Cost benefit analysis of wilding conifer management in New Zealand

Part I – Important impacts under current management

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REPORT INFORMATION SHEET

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Cover photo: *Aerial-boom sprayed lodgepole pine on the Front Face of Mid Dome. T.S.H. Paul*

SUMMARY

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Wilding conifers could affect over 5 million hectares or 20% of New Zealand's land area by 2035 if the current levels of management do not change. The amount of land affected is likely to treble from 1.82 M ha (2015) to 5.43 M ha by 2035. The land affected by scattered wilding conifer trees (0.01 to 400 trees per hectare) will increase from 1.71 M ha to 5.1 M ha. Dense wilding conifer stands will increase from 0.11 M ha to 0.33 M ha in 2035.

The ongoing infestation[1] of land with wilding conifers could result in approximate average annual losses of $141 million or $ 1.2 billion net present value between 2015 and 2035. The increasing infestation will affect productive dry stock land, water supply/availability, biodiversity, nature-based international tourism, forest fire propensities, carbon stocks and sequestration, and sedimentation.

The current annual management cost of wilding conifers is $5.8 million. Assuming that annual expenditures do not change over the next 20 years the total discounted expenditures would be approximately $55 million. Current management control would not prevent the losses described in this report.

The Ministry for Primary Industries has led the development of a non-regulatory strategy that proposes actions to improve the efficiency and effectiveness of wilding control (MPI, 2014a). In the right place, exotic conifers can provide economic, environmental, social and cultural benefits. In the wrong place, unwanted exotic conifers (wilding conifers) can impact on a range of ecosystem services.

Scion was contracted (MPI contract 17234) to understand and quantify, where possible, the current and future economic impacts of wilding conifers on New Zealand over the next 20 years as no recent, national-level, cost-benefit analysis for wilding management has been carried out. The analysis does not represent a comprehensive assessment of all impacts and benefits of wilding conifers in New Zealand. For many of the direct and indirect impacts of wilding conifers identified no data exist that would allow the quantification and monetisation of their value losses or gains. All identified but not quantified impacts are shown provided in the results and reasons given for their exclusion in this report.

This report establishes the assumptions used; the limitations of these assumptions; describes the impact variables and their assessment methods; and provides the results, conclusions and recommendations of the analysis.

The discounted national impacts that could result from wilding conifers over the next 20 years under current management levels are listed in the following table. Additional impacts that could not be quantified in monetary terms were carbon sequestration and forest fire propensity. Carbon sequestration benefit was quantified as tonnes of CO_2equivalents (CO_2eq).

[1] Infested area is defined as area where wilding conifers are present, even at low densities.

National discounted impacts of wildings under current control. Upper and lower bounds are given for loss in pasture production.

Pasture production ($)	-88 to -221
International nature-based tourism ($)	-152
Indigenous Biodiversity value (i$)	*-866*
Available surface water (i$)	*-18*
Sediment reduction (i$)	*+4*
Carbon sequestration (t CO_2eq)	*+54*
Total discounted impact (million i$)	***-1.120 to 1.254****

*The impacts were estimated using different market and non-market valuation methods. Hence, the total value should be considered as an indicative (i$), not an absolute dollar value, and only used for discussion purposes.

These values should be used to scope possible scenarios and set potential boundaries for discussion. The values are estimates and should only be considered as indicative and not absolute dollar values due to the uncertainties around key assumptions.

The next steps are to compare the impacts identified in this study and the expenditures for alternative management approaches to estimate benefit-cost ratios for these different approaches (Phase 2 of MPI contract 17234). Of further importance but outside the scope of this work would be to fill key knowledge gaps such as the improvements on estimating wilding conifer expansion and density values in a spatial explicit way and possibly estimating the value of biodiversity and tourism more accurately and include other direct and significant wilding infestations related values if data becomes available.

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Introduction

The Ministry for Primary Industries (MPI) has led the development of a non-regulatory strategy that proposes actions to improve the efficiency and effectiveness of managing wilding conifers (MPI, 2014a). In the right place, exotic conifers can provide economic, environmental, social and cultural benefits. In the wrong place, wilding conifers – unwanted trees that resulted from seed spread, germination and establishment – can impact on a range of ecosystem services. The Strategy's vision, "the right tree in the right place", developed in collaboration with a multi-stakeholder working group, reflects this situation in the landscape

Over 1.8M ha of New Zealand is estimated to be affected by the spread of wilding conifers (1.7M ha as scattered trees and 0.11M as dense wilding stands; Figure 1.). They compete with native vegetation, change existing ecosystems, reduce available grazing land, limit future land use options, visually change landscapes, can affect surface water flows and aquifer recharge and can result in increasing the risk of damaging wild fires.

A national-level cost-benefit analysis for wilding management has not been carried out so far for the New Zealand wilding conifer situation, although the above negative impacts of wilding conifers are well recognised. This is due to the difficulties in quantifying the monetary and non-monetary impacts that wilding conifers can have and because no detailed nationwide information on the extent and density of wilding conifer infestation exists.

A number of survey and inventories have been undertaken over the last few years to assess the wilding conifer situation in its extent and severity in New Zealand (North, et al., 2007; Paul, 2013). MPI recently completed a survey with the aim of collating all known wilding areas by asking all territorial authorities and many landowners to provide location and area estimates plus a number of additional metrics and variables (MPI, 2014b). The results of this survey estimate the wilding conifer affected area to be greater than1.8M ha. Using the historic development of the area infested by wilding conifers included in the national strategy, the area infested is increasing 6% per year on average (MPI, 2014a).

Starting with the information on the current area and infestation level; and the past and current development of wilding infestations, Scion was contracted to carry out work to:

- Understand and quantify (where possible) the current and future impacts of wilding conifers on New Zealand over the next 20 years from an economic perspective (Phase 1 – this report).
- Understand and quantify where possible the benefits gained through different wilding conifer management approaches (Phase 2 – not included in this report).

To understand and quantify current and future impacts of wilding conifers over the next 20 years we:

- Undertook a literature review to identify possible impacts of wilding conifers and methods to estimate their associated costs,
- Estimated the change of the extent for present scattered and dense wilding conifer infestations from 2015 to 2035 and the land structure (land-use classes) affected,
- And, for the chosen impact areas, calculated the costs based on the selected methods.

The choice of impact areas and methods to estimate their costs and benefit were based on the initial literature review and the data available for the analysis. Impact assessments were carried out for low producing pasture farming, nature-based tourism, biodiversity, water availability, fire risk and carbon sequestration.

This report (1) establishes the assumptions used in general and for the analysis of the separate impact areas; (2) describes the economic impact areas and their assessment method; provides (3) the results of the analysis and (4) conclusions and recommendations.

Assumptions

The cost benefit analysis (CBA) reported here was undertaken from a national perspective (excluding international impacts) to capture potential benefits and costs for key land-based economic sectors directly affected by wilding conifers in the period 2015 to 2035. Where possible, a qualitative assessment of the intangible costs and benefits was carried out. A discount rate of 10% was used, based on the recommendations from New Zealand Treasury (Treasury, 2005).The main assumptions used in this report are:

- **Loss in pasture production –** The potential loss in pasture production due to wilding conifers was estimated using the difference in per hectare gross margins between the current situation and the projected wilding conifer expansion. Underlying assumptions were: 1) that land-cover classes are an approximation of the current farm classes in a region, 2) that gross margin per stock unit for a farm class corresponds to stock unit for a land-cover class in a specific region. We also assumed a 100% decrease in yield (stock units per hectare) for dense wilding conifer infestations and a 30% average decrease in yield for scattered wilding conifer infestations in the baseline. The method to estimate loss in pasture production was based on Sinden et al, 2004.
- **Loss in international nature-based tourism –** Potential monetary loss from international nature-based tourism due to wilding conifers was calculated using: 1) projections of international visits and the associated expenditure (MBIE, 2014) and 2) an approximation of the proportion of visitors that would be affected by wilding conifer spread. The main assumption made was that the effect of wilding conifer spread on tourism is negative, i.e. tourists would decrease their visits if an increase of wilding conifers in the area occurs. The number of reduced visits was estimated by adapting a function that relates number of visits to a national park and density of a woody weed in New South Wales, Australia (Odom, et al., 2005).
- **Loss in biodiversity values–** An indicative national non-market value for controlling wilding pines was developed based on work by Kerr & Sharp (2007) in the Mckenzie basin. The main assumption made was that the results from that study are scalable to a national level and provide an indicative figure for the willingness-to-pay for wilding conifer management to protect biodiversity.
- **Loss in available surface water–** Water yield reductions under low flow conditions were obtained from a number of studies (Davie, et al., 2004; Davie, et al., 2005). The underlying assumption made was that the average low-flow reduction based on Davie, et al. (2004), taken from three catchment studies are representative to areas were wilding infestations will occur. As a surrogate to monetise the loss of water under low-flow conditions the water value for irrigation (Doak, et al., 2004) was used as an indicative value representing water supply, loss in in-stream biodiversity and recreation. Indicative surface water availability impacts were calculated in four regions – Marlborough, Canterbury, Otago and Southland.
- **Fire management** – The working hypothesis was that wilding conifers would have an impact on fire risk. A survey of rural fire research experts allowed us to asses this risk in a qualitative way (see results and appendix E).
- **Carbon** – The carbon sequestered by dense wilding conifer infestations over the next 20 years was estimated in tonnes of CO_2equivalents (CO_2 eq), but not monetised, because the associated carbon is not tradeable nationally or internationally and currently does not incur any international liabilities to New Zealand if it would be removed. Therefore, there is no positive or negative monetary impact that can be estimated. The quantitative estimations are based solely on the increase in area of dense wilding conifer infestations across all land (including conservation estate). Data for carbon stocks and sequestration in CO_2 equivalents (CO_2eq) was taken from the original data sets used for the Softwood deforestation tables published by MAF (2011). Key assumptions include that dense wilding

conifer infestations have CO_2eq stocks of 247 t/ha based on an average of stored carbon in 15-25 year old softwood stands.

