Predicting harvestability of existing *Pinus radiata* stands: 2013-2030 projections of stumpage profits from pre-90 and post-89 forests

Matt Thirkettle and Suzi Kerr

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Author contact details

Matt Thirkettle
Motu Economic and Public Policy Research
mkt68@cornell.edu

Suzi Kerr
Motu Economic and Public Policy Research
suzi.kerr@motu.org.nz

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Motu Economic and Public Policy Research

PO Box 24390
Wellington
New Zealand

Email	info@motu.org.nz
Telephone	+64 4 9394250
Website	www.motu.org.nz

Abstract
Our goal is to predict which forests are harvestable in New Zealand each year, and the stumpage profits attained from harvesting. We begin by documenting how Motu updates the 2008 Land Use in Rural New Zealand map to match the 2013 National Exotic Forest Description planted forest dataset. We then produce forest stand maps for the years 2013-2030. Last, we describe how we assign stumpage profits, and the distribution of stumpage profits over the simulation years (2013-2030). We find that stumpage profits are: always positive; increasing through time (2013-2030); lowest (on average) in the West Coast; and highest (on average) in the North Island East Coast. Our results suggest that forest owners will always harvest given that they have already incurred planting and growing costs. Limitations in data, including the need to use averages of yields and some costs across wide areas, and the effect of market conditions, and their role in determining the pace and average age at which the estate is harvested, mean that the true distribution of stumpage profits is likely to be wider. Those most likely to not harvest would be those with low estimated stumpage.

JEL codes
Q23, Q55

Keywords
Forestry, New Zealand, land use, stumpage profits, harvesting

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1. Introduction

Our goal is to predict which forests are harvestable each year in New Zealand in terms of age, and the stumpage profits likely to be attained from harvesting, in order to gain insight into the likelihood that some forests will not be harvested, with implications for New Zealand's net greenhouse gas emissions and United Nations Framework Convention on Climate Change reporting.

For the years 2014-2030 we use Motu's Land Use in Rural New Zealand (LURNZ) program to simulate the forest stands (at a 25 hectare resolution) that are likely to be harvested.[1] Next, we calculate stumpage profits for each forest pixel, which can vary by, among other things, when the forest is first planted (either prior to 1990 (pre-90) or after 1989 (post-89)). We aggregate stumpage profits to the wood supply region (WSR) level for each forest type (either pre-90 or post-89). We also plot the stumpage profit distribution by year (2013-2030), where 2013 is the base year. Last, we produce 2013 net present value (NPV) and internal rate of return (IRR) on existing radiata forest in the form of a table by wood supply region and maps. These are an updated version of the results produced in Olssen et al. (2012). The 2013 maps take into account price changes documented here.

We find that stumpage profits are always positive. This would suggest that forest owners will always harvest. Limitations in data, however, including the need to use averages of yields and some costs across wide areas, and the effect of market conditions, and their role in determining the pace and average age at which the estate is harvested, mean that the true distribution of stumpage profits is likely to be wider than our estimates. Those most likely to actually face negative stumpage and hence not harvest would be those with low, but positive, estimated stumpage. The West Coast region in 2013 is projected to receive the lowest average stumpage profit over all WSRs and simulation years ($11,224/ha) and the North Island East Coast region in 2027 is projected to receive the highest average stumpage profit over all WSRs and simulation years ($41,680/ha).[2] In 2013, the estimated stumpage profits range from around

[1] For code, other documentation, and access to data for research purposes go to http://www.motu.org.nz/our-work/environment-and-resources/lurnz/.

[2] All reported values are measured in 2013 dollars.

$6,000 per ha up to over $50,000. Varying cost and yield data explains the variation in stumpage profits over WSRs. The West Coast typically has steeper land that is far from a port or mill, which both increase stumpage cost. Forest stands also have low yield rates in the West Coast due to poor weather conditions (trees grow slowly and produce poor quality timber in wet regions). On the other hand, the weather in North Island East Coast is dry and warm, which both contribute to higher yield rates. The land is typically flat there as well, so that harvest costs are relatively cheaper (on average) in the North Island East Coast.

Average stumpage profit over all WSRs is projected to increase from $25,554/ha in 2013 to $32,151/ha in 2030. The increasing proportion of post-89 forest stands is driving this time trend, as these typically have higher yields than pre-90 forest stands.

Key Steps:

1. Create a 2013 forest map that matches areas of forest by territory authority (TA) to the 2013 NEFD planted forest dataset.
2. Identify and adjust pre-90 and post-89 forest stands to match the NEFD areas by TA and forest type.
3. Adjust the 2013 age-class distribution in each TA for each forest type to match the NEFD 2013 planted forest dataset.
4. Predict potentially harvestable forest and assign harvest regimes.[3]
5. Estimate stumpage profit for each pixel in each year under the assumptions: (1) it is a pruned forest stand; and (2) it is an unpruned forest stand.
6. Assign a pruning regime for each pixel (either pruned or not pruned) and assign stumpage profits accordingly.
7. Interpret the results.

2. Create a 2013 forest map that matches areas of forest by territory authority (TA) to the 2013 NEFD planted forest dataset

We use Motu's LURNZ model to simulate a 2013 forest map of New Zealand. LURNZ is a partial equilibrium model that is currently set up to simulate changes in private dairy, sheep-beef, plantation forestry, and scrub land uses over time and space. The model uses the 25ha

[3] Harvestable forest is defined to be *Pinus radiata* between the age of 26 and 40 (inclusive), as described in Section 0.

2008 LUCAS map to determine where forest stands are located in New Zealand in 2008. Then LURNZ simulates and allocates national-level land-use change to produce a 2013 forest map.[4]

We compare LURNZ's simulated 2013 forest map to the 2013 National Exotic Forest Description (NEFD) dataset for planted exotic forest stands in New Zealand.[5] This NEFD dataset reports the number of hectares in 2013 of exotic forest stands planted by TA, age class, and forest type (forest that was planted before 1990 (pre-90) or forest on land that changed land use to forestry post 1989 (post-89)).[6]

The area of forests planted at the TA level in the 2013 LURNZ map does not match the NEFD planted forest dataset. We assume the NEFD dataset is more accurate than our LURNZ map, so we adjust our LURNZ map accordingly. In particular, we assume that the LUCAS 2008 map used in the LURNZ model incorrectly assigned land between forest and scrub (scrub is land naturally reverting to native forest). So, if adjustments are needed in our LURNZ map, we reassign forest to scrub or *vice versa*. For a given TA, if LURNZ reports more forest area than the NEFD dataset, we reassign forest stands in our map to scrub land. The land that is assigned to forest that is least suited for forest (as measured by forest pixel ranking) are likely to be scrub.[7,8] In this TA, we convert LURNZ – NEFD pixels of the poorest quality forest to scrub. On the other hand, for a given TA, if LURNZ reports less forest than the NEFD dataset, then we reassign pixels of scrubland to forest (we select the best quality land for forest in this case).[9]

Table 9 in Appendix 1 reports the absolute and relative difference between the 2013 NEFD planted forest dataset and the 2013 LURNZ simulated map.[10] Absolute differences are in

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[4] The spatial allocation of land in LURNZ is documented and validated in (Anastasiadis et al. 2014).

[5] Exotic forest stands include *Pinus radiata* (radiata pine), *Pseudotsuga menziesii* (Douglas-fir or Oregon pine), and other exotic forest species. Of the total area of exotic forests planted in the NEFD dataset, 89.9% is radiata pine, 6.2% is Douglas-fir, and 3.9% is other exotic forest species (categorized as cypress, softwoods, eucalyptus, hardwoods) (Ministry for Primary Industries, 2013b).

[6] The NEFD planted dataset is restricted and provided to Motu by MPI. The Motu data library reference is R10080.

[7] Poor quality land tends to be steep, far from a port or mill, far from nearest town, and have a poor land-use capability (LUC) rating.

[8] Each pixel is assigned a ranking number from zero to one for each land-use type (dairy, sheep/beef, scrub, and forestry. A pixel with a ranking close to one for, say, dairy is better suited for dairy land than a pixel with a dairy ranking close to zero. Ranking is determined by a logit model using coefficients estimated by Timar (2011). Moreover, for a given pixel the pixel ranking for each land-use type sums to one.

[9] If we run out of scrub land, then we covert the poorest quality sheep and beef land to forest. If we also run out of sheep and beef land, then we convert the poorest quality dairy land to forest.

[10] Differences between LURNZ and NEFD can be attributed to measurement error in each dataset. LURNZ produces a simulated map building on the 2008 LUCAS map; it is subject to simulation error within the LURNZ algorithm and remote sensing error in the LUCAS map. For the 2013 NEFD data was collected from a

hectares and relative differences are in percent. The NEFD dataset has 296,500ha (or 17%) more plantation forests than the 2013 LURNZ map. The NEFD dataset has more forest than LURNZ in 36 TAs, has less forest in 33 TAs, and the same in 1 TA. The largest differences between NEFD and LURNZ (in magnitude) occurs in Whakatane (58,000ha), Taupo (57,500ha), and Gisborne (35,000ha).[11] There is also a large relative difference between the two datasets in: Whakatane (56%), lower forest areas Queenstown-Lake District (73%) and Christchurch (77%) as well as some areas with very small amounts of forest.[12] After our adjustments, the area of exotic forest in LURNZ matches that in NEFD in every Territorial Authority; we henceforth assume that this forest is all *Pinus radiata*.[13]

3. Identify and adjust pre-90 and post-89 forest stands to match the NEFD areas by TA and forest type

For each pixel in the LURNZ map we assign an indicator variable for pre-90 and post-89 forest types using the forest stand's age and the LUCAS map: All forest stands older than 24 are classified as pre-90; forest stands with LUCAS ID = 71 or 72 are classified as pre-90; stands with LUCAS ID = 73 are classified as post-89; remaining stands are temporarily classified as unassigned.[14]

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questionnaire sent to all known forest owners and managers with more than 1000 hectares of forest combined with imputed data on smaller forest owners from the 2012 NEFD. These data were supplemented by 2004 data from AgriQuality Small Forest Grower Surveys. Imputation error (leading to a small overstatement of areas in the older age classes), inaccurate reporting by forest owners and sampling error contribute to the measurement error in the NEFD dataset.

