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Predicting harvesting and deforestation of radiata pine forest blocks using national spatial datasets

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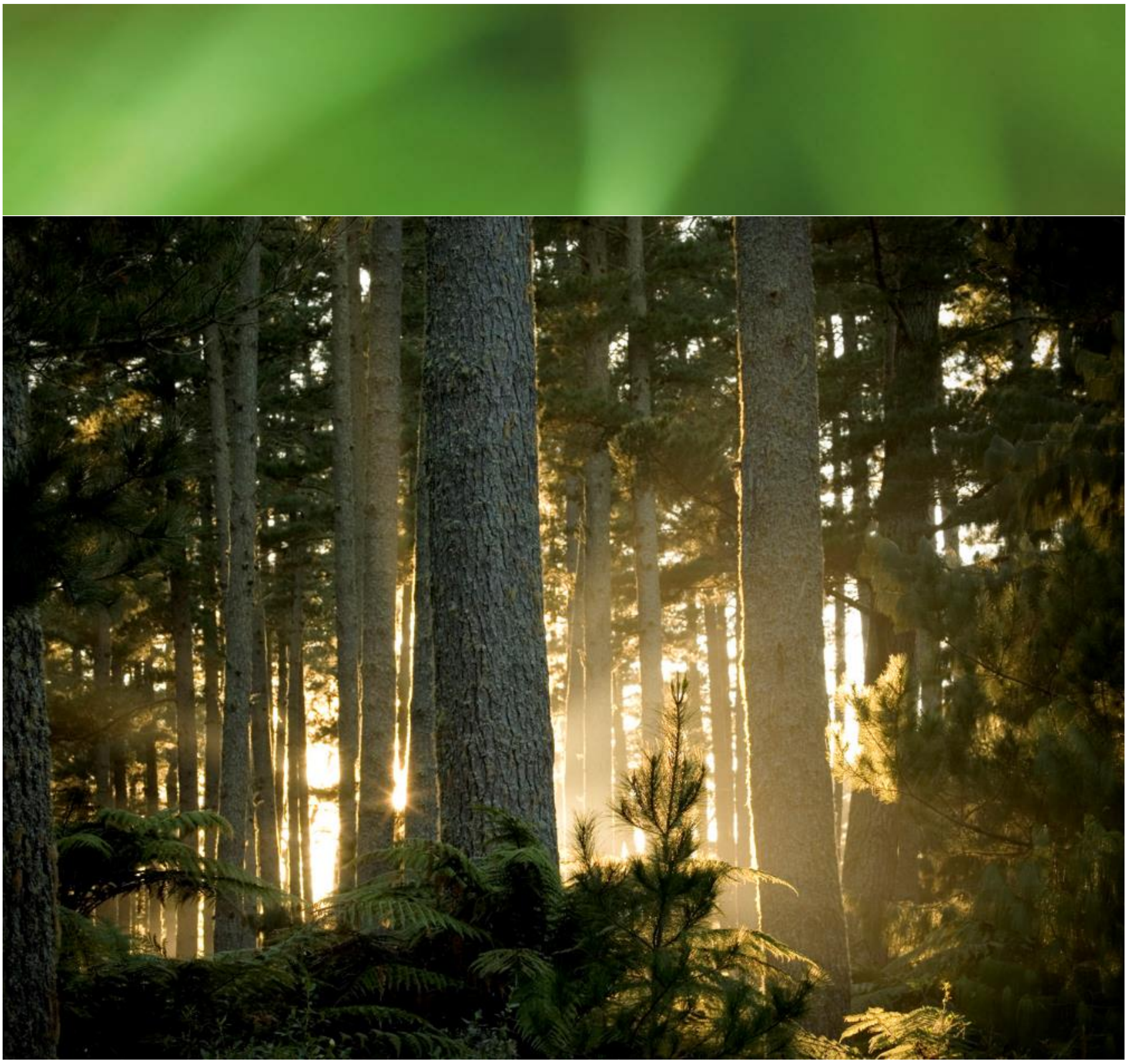
CLIENT REPORT

Predicting harvesting and deforestation of radiata pine forest blocks using national spatial datasets

B Hock, D Harrison and R Yao



REPORT INFORMATION SHEET

REPORT TITLE	PREDICTING HARVESTING AND DEFORESTATION OF RADIATA PINE FOREST BLOCKS USING NATIONAL SPATIAL DATASETS
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EXECUTIVE SUMMARY

Report Title: Predicting harvesting and deforestation of radiata pine forest blocks using national spatial datasets
Authors: Barbara Hock, Duncan Harrison and Richard Yao

National spatial datasets add valuable information to land-based modelling; this research set out to determine the contribution such datasets could make to two issues affecting the ability to forecast future wood availability from planted forests and the size of the planted forests estate:

- The likelihood that individual forest blocks would be harvested; and
- The probability that forest blocks would be deforested

Quantifying these likelihoods through spatial analysis can improve models of regional wood availability forecasting and projecting for example net carbon uptake, by incorporating a better understanding of where deforestation is likely to occur, and where forest areas are likely to be left unharvested.

Methodology
The key methodologies used were the Forest Investment Finder (FIF), Scion's spatial model of forest economics, for modelling harvest intentions, and regression modelling for deforestation analysis and predictions.

Harvest intentions
The results relating to harvesting intentions include:

- The likelihood of harvesting is high (>90% likelihood of harvesting for small forests)
- Forests uneconomic to harvest are spread around country; and likely are remote
- The spatial-based modelling is not linear; it is influenced by proximity to roads and the harvest infrastructure required
- Sharing costs with nearby larger forests improves returns for 1,627 ha of small forests
- Considering harvest-only economics c.f. forest NPV improves harvest economics for about 10% of small forests
- Increasing carbon price increases returns – however this is complicated by the liabilities on harvesting
- Pruning vs framing regimes have little effect on the likelihood of harvesting
- Increasing log price means more small forests are economic to harvest (2 and 3% more hectarage with 5 and 10% increases). Decreasing log prices however results in a greater amount of hectarage uneconomic to harvest.

Detailed results are reported for each region according to pre-1990/post-1989 categories, and by approximate Landcover Database age bands.

Deforestation
The results relating to deforestation include:

- Greatest amount of deforestation was in Waikato and Canterbury
- More deforestation likely at lower slopes
- The better pasture productivity is, the more likely that there is deforestation
- Deforestation is less related to Māori owned lands
- Deforestation is more related to higher roading densities and more built environment present
- Distance to market is important, in that more deforestation is likely the further the forests are from log markets
- Societal include that deforestation is more in lower income areas

Correlation analysis also identified that Māori land has less deforestation, and more of the less productive Land Use Classes, LUC 5-7.

The regression analysis computed probabilities of deforestation. The analysis is suitable for indicating areas at risk of conversion, however the results remain predictive at the individual forest block level. Nevertheless they can be used to investigate at-risk forests more closely.

Recommendations

Recommendations to improve the analysis include:

- Improved spatial NEFD
- Addition of land value data
- Building in improvements in harvesting technology
- More individual forest analysis
- computing other scenarios such as the permutations of carbon credit implementations, and modelling delivered wood costs for harvesting intentions (i.e. without NPV)

The recommendation is that now that the FIF datasets have been developed, more analysis becomes possible. A similar approach such as was used for this project, a workshop to set parameters for the analysis followed by the actual analysis, may be an effective way to utilise the datasets developed in this research.

Predicting harvesting and deforestation of radiata pine forest blocks using national spatial datasets

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June 2016

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Introduction

The forestry sector is an important part of the New Zealand economy, contributing 3% of GDP, $5 billion in annual gross income and providing direct employment for 20,000 people in forestry and wood processing[1]. It has played an important part in regional development and this is expected to continue.

Planted forests are also a cornerstone of New Zealand's Climate Change policy, primarily due to the role they play in taking up and storing CO_2 and therefore mitigating dangerous climate change by reducing atmospheric greenhouse gas concentrations. Planted forests offset one-third of New Zealand's gross emissions during the period from 1990-2014 and are expected to play a key role in achieving New Zealand's Nationally Determined Contribution under the Paris Climate Agreement – a reduction in net greenhouse gas emissions in 2030 to a level 30% lower than in 2005. Harvesting is a key driver of net CO_2 uptake by planted forests. Afforestation, deforestation and replanting decisions are also important factors in determining the timing of changes to net uptake and the level reached.

The Ministry for Primary Industries (MPI) periodically produces regional wood availability forecasts to inform policy development and provide information to assist with resource planning, investment decisions, biosecurity planning and determining infrastructure requirements. Assumptions on harvesting and replanting underlie these forecasts.

Models used to project net carbon uptake by forest and future wood availability are essentially supply-based – net stocked areas from the National Exotic Forest Database (NEFD) are assumed to be harvested when they reach a nominal rotation age, tempered by the harvest intentions provided by the larger forest owners and constraints intended to smooth overall harvest volumes. However, it has been noted that "*… forests on steep terrain, distant from processing plants/ports, small in size or without existing roads may be uneconomic to harvest if logging and transport costs are higher than the market value of the forests' recoverable log volume*" (MAF, 2010). It was also suggested that a sufficiently high carbon price might deter owners who have registered their forests in the Emissions Trading Scheme (ETS) from harvesting.

Large areas of planted forest have also been converted to other land uses in the past decade. The Ministry for the Environment (MFE) (2016) reports that 112,002 ha of pre-1990 planted forest and 24,657 ha of post-1989 planted forest were deforested in between 1990 and 2014.

These two factors – the potential for some forests to remain unharvested, and the conversion of planted forests to other land uses (notably dairy) – have the potential to affect both projections of New Zealand's net greenhouse gas balance and regional wood availability forecasts.

Objectives

The objective of this study was to determine if national spatial datasets could be combined to shed light on two issues affecting the ability to forecast future wood availability from planted forests and the net uptake of atmospheric CO_2 by these forests:

1. The likelihood that individual forest blocks would be harvested; and
2. The likelihood that harvested forest blocks would be deforested.

Quantifying these likelihoods through spatial analysis allows improvement of models for regional wood availability forecasting and projecting net carbon uptake by incorporating a

[1] https://mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/

better understanding of where deforestation is likely to occur, and where forest area is likely to be left unharvested.

Previous projections of harvesting and deforestation

Land use decision-making is influenced by multiple drivers that vary over time and from place to place. MAF (2010) noted that there have been fluctuations in harvest volume in response to market conditions such as log and lumber prices, shipping costs and movements in exchange rates. However, forests have been established for a variety of reasons and it follows that individual forest owners will approach decisions regarding harvesting and replanting in different ways. Wakelin et al (2014) provide a review of small to medium forests and their owners in New Zealand, including factors affecting decision-making. Observations made include:

- Firms are often assumed to be profit maximisers, but in practice they take many factors into account including marketing and market access, license to operate, long-term strategy, risk management, environmental issues, contractual obligations, strategic alliances and health and safety issues.
- Before the 1990s, the primary drivers for tree planting by farmers were shelter, making use of otherwise unproductive land and aesthetic considerations. Direct financial returns from timber ranked only fourth. However, financial returns (particularly related to superannuation) were a more important factor in the increased afforestation in the 1990s.
- Private forest owners overseas often manage forests based on personal financial criteria rather than forest economics, with forests treated as a capital reserve. This is also likely to be true for many small forest owners in New Zealand.

Harvest intentions from owners of large forests (> 1000 ha) have been used to calibrate harvesting in the short to medium term for wood availability and carbon balance forecasts (e.g. Chandler, 2016; Wakelin 2015). The potential for small forests to remain unharvested has been investigated by Park (2011), Park et al (2012) and Manley et al (2014). Each of these studies made a detailed analysis of a sample of small-scale forest blocks in one or more regions. Blocks with a negative stumpage were considered unlikely to be harvested. Internal rate of return (IRR) was calculated as an indicator of the likelihood or a crop being re-established. Previous modelling of deforestation has been based on surveys of intentions (e.g. Manley 2015), econometric analysis (e.g. Smith and Horgan 2006) and the used of agent-based models (e.g. Adams and Turner 2012).

The availability of spatial datasets makes it possible to explore their potential for determining areas that are more or less likely to be candidates for either of these events. Datasets included remote sensing-based data of environmental and biophysical characteristics, spatially-based economics such as terrain-based and distance costs, and human geography-related such as property characteristics and census data. This provides a range of variables likely to have an influence on harvesting and replanting decisions. It is also possible to classify forests according to their Kyoto Protocol status (pre-1990 versus post-1989 forests) and determine approximate age classes, which are required to allow forecasts of harvest likelihood over time.

Project scope

Reasonable information about the management goals and harvest and replanting intentions of large-scale forest owners is available as these owners participate in the wood availability forecasting process and deforestation surveys. Less is known about the small (< 40 ha) and medium (40–1000 ha) owner classes. Table 1 gives a breakdown of the NEFD area by size class. Of the surveyed area in the 40–1000 ha class, about 75% is over 100 ha. It is reasonable to assume that the economics of harvesting would have been carefully considered before making an investment at this scale and larger forests are likely to have been professionally managed. Area imputed from nursery survey returns makes up about 40% of the total small-medium forest owner resource with just over half of all small-medium owner area being in the < 40 ha class. These areas are of particular interest with respect to the harvest and replanting intentions of their owners. The analysis reported here has been undertaken for all planted forests, and separately for three different estimates of small forests.

Table 1. NEFD area and average age by size class (MPI data)

Size Class	Area (ha)	% of Total area	Avg. age (years)
Small Forest Grower Survey	66,517	3.8	
New Planting Adjustment	202,740	11.7	
Under 40 ha*	8,604	0.5	21.3
40–59 ha	24,603	3.5	20.1
60–79 ha	20,064		
80–99 ha	15,712		
100–199 ha	55,764	7.8	18.6
200–399 ha	62,610		
400–499 ha	16,313		
500–599 ha	8,566	2.9	17.4
600–799 ha	26,631		
800–999 ha	14,943		
1,000–1,999 ha	45,448	13.6	15.8
2,000–3,999 ha	77,098		
4,000–9,999 ha	112,119		
Over 10,000 ha	970,768	56.2	16.7

* i.e. owners surveyed as part of the 40-1000 ha class but who now have < 40 ha.

The intent of this project was to use national spatial datasets to assess 100% of forest area in the size classes of interest, rather than taking a sampling approach. There was no attempt to verify information or obtain greater accuracy through the use of more detailed imagery (e.g. aerial photography), local expertise or ground-survey.

The broad assumption is that forestry economics drives harvesting and deforestation decisions. There is no additional information on the attitudes, objectives and behaviour of forest owners that is suitable for inclusion in the analysis.

The harvest likelihood analysis aims to characterise where and when stands may reach harvest age and be left standing. Deforestation rates have been influenced by a number of policy decisions, including the deforestation liabilities under the ETS introduced in 2008 for the first commitment period of the Kyoto Protocol. Temporal deforestation modelling, i.e. where deforestation rates increased or decreased according to policy dates, was outside the scope of this project. Instead this work focused on the location of such changes and their key characteristics.

Modelling systems background

Two modelling systems developed by Scion provide functionality to assist in determining which forests are more or less likely to be harvested and/or deforested: the Forest Investment Finder (FIF) and the Biomass Supply Model (BSM).

FIF (Harrison et al 2012) models and maps the economic viability of forests by calculating the baseline revenue for the forest grower. FIF currently estimates radiata pine plantation costs that include the establishment of trees, harvesting and transport to markets using representative 25m resolution surfaces. The returns from forestry are estimated from predictive surfaces of volume, tons of biomass (bioenergy) and carbon sequestration (CO_2 equivalents, t ha^{-1}). FIF not only estimates the economic return in terms of profitability ($ ha^{-1}) but can also account for the economic benefits of some ecosystem services (carbon sequestration and avoided erosion).

FIF combines all the components that affect the economic feasibility of forestry projects in New Zealand. The major drivers for determining economic feasibility are log yields and prices along with roading construction costs, harvesting and transport of timber to market. Transport of logs to market is the largest component of direct costs that a remote forest has to bear at harvest time. If a forest is not connected to the current road network, a harvest access road must be constructed. In large forests, this cost can be small when compared to the cost of harvesting and transport. However this cost can be a significant for small forests and small inaccessible forests will incur greater costs than a forest that is close to the existing road network and market, making its profitability lower.

FIF uses Discounted Cash Flow analysis, the most common method in New Zealand forestry for assessing the economic merits of a forestry project. This method allows the time delays occurring between costs and revenues to be accurately reflected in today's dollar terms by discounting the value of future cost and revenue cash flows. Important to this methodology is the discount factor used by the analysts preparing the cash flow: a high discount rate forms a higher hurdle for the project to demonstrate profitability, and similarly a lower discount rate makes it easier for a project to demonstrate profitability.

BSM (Hock et al 2012) includes modelled information useful to the deforestation assessments and future change likelihood assessments. The most important is national spatial age-range information for planted trees; this data is not nationally available for reasons of commercial confidentiality and is required to allow an assessment of likelihood over time.

Limitations and assumptions

There are some limitations in the approach that relate specifically to the models and data used.

New Zealand's national spatial databases that map forests are the Landcover Database (LCDB version 1-4) (Anon 2013) and the Land Use Carbon Analysis System (LUCAS) Land Use Map (LUM) (Beets et al 2011). The advantage of LUM is that a rigorous data checking process was used to develop the dataset, and that the forests are classified into pre-1990/post-1989 plantings. The advantages of LCDB are that the dataset has the most recent data and that the non-forest classes and the harvested class allow approximate age classes to be determined for the forests. The disadvantage of LCDB is that the 'exotic forest' class is a broad categorisation that includes planted trees not usually characterised as part of the national forest resource, e.g. willow riparian plantings. Differences in the mapping approaches mean that the forests in the two datasets are not perfectly aligned; nationally this can amount to up to a 6% difference in location (Hock, Payn & Heaphy 2014).

The LCDB and LUM datasets also do not differentiate to the level of detail that the non-spatial National Exotic Forest Description (NEFD) does. For example, NEFD shows older trees that are unlikely to be harvested; LCDB does not differentiate according to age in its classification system and only through change detection can a potential age range be surmised.

Spatial datasets are collected at varying spatial resolutions. For example, the LCDB has a Minimum Mapping Unit of 1 ha, while Digital Elevation Models can be to 25 m resolution. A modelling resolution needed to be set that adequately addresses the problem while avoiding the large volumes of data required of high resolution national mapping. A 500 m resolution was selected; this does averages higher resolution data within each 500 m extent, however many datasets were simplified into broad classes of values as part of the modelling process, hence a 500 m spatial resolution was considered adequate.

FIF modelled all forest as radiata pine, with areas not suitable for radiata pine excluded. Other species make up ten percent of the resource nationally but can be more important regionally. About 25% of the estate in Otago-Southland is Douglas-fir, which is grown, harvested and replanted on sites that are marginal or uneconomic for radiata pine. FIF is likely to under-estimate the profitability of forestry on those sites. FIF also assumes a standard rotation age and management regime, so will not accurately reflect decisions for stands that have been poorly managed or have been damaged. Since log yield is a key driver of profitability, a stand that is uneconomic to harvest at age 28 may become economic as the volume increases with age.

The economic data used by FIF may differ from the actual costs for a specific site. FIF uses national unit rates for costs which are adjusted according to slope class, but there may be other local or regional factors that are not considered. The sensitivity of the modelled findings to variations in key economic variables, carbon prices, NPV, and economies of scale (shared harvest roading costs) is explored.

It is also recognised that the assumption that harvesting and deforestation decisions will be based on forest profitability may not always be the case. There are many reasons why a landowner may choose to harvest a forest that appears to have a negative NPV, or choose not to harvest a stand that has a positive NPV (Table 2). The analysis presented here is limited to those factors that can be readily determined from available datasets.

Table 2. Decisions based on factors other than profitability

Negative stumpage but still harvest	**Positive stumpage but no harvest**
There is an opportunity cost in not converting to higher land use (including a new forestry crop).	Perception that higher profits are possible in future.
Capital value of land may be improved with the removal of trees.	Local government environmental constraints; red tape.
Not wanting to leave next generation with a carbon liability.	Avoid carbon liability from harvest, or earn carbon credits from growing the stand on
Aesthetics, health and safety (dangerous old stand), weed control, “maximising productive use of land”, removing the evidence of a bad investment for peace of mind etc.	Retain the forest for shelter, aesthetics, recreation, environmental benefits etc.
Perception that harvesting will be profitable; optimism.	Perception that the stand can’t be harvested profitably, risk aversion.
Tax purposes (e.g. to offset profits elsewhere in the business).	Don’t need the money yet; want to spread income, minimise tax.
Contractual obligation e.g. investment syndicates.	

The scope of this project did not extend to investigating other land uses: harvesting may happen even when uneconomic if the land manager considers the potential of the land is higher under other land uses. For example, highly profitable forestry sites may be converted into lifestyle blocks when the demand for such blocks raises the value of the land.

The effects of differences in ownership types were largely not modelled, as data on ownership type was not easily available. The exception is Māori ownership, which was included as a parameter in the deforestation modelling.

Despite these limitations, this high level spatial analysis is an approach that may provide useful insights and can be improved as more datasets become available.

Methods

This project uses spatial analytical capabilities for assessing the effects of land use change related to forestry (Watt et al, 2011; Hock et al 2012; Hock et al, in prep). For assessing harvest intentions, the key step uses the FIF model to determine the economic viability of harvesting smaller forests. For the spatial analysis of deforestation, the methodology focuses on assessing drivers for past deforestation. For both harvest intentions and deforestation intentions, likelihood categories for future potential change are developed. The forest areas are categorised according to these likelihoods across pre-1990/post-1989 planted areas and, where possible, by age class. The final step was to review the results in light of farm-forestry decision makers' views based on an extract from a 2015 survey on rural decision makers.

Methodology workshop

A workshop was held on 17 February 2016 to steer the development of the methodology of the project. The meeting was attended by representatives from MPI (Craig Elvidge, Peter Lough), MfE (Nigel Searles), University of Canterbury (Bruce Manley) and Scion (Barbara Hock, Graham West, Steve Wakelin and Les Dowling). The outcome of the workshop was a list of potential drivers of deforestation that would be desirable to assess. The drivers that could be important for the conversion of New Zealand forests into other land uses are given in Table 3. In regard to the modelling of harvest intentions, the conclusion of the workshop was to use FIF to assess New Zealand's smaller forests.

Table 3: Potential drivers or factors influencing deforestation intentions

Groupings	Potentially contributing factors
Biophysical	Site Index / 300 Index Slope Risk (wind/fire) Land Use Class (LUC) Soil type Rainfall / Temperature / Altitude Land Environments NZ (LENZ)
Infrastructure	Distance to port (market) Urban / lifestyle
Forest-based	Size Proximity to deforestation Ownership structure – farm in title
Competing land use (LU)	Pasture productivity Dairy potential Irrigation potential / schemes Proximity to dairy Cost of new land Water quality / offset leaching
Returns	Carbon price (liability has negative impact on the returns) Log price Dairy price

Key data sets

Two national datasets were important to both the harvest intentions and deforest intentions assessments. These are listed in Table 4 lists and their specific use is described in the individual methodology sections.

Table 4: Key datasets for the assessment of harvest intentions and deforestation intentions

Dataset	Contents	Reference
Landcover database (LCDB versions 1-4)	Land cover classes for New Zealand as recorded in the summers of 1996/97, 2001/02, 2008/09 and 2012/13	Anon 2013
Land Use Carbon Analysis System (LUCAS) Land Use Map (LUM)	Land use as at 1990, 2008 or 2012 for tracking changes in New Zealand land use for carbon accounting under United Nations Framework Convention on Climate Change (UNFCCC)	Beets et al 2011

Notable features of the datasets for this project are that:

- The verification assessments of the LUM data ensured high levels of accuracy. The dataset includes pre-1990 and post-1989 categorisations of the planted forests.
- LCDB 4.2 contains more recent national land cover data. Approximate age ranges can be determined for the forests identified in LCDB based on the version 1-4 (Hock et al 2016).

All GIS modelling used the Arcmap IS products by ESRI[2].

OBJECTIVE 1: Modelling harvest intentions

In order to determine the potential that the exotic forests planted in New Zealand will also be harvested, the assumption was made that economic viability was an important component of the decision making. Where the cost of harvesting exceeds returns, there is a potential that the trees may not be harvested unless factors such as log prices change. (Harvesting for the purpose of changing to another land use, i.e. harvesting regardless of return, was not considered here. Harvesting for the purpose of changing to a different land use is explored in the deforestation analysis.)

FIF models the discounted return on forestry which incorporates multiple variables that relate to harvesting. Within-forest costs include the cost of landings and an estimate of the roading required within a forest, and the cost of the harvest operations. For forests not connected to the existing New Zealand road network, realistic least-cost road construction estimates are calculated for establishing new roads between the existing network and the forests being modelled. This calculation includes an assumption that forests distant from roads could share road construction costs. Finally, transport costs are calculated from the forest to destination markets (ports, sawmills and processing plants).

[2] www.esri.com

The FIF model

The FIF model (Yao, Harrison, Velarde & Barry 2016 and Yao, Harrison, Hock, & Payn 2016), as described in detail in Appendix A, estimates the NPV value[3] of a forest based on the revenue expected from the resource, and the costs associated with planting, tending and harvesting the resource. The standard model was run based on a structural (framing) regime and using costs and prices as at June 2015. All ports and mills are included, with the assumption that logs can be delivered to the port or mill closest to the forest. The FIF runs did not include land value as that data only became available after the conclusion of the contracted work. FIF is also limited to areas where road connections are possible, hence it does not model planted forests on islands such as in the Marlborough Sounds. The grid resolution used for the model runs is 25 m.

Scenarios for FIF modelling

A number of factors can influence the harvesting of planted trees (Manley et al 2015). This work focused on smaller forests, as they are less likely to achieve economies of scale compared to larger forests.

There is no one dataset that identifies small forests in New Zealand. National datasets like LUM and LCDB can be queried for small forests. However these datasets do not differentiate continuous forest areas according to different properties and hence potentially different owners. The New Zealand Farm Forest Association (NZFFA) has a database on owner information, however the database does not include an explicit link to the owners' forests.

The methodology applied uses the different datasets as the source for three different scenarios of small forests, and one reference scenario (Table 5). For forests based on the LCDB and LUM datasets, the New Zealand definition of the minimum size of a forest was used, namely that it needs to cover a contiguous area of at least one hectare (MPI 2015). For the maximum size of the small forests, an amount of 40 hectares was used.

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[3] In theory NPV considers more than the economics of only harvesting, because it captures planting and tending costs and the effect of rotation length. These are important in determining how profitable a rotation has been and for the replanting decision; however if someone is focused purely on the harvest decision then they may consider only whether stumpage is positive, i.e. revenue from log sales minus the cost of harvest and transport. In practice, for the broad level analysis of this assessment, NPV works as a reasonably effective surrogate as all forests are harvested at a fixed rotation age and NPV is dominated by log price and harvest and transport costs.
Regarding stumpage: Stumpage is not to be confused with delivered timber prices, i.e. at the mill/port. A timber buyer will offer landowners a price for the standing trees in a forest. Trees are valued by timber buyers "on the stump" after deducting costs associated with cutting, transporting the log to landing, hauling the logs to the mill and other costs. These costs vary with equipment costs, maintenance, fuel prices, insurance, labour, markets for forest products, logging conditions, volume of timber per hectare, and other variable costs. The mill/port delivered price, if the timber buyer has calculated correctly, should cover those costs with a small profit.

Table 5: Scenarios developed for modelling harvest intentions and their datasets

Scenario name	Small forests based on	Data source	Description	Rational
Small forests – NZFFA	NZFFA's Small Forest Owners Database	NZFFA Database & LUM	Refer Figure 1	NZFFA developed and verified a comprehensive list of farm-forest owners
Small forests – LUM	LUM planted forests	LUM	Planted forests 1–40 ha	LUM data is highly verified for carbon accounting
Small forests – LUM/LCDB	LUM & LCDB planted forests	LUM, LCDB	Planted forests 1–40 ha per dataset	Adds recent data in LCDB 4.2
All forests	Reference scenario: all planted forests	LUM, LCDB	All LUM planted forests, plus LCDB 1–40 ha	Evaluate benefit of shared costs between nearby forests

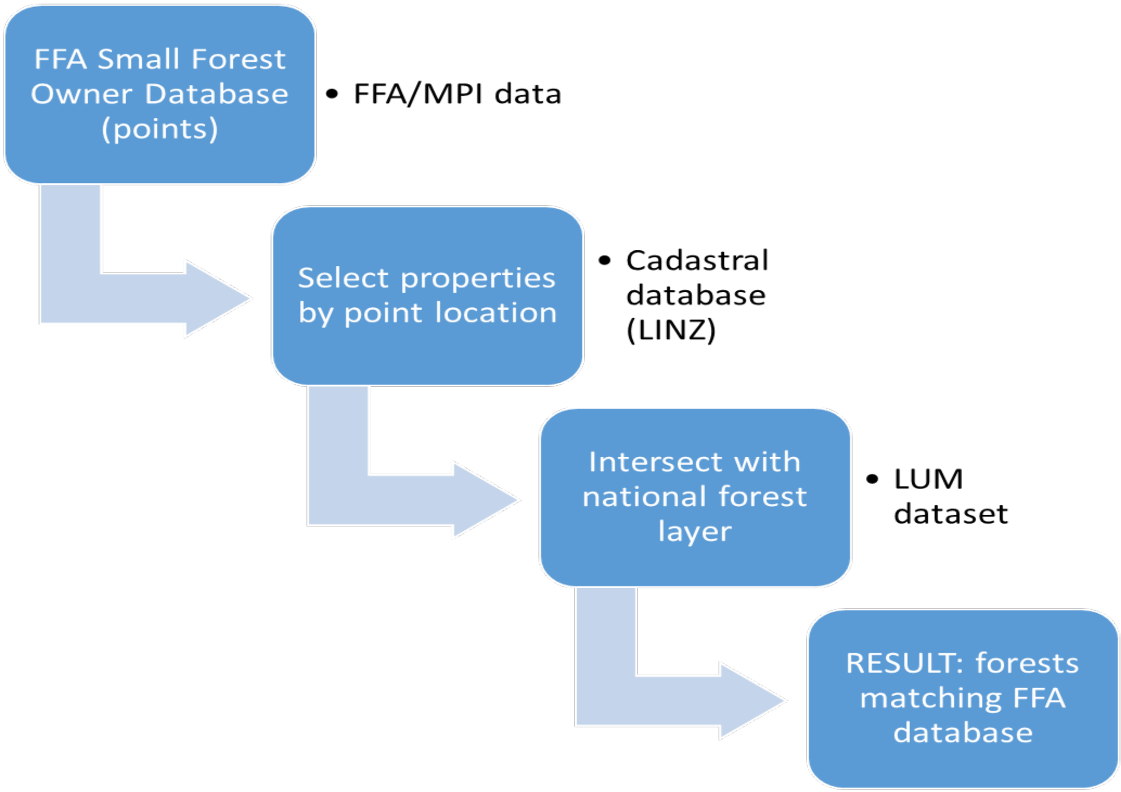


Figure 1. NZFFA points identified farms; property boundaries for the points were selected from cadastral data, then overlaid with LUM to get forest boundaries

FIF was run per scenario (Table 6), for the South and North Islands. The forest areas of the combined-database scenarios more closely reflect gross rather than nett area of New Zealand's planted forest. For example, according to NEFD (2015), the national net stocked area is 280,000ha in the 1–40 ha class, and the total net stocked area is 1,717,000 ha. For this exercise, two national spatial datasets were additively combined with resultant overestimation of total areas. While some of the scenario modelling areas exceeded national statistics, the approach allowed the scenarios to be developed in a consistent manner hence allowing comparison between scenarios, and allowed the testing of small forests from to multiple sources. Data detail loss during the modelling process, as described in the detailed results, partly negated the overestimation from the modelled results.

Table 6: Scenarios modelled by FIF

Scenario	Total area (ha)	Number polygons
Small forests – NZFFA	57,093	4,797
Small forests – LUM	256,495	44,435
Small forests – LUM/LCDB	363,546	127,768
All forests	2,189,639	167,328

Model runs were verified against in-house data and other FIF runs, and rerun where needed.

Summarising FIF results

The FIF outputs were linked to the input shapefiles to produce maps and summaries of the scenarios.

A set of likelihood indicators was developed based in part on economic theory. For example, a profit of approximately zero is the breakeven or ‘point of indifference’ for the forest, because the business is able to generate the revenue needed to cover all the costs (labour, capital, contractors and overheads). While economic considerations are not the sole drivers of harvest decision making, they do influence such decisions at least in part, hence this information is valuable for planning.

Six harvest likelihoods were developed for the FIF results (Table 7). Specific cut-off values needed to be set in order to categorise the likelihood classes. Which dollar value to use as cut-off can be substantiated in different ways (see Manley et al, 2015 for a different set of cut-off values); the values used in this report were based on an internal discussion. The results data supplied to MPI include Arcmap feature classes (equivalent to shapefiles) allowing MPI to modify cut-off levels and hence summarise data by different criteria should they wish.

Table 7: Likelihood classes for harvesting based on modelled NPV for a forest

Likelihood	NPV range ($)
Highly unlikely	< -1,000
Unlikely	-1,000 to -100
Fairly unlikely	-100 to 100
Fairly likely	100 to 1,000
Likely	1,000 to 10,000
Highly likely	> 10,000

Comparing FIF scenarios

The reference scenario (all planted forests in LCDB and LUM) provided a dataset for an indicative comparison of the economies of scale for small forests. In other words, if large costs such as roading construction could be shared between forests in sufficiently close proximity, a number of small forests could become more profitable.

The scenario based on NZFFA's Small Forest Owners Database was used in the comparison ("Small forests – NZFFA"). The FIF results for "Small forests – NZFFA" was overlaid with the "All forests" scenario and the returns compared.

