sapere

Benefits and Costs of Additional Investment in Wilding Conifer Control

Prepared for the Ministry for Primary Industries on behalf of the National Wilding Conifer Control Programme

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Glossary

Abbreviation	Stands for
BCR	Benefit cost ratio
CBA	Cost benefit analysis – a structured method for analysing the economic impact (costs and benefits) of a decision.
Density classes	Outlier: 0-1 % OPC infestation Sparse: 1-15% OPC infestation Intermediate: 15-75% OPC infestation Dense: 75-100% OPC infestation
EBITR	Earnings Before Interest and Taxes and Rent. Used as a measure of business profitability.
ETS	Emissions Trading Scheme - a market-based approach for reducing emissions of greenhouse gases by charging producers for the gases they emit and providing credits for those that remove gasses.
MPI	Ministry for Primary Industries
MU	Management unit – the administrative boundaries the country has been divided into for the National Wilding Conifer Control Programme
NWCCP	National Wilding Conifer Control Programme
NPV	Net present value – the sum of all costs and benefits discounted to today's dollars.
NZU	New Zealand Units – the emissions units that are traded as part of the ETS.
OAG	Operational Advisory Group – advisory group within the NWCCP providing advice on how and where operational activities are best delivered.
OPC	Overall percentage cover. Used to describe density of wilding infestation.
Phase one	Activity funded under the NWCCP between 2016/17 and 2018/19. $16m was allocated for this phase.
Phase two	Activity funded under the NWCCP between 2019/20 and 2020/21. In Budget 2019 ($21m) was allocated for this phase.
PV	Present value – the sum of costs or benefits discounted to today's dollars. Discounting is a way of recognising that a dollar today is worth more than a dollar tomorrow.
TEV	Total Economic Framework – a structured framework for valuing the benefits and costs of ecosystem services.
WCIS	Wilding Conifer Information System – administered by LINZ, WCIS collects details of infestations, control activities, operational areas and points of interest.

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Executive summary

Wilding conifers are invasive weeds that have a serious impact on New Zealand's primary industries and natural environment affecting native landscapes, land use, biodiversity, and cultural values. Introduced in the 1880s, these trees have spread from forests, shelterbelts and erosion control plantings and without control they will form dense forests (Department of Conservation). Manaaki Whenua modelling shows that if left unchecked, over the next fifty years wildings would spread to a further 500,000 hectares and 1.8 million hectares would be covered in dense forest. The aims of the New Zealand Wilding Conifer Management Strategy 2015–2030 are to prevent the spread of wilding conifers and to contain or eradicate established areas of wilding conifers by 2030.

Investment to date recognises the substantial benefits from controlling wilding conifers

$37 million, covering five years from July 2016 to June 2021, was invested in the National Wilding Conifer Control Programme (NWCCP). A 2018 cost benefit analysis concluded that the benefits of control greatly outweighed the costs (Wyatt, 2018). It also highlighted that sustainable management of wilding conifers would require investment well into the future if the intention is to reduce infestations to a level that is manageable by landowners.

Additional investment was made in Budget 2020 with $100 million committed over four years to the NWCCP under the Jobs for Nature programme. This has seen the expansion of the control programme across New Zealand and with it, immediate benefits from job creation in regions that were hit hard economically by COVID-19. While the benefits of job creation were important for these communities, controlling wilding conifers has much larger societal benefits by protecting water for hydro power generation and irrigation, and the productive land saved from infestation.

Jobs for Nature funding comes to an end from 2023/24 with ongoing funding of $10 million per annum committed to the NWCCP. This level of funding would be insufficient for the programme to achieve control of wilding conifers on a national scale, with control activity scaled back from 49 active management units to 10 over a four-year period. Under this scenario, 42 per cent of the known national infestation would be actively managed while spread and regrowth would continue in the abandoned management units (MUs).

Reducing funding would result in a net loss of $3.8 billion

Realising the benefits of wilding conifer control requires sustained investment to prevent seedlings from re-establishing. If no further investment is made, the gains made by the programme so far would largely be lost, wilding conifers would reinfest much of the previously controlled land and continue to spread. The losses would be substantial, we estimate rolling back funding to $10 million per annum would result in losses of $3.8 billion over 50 years (measured in today's dollars) through losses in primary production, water yields, biodiversity, and increased fire risk. These losses are compared against the avoided expenditure and associated deadweight loss of $71 million for net losses of $3.8 billion. These losses are avoided if funding continues at a similar level as under the Jobs for Nature programme.

Table 1: Losses under the status quo scenario ($ millions)

Present value ($ million)		Status quo
Benefits	Productive land use	-$1,328
	Hydro	-$373
	Irrigation	-$695
	Biodiversity	-$1,262
	Fire	-$222
	TOTAL	**-$3,881**
Costs	Programme	-$59
	DWL	-$12
	TOTAL	**-$71**
Net present value		**-$3,810**

Source: Sapere Analysis

We assessed the costs and benefits of four investment options

This report presents an updated cost benefit analysis of wilding conifer control for the NWCCP and assesses the economic impact of additional investment in wilding conifer control for four investment options:

1) Status quo "losing the investment" – reduce funding to $10 million per annum and scale back control activities to 10 management units.
2) Minimum "protect the investment" – continue control activity across the existing 49 management units[1].
3) Intermediate "extend the investment" – expanding the activity to include a further 11 priority management units.
4) Maximum "national control" – the intermediate option plus a further 19 priority management units.

[1] the administrative boundaries the country has been divided into for the National Wilding Conifer Control Programme

The purpose of this cost benefit analysis is to inform the investment decision. We, therefore, compare the costs and benefits from additional investment to the counterfactual (also referred to as the Status quo option) of $10 million per annum ongoing funding.

A total economic value framework has been used for categorising and calculating the costs and benefits of the programme. The framework includes the economic impact on both productive land use values, and 'non-use' cultural and biodiversity values of the controlled land. Modelling of wilding conifer spread and ecological system impacts, developed by Manaaki Whenua (Landcare Research), was used to calculate the result and is a significant advancement on previous analyses. The benefits of the programme were monetised using market and non-market valuation techniques. The only benefit that has not been monetised is Māori cultural values, which is described qualitatively and should be presented alongside the monetary results of the CBA.

All options represent outstanding value for money

The results show that investment in wilding conifer control activities continues to be outstanding value for money for all options. Table 3 shows the benefits and costs of additional investment. Investment in maintaining the current level of activity would provide net benefits of $5.7 billion over 50 years at a benefit to cost ratio of 34:1. Extending the area controlled under the intermediate and maximum options would yield additional net benefits of $608 million and $963 million compared to the minimum option. As noted in table 2, reducing control to just the ten management units under the 'Status quo' option results in a significantly reduced net present value of $1.90 billion. While still good 'value for money' in the sense that it is better than not attempting to control wilding conifers at all it represents a significantly worse outcome than the other options analysed.

Table 2: CBA results for additional investment in wilding conifer control

Present value ($ million)	Status quo – losing the investment	Minimum – protect the investment	Intermediate – extend the investment	Maximum – national control
Management units actively managed	10	49	60	79
Per cent of known infestation	42.4%	90.0%	94.8%	95.1%
Present value of benefits	$1,998	$5,879	$6,515	$6,887
Present value of costs	$100	$171	$198	$216
Net present value	$1,898	$5,708	$6,316	$6,671
Benefits: Cost Ratio (BCR)	20	34	33	32

In line with the 2018 analysis, the benefits to cost ratio of wilding conifer control shows significant return for every dollar spent for the minimum option at 34:1, intermediate option at 33:1 and maximum option at 32:1.

The main components of the benefits of the options were avoided loss of water yields for food and fibre production, and productive land use, with shares of around 40 per cent and 35 per cent of the total benefits respectively. Many of the benefits accrue in the medium to long term since they represent the losses that would be avoided by controlling wilding conifers before they spread and densify.

The results also show that the minimum option "protect the investment" delivers the greatest return on investment. This is to be expected and reflects the programme's prioritisation of control activity and previous investment in these areas. Expansion of the programme into the next priority areas under the intermediate and maximum options would also provide very high returns on investment. Given all options show a very high return on investment, a decision on the preferred option needs to be considered in a broader context of the business case, especially the problem statement and strategic case for further investment in wilding conifer control.

1. The wilding conifer problem

Wilding conifers are a major threat to New Zealand's native ecosystem, economy and cultural values. Native shrubland and ungrazed grassland are most vulnerable to invasion (Buckley et al., 2005) and by allowing wildings to spread and densify risks serious impacts on biodiversity, pasture or primary production, ecosystem processes, and below-ground nutrient cycling and soil biota (Peltzer, 2018; Froude, 2011).

The impact of wilding conifer invasion is seen across the country. Over two million hectares are currently infested with wilding conifers. By density class, roughly 80% of the land infested is classified as sparse, 15% intermediate, 3.5% outlier and 1.5% dense[2]. However, left unmanaged, the large areas of outlier and sparse infestations would become dense forests within thirty years, in some cases as little as 14 to 21 years for *Pinus contorta* forests. The total area of infestation would also increase significantly over time

Substantial investment in wilding conifer control has already been made. Further work is needed to lock in the benefits in areas where the programme has worked to date and prevent wildings from reinfesting controlled areas. Wildings continue to be a growing problem in areas not yet covered by the programme. Many of the worst wilding conifer infestations stem from early/legacy plantings, often by Crown agencies in an attempt to stabilise land and prevent erosion (Froude, 2011; Hansford, 2021).

1.1 The importance of tackling the problem early

Allowing wilding pines to spread and densify increases the time and cost of control and impacts on the benefits that could be achieved post control. For example, some studies have shown the importance of early control of seedlings and saplings where the aim is to restore native tussock grasslands, as later removal of trees can lead to non-native vegetation dominance (Peltzer, 2018).

Control of wilding pines varies in method and cost depending on ease of access to the site and density of infestation, post-control land use, presence of nearby sensitive vegetation, waterways, current land use and proximity to dwellings. The costs for initial control typically range from $100[3] to $3,000 per ha[4]. The range of costs for follow up control are similar (Edwards et al., 2021). Broadly speaking, ground control of scattered infestations by hand or handheld machinery is much cheaper than controlling dense infestations that may require heavy machinery or aerial control. The higher costs associated with controlling denser infestations demonstrate the economic importance of tackling the problem early.

An example of control of a dense infestation in the Mackenzie Basin (Figure 1) shows the speed of invasion of *Pinus contorta*, the density and subsequent loss of native vegetation, and finally the scale of the control. There are now a range of land management options available such as grazing and forestry, natural native regeneration and active revegetation and it is likely a combination of all these

[2] Land Information New Zealand infestation data, updated 27 January 2022
[3] Low density, flat land, large trees, no hinderance or native vegetation
[4] High density, flat land, large trees, no hinderance, sensitive vegetation

things will be used. The impacts and need for restoration are significantly reduced if intervention is done early.

Figure 1: Control of a dense infestation in the Mackenzie basin

Taken 2014 | Taken 2020 (6 years later) | Taken February 2021 (post control)

Source: Environment Canterbury

While only a small percentage of the current infestation is dense, this will change quickly. If left unchecked, modelling shows that large swathes of productive land and indigenous ecosystems would be covered in wilding pines. Manaaki Whenua modelling shows that over the next fifty years wildings would spread to a further 500,000 hectares and 1.8 million hectares would be covered in dense forest.

Figure 2: Baseline infestation, 2021

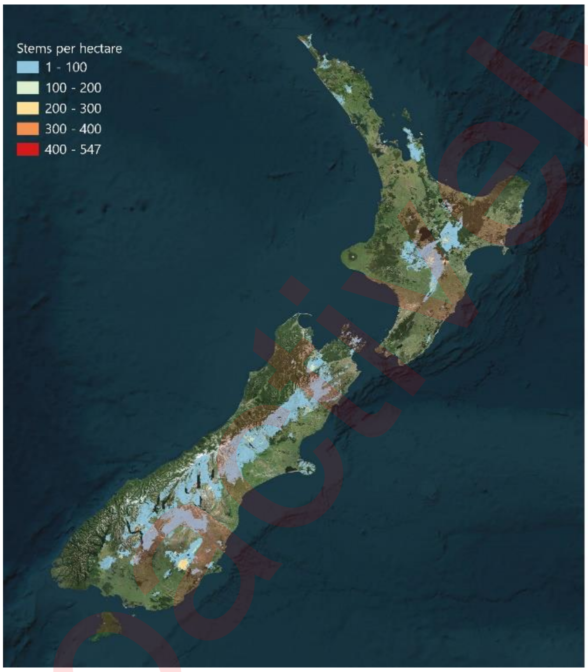
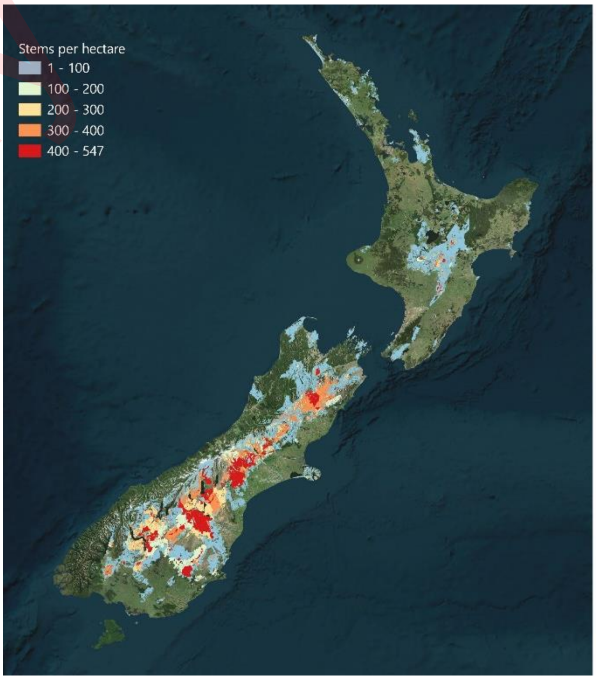


Figure 3 Abandon all control activities, 2072



Source: Forecast spread was developed in conjunction with Manaaki Whenua

1.2 Wilding Conifer Management

Wilding conifers have been managed at the national level since 2016 when the National Wilding Conifer Control Programme (NWCCP) was established to ensure a collaborative, coordinated and effective approach to national wilding management. The programme aims to prevent wilding conifers from spreading, by progressively removing them from land already invaded.

Governance for the programme includes representatives from regional councils, trusts, and LINZ, DOC, NZDF, Forest Owners Association, Federated Farmers and MPI as the lead agency (NWCCP). The programme is also supported by advisory groups made up of wider stakeholders and technical experts. This collaborative approach has proved to be effective in supporting the delivery of the programme.

The National Strategy sets out the programme's broad approach (NWCCP):

The strategy:

- supports collaborative action between land occupiers, researchers, regulators and communities.
- identifies actions under four principles:
  - individual and collective responsibility
  - cost-effective and timely action
  - prioritisation
  - co-ordination
- clarifies that wilding conifers are pests, but planted conifers are valuable resources – radiata pine and Douglas fir are New Zealand's third-largest export earner after dairy and meat
- says that effective management of wilding conifers:
  - protects conservation values including native ecosystems and plant species
  - protects iconic landscapes for local communities and tourists
  - supports New Zealand's brand of responsible natural wood products
  - protects productive farming and forestry land.

1.2.1 Centralised prioritisation of control activity

New Zealand is divided into 129 management units (MUs) of which 49 are currently active. Funds are allocated based on the priority of the control area, where scattered wildings are most prone to spreading (NWCCP, n.d.). The Operational Advisory Group (OAG) advises on the relative priority of control areas as part of annual planning.

Regional councils hold the funds for the control activity across their region. Each Management Unit has one or more project managers, who each oversee a contracting workforce for ground or aerial operations.

1.2.2 Types of control

Wilding conifers are usually controlled using the following physical methods:

- Hand pulling – this is only effective for very small seedlings.
- Cutting/felling – medium-sized conifers can be cut down with loppers or handsaws and large trees can be felled with a chainsaw. Herbicide gel is applied to the cut stump to prevent regrowth.
- Harvesting – some wildings provide a return from timber which can be used to offset control costs.
- Large machinery clearing – e.g. excavator, dozer, etc.
- Drilling and Filling – herbicide is injected into holes drilled into the trunks of trees.
- Basal Bark Application - herbicide is applied around the basal bark area of trees by ground crews or by an operator in a helicopter using a wand.
- Aerial foliar spray application – herbicide is sprayed over trees by helicopters using a boom to achieve full foliar coverage.[5]

1.2.3 Observable benefits

Wilding conifer management has already provided some tangible benefits. Some examples include:

- Monitoring of control activity on Flock Hill Station in Canterbury noted significantly reduced wilding numbers and the potential for restoration (Paul & Ledgard, 2020). However, the authors note that there is still a way to go for elimination.
- In the Wakatipu area, the National Programme has removed most coning trees from Kingston to Jack's Point under the Remarkables, from the Roaring Meg to Swift Burn, and is continuing to bring the containment lines closer into Queenstown. This work saves existing beech forests and tussock lands from being dominated by exotic conifers. (Ministry for Primary Industries, personal communication, 15 December 2021).
- Extensive conifer control investment has provided economic benefits to the Mackenzie Basin. The main businesses in the area – farming, power generation and tourism – all benefit, by making farming possible again, freeing up water for hydro stations or returning the environment to the state that made the region a tourist attraction (Ministry for Primary Industries, personal communication, 15 December 2021).

