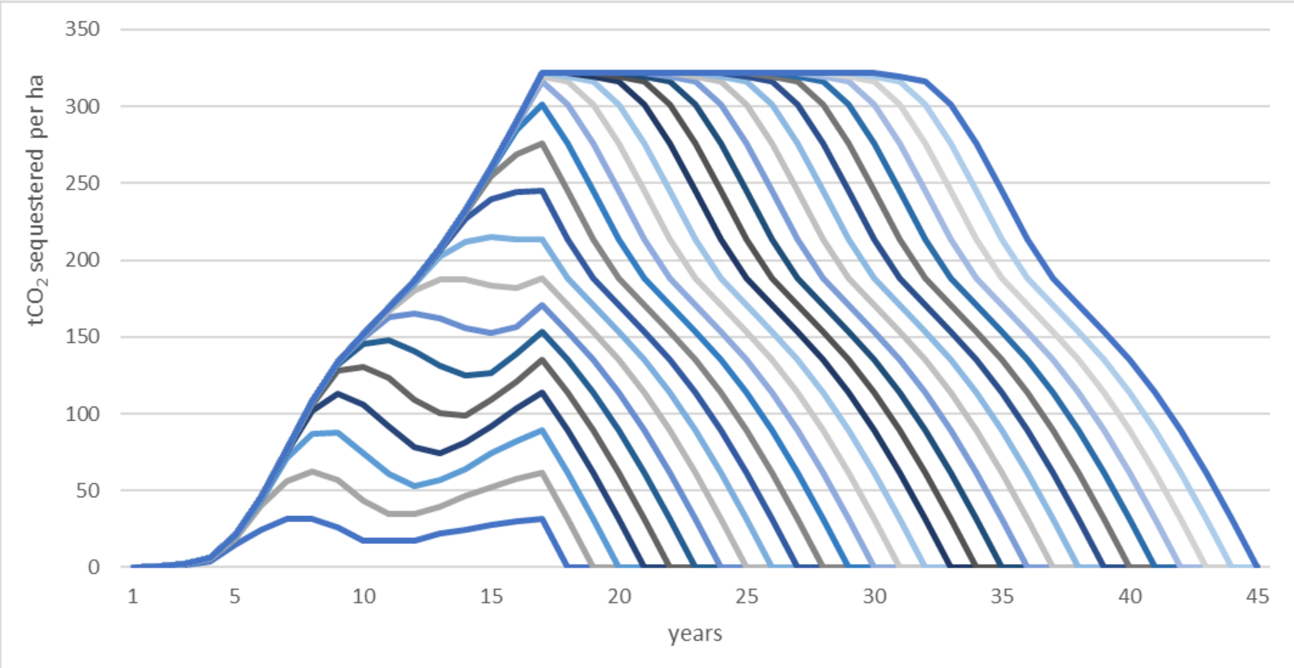
The residual woody biomass estimates were calculated from tables found in Hall, P. (2022). This is given as gross supply of residues by region in m^3 and also GJ. This has been taken as a proportion of forest in 2021 to indicate the percentage of forest residue to area.

Greenhouse gas emission calculations

The assumptions around greenhouse gas emissions for productive forestry are that sequestration gained from planting and growing trees are negated by the uses of forest products post-harvest. Thus, the ongoing emissions profile of rotation forestry is neutral. There is, however, some sequestration gains associated with new land entering into forestry production. Outside of the ongoing cycle of harvest and planting, the sequestration from the first half of the first rotation (16 years for *Pinus radiata*) is considered as a net change in emissions from the baseline. The scenarios which entail an increase in productive forestry will account for an increase in sequestered greenhouse gases for the first 16 years of new plantings, after which the ongoing rotations are considers emissions neutral.

Additionally, some scenarios discuss staging plantings to ensure annual harvests necessary for supplying bioenergy. In these scenarios the sequestered carbon from the first 16 years of planting would similarly be staggered. Figure 3-2 shows how this staggered planting in 28 cohorts would account for sequestration over a 45-year period.

Figure 3-2: Average carbon sequestered by new Pinus radiata plantations.



Scenarios 1 and 2, both imply a large cohort of new exotic plantings in order to produce the continuing biomass required for energy production. There is thus an expectation of significant sequestration from these newly planted cohorts in their first rotation.

3.2.1 Baseline

In this analysis, the baseline presents the 'no change' case or current situation. This will be used to compare the impacts of the scenarios.

Figure 3-3 shows the direct, indirect and induced annual gross output in the 16 regions of New Zealand for the base scenario. The direct economic gross output has been estimated to be $34,505m for total New Zealand, highest gross output estimated for Waikato ($6,714m), followed by Canterbury ($6,272m), then Otago ($3,029m).

Total economic gross output (including direct, indirect and induced effects) is valued at $46,620m for New Zealand.

By land use type (shown in Figure 3-4), highest direct gross output was estimated for Dairy ($19,375m), followed by Sheep & Beef ($6,505m), then horticulture ($3,318m). The total aggregated output for Dairy is estimated at $25,296m; Sheep & Beef is valued at $8,867m and $4,683 for horticulture.

Figure 3-5 shows the direct, indirect, induced and total impact on employment in 16 regions and total New Zealand for the base scenario. It was estimated that the direct employment impact in the base scenario totalled 94,176 FTES's in New Zealand with the largest number of FTE's estimated for Waikato (17,830 FTEs), followed by Canterbury (13,963 FTEs), then Otago (9,641 FTEs). Total employment (including direct, indirect and induced effects) is 143,758 FTEs for New Zealand.

By land use type (shown in Figure 3-6), largest direct employment was for Dairy (48,493 FTEs), then Sheep & Beef (19,805 FTEs) and horticulture (13,343 FTEs). Total aggregated employment (including indirect and induced effects) was estimated at 72,356 FTEs for Dairy, followed by 29,602 FTEs for Sheep & Beef, then 19,239 FTEs for horticulture.

Figure 3-7 shows the emissions profile by region. This shows Waikato, Canterbury and Manawatu-Whanganui are the regions with the highest annual emissions in the country.

Figure 3-8 shows the emissions profile by land-use in New Zealand. This shows that dairy is the main emitter, followed by Sheep & Beef, then Arable. Indigenous forests and wetlands are the main sequestration of emissions.

Table 3-2 shows the value of exports by sectors derived from the Input-Output table provided by Butcher (2022). Exports from the sectors of interest were valued $39,683m in 2019.

In the baseline, the gross supply of in-forest residues (from landings and cutovers) was highest in the Bay of Plenty (1,547,020m^3) annually, followed by Gisborne (846,784m^3); then Hawkes Bay (621,980m^3); shown in Figure 3-9. Hall emphasises that these are the theoretical maximum, and that recovery factors need to be applied to the recoverable volumes from landings, and cutover areas. In Bay of Plenty, 900,303 m3 of in-forest residues could be recovered at Recovery Level 1 (landings 80%, GB cutover 70%, hauler cutover 10%) or 213,455m3 recovered at Recovery Level 2 (landings 65%, GB cutover 56%, hauler cutover 5%).

Figure 3-3: Baseline - direct, indirect and induced gross output impacts by region, in NZ$m per annum.

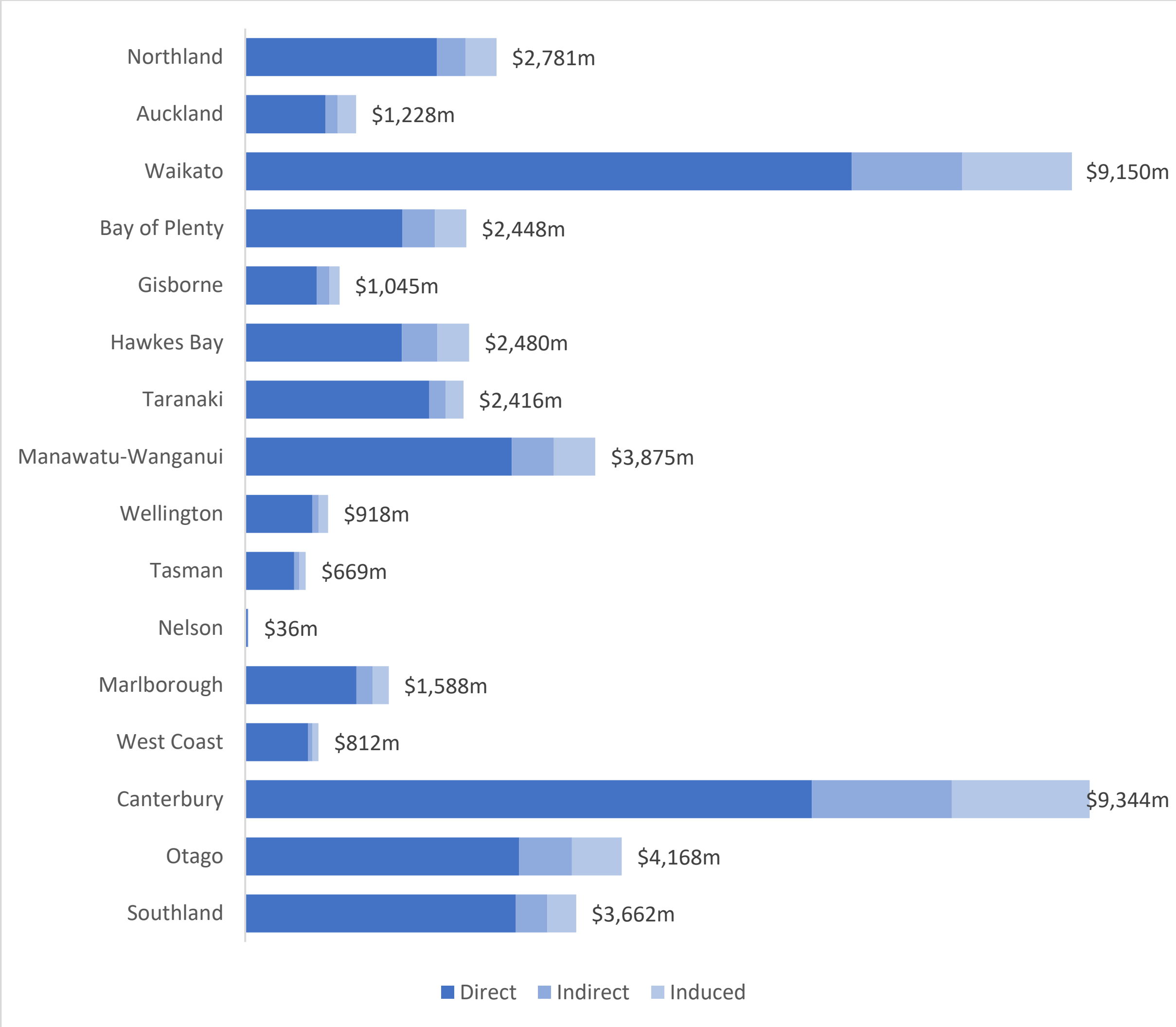


Figure 3-4: Baseline - direct, indirect and induced gross output impacts, in NZ$ per annum.

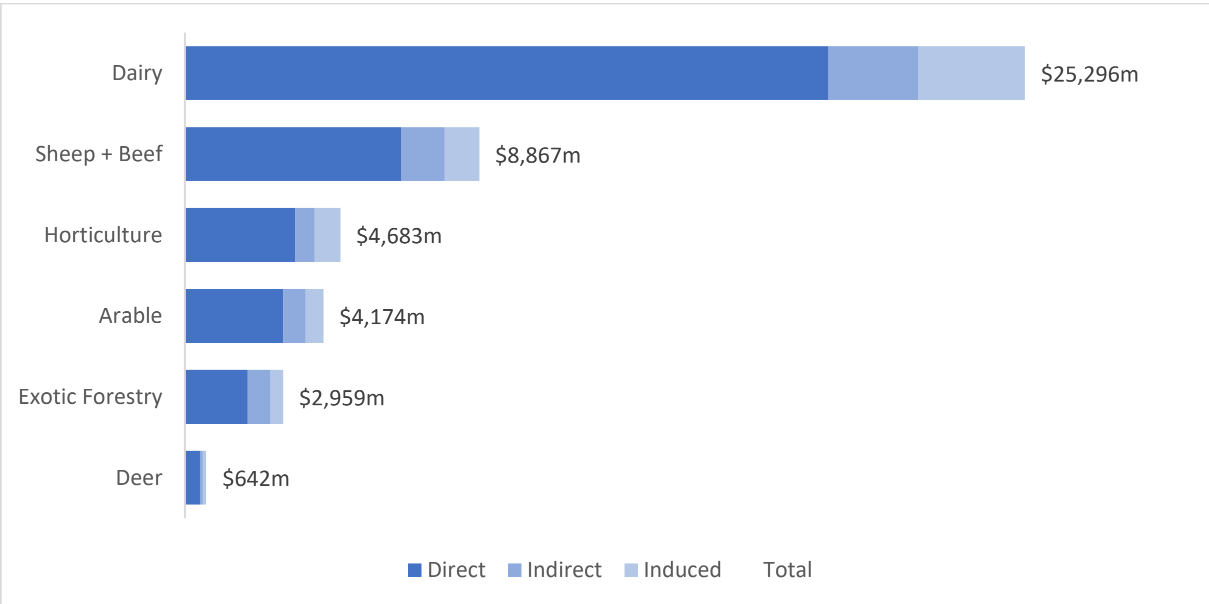


Figure 3-5: Baseline - direct, indirect and induced employment impacts by region, in FTEs.

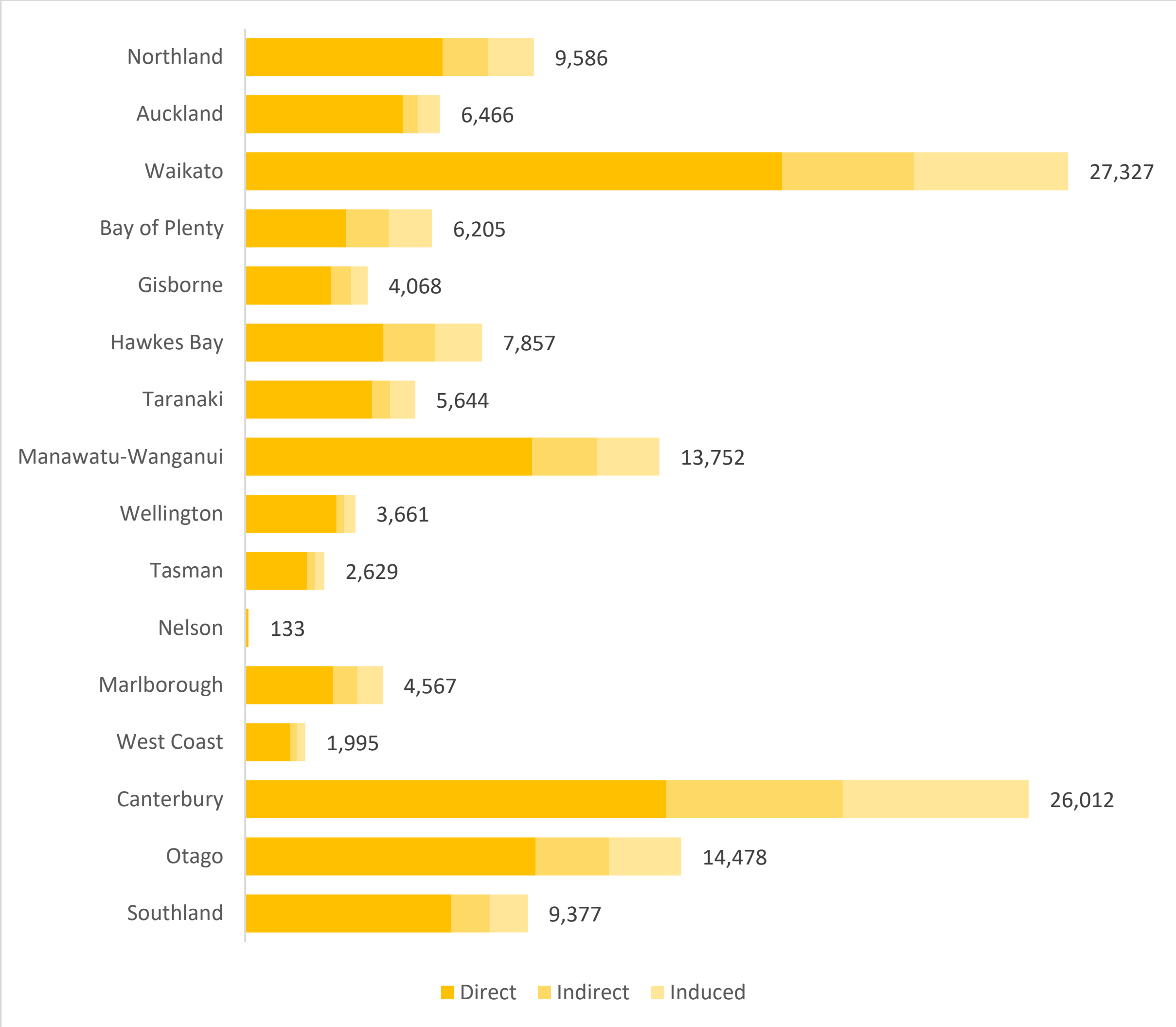


Figure 3-6: Baseline - direct, indirect and induced employment impacts by land use, in FTEs.

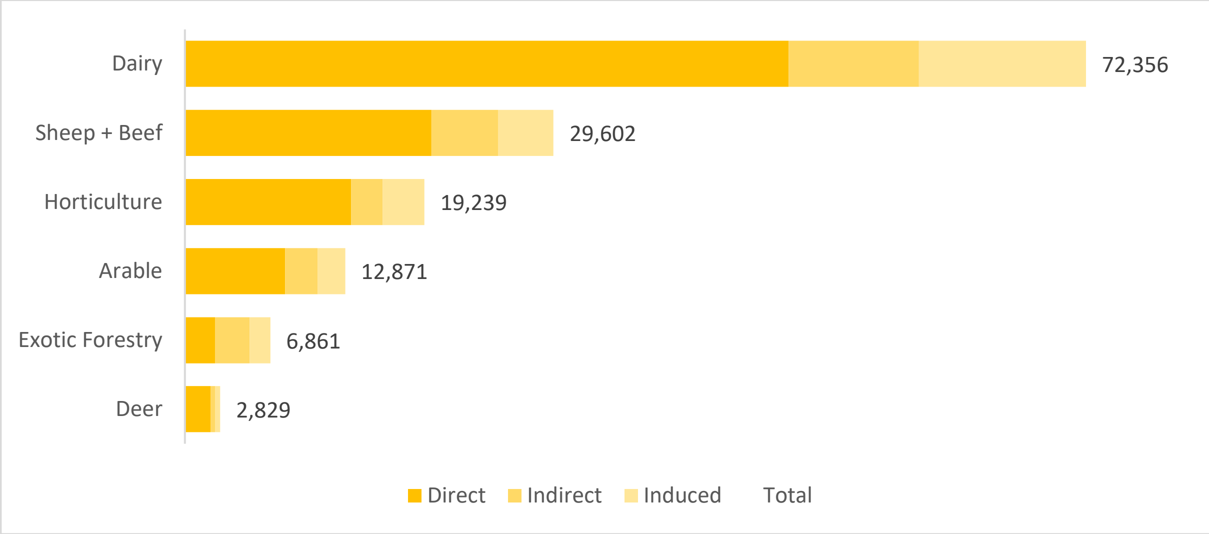
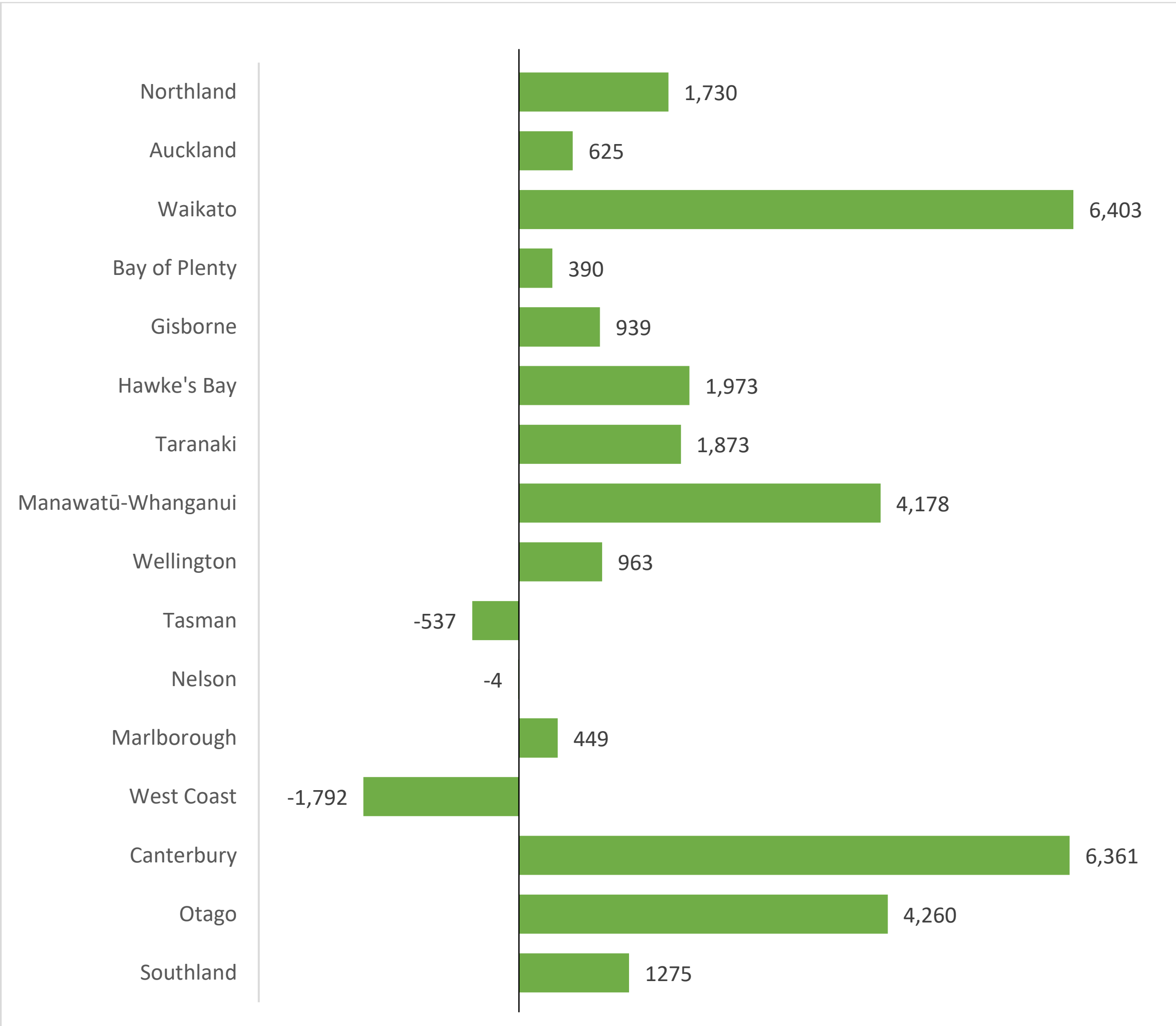


Figure 3-7: Baseline - greenhouse gas emissions by region, in kt CO_2 eq. per annum.



Note: Urban / transport is excluded.

Figure 3-8: Baseline - greenhouse gas emissions by land use, in kt CO_2 eq. per annum.

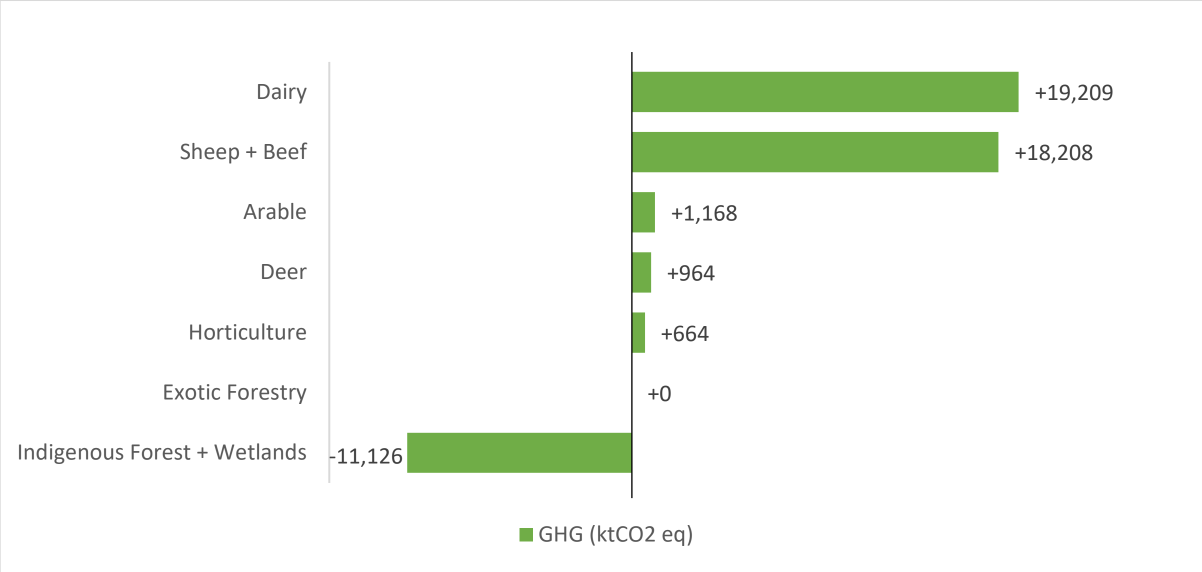
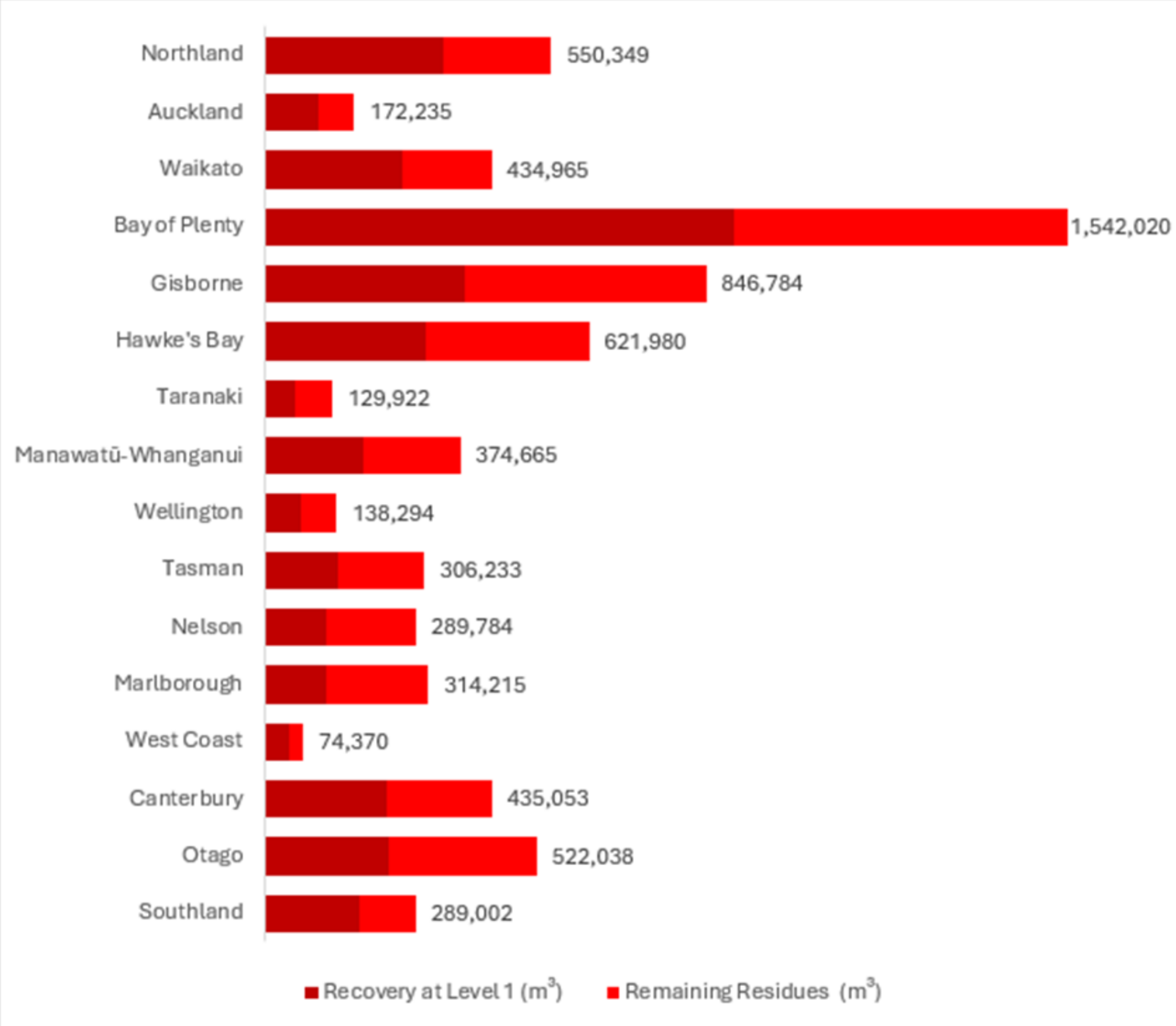


Table 3-2: Exports by sector, NZ$m FOB, 2019.

Sector	**Export value $m FOB**
Horticulture	6,374
Sheep, Beef	9,255
Dairy	19,437
Poultry, deer, and other livestock farming	648
Forestry	5,294
TOTAL	**39,683**

Source: Butcher, 2022.

Figure 3-9: Baseline - gross supply all in-forest residues, in m³ per annum.



Note: In-forest residues include landing / roadside residues, flat to rolling terrain (ground-based harvest) cutover, and steep terrain (hauler harvest) cutover. These residues have differing levels of accessibility, cost of recovery and levels of recoverability. There are environmental limits which need to be applied to some resources (e.g. straw and stover and in forest cutover residues) to maintain soil fertility, biodiversity and potentially mitigate soil erosion.
Source: 'Residual biomass fuel projections for New Zealand; 2021', Peter Hall, Scion; Appendix A.

3.3 Scenarios

In this section, six scenarios and their results are presented. The graphs show the direct, indirect and induced impact on gross output and employment by region and by land-use as well as the total impact which comprises direct, indirect and induced impact from the scenario. Also, the direct, indirect and induced impacts on employment by region and by land-use are presented. Further, changes to the baseline by region and by land-use from each scenario are presented as well. Greenhouse gas emissions and forestry slash (in-forest residues from landings and cutovers) and their respective change from the baseline to the scenario are also outlined. In addition, social and environmental impacts are presented in scoring spider graphs.

Variables not considered in the two bioenergy scenarios

The model is designed to provide the direction of impact that land use change will have on multiple outcomes. It is not a detailed model assessing current woody residues supply (analysis which is currently being undertaken by MPI). For example, the availability and collection of windrow slash, skid site residues and cord recovery depend upon a number of factors including distance from market and cost of recovery. Residues supply might be reduced due to costs associated with the transport of residues, making a proportion of these supplies uneconomic for bioenergy. More detailed analysis using other models is required to understand the detailed cost, volumes, energy content and methods of recovery. The infrastructure and logistics to harvest residues also needs to be better understood and these will vary depending on the geography of the region. Finally it should be noted that there are time lags until residues supply become available.

Conversely a proportion of the biomass requirements could be generated with a lower than modelled impact on current sheep and beef outputs by;

1) *Utilising residues from existing forestry.* The model assumes the biomass for bioenergy is from additional forestry plantings arising from land use change. While there may be sufficient residues from current forestry production, economically recoverable forest and mill residues are utilised for a range of purposes including process heat (through boilers systems), feedstock for MDF plants, animal bedding and so forth. Bioenergy feedstock would need to be able to compete on price with existing uses. In addition, ways could potentially be found to recover residues that are currently uneconomic or operationally challenging to recover.
2) *Converting the least productive parts of farms to forestry (versus whole farm conversions).* The scenarios for bioenergy production assume that sheep and beef production is fully impacted by the change in land use to forestry. However supply could also be created through converting the least productive areas of hill country grazing properties, with a lower impact on production and employment than forecast in the scenarios. There is evidence that if a proportion of a sheep and beef farm was converted to forestry this would have a lower negative impact on sheep and beef output. For example Matheson et al (2013) found that in areas where potential pasture production is low (<4t DM/ha), conversion from pastoral farming to forestry is likely to have minimal impact on farm profitability when considered on the basis of long-term pricing for timber and animal products. They found that when afforestation of steep hill country was modelled on case study farms in the Upper Waikato, there was limited (if any) reduction of long-term enterprise operating profit. However, this does depend on access to market. Reisinger et al (2017) found on sheep and beef farms, there is much higher potential to plant small blocks of unimproved land into trees without significantly affecting overall production of the farm. In some cases, this land will be steep and not suitable to harvest, whereas in others harvesting would be possible. They assumed that about 6% of current sheep and beef land (amounting to about half of the unimproved

land on a typical farm) could be planted in trees, with half of this intended for harvesting and the other half planted for conservation purposes. They also assumed that this would be from grazing land and hence would be counted as land-use change. There are also other benefits of converting land from sheep and beef to forestry. Dooley et al (2021) studied Six farming case studies in the Waikato and Bay of Plenty, and four in the Rangitikei (Taihape area). They found famers had multiple reasons for integrating trees into the business, apart from income timber and/or carbon, including retirement of poor-quality farmland, easier management of hill slopes, environmental reasons (e.g. reduction of nutrients or greenhouse gases, nutrient trading, erosion control, cleaner waterways), and shade and shelter. Also converting land into forestry can reduce costs such as pest and weed control on sheep and beef land allowing those resources to be saved or used more productively elsewhere on the farm.

3) *Use of short rotation crops*. Trials are underway on short rotation crops which can boost residue supply. However short rotation crops require relatively flat land which will bring about other land use changes.

3.3.1 Scenario 1 – Bioenergy 75PJ

Bioenergy Scenario 1 looks at creating 75PJ (Peta Joules) per year, by transitioning Sheep & Beef hill land to Exotic Forestry for Bioenergy production. The target of 75PJ per year is the primary energy demand for bioenergy in 2030, based on EECA's "TIMES-NZ 2.0" Model (2021), which looks at economic cost and availability of bioenergy.

Current in-forest residues and other material could potentially meet this demand but the majority of economically recoverable residues are well utilised by other purposes including mills firing their own boilers, sending residues to MDF plants if nearby, and use for animal bedding and additional demand would need to compete on price. However, if current sources of in-forest residues (thinnings and post-harvest landing and cut-over material) could be made available for bioenergy this scenario would show what is needed to meet the 150PJ target. Other benefits of removing in-forest residues and other waste would also be derived including reduced environmental risks, landing slash reductions and productivity gains in establishment (EECA, 2023)

Figure 3-10 to Figure 3-12 show the land use changes applied in this scenario. To meet the 75PJ level of demand, an area of just over 974 000 hectares would need to be transitioned to bioenergy forests. On a 28 year rotation, this provides for a harvestable area of around 34 800 hectares annually and a sustainable harvest of 21 305 850 cubic metres of woody biomass for energy production. The land changes were calculated by determining the area that each region would need to convert to exotic forestry for bioenergy to meet its share of the Peta Joule (PJ) target every year (after 28 years), ongoing. This implies staged planting to ensure a cohort sufficient of providing the bioenergy target being harvested every year. Areas were allocated proportional to the size of each region and yield of Exotic Forestry in that region. That area would then be proportionally deducted from the hill country Sheep & Beef classes (Classes 1-4). It must be emphasised that the conversion here is at the regional level and doesn't allow for the fact that the agricultural land less suitable to sheep and beef farming will be converted first so the economic impacts in particular may be a lower loss to sheep and beef incomes. This is compared to if whole farms are converted. The West Coast did not have enough Sheep & Beef hill country land to meet its share based on land mass, so the shortfall was made up around the rest of the country.

Figure 3-10: Bioenergy 75PJ - land use change in hectares.

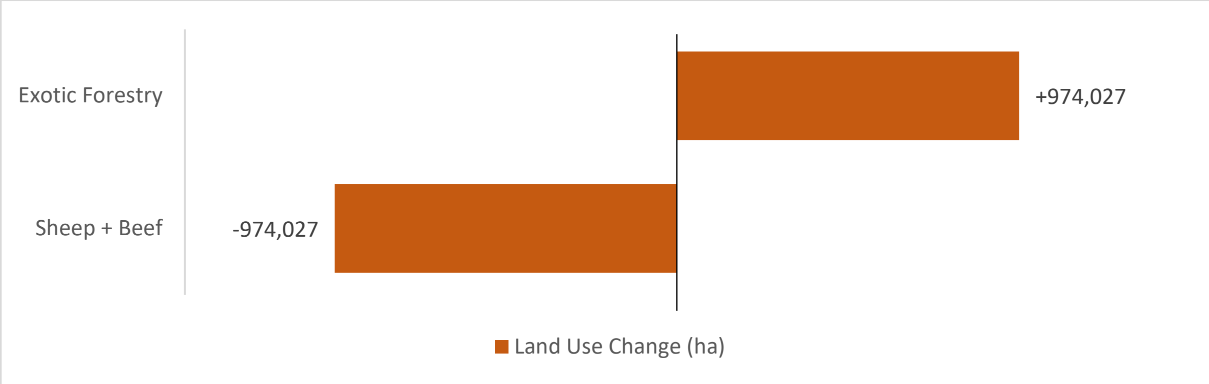


Figure 3-11: Bioenergy 75PJ - land use change in per cent.

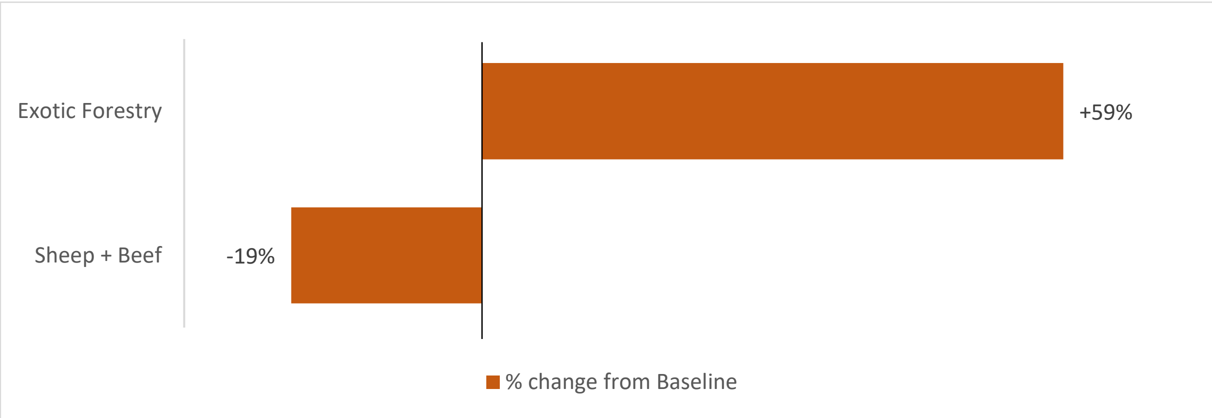
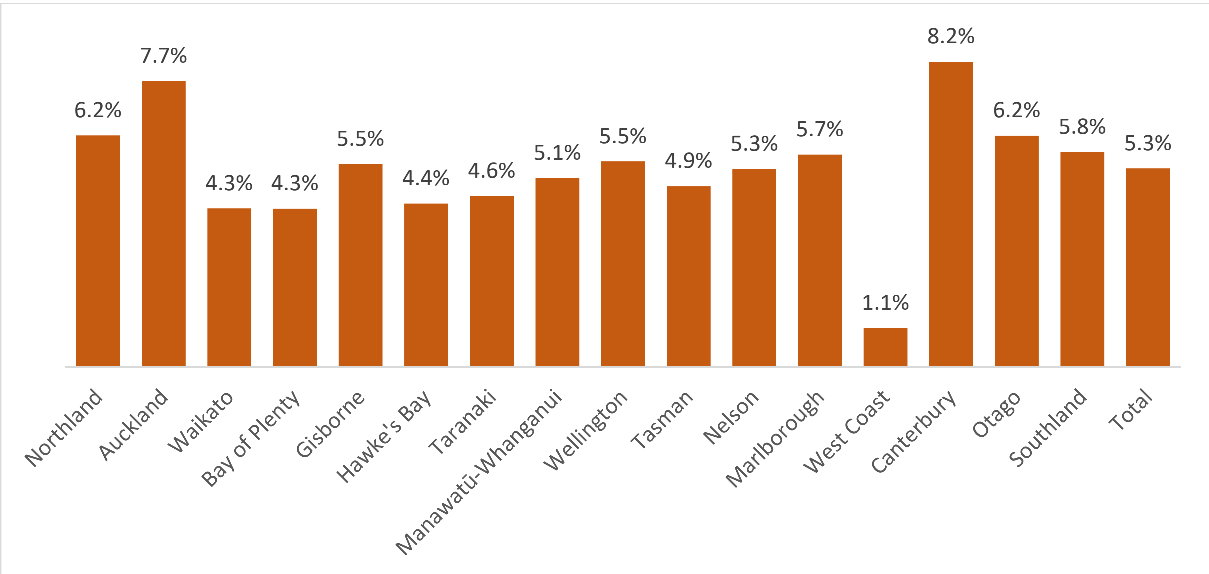


Figure 3-12: Bioenergy 75PJ - land use change in each region in per cent.



Economic impacts

Figure 3-13 shows direct, indirect and induced annual gross output in the 16 regions of New Zealand, with adjustments to land use for the scenario 'Bioenergy 75PJ'. The direct economic impact on gross output has been a marginal increase from the baseline to $34,725m for total New Zealand, highest gross output estimated for Canterbury ($6,280m) followed by Waikato ($6,720m), then Otago ($3,106m).

Total economic impact (including direct, indirect and induced effects) on gross output was valued at $47,909m for New Zealand.

Changes of total gross output (including direct, indirect and induced effects) to the baseline are presented in Figure 3-14. The largest change in direct gross output from this scenario is estimated for Otago (+$142m/ per annum), followed by Southland (+$111m/ per annum), then Hawke's Bay (+$61m/ per annum). In contrast, total gross output is calculated to fall annually by $14m in Northland and by $12m in Manawatū-Whanganui.

Figure 3-13: Bioenergy 75PJ - direct, indirect and induced gross output by region, in NZ$m per annum.

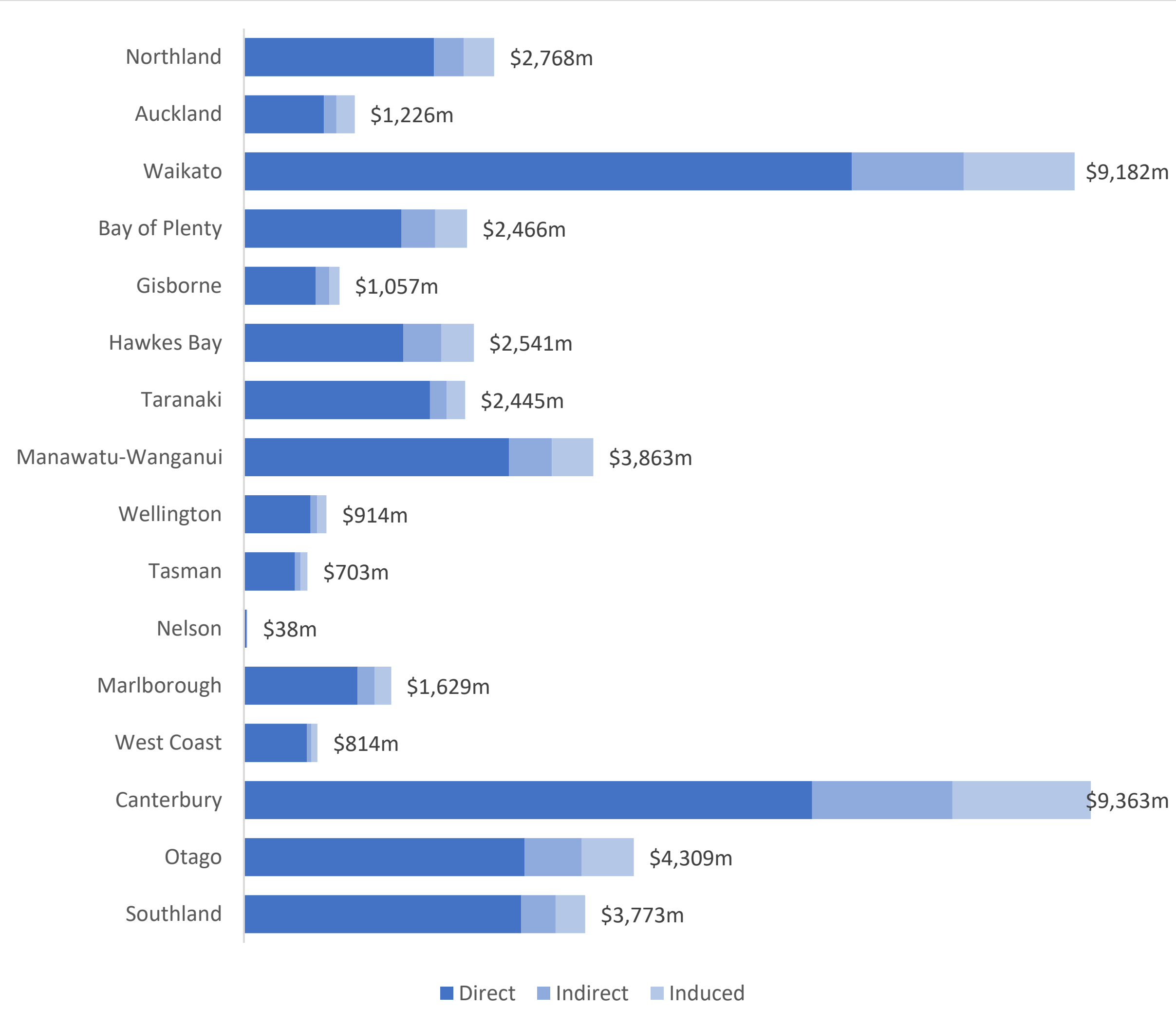


Figure 3-14: Bioenergy 75PJ - total change in gross output from baseline by region, in NZ$m per annum.

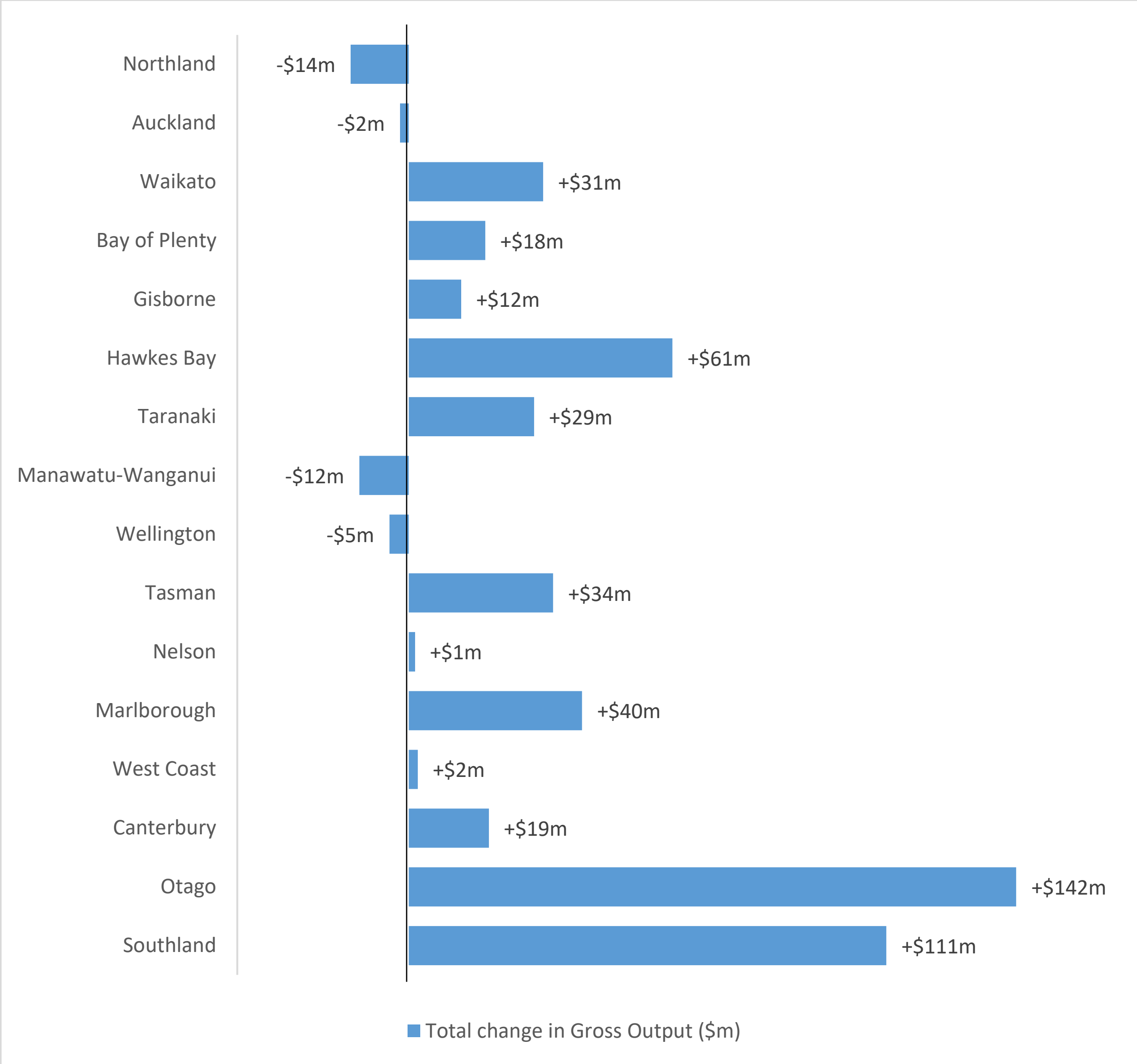


Figure 3-15: Bioenergy 75PJ - direct, indirect and induced gross output by land-use, in NZ$m per annum.

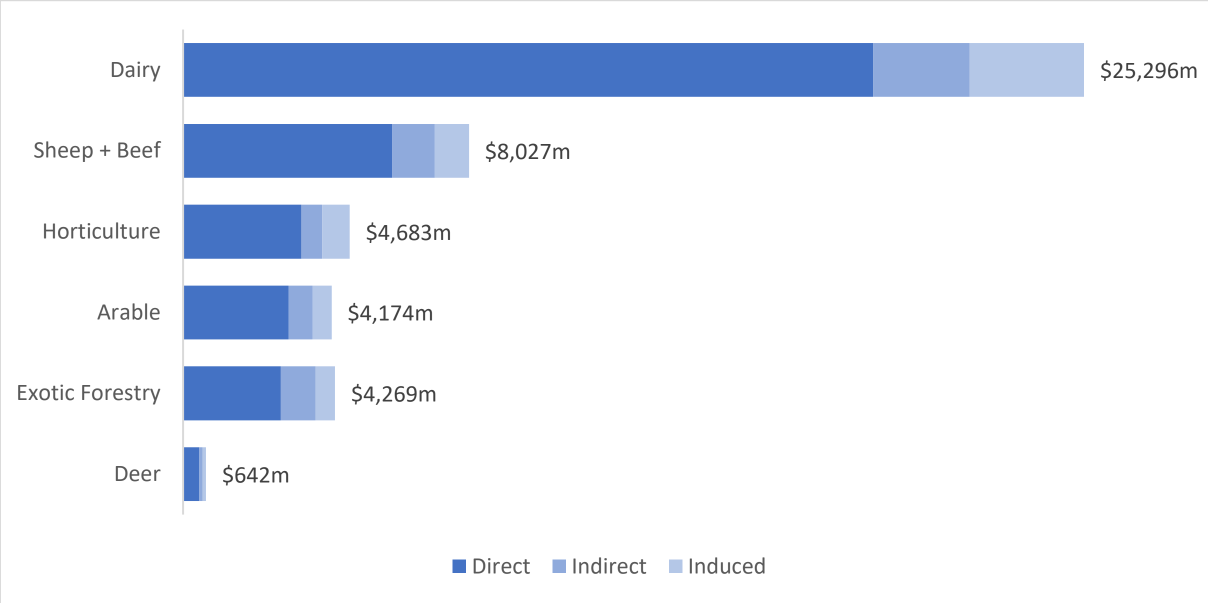
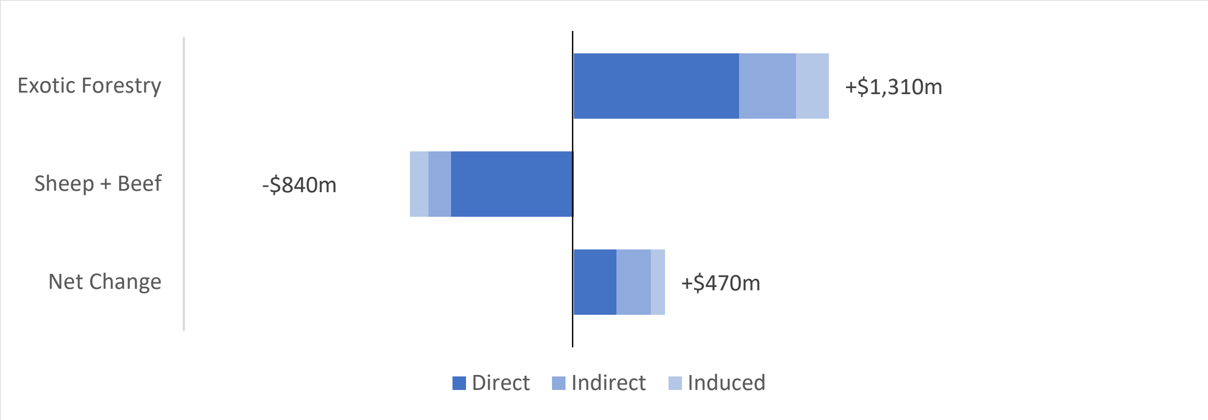


Figure 3-15 shows the direct, indirect and induced annual impacts on gross output by land-use for New Zealand for scenario 'Bioenergy 75PJ'. Results show that direct gross output from Sheep & Beef is calculated at $5,876m per annum and Exotic Forestry at $2,743m per annum. The total annual economic impact by land use for New Zealand is estimated at $8,027m for Sheep & Beef and $4,629m for Exotic Forestry.

Compared to the baseline, as expected, annual direct gross output from Exotic Forestry had the largest increase, growing annually by $850m per annum as shown in Figure 3-16. In contrast and again as expected annual direct gross output from Sheep & Beef was expected to fall by $629m per annum. After the multiplier analysis, total annual direct gross output from in New Zealand was calculated to grow by $1,310 million for Exotic Forestry; and to drop by $840 million for Sheep & Beef. Total gross output (including direct, indirect and induced effects) is calculated to increase by $470m per annum in New Zealand.

Figure 3-16: Bioenergy 75PJ - change in direct, indirect and induced gross output from baseline by land-use, in NZ$m per annum.



Employment impacts

Figure 3-17 shows the estimated direct, indirect, induced and total impact on employment in 16 regions from scenario 'Bioenergy 75PJ'. It was estimated that the direct employment impact from the scenario totalled 93,054 FTEs in New Zealand with the largest number of FTEs estimated for Waikato (17,537 FTEs), followed by Canterbury (13,879 FTEs), then Otago (9,633 FTEs).

Total changes to the baseline scenario (including the direct, indirect and induced effects) are presented in Figure 3-18. The largest total decrease was estimated for Manawatū-Whanganui (-200 FTEs/ per annum); followed by Waikato (-195 FTEs/ per annum), then Auckland (-178 FTEs/per annum).

Figure 3-19 shows the estimated direct, indirect and induced impact on employment by land use in New Zealand from scenario 'Bioenergy 75PJ'. By land use type, it estimated that the direct employment is 48,493 FTEs annually in the Dairy sector; followed by Sheep & Beef with 17,645 FTEs and Horticulture with 13,343 FTEs. Total aggregated employment (including indirect and induced effects) were estimated at 72,356 FTEs for the Dairy sector, followed by 26,565 FTEs for Sheep & Beef, then 19,239 FTEs for horticulture.

Figure 3-20 compares scenario results to the baseline. As expected, annual direct employment in the Sheep & Beef sector dropped by 2,106 FTEs (total impact -3,037 FTEs) in this scenario while direct employment in the Exotic Forestry sector increased by 1038 FTEs (total impact +2,934 FTEs) nationally per annum. It is estimated that the total contribution to employment (including direct, indirect and induced employment effects) from the scenario was a drop of 103 FTEs per annum in New Zealand.

The fall in employment in the sheep and beef sector is concentrated in direct employment whereas the rise in employment in forestry mainly in indirect employment. This may well have consequences for local rural populations with fewer being employed in these areas. Also, there are downstream impacts on the processing industries with a fall of 2,885 FTEs in sheep and beef processing. There is likely to be a rise in the processing of the biomass however this would be different from existing uses and therefore could not be calculated.

Figure 3-17: Bioenergy 75PJ -direct, indirect and induced employment by region, in FTEs.

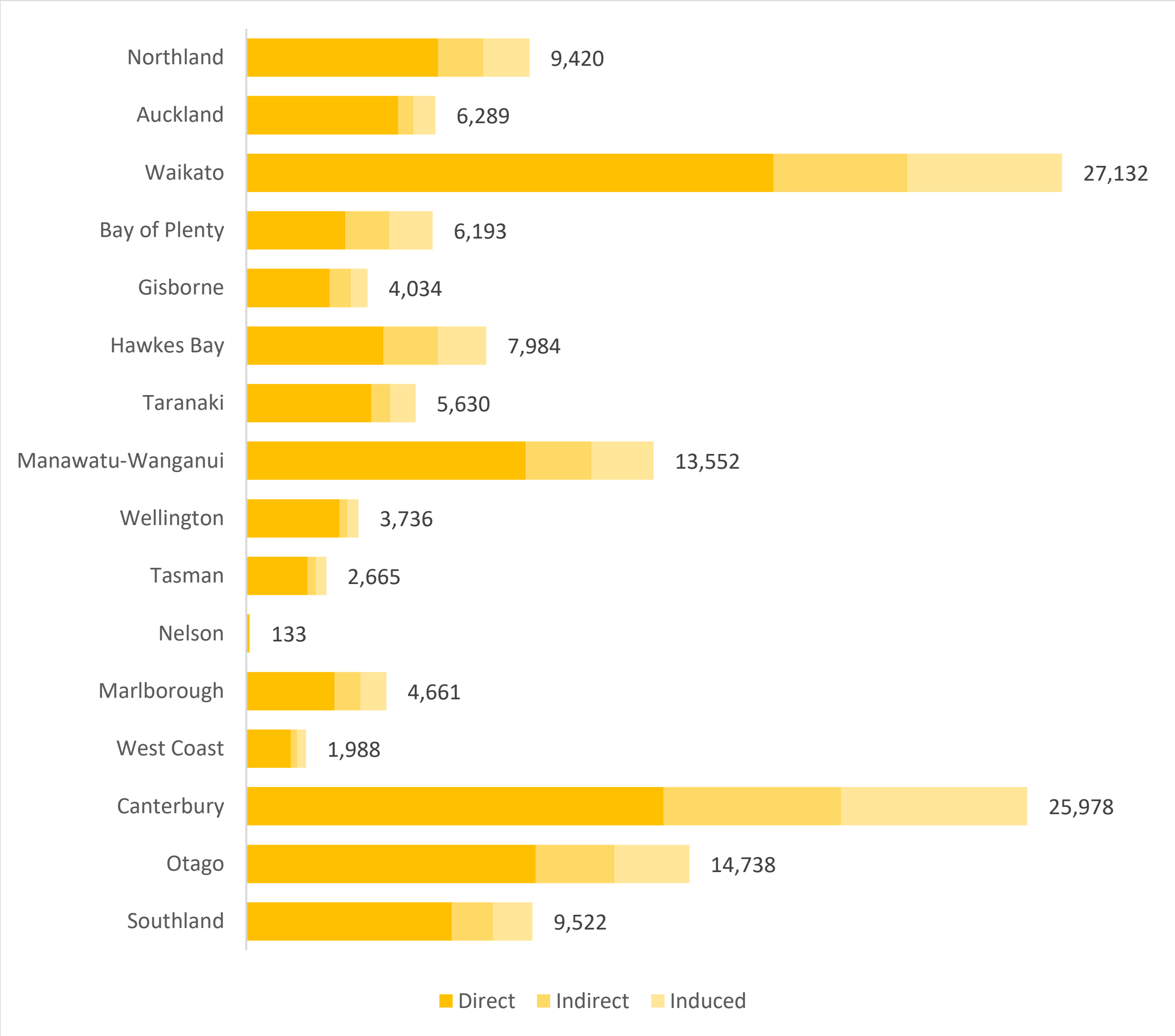


Figure 3-18: Bioenergy 75PJ - total change in employment from baseline by region, in FTEs.