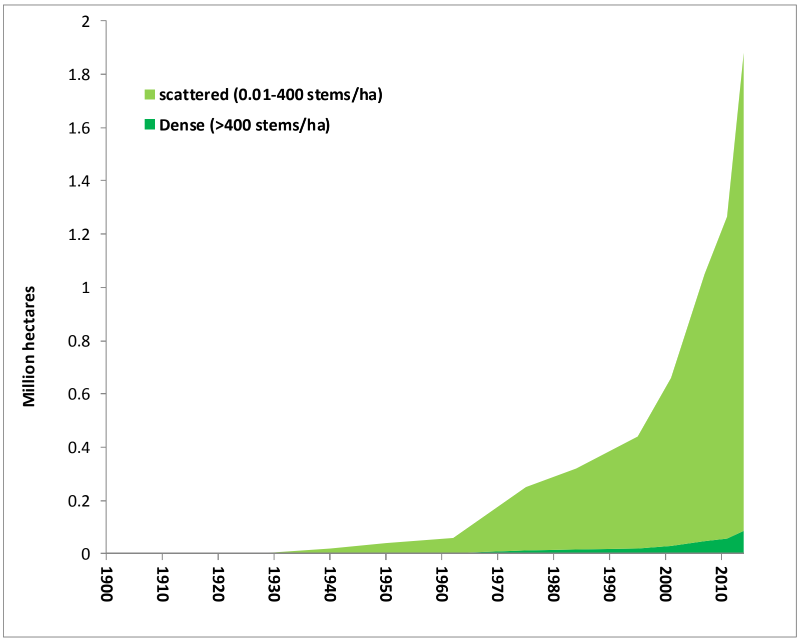
- **Reduced sediment loss –** The reduction in sedimentation through the introduction of a protective woody vegetation cover (wilding conifers) was assumed to be a positive effect of wilding conifers. We used New Zealand empirical erosion model (NZEEM) (Dymond, et al., 2010) to quantify the sediment reduction as a result from transitioning from current land use towards dense wilding conifer stands. To monetise the benefit of reduced sediment loss we used a value estimated by Dymond, et al. (2012) using Krause, et al. (2001).

Wilding extent and spread modelling exercise

The modelling exercise of the spread of current wilding conifer infested areas that underlies all the economic impact calculations above is based on:

1) The available database of wilding conifer areas provided by MPI (MPI, 2014b)[2] and,
2) The projections of area increase of wilding infestations based on the past and current areas estimates (Figure 1) supplied by the Department of Conservation (DOC) and MPI (MPI, 2014a).

Figure 1. Development of wilding affected areas in New Zealand since 1900. (modified from MPI (2014a)).



Underlying assumptions are: That the database in (1) provides a complete and accurate inventory of all wilding infestations in New Zealand in terms of area and location and that (2) the historic and current trend of wilding area increase will continue over the next 20 years.
The actual modelling of the estimated expansion of the current wilding conifer infestations given by the locality and area in the MPI wilding conifer database holds also a number of assumptions:

- Locations and area estimates were translated into the estimated current extent, assuming the area is evenly distributed around the location point given.

[2] As the database did not provide spatial explicit datasets nor detailed area estimates and locations with a given accuracy the data need to be seen as seriously limited (e.g. not based on a standardised national monitoring or inventory system).

- Expansion of wilding areas was assumed to be non-directional. Modelling of directional spread was not possible as local detailed wind-behaviour for each location was unknown and spatial-explicit area locations were not available.
- The historic trend data assumes similar spread rates for scattered and dense infestations and therefore maintaining the proportionality between these classes[3]. This is reflected in the ratio of scattered and dense infestations over time.
- According to MPI (2014a) it was assumed that scattered infestations have a tree density ranging from 0.01 to up to 400 stems per hectare (includes medium density class) and dense infestations have a nearly complete or full wilding conifer coverage (>400 stems/ha; see Figure 2).
- Wilding conifer establishment is not the same in different land use classes (vegetation and grazing differences). We did not include gradual differences between land uses in our modelling but excluded a number of land use/cover classes that would not host wilding conifers or in which the possibility for wilding conifer establishment is minimal. No changes of land use over the next 20 years were assumed in the modelled areas.

Figure 2: Various densities of wilding conifer infestations. Left and middle photos represent scattered infestations. Right photo shows dense infestations near Hanmer (T.S.H. Paul).

[3] This ratio is based currently on expert knowledge and recent data (Howell pers.com). However this might not hold true for the future.

Economic impacts and chosen assessment method

The impacts selected for assessment, the regional analysis approach, and approach to estimate the current and future development of wilding infestations over the next 20 years are described below. The reasoning for the chosen assessment method for the selected impacts is also described.

Selected impacts for assessment

This study includes impacts on dry stock pasture production, nature-based international tourism, biodiversity, water availability, fire, carbon and reduced sediment loss (Table 1). Information on the potential impacts of wildings on landscapes values – although identified in regional wilding conifer control strategies and the national wilding conifer strategy– was sought but no evidence found to guarantee an assessment. Due to the inherent difficulties of separating recreation from nature-based tourism and obtaining estimates for each, only international nature-based tourism was analysed. Carbon sequestration (neither negative nor positive) and the reduction of sedimentation (positive) were also quantified. Out of the scope of this study were the potential impacts on cultural and historical values, including Māori cultural values. . And the potential positive impact of wildings for be watershed protection (Table 1).

Table 1. Categorisation of costs and benefits from wilding conifers that were assessed or excluded because of limitations and gaps in the baseline classified according to the Cost Benefit Analysis Primer (Treasury, 2005). Benefits are shown in grey.

Included in CBA	Type	Description	Sources	Limitations/Gaps
Monetary				
Yes	Quantitative – fixed costs	Wilding conifer control costs: management	Current regional and national control cost estimates provided by MPI based on regional reporting.	Data available is aggregated, not split between variable and fixed costs. Estimates are based mostly on annual budgets, not current expenditure, incomplete account for input from community trusts and private occupiers and in-kind, therefore currently underestimated. No New Zealand studies available about long-term efficiency and effectiveness of current investment on wilding control.
Yes	Quantitative – variable costs	Wilding conifer control costs: Labour and inputs for detection, search and control.		
Yes	Quantitative – variable costs	Loss in pasture production	Estimation based on loss in production method (Sinden, et al., 2004). Regional gross margins and stock units data (Beef and Lamb New Zealand, 2014; Morris, 2013).	No specific studies available about the gradual reduction of stock units under wilding conifer invasion in New Zealand.
Yes	Quantitative – variable costs	Reduction in nature-based tourism (international visits)	Adapted a recreation (visitor entry) function from Scotch broom invasion in a national park, Australia (Odom et al, 2005) International visitor survey (Statistics New Zealand, 2015) and international tourism projections 2014-2020 (MBIE, 2014): Visitors and expenditure only.	Projections of international visitors for 2021 to 2035 estimated based on linear regression. Only expenditure data available. No data readily available for domestic tourism by activities for reference year (2012-2013). No data available on local or international tourist's attitudes on wilding conifer conifers and how those attitudes influence their travel decisions.
Yes	Quantitative – variable costs	Recreation	Recreation function that relates weed density to visitor numbers found that at 60% weed density, visits reduce to zero to a national park (Odom et al, 2005).	No data on how wilding conifers affect or could affect recreation, directly or indirectly. Assumed that nature-based tourism as proxy for recreation values (so no 'recreation only' value provided).
Non-monetary				
Yes	Quantitative	Reduction in water availability	Average reduction in water yield during low-flow conditions (Davie, et al., 2004) used to estimate water availability reduction during low-flow conditions in Marlborough, Canterbury, Southland.	Strong assumption that low-flow water reductions in three South Island catchments are representative and applicable for wilding conifer infestations in general.
Yes	Quantitative	Impact on indigenous biodiversity	Estimations based on willingness to pay for a wilding conifer control program that would protect indigenous species (Kerr, et al., 2007) .	Simplified benefit transfer function to a national level. Studies on reduction or extinction of native plants not available.
Yes	Qualitative	Increased fire risk	Fires could burn longer and hotter with wilding conifers than without (Clifford, et al., 2013; Environment Canterbury, 2010)	Regional economic costs for different fire events are not available to compare control and prevention cost differences between forest and grassland.

Included in CBA	Type	Description	Sources	Limitations/Gaps
Non-monetary (continuation)				
Yes	Qualitative	Carbon sequestration	Estimations based on area expansion of dense wilding stands using carbon stocks from national carbon yield tables (MAF, 2011)	No wilding conifer specific carbon sequestration data available. No stand level growth information available for wilding conifer stands in New Zealand.
No	Qualitative	Loss of landscape values	Loss of landscape values in particular for those characterised by indigenous tussock and other low stature indigenous vegetation (Environment Canterbury, 2010; MPI, 2014a). Found both positive and negative perceptions of invasive trees (van Wilgen, 2012), but negative in New Zealand (Harding, 1994)).	No recent studies in New Zealand deal specifically with these values, either qualitatively or quantitatively. This issue could be both a cost and a benefit depending on who the respondent is.
No	Qualitative	Impact on cultural and historical values, including Māori cultural values	"Damage of historic buildings, structures, earthworks and *urupa* and grave sites by wilding conifers and their roots" (Environment Canterbury, 2010, p.25)	Preferences and cultural values surrounding wilding pines, including public's understanding and awareness is a major knowledge gap. *Out of the scope of this study*.
Yes	Qualitative	Reduced sediment loss, Soil conservation, erosion control	Afforestation can have a positive effect on sediment reduction (Barry, et al., 2014). To estimate sediment reduction we used NZEEM to calculate the effect of dense wilding infestations on sediment loss (Dymond, et al., 2010)	Estimation is based on afforestation studies and we assume the same positive effect can be realised by dense wilding conifer stands.
No	Qualitative	Watershed protection	---	No data available

Nomenclature

Nomenclature in this report follows the recommendations outlined in the Cost Benefit Analysis Primer V1.12 (Treasury, 2005). Non-monetary values in this document are indicative only, not absolute dollar values. These values are presented as *i$* or indicative dollars. They include potential losses related to biodiversity, loss in available surface water and gains in sediment reduction. These values are high level figures and should be taken with caution. The only non-monetary benefit quantified but not monetised was carbon sequestration, expressed in CO_2 equivalents (in tonnes; CO_2eq).

Wilding conifer infestation projections

All economic impact calculations are based on the current estimate of wilding infested areas and the expansion of these areas over time. Our approach was to estimate the affected area and the estimation of affected land type (land-use class and ownership). Land 'ownership' in this study refers to areas either managed by the Department of Conservation (DOC) or by other landholders. DOC land consists of conservation areas, marginal strips, national parks and reserves. Non-DOC land includes farms, forests and other private and government owned properties.

Current estimates of the wilding conifer-affected land area are 1.8M hectares (6% of NZ land area) with approximately 5% of this area densely covered by wildings, 20% moderately covered and 75% scattered with few wildings per hectare (MPI, 2014a). The current national extent of wilding conifer infestations was calculated using MPI's wilding conifer area database (MPI, 2014b). The database includes (among other variables), individual area estimates and location points for all known wilding conifer infestations, classified as scattered or dense infestations (medium density was not a class in the database). Based on the given location (geospatial points) and the estimated wilding conifer infestation area, circular polygons were generated assuming that the given location represents the centre point of an infestation and equally expands in all directions[4].

Past trends in spread were used to determine the spread of wilding conifer-affected areas in the future. Wilding conifer-affected area and expansion of the affected area since the introduction of exotic conifers has been reported by MPI (2014a) and is based on historical and current data on the extent of wildings. The expansion of wildings conifer infestations to date inherently includes the effect of past and current management, which has not halted their expansion. Furthermore, the reported data (MPI 2014) showed the rate of wilding conifer area increase is the same for dense, medium and scattered infestations. Based on the provided data, we derived two functions describing the historic area development and then projected the development of scattered and dense infestations over the next 20 years.