[5] DoC, available from: https://www.doc.govt.nz/nature/pests-and-threats/weeds/common-weeds/wilding-conifers/methods-of-control/

1.3 Programme funding reduces from 23/24

With the establishment of the programme, the Crown allocated $16 million in total over three years from July 2016 to June 2019 to deliver Phase one of the programme. For phase two the government committed $21 million in total over the next two years. In Budget 2020, the programme was allocated an extra $100 million over four years through Jobs for Nature. This investment enabled the expansion of the control programme to more sites across New Zealand and with it immediate benefits from job creation, particularly in regions hit hard economically by COVID-19 (Ministry for Primary Industries, 2021).

From 2023/24, $10 million is allocated annually to the programme as baseline funding. This is a $15 million reduction on 2022/23 funding and as a result control activity would need to be scaled back.

Table 3: Government funding for NWCCP

	16/17	17/18	18/19	19/20	20/21	21/22	22/23	23/24	Future Years
Phase one ($16m)	$5.4	$7.5	$3.1						
Phase two - Budget 2019 ($21m)				$14.1	$6.9				
COVID-19 relief				$3.0					
Jobs for nature allocation - Budget 2020 ($100m)					$32.5	$32.5	$25.0	$10.0	
Baseline									$10.0
Total	$5.4	$7.5	$3.1	$17.1	$39.4	$32.5	$25.0	$10.0	$10.0

Source: MPI

In addition to the funding above, regional councils, trusts and landowners have historically contributed a further twenty percent plus time and resources (known as in kind payments) towards wilding conifer control.

1.4 Investment options being assessed

This CBA assesses the impact of three investment options against the counterfactual. The counterfactual is what would happen if additional funding was not secured , we call this the “Status quo” option.

The options were developed through an iterative process with the programme's Operational Advisory Group (OAG). The group reprioritised all management units and used this ranking to determine which areas would be abandoned under the status quo option and which would be included under the minimum, intermediate and maximum options. A full list of the management units controlled under the options is provided in Appendix A.

Status quo – baseline funding (control 42.4% of the known infestation)

Baseline funding of $10 million per annum continues from 2023/24. If no further investment is made, the programme would be substantially scaled back over the next four years. This would result in areas which are currently free from wilding conifers becoming re-invaded, the gains made on abandoned land would be lost and future benefits foregone as wilding conifers spread.

Of the 49 active management units, only the ten highest priority MUs (covering 42 per cent of the known infestation) would continue to be actively managed by 2025/26.

Proposed investment options

This report assesses the economic impact of additional investment in wilding conifer control for three investment options:

1. **Minimum "protect the investment"** (**control 90.0% of the known infestation)** – continue to support existing control activity across 49 management units
2. **Intermediate "extend the investment" (control 94.8% of the known infestation)** – expanding the activity to include a further 11 priority management units
3. **Maximum "national control" (control 95.1% of the known infestation)** – the intermediate option plus a further 19 priority management units.

A summary, by region, of the total hectares of known infestation that would be controlled under each of the proposed options is shown on the next page.

Table 4: Control (ha) by region for each option assessed

Region	Infestation (ha)	Hectares controlled for each option			
		Status quo	Minimum	intermediate	Maximum
Auckland	116	0	0	0	29
Bay of Plenty	40,921	0	39,343	39,343	39,343
Canterbury	1,383,571	453,963	1,264,611	1,269,697	1,272,736
Central NI	217,512	171,455	191,887	216,276	216,439
Gisborne	381	0	0	0	0
Hawkes Bay	2,557	0	0	0	125
Marlborough	263,070	219,591	251,654	260,075	262,710
Nelson Tasman	64,469	0	52,394	63,563	64,469
Northland	14,564	0	11,201	11,201	11,201
Otago	481,514	239,090	430,500	480,894	480,894
Southland	83,673	5,444	57,277	79,879	79,879
Taranaki	19	0	0	0	0
Waikato	14,017	0	12,977	12,977	13,993
Wellington	1,215	0	0	0	0
West Coast	1,090	0	0	0	976
Area Outside Region	0	0	0	0	0
	2,568,691	1,089,543	2,311,844	2,433,906	2,442,794
Per cent of known infestation controlled		42.4%	90.0%	94.8%	95.1%

Source: WCIS

2. Framework for this cost benefit analysis

We constructed the CBA within a Total Economic Value (TEV) framework, due to the importance of ecosystem services including 'non-use' such as biodiversity along with 'use' values (or market values). For example, 'use' values would be the value generated by primary producers on controlled land, whereas 'non-use' may be the value people place on biodiversity or pristine natural landscapes or significant cultural or historical sites, in particular for Mana Whenua, even though the general population may not use or see them; knowing they exist and will exist for future generations is of value.

Within a TEV Framework, an allowance is conceptually made for people who are willing to pay for the continued existence of a particular landscape, ecosystem or species. This is of importance when assessing pest control practices, when there is a reduced risk of losing species and biodiversity is retained or enhanced. The TEV framework is appropriate for this CBA and is widely used when dealing with ecosystem services and environmental impacts (Rohani et al., 2018; Sharp & Kerr, 2005).

An ecosystem services approach is a way of quantifying and incorporating what we implicitly value in the environment into production and governance practices. From a Te Ao Māori perspective (in line with MPI's Fit for a Better World strategic roadmap) the value of the environment and obligation to protect it has particular value, at national level, in addition to the value to Iwi and Hapū of specific sites and collectively owned Māori land that may be affected by or need protecting from wilding conifers. When the value of these services is not recognised in the marketplace, this leads to decision-making failures. In contrast, their inclusion enables practices that enhance overall economic, environmental, and social values and advances decision-making that leads to more efficient and acceptable trade-offs between different values (The Royal Society of New Zealand, 2011).

2.1 The identified impacts

We identified the following 'use' benefits New Zealand would obtain from wilding conifer control:

- Primary production / productive land use
- Water yields for hydro generation and irrigation
- Reduced wildfire spread and damage risk
- Protecting iconic landscapes for recreation and aesthetic value

And 'non-use' benefits

- Avoiding biodiversity losses – including preventing soil legacies
- Protecting Māori cultural values e.g. protecting sites of significance to Mana Whenua, and Māori land, from the impacts of introduced species.

The aim is to monetise the impacts where possible, though where this in not possible a qualitative assessment of the impact is appropriate and should be considered alongside the monetised CBA result.

The impacts on ecosystem services are measured and monetised through the TEV framework. A report published by Treasury (NZIER, 2018) usefully demonstrates the relationship between the ecosystem services approach and its components and the valuation techniques that are appropriate for monetisation of their use and non-use values.

Figure 4: The relationship between ecosystem services and the TEV framework

Identify		Quantify	Value	
Ecosystem services			Use values	Non-use values
Provisioning	Food	Various measures depending on subject matter	Forgone production, Loss averting expenditures, Alternative sources	
	Fibre			
	Materials			
	Energy			
	Water Quantity			
Regulating	Water quality		Avoided treatment cost	Stated preferences
	Water flow variability		Avoided flood damage	
	Climate amelioration (local)		Avoided costs	
	Climate amelioration (global)		Carbon credit values	
	Soil stabilisation		Avoided erosion costs	
	Biodiversity (resilience)		Biodiversity offsets/ Replacement costs	
Cultural	Biodiversity (preference)		Wildlife viewing	Stated preferences
	Recreation		Revealed preferences	
	Aesthetic			
	Heritage			
Supporting	Nutrient cycling		Forgone production	
	Pollination		Alternative sources	

Source: (NZIER, 2018)

2.1.1 Monetised benefits

Using the framework in Figure 4 as a guide, we have monetised productive land use, and water yield benefits using market values for foregone production. Specifically, these include:

- Productive land use – valued using sheep and beef farm profitability (Earnings Before Interest and Taxes and Rent (EBITR) from sheep + beef survey data)
- Water yields (in hydro catchments) - value of foregone hydro generation using the resource rents series produced by Statistics NZ, which is broadly equivalent to the EBITR measure
- Water yields (irrigation) – valued using the value of irrigation based on profitability of farms on irrigated land (NZIER & AgFirst Consultants NZ Ltd, 2014)

We value reduced fire risk using an avoided costs method. To do this we use a paper on the economic cost of wildfires (BERL, 2009) prepared for Fire and Emergency NZ.

We have applied a non-market value for the cultural ecosystem services - biodiversity, recreation and landscape aesthetics. There are monetised using a stated preference method. The non-market valuation study (Polyakov et al., 2021) reveals the use and non-use values from wilding control such as scenery, recreation and the existence of ecosystems and species through Willingness to Pay (WTP) survey of households. We used this study's results through the value transfer methodology for monetisation of these benefits.

A full list of calculated costs and benefits and values used to calculate them is provided in Appendix B.

2.1.2 Non-monetised benefits

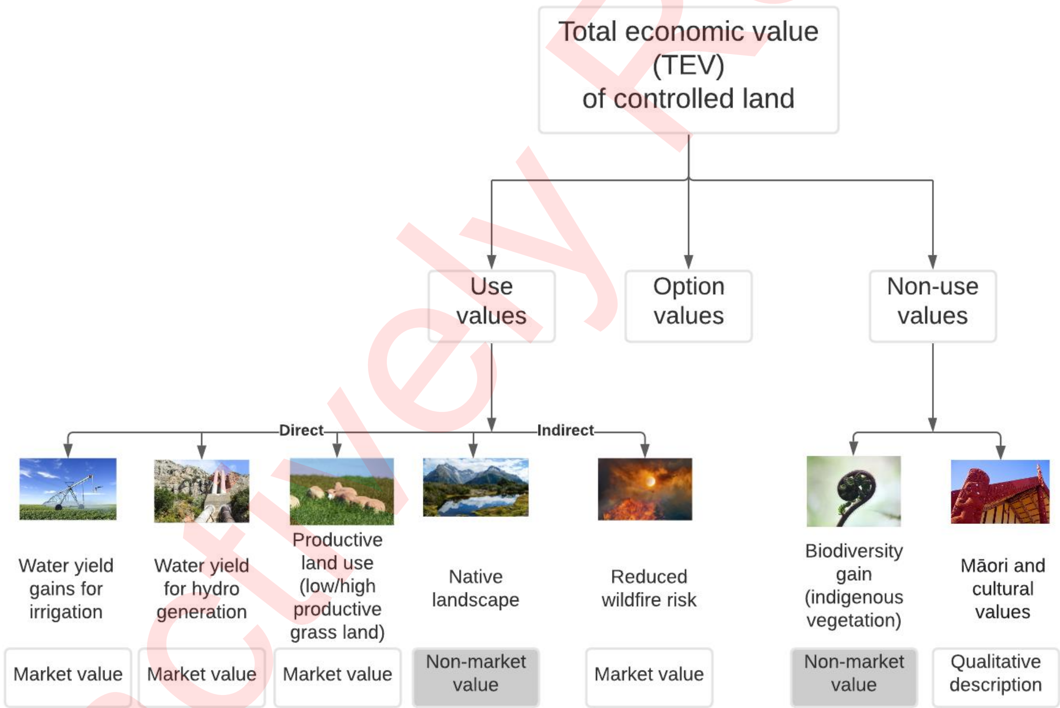
While every effort has been made to monetise the identified benefits, Māori cultural values have not been monetised. There are two main reasons for this:

- Māori values are holistic and can include principles, intrinsic, tangible and intangible values, and there is not enough information available for these values.
- Each iwi/hapū may have its own tradition in this respect, which makes a uniform discussion of 'Māori heritage values' problematic.

Therefore, the value Māori would place on control of wilding conifers has been qualitatively described in section 6.5 Māori cultural values. This qualitative assessment should be considered alongside the Benefits to Cost Ratio (BCR) calculation when funding decisions are made for wilding conifer control.

A summary of the benefits under the total economic framework is illustrated below.

Figure 5: Wilding conifer benefits under TEV framework



Source: Sapere. Wildfire photo: credit Brian High

2.1.3 Costs

Costs of each option are defined as the additional financial costs (or required fund) of the option compared with the status quo option. The costs included in this CBA consist of:

- Programme control costs
- Fixed programme management costs

- Deadweight loss of taxation (20 percent of control and programme costs)

Programme control and programme management costs have been provided by MPI for the nine year period from July 2022 to June 3031.

2.1.4 Valuing the area controlled and avoided spread

By controlling wilding conifers, we gain back some or all of what has been lost due to the impacts of wildings. By reducing or eliminating seed sources, the programme is also protecting against future spread and the losses that result. We have calculated the benefits based on the removal of existing infestations and the spread avoided as a result.

Modelling of future wilding conifer spread was developed by Manaaki Whenua and adapted for this CBA. Forecasts were provided at a highly granular level (1km x 1km grid squares) and included forecasts of infilling (local increase in population density) and invasion to neighbouring grid squares. The modelling does not include the impact of long distance spread events, so is likely to underestimate the extent of spread and impacts over the longer term.

The methods used and efforts put into calculating wilding conifer spread and the impacts on ecosystem services are a significant advancement on previous cost benefit analyses. Geospatial modelling has been used to ensure the impacts from wilding infestation on water yields, productive land use, and biodiversity have been accurately mapped to layers on land use, hydro and irrigation catchments and native vegetation. A description of the methods used by Manaaki Whenua is included in Appendix D. The application of these forecasts and geospatial modelling methods used to calculate the benefits are described in section 6 *Calculation of benefits*.

2.1.5 Employment gains and ETS impacts are excluded

In CBAs, additional benefits from employment are usually ignored. In most cases there is a displacement effect where the investment results in workforce movement from one job/sector to another meaning there is no net gain. Gains from employment should be included when there is high unemployment, but this is not the case at the moment, so we have excluded marginal employment benefits from the CBA.

We have also not included the impact of carbon emissions in the CBA. There are two reasons for this:

1. Emissions are capped under the Emissions Trading Scheme (ETS) so emission reductions in one area in the economy will free up New Zealand Units (NZUs) to be used by emitters in another area. This is also known as the waterbed effect (Energy Resources Aotearoa, 2021). We have assumed any changes to carbon sequestration or emissions are transfer payments and should not be counted in the CBA.

2. Wilding conifers cannot be registered under the ETS due to their status as tree weeds. Consequently, there is no market value for the carbon sequestered by wilding conifers and no obligations under the ETS to surrender NZUs for the removal of wildings[6].

Despite not including emissions in the CBA, we have quantified the benefits of avoided carbon emissions from non-renewable energy generation to provide context on the impact of reduced water yields for hydroelectricity. This analysis is provided in Appendix C.

[6] With the exception of a few wilding conifer forests that were registered with the ETS before the rule change to exclude pest trees. The impact of these forests is assumed to be negligible.

3. Summary of the CBA result

Table 5 summarises the present value of costs and benefits for each wilding conifer control option over 50 years (consistent with the time period used in the 2018 CBA). The net present value (NPV) and benefit cost ratio (BCR), two of the efficiency tools that are used in CBAs, are also presented.

We have included the counterfactual option (status quo) for comparison. Cost benefit analysis are used to inform investment decisions and would ordinarily show only the additional costs and benefits for the identified investment options compared to the counterfactual.

Table 5: Summary of the CBA results for the status quo, minimum, intermediate and maximum options modelled over 50 years

Present value ($ million)		Status quo – Base line funding	Minimum – protect the investment	Intermediate – extend the investment	Maximum – national control
Benefits	Productive land use	$638	$1,967	$2,052	$2,059
	Hydro	-$66	$307	$415	$458
	Irrigation	$465	$1,160	$1,595	$1,915
	Cultural / biodiversity	$875	$2,137	$2,137	$2,137
	Fire	$86	$308	$316	$318
	Total benefits	**$1,998**	**$5,879**	**$6,515**	**$6,887**
Costs	Programme	$84	$143	$165	$180
	DWL	$17	$29	$33	$36
	Total costs	**$100**	**$171**	**$198**	**$216**
Net present value		**$1,898**	**$5,708**	**$6,316**	**$6,671**
Benefits : Cost Ratio (BCR)		**20**	**34**	**33**	**32**

3.1 Status quo would result in lost benefits of $3.8 billion

The status quo option has a net present value of $1.898 billion over 50 years. However, this option is actually a substantial disinvestment that would see the area controlled reduce from 90 per cent of the known infestation to 42 per cent. As a result, there would be a substantial loss in benefits as wilding conifers re-infest land no longer under active management. Relative to the minimum option (continuing funding at the level provided under the Jobs for Nature programme) we estimate losses of $3.8 billion over 50 years (measured in today's dollars) from lost primary production, reduced water yields, loss of biodiversity and cultural values and increased fire spread and damages. These losses are enormous compared against the cost savings of $71 million by scaling back the programme.