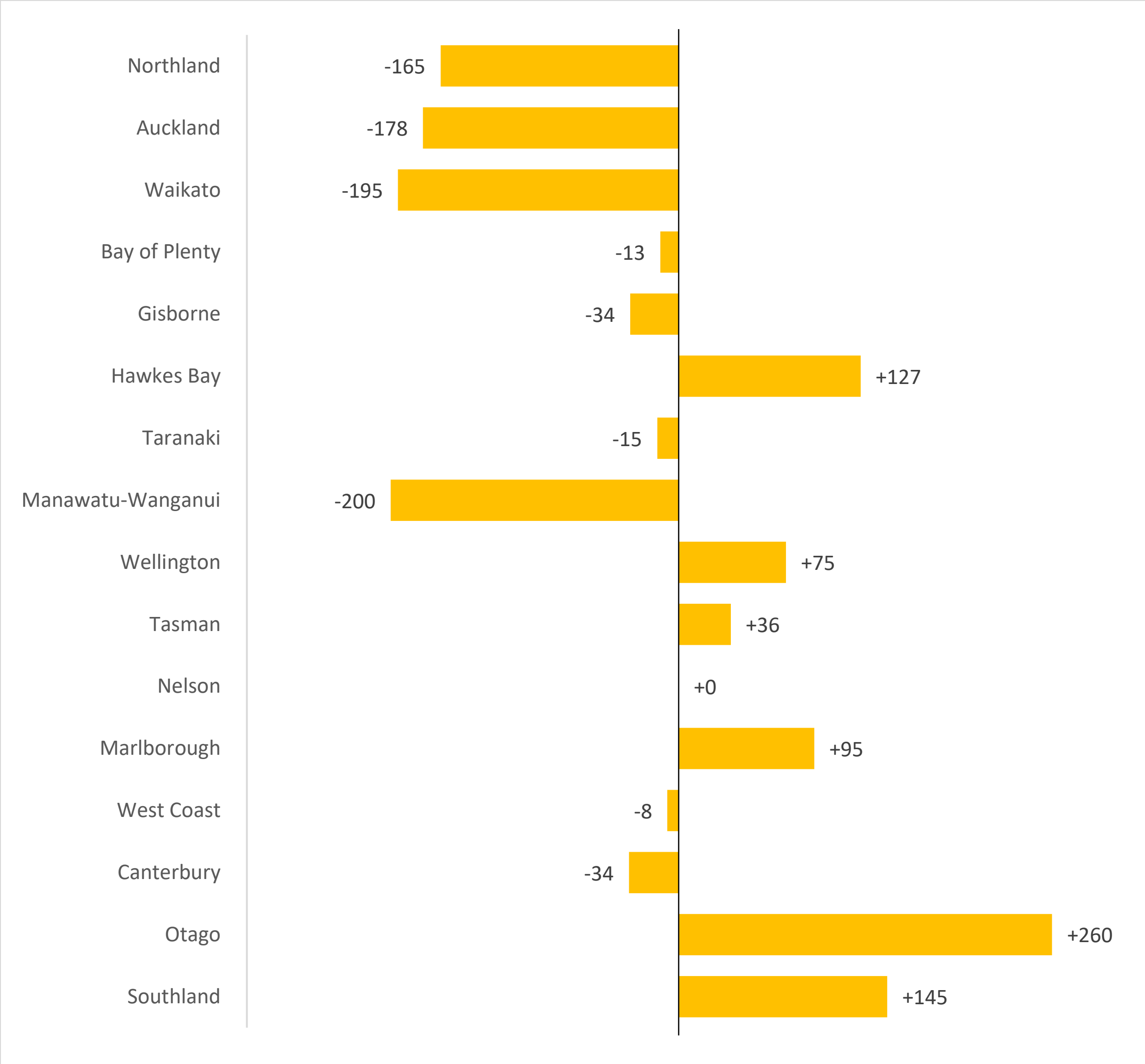


Figure 3-19: Bioenergy 75PJ - direct, indirect and induced employment by land-use, in FTEs.

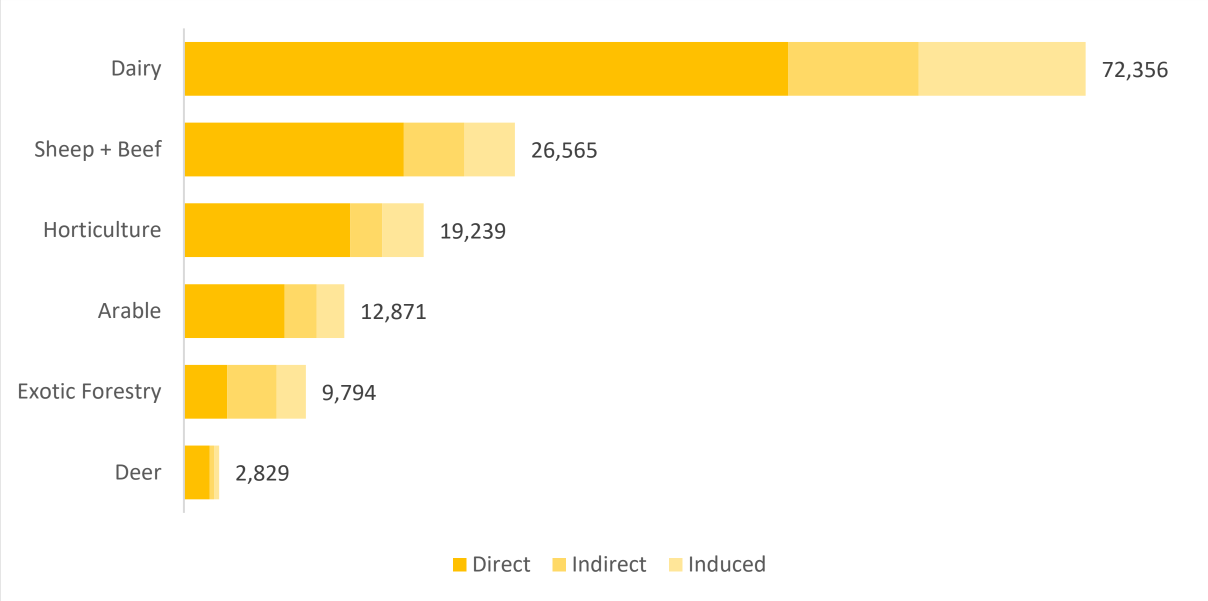
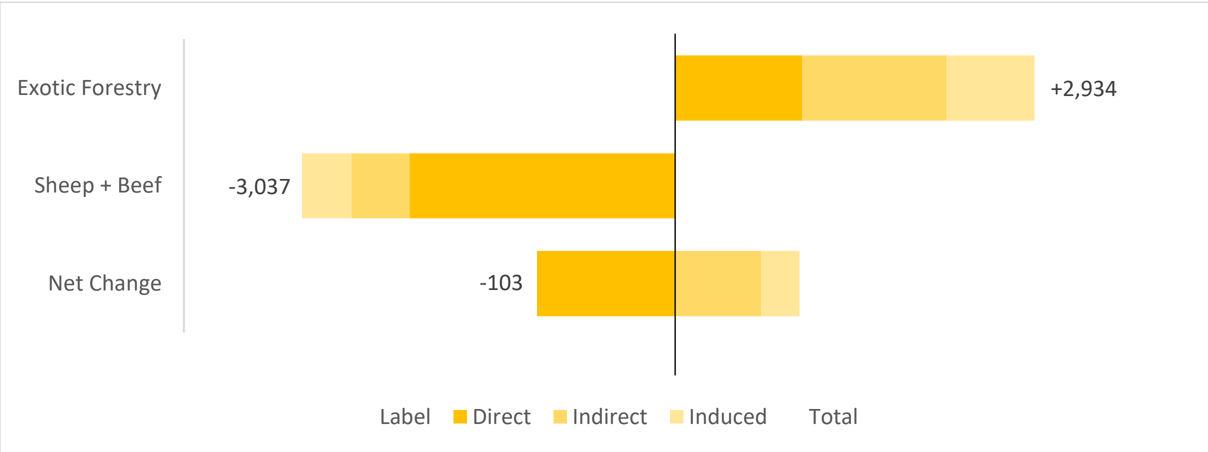


Figure 3-20: Bioenergy 75PJ - change in direct, indirect and induced employment by land-use from baseline, in FTEs.



Effects on greenhouse gas emissions

Greenhouse gas emissions are changed in this scenario by the sequestration of the newly planted exotic forestry for bioenergy. Fewer greenhouse gases are emitted due to the reduction in Sheep & Beef farming, leading to a net reduction in greenhouse gas emissions.

As described earlier the assumptions around greenhouse gas emissions for productive forestry are that only sequestration gained from the first half a rotation from new planting is considered. As this is only considered for 16 years it is documented separately from the ongoing annual emissions. Table 3-3 shows the total sequestration gained from this new planting by region.

Table 3-3: Total sequestration from new rotation forest planting.

	Change from baseline Greenhouse gas (kt CO_2 eq p.a.)
Northland	-24,268
Auckland	-9,590
Waikato	-33,845
Bay of Plenty	-15,915
Gisborne	-14,391
Hawke's Bay	-20,703
Taranaki	-11,029
Manawatū-Whanganui	-35,493
Wellington	-12,856
Tasman	-11,840
Nelson	-520
Marlborough	-13,080
West Coast	-4,875
Canterbury	-60,998
Otago	-47,799
Southland	-49,699
TOTAL New Zealand	-366,901

Figure 3-21 below shows the emissions profile by regions from scenario 'Bioenergy 75PJ'. This shows that in this scenario emissions are greatest from Waikato and Canterbury. Change from baseline results are shown in Figure 3-22 (in kt CO_2 eq per annum) and Figure 3-23 (in per cent). Largest sequestration in this scenario is gained from Canterbury, Southland and Otago.

Results by land-use are shown in Figure 3-24. Dairy is the main emitter in this scenario, followed by Sheep & Beef. Change from baseline results are shown in Figure 3-25 (in kt CO_2 eq per annum) and in Figure 3-26 (in per cent). This shows a net change of 25,026 kt CO_2 equivalents.

Figure 3-21: Bioenergy 75PJ - greenhouse gas emissions by region, in kt CO_2 eq. per annum.

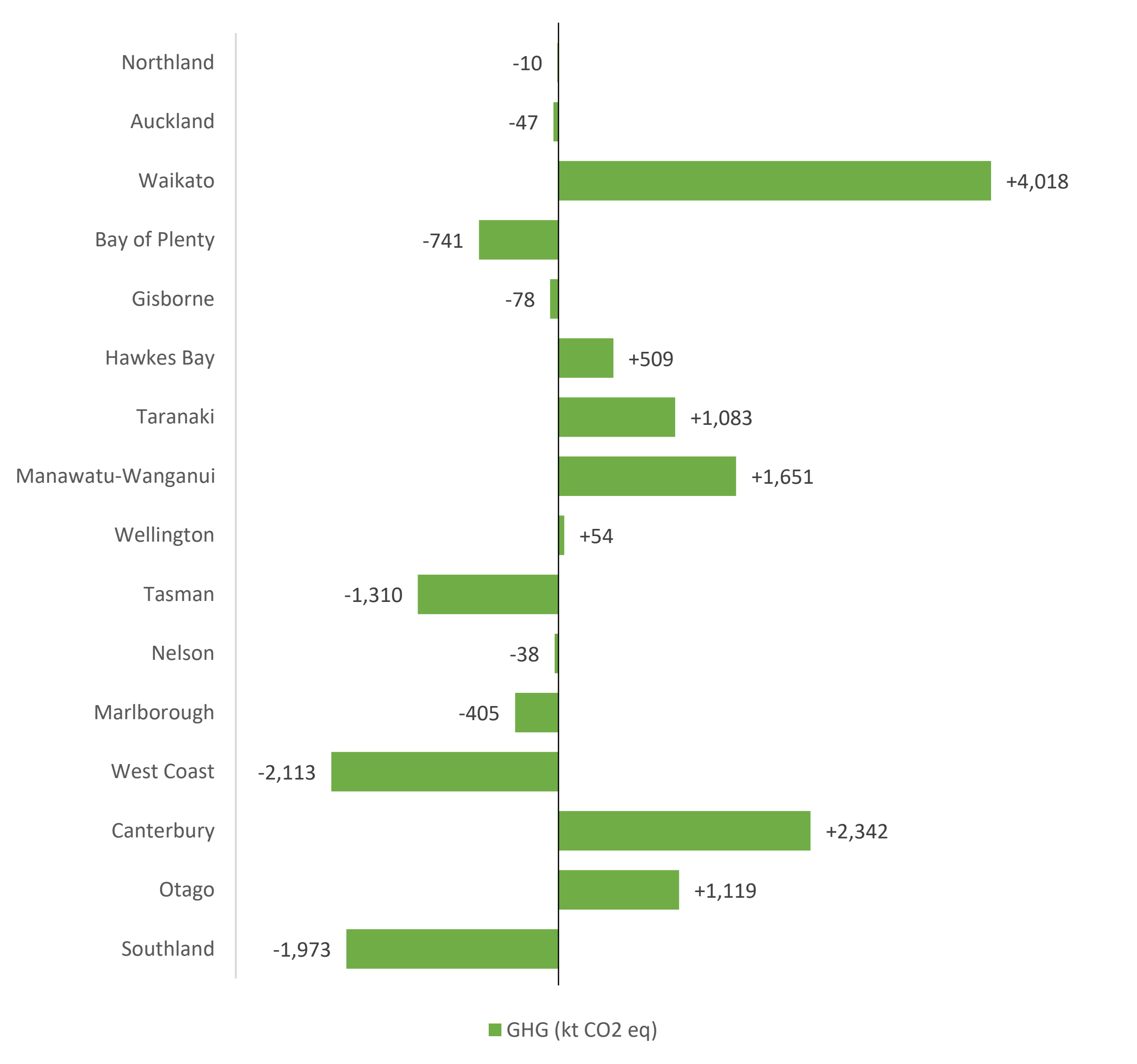


Figure 3-22: Bioenergy 75PJ - change in greenhouse gas emissions from baseline by region, in kt CO_2 eq. per annum.

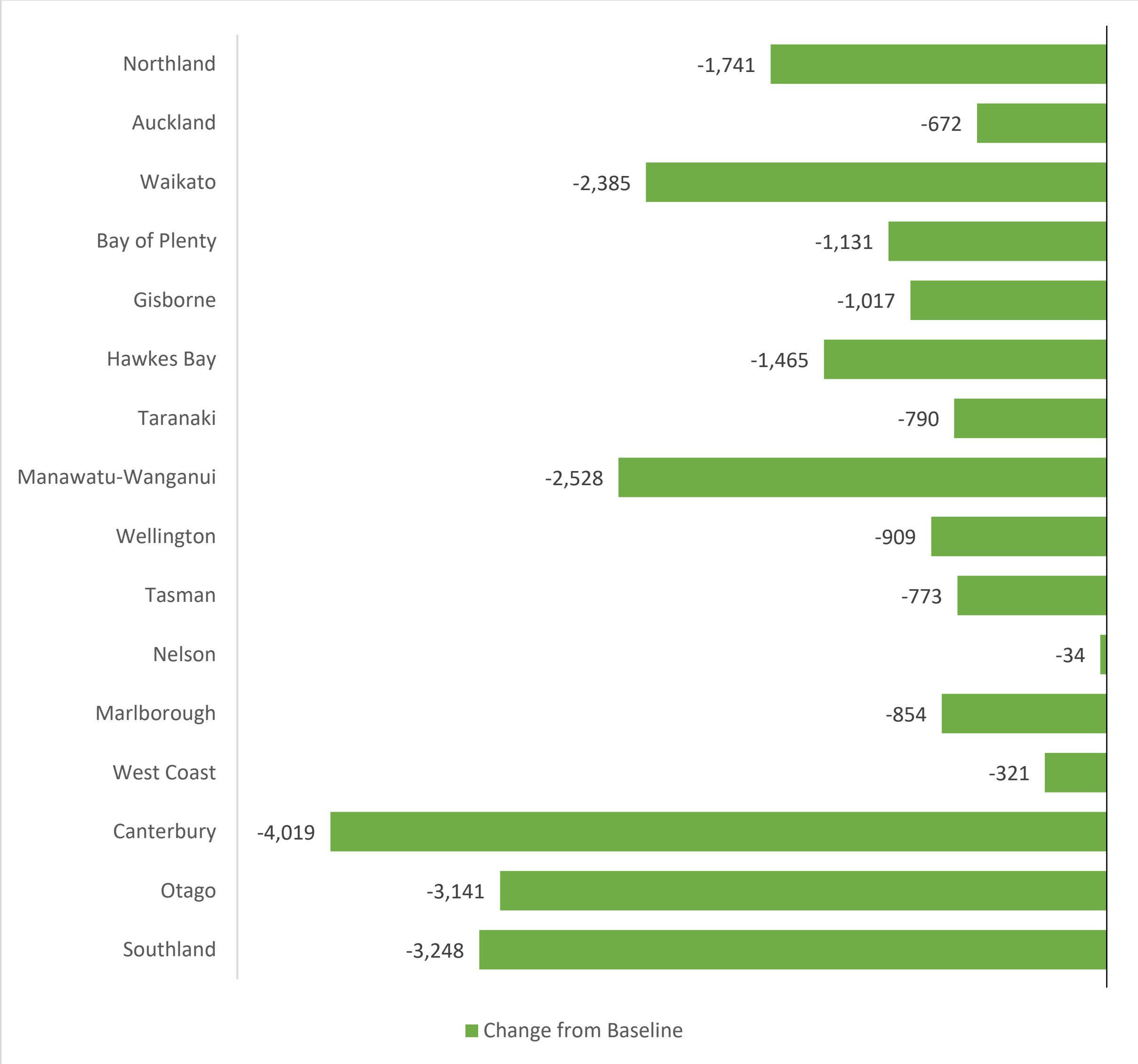


Figure 3-23: Bioenergy 75PJ - change in greenhouse gas emissions from baseline by region, in per cent.

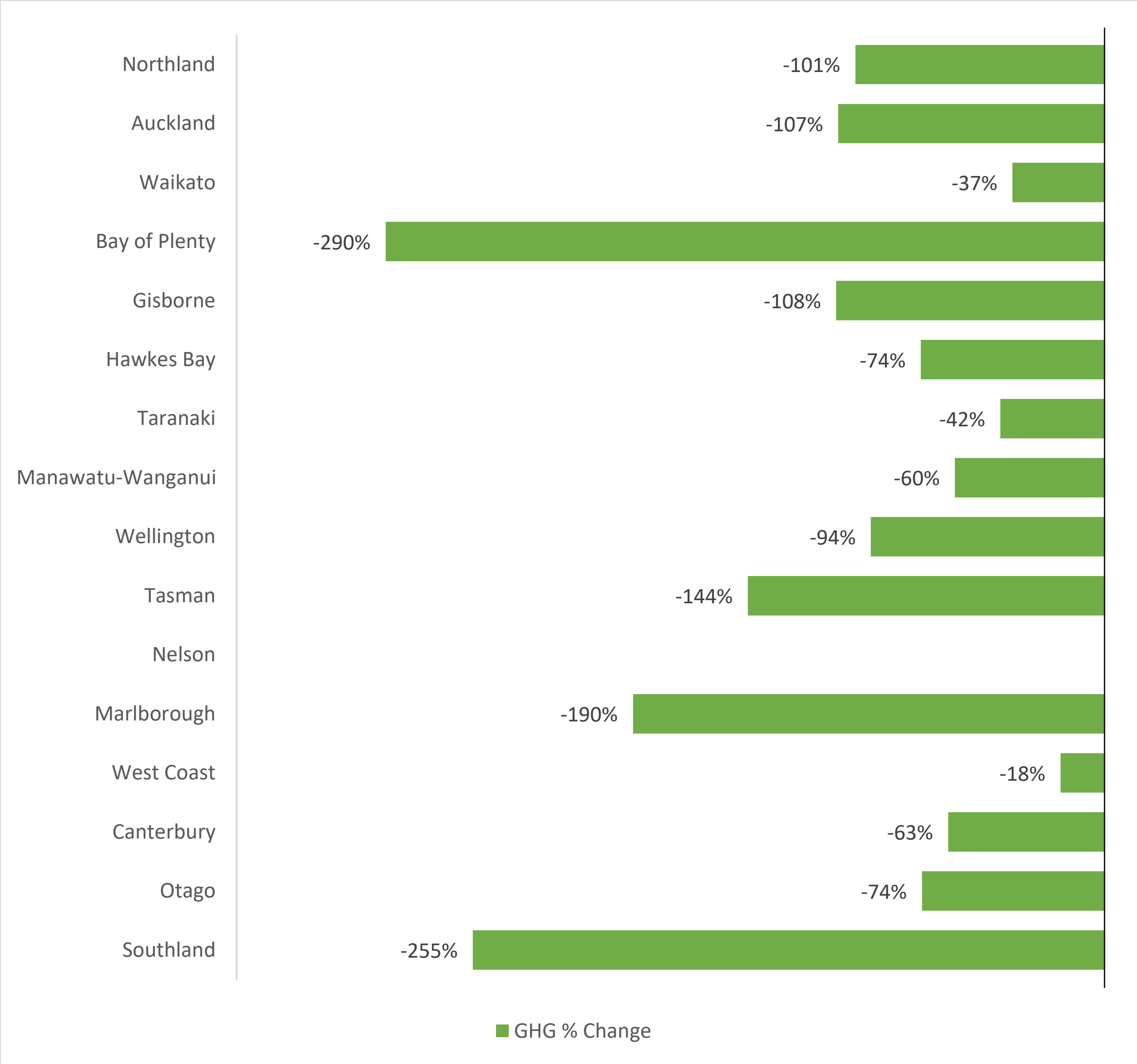


Figure 3-24: Bioenergy 75PJ - greenhouse gas emissions by land-use, in kt CO_2 eq. per annum.

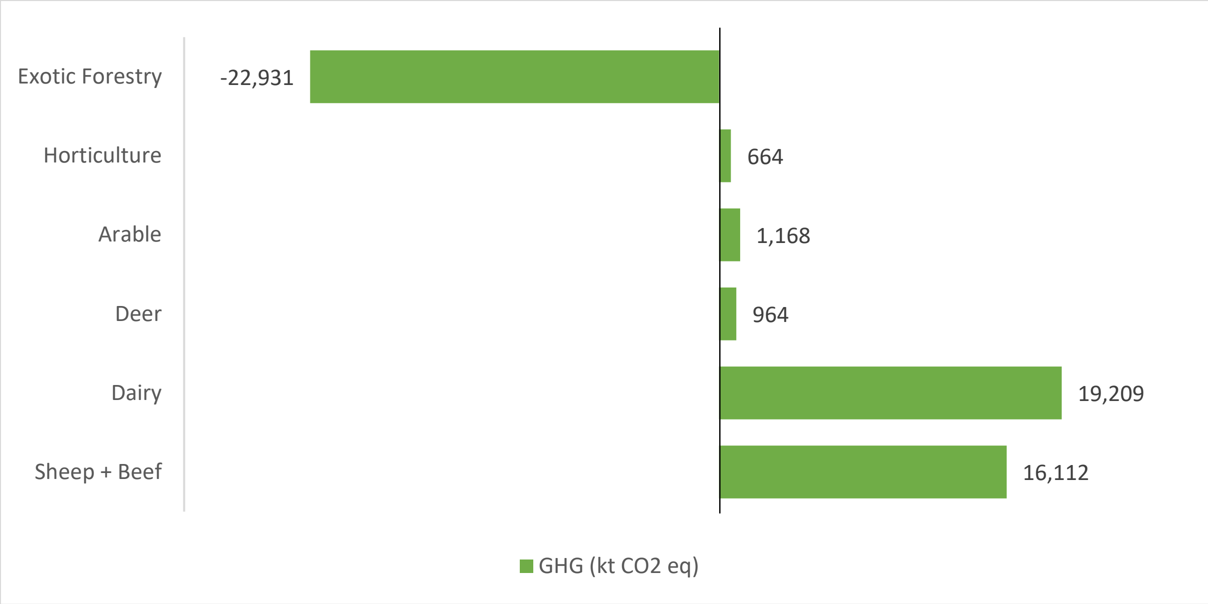


Figure 3-25: Bioenergy 75PJ - change in greenhouse gas emissions from baseline by land-use, in kt CO_2 eq per annum.

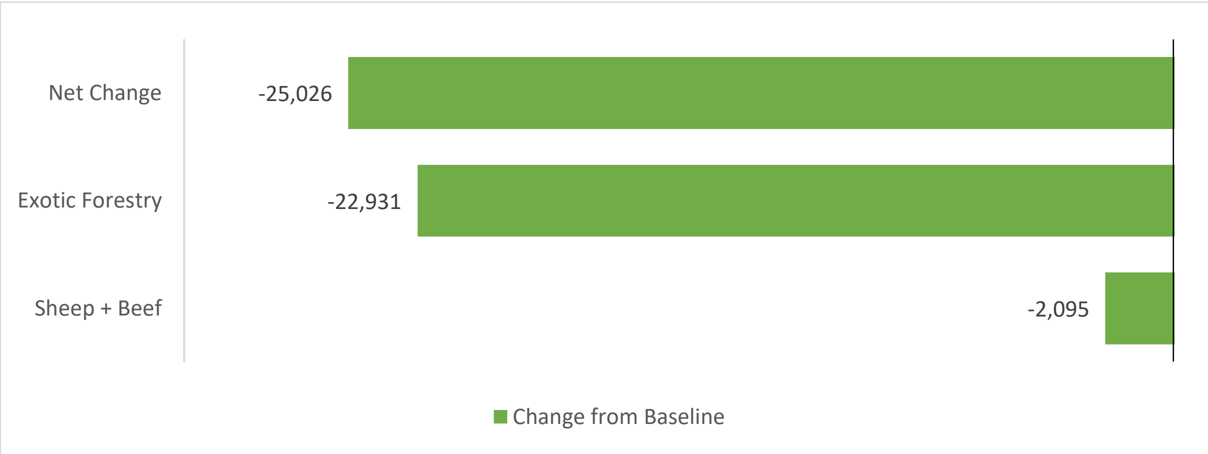
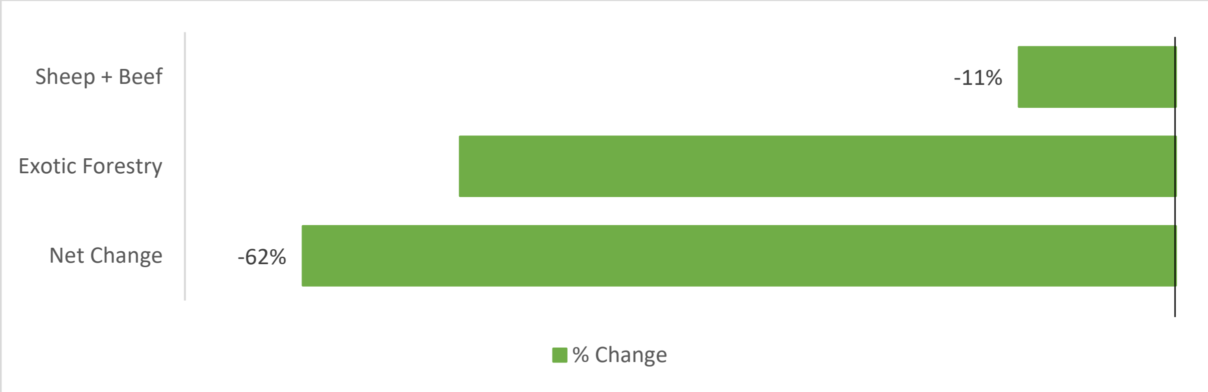


Figure 3-26: Bioenergy 75PJ - change in greenhouse gas emissions from baseline by land-use, in per cent.

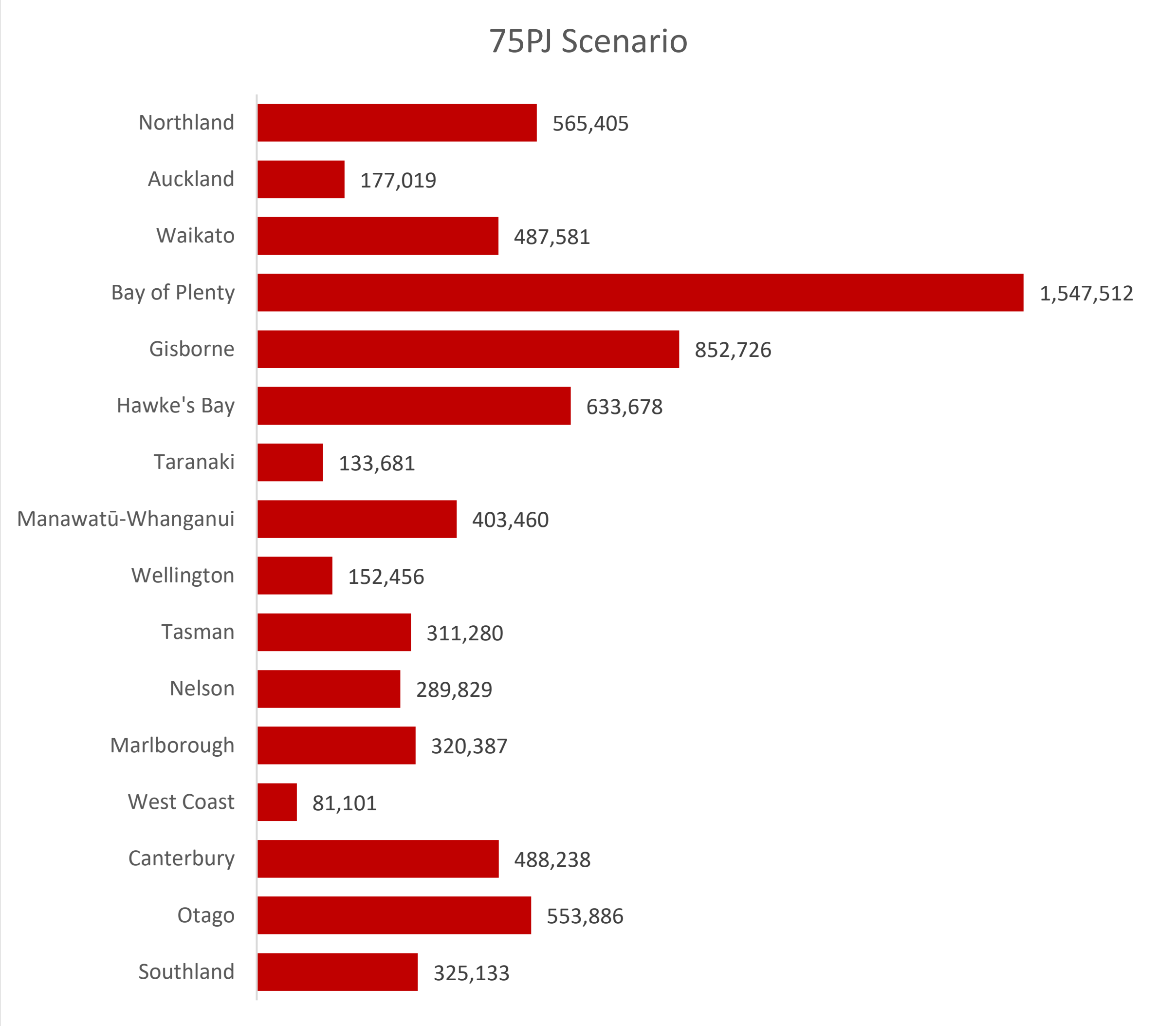


In-forest residues

In scenario 'Bioenergy 75PJ', results for all in-forest residues are shown in Figure 3-27. In-forest residues use regionally specific m^3 rates per total forest land area, calculated from gross supply of all in-forest residues (Hall, 2022). Using these rates and the regional change in forest land implied by the 'Bioenergy 75PJ' scenario, shows the highest in-forest residues in the Bay of Plenty (1,574,512m^3 / p.a.), followed by Gisborne (852,726m^3/ p.a.) then Hawkes Bay (633,678m^3/ p.a.). Figure 3-28 shows the change to baseline, it can be seen that largest annual change was calculated for Canterbury (+53,185 m^3/p.a.), followed by Waikato (+52,616m^3 /p.a.), then Southland (+36,131m^3 /p.a.). The total increase in forest residues was estimated at 281,767 m^3 annually. This assumes that these residues are not used for bioenergy. However, if it is possible to reclaim this, the bioenergy produced would be higher. The detailed results are given in table A2 in Appendix A. The residues do not double between the 75PJ and 150PJ scenarios due the differences in regions where the forestry is undertaken.

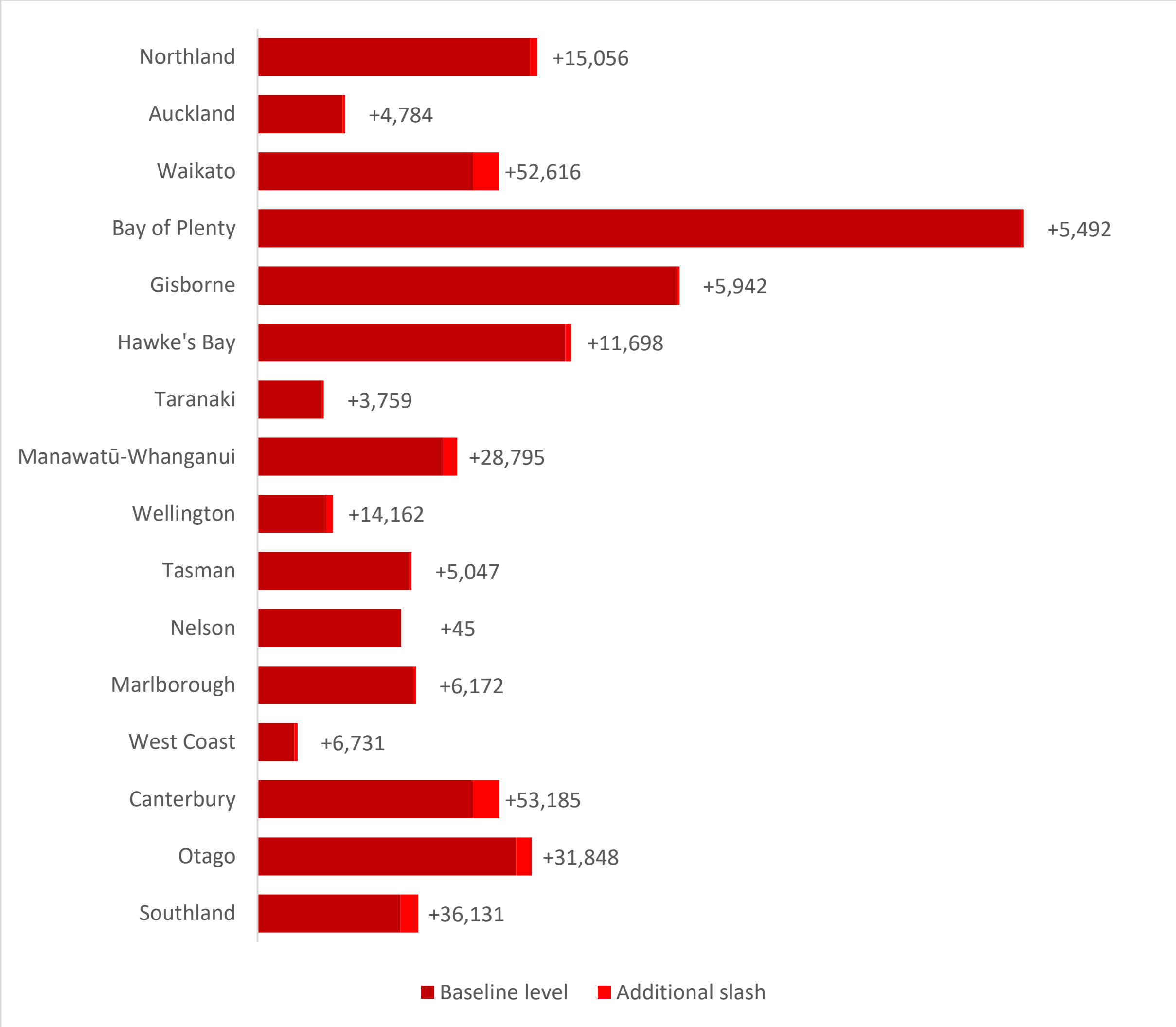
If sensitivity of current in-forest residues production per hectare is ±5%, this would mean ±14,088 m^3 per year, at ±10% this would mean ±28,177 m^3 per year.

Figure 3-27: Bioenergy 75PJ - all in-forest residuals, in m³ per annum.



Note: This assumes that in-forest residuals accumulate at the same rate as exotic forestry for logging.

Figure 3-28: Bioenergy 75PJ - change in all in-forest residuals from baseline, in m³ per annum.



Social and environmental scoring

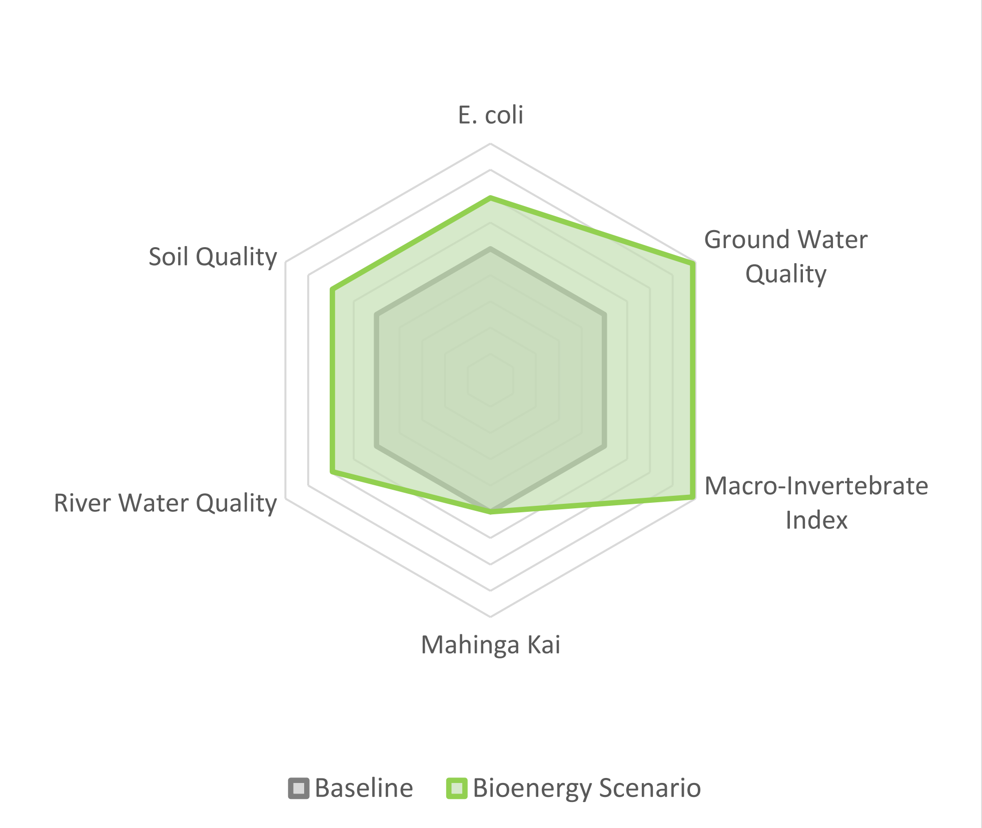
The social and environmental impacts from this scenario have been assessed using the Scoring Matrix developed for the Integrated Assessment Framework and are shown in Figure 3-29 and Table 3-4.

In reading the Scoring spider graphs, the thick grey line shows the baseline impact, and the yellow and green shapes show change in social- and environmental-scoring respectively. Where the coloured shape shrinks inwards, this indicates a reduction in score. Where the coloured shape grows outwards, this indicates an increase in score.

Results suggest that socially, there may be a reduction in self-rated health, life satisfaction, and access to basic amenities. These changes come from the change to forestry, which is a higher risk activity for workers. Plantations are in more remote locations, so reducing access to basic amenities, and longer travel times, reducing life satisfaction.

The environmental scores, however, are positive across the board. These changes come from the change of farming practices to forestry, which generally has neutral to positive impacts.

Figure 3-29: Bioenergy Scenarios - change in Environmental and Social impacts from baseline.



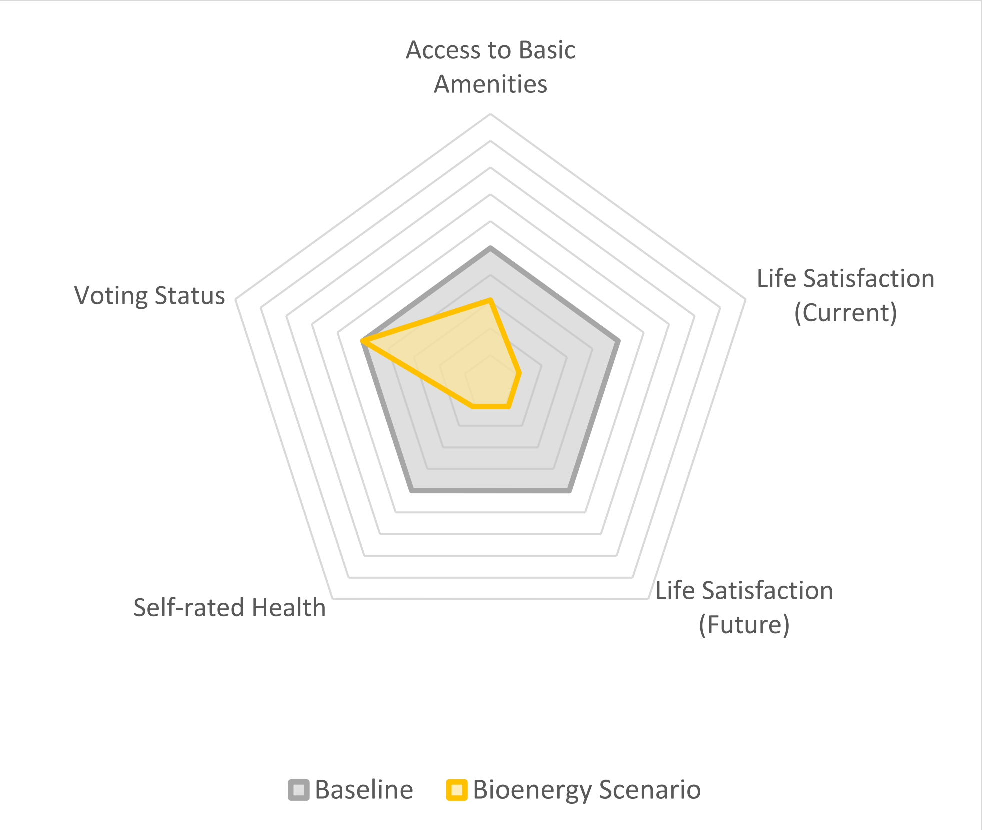


Table 3-4: Environmental and social scores from Scenario 75PJ.

Environmental Variable	Score
E. coli	+1.9
Greenhouse Gas Emissions	+5.9
Ground Water Quality	+3.9
Macro-Invertebrate Index	+3.9
Mahinga Kai	-0.1
River Water Quality	+1.9
Soil Quality	+1.9
Swimming Index	+3.9

Social Variable	Score
Access to Basic Amenities	-2.1
Life Satisfaction (Current)	-3.9
Life Satisfaction (Future)	-3.9
Self-rated Health	-4.0

The impact on the environment is generally positive as shown in Table 3-4. In particular, there was improvement in the reduction of greenhouse gas emissions quantified in Figure 3-26 which shows an 85 per cent reduction. Ground water quality, the Macro-Invertebrate Index and swimming index all are judged to have increased similarly. *E. coli*, river water quality and soil quality also are judged to have increased by a smaller amount. Whereas there is slight fall in Mahinga Kai. It must be stressed that these are judgements and likely to vary according to local conditions.

In the case of social indicators these are judged to have fallen in particular self-rates health status and life satisfaction followed by access to basic amenities. This is not surprising given the switch to forestry means local employment is likely to fall with consequences for the population in these areas.

3.3.2 Scenario 2 – Bioenergy 150PJ

Scenario 'Bioenergy 150PJ' looks at creating 150PJ (Peta Joules) per year, by transitioning 1.8445 million hectares of Sheep & Beef land to Exotic Forestry for Bioenergy production. On a 28 year rotation, this provides for a harvestable area of around 65 875 hectares annually and a sustainable harvest of 42 611 700 cubic metres of woody biomass for energy production. Figure 3-30 to Figure 3-32 show the land use changes applied in this scenario. The target of 150PJ by 2050 comes from Bioenergy NZ, this is considered to be upper estimate of primary energy demand for bioenergy (noting that EECA's "TIMES-NZ 2.0" Model estimates a maximum primary energy demand for bioenergy of 107PJ). To implement this scenario, hill country sheep & beef is transitioned to exotic forestry for bioenergy production.

As for Scenario 1, areas were allocated proportional to the size of each region and yield of Exotic Forestry in that region. That area would then be proportionally deducted from the hill country Sheep & Beef classes (Classes 1-4). Several regions did not have enough Sheep & Beef hill country land to meet their share based on land mass, so the after the Sheep & Beef hill country land was exhausted the shortfall was made up around the rest of the country. Those regions were Bay of Plenty, Nelson, Tasman, and West Coast.

Figure 3-30: Bioenergy 150PJ - land use changes in hectares applied.

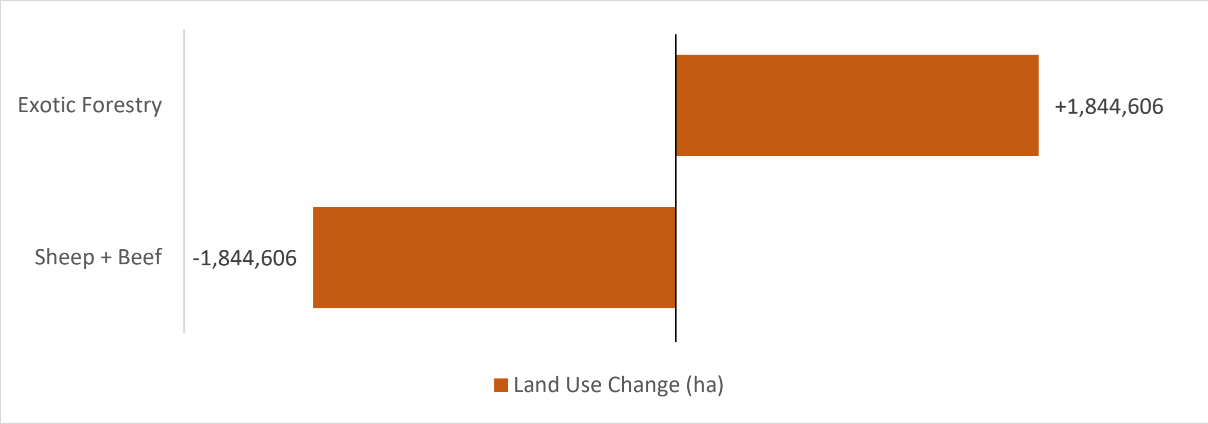


Figure 3-31: Bioenergy 150PJ - land use changes in per cent applied.

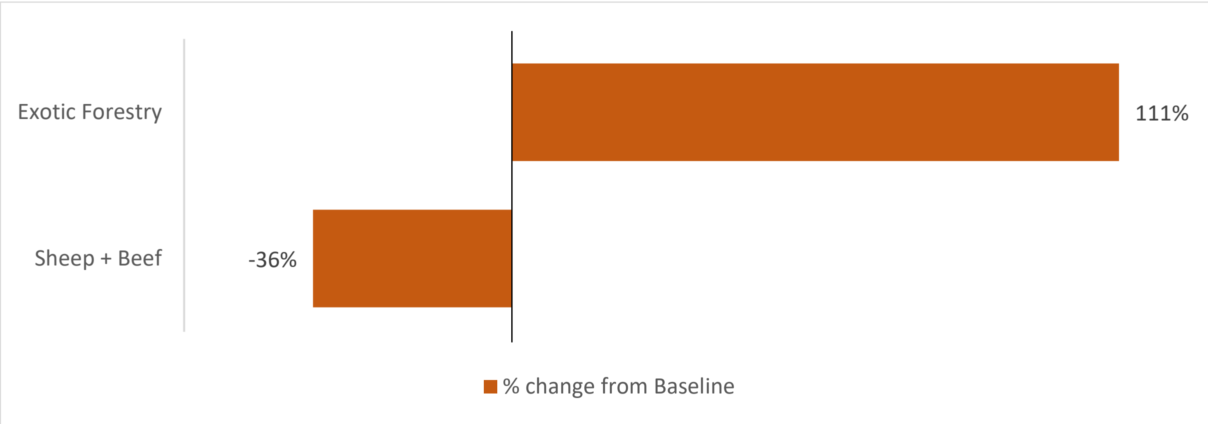
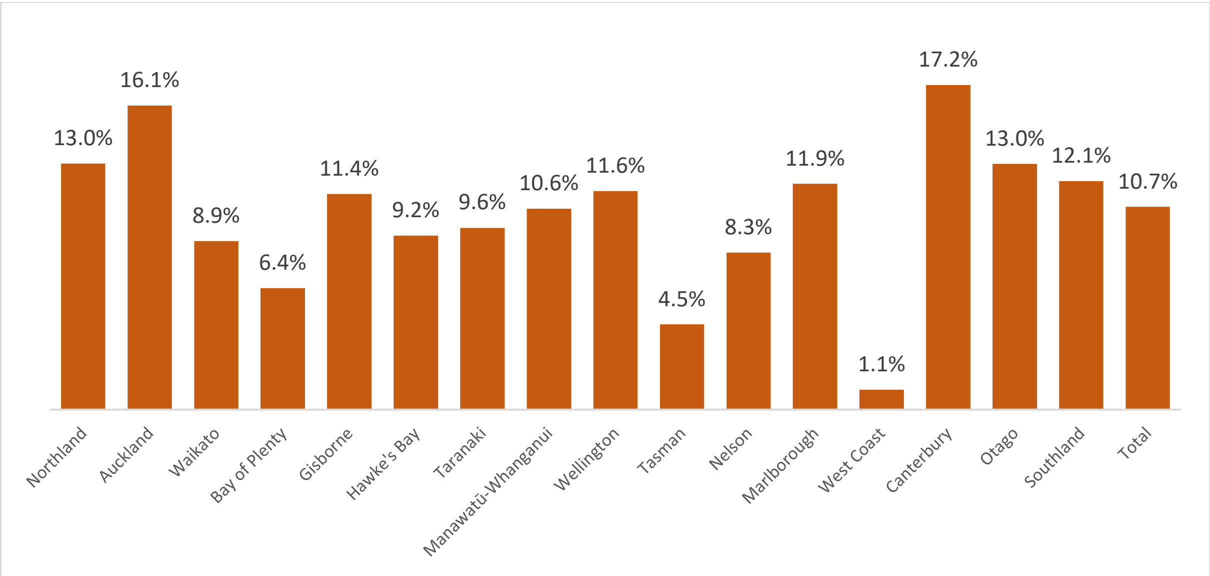


Figure 3-32: Bioenergy 150PJ - land use changes by region in per cent.



Economic impacts

Figure 3-33 shows direct, indirect and induced annual gross output in the 16 regions of New Zealand, with adjustments to land use for Scenario 'Bioenergy 150PJ'. Annual direct economic impact on gross output has been estimated to be $34,936m for total New Zealand, highest direct gross output was estimated for Waikato ($6,726m), Canterbury ($6,289m), and Otago ($3,189m).

Total economic impact (including direct, indirect and induced effects) on gross output were valued at $47,550m for New Zealand.

Total changes to baseline scenario (including direct, indirect and induced effects) are presented in Figure 3-34. The largest change in annual total gross output from this scenario is estimated for Otago (+$296m/ per annum), followed by Southland (+$232m/ per annum), then Hawke's Bay (+$129m/ per annum). In contrast, annual total gross output is calculated to fall by $28m in Northland and by $24m in Manawatū-Whanganui.

Results by land-use type are presented in Figure 3-35. Results show the largest direct gross output is estimated for the Dairy sector at $19,375m annually, then Sheep & Beef ($5,233m); then Exotic Forestry ($3,597m). The total economic impact (i.e. contribution to output) by land use for New Zealand is estimated at $25,296m annually for Dairy, followed by $7,166m for Sheep & Beef, and $5,590 for Exotic Forestry. Changes to baseline are presented in Figure 3-36. By land-use, as expected national direct gross output for Sheep & Beef sector was calculated to drop by $1,273 million annually (total direct, indirect and induced impact -$1,701m), while direct gross output for Exotic Forestry was calculated to increase by $1,704m per annum in New Zealand (total direct, indirect and induced impact +$2,631m). The net change in annual total gross output (including direct, indirect and induced effects) is calculated to increase by $930m in New Zealand.

Figure 3-33: Bioenergy 150PJ - direct, indirect and induced gross output by region, in NZ$m per annum.

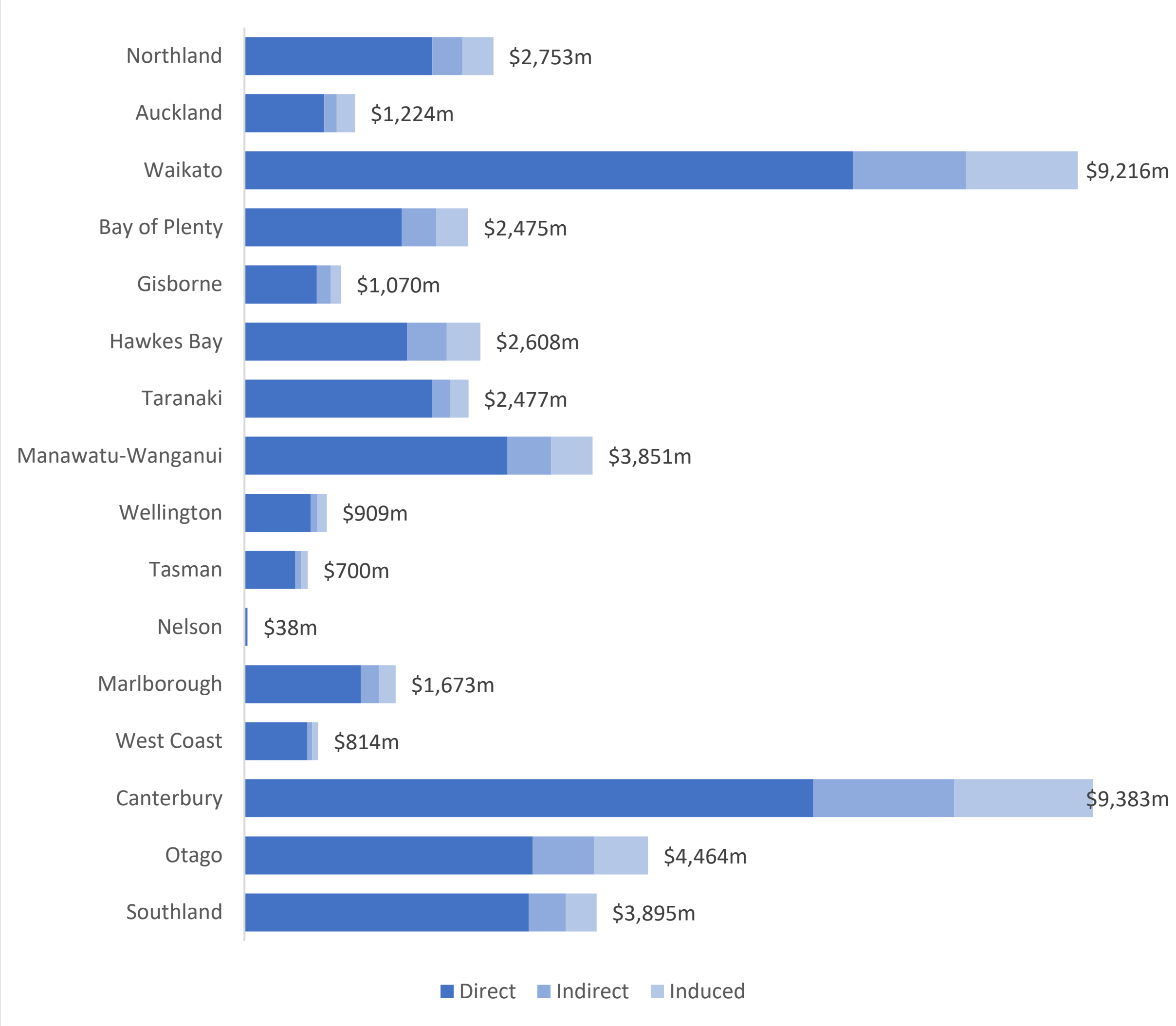


Figure 3-34: Bioenergy 150PJ - total change in gross output from baseline by region, in NZ$m per annum.