Sensitivity analysis of FIF scenarios

The scenarios based on the different combinations of small and large forests (Table 3) modelled the effects on profitability of the location of the forests. This section assesses the FIF results in terms of sensitivities to differences in economic data. Four assessments were made: carbon prices, regimes, log prices, and NPV. This allowed the investigation of:

- The harvest-only component (delivered wood cost) in comparison to the NPV results. As indicated above, there are limitations to using NPV.
- A simple exercise[4] of the effect of carbon price on harvesting decisions was performed. Five carbon prices at time of harvest were investigated: \$15, \$18, \$25, \$35 and \$50. The carbon liability based on these prices were compared against the returns indicated by the FIF run that excluded carbon returns. There are options for mitigating high carbon liabilities such as banking carbon credits earned during the rotation, however performing such an analysis was outside the scope of this investigation.
- A pruned regime as an alternate to the modelled structural (framing) regime, as 54% of the national resource is pruned (FOA & MPI 2014). The final stocking was 350 stems per hectare and log prices are listed in Table 8.
- The sensitivity to log prices. Log prices were raised and lowered by 5% and 10%.

Table 8: Log prices for the FIF model run of an example pruned forestry regime

Log Grade	Log Price (\$ m^{-3})
P1	150
P2	130
S1	105
S2	100
S3	97

The FIF scenario used for this analysis was the one that was based on the forests identified using NZFFA's Small Forest Owners Database. The FIF modelling results for the North Island NZFFA-based forests were transferred to FIF's assessment spreadsheet. The results were characterised into the respective pre-1990/post-1989 forest classifications.

[4] The interaction of implementation options for carbon credits, liabilities, harvest ages, and even if harvesting at all interact in different ways. The trading (price speculation) of carbon credits also influence decisions and potential outcomes. The example investigated is hence a simple example that does not cover all the permutations of options available.

OBJECTIVE 2: Assessing deforestation intentions

Deforestation is assessed by comparing previous deforestation events against likely contributing variables as developed in workshop (Table 1). Two econometric analyses were performed. The first tested deforestation against the variables in order to identify key factors that would likely influence the size of the deforested areas. The second considered deforestation within the context of the national forest estate. Ideally' this analysis would have considered only those areas of the national estate that have been harvested and not deforested. However, as such a dataset does not exist, this research considered deforestation in comparison to all the forests known to not be new plantings within the time periods covered by the national datasets.

Both the LUM and the LCDB datasets indicate deforestation events. Deforestation is indicated where land use or land cover is recorded as planted forest or as harvested at some point in time, and then in the subsequent time period the land has a different use respectively vegetation cover. For example, LCDB 1996 (imagery from summer 1996/97) may show land as “Forest - Harvested” while LCDB 2001 (imagery from summer 2001/02) shows this land as “High Producing Exotic Grassland”. The deforestation areas from the LUM and LCDB datasets were combined into a single dataset for modelling.

Data for modelling deforestation intentions

Data was collected to correlate against the deforested areas. Datasets for the correlation assessment were selected or derived to as best as possible achieve the desired potential drivers of deforestation listed in Table 3. The data collection process included a range of sources and GIS techniques to derive the required GIS layers. Table 9 lists the final datasets, classes developed and source information.

Table 9: Data layers for deforestation modelling

Data	Unit	Classes	Reference
General biophysical0			
Rainfall	mm	< 400(low), < 800(m-low), < 1600(med), > 1600(hi)	LUC Handbook (3rd ed., Landcare)
Temperature	°C	< 7.9, > 7.9	Watt et al 2011
Elevation	m	< 200,< 400,< 600,< 750,< 950,> 950	LUC Handbook (3rd ed. , Landcare)
Slope	°	< 7(flat), < 20(mod), < 35(hill), > 35(steep)	LUC Handbook (3rd ed. , Landcare)
Governance related			
Region / N.I. vs S.I.	Index	Regions#	Statistics NZ
Ownership structure	Index	Ownership type	Global Forest Watch
Water quality constrained catchments	Index	Taupo, Rotorua, Waikato catchments	NIWA catchments
Competing land uses			
LUC*	Index	LUC 1&2 (arable), 3-4 (arable limits), 5-7 (non-arable)	LUC Handbook (3rd ed. , Landcare)
Pasture potential	Index	LRI CCAV from low to high: 0–4, 4–8, 8–12, 12–16, 16–21	MOTU 14-07
Potential for irrigation	m	Proximity (500 m) to larger rivers	Irrigation systems advertising
Growing degree days (horticulture)	number days	Suitable for a range of horticulture (GDD5 < 2700, GDD5 > 2700)	Brent Clothier, Plant&Food, pers comm.
Proximity to dairy LU	km	< 10, > 10	Agribase

Proximity to high producing/horticulture	km	< 10, > 10	Agribase
<u>Infrastructure</u>			
Road density	Index	index 0 (low), to 1 (med), > 1 (hi)	LINZ Topo
Built-up density	Index	index 0 (low), > 5 (med-hi)	LCDB
Proximity to urban centre	km	< 30, > 30	LCDB
Proximity to dairy/meat works infrastructure	km	< 30, < 100, > 100	Scion data
<u>Forestry related</u>			
Distance to port / mill (road distance)	km	< 30, < 100, > 100	Hock et al 2012
Distance from roads	km	< 1, > 1	LINZ Topo
Impediment surface from FIF	Index	Used in this analysis as index for harvest roading costs	Yao et al 2016
Size of deforestation over property	Index	< 50%, > 50%	LCDB & LINZ
<u>Societal</u>			
Predominant income	$	MedianIncome2013 (< 40k, < 50k, < 60k, < 70k, < 80k, > 80k)	Statistics NZ census
Predominant age	Index	Highest # people in range 20–40, 40–60, > 60	Statistics NZ census
Property size	ha	to 10 (small), to 40 (small forest), to 100 (med-large), 100+	LINZ cadastral
Coastal proximity	km	< 5, > 5	LINZ Topo

*LUC is a standard land characterisation technique commonly used across New Zealand when developing land use plans. It is possible to change the characteristics of a piece of land sufficiently for it to change to a different LUC class, as the definition of a class includes the limiting factors of the class. Examples of improvements include irrigation, contouring and soil nutrient inputs. For investigating deforestation, the LUC dataset reflects the land characteristics before post-harvest improvements rather than after such a change.

To determine the extent of the characteristics of all forests in the national forest estate, the above variables were sampled based on a 1 km grid with random origin.

Modelling deforestation by size (area)

The first step of the econometric analysis was to analyse the data set using the basic Ordinary Least Squares (OLS) estimator (Kennedy 2008). The data collected for analysis (Table 6) was assigned to the centroids of the polygons representing an area of deforestation, with the size of the polygon as the dependent variable in the regression analysis.

The results of the OLS were assessed using post estimation diagnostics to check for any regression problems (e.g. multicollinearity, heteroscedasticity). The assessment indicated that the natural log of the deforested area, ln (ha), provided a better fit.

Having resolved any regression issues, it was possible to apply models appropriate to account for the econometric issues identified. A more general econometric model, Tobit (Kennedy 2008) was used to run a number of scenarios including censoring the deforestation areas less than one hectare in size, and similarly censoring areas less than 40 hectares in size. These values were chosen as one hectare conforms to New Zealand's definition for the minimum area of a forest (MPI 2015) and because 40 hectares is used in the NEFD for small planted forests. Finally an example correlation matrix was calculated based on the Māori land ownership variable.

Modelling deforestation against not-deforested

For the regression on the occurrence of deforestation within the forest population, the country was divided into observations points based on a 500 m grid with random origin. The dependent variable in the analysis was the binary presence/absence of deforestation. This variable was regressed against the variables developed above (Table 6) however excluding the variable 'Size of deforestation over property'. In addition, the variable indicating area, respectively area of deforestation or the forest area in a grid cell, was added to the list of independent variables.

The basic Ordinary Least Squares (OLS) estimator was used to analyse the dataset and determine the appropriate functional form (Kennedy 2008). After running the OLS, post estimation diagnostics were undertaken to check for any regression problems such as multicollinearity and heteroscedasticity. Based on any econometric issues identified, appropriate models were employed to account for them. To account for the probabilistic nature of the dependent variable (the Probability of Deforestation = Y/N), the Logit and Probit econometric models were employed (Kennedy 2008 and Wooldridge 2010).

To develop a manageable dataset for the regression analysis, the grid cells with the presence/absence observations (207,260 with forest areas, 24,925 with deforested areas) were summarised across unique combinations of all the variable classes. The resulting 109,590 forest observations were found to be skewed to small areas, i.e. small-area observations (forest and deforestation) dominated the regression results. In order to have a high substantiation reliability for each observation used in the regression, the potential margins of accuracy of the regressed data sets was considered. The LCDB has a Minimum Mapping Unit (MMU) of 1 ha – formatted to the simple contiguous and continuous shape structure that is provided by the grid approach, 1 ha MMU equates to a 100x100 m. A 100 m grid cell overlaid on a spatial boundary equates to +/-50 m, which for a 500x500 m area reduces the reliability extent to the 400x400 m 'core' area of Figure 2. For the forest/deforest area to form a substantial (substantiating) component of a cell, it was decided that the minimum area should be larger than the area outside the grid core, namely 25 ha less 14 ha for the core means areas less than 9 ha are excluded from the analysis. In other words, areas with less than 9 ha across all of NZ for a particular combination of the variable classes are removed from further consideration. This resulted in 37,012 observations available for the regression analysis.

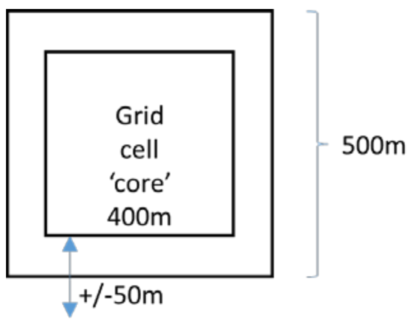


Figure 2. Diagrammatic representation of substantiating area calculation for the minimum forest/deforestation area included in the regression analysis

The OLS regression model was run with area in linear form (hectares) in Model 1 and in log form in Model 2. To address the econometric problem of heteroscedasticity in these runs, i.e. the variance of the regression error terms differs across the observations, these two models were run using White's corrected standard errors (Kennedy 2008). To account for the probabilistic nature of the binary dependent variable, limited dependent variable models (Models 3-Probit and 4-Logit) were employed.

As the Logit model is a highly non-linear regression model, interpreting the coefficient estimates is not straightforward. To address this, the marginal effects value (dy/dx) were calculated. They can be interpreted as linear effects on the probability of a successful outcome. After running Model 4, the probability of deforestation was calculated for each observation. The probabilities were classified into three probability ranges for reporting: (1) 0 to 10%, (2) 11% to 20%, and (3) 21% and above. The probabilities were also linked to the originating forest/deforest observations to develop map views.

Rural decision makers whose land includes forestry

In 2015, Landcare Research conducted a survey of rural decision makers towards understanding the potential future of the New Zealand farming environment (Brown 2015). The survey covered a wide spectrum of primary industry and lifestyle farming. The number of responses was considered sufficient for a separate assessment of rural decision makers involved in forestry: 409 respondents indicated involvement with forestry to some degree. 351 of these respondents identified themselves as commercial farmers, i.e. dependant of farming for their livelihood, with approximately 25% of the commercial farmers identifying themselves primarily as foresters. The non-commercial farmers identified themselves as lifestyle farmers.

The survey was reviewed for survey questions relevant to forestry, such as “Do you intend to harvest your forest in the next 2 years?” Regional analyses were performed where there were with sufficient responses, otherwise a national summary was made.

Results and Discussion

The results for each modelling approach are presented. They are summarised to likelihood classes – across a range from very likely to very unlikely – for each of the harvesting and deforestation intentions.

OBJECTIVE 1: FIF modelling results for harvest intentions

Figures 3 and 4 present the results for radiata pine for the North Island and the South Island respectively. Map representation required additional emphasis for the small forests to be sufficiently visible at the national scale; for each map there is an indication if such emphasis has been utilised.

The results are summarised in Table 10. The detailed regional results for pre-1990/post-1989 areas are given in Appendix B. The detailed age-class results, by region, are given in Appendix C. The tabulation in this report uses the dollar value cut-offs of Table 7. However, the spatial and spreadsheet data provided to MPI allow for summarising by different cut-off levels.

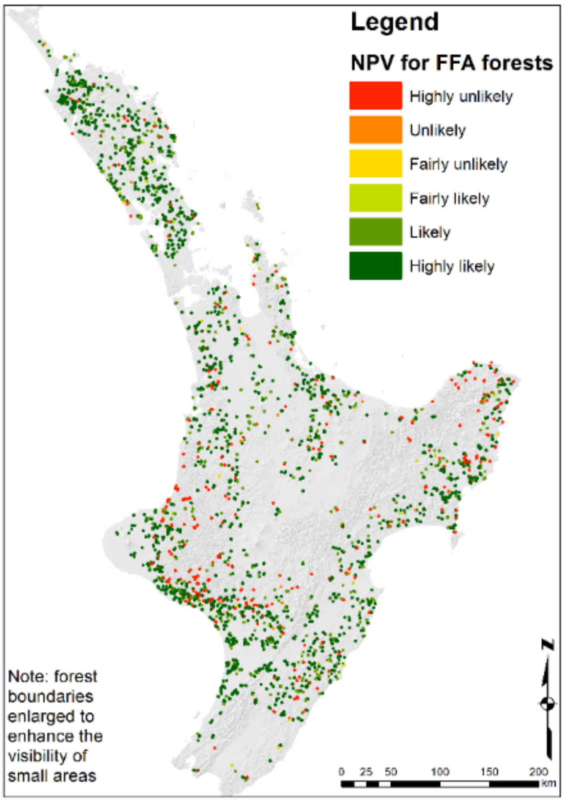
Table 10: Summary of the harvest intentions for each scenario, as proportion of total scenario area

Scenario	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely
Small forests – NZFFA	6.5%	0.3%	0.2%	0.6%	9.0%	83.4%
		7.0%			***93.0%***	
Small forests – LUM	5.7%	0.4%	0.2%	0.8%	12.2%	80.7%
		6.3%			***93.7%***	
Small forests – LUM/LCDB	8.1%	0.4%	0.1%	0.7%	11.5%	79.2%
		8.7%			***91.3%***	
All forests	1.3%	0.0%	0.0%	0.1%	1.4%	97.2%
		1.4%			***98.6%***	

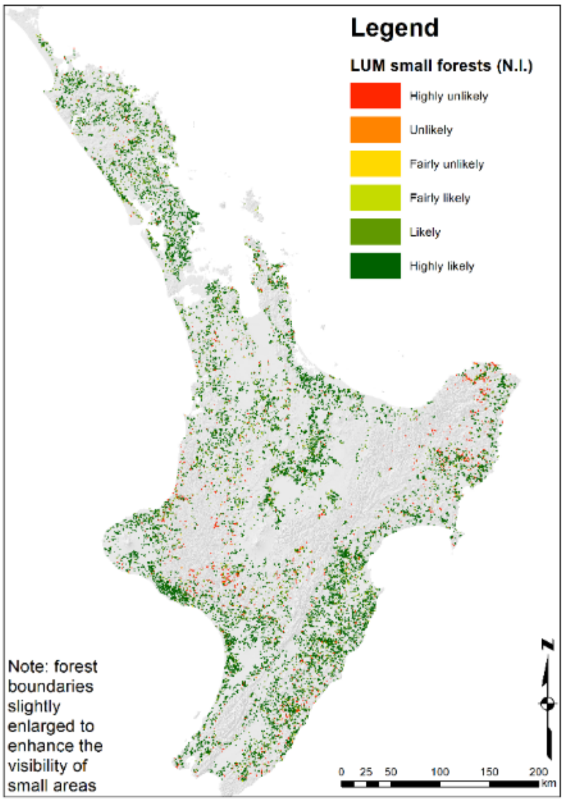
The less economic forests are spread across multiple regions typically in remote parts of the country. NPV is influenced, as expected, by factors such as proximity to roads and the ability to shared harvest road development costs. FIF computes this as part of each forest NPV. However, it makes the assumption that proximate forests are sufficiently close in harvest age for this to be implemented.

The FIF results indicate a high level of harvest likelihood. The assumption is that the stand is well-stocked and well-tended to meet reasonable grade log prices, hence actual profitability can be lower than modelled. While the log prices used for the modelling are at higher levels than for several of the preceding years (Scion data), they are below current prices (June 2016) which would further increase viability.

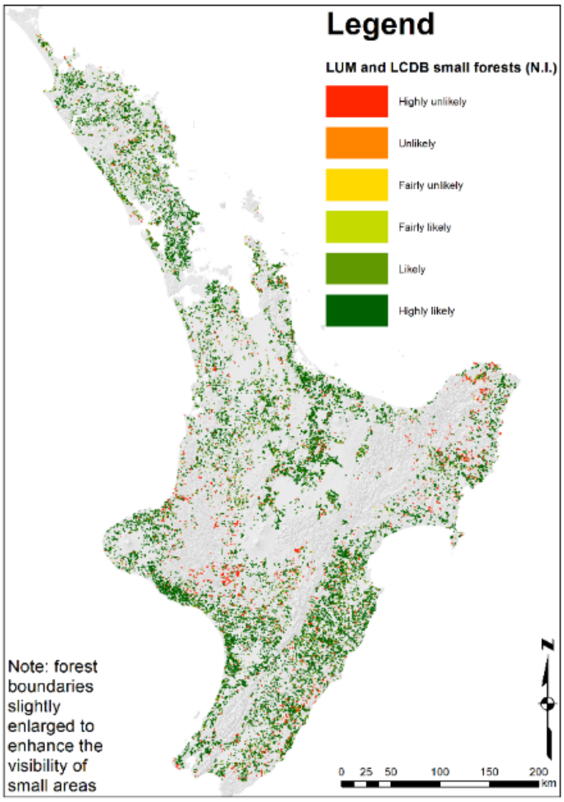
The three small forest scenarios have a higher proportion of forests unlikely to be harvested than the fourth all New Zealand forests scenario. In other words, more small forests are at risk of not being harvested than larger forests, particularly when it becomes possible to exploit economies of scale through, for example, sharing construction costs for an access road. Combining small forests for harvesting provides economies of scale is frequently practised; this analysis indicates the extent to which the economy of scale can be modelled.



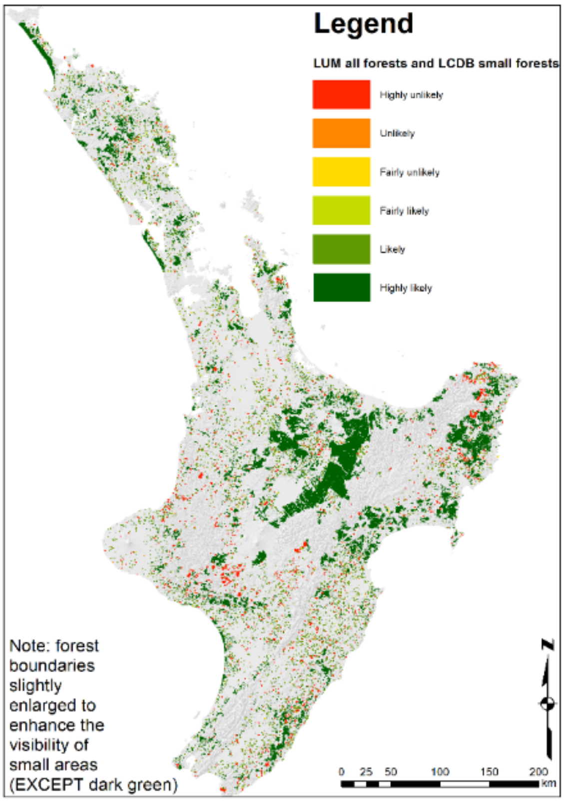
(a) Scenario: Small forests – NZFFA



(b) Scenario: LUM small forests

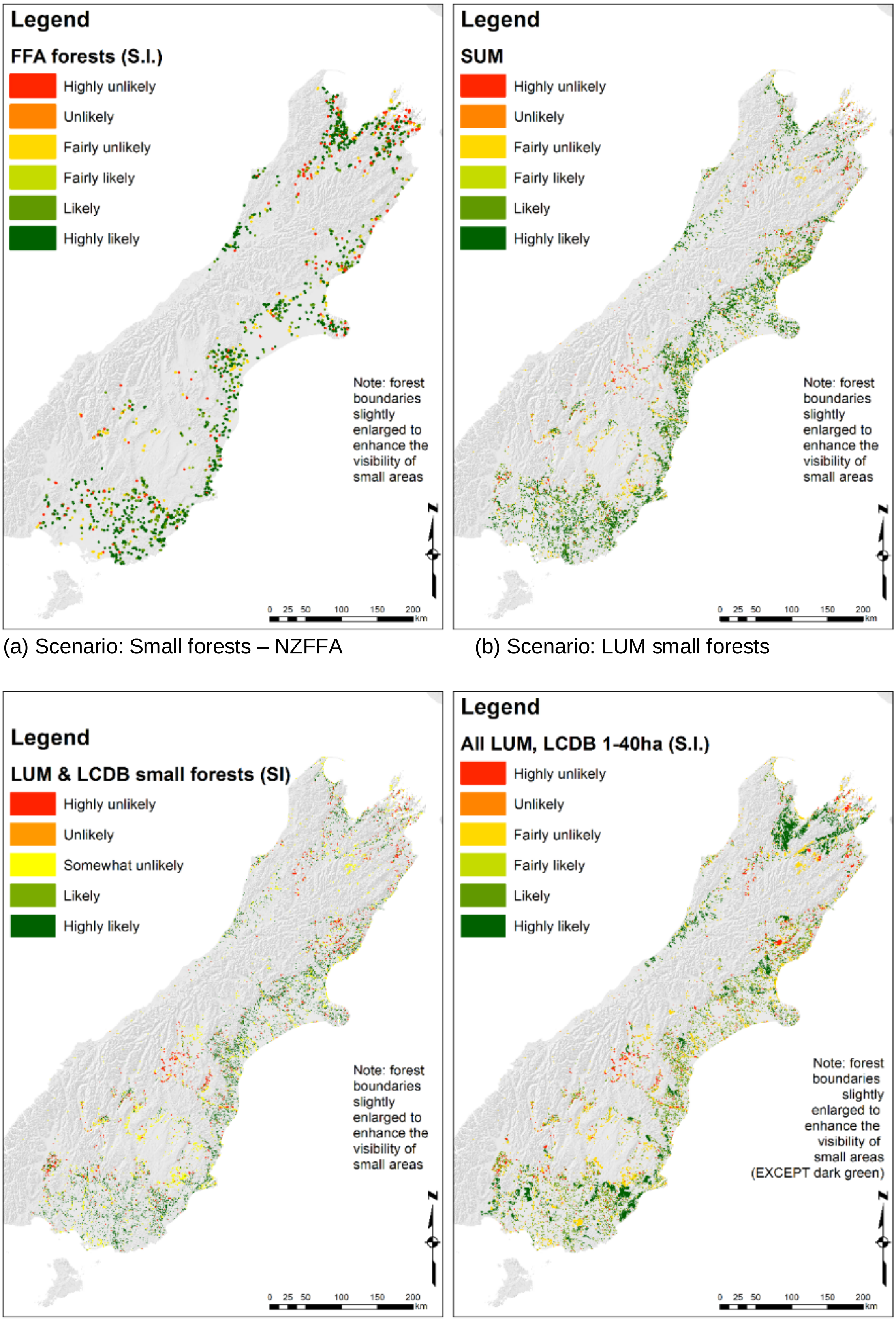


(c) Scenario: LUM & LCDB small forests



(d) Scenario: all-LUM plus small-LCDB forests

Figure 3: Indicative maps of forest likelihood of being harvested



(a) Scenario: Small forests – NZFFA

(b) Scenario: LUM small forests

(c) Scenario: LUM & LCDB small forests

(d) Scenario: all-LUM plus small-LCDB forests

Figure 4: Indicative maps of forest likelihood of being harvested

The results for the small forest blocks (less than 40 ha) unlikely to be harvested are a little higher than those reported by Manley et al (2015) for a sample of 60 forest blocks of less than 1000 ha in each in the North Island. Manley et al (2015) considered case blocks to be uneconomic to harvest if the delivered wood cost was greater than the maximum log price over the previous four years, and marginal if delivered wood cost was greater than the average log price but less than the maximum. The proportion of sampled blocks rated as uneconomic to harvest ranged from 0–2.9% in each region, with a further 1.2%–6.7% rated as marginal. The mean for the North Island was 1% uneconomic and 3.5% marginal. The inclusion of blocks in the 40–1000 ha size class in the Manley et al (2015) analysis is likely to have reduced the proportion of uneconomic forests.

Comparison of FIF scenarios

The returns modelled by FIF for a number of small forests improved with the inclusion of larger forests. Comparing the scenario “Small forests – NZFFA” with the results of the “All forests” scenario, 725 forests totalling approximately 1,627 hectares showed at least partial improvements in returns were possible through sharing the development of local infrastructure (Table 11).

Table 11: Increases in harvest likelihoods for small forests when nearby forests are included in the FIF modelling

FIF results for scenario ‘small forests–NZFFA’	Changes in harvest likelihood when include nearby forests (ha)				
	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely
Highly unlikely	30	–	19	123	969
Unlikely		5	1	10	37
Fairly unlikely			11	19	38
Fairly likely				10	114
Likely					1,627

A small proportion of forest areas (approximately 10%) went from likely to unlikely to be harvested because the computations for shared roads makes a number of assumption during a model run. FIF calculates the overall least road cost per scenario, i.e. as though all forests have a single owner. For example, if a forest is adjacent to other forests, the assumption is made that they can share roading costs. In a different scenario, such as when more forests are added, some forests gain from proximity while others are no longer able to share costs in the same way – at least computationally – hence for the latter forests the harvest costs would increase and returns would be reduced.

Results of the FIF sensitivity analysis

Three sensitivity analyses were performed:

- The harvest-only component (delivered wood cost) in comparison to the NPV results
- Carbon prices of $15, $18, $25, $35 and $50 compared to the base FIF run excluding carbon returns
- Structural regime compared to pruned regime
- Log prices increasing or decreasing by 5% and 10%.

Delivered wood cost

Considering the delivered wood costs only improved some of the modelled economic returns (Table 12). In total, 11% of the small forests were predicted to change from uneconomic (highly unlikely, unlikely, or fairly unlikely to be harvested) to potentially economic or at least partly economic to harvest (fairly likely, likely, and highly likely to harvest) (Figure 5). The availability of the FIF results allows further investigation of outcomes without NPV; the magnitude of the study limited the investigation of delivered wood costs across all the scenarios.

Table 10: Changes in harvest likelihoods for small forests when consider only delivered wood cost

FIF scenario: small forests – NZFFA	Harvest likelihood based on delivered cost (ha)						
Harvest likelihood based on NPV:	**Highly unlikely**	**Un-likely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**TOTAL**
Highly unlikely	***653***	***4***	***5***	***9***	***59***	***1,198***	***1,927***
Pre-1990 Forest	216	-	-	2	32	410	661
Post 1989 Forest	388	3	5	6	21	714	1,138
Unlikely	**-**	**-**	**-**	**-**	**-**	***80***	***80***
Pre-1990 Forest	-	-	-	-	-	29	29
Post 1989 Forest	-	-	-	-	-	45	45
Fairly unlikely	**-**	**-**	**-**	**-**	***8***	***66***	***74***
Pre-1990 Forest	-	-	-	-	-	31	31
Post 1989 Forest	-	-	-	-	7	31	39
Fairly likely	**-**	**-**	**-**	**-**	***11***	***181***	***193***
Pre-1990 Forest	-	-	-	-	7	113	120
Post 1989 Forest	-	-	-	-	3	58	61
Likely	**-**	**-**	**-**	**-**	**-**	***2,669***	***2,669***
Pre-1990 Forest	-	-	-	-	-	1,348	1,348
Post 1989 Forest	-	-	-	-	-	1,170	1,170
TOTAL	653	4	5	9	78	4,194	4,942

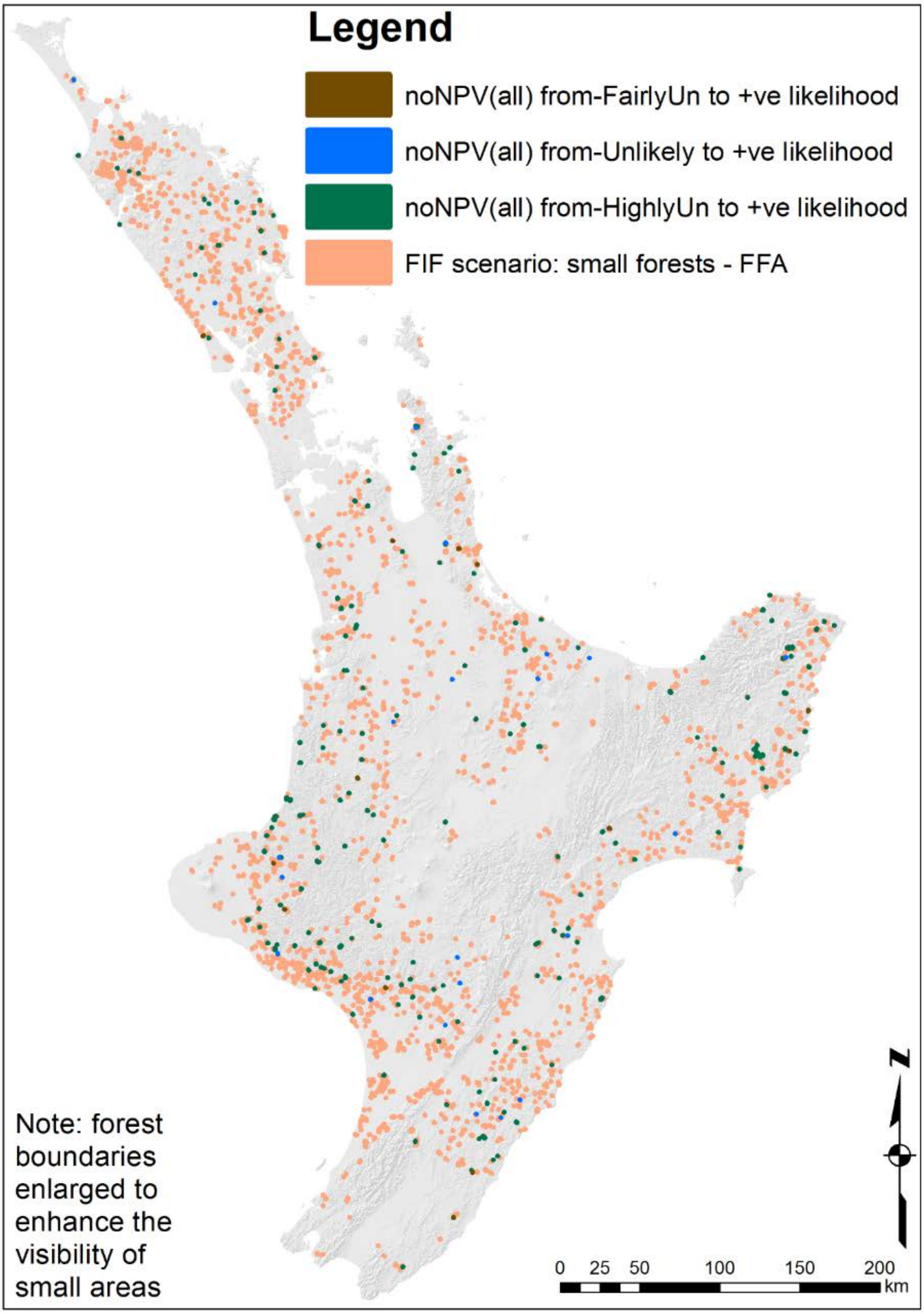


Figure 5: Map of forests that change from uneconomic to economic to harvest when only harvesting costs are considered rather than NPV (Scenario: small forests – NZFAA)

Carbon prices

There are a number of ways of implementing carbon credits; and each can have different outcomes depending on rises or falls in carbon prices and changes in policy and legislation. Examples include when carbon price rises are less than increasing log demands – a scenario favourable to those wanting a return from forestry – then income may exceed liabilities. Higher carbon prices, however, can result in liabilities exceeding returns from log harvesting. While this can be mitigated by banking the carbon-based income during the rotation, investigating all carbon options was outside the scope of this assessment.

This study only compared the carbon liability under different price scenarios to the predicted harvest returns. Table 13 shows the areas (hectares) where carbon liabilities exceed harvest returns, for one scenario of log prices (the FIF base run of this research) and multiple carbon prices. Figure 6 shows a map of the results for the $15 carbon scenario. FIF calculates the discounted returns from the carbon credits; other scenarios of carbon liabilities can be modelled. All forests in the ETS have lower returns at time of harvesting when the carbon price rises significantly. The limitation of this study is that all post-1989 forests are modelled as earning carbon credits as ETS data is not publicly available.

Table 13: Effects of carbon pricing on the post-1989 forests (FIF scenario 'North Island small forests – NZ FFA database')

Probability of harvest based on FIF NPV	**Percentage *STILL* likely to be harvested in Carbon scenario**		
	Carbon $15	Carbon $18	Carbon $25 (*)
1 Highly unlikely	0%	0%	0%
2 Unlikely	0%	0%	0%
3 Fairly unlikely	0%	0%	0%
4 Fairly likely	6%	6%	0%
5 Likely	3%	1%	0%
6 Highly likely	35%	10%	0%

(*) For carbon prices $25 and higher, the carbon liabilities exceed modelled returns. For this small-forest scenario, the tipping point where no harvesting occurs based purely on carbon liabilities (i.e. liabilities separate from carbon returns) lies between a carbon price of $18 and of $25

Carbon prices particularly affect the decision to harvest for those forests that are only marginally economic to harvest. For the highly profitable forests, the gains from harvesting are considered to have a low risk and to exceed all except the highest carbon price scenarios. For the marginally profitable forests, higher carbon prices has a high risk of resulting in decisions to not harvest, instead continuing to earn carbon credits.