The wilding conifer areas were used to identify current land-use/cover classes and land ownership so that each wilding conifer site has an estimate of the area of affected land-use/cover classes and ownership. The resulting matrix was recalculated for each of the 20 years accounting for the increasingly larger areas, which were calculated with the developed power functions, predicting an annual average increase of 6% in area each year.

[4] Fringe spread (high amounts of seed falling close and around the seed source) occurs often in all directions, providing some support to use a non-directional spread approach of an already infested area.

Assessment method for the selected impacts and costs

Loss in pasture production

The potential monetary loss in pasture production due to wilding conifer expansion was estimated based on the difference of gross margins per hectare between wilding conifers expanding as modelled versus no expansion of current wilding conifers.

Farm economics information across New Zealand that includes income, operating expenses and yield (stock units per hectare) for the year 2012-13 (Beef+Lamb, 2014a) was used to estimate productivity losses due to wildings. First, the different land cover classes (LCDB 4.0) were mapped to farm classes excluding intensive dairy farm classes (see Table 2) and the gross margins per stock units were estimated ($/SU), either by region or using national farm data if regional data was not available. The sheep and beef farm classes (Beef+Lamb, n/d.) were used to identify the minimum stock units by farm class (min SU/ha, see Appendix B) except for South Island high country and southern South Island hill country, where the yield assumed was 0.7 SU/ha (Morris, 2013)[5]. This minimum yield was then multiplied by the gross margins per stock unit ($/SU) in the given farm class. The minimum yield was used as a conservative estimation. The result ($/ha) was then multiplied by the assumed yield loss (-30% or -100% of SU/ha if scattered or dense wilding conifer infestation, respectively) in order to estimate the potential monetary loss in pasture production, following Sinden et al (2004).

The final step to estimate the potential loss in pasture production was to multiply the losses ($/ha) derived from scattered and dense wilding conifer infestations by their corresponding areas in each region (details described in Appendix B).

Table 2. Land cover and beef and land farm class equivalent.

Land cover (LCDB 4.0)	*Farm class equivalent (assumption)*	*Regions*
North Island High producing exotic grasslands	North Island hard hill country	General, NNI, ENI, WNI
North Island Low producing grasslands	North Island hard hill country	General, NNI, ENI
South Island High producing exotic grasslands	South Island hill country	All South Island regions, mostly Canterbury, Otago
South Island Low producing grasslands	South Island hill country	
Tall Tussock Grassland. Depleted Grassland, Matagouri and Grey Shrub, Alpine Grass/herbfield	High hill country (Morris 2013)	General
Any other land cover (fernland, Kanuka/Manuka, Gorse/Broom, exotic forest, subalpine shrubland, landslide and mixed exotic shrubland	None	General

NNI = Northern North Island, ENI = Eastern SI = South Island, WNI = Western North Island.

Impacts on indigenous biodiversity

The potential impact of wilding conifers on biodiversity values was estimated based on a choice experiment study for part of the South Island high country carried out by Kerr & Sharp (2007). This study analysed people's preferences on the outcomes of a proposed

[5] Again, only stock unit levels that represent sheep and beef farms were used as in areas where wilding conifer infestations occur, dairy farming is highly unlikely (e.g. high country and steeper hill country).

wilding conifer control programme in the Mackenzie basin. The outcomes of the programme included the conservation of three endangered native species in the basin, *Hebe cupressoides* (plant), *Brachasois robustus* (grasshopper), and *Galaxias macronasus* (fish).

The study provided estimates of the amount of money that a “typical” respondent would pay per year for a five-year programme that guarantees the prevention of extinction of these three endangered species found in the basin. To the best of our knowledge, Kerr & Sharp (2007) is the only economic valuation exercise in New Zealand that estimated biodiversity values from a proposed wilding conifer control programme. Their estimated values account for both use and non-use values. Use values include recreational use value while non-use values include existence and bequest values.

The estimated household conservation values (Kerr & Sharp, 2007) were aggregated to the national level following Morrison (2000), assuming that 50% of the households have a willingness-to-pay of $0 while 50% have willingness-to-pay greater than zero. Values were inflated from 2007 to 2012/2013 dollar values. Statistics New Zealand (2014) reported that the country had approximately 1.55 million households in 2013. We then used 50% of the 2013 New Zealand household population of 774,945 and multiplied by the inflated values to estimate national biodiversity values.

Water availability

The potential reduction in river water flow rates can have an impact on water supply (e.g. irrigation, power generation, drinking water), recreation, biodiversity and stream dynamics (flushing and sediment transport). Previous New Zealand studies have suggested that land use change from shrubs and grasses to plantation forestry leads to a reduction in water yield in catchments (Beets, et al., 2007; Dons, 1986, 1987; Dymond, et al., 2012; Fahey, 1994; Mark, et al., 2008; Morris, 2013; Smith, 1987). Increased water interception by woody vegetation such as wilding conifers can have a negative impact on downstream or ground water yield in dry areas where water yield is already low (Davie, et al., 2005). However, the impact of the reduction in water yield due to the spread of wilding conifers has not yet been quantified nor valued in New Zealand.

Our calculation on water yield reduction through dense wilding conifer infestations is focused on low flow conditions as these are the times when shortages of water are most critical and a certain flow need to be sustained for water use, biodiversity and recreation. Our calculations on water yield during low flow conditions are –as they are on a national scale– highly simplistic and can only provide indicative results. They are based on the general conclusion of Bosch, et al. (1982) *“…that increasing the scale of vegetation cover (both upwards e.g. from pasture to tall trees; and outwards e.g. area expansion of woody vegetation) in a catchment does lead to a decrease in water yield, however we were not able to account for the much spatial and temporal variability that is the result of variations in climate and soils and the different influence of low and peak flow, that should be taken into account “* (Davie, et al., 2005).

To estimate the approximate reduction of water yield during low flow events on a large regional and national scale and account for some of the variability regional and nationally we averaged mean annual low flow (7 day duration periods) results given by Davie, et al. (2004) for three South Island catchments (Glendhu, Kakahu and Berwick) that were part of earlier catchment based experimental water-afforestation studies. The average reduction in water yield during low flow conditions was approximately 16%[6]. This

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[6] The reduction of water yield from dense wilding conifer stands could be higher than from afforestation as wilding conifer stands might have a much higher interception effect, because of their rougher canopy surface. In addition wilding conifers might occur in the far upper reaches of

percentage was then applied to Marlborough, Canterbury, Otago and Southland regions. These regions were chosen as they have significant spread of wilding conifers and use surface water as a significant water supply source (e.g. hydro power, irrigation). Other regions were not assessed as wilding conifer infestations were not seen as significant to the availability of surface water.

The calculations were based on indicative costs of the reduction in surface water using estimated values for a cubic metre of irrigation water in New Zealand regions, reported in Doak, et al. (2004). Data on the volume of surface water by regions were derived from Aqualinc (2010). We use those values to estimate the potential losses that are associated with lower surface water supplies during low flow conditions[7] and its implications for all other impacts e.g. biodiversity, hydro power generation and recreation.

Using a 6% average annual spread rate of wilding conifers (MPI, 2014a), the area of wilding conifers would more than triple cumulatively over the next 20 years. This implies that surface water availability reduction would intensify every year. Such a reduction is associated with a decrease in surface water flow and would have an impact on water supply during low flow conditions.

Nature-based international tourism

The potential monetary loss in nature-based tourism due to wilding conifer spread was calculated using projections of the number of international visitors and expenditure per visitor from 2013-2020 (MBIE, 2014) and a linear regression to project these estimates to 2035. The percentage of international tourist visits that are nature-based and could be affected by wilding conifers was estimated as 28% of the total tourist visits based on detailed information from the period March 2012–March 2013, explained in Appendix C.

The main assumption made was that the effect of wilding conifers spread on international nature-based tourism is negative, tourists would reduce the number of visits if they see an increase of wilding conifer areas (Harding, 1994; Turner, et al., 2004). Moreover, tourists may be discouraged to travel to a less natural environment as the national brand suggests ("100% Pure"). The reduction in visits was estimated by adapting a function that relates number of visits to a national park and scotch broom (a woody weed) density in New South Wales, Australia (Odom et al 2005).

The estimated wilding conifer density in 2015 (considering both scattered and dense) in DOC areas is 11% based on our analysis. Invasion in 2035 is projected to rise to 26% of DOC areas. These invasion densities were used to calculate the reduction in visits per year and multiplied by the expenditure per international visitor in New Zealand to obtain the potential annual loss in nature-based tourism. Calculations exclude domestic tourism. Caveats include an underestimation of potential losses due to domestic tourism.

A note of caution in the interpretation of the results is needed because there is a knowledge gap and the issue of the impact of wildings on nature-based tourism is uncertain. In 1994, a survey in the high country of New Zealand estimated that 75% of respondents considered wilding conifer spread undesirable (Harding, 1994). On the other hand, a recent study from South Africa (van Wilgen, 2012) found both positive and negative reactions to invasive trees in a protected area. Therefore, although we assumed that tourists may decrease their visits due to wilding conifers, the issue is uncertain and a study on visitor perspectives is needed, for both local and international visitors to areas infested with wilding conifers.

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catchments and therefore can affect low flow yields more significantly than mid-altitude afforestations.

[7] For water storage systems for irrigation the reduction in the overall water availability is important. We did however not separate these systems and used the low-flow impact as a conservative value.

Fire

The presence of wilding conifers in a specific area would result in higher economic losses compared to grassland fires. This is due to a higher fire intensity resulting from increased fire spread rates and fuel loads (Clifford, et al., 2013). Fire spread rates are faster in open grassy fuels, intermediate in mixed forest/grassland and slower in dense forest fuels. However, fuel loads can be higher in forests, especially in dense intermediate age stands with lots of dead material or understory present, which is the case of wilding conifer stands. Thus fire intensity, which is the combination of the rate of spread and fuel load, is more variable and tends to be highest from the intermediate stages where rate of spread is intermediate but fuel loads are higher. Fire intensity, which represents the heat output of a fire, is most apparent as flame size but is also the key determinant of how difficult fires are to control. Hence, it is hypothesised that higher intensity fires are more difficult and more expensive to extinguish.

Scion rural fire experts were interviewed to comment on potential economic losses from wilding conifer presence to investigate the hypothesis. The results from such interviews were compiled and are presented in the results section of this document and in Appendix E.

Carbon

Wilding conifers have the ability to store and sequester carbon over time. However, current carbon sequestration rates for the most common wilding conifer species, and for different sites, are unknown as wilding conifer stands are very heterogeneous in structure, multi-aged and with a wide range of tree densities. Furthermore, there have been no suitable studies carried out in New Zealand regarding their growth rates. Hence, a simplified was used to estimate carbon stocks and sequestration in this study[8].

Areas affected by scattered wilding conifers do not currently count as forests and therefore are not part of New Zealand's Emission Trading Scheme. Their carbon stocks and sequestration does not contribute to NZ carbon sequestration under the forest category for international reporting requirements such as UNFCCC or Kyoto. Instead they are included in the land categories "grassland" and "grassland with woody biomass".