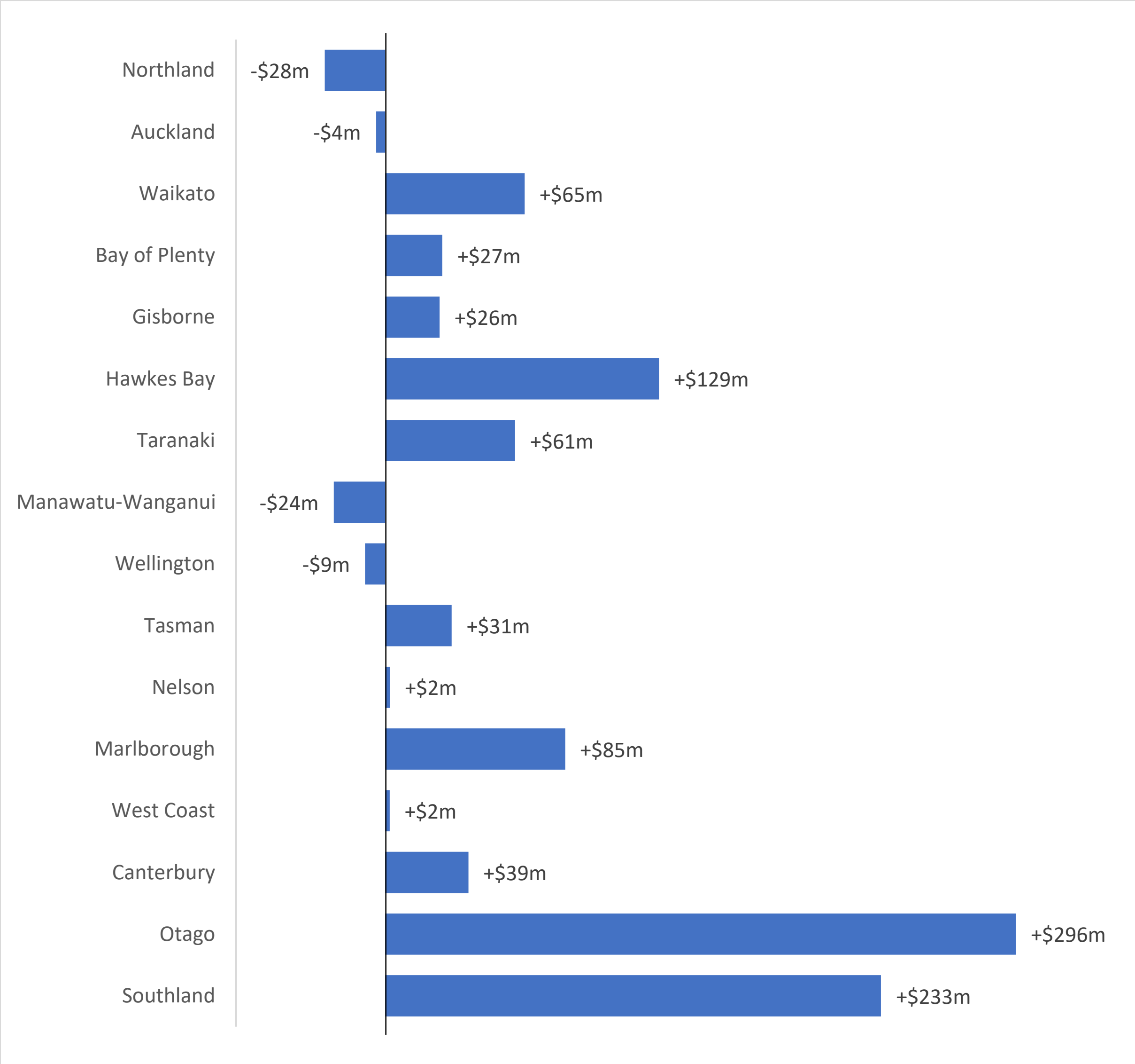


Figure 3-35: Bioenergy 150PJ - direct, indirect and induced gross output by land-use, in NZ$m per annum.

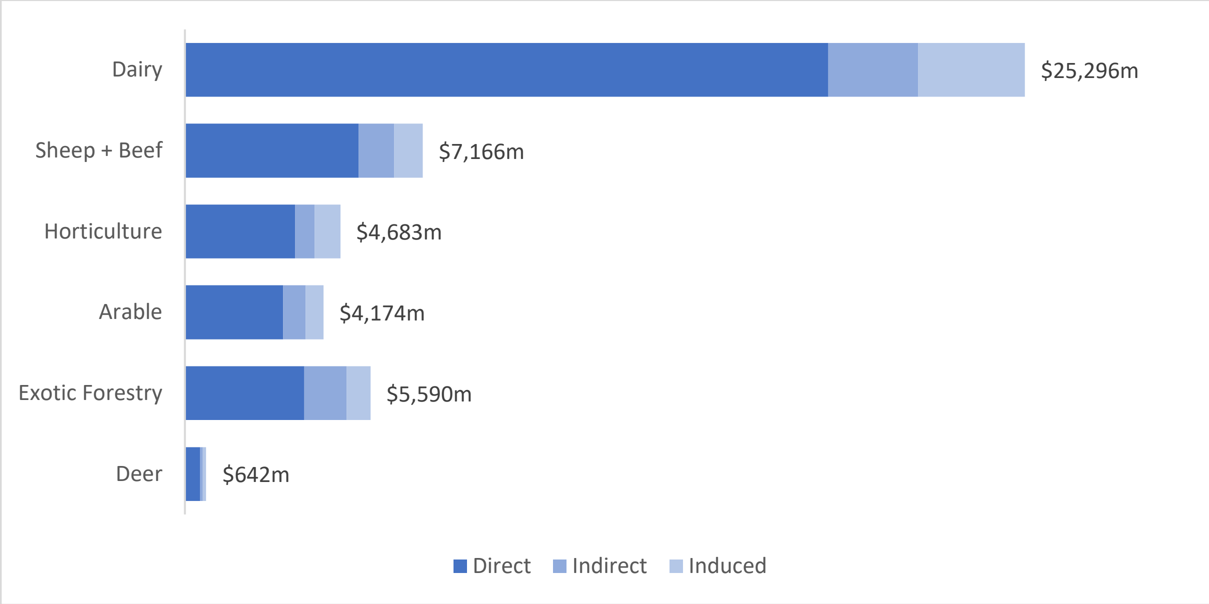
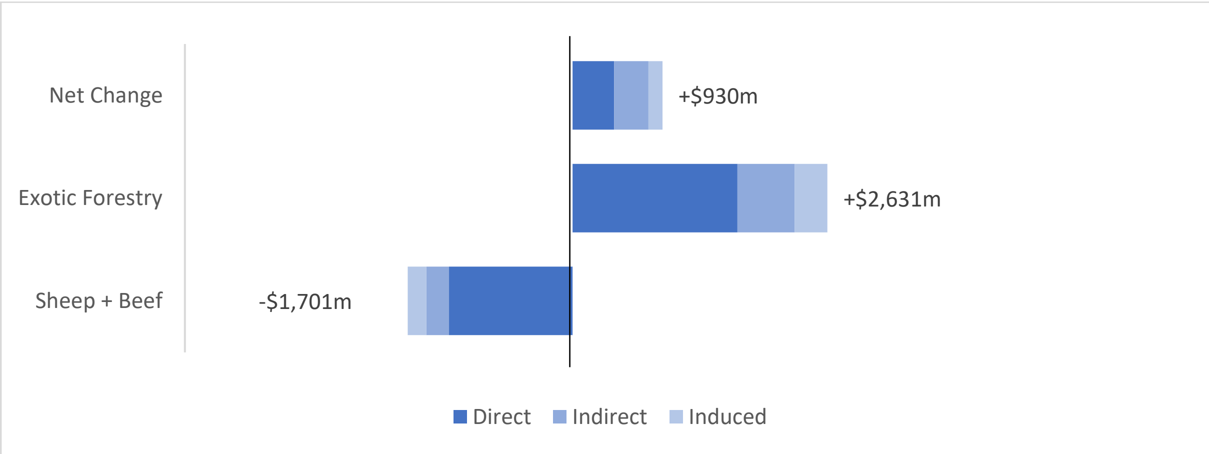


Figure 3-36: Bioenergy 150PJ - change in direct, indirect and induced gross output from Baseline by land-use, in NZ$m per annum.



Employment impacts

Figure 3-37 shows the estimated direct, indirect, induced and total impact on employment in 16 regions from scenario 'Bioenergy 150PJ'. It was estimated that the direct employment impact from the scenario totalled 91,897 FTES's in New Zealand with the largest number of FTE's estimated for Waikato (17,213 FTEs), followed by Canterbury (13,786 FTEs), then Otago (9,624 FTEs). Total employment (including direct, indirect and induced effects) is 143,516 FTEs for New Zealand. Overall, direct employment in New Zealand is calculated to fall by 2,279 FTEs per annum.

Total change in employment (including direct, indirect and induced effects) to the baseline are presented in Figure 3-38. The largest total annual decrease estimated for Manawatū-Whanganui (-418 FTEs), followed by Waikato (-408 FTEs), then Auckland (-371FTEs).

As shown in Figure 3-39, by land use type, it estimated that the direct annual employment is 48,493 FTEs in the Dairy sector; followed by Sheep & Beef with 15,456 FTEs and Horticulture with 13,343 FTEs. Total aggregated employment (including indirect and induced effects) was estimated at 72,356 FTEs annually for the Dairy sector, followed by 23,471 FTEs for Sheep & Beef, then 19,239 FTEs for Horticulture. Results from the scenario compared to the baseline are shown in Figure 3-40. As expected, annual direct employment in the Sheep & Beef sector fell by 4,349 FTEs (total direct, indirect and induced impact -6,131 FTEs) per annum while direct employment in the Exotic Forestry sector increased by 2,070 FTEs nationally per (total direct, indirect and induced impact of 5,889 FTEs). It was estimated that the total contribution to employment (including direct, indirect and induced employment effects) from the scenario was a drop of 242 FTEs per annum in New Zealand.

As in the case of the 75PJ scenario the fall in employment in the sheep and beef sector is concentrated in direct employment whereas the rise in employment in forestry mainly in indirect employment. This may well have consequences for local rural populations with fewer being employed in these areas. Also there are downstream impacts on the processing industries with a fall of 5,824 FTEs in sheep and beef processing. There is likely to be a rise in the processing of the biomass however this would be different from existing uses and therefore could not be calculated.

Figure 3-37: Bioenergy 150PJ - direct, indirect and induced employment by region, in FTEs.

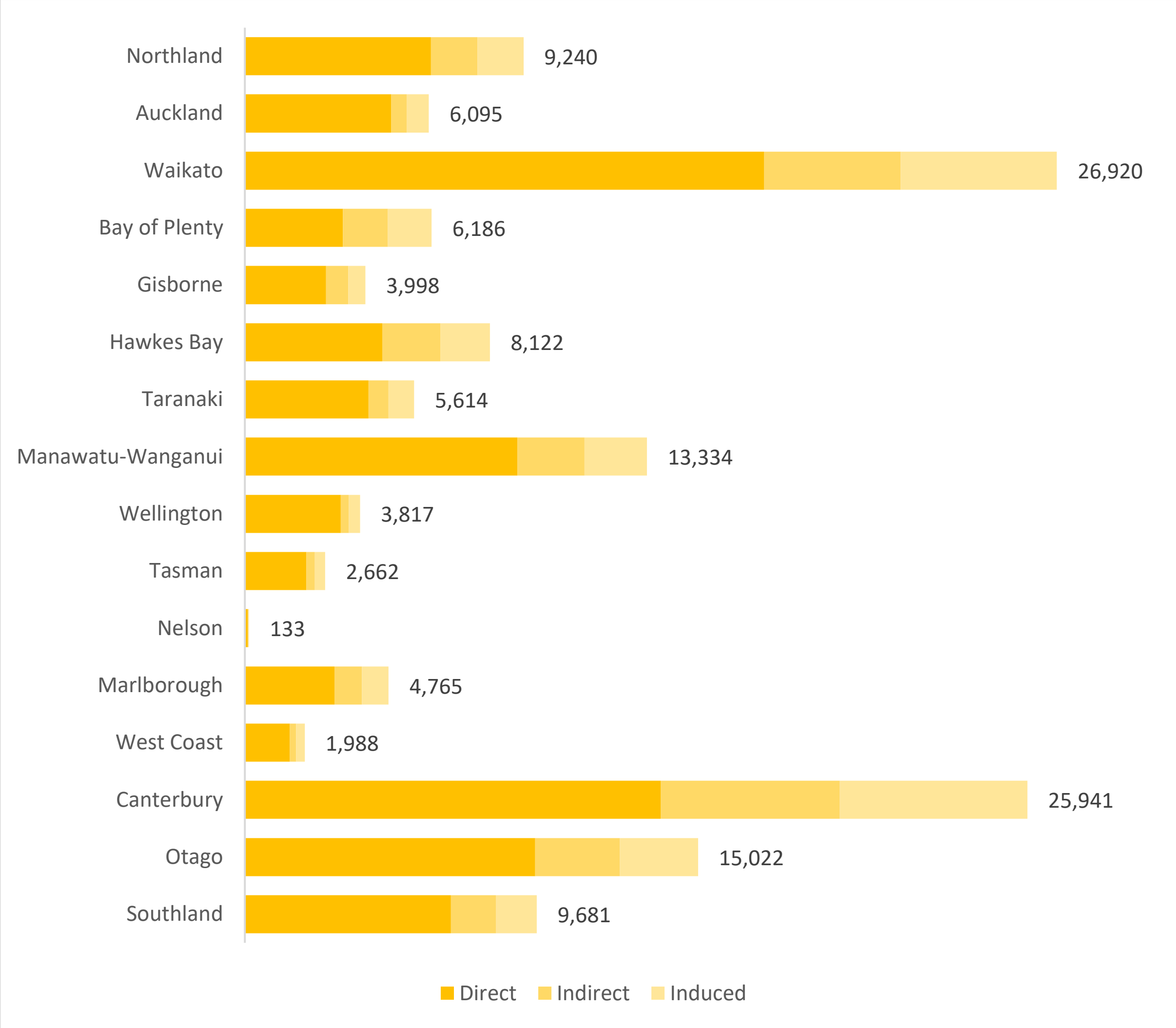


Figure 3-38: Bioenergy 150PJ - total change in employment from baseline by region, in FTEs.

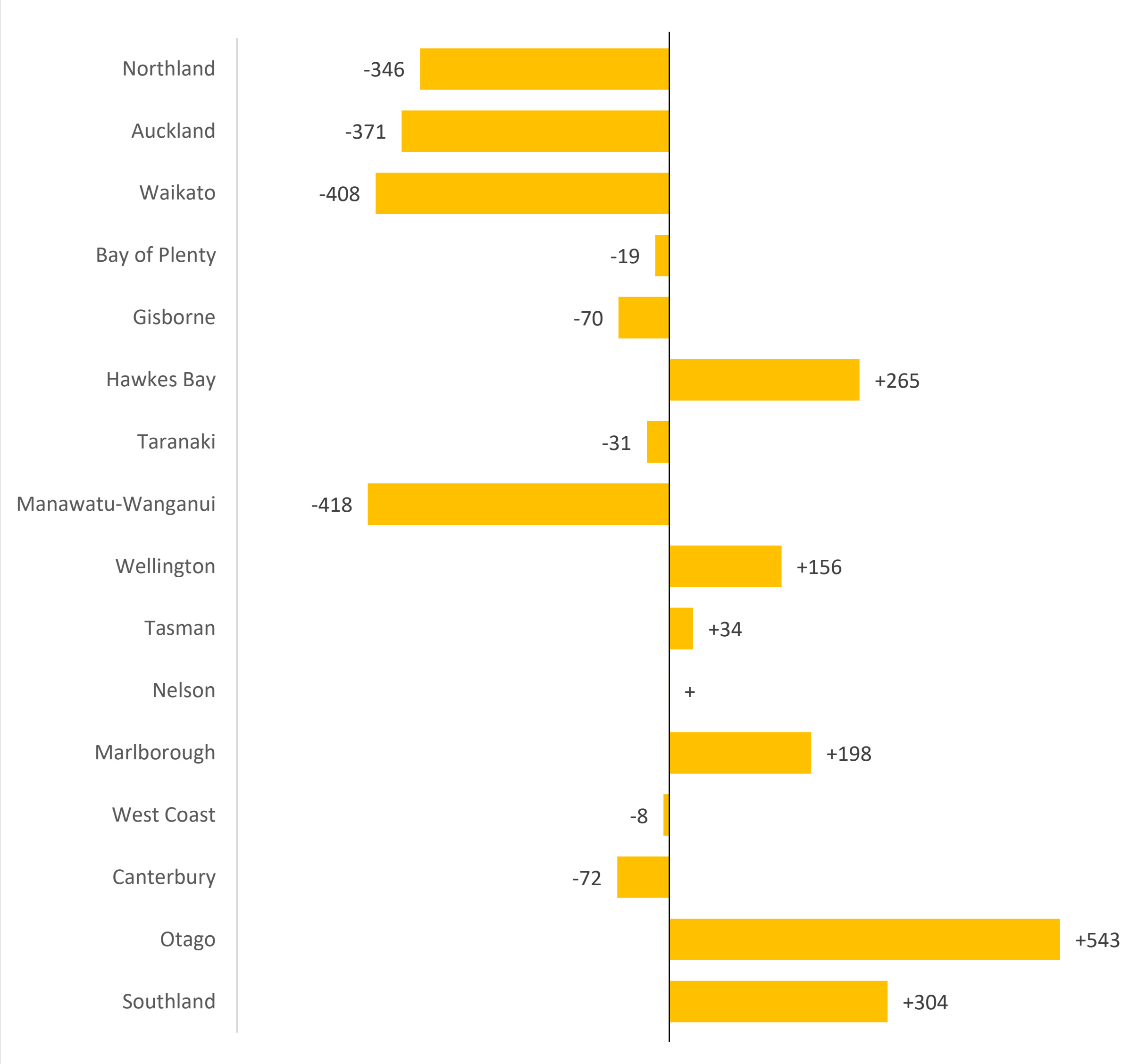


Figure 3-39: Bioenergy 150PJ - direct, indirect and induced employment by land-use, in FTEs.

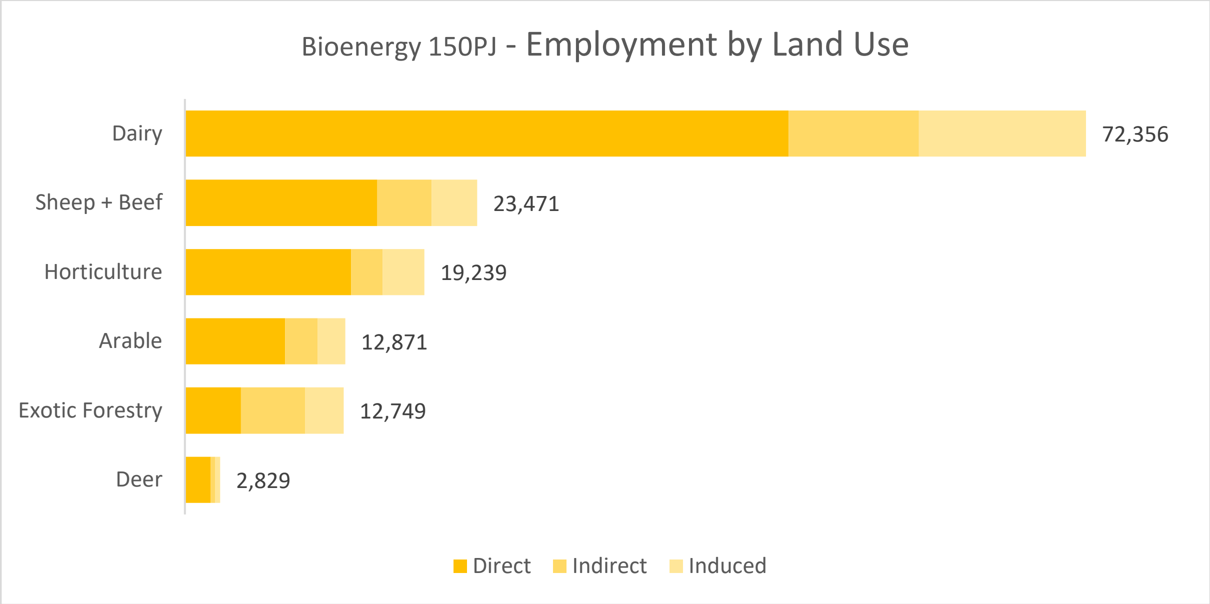
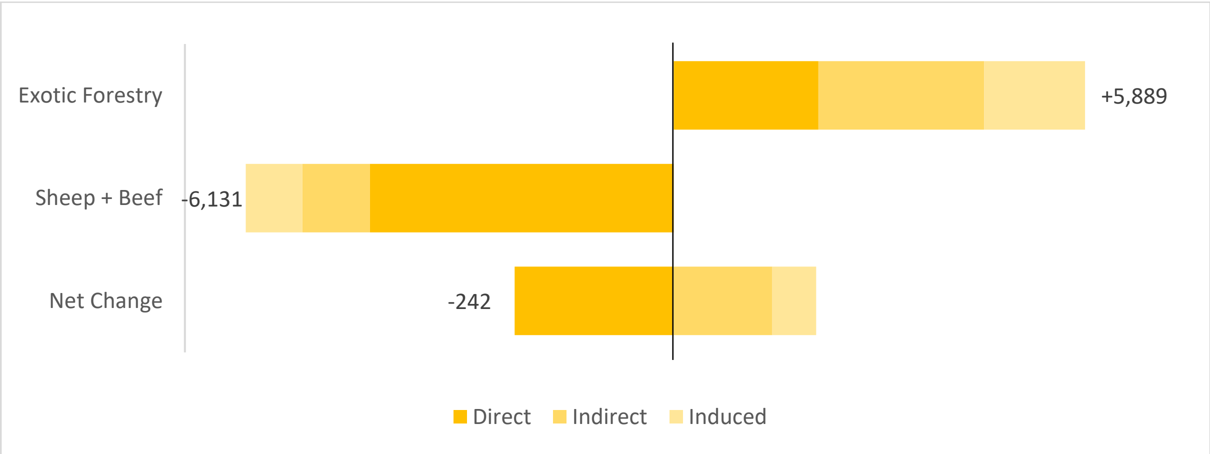


Figure 3-40: Bioenergy 150PJ - change in direct, indirect and induced employment from baseline by land-use, in FTEs.



Effects on greenhouse gas emissions

Greenhouse gas emissions are changed in this scenario by the sequestration of the newly planted exotic forestry for bioenergy. Fewer greenhouse gases are emitted due to the reduction in Sheep & Beef farming, leading to a net reduction in greenhouse gas emissions.

As described earlier the assumptions around GHG emissions for productive forestry are that only sequestration gained from the first half a rotation from new planting is considered. As this is only considered for 16 years it is documented separately from the ongoing annual emissions. Table 3-5 shows the total sequestration gained from this new planting by region.

Table 3-5: Total sequestration from new rotation forest planting.

	Change from baseline Greenhouse gas emissions (kt CO_2 eq)
Northland	-50,753
Auckland	-20,055
Waikato	-70,782
Bay of Plenty	-24,017
Gisborne	-30,097
Hawke's Bay	-43,297
Taranaki	-23,066
Manawatū-Whanganui	-74,229
Wellington	-26,888
Tasman	-10,978
Nelson	-810
Marlborough	-27,356
West Coast	-4,875
Canterbury	-127,570
Otago	-99,965
Southland	-103,939
TOTAL New Zealand	-738,677

Figure 3-41 shows the emissions profile by regions from scenario 'Bioenergy 150PJ'. This shows that emissions are greatest from Waikato. Changes in greenhouse gas emissions by region to the baseline are presented in Figure 3-42 (in per cent) and Figure 3-43 (in kt CO_2 eq. p.a.). This shows that the largest decrease has been estimated for the Canterbury. By land-use, as shown in Figure 3-44, Dairy is the main emitter in this scenario, followed by Sheep & Beef. Changes in greenhouse gas emissions by land-use to the baseline are presented in Figure 3-45 (in kt CO_2 eq. p.a.) and Figure 3-46 (in per cent); this shows a net change of - 50,413 kt CO_2 equivalents (-125 per cent).

Figure 3-41: Bioenergy 150PJ - greenhouse gas emissions by region, in kt CO_2 eq.

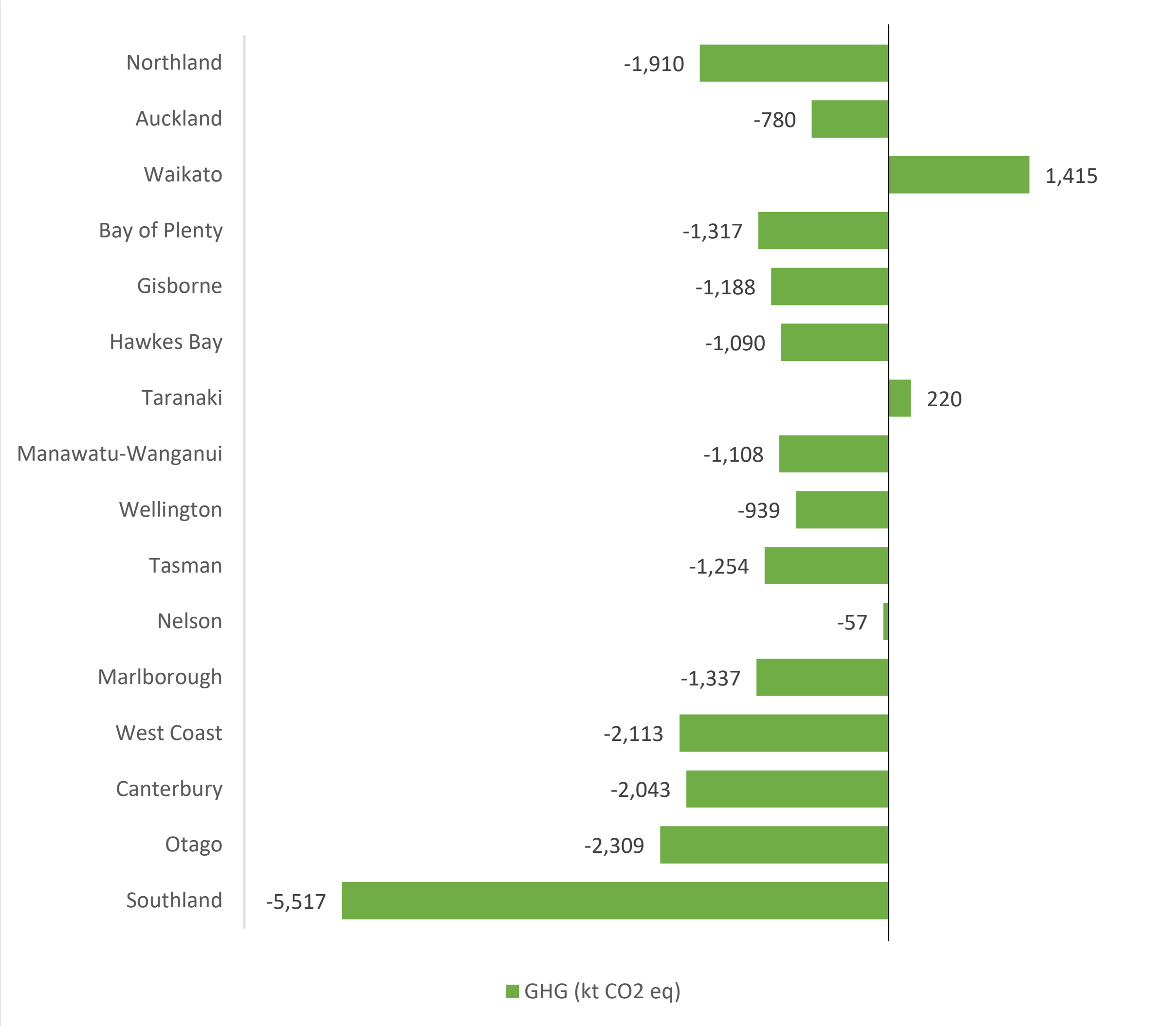


Figure 3-42: Bioenergy 150PJ - greenhouse gas emissions change from baseline, kt CO_2 eq.

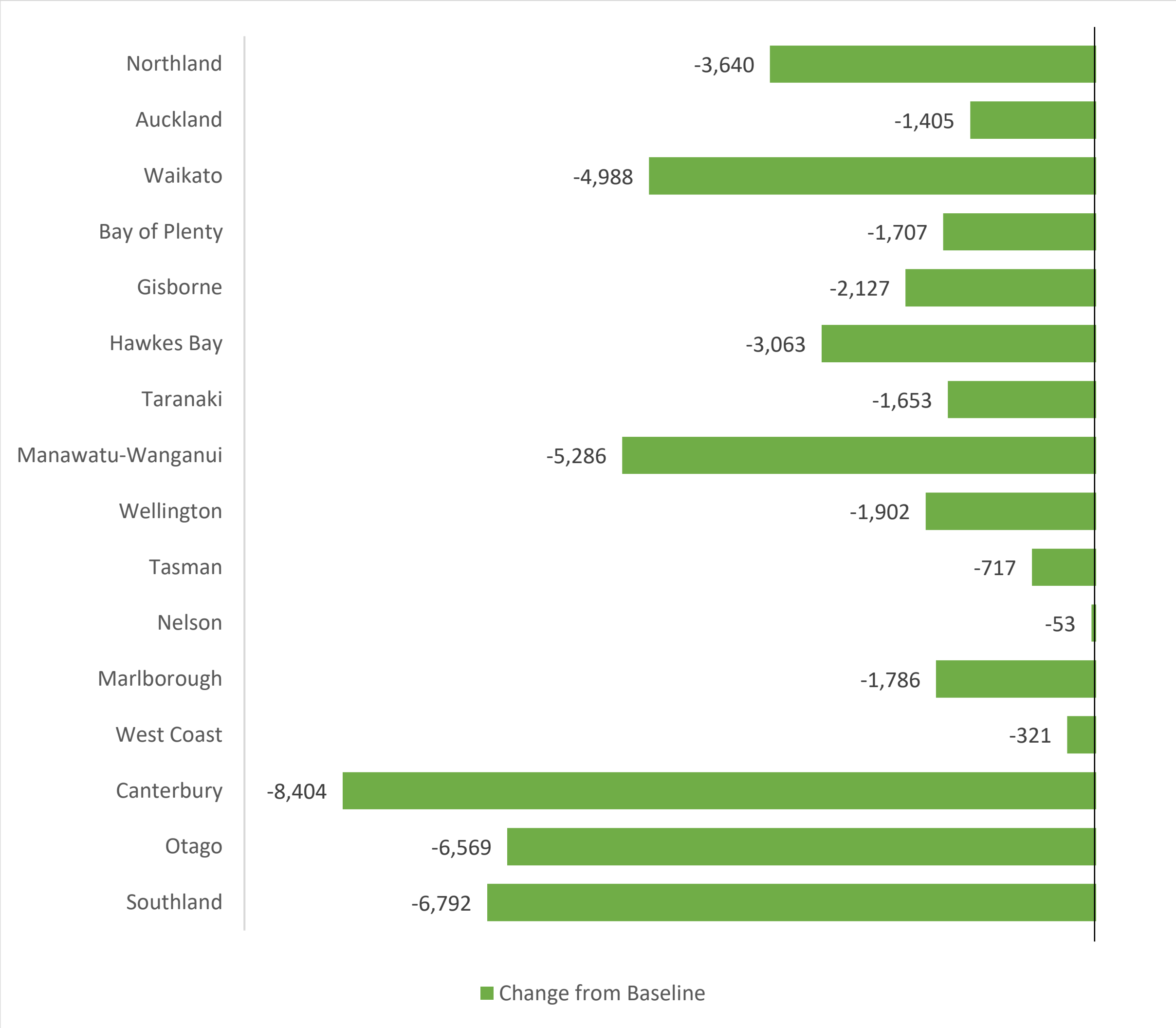


Figure 3-43: Bioenergy 150PJ - change in greenhouse gas emissions by region, in per cent.

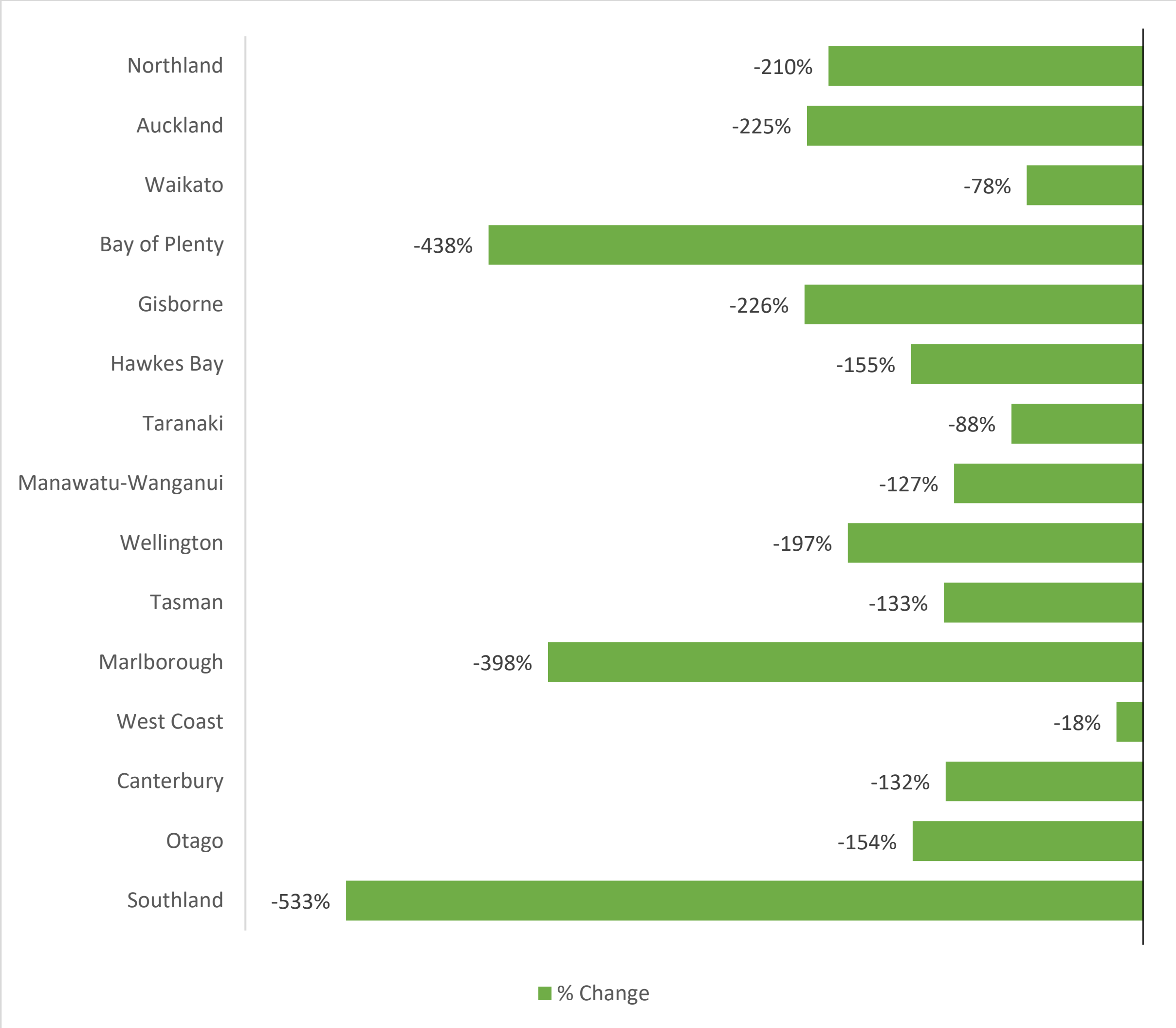


Figure 3-44: Bioenergy 150PJ - greenhouse gas emissions by land-use, kt CO_2 eq.

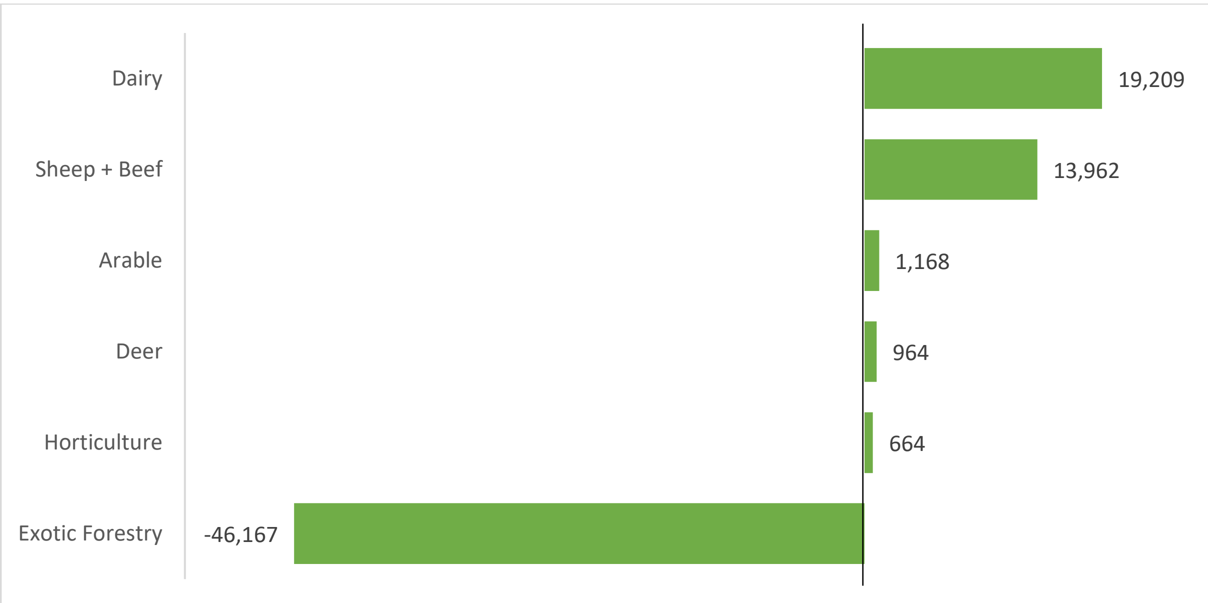


Figure 3-45: Bioenergy 150PJ - change in greenhouse gas emissions from baseline by land-use, kt CO_2 eq per annum.

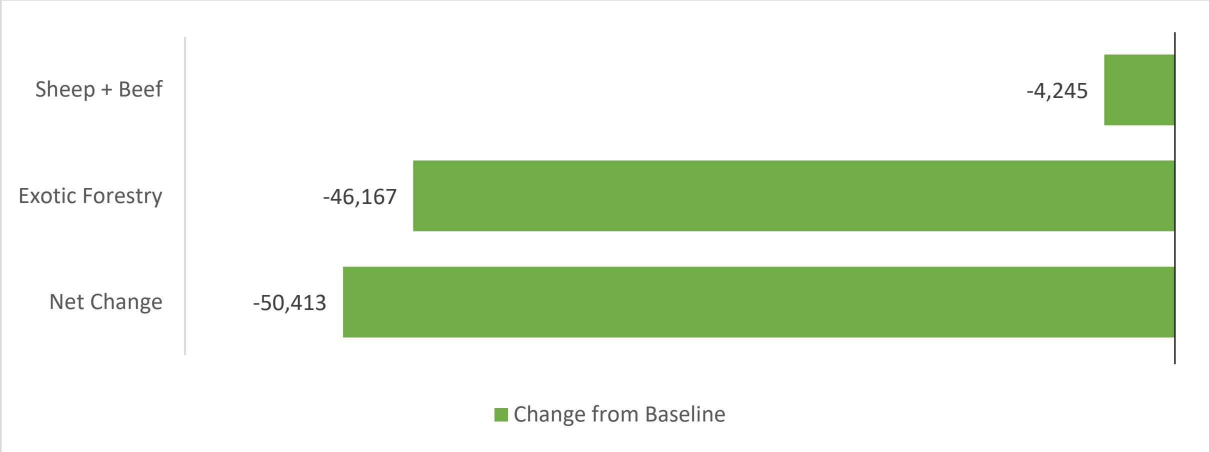
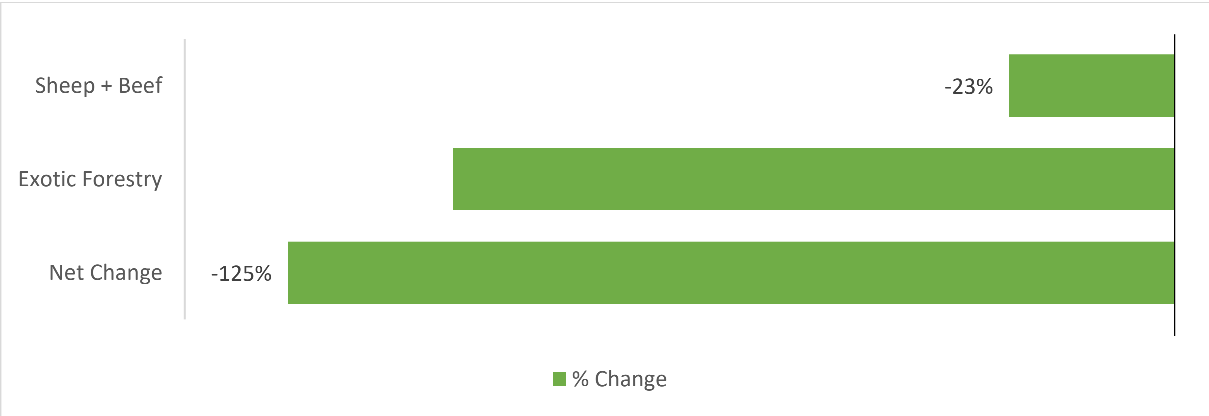


Figure 3-46: Bioenergy 150PJ - change in greenhouse gas emissions from baseline by land-use, in per cent, per annum.



In-forest residues

In scenario 'Bioenergy 150PJ', results for all in-forest residues are shown in Figure 3-47. In-forest residues use regionally specific m^3 rates per total forest land area, calculated from gross supply of all in-forest residues (Hall, 2022). Using these rates and the regional change in forest land implied by the 'Bioenergy 150PJ' scenario, shows the highest in-forest residues in the Bay of Plenty (1,550,309m^3 / p.a.), followed by Gisborne (859,210m^3/ p.a.) then Hawkes Bay (646,445m^3/ p.a.). Figure 3-48 shows the change to baseline, it can be seen that largest annual change was calculated for Canterbury (+111,229m^3 /p.a.), followed by Waikato (+110,040 m^3/p.a.), then Southland (+75,564m^3 /p.a.). The total increase in forest residues was estimated at 565,737m^3 annually. This assumes that these residues are not used for bioenergy. However, if it is possible to reclaim this, the bioenergy produced would be higher. The detail results of this and the residues are in table Appendix A1.

If sensitivity of current in-forest residues production per hectare is ±5%, this would mean ±28,287 m^3 per year, at ±10% this would mean ±56,574 m^3 per year.

Figure 3-47: Bioenergy 150PJ - all in-forest residues by region, in m³ per annum.

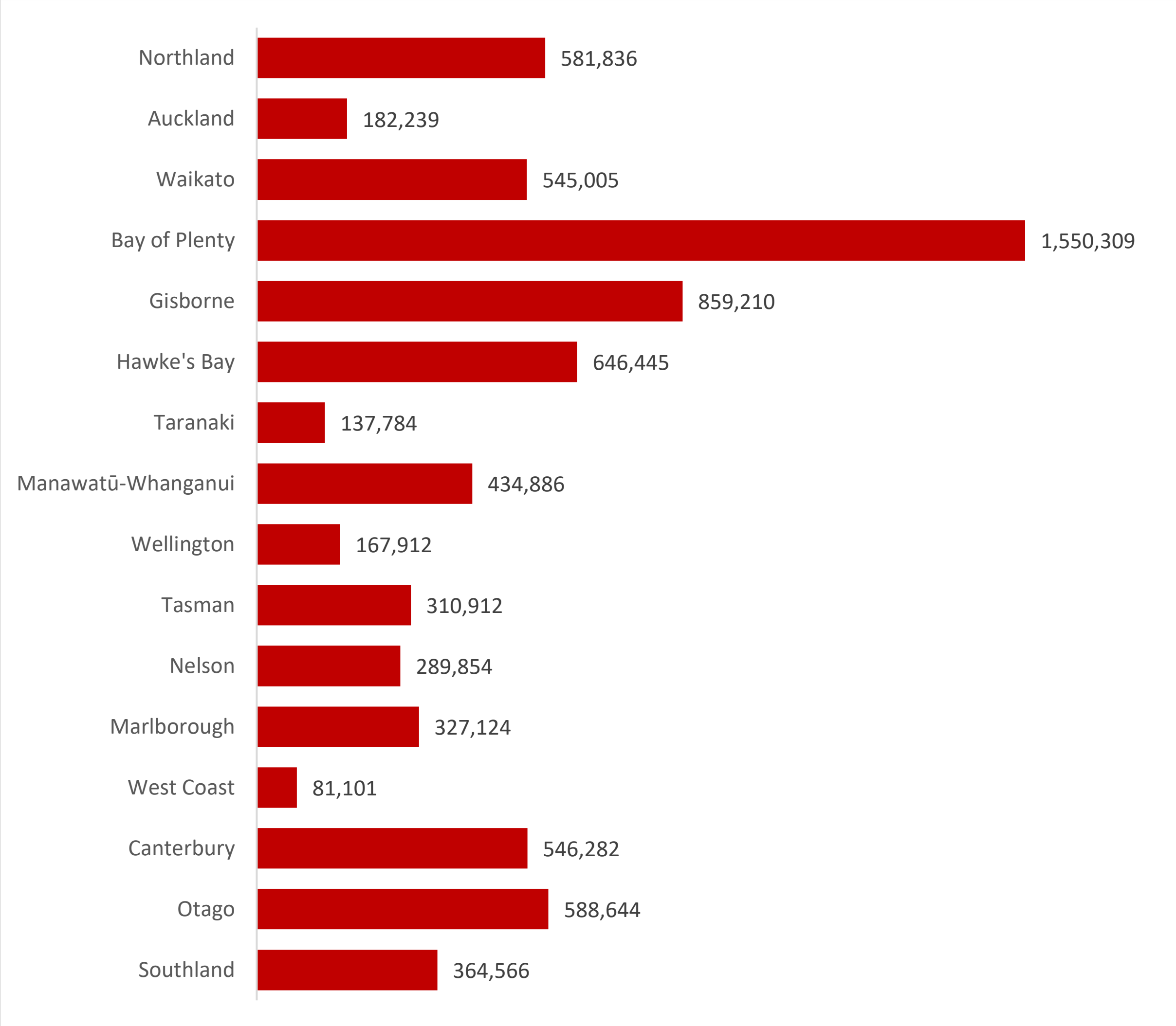
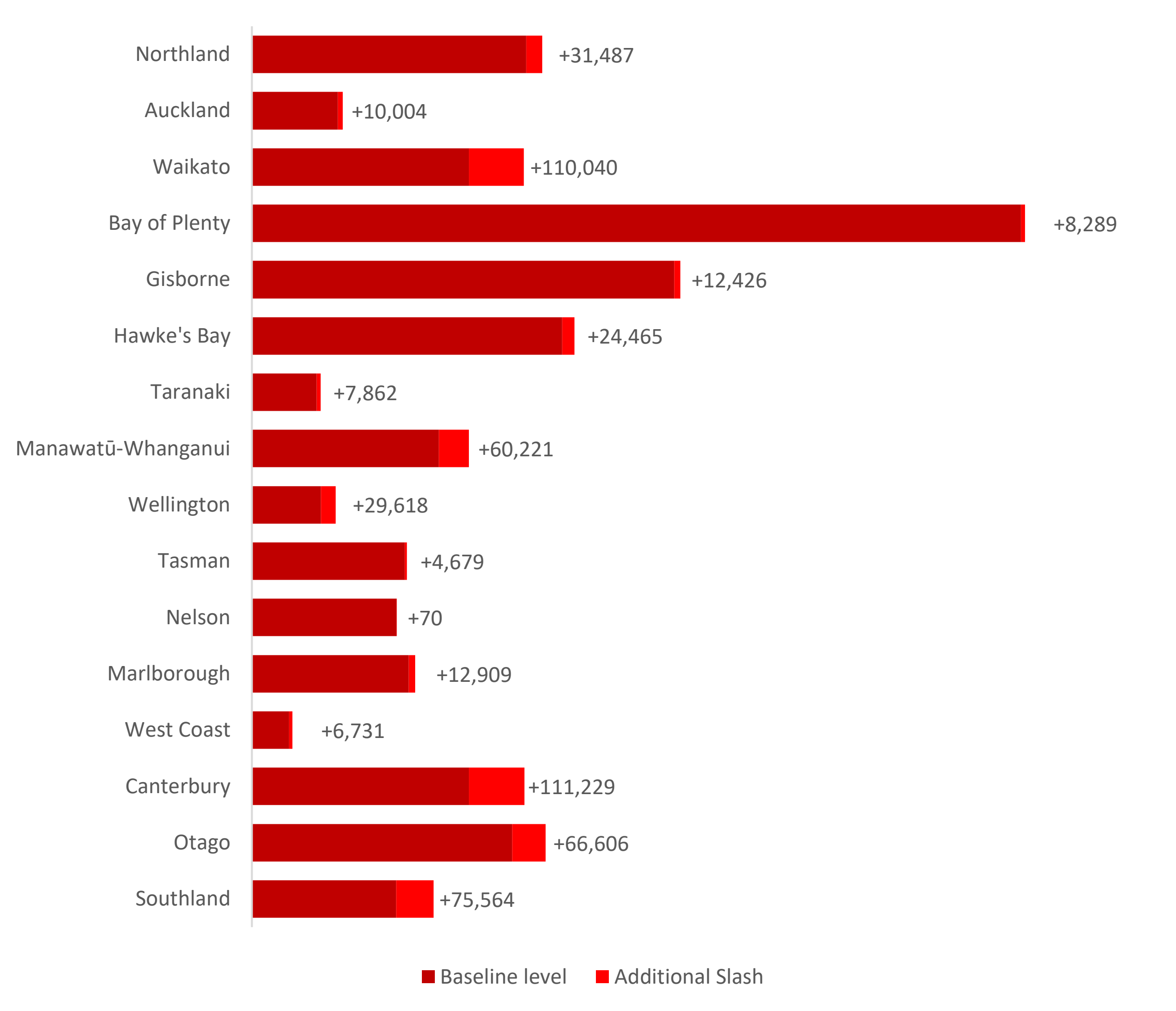


Figure 3-48: Bioenergy 150PJ - change in all in-forest residues from baseline by region, in m³ per annum.



3.3.3 4 export scenarios

The current government has the target of doubling exports. This chapter focusses on how exports could be increased from our existing production and products. Four scenarios are provided;

- Scenario 3, export 1- large scale conversion of sheep and beef land to dairy production.
- Scenario 4, export 2 - 20% export premium on primary production. This scenario looks at the impact of all New Zealand's export products achieving a 20% premium on their various attributes. Research has shown that overseas consumers are willing to pay for credence attributes such as animal welfare, food safety, environmental quality, and carbon neutral. A 20 per cent premium is considered by many as achievable across the range of our existing exports.
- Scenario 5, export 3 - 50% export premium on primary production. This would be a stretch scenario and require considerable changes in R&D, strategy, production and marketing practices.

Scenario 6, export 4 - Combination of mass dairy conversion and 50 % on export premium on primary production. This is an unfeasible scenario, as it requires both the intensification of a system and maintaining the clean environmental attributes that overseas consumers are willing to pay more for.

The scenarios have been developed to show what it needs to achieve the target of doubling exports through land-use change only, premiums or a combination of the two and their impact on the environment, especially on GHG emissions. Chapter 4 provides case studies of other ways to reduce emissions and increase productivity and value in the bioeconomy.

3.3.4 Scenario 3 – Export 1, large scale conversion of sheep and beef to dairy production

This scenario assesses the impact of conversion of sheep and beef and arable into dairy . Whilst we have seen large conversion in the past into dairy, the feasibility of this is questionable but does illustrate the challenge of reaching the export target from existing high value export products and the impact on environmental variables in particular greenhouse gas emission. For this, large scale conversion of 80 per cent of flat land sheep and beef and 50 per cent of arable land was assumed to be converted to dairy production. As stated above, this requires a much larger shift into dairy. The shift is greater than the growth of dairy from 2002 to 2016 when dairy increased by 254,508 hectares in Canterbury and 184,472 hectares in Southland compared to the shift proposed here which would be another 575,853 hectares in Canterbury and 160,201 hectares in Southland. A main reason why conversions to dairy have slowed is due to the ability of meeting environmental regulations (physical and environmental constraints of the land that would need to be converted). The environmental consequences of this scenario includes significantly higher emissions and further pollution to water ways.

Economic impacts

In this scenario, 80 per cent of flatland sheep & beef farming and 50 per cent of arable farming is transitioned to intensive dairy farming. The sectors chosen to transition from were seen as the easiest to transition to dairy, and dairy was chosen as the most profitable industry. It is assumed that all extra production is for exports.

Figure 3-49 shows direct, indirect and induced annual gross output in the 16 regions of New Zealand, with adjustments to land use for Scenario ’Exports 1’. The direct economic impact on gross output has been estimated at $47,446m for total New Zealand, highest gross output was estimated for Canterbury ($10,619m), then Waikato ($7,136m), then Otago ($6,627m).

Total economic impact (including direct, indirect and induced effects) on gross output were valued at $63,775m for New Zealand.

Results by land-use type are presented in Figure 3-50. Results show the largest direct gross output is estimated for the Dairy sector at $36,176m annually, followed by Sheep & Beef ($4,147m/ per annum), then Horticulture ($3,318m/ per annum). The total economic impact (including direct, indirect and induced effects) for New Zealand is estimated at $47,823 annually for Dairy, followed by $5,580 for Sheep & Beef, and $4,683m for Horticulture.

Regional total changes (including direct, indirect and induced effects) to the baseline scenario are presented in Figure 3-51. The largest annual change in total gross output from this scenario is estimated for Canterbury (+$6,201m/ per annum), followed by Otago (+$4749m/ per annum), then Southland (+$1,511m/ per annum).

For land-use, the scenario changes to baseline are presented in Figure 3-52. As expected, national direct gross output for Sheep & Beef sector was calculated to drop by $2,358 million annually (total impact -$3,287m), while direct gross output for Dairy was calculated to increase by $16,801m per annum (total impact +22,527m). New Zealand’s direct impact on gross output from the scenario is calculated to increase by $12,961m per annum (total net change +17,153m).

Figure 3-49: Export 1 - direct, indirect and induced gross output by region, in NZ$m per annum.

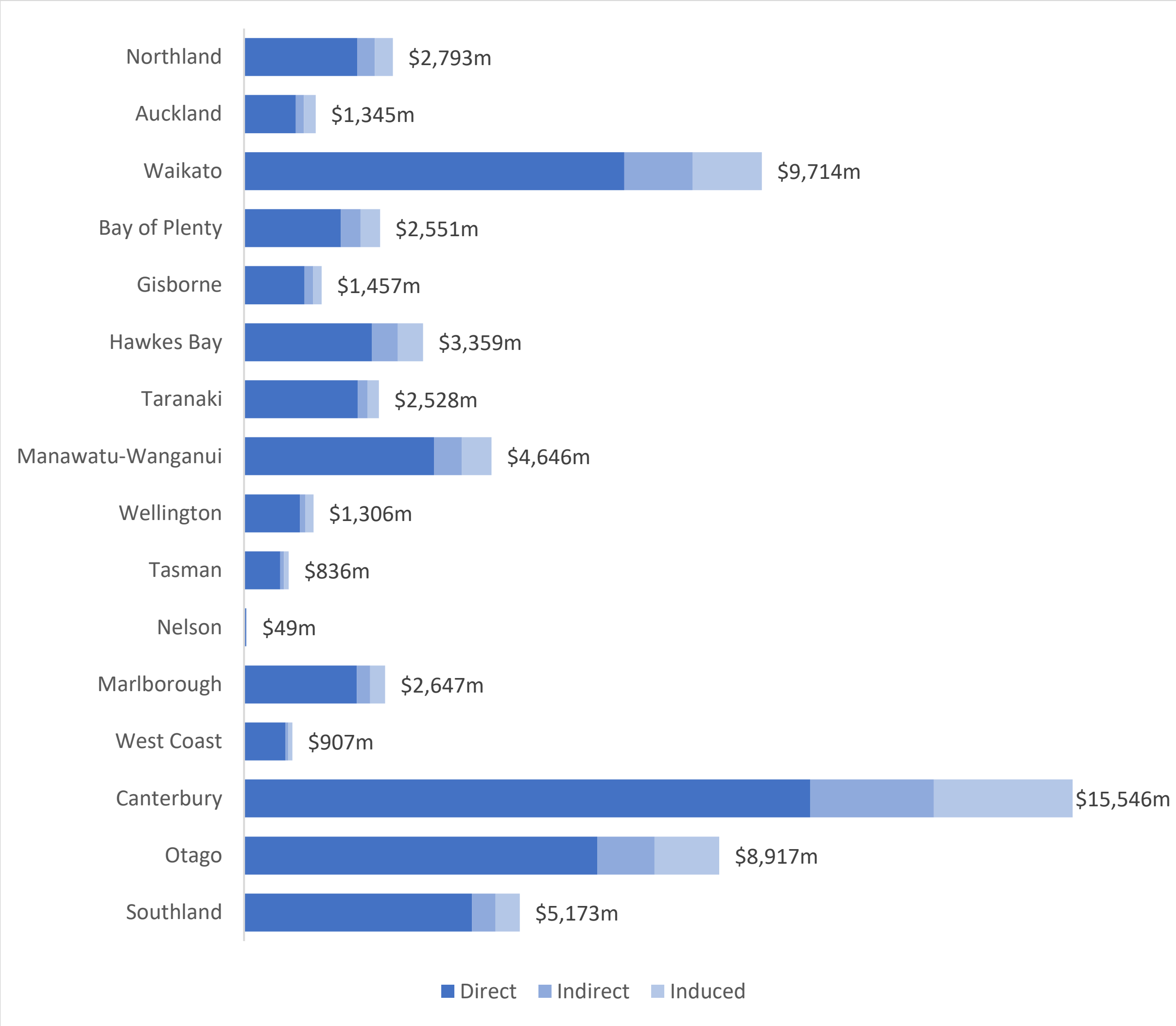


Figure 3-50: Export 1 - direct, indirect and induced gross output by land-use, in NZ$m per annum.

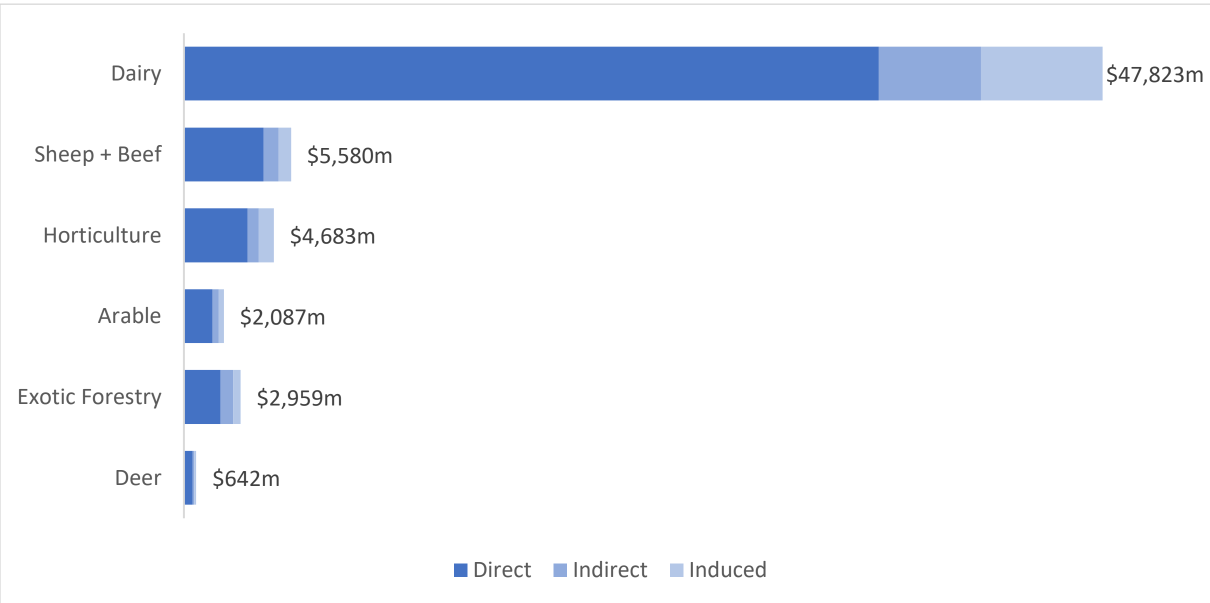


Figure 3-51: Export 1 - total change in gross output from baseline by region, in NZ$m per annum.