Carbon-based returns need to be considered in comparison to other land use returns. For places where other land uses are biophysically feasible, considering carbon returns (and later liabilities) for a forest remote from log markets may not be sufficient for the land to remain as or be converted to forestry. For example, horticultural returns are approximately $10,000-$15,000 per hectare and dairy farming returns approximately $5,000-$8,000 per hectare. These values significantly exceed annual carbon returns from planted trees and do not attract a liability every 28-30 years until such time as the emissions from all land uses are accounted for in New Zealand's annual carbon budget.

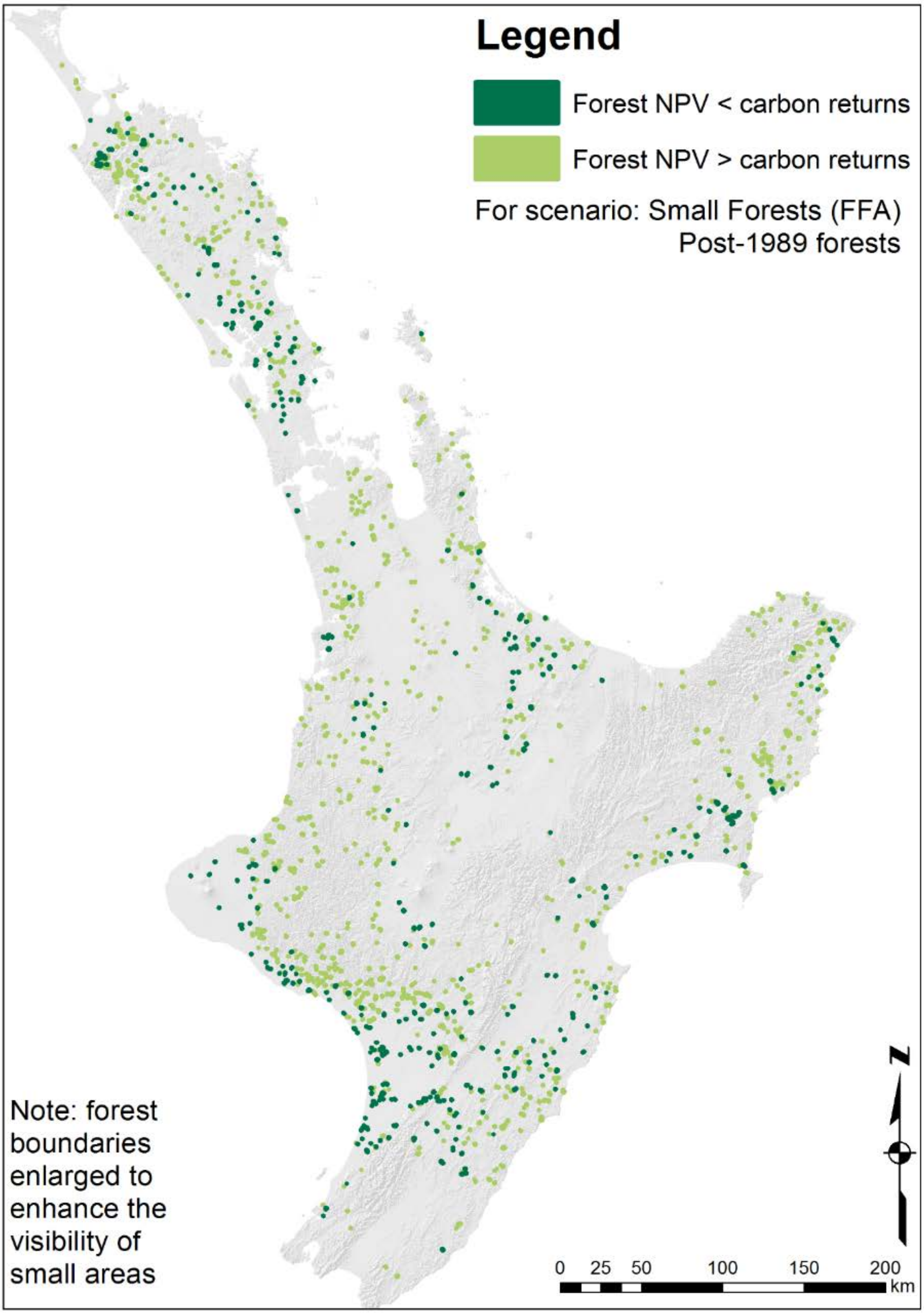


Figure 6: Example of discounted carbon returns exceeding forest NPV (for carbon at $15)

Pruned regime

A pruned regime did not necessarily result in higher returns – in most cases the harvest intentions classification remains unchanged. The comparison between a structural regime and a pruned regime is shown in Table 14 and Figure 7. Where economic returns changed for forests, this resulted in more forests showing lower returns at the prices modelled, as lower final stocking rates result in lower harvested log volumes.

Table 14: Comparison between a structural and a pruned regime for an example FIF scenario ('North Island small forests – NZFFA database')

FIF scenario: small forests – NZFFA	Harvest likelihood pruned regime (ha)						
Harvest likelihood structural regime	**Highly un-likely**	**Un-likely**	**Fairly un-likely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
Highly unlikely	***1,794***				***4***		***1,799***
Pre-1990 Forest	657				4		661
Post-1989 Forest	1,138						1,138
Unlikely	***68***	***6***					***74***
Pre-1990 Forest	25	4					29
Post-1989 Forest	43	2					45
Fairly unlikely	***52***	***2***	***16***				***70***
Pre-1990 Forest	29	2					31
Post-1989 Forest	23		16				39
Fairly likely	***62***	***41***	***7***	***7***	***32***	***31***	***182***
Pre-1990 Forest	36	39	7	2	32	4	120
Post-1989 Forest	26	2		5		27	61
Likely	***165***	***156***	***36***	***124***	***1,865***	***172***	***2,518***
Pre-1990 Forest	91	56	26	60	1,083	31	1,348
Post-1989 Forest	74	100	10	65	782	140	1,170
Highly likely	***51***				***1,162***	***22,924***	***24,136***
Pre-1990 Forest	14				574	6,932	7,520
Post-1989 Forest	37				587	15,992	16,615
Total	**2,191**	**206**	**60**	**132**	**3,063**	**23,127**	**28,778**

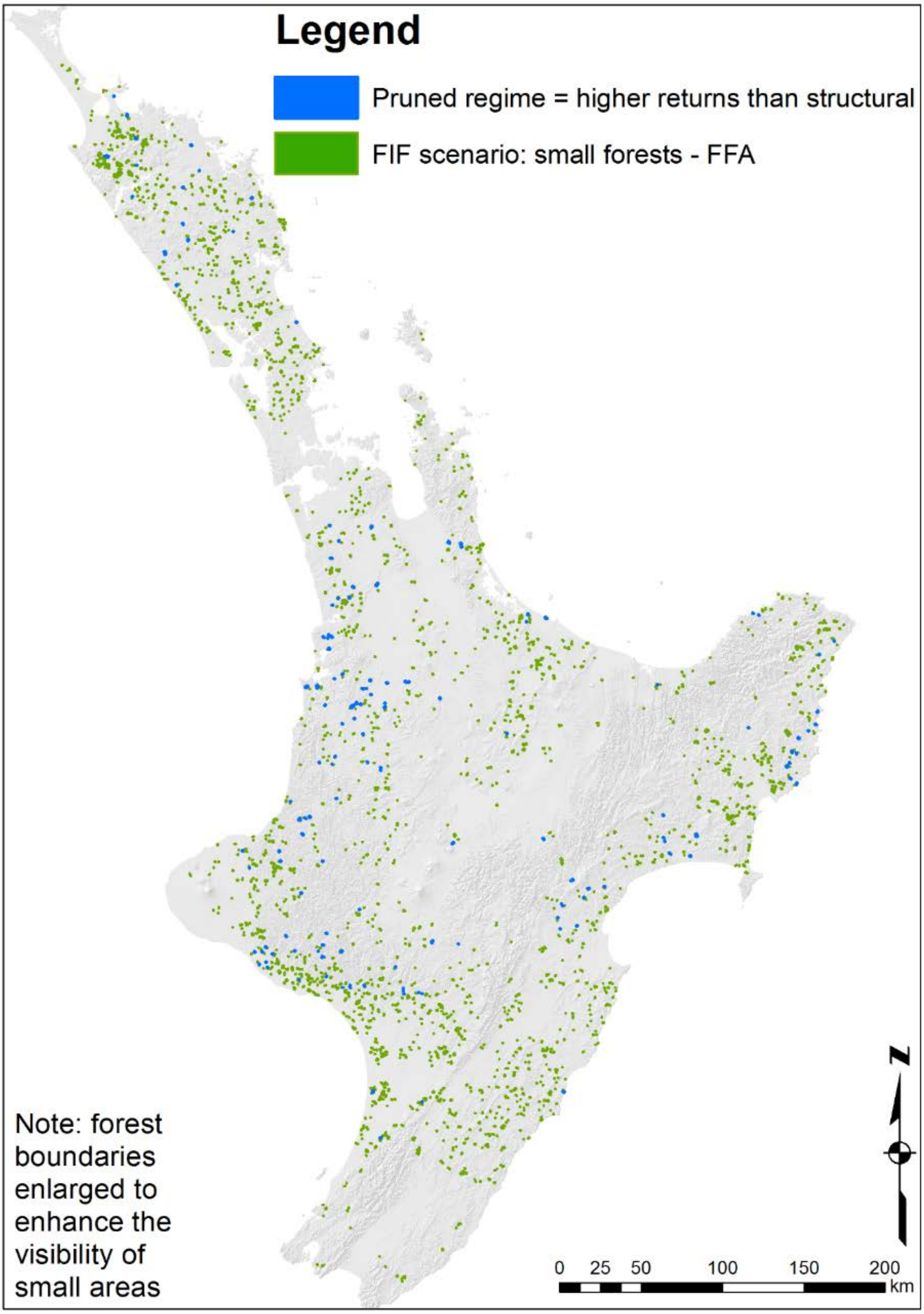


Figure 7: Example difference between a structural and a pruned regime

Log prices

A 5% or 10% increase in log price increases the percentage of forest that becomes economic to harvest by 2.1% and 3.4% respectively. Conversely, a 5% or 10% decrease in log prices decreases the percentage of forest that becomes uneconomic to harvest by 3.8% and 10.3% respectively. Note that the percentage change of forest economic to harvest is not the same for increasing versus decreasing log price. The results of these two positive and two negative variations in log prices are shown in Table 15 and Figure 8.

Table 15: Effects of log price variations for an example FIF scenario ('North Island small forests – NZFFA database')

(a) Log price increase 5%

Harvest likelihood at base price	Harvest likelihood at changed price (ha)						
	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	highly likely	Total
Highly unlikely	**1,954**	**125**	**33**	**119**	**266**	**56**	**2,553**
Pre-1990 Forest	718	94	17	54	87	2	972
Post-1989 Forest	1,235	31	17	65	179	54	1,581
Unlikely		**2**	**2**	**47**	**107**		**158**
Pre-1990 Forest		2	2	33	42		79
Post-1989 Forest				14	65		79
Fairly unlikely			**15**	**3**	**18**		**36**
Pre-1990 Forest			7	3	14		24
Post-1989 Forest			7		4		11
Fairly likely				**3**	**158**	**41**	**202**
Pre-1990 Forest					87	21	108
Post-1989 Forest				3	71	20	94
Likely					**1,808**	**1,498**	**3,305**
Pre-1990 Forest					1,046	645	1,691
Post-1989 Forest					762	853	1,615
Highly likely						**22,524**	**22,524**
Forest–Pre-1990						6,835	6,835
Post-1989 Forest						15,689	15,689
Total	**1,954**	**127**	**50**	**172**	**2,357**	**24,118**	**28,778**

(b) Log price increase 10%

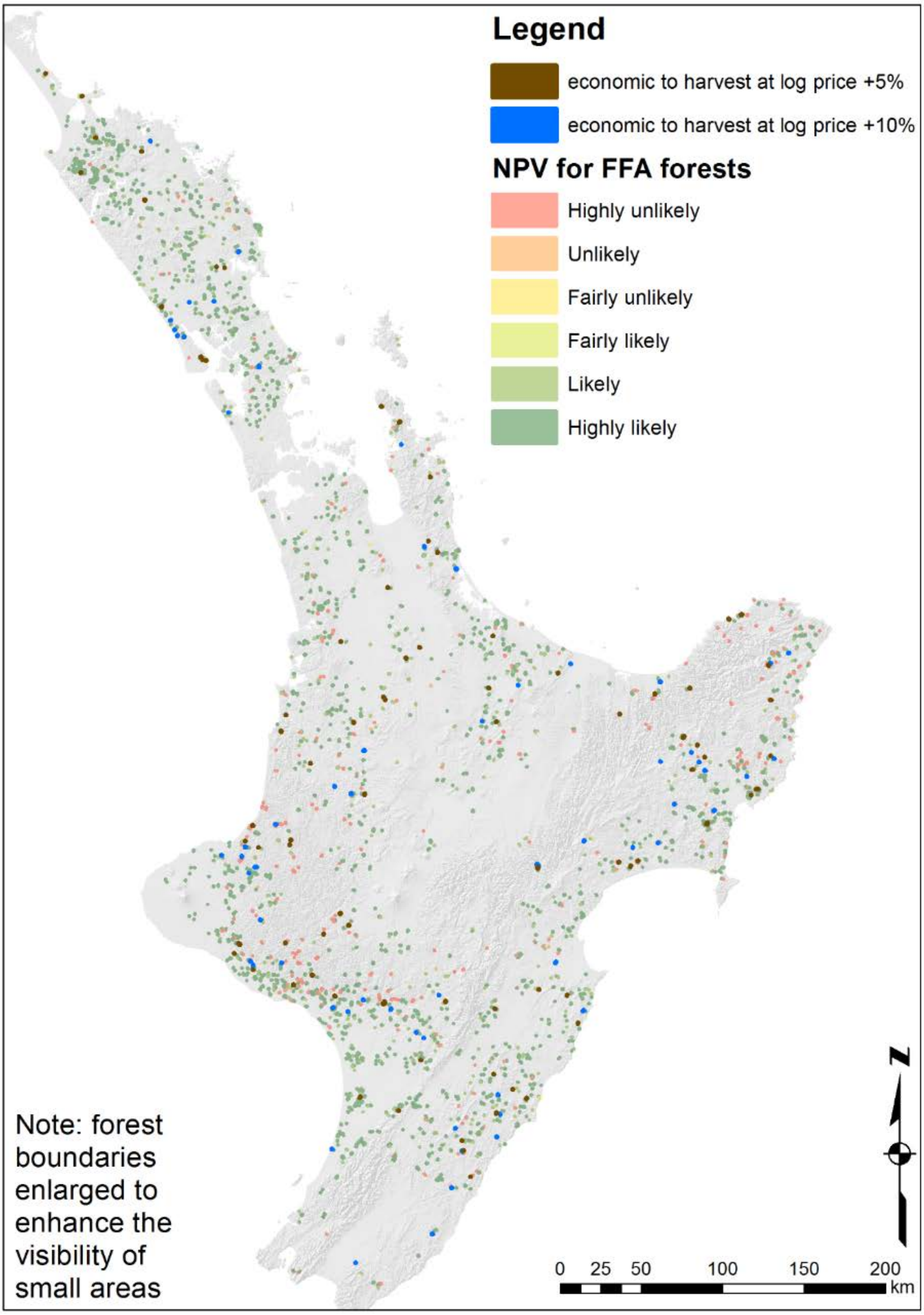
Harvest likelihood at base price	Harvest likelihood at changed price (ha)						
	Highly unlikely	Un-likely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
Highly unlikely	**1,626**	**122**	**2**	**111**	**497**	**195**	**2,553**
Pre-1990 Forest	559	93	2	55	225	38	972
Post-1989 Forest	1,066	29		55	272	158	1,581
Unlikely				**4**	**120**	**34**	**158**
Pre-1990 Forest				4	75		79
Post-1989 Forest					45	34	79
Fairly unlikely			**7**	**7**	**21**		**36**
Pre-1990 Forest				7	17		24
Post-1989 Forest			7		4		11
Fairly likely				**3**	**142**	**57**	**202**
Pre-1990 Forest					71	36	108
Post-1989 Forest				3	71	20	94
Likely					**1,008**	**2,297**	**3,305**
Pre-1990 Forest					665	1,026	1,691
Post-1989 Forest					344	1,271	1,615
Highly likely						**22,524**	**22,524**
Pre-1990 Forest						6,835	6,835
Post-1989 Forest						15,689	15,689
Total	**1,626**	**122**	**9**	**126**	**1,789**	**25,107**	**28,778**

(c) Log price decrease 5%

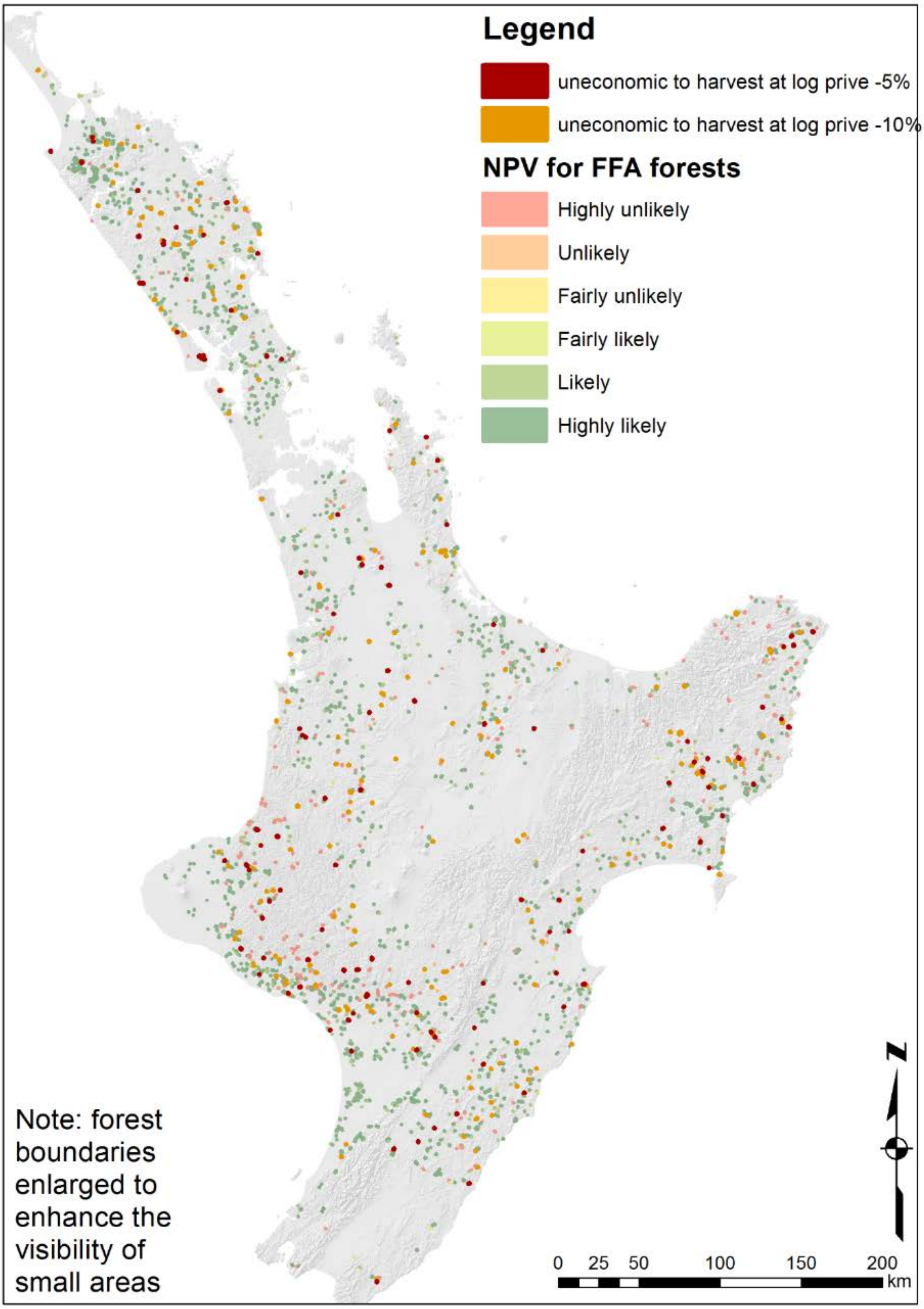
Harvest likelihood at base price	Harvest likelihood at changed price (ha)						
	Highly unlikely	Un-likely	Fairly unlikely	Fairly likely	Like-ly	Highly likely	Total
Highly unlikely	**2,553**						**2,553**
Pre-1990 Forest	972						972
Post-1989 Forest	1,581						1,581
Unlikely	**149**	**9**					**158**
Pre-1990 Forest	79						79
Post-1989 Forest	70	9					79
Fairly unlikely	**21**	**7**	**7**				**36**
Pre-1990 Forest	17	7					24
Post-1989 Forest	4		7				11
Fairly likely	**139**	**55**	**2**	**6**			**202**
Pre-1990 Forest	70	33	2	2			108
Post-1989 Forest	69	22		3			94
Likely	**596**	**190**	**19**	**335**	**2,165**		**3,305**
Pre-1990 Forest	139	97	7	156	1,292		1,691
Post-1989 Forest	457	93	12	179	873		1,615
Highly likely	**98**				**1,632**	**20,794**	**22,524**
Pre-1990 Forest					681	6,153	6,835
Post-1989 Forest	98				950	14,641	15,689
Total	**3,556**	**262**	**29**	**341**	**3,797**	**20,794**	**28,778**

(d) Log price decrease 10%

Harvest likelihood at base price	Harvest likelihood at changed price (ha)						
	Highly unlikely	Un-likely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
Highly unlikely	**2,553**						**2,553**
Pre-1990 Forest	972						972
Post-1989 Forest	1,581						1,581
Unlikely	**158**						**158**
Pre-1990 Forest	79						79
Post-1989 Forest	79						79
Fairly unlikely	**21**	**7**	**7**				**36**
Pre-1990 Forest	17	7					24
Post-1989 Forest	4		7				11
Fairly likely	**194**	**2**		**6**			**202**
Pre-1990 Forest	103	2		2			108
Post-1989 Forest	91			3			94
Likely	**1,421**	**343**	**87**	**255**	**1,199**		**3,305**
Pre-1990 Forest	515	204	24	144	805		1,691
Post-1989 Forest	906	140	63	111	394		1,615
Highly likely	**826**	**60**	**35**	**91**	**3,522**	**17,990**	**22,524**
Pre-1990 Forest	190		4	23	1,520	5,099	6,835
Post-1989 Forest	637	60	32	68	2,002	12,891	15,689
Total	**5,174**	**412**	**130**	**351**	**4,721**	**17,990**	**28,778**



(a) Increasing log price (+5%, +10%)



(b) Decreasing log price (-5%, -10%)

Figure 8: An example of forests becoming economic or uneconomic to harvest as a result of changes in log prices

Rotation age and other economic influences

Investigating increased log-prices also simulates harvesting older trees, for example, when the forest managers decides to wait until market conditions are more favourable in regard to the log prices. However, there may be costs associated with this approach. Harvesting older trees, e.g. at age 34, also means the logs will be larger. While this may be desirable in slower growing areas, larger log sizes also raise the cost of harvesting. The increased costs can mitigate the increased returns, hence we expect stands of older trees to not differ much in total returns.

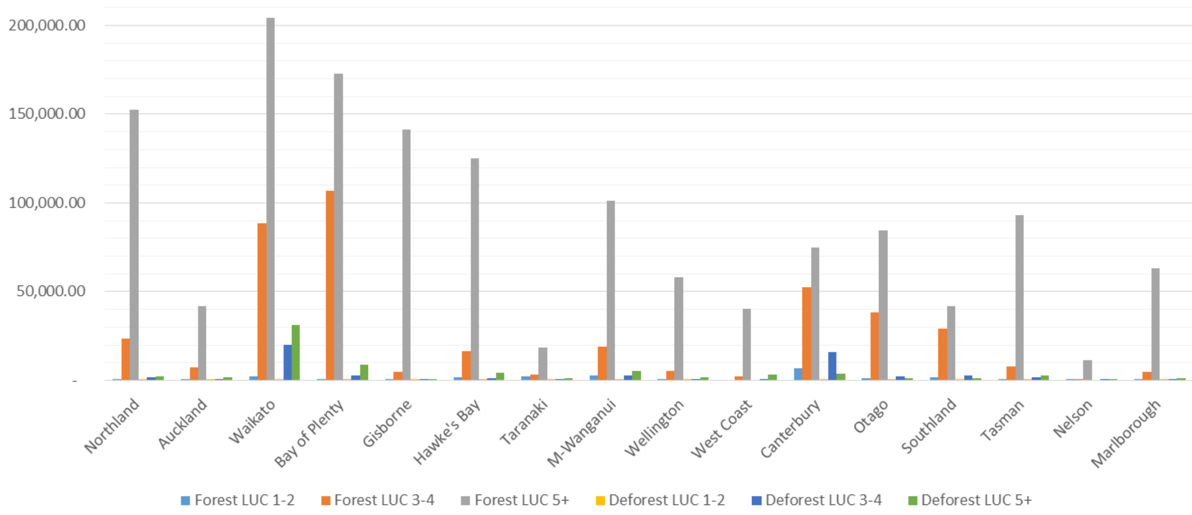
Price fluctuations such as changes in diesel prices affect the harvest economics of forests, particularly those remote from markets. The effects are similar to log price fluctuations albeit inversely related to returns (increased log prices increase forest returns, while increased fuel prices lower the returns).

The modelling in this report is based on radiata pine. This approach is likely to underestimate the returns from other species that have a longer rotation but also attract a higher log price.

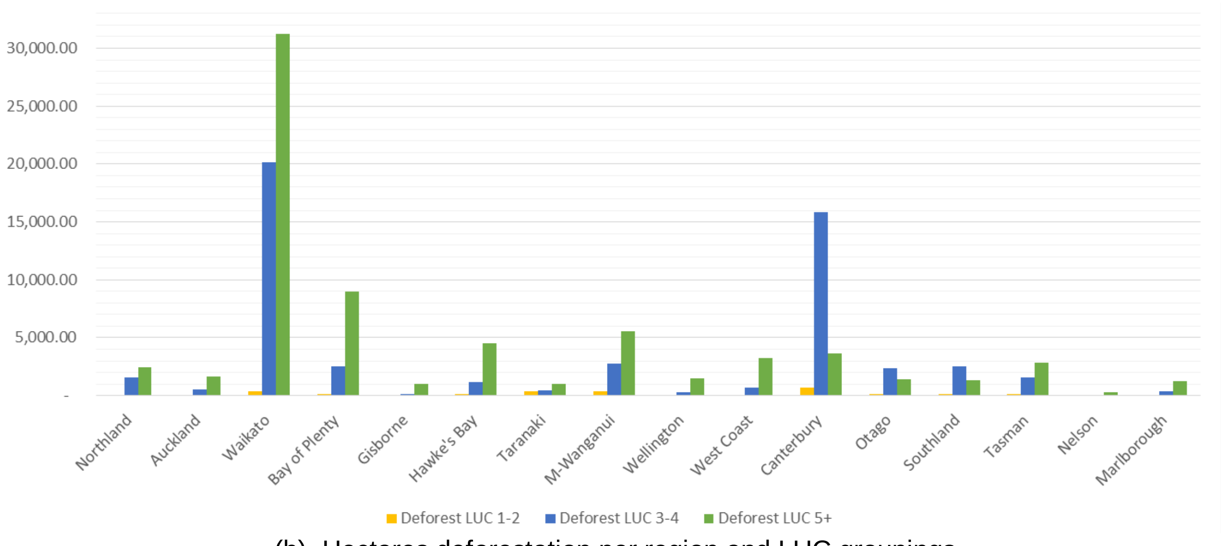
OBJECTIVE 2: Deforestation modelling

Data summary for modelling deforestation intentions

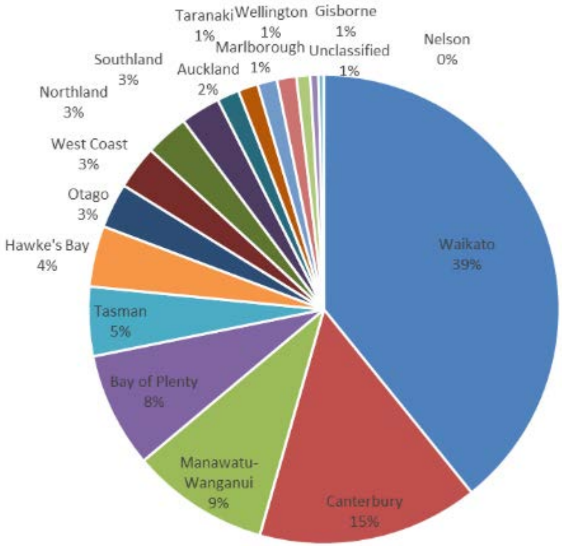
The distribution of deforestation areas in terms of hectares per region (total of 136,086 ha), and proportion by region, are presented in Figure 9a, b and c. More than half of all deforestation (54%) occurred in the Waikato and Canterbury regions according to LUM and LCDB data.



(a) Hectares forest per region and LUC groupings



(b) Hectares deforestation per region and LUC groupings



(c) Contribution of each region to total deforestation (LCDB and LUM datasets)

Figure 9: Amount of deforestation by regions and LUC groupings, with (a) forest and deforestation areas compared, (b) deforestation data in hectares, and (c) regional deforestation as percentage of the total deforestation modelled
(Deforestation derived from LCDB and LUM datasets, based on presence of exotic forest or harvested land use/land cover followed by its absence as recorded in the years 1996, 2001, 2008 and 2012 for LCDB, and 1990, 2008 or 2012 for LUM)

Example maps of the data layers used in the regression analysis (Table 9) are given in Appendix D.

Modelling results for areas of deforestation

There were 39,636 deforestation observations included in the econometric analysis. Statistics on the collected and compiled data are given in Appendix E (Table E.1).

The significant relationships from econometric regression for six econometric models for the modelled data descriptors, significant variables and their coefficient estimates are summarised in Table 16. The detailed results underpinning these conclusions are in Appendix E (Table E.2).

Table 16: Summary of the significant variables for the deforestation intentions modelling, for the regression on the area (size) of deforestation

Contributing variable	**Variable name (Appendix E)**	**Relationship to base is positive (+) or negative (–)**	**Interpretation**
Biophysical			
Rainfall	AveAnnRain3 AveAnnRain4	- for 800–1600mm - for > 1600mm	When controlling for other factors, deforestation area would likely be smaller in higher rainfall areas.
Temperature	AveAnnTemp2	+ for > 7.9°C	The size of a deforested area would likely be larger in an area suited to radiata than in an area with slow growth.
Elevation	Nz_dem_cla2 Nz_dem_cla3 Nz_dem_cla4 Nz_dem_cla5 Nz_dem_cla6	+ for 200–400m + for 400–600m + for 600–750m + for 750–950m + for > 950m	The area of deforestation would likely increase with elevation
Slope	Nz_slope_c2 Nz_slope_c3 Nz_slope_c4	– for 7–20° – for 20–35° – for > 35°	The size of a deforested area would likely be smaller in an area with a steeper slope i.e. >7°.
Governance related			
Region	Southis2	– for N.I.	Larger deforested areas are more likely in the North Island
Ownership	Māoriland2	+ for Māori land for > 40 ha	The size of large deforested areas is more significant for Māori lands
Constrained catchments	Catchment2	+ for outside these catchments	The size of deforested areas would likely be more outside of the constrained catchments
Competing LU			
LUC	LUCclass2	For > 40 ha: + for LUC 3&4 + for LUC 5–7	For the >40ha areas, deforestation would likely be larger for higher LUCs
Pasture potential	Lri3 Lri4	– for CCAV 8–12 and area > 1 ha – for CCAV 12–16 (all models)	There is some significance in the inverse relationship between moderate pasture productivity and the size of deforestation
Irrigation potential	River2	(Not significant)	Proximity to large rivers (irrigation potential) is not significant for deforestation
GDD	AnnGDD2	– for GDD > 2700 (suitable for hort)	The size of a deforested area would likely be smaller where land is suitable for horticulture. This may be influenced by there not being much forestry on

			higher producing lands such as LUC1&2
Proximity to dairy LU	DairyProx2	+ for > 10 km away	The size of a deforested area would likely be larger further away from dairy compared to locations < 10 km away
Proximity to high producing / horticulture	Hort2	– for > 10 km away	The size of a deforested area would likely be smaller further away from intensive land use, i.e. likely larger deforestation closer to high production land
Infrastructure			
Road density	Lineden9km2 Lineden9km3 Lineden15km2 Lineden15km3	+ for almost all models for medium (2) and high (3) density of roads per 9 km^2 or 15 km^2	The higher the road density, the larger the size that a deforested area is likely to be
Built density	Built9km2 Built15km2	– for some models re higher urban density per 9 km^2 or 15 km^2	The size of a deforested area would likely be smaller further away from built areas, i.e. likely larger deforestation closer to built areas
Proximity to urban	UrbanProx2	+ for > 40 ha deforest that's > 30 km away	Larger areas would be more likely harvested further from urban centres
Proximity to dairy/meat works	MeatDairyP2 MeatDairyP3	Not significant	Proximity to dairy/meat infrastructure is not significant for deforestation
Forestry related			
Distance to market	PathDis_cl2 PathDis_cl3	Not significant	Distance to market is not significant for deforestation
Distance from roads	Road1km2	– for > 1 km	The size of a deforested area would likely be smaller further away from existing roads, i.e. likely larger deforestation within 1 km roads
FIF impedance surface	Impedance2 Impedance3	Not significant – for high impedance index	The size of a deforested area would likely be smaller for highest impedance values, potentially reflecting the higher cost of harvesting these areas
% de-forestation	Propdef2	+ for high %	The larger the size that a deforested area is, the higher the % of a property that is affected. E.g. a larger proportion of a property may become available for other LU when deforested
Societal			
Predominant income	CwardMedIn3 CwardMedIn4 CwardMedIn5 CwardMedIn6	– for \$50–60k (> 1 ha) – for \$60–70k (> 1 ha) Not sign \$70–80k – for > \$80k	Indications of negative relationship are present (the higher the income, the smaller the deforestation areas) BUT not consistently significant
Predominant age	CWardAgeCL~2 CWardAgeCL~2	+ for age 40–60 + for age 60+	The area of deforestation would likely increase with age
Property size	Cadastral2 Cadastral3 Cadastral4	+ for 10–40 ha + for 40–100 ha + for > 100 ha	The area of deforestation would likely increase with property size

Coastal proximity	Coastline2	For > 5 km away: – for base model + for > 40 ha deforest	Mixed results: without area constraints there is a negative relationship, and for deforestation > 40 ha the relationship is positive

*Regression results for **Māori** land*

The regression support for the results based on the correlation matrix was calculated for the Māori land variable, as an example correlation calculation. The correlation matrix for Māori land ownership was computed for three assessments: all observations, censoring of areas with less than one hectare (i.e. exclusion from the correlation matrix calculation), and for only observations where the Māori land exceeds 40 ha in size (to explore correlations specific to larger forest areas). The correlation matrices (Appendix E, Tables D.3-D.5) show

- Only 428 (1%) of the 39,626 deforestation observations represent Māori lands. The average area for Māori deforestation is about 6.5 ha, which is twice the average of non-Māori-land. In other words, deforestation on Māori land occurred on more homogenous land (larger areas of the same characteristics) than for non-Māori lands which were more diversely characterised (areas with the same characteristics were smaller). Of note is that a larger proportion (72%) of Māori land is characterised as LUC 5 to 7[5] compared to 54% for non-Māori land.
- LUC 5 to 7 is significantly positively associated with the Māori lands, while LUC 1&2 and LUC 3&4 are significantly negatively associated, based on the correlation analysis for the full sample of deforested areas. The correlation coefficients (Appendix E) increase as areas less than one hectare and 40 hectares are filtered out. This indicates that the larger the deforested area, the greater the proportion of LUC 5 to 7 for Māori land. In fact, the data indicate that all Māori land areas that are at least 40 hectares in size belong to LUC 5 to 7.
- Although the large majority of Māori lands are in the non-arable areas, they are also significantly positively associated with water quality restrictions. However, the magnitude of the positive correlation is small (7%).