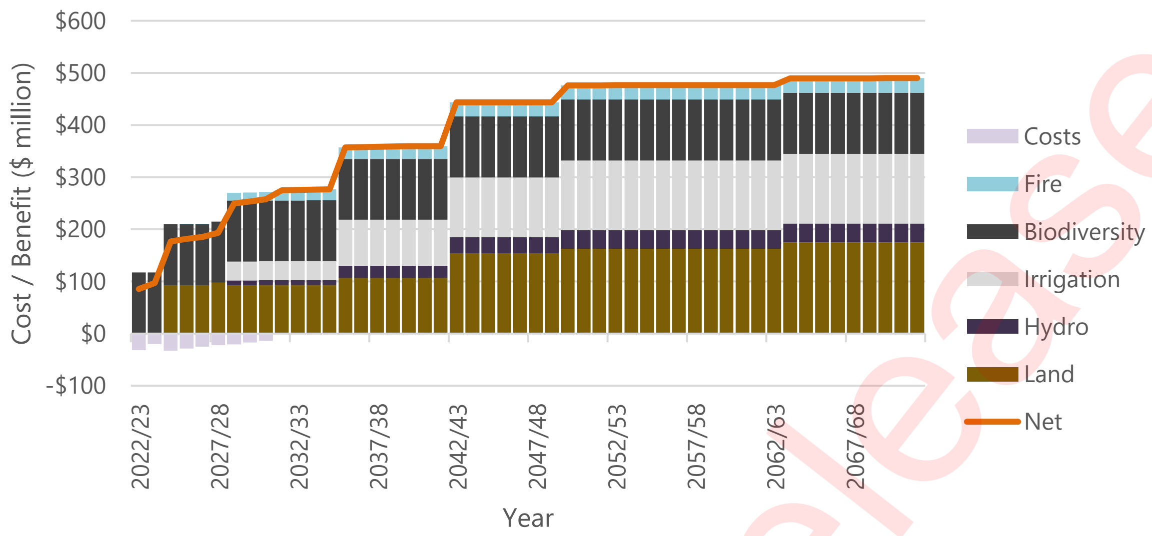
3.2 Significant benefits from additional control

Investment in the minimum, intermediate and maximum options would ensure the losses from scaling back activity are avoided and provide additional benefits. The benefits to cost ratio of wilding conifer control shows significant return for every additional dollar spent for the minimum option at 34:1, intermediate option at 33:1 and maximum option at 32:1, this is in line with previous analysis (Wyatt, 2018).

We note that, across all three options:

- Irrigation benefits and productive land use account for 55 per cent of the TEV-based benefits, at around 24 per cent and 31 per cent of the total benefits respectively. Irrigation is particularly important due to the high value derived from irrigation in Canterbury and Otago in particular, and the infestation of wilding conifers in the irrigation catchments for these regions. This is discussed further in section 6.2.2
- Benefits from reduced fire risk account for 5 per cent of the total benefits.
- Cultural / biodiversity value makes up 30 - 36 per cent of the benefit and is a significant component. We consider this to be a low estimate for two reasons:
    - The willingness to pay study used to derive the benefits limited the choices experiment to reducing the infestation by half and limited willingness to pay estimates to control over a maximum of two regions at a time only. As a result, we cannot extrapolate the result to full control over all of New Zealand as assumed in this CBA.
    - Māori cultural values are not monetised. A qualitative discussion on Māori cultural values is included in 6.5 *Māori cultural values*.
- Many of the benefits accrue in the medium to long term since they represent the losses that would be avoided by controlling wilding conifers before they spread and densify. Figure 6 illustrates the timeline of marginal costs and benefits (by component) of the minimum option.

Figure 6: Value of costs and benefits on minimum option over the 50 year time horizon (undiscounted)

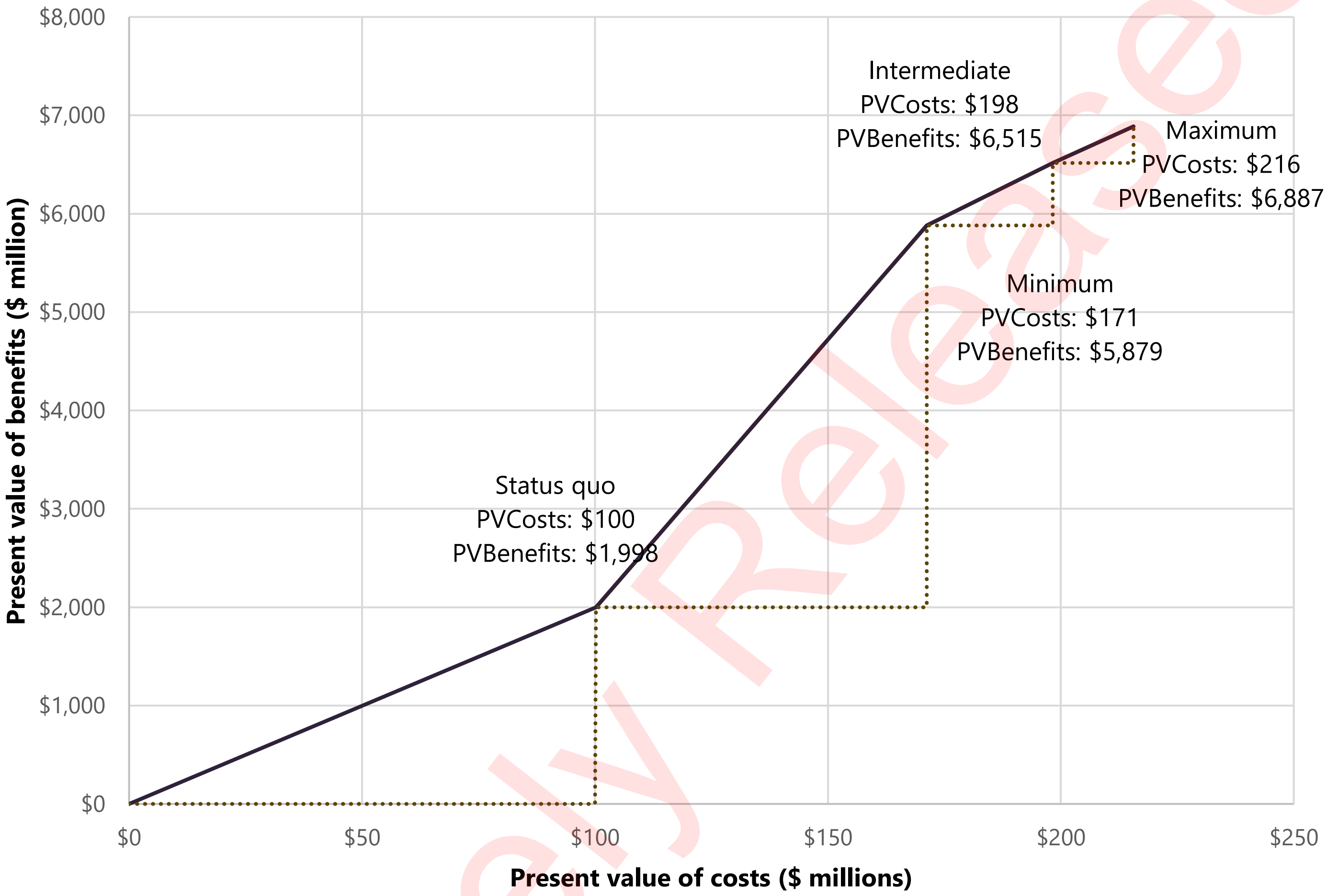


The detailed information of the marginal costs and benefits of each option is provided in sections 4 and 5.

3.3 Minimum option represents the best value for money

The results of the CBA shows that the minimum option with a BCR of 34 presents the best value for each dollar spent in this programme. Figure 7 shows that the net present value of the control programme increases at a decreasing rate. Therefore, the 49 MUs controlled under the minimum option produce greater benefits per dollar spent than the next groups of MUs added, i.e., 11 and 13 additional MUs under the intermediate and maximum options. Additionally, the Status quo option produces less benefits per dollar spent than the minimum option. This reflects the large disbenefits experienced under this option on land currently controlled.

Figure 7: Marginal benefits compared to costs for each option ($ millions)



Source: Sapere

High priority areas are selected based on the spread risk of the wilding species, the vulnerability of the landscape to invasion, and the cost effectiveness of control. The decreasing BCR for intermediate and maximum options reflects this prioritisation.

3.3.1 The result needs to be viewed alongside practical and strategic considerations

While the minimum option is the preferred option based on a 'maximise benefits: cost ratio rule', it might not be the preferred option to achieve the National Programme objectives or deliver the required level of wilding conifer control to the point that land can be managed by landowners, or when considering non-monetized values such as Māori cultural values. In addition, significant additional risk-adjusted returns are accrued in the intermediate and maximum options, both of which have a higher NPV than the minimum option. Therefore, the decision makers should look at the CBA results in the context of the wider business case and specifically the strategic case.

3.4 General assumptions

We carried out the CBA based on the following assumptions and considerations:

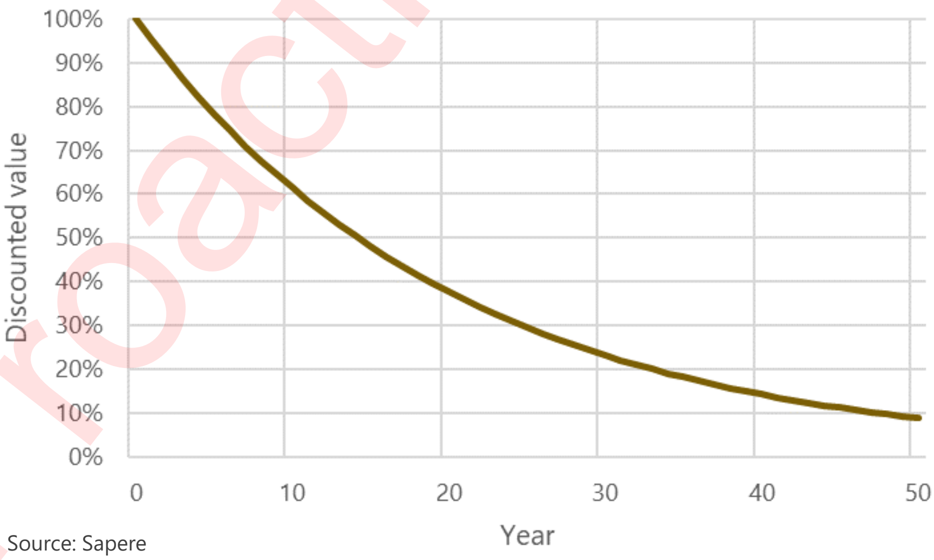
- Time zero, future costs and benefits are calculated starting 2022/23.
- Base date, the date that is used to standardise the valuation of all monetised benefits and costs, is 2021/22.
- The analysis period starting from time zero is 50 years. The nature of wilding conifer control is that costs are largely incurred up-front, and the benefits accrue gradually thereafter. A 50-year horizon would seem appropriate to ensure the benefits are adequately included in the result.
- While the cost of controlling each MU reduces over time, the cost of control activity will be ongoing until infestations are controlled to a level that they can be managed by landowners and communities. With the required funding, the majority of MUs under the minimum option will be transitioned to local management by 2030/31. MUs under the intermediate and maximum options are likely to be able to transition 6 – 12 years after commencement of control.
- Discount rate is 5 per cent per annum as per Treasury guidance (The Treasury, 2020) – this is the rate that reflects the time value for money and used to calculate the present value of the costs and benefits at time zero.

The effect of discounting costs and benefits

We discount because a dollar today is worth more than a dollar in a year's time. It also assures the decision maker that when assessing an investment decision it can be compared against any other investment decision of equal risk (The Treasury, 2015).

A 5 per cent discount rate means that at 15 years the benefits and costs are halved, and by 30 years we recognise less than 25 per cent of the value.

Figure 8: Impact of discounting



Source: Sapere

4. Calculation of costs

Additional costs have been estimated for each investment option, these include:

1. Control costs – the cost of control activity including control staff, project managers and contractors.
2. Fixed programme management costs – the cost of managing and administering the NWCCP. This also includes the cost of post control monitoring.
3. Deadweight loss of taxation (DWL) - this is the welfare loss of taxpayers, and NZ Treasury suggests CBAs should include a deadweight cost equal to 20 per cent of project costs that are funded from general taxation (The Treasury, 2015).

Control and programme management costs have been provided by MPI.

Where an investment is funded from taxation we must also account for the deadweight loss of taxation. The deadweight loss of taxation recognises the welfare loss that arises when money is taken away in the form of taxes, for example, income tax on labour income tends to discourage working in favour of leisure or home-based activities (The Treasury, 2015). Treasury guidance is to apply twenty per cent to the cost of a project funded through general taxation.

The costs used in this CBA are summarised below both in nominal terms and as a present value (PV)

Table 6: Costs of the Status quo option ($ millions)

Status quo	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	PV
Control	$20	$7	$7	$7	$7	$7	$7	$7	$7	$63
Programme	$3	$3	$3	$3	$3	$3	$3	$3	$3	$20
DWL	$5	$2	$2	$2	$2	$2	$2	$2	$2	$17
Total	$28	$12	$12	$12	$12	$12	$12	$12	$12	$100

Table 7: Costs of the minimum option ($ millions)

Minimum	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	PV
Control	$23	$14	$24	$21	$18	$16	$14	$11	$9	$122
Programme	$3	$3	$3	$3	$3	$3	$3	$3	$3	$21
DWL	$5	$3	$5	$5	$4	$4	$3	$3	$2	$29
Total	$31	$20	$33	$29	$25	$22	$21	$17	$14	$171

Table 8: Costs of the intermediate option ($ millions)

Intermediate	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	PV
Control	$29	$18	$28	$24	$21	$17	$15	$12	$10	$142
Programme	$3	$3	$3	$3	$3	$3	$3	$3	$3	$23
DWL	$6	$4	$6	$5	$5	$4	$4	$3	$3	$33
Total	$39	$26	$38	$32	$30	$24	$22	$18	$16	$198

Table 9: Costs of the maximum option ($ millions)

Maximum	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	PV
Control	$32	$23	$32	$28	$22	$17	$15	$12	$10	$157
Programme	$3	$3	$3	$3	$3	$3	$3	$3	$3	$23
DWL	$7	$5	$7	$6	$5	$4	$4	$3	$3	$36
Total	$42	$32	$42	$37	$30	$24	$22	$18	$16	$216

Source: MPI, Sapere Analysis

5. Area controlled

Costs and benefits are a function of the area controlled. The impact of controlling an area means existing infestations are removed and future spread is avoided.

5.1.1 Control of existing infestations

Currently the programme has funding to control 2,311,844 hectares of infestation. A reduction in funding to $10 million per annum under the Status quo option would see this amount drop to 1,089,543 hectares. Table 9 displays the hectares controlled under each option by density class[7].

Table 10: Additional hectares controlled by density class

Density	Status quo	Minimum	Intermediate	Maximum
Outlier	60,342	94,913	96,138	96,475
Sparse	856,519	1,837,838	1,917,515	1,924,784
Intermediate	150,824	339,583	374,914	376,010
Dense	21,858	39,510	45,338	45,525
Total	1,089,543	2,311,844	2,433,906	2,442,794

Source: Sapere analysis

We have applied general assumptions for the time required to control an infestation based on density class. These assumptions are based on an area being controlled once every three years. There will also be some level of ongoing maintenance control that may be required by landowners.