Carbon in dense wilding conifer forest cannot be monetised as a liability or benefit. This is the result of the current legislation and New Zealand's position internationally and explained below:

- Under the current regulations of the New Zealand Emission Trading Scheme (NZETS), post-1989 tree weed forest is effectively prevented from entering the NZETS and earning NZUs. Therefore no monetary benefit exists on the domestic market for any carbon credits from post-1989 wilding forests (Peter Lough, MPI, pers.com.).

- For pre-1990 wilding forests, the Crown carries any liability for the deforestation of such wilding forests. Currently these liabilities are limited to deforestation during the first commitment period (CP 1: 2008-2012), since New Zealand did not accept a binding target during the second commitment period (CP 2: 2013-2020). Owners may deforest these wilding forests without liability under a special exemption in the NZETS. No monetary or tradeable benefit can be made from the positive

[8] Carbon stock estimates, obtained from the underlying datasets for the Softwood deforestation tables published by MAF (2011) were used to estimate the increase in CO2eq through area expansion of dense wilding stands. CO2eq stocks of 247 t/ha were assumed for dense wilding conifer infestations, based on average planted CO2eq stock for 15-25 year old softwood stands, an age when the canopy has already closed.

sequestration of these forests under either the NZETS or Kyoto Protocol, because NZ did not elect to account for pre-1990 forests during CP1 and does not have a binding target for CP2.

- For any post-1989 wilding forests that were accounted for under the first commitment period 2008-2012 (i.e. their sequestration was benefiting New Zealand's carbon balance) the Crown is responsible for the carbon stock in these forests. If these forests were to be deforested the carbon stock change would be the liability of the Crown (although currently the Crown only faces a liability for deforestation during CP1, since a binding target was not undertaken for CP2). Owners who deforest these wilding forests are exempt from liabilities under the NZETS.

- Stock changes that occur in wilding forests after 2012 do not result in any liability or benefit to the Crown or anybody else as we are not signatories of a binding international agreement. We still report on losses and gains, but are current not liable for any changes. This might change if New Zealand signed an Agreement in 2020 in which case New Zealand may be liable for stock changes since 2020.

- Therefore, owners have no benefit or liability from wilding forests under the NZETS. The Crown only has a minimal benefit from the sequestration of carbon for the period of 2008-2012 on post-1989 wilding forests, offset by a liability for any deforestation of pre-1990 wilding forests and post-1989 wilding forests between 2008 and 2012. Any further carbon gains through dense wilding conifer expansion are hypothetical and contingent on New Zealand signing up to a post-2020 agreement.

Based on the above, no current carbon related monetary liability or benefit for the Crown or private owners was estimated, only the potential carbon sequestration in tons of CO_2eq.

Reduced sediment loss

Reduced sediment loss is measured as the change in sedimentation levels from the occurrence of dense wilding conifer infestations and estimated using the New Zealand Empirical Erosion Model (NZEEM) (Dymond, et al., 2010). NZEEM allows the estimation of the amount of sediment generated under current land use in tonnes of sediment per km^2 per year. The model assumes a reduction in erosion rate when land use changes from non-woody (e.g. pasture) to woody vegetation. A stand of dense wilding conifers falls under woody vegetation which can reduce erosion at full canopy closure. We used our annually predicted dense wilding infestation area as the area converted into woody vegetation. Then calculated the difference between the sediment loss before the conversion (various land-cover classes as the baseline) and after.

Indicative values were assigned to the avoided erosion to measure the marginal environmental effects of erosion and sedimentation under wilding spread. Avoided erosion under the wilding spread would be considered a benefit from the higher soil protection offered by wildings. Krause, et al. (2001) estimated that the national economic cost of soil erosion and sedimentation in New Zealand is approximately i$126 million per year. They included costs from on- and off-site impacts directly related to erosion and sedimentation phenomena. The on-site erosion cost was estimated to be i$75.8 million per year largely due to agricultural production losses and damages to farm infrastructure, private property, road/rail infrastructure, utility network, and recreational facilities. The off-site sedimentation cost was estimated to be i$27.4 million per year due to insured losses from increased flood severity and impacts on consumptive water quality, water storage, power generation, navigation, and water conveyance. In the total annual economic cost, they also included avoidance/prevention costs of approximately i$23.5 million per year. Dymond et al. (2012) then inflated and used the total cost estimated in Krause, et al.

(2001), and the annual estimate of eroded soil exported to the sea of 200 million tonnes by Dymond et al. (2010), to arrive at a cost of $1 per-tonne.

Wilding Control Costs

Cost and expenses for wilding management were taken from the survey data provided by the Ministry for Primary Industries (MPI, 2014b). The survey collated the costs for currently funded programmes including Crown contributions to larger community and voluntary programmes (e.g. Waimakariri Ecological and Landscape Restoration Alliance (WELRA), Wakatipu Wilding Conifer Control Group (WCC)) which are partly funded by stakeholders and grants (such as the lottery grant). The latter contributions were not accounted for (no data was available). We also did not include “in-kind” costs such as volunteer or practitioner time (e.g. farmer spend hours to clean fringe spread) as such data could only be gathered via a representative survey, which was outside the scope of this report.

Results

Wilding Costs and Benefits

The costs and benefits identified as being provided by wilding conifers are summarised in Table 1. They are categorised as monetary and non-monetary values, and as quantitative (fixed and variable) and qualitative costs and benefits following the Cost Benefit Analysis Primer (Treasury, 2005). The data sources reviewed and used in this analysis are also included.

Conservative estimates of economic losses and potential benefits from wilding conifers were made based on the data sources indicated in Table 1.

Identified impacts that could not be monetised but were included in the analysis are carbon sequestration and forest fire propensity. Table 4 lists all issues assessed and the reasons why they were included or excluded from the CBA. Some issues were beyond the scope of this study and in some cases, efforts to include them would probably exceed their importance to the overall outcome of the impact study.

Expansion of wilding infestations over the next 20 years

The extent of wilding conifer-infested land is expected to treble over the next 20 years, increasing from 1.82 M ha in 2015 to 5.43 M ha in 2035 if there is no change in current management levels. In relative terms, the infested area will grow from 6.7% to 20% of New Zealand’s current land area (26.96M ha) by 2035.

The majority of current wilding conifer-infested land has a low density of wilding conifers (1.71M ha); 0.11 M ha is occupied by dense wilding conifer stands. Land with scattered wilding conifers is estimated to increase to 5.1 M ha and dense wilding conifer areas to 0.33M ha by 2035.

We estimate that the Department of Conservation (DOC) currently manages 0.97 M ha of wilding conifer-infested land. This could increase to 2.24 M ha by 2035, which would represent 26% of current DOC land. The area of wilding conifer-infested non-DOC land will increase from 0.86M ha to 3.18 M ha over the next 20 years (figure 3). The reason for the greater increase of infested private land is that many already infested public areas are surrounded or bordered by private land and over time a spill over effect takes place. Changes on a regional level are provided as supplementary data (Appendix F).

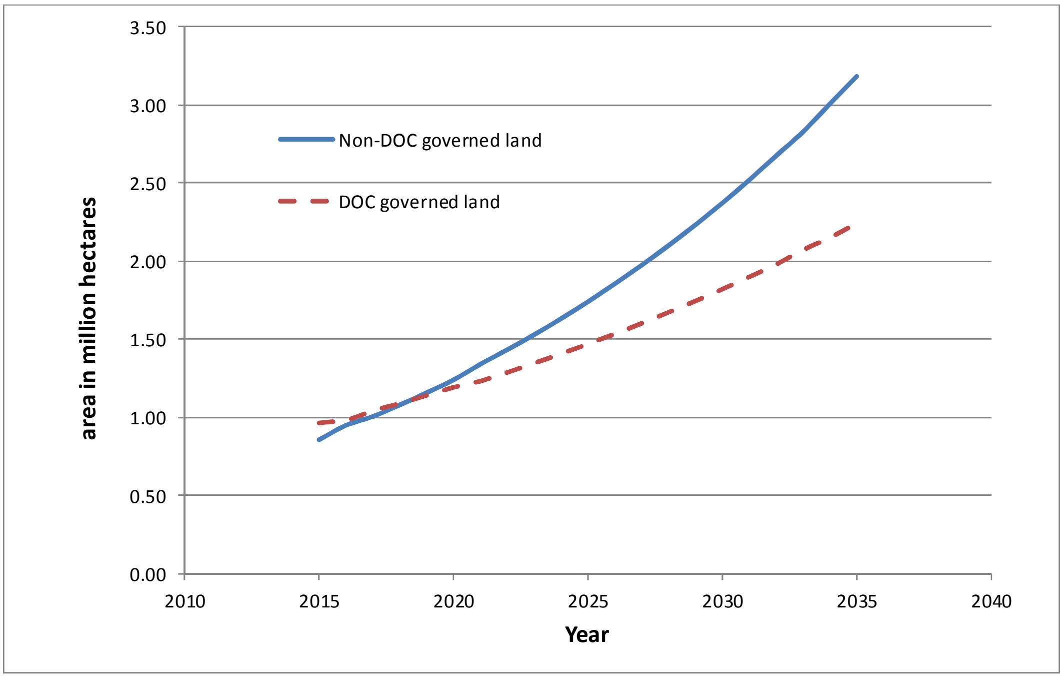

Figure 3: Estimated total wilding infested area over time for two types of lands (DOC governed and non-DOC governed land). It is estimated that private land could be increasingly more affected than DOC governed land based on our modelling approach and the underlying assumptions.

Economic assessment of the baseline

The total impact of wilding conifers under current control (status quo) conditions amounts to approximately i$2.1 billion accumulated over 20 years and discounted to the present (Table 3). All estimates were discounted to the present with a 10% discount rate as suggested by the Cost Benefit Analysis Primer (Treasury, 2005).

Table 3. National discounted impacts of wildings under current control (million)

Loss in pasture production ($)	-88 to -222
Loss in international nature-based tourism ($)	-152
Loss in biodiversity (i$)	*-866*
Loss in low flow water availability (i$)	*-18*
Reduction in sediment loss (i$)	*+4*
Carbon sequestration (t CO_2eq)	*+54*
Total discounted impact (million i$)	***-1.120 to 1.254****

*The impacts were estimated using different market and non-market valuation methods. Hence, the total value should be considered as an indicative (i$), not an absolute dollar value, and only used for discussion purposes.

Table 4 gives an overview on the costs and benefits that were assessed, the sources used and the limitations associated with these costs. In addition, it provides a list of further costs and benefits that were identified, however not included in the impact study as the effort or resources required to quantify them would have out-weighted the advantages of including them. A more qualitative assessment of their potential impact was made in the light that these costs and benefits would probably not greatly influence the overall outcome of this analysis.

Table 4. Issues assessed in this impact study (grey rows) and additional identified costs and benefits with lower importance.