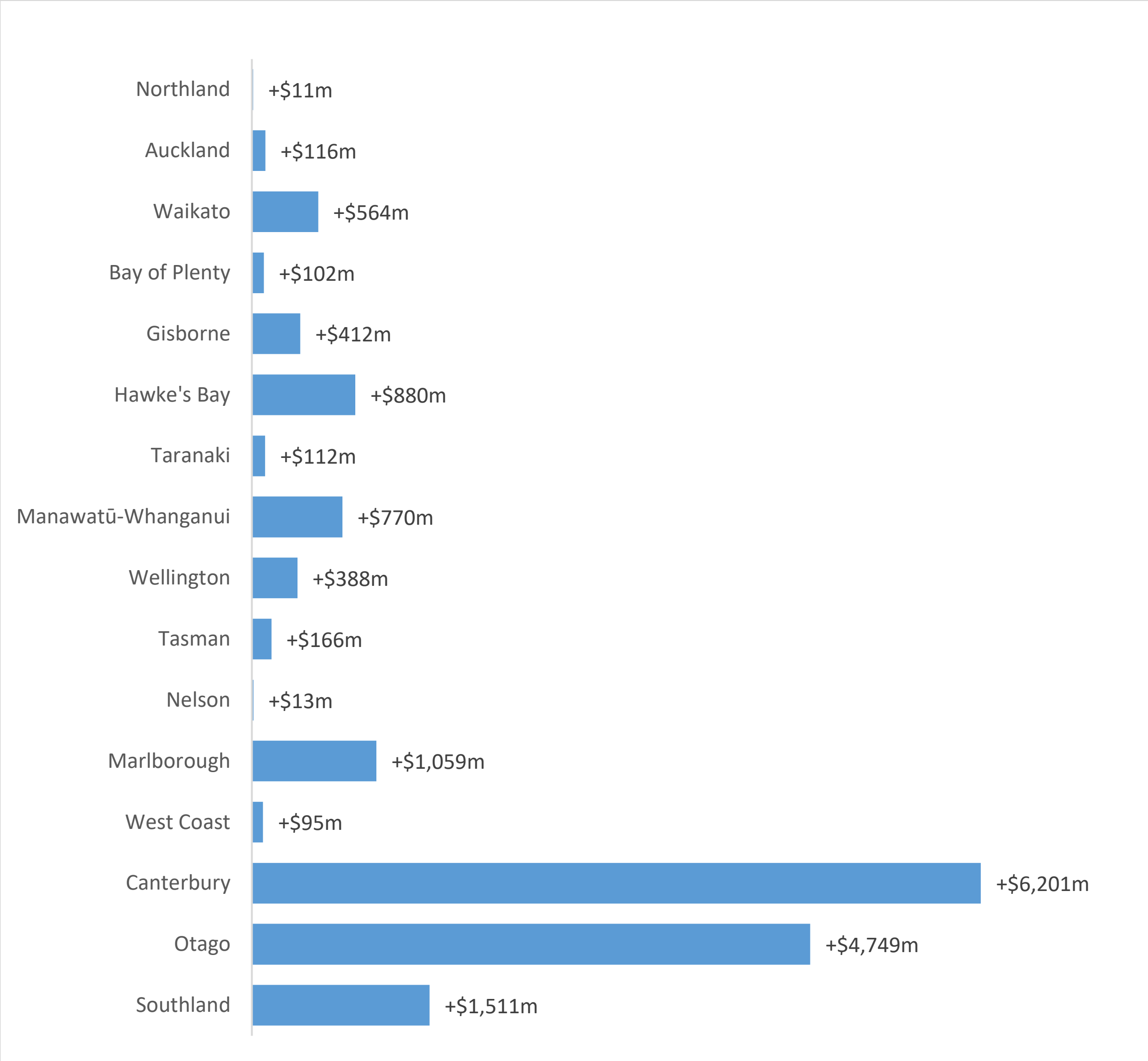
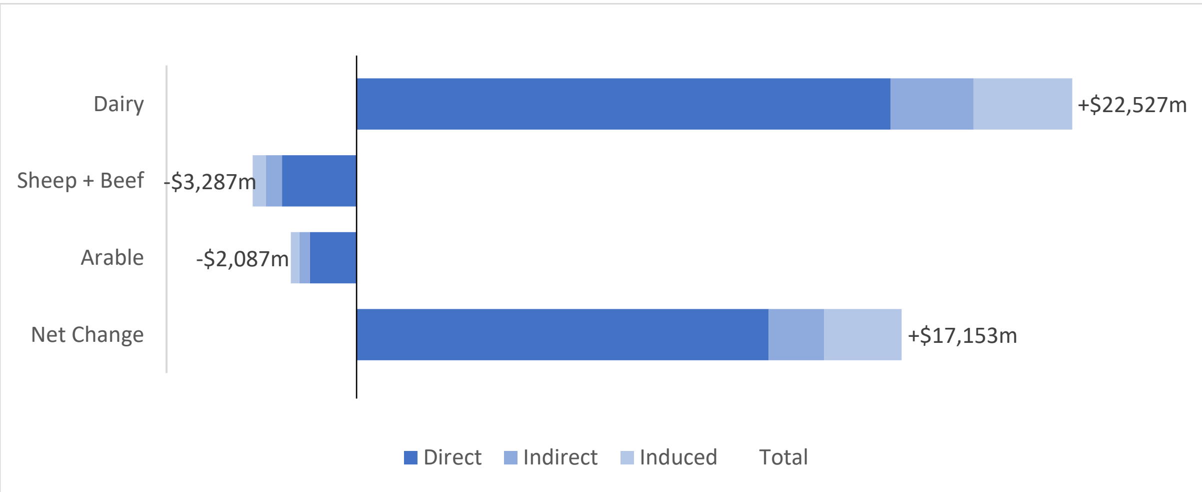


Figure 3-52: Export 1 - change in direct, indirect and induced gross output from baseline by land-use, in NZ$m per annum.



Employment impacts

Figure 3-53 shows the estimated direct, indirect, induced and total impact on employment in 16 regions and total New Zealand from Scenario 'Exports 1'. It was estimated that the direct employment impact from the scenario totalled 127,766 FTES's in New Zealand with the largest number of FTE's estimated for Otago (22,551 FTEs), followed by Canterbury (21,015 FTEs), then Waikato (18,474 FTEs). Total employment (including direct, indirect and induced effects) is calculated at 194,665 FTEs for New Zealand.

Scenario results by land-use are shown in Figure 3-54. It was estimated that the total employment impact (including direct, indirect and induced effects) from the scenario totalled 139,864 FTEs for the Dairy sector, followed by Sheep & Beef (19,437 FTEs), then Horticulture (19,239 FTEs). Scenario changes by land-use is presented in Figure 3-56; the largest increase in total FTEs (including direct, indirect and induced impacts) was calculated for Dairy (+67,508 FTEs) while the largest drop in total FTEs was calculated for Sheep & Beef (-10,165 FTEs). It is estimated that the total contribution to employment (including direct, indirect and induced employment effects) from the scenario was an increase of 50,907 FTEs per annum.

Figure 3-55 presents the total regional changes (including direct, indirect and induced effects) from the baseline for employment. The largest growth estimated for Otago (+17,834 FTEs), followed by Canterbury (+14,415 FTEs), then Southland (+3,304 FTEs).

Figure 3-53: Export 1- direct, indirect and induced employment by region, in FTEs.

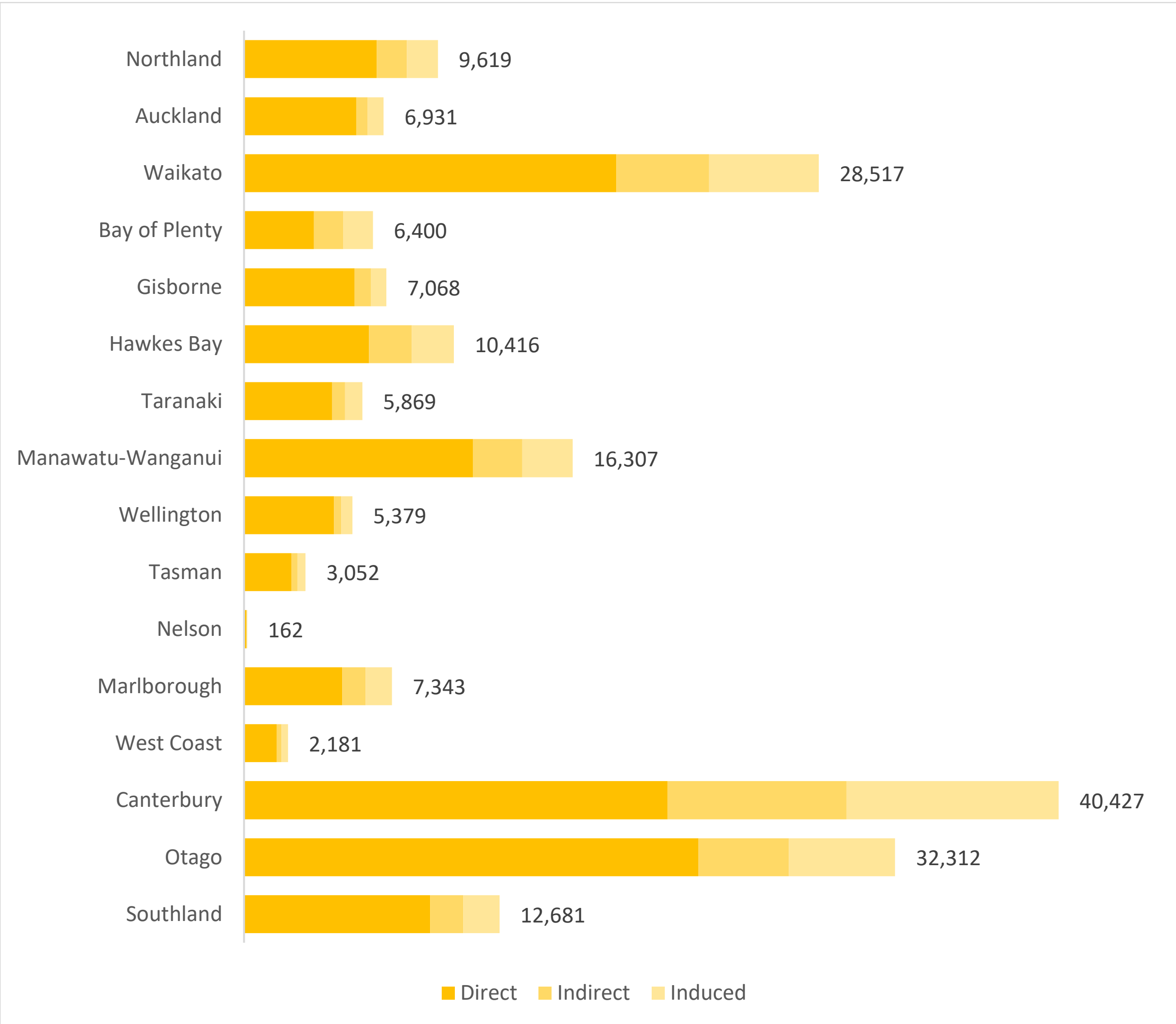


Figure 3-54: Export 1 - direct, indirect and induced employment by land-use, in FTEs.

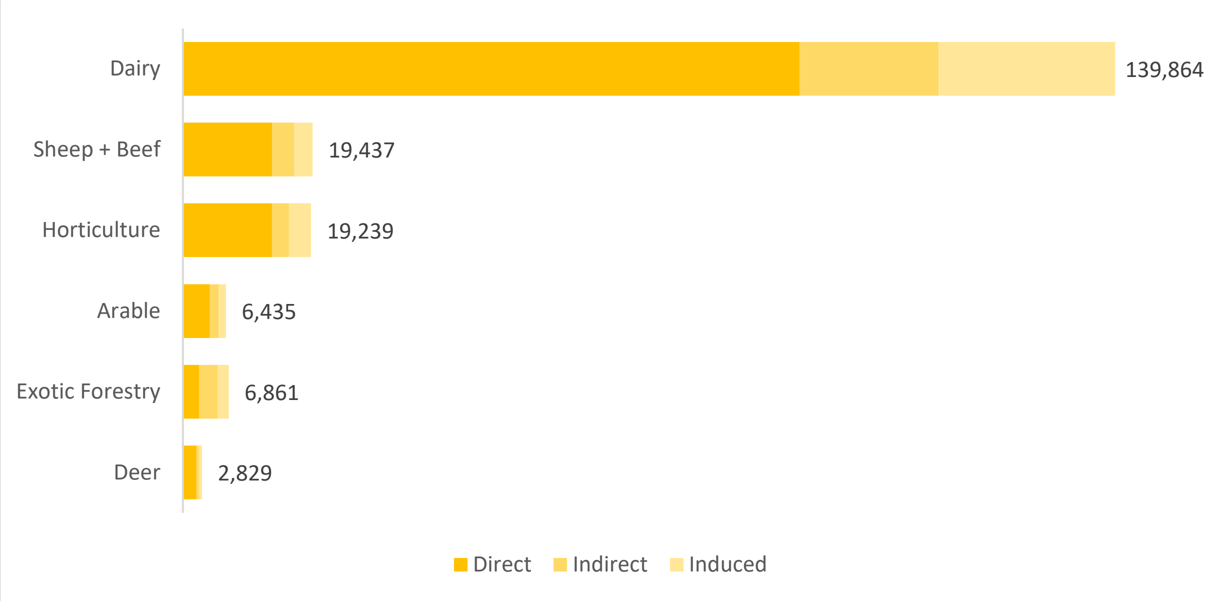


Figure 3-55: Export 1 - total change in employment from baseline by region, in FTEs.

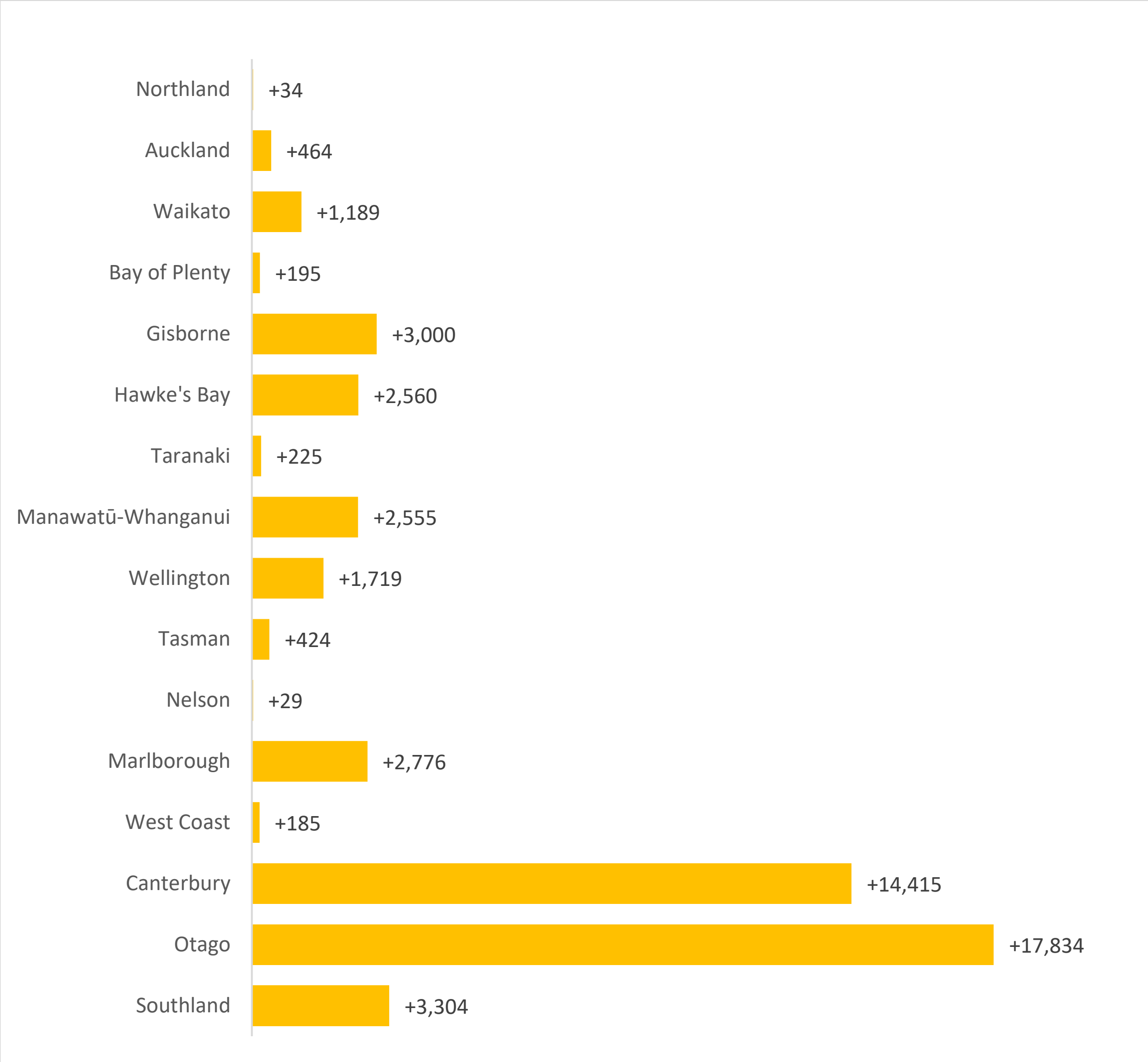
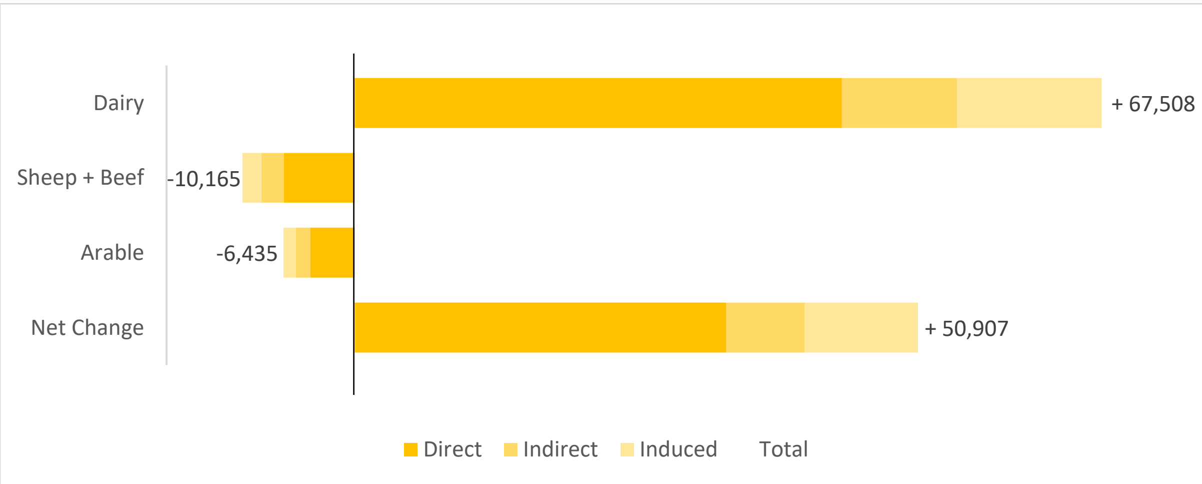


Figure 3-56: Export 1 - change in direct, indirect and induced employment from baseline by land-use, in FTEs.



Effects on greenhouse gas emissions

Figure 3-57 shows the emissions profile by regions from scenario 'Export 1'. This shows that emissions are greatest from Canterbury. Changes to the baseline by region are presented in Figure 3-58 and Figure 3-59. It can be seen that the smallest increase in emission was estimated for Nelson while the largest increase in emissions was calculated for Marlborough. By land-use, as shown in Figure 3-60, Dairy is the main emitter in this scenario, followed by Sheep & Beef. Changes to the baseline by land -use are presented in Figure 3-61 (in kt CO_2 eq.) and Figure 2-53 (in per cent); this shows a net change of +9,392kt CO_2 equivalents.

Figure 3-57: Export 1 - greenhouse gas emissions by region, in kt CO_2 eq. per annum.

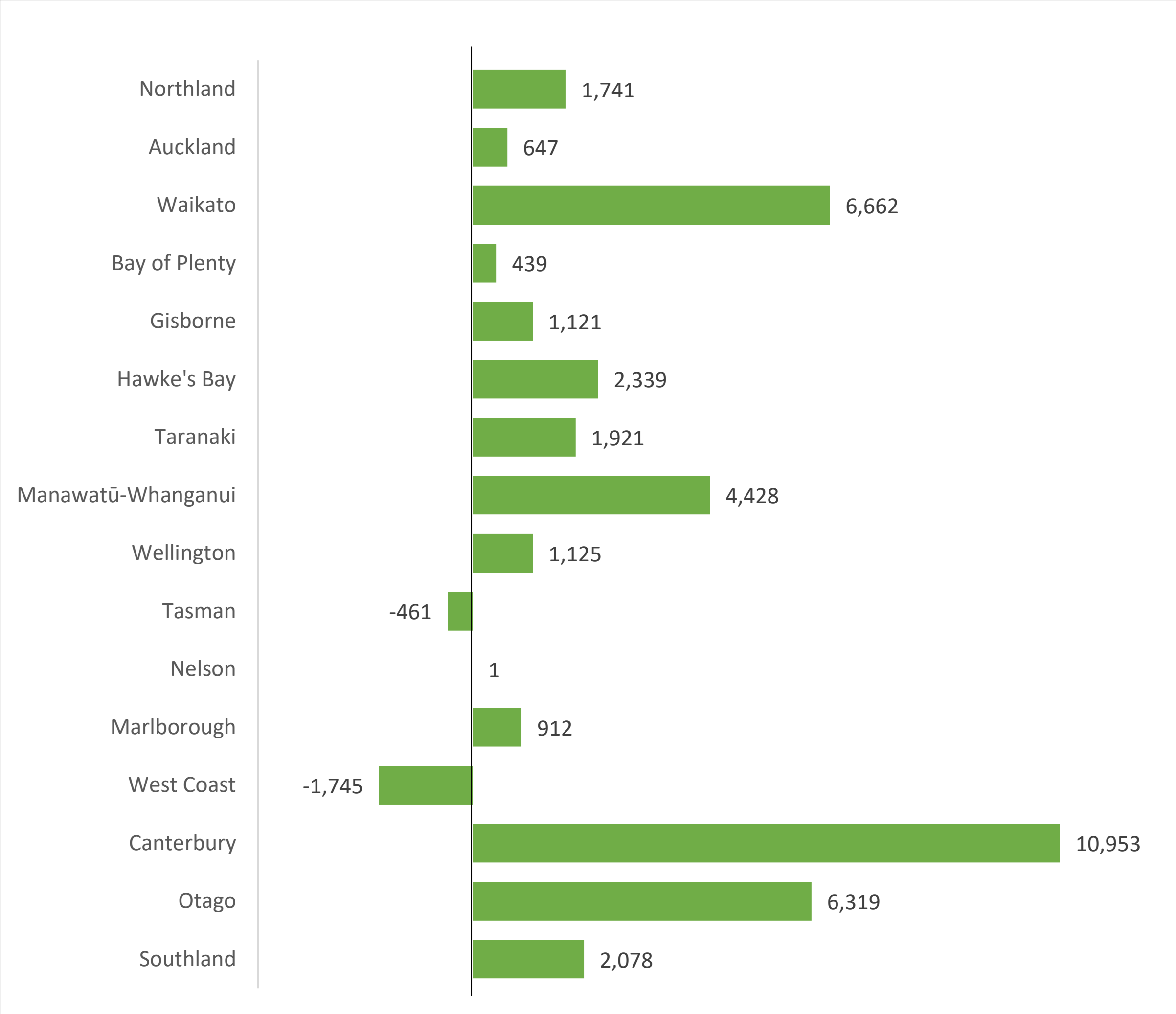


Figure 3-58: Export 1 - change in greenhouse gas emissions from baseline by region, in kt CO_2 eq. per annum.

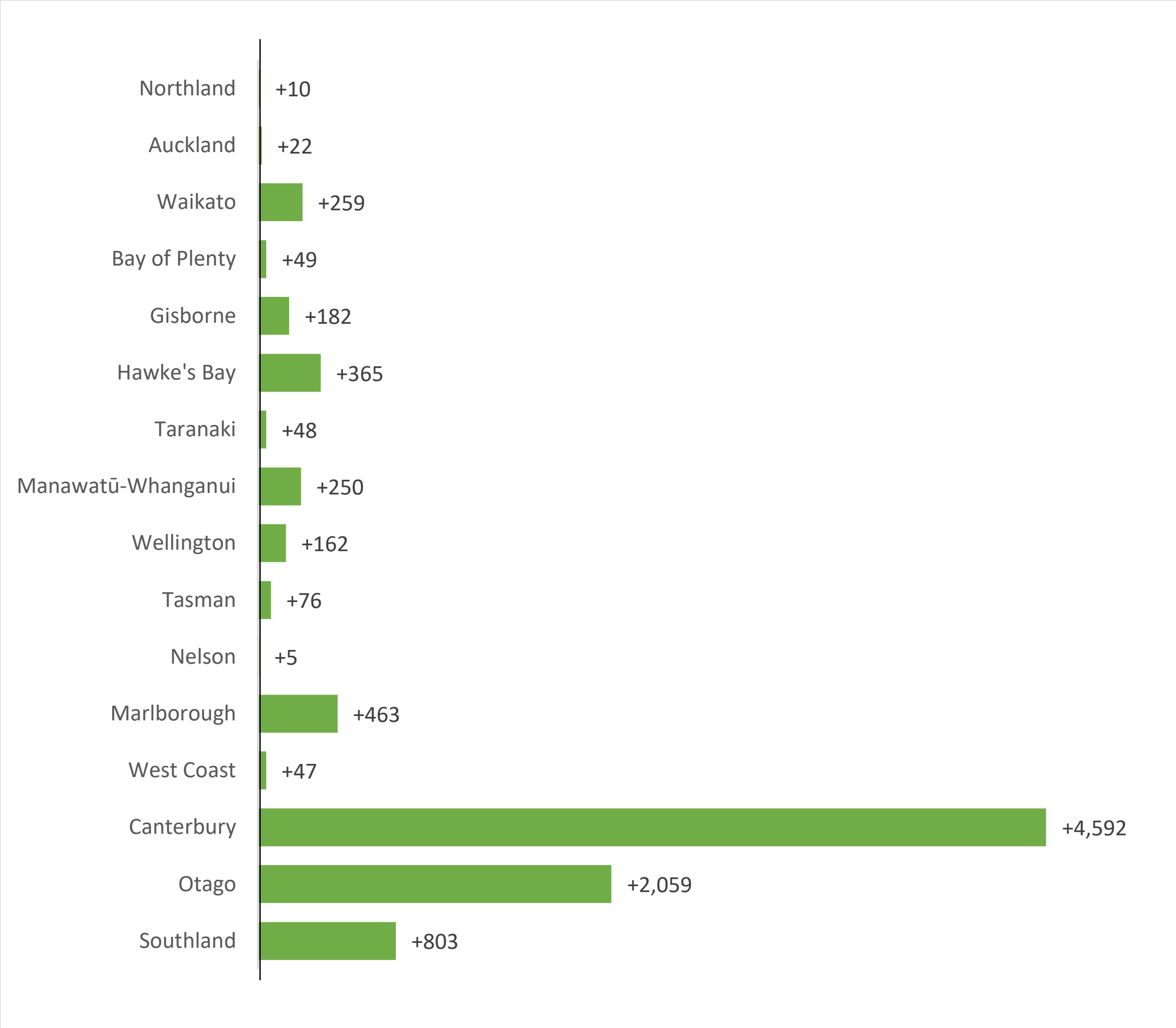


Figure 3-59: Export 1 - greenhouse gas emissions by region, percentage change to baseline.

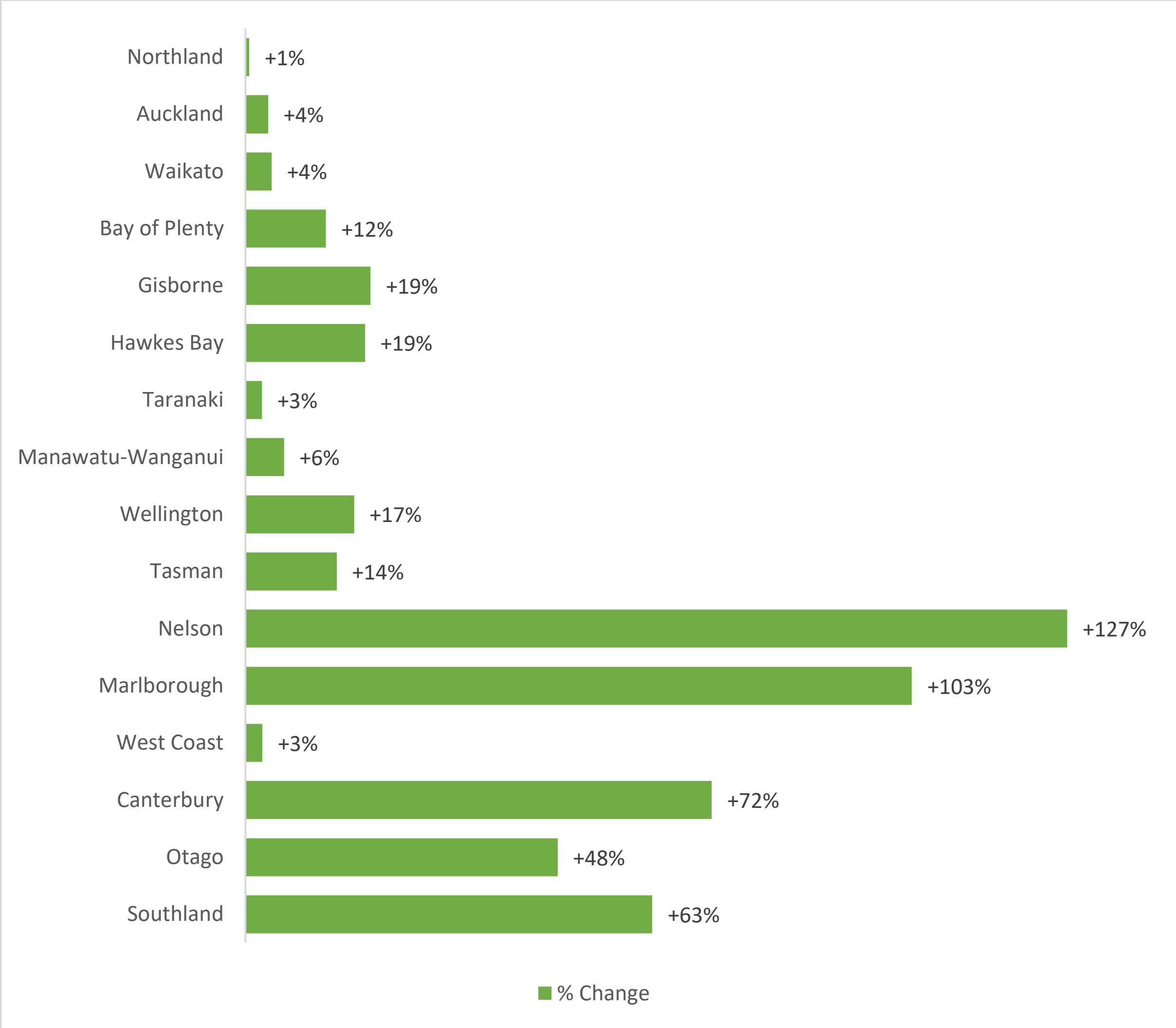


Figure 3-60: Export 1 - greenhouse gas emissions by land-use, in kt CO_2 eq. per annum.

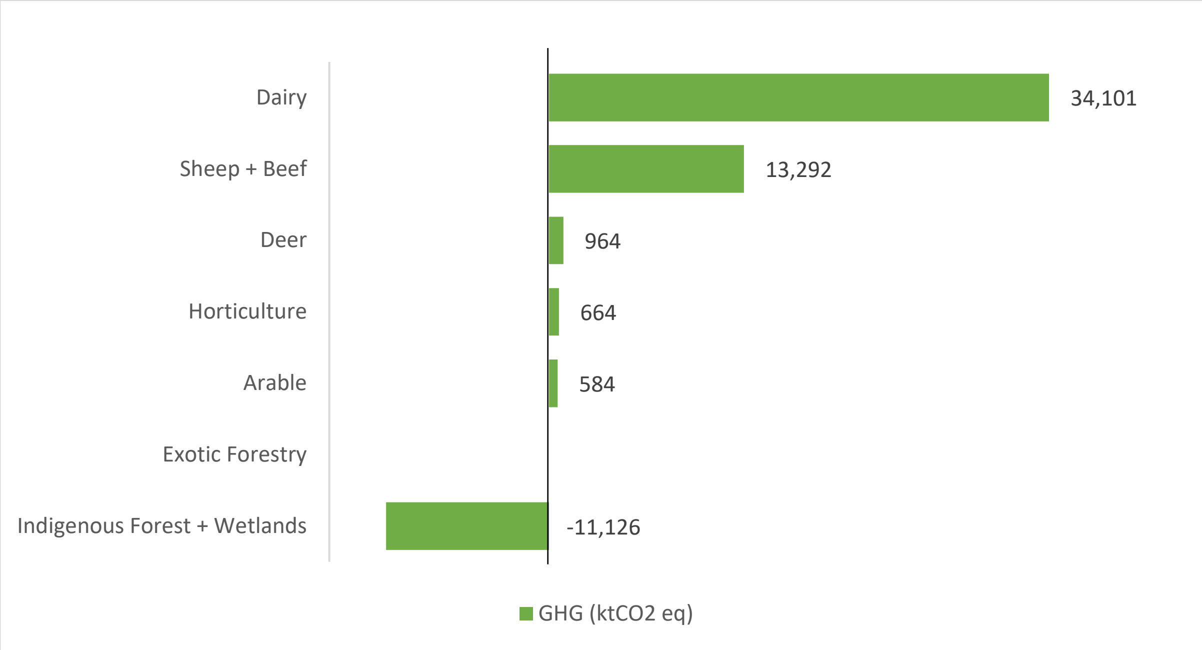


Figure 3-61: Export 1 - change in greenhouse gas emissions from baseline by land-use, in kt CO_2 eq. per annum.

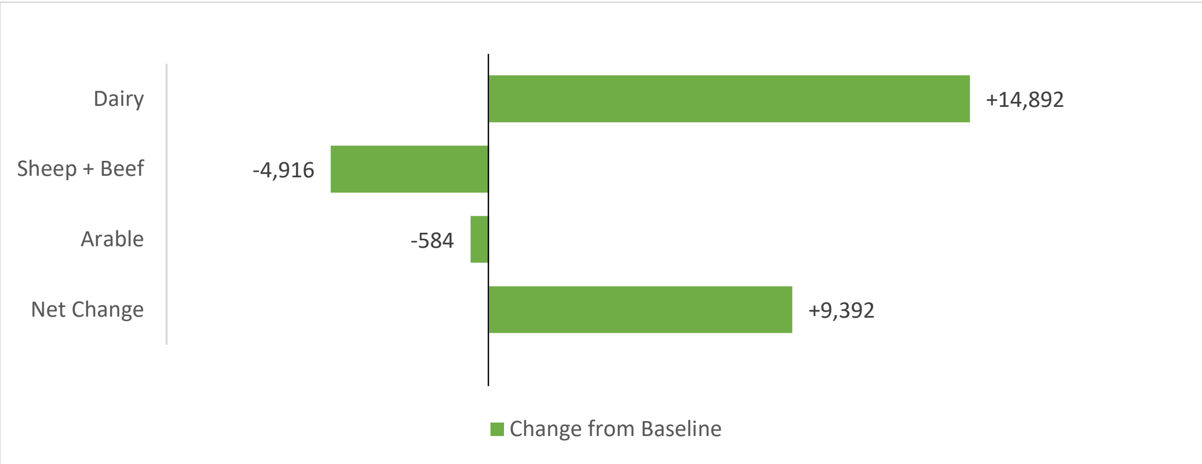
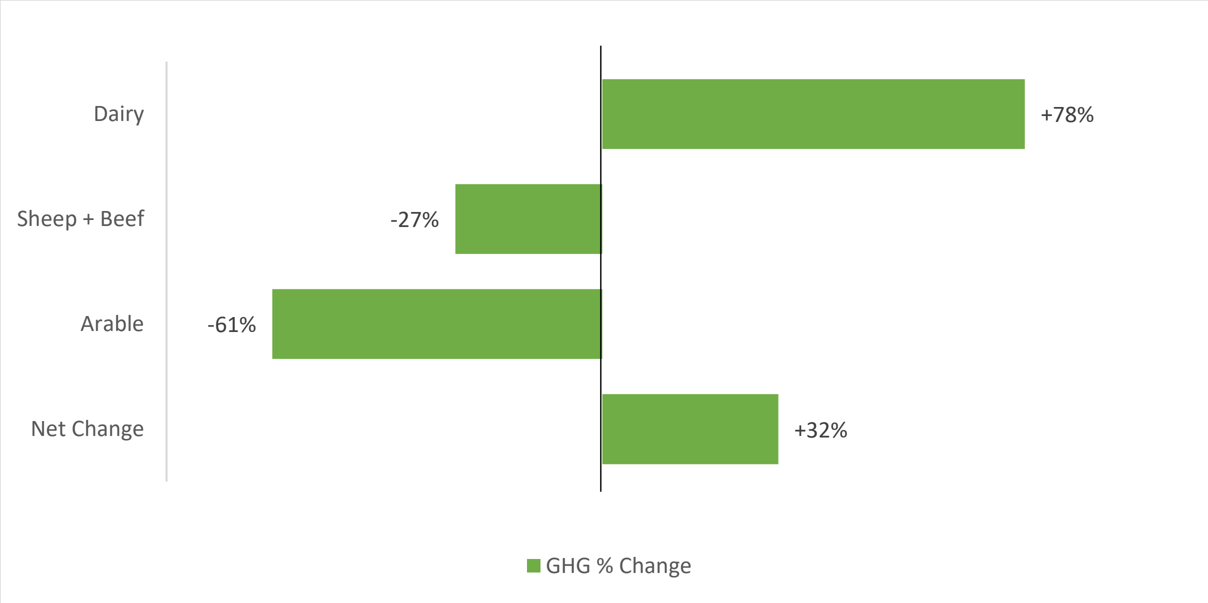


Figure 3-62: Export 1 - change in greenhouse gas emissions from baseline by land-use, in per cent, per annum.



Social and environmental scoring

The social and environmental impacts from this scenario have been assessed using the Scoring Matrix developed for the Integrated Assessment Framework and are shown in Figure 3-63 and Table 3-6.

In reading the Scoring spidergraphs, the thick grey line shows the baseline impact, and the yellow and green shapes show change in social- and environmental-scoring respectively. Where the coloured shape shrinks inwards, this indicates a reduction in score. Where the coloured shape grows outwards, this indicates an increase in score.

Results suggest that socially, there may be an increase in life satisfaction and a decrease in access to basic amenities. These changes come from the change from Sheep & Beef farming to dairy farming. For example, life satisfaction may increase due to higher incomes.

The environmental scores, however, are negative across the board. These changes come from the change to more intense farming practices, which are more detrimental environmentally.

Figure 3-63: Export 1 - change in Environmental and Social impacts from baseline.

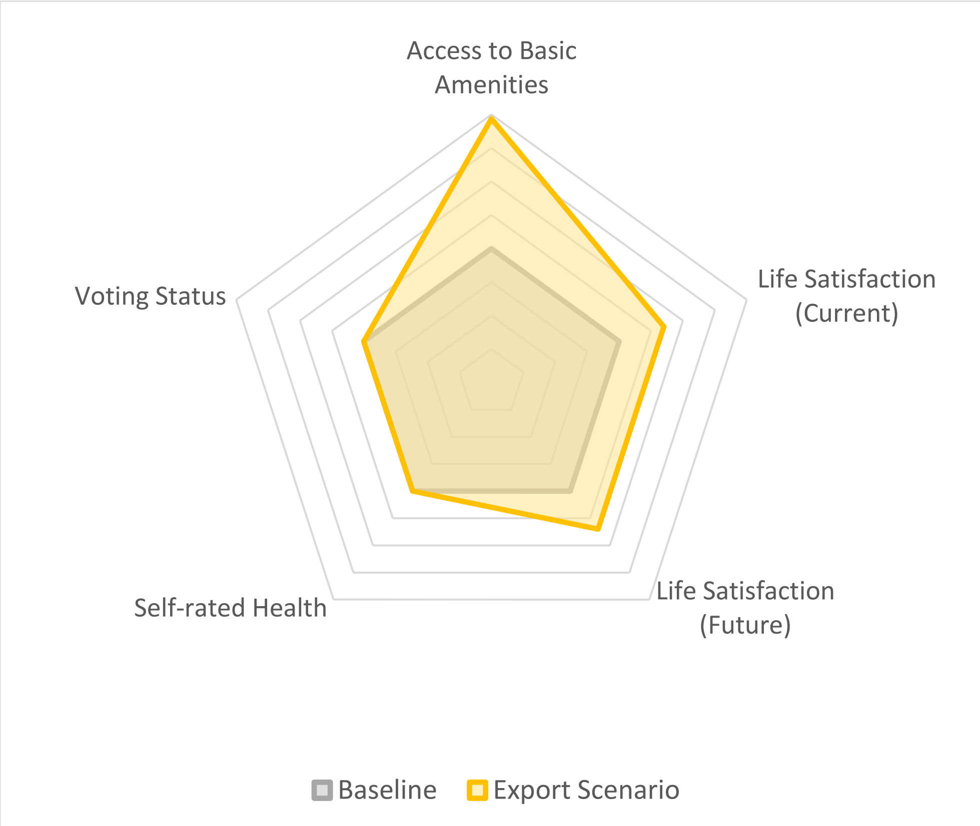


Table 3-6: Environmental and social scores from Scenario Export 1.

Environmental Variable	Score
E. coli	-3.7
Greenhouse Gas Emissions	-3.7
Ground Water Quality	-3.7
Macro-Invertebrate Index	-3.7
Mahinga Kai	-1.4
River Water Quality	-3.7
Soil Quality	-3.7
Swimming Index	-3.7

Social Variable	Score
Access to Basic Amenities	1.9
Life Satisfaction (Current)	0.7
Life Satisfaction (Future)	0.7
Self-rated Health	0.0

The impact on the environment is negative as shown in Table 3-6. In particular there was an increase in greenhouse gas emissions quantified in Figure 2-53 which shows a 32 per cent increase. Ground water quality, the Macro-Invertebrate Index, *E. coli*, river water quality, soil quality and swimming index all are judged to have fallen by a similar amount. Whereas there is a relatively smaller fall in Mahinga Kai. As stated earlier it must be stressed that these are judgements and likely to vary according to local conditions.

In the case of social indicators, these are judged to have risen. Access to basic amenities, self-rated health status and life satisfaction rose slightly due the higher incomes.

3.3.5 Basis for the product premium scenarios (export 2 & 3)

Studies have shown that consumers in New Zealand export markets would pay a premium for credence attributes (i.e. those attributes that cannot be seen or experienced at the point of sale) in food products. There is a range of premiums for the environmental, social and cultural attributes in food products.

A series of research conducted by the Agribusiness and Economics Research Unit (AERU) at Lincoln University, New Zealand, has investigated the comparative preferences of consumers in a number of international markets (Guenther et al., 2015, 2021; Saunders et al., 2013, 2015; Tait et al., 2016, 2018a–d, 2020a–h, 2021, 2022). In a recent cross-country study, Guenther et al. (2021) surveyed consumers in China, Japan, and the UK in the years 2019, 2020, and 2021 about the importance of factors underpinning the attribute environmental condition in relation to food supply. Results showed that water quality was the most important factor underpinning environmental condition for China and Japan across all survey years, while recycling was the most important factor associated with environmental condition for UK consumers across all survey years. Air quality was also an important factor underpinning environmental condition in all countries, as were factors of biodiversity and wildlife protection, including protecting coastal and sea life and protecting endangered animals and plants. In China, an important factor for environmental condition was organic production – however, this factor was not as important in Japan and the UK, where it was rated among the least important factors of environmental condition. The factors wilderness and GHG emissions were also not important factors for China and UK participants (Guenther et al., 2021). The ranking of the importance of these factors was consistent over the three survey years for all countries (Guenther et al., 2021). This study reinforced previous work by the AERU, which showed similar findings to the previous one (Guenther et al., 2015; Miller et al., 2017; Saunders et al., 2013, 2016; Tait et al., 2016).

Tait et al. (2016) conducted a cross-country analysis of lamb consumer preferences and WTP for environmental attributes (GHG emissions minimisation, water management, and biodiversity enhancement) against other attributes in developed (UK) and developing economies (China and India). Results shows that food safety, followed by animal welfare, appeared to be the most valued attribute, with premiums of between 9 per cent and 49 per cent for certified products. Of the environmental attributes, GHG minimisation certification was valued the most highly (by a thin margin) across all countries. A key difference was that Indian respondents indicated much higher WTP for environmental attributes compared with UK and Chinese consumers (Tait et al., 2016). This is consistent with previous work indicating that Chinese and Indian consumers were willing to pay higher premiums for the environmental attributes of water pollution minimisation, GHG minimisation, and improved biodiversity relative to UK consumers (Saunders et al., 2013).

Individual results of these surveys are outlined in Appendix B; and they are summarised in Table 3-7 which shows the range of the potential premiums depending on the market and product and by consumer segment.

Table 3-7: Average and range of WTP values from AERU research.

Attribute type	**Average WTP (% of product price)**	**Range of WTP values (% of product price)**
Generic environmental credentials	12%	3–25%
Water protection	20%	6–67%
GHG emissions reduction	23%	5–155%
Biodiversity/wildlife protection	19%	4–56%
Waste management/reduction	22%	11–40%

Other key studies in estimating premiums are Yang and Renwick (2019) who conducted a meta-analysis of credence attributes for livestock products. To do this, the authors conducted a systematic literature review and applied a meta regression analysis in an effort to introduce some generality to WTP studies. The authors initially identified 566 WTP estimates from 94 studies. However, 11 of these were negative and excluded from the meta-analysis but controlled for using a dummy variable in the meta regression. Yang and Renwick (ibid.) created two subsamples within the data to separate red meat from dairy. The applied regression model highlighted that in the red meat sample there is a higher WTP for beef products than for lamb, with organic production associated with the highest price premium, and environmentally friendly attributes values the least by consumers. In terms of dairy products, food safety was associated with the highest price premium, and environmentally friendly the lowest. In addition, WTP estimates were modelled based on the meta-regression results with the study year was set after 2010 to capture recent market demand for livestock products. Their study results are presented in Table 2-5.

Table 3-8: WTP estimates of a price premium for livestock products, in per cent.

	Whole sample model	Red Meat Model	Dairy Model
Environmentally Friendly	24.1	18.9	25
Animal Welfare	31.9	19.3	31
Organic	35.8	31.4	28.5
Hormone/antibiotic free	32.2	24	34.3
Grass-based	24.9	22.3	25.1
Food Safety	29.9	23	39.2
PDO/PGI	24.7	22.4	25.7
COOs/ROOs	29.8	22.5	29.9
Traceability	20.1	17.7	26.1
Mixed attributes	25.7	19.2	25.8

PDO – protected designation of origin (food and wine), PGI – protected geographical indication (food and wine), COOs/ROOs country or region of origin.
Source: Yang and Renwick (2019)

Alsubhi et al. (2023) conducted a systematic review of studies reporting in consumer WTP experiments regarding healthier food products, presenting broad results across a range of countries and product categories. Studies consistently found positive WTP for healthier food options, with consumers willing to pay an average premium of 30.7 per cent (ranging between 5.6 and 91.5 per cent) for healthier food products (Alsubhi et al., 2023).

Overall, these studies show the potential of premiums for New Zealand exports based on credence attributes. The general consensus average is around 20 per cent, therefore this was chosen as one scenario for this research. However, premiums do exist above this level which, whilst would be more challenging to achieve could be feasible, therefore a 50 per cent premiums was also selected to show the upper bounds of what could be possible. In fact, our kiwifruit industry earns a 100 per cent premium over other suppliers and there are other examples including wine.

The challenges that exist to achieve this would take some resources such as improved in market research of different business models which emphasise the value chain rather than supply chain as explored by AERU research in *Rewarding sustainable practices* with the *Value Chain Compass* to be sourced https://www.aeru.co.nz/valuecompass (AERU, 2022a). Further, while there were early premiums, certification has become more of a market access condition, for our key, higher value markets. In essence, certification is required to maintain market share in an increasingly competitive international environment, where consumers are wanting information on the sourcing of their products. As such, the normalisation of 'credence attributes' that provide premiums could affect the aim of increasing premiums.

3.3.6 Scenario 4 – Export 2, 20% premium

This scenario looks at the impact of all New Zealand's export products achieving a 20% premium on their various attributes. The assumption is that as New Zealand is producing products with these attributes already and not necessarily capturing all of that added value; this scenario does not require any land use change. A 20 per cent premium is considered by many studies as achievable across the range of our existing exports.

Economic and employment impacts for New Zealand

Figure 3-64 shows direct, indirect and induced annual gross output for New Zealand with the 20% premium scenario and compared to the baseline. The direct gross output has been estimated to be $41,406m for total New Zealand, this is an increase of $6,901m from the baseline. Total gross output (including direct, indirect and induced effects) was estimated at $55,945m, growing by $9,324m from the base scenario.

Figure 3-65 shows the direct, indirect and induced annual impacts on employment for New Zealand from the Scenario and compared to the baseline. The employment impacts assume the same multipliers as the baseline; this is not likely to be the case as it could be expected they would be lower, so these estimates are likely to overestimate the impact on employment. Employment increased by 20 per cent in this scenario. A total of 113,012 FTEs (direct) are employed nationally per year in this scenario, which translates into an additional 18,835 FTEs when compared to the baseline. When indirect and induced effects are applied, a total of 172,509 FTEs are employed per annum.

Table 3-9 shows the direct, indirect and induced annual impacts on Value added, including changes from the baseline. Direct Value added for New Zealand was estimated at $20,891m per annum from this scenario (which is an increase of $3,482m from the baseline). Total value added (including direct, indirect and induced effects) was calculated to be $29,528m (which is an increase of $4,921m from the baseline).

Results on gross output by land-use type are presented in Figure 3-66. Results show the largest direct gross output is estimated for the Dairy sector at $23,250m annually, then Sheep & Beef ($7,806m/ per annum); then Horticulture ($5,619m/per annum). The total economic impact (including direct, indirect and induced impacts) by land use for Dairy is estimated at $30,356m annually, followed by $10,641m annually for Sheep & Beef, and $5,619m annually for Horticulture. Changes to baseline are presented in Figure 3-68. By land-use, direct gross output for all land-use types were projected to increase, the largest annual increase was calculated for Dairy (+$3,875m/ per annum; total impact +$5,059m/ per annum), then Sheep & Beef (+$1,301m/ per annum; total impact +$1,773/ per annum), then Horticulture (+$664m/ per annum; total impact +$937m/ per annum).

As shown in Figure 3-67, by land use type, it estimated that the direct annual employment is 58,192 FTEs in the Dairy sector; followed by Sheep & Beef with 23,767 FTEs, and Horticulture with 16,012 FTEs. Total aggregated employment (including indirect and induced effects) was estimated at 86,828 FTEs for the Dairy sector, followed by 35,522FTEs for Sheep & Beef, then 23,086 FTEs for Horticulture. Changes to baseline are presented in Figure 3-69. By land-use, employment for all land-use types was projected to increase, the largest annual increase was calculated for Dairy (+9,699 FTEs/per annum; total impact +14,471 FTEs/ per annum), then Sheep & Beef (+3,961 FTEs/ per annum; total impact +5,920 FTEs/ per annum), then Horticulture (+2,669 FTEs/ per annum; total impact +3,848 FTEs/ per annum).

Figure 3-64: Export 2 - gross output against baseline, in NZ$m per annum.

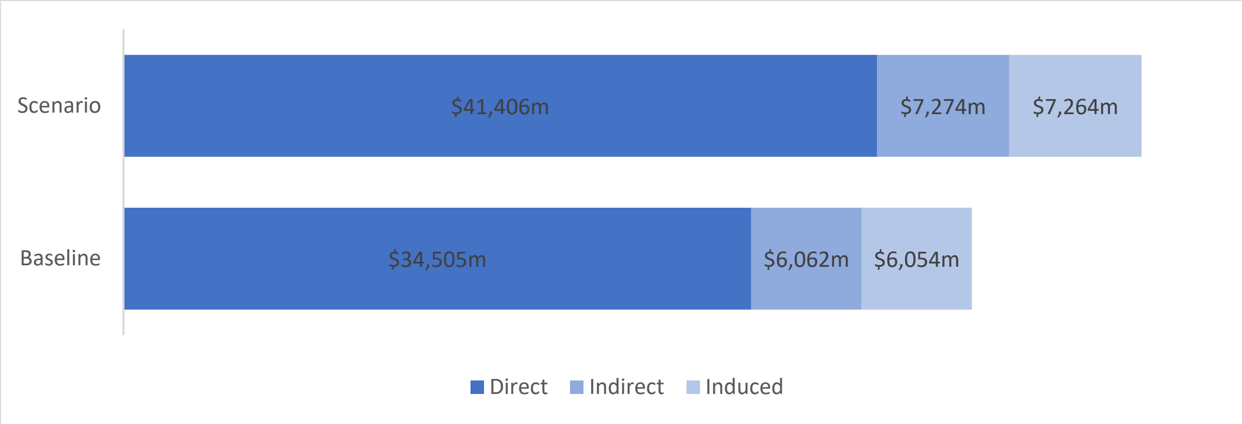


Figure 3-65: Export 2 - employment against baseline, in FTEs.

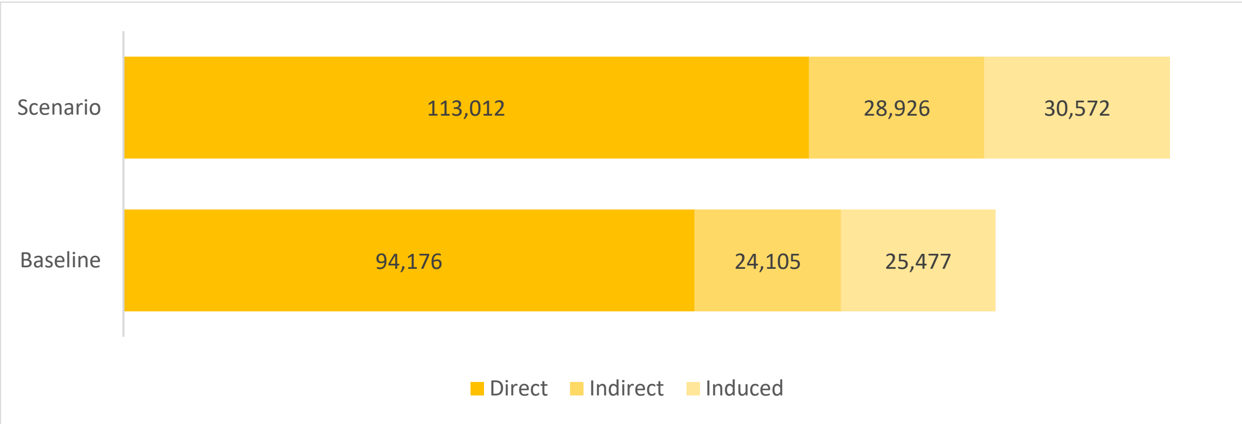


Figure 3-66: Export 2 - direct, indirect and induced gross output by land use, in NZ$m, per annum.

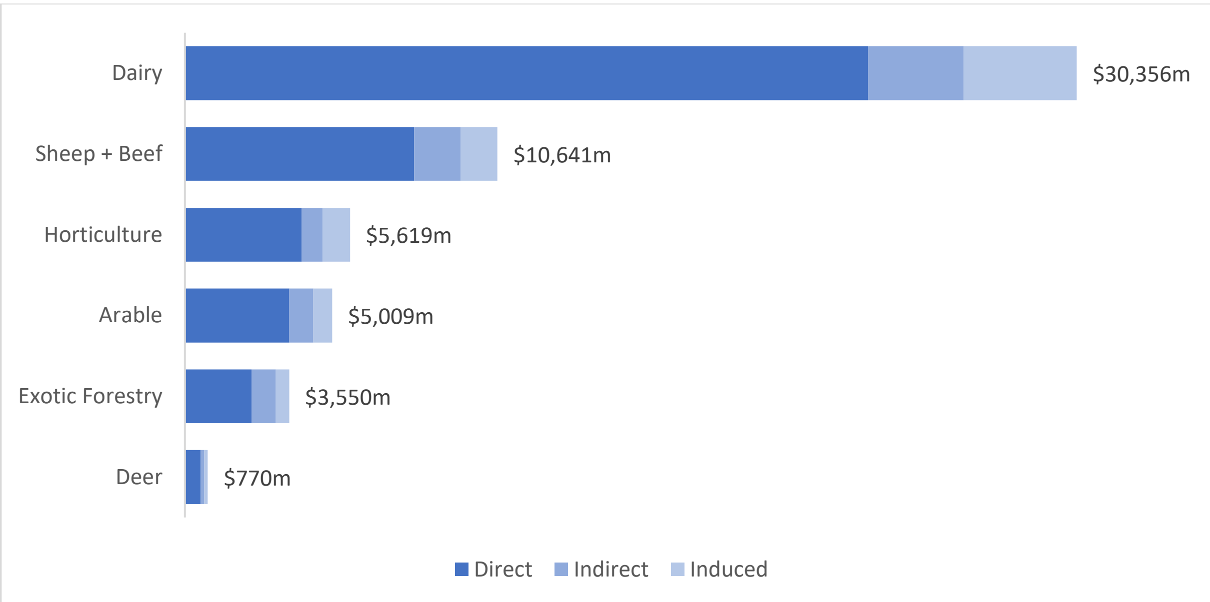


Figure 3-67: Export 2 - direct, indirect and induced employment by land use, in FTE.