[5] LUC classifies land according to productive potential. LUC 1&2 indicate arable lands that are regarded as the most productive among the land classes. LUC 3&4 are less productive than 1&2 but are still usable as pastoral land, e.g. for dry stock production. LUC 5 to 7 are regarded as non-arable while still having degrees of productivity under, for example, trees. LUC 8 is considered not usable for production uses.

Modelling results for deforestation against not-deforested

The descriptors of the data observations are listed in Tables F.1 and F.2 in Appendix F, and represented in Figure 10.

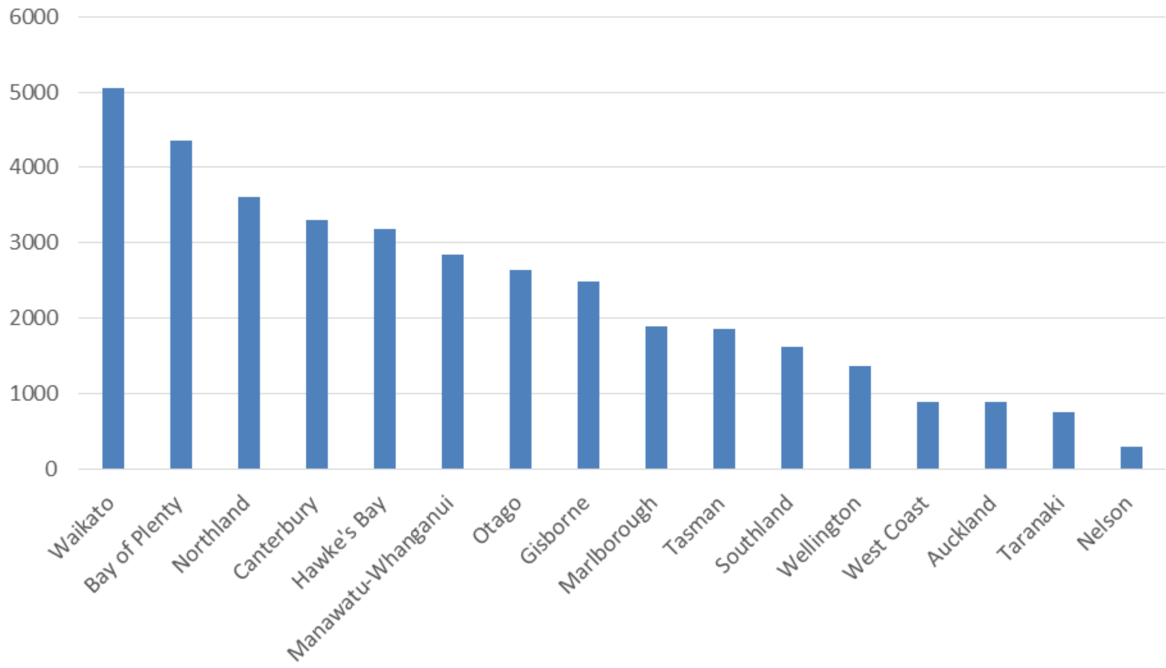


Figure 10: Number of forest/deforest observations per region

Four models were tested for the regression analysis (Appendix F, Table F.3), labelled 1-4.

For Models 1 (linear form of the area) and 2 (area in log form), the explanatory power of the model increases when the log of the area is used as independent variable as indicated by the higher R^2 and F values. Nevertheless, as this is a model of a binary dependent variable, the estimated coefficients from Models 1 and 2 may be biased as OLS does not support the probabilistic nature of the dependent variable (Wooldridge 2010). The limited dependent variable Probit and Logit models (Models 3 and 4) were used with corrected standard errors to address the issue of heteroscedasticity detected in Models 1 and 2.

Measures of model goodness of fit suggest that Models 3 and 4 provide a significant improvement in model goodness of fit. Model 4 (Logit model) has the highest pseudo R^2, indicating that it provides the highest explanatory power, making the best use of the data for predicting the probability of deforestation for each forest observation.

The estimates from Model 4 can be used to explain the different factors that influence the probability of deforestation. A negative coefficient indicates that a marginal increase in that variable would result to a reduction in the likelihood of deforestation. However, as the Logit model is a highly non-linear regression model, interpreting the coefficient estimates is not straightforward. To address this issue, we calculated for the marginal effects value (dy/dx), which can be interpreted as linear effects on the probability of a successful outcome. For example, the third-to-last column of Table F.3 (Appendix F) shows a dy/dx value of -0.047 for log(area). This indicates that a one percent increase in the area of forest (while controlling for the effects of other variables in the regression) would contribute to an approximately five percent reduction in the probability of deforestation. This is statistically significant at the 99.9% confidence level (p-value < 0.001). The significantly positive sign for the log of area squared suggests a quadratic effect wherein the reduction in probability of deforestation flattens at some point of forest area increase and then would likely marginally increase as forest area further increase.

The significant relationships from econometric regression for the modelled data descriptors, significant variables and their coefficient estimates are summarised in Table 17. The detailed results underpinning these conclusions are in Appendix F (Table F.3).

Table 17: Summary of the significant variables for the deforestation probability modelling

Contributing variable	Variable name (Appendix F)	Relationship to base is positive (+) or negative (–)	Interpretation
Biophysical			
Rainfall	AveAnnRain3 AveAnnRain4	+ for all	Increased deforestation occurs as rainfall levels are higher
Temperature	AveAnnTemp2	+ for > 7.9°C	
Elevation	Nz_dem_cla2 Nz_dem_cla3 Nz_dem_cla4 Nz_dem_cla5 Nz_dem_cla6	Not significant Not significant Not significant + for 750–950m + for > 950m	Deforestation is higher at higher elevations; this is likely to have been influenced by the land conversions near Taupo
Slope	Nz_slope_c2 Nz_slope_c3 Nz_slope_c4	– for 7–20° – for 20–35° – for > 35°	Monotonic decrease in deforestation with increasing slope – more deforestation at lower slopes
Governance related			
Region	Southis2	– for N.I.	
Ownership	Māoriland2	– for Māori land	Less deforestation for Māori owned lands – though this may change as Māori have more ability to determine the land new uses of their land
Constrained catchments	Catchment2	+ for inside these catchments	This indicates more deforestation within the constrained catchments – potentially indicative of land use conversions before constraints.
Competing LU			
LUC	LUCclass2	Not significant	-
Pasture potential	Lri2-5 CCAV	+ for all	The better the pasture productivity, the more likely that there is deforestation, with this being twice as likely for the highest productivity (Lri5-CCAV) than other pasture classes
Irrigation potential	River2	Not significant	-
GDD	AnnGDD2	– related; increased GDD areas have less deforestation	May be function of highest GDD areas already being in horticulture e.g. kiwi fruit areas
Proximity to dairy LU	DairyProx2	- for > 10 km away	The closer to dairy land use, the more deforestation is likely
Proximity to high producing / horticulture	Hort2	Not significant	-

Infrastructure			
Road density	Lineden9km2 Lineden9km3 Lineden15km2 Lineden15km3	+ for almost all models for medium (2) and high (3) density of roads per 9 km^2 or 15 km^2	The higher the roading density, the more deforestation has happened
Built density	Built9km2 Built15km2	+ for all	The more built environment present, the more deforestation has happened
Proximity to urban	UrbanProx2	Not significant	-
Proximity to dairy/meat works	MeatDairyP2 MeatDairyP3	Not significant	Land use conversion are not constrained to close proximity to dairy/meat infrastructure
Forestry related			
Distance to market	PathDis_cl3	+ for further from market	More deforestation likely the further from log markets; given transport distances factor in profitability, further from market means lower profits
Distance from roads	Road1km2	+ for further from road	The further from existing roads, the lower the deforestation = proximity to roads leads to pressure to develop, or may be a function that roads often follow valleys
FIF impedance surface	Impedance2 Impedance3	+ for higher impedance	The more difficult to harvesting, the more deforestation has happened – this is contradictory to, for example, the pasture productivity results. The averaging to 500m resolution may have lost necessary detail for this layer.
Area of forest / deforest	Area	– for smallest areas, plateaus, then +for largest areas	Area related in a quadratic effect
Societal			
Predominant income	CwardMedIn2 CwardMedIn4	+ for up to \$70k – for > \$70k	Deforestation is more in lower income areas (potentially other land uses are desirable to raise income levels), and less in higher income areas
Predominant age	CWardAgeCL~2 CWardAgeCL~2	+ for age 40–60 – for age 60+	More deforestation at middle age – more active in developing land uses; less deforestation in the older age group – less active in conversion, potentially retirement focused
Property size	Cadastral2 Cadastral3 Cadastral4	+ for 10–40 ha (significant)	Small deforestation are significant contributors in regard to deforestation
Coastal proximity	Coastline2	+ for further from coast	More deforestation has happened >5km from coast

Forests on steeper slopes are less likely to be deforested compared to gently sloping areas. The dy/dx estimates for the higher slope classes are significantly negative compared to the base slope class 1. This indicates that slope matters and the probability of deforestation seems to monotonically decrease with slope. A forest located on slope class level of approximately four percent is less likely to be deforested compared to a forest on a flatter area.

Forest on Māori land (two percent of the sample) is less likely to be deforested compared to forest on non-Māori land.

The probability of deforestation varies across regions, with forests located in the Waikato, Canterbury, West Coast, Taranaki and Manawatu-Whanganui, having, on average, higher chances of being deforested compared to other regions. Figure 11 shows the average probability across regions, with Gisborne and Marlborough showing the lowest average probabilities.

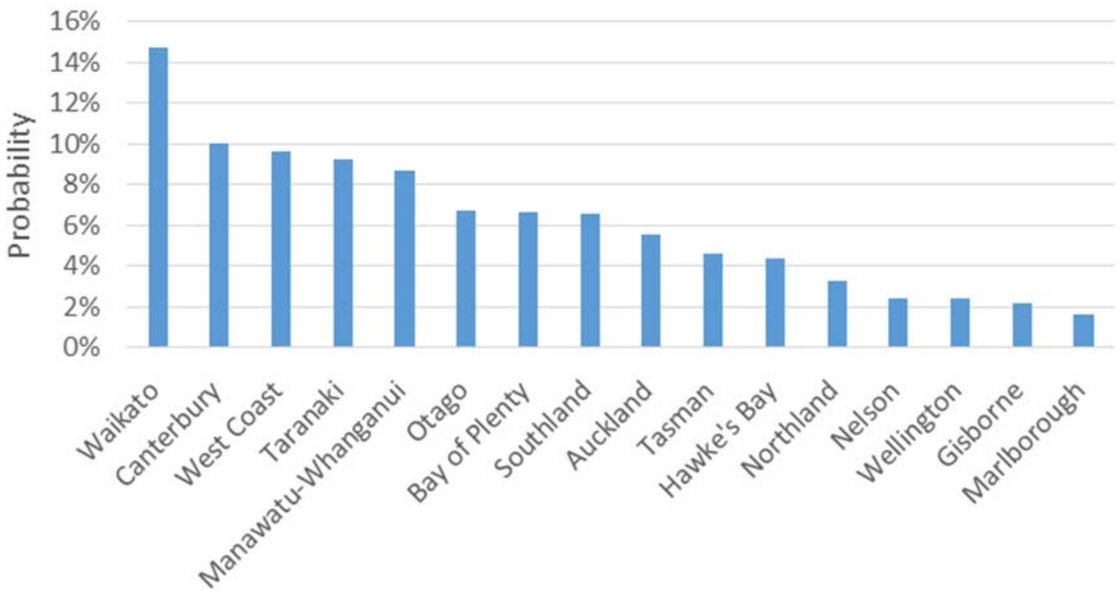
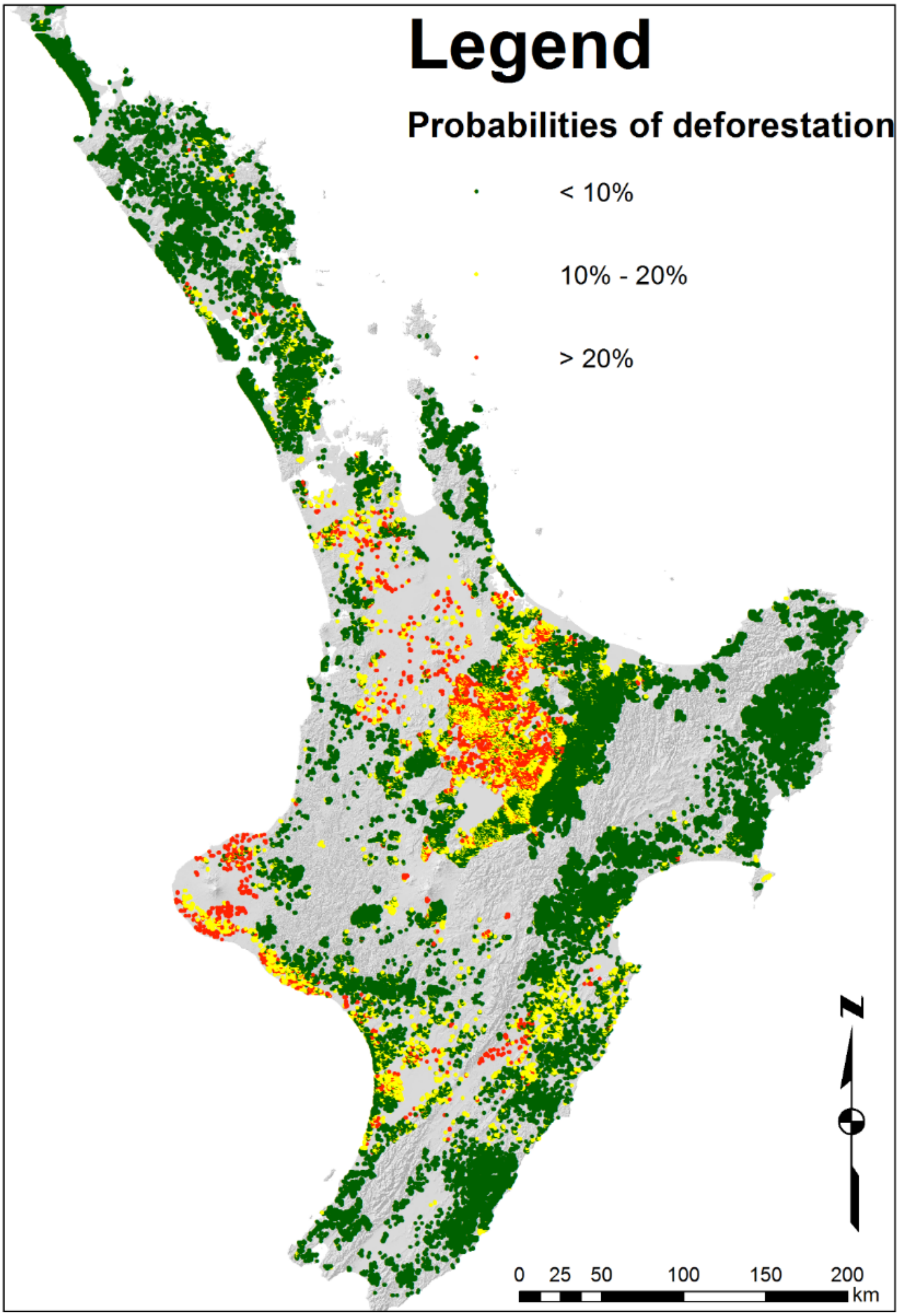
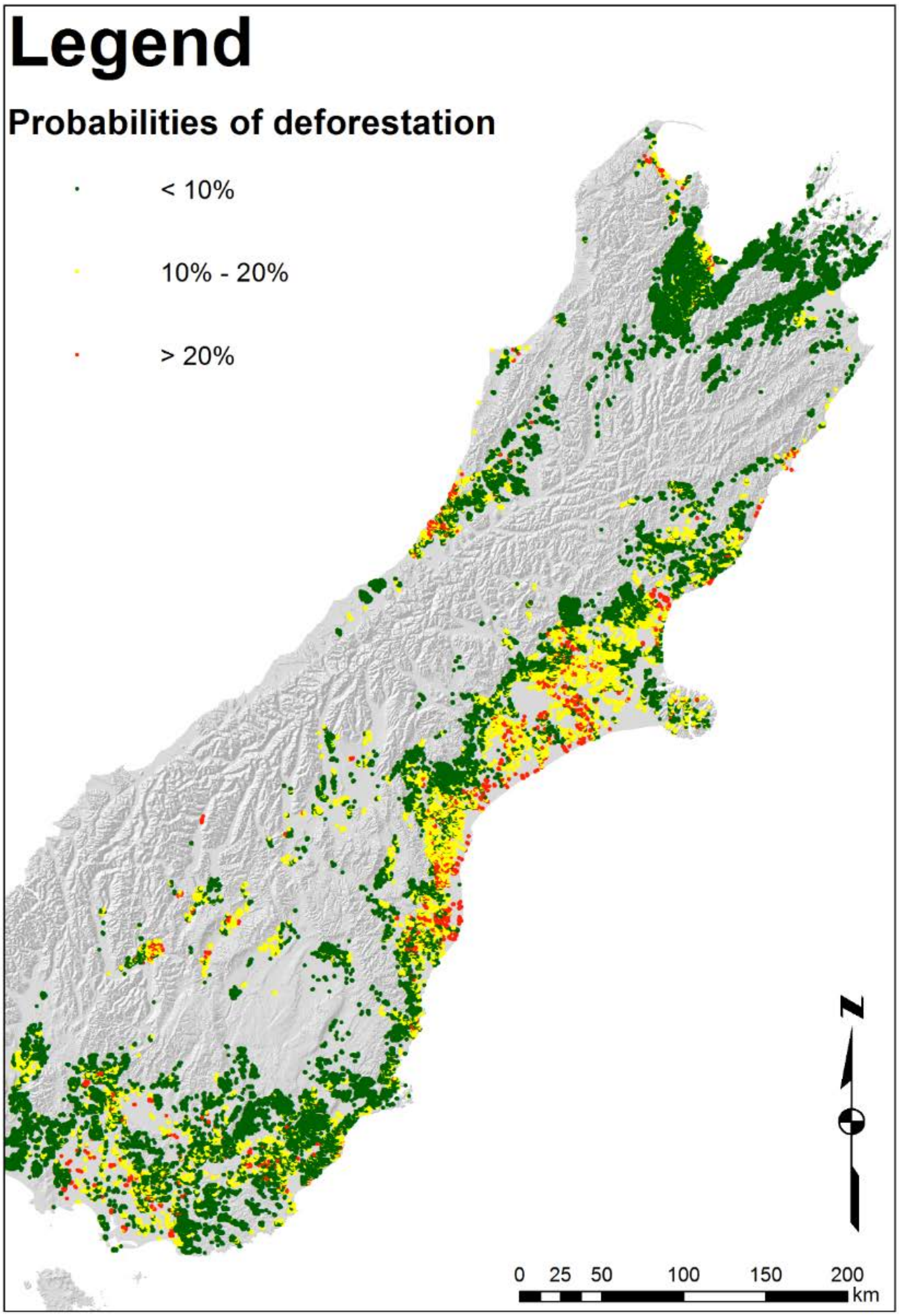


Figure 11: Average probability of deforestation by region

The probability of deforestation was calculated for each observation after running Model 4. We have classified the sample of forest observations based on three deforestation probability ranges: (1) 0 to 10%; (2) 11% to 20%; and (3) 21% and above. Figure 12 shows the deforestation probabilities for New Zealand forest sites.



(a) Probabilities for deforestation – North Island



(b) Probabilities for deforestation – South Island

Figure 12: Probability of deforestation for forest areas

Rural decision makers whose land includes forestry

The survey findings most relevant to harvesting intentions and deforestation intentions were from the set of forestry practice questions and the set of future planning questions. The three relevant questions from the forestry practice questions were:

- Do you intend to harvest your forest in the next 2 years?
- What percentage do you intend to harvest?
- Do you intend to replant after harvesting?

The responses as percentages are shown in Figure 13. Responses for 5 regions indicated intentions to replant in full (Waikato, Tasman/Nelson, Canterbury, Otago and Southland). In comparison, responses for Auckland, Wellington, Marlborough and the West Coast indicated half or fewer intended to replant. These results show regional variations to the findings from MPI's recent survey on owners of small forests harvest and planting intentions (James Mcdevitt via Colmar Brunton) who were asked about intentions of harvesting within the next 3 years, and subsequent replanting intentions. The MPI survey results suggested a 70% replanting rate, while the rural decision makers' survey results show both higher (9 regions) and lower (4 regions) replanting rates (responses from 2 regions are close to MPI's 70% replant rate). A simple average of the regional returns indicates a national average replant rate of 77%. It is worth noting that those who did not indicate replanting, i.e. the converse of those who indicated they would replant, may not necessarily be intending to deforest. For example, land that has not been replanted in a plantation tress may remain as a forest through conversion or reversion to native trees.

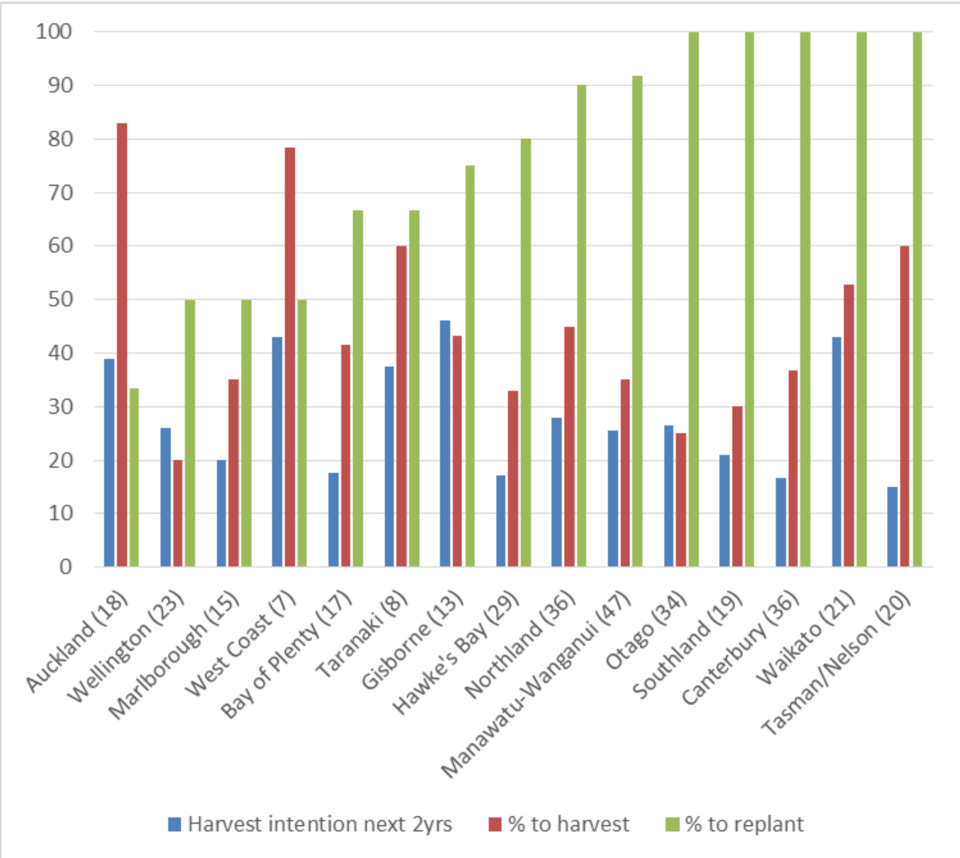


Figure 13: National responses regarding harvesting and replanting, ordered by replant intentions. (The number of responses per region are shown in the brackets after the region names.)

A further set of questions about future planning asked about intentions to convert land and plans to increase, reduce or intensify land use. There were insufficient responses from the forest-based decision makers to summarise at the regional level. The overall figures were:

- 167 out of 1989 (8.4%) respondents report that it is "very likely" that they will convert land in the next 2 years. Of these, 12 (7.2%) plan to convert land to forestry.
- 40 out of 349 (11.5%) respondents with existing forestry report that it is "very likely" that they will add land to existing land uses in the next 2 years. Of these, 11 (27.5%) plan to add land to existing forestry.
- 54 out of 349 (15.5%) respondents with existing forestry report that it is "very likely" that they will intensify existing land uses in the next 2 years. Of these, 4 (7.4%) plan to intensify forestry.

The average age of the forest-based decision makers in the survey was 57.3 with regional variations given in Table G.1 (Appendix G). The age profile indicates the potential for the farm forests to be important for inter-generational farm planning, whereby older owners are provided with capital for e.g. handing down the property or paying out siblings. In other words, older owners may have an interest in not delaying harvesting, whereas younger owners may have more long term interests and may wait for favourable log prices.

Recommendations and Conclusions

The research demonstrated that national spatial datasets play a useful role in the prediction of harvesting and deforestation of radiata pine forest blocks. Despite the limitations of the datasets, such as a lack of accurate age class information and differences between LCDB's and LUM's national forests extents, the results can be used to inform on harvest and deforestation intentions.

Intentions to harvest

The majority of small forests (> 91%) were identified as likely to be economic to harvest by FIF modelling. Those that were identified as uneconomic to harvest are spread around remote areas across New Zealand. Access to roading and infrastructure, or the possibility of sharing costs with other and/or larger forests increases the likelihood of harvesting. FIF modelling also found that considering delivered wood costs only, or increasing log prices also increases the likelihood small forests will be harvested. Pruning regime had little effect on intention to harvest.

The relationship between carbon price and intention to harvest is complex and its effects are perhaps better considered case-by-case. This investigate only considered a simple example. Now that the forest scenarios have been developed as FIF scenarios, it is possible to run a number of carbon decision-making scenarios, which is recommended in order to more fully explore the permutations of carbon-related decisions.

The forests identified as uneconomic to harvest in this analysis can be considered to definitely be uneconomic in real life as FIF assumes forestry best practice to ensure favourable returns. In reality, such practices are not guaranteed. Further, unless there are significant changes to costs or returns – the log prices or the price of carbon credits – these forests will also be uneconomic to replant.

FIF was developed for the purpose of large area analysis such as regional analysis for which it is well suited (Yao et al, 2015). At the individual forest level, however, it has limitations. For example, the model disregards property boundaries and differences in ages between trees in a common landscape. In reality, property boundaries may restrict the location of road construction to the forests and a more costly route may need to be followed. In regard to forest age, FIF assumes close forests can share harvest road construction costs. However in reality forests near one another may be of different ages and owners of younger trees may not wish to spend money on road costs long before a harvest road is needed. Hence the roads costs may have to be carried by an individual forest, reducing its profitability. These modelling limitations also support the conclusion that the areas identified as uneconomic will definitely be so in real life.

The analysis provides regional results by pre-1990/post-1989 categories (Appendix B). These can be used towards assessing potential impacts on wood flows and for greenhouse gas projections.

As for any modelling, improved data inputs result in improved outputs. The national databases are effective at the general level; however should relatively few (at the national level) small forests be important contributors to local wood flows, more local precision is required.

A study of different scenarios is recommended, including covering the breadth of carbon-related decision making, and such analyses as wood delivery returns (no NPV). The computed FIF datasets provide the opportunity for much more assessments.

Deforestation

Key environmental, social and spatial factors likely to influence deforestation and replanting were identified using an econometric analysis. They relate to biophysical factors such as more deforestation at lower slopes, and – in competition with other land uses – that the better the pasture productivity, the more likely that there is deforestation. Deforestation is less related to Māori owned lands, instead more related to higher roading densities and more built environment present. Distance to market is important, in that more deforestation is likely the further they are from log markets; given transport distances factor in forest profitability, being further away from markets means lower profits. Significant societal include that deforestation is more in lower income areas – potentially other land uses are desirable to raise income levels.

The econometric analysis undertaken for deforestation made use of the best available spatial data on deforestation. The observations were derived by combining LCDB and LUCAS LUM datasets to provide a more exhaustive deforestation dataset than would be provided by either individually. The observations were related to a number of national datasets including cadastral, topography, productivity indices including LRI, census data and policy-related information. In assembling such diverse datasets, assumptions and caveats are naturally present, however we believe there is sufficient robust data and modelling that any issues connected to the construction of the deforestation dataset and the modelling are mitigated.

The results as presented in this report are not counter to common sense. However the deforestation analysis relies on a number of variables as they are currently and not how they may have been at the point in time when the deforestation happened. For example, changes have occurred in dairy land use hence proximity to dairy land has changed over time, also sawmills close or new ones open. LRI's LUC classification is based on impedances to productivity, however impedances can be mitigated by actions such as irrigation and fertilisation, such as for CNI and Canterbury. Policy analysis may be able to cast additional light to the way the trends and patterns have been reported here.

New Zealand's national datasets are mostly of sufficient resolution and detail for national level modelling. For example, the DEM layer is available at up to 15m resolution. For the national forest data, however, there are known mismatches between the National Exotic Forest Description (NEFD) and remote sensing based forest data (Hock et al 2015), hence the need for various commentary in the methods and discussion sections when there are mismatches in area totals based on the national spatial datasets compared to the NEFD. This supports the need for an improved national spatial NEFD, as this would allow spatial analysis and modelling such as in this research without or with less of the limitations on the modelled results. The recommendation for a national spatial exotic forest description is to capture more information than, for example, LCDB's binary distinction between exotic and native tree species. An important differentiations would be to distinguish the principle exotic plantation species of radiata pine, Douglas-fir and eucalypts from other plantings such as willows, and ideal would be to include relevant forest details such as age classes and stocking rates.

The potential effects on land values of the presence/absence of forests may be significant influences in harvesting and deforestation decisions. With the availability of land valuation data, a number of investigations are possible of potential impacts on the forest estate under different scenarios and trends in land values.

Steepland harvesting techniques are evolving – it may be worth investigating the potential effect that such changes in technology, alongside the changes in the costs of steepland harvesting, may have on the economic viability of some of the forests.

Regarding the forests indicated as positive probability for deforestation: further investigation of their individual characteristic are possible. For example, more data may be available locally; the ownership structure of the forest may be relevant to decision-making; current council requirements around land use change may influence the ability to change; local trends in markets such as sawmill closures; the inclusion of the forest within the ETS is relevant; the value of the land may influence perceived options; potentially also how they identify themselves/their farm in Agribase can indicate their focus and hence potential intentions regarding trees. Such an investigation would add more local understanding to this national-level analysis.

Spatial analytical analysis

As indicated, the spatial analysis based on national datasets contributes to information on Harvest intentions and deforestation. The analysis of this report may not have addressed all that is needed for policy development, for example, computing the permutations of carbon credit implementations, and modelling delivered wood costs for harvesting intentions (i.e. without NPV). The recommendation is that now that the FIF datasets have been developed, this analysis becomes possible. A similar approach such as was used when developing the methodology of this project, i.e. a workshop to set parameters for the analysis, may be an effective way to develop additional analyses from the spatial datasets. Other analyses possible include determining economic ‘tipping points’ such as the log prices when all forests become uneconomic to harvest, and conversely the log prices when all forests become economic to harvest.

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References

Anon (2013). About LCDB. Available from: http://www.lcdb.scinfo.org.nz/about-lcdb

Adams, T. H., & Turner, J. A. (2012). An investigation into the effects of an emissions trading scheme on forest management and land use in New Zealand. *Forest Policy and Economics, 15*, 78-90.