Issue	Relevant and material to the Wildings CBA analysis	Information accessible and assessable within scope and budget available for this CBA	Value basis	Comment
Wilding control costs	High	Yes (limited)	Monetary	Value from reported estimations from regional councils. Estimations for community trusts and private occupiers and in-kind, need a specific survey out of the scope of this report.
Loss in pasture production	High	Yes	Monetary	Value from opportunity costs of wilding infestation in dry-stock areas.
Loss in honey production	Low	No	Monetary	Value from opportunity costs of wilding infestation in natural manuka shrublands.
Reduction in international tourist visits	High	Yes but limited: focus on international nature-based tourism	Monetary	Value from potential reduction in tourists' expenditures, estimated from tourist visits.
Domestic tourism	High	No	Non-monetary	Domestic tourism not included for two reasons: 1) data not readily available, 2) uncertain effect of wildings on domestic tourism (can be positive or negative).
Impact on recreational use of water	Medium	No	Non-monetary	Value from reduced visits because of damage to recreational value of a water body possibly because of view. This is a very specific issue that is included in the assumptions made under the reduction in tourist visits.
Reduction in water availability during low flow conditions	High	Yes (limited to specific regions)	Non-monetary	Value from reduction in water yield due to infestation. Only four regions assessed where wilding infestations estimated to be larger: Canterbury, Otago, Southland and Marlborough
Watershed protection and water quality (e.g. drinking water supply and hydro power)	Medium	No	Non-monetary	Value from how wildings impact water flows in terms of quality and quantity. These impacts need to be analysed at a catchment level first to estimate more detailed data on yield reduction and water quality, which would be out of the scope for is CBA.
Soil conservation, erosion control	Medium	Yes (quantitative, high level)	Monetary	Value from avoided erosion (sedimentation) using NZEEM (NZ Empirical Erosion Model (Dymond, et al., 2010))
Impact on indigenous biodiversity	High	Yes (high level)	Non-monetary	Value from a state preferences study for the conservation of three native species due to a wilding pine control programme. The study for the Mckenzie basin was extrapolated to a national level.
Loss of landscape values	High	No	Non-monetary	Value from loss of landscape values in particular for those characterised by indigenous tussock and other low stature indigenous vegetation. Uncertain.

Table 4 cont.

Issue	Relevant and material to the Wildings CBA analysis	Information accessible and assessable within scope and budget available for this CBA	Value basis	Comment
Impact on cultural and historical values, including Māori cultural values	Low	No (out of scope)	Non-monetary	Value from damage of historic buildings, structures, earthworks and *urupa* and grave sites by wilding conifers and their roots.
Increased fire risk	Medium	Yes (qualitative)	Non-monetary	Value from risk of increased biomass available, no quantitative assessment of risk specific to wildings.
Impact as host of pests off commercial forestry	Medium to low	No	Monetary	Value from commercial forestry expenses on combating wildings as hosts for pests. Hard to determine as forest companies would include pest protection as a whole in their budgets. Further analysis would need a detailed survey to identify specific expenses in wilding control as pests hosts , out of the scope of the report.
Carbon sequestration	High	Yes (limited, high level)	Non-monetary	Value from growth data of wilding conifer stands. This data is not readily available, so estimates are high level.

Loss of indigenous biodiversity (calculated at the national level) is estimated to account for 69% to 77% of the total impact of wilding conifer infestation over a 20 year period. This aggregated value should be considered as indicative only and not absolute dollar values. If robust estimates of biodiversity values are needed for policy decision making, a more comprehensive survey would need to be conducted.

The economic losses related to surface water availability during low flow conditions amount to 1.4% of total losses, or $18 million. These losses were estimated by relating dense wilding conifer spread through space and time, and valuing water in four regions where water availability is critical and wilding spread is high. We used values ($/m^3) estimated from irrigation as a surrogate for the value of surface water for water supply, biodiversity and recreation. Hence, the estimated impact is just an indicative representation of the magnitude of the impact exerted by wilding conifers. Out of the four regions investigated for this issue, the Marlborough and Canterbury regions are likely to experience the highest monetary impacts related to loss of surface water availability.

The monetary impacts on dry-stock pasture land production were estimated nationally and amount to 8% to 18% of the total monetary losses, or $88 to $221 million.

The impacts on nature-based tourism were estimated at the national level and amounts to approximately 12% to 14% of total impact. This aggregated value should be considered as indicative only and not absolute dollar values.

The benefits of sediment reduction from dense wilding conifer stands were estimated nationally to amount to 0.3% or $4 million over the 20 year period.

The average annual impacts including monetary and non-monetary impacts are listed in Table 5.

Table 5. Average annual impact of wildings

Loss in production in pasture land ($)	-12 to -30
Loss in tourist visits ($)	-22
Loss in water availability at low flows (i$)	-2.3
Loss in biodiversity values (i$)	-91
Sediment reduction (i$)	+0.5
Carbon sequestered (t CO_2eq)	+2.7
Total National – million i$	**-127 to -144**

Loss in pasture production

The potential monetary loss in pasture production due to wilding conifer expansion in low producing pastoral land is an average annual loss of $30 million and total discounted loss of $221 million and based on the assumptions discussed above.

Sensitivity analysis of results given different loss in pasture production

A sensitivity analysis was undertaken for the percentage losses in stock units considered for productive dry stock land in scattered wilding infestations (Table 6)[9]. Although a 30% reduction was assumed in the base case scenario, this loss in stock units might be lower due to variations in geo-climatic factors. A 10% stock unit reduction in scattered areas results in a total monetary loss of approximately $1.1 billion, which is a 11% reduction from the monetary losses estimated for the baseline.

Table 6. Sensitivity analysis of the stock units percentage loss in scattered wilding areas. Stock unit loss in dense wilding stands was held constant (100% reduction)

Stock units percentage loss in scattered areas	10%	20%	30%
Average annual loss in pasture production (million $)	-12	-21	-30
Total discounted loss in pasture production (million $)	-88	-155	-221
Total costs including water, nature-based tourism, conservation losses and sediment reduction (million i$)	***-1,120***	***-1,187***	***-1,254***

International nature-based tourism

Nature-based tourism loss estimates indicate that an average annual loss of $22 million and total discounted loss of $151 million might be expected due to the increase of wilding pines from 11% to 26% in DOC areas. This result is based on the assumptions explained above and detailed in Appendix C.

Impacts on indigenous biodiversity

We arrived at an aggregated willingness to pay value of $91 million per year for five years using Kerr & Sharp's (2007) results adjusted and scaled up to the national level. This represents an indicative national non-market value of controlling wilding conifers in the Mackenzie basin for the conservation of three native species. Using a 10% discount rate, the present value is *i$866 million*. The aggregated values should be considered as indicative and not absolute dollar values. The values may be used for discussions only as the base data is not a representative sample for the national level.

[9] A direct negative relationship was assumed between stock unit percentage loss and the percentage of wilding cover in scattered areas. For example, a cover of wilding conifers of 10% in a scattered wilding area would result in a 10% loss in stock units.

Water availability

The Marlborough region, with the highest proportion (9%) of wilding conifer spread, would exhibit the greatest reduction in water yield in low flow conditions (at 1.5%) among the four regions considered (Table 7). Southland has the lowest proportion of wilding conifer spread among the four regions analysed.

Table 7: Percent coverage of dense wilding conifer stands the associated reduction in water supply in low flow conditions and the associated value loss for four different regions in 2035.

Region	% of dense wilding conifer cover per region	Reduction in water supply (%) (W_{it})	Value per m^3 (\$/m^3)*	Value of surface water (million i$ /year) (S_i)**	Reduced value of surface water (million i$/ year)***
Marlborough	9.64%	1.54%	1.07	*135*	*1.312*
Canterbury	3.35%	0.54%	0.13	*266*	*0.885*
Otago	0.66%	0.11%	0.19	*194*	*0.127*
Southland	0.21%	0.03%	0.10	*0.013*	*0.000003*

*Value of a m^3 of water was derived based on its value for irrigation in each of the four regions as a surrogate of surface water value (water supply, in stream biodiversity and recreational use of water).
** Total value of water supply was calculated by multiplying the m^3 value with the total amount of irrigation water used in the respective region.
***Reduced value of surface water is the result of the % reduction of total value of water (based on irrigation figures) through dense wilding conifer stands.

Marlborough has the highest cost of water supply reduction based on our calculations over a 20-year period (see above). This can be attributed to its high rate of reduction in water supply and the high value of a cubic metre of water for irrigation compared to the other three regions as listed in Table 7. Canterbury has the second highest cost in terms of loss water supply.

Fire

The hypothesis of negative economic impacts from wildings cannot be rejected based on interviews with rural fire experts at Scion. Experts estimate the costs of fighting fires in wildings (NZ$ 1000-2000/ha) to lie between those in grassfires (NZ$500 -1500/ha) and plantation fires (NZ$1500-3000/ha) but this also is driven by size of the fire, use of special equipment (e.g. aircraft) and the assets at risk (Grant Pearce, Scion, pers.com.). The reasons for the higher control and prevention costs are detailed in Appendix E. The risk of fires might increase overall and we can expect a negative impact. As we cannot quantify the potential increase in fires driven by the increase in wilding area we are not able to quantify the impact overall.

Carbon sequestration

Current dense wilding conifer infestations stock 27.66 million t CO_2eq. Due to the annual increase in area, dense wilding conifer infestations would accumulate an estimated 2.73 million tonnes CO_2eq per year on average, resulting in a total of 54.65 million t CO_2eq over the next 20 years.

In comparison, properly managed and well-tended afforestation can produce carbon stocks that well exceed wilding conifer stands and derived CO_2eq would be tradeable on the domestic market. In high country environments, 15-25 year old radiata pine plantations could stock an average 379 t CO_2eq per hectare –over 1.5 times more than the value used for wilding conifers (using Otago Radiata Pine yield tables (MAF, 2011). Converting the annual amount of wilding infested areas into plantations would result in a far higher carbon sequestration of 68 M t CO_2eq per year on average. In comparison, unimproved pasture or woody scrub areas would stock 7 t CO_2eq and 128 t CO_2eq per hectare, respectively (Tate, et al., 1997).

Wilding control costs

Approximately $5.8 million is spent annually on wilding conifer management by central and local governments (Table 8). Assuming that annual expenditure for the next 20 years will be constant, inflation adjusted, the total discounted expenditures would be approximately $55 million. The total impacts are *i$2 billion* for the current wilding conifer control level.

Table 8: Estimated central and local government spending on wilding conifer control (2013/14)

Organisation	**Estimated Spending ($)**
Department of Conservation	3,500,000
Land Information New Zealand	200,000 + 400,000[1]
New Zealand Defence Force	900,000
Marlborough District Council	34,000
Environment Southland	70,000
Greater Wellington Regional Council	50,000
Hawke's Bay Regional Council	32,000
Horizons Regional Council	200,000
Waikato Regional Council	16,000[2]
Auckland Council	10,000
Bay of Plenty Regional Council[3]	65,000
Canterbury Regional Council	300,000
Total spend	**5,777,000**

Source: MPI (2014)

[1] An additional $400,000 (approx.) is currently being spent annually from a one-off $1.2 million Government grant administered by LINZ for wildings control at Mid Dome in Southland.