[11] The largest relative differences occur in the Franklin District. LURNZ reports 6,950 ha and NEFD reports 43ha giving a -16,000% difference. Franklin was divided between the Waikato and Auckland City district in 2010.[11] The 2011 NEFD report (MAF, 2012) reported 5,990ha of *Pinus radiata* in the Franklin District. So the 2013 NEFD dataset incorrectly defines the Franklin District. The ungated versions of the 2011 and 2012 NEFD datasets do not report the Franklin District. We suspect that the inclusion of the Franklin District in the 2013 NEFD was a mistake.

[12] To calculate the 'relative error' we calculate the percentage error using each of the datasets in turn as the base, then take the minimum of the absolute value of the percentage errors. This minimises the influence of the choice of base dataset.

[13] Henceforth we assume that all forest reported in the NEFD dataset and in maps that we generate are radiata pine. This assumption is motivated by data limitations (the NEFD dataset does not separately report radiata pine and other exotic forest stands), the similarity between radiata pine and Douglas-fir, and the prominence of radiata pine in New Zealand. The NEFD 2013 (Ministry for Primary Industries, 2013b) reports total planted forest by species. The difference between forest stands in the NEFD dataset and radiata pine in NEFD 2013 is 159,118 ha, suggesting that we over-report radiata pine by 9.3%.

[14] The age of a forest stand in 2008 is determined by Zhang and Kerr (2011). The LURNZ algorithm aged the stands appropriately when creating the 2013 basemap. In our 2013 base map, each pixel has a corresponding age:

We adjust pre-90 and post-89 forests to match the NEFD planted forest dataset at the TA-level. We start with post-89 stands. For each TA:

1) If $NEFD_{post\text{-}89} > LURNZ_{post\text{-}89}$, then we need more post-89 forest stands. We increase post-89 forest by reassigning pixels in the following order:
   a. Unassigned pixels with forest age≤24;
   b. Pre-90 pixels with forest age≤24;[15]
2) If $NEFD_{post\text{-}89} < LURNZ_{post\text{-}89}$, then we need fewer post-89 forest stands. We randomly reassign $LURNZ_{post\text{-}89} - NEFD_{post\text{-}89}$ pixels to pre-90 pixels.
3) Remaining unassigned pixels are reassigned to pre-90 forest.

By construction the NEFD and LURNZ planted forest areas now match at the TA-level by forest type (pre-90 and post-89).

4. Adjust the 2013 age-class distribution in each TA for each forest type to match NEFD 2013 planted forest dataset

Our LURNZ map has some forest pixels with an unassigned age (sheep and beef pixels that were changed to forest in Step 1, for example). Also, in our map the number of forest pixels with a particular age may not match the NEFD planting dataset at the TA level. We construct an algorithm so that our map agrees with the NEFD planted forest dataset while minimizing absolute changes in age.

either unassigned or 0-80. Forest pixels with age = 0 are blocks awaiting replanting. We assign these pixels age=1. Moreover, forests with age greater than 40 are deemed unharvestable. So pixels with age>40 are reassigned to age=41.

[15] If there are insufficient pixels in a step, then all pixels at that step are renamed post-89 and the remaining pixels to be allocated are pulled from following steps. If there are sufficient pixels in a step, then a random number generator is used to reassign the required number of pixels as post-89.

We start with post-89 forest pixels (order does not matter). We then consider pixels with age=j, j=1,… 40 and TA=k, k = 1,…71:[16]

1. If there are too many forest pixels with age= j, we randomly age $LURNZ_{post\text{-}89j,k}$ – $NEFD_{post\text{-}89,j,k}$ pixels to age= j+1.
2. If there are too few forest pixels with age=j, then we reassign $NEFD_{post\text{-}89,x,k}$ – $LURNZ_{post\text{-}89,x,k}$ forest pixels to age=j (where $LURNZ_{post-89,x,k}$ ∈ {forest stands : post-89 stand in TA=k and *x* indicates either an unassigned pixels or a pixel with age> *j* }) in the following order:
    a. Pixels with unassigned age class
    b. Pixels with
        - age=j +1;
        - age=j+2;

        …
        - age=41.[17]

We repeat the above algorithm for pre-90 forest stands.

Now our base map and NEFD planted forest dataset agree at the TA-level by forest type for each age class. In other words, our LURNZ map agrees with the NEFD dataset in all respects, and we are ready to assign harvesting regimes as well as calculate stumpage profits.

5. Predict potentially harvestable forest and assign harvest rates

Forest stands tend to be harvested between ages 26 and 40 – on average, 28.[18] Once a forestry stand reaches age 41 it is too large to send to the mill and specialized equipment is needed to harvest (larger grapple yarders, trucks, and skidders are needed). It therefore becomes too expensive to harvest trees 41 years or older. On the other hand, forest stands aged less than 26 are too immature: the wood is not suitable for construction and the tree produces insufficient

[16] It is important to start with age=1, then move to age=2, … then move to 40 to minimize changes made. Order of TA does not matter.

[17] If there is insufficient forest area in a step (say the first step), then the age of all unassigned pixels is set to j and the remaining forest area to be allocated age=j is settled in the following steps. On the other hand, if there is sufficient forest area in a step (say the first step), then a random number generator is used to allocate NEFD – LURNZ unassigned pixels as age=j.

[18] The average age of harvest is 27.7 years (Ministry for Primary Industries, 2013b).

wood product. As a result, immature forest stands generally do not produce sufficient levels of profit. Therefore only forest stands with age between 26 and 40 are considered harvestable.[19]

Definition: A forest stand is *harvestable* if and only if its age is between 26 and 40 (inclusive).[20]

Each year we select a proportion of harvestable forest stands to be harvested. The proportion depends on the age of the forest stand. One could imagine that a forest stand aged 26 is less likely to be harvested than one aged 27, as stands aged 27 are more mature but not too big to make it infeasible to harvest. We use total planted forest by age class to determine harvest rates.

Figure 1 illustrates total planted *Pinus radiata* by age class in New Zealand in 2013. Stands aged 26 and above diminish to zero, consistent with harvest age above 26. There is a large spike in forest stands with age between 13 and 19; trees that were planted during the '90s planting boom. Ideally we would observe these data consistently for several years and could estimate the hazard rate - the probability of a forest stand being cleared at a given age, given that it had not been cleared previously. Because we cannot, we assume that the number of trees planted (and replanted) each year between 26 and 40 years ago was roughly consistent so that changes across age classes indicate harvesting.

To reduce the effect of historical variation in planting rates across years we compute the average of planted forest for trees aged 1 to 25 in to get a proxy for total planted trees before forests are harvested. We further smooth the planted stand proxy by taking a 3-period centred moving average. The proxy for each age class is determined as follows:

$$\text{Proxy}_{\text{age}=25} = \frac{\text{Forest}_{\text{age}=26}}{3} + \frac{2}{3} \cdot \frac{1}{25} \sum_{i=1}^{25} \text{Forest}_{\text{age}=i}$$

$$\text{Proxy}_{\text{age}=26} = \frac{\text{Forest}_{\text{age}=27} + \text{Forest}_{\text{age}=26}}{3} + \frac{1}{3} \cdot \frac{1}{25} \sum_{i=1}^{25} \text{Forest}_{\text{age}=i}$$

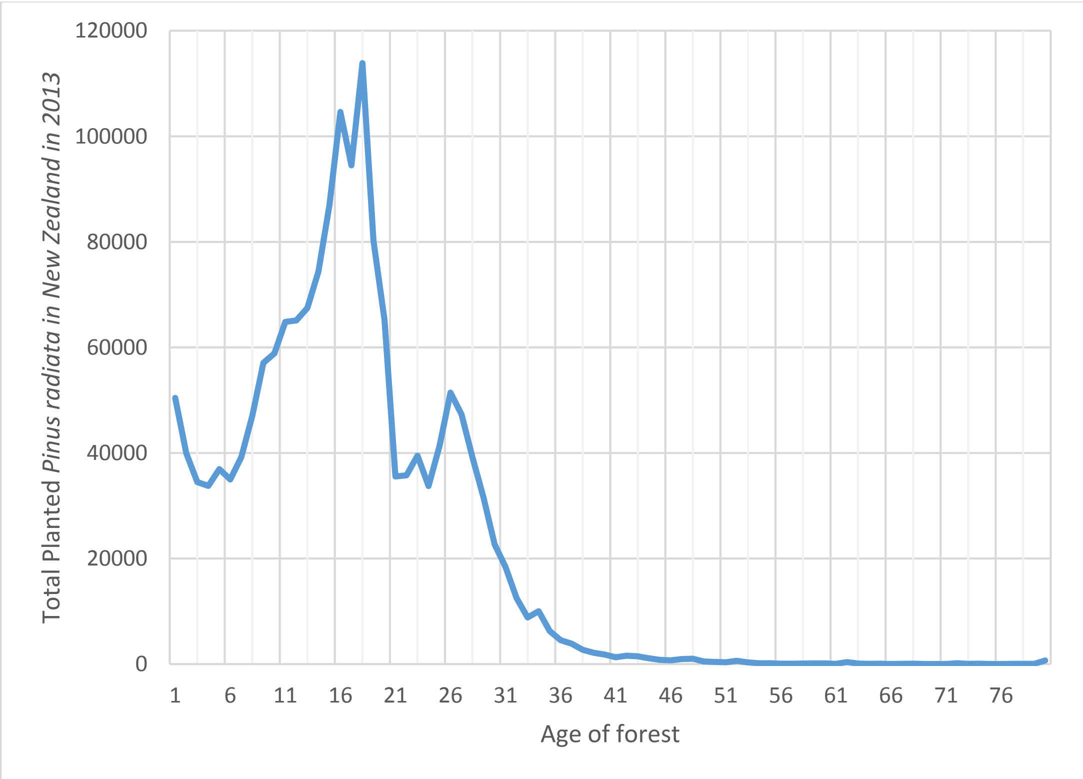
$$\text{Proxy}_{\text{age}=i\geq 27} = \frac{\text{Forest}_{\text{age}=i+1} + \text{Forest}_{\text{age}=i} + \text{Forest}_{\text{age}=i-1}}{3}.$$

[19] This does not imply that all forests between age 26 and 40 will be harvested.
[20] This definition is motivated by expert advice from Gerard Horgan.