Table 11: Transition through density classes as a result of control

Starting density	Infestation at 3 years	Infestation at 6 years	Infestation at 9 years	Infestation at 12 years
Dense	Dense	Sparse	Outlier	None
Intermediate	Sparse	Outlier	None	
Sparse	Outlier	None		
Outlier	None			

The above assumptions are based on advice from the NWCCP. For the purposes of this CBA we assume that as an end state, no wilding conifers remain post-control but we note that this is not always the case. Control with the aim of removing wilding conifers frequently fails to kill 100 per cent

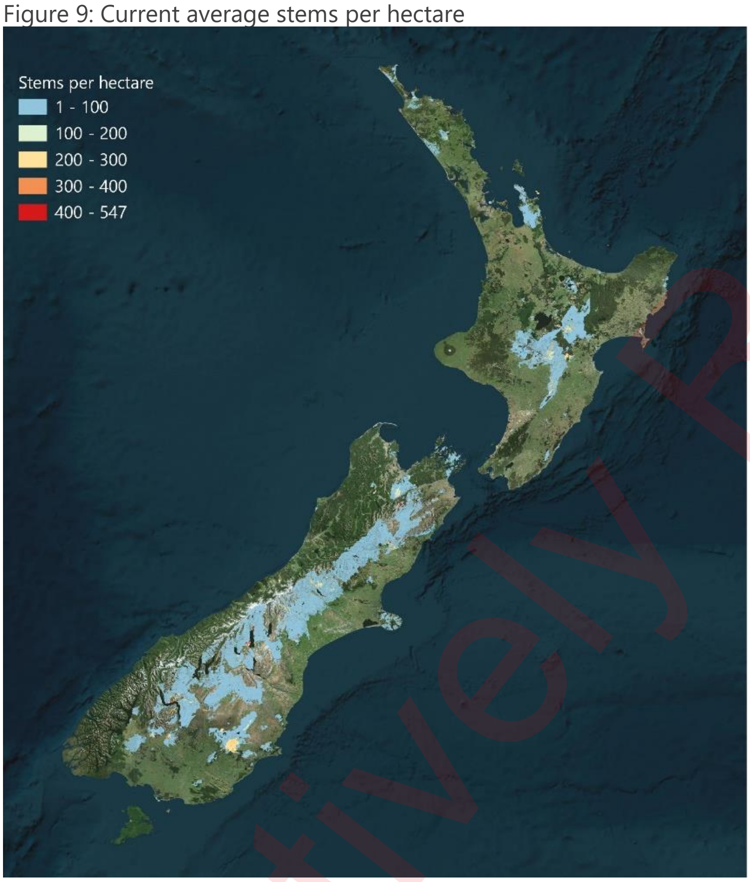
[7] Density classes are defined as: outlier 1-0% overall percentage cover (OPC), sparse 15-1% OPC, intermediate 75-15% OPC, dense 100-75% OPC

of trees, and may result in post-removal dominance by other non-native species, or reinvasion by wilding conifers (Dickie et al., 2021).

5.1.2 Future spread avoided

By controlling existing infestations, we avoid future spread and densification. Maps of the current infestation and the infestation following control under each of the options are presented below. The results are dramatic, particularly the difference in coverage between the minimum and status quo options.

Figure 9: Current average stems per hectare



Source: Sapere Analysis in conjunction with Landcare Research

Figure 10: Current infestation, South Island

Figure 11: Current infestation, Central North Island

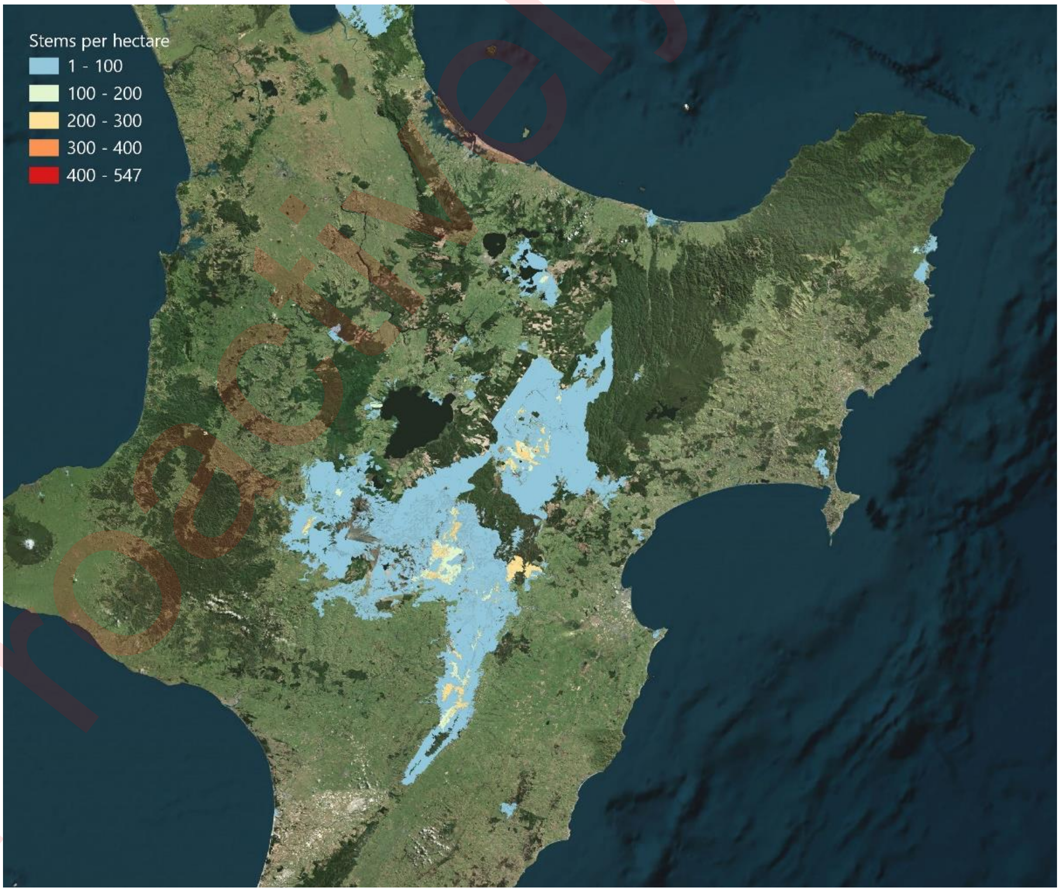
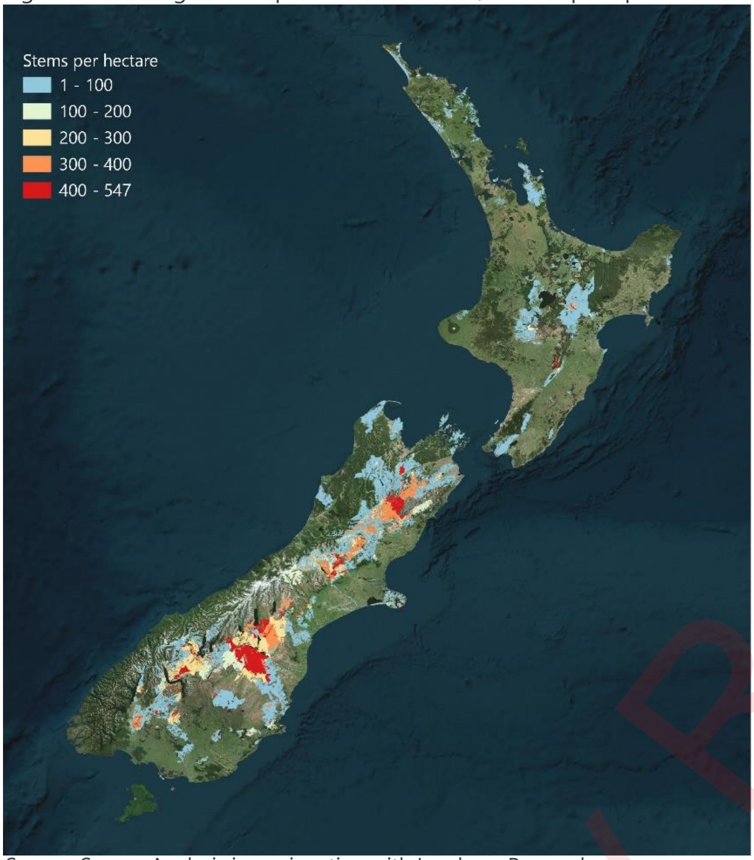
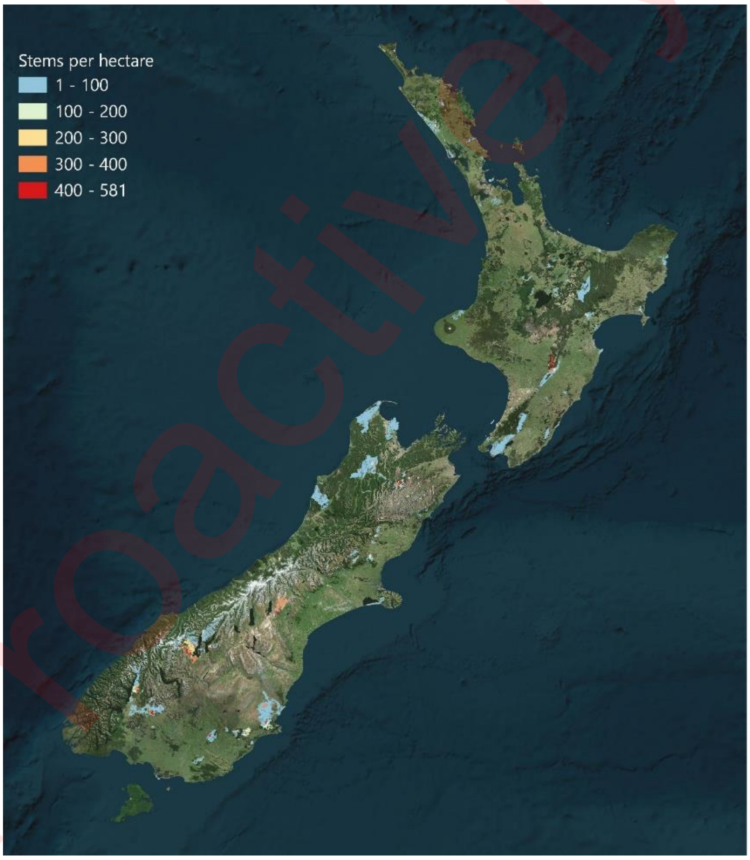


Figure 12: Average stems per hectare in 2072, Status quo option



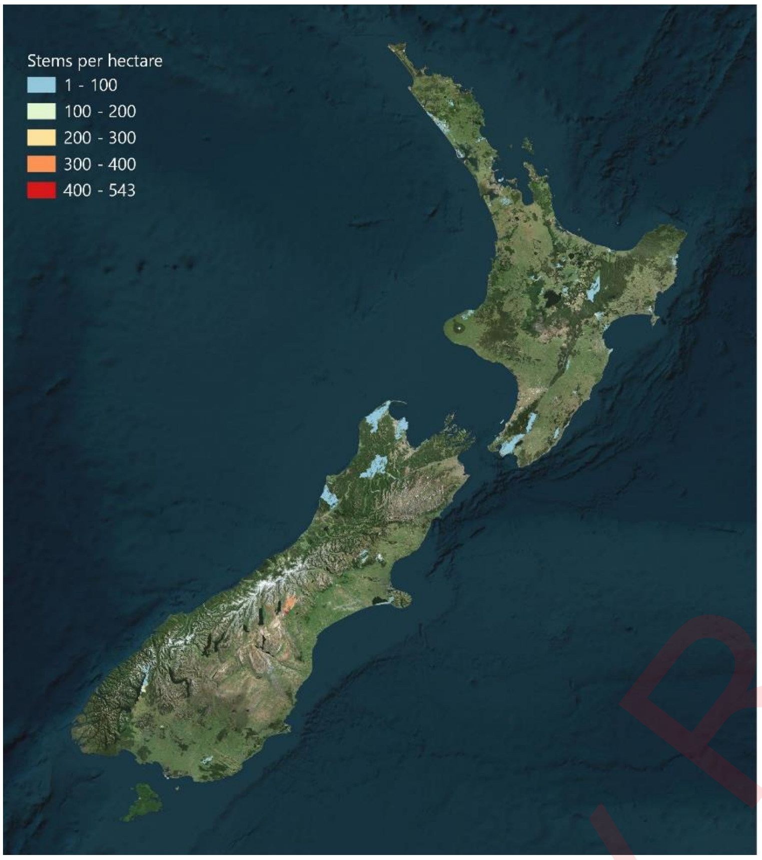
Source: Sapere Analysis in conjunction with Landcare Research

Figure 13: Average stems per hectare in 2072, Minimum option



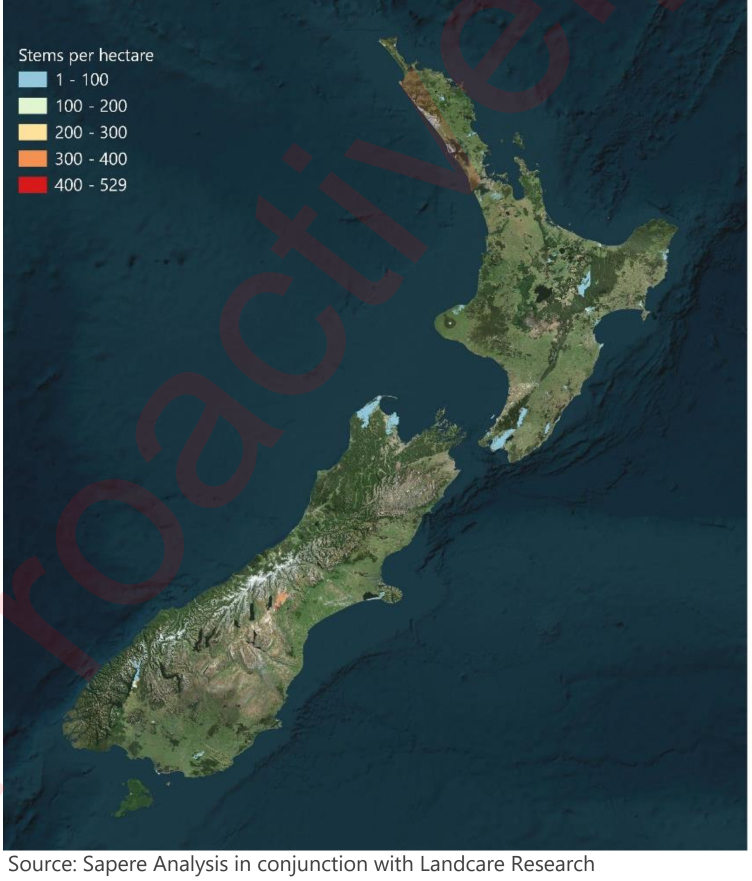
Source: Sapere Analysis in conjunction with Landcare Research

Figure 14: Average stems per hectare in 2072, Intermediate option



Source: Sapere Analysis in conjunction with Landcare Research

Figure 15: Average stems per hectare in 2072, Maximum option



Source: Sapere Analysis in conjunction with Landcare Research

6. Calculation of benefits

This section steps through the benefits from control of wilding conifers. We outline the volumes, values and assumptions used to arrive at the result.

6.1 Productive land use

Invasion of wilding conifers reduces the productive potential of land. Spread occurs most readily on ungrazed land with low vegetation density, and is least likely to occur in dense vegetation, or where intensive grazing is practiced (Ledgard, 2001) (Buckley et al., 2005). In the absence of control, moderately or infrequently grazed grassland and pasture will be lost to wilding pine invasion, and economic potential with it.

6.1.1 Defining vulnerable productive grassland impacted by wilding invasion

We define the land most susceptible to production loss as low producing and high producing grasslands using the Ministry for the Environment's land use classifications 2016 (Ministry for the Environment, 2020). Sub classifications were used to identify grazed and ungrazed land. Other productive land use types like forestry and horticulture, are assumed to be less vulnerable to wilding conifer spread, and self-manage the impact of wilding spread on their operations.

Manaaki Whenua modelling of infilling and long distance spread is used to define invasion of low and high producing grasslands. Spread assumptions are determined by land cover and grazing intensity and use establishment rates derived from (Buckley et al., 2005). Based on this modelling, we assume spread on intensively grazed land is zero and on all other grasslands the average population growth rate has been applied.

Grazing intensity is defined at a regional level using Statistics NZ Agricultural Census data. Regions with an average sheep per hectare of 8 or higher across land dedicated to sheep farming are considered to have intensive sheep farming.

Table 12: Grazing intensity, sheep per hectare by region

Region	Grazing Intensity	Sheep per ha
Auckland	Low	6
Bay of Plenty	High	8.3
Canterbury	Low	4.2
Gisborne	High	9.1
Hawke's Bay	High	9.4
Manawatu-Whanganui	High	9.4
Marlborough	Low	3.1
Nelson	Low	..c*
Northland	High	9.1
Otago	Low	3.9
Southland	High	8.4
Taranaki	High	8.5
Tasman	High	8.5
Waikato	High	9.4
Wellington	High	9.1
West Coast	Low	5.1

Source: Sapere analysis using Statistics NZ data, *data supressed for confidentiality reasons

6.1.1.1 Adjustment for loss of vulnerable productive grassland to permanent forestry

An emerging issue is the impact of the Emissions Trading Scheme on land conversions. High carbon prices are driving sales and conversion of marginal productive grassland into permanent forest. Since we have assumed the impacts of carbon credits and emissions balance out in the economy, we do not value this income. However, looking at recent land sales and conversions (Orme & Orme, 2021) as a percentage of all grasslands we estimate this affects less than 1% of vulnerable productive land. Given the impacts are expected to grow as carbon prices increase, we have assumed no benefits would be gained on 1% of vulnerable productive grassland.