Barry, L. E., Yao, R. T., Paragahawewa, U. H. & Harrison, D. R. (2012). Where and how can policy encourage afforestation to avoid soil erosion? Paper presented at the New Zealand Agricultural and Resource Economics Society 2012 Conference, August 31, 2012, Nelson, New Zealand. Available online from http://ageconsearch.umn.edu/handle/136042

Barry, L. E., Yao, R. T., Harrison, D. R., Paragahawewa, U. H. & Pannell, D. J. (2014). Enhancing Ecosystem Services through Afforestation: How Policy Can Help. *Land Use Policy, 39*, 135-145.

Beets, P.N., Brandon, A.M., Goulding, C.J., Kimberley, M.O., Paul, T.S.H., & Searles, N. (2011). The inventory of carbon stock in New Zealand's post-1989 planted forest for reporting under the Kyoto protocol. Forest Ecology and Management, vol. 262, no. 6, pp. 1119–1130.

Brown P. (2015). Survey of Rural Decision Makers. Landcare Research NZ Ltd. Available from www.landcareresearch.co.nz/srdm2015. Date accessed: 16 March 2016. DOI: 10.7931/J28913S8

Chandler, N. 2016 Observations on the wood availability forecasts. *New Zealand Journal of Forestry* 61 (1) May 2016.

FOA & MPI (2014). New Zealand Plantation Forest Industry Facts and Figures. Forest Owners Association and Ministry for Primary Industries, Wellington.

Harrison, D. R., Barry, L. E., Palmer, D. J., Kimberley, M. O., Turner, J. A., Hock, B. K. & Hall, P. (2012). Developing a forest investment finder for New Zealand. *Technical Report*, Future Forest Research, Rotorua.

Hock, B. K., Blomqvist, L., Moller, B., Hall, P., Jack, M. & Wakelin, S. (2012). Understanding biofuel supply with GIS. *Journal of Spatial Sciences, 57*(2), 217-236.

Hock, B. K., Payn, T. W. & Heaphy, M. J. (2014). Issues in the reuse of spatial data for national environmental reporting on planted forests in New Zealand. *Journal of Spatial Science, 59*(2), 1-16.

Kennedy, P. (2008). *A Guide to Econometrics*. 6th edition. Blackwell Publishing, Massachusetts, U.S.A.

Manley, B.R. 2015. Deforestation Intentions Survey 2015 *Final Report MPI Technical Paper* No: 2016/13. Ministry for Primary Industries, Wellington.

Manley, B. (2011). Deforestation Survey 2011. *MAF Technical Report*, No. 2012/11, February 2011.

Manley, B., Morgenroth, J., Visser, R. & final year BForSc students of 2014. (2015). What proportion of the small-scale owners' estate in the North Island is likely to be harvested? *New Zealand Journal of Forestry, 60*(3), 26-34.

Ministry of Agriculture and Forestry (2010). New Zealand Wood availability Forecasts 2010-2040. Ministry of Agriculture and Forestry, Wellington.

Ministry for the Environment. 2016. New Zealand's Greenhouse gas Inventory 1990-2014.

MPI. (2013). *National exotic forest description as at 1 April 2013*. Ministry for Primary Industries, Wellington, 71 p.

MPI. (2015). An overview of forestry in the Emissions Trading Scheme. Accessed online on 17 June 2016 at https://www.mpi.govt.nz/document-vault/6991

MPI. (2016). National exotic forest description at 1 April 2015. Ministry for Primary Industries, Wellington, p. 78.

Park, D. (2011). Economic Wood Availability and Profitability of Small-Scale Forests in Wanganui District. http://ir.canterbury.ac.nz/bitstream/handle/10092/6286/Thesis_fulltext.pdf

Park, D., Manley, B., Morgenroth, J. & Visser, R. (2012). What proportion of the forest of small-scale owners is likely to be harvested – a Whanganui case study. http://www.nzjf.org/free_issues/NZJF57_3_2012/5CACFA1D-C50E-488a-B705-C208E80012CC.pdf

Smith, B., Horgan, G. 2006 area at risk from deforestation report http://maxa.maf.govt.nz/climatechange/reports/area-at-risk/area-of-forest-at-risk-of-def.pdf

Wakelin, S.J., Bayne, K.M., Langer, E.R., West, G.G. (2014). A Typology of Small and Medium-Sized Forest Owners: Method Development. *Contract report* for MPI.

Watt, M. S., Palmer, D. J. & Hock, B. K. (2011). Spatial description of potential areas suitable for afforestation within New Zealand and quantification of their productivity under Pinus radiata. *New Zealand Journal of Forestry Science, 41*, 115-129.

Wooldridge, J. M. (2010). Econometric Analysis of Cross Section and Panel Data. 2nd ed. Cambridge, MA: MIT Press.

Yao, R., Harrison, D., Velarde, S.J. & Barry, L. (2016). Validation and enhancement of a spatial economic tool for assessing ecosystem services provided by planted forests. *Forest Policy and Economics*. In press

Yao, R., Harrison, D., Hock, B.K. & Payn, T. (2016). A spatial economic framework that accounts for the wider benefits of planted forests in policy and investment. *Ecosystem Services*. In Review

CLIENT REPORT

Predicting harvesting and replanting of radiata pine forest blocks using national spatial datasets:

APPENDICES

B Hock, D Harrison and R Yao

REPORT INFORMATION SHEET - APPENDICES

APPENDICES FOR ***REPORT TITLE***	PREDICTING HARVESTING AND REPLANTING OF RADIATA PINE FOREST BLOCKS USING NATIONAL SPATIAL DATASETS
AUTHORS	BARBARA HOCK, DUNCAN HARRISON AND RICHARD YAO
CLIENT	MPI
CLIENT CONTRACT NO:	405024
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SIDNEY OUTPUT NUMBER	
SIGNED OFF BY	CRAIG ELVIDGE AND PETER LOUGH
DATE	AUGUST 2016
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INTELLECTUAL PROPERTY	

APPENDICES FOR REPORT

Predicting harvesting and replanting of radiata pine forest blocks using national spatial datasets

Barbara Hock, Duncan Harrison and Richard Yao
Scion, Sala Street, Rotorua, New Zealand

June 2016

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Appendix A. The FIF Model

Key assumptions

All data on costs and prices are an estimate at a generic/national level. These may not represent site specific costs precisely.

Data was extracted for each sub-catchment for a blanket cover (excluding urban, water bodies and Department of Conservation areas) of Pinus radiata **structural** (framing) regime (thinned to 600 stems ha^{-1} (spha) from initial planting of 900 stems ha^{-1}), with a rotation length of **28 years.**

A discount rate of **8%** was used as it broadly represents the range of discount rates used currently by forest growers for forest market valuations.

Prices for timber (Table A.1) were based on an average price for each grade over 16 quarters (June 2012 – June 2015, inclusive) taken from MPI and Agrifax indicative domestic radiata pine log prices.

Table A.1: Regime, log grades and carbon price

Regime	Discount Rate	Timber $/tonne	Carbon $/NZU
Structural (framing) regime (thinned to 600 spha from initial planting of 900 spha)	8%	S1 – $105 S2 – $100 S3 – $97 Pulp – $50	n/a

For each regime the Net Present Value (NPV) of forestry in perpetuity was determined using discounted cash flow analysis. The economic analysis follows largely from that of Polglase et al (2008). The NPV represents the difference between costs and revenues, all related to the same time period; the present. Each cost and revenue surface (Table A.2) was discounted to the present depending on the year for which the cash-flow occurred. The cash-flow analysis followed that of Boardman et al. (2001).

Table A.2: Data used to estimate the financial return

Costs (C)	Revenues (R)
Establishment (years 1,2,3 $/625m²)	Timber ($/tonne)
Silviculture (Thinning, year 7 $/625m²)	
Access road* construction ($/km)	
Internal landings ($/625m²)	Carbon ($/NZU)
Internal road construction ($/625m²)	
Harvesting ($/tonne)	
Transport[#] ($/tonne/km)	
ETS compliance ($/625m²)	

$1m^3$ of *Pinus radiata* timber = 1 tonne

Methodology

Modelling plantation forest establishment costs

The cost of establishing a new plantation forest involves purchasing and planting the crop, and the control of weeds to allow maximum tree growth during the crop establishment period. Some assumptions were made in order to develop the cost estimates, these were;

- Labour cost: $36 per hour (this is a labour cost not a wage rate, and includes transport, equipment, consumables and contractor overhead)
- Releasing operations base time: 3.5 man hours per hectare
- Planting operations base time: 8 man hours per hectare
- Tree stock: $400 per thousand seedlings
- Releasing chemical: $80 per hectare
- Mechanical preparation (cultivation or slash management): $20 per ha, applied to 7% of the total area to be established.

An adjustment factor was developed to adjust costs based on slope steepness. From a modelling perspective we divided all catchments into four slope classes (Table A.3).

Table A.3: Slope adjustment factors for plantation forest establishment costs.

Slope°	Description	Slope adjustment factor
0–5	Flat	1.00
5–15	Rolling	1.08
15–25	Steep	1.25
> 25	Very Steep	1.72

A hindrance adjustment factor was also developed to allow for the extra time/cost based on how difficult it is to travel across a site because of obstacles such as vegetation and slash (Table A.4). We assigned a hindrance factor of *light* for initial planting and preparation spraying stages, and a moderate factor was assigned to releasing operation.

Table A.4: Hindrance adjustment factors for traversing across a site while undertaking establishment.

Hindrance	Description.	Hindrance adjustment. factor
No hindrance	Nil	1.00
Occasional impedance	Light	1.08
Frequent impedance	Moderate	1.15
Constant impedance	Heavy	1.54
Constantly struggling	Very heavy	1.97

The final establishment costs per hectare for the first, second, and third years is given in Table A.5 for a structural (framing) regime established at 900 stems per hectare. Establishment costs were derived in a spreadsheet calculator and included the following:

- Pre-plant spraying (assumes a manual spot operation, including labour and chemical)
- Planting (labour and tree-stocks)
- Two post-plant releasing operations (manual / spot including labour and chemical)
- The costs (labour, chemical and trees) for different regimes were adjusted for stockings

The final establishment costs were converted to a cost per 625m^2 cell.

Table A.5: Cost of plantation forest establishment for a structural (framing) regime established at 900 stems per hectare.

		Planting regime at 900 spha		
Slope	**Description**	**Year 1 ($ha^{-1})**	**Year 2 ($ha^{-1})**	**Year 3 ($ha^{-1})**
0–5	Flat	1081.42	224.90	224.90
5–15	Rolling	1114.95	235.77	235.77
15–25	Steep	1193.20	261.13	261.13
> 25	Very Steep	1403.35	329.23	329.23

Modelling thinning costs

A thinning regime was developed for a structural (framing) regime with an initial stocking of 900 spha, and thinned to 600 spha at age 7. Table A.6 describes the hindrance adjustment factors used in assessing pruning of the stands.

Table A.6: Description of the adjustment factors for traversing across a site while undertaking thinning.

		Thinning	
Hindrance	**Description**	**Clear**	**Walk**
No hindrance	Nil	0.00	0.14
Occasional impedance	Light	0.01	0.17
Frequent impedance	Moderate	0.01	0.20
Constant impedance	Heavy	0.02	0.31
Constantly struggling	Very heavy	0.02	0.44

Labour costs for the thinning operations were assumed to be $45 per hour (including the costs of chainsaws, fuel, protective clothing, transport and overheads). Production rates and costs per hectare pruning and thinning were derived from relevant silvicultural time standards. Table A.7 provides the costs of thinning classified by slope.

Table A.7: Cost of thinning for a structural (framing) regime with an initial stocking of 900 spha, and thinned to 600 spha at age 7.

	Structural (framing) regime	
Slope	**Description**	**Year 7 ($ha^{-1})**
0–5	Flat	169.56
5–15	Rolling	174.72
15–25	Steep	186.78
> 25	Very Steep	219.16

A python programming language script was developed to automate model calculations using ArcGIS™ software.

Estimating within plantation forest landing and road costs

Modelling the cost of landings and roads was undertaken using landing and road density estimates. The density at which landings and roads occur within a forest was assigned to slope classes 0-10, 10-20, and >20 degree slope (Table A.8).

Classification of landing density (L_{den}) was estimated from maximum haul distance (*MHD*) associated with rubber-tyred ground-based (0-10 degree slope), tracked ground-based (10-20 degree slope), and hauler (>20 degree slope), with estimated maximum haul distances of 325 m, 350 m, and 370 m, respectively.

Table A.8: Landing and road densities developed across slope classes.

Slope (°)	Landing density (ha landing^{-1})	Road density (km ha^{-1})
0-10	10.6	0.062
10-20	12.3	0.057
>20	13.7	0.054

Road density used the same slope classification as landing density, but was calculated using:

$$R_{den} = (MHD * 2 / L_{den}) / 1000 \qquad (1)$$

The spatial datasets developed and used to estimate landing costs were grouped into three soil classes (Table A.9), and into three slope classes (Table A.8). Soil class was developed by identifying the main soil occurring within the New Zealand Soil Classification (NZSC) field of the Land Resource Inventory (LRI) digital data and assigning an easy, moderate, or hard *difficulty of earthworks* using expert knowledge provided by forest industry roading engineers and publications (Richardson 1989, Robinson 1990). The *difficulty of earthworks* was assigned to all 15 soil orders with the exception of the Brown Soil Order. The rationale for separating out this class is that the Brown Soil Order tends to contain disparate soils that often struggle to fit within other soil orders. Therefore it was considered appropriate to separate out Brown Soils at the finer group level of NZSC system.

Table A.9: Description of soil classes for estimating the *difficulty of earthworks* at landings based on prominent soil occurring within a LRI unit using the NZSC field.

Desc.	Soil Order and Group description	Class
L	Allophanic	Easy
A	Anthropic	Easy
BL	Brown Allophanic	Easy
BS	Brown Sandy	Easy
BX	Brown Oxidic	Hard
BM	Brown Mafic	Moderate
BA	Brown Acidic	Moderate
BF	Brown Firm	Hard
BO	Brown Orthic	Moderate
G	Gley	Hard
N	Granular	Hard
E	Melanic	Hard

O	Organic	Hard
X	Oxidic	Hard
P	Pallic	Moderate
Z	Podzols	Moderate
M	Pumice	Easy
W	Raw	Easy
R	Recent	Easy
S	Semiarid	Hard
U	Ultic	Hard

Using the three soil and slope spatial datasets, Table A.10 provides the estimated cost of landing construction. Costs were based on expert knowledge and published reports (Richardson 1989). Landing construction times were derived by soil type and slope, and costs were calculated using 2011 machine costs.

Table A.10: Estimated cost associated with the establishment of landings based on slope and soil class (Table A.9).

Soil class	**Slope°**		
	Flat (0-10)	**Moderate (10-20)**	**Steep (>20)**
Easy	$1,645	$2,820	$3,760
Moderate	$2,115	$3,290	$4,700
Hard	$2,820	$3,760	$7,520

For the estimation of internal road costs, a simplified version of impedance cost was developed from three slope classes, 0-5, 5-15, and >15 °ree and four classes of erosion (Bloomberg, et al., 2011). The Erosion Susceptibility Classification (ESC) relates soil erosion to forest resource management by assigning a low, moderate, high, or very high ESC class. Table A.11 provides the estimated cost for the construction of internal road networks within a forest. Expert knowledge and published data (Robinson 1990, LIRO Cable Logging Handbook) were used to estimate realistic densities and costs across the ESC and slope classes.

Table A.11: Construction costs associated with the construction of internal roads within potential future forests.

Slope°	**Erosion Susceptibility Classification**			
	Low	**Moderate**	**High**	**Very high**
0-5	$33,990	$35,020	$37,080	$41,200
5-15	$40,170	$49,440	$58,710	$63,860
>15	$64,890	$73,130	$80,340	$103,000

Landing density (Table A.8) was used to calculate the number of landings required for each slope class area within each forest. The costs associated with these landing densities where portioned to the number of landings required per cell (625 m2) within each slope class.

Slope classes in Table A.8 were also used to estimate the road density requirements on a km ha^{-1} within a forest (Equation 1). The construction cost (Table A.11) was then used to estimate the realistic cost of road construction within forests on a per cell basis assigned across the slope and ESC classes.

The calculation of harvesting costs

Harvesting costs (H_{cost}) were given to forests using slope classes for the North and South Islands by assigning the Agrifax value (Table A.12). The stems per hectare to be harvested were converted to stems per 625 m^2 cell and given the Agrifax value associated with harvesting costs. Harvesting cost was calculated using:

$$H_{cost} = Yield \ast \text{Agrifax value} \quad (2)$$

Table A.12: Estimated logging cost ($ per tonne) by terrain/system and location

Slope	Island	Extraction type	Agrifax value ($)
0-10	North Island	Flat Ground-based	21
10-15	North Island	Tracked Ground-based	26
15-20	North Island	Steep Tracked	30
>20	North Island	Hauler	39
0-10	South Island	Flat Ground-based	26
10-15	South Island	Tracked Ground-based	26
15-20	South Island	Steep Tracked	31
>20	South Island	Hauler	33

A python script was developed to automate model calculations using ArcGIS™. The costs associated with establishing each landing and road construction costs were calculated using lookup tables.

Calculating cost of building new Roads

Determining where new roads that connect the existing New Zealand road network with the forest locations and calculating realistic associated costs was undertaken. Initially we assessed which forest locations required the construct of new roads, and which did not

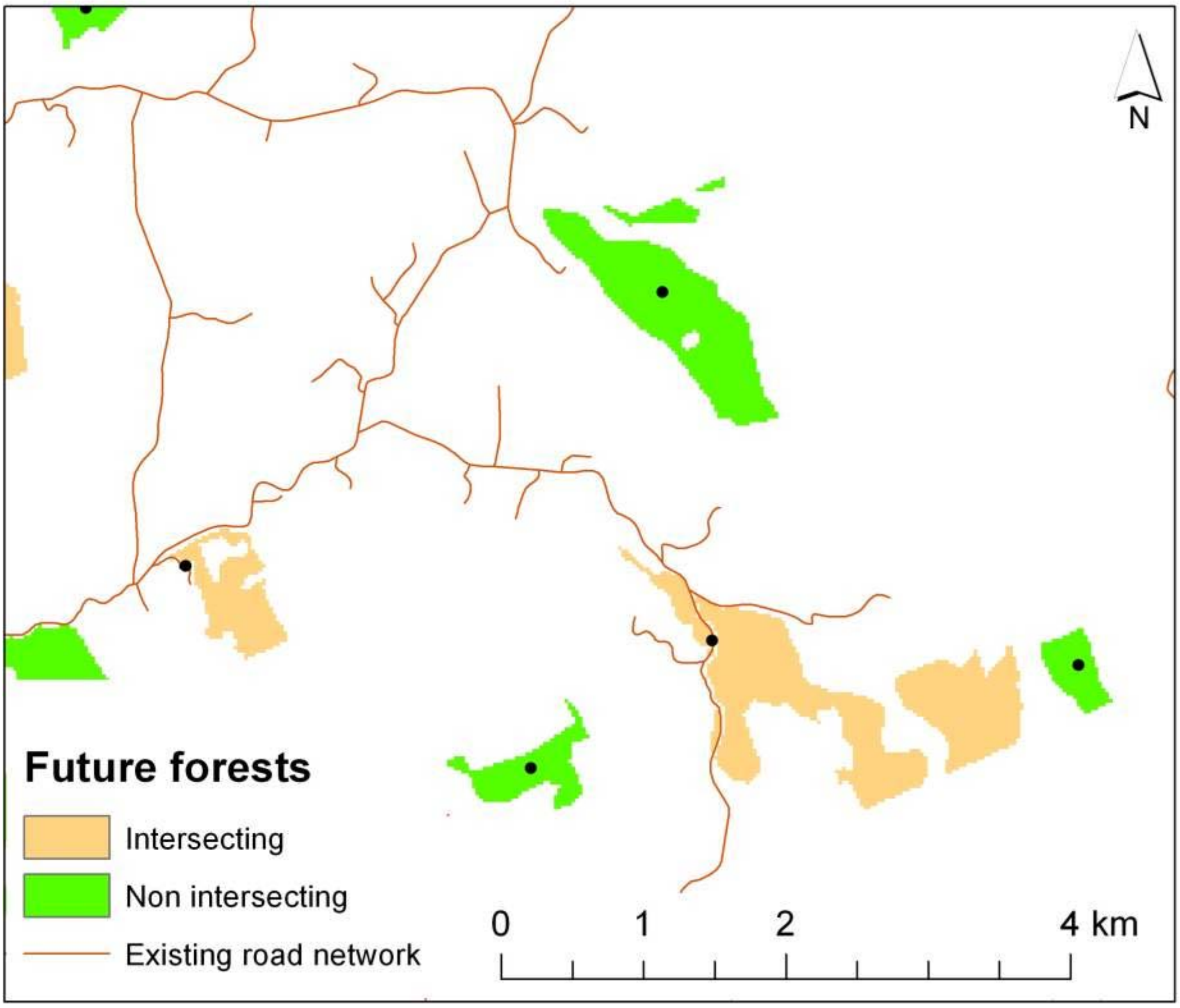


Figure A.1 Graphic showing an example of the existing road network, forest locations for forests intersecting and non-intersecting roads, and the combined forest areas with their associated unique identifier (enclosed dashed polygon).

A python script was used to automate identifying the central locations that intersect with existing roads, and the central forest locations.

Figure A.2 Graphics showing the selection of the central location within the largest combined future forest area for (A) forests that do not intersect with roads, and (B) forests intersecting roads.

In determining which location the access roads should be modelled or constructed to within the new non-intersecting forests (Figure A.2), we developed an impedance surface to account for the cost of moving across a digital surface using costpath analysis. In constructing the impedance surface we developed a table and assigned costs (NZ$) associated with travelling across slope, erosion, and rainfall classes (Table A.13). Because of the large costs incurred when crossing a stream or river we developed the likely cost of installing a culvert, or a bridge for River Environment Classification (REC) stream orders 3, to 9, respectively. Swamps and wetland areas were identified using New Zealand digital Topo maps and given large costs to ensure avoidance. Table A.14 provides the estimated costs of entering or crossing a cell representing a stream, river, swamp, or wetland area. The costs were assessed by running the model for known forests and using expert knowledge to adjust impedance values against reasonable real world costs. The scripting of the impedance cost development was undertaken using scripts and a look-up table that can easily be updated should new information or data sets become available.

Table A.13. Impedance values in NZ$ per km (× 1000).

Erosion	Rainfall	Slope 0-3	3-7	7-15	15-22	22-29	29-36	>36
Low	0-500	29	32	42	62	125	520	1,300
	500-1500	29	32	42	62	125	520	1,300
	>1500	29	32	42	62	125	520	1,300
Slight to Moderate	0-500	31	35	47	73	156	692	1,730
	500-1500	31	35	47	73	156	692	1,730
	>1500	33	38	52	83	177	808	2,020
Severe	0-500	33	38	55	93	213	940	2,350
	500-1500	34	40	59	103	237	1,092	2,730
	>1500	39	46	66	115	235	1,192	2,980
Very Severe to extreme	0-500	39	46	66	115	235	1,192	2,980
	500-1500	45	52	74	127	282	1,264	3,160
	>1500	52	60	86	149	325	1,520	3,800

Table A.14. Impedance values in NZ$ for crossing streams and rivers identified using stream order within the River Environment Classification (REC) and for incurring low lying wetland areas using New Zealand Topographic data.

REC	NZ$ (× 1000)
Stream order 1	2
Stream order 2	5
Stream order 3	75
Stream order 4	240
Stream order 5	370
Stream order 6	5,000
Stream order 7	10,000
Stream order 8	15,000
Stream order 9	20,000
Swamps and wetlands	20,000

The modelling of path taken and cost associated with that path was developed using python. The modelling was undertaken in two parts, (1) to determine the paths to all forests that do not intersect existing roads, and (2) to determine the individual paths to newly constructed roads that share a common path. Because the analysis utilises common paths to reduce costs, we needed to iterate (loop) through each of the roads that share a common path to enable us to portion the correct impedance values to a forest. In Figure A.3 we have an example where three forests share a single access road. In order to portion road construction costs correctly we developed a method of assigning the shared cost correctly.

Determining the correct cost was achieved by first identifying all shared access roads and assigning a unique identifier for each associated grouping. A *division* surface (surface to divide the impedance cost by) was developed by iterating (looping) through each individual road using a Python script and assigning a value of one to the individual access roads. In each iteration the road is added to the previous road values (one), thereby producing a surface with the value of one (no change), or 2, 3, 4, etc. where multiple shared roads exist, and with the correct number of forests associated with each access road. Assigning the impedance cost to each road was again undertaken by iterating (looping) through each individual road and extracting the impedance cost. At the end of each iteration, the impedance cost was divided by the earlier created *division* surface, and finally summed to correctly assign the cost to each access road.

For forests with only one access road the impedance costs were extracted and summed in one process without an iterative loop in a python script. On completion of the access impedance costs, future forests where assigned the value of road construction costs to the combined future forest locations on a cost per cell basis.

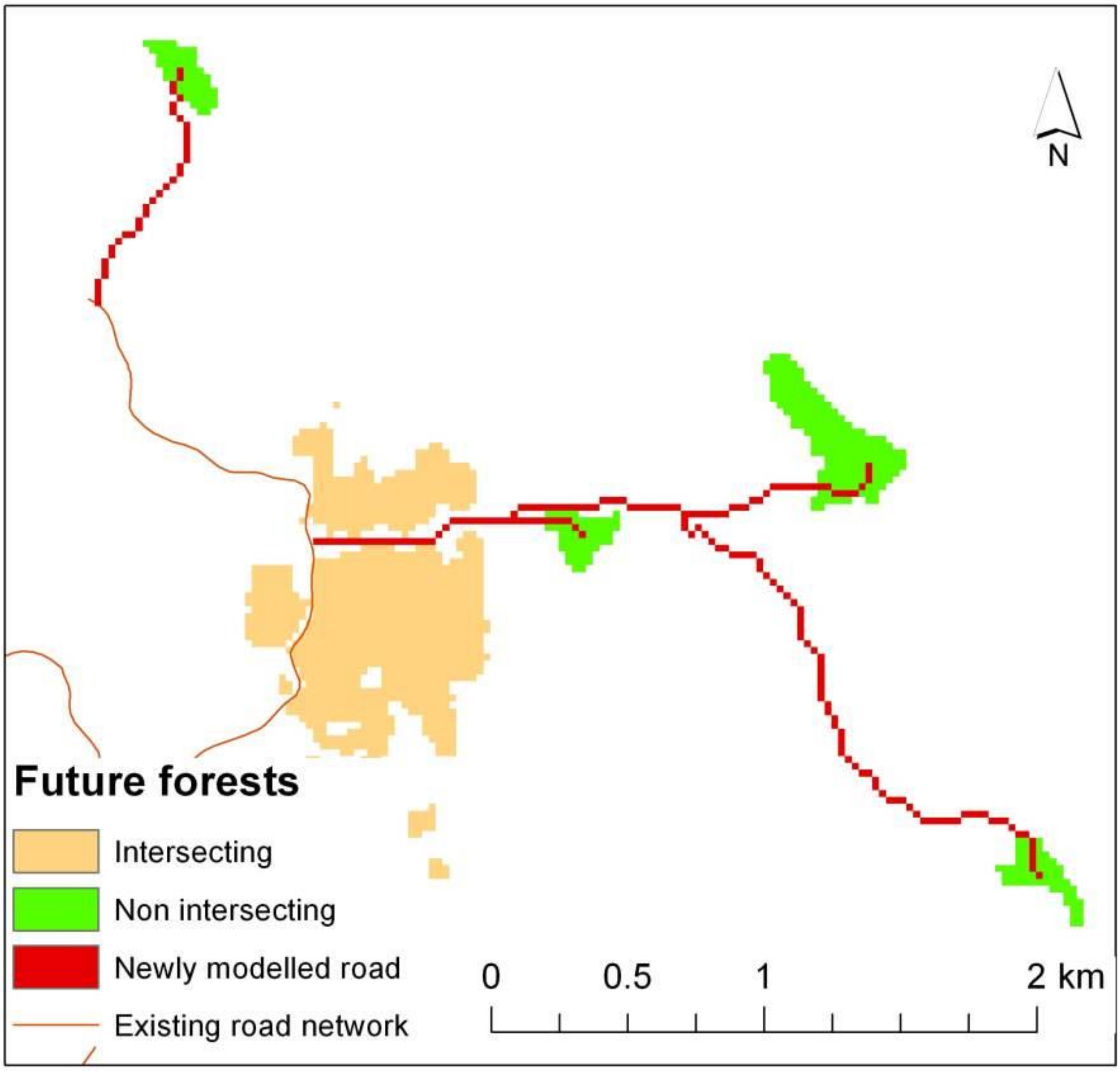


Figure A.3 Graphic showing the shared common paths from the modelling.

Calculating transport costs

The calculation of transport costs from the forest location to the destination (port, saw mill, processing plant) was undertaken on a distance basis.

The total tonnage of timber produced from each cell was multiplied by distance in kilometres and the cost of transport, estimated to be $0.22 per km.

Development of productivity surfaces

The productivity surfaces for *Pinus radiata* (Palmer et al., 2009; 2010a and 2010b) was developed by combining advanced statistical techniques with mapping technology to predict 300 Index and Site Index for any location in New Zealand. The 300 Index is an index of volume mean annual increment, and Site Index measures height at a reference age. The maps of Site Index and 300 Index were developed using growth measurement data from trees in 1,146 permanent sample plots in radiata pine stands planted between 1975 and 2003. The data was combined with a number of climate, land use, terrain and environmental variables to predict forest productivity under a range of conditions. For more details refer to Palmer et al. (2009).

A purpose written python routine calculates volumes of each log grade in cubic metres per hectare for a structural regime, based on the 300 Index and Site Index surfaces in association with regression model coefficients. A similar routine calculates annual carbon sequestration surfaces in tonnes of CO_2.

Determining NPV

For each regime the Net Present Value (NPV) of forestry in perpetuity was determined. This is calculated across multiple rotations, to ensure the lower infrastructural costs post-first rotation are taken into consideration.

References Appendix A

Barry, L.E., Yao, R.T., Harrison, D.R., Paragahawewa, U.H., Pannell, D.J. (2014). Enhancing ecosystem services through afforestation: How policy can help. Land *Use Policy 39*, 135-145.

Bloomberg, M., Davies, T., Visser, R., Morgenroth, J. (2011). Erosion Susceptibility Classification and Analysis of Erosion Risks for Plantation Forestry. *Ministry for the Environment Report*.

Boardman, A.E., Greenberg, D.H., Vining, A.R., and Weimer, D.L. (2006). *Cost-Benefit analysis: Concepts and practice*. 3rd Edition ed. Upper Saddle River, New Jersey: Prentice Hall.

Buongiorno, J., and Gilles, J.K. (2003). *Decision methods for forest resource management*. San Diego: Academic Press.

Dymond, J.R., Betts, H.D., Schierlitz, C.S., (2010). An erosion model for evaluating regional land-use scenarios. *Envirn.Model.Softw*. 25, 289-298.

Liley, W.D. (1983). Cable logging handbook. Logging Industry Research Association Inc. Rotorua, New Zealand.

Maclaren, J.P. (2000). *Trees in the greenhouse: The role of forestry in mitigating the enhanced greenhouse effect.* In Forest Research Bulletin. Scion: Rotorua, NZ.

MPI (2011) *A guide to forestry in the emissions trading scheme*. Wellington: Ministry of Agriculture and Forestry.

Palmer, D.J., Höck, B.K., Kimberley, M.O., Watt, M.S., Lowe, D.J., Payn, T.W., (2009). Comparison of spatial prediction techniques for developing Pinus radiata surfaces across New Zealand. *Forest Ecology and Management, 258*: 2046-2055.

Palmer, D., Watt, M., Kimberley, M., Höck, B., Payn, T., Lowe, D. (2010a). Mapping and explaining the productivity of Pinus radiata in New Zealand. *New Zealand Journal of Forestry 55*, 15-21.

Palmer, D., Watt, M., Kimberley, M., Höck, B., Payn, T., Lowe, D. (2010b). Mapping the productivity of Pinus radiata in New Zealand. *New Zealand Tree Grower 31*, 18-19.

Polglase, P., Paul, K., Hawkins, C., Siggins, A., Turner, J.A., Booth, T., Crawford, D., Jovanovic, T., Hobbs, T., Opie, K., Almeida, A., and Carter, J. (2008). *Regional opportunities for agroforestry systems in Australia*. Kingston, Australia: Rural Industries Research Development Corporation.

Richardson P. (1989). The cost of landing formation in pumice and clay soils. *LIRO Project Report* No. 46.

Robinson D. (1990). Construction cost estimation for forest roads. *LIRO Project Report* No. 50.

Turner, J.A., West, G., Dungey, H., Wakelin, S., MacLaren, P., Adams, T., and Silcock, P. (2008). *Managing New Zealand planted forests for carbon.* A review of selected scenarios and identification of knowledge gaps. Report to the Ministry of Agriculture and Forestry 130pp.

United States Environmental Protection Agency, *Greenhouse gas mitigation potential in U.S. forestry and agriculture*. Washinton DC: USEPA Retrieved from http://www.epa.gov/sequestration/pdf/ghg_part3.pdf. (2005).