The proxy is constant up to age 26, and decreasing thereafter, which is driven by our assumption that forestry begins to be harvested at age 26. The proxy is also monotonically decreasing, which is a sufficient condition to get non-negative harvest rates. We use the proxy to estimate the harvesting rate for trees aged 26 to 40:

$$\text{Harvest rate}_{\text{age}=i} \approx \frac{\text{Proxy}_{\text{age}=i-1} - \text{Proxy}_{\text{age}=i}}{\text{Proxy}_{\text{age}=i-1}}.$$

Figure 1: Total planting by age class



We allow the harvest rate to vary by North and South Island.[21] These harvest and survival rates are reported in Table 1, which are the harvest rates we use in the harvesting algorithm.

[21] We tried varying by WSR, but there was insufficient data to calculate positive harvest rates for all WSRs and age classes 26-40. We could estimate harvesting rates by WSR if we had a time series of planted forest by year and WSR.

The survival rate for each age class is also reported, which is the *ex ante* probability that a forest block survives past the corresponding age, that is

$$\text{Survival Rate}_{\text{age}=i} = \Pr(\text{not harvested at age} = 1, \dots, i).$$

Table 1: Harvest Rate by Island

Age	**North Island Harvest Rate**	**North Island Survival Rate**	**South Island Harvest Rate**	**South Island Survival Rate**
26	5%	95%	9%	91%
27	10%	86%	17%	76%
28	14%	74%	16%	64%
29	20%	59%	24%	49%
30	23%	46%	21%	39%
31	28%	33%	21%	30%
32	29%	24%	19%	25%
33	24%	18%	14%	21%
34	20%	14%	20%	17%
35	17%	12%	17%	14%
36	31%	8%	26%	11%
37	25%	6%	23%	8%
38	22%	5%	20%	6%
39	18%	4%	33%	4%
40	23%	3%	18%	4%

For each year t we harvest $harvest\ rate_{ij} \times total\ planted\ forest_{ijt}$ pixels of forest in age class i and WSR j. The age of remaining planted forests is increased by one year, and stands can be harvested the following year provided its new age is between 26 and 40. This gives us a map of harvestable forest for 2013-2030.[22]

6. Estimate stumpage profit for each pixel in each year under the assumptions: (1) it is a pruned forest stand; and (2) it is an unpruned forest stand

We calculate revenue, cost, and stumpage profits for each 25ha forest pixel. Stumpage profits account only for revenue and costs incurred at harvest. Therefore planting, pruning, and maintenance costs are ignored; they are sunk costs.

6.1. Revenue

Revenue is calculated as follows.

$$\text{Revenue}_{ijt} = \sum_{k=1}^{3} \text{Price}_{kt} \times \text{Quantity}_{ijt},$$

Where:

1. WSR=i indicates the stand's wood supply region.
2. Regime=j is either: pruned or not pruned, both without production thinning.[23]
3. Year=t is the simulation year ($t \in \{2014, \dots, 2030\}$).
4. A 25ha stand produces up to three log types: pruned (if the forest is a pruned stand), unpruned, and pulp. So k indicates log type, and $price_{kt}$ is the price of log type k at time t.
5. $Quantity_{ijk}$ is the yield of log type k in regime j and WSR i.

[22] A note to the analyst: Harvest code is located in R:\Environment\LURNZ\Projects - creating resources\Forestry profitability\Version 5 - MPI Project\Code\5. Profit Map by Year\Code\Profit3.m. To apply this to LURNZ, minor alternations need to be made including changing harvest age assumption. For simplicity I did not keep track of harvested forests' age. One would need to insert an indicator to do this. The code could be faster with a more efficient sorting algorithm.

[23] We lack yield data for forests that have production thinning. So we assume production thinning does not take place.

We use MPI's indicative domestic price series get 2013 price data for: pruned, unpruned, and pulp logs.[24] Next, we calculate real price changes for logs (this is treated as either pruned or unpruned logs) and pulp using SOPI's inflation and forest forecasts (Ministry for Primary Industries, 2013a).[25] Price changes are reported in Table 2. Last, we extrapolate the indicative price series using SOPI's forecasts to estimate the prices for pruned, unpruned, and pulp logs in 2014-2017. The 2013 indicative price for: pruned logs is $130/m^3$; unpruned logs is $94/m^3$; and pulp is $51/m^3$. Extrapolated prices are reported in Table 3, and they are calculated as follows:

$$\text{Price}_{2014} = \left(1 + \text{Change}_{2014}\right) \times \text{Indicative Price}_{2013}; \text{ and}$$

$$\text{Price}_t = \left(1 + \text{Change}_t\right) \times \text{Price}_{t-1} \text{ for } t = 2015 - 2017; \text{where}$$

$$\text{Change}_t = \frac{\text{Price}_t - \text{Price}_{t-1}}{\text{Price}_{t-1}}.$$

Prices beyond 2017 are assumed to be constant and equal to the forecasted 2017 price.

Table 2: Real forecasted log price

Year	2013	2014	2015	2016	2017
Log price (FOB $ per m^3)	$119	$122.91	$122.55	$124.88	$129.59
Change in log price	N/A	+3.3%	-0.3%	+1.9%	+3.8%
Pulp price (FOB $ per tonne)	590	561.5	558.7	569.5	591.5
Change in pulp price	N/A	-4.8%	-0.5%	+1.9%	+3.9%

[24] Go to http://www.mpi.govt.nz/ and search for Indicative NZ Radiata Pine Log Prices. Open the log price series. Select the December 2013 average over 12 quarters price for pruned logs. Go to the domestic price sheet. Let the price of: pruned logs be the average of class P1 and P2; unpruned logs to be the average of class S1, S2, L1&L2, and S3&L3; pulp be the class pulp. Go to http://www.mpi.govt.nz/ and search for Indicative NZ Radiata Pine Log Prices. Open the log price series. Select the December 2013 average over 12 quarters price for pruned logs. Let unpruned logs be the average of class A, J, and K.

[25] Inflation is reported in Table 1.1, and forest price estimates are reported in Table 3.1.

Table 3: Forecast real stumpage prices by type (pruned, unpruned, pulp)

Year	2014	2015	2016	2017
Pruned logs (domestic $ per m^3)	129.8	134.1	133.7	136.2
Unpruned logs (domestic $ per m^3)	93.5	96.6	96.3	98.1
Pulp (domestic $ per m^3)	50.8	48.3	48.1	49.0

Quantity varies by WSR, age, forest type, regime, and log type. We use NEFD yield tables to estimate quantity.[26] For each regime there are missing datasheets. The only consistent regimes reported are pruned *Pinus radiata* stands and unpruned *Pinus radiata* stands, both without production thinning. We limit our analysis to these two regimes.

6.2. Forest Cost

Stumpage costs consist of road construction, harvesting, and cartage cost:

$$Total\ cost_{ij} = \left(Road\ cost_j + Harvest\ cost_j + Cartage\ cost_j\right) \times Quantity_i,$$

Where *j* indicates forest pixel and *i* is the WSR. Harvest and road cost depends on island (North or South) and forest gradient, and cartage cost depends on distance to nearest port or mill.[27] Costs are reproduced below.[28,29]

[26] Go to http://www.mpi.govt.nz/ and search for NEFD yield tables. Download the yield tables for each WSR at the bottom of the page. The current yield tables do does not include the West Coast WSR. We use the same yield tables as discussed in Olssen et al. (2012), which "halve the West Coast yield from the earlier tables … as recommended by Steve Wakelin from Scion Ltd … [since] it is widely believed that the earlier tables overstated West Coast yields".

[27] Forest gradient and distance to port or mill are calculated in Olssen et al. (2012).

[28] Cost data is restricted. Contact AgriFax, and purchase the Regional Log Price and Cost Report. Go to http://www.nzxagri.com/agrifax for contact details.

[29] Costs are denominated in dollars per tonne. We use the conversion factor of 0.926 for pruned, 0.893 for unpruned, and 0.812 for pulp to convert costs to dollars per m^3 as recommended by AgriFax's Forest Analyst Ivan Luketina.

Table 4: Harvest cost ($ per tonne)

Gradient	North Island	South Island
Flat (0-7°)	16	18
Easy (7-20°)	19	22
Steep (20-25°)	22	25
Very steep (25+°)	26	28

Table 5: Roading cost ($ per tonne)

Gradient	North Island	South Island
Flat (0-7°)	3	3
Easy (7-20°)	3	3
Steep (20-25°)	5	5
Very steep (25+°)	8	8

Table 6: Cartage cost ($ per tonne)

Distance to Port/Mill (km)	Cartage Cost ($ per tonne)
0-40	12
41-60	15
61-80	17
81-100	19
101-120	23
121-160	28
161-200	32

6.3. Stumpage Profit

Stumpage profits are calculated as follows.

$$\text{Stumpage Profit}_{ijt} = \text{Revenue}_{it} - \text{Total cost}_{ij}.$$

Therefore, stumpage profits depend on: age of stand harvested; ownership; year; WSR; island; distance to port; and gradient of forestry block. Stumpage profits can now be used to calculate average stumpage profits by WSR for each harvest year. We can also plot a profit distribution.

7. Assign a pruning regime for each pixel (either pruned or not pruned)

We cannot determine whether a forest stand has been pruned or not. For each pixel, we calculate stumpage profits under two assumptions: it is pruned and it is not pruned. We assign a proportion of pixels with the highest 2013 pruned stumpage profit as pruned (forest owners are more likely to prune blocks that they believe will yield higher profits).[30] In the end, imputed pruned forests are assigned pruned stumpage profits; remaining forests are assigned unpruned stumpage profits.

The proportion of forest assigned pruned, $\theta_{\text{pruned and not thinned}}$, is calculated using Tables 9.14-9.17 in the 2013 NEFD (Ministry for Primary Industries, 2013b). In particular, θ_{ij} is equal to the proportion of forest planted in regime *j* and wood supply region (WSR) *i*.[31] We have reported the proportion of pruned forest by regime in Table 7.[32]

Each forest pixel now has a stumpage profit associated with it. We have forest maps for years 2013-2030. We use this to calculate average stumpage profit by WSR and stumpage profit distributions by year.

[30] Pruning regime is determined in the 2013 map, and carried through to all other maps.

[31] We are implicitly assuming that the proportion of pruned forest will remain constant from 2013-2030. The NEFD report might be underestimating the number of pruned forest: forest owners do not decide on pruning regimes until the forest is aged 10, and very few forest owners declare that they will prune the forest when it is less than 10 years old.

[32] We assume that all forests that will be harvested by 2030 have already been pruned in 2013 if they are going to be pruned. The youngest are 9 years old.