6.1.2 Value of productive sheep & beef land

The value of productive grassland has been estimated applying the earnings before interest, tax, and rent (EBITR) per hectare for sheep and beef farming. Beef + Lamb NZ recommend using EBITR as a measure of "earning power" (Beef + Lamb New Zealand, n.d.). The values we have applied for low and high producing grasslands are:

Figure 16: Values applied to low and high producing grasslands

Land Use Classification	Value per hectare, per annum
Low producing grassland	$52.89[8]
High producing grassland	$344.45[9]

Source: Beef + Lamb NZ: Sheep & beef farm survey

6.1.3 Production loss from invasion

We apply the following loss assumptions based on density class:

Table 13: Assumed production loss by density class

Density	Production loss
Outlier	2%
Sparse	20%
Intermediate	30%
Dense	100%

[8] 2020/21 estimated EBITR for Class 1 S.I. High Country New Zealand
[9] Mean EBITR for all Hard Hill Country and Hill Country classes

6.1.4 Productive land use benefits

The following shows the value of the additional benefits derived over 50 years under the four investment options:

Table 14: Productive land use benefits 50 year PV ($ millions)

Component	Status quo	Minimum	Intermediate	Maximum
Low producing sheep and beef	$588	$1,675	$1,738	$1,741
High producing sheep and beef	$57	$313	$336	$340
Loss of productive land due to ETS	-$7	-$21	-$22	-$22
Total Present Value	$638	$1,967	$2,052	$2,059

Source: Sapere analysis

6.2 Water yield benefits

The spread of wilding conifers reduces surface flows and aquifer recharge in water-sensitive catchments. Less water reduces the productive value derived from irrigation and hydro generators, and the use values enjoyed in outdoor recreation. Several studies have attempted to estimate the water yield reduction attributable to wilding conifer spread. When pastoral land becomes densely infested with wilding conifers, annual water yield reductions of between 30 – 81% have been found[10]. Work undertaken by Scion found an average reduction during low-flow conditions of approximately 16% across three South Island catchments in water-afforestation studies. Scion noted that for the purposes of estimating the water impact of wilding conifers, this value could be conservative as wilding conifer stands have a much higher interception effect, because of their rougher canopy surface. Wilding conifer stands can also grow in the upper reaches of catchments where plantation planting wouldn't and can therefore reduce low-flow yields more significantly. Water yield reduction in this CBA relies on the analysis of Manaaki Whenua, which uses the WATYIELD model (Fahey et al., 2010). Fahey's research found a 40% reduction in mean annual flow with 2/3 of an experimental catchment planted in pines.

The previous CBA (Wyatt, 2018) evaluating phase two of the wilding conifer control programme found that impacts on water yields dominated the results. This remains the case for phase three of the control programme.

[10] Data from a number of catchment studies have shown that where pasture has been replaced by radiata pine forest, there was a reduction in annual surface water yields of 30-81%.

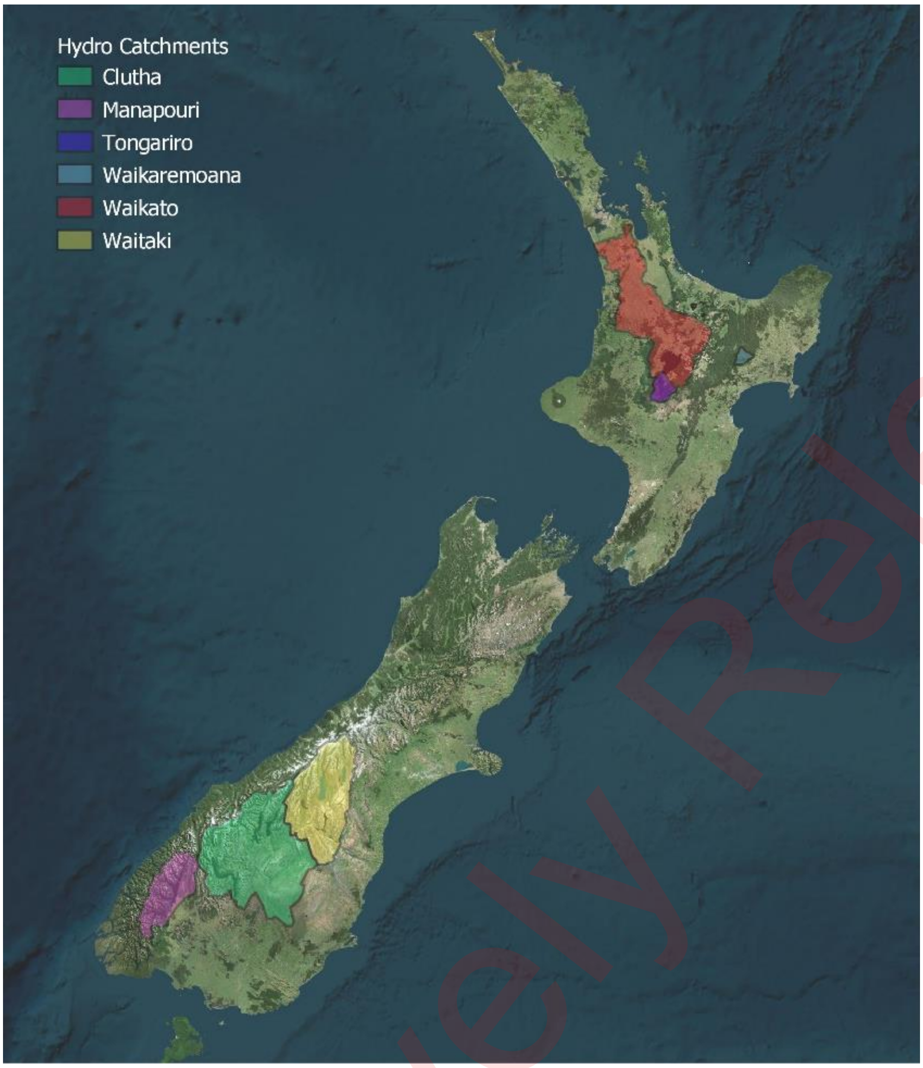
6.2.1 Hydro impacts

The spread of wilding conifers in hydro lake catchments can reduce water yields and therefore the electricity generating capacity of our hydro dams. This is a substantial economic cost. Additionally, it is worth noting that a reduction in the generating capacity of our hydro dams without an equal reduction in electricity demand, would see that demand met by alternative electricity generators. This would most likely be from non-renewable sources in the short term, gradually being replaced by renewable sources as New Zealand plans to move to 100 percent renewable energy ('Labour Promises 100% Renewable Electricity Generation by 2030', 2020).

6.2.1.1 Water yield loss in hydro catchments

The impact of wilding conifer spread on hydro catchments was determined by combining Landcare Research analysis on the reduction in water yield attributable to wilding conifer spread, with a geospatial analysis of the catchments of hydro power generators. Catchments are determined using NIWA's River Environment Classification dataset, which includes all water segments in the country and their up and downstream relationships to each other. Catchments are determined by including all upstream nodes from selected hydro generation plants. A reduction in upstream water yields reduces the amount of water passing through a plant and therefore it's generating capacity. Figure 17 displays the extent of hydro catchments used in this analysis.

Figure 17: Hydro generator catchments



Source: Sapere analysis

6.2.1.2 Value of hydro generation

Consistent with the CBA undertaken for Phase two of the wilding conifer control programme, the hydro resource rent series produced by Statistics NZ is used to express the value of hydroelectricity catchments. This is broadly equivalent to the EBITR measure used to estimate productivity losses from land use changes and the value derived from hydroelectricity generation when calculating GDP.

Table 15: Resource rents for hydro catchments

Hydro catchment	Estimated annual value of hydro resource rent (2018, forecast to 2021)
Waitaki	$176,072,000
Waikato	$89,806,000
Manapouri	$118,911,000
Clutha	$91,768,000
Tongariro	$30,917,000
Waikaremoana	$7,826,000

Source: Statistics NZ

6.2.1.3 Hydro generation benefits by option

The benefits represent the additional water yield loss avoided by controlling the spread and densification of wilding conifers. The present value of controlling wilding conifer spread on hydro generation ranges from -$66 - $458 million over the next 50 years under the range of options assessed. The value of controlling wilding conifer spread in the Waitaki and Clutha catchments dominates results. This is consistent with expectations. The Waitaki catchment has the largest allocation of current resource rent of the catchments analysed and is vulnerable to wilding conifer spread due to the location of current infestation and land use choices within the catchment. This is clearly recognized by the NWCCP with the minimum option capturing the majority of the potential benefits of control within this catchment. The Clutha catchment has the third largest allocation of current resource rent and is similarly vulnerable to wilding conifer spread. Wilding conifer control under the Status quo option is inadequate to prevent net hydroelectricity disbenefits from occurring.

Table 16: PV of hydroelectricity benefits over 50 years ($ millions)

Hydro catchment	Status quo	Minimum	Intermediate	Maximum
Waitaki	$45	$267	$267	$267
Waikato	-$32	-$10	-$10	$30
Manapouri	-$4	-$4	-$3	-$3
Clutha	-$68	$40	$147	$147
Tongariro	-$7	$14	$14	$16
Waikaremoana	$0	$0	$0	$0
Total benefits	**-$66**	**$307**	**$415**	**$458**

Source: Sapere Analysis

6.2.2 Irrigation impacts

The spread of wilding conifers upstream from irrigated land can reduce water yields and the value derived from these irrigation systems.

Consistent with the previous CBA, the value of irrigation is determined at the regional level, extrapolating forward a 2014 *Value of Irrigation* study (NZIER & AgFirst Consultants NZ Ltd, 2014) to determine the value per hectare of irrigated land. This is then adjusted for the increase in irrigated land using an irrigated land area geospatial dataset created by Aqualinc Research Limited and adapted by Statistics NZ and the Ministry for the Environment. The estimated value obtained from irrigation for non-forestry activities is displayed in Table 17.

Table 17: Value received from non-forestry irrigated land

Region	Regional value of irrigation (2022)	Irrigated Hectares of productive, non-forestry land (2020)
Canterbury	$1,394,100,000	478,026
Otago	$264,400,000	94,073
Marlborough	$148,600,000	26,545
Hawke's Bay	$88,368,000	21,855
Bay of Plenty	$62,720,000	12,939
Tasman	$58,800,000	9,592
Manawatu	$48,272,000	19,176
Waikato	$35,168,000	26,043
Wellington	$25,984,000	14,284
Northland	$22,176,000	7,289
Southland	$19,300,000	13,800
Auckland	$15,344,000	7,631
Taranaki	$13,664,000	6,355
Gisborne	$10,528,000	3,030
West Coast	$2,800,000	2,751
Total	$2,210,224,000	743,389

Source: Aqualinc Research, Ministry for the Environment, Statistics NZ, NZIER

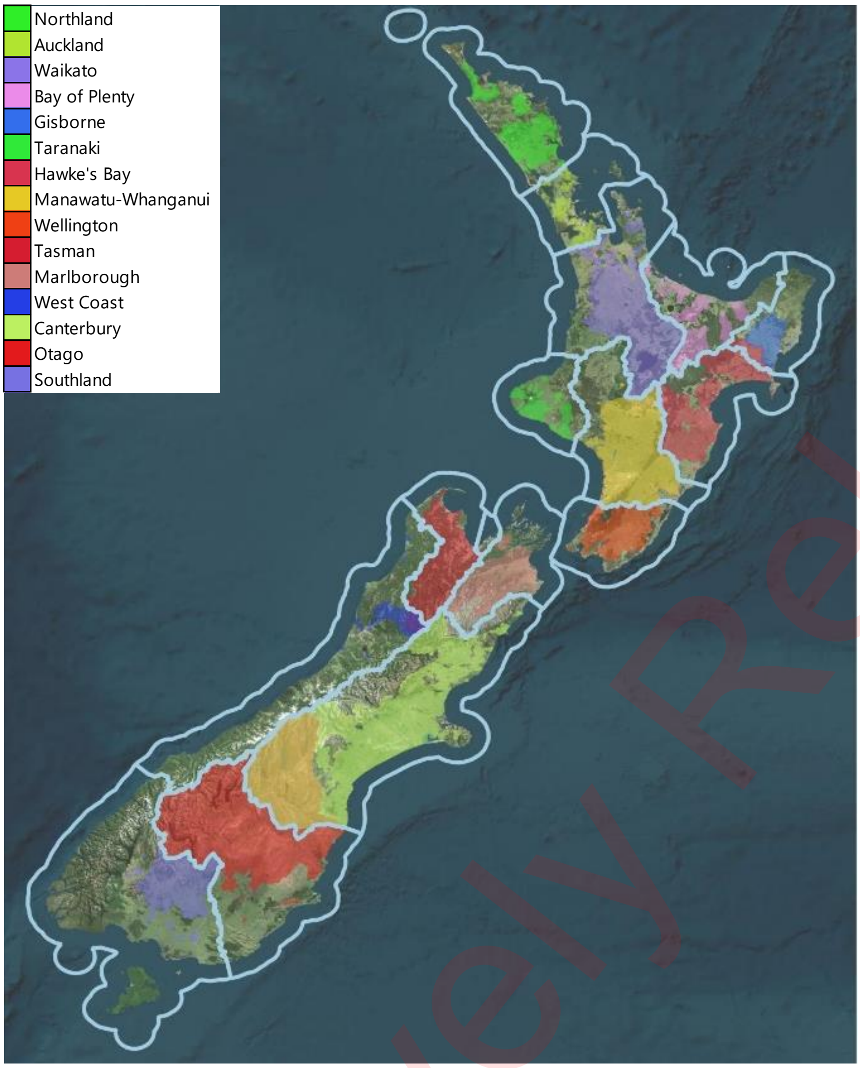
Irrigation values are highest in Canterbury, Otago and Marlborough. These areas are also at risk of wilding infestation. Canterbury and Otago in particular, are predicted to have large areas of dense infestation under the Status quo option.

Similar to the methodology used to determine hydro generation catchments, the water yield reduction from wilding conifer spread was determined using a combination of an irrigated land area geospatial dataset created by Aqualinc Research Limited, and NIWA's River Environment Classification dataset. A map of irrigated land (Figure 18) and their corresponding upstream catchments (Figure 19) are shown below. Some regional catchments overlap providing additional value from controlling spread in these areas. Notably, the orange shaded area in South Canterbury where the Canterbury catchment overlaps with the Otago catchment and the dark purple shaded area at the top of the West Coast where the West Coast and Tasman catchments overlap

Figure 18: Irrigated land areas, 2020

Source: Aqualinc Research Limited

Figure 19: Regional irrigation catchments



Source: Sapere analysis using Aqualinc Research Limited and NIWA's River Environment Classification data

Under the status quo option, a significant reduction in water yields will occur across irrigation catchments as wilding conifers spread. The benefits displayed in Table 18 represent the water yield loss avoided by controlling the spread of wilding conifers. The PV of controlling wilding conifer spread on irrigation ranges from $465 - $1,915 million over the next 50 years under the range of options assessed. Benefits are heavily concentrated in Canterbury, Otago and Marlborough with notable benefits also accruing in the Tasman, Bay of Plenty and Waikato under the maximum option.

Table 18: PV of irrigation benefits over 50 years (millions)

Irrigation Catchment	Status quo	Minimum	Intermediate	Maximum
Canterbury	$301	$767	$959	$1,193
Otago	$170	$316	$519	$519
Marlborough	$52	$108	$134	$171
Tasman	-$1	$5	$13	$43
Bay of Plenty	-$20	$4	$4	$5
Manawatu	-$10	-$10	-$7	-$5
Hawke's Bay	-$13	-$15	-$15	-$8
Waikato	$1	-$1	-$1	$7
Southland	-$2	-$2	$0	$0
Northland	-$3	-$1	-$1	-$1
West Coast	$0	-$1	-$1	$1
Auckland	$0	$0	$0	$0
Gisborne	$0	$0	$0	$0
Taranaki	$0	$0	$0	$0
Wellington	-$10	-$10	-$10	-$10
Total	**$465**	**$1,160**	**$1,595**	**$1,915**

Source: Sapere Analysis

6.3 Avoided cultural / biodiversity losses

Wilding conifer spread has a negative impact on cultural ecosystem services (biodiversity, recreation, aesthetic, and heritage values) as wilding conifers grow and outcompete natives for resources and quickly overtake natural landscapes. For cultural ecosystem services, a stated preference method can be used to monetise the values. Stated preference methods attempt to learn people's willingness to pay by directly asking them how much they value a certain environmental good or service. Careful survey design is key to the success of stated preference methods at eliciting willingness to pay information from participants. A recent willingness to pay study on wilding conifer control in New Zealand has been used as the basis for analysis on avoided cultural/biodiversity losses.

6.3.1 Monetised using non-market valuation (WTP) study

The non-market valuation study reveals the use and non-use values from wilding control such as scenery, recreation and the existence of ecosystems and species through Willingness to Pay (WTP) survey of households (Polyakov et al., 2021). We used this study's results through the value transfer methodology for monetisation of these benefits.

Polyakov's study looked at New Zealand households' willingness to pay for wilding conifer control using a choice experiment. Participants were presented with a choice set, which displayed different control scenarios across different regions combined with a dollar value displaying the cost to the participant's household under each option. The control scenarios were to allow wilding to spread, to contain infestation to its current extent, or to reduce the infestation.