[2] This spending includes baseline spending of $15,000 plus an additional $30,000 to $50,000 annually.

Conclusions and Recommendations

Conclusions

Wilding conifers could affect over 5 million hectares or 20% of New Zealand's land area by 2035 with the majority of the area being affected by scattered wilding conifers (5.1M hectares) and 0.33 M in dense wilding conifer stands. The ongoing spread of wilding conifers could result in approximate total losses of $141 million per annum or $1.232 billion net present value over the period between 2015 and 2035.

The current annual management cost of wilding conifers is $5.8 million. This level of governmental expenditure and current management control is inadequate and will not prevent the losses described in this report. This conclusion supports the recommendation of the Ministry of Conservation and the Ministry of Tourism to seek additional funding for a sustained woody weed eradication program (Parliamentary Commissioner for the Environment, 2011).

This is the first nationwide CBA for wilding conifer spread in New Zealand. The estimated costs and benefits assume a conservative approach. Results should be used as a first approximation of the situation where the wilding conifer infestations expand even under current management and control efforts. It is extremely important to emphasise that the estimates presented should be considered as indicative and not absolute dollar values. These values should be used for discussion at a national level.

Recommendations

We recommend:

- To use this study for further consultation on the costs and benefits of wilding conifers with stakeholders.
- To continue with Phase 2 of the project – comparing impacts and the expenditures for alternative management approaches to estimate benefit-cost ratios for different approaches.
- To fill in key knowledge gaps in future research such as:
    - Spatially monitoring the wilding conifer extent and density nationwide. This process is critical for future reporting on control success (e.g. area reduction), which would allow to improve the economic analysis of the impact that future management actions would have, and
    - Improving the estimation of the value of the impacts of wilding conifers on biodiversity and tourism and other related values if significant, as new data becomes available.

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Appendix A

Detailed methodology and assumptions for estimating spread rate, current and future wilding conifer area and affected land type estimation

Estimating current wilding conifer area and affected land type

Estimating the economic impact of wilding conifers requires information on the area affected by land-type/land use. Ideally, spatial explicit data on the wilding conifer infestations would allow for a detailed analysis. Detailed data was not available and an alternative spatial approach was taken, described below.

The current national extent of wilding conifer infestations was calculated from the wilding conifer area database, collated by MPI via a survey and data collection exercise in 2014 (MPI, 2014b). The database provides, beside many other variables, individual area estimates and location points for all known wilding conifer infestations, classified in scattered and dense infestations. Based on the given location (geospatial points) and the estimated wilding conifer infestation area, circular polygons were calculated assuming the given location represents the centre point of an infestation and equal expansion in all directions[10].

In a next step land-use/cover classes were identified in the generation of polygons, which represent the approximate area affected by wilding conifers. During this process we excluded land-use/cover classes assumed to have a small or zero probability of wilding conifer presence due to unsuitable substrate, altitude, high competition from vegetation or human influence (Table A1).

Table A1: Land Cover Data Base Version 4 (LCDB4) classes not included in the analysis

LCDB4 class	*Reason for exclusion, that will prevent wilding conifer establishment*
Broadleaved Indigenous Hardwoods	Competition, shading
Built-up Area (settlement)	Human activity
Deciduous Hardwoods	Competition, shading
Estuarine Open Water	Non-suitable habitat
Flaxland	Competition, Non-suitable habitat
Forest - Harvested	Human activity
Gravel or Rock	Non-suitable habitat
Herbaceous Freshwater Vegetation	Non-suitable habitat
Herbaceous Saline Vegetation	Non-suitable habitat
Indigenous Forest	Competition, shading[11]
Lake or Pond	Non-suitable habitat
Mangrove	Non-suitable habitat
Orchard, Vineyard or Other Perennial Crop	Human activity
Permanent Snow and Ice	Non-suitable habitat, altitude
River	Non-suitable habitat
Sand or Gravel	Non-suitable habitat
Short-rotation Cropland	Human activity
Surface Mine or Dump	Human activity
Transport Infrastructure	Human activity
Urban Parkland/Open Space	Human activity

[10] Fringe spread (high amounts of seed falling close and around the seed source) occurs often in all directions, providing support to use a non-directional spread approach for an already infested area.
[11] Douglas-fir is able to invade gaps in indigenous forests, however we excluded this category based on the current low probability given most indigenous forest have a dense structure and closed canopies.

The included LCDB4 classes are dominated by grassland and shrubland types, prone to wilding conifer establishment such as depleted grasslands, tall tussock grassland and low producing grassland. Included were also less prone land-use classes such as high producing grasslands, gorse and broom and kanuka/manuka shrublands. Exotic forests were also included as current dense wilding conifer infestations have been classified as exotic forests in LCDB4[12].

As such an exclusion of unsuitable land-use/cover classes would result in a mismatch to actual infested area (based on the wilding conifer polygons), we estimated the full area of each land-use class in the estimated wilding conifer area using the following function.

[A1] $$LU_{x,y} = Y \times \left(\frac{LU_x}{z}\right)$$

Where; $LU_{x,y}$ is area of land-use class *x* in wilding conifer area *y*
Y is the estimated area of the wilding conifer infestation
z is the area of all land-use classes used in the wilding conifer area

The approach provides for each site an estimate of the number and type of affected land-use/cover classes that are affected by wilding conifers and their approximate area.

In addition to land-use/cover classes and their areas, further classification conservation estate and private/other governmental land was introduced to determine land area actively managed for economic profit (all non- conservation estate).

The results of this process is a matrix of land use classes and their approximate area, affected by dense or scattered wilding conifer infestations by area, in each region, and on a national level by conservation estate and non-conservation land.

Estimating the future wilding conifer spread rate

Using historical and the current data on extent, collated by MPI, a graph of the development of wilding conifer affected area since the introduction of exotic conifers was published (MPI, 2014a). The shown expansion of wildings conifer infested area up to now includes inherently the effect of past and current management which has not halted the expansion[13]. The published data showed also that the rate of area increase is the same for dense, medium and scattered infestations.

Based on the provided data we derived two power -functions, one for dense infestations and one for scattered wilding conifer infestations, respectively

[A2] $$a_{dense} = 1.178E - 10 \times t^{7.192}$$

[A3] $$a_{scattered} = 1.766E - 09 \times t^{7.192}$$

Where; a is area;
t is years after the introduction of wilding conifers in 1900.

These two functions described the historic area development and were used to project the development of scattered and dense infestations over the next 20 years (Figure A1).

[12] During the economic analysis exotic forest area was excluded, resulting in a more conservative (lower) estimate of all impacts (less area was analysed, approx. 5% nationally).
[13] Effort in wilding conifer management has not greatly increased in recent times, rather experiences a reduction in funding, which was compensated by being more cost efficient.

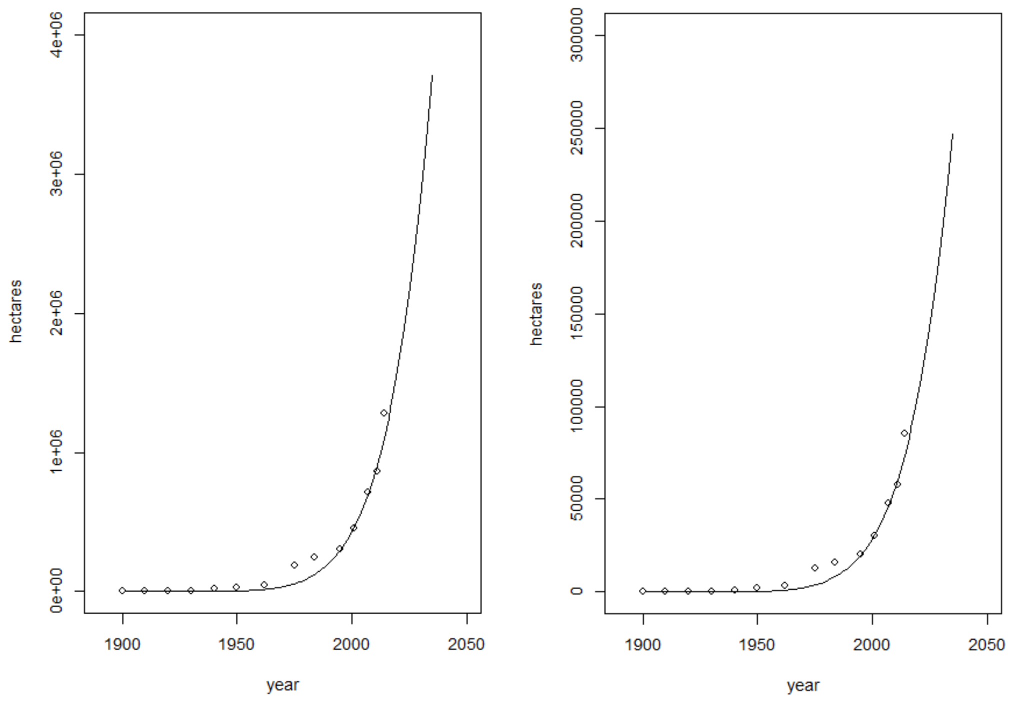

Figure A1: Increase in wilding conifer area since introduction (1900) to 2035 for two density classes, scattered (left) – low tree density; and dense (right) - closed wilding conifer canopy. Y-axes shown are in different scales. Points represent data provided by MPI and DoC.

Estimating future wilding conifer area and affected land type up to 2035

Based on the developed functions for future dense [1] and scattered [2] wilding conifer spread, we calculated the annual area increase for all existing dense and scattered wilding conifer infestations. This increase was translated into an even annual expansion of the created polygons, again assuming a non-directional spread[14].

Based on the annual polygons the land-use calculation process described above was followed to estimate the wilding conifer affected land-use/cover area for each year. This resulted in a matrix of land-use/cover classes by region, conservation or non-conservation land for each year from 2015 to 2035.

Estimated areas of different non-conservation land-use/cover classes were used for estimating the impact on pasture productivity. The estimated area of conservation land was used to estimate nature-based tourism and biodiversity impacts. Only land affected by dense wilding conifer stands was used for estimating the impact of wilding conifers on water availability, carbon sequestration and sediment reduction.

[14] Directional spread modelling is only appropriate where data on local and detailed wind patterns exist and the locations and areas are clearly defined and are spatial explicit. Also local directional models can result in different spread rates.

Appendix B

Loss in pasture production –detailed assumptions

Table B1: Assumptions for yield, gross margins and estimations of productions lost production per farm class. Farm classes in grey were used in the analysis.