Table 7: Proportion of Pruned and Unpruned Planted Forest by WSR (2013)

WSR	Pruned	Unpruned
Northland	0.42	0.58
Auckland	0.34	0.66
Central North Island	0.46	0.54
North Island East Cost	0.73	0.27
Hawke's Bay	0.69	0.31
Southern North Island West	0.67	0.33
Southern North Island East	0.67	0.33
Nelson	0.25	0.75
Marlborough	0.53	0.47
West Coast	0.54	0.46
Canterbury	0.44	0.56
Otago	0.69	0.31
Southland	0.55	0.45

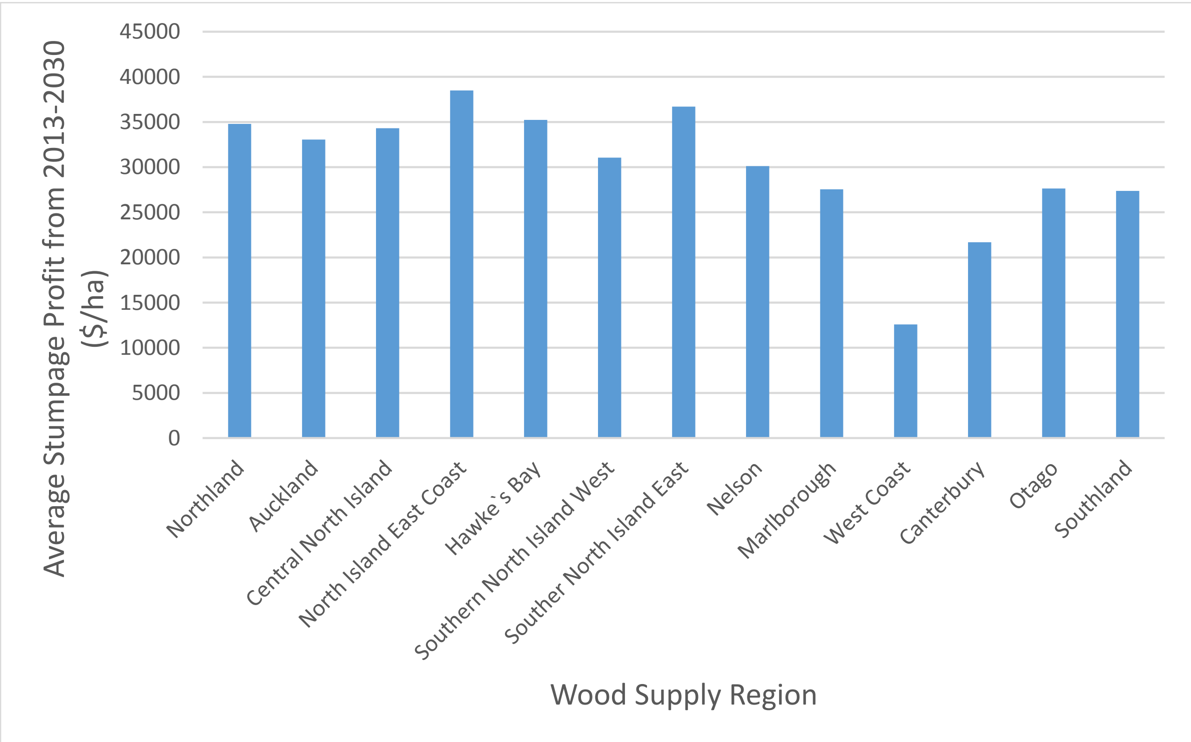
8. Interpret the results

In this section we discuss the main results of our harvest simulation. In particular, we produce stumpage profit tables, histograms, and maps. We also compare stumpage profits by wood supply region and year.

8.1. All Forests

Average stumpage profits (denominated in 2013 dollars per hectare) by year and wood supply region are reported in Table 10 (tables and figures for the results section are reported in Appendix: Tables and Figures). We compare stumpage profits by WSR in Figure 2 which shows simulated average stumpage profits over years 2013-2030 for each WSR. All regions except for West Coast and Canterbury have average stumpage profits in the range $27,400 - $38,500 per hectare.[33] West Coast's simulated average stumpage profit over 2013-2030 is $12,600 per hectare, which is well below the mean ($30,000 per hectare). Canterbury's simulated average stumpage profit is equal to $21,700 per hectare over 2013-2030.

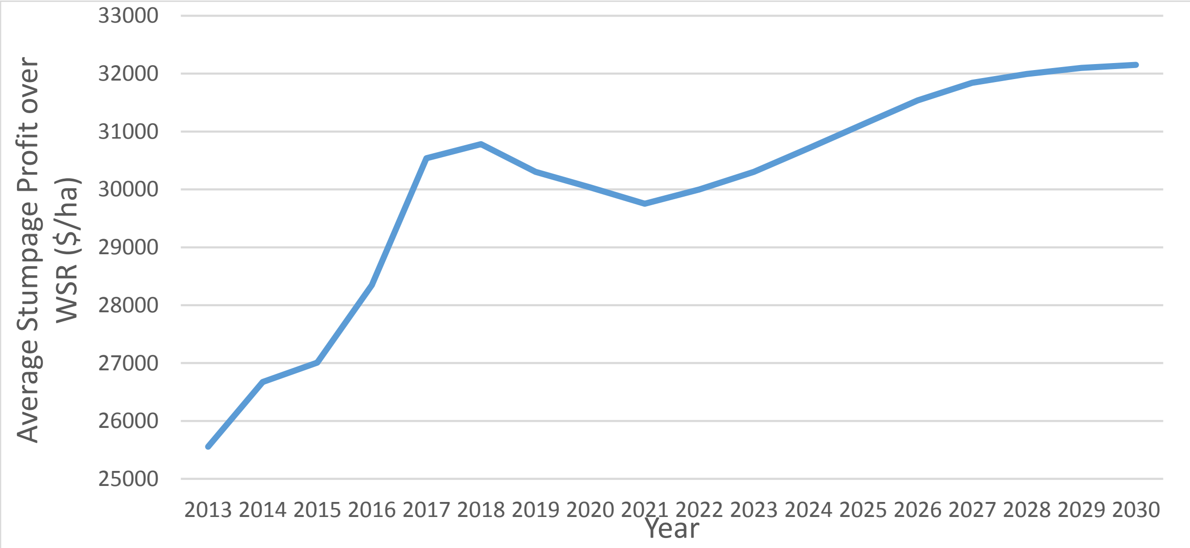
Figure 2: Average Stumpage Profit over 2013-2030 by Wood Supply Region for All Planted Forest



[33] We round stumpage profits to the nearest $100.

Figure 3 compares simulated average stumpage profit over WSR by year (2013-2030). Between 2013 and 2018 average real stumpage profits are projected to increase from $25,600 to $30,800 per hectare. Stumpage profits fall from 2018 to 2021 (down to $29,800 per hectare), then gradually rise to $32,200 per hectare in 2030.

Figure 3: Average Stumpage Profit over Wood Supply Regions by Year for All Planted Forest



We produce stumpage profit histograms for each year (2013-2030). Figure 4 and Figure 5 are the stumpage profit histograms for 2013 and 2030. Both histograms are unimodal, but they are not normally distributed. In 2013 the right tail is smooth and diminishes to zero. The left tail has a large drop in frequency in the $20,000-22,300 bin. This pattern persists in the 2030 histogram. The right tail, however, is thicker in 2030. Simulated average stumpage profits increase from $25,600 to $32,200 per hectare. Standard deviation also increases from $7,000 to $9,500 per hectare. Therefore, the coefficient of variation, $c = \frac{\sigma}{\mu}$, increases from 0.26 to 0.28, as well. The increase in c implies that the relative disparity of stumpage profits between 2013 and 2030 increases (but not by much).