The study controlled for:

- household incomes,
- the region of the participant,
- whether the participant had been hiking in the last five years,
- the level of invasion within the participant's region,
- whether they were financially impacted by Covid
- whether they lived in the city centre, suburbs or countryside.

By presenting choice sets with different control outcomes for different regions, the study also controlled for the distance from the participant's region to the invasion.

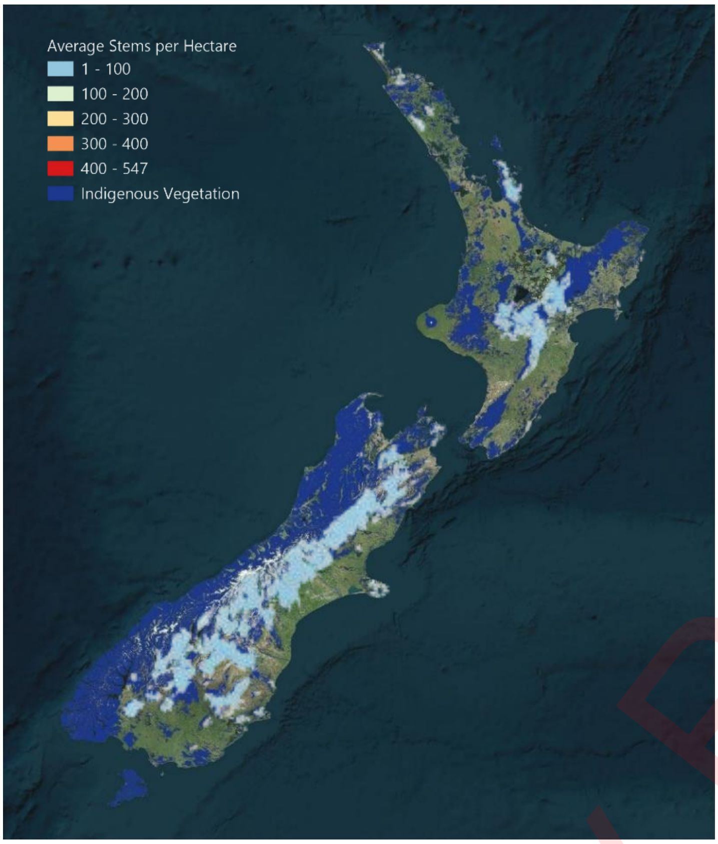
The average household is willing to pay $105 a year for five years to reduce the area infested with wilding conifers by 1000 km^2 (Polyakov et al., 2021). This value diminishes the greater the areas controlled, the further away the household is from the control area and for low-income groups or those financially impacted by Covid-19. High income groups and rural households are willing to pay slightly more.

6.3.2 Area valued

The study only looked at control and invasion across areas of indigenous vegetation. This makes it useful for evaluating willingness to pay in the context of protecting and enhancing native biodiversity values.

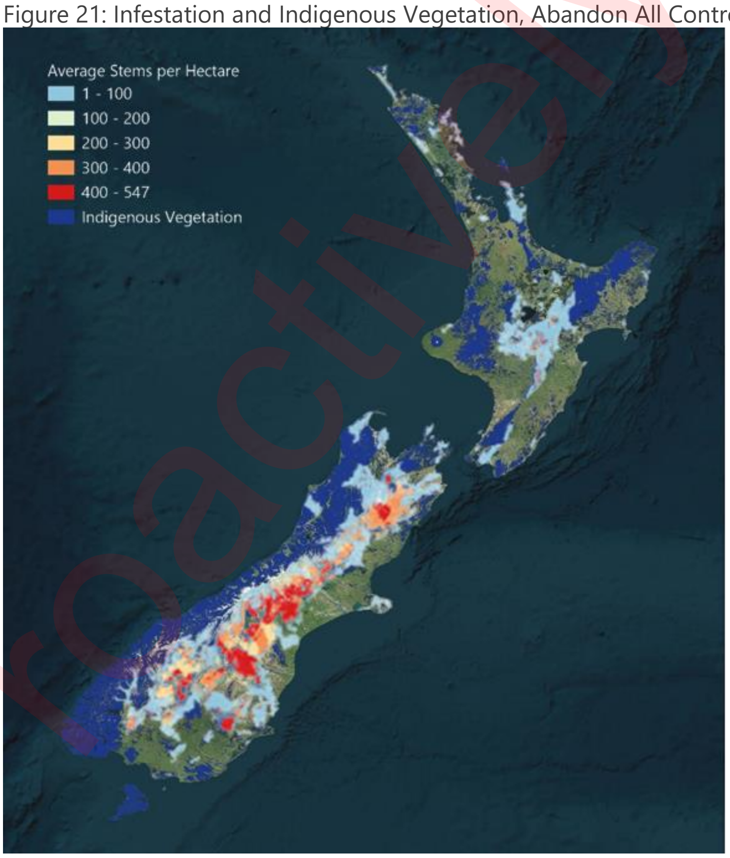
Polyakov selected landcover database classes 43 – 70 as 'indigenous vegetation'. The following figures show the current invasion overlaid on top of the areas considered indigenous vegetation and the invasion in year 50 under the different options. The purple shaded areas are indigenous vegetation with no wilding conifers present.

Figure 20: Existing Infestation and Indigenous Vegetation



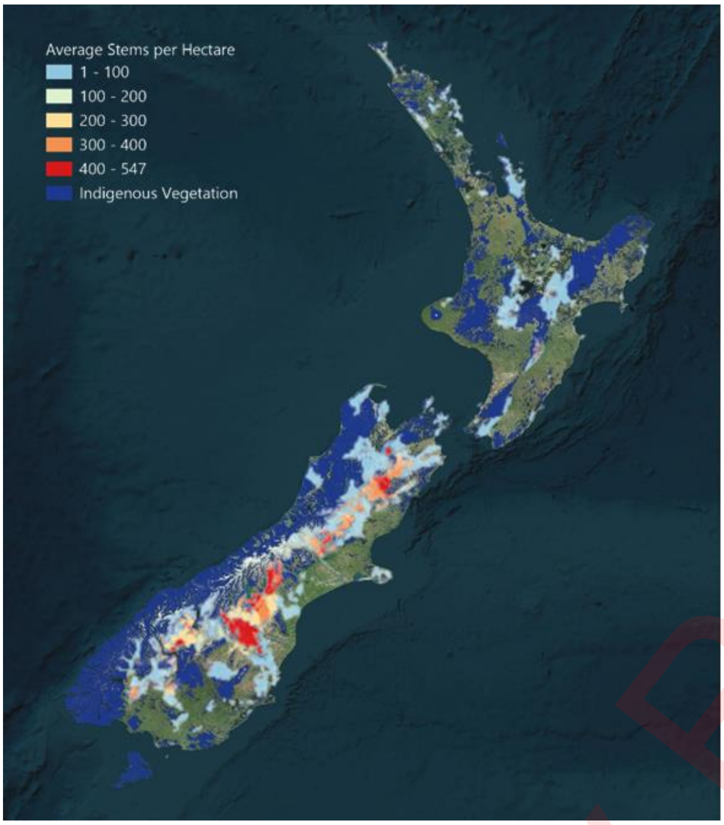
Source: Sapere Analysis, Landcare Research

Figure 21: Infestation and Indigenous Vegetation, Abandon All Control Activities, 2072



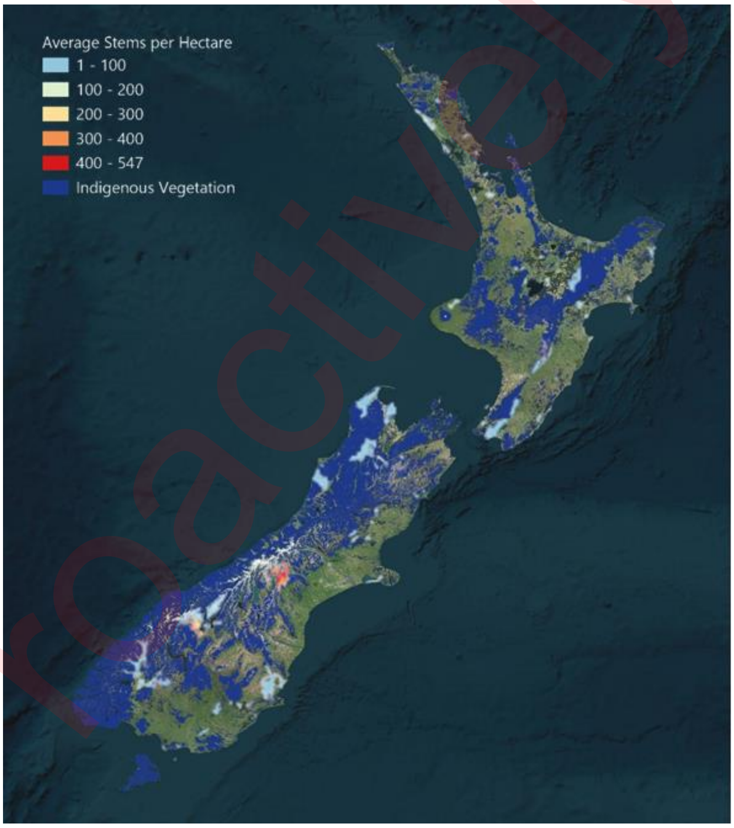
Source: Sapere Analysis, Landcare Research

Figure 22: Infestation and Indigenous Vegetation, Status quo Option, 2072



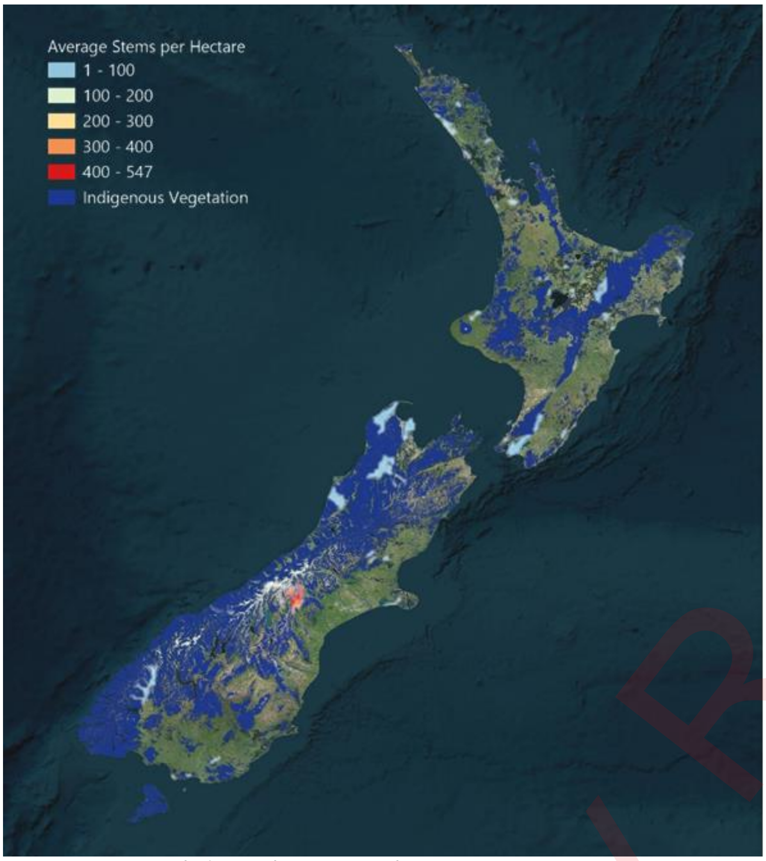
Source: Sapere Analysis, Landcare Research

Figure 23: Infestation and Indigenous Vegetation, Minimum Option, 2072



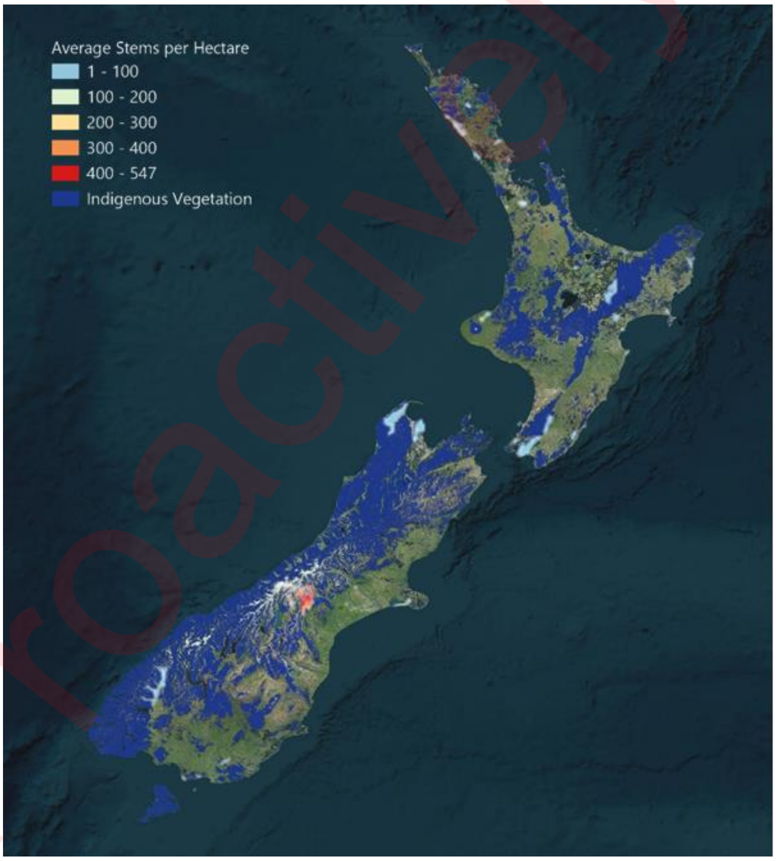
Source: Sapere Analysis, Landcare Research

Figure 24: Infestation and Indigenous Vegetation, Intermediate Option, 2072



Source: Sapere Analysis, Landcare Research

Figure 25: Infestation and Indigenous Vegetation, Maximum Option, 2072



Source: Sapere Analysis, Landcare Research

6.3.3 Values used per ha controlled

We use the logit model developed by Polyakov to estimate the total willingness to pay (each year for 5 years) for all households in New Zealand based on the areas controlled under the three options. This gives the following values:

Table 19: Value of cultural/biodiversity benefits based on WTP study ($ millions)

	Status quo	Minimum	Intermediate	Maximum
Willingness to pay by all NZ households each year for 5 years ($ millions)	$348	$493	$493	$493
Value per year ($ millions)	$48	$117	$117	$117
Present value over 50 years ($ millions)	$875	$2,137	$2,137	$2,137

Source: Sapere analysis

The total willingness to pay is each year for five years. This gives us the total non-market value for the use and non-use benefits arising from control of wilding conifers. We have made an assumption that cultural / biodiversity values are ongoing so the value of control per year is the total willingness to pay for 5 years spread across 50 years.

One limitation in using this study is that participants were not presented with a choice to remove wilding conifers completely. At most, an option to remove half of the existing infestation was presented. In addition, household's willingness to pay diminishes the greater the area controlled. As a result, we hit a ceiling at the minimum option and no additional value is generated under the intermediate or maximum option. This is because the hectares controlled under these options are greater than the scope of the WTP study. It would not be appropriate to extrapolate the model beyond its limits as this results in negative marginal willingness to pay values. This limitation may mean that the benefits from avoiding cultural/biodiversity losses is understated.

An additional limitation of the model is that each choice set that participants were presented with provided reduction or containment of wilding conifer spread choices across a maximum of two regions. For this reason, only the willingness to pay across the two regions[11] with the largest nominal spread prevented by the control programme has been analysed. This limitation also has the impact of understating the benefits of avoided biodiversity losses.

[11] Canterbury and Otago

6.4 Benefits from reduced wildfire risk and hazard

The likelihood of wildfires (**fire risk**) is determined by weather and a source of ignition, e.g. machinery, burn offs, rubbish fire. Fire behaviour (or **fire hazard**) is affected by the interaction between the topography of the land, fuel load (what is available to burn) and weather conditions.

The impact of wilding conifer spread on the cost of wildfires has not been quantified, but the commonly held view is that the establishment of wilding conifers increases fire risk and hazard. Wilding conifers typically replace grasslands which are associated with lower fire intensity and less damage to vegetation and property (V. Clifford et al., 2013).

Some control methods can also contribute to fire risk and hazard. Increases in fuel loads (either as dead standing or felled trees on the ground, or as more grass or scrub cover) will result in an increased chance of ignition, greater potential for fire spread and higher fire intensity. The length of this increased flammability will depend on the amount of material left on the ground, the rate of decomposition, fuel moisture and other vegetation present (V. Clifford et al., 2013).

Wildfires fuelled by wilding conifers are rare, however, there are some notable examples, the 2008 Mt Cook wildfire covering 756 hectares was fuelled by dense stands of wilding pines (V. R. Clifford & Pearce, 2009), the Aoraki/Mt Cook fire in August-September 2020, which burnt through more than 3,100 ha of wilding forest and tussock on private land, and 2020 Lake Ohau fire covering 5043 hectares (Fire and Emergency New Zealand, 2021), which destroyed or damaged 53 houses.