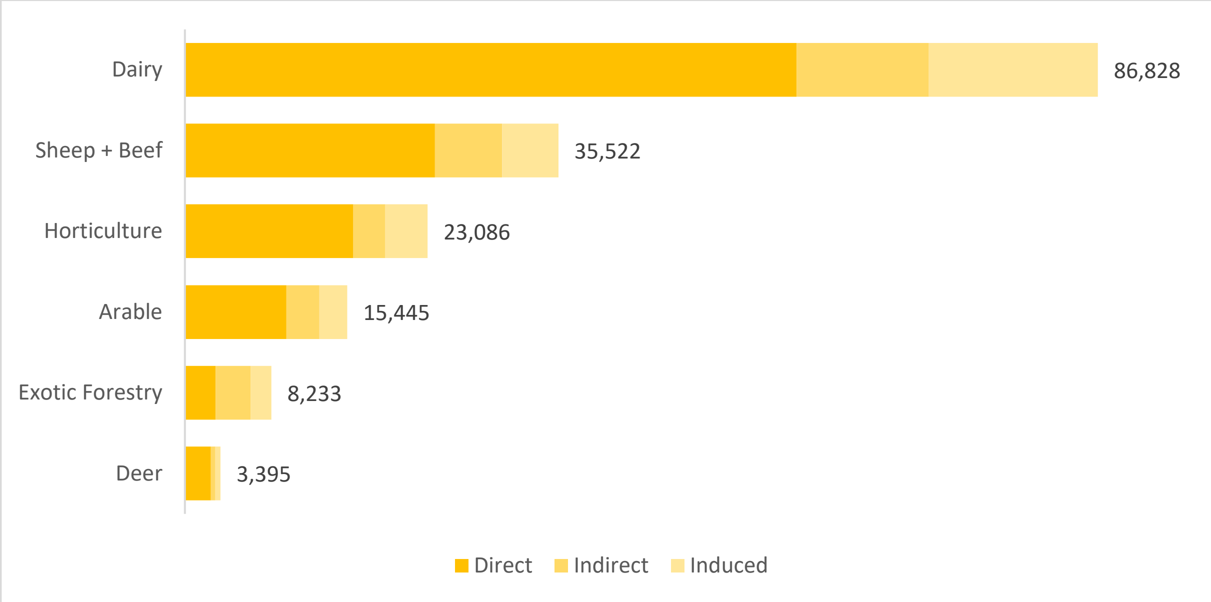


Table 3-9: Export 2 - effects on Value added, in NZ$m, per annum.

	'Baseline'	'20% Premium'	'Change from base to 20% Premium'
Value Added Direct ($m)	17,409	20,891	3,482
Value Added Indirect ($m)	3,193	3,832	639
Value Added Induced ($m)	4,004	4,805	801
TOTAL Value Added ($m)	24,607	29,528	4921

Figure 3-68: Export 2 - change in direct, indirect and induced gross output from baseline by land use, in NZ$m per annum.

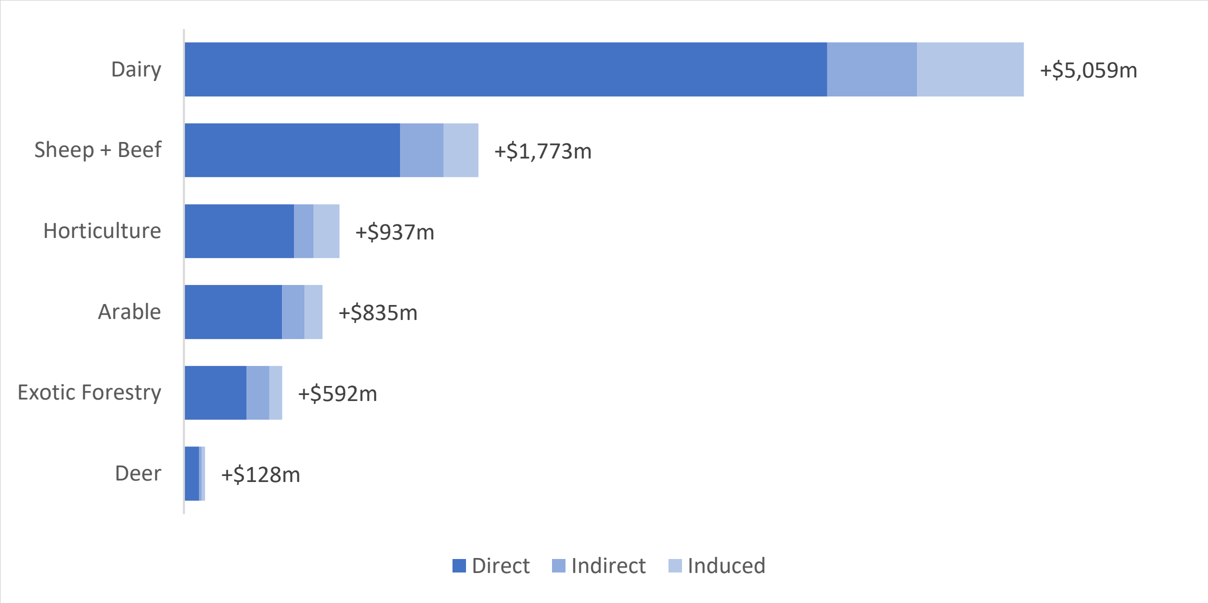
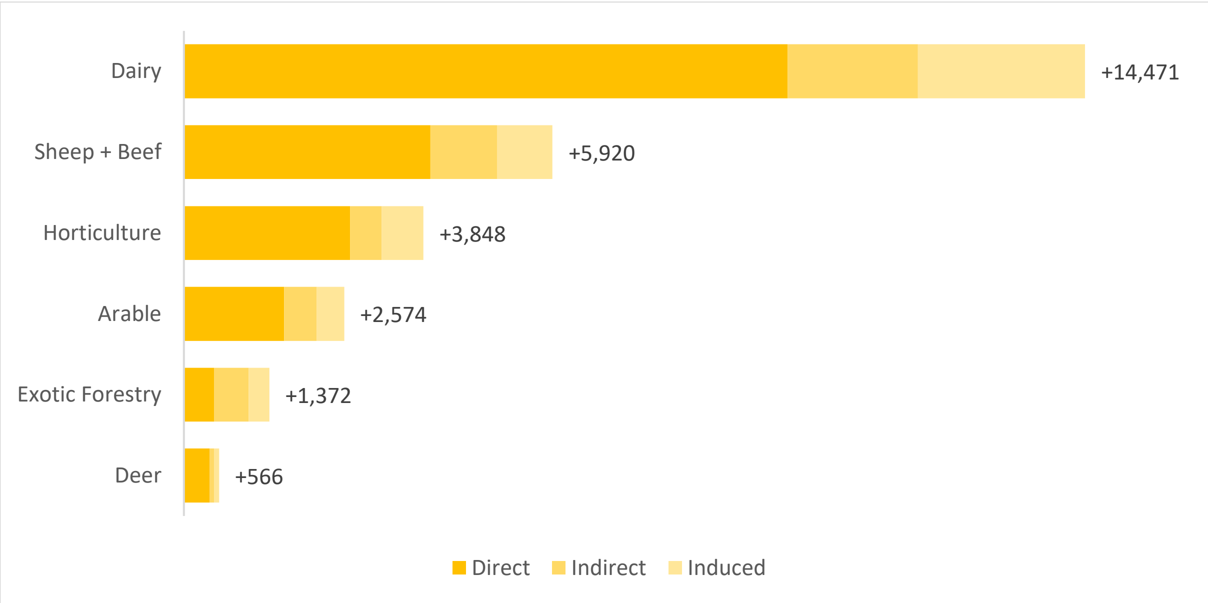


Figure 3-69: Export 2 - change in direct, indirect and induced employment from baseline by land use, in FTE.



3.3.7 Scenario 5 – Export 3, 50% premium

This scenario looks at the impact of all New Zealand's export products achieving a 50% premium on their various attributes. Research has shown that overseas consumers are willing to pay for credence attributes such as animal welfare, food safety, environmental quality, and carbon neutral. The assumption is that as New Zealand is producing products with these attributes already and not necessarily capturing all of that added value; this scenario does not require any land use change. In contrast to the previous '20%

premium' scenario, that many considered as achievable across the range of our existing exports, the 50% premium assumed in this scenario would be a considerable stretch.

Economic and employment impacts

Figure 3-70 shows direct, indirect and induced annual gross output for New Zealand from the Scenario '50%' compared to the baseline. The direct gross output has been estimated to be $51,757m for total New Zealand, this is an increase of $17,252m per annum from the baseline. Total gross output (including direct, indirect and induced effects) was estimated at $69,931m per annum for New Zealand, which grew by $23,310m.

Figure 3-71 shows the direct, indirect and induced annual impacts on employment for New Zealand and compared to the baseline. Employment increased by 50 per cent in this scenario. A total of 141,264 FTEs (direct) are employed nationally per annum in this scenario, which translates into an additional 47,088 FTEs per annum when compared to the baseline. When indirect and induced effects are applied, a total of 215,637 FTEs are employed per annum.

Table 3-10 presents the direct, indirect and induced annual impacts on Direct Value added for New Zealand, including the change to the baseline. Value -added was estimated $26,113 for total New Zealand, this is an increase of $8,704m per annum from the baseline. Total value added (including direct, indirect and induced effects) for New Zealand was calculated to be $36,910m (which is an increase of $12,303m annually from the baseline).

Results by land-use type are presented in Figure 3-72. Results show the largest direct gross output is estimated for the Dairy sector at $29,062m annually, then Sheep & Beef ($9,758m/ per annum); then Horticulture ($4,977m/per annum). The total economic impact (including direct, indirect and induced impacts) by land use for Dairy is estimated at $37,945m annually, followed by $13,301m annually for Sheep & Beef, and $7,024m annually for Horticulture. Changes to baseline are presented in Figure 3-74. By land-use, direct gross output for all land-use types were projected to increase, the largest annual increase was calculated for Dairy (+$9,687m/ per annum; total impact +$12,648m/ per annum), then Sheep & Beef (+$3,253m/ per annum; total impact +$4,434m/ per annum), then Horticulture (+$1,659m/ per annum; total impact +$2,341m/ per annum).

As stated above the employment impacts assumes the same multipliers as the baseline, this is not likely to be the case, so these estimates are likely to overestimate the impact on employment. As shown in Figure 3-73, by land use type, it estimated that the direct annual employment is 72,740 FTEs in Dairy; followed by Sheep & Beef with 29,708 FTEs, and Horticulture with 20,014 FTEs. Total aggregated employment (including indirect and induced effects) was estimated at 108,535 FTEs for Dairy, followed by 44,403 FTEs for Sheep & Beef, then 28,858 FTEs for Horticulture. Changes to baseline are presented in Figure 3-75. By land-use, employment for all land-use types was projected to increase, the largest annual increase was calculated for Dairy (+24,247 FTEs/per annum; total impact +36,178 FTEs/ per annum), then Sheep & Beef (+9,903 FTEs/ per annum; total impact +14,801 FTEs/ per annum), then Horticulture (+6,671 FTEs/ per annum; total impact +9,619 FTEs/ per annum).

In this scenario there is a rise in dairy processing employment of 6,367 FTEs, sheep and beef processing of 8,407 FTEs and horticulture 4,501 FTEs .

Figure 3-70: Export 3 – direct , indirect and induced annual impacts on Gross output against baseline, in $NZ, per annum.

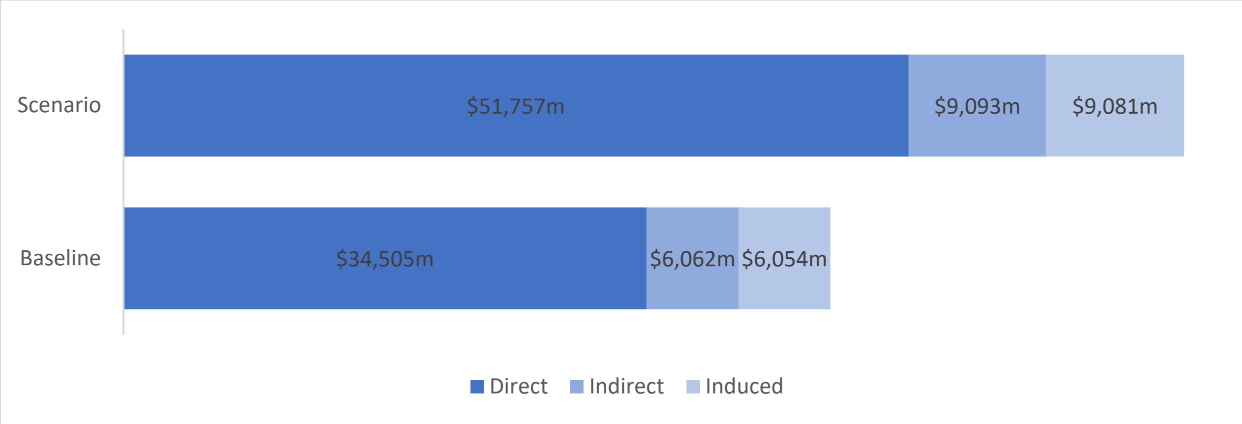


Figure 3-71: Export 3 - Employment against baseline, in FTEs.

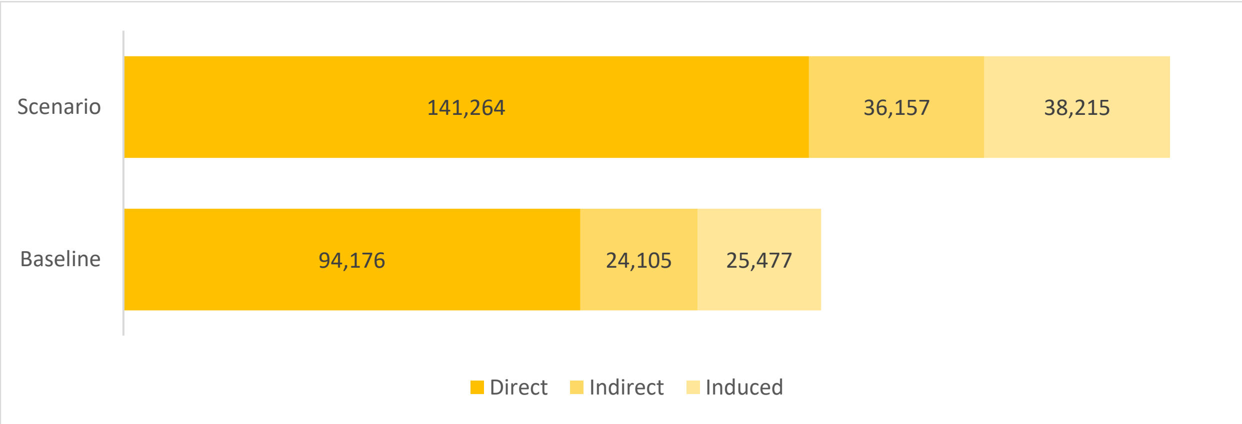


Figure 3-72: Export 3 - direct, indirect and induced gross output by land use, in NZ$m per annum.

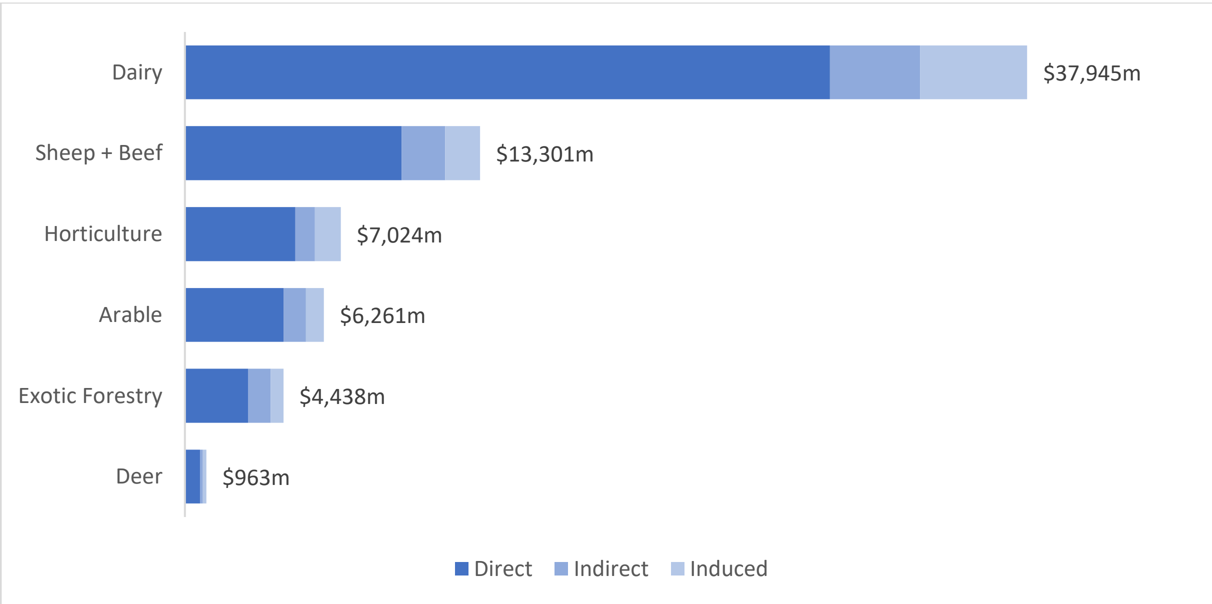


Figure 3-73: Export 3 - direct, indirect and induced employment by land use, in FTE.

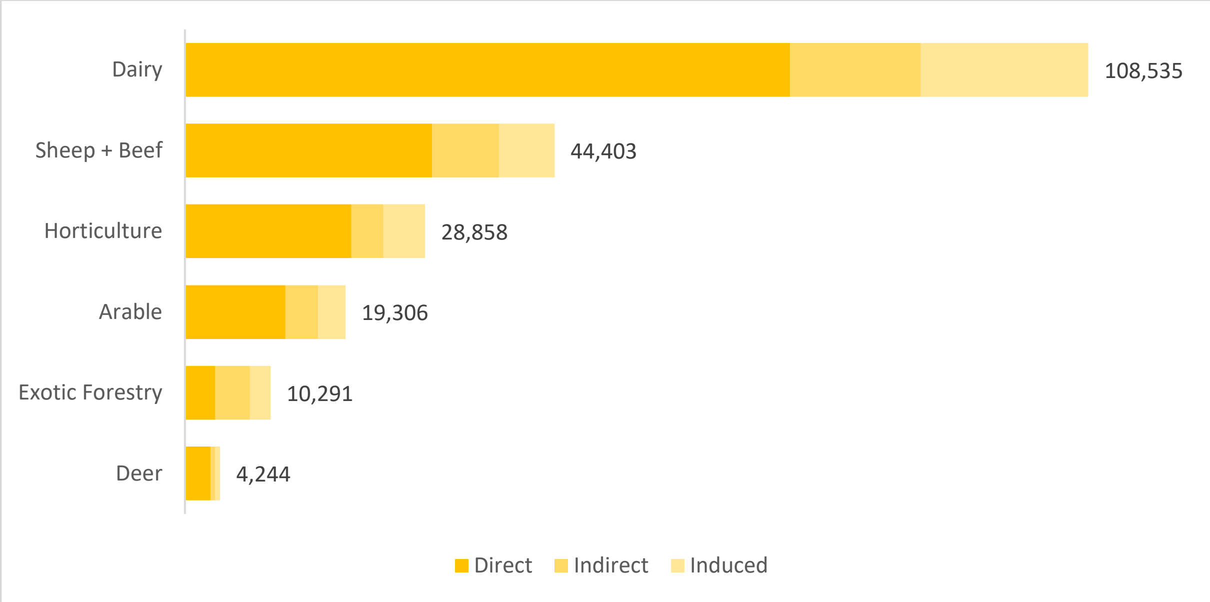


Figure 3-74: Export 3 - change in direct, indirect and induced gross output from baseline by land use, in NZ$m per annum.

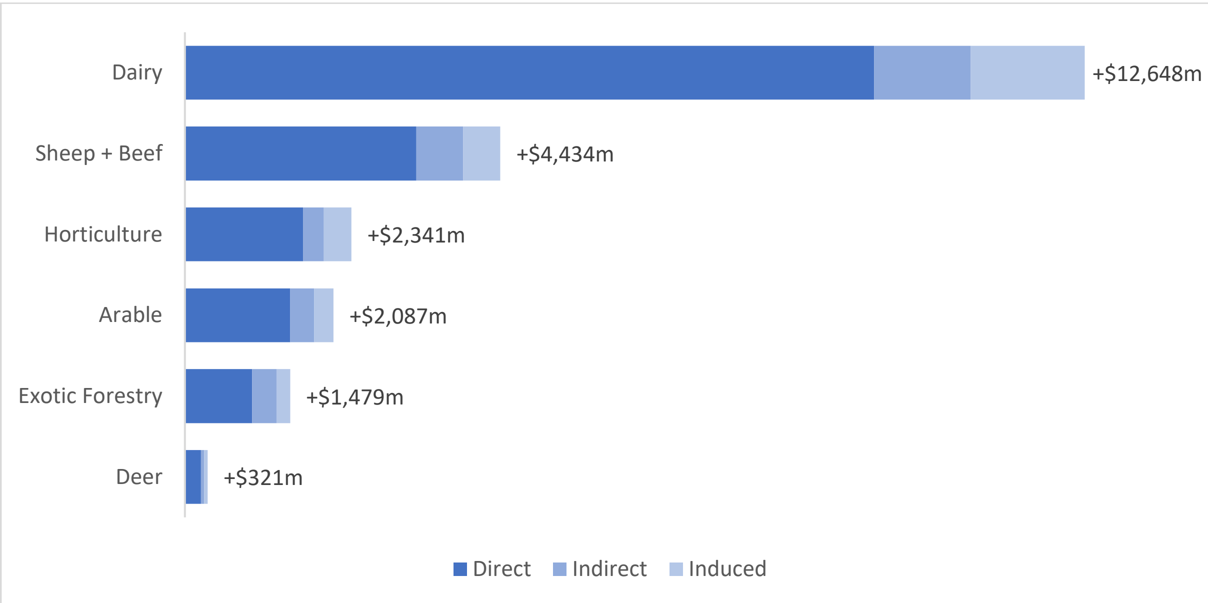


Figure 3-75: Export 3 - change in direct, indirect and induced employment from baseline by land use, in FTE, per annum.

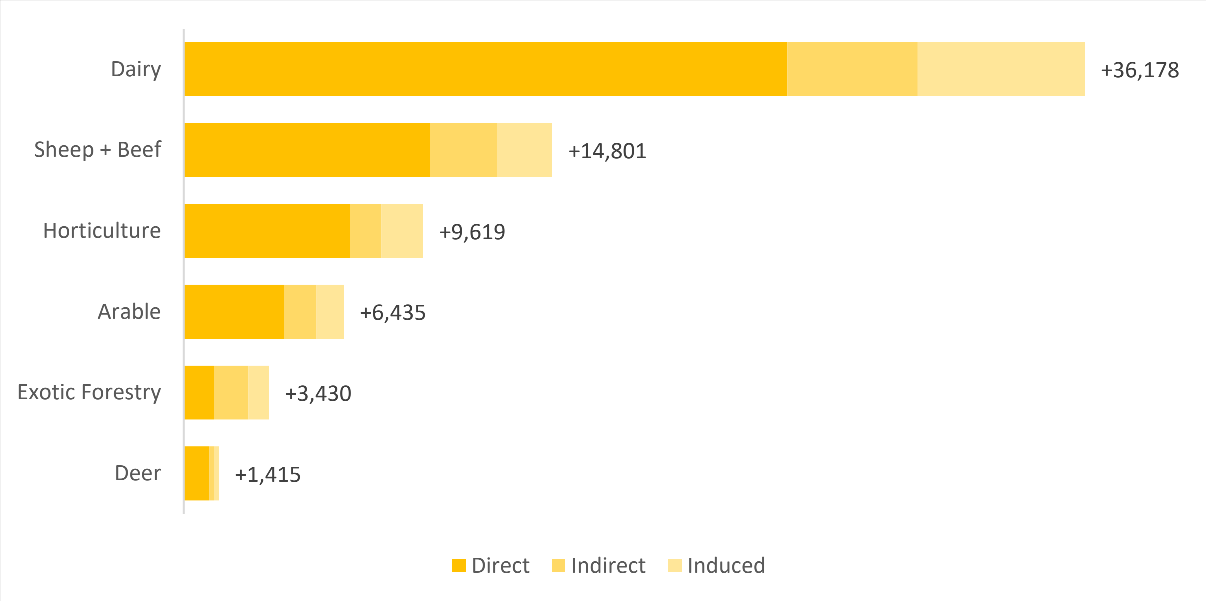


Table 3-10: Export 3 - direct, indirect and induced value -added in New Zealand, in NZ$m, per annum.

	'Baseline'	'50% Premium'	'Change from Base to '50% Premium'
Value Added Direct ($m)	17,409	26,113	8,704
Value Added Indirect ($m)	3,193	4,790	1,597
Value Added Induced ($m)	4,004	6,007	2,002
TOTAL Value Added	24,607	36,910	12303

3.3.8 Scenario 6 – Export 4, Land use change and 50% premium

In this scenario, the intensification of dairy farming shown in scenario Export 1, through land use change from sheep and beef and arable farming to dairy, is combined with the export scenario 50% premium, in which all of New Zealand's export products were assumed to achieve a 50% premium. This is a stretch scenario, as it requires both the intensification of a system and maintaining the clean environmental attributes that overseas consumers are willing to pay more for.

Economic and employment impacts for New Zealand

Figure 3-76 shows direct, indirect and induced annual gross output for New Zealand from the Scenario '50% + land use change' compared to the baseline. The direct gross output has been estimated to be $71,198m for total New Zealand, this is an increase of $36,694m per annum from the baseline. Total gross output (including direct, indirect and induced effects) was estimated at $95,659m per annum for New Zealand, which grew by $49,039m.

Figure 3-77 shows the direct, indirect and induced annual impacts on employment for New Zealand from the Scenario '50% + land use change' compared to the baseline. Employment increased by 50 per cent in this scenario. A total of 191,649 FTEs (direct) are employed in New Zealand in this scenario, which translates into an additional 97,473 FTEs per annum when compared to the baseline. When indirect and induced effects are applied, a total of 291,997 FTEs are employed in the economy per annum.

Table 3-11 shows the direct, indirect and induced annual impacts on Value added for New Zealand from the Scenario '50% + land use change'; including change to the baseline. Direct Value added for New Zealand was estimated $36,355m for total New Zealand per year, this is an increase of $18,946m per annum from the baseline. Total value added (including direct, indirect and induced effects) for New Zealand was calculated to be $50,487m (which is an increase of $25,880m from the baseline).

Results by land-use type are presented in Figure 3-78. Results show the largest direct gross output is estimated for the Dairy sector at $54,263m annually, then Sheep & Beef ($6,220m/ per annum); then Horticulture ($4,977m/per annum). The total economic impact (including direct, indirect and induced impacts) by land use for New Zealand is estimated at $71,735m annually for Dairy, followed by $8,369m for Sheep & Beef, then $7,024m annually for Horticulture. Changes to baseline are presented in Figure 3-80. Mixed results on gross output were calculated for the different land use types. Increases were projected for Dairy, Horticulture and Exotic Forestry. Decreases were calculated for Sheep & Beef and Arable. Overall, total net change (including direct, indirect and induced effects) on gross output was an increase of $49,039m per year.

As shown in Figure 3-79, by land use type, it estimated that the direct annual employment is 138,770 FTEs in the Dairy sector; followed by Sheep & Beef with 20,103 FTEs and Horticulture with 20,014 FTEs. Total aggregated employment (including indirect and induced effects) was estimated at 209,796 FTEs for the Dairy sector, followed by 29,155 FTEs for Sheep & Beef, and 28,858 FTEs for Horticulture. Changes to baseline are presented in Figure 3-81. Mixed results were calculated for the different land use types. In line with gross output impacts described above, increases in employment were projected for Dairy, Deer, Horticulture and Forestry. Decreases were calculated for Sheep & Beef and Arable. Overall, total net change (including direct, indirect and induced effects) on employment was an increase of 148,240 FTEs per year.

Table 3-11: Export 4 - effects on Value -added, in NZ$m per annum.

	Baseline	Land Use Change + 50% Premium	Change from BS to Land Use change + 50% Premium
Value Added Direct ($m)	17,409	36,355	+18,946
Value Added Indirect ($m)	3,193	6,034	+2,840
Value Added Induced ($m)	4,004	8,098	+4,093
TOTAL Value Added ($m)	24,607	50,487	+25,880

Figure 3-76: Export 4 - direct, indirect and induced gross output against baseline, in NZ$m, per annum.

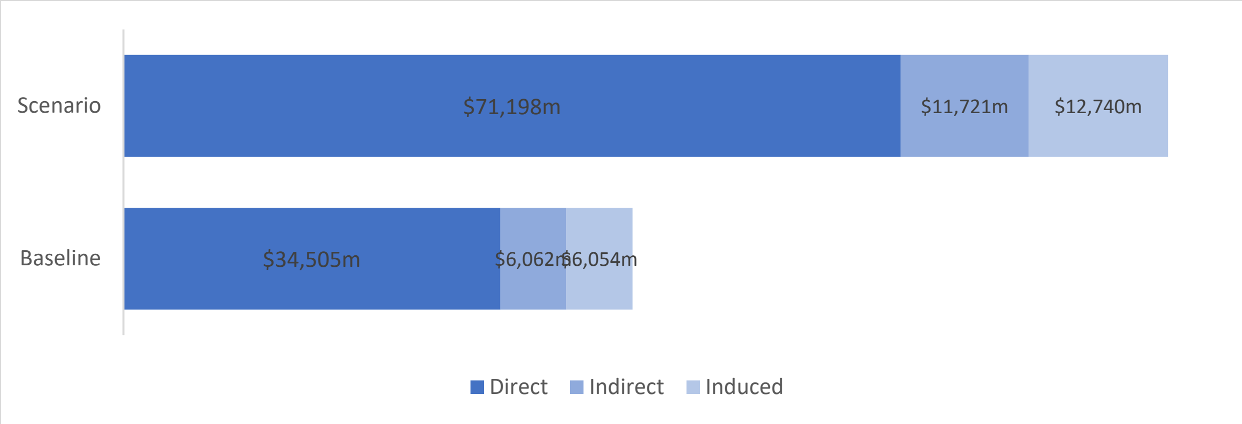


Figure 3-77: Export 4 - direct, indirect and induced employment, in FTE, per annum.

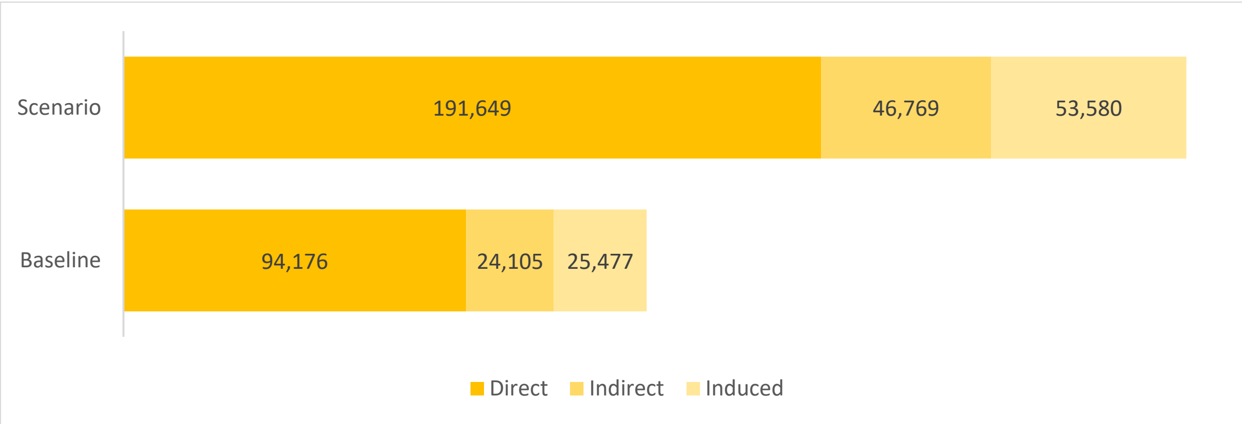


Figure 3-78: Export 4 - direct, indirect and induced gross output by land use, in NZ$m, per annum.

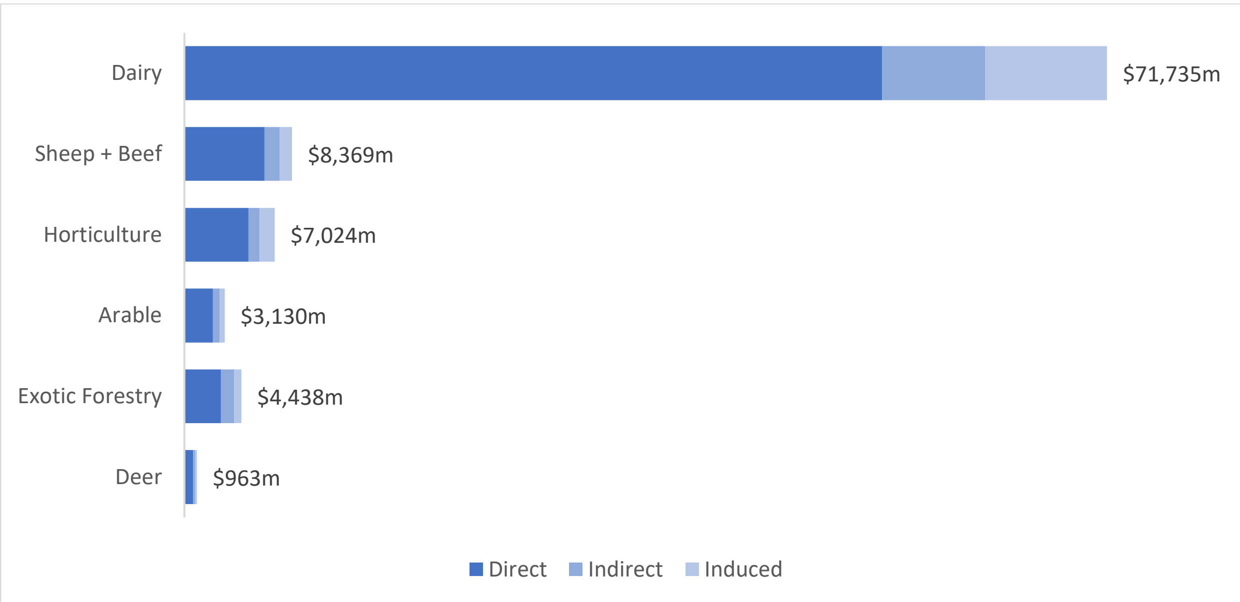


Figure 3-79: Export 4 - direct, indirect and induced employment by land use, in FTE, per annum.

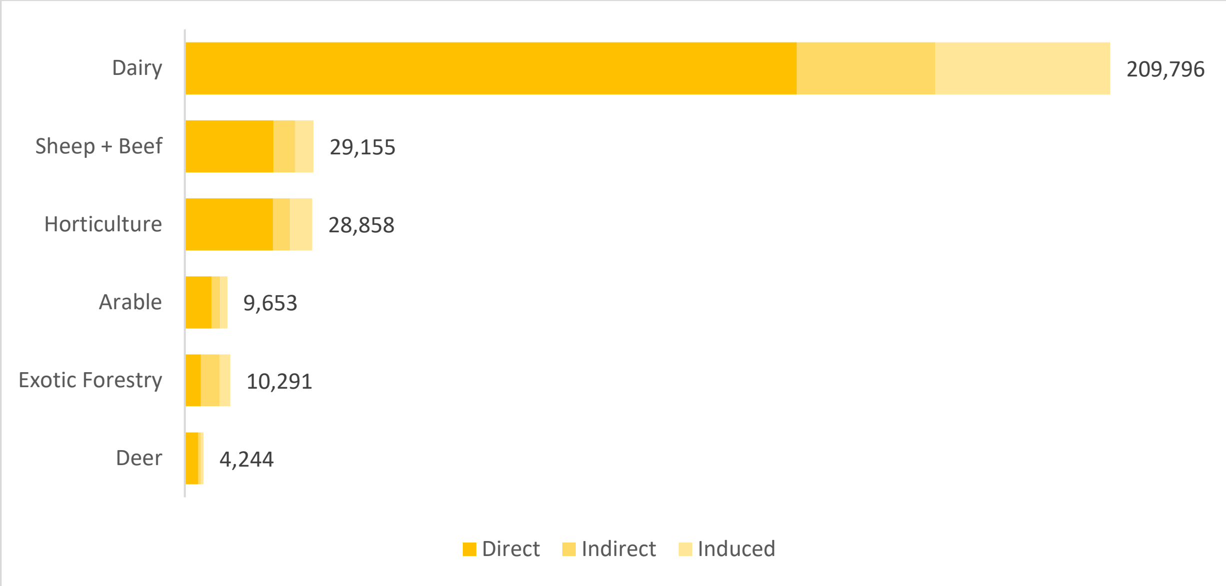


Figure 3-80: Export 4 - change in direct, indirect and induced gross output from baseline by land use, in NZ$m, per annum.

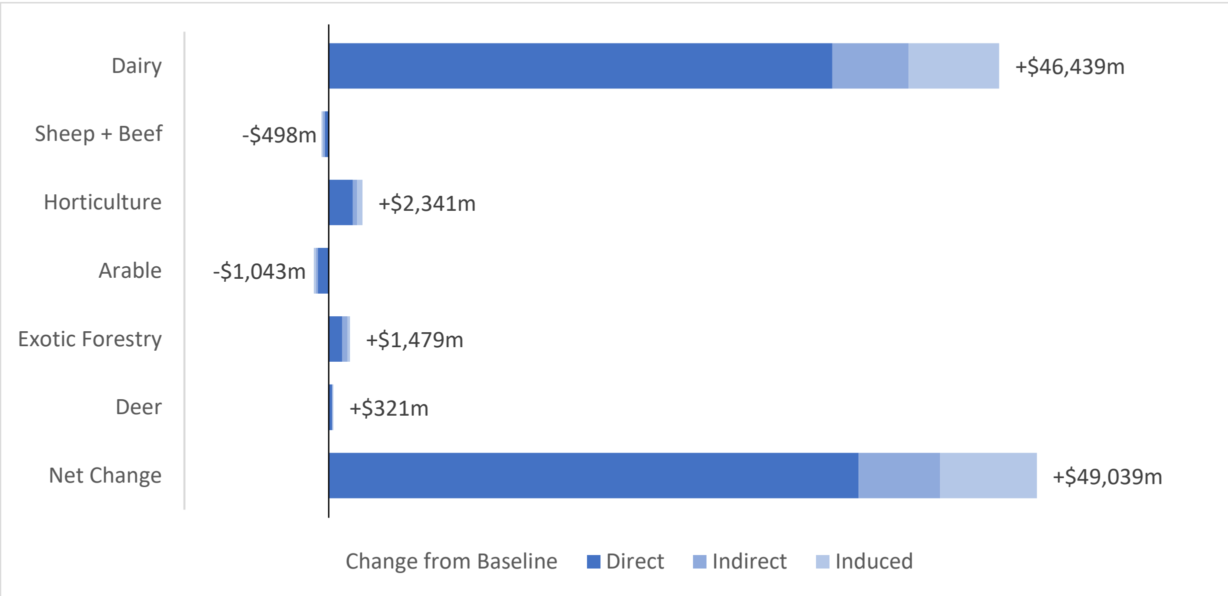
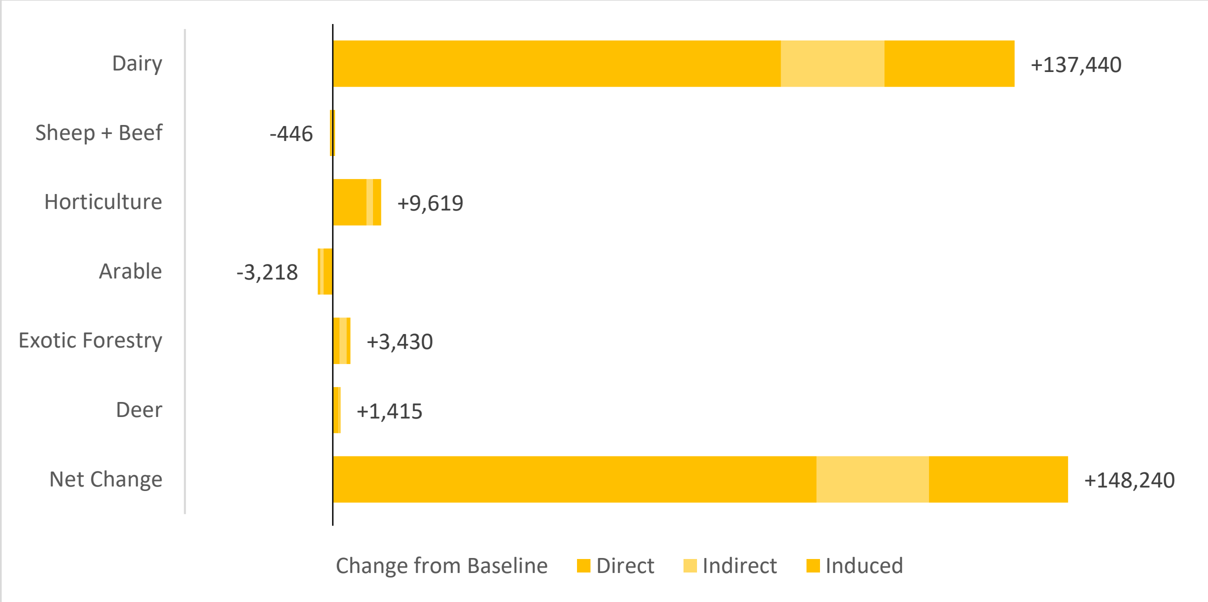


Figure 3-81: Export 4 - change in direct, indirect and induced employment from baseline by land use, in FTE, per annum.



3.4 Summary

This chapter assessed impacts on measures of economic, social, cultural and environmental wellbeing from current uses of biological resources. For this, two bioenergy scenarios and four export scenarios were developed. The AERU Integrated Assessment Framework was deployed for the analysis. The bioenergy scenarios were creating 75PJ and 150PJ (Peta Joules), respectively per year, transferring Sheep and Beef hill land to Exotic Forestry for Bioenergy production. The assumption was that new forestry was needed as current in-forest residues was utilised. It is noted that these high level scenarios do not take into account a range of granular factors which might impact both demand and supply of woody residues. Four export scenarios were then modelled assuming different levels of premiums on products and land-use change.

For the bioenergy scenarios, economic and employment effects were positive and increased when compared to the baseline. With regards to land – use, as expected, in both scenarios forestry production increased while sheep and beef production decreases in these scenarios. The bioenergy scenario producing 75PJ shows an increase in gross output of $1.2 billion and a loss to sheep and beef of $811 million, a net gain of $445 million. There is a gain of 991 FTEs for direct employment in forestry and a loss of direct employment in sheep and beef of 2,096 FTEs, a net loss 1,185 FTEs. When the full impact on employment is calculated, this changes to a loss of 135 jobs showing the importance of service industry employment to forestry. There are downstream impacts on the processing industries with a fall of 2,782 FTEs in sheep and beef processing. There is likely to be a rise in the processing of the biomass however this would be different from existing uses and therefore could not be calculated.

The bioenergy scenario producing 150PJ showed an increase in total gross output of $2.5 billion from exotic forestry and a loss to sheep and beef of $1.6 million, a net gain of $891 million. There was a gain of 5,589 FTE for total employment in forestry and a loss of total employment in sheep and beef of 5,858 FTEs, a net loss 269 FTEs. The downstream impact through the loss of sheep and beef processing showed a fall in employment of 5,564 FTE.

In both bioenergy scenarios the impact on GHG emissions were positive because sequestration is gained from planting and growing trees. The impact on social variables shows a drop in life satisfaction and access to basic amenities. The impact on other environmental variables show an increase in river and ground water quality, however, the amount of in-forest residues does increase.

The two scenarios do assume that the infrastructure and market is available which is certainly not the case. These scenarios are likely to have a significant impact on rural communities. The fall in sheep and beef direct employment on farm is 2,929 FTEs and 4,192 FTEs for the 75PJ and 150PJ scenarios respectively. This compares to a direct employment gain for forestry of 991 FTEs and 1,981 FTEs, respectively. Not only is this a net loss, as the forest employees are unlikely to live near the forest the consequences for local communities could be large. The environmental benefits of the scenarios have also to be seen in the light of considerable risks with increased in-forest residues and potential for storm events to show consequences as in the Gisborne region after cyclone Gabrielle in 2023. Another risk is the fire risk especially as climate change increase storm and drought conditions. The loss of sheep and beef also will affect our export income this loss of $891 million or $1.6 billion could have impact on our exchange rate making imports more expensive although this is likely to be marginal.

The four export scenarios included a large conversion of sheep and beef and arable land to dairy especially in Canterbury and Otago. This conversion was not considered realistic especially given environmental constraints in particular around freshwater nitrate limits and meeting greenhouse gas targets. Not surprisingly this scenario showed a large increase in output and employment with a net increase in gross output of $17 billion and extra 50,907 FTEs. This also assumes that prices for dairy are not affected and as New Zealand does influence the world price, prices may well fall, so the gains may be lower. Greenhouse gas emissions increase substantially by 32 per cent, and the other environmental variables decline. Although the social indicators rise due to higher incomes and more amenities.

The next two export scenarios estimate assume a 20% and 50% premium for our exports based on their various attributes. A 20 per cent premium is considered by many as achievable across the range of our existing exports, however the 50 per cent would be a considerable stretch. These, not surprisingly, both lead to increase in output. In the case of the 20 per cent premium, gross output increased by $10.5 billion. With the 50% premium, gross output is an extra $26.2 billion, mainly from dairy followed by sheep and beef.

The final export scenario combines the land use change (as simulated in Scenario Export 1) and a 50% premium (as in Export 3), this is not a realistic scenario but shows the stretch need if we rely on existing land uses to meet the export target of doubling exports. In this scenario output rises by $52 billion, greenhouse gases again increase by 32 per cent and environmental variables fall. In fact, the very reason why we may gain premiums for our products is contradicted here as the environmental attributes fall.

Table 3-12: Export totals from scenarios.

Scenario	Total annual direct gross output increase in NZ$m	% increase from actual export total from Baseline
Export 1	12,961	32.7%
Export 2	8,175	20.6%
Export 3	17,028	42.9%
Export 4	38,738	97.6%

Table 3-12 shows the export totals from the four export scenarios. It can be seen that impact on exports varied depending on the level of premium and conversion. The highest increase in exports was projected in Export Scenario 4 when land-use change is combined with a 50% premium on New Zealand exports. Under this scenario, exports from these land-uses were projected to almost double. As mentioned above, these are not realistic scenarios. The scenarios have been developed to show what it needs to achieve the target of doubling exports. It has been shown that a combination of product premium and land-use change would achieve this target, however with a significant negative impact on the environment especially the increase in GHG emissions were projected to increase.

These scenarios were developed to assess the impacts of producing more bioenergy and attempting to double primary sector exports. However, for these to be achieved barriers to change have to be addressed. In the case of the bioenergy scenarios, incentives for uptake and infrastructural development would be necessary. The conversion of sheep and beef and arable into dairy may well be infeasible and certainly not within environmental limits. In the case of premiums in market, again incentives for change would be needed. The supply chain has served New Zealand exporters, especially through preferential access into the UK and Europe, followed by first mover advantage into China. However, other competitors are gaining market access and also major firms such as Nestlé and Tesco are demanding a move to carbon-zero supply by 2050 with Nestlé aiming for emissions to be reduced by 20 per cent by 2025. For change to occur, it often requires disruption. Two of our most successful industries kiwifruit and wine faced serious disruptions in the 1980's and therefore had to change. They developed new products but also changed to a value chain model which was market- led. This has led to kiwifruit obtaining 100% premium in market and our wine industry obtains considerable premiums.

This chapter has shown the impact of various scenarios of land-use changes assuming the current uses of land. The next chapter explores other uses of our bioresources to meet export targets and meet environmental targets.

Chapter 4
Case Studies of other uses of our Biological Resources and Increasing Value whilst Lowering the Environmental Impact

This chapter presents several case studies that explore alternative uses for our biological resources with a view to achieving higher economic, social, environmental outcomes.

The previous chapters focused on the current use of our biological resources, their impact on emissions and how we could derive more value from our existing rural land use under several scenarios and the consequences of each. This assumed that productivity didn't change within the existing land uses. However, there are opportunities for productivity to increase through improvements in technology, management, different production systems, skills, and more efficient use of resources, as identified in Rys et al (2021).

There are a growing number of farm innovations and systems that aim to improve factors such as quality, efficiency, and sustainability.

It is likely that the global industry will continue to see the growth of precision agriculture. This farming strategy uses big data to aid management decisions. It is a technology intense system using tools such as remote sensing, drones, automation, and robotics. Data such as electronic identification allows farmers to track individual livestock to monitor health, production, and feed. Machine technology such as self-steering tractors allow the GPS installed to spread fertiliser evenly, only requiring the driver to manually step in for an emergency.

Drones are one of the fastest growing areas of technology to aid in precision agriculture. They can perform a variety of tasks. Scouting drones can measure indicators such as moisture, heat, and ground cover. Spraying and spreading drones disperse pesticides and fertilisers.

Other technologies include digital twins and robotic systems. The uptake of robotic systems is estimated to be worth nearly NZ$22 billion in 2023 and is anticipated to increase to NZ$65 billion by 2028 (MarketsandMarkets, 2023).

Indoor vertical farming for horticultural is at an early stage of adoption. It is difficult to predict how this will progress. New Zealand Greengrower, the country's first vertical farm, only reached commercialisation at the end of 2022. New Zealand Greengrower is a Sustainable Food and Fibres Future (SFFF) project with the aim of testing and proving concept to build a controlled environment farming industry in New Zealand (MPI, n.d). The process uses 250 times less water than conventional cropping and has potential to free up land that would otherwise be used to produce food such as leafy green vegetables (Masterson, 2022). The flipside of this however, is the cost associated with the land, buildings, and energy where growth relies on a controlled environment. It is unlikely that this form of horticulture will replace all crops for human consumption.

This chapter will explore through case studies other ways we can increase that value from our biological resources and reduce our environmental impact. Firstly, we examine the potential for higher value production from higher value products. This could be through additional processing or positioning products in high value markets such as nutraceuticals. New Zealand already exports a wide range of alternative products and there is potential to grow these. The chapter will then consider other biological resources which have wider social, environmental, and cultural benefits such as the conservation estate, wetlands, marine and trust land.

4.1 The potential for higher value production from higher value products

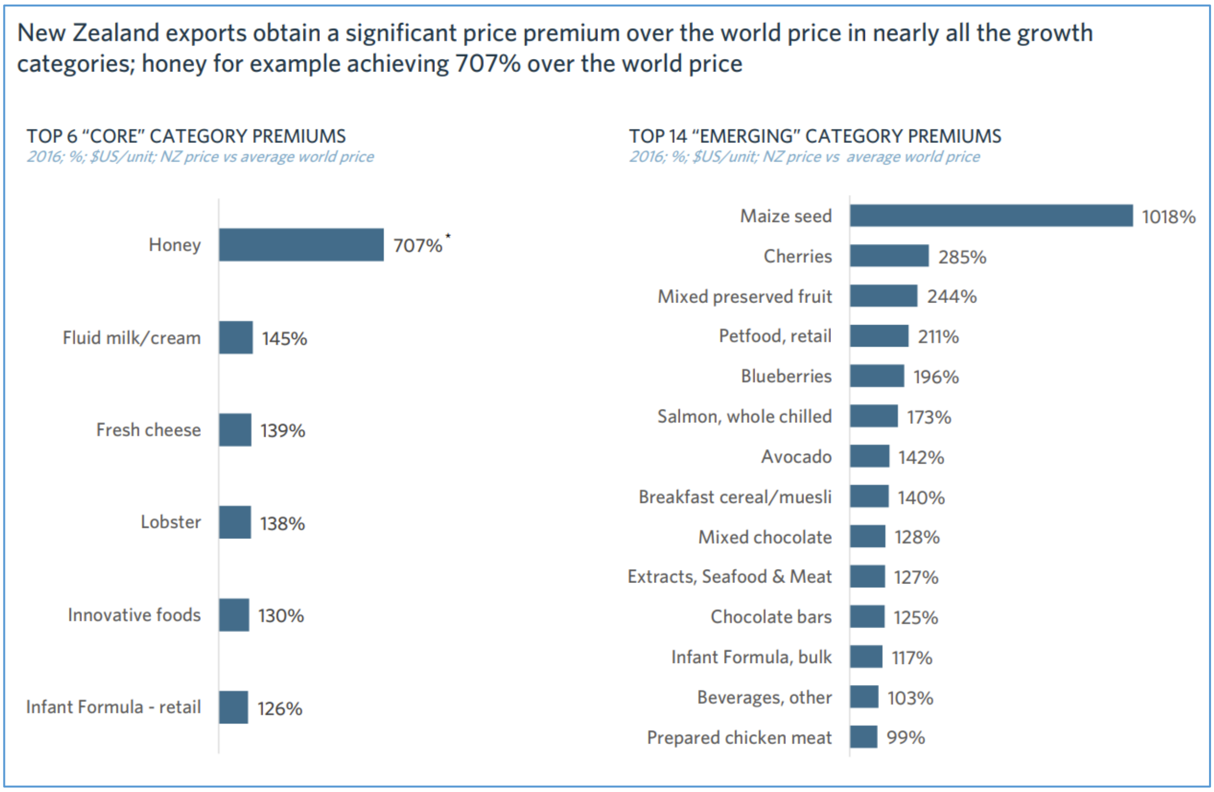
The previous chapter explored the potential premiums for our basic commodities based on consumers' willingness to pay for certain attributes. Whilst some of our existing producers are obtaining premiums, as shown in Figure 4-1 (such as taste pure New Zealand from Beef and Lamb, Zespri and wine), in the main, it is easier to obtain premiums for products that consumers buy in a supermarket or in a high-end restaurant. Obtaining this premium requires differentiation in the market based on certain attractive attributes. Examples could be carbon zero or animal welfare. As stated earlier, this requires different business models and value chain approaches. The objective is to increase the value of our main exports whilst reducing environmental damage.

New Zealand has an historic reliance on low- cost production of commodities, built on preferential access to key markets and strong demand. This model [by itself] is unlikely to deliver rising real incomes and improvements to our environmental and social situation. It is vulnerable to changes in market access, competitors and requires a relentless focus on driving efficiencies. The clear direction for New Zealand is derive premiums based on the attractive attributes of existing products as well as processing more of our ingredients into high value consumer products.

A value-added or branded product is one where the quality and features may be significantly different depending on the producer. Hence the market (aka consumer) may pay a premium for unique features, real (or perceived) value, brand, or provenance. Hence as above a premium may be obtained through differentiating in the market. This may not be a processed product but as explored in the previous chapter could be a basic commodity product such as an apple, a kiwifruit, a cherry, or a lobster.

If premium is defined as price above the average world trade price, then New Zealand obtains a premium in several categories but typically in newer emerging growth categories. Figure 4-1 shows the premiums for key products and emerging category products for 2016. These do change when market access alters if competitors arise. For example, avocadoes had a premium in 2016 because New Zealand had exclusive access to the Australian market. Now Chile can export to Australia and the premiums have dropped, hence recent 50c avocadoes for a short time.

Figure 4-1: Price premiums obtained for New Zealand exports, 2016.

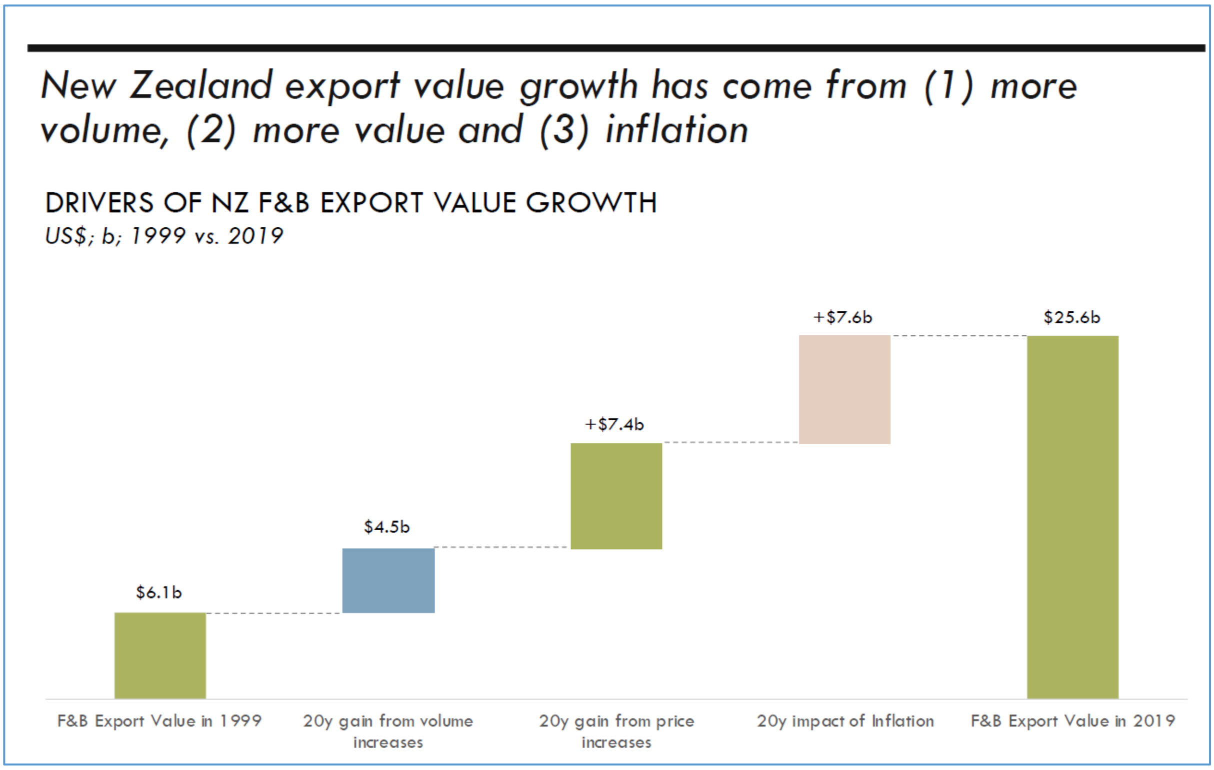


Source: Emerging growth opportunities in New Zealand Food & Beverage (Coriolis, 2018) p 19.

The premium equates to US$880 million in 2016, that is NZ$1,273 million. Given the average exchange rate New Zealand – US in 2016 exchange rate was $1.435. Given the total agricultural sector exports were nearly $30 billion in 2016; this premium is 4 per cent of exports.

Moreover, in the twenty years to 2019 at the aggregate level, price increases account for $7.4 billion (38 per cent) of the total value growth. So, overall, our customers are paying more for our food as shown in Figure 4-2.

Figure 4-2: Drivers of New Zealand Export Growth, 2016.