Farm class No.	Farm classes New Zealand	Regions	min SU/ha used (range of SU per ha)	Gross margins $/SU	Loss in production due to scattered wilding conifers ($/ha)	Loss in production due to dense wilding conifers ($/ha)
1	South Island high country	Marlborough, Canterbury and Otago	0.7	34.35	-7.21	-24.05
2	South Island hill country		2 (2-7)	39.45	-23.67	-78.90
3	NI hard hill country		6 (6-10)	29.26	-52.67	-175.56
4	NI hill country		7 (7-13)	40.02	-84.04	-280.14
5	NI intensive finishing		8 (8-15)	50.93	-122.23	-407.44
6	SI finishing-breeding	Canterbury, Otago - dominant farm class in SI	6 (6-11)	48.73	-87.71	-292.38
7	SI intensive finishing	Southland, South & West Otago	10 (10-14)	51.47	-154.41	-514.70
	Regional farm class data if available					
3	NNI hard hill country	Hard hill country - Northland-Waikato-BoP	6 (6-10)	32.77	-58.99	-196.62
4	NNI hill country	Hill country - Northland-Waikato-BoP	7 (7-13)	42.58	-89.42	-298.06
3	ENI hard hill country	Hard hill country - East Coast Gisborne	6 (6-10)	28.09	-50.56	-168.54
4	ENI hill country	Hill country - East Coast Gisborne	7 (7-13)	37.04	-77.78	-259.28
3	WNI hard hill country	Hard hill Country - Taranaki-Manawatu	6 (6-10)	28.58	-51.44	-171.48
4	WNI hill country	Hill country - Taranaki-Manawatu	7 (7-13)	41.39	-86.92	-289.73
1	SI high country	Northern-Central South Island: Malborough Nelson Canterbury	0.7	34.35	-7.21	-24.05
2	NSI SI hill country	Hill country - Marlborough-Canterbury	2 (2-7)	38.10	-22.86	-76.20
1	SSI high country	Southern South island Otago	0.7	34.35	-7.21	-24.05
2	SSI hill country	Southern South island Otago	2 (2-7)	39.45	-23.67	-78.90

(Beef + Lamb New Zealand, 2014)

Appendix C

Detailed methodology and assumptions for estimating nature-based tourist visits

In 2013, out of the more than 13 million international tourist visits, more than 67% enjoyed mainly an outdoors activity. From this group, more than 78% enjoyed activities either on land, air or water where experiencing nature was their main focus, while the remaining 22% experienced an activity focused on a man-made outdoor attraction (eg. vineyard, zoo, cable car, garden visits) or extreme adventure experience (eg. bungy jumping, paragliding). We assumed that the latter subgroup will not be affected by an increase in the spread of wilding conifers.

The first group comprises 27 nature-based activities. We classified each activity as water based or land/air based and assigned a value for the potential impact of wilding conifers or impact factor (IF). The impact factor values assigned were: 1 = impact is expected, 0.5 = impact is uncertain, 0 = no impact. Most water based activities were assigned zero impact, except for 'scenic boat trip' and 'fishing or hunting' where the impact factor assigned was 0.5.

A total impact factor (Total IF) was estimated as follows:

[C1] $$\text{Total IF} = \text{Type of activity } (\text{Water } [0,1] + \text{Land/air } [0,1]) * IF$$

The number of tourists by activity was then multiplied by the total impact factor to obtain an estimate of how many tourists would potentially be affected by a spread of wilding conifers. The results indicate that 3 656 818 visits, equivalent to 28.09% of all international tourists visits in the period March 2012-March 2013 would be affected by wilding conifers. Therefore, we assumed that 28.09% of the total number of international visitors to New Zealand would be affected if the area of wilding conifers increased.

In order to estimate the potential loss of nature-based tourism revenue, we assumed that all of the tourist visits potentially affected by wilding conifers (28.09%) are in DOC areas. Table C1 shows the area of wilding conifer extent for 2014 and 2035 as a reference[15].

The reduction of nature-based tourist visits per year due to wilding conifer invasion was estimated adapting a function of value of recreation output (Odom et al, 2005) conditioned to the change in wilding conifers density in each year, change in total number of visitors potentially affected by wilding conifers and change in expenditure per visitor:

[C2] $$v_j = P_j \frac{V_{maxj}(X_{\min j} - W_t)}{k_{mj}(X_{\min j} - W_t)}$$

Where:

v_j = Value of tourist visits in year j
P_j = value (expenditure) per visitor in year j in NZ$
$V_{max\,j}$ = Maximum number of visitors when wilding conifer density is zero
X_{min} = weed concentration at which vj becomes zero = 0.6
K_m = half saturation constant = 0.3
W_t = wilding conifer density

For year j, the initial number of visitors (*visitor$_j$*) is known based on our estimations of number of visitors that would be affected by wilding conifers and corresponds to the term that follows P_j in Equation 5. This number (visitor$_j$) was used to estimate $V_{max\,j}$ for each year given an initial

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[15] We realise that tourists will not visit all wilding conifer infested DOC lands. However we do not have detailed information on tourist movements and number of visits, that would have allowed us carry out a more detailed analysis.

wilding conifer density (W_t) obtained from the wilding conifer spread calculation in Appendix A. $V_{max\,j}$ was then used to estimate the potential number of visitors at the end of year j (*visitor* $_{j+1}$). The difference between $visitor_{j+1}$ and $visitor_j$ is the variation in visitors at the end of the year given a change in wilding conifer density.

When multiplying this difference by P_j or expenditure per visitor in year *j*, we obtain the total loss in year *j*. The process is repeated with annual data available for number of visitors and expenditure per visitor. Given that wilding conifer density of year *j+1* is needed and estimations for this variable were only available until year 2035, we assumed a wilding conifer density value of 0.268 for the year 2036. Figure C1 shows the loss in number of visitors per year given a wilding conifer density.

Table C1: Invasion of wilding conifers in DOC areas, 2014 and 2035.

No.	Description of area	2014	2035
1.	Scattered DOC total (ha)	897,230	2,027,550
2.	Dense DOC Total (ha)	69,007	164,241
3.	Total DOC area (ha)	8,722,453	8,722,453
4.	Proportion of invasion 2014 scattered DOC (1÷3)	0.10	0.23
5.	Proportion of invasion 2014 dense DOC (2÷3)	0.01	0.02
6.	Total invasion (4 + 5)	**0.11**	**0.26**

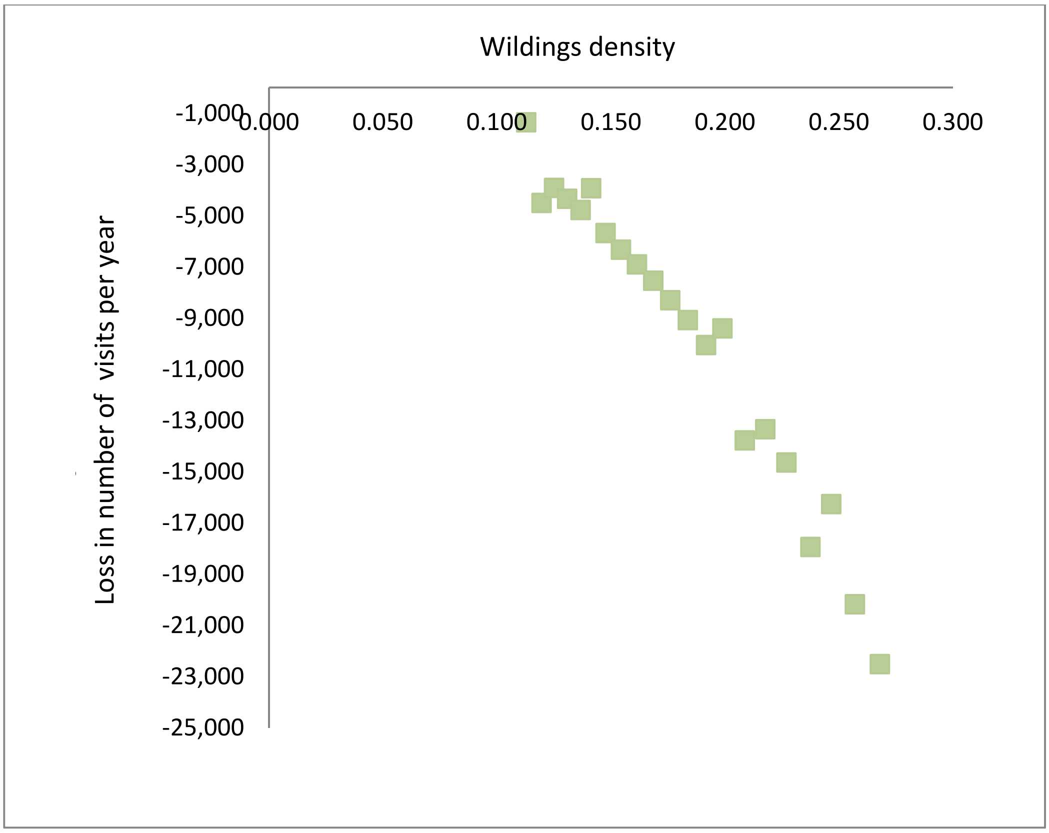

Figure C1: Loss in number of international tourist visits by wilding conifer density.

Appendix D

Surface water availability impacts–detailed methodology and assumptions

An impact factor for the spread of wilding conifers in the four regions Canterbury, Otago, Southland and Marlborough was estimated using the average 16% reduction in water yield during low flow conditions from Glendhu, Kakahu and Berwick catchment studies.
The reduction in surface water availability during low flow conditions was estimated only for dense wilding infestations (assumed 100% canopy coverage).

We use a ratio approach to estimate the water yield reduction for a region based on the estimated area of wilding conifers (dense infestations) compared to the total area of a region:

[D1] $$R = \frac{\Delta L * M_i}{Q}$$

where R represents the % reduction in water yield for a region. ΔL is the percentage change in water yield during low flow events averaged for the included study sites (16% reduction). M_i is the reported wilding conifers coverage area in region i, Q is the total area of the region i. The formula above indicates a negative linear relationship between wilding conifer spread and water yield.

For example, if the susceptible areas in the region have 20% wilding conifer coverage, we multiply 0.20 by 0.16, which leads to a 3% reduction in total water yield during low flow conditions.

To estimate the cost of water losses, we used data on the volume of annual consumptive surface water allocation for irrigation by region and primary use (Aqualinc, 2010). This served as a surrogate for the overall impact of wildings on water-supply reduction. Values for irrigation by hectare in 14 New Zealand regions were obtained from Doak, et al. (2004). Based on their analysis, on average, the added value of irrigation to non-irrigated land to average approximately $4,500 (2003 NZ$) per hectare across the regions. The values (inflated to 2012 NZ$) of irrigation by region (represented by S_i in Equation 7) reported in Doak et al. (2004) were used to estimate the irrigation value per cubic metre of surface water by region which serves as an indicative value for the reduction of water flow through wilding conifer infestations that affects water supply (e.g. irrigation, hydro power), stream biodiversity and recreation.

The estimated indicative value of a cubic metre of water ranges from \$0.10 per m^3 in Southland to \$0.13 in Canterbury to \$1.07 per m^3 in Marlborough. As the surface irrigation volume is highest in the Canterbury, this region appears to have the highest value of irrigation among the four regions (Doak, et al., 2004).