In researching the potential costs avoided by controlling wilding conifers we spoke with staff at Fire and Emergency NZ (FENZ) and Scion Research. The impact of wilding conifers on wildfire costs is an area requiring further research but the costs would depend on specific and localised factors such as the control method, the characteristics of the area controlled, potential ignition sources and the presence of fire breaks. The resources committed to suppressing fires would also be weighed against the potential for damage, i.e. more would be put into suppressing a fire close to residential areas and sites of cultural significance. As a result, we have opted for a simple but defensible approach to valuing the benefits of control on wildfire costs.

For this CBA we assume the impact of wilding conifer control reduces the cost of wildfires by controlling trees before they spread and grow, preventing them from becoming a major fuel source. We do not assume that wildfire risk is removed entirely but as a result of control we assume benefits from a reduction in future suppression costs and associated damages.

6.4.1 Value of avoided costs

The value of avoided suppression costs and damages is based on an economic analysis of the cost of wildfires (BERL, 2009), inflation adjusted to 2021 dollars. Using this we get the following values:

Figure 26: Avoided wildfire costs

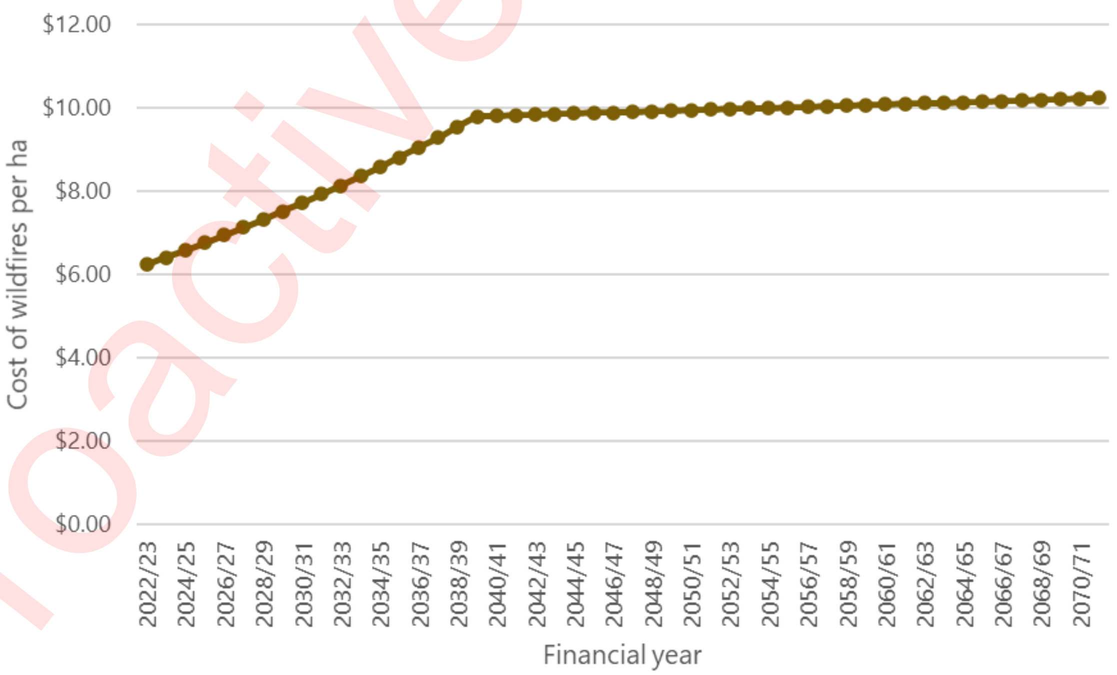
Component	Cost per ha per year
Suppression costs	$2.13
Cost of damages	$4.11
Benefit per hectare controlled per annum	$6.24

Source: BERL

6.4.1.1 The value is adjusted to reflect the increased risk of wildfires because of climate change

Climate change is also expected to have an impact on wildfires with an increase in the frequency and severity of wildfire events. Modelling shows a 70% increase in very high and extreme fire risk days by 2040, increasing to 82% by 2090 (Watt et al., 2019). The benefits per hectare controlled is adjusted to account for the expected change in very high and extreme fire risk days due to climate change as shown in Figure 27.

Figure 27 Benefits per hectare controlled adjusted for increased very high and extreme fire risk days due to climate change



Source: Sapere analysis

6.4.2 The benefits from avoided wildfire costs

We assume that all land controlled, plus the avoided spread, contributes to the avoided cost of wildfires. Applying the cost of fire to this area we derive the following benefits over 50 years from control activity on wildfire costs.

Figure 28: Present value of fire benefits by investment option ($ millions)

Component	Status quo	Minimum	Intermediate	Maximum
Avoided spending on wildfire suppression costs	$29	$105	$108	$109
Avoided spending on damages caused by wildfires	$57	$203	$208	$209
Proportion of costs caused by climate change	48%	49%	50%	50%
Total benefits (PV)	$86	$308	$316	$318

Source: Sapere analysis

The benefits from reduced fire risk range from $86 million over 50 years under the status quo option to $318 million under the maximum option. The impact of climate change risk is significant, accounting for forty-eight to fifty percent, or $41 - $159 million of the avoided costs.

6.5 Māori cultural values (qualitative)

The term cultural value has wide meaning and can include historic and aesthetic value of sites or landscapes, recreation, indigenous biodiversity, ancestral and spiritual values, people's sense of place and identity, kaitiakitanga (guardianship), and bequest value for future generations. This list is not exhaustive, but it highlights how difficult it is to simply define cultural value. In their report on non-market impacts of wilding conifers on cultural values Greenaway et al. use the definition:

> **the collective norms and expectations that influence how ecosystems accrue meaning and significance to people (Greenaway et al., 2015)**

For Māori, there are clear links between healthy ecosystems and people's cultural and spiritual well-being (Harmsworth & Awatere, 2013). The depth of Māori cultural values is well articulated in the introduction to Indigenous Māori Knowledge and Perspectives of Ecosystems:

> **Indigenous Māori have an intricate, holistic and interconnected relationship with the natural world and its resources, with a rich knowledge base – mātauranga Māori – developed over thousands of years and dating back to life in Polynesia and trans-Pacific migrations. This ancestral traditional bond links indigenous Māori to ecosystems and**

governs how they see and understand ecosystems and ecosystem services (Harmsworth & Awatere, 2013).

In effect, some Māori values are deep rooted and accrue indefinitely so are not able to be adequately monetised in this CBA. Protection of waterway health (Te Mana o te Wai), native landscapes (whenua ora) are also important in Te Ao Māori and at Iwi level, sustainable productive land use will also be of importance of many Iwi and Hapū. Some of these values have been included, through the monetised benefits of productive land use and water yields, fire risk and in biodiversity values. In their willingness to pay study, Polyakov et al estimate non-market values such as existence values of ecosystems and species resulting from wilding conifer control.

In the 2011 Wilding Conifer Status report it is noted that the impact on Māori cultural values has been low but could become significant should wilding spread reach a tipping point. Impacts described in this report included the loss of culturally significant sites and impact on water flows and health of waterways (Froude, 2011).

Cultural assessment models can be used to provide a cultural lens to policy and decision making on ecosystem projects. The Wilding Conifer Management Programme also recognises Māori cultural values in its activities. Iwi-involvement are involved in a number of projects and all conifer control programme applications ask for info on the Māori cultural values and to note where there is support or involvement of local Iwi or Hapū.

Qualitatively, the following Māori values can provide a basis for what is valued (Harmsworth & Awatere, 2013).

- Rangatiratanga: The right to exercise authority and self-determination within one's own iwi and/or hapū realm.
- Kaitiakitanga: Guardianship, stewardship, trusteeship, trustee. Kaitiakitanga is an important Māori value that bestows an obligation of stewardship on Māori to care for the environment.
- Whanaungatanga: Relationship, kinship, sense of family connection – a relationship through shared experiences and working together, which provides people with a sense of belonging.
- Wairuatanga: The immutable spiritual connection between people and their environments.
- Mātauranga: Māori/mana whenua knowledge and understanding.

7. Case study – Motupōhue (Bluff Hill) Restoration

7.1 Background

Motupōhue (Bluff Hill)[12] is located at the southern tip of Te Wai Pounamu the South Island, in an area known by Ngāi Tahu as Awarua. The hill encompasses approximately 960 hectares of land in total, and is a significant site of cultural, recreational and ecological importance.

Today there are multiple owners and managers of land within the maunga: The town of Bluff takes up 221 hectares (ha), farmland 118 ha, and the Isthmus 122 ha. The DoC Scenic Reserve covers 204 ha and Invercargill City Council Reserves 295 ha.

Once known for deafening birdsong, Motupōhue is home to declining at-risk, nationally vulnerable and endangered bird species[13]: black-backed gull (Karoro), little blue and yellow penguins (Kororā and Hoiho), Stewart Island shag (Koau), mainland sooty shearwater (Tītī), red-crowned parakeet (Kakariki), South Island rifleman (Titipounamu), fernbird (Mātā), Kākā and New Zealand pigeon (Kukupa/Kereru).

Many have been in decline due to pest predators and the degradation of native bush.

Within the 295 hectares on the maunga owned by Invercargill City Council (ICC), a section was used for plantation forestry for several decades, until being cleared for the last time in 2013. There remained the need to remove resulting wildings. Over the years ICC and Bluff Hill Motupōhue Environment Trust volunteers removed several thousand small conifers, though they were only able to deal with small stems. Removing larger mature trees would need specialist help and funding.

The value of wilding control work on Motupōhue, while it has economic benefits for the local community through tourism and recreational uses, is beyond what can be quantified in financial terms.

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[12] ***From Kā Huru Manu, cultural atlas published by Te Runanga o Ngāi Tahu:***

Motupōhue (Bluff Hill) is the prominent forested hill located behind Bluff township. Motu in this case means "a clump of trees", and pōhue is the native convolvulus (Calystegia sepium). In accordance with his dying wish, the celebrated Kāti Māmoe leader Te Rakitauneke was buried on Motupōhue with his face to the rising sun, so that he could overlook Murihiku (Southland). Te Rakitauneke's saying was: "Tāpuketia au ki Motupōhue kia mārama ai tāku titiro ki Te Ara-a-Kiwa" — "Bury me upon Bluff Hill so that I may gaze upon Foveaux Strait".

[13] Ngāi Tahu names for Taonga species Ngai Tahu Settlement | Beehive.govt.nz

7.2 Significance for Ngāi Tahu

Motupōhue is recognised as Tōpuni in the Ngāi Tahu deed of settlement with the Crown (1998), reflecting the mana of the site and recognising the role of the people of Ngāi Tahu as kaitiaki (guardians of wellbeing) and manawhenua (holding customary authority, rights and responsibilities for the life of the natural environment and resources in their rohe).

In Ngāi Tahu legend, Motupōhue is Te Tau Rapa o te Waka o Maui (the stern of Maui's waka – where the chiefs stand, where it is steered from). I In cultural history it was the lookout site at the very south of Te Waipounamu, connected with Te Punga o Te Waka a Maui (the anchor of Maui's waka) the other lookout site in the area – across the strait on Rakiura (Stewart Island). It is also a burial ground for chiefs, including Ngāti Mamoe leader, Te Rakitauneke.

This makes it a sacred place of extra special historical significance and equally treasured by today's generations of Ngāi Tahu, including the tamariki at the marae based Kohanga Reo operated at Te Aroha Marae on the maunga

Tamariki attending Te Rourou Whakatipuranga O Awarua, are growing up with the maunga, as a part of their past present and future. It's a place to be connected with their whakapapa, and where they learn about biodiversity and conservation. They are taken up the hill to learn about the native ecosystems, to participate in protecting the maanu (birds) by trapping pests, and to gather kai.

Mātauranga Māori connects whenua and whanau. When the land is damaged, the people are damaged. When exotic species invade the whenua, they displace native flora and fauna and the mana of whanau is impacted. Clearing wilding pine helps to restore that mana.

Dealing with the wilding conifer problem

In 2018 the Council spent about $30,000 to boost the wilding pine removal process.

"We realised it was going to be a big job, and that it would take a long time to finish," says Kate Gough, then Council Team Leader Parks Environmental Reserves.

In 2019, Invercargill City Council applied for and received a Community Partnership Projects funding grant of $200,000 from the National Wilding Conifer Control Programme, via Environment Southland. Council also providing funding and staff time to make sure the project was completed.

In total, the wilding control work funded by the National Wilding Conifer Control Programme covered around 127 hectares – the area outlined in black on the aerial image below.

Figure 29: Area of wilding control, Bluff Hill

Image from National Wilding Conifer Control Programme's Wilding Conifer Information System, provided by Toitū Te Whenua Land Information New Zealand

This support to clear much of the wilding infestation coincided with the Bluff Hill Motupōhue Environment Trust (BHMET) receiving funding to expand its predator control work, via the Department of Conservation (DoC) Jobs for Nature Community Conservation Group funding.

"That alignment of the two sources of funding was very fortunate and is allowing a real acceleration of habitat restoration across the whole of Motupōhue," said David Swann, BHMET Project Manager.

Bluff Hill Motupōhue Environment Trust (BHMET)

Bluff Hill Motupōhue Environment Trust (BHMET) was formed in early 2008 by members of Runaka Awarua o Ngāi Tahu, and other concerned Bluff residents. Their passion for the protection and restoration of Motupōhue and concern about pests were galvanised when adult tītī were found killed by a stoat.

Estelle Pera-Leask, Chair of BHMET and member of Runaka Awarua o Ngai Tahu relates the feeling of the community at the time "We've lost so much, we can't afford to lose anymore… There are penguin colonies, tītī, and other species you won't find in many other places – it's a no brainer."

Despite meeting initial scepticism for what they hoped to achieve, BHMET eventually entered into a Management Agreement with the Department of Conservation (DOC) and the Invercargill City Council (ICC) to undertake environmental restoration in the Bluff Hill area.

The Trust is supported by volunteers (including its Trustees) to carry out pest control, management and administration duties and receives generous and critical support, including funding, from other agencies and local organisations for various aspects of the restoration work.

Soon after setting out towards its vision, the Trust received in 2009 its first of numerous environmental and community awards recognising its mahi.

Trapping lines with more than 2000 pest control devices stretch for over 75 kilometres around the whole hill and the numbers are staggering. Predator catches in one month can count in the dozens for multiple predator species, mostly rodents and mustelids. A record was set in 2012 for 39 possums in one month.

While removing pest animals and overshadowing wildings helps make space for native species to re-establish, the birds the maunga was once known for need food sources and habitat to safely live and breed, explains David Swann, BHMET Trustee & Project Leader. To this end, the Trust established its own nursery to re-populate the whenua with plants that belong there and support its treasured inhabitants.

Seeds in the hundreds of thousands are gathered from the maunga, sown, nursed and re-planted - replacing natives damaged by pests, and the spaces now cleared of invading wildings.

"What was the wilding pine mess will now be native vegetation," explains Estelle.

Outcomes

With the bulk of wildings mostly cleared, though some remain, the potential damage of a wilding-fuelled fire getting out of control is reduced, and fresh water from aquifers and underwater springs (natural awa) can be purified by running through restored native bush. Kōura (freshwater crayfish) and tuna (eels) are now able to thrive.

With Jobs for Nature funding the trust is involved in a major habitat restoration on that part of the hill. David Swann, says "in the few months that have passed, the extent of native regrowth is staggering and is a joy to see for the trust and the community."

Native birds including Kākā and kereru, that were unable to thrive in the pine forest, have been returning to the area. The South Island robin (Kakaruwai) has been translocated back to the hill now that their food sources are available again. These birds only establish on podocarps full of invertebrates and berries. Maximising area available for podocarps is also important for the movement of ground dwelling birds as well, such as kiwi when they are re-introduced.

Once the native bush regenerates (up to 15 years) it will outcompete wildings and gorse stopping them from re-establishing, but, David says, "in the short term, as long as any wilding pine remains, the threat remains for any native bush still in its regenerating phase."

The mahi to rid Motupōhue of the last of the outlying wilding pines will continue for some time, led by Invercargill City Council.

Kate Gough, Invercargill City Council, says in 2022 "It is great to have made some really positive progress on the hill, but this isn't the end. Seedlings and small pines that have been missed will show up over the next few years, so we now need to keep monitoring this and remove them as they're found. So yes, we have got a great head start to the wilding pine removal, but the job is not done yet!"

Kate Gough, Invercargill City Council, has great respect for the Trust's commitment and achievements.

“It’s wonderful to work with a community that has real drive and a clear vision of what they are wanting to achieve. Bluff has so much potential and the work that the community are putting into it to make the place shine is humbling and is a journey that I feel privileged to be able to be part of.”