Figure 4: Histogram of Stumpage Profit for 2013 for All Planted Forest

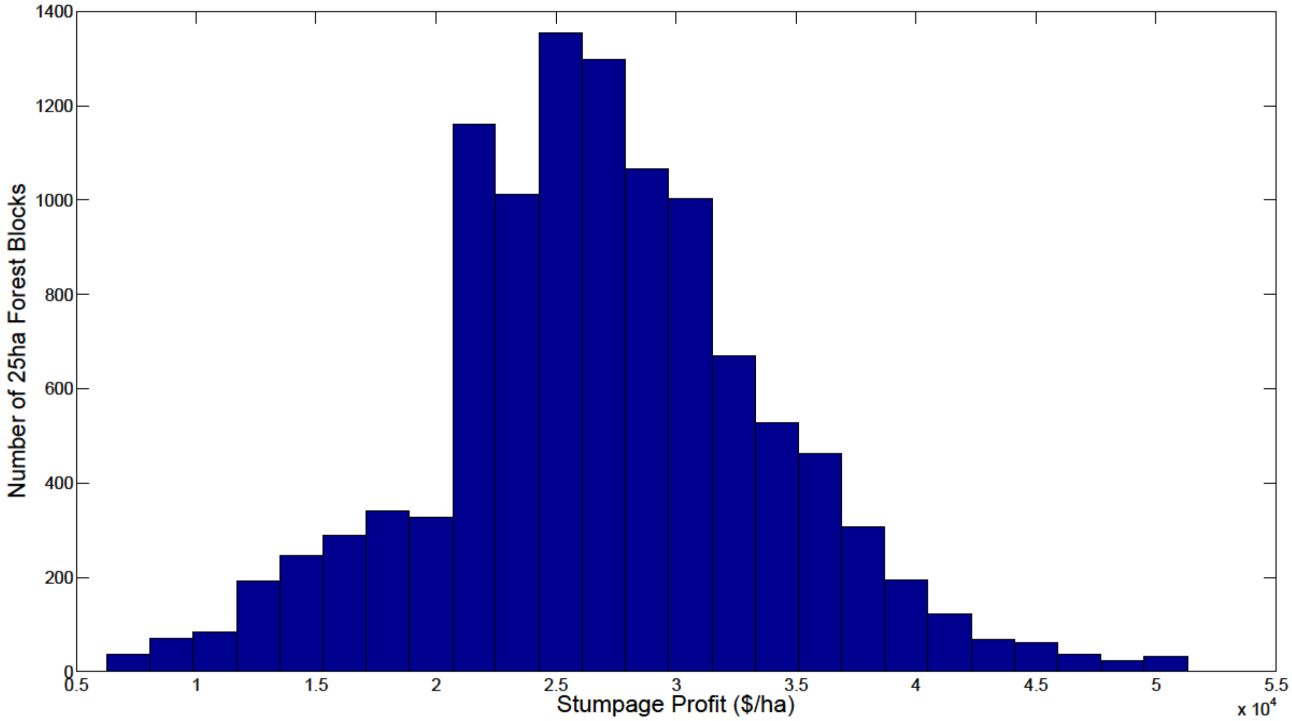
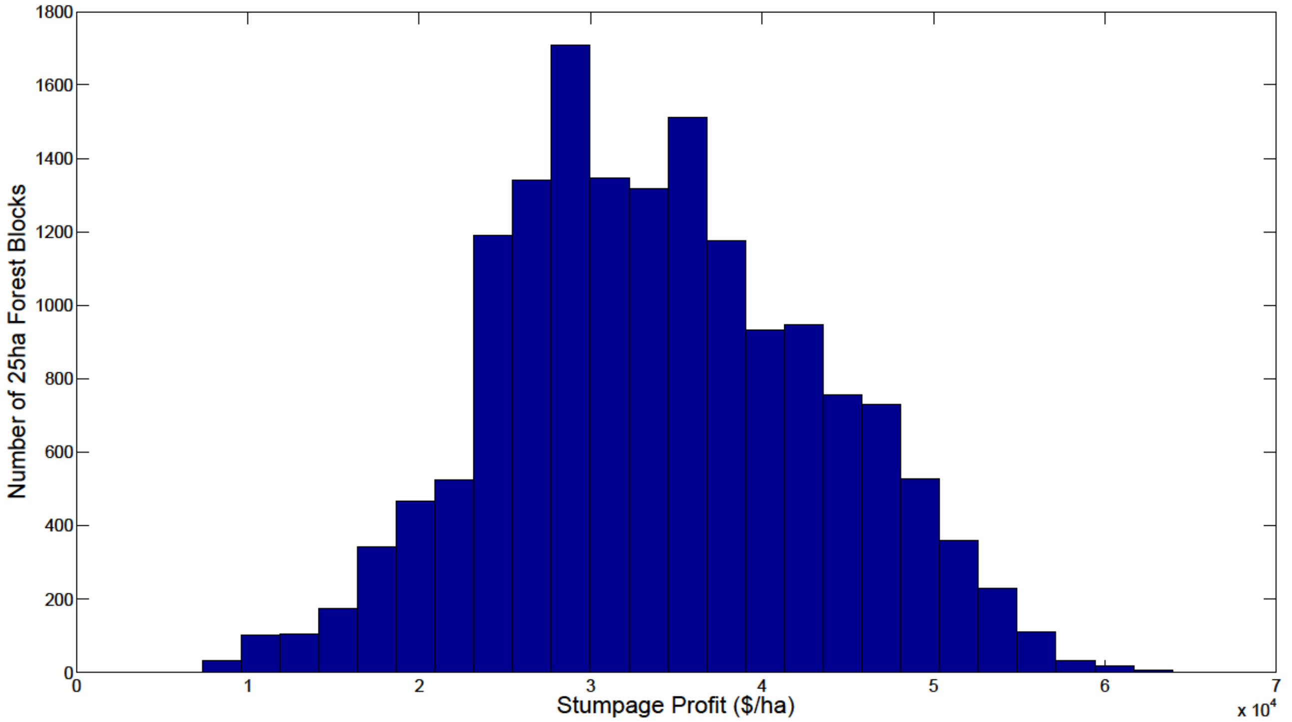


Figure 5: Histogram of Stumpage Profit for 2030 for All Planted Forest



Last, stumpage profit maps for 2013 and 2030 are included (Figure 6 and Figure 7 in Appendix). Map resolution (size of pixel) is 25 hectares. White pixels are non-harvestable forest and grey pixels are sea. Remaining pixels are coloured either red (forest stands with simulated stumpage profit less than $20,100 per hectare); magenta, blue, cyan (forest stands with simulated stumpage profit between $20,100 and $49,000 per hectare); or green (forest stands with simulated stumpage profit more than $49,000 per hectare). We can see that the North Island is more profitable in 2030 than in 2013, and the West Coast's relatively low stumpage profits is persistent through time. We now compare stumpage profits for post-89 and pre-90 forests.

8.2. Post-89 versus Pre-90

Average stumpage profits by WSR and year (2013-2030) for pre-90 and post-89 forests are reported in

Table 11 and

Table 12, respectively. There are no harvestable post-89 forest stands until 2015 when the first stands reach age 26; this is why the first two columns in

Table 12 are filled with N/A values.

We compare average stumpage profits over 2013-2030 by wood supply region for pre-90 and post-89 forest in Figure 8: Average Stumpage Profit over 2013-2030 by Wood Supply Region by Forest TypeFigure 8: Post-89 forests appear $10,300 per hectare more profitable than pre-90 forests in the Central North Island WSR; post-89 forests are $5,700 per hectare more profitable than pre-90 forests in the Auckland WSR; and post-89 forests are $4,610 per hectare more profitable than pre-90 forests in the Otago WSR; Remaining wood supply regions differ at most by $4,000 per hectare.

Stumpage profit histograms for each forest type (pre-90 and post-89) in 2030 are reported Figure 10 and Figure 11.[34]

[34] 2030 is the first year that post-89 forests have a full age-class distribution (from 1-41). It makes sense to compare histograms and stumpage profit maps in 2030, but no earlier.

The histogram for pre-90 forests has stumpage profits concentrated near the mean, it is unimodal, and it follows the same asymmetric pattern as in the *all forest* case. The mean is $30,200 per hectare, the standard deviation is $7,400, and the coefficient of variation is $c = 0.25$. There is a significant amount of variation in stumpage profits: the maximum stumpage profit is $57,900 (3.75 standard deviations above the mean), and the minimum stumpage profit is $7,400 (3.08 standard deviations below the mean).

On the other hand, the histogram for post-89 forests looks closer to uniform distribution than a normal distribution. The mean is $37,600, the standard deviation is $9,800, and the coefficient of variation is $c = 0.26$ (implying that post-89 forest stands have slightly more dispersion than for pre-90 forest stands). The maximum is $64,900 (2.76 standard deviations above the mean), and the minimum is $9,000 (2.91 standard deviations below the mean). We also produce stumpage profit maps for pre-90 (Figure 12) and post-89 (Figure 13) forests.

Following the procedure in Olssen et al. (2012) but updating and using our updated methodology for stumpage we produce measures of net present value (NPV), internal rate of return (IRR), land expectation value (LEV) and expected annual earnings (EAE). These are shown by wood supply region in Table 8. Figure 14 and Figure 15 are the NPV maps for pre-90 and post-89 forests, respectively. When the real subjective discount rate is equal to 7% we find that NPV is positive for most forest stands in Nelson, Northland, Central North Island, and North Island East Coast. NPV is negative elsewhere, so forest owners may choose not to replant after harvest in these regions. Figure 16 and Figure 17 are the IRR maps for pre-90 and post-89 forests, respectively. Most of the North Island stands have IRR equal to 6.5% or above. All forest stands excluding the West Coast and patches of forest in the South Island have IRR equal to 5% or higher.[35] This suggests that foresters probably will not replant in the South Island (other than Nelson) unless their discount rate is lower than 7%, say around 5%. For replanting on the West Coast, investors could get a higher rate of return from Treasury Bonds.

[35] Forest stands with IRR less than 5% in Nelson and Canterbury are on steep land.

Table 8 Mean expected forest profit by WSR for land in radiata pine in 2013

7% discount rate	NPV	IRR	LEV	EAE
Northland	490	7.65	577	40
Auckland	450	7.44	529	37
Central North Island	671	7.71	789	55
East Coast	507	7.43	597	42
Hawke's Bay	228	7.34	268	19
Southern North Island East Coast	327	7.21	385	27
Southern North Island West Coast	-312	6.77	-367	-26
Marlborough	-492	6.36	-579	-41
Nelson	251	7.37	296	21
West Coast	-2421	1.99	-2850	-199
Canterbury	-1127	5.19	-1327	-93
Otago	-827	5.9	-973	-68
Southland	-610	6.2	-718	-50
New Zealand Weighted Average	61	6.96	72	5

In short, stumpage profit for the average forest is increasing through time, and stumpage profits are significantly lower for West Coast than any other wood supply region. Our 2030 simulation shows that post-89 forests have higher stumpage profits than pre-90 forests (averaged over New Zealand). We also show that post-89 forests have much higher stumpage profits than pre-90 forests in the Central North Island wood supply region.

Our stumpage analysis does not include fixed costs per block at harvest (management costs, costs to move forestry equipment, forest permits). These will have a greater impact on average stumpage per hectare for small forest stands than large ones. Including fixed costs at harvest, as well as unobserved variation in yield, harvest and transport, is likely to increase the dispersion of stumpage profit and may lead to non-harvest of some blocks.

9. References

Anastasiadis, Simon, Suzi Kerr, Wei Zhang, Corey Allan, and William Power. 2014. *Land Use in Rural New Zealand: Spatial Land Use, Land-Use Change, and Model Validation*. Motu Working Paper 14-07. Motu Working Paper Series. Wellington, New Zealand: Motu Economic and Public Policy Research. www.motu.org.nz/publications/detail/land_use_in_rural_new_zealand_spatial_land_use_land-use_change_and_model_va.

Ministry for Primary Industries. 2013a. "Situation and Outlook for Primary Industries."

———. 2013b. "National Exotic Forest Description as at 1 April 2013."

Ministry of Agriculture and Forestry, New Zealand Forest Owners Association, and New Zealand Farm Forestry Association. 2012. *National Exotic Forest Description as at 1 April 2011*. Wellington: Ministry of Agriculture and Forestry. http://www.maf.govt.nz/news-resources/publications.

Olssen, Alex, Wei Zhang, David Evison, and Suzi Kerr. 2012. *A Forest-Profit Expectations Dataset for New Zealand, 1990-2008*. Wellington: Motu Economic and Public Policy Research. http://www.motu.org.nz/publications/detail/a_forest-profit_expectations_dataset_for_new_zealand_19902008.

Timar, Levente. 2011. *Rural Land Use and Land Tenure in New Zealand*. Motu Working Paper 11-13. Motu Working Paper Series. Wellington: Motu Economic and Public Policy Research.

Zhang, Wei, and Suzi Kerr. 2011. *Creating New Zealand Forestry Age Maps in 2002 and 2008 and Estimating and Projecting Plantation Forest Removals and Emissions in LURNZ*. Draft. Wellington: Motu Economic and Public Policy Research.