Appendix B. Results for the harvest intentions – pre-1990/post-1989

Tables B.1 – B.4 present results per region classified into pre-1989/post-1990, for scenarios:

- Harvest intentions for NZFFA-based forests
- Harvest intentions for LUM 1–40ha forests
- Harvest intentions for LUM and LCDB 1–40ha forests
- Harvest intentions for all LUM forests plus LCDB 1–40ha forests

Factors in the FIF area results

Regarding the area loss from the input data in Table 4 to the model output results in the tables of this Appendix: the contributing factors are

- Forest data is available as vector data which FIF converts to grids for modelling. During the conversion to grids, if a forest polygon fills the majority of the grid then then grid cell becomes a forest cell, and vice versa for filling less than the majority of a cell. This process does change the area of forest and is particularly sensitive where there are many boundaries. Conversions of small forest areas are thus more affected than large forest areas.
  For LCDB this can be advantageous as, for example, shelter belts larger than 1ha in area but with a narrow and long shape tend to be reduced or even mostly deleted by a grid conversion.
- FIF masks areas unsuited for radiata growth from the modelling, such as areas below a minimum temperature and certain soil types. Scenario trees in these areas are hence also masked.
- FIF also masks areas such as urban areas and does not model forests on islands. The model also excludes exotic forests in the DoC estate.
- The modelling process requires road connectivity between all NZ roads, i.e. the model assumes the closest road is available for and that it connects to at least one of the destinations for the logs. However there are some unconnected roads in the LINZ datasets; where these have become known in Scion's version of the road dataset they have been edited. Forests modelled to unconnected roads cannot be computed to their destination so are excluded during the modelling process.
- For all the datasets some edge differences can occur, for example for coastlines and lake edges. This contributes to area differences.

FIF results by North Island region and pre-1989/post-1990 classification

Table B.1: North Island results of the FIF model run on the NZFFA Small Owner Database scenario by pre-1989/post-1990

	1 Highly unlikely	2 Unlikely	3 Fairly unlikely	4 Fairly likely	5 Likely	6 Highly likely	Total
01 Northland Region	**92.4**	**4.5**	**3.3**	**55.0**	**523.6**	**6,401.7**	**7,080.4**
Planted Forest–Pre-1990	47.6	4.5	3.3	51.6	290.6	2,099.7	2,497.3
Post 1989 Forest	44.7			3.4	233.1	4,301.9	4,583.1
02 Auckland Region	**28.1**			**9.5**	**89.5**	**1,109.9**	**1,236.9**
Planted Forest–Pre-1990	15.6			2.3	46.6	406.1	470.6
Post 1989 Forest	12.5			7.2	42.8	703.8	766.4
03 Waikato Region	**224.8**	**18.5**	**10.7**	**14.5**	**461.6**	**3,442.6**	**4,172.7**
Planted Forest–Pre-1990	100.0	8.2	2.0	8.0	243.5	1,047.3	1,409.1
Post 1989 Forest	124.8	10.4	8.7	6.5	218.1	2,395.3	2,763.6
04 Bay of Plenty Region	**159.3**	**7.6**	**3.9**	**2.0**	**173.1**	**1,265.3**	**1,611.3**
Planted Forest–Pre-1990	91.1	7.6	3.9		133.3	530.1	765.9
Post 1989 Forest	68.2		0.0	2.0	39.8	735.3	845.4
05 Gisborne Region	**349.5**	**5.1**	**9.6**	**33.2**	**199.9**	**2,445.3**	**3,042.6**
Planted Forest–Pre-1990	79.4		2.1	27.4	103.7	501.8	714.4
Post 1989 Forest	270.1	5.1	7.5	5.8	96.2	1,943.5	2,328.2
08 Manawatu-Wanganui Region	**453.1**	**22.5**	**13.1**	**18.7**	**488.8**	**5,549.6**	**6,545.8**
Planted Forest–Pre-1990	149.7	4.1		5.7	235.8	1,432.8	1,828.1
Post 1989 Forest	303.4	18.4	13.1	13.0	253.1	4,116.7	4,717.7
07 Taranaki Region	**342.5**	**11.2**	**9.0**	**7.1**	**281.9**	**1,657.7**	**2,309.4**
Planted Forest–Pre-1990	77.1	2.1	9.0	4.7	113.8	685.8	892.5
Post 1989 Forest	265.5	9.1		2.4	168.1	971.9	1,416.9
06 Hawke's Bay Region	**119.2**	**4.5**	**10.8**	**37.0**	**260.7**	**1,708.4**	**2,140.7**
Planted Forest–Pre-1990	78.5	2.2	10.8	16.1	166.2	653.6	927.4

Post 1989 Forest	40.8	2.2		20.9	94.6	1,054.8	1,213.3
09 Wellington Region	**29.6**		**9.4**	**4.7**	**27.7**	**544.0**	**615.4**
Planted Forest–Pre-1990	22.0			4.7	14.1	151.7	192.5
Post 1989 Forest	7.6		9.4		13.6	392.3	422.9
Total	**1,798.5**	**73.7**	**69.9**	**181.7**	**2,506.9**	**24,124.5**	**28,755.3**

Table B.2: Results of the FIF model run on the LUM 1–40ha scenario by pre-1989/post-1990

	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
01 Northland Region	**389.2**	**37.8**	**33.9**	**187.6**	**2,525.7**	**12,830.3**	**16,004.6**
Planted Forest–Pre-1990	244.7	18.2	6.1	144.1	1,834.7	7,313.7	9,561.6
Post 1989 Forest	144.5	19.6	27.8	43.5	691.0	5,516.6	6,443.0
02 Auckland Region	**80.9**		**4.3**	**66.4**	**628.7**	**5,733.8**	**6,514.1**
Planted Forest–Pre-1990	50.0		4.3	24.1	490.9	2,970.0	3,539.4
Post 1989 Forest	30.9			42.4	137.8	2,763.7	2,974.7
03 Waikato Region	**847.6**	**67.2**	**34.2**	**196.4**	**3,426.3**	**19,277.3**	**23,849.0**
Planted Forest–Pre-1990	444.7	37.3	6.9	89.1	2,188.1	9,864.8	12,630.9
Post 1989 Forest	402.9	29.9	27.2	107.3	1,238.2	9,412.5	11,218.1
04 Bay of Plenty Region	**532.9**	**27.6**	**32.3**	**16.4**	**618.2**	**7,314.1**	**8,541.5**
Planted Forest–Pre-1990	186.5		26.6	10.3	319.6	3,539.5	4,082.6
Post 1989 Forest	346.4	27.6	5.7	6.0	298.7	3,774.6	4,459.0
05 Gisborne Region	**1,319.8**	**52.5**	**18.9**	**72.7**	**1,129.4**	**7,484.9**	**10,078.1**
Planted Forest–Pre-1990	371.0	27.0	3.3	43.4	552.5	3,486.9	4,484.1
Post 1989 Forest	948.8	25.4	15.6	29.4	576.9	3,997.9	5,594.0
06 Hawke's Bay Region	**622.9**	**40.6**	**11.5**	**85.2**	**2,033.4**	**14,632.8**	**17,426.3**
Planted Forest–Pre-1990	228.9	18.1	5.2	54.0	1,289.6	7,742.1	9,337.8
Post 1989 Forest	393.9	22.5	6.3	31.2	743.9	6,890.8	8,088.5
07 Taranaki Region	**675.0**	**40.4**	**7.9**	**43.4**	**982.1**	**7,124.8**	**8,873.6**
Planted Forest–Pre-1990	187.1	11.5	2.2	22.1	612.0	4,119.0	4,953.9
Post 1989 Forest	487.9	28.9	5.6	21.3	370.1	3,005.8	3,919.7
08 Manawatu-Wanganui Region	**1,844.6**	**110.1**	**28.6**	**227.7**	**2,572.0**	**18,081.7**	**22,864.7**
Planted Forest–Pre-1990	446.0	20.4		49.5	958.3	6,752.1	8,226.3
Post 1989 Forest	1,398.7	89.7	28.6	178.2	1,613.7	11,329.5	14,638.4
09 Wellington Region	**820.9**	**58.8**	**21.6**	**68.8**	**1,066.9**	**9,303.1**	**11,340.0**

Planted Forest–Pre-1990	418.4	38.7	16.3	50.3	702.1	4,883.6	6,109.4
Post 1989 Forest	402.5	20.2	5.3	18.5	364.7	4,419.5	5,230.6
Total	**7,133.8**	**435.0**	**193.2**	**964.6**	**14,982.6**	**101,782.7**	**125,491.9**

Table B.3: Results of the FIF model run on the LUM and LCDB 1–40ha scenario by pre-1989/post-1990

	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
01 Northland Region	**607.1**	**47.8**	**14.6**	**186.4**	**2,554.2**	**14,327.7**	**17,737.7**
Planted Forest–Pre-1990	399.9	38.3	6.2	147.5	1,818.8	7,940.3	10,350.9
Post 1989 Forest	207.2	9.5	8.4	38.9	735.4	6,387.3	7,386.7
02 Auckland Region	**113.2**		**2.0**	**49.4**	**684.7**	**6,607.7**	**7,457.1**
Planted Forest–Pre-1990	70.9		2.0	10.8	518.6	3,361.2	3,963.4
Post 1989 Forest	42.3			38.7	166.2	3,246.6	3,493.7
03 Waikato Region	**1,629.1**	**76.1**	**50.0**	**188.3**	**3,049.4**	**21,504.8**	**26,497.6**
Planted Forest–Pre-1990	586.7	42.5	9.5	119.5	2,066.6	11,379.6	14,204.5
Post 1989 Forest	1,042.3	33.5	40.5	68.8	982.8	10,125.2	12,293.1
04 Bay of Plenty Region	**794.4**	**42.0**		**31.3**	**682.7**	**9,057.5**	**10,607.9**
Planted Forest–Pre-1990	293.1	34.6		25.1	335.4	4,613.4	5,301.7
Post 1989 Forest	501.3	7.4		6.2	347.3	4,444.0	5,306.1
05 Gisborne Region	**2,003.0**	**71.1**	**55.0**	**72.7**	**1,225.8**	**8,283.2**	**11,710.8**
Planted Forest–Pre-1990	515.8	37.1	34.6	40.7	570.2	4,174.7	5,373.1
Post 1989 Forest	1,487.1	34.0	20.4	32.0	655.6	4,108.5	6,337.7
06 Hawke's Bay Region	**1,082.4**	**55.6**	**39.1**	**62.9**	**1,892.3**	**16,383.6**	**19,516.0**
Planted Forest–Pre-1990	440.1	46.6	21.5	27.9	1,138.5	8,916.9	10,591.5
Post 1989 Forest	642.3	9.0	17.7	35.0	753.8	7,466.7	8,924.5
07 Taranaki Region	**1,025.5**	**80.8**	**6.2**	**54.3**	**785.3**	**8,304.6**	**10,256.8**
Planted Forest–Pre-1990	214.3	13.1	6.2	29.0	572.3	4,849.3	5,684.2
Post 1989 Forest	811.2	67.7		25.4	213.0	3,455.3	4,572.6
08 Manawatu-Wanganui Region	**3,150.5**	**153.0**	**8.7**	**119.5**	**2,337.9**	**20,168.6**	**25,938.1**
Planted Forest–Pre-1990	552.8	43.0	6.6	39.9	1,018.2	7,754.5	9,415.0
Post 1989 Forest	2,597.6	110.0	2.1	79.6	1,319.6	12,414.1	16,523.1
09 Wellington Region	**1,327.8**	**59.7**	**15.4**	**97.9**	**1,059.2**	**10,471.4**	**13,031.4**

Planted Forest–Pre-1990	695.1	40.3	15.4	58.9	614.1	5,585.9	7,009.8
Post 1989 Forest	632.7	19.4		39.0	445.1	4,885.4	6,021.5
Total	**11,732.8**	**586.1**	**191.1**	**862.7**	**14,271.6**	**115,109.1**	**142,753.4**

Table B.4: Results of the FIF model run on the LUM all-forests plus LCDB 1–40ha scenario by pre-1989/post-1990

	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
01 Northland Region	**657.4**	**43.1**	**31.4**	**181.7**	**2,300.5**	**157,530.5**	**160,744.6**
Planted Forest–Pre-1990	346.6	38.4	2.3	131.2	1,744.7	123,259.0	125,522.2
Post 1989 Forest	310.8	4.7	29.1	50.5	555.8	34,271.5	35,222.4
02 Auckland Region	**74.1**		**2.0**	**44.5**	**925.6**	**47,006.6**	**48,052.9**
Planted Forest–Pre-1990	32.8		2.0	13.2	538.8	37,907.8	38,494.6
Post 1989 Forest	41.3			31.3	386.9	9,098.8	9,558.3
03 Waikato Region	**2,879.7**	**80.3**	**13.8**	**222.4**	**2,802.8**	**296,930.0**	**302,928.9**
Planted Forest–Pre-1990	1,303.3	46.8	9.3	144.2	1,966.4	253,895.4	257,365.3
Post 1989 Forest	1,576.4	33.5	4.5	78.2	836.4	43,034.6	45,563.6
04 Bay of Plenty Region	**887.5**	**7.4**		**16.9**	**561.6**	**274,202.5**	**275,675.8**
Planted Forest–Pre-1990	373.3	2.3		10.7	254.5	256,305.4	256,946.1
Post 1989 Forest	514.2	5.1		6.2	307.1	17,897.1	18,729.8
05 Gisborne Region	**3,162.4**	**59.1**	**39.7**	**171.7**	**1,042.2**	**179,897.6**	**184,372.7**
Planted Forest–Pre-1990	517.6	28.1	2.7	38.9	506.4	90,843.8	91,937.5
Post 1989 Forest	2,644.8	31.0	37.1	132.7	535.7	89,053.8	92,435.2
06 Hawke's Bay Region	**1,669.8**	**38.5**	**14.0**	**82.2**	**1,879.2**	**160,684.2**	**164,367.9**
Planted Forest–Pre-1990	531.9	32.5	8.9	48.9	1,196.3	93,003.8	94,822.4
Post 1989 Forest	1,137.9	5.9	5.1	33.3	683.0	67,680.4	69,545.6
07 Taranaki Region	**1,422.4**	**54.8**	**10.9**	**38.2**	**758.9**	**29,434.2**	**31,719.4**
Planted Forest–Pre-1990	261.6	6.8	6.2	27.3	461.6	12,491.6	13,255.1
Post 1989 Forest	1,160.8	48.1	4.7	10.8	297.3	16,942.7	18,464.3
08 Manawatu-Wanganui Region	**3,692.5**	**106.9**	**8.4**	**109.5**	**2,082.6**	**148,150.4**	**154,150.4**
Planted Forest–Pre-1990	844.8	27.2	6.6	38.1	887.7	73,120.6	74,925.1
Post 1989 Forest	2,847.7	79.7	1.8	71.4	1,194.9	75,029.8	79,225.3
09 Wellington Region	**1,476.7**	**26.9**	**9.0**	**126.7**	**1,013.1**	**77,878.1**	**80,530.4**

Planted Forest–Pre-1990	521.5	7.4	9.0	49.3	580.4	40,594.0	41,761.5
Post 1989 Forest	955.2	19.5		77.5	432.6	37,284.1	38,768.9
Total	**15,922.5**	**417.0**	**129.3**	**993.8**	**13,366.5**	**1,371,714.1**	**1,402,543.1**

FIF results by South Island regions and pre-1989/post-1990 classification

Table B.5: South Island results of the FIF model run on the NZFFA Small Owner Database scenario by pre-1989/post-1990

Sum of Area (ha)	Harvest likelihood						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
12 West Coast Region	**24.8**	**6.8**	**65.1**		**90.2**	**868.8**	**1,055.7**
Planted Forest - Pre-1990	13.2		35.0		64.9	482.1	595.3
Post 1989 Forest	11.6	6.8	30.1		25.2	386.6	460.4
13 Canterbury Region	**474.9**	**23.5**	**417.1**	**37.1**	**662.6**	**3,430.9**	**5,046.1**
Planted Forest - Pre-1990	238.9	17.8	321.7	29.9	500.0	1,486.1	2,594.4
Post 1989 Forest	236.0	5.7	95.4	7.2	162.6	1,944.8	2,451.7
14 Otago Region	**191.3**	**17.6**	**196.9**	**32.6**	**602.4**	**3,874.7**	**4,915.4**
Planted Forest - Pre-1990	146.5	7.1	144.7	13.5	393.0	1,255.2	1,960.1
Post 1989 Forest	44.8	10.4	52.2	19.1	209.4	2,619.4	2,955.3
15 Southland Region	**100.0**	**2.1**	**189.8**	**12.2**	**194.1**	**1,358.3**	**1,856.5**
Planted Forest - Pre-1990	55.6	2.1	98.8		140.9	699.7	997.2
Post 1989 Forest	44.3		91.0	12.2	53.2	658.6	859.3
16 Tasman Region	**485.9**	**42.5**	**284.4**	**2.3**	**354.4**	**2,111.8**	**3,281.3**
Planted Forest - Pre-1990	125.5	15.5	143.4		117.5	1,362.8	1,764.7
Post 1989 Forest	360.4	27.0	141.0	2.3	236.8	749.0	1,516.6
17 Nelson Region	**4.0**		**8.1**	**11.1**	**16.4**	**271.2**	**310.9**
Planted Forest - Pre-1990	4.0		0.0		11.2	179.4	194.7
Post 1989 Forest			8.1	11.1	5.2	91.8	116.2
18 Marlborough Region	**1,034.8**	**62.9**	**143.0**	**25.4**	**335.9**	**1,856.7**	**3,458.5**
Planted Forest - Pre-1990	483.7	25.7	68.1	4.0	129.7	881.6	1,592.8
Post 1989 Forest	551.1	37.2	74.9	21.4	206.1	975.1	1,865.8
Total	**2,315.7**	**155.4**	**1,304.4**	**120.7**	**2,255.8**	**13,772.4**	**19,924.4**

Table B.6: South Island results of the FIF model run on the LUM 1–40ha scenario by pre-1989/post-1990

Sum of ha	Harvest intentions						
	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
12 West Coast Region	**150.8**	**50.9**	**764.3**	**36.2**	**434.8**	**2,679.7**	**4,116.7**
Planted Forest - Pre-1990	75.3	20.5	543.6	31.6	297.5	1,739.3	2,707.8
Post 1989 Forest	75.5	30.5	220.8	4.6	137.2	940.3	1,408.9
13 Canterbury Region	**2,459.7**	**233.8**	**4,852.0**	**548.1**	**5,567.1**	**20,464.0**	**34,124.7**
Planted Forest - Pre-1990	1,508.2	161.5	3,618.9	401.4	4,265.5	13,262.7	23,218.2
Post 1989 Forest	951.5	72.3	1,233.1	146.7	1,301.6	7,201.3	10,906.5
14 Otago Region	**986.4**	**153.0**	**3,503.5**	**259.1**	**3,938.0**	**12,153.2**	**20,993.2**
Planted Forest - Pre-1990	737.9	119.1	2,539.8	237.5	2,936.6	7,393.7	13,964.6
Post 1989 Forest	248.5	34.0	963.7	21.5	1,001.4	4,759.4	7,028.5
15 Southland Region	**814.2**	**43.0**	**1,701.0**	**111.8**	**2,037.6**	**8,020.3**	**12,727.9**
Planted Forest - Pre-1990	306.1	8.2	984.5	98.9	1,443.9	4,741.2	7,582.9
Post 1989 Forest	508.0	34.8	716.5	12.9	593.7	3,279.2	5,145.1
16 Tasman Region	**798.8**	**48.4**	**641.8**	**52.8**	**875.2**	**3,445.6**	**5,862.5**
Planted Forest - Pre-1990	300.8	11.2	381.0	46.9	515.4	2,061.3	3,316.7
Post 1989 Forest	498.0	37.1	260.7	5.9	359.7	1,384.3	2,545.7
17 Nelson Region	**41.3**	**2.3**	**9.3**		**115.6**	**526.9**	**695.4**
Planted Forest - Pre-1990	34.8	2.3			76.1	310.2	423.4
Post 1989 Forest	6.5		9.3		39.5	216.7	272.0
18 Marlborough Region	**1,246.9**	**67.2**	**1,317.7**	**120.9**	**789.2**	**2,429.5**	**5,971.3**
Planted Forest - Pre-1990	649.0	23.2	544.3	44.4	527.6	1,351.8	3,140.2
Post 1989 Forest	597.8	43.9	773.4	76.6	261.6	1,077.8	2,831.1
Total	**6,498.0**	**598.7**	**12,789.6**	**1,128.9**	**13,757.4**	**49,719.1**	**84,491.7**

Table B.7: South Island results of the FIF model run on the LUM and LCDB 1–40ha scenario by pre-1989/post-1990

Sum of ha	**Harvest intentions**						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
12 West Coast Region	**236.4**	**45.4**	**843.5**	**17.7**	**456.9**	**3,311.4**	**4,911.3**
Planted Forest - Pre-1990	122.9	20.6	611.8	13.1	346.8	2,136.6	3,251.9
Post 1989 Forest	113.4	24.8	231.8	4.6	110.1	1,174.8	1,659.5
13 Canterbury Region	**2,813.3**	**188.8**	**4,633.1**	**576.8**	**5,427.3**	**24,349.9**	**37,989.2**
Planted Forest - Pre-1990	1,715.9	139.9	3,507.3	424.0	4,035.7	15,566.9	25,389.7
Post 1989 Forest	1,097.4	49.0	1,125.8	152.7	1,391.5	8,783.1	12,599.5
14 Otago Region	**1,058.2**	**146.6**	**3,816.7**	**207.6**	**3,559.5**	**14,500.7**	**23,289.2**
Planted Forest - Pre-1990	754.4	136.6	2,773.3	190.8	2,668.8	8,871.0	15,394.9
Post 1989 Forest	303.8	9.9	1,043.4	16.8	890.6	5,629.7	7,894.3
15 Southland Region	**789.7**	**44.3**	**1,699.8**	**119.0**	**1,893.2**	**9,438.5**	**13,984.4**
Planted Forest - Pre-1990	351.8	8.7	956.7	93.0	1,284.2	5,634.7	8,329.1
Post 1989 Forest	437.9	35.6	743.1	26.0	609.0	3,803.8	5,655.4
16 Tasman Region	**992.9**	**46.5**	**776.4**	**80.9**	**841.0**	**4,397.6**	**7,135.2**
Planted Forest - Pre-1990	359.7	9.4	564.2	47.4	467.8	2,639.7	4,088.1
Post 1989 Forest	633.1	37.1	212.2	33.5	373.2	1,757.9	3,047.1
17 Nelson Region	**39.0**	**5.8**	**10.3**	**3.3**	**108.9**	**695.6**	**863.0**
Planted Forest - Pre-1990	32.6	3.5			62.1	426.9	525.0
Post 1989 Forest	6.5	2.2	10.3	3.3	46.8	268.7	338.0
18 Marlborough Region	**1,418.1**	**49.0**	**1,362.3**	**123.9**	**813.6**	**3,348.7**	**7,115.7**
Planted Forest - Pre-1990	744.1	16.1	551.3	63.6	535.8	1,939.7	3,850.5
Post 1989 Forest	674.0	32.9	811.0	60.3	277.9	1,409.0	3,265.1
Total	**10,217.6**	**810.1**	**18,362.3**	**1,614.0**	**20,717.8**	**78,516.8**	**130,238.5**

Table B.8: South Island results of the FIF model run on the LUM all-forests plus LCDB 1–40ha scenario by pre-1989/post-1990

Sum of Area (ha)	Harvest intentions						
	Highly unlikely	Unlikely	Fairly unlikely	Fairly likely	Likely	Highly likely	Total
12 West Coast Region	**533.3**	**39.9**	**1,573.9**	**17.9**	**438.1**	**40,024.8**	**42,627.8**
Planted Forest - Pre-1990	71.8	15.1	1,288.4	10.8	321.3	31,389.1	33,096.6
Post 1989 Forest	461.5	24.8	285.4	7.1	116.8	8,635.7	9,531.3
13 Canterbury Region	**6,460.9**	**225.3**	**10,688.9**	**424.2**	**5,631.6**	**107,781.3**	**131,212.2**
Planted Forest - Pre-1990	4,657.4	171.9	7,200.5	325.5	4,105.7	67,289.8	83,750.8
Post 1989 Forest	1,803.6	53.3	3,488.3	98.8	1,525.9	40,491.5	47,461.4
14 Otago Region	**1,150.6**	**190.8**	**9,392.2**	**173.4**	**3,483.3**	**130,261.7**	**144,652.1**
Planted Forest - Pre-1990	829.0	127.8	5,121.3	157.1	2,660.9	85,386.7	94,282.8
Post 1989 Forest	321.6	63.0	4,270.9	16.3	822.4	44,875.0	50,369.2
15 Southland Region	**1,666.9**	**51.2**	**10,769.0**	**82.4**	**2,059.6**	**78,066.4**	**92,695.5**
Planted Forest - Pre-1990	585.8	13.3	4,867.5	55.8	1,434.0	39,528.2	46,484.6
Post 1989 Forest	1,081.1	37.8	5,901.5	26.6	625.6	38,538.2	46,210.9
16 Tasman Region	**1,194.4**	**53.0**	**2,036.3**	**90.0**	**725.3**	**98,405.1**	**102,504.2**
Planted Forest - Pre-1990	221.1	15.8	900.6	25.6	354.5	84,570.5	86,088.2
Post 1989 Forest	973.3	37.1	1,135.7	64.4	370.9	13,834.6	16,416.0
17 Nelson Region	**23.1**	**1.2**	**282.0**		**56.7**	**10,947.0**	**11,310.0**
Planted Forest - Pre-1990	16.6	1.2	272.7		38.0	10,010.6	10,339.2
Post 1989 Forest	6.5		9.3		18.6	936.3	970.7
18 Marlborough Region	**5,155.0**	**52.2**	**6,425.6**	**94.1**	**914.7**	**69,145.5**	**81,787.2**
Planted Forest - Pre-1990	1,126.9	24.3	1,432.8	45.2	543.9	42,034.9	45,207.9
Post 1989 Forest	4,028.1	27.9	4,992.9	48.9	370.9	27,110.6	36,579.3
Total	**16,184.3**	**613.5**	**41,167.9**	**882.1**	**13,309.4**	**534,631.9**	**606,789.0**

Appendix C. Results for the harvest intentions – by age-class

Tables C.1 – C.8 present results per region classified by LCDB age classes, for scenarios:

- Harvest intentions for NZFFA-based forests
- Harvest intentions for LUM 1–40ha forests
- Harvest intentions for LUM and LCDB 1–40ha forests
- Harvest intentions for all LUM forests plus LCDB 1–40ha forests

Regarding the area loss from the input data in Table 4 to the model output results in the tables of this Appendix: the contributing factors are described in Appendix B.

Age codes represent:

1 R3-7	Tree age 3-7
2 R7-11	Tree age 7-11
3 R12-18	Tree age 12-18
4 R19-23	Tree age 19-23
5 R24plus	Tree age 24 or older

FIF results by North Island regions and LCDB age-classes

Table C.1: North Island results of the FIF model run on the NZFFA Small Owner Database scenario by LCDB age classes

Sum of Ha	Likelihood to harvest						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
01 Northland Region	**62.7**	**4.0**	**2.0**	**46.1**	**405.1**	**5,862.6**	**6,382.5**
1 R3-7	4.7				0.3	248.1	253.1
2 R7-11					8.2	67.4	75.6
3 R12-18	1.2			2.2	15.3	167.7	186.4
4 R19-23	18.4			2.2	95.2	1,115.8	1,231.6
5 R24plus	38.5	4.0	2.0	41.7	286.1	4,263.6	4,635.8
02 Auckland Region	**17.4**			**8.1**	**60.3**	**952.2**	**1,037.9**

1 R3-7	0.1				0.5	60.6	61.1
2 R7-11					0.0	0.1	0.1
3 R12-18					0.3	60.9	61.2
4 R19-23	0.1			6.0	17.1	261.7	284.9
5 R24plus	17.2			2.1	42.3	569.0	630.7
03 Waikato Region	**119.6**	**10.0**	**10.0**	**10.2**	**383.7**	**2,922.3**	**3,455.8**
1 R3-7	13.3	2.2			28.1	137.9	181.4
2 R7-11	0.7				2.6	19.0	22.2
3 R12-18	4.3	2.6		1.4	22.6	78.5	109.5
4 R19-23	20.0	5.3	1.5	6.1	124.3	1,406.1	1,563.2
5 R24plus	81.2		8.5	2.7	206.1	1,280.9	1,579.5
04 Bay of Plenty Region	**75.1**	**5.0**	**3.6**	**0.0**	**126.6**	**1,050.9**	**1,261.1**
1 R3-7	5.1				11.0	99.1	115.1
2 R7-11					3.4	23.3	26.7
3 R12-18					6.2	54.9	61.1
4 R19-23	9.7		0.1		8.2	255.0	273.0
5 R24plus	60.4	5.0	3.5	0.0	97.8	618.6	785.2
05 Gisborne Region	**82.5**	**0.1**	**1.2**	**31.0**	**122.8**	**1,887.3**	**2,125.0**
1 R3-7	0.0				2.8	0.7	3.5
2 R7-11	2.0			3.0	12.4	13.4	30.9
3 R12-18	4.9				0.7	156.4	162.0
4 R19-23	23.0			5.6	5.5	612.6	646.6
5 R24plus	52.6	0.1	1.2	22.4	101.4	1,104.2	1,282.0
06 Hawke's Bay Region	**63.0**	**2.2**	**10.6**	**16.3**	**145.6**	**1,418.7**	**1,656.4**
1 R3-7	2.2				1.9	74.5	78.6
2 R7-11					0.5	15.9	16.4
3 R12-18	4.4		10.6	13.7	23.1	75.1	126.9
4 R19-23	13.8				23.3	379.4	416.5

5 R24plus	42.5	2.2		2.6	96.9	873.8	1,018.0
07 Taranaki Region	**132.6**	**3.6**	**8.9**	**3.7**	**160.2**	**1,386.5**	**1,695.5**
1 R3-7				0.1	2.2	45.9	48.2
2 R7-11	1.8				0.1	8.9	10.8
3 R12-18	23.5				4.5	129.5	157.4
4 R19-23	46.3			0.0	22.1	379.9	448.3
5 R24plus	61.0	3.6	8.9	3.6	131.3	822.4	1,030.8
08 Manawatu-Wanganui Region	**214.7**	**11.7**	**7.7**	**15.8**	**313.7**	**4,683.4**	**5,247.1**
1 R3-7	6.9				14.3	301.6	322.9
2 R7-11	21.5	3.8			3.6	111.8	140.7
3 R12-18	37.0				44.0	376.9	458.0
4 R19-23	38.6		7.7		31.7	1,302.8	1,380.9
5 R24plus	110.7	8.0		15.8	220.0	2,590.2	2,944.7
09 Wellington Region	**20.1**		**3.5**	**3.7**	**20.7**	**515.1**	**563.1**
1 R3-7						33.8	33.8
2 R7-11					5.5	18.9	24.4
3 R12-18	3.7		0.3			62.6	66.7
4 R19-23	2.7		1.1		6.8	121.8	132.5
5 R24plus	13.7		2.1	3.7	8.3	277.9	305.7
Grand Total	**787.6**	**36.6**	**47.5**	**135.0**	**1,738.7**	**20,679.0**	**23,424.5**

Table C.2: North Island results of the FIF model run on the LUM 1–40ha scenario by LCDB age classes

Sum of Ha	Likelihood of harvesting						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
01 Northland Region	**221.2**	**17.2**	**24.3**	**115.8**	**1,684.4**	**9,603.9**	**11,666.7**
1 R3-7	2.2			5.2	31.4	430.0	468.7
2 R7-11	11.1				40.8	222.8	274.8
3 R12-18	17.4			10.8	41.6	646.2	716.0
4 R19-23	33.5	5.6	11.0	23.4	401.2	2,165.7	2,640.5
5 R24plus	156.9	11.6	13.2	76.5	1,169.4	6,139.1	7,566.7
02 Auckland Region	**66.6**		**3.5**	**52.1**	**454.6**	**4,065.2**	**4,642.1**
1 R3-7				0.0	0.1	123.6	123.7
2 R7-11					4.6	105.1	109.7
3 R12-18	1.7				16.4	239.7	257.8
4 R19-23	27.2			24.5	56.6	805.4	913.7
5 R24plus	37.8		3.5	27.6	376.9	2,791.4	3,237.2
03 Waikato Region	**473.7**	**44.9**	**28.5**	**135.1**	**2,377.3**	**15,106.6**	**18,166.1**
1 R3-7	13.4			13.0	211.1	1,150.6	1,388.1
2 R7-11	21.7		2.5		48.2	928.0	1,000.4
3 R12-18	50.5		4.7	6.8	179.3	1,050.5	1,291.8
4 R19-23	116.4	15.5	3.4	46.7	579.0	3,788.9	4,550.0
5 R24plus	271.6	29.5	17.9	68.5	1,359.6	8,188.6	9,935.7
04 Bay of Plenty Region	**290.4**	**14.2**	**20.1**	**9.8**	**378.2**	**5,381.0**	**6,093.8**
1 R3-7	9.5				43.2	601.5	654.2
2 R7-11	1.9				6.7	204.3	213.0
3 R12-18	44.0			6.6	54.5	693.2	798.3
4 R19-23	31.9	5.8		1.4	46.4	679.4	764.9
5 R24plus	203.1	8.4	20.1	1.8	227.4	3,202.6	3,663.4