Estelle, David and the Trust see a restored Motupōhue Bluff Hill as an important site to support genetic diversity of Kākā and Kereru. It forms part of an essential corridor for flocks of kereru to travel, feed and rest (and next), between Rakiura, Motupōhue and Fiordland – supplying important variety in food sources, and allowing flocks to inter-breed, enhancing healthy genetic biodiversity.

The members and supporters of the Bluff Hill Motupōhue Environment Trust have a long-term vision for the restoration of whole of the maunga. This includes plans to reintroduce Tīeke (saddleback) in 2023 from one of the nearby titi islands and reintroduce kiwi by 2030.

For Estelle and the people of Ngāi Tahu ki Murihiku, particularly Runaka Awarua, it’s about restoring the mana to the area. “It (the restoration occurring) means everything to us – the mana and mauri (life force) of that hill is restored… “We have native forest that people can visit. Visitors rave about what they see. We’re super proud of it”.

For more information visit https://www.motupohue.nz/

8. Area for further research

Post-completion of this CBA, discussion with stakeholder groups revealed areas of further research that could complement this analysis.

Economic value from harvesting wildings: some value is generated from harvesting wilding logs and biomass. Incorporating this effect would reduce the net costs of clearing wildings in areas where it is practical, further increasing the BCR.

Slope stability, flooding intensity and root system aquifer retention impacts: clearing trees has environmental impacts regardless of whether the tree is a 'pest' or not. Wilding conifers do provide some environmental benefits which would be lost if land is transitioned to another, non-forestry use. Monetising and incorporating these benefits of wilding pines would decrease the net benefits from clearing wildings in some areas.

Wider biodiversity impacts: as a function of limitations discussed in the body of the report, as a measure of biodiversity, this report has only considered the impact of wilding conifers on areas of native vegetation.

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Appendix A Options by Management Unit

Investment options by management unit, shaded indicates the area is controlled under the option

Table 20 Investment options by MU

Management Unit	Existing control	Status quo (as at 2025/26)	Minimum	Intermediate	Maximum
Albury	1		1	1	1
Alexandra	1		1	1	1
Awatere	1		1	1	1
Banks Peninsula	1		1	1	1
Barrier Islands	1		1	1	1
Coromandel	1		1	1	1
Craigieburn	1		1	1	1
Dunedin	1		1	1	1
Dunstan	1	1	1	1	1
Flagstaff	1	1	1	1	1
Four Peaks	1		1	1	1
Glenorchy	1		1	1	1
Golden Bay	1		1	1	1
Hakatere	1	1	1	1	1
Hunter Hills	1		1	1	1
Kaimanawa	1	1	1	1	1
Kawarau	1	1	1	1	1
Kurow	1		1	1	1
Lammermoor	1	1	1	1	1
Lewis	1		1	1	1
Lower Wairau	1		1	1	1
Luggate	1		1	1	1
Mid Dome	1		1	1	1
Molesworth	1	1	1	1	1
Mount Richmond	1		1	1	1
Naseby	1		1	1	1
Northern Eyre	1		1	1	1
Ohau	1	1	1	1	1

Porters	1		1	1	1
Pukaki	1		1	1	1
Rangitaiki	1		1	1	1
Rawhiti	1		1	1	1
Remarkables	1	1	1	1	1
Rotorua Lakes	1		1	1	1
Rough Ridge	1		1	1	1
Shotover	1		1	1	1
Sounds	1		1	1	1
Takitimu	1		1	1	1
Taupo West	1		1	1	1
Tauranga	1		1	1	1
Te Hiku	1		1	1	1
Tekapo East	1		1	1	1
Tekapo West	1	1	1	1	1
Tongariro	1		1	1	1
Twizel	1		1	1	1
Waiau	1		1	1	1
Waihopai	1		1	1	1
Waitaki	1		1	1	1
Wakatipu	1		1	1	1
Branch/Leatham				1	1
Clutha				1	1
East Otago				1	1
Ernslaw				1	1
Hurunui				1	1
Kaikoura				1	1
Mavora				1	1
Ruahine				1	1
Wanaka				1	1
Wangapeka				1	1
West Otago				1	1
Ashley					1
Broadlands					1

Grey					1
Gwavas					1
Hunua					1
Inner Gulf Islands					1
Nelson Lakes					1
Pureora					1
Rainbow					1
Taupo East					1
Waipa					1
Wairau Foothills					1
Waitakere Ranges					1
MU's controlled	49	10	49	60	73

Source: MPI

Appendix B Value of impacts used in the CBA

The following table summarises the impacts calculated in the CBA, assumptions, evidence, values and the present value under the proposed options.

Table 21 Summary of impacts

ID	Impact	Description	Assumptions	Evidence	Wellbeing domain	Group impacted	Sub group	Annual value	per	Status quo	Minimum	Intermediate	Maximum
1	Land use (productive potential)	Invasion of wildings reduces productive potential on low and high producing grasslands. Differentiating between grazed and ungrazed with no spread on intensively grazed grasslands and high spread on ungrazed.	Grasslands are most exposed to wilding spread but grazing controls that spread. Spread on grazed land is assumed to be zero. The average survival rate of 50% is applied to all other grassland areas.	Buckley et al (2005) Slowing down a pine invasion despite uncertainty in demography and dispersal	Income and consumption	Land owners	Low producing sheep and beef	$53	ha	$512	$1,600	$1,663	$1,665
2							High producing sheep and beef	$344	ha	$50	$305	$328	$333
5	Land use (ETS impact)	Reduction in land use benefits due to conversion to permanent forest. High carbon prices are driving conversion of productive land into permanent forest to earn carbon credits.	1% loss on grasslands	PWC, Economic impact of forestry in New Zealand (2020), BakerAg (2021) Independent validation of land-use change from pastoral farming to large-scale forestry	Income and consumption	NZ Inc		1%	ha	-$6	-$20	-$21	-$21
6	Water (hydro generation)	Hydro impacts - invasion of wildings reduces water flowing into hydro catchments. The loss/gain applies to significantly vulnerable land (grassed) in hydro catchments.	Water yield loss is predicted for 1x1km grid square for all infested land using the WATYIELD model. Loss by catchment is the cumulative loss.	Fahey et al. (2010), Using the WATYIELD water balance model to predict catchment water yields and low flows	Income and consumption	Hydro power generators	Waitaki	$176,072,000	hydro catchment	$11	$233	$233	$233
7							Waikato	$89,806,000	hydro catchment	-$32	-$10	-$10	$30
8							Manapouri	$118,911,000	hydro catchment	-$4	-$4	-$3	-$3
9							Clutha	$91,768,000	hydro catchment	-$68	$40	$147	$147
10							Tongariro	$30,917,000	hydro catchment	-$7	$14	$14	$16

ID	Impact	Description	Assumptions	Evidence	Wellbeing domain	Group impacted	Sub group	Annual value	per	Status quo	Minimum	Intermediate	Maximum
11							Waikaremoana	$7,826,000	hydro catchment	$0	$0	$0	$0
12	Water (irrigation)	Irrigation impacts - invasion of wildings in very high water stress areas reduces surface flows which means less water is available for farmers' irrigation needs	Water yield loss is predicted for 1x1km grid square for all infested land using the WATYIELD model. Loss by catchment is the cumulative loss.	NZ Hydrology society (2010), Using the WATYIELD water balance model to predict catchment water yields and low flows	Income and consumption	Farmers	Canterbury	$1,394,100,000	region	$188	$655	$846	$1,080
13							Otago	$264,400,000	region	$155	$300	$503	$503
14							Southland	$19,300,000	region	-$2	-$2	$0	$0
15							Northland	$22,176,000	region	-$3	-$1	-$1	-$1
16							Auckland	$15,344,000	region	$0	$0	$0	$0
17							Waikato	$35,168,000	region	$1	-$1	-$1	$7
18							Bay of Plenty	$62,720,000	region	-$20	$4	$4	$5
19							Gisborne	$10,528,000	region	$0	$0	$0	$0
20							Hawke's Bay	$88,368,000	region	-$13	-$15	-$15	-$8
21							Taranaki	$13,664,000	region	$0	$0	$0	$0
22							Manawatu	$48,272,000	region	-$10	-$10	-$7	-$5
23							Wellington	$25,984,000	region	-$10	-$10	-$10	-$10
24							Tasman	$58,800,000	region	-$1	$5	$13	$43
25							Marlborough	$148,600,000	region	-$1	$5	$13	$43
26							West Coast	$2,800,000	region	$0	-$1	-$1	$1
27	Cultural / Biodiversity	Avoidance of biodiversity losses by protecting indigenous vegetation from wildings invasion. We value biodiversity as households' willingness to pay to control wilding conifers.	The maximum area the WTP value applies is a 50% reduction infestation area and up to $600 per household. The study cannot be applied to complete eradication of wildings.	Maksym 2021, The value of controlling wilding conifers in New Zealand (unpublished)	Environment	General public		$493,490,196	total nz households	$875	$2137	$2137	$2137

ID	Impact	Description	Assumptions	Evidence	Wellbeing domain	Group impacted	Sub group	Annual value	per	Status quo	Minimum	Intermediate	Maximum
30	Fire	Change in headfire intensity as a result of wildings spread has a proportionate impact on suppression cost	The change in headfire intensity is capped at 4000, above this level fire crews lose the ability to control wildfires.	Manaaki Whenua modelling	Safety	General public		$2.13	ha	$28	$104	$106	$107
31		Change in headfire intensity as a result of wildings spread has a proportionate impact on damages	The change in headfire intensity for values above 4000, above this level fire crews lose the ability to control wildfires and increased damages would be the result.	Manaaki Whenua modelling	Safety	General public		$4.11	ha	$54	$200	$205	$206
39	Costs	Programme control costs		MPI budget estimates		Government			Total	$28	$104	$106	$107
40		Fixed programme management costs (includes post control monitoring)		MPI budget estimates		Government			Total	$54	$200	$205	$206
42		Deadweight loss of tax associated with fiscal cost	As per Treasury guidance				As per Treasury guidance	20%	% of total control cost	$15	$29	$33	$36

Appendix C Cost of carbon emissions from a switch to non-renewable electricity generation

Within the New Zealand electricity generation network, Huntly performs the role of a back-up power source, to safeguard from dry years affecting Hydro generation or unexpected demand spikes outstripping demand.

The spread of wilding conifers unchecked across hydro lake catchments increases the frequency of hydro lake generation falling short of meeting demand and increases the amount of power that needs to be generated from Huntly. By replacing green energy generation with coal and gas generation, New Zealand's emissions will increase. While this impact is excluded from the CBA, it is displayed here for context.

High estimate - 1.1 to 8.5 million tonnes over 50 years

As a high estimate we calculate an emissions increase of 1.1 to 8.5 million tonnes over the next 50 years. This estimate does not account for any efficiency gains and subsequent reduction in emissions produced per GWh of coal or gas generation that may occur over the next 50 years. It also assumes that all power generation comes from generation units 5 & 6 in proportion to their current generating capacity at Huntly.

Each NZU offsets one tonne of carbon emissions (*About the New Zealand Emissions Trading Scheme*, 2021). Taking a carbon price of $50 per unit, this equates to an additional carbon cost of $16.9 – $120.5 million in present value terms over the next 50 years.

Table 22 Increase in emissions from replacing lost hydropower with generation at Huntly, over 50 years

	Status quo	Do Minimum	Intermediate	Maximum
Hydro generation lost (GWh)	21,178	7,909	4,306	2,765
Emissions increase (tonnes, CO2)	8,471,331	3,163,569	1,722,416	1,105,924
Additional NZUs demanded	8,471,331	3,163,569	1,722,416	1,105,924
Present Value of additional NZUs demanded ($m)	$120.5	$46.6	$26.3	$16.9

Source: Sapere analysis

Low estimate – 0.1 to 0.5 million tonnes over 8 years

As a low estimate we have also calculated the additional emissions over the next eight years to 2030 to account for the Government's stated aim of 100 percent renewable energy by 2030 ('Labour Promises 100% Renewable Electricity Generation by 2030', 2020). Over eight years, carbon dioxide emissions would increase by 0.09 – 0.44 million. With an additional $3.4 - $16.9 million of NZUs demanded in present value terms.

Table 23 Increase in emissions from replacing lost hydropower with generation at Huntly, over 8 years

	Status quo	Do Minimum	Intermediate	Maximum
Hydro generation lost (GWh)	1,107	523	346	226
Emissions increase (tonnes, CO2)	442,794	209,020	138,445	90,261
Additional NZUs demanded	442,794	209,020	138,445	90,261
Present Value of additional NZUs demanded ($m)	$16.9	$8.0	$5.3	$3.4

Source: Sapere analysis

Appendix D Wilding conifer forecasting method

The following description of the wilding conifer forecasting method has been provided by Norman Mason, Manaaki Whenua.

Background

- The aim of this work was to implement the spread and impacts forecasting system of Mason et al. (2021) using an updated infestation database from WCIS in order to support the preparation of a business case for ongoing funding of the National Wilding Conifer Control Programme (NWCCP).
- Separate realisations of the modelling system were implemented to generate forecasts for different management scenarios
  - Status quo scenario: This provides estimates of impacts in the absence of any management. These forecasts also permit counterfactual comparisons quantifying the difference made by current and future wilding conifer control
  - Abandoned control: This provides estimates of ecosystem impacts if management units that are currently managed by the NWCCP were abandoned.

Major updates on Mason et al. 2021 method

- Up-to-date infestation data. See LINZ for documentation on dataset generation
- Separate model runs performed with Landcover Database cover class "High Producing Exotic Grassland" reclassified either as "Grass" (high invasion risk) or "Other" (zero invasion risk). This reflects the fact that invasion is unlikely for this cover class where pastoral stocking rates are high, but it may be highly vulnerable in regions with low stocking rates. See Sapere CBA report for information on where predictions from either model run were used in the cost benefit analysis.
- Assumption of zero containment of spread from current infestations. Mason et al. assumed containment was 100% effective
- Incorporate future ecosystem impacts from new infestations (i.e. outside existing infestation areas) in impact assessment.

Key datasets

- 2021 infestation data (in file **"Linz1kmGrid.txt"**). Data are proportion of each 1 km x 1 km grid square covered by one of four density classes – "Dense", "Intermediate", "Sparse" and "Outliers"
- Landcover Database v5 for each 1km grid square (summarised in file **"A00_LCDB50_InfestationGrid_Summary_2012.txt"**). This was generated using the R script file **"A00_P01_LCDB5_InfestationGrid_Summary.R"**
- Small-scale infill model outputs (in file **"Infillrevised_1HA_results.csv"**)
- Ecosystem service data (in file **"ESGridCore1000m.txt"**). These data were extracted from rasters using the R script file **"A00_P01_LINZgridESgridcoreV01.R"**

- Landcover in 100m downwind dispersal bands adjacent to existing infestations (**“DispersalBands_InfestationGrid_LCDB50_V16WindDir315_Summary.txt”**). This is generated via a separate process requiring analyses in R and ARC GIS.
- LCDB reclassification table (**“LCDBReclass.csv”**) – note the same filename is used for different reclassifications of “High Producing Exotic Grassland”. Separate model runs with this cover class reclassified either as “Grass” or “Other” were performed in different directories.
- Mean wind speed (**“windoct1000m.txt”**)

Source code

- Script files are run in series using a mainline script file (**“A01_MainlineBatchFile.R”**)
- High-level descriptions of the function of individual script files are provided in the mainline script file.
- More detailed descriptions are provided through comments within individual script files

Output files

- Infilling and downwind invasion from existing seed sources **“A08R02_AllInvasionResultsCombined_TX.csv”** (X being time in years for which forecasts are produced)
- Current and forecast control costs **“A09R01_LinzAllRemovalContainmentCosts_TX.csv”**
- Forecast ecosystem impacts for existing infestations **“A10_AllWildingESImpacts_TX.csv”** and **“A10S02_WildfireFuture_TX.csv”**. Information on the methods and units for each ecosystem service modelled are available via the wilding conifer scenario exploration web tool: https://wildingconifers.landcareresearch.co.nz/ by selecting the appropriate thematic layer and clicking on the information button associated with the legend (on left hand side of below image).

Figure 1: Screen grab of wilding conifer scenario exploration web tool illustrating key functions. https://wildingconifers.landcareresearch.co.nz/

- Forecast impacts of new infestations resulting from downwind invasion form existing infestations **"A10b_AllWildingESImpacts_TX_NewInvasions.csv"** and **"A10S02b_WildfireFuture_NewInvasions_TX.csv"**
- Raster files of current and future control costs **"A09R02_XXX_TX.tif"**
- Raster files of forecast ecosystem impacts **"A11S02R01_WildingESImpacts_XXX_TX.tif"** and **"A11S02R04_WildfireFuture_TX.tif"**

Example analyses

- Scripts and data are provided to run the forecast modelling system from step A0_1 onwards for the "Status quo" management scenario with "High Producing Exotic Grassland" reclassified as "Grass".
- Source files for pre-processing steps "A00_xxx.r" are provided for documentation purposes only.
- The source code is designed to be run in R version 4.1.1.

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