Appendix: Tables and Figures

Table 9: Compare Area for the 2013 LURNZ and NEFD Dataset

Territory Authority	LURNZ Area (ha)	NEFD Area (ha)	NEFD – LURNZ Area (ha)	Absolute value of error as percentage
Far North District	75,550	91494	15,944	17%
Whangarei District	31,175	31711	536	2%
Kaipara District	38,950	38354	-596	2%
Auckland Council	33,250	40908	7,658	19%
Papakura District	175	49	-126	72%
Franklin District	6,950	43	-6,907	99%
Thames-Coromandel District	9,650	16332	6,682	41%
Hauraki District	3,175	3255	80	2%
Waikato District	14,875	18271	3,396	19%
Matamata-Piako District	1,400	1400	0	0%
Hamilton City	0	1	1	
Waipa District	2,825	2709	-116	4%
Otorohanga District	5,225	5057	-168	3%
South Waikato District	70,275	62687	-7,588	11%
Waitomo District	20,125	25651	5,526	22%
Taupo District	111,700	169338	57,638	34%
Western Bay Of Plenty District	15,650	23731	8,081	34%
Tauranga District	350	110	-240	69%
Rotorua District	33,175	51384	18,209	35%
Whakatane District	46,300	104348	58,048	56%
Kawerau District	25	34	9	26%

Opotiki District	18,675	16631	-2,044	11%
Gisborne District	119,025	154289	35,264	23%
Wairoa District	40,875	53890	13,015	24%
Hastings District	48,425	60129	11,704	19%
Napier City	175	139	-36	21%
Central Hawkes Bay District	13,575	15405	1,830	12%
New Plymouth District	4,925	4005	-920	19%
Stratford District	38,50	6398	2,548	40%
South Taranaki District	14,100	9859	-4,241	30%
Ruapehu District	36,400	46787	10,387	22%
Wanganui District	21,075	28315	7,240	26%
Rangitikei District	19,475	21911	2,436	11%
Manawatu District	7,925	6646	-1,279	16%
Palmerston North City	2,950	2271	-679	23%
Tararua District	17,625	15885	-1,740	10%
Horowhenua District	6,925	6717	-208	3%
Kapiti Coast District	4,375	3664	-711	16%
Porirua City	2,250	1391	-859	38%
Upper Hutt City	3,375	6240	2,865	46%
Lower Hutt City	350	299	-51	15%
Wellington City	1,125	319	-806	72%
Masterton District	27,250	32880	5,630	17%
Carterton District	9,125	10341	1,216	12%
South Wairarapa District	5,450	8481	3,031	36%
Tasman District	69,250	86386	17,136	20%
Nelson City	7,225	8757	1,532	17%

Marlborough District	57,475	71473	13,998	20%
Kaikoura District	1,525	1345	-180	12%
Buller District	4,800	3869	-931	19%
Grey District	13,625	13940	315	2%
Westland District	12,875	14657	1,782	12%
Hurunui District	31,775	38997	7,222	19%
Waimakariri District	8,675	12458	3,783	30%
Christchurch City	1,400	6015	4,615	77%
Banks Peninsula District	5,225	5465	240	4%
Selwyn District	17,350	13863	-3,487	20%
Ashburton District	6,225	3776	-2,449	39%
Timaru District	12,875	11868	-1,007	8%
Mackenzie District	4,925	4832	-93	2%
Waimate District	13,050	11629	-1,421	11%
Waitaki District	21,050	18097	-2,953	14%
Central Otago District	9,275	6985	-2,290	25%
Queenstown-Lakes District	3,300	875	-2,425	73%
Dunedin City	18,700	14501	-4,199	22%
Clutha District	72,100	81143	9,043	11%
Southland District	68,300	77041	8,741	11%
Gore District	4,850	4404	-446	9%
Invercargill City	850	683	-167	20%
Unidentified	325	0	-325	
Total	1,417,125	1,712,818	295,693	17

Table 10: Average Stumpage Profit by Year and WSR for All Planted Forest ($/ha)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northland	28350	29352	29942	31677	34654	35588	35952	36148	35648	35589
Auckland	28901	29693	29803	31031	32778	32658	32418	32462	32733	33317
Central North Island	27918	29049	29636	31130	33781	34242	34947	35416	35668	35981
North Island East Coast	31648	33236	34040	35202	38033	38742	38915	38527	38579	38986
Hawke`s Bay	29014	30375	31099	32923	35570	35748	34997	34968	34854	35390
Southern North Island West	28643	29700	29513	30145	31888	31945	31074	30614	30047	30230
Southern North Island East	31663	32814	33219	35258	37455	37247	36144	35920	36266	36616
Nelson	27034	28592	28655	29560	31577	30865	29984	29387	28875	29211
Marlborough	22739	24475	24403	26200	28788	29780	28624	27311	26217	26228
West Coast	11244	11991	12247	13107	14132	14202	13127	12590	12294	12109
Canterbury	19791	20627	20666	21192	22641	22629	22291	21869	21362	21437
Otago	21322	21922	22487	24467	27003	27566	27610	28043	27668	28099
Southland	23931	24942	25396	26620	28694	28936	27872	27218	26571	26806
Average	25554	26674	27008	28347	30538	30781	30304	30036	29752	30000

Table 10: **Continued**

Year	2023	2024	2025	2026	2027	2028	2029	2030	Average
Northland	35689	35950	36500	36919	37289	37272	37032	36467	34779
Auckland	33778	34479	35013	35139	35280	35188	35085	35122	33049
Central North Island	36194	36372	36283	36316	36206	36205	36162	36105	34312
North Island East Coast	39556	40122	40824	41311	41680	41241	41007	41279	38496
Hawke`s Bay	36026	36723	37541	38173	38341	37944	37544	37063	35239
Southern North Island West	30595	30885	31262	31704	32214	32601	32790	33045	31050
Southern North Island East	36881	37223	37828	38337	38898	39253	39598	40005	36701
Nelson	29649	30262	30756	31258	31554	31655	31590	31543	30112
Marlborough	26588	27242	27790	28737	29437	29840	30543	30993	27552
West Coast	11960	12022	12181	12260	12494	12633	12832	13008	12580
Canterbury	21296	21510	21788	21982	22152	22362	22583	22281	21692
Otago	28496	28878	29100	29971	30262	31095	31502	31769	27626
Southland	27230	27572	27747	27881	28143	28640	29014	29286	27361
Total	30303	30711	31124	31538	31842	31995	32099	32151	30042

Table 11: Average Stumpage Profit by Year and WSR for Pre-90 Planted Forest ($/ha)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northland	28350	29352	29913	31617	34531	35262	35611	35950	35526	34840
Auckland	28901	29693	29776	30832	32271	31858	31238	30740	30477	30437
Central North Island	27918	29049	29272	30464	32694	32859	33197	33274	33095	33001
North Island East Coast	31648	33236	34124	35686	38782	39379	39594	38835	37738	37359
Hawke`s Bay	29014	30375	31176	33218	35882	36021	35522	35222	34790	34146
Southern North Island West	28643	29700	29900	31221	33545	33697	33206	32932	31700	31760
Southern North Island East	31663	32814	33314	35445	37982	38343	37654	37033	36839	36906
Nelson	27034	28592	29355	30260	32209	31688	31550	30963	30656	30557
Marlborough	22739	24475	25551	27682	30477	32098	32957	33091	32695	32290
West Coast	11244	11991	12294	13269	14464	14731	14339	14329	14055	13583
Canterbury	19791	20627	21035	22077	23788	23935	24157	24105	23831	23780
Otago	21322	21922	22381	24307	26798	27257	27539	27463	26612	26066
Southland	23931	24942	25706	27289	29456	29892	29590	28811	27956	27528
Average	25554	26674	27215	28721	30991	31309	31243	30981	30459	30173

Table 11: **Continued**

Year	2023	2024	2025	2026	2027	2028	2029	2030	Average
Northland	34293	33953	33381	33052	32752	32163	31536	31453	32974
Auckland	30291	30638	31068	31067	30983	30507	30041	29987	30600
Central North Island	32731	32415	32045	31966	31948	32018	32080	32324	31797
North Island East Coast	36534	35265	34764	34702	34438	33446	33114	33402	35669
Hawke`s Bay	33695	33231	32598	31914	31096	30813	30963	30729	32800
Southern North Island West	31648	31504	31871	32002	32027	31947	32180	32034	31751
Southern North Island East	36512	34831	35179	34975	34476	34164	33882	33993	35334
Nelson	30529	30651	30448	30718	30684	30532	30238	30278	30386
Marlborough	31119	30526	29783	29259	28125	26493	26588	27225	29065
West Coast	13161	12358	12082	11800	11600	11339	11339	11600	12754
Canterbury	23017	22724	22108	21734	21778	21611	21681	20868	22369
Otago	25822	26000	25740	25527	24143	24149	23094	23358	24972
Southland	27096	26630	26605	26116	25088	24738	24191	24332	26661
Average	29727	29287	29052	28833	28395	27994	27764	27814	29010

Table 12: Average Stumpage Profit by Year and WSR for Post-89 Planted Forest ($/ha)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northland	N/A	N/A	30188	31902	34966	36254	36402	36326	35719	35934
Auckland	N/A	N/A	30116	32113	35155	36287	34819	34673	34707	35475
Central North Island	N/A	N/A	34376	36704	40152	41336	41876	42104	41720	41914
North Island East Coast	N/A	N/A	32781	34022	37091	38215	38577	38444	38750	39271
Hawke`s Bay	N/A	N/A	29426	31252	34489	35137	34585	34871	34868	35618
Southern North Island West	N/A	N/A	24552	26163	28593	29432	29348	29436	29475	29802
Southern North Island East	N/A	N/A	31643	33601	35259	35290	35099	35433	36081	36547
Nelson	N/A	N/A	22062	24488	27256	27129	26210	26610	26707	27657
Marlborough	N/A	N/A	19097	21514	24375	25325	24577	24349	24396	24968
West Coast	N/A	N/A	9493	9832	11092	11253	10617	10758	11032	11263
Canterbury	N/A	N/A	16877	17653	19674	20239	20387	20355	20214	20568
Otago	N/A	N/A	23638	25638	27903	28530	27703	28618	28380	29132
Southland	N/A	N/A	21622	23023	25733	26484	25742	25935	25857	26495
Average	N/A	N/A	25067	26762	29364	30070	29688	29839	29839	30357