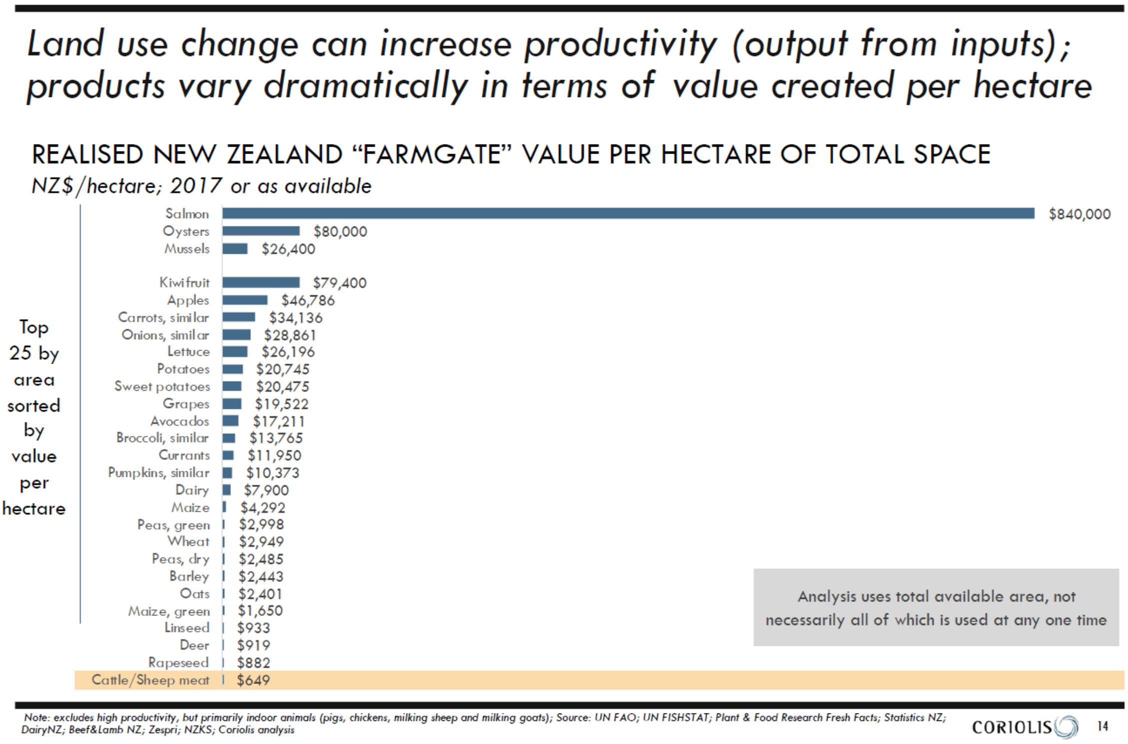


Source: Creating Volume and Value in New Zealand Food & Beverage Exports (Coriolis, 2020).

Alternatively, turning our high-quality ingredients into a consumer product that meets a demand is another way to capture increased value from limited biological resources. For instance, while whole milk powder attracts $6,000 per tonne, Infant formula attracts $16,000 per tonne. Mānuka honey is a premium product, but also provides an extensible platform that can be expanded into a range of new products and categories such as ingredients in cosmetics, unique flavouring for food and beverages, and nutraceutical/natural health products.

This is highlighted in Figure 4-3 which shows the realised farm gate revenue/value of different uses of our biological resources by hectare. Not surprisingly seafood is highest as it does not use much land. However, key crops for New Zealand such as kiwifruit and apples have the highest returns. This is followed by field crops especially vegetables. However, it must be recognised that New Zealand has a relatively limited land type that can be used for these crops.

Figure 4-3: Realised Farmgate value/revenue of biological resources by hectare.



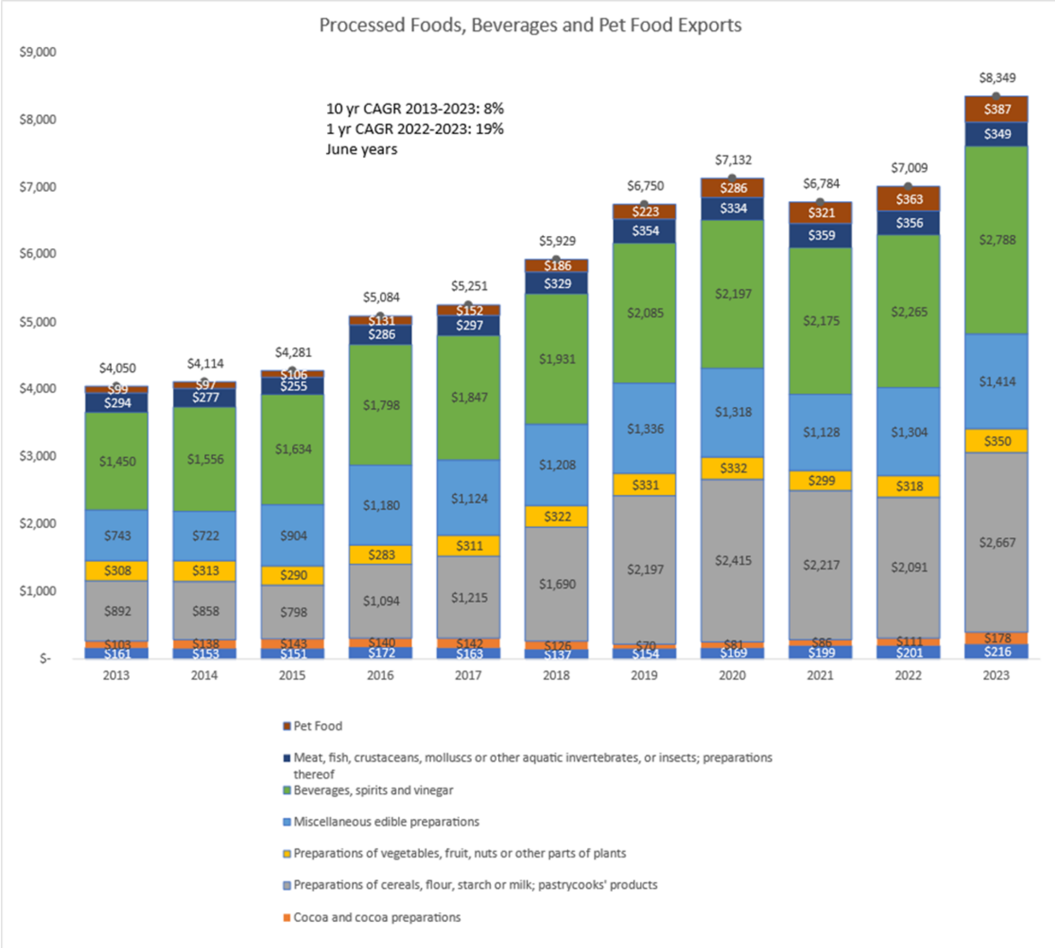
Source: Creating Volume and Value in New Zealand food and beverage exports (Coriolis, 2020).

New Zealand has been adding value through processing products for a long period. Therefore, we have a food and beverage export industry that is no longer "just" a commodity exporter.

Figure 4-4 shows exports of processed foods, alcoholic and non-alcoholic beverages and pet food in aggregate have achieved a 10-year compound annual grow rate of 8 per cent. This is $8.3b total exports, and including honey brings it to $8.7b.

New Zealand has shown that it can develop and export a wide range of differentiated added-value consumer products with premiums (e.g., pet food exports attract considerable premiums). It also needs to be noted that infant formula and pet food have attracted significant Chinese investment. Infant formula may have limited growth going forward due to the declining population in China unless we can capture population growth in alternative markets such as in Africa.

Figure 4-4: Exports of processed food, beverages and pet food, 2013 to 2023.



Source: Stats NZ, MBIE analysis.

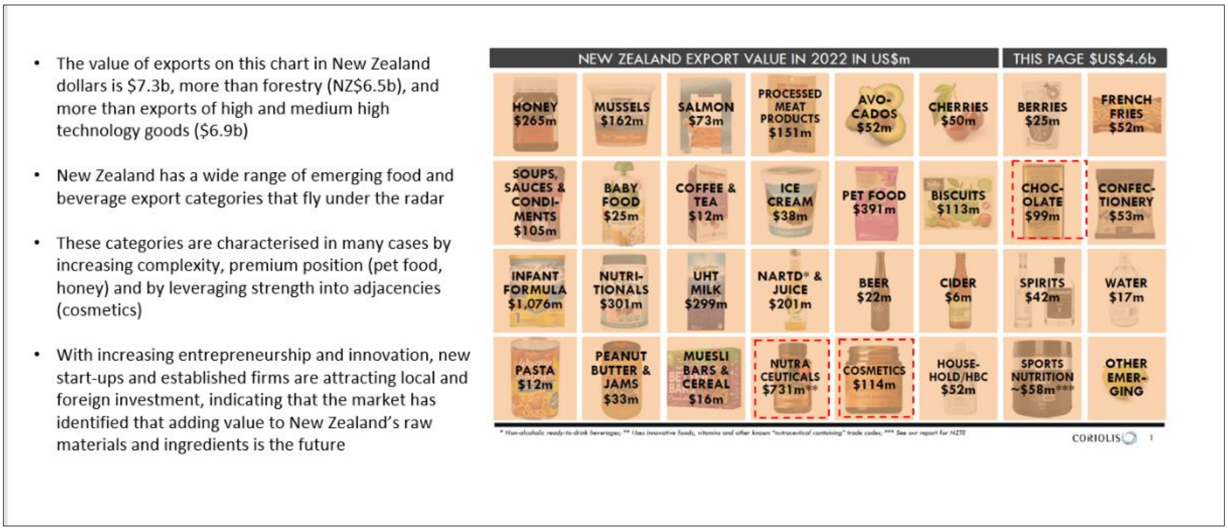
Figure 4-5 below indicates a clear strategic direction – increased complexity. The market appears to have understood this, as that is where new investment and innovation is occurring.

Figure 4-5: Clear strategic direction, add complexity.

Source: Is This The Beginning Of The End or The End of The Beginning? Finding the future of the New Zealand food and beverage industry (Coriolis, 2019)

Figure 4-6 also shows a range of emerging products that in aggregate were valued at NZ7.3b in 2022. They include fruit (e.g., cherries) and adjacencies (bio cosmetics).

Figure 4-6: The value of exports for emerging sectors.



Source: Coriolis research. MBIE comments.

A growing number of "complex" product categories have emerged in New Zealand in recent with potential for strong growth. For example, New Zealand already produces $700 million worth of cosmetic products, with over $100m of exports. The industry believes this could easily be a billion dollar export industry, based around New Zealand's clean green environmental image, access to byproducts from our core industries and our unique native plants which have may attributes, (Coriolis 2023b). Bioactives and sports nutrition also have high growth potential with current sales of New Zealand product estimated at $300 million. The Chinese market in particular is driving demand. (Coriolis, 2023c).

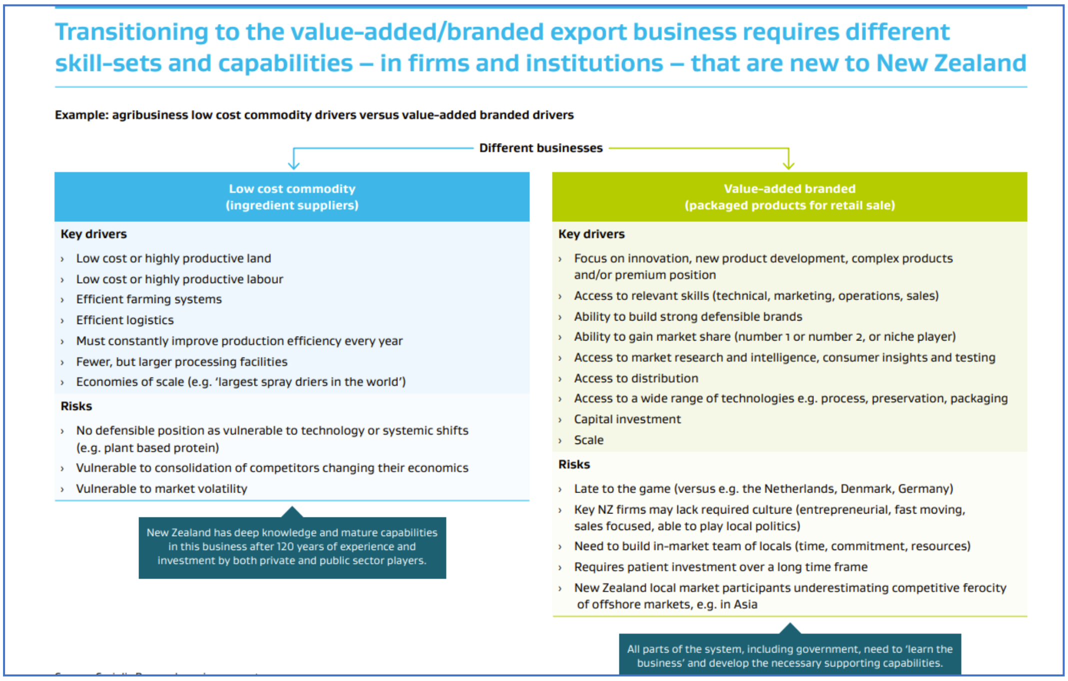
This data provides an entirely different view as to the current composition of the industry and its future direction, with the number of processed F&B firms doubling in the last ten years. The growth required will come from innovation, startups, adding value to New Zealand ingredients and new product development.

Further investment in research and development, innovation capabilities and market opportunities are required to support the ongoing development of high value complex biological consumer products. These emerging industries require a different approach more akin to a high-tech company. It requires investment (venture capital, angel capital and foreign direct investment), an area where New Zealand is thin. It also requires different business models and appropriate government support.

Hence, future growth is as likely to be from many smaller export categories rather than a few large commodities. Moreover, these products are typically high value per unit weight, with a lower carbon footprint (Coriolis, 2023d). Research commissioned by MBIE profiled 30 product categories that had the potential to increase value and reduce environmental impact (Coriolis, 2023d).

The premium/added value consumer Food and Beverage business requires quite different capabilities to the commodity business. New Zealand has excellent capabilities in commodities along the whole supply chain from production to customer, including long-standing market relationships. Capabilities in added value are still developing. New Zealand continues to invest significantly in on-farm production and primary processing, including in the focus in Free Trade Agreements. There is very little investment in the added value/consumer production ecosystem. The difference between these two businesses is set out in Figure 4-7 in particular, a different set of skills is needed, a deeper capital market and willingness to invest.

Figure 4-7: Skills and capabilities required to transition to Value added exports



Source: Beyond commodities: Manufacturing into the future (MBIE, 2018)

To promote these industries possible a Food and Beverage agency, as in Ireland, would take the role of promoting the industries and supporting their growth.

4.2 Environmental impacts from marine

As stated in Chapter 1, New Zealand has one of word largest economic excusive zones at 4 million square kilometres and 15,000 – 18,000 kilometres of coastline. There are 44 marine protect areas covering 1.7 million hectares. There is the ability to increase the economic returns form eth marine area whilst reducing environmental impacts.

In 2019, the New Zealand government set a goal of achieving a $3 billion aquaculture industry by 2035. Whilst ambitious, the industry has been growing at a greater rate than capture fisheries. Further, as the world's population has grown, and incomes have risen so too has demand for seafood products. From an environmental standpoint, the production of aquaculture products provides a much smaller carbon footprint than many other protein sources, emitting 80 per cent less carbon than beef (Forsyth Barr, 2022).

Aside from a relatively low carbon footprint, the aquaculture sector employs around 3,000 people in the production of King salmon (aka Chinook salmon), Greenshell mussels and Pacific oysters (Aquaculture New Zealand, 2022). A social impact study conducted in Southland found that aquaculture provides employment for local community members, while company resources help to facilitate and deliver services for the local community (Baines & Quigley, 2015). Further, year round income was also a benefit and employees were able to learn new skills (ibid).

Considering the environmental footprint of salmon production and domestic distribution, a 2023 report commissioned by the Ministry of Primary Industries and Fisheries New Zealand conducted a life cycle analysis of New Zealand farmed King Salmon, highlighting carbon footprint of New Zealand King Salmon as 8.228 kg CO_2 eq. per kg of edible meat (Thinkstep-anz, 2023). The report found that feed production contributes the most to terrestrial eutrophication, acidification, and smog formation, while salmon waste entering the water contributes the most to marine and freshwater eutrophication. See Table 4-1 for a summary of this.

Table 4-1: Environmental impacts of domestically produced and distributed King salmon (per kg edible meat).

Indicator	Unit	Total (per kg edible meat)
Carbon footprint	Kg CO_2 eq.	8.228
Eutrophication aquatic, freshwater	Kg P eq.	0.003
Eutrophication aquatic, marine	Kg N eq.	0.170
Eutrophication, terrestrial	Mole of N eq.	0.261
Acidification potential	Kg SO_2 eq.	0.063
Chemical smog	Kg $NMVOC^-$ eq.	0.040

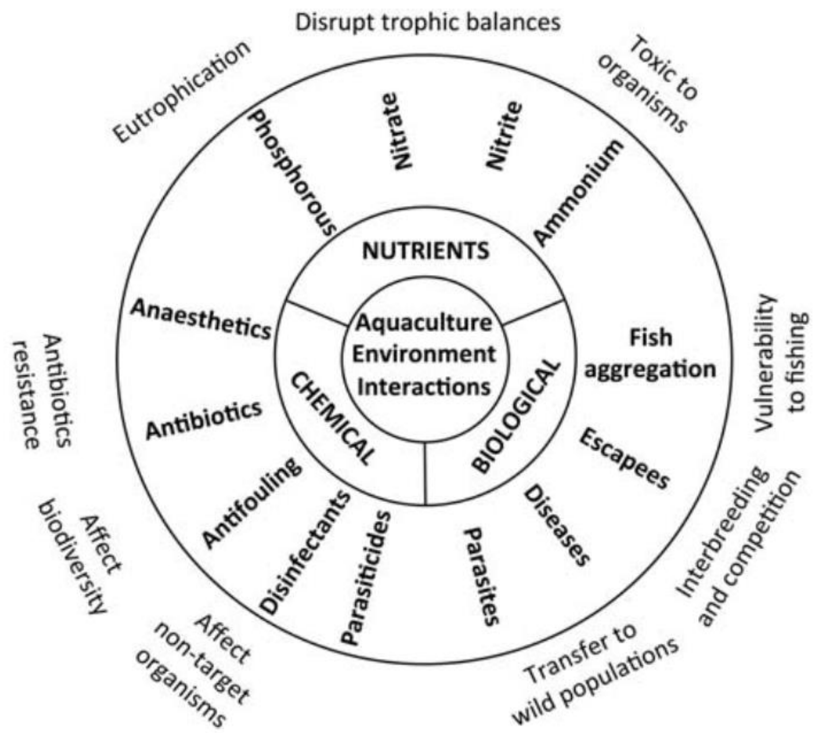
Source: Thinkstep-anz (2023)

In terms of farm waste sources, there are three main types (Dauda et al., 2019):

- Feed (nutrients) – in intensive fish farming feed needs to be supplemented as cannot meet needs naturally
- Chemicals – medications, disinfectants, antifoulants disinfectants, anaesthetic.
- Pathogens (biological) – natural systems have their own ecosystems and discharging pathogens with waste water may upset the balance of natural systems.

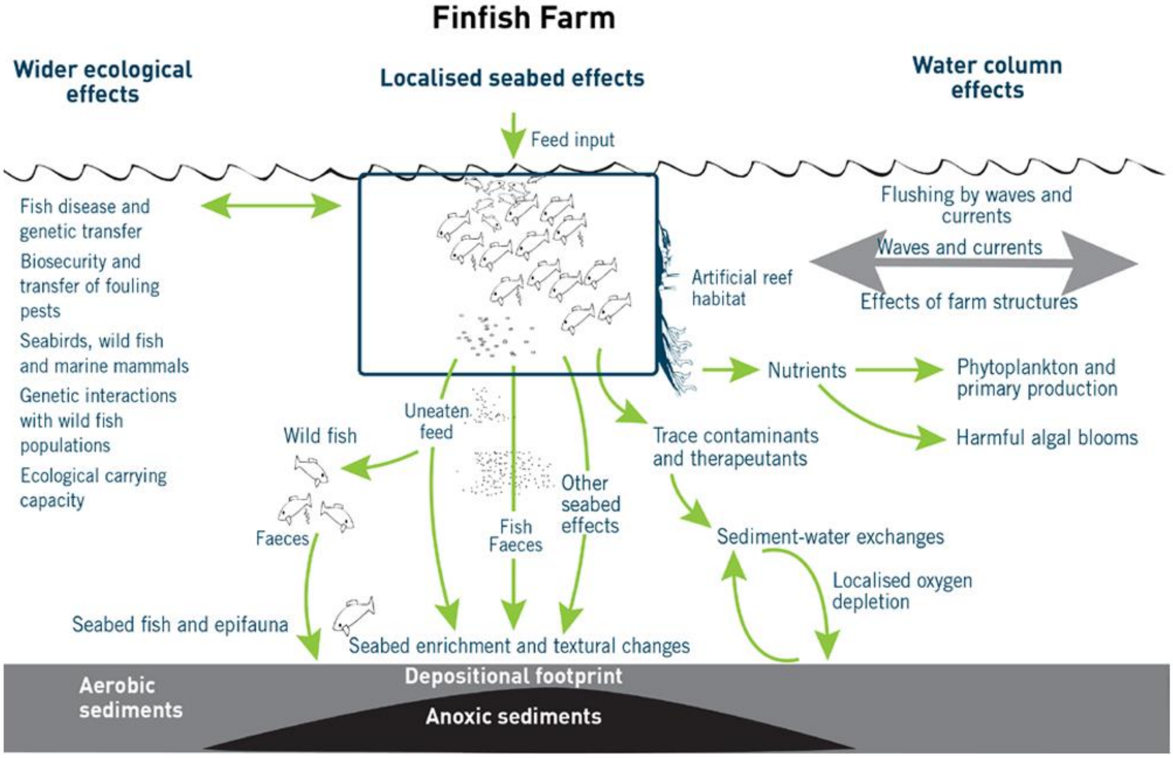
Figure 4-8 highlights the main pollution sources of fish and the negative effect that these may have on the environment. Further, Figure 4-9 graphically shows the ecological effects of finfish farms and how these may develop.

Figure 4-8: Pollution sources and environmental effect of finfish aquaculture.



Source: Braña et al. (2021, p. 2)

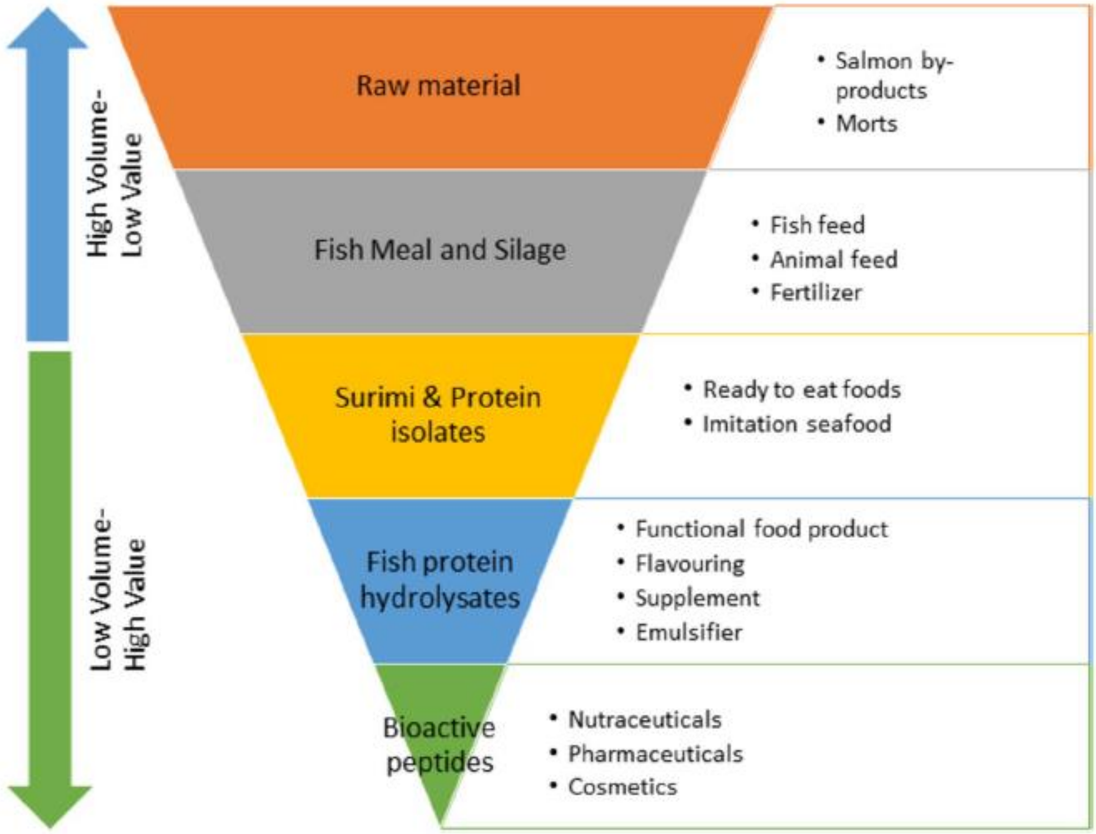
Figure 4-9: Potential ecological effects of finfish aquaculture.



Source: Overview of Ecological Effects of Aquaculture, MPI (2013, p. 33)

Aside from on-farm waste that directly impacts the environment, the processing of salmon also results in waste. Generally, salmon are processed for the consumer market by breaking down the fish into several premium cuts. The remaining carcass is often sold for pet and fish feed (Ramakrishnan et al., 2024). However, there are potential applications for the remainder of the salmon, as highlighted in the following Figure 4-10.

Figure 4-10 Value-added use of salmon by-products.



Source: Ramakrishnan et al. (2024, p. 6)

4.3 Innovation from Blue Marine

Technology

This report has highlighted that marine protein has a relatively low carbon footprint when compared to other animal proteins. However, there will continue to be advancements in the way that fish are landed, particularly in terms of utilising artificial intelligence (AI), sensors, and networks. AI technology linked to underwater sensors and drones to help guide vessels to fishing grounds – reducing the carbon footprint of vessels as efficiency is improved (Seafood NZ, 2023c). AI is also likely to aid in electronic reporting of fish landings on boats, leading to simplified catch documentation. The EU is leading this advancement with researchers developing a tool that leverages AI to scan two conveyor belts in real time and then recognise size, species, and weight of landed fish (Waycott, 2024).

In addition, an AI project in the Western Indian Ocean uses satellite data and machine learning algorithms to estimate coastal fish stocks and is able to do so with about 85 per cent accuracy. The aim is to allow local and national governments to quickly and cheaply identify stock numbers and make informed decisions around management options (McClanahan et al., 2023). Whilst this model was designed to estimate reef stocks in an area with low nutrition and food security, there may be future applications for other geographical areas such as New Zealand where the country has a long coastline. Combining some of these emerging technologies would provide much greater estimates of fish stocks within the country's EEZ and allow for better management of the QMS system.

Through the installation and utilisation of AI and sensing technology, fishing vessels themselves may help to form data networks. Through the hosting of communications and sensor equipment, many vessels would be able to conduct depth-profiles during normal fishing activities (Van Vranken et al., 2023). Many stakeholders would receive potential benefits such as improved climate monitoring and ocean modelling, STEM education, improved safety, informed spatial planning, and more accurate forecasting of extreme weather events (ibid).

Technology such as **AI, sensors, and networks** will provide benefits to fishers in terms of documentation, safety, and locating fishing grounds. This technology will also aid scientists and policy makers in accurately documenting fish stocks, forecasting extreme weather events, and conducting depth-profiles of the ocean.

Aside from AI, sensors, and networks, there will likely be changes to fishing vessels in terms of fuel source. Moving away from fossil fuels towards renewables will significantly reduce the carbon footprint of fishing. This potential future market is still in the relatively early stages of development with the first hybrid commercial fishing boat “Karoline” being built in 2015. The vessel runs on diesel to and from fishing grounds, while operating on electric for fishing, loading, and unloading (Corvus Energy, n.d). There are now more of these vessels being built. However, there are challenges in terms of available charging infrastructure, energy demand, and costs. Many ports are not equipped with charging infrastructure and the charging of e-vessels or hybrids causes spikes in energy demand. Further, while the cost of battery technology is reducing, a recent article highlights the cost of a fully electric vessel are currently two to six times more expensive than a comparable conventional vessel (Burnett, 2023).

A recent European Commission (2023) report also highlights the emergence of liquid natural gas (LNG) fired dual-fuel engine trawlers, hydrogen powered vessels, and wind-assisted propulsion. Whilst LNG is a cleaner energy than other fossil fuels, producing around 20 per cent less CO_2 than oil, it is in of itself a fossil fuel (NGI, n.d.). However, New Zealand does not currently have the infrastructure to handle LNG and is the only OECD country that does not trade gas across its borders (Enerlytica, 2023). Hydrogen powered vessels are in their infancy, with hybrid diesel/hydrogen vessels entering service in December 2022 (European Commission, 2023) and the first electric/hydrogen hybrid vessel expected to enter service towards the end of 2024 (MarineLink, 2023). As hydrogen is still an emerging technology there are many challenges in implementation. These are around factors such as cost, infrastructure, filling time and procedures, safety standards, and possible retrofitting the technology (Melideo & Desideri, 2024). Finally, wind-assisted propulsion is viewed as a promising source of alternative energy for fishing vessels (European Commission, 2023). This technology allows boats and ships to use a free and renewable resource to reduce fuel use. However, there are issues around this technology in terms of deck space, loading and unloading hindrances, and the height of sails and passing through bridges (Laursen et al., 2023).

Hybrid vessels are still in their relative infancy as a commercial technology. There are currently issues around factors such as infrastructure and cost. However, it is likely that this technology will continue to advance as the world begins to move away from fossil fuels. The advantage of adopting this technology lies in the reduction of carbon emissions and the scale of potential fuel spills in the ocean environment. The current disadvantages lie around the cost and current infrastructure available for fuelling.

Based on FAO projections, total fisheries and aquaculture production is expected to reach 202 million tonnes in 2030; an increase of 14 per cent on 2020 numbers (FAO, 2022). According to the FAO (2022), it is projected that fisheries will increase by 12.1 per cent in New Zealand and of this, aquaculture will contribute 10.3 per cent. In terms of aquaculture, this means the consenting and building of additional farms. Specifically, open sea fish farms are emerging as a potential new farm system in New Zealand. While in operation overseas for a few years now, this is still an emerging farm system in New Zealand, with researchers at Plant and Food working to develop new open ocean technology that will allow the fish to grow in a more natural environment than current farming practices allow (Plant & Food Research, n.d). Further, open ocean farming will allow for greater diversity in farmed species.

The use of open sea farms arguably do not have the same detrimental effect on the local environment as inshore operations because they are in deeper waters and more open to the weather, with the current helping to disperse waste and ensure continuous water movement (MPI, 2023e). However, they still pose an ecological risk; for example as escaped farmed species can cause great harm to wild fish populations. Therefore, species types and farm location are important considerations. Given the variability in ocean temperatures around the country, Salmon farms are in the South Island. This will continue to be the case due to the ideal temperatures needed for growth and survival. Over time climate change and rising ocean temperatures may require salmon farms to relocate further south. Other species will be able to be farmed further north. For example, in July 2023 resource consent was granted in the Hauraki for the development of a 300-hectare kingfish farm (Kitchin, 2023).

Open ocean aquaculture farms offer the potential to meet the worlds growing demand for seafood. Often considered more environmentally friendly than offshore aquaculture, this farm system is still in its relative infancy. New Zealand scientists are working on technology and innovation development to ensure sustainable farms are developed. However, the full extent of environmental and ecological impacts of these farms is not known at this time.

Emerging Algae Industry

Algae is an emerging industry with uses in industries such as fuel, energy, food, clothing, building, pharmaceuticals, agriculture (as a fertiliser) and plastics. In New Zealand, seaweed aquaculture is considered an emerging industry and has mostly taken place through pilot operations without commercialisation (Fisheries NZ, 2023b). Here we discuss algae as a possible animal feed and as a biofuel.

In terms of animal feed, algae have traditionally been fed to animals in times of scarcity and it has been shown that many ruminants as well as pigs and poultry are able to consume algae as a feed supplement. Some animals such as the North Ronaldsay in the Orkney Islands, Scotland, still have a diet consisting almost entirely of algae (Makker et al., 2016). There is growing interest in seaweed as an animal feed

In New Zealand, Fonterra and Sea Forest entered into a partnership in 2020 to run on-farm trials of *Asparagopsis* as a supplement. The aim of this partnership is to test that the supplement is indeed safe for cows, safe for human consumption, and that milk taste and quality is not affected (Fonterra, 2022). The first phase of the trial was carried out in Tasmania on a 900 dairy cow farm, with no red flags and has since expanded to multiple farms, feeding over 1000 cattle the supplement and investigating investment for commercialisation.

supplement to reduce enteric methane emissions from ruminants. Red seaweeds are the most efficient at this, containing the compound bromoform (Abbott et al., 2020). Recent studies of cattle have found the species *Asparagopsis taxiformis* (native to South Australian and the South Island of New Zealand) reduce methane emissions by around 80 per cent when a small amount of dry matter is supplemented for seaweed (Nunes et al., 2024; Roque et al., 2021).

Considering microalgae, varieties such as *Chlorella, Scenedesmus,* and *Arthrospira* have been showing promise as a supplement feed in ruminants and swine. Combining these microalgae with traditional feed has shown positive effects on animal growth, health, and physiology, and also product quality and quantity (Saadaoui et al., 2021). However, it should be noted that this research is still largely linked to field studies, rather than commercial use. Additionally, microalgae are currently grown in warm climates such as Asia and South America, and its suitability for growth in New Zealand's climate is not yet fully known.

Aside from feed, algae may also act as a biofuel. Both microalgae and macroalgae have this potential and several countries throughout Asia, Europe, and America have started to produce bioenergy (Khan et al., 2018). One of the greatest challenges that biofuel production has faced to date has been the competition for land use. Macro-algal production has the potential to mitigate this as it can be grown in the open ocean. However, the industry faces many challenges such as the efficiency of growth, harvesting and processing, nutrient requirements, and death from biotic and abiotic factors (Hannon et al., 2010). More recently, it has been shown that significant commercialisation will require billions of dollars. It appears that there is currently little appetite from the large oil producers to transition to biofuels (Westervelt, 2023).

Finally, algae are rich in micro and macro nutrients, having the ability to enhance soil fertility. It is currently widely available in hardware stores, but not so widely used in agricultural and horticultural contexts. This is largely due to cost. A research department at Bielfeld University in Germany have been running a test program on fertiliser production and believe that with plant modification and some process tweaks they could bring the cost of production down to around €2.22 a kilogram, comparable to other organic fertilisers (Werths, 2023). Further, algae are able to be grown at a sewage treatment plant, harvested once a week, providing potential for it undergo pyrolysis and be used for heat or electricity, or converted into fertiliser. Considering the size of a treatment plant, scale becomes a key issue.

4.4 Marine environment and carbon sequestration

New Zealand also has the scientific expertise to research the potential for harnessing its seas to help achieve national net zero ambitions. Currently, researchers from universities, crown and private research institutes, local government, non-governmental organisations, and local communities are focused on a range of relevant topics, including carbon burial in coastal wetlands and fiords, lateral transport of sediment via submarine canyons, ocean fertilisation and alkalinity enhancement, kelp aquaculture and biomarkers for tracing seafloor burial, and the impacts of seafloor disturbance on carbon stores. However, these research efforts are funded and conducted in an *ad hoc* manner, and there are no clear pathways to policy for research on the broader topic of marine carbon dioxide removal (mCDR).

There is a spectrum of the amount of human intervention involved with marine carbon removal: from identifying and protecting important carbon stores in the seafloor, to active restoration of degraded carbon sinks, to large scale enhancement of natural processes. Restoration and enhancement interventions fall under the umbrella of mCDR, and this is a rapidly developing area of interest for scientists, governments, communities and private entities alike. A wide range of potential mCDR approaches are being investigated, and in many cases advanced, internationally. These include restoring coastal wetlands and carbon burial hotspots, seaweed cultivation, ocean fertilisation, alkalinity enhancement, artificial upwelling/downwelling, electrochemical processes and sinking of biomass to the seafloor.

Whilst there is potential to scale these approaches to make a meaningful difference to atmospheric CO_2 removal, each approach must be carefully assessed in terms of environmental and ecological risks, feasibility, efficacy, co-benefits and economic returns. Many of these methods are in relatively early stages of development and there is still limited evidence that these offer effective sequestration and may do more harm than good to the existing ecosystem and environment (Chopin et al., 2024). All of these factors require extensive scientific knowledge and understanding. Furthermore, the ability to closely monitor, report, and verify the climate benefits of each approach is critical to the integrity of pursuing mCDR. Applying this knowledge to New Zealand's unique environmental and cultural settings will involve <u>weighing up the relative merits of each solution</u> before committing to a strategy. It is proposed to establish a Blue Carbon Forum in New Zealand to assess this.

Importantly, international climate policy and governance needs to be developed in parallel with scientific advances. Currently, coastal wetlands are the only marine environment included in the International Panel for Climate Change guidelines for greenhouse gas inventories. Work is progressing to apply those guidelines to New Zealand's coastal wetlands. There is also very little international regulation of mCDR in the High Seas.

Fjords as a Carbon sink

Fiords are carbon cycle 'hotspots' that bury the largest amount of organic carbon per unit area in the world, Smith et al. (2015). It is estimated that, though they occupy less than 0.1% of Earth's surface, annual fiord carbon burial accounts for 11 per cent of the total annual global marine sequestration (blue carbon) (Keil, 2015).

The South Island's fiords may be one of New Zealand's largest natural carbon sinks, and some of the highest carbon burial rates in the world have been observed here. Forest carbon is efficiently sequestered in fiords because plants and soils rapidly enter the marine environment rather than oxidising on the landscape. The combination of steep country, dense native forest, high precipitation (6-8 meters per year) and frequent landslides drive an efficient system that continuously fixes carbon, transports it to sub-oxic deep marine basins and sequesters it long term.

A recent estimate of Aotearoa New Zealand's carbon budget derived from atmospheric measurements and modelling found a previously unidentified carbon sink in Fiordland that is large enough to offset 10 to 20 per cent of the country's greenhouse gas emissions.

Given the valuable ecosystem service provided by natural climate regulation, it is important that New Zealand understands the drivers of carbon sequestration, the size of the carbon sink in Fiordland, and the vulnerability of this natural asset to future changes in climate, ocean circulation and management of the forests, water ways and marine environment.

At present the sensitivity of the carbon sink to environmental forcing is unknown. Nor do we know where the crucial tipping points that, once crossed, will dramatically reduce the efficiency of carbon sequestration, leaving more emissions in the atmosphere. These unknown aspects limit New Zealand's ability to undertake effective environmental management strategies. This includes determining how the system will respond to future climate change, and - as more pressure is placed on the Manapouri Power Station (MPS) to meet our 100% renewable electricity ambitions - determining how variability in high volumes of introduced freshwater threatens carbon loss in Doubtful Sound.

The research is therefore investigating the natural ability of Fiordland's marine sediments to collect and store carbon that is fixed from the atmosphere by the surrounding rainforest and marine ecosystem. It is assessing the vulnerability of this significant carbon sink to human impacts including forest and water management and changing climate and ocean conditions.

This 5-year programme is funded by MBIE-Endeavour and is co-hosted by the University of Otago and GNS Science. The team includes mana whenua, paleo scientists, sedimentologists, atmospheric scientists and modellers, oceanographers, geochemists, economists and marine managers from a wide range of institutions in Aotearoa New Zealand and abroad.

The research findings will support the government to improve reporting of blue carbon (marine sequestration) in the New Zealand Greenhouse Gas Inventory. We will assess options to protect and possibly enhance the storage potential of this valuable natural asset.

Figure 4-11: Illustration of carbon cycle and of the Fjord carbon cycle.

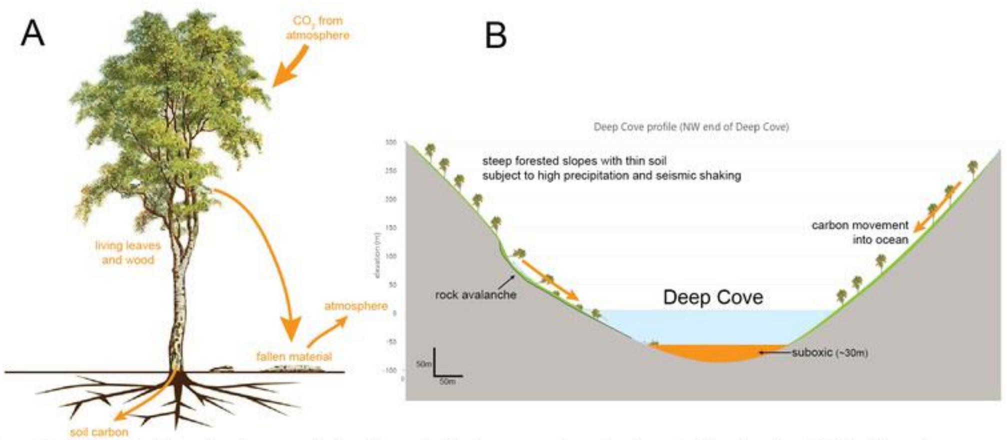


Figure 2. (A) Illustration of carbon cycle in a forest with decomposing plant material releasing CO_2 to the atmosphere. (B) Schematic of the Fiordland carbon cycle where terrestrial carbon can be efficiently sequestered in fjords as organic detritus is rapidly transported downslope and stored in adjacent sub-oxic basins (Fig. 2), rather than oxidising on the landscape. The combination of high relief, dense native forest, high precipitation (6-8 m/yr) and earthquake-triggered landslides drive an efficient system that continuously produces large amounts of stable, terrestrially-derived organic matter and sequesters it on decadal to centennial timescales.

Figure 4-11 shows the carbon cycle in the fjords. Earthquakes and landslides cause the dense native forest to fall into the fjords where it does not decompose and is sub-oxic this sequesters the carbon for centuries. The areas where the slips and earthquakes have affected then regrow with tutu - Coriaria aborea and then native forest sequestering more carbon. This regrowth can be affected by pest management which affects the rate it grows back. The carbon sink at the bottom of the fjords is affected by water flow including the impact of the Manapori powerstation on sequestering carbon.

Figure 4-12: Illustrating the impact of the tail race on sequestration of sub-oxic carbon in the Fjord.

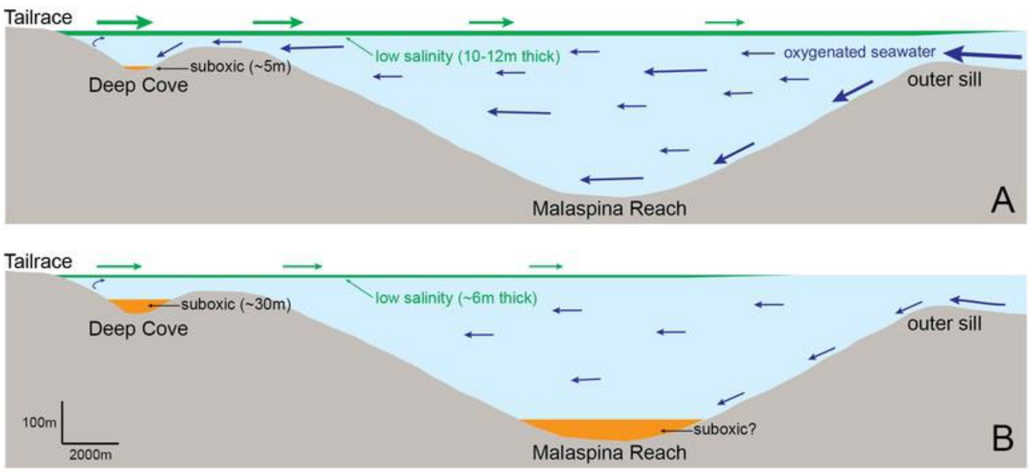
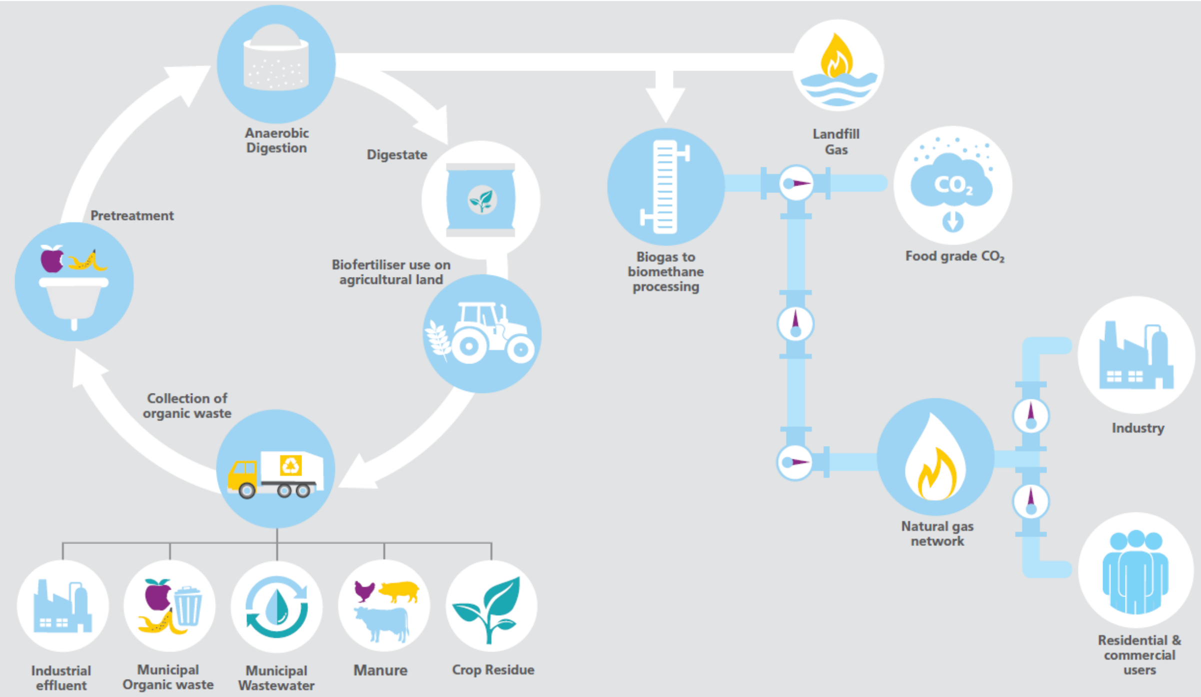


Figure 3. Conceptual model of Doubtful Sound circulation showing the relationship between tailrace discharge, downfjord propagation of the low salinity layer (green) and inflowing oxygenated seawater (blue arrows). Under high discharge regimes (A), enhanced fjord circulation facilitates mixing between seawater and freshwater just below the low salinity layer, which causes oxygenated seawater to propagate towards fjord-head basins reducing the presence of sub-oxic waters at depth. In low discharge conditions (B), the extent of the low salinity layer is reduced and fjord circulation slows, increasing the presence of sub-oxic waters that preserve organic matter in fjord sub-basins.

4.5 Alternative energy from biomass

Aside from traditional methods of energy production, there are emerging technologies that provide alternative methods of energy generation using biological resources. One technology of promise is anaerobic digestion and the production of biomethane. Biomethane is produced by diverting organic waste away from landfills to anaerobic digestion. The waste is broken down in a controlled and sealed environment, reducing biogenic emissions up to 95 per cent. The captured methane is then able to be treated and used to offset fossil fuel consumption in processes such as heat production and food grade CO_2 (Beca et al., 2021). The value chain of this may be seen below in Figure 4-13. New Zealand's current total annual energy consumption is around 543 petajoules (PJ) (MBIE, 2023). Beca et al (2021) estimate that if anaerobic digestion practices were taken up widely in New Zealand, the biogas production potential would be 13-17 PJ (see Table 4-2).

Figure 4-13: Biomethane Value Chain.



Source: Beca et al (2021)

Table 4-2: Biogas potential.

Category	Feedstock Type	Biogas Potential (PJ/year)
Municipal Waste	Municipal Wastewater solids	0.6 to 0.9
	Source-Segregated Food Waste	1.5
Industrial Wastewater	Dairy	1.1 to 1.9
	Meat	0.7
	Pulp and Paper	0.6
Agricultural Waste	Dairy Manure	6.8
	Pig Manure	0.4
	Poultry Manure	1.3
	Crop Residue	1.4 to 2.9
	Total	12.6 to 16.9 PJ
Landfill Gas	Existing Landfill Gas Capture	3
	Total	15.6 to 19.9 PJ

These figures are based on a set of assumptions around achievable collection of different feedstocks in a New Zealand context, typical conversion rates and technical limitations on processing different waste streams.

Source: Beca et al (2021)

Biomethane is not currently being produced at a large scale in New Zealand and is currently being used by councils at wastewater treatment plants and kerbside food waste pickup, piggeries, and Fonterra. One piggery in Taranaki for example, purpose built an anaerobic digester pond for pig waste. The methane supplies around half of the daily electricity needs to an electricity generator and heat exchangers then capture the engines heat to warm part of the piggery via under-floor pipes (NIWA, 2012). On the other hand, Fonterra are utilising anaerobic digesters at their Tirau and Darfield factories to process fats and proteins in the waste water, cleaning the wastewater, creating gas, and a nutrient dense slurry that can be spread on paddocks and crops as fertiliser (Fonterra, 2021). Finally, Auckland council have entered into a 20 year partnership with Ecogas to divert food scraps from landfill and process the city's food scraps using anaerobic technology. The biogas generates electricity to power the site and to provide heating for the tomato greenhouse facility next door. The CO_2 is also used by the tomato facility to help speed up production, and the remaining biomethane is pumped into the country's natural gas pipeline. The liquid digestate is then spread on to a neighbouring dairy farm as a fertiliser (Auckland Council, 2023).

The use of this technology is well established overseas. However, New Zealand has been slow to adapt this technology due to factors such as low landfill taxes, an unestablished market, lack of coordination across councils, lack of capabilities and infrastructure, perceptions of waste as a low value product, low carbon price and high investment costs (Beca, 2021). This is not to say that these are insurmountable challenges, but rather that there has previously been a lack of incentives for investing in this technology.

> Anaerobic digestion has the potential to divert food and other organic waste away from landfill, instead converting this waste to biomethane, CO_2 and nutrient dense digestate. This method of energy generation offsets fossil fuel consumption and the technology is well established overseas.

4.6 Other biological resources

As Chapter 1 showed there are considerable biological resources such as the conversation estate, wetlands, marine and trust lands. The conservation estate is 8.8 million hectares; 30 per cent of New Zealand's land area. These are in public and private ownership. This includes the QE2 trust, Department of Conservation, regional councils and Nga Whenua Rahui covenants. The QE2 trusts are where landowner voluntarily takes out a covenant to ensure the land is kept in perpetuity in native fauna. A Beef and Lamb survey found 20 per cent per cent of beef and sheep farms had at least one covenant, comprising a sizable contribution to New Zealand's biodiversity. Most of the conservation estate is under public ownership under Department of Conservation management. They may issue concessions for recreation or even farming activities and stress the multi-functional use of this biological resource. Which also provides huge environmental, social, and cultural benefits, including biodiversity, scenery, sequestration of carbon among others. Thus, the majority of their funding comes from the public purse funding, however, they also raise funding from recreational consents, ($15 million), sponsorship and donations ($39 million) and retail ($1.4 million) compared to total budget of around $300 million (DoC, 2023).

Wetlands are considered some of the most biological productive ecosystems in the world providing diverse habitats of aquatic species, fish and wildlife. They account for 75 per cent of the commercial fish caught and 95 per cent of fish and shellfish. They also provide improvements in water quality by trapping nutrients from fertiliser, septic tanks and other sources in the plant roots and microorganism in the soil. They are often created just for this purpose. Wetlands also can protect from storm water damage acting like sponges and releasing the water slowly so avoiding flooding and enables ground water to recharge (EPA, 2001).

These resources do produce market benefits through production of products such as honey and tourism. However, their main value is through the wider social, environmental and cultural values they provide. These are often classed as non-market benefits and include biodiversity, sequestration, ecosystem services, absorption of pollutants and recreational resources. The non-market value of biodiversity is explored below.

Biodiversity

Biodiversity provides significant benefits to New Zealand. Consumers in our export markets value biodiversity as part of the 'clean and green' brand. Likewise, tourists value the 'natural' experience which our native biodiversity provides. To the wider NZ public, recreational opportunities and aesthetic benefits are placed alongside the role that native biodiversity has in forming our cultural identity.

The economic value of such biodiversity is difficult to estimate. Some direct benefits, such as those captured by eco-tourist businesses can provide estimates of value through market prices. However, many of the benefits that flow from biodiversity are not so readily captured. There are no markets that allow the general public to express their preferences for biodiversity outcomes. Measurement of these benefits therefore requires non-market economic valuation methodology.

Choice experiments are a non-market valuation method that is used to value goods and services that do not have observable market prices. This approach is appropriate for valuing biodiversity because we do not have prices to indicate how much people are willing to pay to protect or enhance for example, native forests and birds from introduced pests such as possums and rats. Choice experiments have been widely used internationally to value biodiversity but less frequently in New Zealand.

Choice experiments are a survey-based method that presents respondents with a series of choice tasks. For each task, respondents choose between at least two options that represent alternative biodiversity management possibilities. Each option is described by a number of attributes which show possible biodiversity outcomes for. In each choice task, the levels of each attribute is systematically varied and combined to create a range of management outcomes that are then formed into the choice sets that respondents face. Respondents are asked to choose their preferred option. A monetary attribute is deliberately included in each choice set, either as the cost of action required to deliver that particular scenario, or in terms of how much extra (if any) the respondent would pay for the specified outcome. From these monetary attributes, the monetary value of other attributes can be calculated, and expressed as a 'willingness to pay'. Essentially people are asked how much more they are willing to pay to have for example, more native forest with unbrowsed canopy. A few studies are included below.

The first study considered hydrilla weed invasion in Lake Rotoroa, North Island (Bell et al. 2009). The benefits of hydrilla control were framed as avoided negative impacts to charophytes cover (native submerged plants), shags visiting the lake (native bird), fish and mussel species, and water quality. CEs were conducted in community meetings of samples beside or near the lake, and also a distant urban location sample with total 213 participants. On average, citizens were willing to pay most to fully remove the hydrilla cover. However, at a percentage change level people valued charophytes preservation ($7.76/1%) higher than removing hydrilla ($2.01/1%). Regarding species preservation, people were willing to pay more for one additional fish/mussel ($41.67/species) compared to one additional shag ($33.75/bird). The authors found no evidence of a distance-decay effect; they suggest a possible reason is existence value behaviour where the value of a species to be preserved is independent of the location.

In another study Bell (2008) considered the European shore crab that poses a risk for biodiversity in coastal estuaries including their surrounding vegetation, loss of shellfish, alongside recreational fishing and swimming/paddling. The case study focused on the Pauatahanui Inlet estuary near Wellington. The study estimated the general public's WTP for redeeming loss of negative impacts. A total of 47 people from around the Pauatahanui Inlet participated in the study. Results show that people were willing to pay most to avoid loss of shellfish species, and slightly less to avoid loss of children's ability to paddle at the water edge. These were valued about 40-60% higher than recreational shellfish take and loss of vegetation.

In Auckland, Kerr and Sharp (2008) explored land-use impacts on both natural and degraded urban streams. The CE included changes in amount of fish species, the amount of suitable fish habitat, the presence of streamside vegetation, alongside water quality and channel form (natural or modified). Interviews amongst the general public were carried out by a research company resulting in 308 responses. Data were analysed using a latent class model; weighted WTP from latent groups are reported here. It was found that in both types of streams, moderate vegetation was valued higher than plentiful vegetation. In the case of natural streams, respondents were WTP more for increased variety of native fish species compared to increased habitat, while the converse was found for degraded streams.

In Canterbury, Baskaran et al. (2009) estimated WTP for reducing detrimental environmental effects of dairy farming. This included a biodiversity element as farming development can reduce native forest coverage due to removal of shelter belts. This effect was captured in "scenic views" associated with variety of trees and plantations on pastoral farms. A total of 155 residents of Canterbury completed the CE. The authors found that the "biodiversity" attribute was positively valued; WTP $16.34/year for having 30% more variety of scenic views. This was however, lower than other study attributes.

Yao and Kaval (2009) valued biodiversity enhancement on private land in terms of a hypothetical tree planting program offered to private land-owners. The cost attribute was framed as the value of trees and expert advice, at $45 for the status-quo level. The choice set included an attribute 'free expert advice about tree planting'; with a static level for each alternative. A nationwide mail survey included 718 participants. Results indicated that, compared to having only non-native trees, people were WTP $112 for non-native plants and $120 for a mix of native and non-natives. This implies that while native trees are preferred, people also consider non-natives as good complements. An option for rebate was valued at $18 relative to trees provided by council, suggesting that people prefer flexibility in choosing which trees are planted.

Lee et al. (2013) estimated use and non-use values in the Abel Tasman National Park. This included a biodiversity attribute defined as the number of different native bird species present in the park. An intercept survey achieved responses from 74 park visitors. The payment vehicle was framed as an entrance fee. Results show that visitors were most concerned about keeping accommodation facilities as they are. Indeed, respondents require compensation for development of the cabin and lodge facilities. Regarding biodiversity, people were WTP $0.64 for each additional native bird species. This was lower than WTP for increased on-site information and almost the same as WTP to avoid meeting another visitor. Thus overall, visitors would like to maintain closeness to nature and valued a less crowed experience when visiting the Abel Tasman National Park.

Yao et al. (2014) valued biodiversity enhancement in planted forestry by exploring preferences toward improved habitat for familiar key species. A nationwide survey resulted in 209 respondents. On average people were WTP most for protecting native birds, both Bush Falcon and Brown Kiwi. People also wanted abundant fish in streams and better management of Kakabeak shrubs while WTP for gecko was zero. Furthermore, it was found that respondents' education, being in the labour force, and being a DOC volunteer or a Forest and Bird member increased WTP by $2.90-$12.60; in contrast a "Government Should Pay" attitude reduced WTP by $3.13. A significant spatial effect indicated that people living closer (at the 10 km radius) to a planted forest were WTP approx. $2.20 more for expansion of forest biodiversity programmes compared to those living further away.

Tait et al (2017) applied the economic non-market valuation approach of choice experiments, to estimate the value that New Zealand residents place on native biodiversity outcomes across different environments. The WTP results found here are consistent with those of comparable choice experiment studies, finding significant public support for enhancement of native biodiversity outcomes. The survey process achieved a sample of 985 respondents demographically representative of the NZ population.

Table 4-3: Willingness to pay for native biodiversity outcomes.

Native biodiversity outcomes across environments	WTP ($) **without** environment engagement	WTP ($) **with** environment engagement
Native Forest: Moderate outcomes	54(22,124)	56(24,130)
Native Forest: Good outcomes	82(43,162)	89(28,175)
Farmed Landscapes: Moderate outcomes	40(7,112)	46(11,122)
Farmed Landscapes: Good outcomes	62(36,116)	75(47,139)
Lowland Freshwater: Moderate outcomes	65(26,151)	69(28,159)
Lowland Freshwater: Good outcomes	73(33,164)	78(35,174)
Marine: Moderate outcomes	73(20,173)	80(26,197)
Marine: Good outcomes	87(34,198)	91(35,213)
Urban: Moderate outcomes	22(16,33)	54(42,79)
Urban: Good outcomes	53(43,78)	99(80,145)

Note: $NZ 2015 Median (25th percentile, 75th percentile)

Table 4-3 presents consumers' willingness to pay per year. This shows that for respondents who do not participate in any activities in the five environments considered here good outcomes in marine environments are valued highest, closely followed by good outcomes in native forest. For the average respondent level of activities: good outcomes in urban environments are valued highest, followed by good outcomes in marine and native forest environments. The median respondent is willing to pay the most for native biodiversity outcomes in urban environments.

If these results are multiplied by the population over 20- years old in 2018 in New Zealand, then the total WTP varies from $300 million for good marine outcomes, $291 million for good outcomes for native forest, $259 million for good outcomes for lowland freshwater to $188 million for good urban outcomes.