The cost of the reduction in surface water during low flow conditions by region (V_i) was calculated using the formula:

[D2] $$V_i = (W_{it} * S_i)h_t,\ W_{it} = \frac{C_i}{A_i} * R$$

where i represents region i, W_{it} is the reduction in water yield derived by multiplying the ratio of the wilding conifer coverage area for region i (C_i) and the area in the region with or susceptible to wilding conifer infestation (A_i), by the water reduction factor ($R = 0.16$); S_i represents the overall value of irrigation in region i; h_t is a vector that takes into account the cumulative rate of spread of wilding conifers in year t given the current level of control; t represents the time which starts from year 0 to year 20.

Appendix E

Impacts of wilding conifers on rural fire

Grass fires and forest fires are different to control, both in terms of difficulty and cost. Grass fires typically involve the fine grassy fuels, whereas forest fires can (depending on the level of fuel dryness) also involve the medium and heavy dead woody fuels (branches and logs, etc.). Forests are also more likely to contain deeper duff layers, so that forest fuels can also burn down into these soil organic layers, making them much more difficult and time-consuming to extinguish.

Forest fires are usually more expensive to control due to the need for heavier equipment and more aircraft and fire fighting chemicals, especially in monetary terms (NZ$1500-3000). Generally, grassfires are considered to spread rapidly but involve only light fuels, so they can be extinguished with faster moving fire trucks with “pump and roll” capability (e.g. smoke chasers and medium capacity fire trucks, NZ$500-1500/ha). On the other hand, forest fires are considered to burn slower but consume greater amounts of woody and duff fuels, requiring more static fire suppression with greater water capacity (i.e. fire trucks and tankers), heavy machinery (bulldozers, etc.) and (in the case of plantations, due to the higher asset value) also aircraft (helicopters and fixed-wing). Occasionally, aircrafts would also be required to extinguish grass fires, but this is typically due to a need for asset protection or to create firebreaks where there are no natural barriers present, or to aid “knockdown” of fast-moving or high-intensity grass fires so that ground resources can then get in to complete containment.

Grass fires can also usually be controlled with water, or water with surfactant chemicals (such as soap capsules or foam solution) to make the water “go further”, whereas forest fires will require foam to penetrate into heavy fuels or deep soil layers or retardants to coat fuels to create a barrier to fire spread (Alexander, 2000).

Due to the greater asset value, fire protection/prevention costs for plantation forests are considerably higher than for grasslands. However, for wilding conifer forests this is not currently the case and there is no evidence of fire protection measures undertaken other than perhaps insurance. Insurance cover is one potential additional cost. If they were to provide other fire protection, such as fire equipment or fire breaks around boundaries or within these forests, then this would incur additional costs that would not typically be present for adjacent farmland.

In the case of houses built amongst wilding conifer forests, the upfront and ongoing maintenance costs of clearing setbacks for fire protection would obviously be greater in wilding conifers than for grasslands. However, property owners often do not undertake these sorts of protective actions. Hence, houses are much more likely to burn down in forests due to less defensible space, the higher fire intensities mentioned above, and also the prevalence of ‘spotting’ in forests caused by embers from the trees. Therefore, residential property exposure is a potential loss issue rather than a cost where more houses would be likely to burn down if present in wilding conifers than in grasslands.

In terms of other fire prevention costs, it is possible that undertaking prevention activities could cost more for wilding conifers than in grasslands. This could include the need to restrict access to forest through locked gates, signage, and undertaking patrols –on hunting, camping and recreational activities that could start fires and these fires are possibly more likely to occur in forests than in grasslands.

Appendix F

Regional estimates of infested wilding areas in thousand hectares, grouped in conservation and non-conservation land over time (20 years).

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Auckland- DOC governed land	2.355	2.492	2.642	2.793	2.951	3.122	3.302	3.433	3.553	3.798	4.059	4.302	4.546	4.790	5.044	5.299	5.569	5.855	6.157	6.477	6.753
Auckland- Non-DOC governed land	0.082	0.092	0.098	0.109	0.122	0.135	0.218	0.288	0.314	0.329	0.330	0.336	0.348	0.365	0.385	0.412	0.444	0.472	0.502	0.533	0.590
Bay of Plenty- DOC governed land	5.234	5.511	5.840	5.914	6.007	6.133	6.134	6.326	6.494	6.658	6.871	7.088	7.324	7.582	7.842	8.075	8.303	8.558	8.738	9.139	9.442
Bay of Plenty- Non-DOC governed land	9.301	9.977	10.575	11.602	12.526	13.496	14.603	15.468	16.352	17.274	18.079	18.920	19.772	20.575	21.373	22.275	23.275	24.258	25.523	26.575	27.732
Canterbury- DOC governed land	314.503	309.991	328.542	343.994	360.466	377.658	391.196	409.603	429.162	449.374	470.095	491.363	513.350	536.899	561.071	586.135	612.263	639.538	674.816	697.779	728.467
Canterbury- Non-DOC governed land	267.966	291.815	309.289	333.113	357.945	384.284	417.709	447.384	478.282	511.153	546.139	583.433	622.873	663.512	706.633	751.798	799.177	848.867	897.925	954.518	1,010.834
Gisborne- DOC governed land	2.099	1.957	2.075	2.101	2.227	2.286	2.187	2.098	1.991	1.919	1.877	1.869	1.850	1.834	1.833	1.835	1.820	1.805	1.795	1.796	1.819
Gisborne- Non-DOC governed land	6.936	7.525	7.975	8.393	8.903	9.473	10.333	11.272	12.329	13.412	14.641	15.900	17.249	18.740	20.337	21.978	23.675	25.500	27.309	29.182	31.169
Hawkes Bay- DOC governed land	32.370	28.493	30.187	31.439	32.734	33.987	34.663	36.007	37.474	39.062	40.833	42.681	44.618	46.439	48.443	50.593	52.736	54.999	57.526	59.780	62.488
Hawkes Bay- Non-DOC governed land	32.374	29.702	31.492	34.077	36.857	39.921	44.415	48.209	52.223	56.492	60.979	65.732	70.818	76.429	82.269	88.373	94.916	101.890	111.795	117.052	125.172
Malborough- DOC governed land	267.381	285.316	302.263	316.818	331.906	347.585	361.924	379.350	397.881	416.854	436.387	456.718	477.748	499.714	522.270	546.151	570.818	595.630	618.398	648.582	676.995
Malborough- Non-DOC governed land	143.840	167.699	177.874	190.340	203.608	217.602	233.004	248.112	263.598	280.248	298.037	316.608	336.132	356.729	378.418	400.795	424.387	449.712	474.997	503.808	532.895
Manawatu - Wanganui- DOC governed land	69.722	77.207	81.829	86.513	91.376	96.522	101.669	107.162	112.851	118.768	124.879	131.151	137.548	144.067	150.891	157.916	164.944	172.094	181.847	186.922	194.760
Manawatu - Wanganui- Non-DOC governed land	125.186	147.390	156.214	166.182	176.616	187.496	199.101	210.695	222.759	235.368	248.537	262.373	276.952	292.487	308.846	326.012	344.105	362.912	378.085	403.115	424.337
Nelson- DOC governed land	0.094	0.102	0.108	0.115	0.119	0.120	0.306	0.387	0.459	0.524	0.589	0.661	0.730	0.760	0.762	0.773	0.772	0.755	0.721	0.656	0.597
Nelson- Non-DOC governed land	3.513	3.724	3.947	4.188	4.445	4.714	5.005	5.298	5.601	5.917	6.257	6.597	6.934	7.314	7.767	8.266	8.813	9.372	10.015	10.559	11.132
Northland- DOC governed land	0.346	0.364	0.385	0.404	0.425	0.449	0.471	0.496	0.522	0.549	0.577	0.607	0.638	0.672	0.708	0.745	0.782	0.821	0.860	0.899	0.937
Northland- Non-DOC governed land	0.300	0.322	0.342	0.365	0.390	0.414	0.442	0.470	0.499	0.529	0.562	0.595	0.631	0.667	0.703	0.742	0.785	0.830	0.877	0.929	0.985
Otago- DOC governed land	159.674	159.705	169.284	175.459	181.752	188.231	190.670	197.302	204.093	211.028	218.070	225.499	233.204	241.247	249.557	258.176	267.276	276.626	289.590	296.298	306.999
Otago- Non-DOC governed land	146.370	164.938	174.795	189.024	204.168	220.203	241.369	259.533	278.751	299.090	320.640	343.169	366.850	391.685	417.811	445.264	473.918	504.110	532.549	569.124	603.687
Southland- DOC governed land	7.032	7.652	8.095	8.542	8.984	9.445	9.899	10.343	10.799	11.261	11.758	12.312	12.900	13.587	14.280	14.928	15.462	15.964	16.306	16.946	17.512
Southland- Non-DOC governed land	14.423	16.715	17.684	19.169	20.605	21.991	23.526	24.941	26.381	27.948	29.587	31.276	33.057	34.964	37.055	39.199	41.412	43.645	45.528	48.575	51.375
Tasman- DOC governed land	45.108	46.857	49.664	52.565	55.420	58.155	60.048	62.609	65.294	67.985	70.867	73.989	77.258	80.599	83.933	87.497	91.380	95.731	100.967	105.495	110.910
Tasman- Non-DOC governed land	23.016	24.263	25.714	27.370	29.295	31.538	34.855	37.766	40.946	44.301	47.676	51.169	54.964	59.049	63.620	68.532	73.629	78.850	83.992	90.294	96.412
Waikato- DOC governed land	55.702	54.034	57.242	59.367	61.616	63.976	65.277	68.037	71.051	74.225	77.633	81.267	85.061	88.884	92.887	97.075	101.252	105.401	108.530	114.019	118.530
Waikato- Non-DOC governed land	68.607	70.324	74.561	79.567	84.874	90.454	96.931	103.110	109.557	116.287	123.281	130.601	138.263	146.272	154.519	163.154	172.512	182.651	193.912	204.933	217.086
Wellington- DOC governed land	4.084	4.328	4.586	4.785	4.981	5.188	5.317	5.528	5.726	5.861	5.962	6.052	6.094	6.144	6.167	6.147	6.090	6.287	6.368	6.388	6.334
Wellington- Non-DOC governed land	6.576	6.976	7.394	7.906	8.458	9.036	9.731	10.385	11.095	11.911	12.808	13.763	14.816	15.913	17.090	18.367	19.738	21.031	22.393	23.881	25.511
West Coast- DOC governed land	0.017	0.018	0.019	0.019	0.020	0.021	0.022	0.023	0.025	0.027	0.028	0.030	0.031	0.032	0.034	0.034	0.035	0.035	0.036	0.037	0.038
West Coast- Non-DOC governed land	0.333	0.354	0.375	0.398	0.421	0.446	0.472	0.499	0.527	0.557	0.588	0.621	0.656	0.692	0.730	0.771	0.813	0.858	0.904	0.953	1.003