05 Gisborne Region	**292.8**	**12.8**	**2.6**	**34.5**	**488.3**	**3,888.1**	**4,719.0**
1 R3-7	4.0	0.3			15.0	85.2	104.4
2 R7-11	40.5			9.8	52.6	107.6	210.5
3 R12-18	23.9				16.4	268.8	309.1
4 R19-23	47.5	2.2		2.7	58.7	419.2	530.3
5 R24plus	177.0	10.3	2.6	22.0	345.6	3,007.2	3,564.6
06 Hawke's Bay Region	**160.9**	**21.4**	**8.2**	**33.2**	**1,186.0**	**9,545.0**	**10,954.7**
1 R3-7	8.6			4.9	47.5	567.1	628.2
2 R7-11	6.3	4.5			39.5	484.9	535.3
3 R12-18	19.4	1.3	1.2	7.9	105.0	1,075.8	1,210.5
4 R19-23	14.0	6.0		8.4	189.5	1,831.6	2,049.4
5 R24plus	112.6	9.6	7.1	12.0	804.5	5,585.5	6,531.3
07 Taranaki Region	**186.0**	**3.1**	**4.3**	**17.8**	**607.8**	**5,005.1**	**5,824.1**
1 R3-7	2.4		0.3		14.7	180.3	197.7
2 R7-11	14.8				18.0	117.8	150.6
3 R12-18	14.7				56.4	276.2	347.3
4 R19-23	25.9				86.8	847.8	960.4
5 R24plus	128.2	3.1	4.0	17.8	431.9	3,583.1	4,168.1
08 Manawatu-Wanganui Region	**615.4**	**46.6**	**5.2**	**62.4**	**1,205.9**	**12,379.1**	**14,314.6**
1 R3-7	26.1	1.7		0.7	46.4	789.8	864.7
2 R7-11	46.4			3.9	52.0	561.8	664.0
3 R12-18	56.0	20.1		6.2	149.3	1,234.4	1,466.1
4 R19-23	162.2	5.3	1.6	16.9	251.5	2,443.8	2,881.3
5 R24plus	324.7	19.5	3.6	34.8	706.7	7,349.3	8,438.6
09 Wellington Region	**500.6**	**36.0**	**14.8**	**56.4**	**718.5**	**6,932.4**	**8,258.8**
1 R3-7			0.1		10.8	116.1	126.9
2 R7-11	25.4			2.8	45.5	293.8	367.5
3 R12-18	131.2	14.2		5.8	102.9	1,468.6	1,722.7

4 R19-23	95.5	1.9		8.5	81.1	1,128.5	1,315.6
5 R24plus	248.5	19.9	14.8	39.3	478.3	3,925.5	4,726.1
Total	**2,807.5**	**196.3**	**111.6**	**517.1**	**9,100.9**	**71,906.4**	**84,639.9**

Table C.3: North Island results of the FIF model run on the LUM and LCDB 1–40ha scenario by LCDB age classes

Sum of Ha	**Harvest intentions**						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
01 Northland Region	**405.6**	**40.4**	**16.5**	**175.0**	**2,229.3**	**12,768.8**	**15,635.6**
1 R3-7	12.8	2.8		5.1	43.6	618.6	682.9
2 R7-11	1.7				40.1	349.9	391.7
3 R12-18	21.7		2.6	7.2	95.0	867.2	993.7
4 R19-23	85.8	11.1	1.3	36.4	527.4	3,063.1	3,725.1
5 R24plus	283.6	26.5	12.6	126.4	1,523.1	7,870.0	9,842.1
02 Auckland Region	**98.9**	**7.1**	**1.3**	**43.0**	**697.2**	**6,240.7**	**7,088.3**
1 R3-7					18.7	395.0	413.7
2 R7-11					6.6	167.8	174.4
3 R12-18	1.1	1.2			23.3	360.7	386.3
4 R19-23	36.7	5.9		25.1	103.0	1,293.3	1,464.1
5 R24plus	61.2		1.3	17.9	545.5	4,023.9	4,649.8
03 Waikato Region	**1,355.8**	**69.0**	**13.0**	**199.0**	**3,006.5**	**20,893.8**	**25,537.2**
1 R3-7	84.9	1.9		18.9	180.1	1,618.4	1,904.2
2 R7-11	186.1				47.3	1,007.6	1,241.0
3 R12-18	102.9	3.8		9.3	207.4	1,576.5	1,899.8
4 R19-23	291.1	15.3	1.7	34.3	781.5	5,351.4	6,475.2
5 R24plus	690.9	48.0	11.3	136.6	1,790.2	11,339.9	14,016.9
04 Bay of Plenty Region	**612.1**	**44.0**	**10.8**	**35.3**	**985.6**	**9,766.6**	**11,454.2**
1 R3-7	11.6		3.2		112.9	1,095.1	1,222.8

2 R7-11	11.5				11.2	326.5	349.3
3 R12-18	108.0	5.7	1.5	5.4	40.2	983.0	1,143.8
4 R19-23	53.6			7.6	104.3	1,357.8	1,523.4
5 R24plus	427.2	38.3	6.1	22.2	716.9	6,004.2	7,215.0
05 Gisborne Region	**721.0**	**35.1**	**40.1**	**37.3**	**717.0**	**6,196.4**	**7,746.9**
1 R3-7	10.8				29.1	341.6	381.5
2 R7-11	47.7	5.8			78.3	246.3	378.0
3 R12-18	84.8				42.4	447.7	574.9
4 R19-23	103.9	3.4		1.8	109.6	745.4	964.1
5 R24plus	473.8	25.9	40.1	35.5	457.8	4,415.3	5,448.4
06 Hawke's Bay Region	**516.4**	**51.1**	**21.7**	**49.4**	**1,556.6**	**14,329.2**	**16,524.4**
1 R3-7	39.9	9.0			46.9	990.8	1,086.6
2 R7-11	12.6			2.1	50.4	648.1	713.2
3 R12-18	54.7	9.1	13.2	7.3	157.7	1,314.9	1,557.0
4 R19-23	61.8	3.6	3.1	6.3	255.1	2,587.4	2,917.3
5 R24plus	347.4	29.4	5.5	33.6	1,046.4	8,788.1	10,250.3
07 Taranaki Region	**447.1**	**18.5**	**4.9**	**44.0**	**703.4**	**7,615.6**	**8,833.5**
1 R3-7	22.2				36.6	520.2	579.0
2 R7-11	13.4				7.7	273.3	294.3
3 R12-18	25.2			3.6	41.3	483.4	553.4
4 R19-23	130.7	2.5			96.2	1,270.2	1,499.6
5 R24plus	255.6	16.0	4.9	40.4	521.7	5,068.6	5,907.2
08 Manawatu-Wanganui Region	**1,415.3**	**107.1**	**14.0**	**131.5**	**2,312.0**	**19,115.7**	**23,095.5**
1 R3-7	56.6	4.0	1.7	1.7	133.8	1,144.8	1,342.7
2 R7-11	177.4	6.1		3.9	31.9	921.9	1,141.1
3 R12-18	155.0	11.3	0.9	1.9	167.0	1,649.7	1,985.8
4 R19-23	274.5	25.7	2.1	58.0	335.0	3,593.4	4,288.7
5 R24plus	751.8	60.0	9.2	66.0	1,644.3	11,805.9	14,337.2

09 Wellington Region	**1,084.2**	**49.2**	**17.0**	**96.8**	**1,207.8**	**10,313.2**	**12,768.1**
1 R3-7				2.1	20.1	216.9	239.0
2 R7-11	60.6	3.5		6.2	50.0	377.0	497.3
3 R12-18	212.5	12.6		18.7	192.5	1,963.5	2,399.9
4 R19-23	158.2	7.3		4.2	140.8	1,581.3	1,891.8
5 R24plus	652.9	25.9	17.0	65.6	804.3	6,174.5	7,740.2
Total	**6,656.4**	**421.5**	**139.2**	**811.2**	**13,415.4**	**107,240.0**	**128,683.8**

Table C.4: North Island results of the FIF model run on the LUM all-forests plus LCDB 1–40ha scenario by LCDB age classes

Sum of Ha	**Likelihood of harvesting**						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
Blank	**10,418.4**	**310.9**	**74.0**	**532.6**	**7,544.0**	**124,588.4**	**143,468.3**
	10,413.4	310.9	74.0	532.6	7,530.9	124,541.0	143,402.7
2 R7-11						0.6	0.6
3 R12-18						0.2	0.2
4 R19-23						0.3	0.3
5 R24plus	5.0				13.1	46.2	64.4
01 Northland Region	**356.6**	**32.6**	**33.8**	**168.0**	**1,992.2**	**151,440.3**	**154,023.5**
1 R3-7	6.8	2.8		7.2	49.3	23,569.1	23,635.3
2 R7-11	1.7				22.1	8,440.2	8,464.1
3 R12-18	15.8			21.6	85.5	8,105.6	8,228.6
4 R19-23	85.2	13.5	20.5	35.4	467.2	14,037.5	14,659.3
5 R24plus	247.1	16.3	13.2	103.8	1,368.0	97,288.0	99,036.4
02 Auckland Region	**67.3**	**7.1**	**8.1**	**47.7**	**832.6**	**44,916.9**	**45,879.7**
1 R3-7					28.8	3,786.8	3,815.5

2 R7-11				1.2	10.3	2,563.4	2,574.9
3 R12-18		1.2		3.8	23.3	6,289.1	6,317.4
4 R19-23	32.4	5.9	3.8	6.1	171.2	5,357.6	5,577.0
5 R24plus	34.9		4.3	36.6	599.1	26,920.0	27,594.9
03 Waikato Region	**2,271.2**	**73.2**	**16.3**	**249.9**	**2,756.3**	**287,720.4**	**293,087.4**
1 R3-7	38.4	1.9		18.9	186.9	35,233.1	35,479.2
2 R7-11	969.0				36.2	20,098.4	21,103.6
3 R12-18	53.9	3.8		31.7	163.8	31,126.4	31,379.6
4 R19-23	444.8	17.2	1.7	29.5	707.3	41,750.0	42,950.3
5 R24plus	765.1	50.4	14.7	169.8	1,662.2	159,512.5	162,174.7
04 Bay of Plenty Region	**590.4**	**14.0**	**10.8**	**35.0**	**816.4**	**266,428.0**	**267,894.7**
1 R3-7	11.6		3.2		51.7	42,892.8	42,959.3
2 R7-11	6.7				4.3	34,855.1	34,866.2
3 R12-18	56.2		1.5	5.4	93.3	33,832.6	33,989.0
4 R19-23	55.1			14.9	61.7	34,392.3	34,524.0
5 R24plus	460.7	14.0	6.1	14.7	605.4	120,455.1	121,556.1
05 Gisborne Region	**1,807.0**	**24.9**	**21.4**	**98.7**	**585.7**	**162,826.9**	**165,364.7**
1 R3-7	29.6				22.2	9,759.0	9,810.8
2 R7-11	530.3	5.8	17.0		38.2	8,913.4	9,504.6
3 R12-18	101.1			78.3	29.0	12,267.3	12,475.8
4 R19-23	623.7	3.4		1.8	83.9	24,551.5	25,264.3
5 R24plus	522.3	15.7	4.5	18.6	412.4	107,335.7	108,309.1
06 Hawke's Bay Region	**562.1**	**39.0**	**6.0**	**54.1**	**1,462.3**	**148,092.5**	**150,216.1**
1 R3-7	45.8	0.1			43.9	15,928.6	16,018.4
2 R7-11	8.2			2.1	45.1	11,316.9	11,372.4
3 R12-18	97.0	6.8		17.2	131.9	15,934.8	16,187.6
4 R19-23	77.8	3.6	3.1	6.3	229.9	28,497.6	28,818.4
5 R24plus	333.2	28.6	2.9	28.5	1,011.5	76,414.6	77,819.3

07 Taranaki Region	**470.6**	**6.8**	**4.9**	**31.3**	**582.3**	**25,050.3**	**26,146.1**
1 R3-7	36.9				45.7	786.0	868.7
2 R7-11	6.8				7.7	1,855.5	1,869.9
3 R12-18	13.9			1.4	33.0	1,587.3	1,635.7
4 R19-23	120.8	2.5			105.2	5,612.0	5,840.5
5 R24plus	292.2	4.3	4.9	30.0	390.6	15,209.4	15,931.3
08 Manawatu-Wanganui Region	**1,646.5**	**66.3**	**7.7**	**95.2**	**2,108.1**	**133,905.3**	**137,829.0**
1 R3-7	34.5		1.7	7.8	79.0	13,253.4	13,376.5
2 R7-11	119.6	1.6		3.9	22.8	6,247.5	6,395.4
3 R12-18	181.5	2.0	0.9		158.0	12,340.4	12,682.9
4 R19-23	323.5	14.1		17.5	302.6	29,962.4	30,620.2
5 R24plus	987.3	48.4	5.0	66.0	1,545.6	72,101.6	74,754.0
09 Wellington Region	**682.5**	**24.6**	**12.8**	**52.1**	**1,061.3**	**69,105.8**	**70,939.2**
1 R3-7	23.9			2.1	16.7	4,709.1	4,751.8
2 R7-11	34.8				49.8	4,246.6	4,331.2
3 R12-18	110.6	11.0		4.0	145.6	9,829.7	10,100.9
4 R19-23	67.9			1.1	126.1	11,165.6	11,360.8
5 R24plus	445.2	13.6	12.8	45.0	723.2	39,154.8	40,394.6
Total	**8,454.3**	**288.6**	**121.8**	**832.0**	**12,197.3**	**1,289,486.4**	**1,311,380.3**

FIF results by South Island regions and LCDB age-classes

Table C.5: South Island results of the FIF model run on the NZFFA Small Owner Database scenario by LCDB age classes

Sum of Ha	Likelihood of harvest						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
12 West Coast Region	**13.5**		**53.3**		**59.8**	**777.7**	**904.3**
1 R3-7	3.2		5.8			18.4	27.4
2 R7-11						1.5	1.5
3 R12-18			2.1		5.1	76.1	83.4
4 R19-23					9.6	220.2	229.8
5 R24plus	10.4		45.4		45.1	461.5	562.3
13 Canterbury Region	**281.0**	**14.7**	**262.5**	**30.7**	**461.3**	**2,849.7**	**3,899.8**
1 R3-7			7.8		12.1	67.6	87.4
2 R7-11	2.9				0.1	53.1	56.1
3 R12-18	39.3		36.7	6.3	78.2	330.3	490.8
4 R19-23	88.2	2.2	9.4		13.4	453.7	566.8
5 R24plus	150.5	12.5	208.7	24.5	357.5	1,945.1	2,698.7
14 Otago Region	**101.0**	**13.2**	**90.7**	**18.6**	**441.7**	**3,382.5**	**4,047.6**
1 R3-7			3.7	2.9	10.0	37.9	54.6
2 R7-11	2.3				1.7	41.9	45.9
3 R12-18	12.6		9.0	0.8	23.9	167.1	213.4
4 R19-23	11.8		7.9	4.2	92.3	911.2	1,027.4
5 R24plus	74.2	13.2	70.1	10.7	313.7	2,224.3	2,706.2
15 Southland Region	**34.8**		**120.0**	**10.5**	**141.3**	**1,134.1**	**1,440.6**
1 R3-7	1.6		1.0		35.9	87.4	125.9
2 R7-11	1.2					9.7	10.8
3 R12-18	0.1		25.1		8.7	95.8	129.8

4 R19-23	13.5		7.6		2.8	128.8	152.7
5 R24plus	18.4		86.2	10.5	94.0	812.4	1,021.4
16 Tasman Region	**363.0**	**38.2**	**259.7**	**2.4**	**283.6**	**1,853.2**	**2,800.1**
1 R3-7	26.8	0.4	8.3		7.0	264.4	306.9
2 R7-11	0.1	2.9	24.4		3.4	87.9	118.8
3 R12-18	29.0	1.8	0.1		55.8	179.0	265.8
4 R19-23	66.0	4.2	35.4		39.3	476.4	621.2
5 R24plus	241.2	28.9	191.5	2.4	178.0	845.3	1,487.4
17 Nelson Region	**2.1**		**0.0**	**6.0**	**9.6**	**237.3**	**255.0**
1 R3-7					0.2	40.1	40.4
2 R7-11						0.4	0.4
3 R12-18					2.7	40.1	42.9
4 R19-23					1.8	3.9	5.6
5 R24plus	2.1		0.0	6.0	4.9	152.8	165.8
18 Marlborough Region	**898.8**	**45.5**	**111.8**	**16.3**	**269.5**	**1,675.7**	**3,017.5**
1 R3-7	37.6	7.1	5.2		31.0	166.9	247.9
2 R7-11	15.7		9.2		1.0	93.8	119.7
3 R12-18	42.2	6.5	22.8		28.7	217.7	317.8
4 R19-23	193.5	2.9	39.3		90.3	340.8	666.8
5 R24plus	609.7	29.0	35.2	16.3	118.4	856.6	1,665.2
Total	**1,694.1**	**111.5**	**897.9**	**84.5**	**1,666.7**	**11,910.1**	**16,364.8**

Table C.6: South Island results of the FIF model run on the LUM 1–40ha scenario by LCDB age classes

The FIF results for this scenario do not overlap with the LCDB age classes

Table C.7: South Island results of the FIF model run on the LUM and LCDB 1–40ha scenario by LCDB age classes

Sum of Ha	Likelihood of harvest						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
12 West Coast Region	**245.8**	**23.0**	**631.6**	**10.6**	**511.6**	**3,355.4**	**4,778.0**
1 R3-7	1.9		64.1		36.9	259.7	362.6
2 R7-11	0.8		17.3		47.8	27.4	93.3
3 R12-18	40.4	5.8	25.3	1.1	42.4	268.9	383.9
4 R19-23	42.0		32.4		31.3	571.7	677.4
5 R24plus	160.6	17.1	492.6	9.4	353.2	2,227.8	3,260.8
13 Canterbury Region	**2,620.2**	**218.2**	**2,645.3**	**470.2**	**6,403.0**	**24,209.8**	**36,566.7**
1 R3-7	41.9	2.0	112.7	4.1	142.7	886.9	1,190.2
2 R7-11	43.2		138.7	32.0	117.2	438.1	769.1
3 R12-18	335.8	15.2	266.5	55.8	705.1	4,014.9	5,393.2
4 R19-23	156.7	8.8	92.1	3.1	254.8	1,502.9	2,018.4
5 R24plus	2,042.6	192.2	2,035.3	375.3	5,183.3	17,366.9	27,195.7
14 Otago Region	**782.9**	**112.9**	**3,342.0**	**187.7**	**3,602.0**	**13,424.3**	**21,451.9**
1 R3-7	24.8		61.6		67.8	451.6	605.8
2 R7-11	38.7		89.3		103.1	494.9	726.0
3 R12-18	69.4	2.9	221.2	10.1	216.5	916.3	1,436.3
4 R19-23	69.2	7.0	281.7	6.7	374.7	2,053.6	2,792.9
5 R24plus	580.8	103.0	2,688.1	171.0	2,840.0	9,507.9	15,890.8
15 Southland Region	**600.6**	**35.0**	**1,210.1**	**70.5**	**2,046.1**	**9,061.4**	**13,023.6**
1 R3-7	24.5	2.1	174.1		118.6	806.6	1,125.8
2 R7-11	29.1	6.5	22.1	4.6	65.7	260.2	388.2
3 R12-18	69.9		124.5	3.1	85.0	717.4	1,000.0
4 R19-23	40.5	9.4	96.0	4.5	122.7	839.3	1,112.4
5 R24plus	436.5	17.0	793.4	58.3	1,654.1	6,437.9	9,397.2

16 Tasman Region	**897.6**	**37.5**	**766.0**	**89.5**	**802.8**	**4,411.8**	**7,005.3**
1 R3-7	42.8	1.4	101.2	9.8	38.9	346.5	540.7
2 R7-11	2.8	3.0	27.9		30.0	261.0	324.8
3 R12-18	165.6	2.0	62.3	8.2	92.3	504.5	834.7
4 R19-23	245.9		52.1	17.5	209.2	952.1	1,476.8
5 R24plus	440.5	31.1	522.6	53.9	432.4	2,347.8	3,828.3
17 Nelson Region	**47.0**	**6.2**	**16.3**	**3.2**	**107.7**	**703.9**	**884.2**
1 R3-7	2.9				10.9	73.4	87.1
2 R7-11						9.1	9.1
3 R12-18	16.8	2.3		3.2	21.0	76.2	119.4
4 R19-23	6.4				3.6	34.5	44.5
5 R24plus	20.9	3.9	16.3		72.2	510.7	624.1
18 Marlborough Region	**1,196.1**	**33.4**	**1,380.8**	**94.1**	**786.5**	**3,146.6**	**6,637.6**
1 R3-7	82.2	7.7	33.7		51.7	237.6	413.0
2 R7-11	2.2		4.3		23.0	90.3	119.9
3 R12-18	263.9	3.6	103.7	27.1	72.5	322.1	793.0
4 R19-23	193.5	1.8	224.8	4.8	72.0	715.5	1,212.3
5 R24plus	654.2	20.4	1,014.4	62.2	567.2	1,781.1	4,099.4
Total	**6,390.3**	**466.1**	**9,992.2**	**925.8**	**14,259.7**	**58,313.2**	**90,347.2**

Table C.8: Results of the FIF model run on the LUM all-forests plus LCDB 1–40ha scenario by LCDB age classes

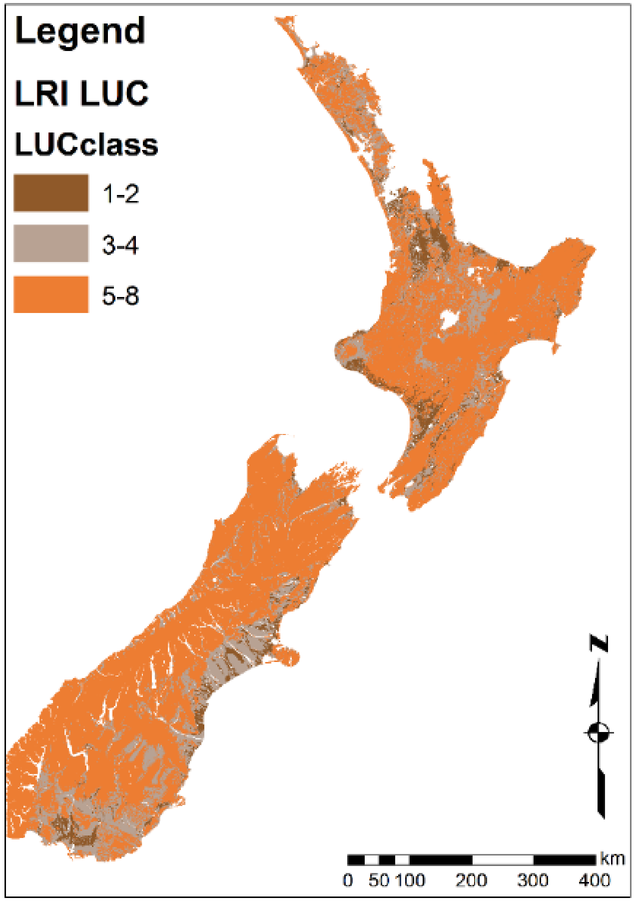
Sum of Ha	**Likelihood of harvest**						
	Highly unlikely	**Unlikely**	**Fairly unlikely**	**Fairly likely**	**Likely**	**Highly likely**	**Total**
12 West Coast Region	**467.1**	**18.1**	**1,251.0**	**9.4**	**458.4**	**36,775.7**	**38,979.7**
1 R3-7	1.9		70.2		26.0	3,277.0	3,375.1
2 R7-11	0.8		138.0		42.0	2,354.3	2,535.2
3 R12-18	317.4	4.0	54.6		35.8	5,737.5	6,149.2

4 R19-23	42.0		84.6		35.1	4,648.5	4,810.2
5 R24plus	104.9	14.1	903.7	9.4	319.4	20,758.4	22,109.9
13 Canterbury Region	**5,507.7**	**245.1**	**6,592.1**	**436.2**	**6,242.0**	**94,128.1**	**113,151.3**
1 R3-7	51.7	2.0	179.1	4.0	131.3	6,293.2	6,661.2
2 R7-11	439.9		925.5	20.8	209.9	6,161.5	7,757.8
3 R12-18	919.3	17.2	1,597.5	37.4	693.2	14,225.6	17,490.2
4 R19-23	1,316.9	9.7	340.6	8.1	259.2	11,821.1	13,755.6
5 R24plus	2,779.8	216.3	3,549.3	366.0	4,948.4	55,626.7	67,486.4
14 Otago Region	**868.6**	**150.2**	**8,065.5**	**193.3**	**3,522.6**	**123,380.5**	**136,180.7**
1 R3-7	12.1		218.1		69.6	10,055.9	10,355.6
2 R7-11	38.1		1,277.1		92.4	13,585.9	14,993.5
3 R12-18	57.9	18.7	1,399.8	12.3	221.1	14,272.0	15,981.8
4 R19-23	62.0	16.3	1,099.6	9.0	304.3	30,655.9	32,147.1
5 R24plus	698.4	115.2	4,070.9	172.0	2,835.3	54,810.9	62,702.8
15 Southland Region	**1,429.8**	**39.7**	**8,920.2**	**70.1**	**2,103.4**	**72,983.5**	**85,546.7**
1 R3-7	24.5	2.1	799.7		126.5	7,034.0	7,986.8
2 R7-11	449.9	4.4	959.3		69.1	3,741.3	5,224.1
3 R12-18	454.4		3,165.9	3.1	136.5	8,498.4	12,258.3
4 R19-23	124.8	7.1	753.3	2.3	103.7	20,487.3	21,478.6
5 R24plus	376.1	26.1	3,242.0	64.7	1,667.5	33,222.5	38,598.9
16 Tasman Region	**1,003.9**	**42.9**	**1,884.7**	**48.0**	**656.1**	**92,836.8**	**96,472.3**
1 R3-7	12.8	1.4	93.2		25.9	11,875.1	12,008.3
2 R7-11	8.3	3.0	151.9		26.7	11,023.9	11,213.8
3 R12-18	228.7	2.0	223.4	8.2	86.5	13,713.9	14,262.6
4 R19-23	274.4		334.7	17.5	175.8	10,191.5	10,993.9
5 R24plus	479.8	36.5	1,081.5	22.2	341.2	46,032.4	47,993.6
17 Nelson Region	**31.9**	**1.9**	**256.1**		**58.6**	**10,418.9**	**10,767.4**
1 R3-7	2.9		43.0		10.9	1,384.8	1,441.6

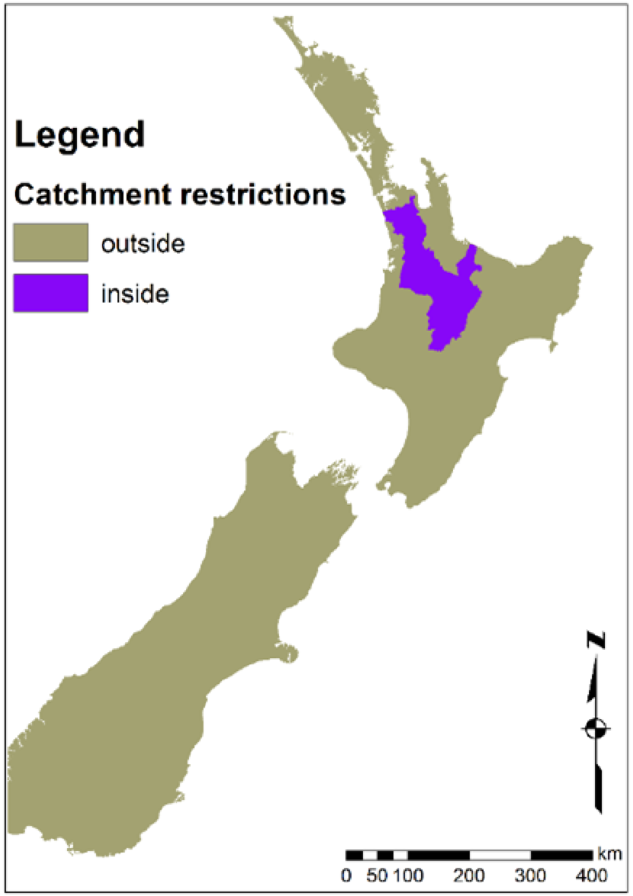
2 R7-11						809.0	809.0
3 R12-18	8.9				13.0	1,547.7	1,569.5
4 R19-23	4.5		4.4		6.8	741.6	757.4
5 R24plus	15.6	1.9	208.7		27.9	5,935.7	6,189.8
18 Marlborough Region	**3,827.0**	**39.8**	**5,119.0**	**67.7**	**849.2**	**63,277.3**	**73,179.9**
1 R3-7	96.6	7.7	142.7		155.8	7,666.2	8,069.0
2 R7-11	29.7	4.3	166.4		22.8	3,625.7	3,849.0
3 R12-18	260.1	3.6	176.7	14.1	45.2	6,751.8	7,251.6
4 R19-23	959.4		2,129.7	4.8	165.6	7,418.8	10,678.2
5 R24plus	2,481.2	24.1	2,503.5	48.8	459.7	37,814.8	43,332.2
Total	**13,135.8**	**537.6**	**32,088.7**	**824.7**	**13,890.3**	**493,800.8**	**554,277.9**

Appendix D. Data layers used in the regression analysis

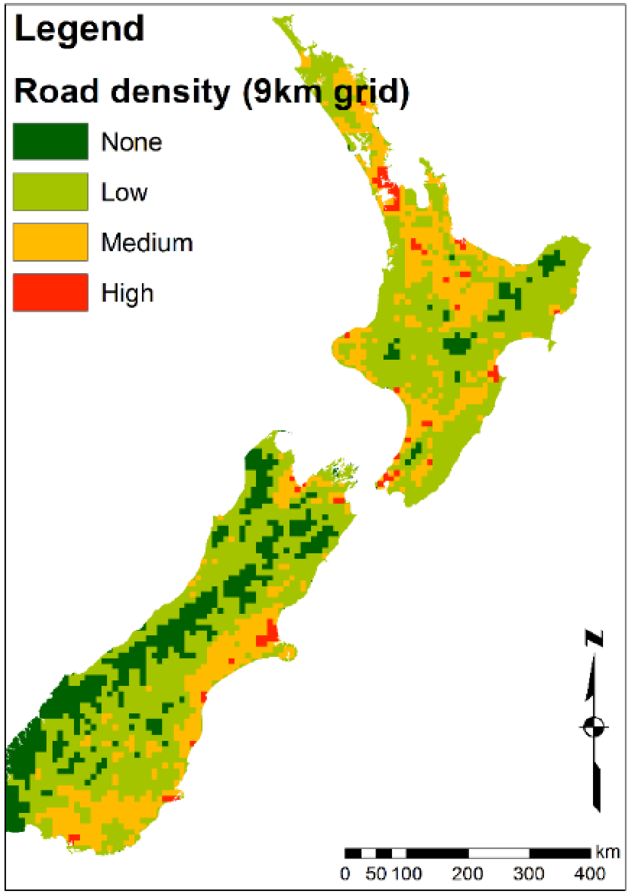
Example maps of the data layers used in the regression analysis are shown in Figure D.1



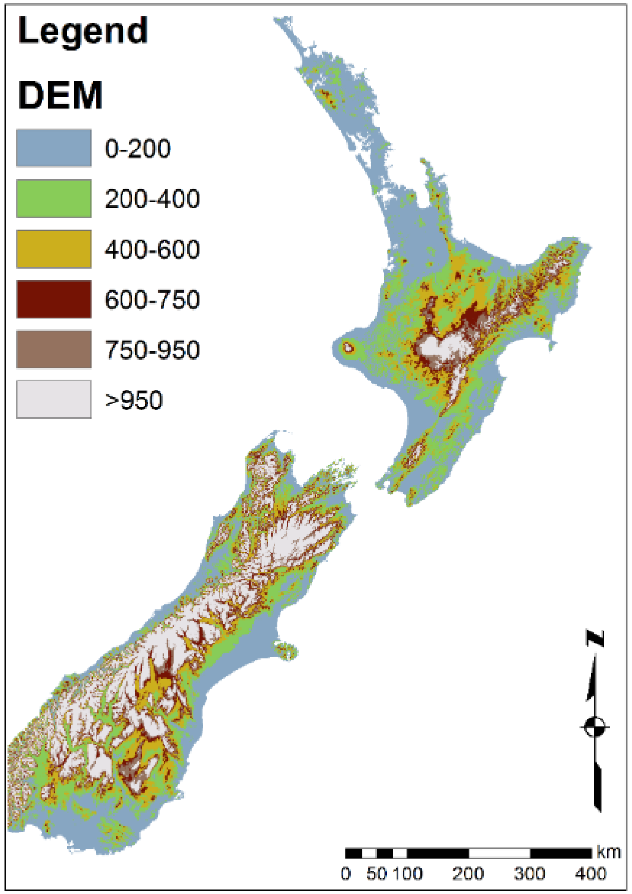
a) LUC classes



b) Catchments with water quality constraints



c) Road density grids



d) Elevation

Figure D.1. Examples of the classifications for the input datasets – the independent variables in the regression analysis

Appendix E. Results for the deforestation intentions econometric modelling: area of forest / deforestation

Regression variable descriptors

Table E.1 Summary of the deforestation observations

Region	Region Name	Obs	%	Mean	Std Dev	Min	Max	Area
1	Northland	2,310	5.8%	1.75	6.58	0.000004	178.579200	4,043
2	Auckland	1,177	3.0%	1.76	7.22	0.000007	143.844500	2,070
3	Waikato	8,838	22.3%	6.04	45.32	0.000004	1,921.910000	53,385
4	Bay of Plenty	3,074	7.8%	3.51	18.86	0.000016	464.482200	10,791
5	Gisborne	595	1.5%	2.14	5.04	0.000026	68.349560	1,273
6	Hawke's Bay	1,995	5.0%	2.86	16.64	0.000024	400.125500	5,704
7	Taranaki	1,869	4.7%	0.99	2.39	0.000009	41.791460	1,859
8	Manawatu-Wanganui	4,027	10.2%	3.20	28.73	0.000005	630.475000	12,891
9	Wellington	983	2.5%	1.85	7.04	0.000005	151.541100	1,815
10	West Coast	1,692	4.3%	2.42	10.05	0.000007	191.193500	4,099
11	Canterbury	5,450	13.8%	3.79	16.33	0.000006	546.285100	20,640
12	Otago	2,344	5.9%	1.80	5.35	0.000016	128.083500	4,211
13	Southland	2,290	5.8%	1.62	5.67	0.000008	210.505000	3,710
14	Tasman	1,803	4.6%	3.60	25.43	0.000024	450.233000	6,498
15	Nelson	313	0.8%	1.60	4.22	0.000156	64.585210	500
16	Marlborough	675	1.7%	2.71	8.19	0.000016	86.027920	1,830
0	Unclassified	191	0.5%	4	20	0.000071	265.605300	767
	TOTAL	39,626	100.0%					136,086