4.7 Summary

This chapter explored ways in which we can enhance economic, environmental, cultural and social outcomes. There are a number of ways this could be achieved such as improvements in productivity through increasing output using new technologies, improved skills and/or investment. Another way to meet our targets of doubling exports whilst improving environmental, social and cultural outcomes can be achieved by pricing high value products and gaining a premium for those. For example, producing infant formula rather than basic milk powder, high value nutraceuticals and/or pet food. The potential of this sector is large but as with obtaining premiums it would require a different approach and business model. The government has a role in facilitating advice, funding research into productivity improvements and access to skilled based training. Farm technologies are developing with the use of precision agriculture, AI, drones, and use of satellite imagery to mention a few. This has the potential to increase productivity whilst reducing the environmental impact.

New Zealand has considerable biological resources in its conservation estate and marine environment. This provides significant economic, social, environmental and cultural values. The economic values include tourism, and honey production. However, the wider benefits include biodiversity, sequestration, ecosystem services, absorption of pollutants and recreational resources. Current carbon sequestration plans rely heavily on planting forests and buying international carbon credits to offset emissions. However, nations are looking at the potential of the oceans to bury more carbon. The potential of the Fjords to sequestrate carbon with potential to sequestrate between 10 and 20 per cent was particularly explored in this chapter.

Chapter 5
Māori Bioeconomy

This chapter gives a detailed description of the Māori bioeconomy including new developments that highlight a dual focus on sustainability and high-value product development that maintain or promote cultural foundations.

5.1 Introduction

Biological resources hold significant importance for Māori. These resources are not merely means of sustenance but are integral to cultural identity, practices, and economy. Māori have always maintained a profound connection to the land (whenua) as a source of identity, spiritual well-being, and sustenance. Agricultural practices were developed to effectively manage and utilise the land, emphasising the importance of sustainability and the interdependence between humans and nature.

Māori agricultural systems were sophisticated, incorporating various techniques to enhance soil fertility and productivity. The cultivation of crops such as kumara (sweet potato) and taro was prevalent. These crops were essential for their nutritional value and as a means of social organisation and economic exchange within and between communities. The success of these agricultural practices is evidenced by the historical abundance and variety of food sources, which supported sizable populations.

In contemporary Māori society, the significance of agriculture and biological resources extends into considerable economic dimensions, shaping what can be referred to as the Māori bioeconomy. This term encompasses all economic activities related to the use of biological resources, including agriculture, forestry, fisheries, and biotechnology. These sectors contribute to the economic sustainability of Māori communities and uphold traditional values and practices.

The Māori economy has grown significantly over the past decades, with agriculture playing a pivotal role. The Māori economy was valued at over $68bn in 2018, 34 per cent of which is derived from the primary sector (BERL, 2021). Integrating traditional knowledge with modern scientific and business practices has been a critical feature of the Māori approach to the bioeconomy. Initiatives such as developing high-value products from indigenous flora and fauna, eco-tourism based on traditional environmental stewardship principles, and using Māori land for renewable energy projects exemplify the innovative ways Māori are leveraging their biological resources. These ventures contribute to the diversification and growth of the Māori economy and align with traditional values of guardianship (kaitiakitanga) and sustainability.

Despite the significant contributions of these sectors to the Māori economy, challenges remain, including access to capital, the impact of climate change, and ensuring the sustainable management of natural resources. The focus on sustainable practices and the incorporation of traditional Māori values into business models represent ongoing efforts to address these challenges.

5.2 Māori biological resources and the Māori Bioeconomy

Māori enterprises are a significant part of Aotearoa's primary sector. In 2018, Māori owned over $23b of food and fibre assets, more than in any other industry (BERL, 2021). These assets added nearly $2.5b to the country's GDP. By sector, the most significant Māori investments are in sheep and beef farming

($8.6b), dairy ($4.9b), forestry ($4.3b), and seafood ($2.9b)(BERL, 2021). Māori comprise 28 per cent of red meat processing/ commercialisation (MPI, 2023c). Around 30 percent of New Zealand's 1.7 million hectares of plantation forestry is estimated to be on Māori land, and this is expected to grow to 40 percent as Te Tiriti settlements are completed (Te Uru Rākau, 2023). Hapū, iwi and whenua Māori entities are estimated to own 30 per cent of sheep and beef production and 10 per cent of dairy production (MfE, 2023c). Total exports by Māori businesses have grown from $630 million in 2017 to $872 million in 2021, with the majority from the food and fibre sector.

The average size of Māori farms in 2022 was almost three times larger than that of non-Māori owned farms in Aotearoa New Zealand. Almost half of Māori farms are owned and operated by Māori authorities. The greater average size of Māori farms was driven by a higher proportion of larger farms, with 16 per cent of all Māori farms being larger than 1,000 hectares, compared with 5 per cent for all New Zealand farms. In addition to larger farm sizes, Māori farms typically hold more stock.

In 2022, Māori farms had, on average, just over double the stock of the average New Zealand farm, including:

- Three times as many beef cattle
- Seven times as many sheep
- Five times as many dairy cattle.

The majority (85 per cent) of Māori farms are in the North Island, which also carry more stock in total than their South Island counterparts. Across both islands, over two-thirds of Māori farms were livestock farms in 2022, including sheep, beef, and dairy cattle farms. In addition to livestock farms, large areas of Māori agricultural land are also dedicated for use as forests. Māori farms used almost seven times as much land on average for forestry compared with the average of all farms in New Zealand. A greater proportion of farms in the South Island (32 per cent) were primarily used for forestry in 2022, compared with 12 per cent of North Island Māori farms.

There is also a regional overlay with most of the Māori workforce located in the North Island and Canterbury. One in five workers (20 per cent) identifies as Māori in the forestry and wood processing/ commercialisation, the red meat and wool, and the seafood sectors (MPI, 2023c).

Tangata whenua have made significant investments in agriculture, particularly in sheep and beef farming and dairy farming, as well as in forestry and land retirement over the past decade.

The most recent data on Māori businesses come from the June 2023 quarter. The June 2023 quarter saw $333 million of primary industry production from Māori authorities, a 1.4 per cent percentage change from the same quarter of the previous year. There was also a substantial increase in employment provided by Māori authorities over the same period, with an 8.2 per cent increase in male employment and a 10.5 per cent increase in female employment.

The most comprehensive statistics on Māori businesses are from the Tatauranga umanga Māori release from Statistics New Zealand in 2022. Māori authorities and Other Māori enterprises are distinguished in the statistics. Māori authorities are businesses involved in the collective management of assets held by Māori. To be included in the count, they must be economically significant enterprises identified as Māori by the Business Register. Other Māori enterprises are Māori businesses that have Māori ownership, have self-identified the business as a Māori business, are economically significant, and are not Māori authorities.

Thirty-two per cent of Māori authorities and 13 per cent of other Māori enterprises are involved in primary industries. Where possible, in the following statistics, we have isolated primary industries for comparison; however, in many cases, due to data limitations, we must compare Māori primary industries to total New Zealand Enterprises. While this is not a good direct comparison, it clearly illustrates the focus of Māori enterprises and how they differ from other business types.

Table 5-1 below provides an overview of the total Māori agricultural land as of 2022.

Table 5-1: Māori agricultural land.

Type of Land Use	Māori Farms Total (Hectares)	NZ Total Farms (Hectares)	Māori Farms Share of NZ Total (%)	Avg per Māori Farm (Hectares)	Avg per NZ Farm (Hectares)
Grassland	219,300	7,351,900	3.0%	569	148
Horticulture land	3,500	129,200	2.7%	9	3
Plantation	126,100	1,633,400	7.7%	327	33
Bush and scrub	85,100	1,157,500	7.3%	221	23
All other land	54,900	3,044,300	1.8%	142	78

Source: Stats NZ – Agriculture production surveys and censuses.

Emissions profiles

While data are available on the size of grassland farming owned by Māori, no statistics could be found that precisely determine the amount of this land used for dairy versus sheep and beef farming. Nor are data available on the number of Māori owned Dairy farms or the number of Māori owned sheep and beef farms. Stats NZ – Agriculture production surveys and censuses show that approximately 2.7x more land is used for sheep and beef farming than it is for dairy farming. Applying this ratio to Māori grassland farming, without accounting for exotic arable farm types such as alpaca or deer farming which likely comprise a very small proportion of Māori owned land, 80,817 ha can be assigned to dairy farming and 138,482 ha to sheep and beef farming. These estimates are used in

Table 5-2 which provides an estimate of the emissions profiles for Māori owned farms.

Table 5-2: Average estimates for emissions profile for Māori owned farms.

Type of Land Use	Māori Farms Total (Hectares)	Emissions	Notes
Dairy	80,817	The total annual greenhouse gas emissions from the 80,817 hectares area with a stocking rate of 2.5 cows per hectare are approximately 1,397,123,888 kg of CO_2 equivalent. This figure represents the methane emissions from enteric fermentation in the dairy cows in this specific area.	Methane emissions per hectare for dairy cows are estimated to be 6,915 kg of CO_2 eq/ha per cow per year. *Stocking rate of 2.5 cows per ha.*
Sheep and Beef	138,482	The total annual nitrous oxide (N2O) emissions are approximately 512,383 kg of N2O-N. The total annual methane (CH4) sink capacity is approximately 88,628 kg of CH4-C.	Measured annual nitrous oxide (N2O) emissions from sheep-grazed pastures are estimated to be 3.7 ± 2.2 kg N2O-N ha−1 year−1, with higher emissions compared to ungrazed control sites. These pastures also act as a methane (CH4) sink, with an annual CH4 sink of 0.64 ± 0.19 kg CH4-C ha−1.
Horticulture land	3,500	*Unknown*	
		Sequestration	
Plantation	126,100	Sequestration of 61,600,000 to 101,866,700 tons of CO_2 by age 28	Gisborne, one of the faster-growing regions for pine, a hectare of Pinus Radiata can sequester up to 807 tons of CO_2 by age 28. In contrast, in slower-growing regions like Canterbury, a hectare of pine would sequester about 488 tons of CO_2 by age 27.
Bush and scrub	85,100	Sequestration of 1,872,200 to 17,275,300 tons of CO_2	The emissions profile for bush and scrub land in New Zealand depends on the proportion of the land covered by secondary forests versus old-growth forests, as well as the type of scrub land. The high estimate assumes the majority of and is covered by old growth forests at 203t/ha, while the low estimate assumes scrub at 22t/ha.
All other land	54,900	*Unknown*	-

Māori farms constitute a significant portion (3 per cent) of New Zealand's total grassland area, with a considerably higher average land area per farm (569 hectares) compared to the national average (148 hectares). Despite a smaller total area in horticulture, Māori farms have a comparable share (2.7 per cent) of the national total. The average land per Māori farm in this category is slightly higher (9 hectares) than the national average (3 hectares). Māori farms have a substantial presence in plantation forestry, covering 7.7 per cent of New Zealand's total plantation area. The average plantation area per Māori farm is significantly higher (327 hectares) than the national average (33 hectares). Māori farms have a higher-than-average presence in bush and scrub areas, with 7.3 per cent of the national total and a larger average area per farm (221 hectares) compared to the national average (23 hectares).

Innovation and adaption

The tatauranga umanga Māori – Statistics on Māori businesses from 2022 provide valuable insights on innovation and adaption of Māori farms. Table 5-3 provides insights on which barriers have a high degree of impact on different enterprises' innovation. These data are helpful in developing more efficient policy interventions to enhance innovation.

Table 5-3: Degree to which barrier affected innovation (high degree/per cent).

Barrier	Māori authorities	Other Māori enterprises	All New Zealand businesses
Cost to develop or introduce	17	22	20
Lack of information	5	3	4
Lack of marketing expertise	3	7	6
Lack of cooperation with other businesses	3	3	3
Access to intellectual property rights	1	0	2
Lack of appropriate personnel	11	14	14
Lack of management resources	15	19	18
Government regulation	6	12	10

Source: Stats NZ – Agriculture production surveys and censuses.

- Financial Constraints (Cost to Develop or Introduce) are a common barrier across all groups.
- Skill-related Issues (Lack of Marketing Expertise and Appropriate Personnel) are more pronounced in Other Māori Enterprises and All NZ Businesses than in Māori authorities.
- Organisational Capacity (Lack of Management Resources) is a significant barrier for Other Māori Enterprises and All NZ Businesses.
- Regulatory Challenges (Government Regulation) affect Other Māori Enterprises and All NZ Businesses more than Māori Authorities.

Overall, Māori authorities face lower-than-average barriers to innovation. Māori businesses are significantly more aware of the potential impacts of climate change, with 70 per cent of Māori authorities being 'very Aware' compared to 39 per cent of all New Zealand businesses.

Climate change

While there are little broad data available on wider sustainability issues, quality data have been gathered on organisational responses to climate change which can serve to illustrate a degree of environmental consciousness and planning. Table 5-4 below illustrates actions that businesses have taken in response to climate change.

Table 5-4: Actions businesses undertook in the last two years in response to climate change (per cent).

Climate change-related action	Māori authorities	Other Māori enterprises	All New Zealand businesses
Developed programmes to offset emissions	26	5	6
Reduced waste	30	25	23
Stopped or reduced using coal and / or natural gas	0	0	1
Developed or expanded offering of low emission goods and services	6	8	6
Changed to lower emission technologies	11	12	8
Switched to more sustainable suppliers	11	12	11
Increased use of digital technologies	9	12	10
Assessed the risks to the business of the physical impacts of climate change (e.g. increased flooding or droughts)	33	15	9
Took steps to reduce the risks to the business of the physical impacts of climate change	28	12	8

Source: Stats NZ – Agriculture production surveys and censuses.

- Māori authorities show a significantly higher engagement in developing programmes to offset emissions.
- Māori enterprises (both authorities and others) are slightly more inclined towards adopting lower emission technologies than the broader spectrum of NZ businesses.

The data show a higher tendency towards climate-related in Māori enterprises, particularly in Māori authorities. The larger size of these enterprises may partially explain this. Other explanatory factors could include export market requirements, regional location of the larger farms and subsequent environmental and regulatory conditions, and other factors that directly influence large collectively owned enterprises, particularly community expectations. Considering why different enterprises took climate-related actions can also help understand the preferences and needs of Māori enterprises.

Table 5-5 provides an overview of the main reasons. In

Table 5-5, we have isolated Māori authorities in primary industries for comparison against business across all sectors. Specific primary industry data are not available for these other businesses.

Table 5-5: **Main reasons that businesses undertook climate change-related actions (per cent).**

Main reason	Māori authorities (primary industry over 30 employees)	Other Māori enterprises	All New Zealand businesses
Experienced the physical impacts of climate change	25	29	17
Participation in government programmes	25	10	6
Demand from management/board/employees	75	24	26
Pressure from competitors	0	4	6
Demand from investors or shareholders	25	10	7
Demand from customers	50	16	26
Public opinion	25	22	23
To minimise supply chain disruptions	25	10	12
To take advantage of opportunities presented by climate change	0	16	10
Potential for litigation	0	0	1

Source: Stats NZ – Agriculture production surveys and censuses.

- Direct experience with the effects of climate change and internal demand (management, board, employees) are key motivators for climate action, particularly in Māori Authorities.
- Participation in government programmes is a more significant driver for Māori Authorities, indicating their engagement with and possibly dependence on these initiatives for climate action.
- Māori Authorities show a unique profile with high internal demand and stakeholder (investors/shareholders) demand driving their climate action, which could be reflective of their organisational values and stakeholder expectations.
- Competitive pressure is not a significant driver for climate action across all business types, suggesting that other factors like direct experience, internal demand, and government programmes play a more crucial role in motivating businesses to take climate-related actions.

The finding that 75 per cent of Māori authorities stated that demand from management/board/ employees is a main reason for their climate change actions is significant. This finding illustrates that demand for a higher environmental ethic is ingrained within Māori enterprises that have obligations to a broad community. The community-driven ethic of Māori authorities provides significant motivation for more sustainable farming operations.

Table 5-6 illustrates different enterprises' barriers in response to climate change.

Table 5-6: **Barriers for businesses not making climate change-related investments in the last two years.**

Barrier	Māori authorities (primary industry over 30 employees)	Other Māori enterprises	All New Zealand businesses
Lack of necessary infrastructure	25	12	7
Lack of information to support decision-making	25	17	13
Difficulty in raising or sourcing funds	25	19	10
Uncertainty around future policy direction	25	22	13
Uncertainty about the future of the New Zealand Emissions Trading Scheme	0	15	10
Risks around adopting new technologies	0	14	6
Lack of viable technology	25	14	11
Lack of appropriate personnel and / or skills	0	15	11
Other	0	5	4
Did not see any barriers	0	29	28
Don't know	25	22	35

Source: Stats NZ – Agriculture production surveys and censuses.

- Māori Authorities face more pronounced barriers in infrastructure, information access, funding, and policy uncertainty than Other Māori Enterprises and All NZ Businesses.
- Funding and policy uncertainties are common concerns across all business types but are more acute for Māori entities.
- The lack of necessary infrastructure is a significant issue for Māori Authorities, indicating a need for targeted support in this area.

Overall, the barriers indicate a need for enhanced support mechanisms, clearer policy directions, and more accessible information and financial resources, especially for Māori businesses, to facilitate climate change-related investments. MPI provides several support mechanisms for Māori agribusiness that may help to address information and support gaps for Māori entities.

Finally, we consider Investments businesses are planning to make in the next five years in relation to climate change

Table 5-7. These data are critical to informing scientific research and policy development that seeks to support the Māori Bioeconomy.

Table 5-7: **Investments businesses are planning to make in the next five years for climate change.**

Investment area	Māori authorities (primary industry over 30 employees)	Other Māori enterprises	All New Zealand businesses
Planning to invest in any climate change-related action	75	63	50
Purchase lower emission plant or equipment	50	32	20
Improve efficiency of buildings	25	29	22
Relocate facilities to lower-risk areas	0	3	2
New software or digital technologies	50	32	25
Education / training for staff to improve resource efficiency and reduce emissions	50	27	23
Research and development of low emission alternatives	25	14	7

Source: Stats NZ – Agriculture production surveys and censuses

- Māori Authorities are leading in their commitment to climate change-related investments, especially in sustainable technology and digital transformation.
- The higher inclination of Māori businesses (both Authorities and Other Enterprises) towards digital technologies highlights a forward-thinking approach in leveraging technology for climate solutions.

Māori enterprises demonstrate a significant future commitment to climate change adaption that reflects a broader environmental ethic. Māori authorities command substantial resources and are innovators in the primary industry. With 75 per cent of these entities planning to invest in climate change-related actions, they will likely need significant scientific support. This innovative approach is reflected by the higher level of investment intended in software and digital technologies. Combined with a focus on environmentally sustainable directions, Māori primary industries are rapidly establishing themselves as leaders in sustainable agriculture.

5.3 Summary of data on the Māori Bioeconomy

Māori businesses, particularly authorities managing collective assets, have seen growth in exports, production, and employment. These entities play a crucial role in the primary sector, with a focus on sustainable practices and climate change adaptation. They are proactive in engaging with emission offset programs and adopting lower-emission technologies. Internal demand from management and stakeholders drives their commitment to environmental sustainability.

Significant challenges for Māori enterprises include financial constraints, skill-related issues, and regulatory challenges, though these are comparatively lower for Māori authorities. Climate change actions are primarily driven by direct experience and internal demand, with a notable participation in government programs.

Māori authorities face unique barriers in infrastructure, information access, funding, and policy uncertainty. These challenges highlight the need for targeted support, clear policy directions, and accessible resources to facilitate climate change-related investments. Māori enterprises, especially authorities, show a strong future commitment to climate change adaptation, with substantial investments planned in sustainable and digital technologies. This approach positions Māori primary industries as leaders in sustainable agriculture, reflecting a broader environmental ethic and the need for scientific support in their innovative endeavours.

5.4 Key Māori values in allocating bioresources

Within traditional Māori society, the cornerstone of exchange was the principle of Tauutuutu. Etiologically, the term combines two foundational elements: 'tau-,' implying reciprocity, and 'utu,' which might translate as price, payment, cost, or even revenge. By repeating "utu," the term underscores the ingrained reciprocity of the concept. In this context, two pivotal 'social currencies' emerge: mana and mauri. While the term 'currency' is used here to describe them, both mana and mauri transcend contemporary understanding of the term. They function as profound cosmic forces driving the operations of Tauutuutu. Mana denotes an individual's or group's authority, prestige, or dignity. When leaders and their communities foster and preserve mutually beneficial relationships, they accumulate mana. Thus, mana catalysed a mostly mutual, yet competitive, dynamic within Māori society.

Mauri represents the animating essence of any entity—whether a person, water body, or ecosystem. Rooted in the Māori deities' lineage, mauri breathes life into the universe, reflecting the inherent capability of organisms and ecosystems to sustain and produce life. If a value exchange involves nature, the currency is mauri. Such transactions can bolster or deplete an environment's mauri, establishing a societal responsibility to counteract that disturbance equivalently.

Every exchange under this system birthed a reciprocal and progressive obligation. In receiving a good or service, the recipient bore the responsibility of reciprocating with an item of similar or superior value at a subsequent time (Metge, 2002). This not only fostered but also prolonged the bond between the parties involved. Traditional Māori economic practices, thus, not only facilitated the barter of goods and services but also fortified social unity through this staggered, amplifying exchange system.

Neglecting this obligation or offering an inadequate return resulted in a significant loss of mana. Such a loss had profound implications on an individual's standing within Māori society, affecting mental well-being and health. Moreover, reciprocating with a more valuable item magnified one's mana. Consequently, transactions typically escalated, with each exchange becoming progressively more valuable (Metge, 2002). Essentially, Tauutuutu encouraged early investments with the allure of promising future yields, a notion that may provide important guidance for corporate sustainability strategy. Through this system, balance, albeit temporary, was attained as obligations oscillated between participants. The overarching objective wasn't a static equilibrium but dynamic, fuelled by a perpetual urge for escalation.

While mana propelled this equilibrium, balance was assessed through mauri. Mauri isn't static but interactive; it flourishes or dwindles based on interactions. Harmony is achieved when exchanges benefit both parties. Mauri served as a yardstick that monitored if exchanges sustained, revived, or disrupted this balance. At the same time, mana encouraged individuals to pursue actions that increased their mana. Consequently, mana can be envisioned as the catalyst of economic expansion in the traditional Māori economy (Harmsworth & Awatere, 2013).

Tauutuutu also balanced various regional resources—both natural and human. Exchanges often included geographically dispersed goods and specialised expertise (Kawharu, 2000). Importantly, since generosity, not hoarding, amplified mana, surpluses were more communal than individual (Reid and Rout, 2016). Tauutuutu didn't hinder economic growth; rather, it assured collective accumulation and balanced dissemination of wealth.

The location of bioresources by Māori enterprises involves a careful balancing of the principles of tauutuutu and other strategic business priorities. Incorporating business priorities with the broader principle of Tauutuutu reshapes organisational strategies and governance decision-making positively. This integration underpins a Māori agribusiness approach to promoting sustainable outcomes, aligning business priorities with higher-order societal imperatives. Tauutuutu emphasises the significance of interdependence. It's not merely about individual and organisational actions but the ripple effects they create. This principle accentuates the interconnectedness of decisions. An action in one domain can have repercussions in another. While individual and organisational values act as internal guides, Tauutuutu provides an overarching external framework, ensuring that decisions align with broader societal needs.

This framework can be instrumental in conflict avoidance and resolution. The dual paradigm can provide a middle ground in scenarios where individual values clash with broader societal principles (Zhang & Wei, 2017). It can help stakeholders find solutions honouring individual convictions while ensuring societal harmony. In organisational and governance decision-making, the challenge lies in navigating the balance between individual values and overarching principles. Traditional Māori society offers insights into this balance through Tauutuutu. Organisations often grapple with decisions that require weighing multiple trade-offs. These trade-offs can span various dimensions, from economic and social to environmental. The traditional 'rational actor' model often falls short in such complex scenarios (Calvert, 1995). This is where the integration of values and Tauutuutu offers a more holistic approach. They ensure that decisions align with the organisation's core beliefs and principles, leading to outcomes that are not only economically viable but also ethically sound.

Tauutuutu emphasises the importance of reciprocity and balance (Metge, 2002). It underscores the need for decisions to be mutually beneficial, ensuring that all stakeholders are considered, and outcomes are equitable. The integration of values and Tauutuutu in decision-making offers several advantages to organisations. Organisations can ensure consistency in their actions and outcomes by anchoring decisions on values. This increases stakeholder trust (Sekhon et al., 2014) and enhances the organisation's reputation (Ang & Wight, 2009). Tauutuutu ensures that decisions consider all stakeholders, leading to holistic and equitable outcomes. This reduces the risk of negative repercussions and enhances stakeholder satisfaction (Fageha & Aibinu, 2013). The combination of values and Tauutuutu ensures that decisions are economically sound and ethically grounded. This enhances the moral integrity of the organisation (Rendtorff, 2011). When stakeholders recognise that an organisation's decisions are based on values and the principle of reciprocity, they are more likely to engage positively with the organisation (Campbell & Finch, 2004). This can lead to better collaboration and improved outcomes. Decisions based on short-term preferences can lead to outcomes that are not sustainable in the long run (Gonzalezet al. 2017). Organisations can ensure long-term viability and success by basing decisions on values and the principle of balance.

5.5 New demands on the Māori Bioeconomy

The Māori Bioeconomy is subject to the same broad trends and preferences as the wider economy; however, there are unique constraints faced by Māori agribusiness that need to be considered to understand the demands Māori face and the high-priority areas Māori need to focus on when responding to broad economic trends.

In the previous sections, the Statistics New Zealand groupings of 'Māori Authorities' and 'Other Māori Enterprises' were used. In this section, we focus on the largest Māori agribusinesses. Land trusts, incorporations, iwi corporations, and Post-Settlement Governance Entities operate Māori agrifood enterprises. These enterprises can be described as Māori agrifood collectives (MACs). MACs present a vision of agribusiness where profits flow to communities and environmental standards can be exceeded to build inter-generational capital. This is particularly evident in the significantly higher emphasis MACs place on environmental outcomes, particularly seeking emission reductions Reid et al. (2019) conducted in-depth interviews with 15 Māori agribusiness leaders to understand the constraints and enablers Māori agribusinesses face in a changing bioeconomy. In this section, the research of Reid et al. (2019) is used as a basis to isolate five critical constraints, which are then discussed with regard to how Māori agribusiness is adapting to new demands.

1. Finance: To invest in farm development, product development, marketing, and sales and to provide working capital to support operations.
2. Skills and Knowledge: To support good governance, management, and operations and to address specific technical/specialist issues.
3. Paths to Market: To develop the organisation's ability to gain premium prices for their products in market through accessing or developing premium supply chains.
4. Relationships and Trust: To build strong relationships and trust between board members and with staff, shareholders, and others beyond the farm (e.g., suppliers, regulators, and customers).
5. Regulations: The capacity to operate within regulatory constraints.

5.5.1 Finance

The need for investment in farm development, product development, marketing, and sales, as well as working capital, requires financial resources and mechanisms that are accessible and tailored to the needs of Māori enterprises. This includes the need for financing models that understand and respect Māori values and aspirations, enabling these enterprises to grow without compromising their principles. Twenty-two per cent of Māori agribusiness leaders surveyed found it difficult to access financial capital, while 72 per cent had little difficulty. While this shows MACs do not typically struggle to access finance in general, the respondents suggested they struggle much more to access finance to make significant shifts in terms of meeting the katiaki goals involving the establishment of blue, green, and grey infrastructure on-farm to improve environmental outcomes. In other words, there was not much of a problem accessing capital for operating within the status-quo, but more difficulty regarding environmental improvements. Funding or investment opportunities for environmental improvements are limited but rapidly developing. Mechanisms such as biodiversity credits and the voluntary carbon credit market may provide a source of funding for greater environmental enhancements, however, these markets are still in their infancy in Aotearoa. There are promising developments in this space illustrated by organisations such as Hinemoana Halo which is actively building a blue carbon funding mechanism and the Eco-index which is working to support the development of biodiversity credits. Additionally, the Kaitiaki Intelligence Platforms programme under Our Land and Water has taken the first steps towards developing a collective of Māori agricultural enterprises to share the development costs for advanced environmental enhancement technologies. This finding underscores a gap in the current financial ecosystem's ability to support sustainable development initiatives integral to Māori values of guardianship (kaitiakitanga) and inter-generational wealth. Any new demands on the Māori economy will need to heed this constraint on Māori farms, particularly regarding accessing premium markets.

There is a need for financial models that not only provide the necessary capital for development and expansion but do so in a manner that aligns with Māori principles. Such models would need to be innovative, flexible, and culturally sensitive, recognising the importance of environmental stewardship and sustainability deeply rooted in Māori culture. Impact investing provides a promising avenue in this context. By focusing on investments that generate social and environmental impacts alongside financial returns, impact investing aligns closely with Māori values. It offers a pathway for MACs to secure the necessary funds for projects that contribute to the well-being of their land and people, such as establishing blue, green, and grey infrastructure to enhance environmental outcomes.

5.5.2 Skills and knowledge

Good governance, management, operations, and addressing specific technical or specialist issues require education, training, and capacity-building within the Māori community. There's a need for programs that not only build business and agricultural skills but also integrate traditional knowledge and practices, fostering a bioeconomy that is innovative and culturally grounded.

Sixty-four per cent of MACs considered a lack of knowledge and skills among governors to be a constraint to a moderate or extreme extent. Forty-three per cent felt there was an overreliance on external consultants to a moderate or extreme extent while 85 per cent of respondents to the survey felt that it was either extremely important or important, to have good external consultants on their boards. Access to skilled employees is a significant constraint on MACs meeting their desired goals, with over 70 per cent of respondents identifying this as an issue.

In meeting new demands on the Māori Bioeconomy, upskilling will be crucial within MACs. There is a significant gap in governance, management, and technical expertise within MACs, where a substantial percentage of MACs recognise the lack of knowledge and skills as a constraint to achieving their desired goals. This constraint may not be unique to MACs as we do not have reliable data to determine whether this constraint is also typical of the wider sector. However, a brief review of the literature, did not reveal any significant concerns in the wider sector relating to leadership and technical capabilities. Instead, the majority of workforce concerns in the wider sector appear to be related to manual labour shortages. Additionally, the reliance on external consultants' points to a need for internal capacity building that aligns with Māori values and aspirations. MACs recognise the significant importance of having external consultants involved, however, they also suggest that they are over relied upon. This suggests they see consultants as a valuable way to develop expertise, while also expressing a desire to build their internal expertise to work so they have reliance on external consultants in the future.

5.5.3 Paths to market

Building the capability to develop high-value products and access premium export markets to gain better product prices is important for MACs. Achieving the demands of premium markets requires the establishment of robust value chains that allow for the transmission of Māori values throughout all stages of the product lifecycle. This encompasses the need for networks, partnerships, and strategies that open domestic and international premium markets for Māori products. Fifty per cent of the Māori agribusinesses surveyed were actively seeking access to premium markets. Currently, however, most MACs are not doing this, with 94 per cent of MACs directly supplying processers. This is perhaps the most significant finding in the research regarding its implications for responding to new demands on the Māori Bioeconomy. To access premium markets, Māori need to emphasise their unique cultural attributes. As discussed under finance, it is difficult for them to access finance for initiatives outside of business as usual. Additionally, without significant influence over supply chains, it is also difficult to communicate or emphasise unique cultural attributes in products, or to further enhance the attributes in the processing stage.

With 50 per cent of the surveyed Māori agribusinesses seeking access to premium markets, while the vast majority directly supply processors, there is a large need to pursue alternative market strategies within

MACs. This will be critical to Māori meeting new demands on their agricultural resources. Developing premium supply chains requires a multi-faceted strategy that leverages the unique attributes of Māori-produced goods. These goods are not merely products but embodiments of rich cultural heritage, sustainable practices, and the Māori worldview. A multi-faceted strategy needs to begin by identifying and strengthening networks, partnerships, and collaborations that can facilitate access to premium markets. This could involve forming alliances with entities that have established market presence and share a commitment to sustainability and ethical practices, aligning with the values inherent in Māori production. The Kaitiaki Intelligence Platforms project is an example of building this kind of strategy. This project brings together an array of entities beginning with Te Rūnanga o Ngāi Tahu and Opepe Land Trust and expanding to a large cohort Post Settlement Governance Entities and Māori Land Incorporations and Trusts across Aotearoa. The underlying strategy is to build networks and pool resources to position Post Settlement Governance Entities and Māori Land Incorporations and Trusts as first-movers in the utilisation of precision, high-resolution environmental monitoring. These technologies will form the basis for Māori led platforms capable of assessing environmental and social performance and communicating this performance to markets. The distinguishing feature of the strategy is a collective approach to ensure that Māori maintain control over core values embedded in their products as these products move through the value chain. The approach is focused on ownership and building the capability and capital resources to exert control over all stages of the supply chain.

Branding and storytelling are powerful tools in distinguishing Māori-produced goods in the global marketplace. A brand that encapsulates the essence of Māori culture, values, and connection to the land can resonate deeply with consumers, creating a unique market niche. Storytelling, an integral part of Māori culture, can be leveraged to communicate the product's journey from its origins in the rich, natural landscapes of New Zealand to the hands of the consumer, emphasising the care, tradition, and values imbued in each item. This narrative can transform the product from a mere commodity to a cultural experience, helping to underpin a premium price. Marketing avenues must be carefully selected to target consumers and segments that value the unique qualities of Māori-produced goods. Research has demonstrated that consumer segments are willing to pay a premium for Māori products (Rout & Reid, 2020); however, connecting to these consumers is proving challenging for MACs.

5.5.4 Relationships and trust

Building strong relationships and trust within and beyond the MACs is a critical feature of their business models. MACs emphasise the importance of collaborative approaches, community engagement, and stakeholder management in business success, emphasising the relational nature of Māori business practices. Ninety-seven per cent of respondents felt it either important, or very important to have strong leadership. Furthermore, 95 per cent of respondents felt it was either extremely important or important to have good and effective governing structures in place. Fifty-three per cent of survey respondents considered their MAC boards to have a problem with interpersonal conflicts to either a moderate or extreme extent. Furthermore, 33 per cent considered board power dynamics to be problematic. The survey also revealed that only 19 per cent found a problem with reaching a consensus. This suggests that the strong cultural value placed upon reaching a consensus on MAC governing boards may be the driver of internal conflict and power dynamics, with these dynamics ultimately leading to consensus.

Despite the challenges of interpersonal conflicts and power dynamics within governing boards, the strong cultural drive towards consensus highlights a unique opportunity for MACs to leverage their cultural values to foster trust and cohesion internally and externally. Transparent governance is foundational to building and maintaining trust within MACs and with external stakeholders. Transparency in decision-making processes, financial management, and strategic planning can help mitigate interpersonal conflicts and power dynamics by ensuring all members feel informed, involved, and respected.

Māori cultural values, such as whanaungatanga (kinship), manaakitanga (hospitality and care), and kaitiakitanga (guardianship), can serve as guiding principles in developing business relationships. These values can be communicated and demonstrated through branding, storytelling, and ethical business practices, resonating with partners, customers, and the broader community. By embedding these values in every aspect of their operations, MACs can differentiate themselves in the market and build a reputation based on integrity, quality, and sustainability.

5.5.5 Regulations

The Te Ture Whenua Māori Act (TTWMA) and the Resource Management Act (RMA) present regulatory frameworks that impact Māori Agricultural Corporations (MACs). The TTWMA aims to prevent Māori land alienation and address collective ownership issues by establishing governance structures. However, it also makes Māori land difficult to value or use as collateral, affecting access to financial capital. Eighty-nine per cent of MAC governors and shareholders surveyed do not view Māori land regulations under the TTWMA as a significant barrier to their activities. However, this perspective does not negate the difficulties a small portion of MACs encounter. The opinions of Māori agribusiness leaders resonate with the Statistics New Zealand findings from Table 5-3, which show that government regulation is less of a barrier for MACs than it is for the general farming population. This finding illustrates that MACs tend to have well-established systems in place that can meet the expectations of the status quo and are instead focused more on innovation and progress. There are some uncertainties around the future of regulation, however, MACs have demonstrated a high level of capability in negotiating the regulatory environment and it is not currently seen as a substantial barrier to progress based on the participant responses.

5.6 Impacts of different scenarios on Māori biological resources

5.6.1 Transferring sheep and beef land to exotic forestry for bioenergy production

Transferring sheep and beef land to exotic forestry for bioenergy production presents a significant shift for Māori agribusiness, particularly given tangata whenua's substantial investments in agriculture and forestry. Māori enterprises own over $23 billion in food and fibre assets. The transition of sheep and beef land to exotic forestry for bioenergy could align with these existing investments in forestry, where Māori already comprise 37 per cent of forestry production. However, it would also necessitate re-evaluating the role and value of their substantial investments in sheep and beef farming, valued at $8.6 billion.

Given the larger average size of Māori farms and their significant stock levels—three times as many beef cattle and seven times as many sheep as the national average—this transition could have considerable economic implications. It would impact the operational structure, employment, and income of Māori agribusinesses, especially in the North Island, where 85 per cent of Māori farms and most of their livestock are based.

The transition would also affect the emissions profiles of Māori agribusinesses. With Māori farms constituting a significant portion of New Zealand's grassland area, the move to forestry could potentially reduce their carbon footprint, aligning with global and national sustainability goals. This shift might also enhance Māori agribusinesses' access to carbon credits and bioenergy markets, presenting new revenue streams and diversifying their economic base.

However, the transition poses challenges, including the need for new skills and knowledge in forestry and bioenergy production, potentially straining the current workforce or requiring significant retraining and education. As discussed in the previous section, Māori already struggle with staff capability. Any transitions would require considerable investment in capability to enhance employment opportunities. MACs emphasise community impact in their operations, and providing employment is a critical concern.

The impact of any transition on employment opportunities would be of significant interest to MACs. Additionally, the immediate financial impact of transitioning from livestock to forestry must be considered, given the time it takes for forests to mature and become profitable.

From an employment perspective, the June 2023 quarter showed a 1.4 per cent increase in primary industry production from Māori authorities and a substantial increase in employment. Transitioning to forestry for bioenergy production could further influence employment trends, potentially offering new jobs in the sector, though possibly at the expense of those in traditional sheep and beef farming. Given Māori authorities and enterprises' involvement in primary industries—32 per cent of Māori authorities and 13 per cent of other Māori enterprises—the shift to forestry for bioenergy production could redefine these businesses' focus and operational strategies. It aligns with the global move towards sustainable and renewable energy sources but requires careful planning and support to manage the transition effectively.

Transitioning sheep and beef land to exotic forestry for bioenergy production could offer Māori agribusinesses sustainable growth and diversification opportunities. However, it necessitates careful consideration of the economic, environmental, and social impacts, including the need for skills development, potential changes in employment, and the management of existing agricultural investments. Strategic planning and support from both the community and governmental bodies will be essential to navigate this transition, ensuring that it aligns with the goals and values of Māori agribusinesses and contributes positively to Aotearoa New Zealand's economy and environment.

5.6.2 Obtaining premiums for Māori products.

The following discussion is mainly based on data gathered from the survey of Māori agribusiness leaders used to inform the previous section (Reid et al., 2019). These data provide insights into the challenges Māori producers face in obtaining premiums. Any scenarios intended to increase premiums from exports will be based on overcoming the constraints in MACs.

Strategies to increase premiums from exports depend on overcoming existing constraints within MACs. Despite a heavy reliance on current processors, half of the Māori agribusinesses strive to develop products that meet the demands of premium markets. Forty-five per cent of these businesses have adopted integrative farming methods to enhance environmental performance and manage risks, elevating their sustainability credentials to align with market expectations and kaitiaki stewardship values. Furthermore, 36 per cent use industry benchmarking and Key Performance Indicators (KPIs) to improve their environmental credentials, responding to the growing consumer demand for these features. An additional 9 per cent participate in quality assurance schemes to provide assurance to international markets about their environmental and social credentials. Beyond these programs, 18 per cent are developing unique brands and narratives to communicate their values, and another 9 per cent are pursuing initiatives aimed at niche premium markets. However, only 5 per cent, presumed to be those supplying directly to consumers, report active engagement in the supply chain to connect with their customers. Thus, most Māori agribusinesses rely on existing supply chains to convey their credentials and access premium pricing.

The survey also inquired about agribusinesses' barriers to accessing premium markets. The primary obstacle, identified by 25 per cent of respondents, is the scarcity of processors willing to handle and market premium products. Additionally, 25 per cent of businesses reported a lack of capability to develop premium products as a barrier, while 18 per cent cited insufficient access to financial capital and supply chain networks. Another 18 per cent pointed to internal decision-making issues as a hindrance to engaging in premium value chains. Some respondents expressed satisfaction with the status quo, viewing the pursuit of premium products as unnecessary.

Regarding industry bodies responsible for, among other duties, coordinating the industry and establishing pathways to premium markets, the majority of participants reported these bodies as offering little to no value. Many expressed a desire to cease paying associated levies. It is important to note, however, that several participants acknowledged positive outcomes in monitoring by these bodies, but the support for accessing market pathways was consistently negative. Several respondents reported receiving no assistance or even contact from these industry bodies. Some believe that these bodies do not understand or cater to Māori agribusinesses, which they perceive as the reason for the lack of support, while others contend that these bodies are significantly behind in providing insights into market pathways.

Māori agribusiness leaders highlighted the significance of whakapapa networks, which they deemed crucial for achieving economies of scale, diversity of land types, and the necessary influence to integrate supply chains and develop effective branding and marketing strategies. They emphasised that collective action served as a key facilitator for accessing market opportunities. There is also the potential that collective action can open new processing pathways and reduce costs. Individually, these operations lacked the capacity to explore alternative market avenues, but collectively, they were equipped to ensure a consistent supply and collaborate on brand creation. The importance of scale and shared values and circumstances inherent to their collective efforts were underscored. This approach aligns with core Māori values and is practical due to shared values and broader contextual similarities and demonstrates a tauutuutu perspective in action.

The interviewees identified three primary benefits of collective scale. First is the capacity to brand and market products effectively, adding value and communicating provenance. Food with Māori branding commands a 43–50 per cent price premium in British markets (MPI 2021). Ngāi Tahu has demonstrated that cultural authenticity can be used to great effect in gaining a premium for Māori products. while not agribusiness, Ngāi Tahu Pounamu enhanced the communication of provenance for the cultural authenticity of pounamu products. This initiative has seen premiums of between 30 per cent and 50 per cent for culturally authentic product over inauthentic product (Barr & Reid, 2014). Other enterprises that have made progress in successfully communicating cultural attributes to obtain price premiums in agribusiness include Kono and Miraka.

While many participants were in the initial stages of this process, they recognised whakapapa networks as vital for achieving the necessary scale and reliability for product delivery and brand development. They acknowledged their unique position, possessing a compelling narrative for consumer engagement, a task beyond the capacity of individual trusts. The second benefit was achieving both production scale and land type diversity, enhancing processor access. Collective efforts ensured the fulfilment of processor contracts, offering a wider range of choices. The utility of completing stock on partner operations was noted, allowing for greater processor access than individual farms, particularly those in marginal or remote areas, could achieve alone. The third advantage was improved measurement and benchmarking capabilities. Collaboration enabled more accurate comparisons and performance assessments, avoiding misleading comparisons with non-Māori farms. This collaborative approach facilitated a more effective and authentic assessment of operations, underscoring the practical and cultural benefits of collective action within Māori agribusinesses.

To enhance the ability of Māori to secure premium prices in export markets, several conditions must be addressed or strengthened based on data from a survey of Māori agribusiness leaders. Firstly, overcoming constraints within Māori Agribusiness Complexes (MACs) is paramount. These constraints include a heavy reliance on existing processors, with only half of the businesses developing products that align with premium market demands. The adoption of integrative farming methods by 45 per cent of farms has been a step forward in enhancing environmental performance and managing risks, aligning sustainability credentials with market expectations and kaitiaki stewardship values. Research from the AERU has demonstrated consumers are willing to pay a premium for products with environmental credence attributes (Tait et al. 2020a).

Addressing barriers to accessing premium markets is crucial for a premium-enhancing scenario to be possible. The scarcity of processors willing to handle and market premium products is a primary obstacle that 25 per cent of respondents identified. Equally, the lack of capability to develop premium products and insufficient access to financial capital and supply chain networks are significant challenges that need addressing.

The role of industry bodies in coordinating the industry and establishing pathways to premium markets requires re-evaluation. The majority of participants perceive these bodies as providing little to no value, with a notable number expressing a desire to discontinue levy payments. A more thorough investigation would be required to determine the value these entities provide and whether perception mirrors reality. There is the potential that the participants are not fully aware of the support that the industry bodies could provide, in which case there would be a communication or information barrier limiting the opportunity for the participants to access the services they desire. Enhancing the support for accessing market pathways and improving engagement with Māori agribusinesses are necessary steps. The significance of whakapapa networks is crucial. These networks are critical for achieving economies of scale, diversity of land types, and integrating supply chains. Collective action, facilitated by these networks, is essential for accessing market opportunities, ensuring a consistent supply, and collaborating on brand creation. The shared values and broader contextual similarities inherent in these collective efforts align with core Māori values and offer practical benefits.

Enhancing access to premium export markets for Māori agribusinesses involves addressing key challenges related to processor availability, capability development, financial and network access, and internal decision-making. Strengthening the support and understanding from industry bodies and leveraging the power of whakapapa networks for collective action are vital strategies. These efforts will improve market access and enable the effective branding and marketing of products, ensuring the fulfilment of processor contracts and enabling more accurate operation measurement and benchmarking.

Ngāi Tahu provides several powerful examples of how cultural authenticity can be used to great effect in gaining a premium for Māori products. Although not a food or fibre initiative, Ngāi Tahu Pounamu uses provenance to communicate the cultural authenticity of pounamu products. This initiative has seen premiums of between 30 per cent and 50 per cent for culturally authentic product over inauthentic product (Barr and Reid, 2014).

5.7 New uses in the Māori Bioeconomy

Several new developments in the Māori bioeconomy highlight a dual focus on sustainability and high-value product development that maintain or promote cultural foundations. Some new resources, such as karengo, are still conceptual and have not been commercialised at scale, but they offer future potential. Others, such as bioactives and extracts, have attracted significant capital investment in recent years and may provide considerable revenue streams for Māori businesses.

Karengo

Karengo is a red seaweed with high protein, omega-3 fatty acids, and vitamin B12 content. With 30-35 per cent protein by dry weight, karengo surpasses most terrestrial plants' protein content and includes significant levels of eicosapentaenoic acid (EPA) and vitamin B12.

Karengo is regarded as a taonga species (a treasure) by Māori. Although individuals are permitted to harvest it from the wild for their own consumption, only a single commercial harvesting license has been issued. This license allows for the hand-collection of a predetermined quantity of karengo. The harvesting period is limited to between July and September and occurs along a specific section of the South Island's coastline.

The Sustainable Seas National Science Challenge has been investigating the commercial potential for karengo farming. Collaborations with Wakatū Incorporation and Te Rūnanga o Ngāi Tahu aim to develop sustainable aquaculture methods for karengo, focusing on producing a protein-enriched extract. Challenges have been encountered in scaling the extraction process from lab to pilot plant, but they have shown promise for commercial viability. The broader context includes efforts to establish a thriving karengo industry in New Zealand but faces challenges such as sustainable production and regulatory frameworks. The research contributes to a larger goal of diversifying New Zealand's economy through the aquaculture sector, aligned with the government's strategy to build a $3 billion industry by 2030. At present, however, the New Zealand regulatory framework is not conducive to establishing seaweed farms.

Karengo is one of a number of seaweed species that provide promise for new bioeconomy opportunities. However, the sector is nascent and little data are available to demonstrate the success of enterprises farming seaweed.

Macrocystis (giant kelp)

Kelp is a fast-growing organism that sequesters CO_2 through photosynthesis, converting it into biomass and organic material. This material, divided into Dissolved Organic Carbon (DOC) and Particulate Organic Carbon (POC), is either consumed by microbes or sinks to the ocean floor, effectively sequestering carbon permanently. The harvested kelp canopy can also be processed into products for agriculture, pharmaceuticals, and textiles.

Kelp Blue is establishing a pilot farm in Akaroa Harbour in partnership with the local papatipu rūnanga, Ōnuku. This farm focuses on sustainable macrocystis (giant kelp) cultivation, environmental impact assessment, and optimising biorefinery processes for agricultural biostimulants.

The kelp growing operation with Ōnuku is world-leading and has attracted significant attention from international investors. Through this operation, Ōnuku wants to showcase the ability of Māori organisations to generate substantial financial returns through a high-tech industry while simultaneously providing a net positive environmental benefit.

Cannabis and cannabis extracts

Rua Bioscience, is a Māori-born biotech company in Aotearoa that stands out as the only medicinal cannabis company in the country with a focus on social impact. Located in Ruatorea at the Mangaoporo cultivation site, Rua leverages intergenerational plant knowledge and advanced research and development to produce research and discovery crops. The company aims to develop unique and superior cannabis strains in Te Tairawhiti for large-scale global distribution, highlighting its commitment to innovation and social responsibility within the medicinal cannabis industry.

Several other Māori entities have entered the cannabis/hemp cultivation and extraction industry. Due to New Zealand having the world's most stringent processing standards for cannabis products, this industry requires a very high level of scientific knowledge and technical competency. While current legislation restricts the ability of the New Zealand cannabis markets to satisfy international demands, this industry presents future potential as a high-value industry within the Māori bioeconomy.

Bioactives - Te Whai Ao and Ligar

Te Awanui Huka Pak and Te Whai Ao, led by CEO Te Horipo Karaitiana, aim to initiate a Māori-led export sector by leveraging bioactives from New Zealand's plant-based foods and horticulture. Focused on sustainable growth and enhancing the value of primary sector exports, Te Whai Ao seeks to expand the impact of horticultural activities and boost Māori capability and enterprise. The initiative's first project involves analysing bioactive molecules in biomass from Māori land, starting with waste from avocado and kiwifruit production. This approach aligns with the government's vision for a productive, sustainable, and inclusive primary sector, transforming horticultural waste into higher-value products and supporting New Zealand's broader economic and environmental goals.

This development is the first of the regional Federation of Māori Authorities' FOMA Innovation Solutions Labs, intended to provide Māori with new pathways into innovative enterprises and the high-tech sector. The conversion of waste products into high-value extracts embraces Māori relationships with the natural world.

5.8 Summary

The Māori Bioeconomy provides insights into the significant role of Māori agribusiness in New Zealand's bioeconomy, emphasising the context in which Māori are responding to changes. Māori enterprises, particularly in agriculture, forestry, and fisheries, play a pivotal role in the nation's economy, contributing substantially to GDP and exports. This chapter further discussed new demands on the Māori bioeconomy, including finance, skills, market access, regulatory challenges, and the need for relationships and trust, highlighting strategies for overcoming these barriers and capitalising on opportunities for growth and sustainability.

The Māori approach to biological resources and their allocation is deeply rooted in traditional values, notably Tauutuutu, emphasising reciprocity and the interdependence of economic, social, and environmental wellbeing. These values guide Māori enterprises in their decisions and interactions, fostering a unique economic model that balances profit with the principles of guardianship (kaitiakitanga) and sustainability.

This chapter also explored the impacts of various scenarios on Māori biological resources, such as the transition of land use from agriculture to forestry for bioenergy and the pursuit of premium market access for Māori products. These scenarios underscore the potential for Māori to lead in sustainable practices and innovations while navigating the complexities of market dynamics and environmental challenges.

This chapter also highlighted new uses within the Māori bioeconomy, for example initiatives like sustainable aquaculture and the development of high-value products from indigenous flora, which exemplify the innovative and adaptive nature of Māori enterprises. Supportive policies, targeted investments, and collaborative efforts to bolster the Māori contribution to New Zealand's bioeconomy are crucial in any land-use changes. The chapter underscored the importance of innovation, scalability, and incorporating Māori values to achieve sustainable wellbeing and economic prosperity.

Chapter 6
Conclusion

The biological sector is essential to New Zealand's economy, wellbeing and quality of life. It accounts for more than three-quarters of the country's merchandise exports and provides a broad range of ecosystem services. However it also contributes over half of New Zealand's GHG emissions. New Zealand will soon be asking even more of our biological resources in order to grow the value of our exports and to transition to bio-based energy and materials. For New Zealand to prosper we need to increase the economic, social, environmental, and cultural outcomes from our limited biological resources and manage the trade-offs arising from increased demand.

This report examined the existing uses of biological resources and their impact on economic, social, environmental, and cultural outcomes. It modelled the trade-offs arising from bioenergy demand and identifies the considerable opportunities to enhance the value and outcomes derived from the bioeconomy.

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Appendix A
Land Use Change in Scenarios by Region

Scenario 1 – Bioenergy 75PJ

Table A1: Energy allocation and bioenergy forestry outcomes for Scenario 1 – Bioenergy 75PJ

Region	Energy per year (PJ)	Bioenergy forestry land for 28 year cycle (Ha)	Hill country Sheep & Beef allocated to Bioenergy forestry (%)	Biomass yield per year (Tonnes)	In-forest residues per year (m^3)
Northland	3.849	55,159	20%	535,736	15,056
Auckland	1.521	21,796	26%	211,698	4,784
Waikato	7.356	81,101	21%	1,024,000	52,616
Bay of Plenty	3.716	40,964	66%	517,227	5,492
Gisborne	2.581	32,483	14%	359,257	5,942
Hawkes Bay	4.352	47,222	10%	605,745	11,698
Taranaki	2.233	26,428	24%	310,799	3,759
Manawatū-Whanganui	6.840	80,958	11%	952,063	28,795
Wellington	2.477	29,325	14%	344,861	14,162
Tasman	2.736	30,826	100%	380,850	5,047
Nelson	0.130	1,463	64%	18,081	45
Marlborough	3.219	36,841	19%	448,075	6,172
West Coast	1.091	16,599	100%	151,922	6,731
Canterbury	13.698	208,335	24%	1,906,783	53,185
Otago	9.599	137,821	13%	1,336,170	31,848
Southland	9.602	127,083	36%	1,336,599	36,131
Total	75.000	974,404	19%	10,439,866	281,767

Table A2: Land use change (ha) for Scenario 1 – Bioenergy 75PJ

	Sheep & Beef 1 SI High Country	Sheep & Beef 2 SI Hill Country	Sheep & Beef 3 NI Hard Hill Country	Sheep & Beef 4 NI Hill Country	Exotic Forestry Unpruned for Bio-Energy
Northland				-54,993	+54,993
Auckland			-11,057	-10,674	+21,731
Waikato			-41,141	-39,715	+80,856
Bay of Plenty			-20,781	-20,060	+40,841
Gisborne			-10,529	-21,855	+32,384
Hawke's Bay			-15,307	-31,773	+47,080
Taranaki			-10,010	-16,339	+26,349
Manawatū-Whanganui			-30,662	-50,051	+80,713
Wellington			-9,506	-19,731	+29,236
Tasman	-21,105	-12,141			+33,246
Nelson	-926	-533			+1,459
Marlborough	-23,316	-13,413			+36,729
West Coast	-10,537	-6,062			+16,599
Canterbury	-131,852	-75,853			+207,706
Otago	-87,225	-50,180			+137,405
Southland	-80,429	-46,270			+126,700
TOTAL New Zealand	-355,391	-204,453	-148,994	-265,190	+974,027

Table A3: Energy allocation and bioenergy forestry outcomes for Scenario 2 – Bioenergy 150PJ

Region	Energy per year (PJ)	Bioenergy forestry land for 28 year cycle (Ha)	Hill country Sheep & Beef allocated to Bioenergy forestry (%)	Biomass yield per year (Tonnes)	In-forest residues per year (m^3)
Northland	8.025	115,010	42%	1,117,038	31,487
Auckland	3.171	45,447	55%	441,401	10,004
Waikato	15.339	169,100	45%	2,135,093	110,040
Bay of Plenty	5.591	61,633	100%	778,191	8,289
Gisborne	5.381	67,728	28%	749,069	12,426
Hawkes Bay	9.073	98,461	21%	1,263,010	24,465
Taranaki	4.655	55,105	51%	648,032	7,862
Manawatū-Whanganui	14.261	168,801	23%	1,985,101	60,221
Wellington	5.166	61,144	30%	719,053	29,618
Tasman	2.736	30,826	100%	380,850	4,679
Nelson	0.202	2,275	100%	28,111	70
Marlborough	6.712	76,815	39%	934,260	12,909
West Coast	1.091	16,599	100%	151,922	6,731
Canterbury	28.562	434,388	50%	3,975,740	111,229
Otago	20.015	287,363	27%	2,785,984	66,606
Southland	20.021	264,975	76%	2,786,877	75,564
Total	150.000	1,955,669	39%	20,879,733	565,737

Energy Scenario 2 – Bioenergy 150PJ

Table A4: Land use change (ha) for Scenario 2 – Bioenergy 150PJ

	Sheep & Beef 1 SI High Country	Sheep & Beef 2 SI Hill Country	Sheep & Beef 3 NI Hard Hill Country	Sheep & Beef 4 NI Hill Country	Exotic Forestry Unpruned for Bio-Energy
Northland				-115,010	115,010
Auckland			-23,124	-22,322	45,447
Waikato			-86,042	-83,058	169,100
Bay of Plenty			-31,360	-30,273	61,633
Gisborne			-22,021	-45,707	67,728
Hawke's Bay			-32,013	-66,448	98,461
Taranaki			-20,934	-34,171	55,105
Manawatū-Whanganui			-64,126	-104,675	168,801
Wellington			-19,880	-41,264	61,144
Tasman	-19,568	-11,257			30,826
Nelson	-1,444	-831			2,275
Marlborough	-48,762	-28,052			76,815
West Coast	-10,537	-6,062			16,599
Canterbury	-275,751	-158,637			434,388
Otago	-182,419	-104,944			287,363
Southland	-168,207	-96,768			264,975
TOTAL New Zealand	-616,837	-354,861	-340,944	-643,027	1,955,669

Exports Scenario 1

Table A5: Land use change (ha) for High Value Export Scenario

	Sheep & Beef 5 NI Intensive Finishing Farms	Sheep & Beef 6 SI Finishing-Breeding Farms	Sheep & Beef 7 SI Intensive Finishing Farms	Sheep & Beef 8 SI Mixed Finishing Farms	Arable	Dairy 4 & 5 High input
Northland					-2,326	+2,326
Auckland	-9,813				-1,145	+10,959
Waikato	-44,679				-13,710	+58,389
Bay of Plenty	-7,299				-4,266	+11,565
Gisborne	-36,975				-2,835	+39,810
Hawke's Bay	-70,954				-8,211	+79,165
Taranaki	-9,465				-3,316	+12,781
Manawatū-Whanganui	-65,107				-13,094	+78,202
Wellington	-31,900				-5,199	+37,100
Tasman		-12,778		-3,523	-1,109	+17,410
Nelson		-943		-260		+1,203
Marlborough		-81,500		-22,474	-2,749	+106,723
West Coast		-6,880		-1,897	-1,926	+10,704
Canterbury		-361,560		-99,700	-114,629	+575,889
Otago		-197,324	-189,350		-37,876	+424,550
Southland		-65,713	-63,058		-31,490	+160,261
Total	**-276,193**	**-726,698**	**-252,408**	**-127,855**	**-243,882**	**+1,627,036**

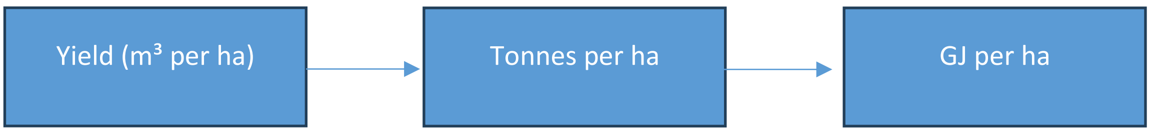
Appendix B
Bioenergy Production Calculation

To assess the bioenergy production potential for a region, the calculation begins with estimating the forest yield, converting this yield into metric tonnes of biomass, and determining the energy potential using specified conversion rates:

1. **Determining Potential Forest Yield**: The bioenergy production calculation starts with estimating the potential yield of forests in the region. This is based on the 2015 MPI Yield tables, which provide information on the Total Recoverable Volume (TRV) of forests. For this calculation, the assumption is made that all exotic forestry consists of unpruned Pinus radiata trees harvested at 28 years of age.