Table 10: **Continued**

Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Average**
Northland	36235	36639	37631	38447	39394	40038	40911	41390	36774
Auckland	36324	37371	37918	38359	38254	38957	39732	40510	36298
Central North Island	41682	42331	43067	44016	44823	45245	46065	46784	42137
North Island East Coast	40039	40925	41770	42340	42853	42768	42969	43598	39651
Hawke`s Bay	36401	37278	38422	39640	40640	41090	41511	41867	36693
Southern North Island West	30309	30712	31099	31628	32268	32813	33003	33430	30129
Southern North Island East	36955	37728	38375	38991	39861	40582	41170	41939	37160
Nelson	28620	29775	31212	32212	33352	34533	36027	36625	29405
Marlborough	25747	26712	27475	28660	29657	30559	31625	32223	26329
West Coast	11436	11871	12221	12468	12977	13534	14147	14628	11789
Canterbury	20703	21127	21673	22080	22309	22697	23014	22993	20785
Otago	29706	30094	30026	30987	31709	32788	33478	34078	29526
Southland	27278	27890	28091	28364	29066	30059	31102	31810	27159
Average	30880	31573	32229	32938	33628	34282	34981	35529	31064

Figure 6: Stumpage Profit Map for 2013 for All Planted Forest ($/ha)

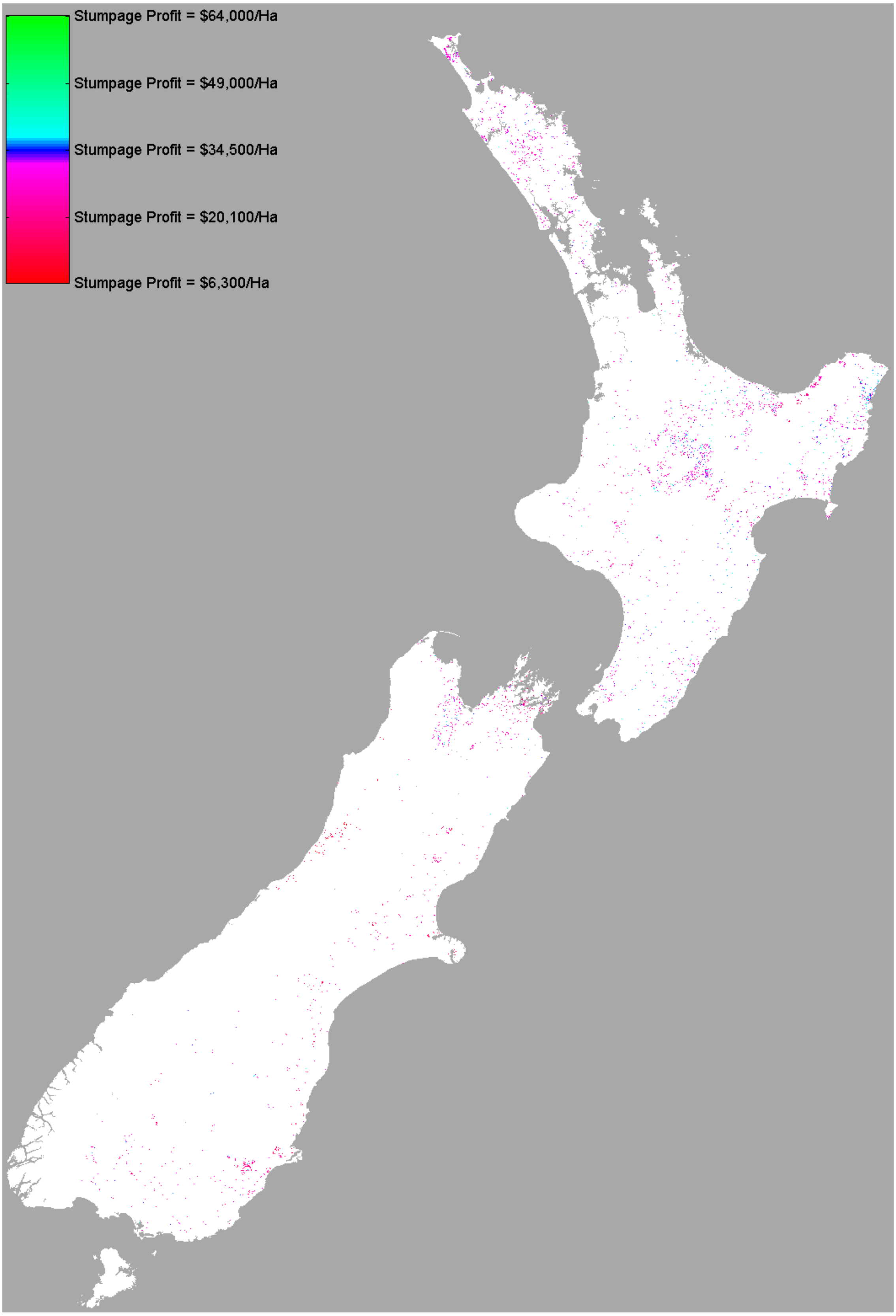


Figure 7: Stumpage Profit Map for 2030 for All Planted Forest ($/ha)

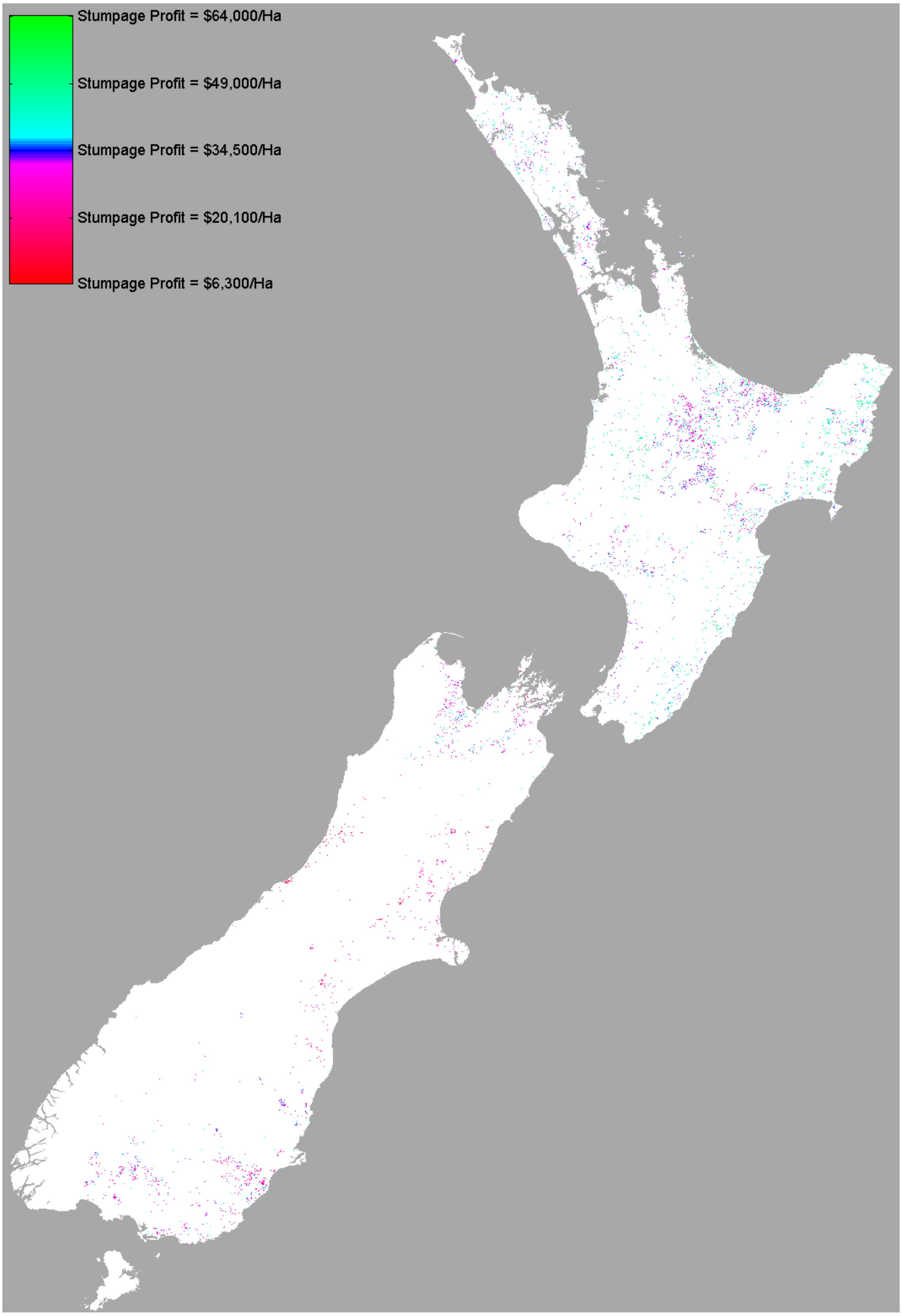


Figure 8: Average Stumpage Profit over 2013-2030 by Wood Supply Region by Forest Type