Results for regression variables

Table E.2: Coefficient estimates from Ordinary Least Squares (OLS) and Tobit regression models

	Model 1 OLS (depvar: areaha)			Model 2 OLS Robust (depvar: areaha)			Model 3 OLS Robust (depvar: lnarea)			Model 4 Tobit (lnarea–uncensored)			Model 5 Tobit (lnarea–< 1 ha censored)			Model 6 Tobit (lnarea–< 40 ha censored)		
Variable name	Coeff	Std Err	p-value	Coeff	Std Err	p-value	Coeff	Std Err	p-value	Coeff	Std Err	p-value	Coeff	Std Err	p-value	Coeff	Std Err	p-value
nz_slope_c2	-0.455	0.317	0.151	-0.455	0.348	0.191	-0.069	0.029	0.017	**-0.069**	**0.029**	**0.017**	**-0.062**	**0.027**	**0.020**	-0.078	0.106	0.458
nz_slope_c3	-0.593	0.462	0.199	-0.593	0.388	0.126	-0.041	0.042	0.327	-0.041	0.042	0.326	**-0.056**	**0.039**	**0.149**	-0.089	0.155	0.565
nz_slope_c4	-0.760	1.545	0.623	-0.760	1.384	0.583	-0.253	0.141	0.072	**-0.253**	**0.140**	**0.070**	**-0.295**	**0.133**	**0.027**	0.204	0.461	0.657
nz_dem_cla2	0.504	0.373	0.177	0.504	0.214	0.019	0.086	0.033	0.009	**0.086**	**0.034**	**0.011**	**0.116**	**0.031**	**0.000**	**0.223**	**0.138**	**0.105**
nz_dem_cla3	0.205	0.573	0.721	0.205	0.673	0.761	0.109	0.052	0.037	**0.109**	**0.052**	**0.036**	**0.154**	**0.048**	**0.001**	0.192	0.186	0.303
nz_dem_cla4	2.581	0.896	0.004	2.581	1.261	0.041	0.216	0.083	0.009	**0.216**	**0.081**	**0.008**	**0.247**	**0.073**	**0.001**	**0.688**	**0.263**	**0.009**
nz_dem_cla5	11.663	1.358	0.000	11.663	3.507	0.001	0.605	0.120	0.000	**0.605**	**0.123**	**0.000**	**0.571**	**0.107**	**0.000**	**1.330**	**0.353**	**0.000**
nz_dem_cla6	32.698	3.086	0.000	32.698	13.379	0.015	0.649	0.303	0.032	**0.649**	**0.279**	**0.020**	**0.576**	**0.244**	**0.018**	**2.489**	**0.615**	**0.000**
CWardAgeCl~2	0.511	0.565	0.365	0.511	0.705	0.469	0.114	0.052	0.027	**0.114**	**0.051**	**0.025**	0.058	0.047	0.220	0.183	0.191	0.337
CWardAgeCl~3	-0.508	0.763	0.505	-0.508	0.785	0.517	0.113	0.068	0.098	**0.113**	**0.069**	**0.101**	0.022	0.064	0.733	-0.081	0.275	0.769
CWardMedIn3	-0.585	0.378	0.122	-0.585	0.372	0.116	0.034	0.034	0.316	0.034	0.034	0.316	**-0.055**	**0.032**	**0.082**	**-0.217**	**0.130**	**0.096**
CWardMedIn4	-1.044	0.459	0.023	-1.044	0.314	0.001	-0.026	0.041	0.532	-0.026	0.042	0.534	**-0.064**	**0.039**	**0.100**	**-0.263**	**0.179**	**0.140**
CWardMedIn5	-0.644	0.518	0.214	-0.644	0.369	0.081	0.064	0.046	0.167	0.064	0.047	0.173	0.046	0.043	0.286	-0.007	0.189	0.970
CWardMedIn6	-1.358	0.747	0.069	-1.358	0.495	0.006	-0.122	0.070	0.081	**-0.122**	**0.068**	**0.070**	-0.012	0.063	0.847	-0.131	0.247	0.595
AveAnnRain3	-0.400	0.473	0.398	-0.400	0.284	0.160	-0.135	0.042	0.001	**-0.135**	**0.043**	**0.002**	**-0.185**	**0.039**	**0.000**	**-0.352**	**0.177**	**0.047**
AveAnnRain4	0.792	0.560	0.158	0.792	0.407	0.052	-0.144	0.050	0.004	**-0.144**	**0.051**	**0.004**	**-0.158**	**0.047**	**0.001**	0.221	0.202	0.273
AveAnnTemp2	19.762	2.815	0.000	19.762	6.975	0.005	0.430	0.244	0.078	**0.430**	**0.254**	**0.091**	0.324	0.223	0.147	**1.466**	**0.936**	**0.117**
AnnGDD2	-1.180	0.444	0.008	-1.180	0.348	0.001	-0.081	0.039	0.041	**-0.081**	**0.040**	**0.045**	**-0.073**	**0.037**	**0.049**	**-0.393**	**0.152**	**0.010**
PathDis_cl2	0.125	0.359	0.728	0.125	0.237	0.598	0.017	0.032	0.603	0.017	0.032	0.609	-0.025	0.030	0.415	-0.073	0.136	0.594
PathDis_cl3	-2.142	0.973	0.028	-2.142	0.690	0.002	-0.115	0.089	0.197	-0.115	0.088	0.192	-0.102	0.080	0.205	-0.445	0.370	0.230
UrbanProx2	0.312	0.481	0.516	0.312	0.439	0.478	0.010	0.042	0.821	0.010	0.043	0.825	**0.095**	**0.040**	**0.017**	**0.405**	**0.162**	**0.012**
MeatDairyP2	-0.138	0.439	0.753	-0.138	0.400	0.730	0.011	0.040	0.791	0.011	0.040	0.791	0.003	0.037	0.932	0.165	0.163	0.312
MeatDairyP3	2.323	1.926	0.228	2.323	1.360	0.088	0.143	0.176	0.417	0.143	0.174	0.411	0.160	0.158	0.311	0.729	0.626	0.245

	Model 1 OLS (depvar: areaha)			Model 2 OLS Robust (depvar: areaha)			Model 3 OLS Robust (depvar: lnarea)			Model 4 Tobit (lnarea–uncensored)			Model 5 Tobit (lnarea–< 1 ha censored)			Model 6 Tobit (lnarea–< 40 ha censored)		
DairyProx2	0.377	0.296	0.203	0.377	0.310	0.224	0.054	0.027	0.042	**0.054**	**0.027**	**0.044**	0.028	0.025	0.253	-0.123	0.100	0.219
LUCclass2	0.610	0.569	0.283	0.610	0.267	0.022	0.053	0.050	0.289	0.053	0.051	0.302	**0.086**	**0.048**	**0.073**	**0.575**	**0.282**	**0.042**
LUCclass3	0.458	0.589	0.437	0.458	0.372	0.218	0.041	0.052	0.436	0.041	0.053	0.446	**0.082**	**0.050**	**0.100**	**0.530**	**0.286**	**0.064**
cadastral2	1.427	0.578	0.014	1.427	0.259	0.000	0.190	0.052	0.000	**0.190**	**0.052**	**0.000**	**0.220**	**0.049**	**0.000**	**0.715**	**0.254**	**0.005**
cadastral3	2.568	0.599	0.000	2.568	0.363	0.000	0.409	0.055	0.000	**0.409**	**0.054**	**0.000**	**0.410**	**0.051**	**0.000**	**1.279**	**0.253**	**0.000**
cadastral4	3.511	0.552	0.000	3.511	0.386	0.000	0.566	0.051	0.000	**0.566**	**0.050**	**0.000**	**0.582**	**0.047**	**0.000**	**1.556**	**0.242**	**0.000**
hort2	-1.052	0.817	0.198	-1.052	1.369	0.442	-0.171	0.074	0.021	**-0.171**	**0.074**	**0.020**	**-0.121**	**0.066**	**0.065**	-0.046	0.233	0.843
road1km2	-0.148	0.449	0.742	-0.148	0.614	0.810	-0.075	0.040	0.061	**-0.075**	**0.041**	**0.066**	**-0.080**	**0.037**	**0.031**	0.010	0.152	0.949
coastline2	0.300	0.394	0.446	0.300	0.190	0.114	-0.146	0.036	0.000	**-0.146**	**0.036**	**0.000**	-0.049	0.034	0.146	**0.279**	**0.162**	**0.085**
impedance2	-0.328	1.514	0.828	-0.328	1.283	0.798	-0.067	0.131	0.606	-0.067	0.137	0.623	-0.095	0.128	0.456	0.123	0.476	0.796
impedance3	-1.388	1.283	0.279	-1.388	0.505	0.006	-0.206	0.117	0.079	**-0.206**	**0.116**	**0.075**	**-0.227**	**0.111**	**0.040**	-0.961	0.729	0.187
southis2	-0.640	0.458	0.162	-0.640	0.339	0.059	0.014	0.040	0.723	0.014	0.041	0.730	-0.045	0.038	0.239	**-0.348**	**0.178**	**0.051**
river2	0.419	0.448	0.350	0.419	0.262	0.110	0.012	0.040	0.763	0.012	0.041	0.766	-0.014	0.037	0.718	0.101	0.164	0.538
Māoriland2	1.894	1.271	0.136	1.894	1.665	0.255	0.059	0.118	0.618	0.059	0.115	0.608	0.071	0.105	0.501	**0.624**	**0.302**	**0.039**
catchment2	2.851	0.465	0.000	2.851	0.448	0.000	0.120	0.042	0.004	**0.120**	**0.042**	**0.004**	**0.154**	**0.039**	**0.000**	**0.976**	**0.161**	**0.000**
lri2	0.414	0.503	0.411	0.414	0.288	0.151	-0.028	0.046	0.539	-0.028	0.045	0.537	0.012	0.042	0.777	0.192	0.174	0.272
lri3	-0.116	0.464	0.803	-0.116	0.372	0.756	-0.047	0.042	0.265	-0.047	0.042	0.263	**-0.139**	**0.039**	**0.000**	-0.404	0.169	0.017
lri4	-0.851	0.495	0.085	-0.851	0.388	0.028	-0.084	0.045	0.062	**-0.084**	**0.045**	**0.060**	**-0.157**	**0.041**	**0.000**	**-0.426**	**0.180**	**0.018**
lri5	-0.561	0.680	0.410	-0.561	0.583	0.336	-0.009	0.062	0.888	-0.009	0.061	0.887	-0.069	0.057	0.224	-0.295	0.231	0.201
built9km2	-2.062	0.736	0.005	-2.062	0.601	0.001	-0.058	0.066	0.383	-0.058	0.067	0.385	-0.068	0.062	0.272	**-0.541**	**0.260**	**0.037**
built15km2	0.558	0.769	0.468	0.558	1.173	0.634	-0.096	0.072	0.182	-0.096	0.069	0.169	**-0.106**	**0.064**	**0.097**	0.003	0.239	0.989
lineden9km2	0.906	0.350	0.010	0.906	0.256	0.000	0.085	0.031	0.006	**0.085**	**0.032**	**0.007**	**0.102**	**0.030**	**0.001**	**0.293**	**0.129**	**0.024**
lineden9km3	1.517	0.566	0.007	1.517	0.559	0.007	0.213	0.051	0.000	**0.213**	**0.051**	**0.000**	**0.221**	**0.047**	**0.000**	**0.681**	**0.181**	**0.000**
lineden15km2	0.372	0.373	0.319	0.372	0.234	0.112	-0.047	0.033	0.153	-0.047	0.034	0.160	**-0.056**	**0.032**	**0.075**	**0.313**	**0.143**	**0.029**
lineden15km3	2.108	0.653	0.001	2.108	0.674	0.002	0.038	0.060	0.533	0.038	0.059	0.525	**0.094**	**0.054**	**0.083**	**0.532**	**0.207**	**0.010**
propdef2	3.852	0.395	0.000	3.852	0.499	0.000	0.749	0.037	0.000	**0.749**	**0.036**	**0.000**	**0.701**	**0.033**	**0.000**	**1.288**	**0.120**	**0.000**
Intercept	-20.373	3.208	0.000	-20.373	7.887	0.010	-1.916	0.286	0.000	**-1.916**	**0.290**	**0.000**	**-1.379**	**0.257**	**0.000**	**-5.583**	**1.135**	**0.000**

	Model 1 OLS (depvar: areaha)	Model 2 OLS Robust (depvar: areaha)	Model 3 OLS Robust (depvar: lnarea)	Model 4 Tobit (lnarea–uncensored)	Model 5 Tobit (lnarea–< 1 ha censored)	Model 6 Tobit (lnarea–< 40 ha censored)
/sigma				2.321 0.008	1.793 0.012	2.313 0.095
Adjusted R squared	0.0153	0.015	0.0212			
Pseudo R2				0.0047	0.0120	0.0882
No. of obs	39626	39626	39626	39626	39626	39626
Left censored obs				0	25785	39143
Uncensored obs				39626	13841	483

Correlation matrices

Table E.3: Correlation matrix–full sample.

Full Sample ***n = 39,626***	Māoriland2	LUCclass1	LUCclass2	LUCclass3	Catchment2
Māoriland2	1.000				
LUCclass1	-0.028	1.000			
p-value	0.000				
LUCclass2	-0.024	-0.216	1.000		
p-value	0.000	0.000			
LUCclass3	0.038	-0.294	-0.870	1.000	
p-value	0.000	0.000	0.000		
Catchment2	0.072	-0.058	-0.073	0.101	1.000
p-value	0.000	0.000	0.000	0.000	

Note 1: Values in the same row as the variable names are correlation coefficients.
Note 2: p-value < 0.15 indicates statistical significance at the 85% confidence level.

Table E.4: Correlation matrix for censoring areas with less than one hectare

> 1 ha n = 13,841	Māoriland2	LUCclass1	LUCclass2	LUCclass3	Catchment2
Māoriland	1.000				
LUCclass1	-0.028	1.000			
p-value	0.001				
LUCclass2	-0.033	-0.216	1.000		
p-value	0.000	0.000			
LUCclass3	0.046	-0.287	-0.874	1.000	
p-value	0.000	0.000	0.000		
Catchment2	0.076	-0.051	-0.094	0.117	1.000
p-value	0.000	0.000	0.000	0.000	

Note 1: Values in the same row as the variable names are correlation coefficients.
Note: p-value < 0.15 indicates statistical significance at the 85% confidence level.

Table E.5: Correlation matrix for areas > 40 hectare

> 40 ha n = 483	Māoriland2	LUCclass1	LUCclass2	LUCclass3	Catchment2
Māoriland2	1.000				
LUCclass1	-0.022	1.000			
p-value	0.630				
LUCclass2	-0.136	-0.117	1.000		
p-value	0.003	0.010			
LUCclass3	0.141	-0.156	-0.963	1.000	
p-value	0.002	0.001	0.000		
Catchment2	0.073	0.063	-0.145	0.127	1.000
p-value	0.108	0.165	0.001	0.005	

Note 1: Values in the same row as the variable names are correlation coefficients.
Note 2: p-value < 0.15 indicates statistical significance at the 85% confidence level.

Appendix F. Results for the deforestation intentions econometric modelling: remain under forest versus deforest

Regression variable descriptors

Table F.1 Summary of the binary forest/deforestation observation

Region number	Region name	Number of Observations	Area (ha)			
			Mean	Std. Dev.	Min	Max
1	Northland	3,606	45.2	103.5	9.0	2895.7
2	Auckland	885	52.1	100.9	9.0	963.4
3	Waikato	5,055	63.9	153.1	9.0	2809.8
4	Bay of Plenty	4,348	64.8	175.3	9.0	5468.7
5	Gisborne	2,478	57.0	104.9	9.0	1673.3
6	Hawke's Bay	3,190	42.1	67.0	9.0	1013.6
7	Taranaki	754	23.7	25.3	9.0	388.8
8	Manawatu-Whanganui	2,840	39.7	79.1	9.0	2044.3
9	Wellington	1,367	42.1	83.0	9.0	1513.5
10	West Coast	897	47.0	80.7	9.0	815.2
11	Canterbury	3,295	38.3	106.2	9.0	3284.5
12	Otago	2,632	41.8	68.5	9.0	870.6
13	Southland	1,628	39.5	67.7	9.0	1369.5
14	Tasman	1,851	54.0	116.1	9.0	2099.7
15	Nelson	296	37.5	46.9	9.0	393.8
16	Marlborough	1,890	33.8	42.8	9.0	599.2
All regions	New Zealand	37,012	48.5	112.1	9.0	5468.7

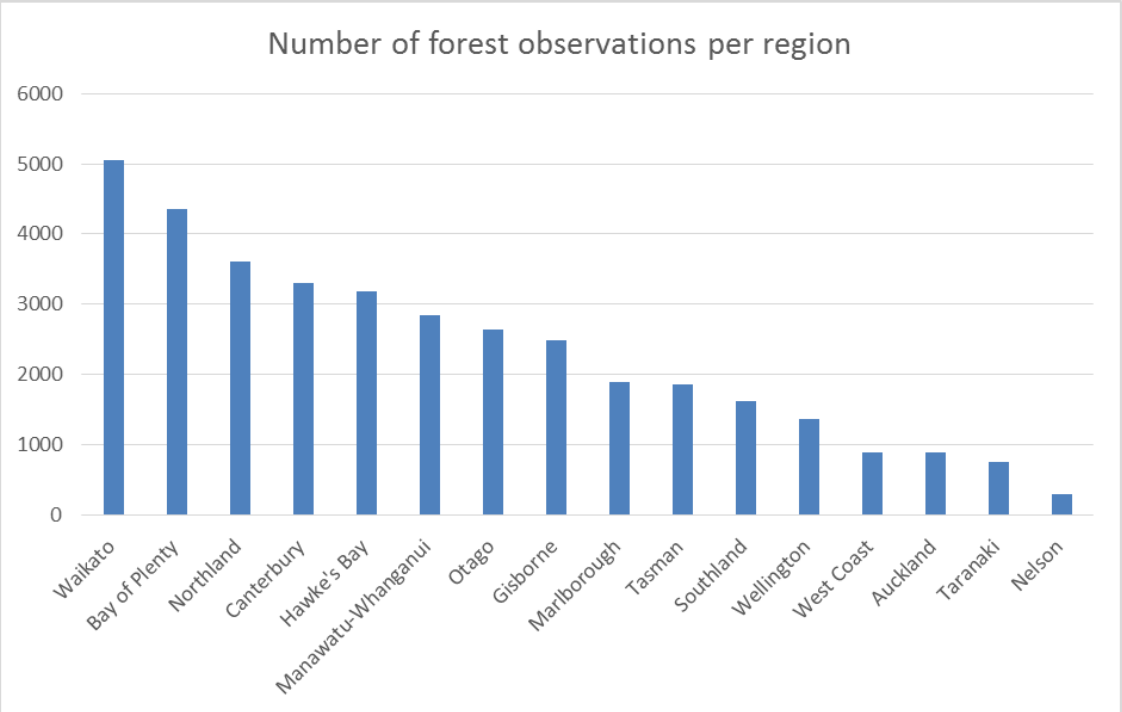


Table F.2 Summary of the variables in the regression model

Slope class	Freq	Percentage	Cumulative percentage
0	13442	36.3%	36.3%
7	13099	35.4%	71.7%
20	8975	24.3%	96.0%
35	1496	4.0%	100.0%
CWardAgeClass			
20	1337	3.6%	3.6%
40	31994	86.4%	90.1%
65	3681	10.0%	100.0%
C Ward Med Income Class			
0	3963	10.7%	10.7%
40000	9993	27.0%	37.7%
50000	11509	31.1%	68.8%
60000	6994	18.9%	87.7%
70000	3691	10.0%	97.7%
Ave Annual Rainfall Class			
0	28	0.1%	0.1%
400	3265	8.8%	8.9%
800	23875	64.5%	73.4%
1600	9844	26.6%	100.0%
Ave Annual Temperature Class			
0	222	0.6%	0.6%
79	36790	99.4%	100.0%
AnnGDDclass			
0	21023	56.8%	56.8%
2700	15989	43.2%	100.0%
PathDis_class			
0	17863	48.3%	48.3%
30	17678	47.8%	96.0%
100	1471	4.0%	100.0%
UrbanProx			
30	27631	74.7%	74.7%
1000	9381	25.4%	100.0%
MeatDairyProx			
30	22733	61.4%	61.4%
100	13744	37.1%	98.6%
1000	535	1.5%	100.0%

DairyProx			
0	2402	6.5%	6.5%
10	26550	71.7%	78.2%
1000	8060	21.8%	100.0%
CadastralClass			
-1	3733	10.1%	10.1%
0	1093	3.0%	13.0%
10	3029	8.2%	21.2%
40	4642	12.5%	33.8%
100	24515	66.2%	100.0%
HortProxClass			
0	3137	8.5%	8.5%
10	33875	91.5%	100.0%
Road_within_1km			
0	8469	22.9%	22.9%
1	28543	77.1%	100.0%
CoastlineProx			
0	30446	82.3%	82.3%
5	6566	17.7%	100.0%
Impedance9_nz			
0	23	0.1%	0.1%
1	36460	98.5%	98.6%
10	234	0.6%	99.2%
100	295	0.8%	100.0%
NZriverProx_500			
0	3321	9.0%	9.0%
500	33691	91.0%	100.0%

Regression variable results

Table F.3: Estimates from four econometric models of the probability of deforestation

	Model 1 – OLS (IV– 0-1model; linear area as independent variable)			Model 2 – OLS (IV– 0-1model; log of area as independent variable)			Model 3 – Probit (IV– 0-1model; log of area as independent variable)			Model 4 – Logit (IV– 0-1model; log of area as independent variable)			Model 4 – Logit (marginal effects)		
Variable	Coeff	Std Error	p-value	Coeff	Std Error	p-value	Coeff	Std Error	p-value	Coeff	Std Error	p-value	dy/dx	Std. Err.	P>z
Area (ha)	0.000	0.000	0.000	-0.072	0.009	0.000	-0.593	0.073	0.000	-1.104	0.145	0.000	-0.047	0.006	0.000
Area squared (ha^2)	0.000	0.000	0.000	0.006	0.001	0.000	0.048	0.009	0.000	0.089	0.018	0.000	0.004	0.001	0.000
nzterwkct	0.043	0.004	0.000	0.041	0.004	0.000	0.404	0.042	0.000	0.905	0.090	0.000	0.050	0.006	0.000
nzterwtm	0.055	0.005	0.000	0.053	0.005	0.000	0.519	0.042	0.000	1.119	0.090	0.000	0.072	0.008	0.000
nztersouthot	0.024	0.004	0.000	0.024	0.004	0.000	0.323	0.039	0.000	0.706	0.086	0.000	0.033	0.004	0.000
nz_slope_c2	-0.030	0.003	0.000	-0.029	0.003	0.000	-0.215	0.025	0.000	-0.414	0.050	0.000	-0.017	0.002	0.000
nz_slope_c3	-0.040	0.004	0.000	-0.038	0.004	0.000	-0.344	0.032	0.000	-0.705	0.066	0.000	-0.026	0.002	0.000
nz_slope_c4	-0.052	0.005	0.000	-0.056	0.005	0.000	-0.640	0.084	0.000	-1.367	0.190	0.000	-0.035	0.003	0.000
nz_dem_cla2	0.003	0.003	0.303	0.004	0.003	0.222	0.021	0.029	0.477	0.059	0.059	0.317	0.003	0.003	0.321
nz_dem_cla3	-0.001	0.004	0.853	0.001	0.004	0.788	0.019	0.038	0.619	0.072	0.077	0.350	0.003	0.003	0.359
nz_dem_cla4	-0.001	0.007	0.851	0.002	0.007	0.787	0.086	0.057	0.129	0.159	0.114	0.164	0.007	0.006	0.191
nz_dem_cla5	0.033	0.011	0.002	0.035	0.011	0.001	0.277	0.078	0.000	0.587	0.153	0.000	0.033	0.011	0.002
nz_dem_cla6	0.044	0.018	0.012	0.049	0.018	0.006	0.470	0.178	0.008	0.981	0.371	0.008	0.066	0.036	0.069
CWardAgeCl~2	0.001	0.010	0.883	0.002	0.010	0.823	0.069	0.049	0.156	0.142	0.091	0.120	0.006	0.004	0.103
CWardAgeCl~3	-0.054	0.011	0.000	-0.054	0.011	0.000	-0.374	0.065	0.000	-0.807	0.133	0.000	-0.026	0.003	0.000
CWardMedIn2	0.019	0.005	0.000	0.017	0.005	0.000	0.188	0.055	0.001	0.434	0.128	0.001	0.020	0.007	0.002
CWardMedIn3	-0.002	0.005	0.721	-0.005	0.005	0.276	0.015	0.053	0.779	0.090	0.120	0.453	0.004	0.005	0.460
CWardMedIn4	0.008	0.005	0.112	0.005	0.005	0.311	0.098	0.056	0.081	0.224	0.128	0.078	0.010	0.006	0.098
CWardMedIn5	-0.007	0.006	0.192	-0.011	0.006	0.064	-0.048	0.062	0.439	-0.080	0.137	0.560	-0.003	0.006	0.549
CWardMedIn6	-0.014	0.010	0.169	-0.015	0.010	0.124	-0.073	0.084	0.382	-0.101	0.178	0.572	-0.004	0.007	0.555
AveAnnRain3	-0.023	0.006	0.000	-0.021	0.006	0.000	-0.167	0.038	0.000	-0.311	0.075	0.000	-0.014	0.004	0.000
AveAnnRain4	-0.012	0.006	0.053	-0.011	0.006	0.077	-0.082	0.045	0.069	-0.135	0.090	0.132	-0.006	0.004	0.122

	Model 1 – OLS (IV– 0-1model; linear area as independent variable)			Model 2 – OLS (IV– 0-1model; log of area as independent variable)			Model 3 – Probit (IV– 0-1model; log of area as independent variable)			Model 4 – Logit (IV– 0-1model; log of area as independent variable)			Model 4 – Logit (marginal effects)		
Variable	Coeff	Std Error	p-value	Coeff	Std Error	p-value	Coeff	Std Error	p-value	Coeff	Std Error	p-value	dy/dx	Std. Err.	P>z
AveAnnTemp2	-0.007	0.013	0.577	-0.011	0.013	0.419	-0.107	0.154	0.489	-0.203	0.336	0.547	-0.010	0.017	0.582
AnnGDD2	**-0.019**	**0.004**	**0.000**	**-0.019**	**0.004**	**0.000**	**-0.131**	**0.030**	**0.000**	**-0.258**	**0.060**	**0.000**	**-0.011**	**0.003**	**0.000**
PathDis_cl2	-0.001	0.003	0.669	-0.002	0.003	0.471	0.008	0.028	0.781	-0.006	0.058	0.922	0.000	0.002	0.922
PathDis_cl3	**0.010**	**0.008**	**0.232**	**0.007**	**0.008**	**0.410**	**0.121**	**0.066**	**0.066**	**0.240**	**0.134**	**0.075**	**0.011**	**0.007**	**0.106**
UrbanProx2	-0.004	0.004	0.282	-0.004	0.004	0.302	-0.045	0.036	0.208	-0.085	0.074	0.252	-0.004	0.003	0.243
MeatDairyP2	**-0.021**	**0.003**	**0.000**	**-0.021**	**0.003**	**0.000**	**-0.191**	**0.033**	**0.000**	**-0.427**	**0.068**	**0.000**	**-0.018**	**0.003**	**0.000**
MeatDairyP3	-0.001	0.011	0.907	-0.002	0.011	0.868	0.052	0.126	0.681	0.177	0.287	0.537	0.008	0.014	0.567
DairyProx2	**-0.050**	**0.004**	**0.000**	**-0.048**	**0.004**	**0.000**	**-0.308**	**0.026**	**0.000**	**-0.636**	**0.051**	**0.000**	**-0.031**	**0.003**	**0.000**
cadastral2	**0.029**	**0.010**	**0.005**	**0.024**	**0.010**	**0.018**	**0.149**	**0.066**	**0.023**	**0.288**	**0.128**	**0.024**	**0.014**	**0.007**	**0.046**
cadastral3	0.007	0.006	0.281	0.006	0.006	0.339	0.025	0.052	0.634	0.001	0.104	0.993	0.000	0.004	0.993
cadastral4	0.008	0.006	0.169	0.008	0.006	0.152	0.055	0.047	0.242	0.052	0.094	0.582	0.002	0.004	0.589
cadastral5	**0.011**	**0.005**	**0.017**	**0.019**	**0.005**	**0.000**	**0.146**	**0.038**	**0.000**	**0.253**	**0.076**	**0.001**	**0.010**	**0.003**	**0.001**
LUCclass3	-0.009	0.004	0.029	-0.006	0.004	0.138	-0.031	0.028	0.262	-0.076	0.054	0.156	-0.003	0.002	0.164
hort2	0.013	0.005	0.010	0.010	0.005	0.036	-0.020	0.044	0.644	-0.039	0.091	0.670	-0.002	0.004	0.674
road1km2	**0.003**	**0.003**	**0.296**	**0.004**	**0.003**	**0.162**	**0.052**	**0.029**	**0.078**	**0.094**	**0.060**	**0.119**	**0.004**	**0.002**	**0.111**
coastline2	**0.027**	**0.004**	**0.000**	**0.027**	**0.004**	**0.000**	**0.248**	**0.034**	**0.000**	**0.479**	**0.068**	**0.000**	**0.024**	**0.004**	**0.000**
impedance2	**0.066**	**0.010**	**0.000**	**0.074**	**0.010**	**0.000**	**0.660**	**0.151**	**0.000**	**1.362**	**0.333**	**0.000**	**0.034**	**0.004**	**0.000**
impedance3	**0.064**	**0.020**	**0.002**	**0.062**	**0.020**	**0.002**	**0.569**	**0.196**	**0.004**	**1.181**	**0.411**	**0.004**	**0.087**	**0.047**	**0.062**
river2	0.001	0.005	0.920	0.005	0.005	0.363	0.013	0.039	0.728	0.049	0.077	0.526	0.002	0.003	0.518
Māoriland2	**-0.032**	**0.008**	**0.000**	**-0.032**	**0.008**	**0.000**	**-0.259**	**0.096**	**0.007**	**-0.538**	**0.201**	**0.007**	**-0.018**	**0.005**	**0.001**
catchment2	**0.081**	**0.006**	**0.000**	**0.082**	**0.006**	**0.000**	**0.445**	**0.037**	**0.000**	**0.806**	**0.069**	**0.000**	**0.046**	**0.005**	**0.000**
lri2 CCAV	**0.011**	**0.003**	**0.001**	**0.010**	**0.003**	**0.002**	**0.114**	**0.035**	**0.001**	**0.260**	**0.074**	**0.000**	**0.012**	**0.004**	**0.001**
lri3 CCAV	**0.008**	**0.004**	**0.028**	**0.007**	**0.004**	**0.046**	**0.119**	**0.035**	**0.001**	**0.264**	**0.072**	**0.000**	**0.012**	**0.003**	**0.000**
lri4 CCAV	**0.022**	**0.011**	**0.041**	**0.019**	**0.011**	**0.075**	**0.127**	**0.060**	**0.035**	**0.248**	**0.115**	**0.032**	**0.012**	**0.006**	**0.053**
lri5 CCAV	**0.031**	**0.005**	**0.000**	**0.029**	**0.005**	**0.000**	**0.254**	**0.039**	**0.000**	**0.499**	**0.079**	**0.000**	**0.025**	**0.005**	**0.000**
built9km2	0.005	0.003	0.172	0.004	0.003	0.258	0.032	0.025	0.195	0.046	0.050	0.355	0.002	0.002	0.358

	Model 1 – OLS (IV– 0-1model; linear area as independent variable)			Model 2 – OLS (IV– 0-1model; log of area as independent variable)			Model 3 – Probit (IV– 0-1model; log of area as independent variable)			Model 4 – Logit (IV– 0-1model; log of area as independent variable)			Model 4 – Logit (marginal effects)		
Variable	Coeff	Std Error	p-value	Coeff	Std Error	p-value	Coeff	Std Error	p-value	Coeff	Std Error	p-value	dy/dx	Std. Err.	P>z
built15km2	**0.020**	**0.003**	**0.000**	**0.020**	**0.003**	**0.000**	**0.193**	**0.029**	**0.000**	**0.432**	**0.062**	**0.000**	**0.018**	**0.002**	**0.000**
lineden9km3	0.005	0.003	0.124	0.006	0.003	0.057	0.036	0.026	0.176	0.071	0.053	0.178	0.003	0.002	0.181
lineden15km3	**0.022**	**0.003**	**0.000**	**0.022**	**0.003**	**0.000**	**0.164**	**0.028**	**0.000**	**0.337**	**0.056**	**0.000**	**0.015**	**0.003**	**0.000**
Intercept	**0.016**	**0.021**	**0.465**	**0.158**	**0.028**	**0.000**	**-1.084**	**0.276**	**0.000**	**-2.211**	**0.592**	**0.000**			
R^2/Pseudo R^2	0.0636			0.0676			0.1283			0.1294					
F(51, 36960)	31.02			34.22											
Log pseudolikelihood							-8149.48			-8139.52					
Number of observations	37012			37012			37012			37012					

Appendix G. Results from the rural decision makers whose land includes forestry

Table F.1: Average age of the forest-based decision makers, by region

Region	Age (years)
Auckland	62.1
Bay of Plenty	58.3
Canterbury	55.0
Gisborne	57.7
Hawke's Bay	56.4
Manawatu-Wanganui	56.9
Marlborough	55.4
Northland	58.8
Otago	58.8
Southland	55.0
Taranaki	54.6
Tasman/Nelson	61.1
Waikato	53.2
Wellington	57.8
West Coast	58.7