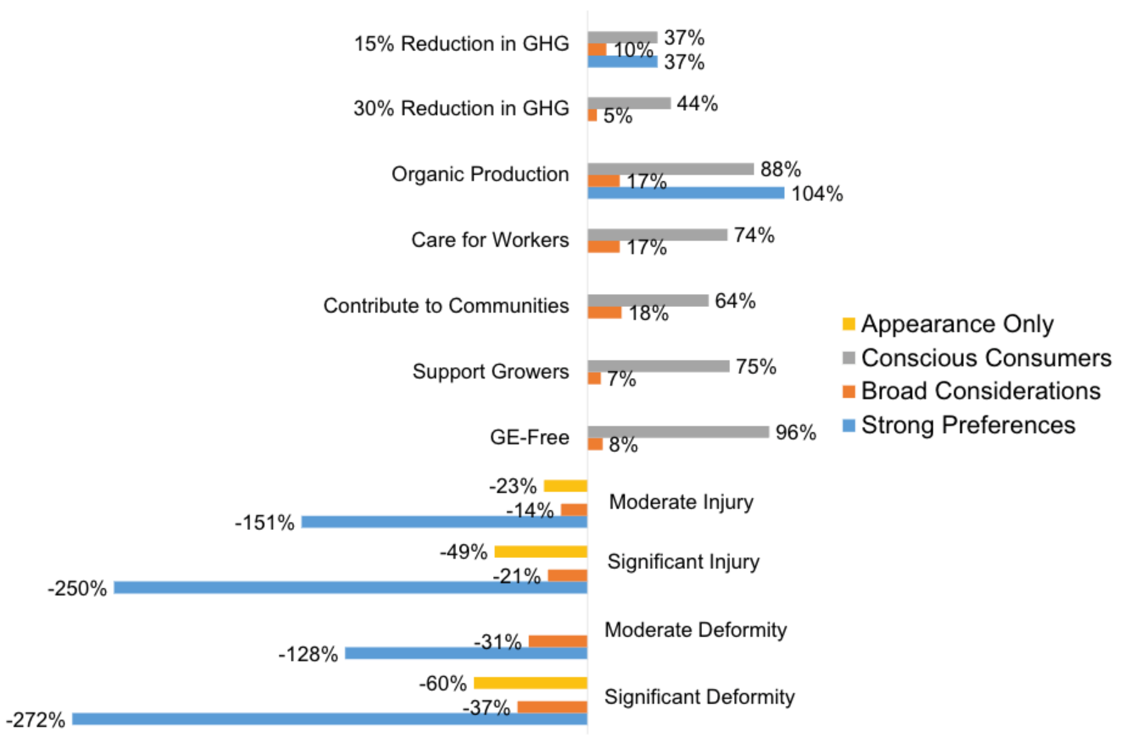
2. **Converting to Metric Tonne of Biomass**: Once the Total Recoverable Volume (TRV) is determined from the MPI Yield tables, it needs to be converted into metric tonnes of biomass. The conversion rate used is 0.49 tonnes of woody biomass per cubic meter (m^3) of woody biomass.

3. **Calculating Energy Potential**: After obtaining the total biomass in metric tonnes, the next step is to calculate the energy potential of this biomass. The constant conversion rate provided is 7.184 gigajoules (GJ) per tonne, which represents the net energy potential of biomass from Pinus radiata wood as advised by EECA (Energy Efficiency and Conservation Authority).



Appendix C
Premiums for Credence Attributes of Horticultural and Agricultural Products by Consumers

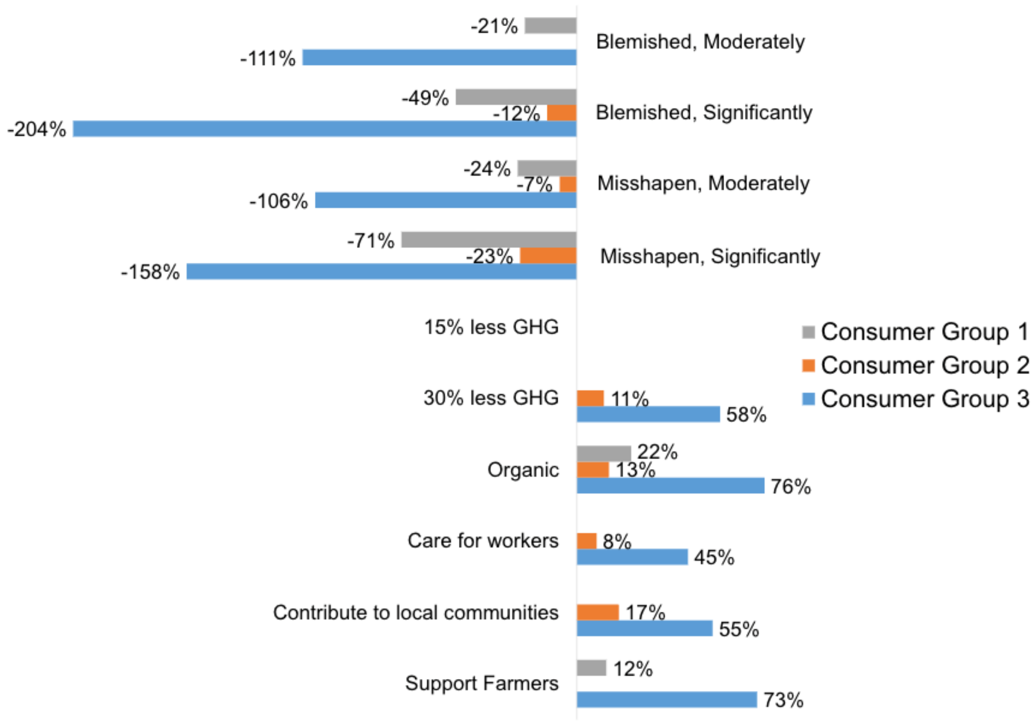
Apples in California, USA (2021)



Californian apple consumers' willingness-to-pay (WTP) for apple attributes (% of product price), 2021

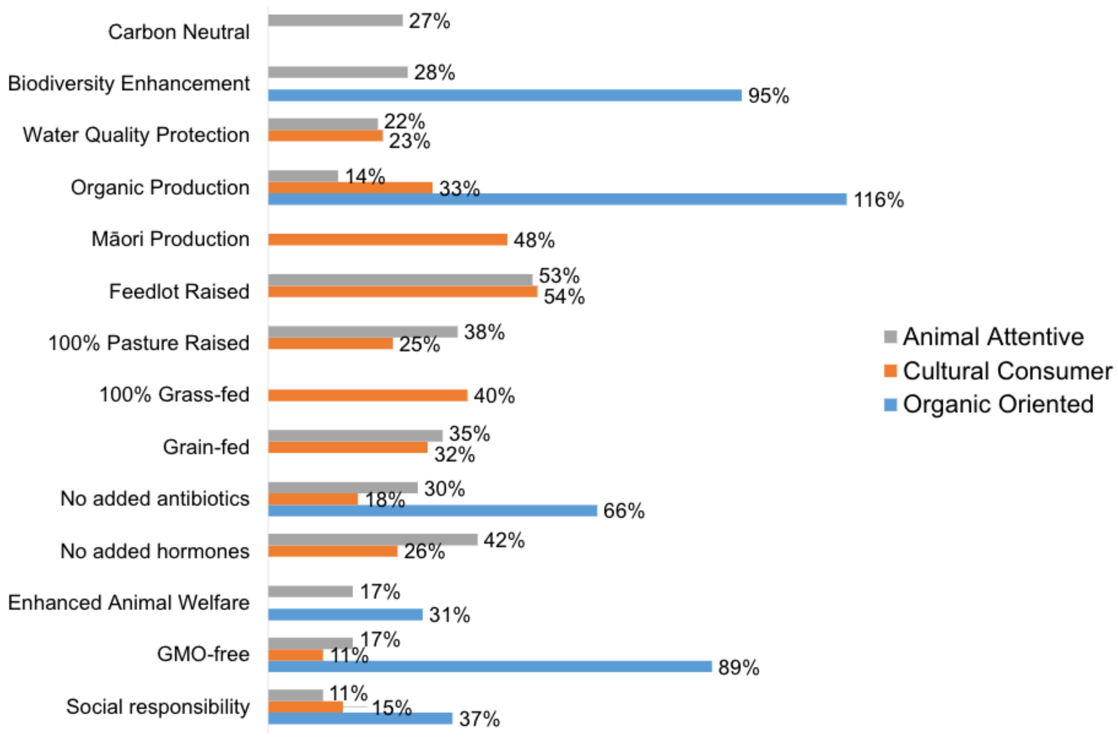
These graphs are derived from the *AERU Data Portal Consumer Willingness-to-pay* sourced from https://www.aeru.co.nz/wtp (AERU, 2022b)

Apples in California, USA (2020)



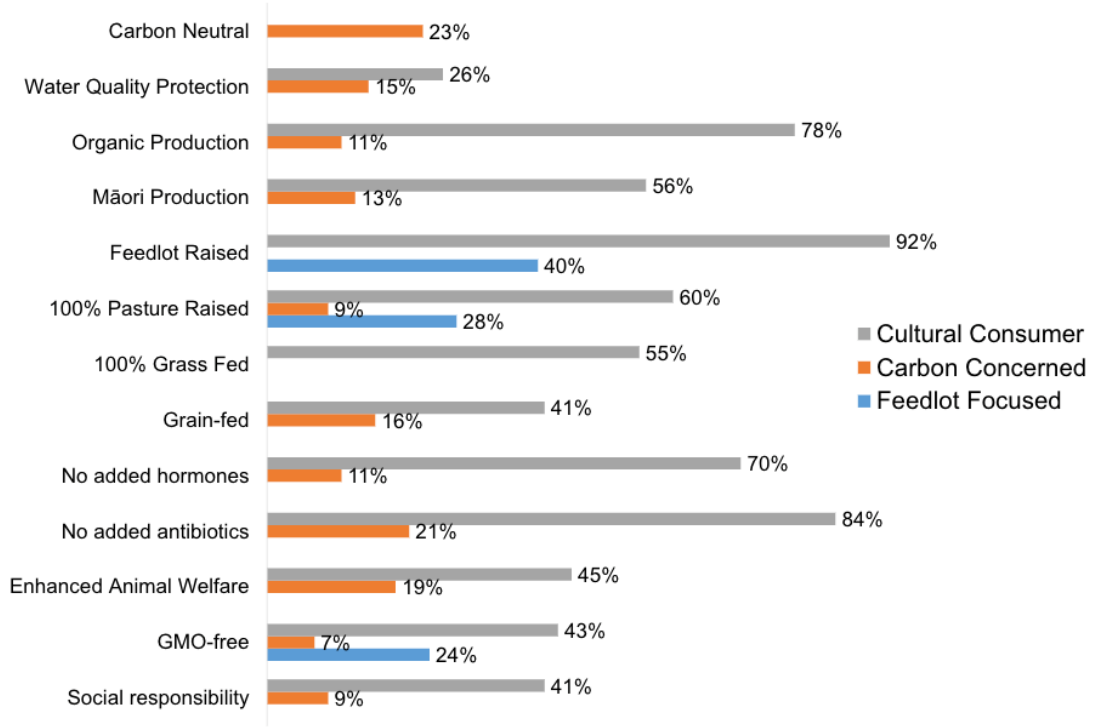
Californian apple consumers' willingness-to-pay (WTP) for apple attributes (% of product price), 2020

Beef in Beijing, China (2021)



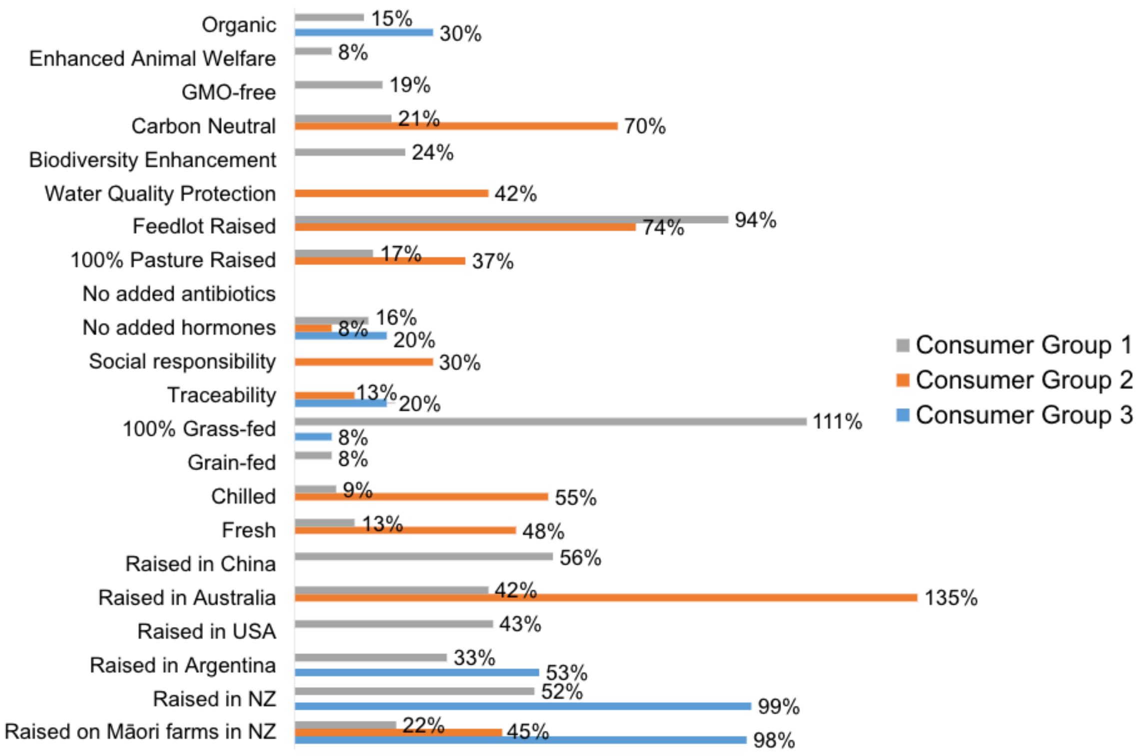
Beijing beef consumers' willingness-to-pay (WTP) for beef tenderloin attributes (% of product price), 2021

Beef in the United Arab Emirates (2021)



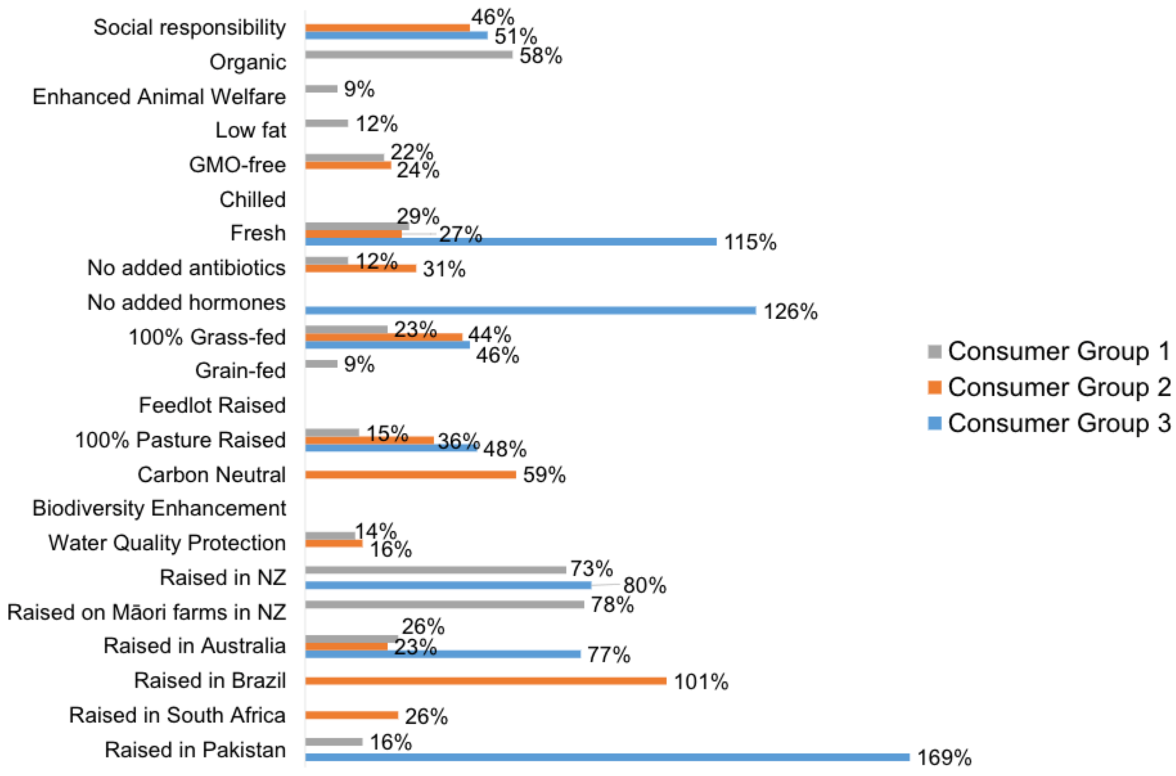
United Arab Emirates beef consumers' willingness-to-pay (WTP) for beef mince attributes (% of product price), 2021

Beef in Beijing, China (2019)



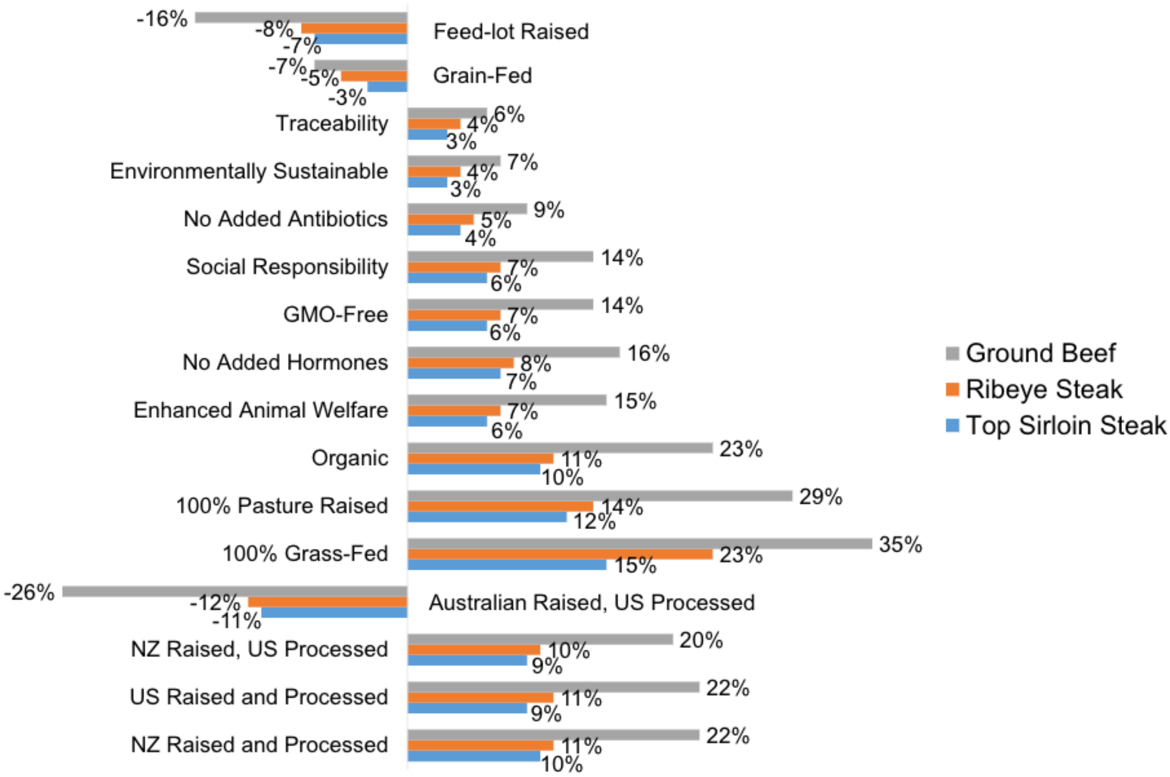
Beijing beef consumers' willingness-to-pay (WTP) for beef tenderloin attributes (% of product price), 2019

Beef in the United Arab Emirates (2019)



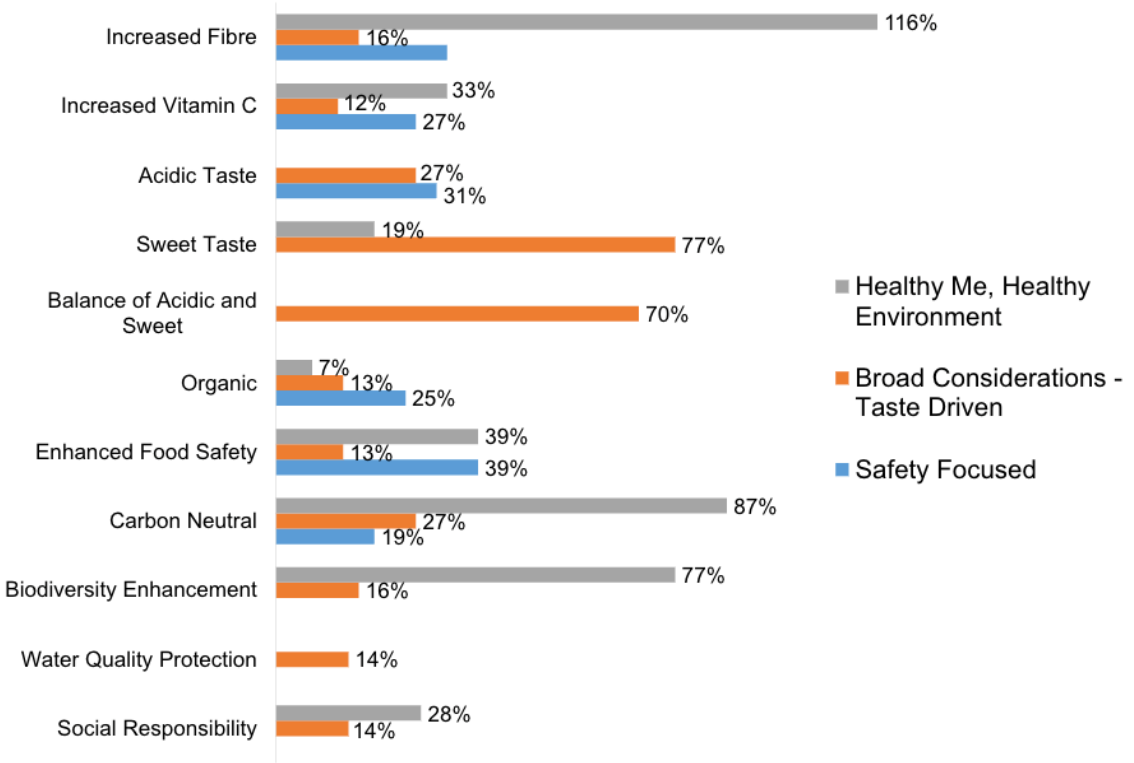
United Arab Emirates beef consumers' willingness-to-pay (WTP) for beef mince attributes (% of product price), 2019

Beef in California, USA (2017)



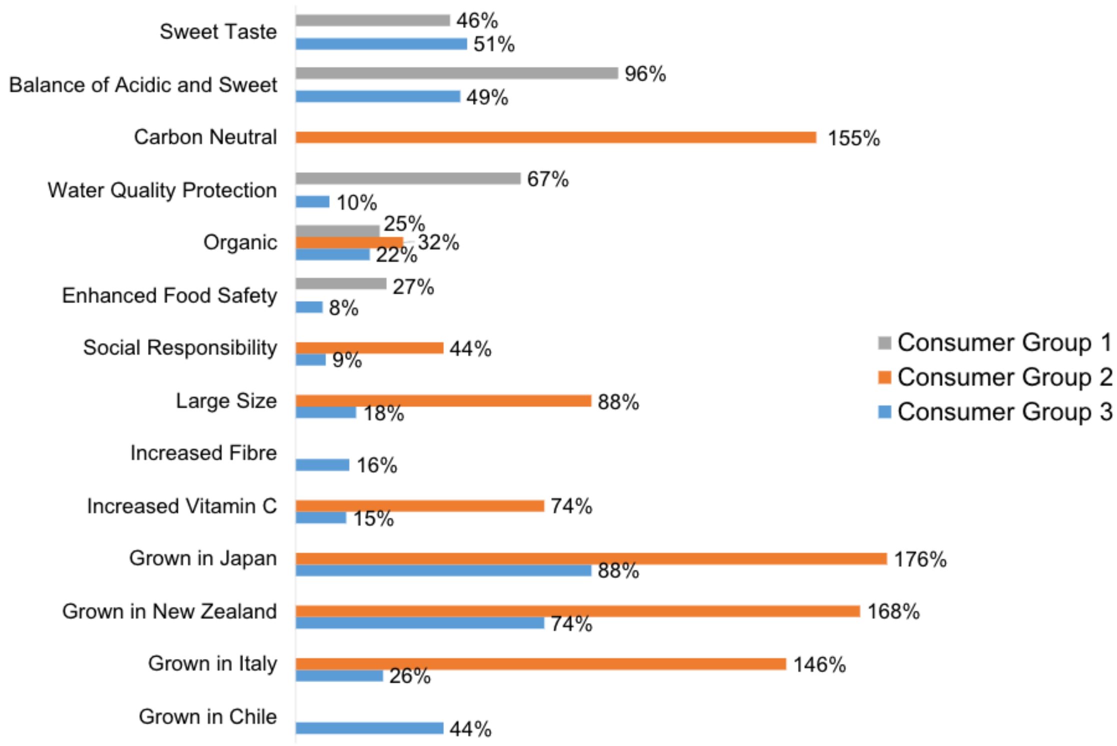
Californian beef consumers' willingness-to-pay (WTP) for beef product attributes (% of product price), 2017

Kiwifruit in Japan (2021)



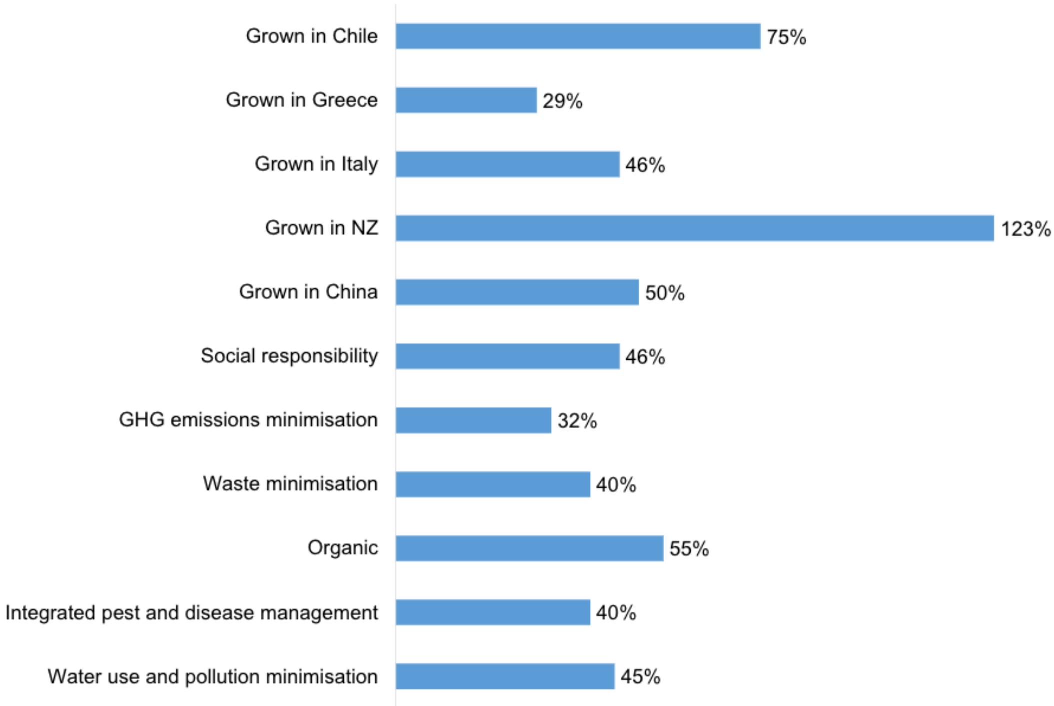
Japanese kiwifruit consumers' willingness-to-pay (WTP) for kiwifruit attributes (% of product price), 2021

Kiwifruit in Japan (2019)



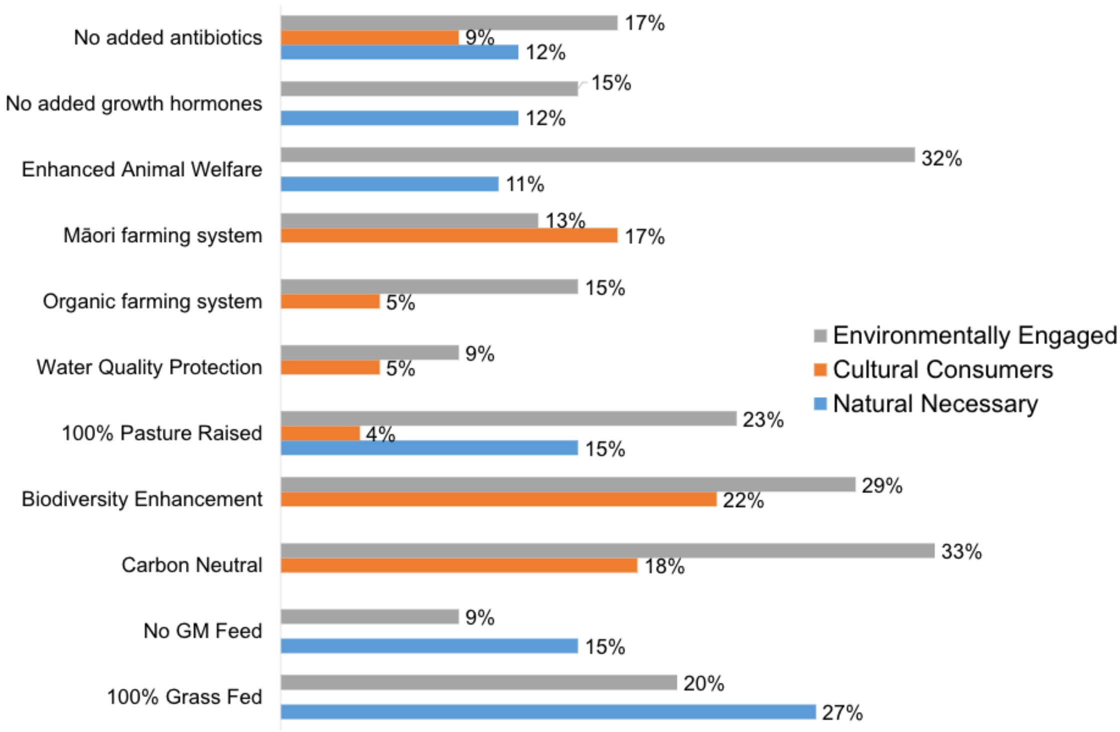
Japanese kiwifruit consumers' willingness-to-pay (WTP) for kiwifruit attributes (% of product price), 2019

Kiwifruit in Shanghai, China (2018)



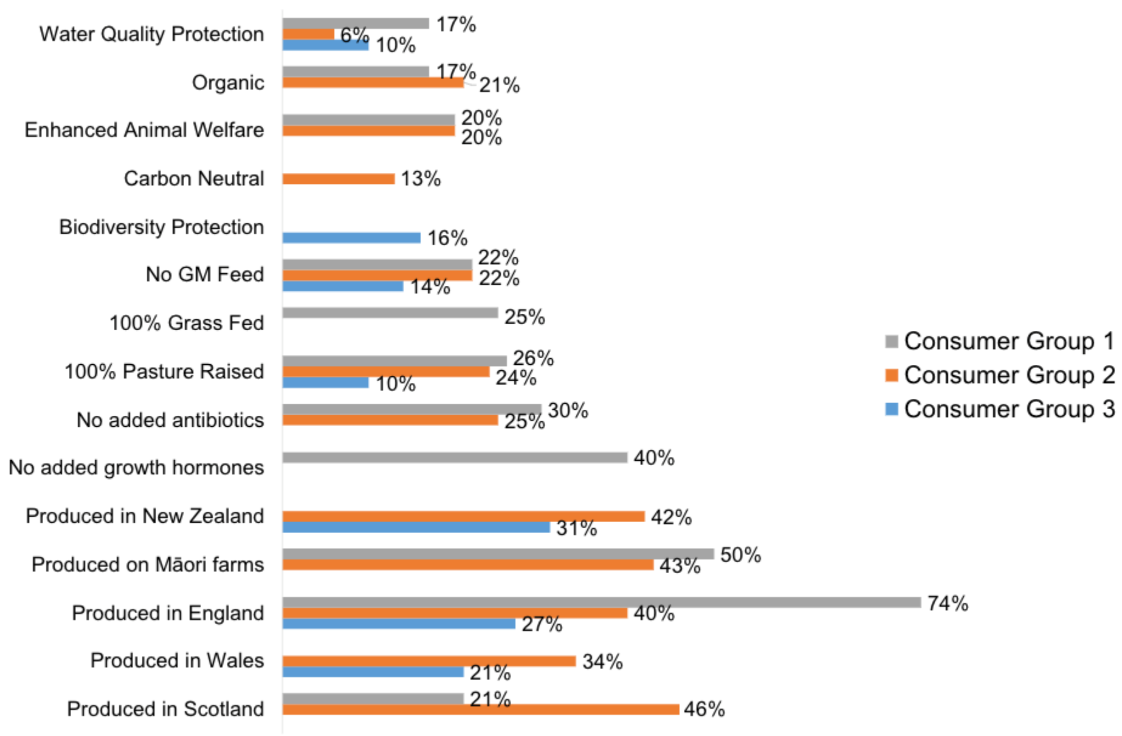
Shanghai kiwifruit consumers' willingness-to-pay (WTP) for kiwifruit attributes (% of product price), 2018

Lamb in the United Kingdom (2021)



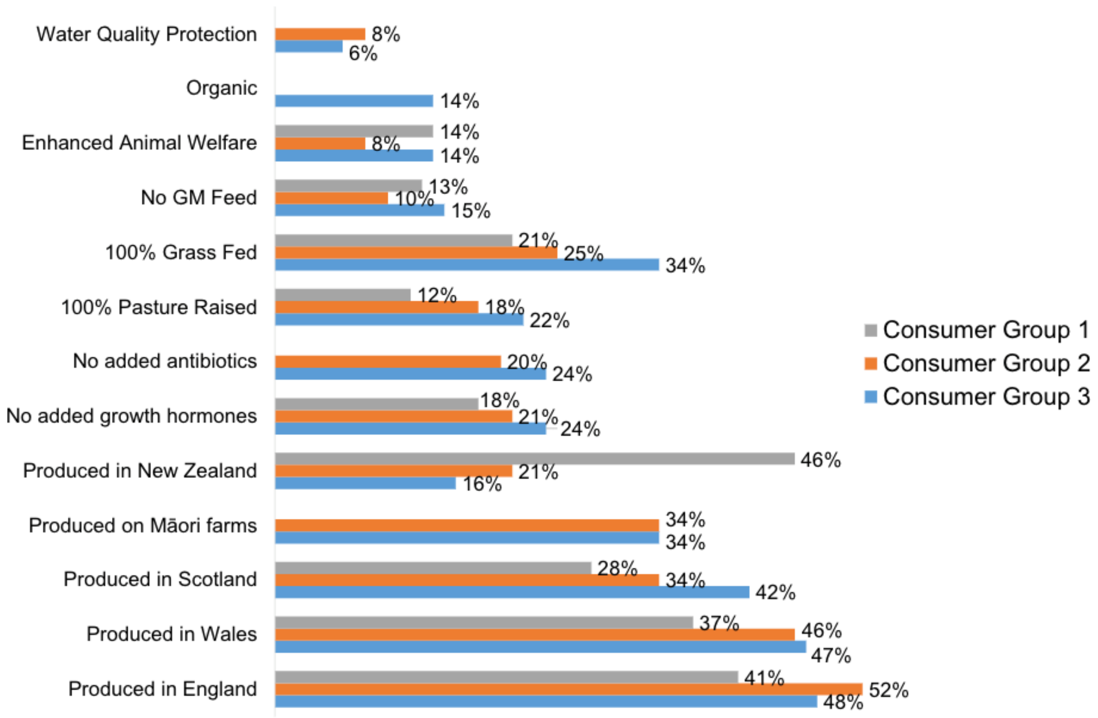
United Kingdom lamb consumers' willingness-to-pay (WTP) for lamb leg attributes (% of product price), 2021

Lamb in the United Kingdom (2020)



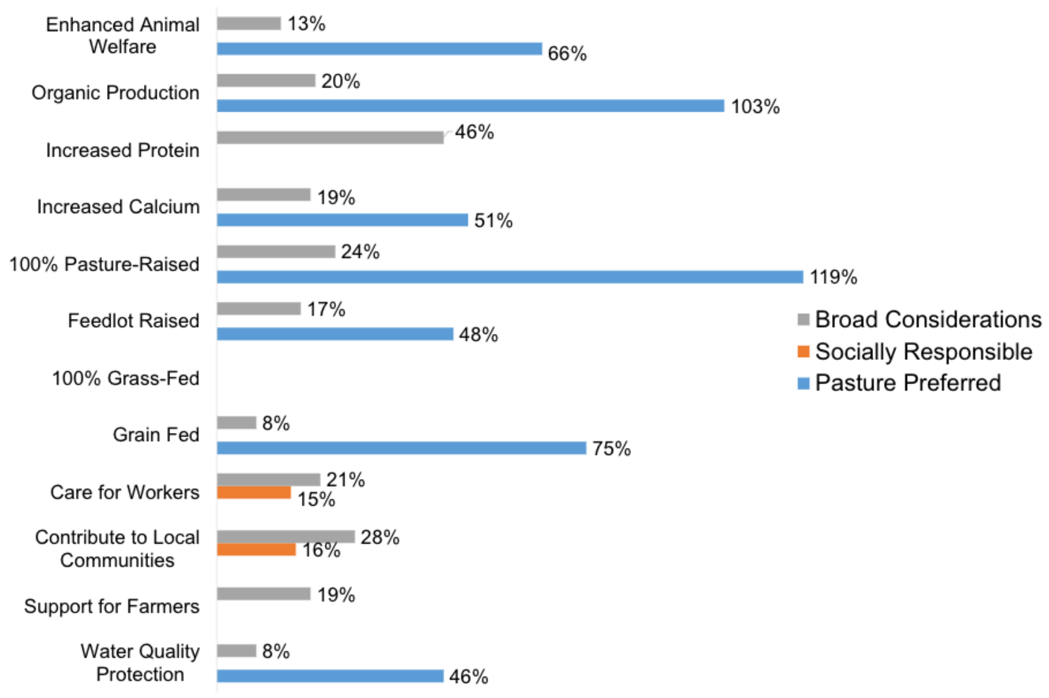
United Kingdom lamb consumers' willingness-to-pay (WTP) for lamb leg attributes (% of product price), 2020

Lamb in the United Kingdom (2019)



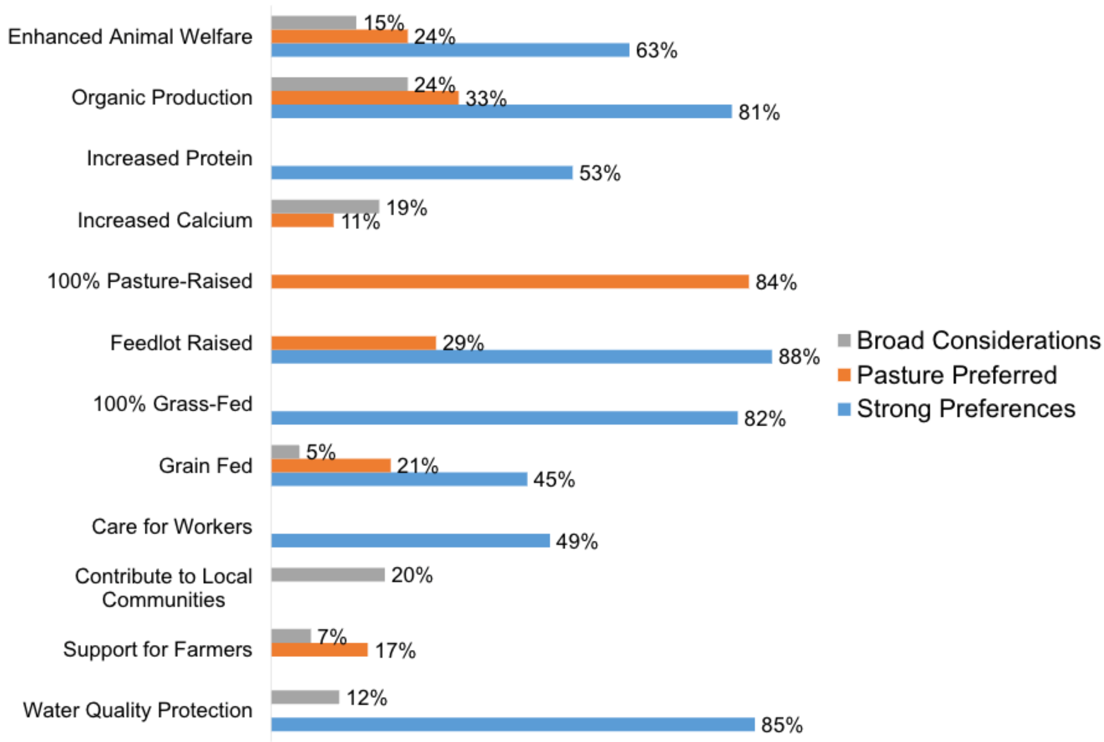
United Kingdom lamb consumers' willingness-to-pay (WTP) for lamb leg attributes (% of product price), 2019

UHT Milk in Beijing, China (2021)



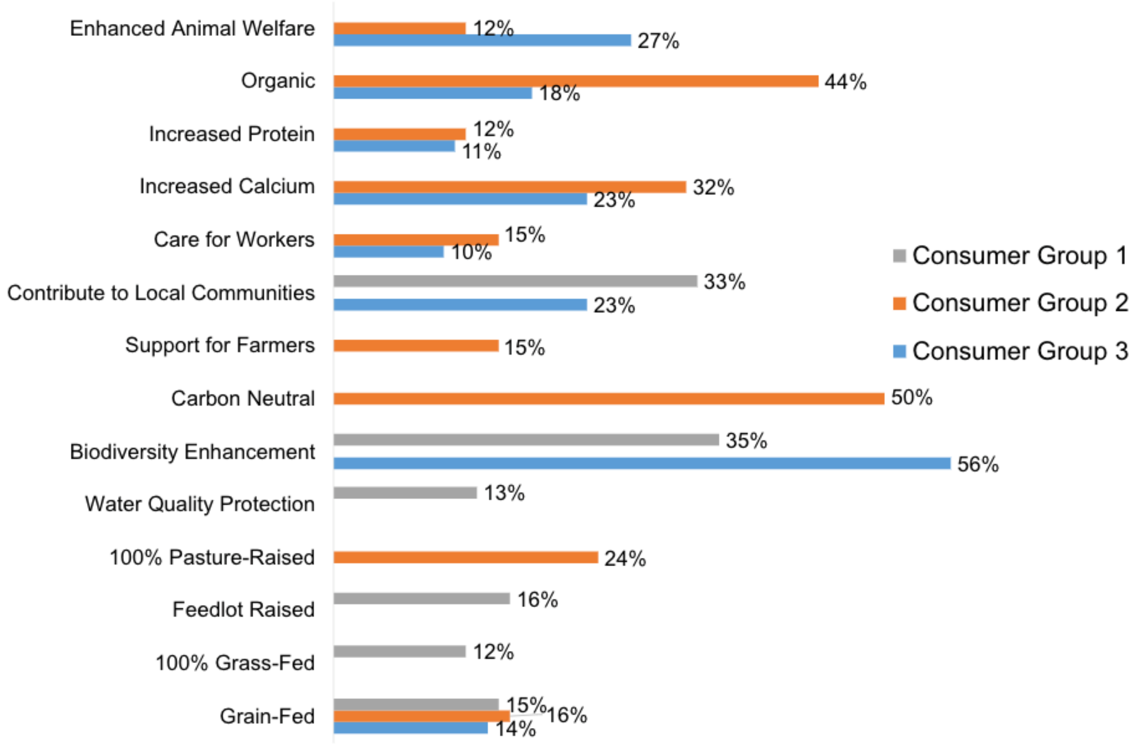
Beijing UHT milk consumers' willingness-to-pay (WTP) for UHT milk product attributes (% of product price), 2021

UHT Milk in Shanghai, China (2021)



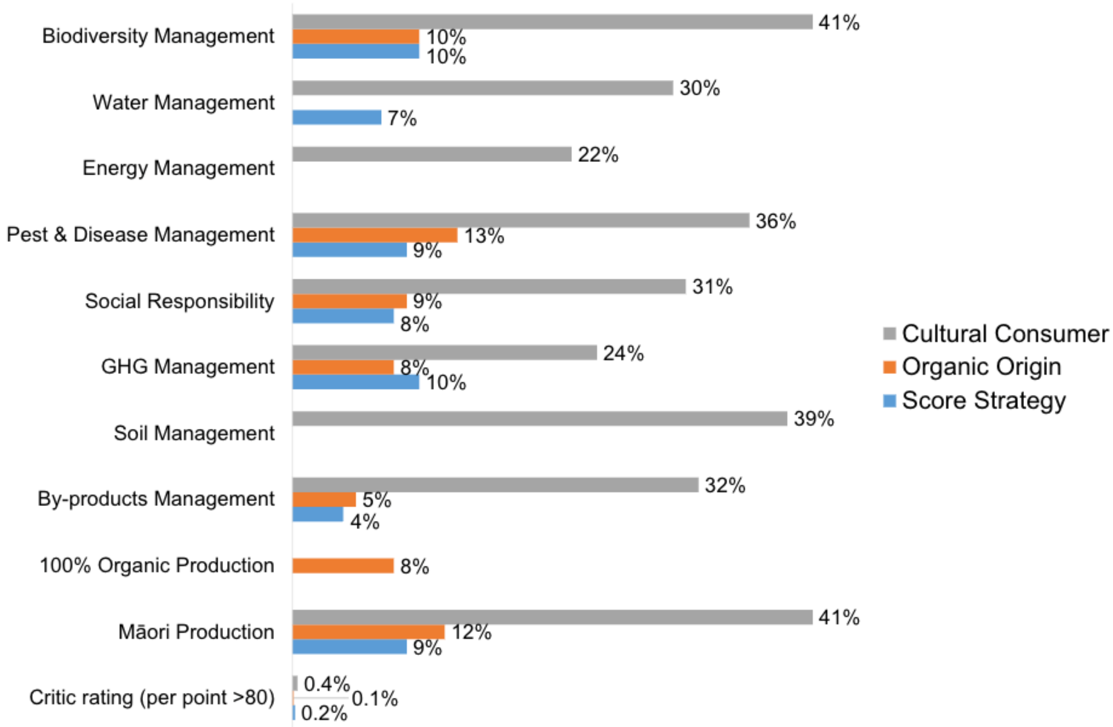
Shanghai UHT milk consumers' willingness-to-pay (WTP) for UHT milk product attributes (% of product price), 2021

UHT Milk in Beijing, China (2019)



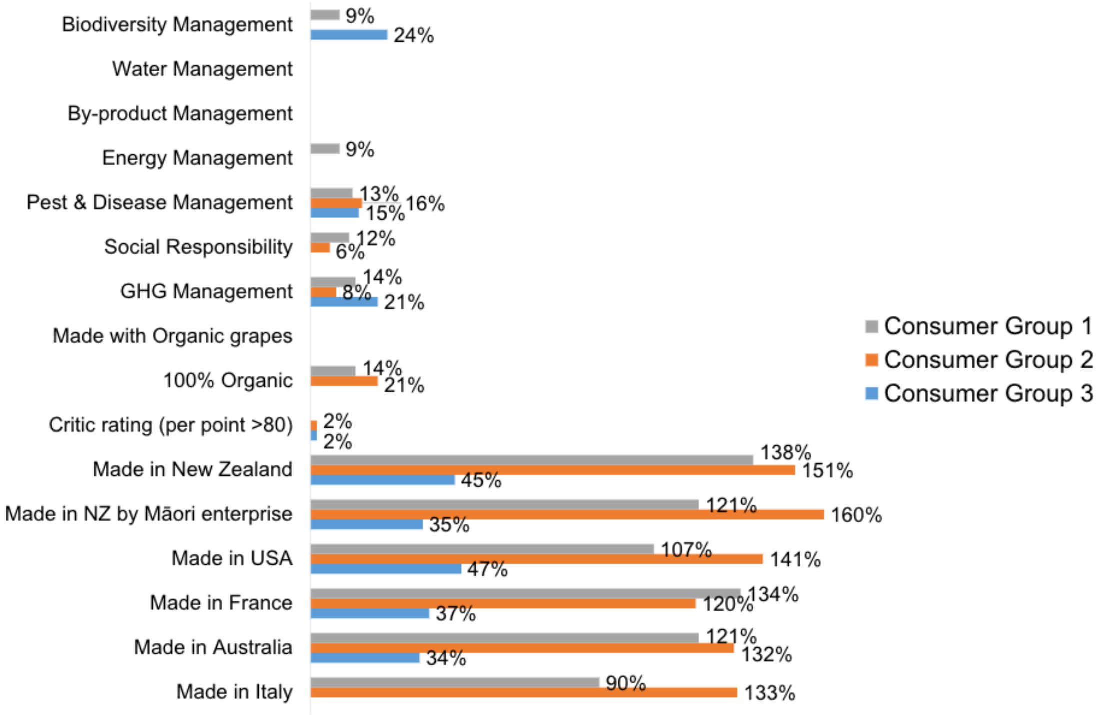
Beijing UHT milk consumers' willingness-to-pay (WTP) for UHT milk product attributes (% of product price), 2019

Wine (Sauvignon Blanc) in California, USA (2021)



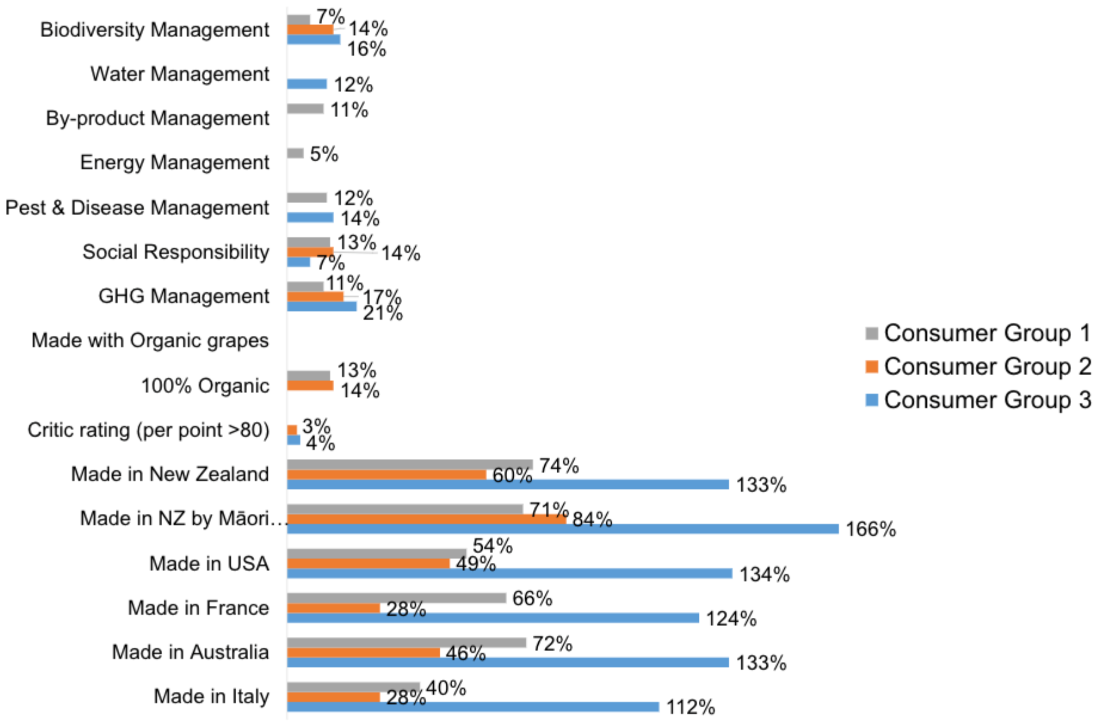
Californian wine consumers' willingness-to-pay (WTP) for sauvignon blanc attributes (% of product price), 2021

Wine (Sauvignon Blanc) in New York, USA (2019)



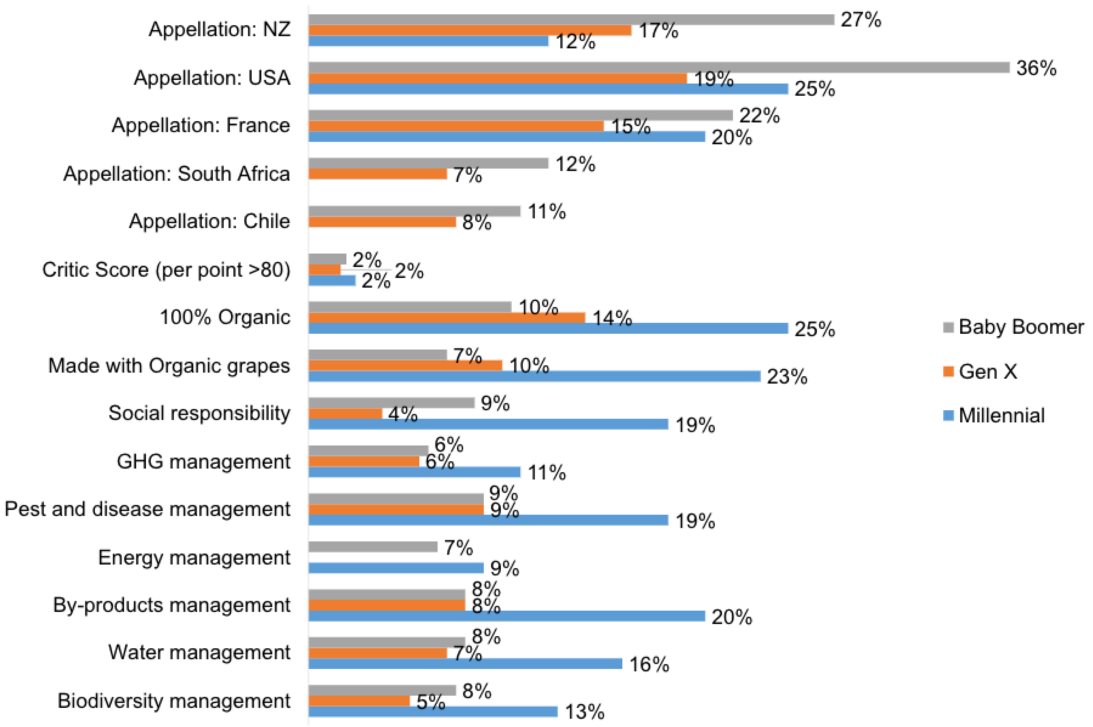
New York wine consumers' willingness-to-pay (WTP) for sauvignon blanc attributes (% of product price), 2019

Wine (Sauvignon Blanc) in Texas, USA (2019)



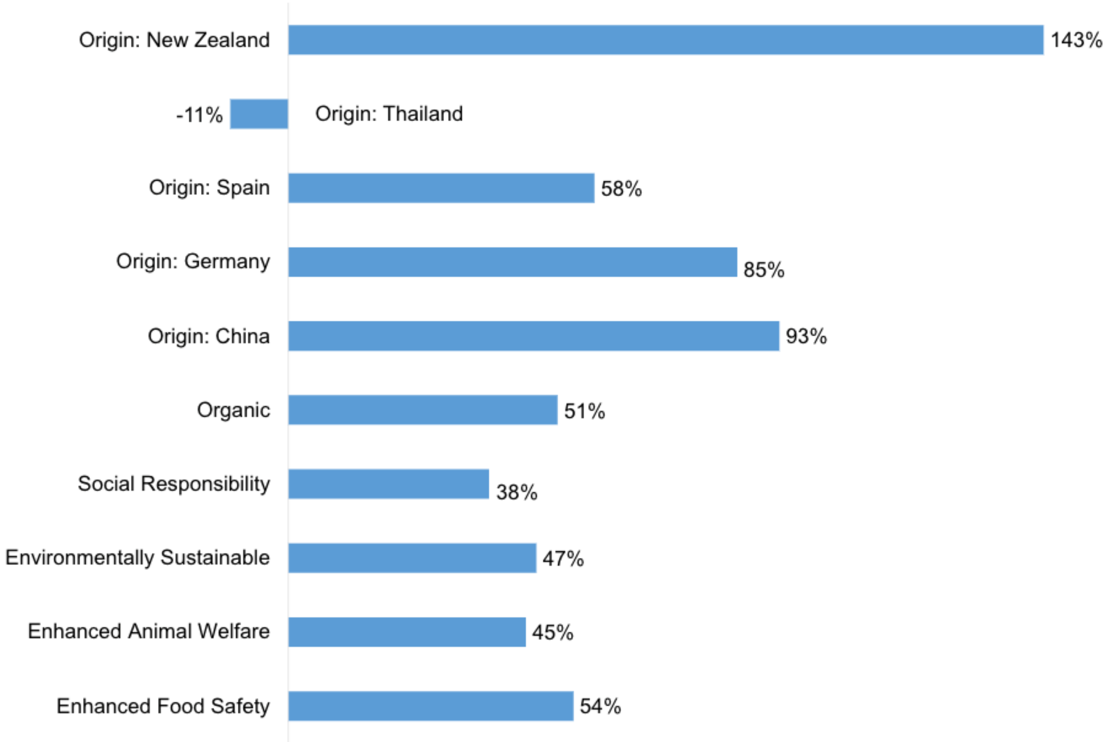
Texas wine consumers' willingness-to-pay (WTP) for sauvignon blanc attributes (% of product price), 2019

Wine (Sauvignon Blanc) in California, USA (2017)



Californian wine consumers' willingness-to-pay (WTP) for sauvignon blanc attributes (% of product price), 2017

Yoghurt in Shanghai, China (2018)



Shanghai yoghurt consumers' willingness-to-pay (WTP) for yoghurt product attributes (% of product price), 2018