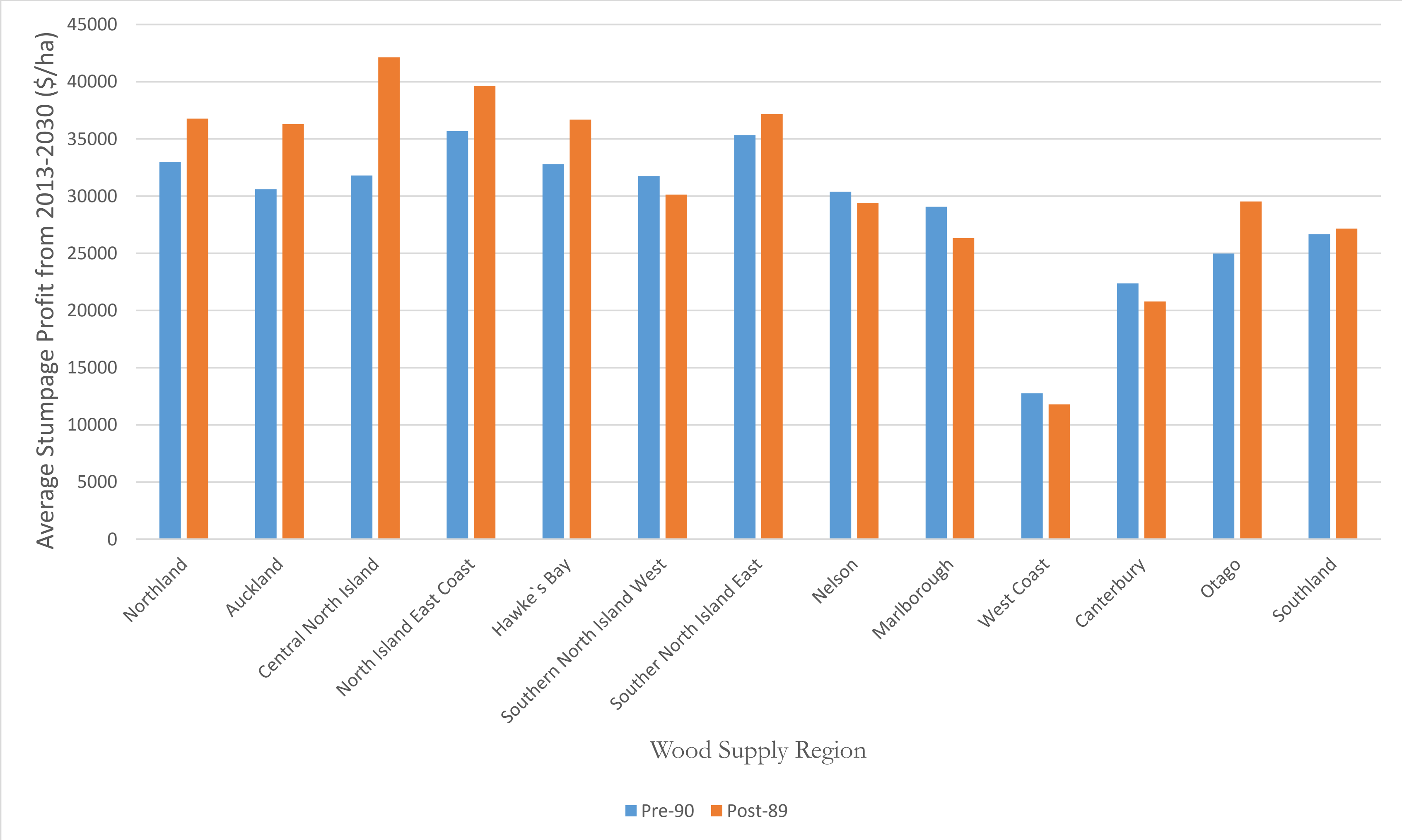


Figure 9: Average Stumpage Profit over Wood Supply Region by Year by Forest Type

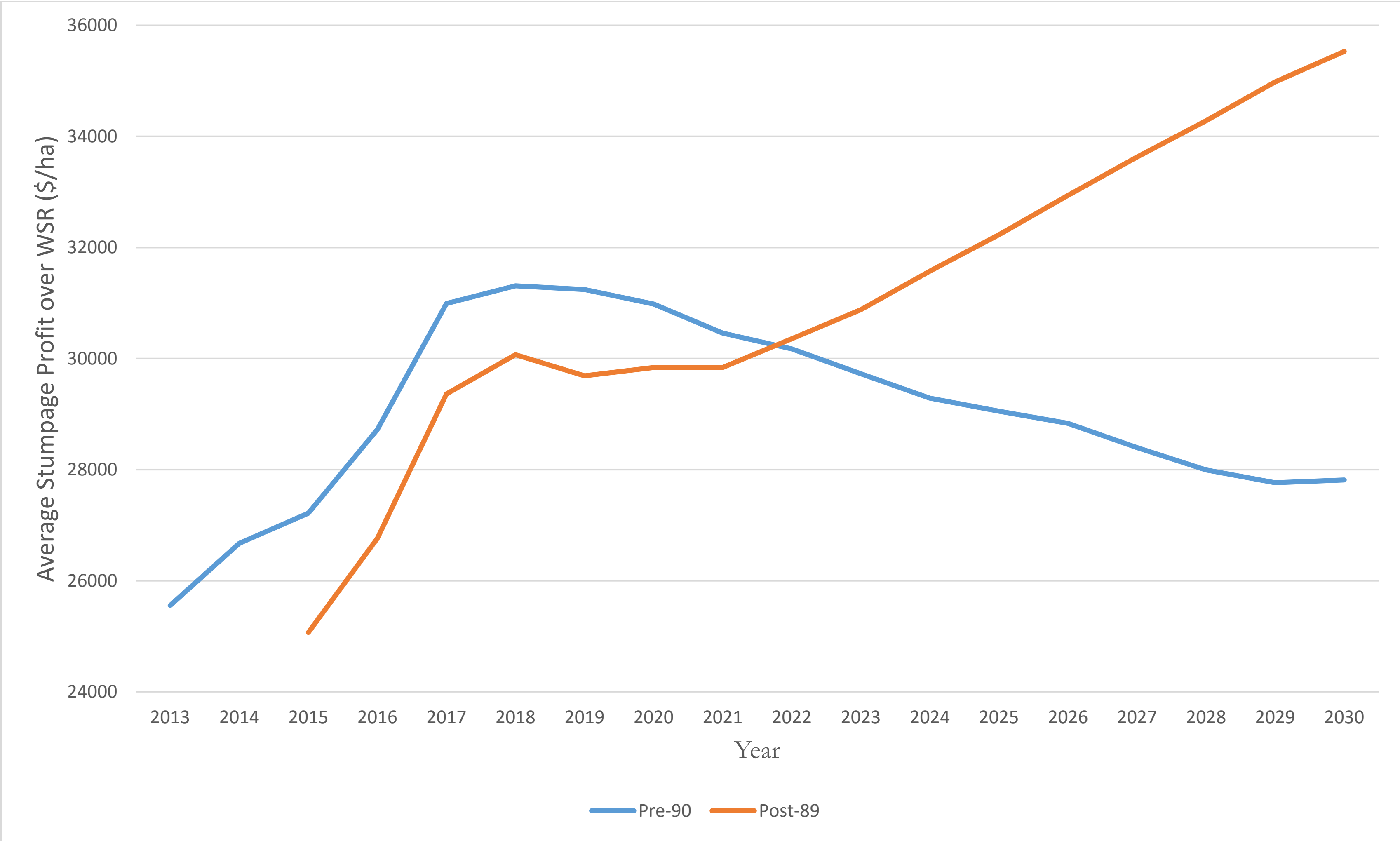


Figure 10: Histogram of Stumpage Profit for 2030 for Pre-90 Forest

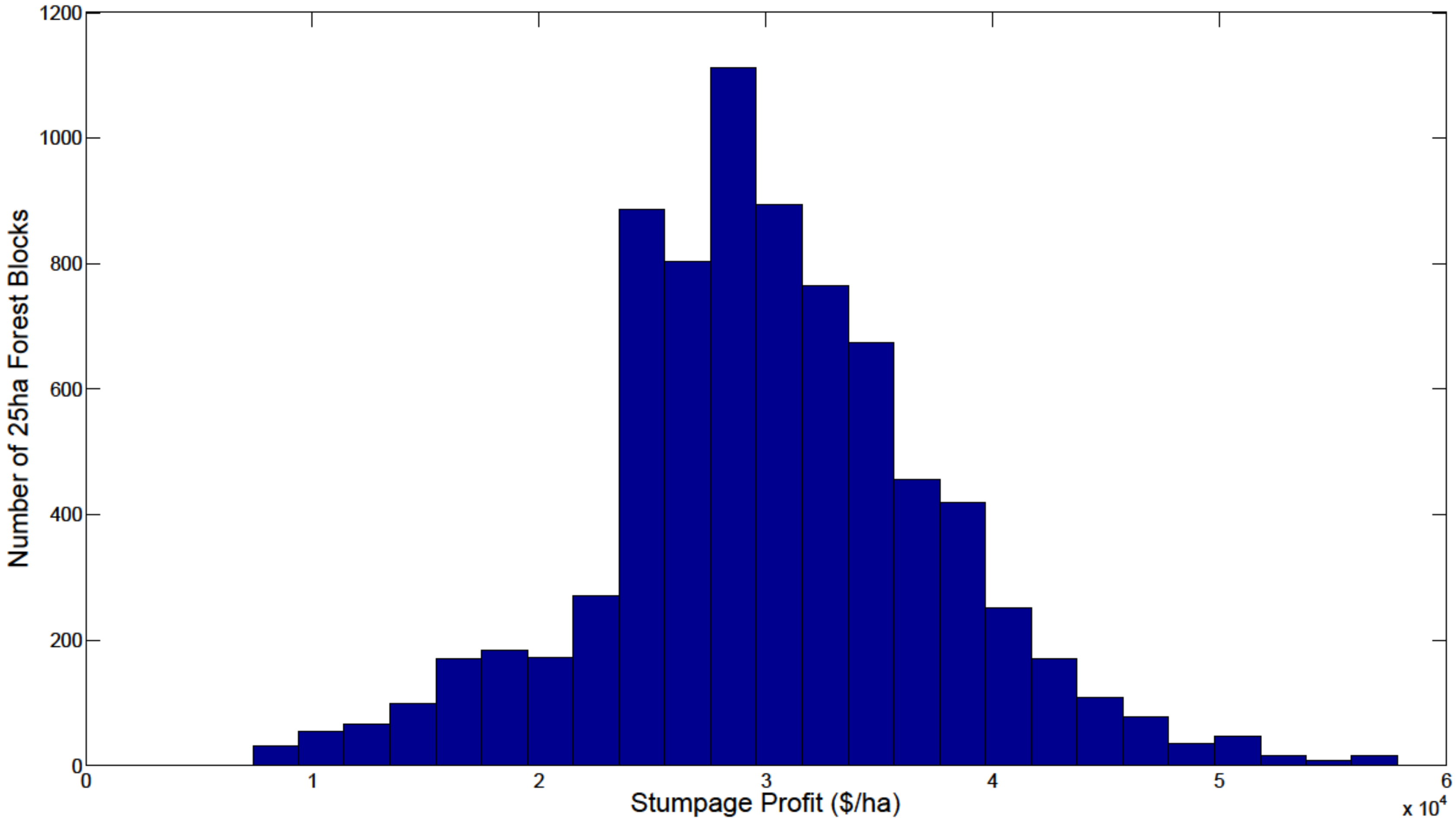


Figure 11: Histogram of Stumpage Profit for 2030 for Post-89 Forest

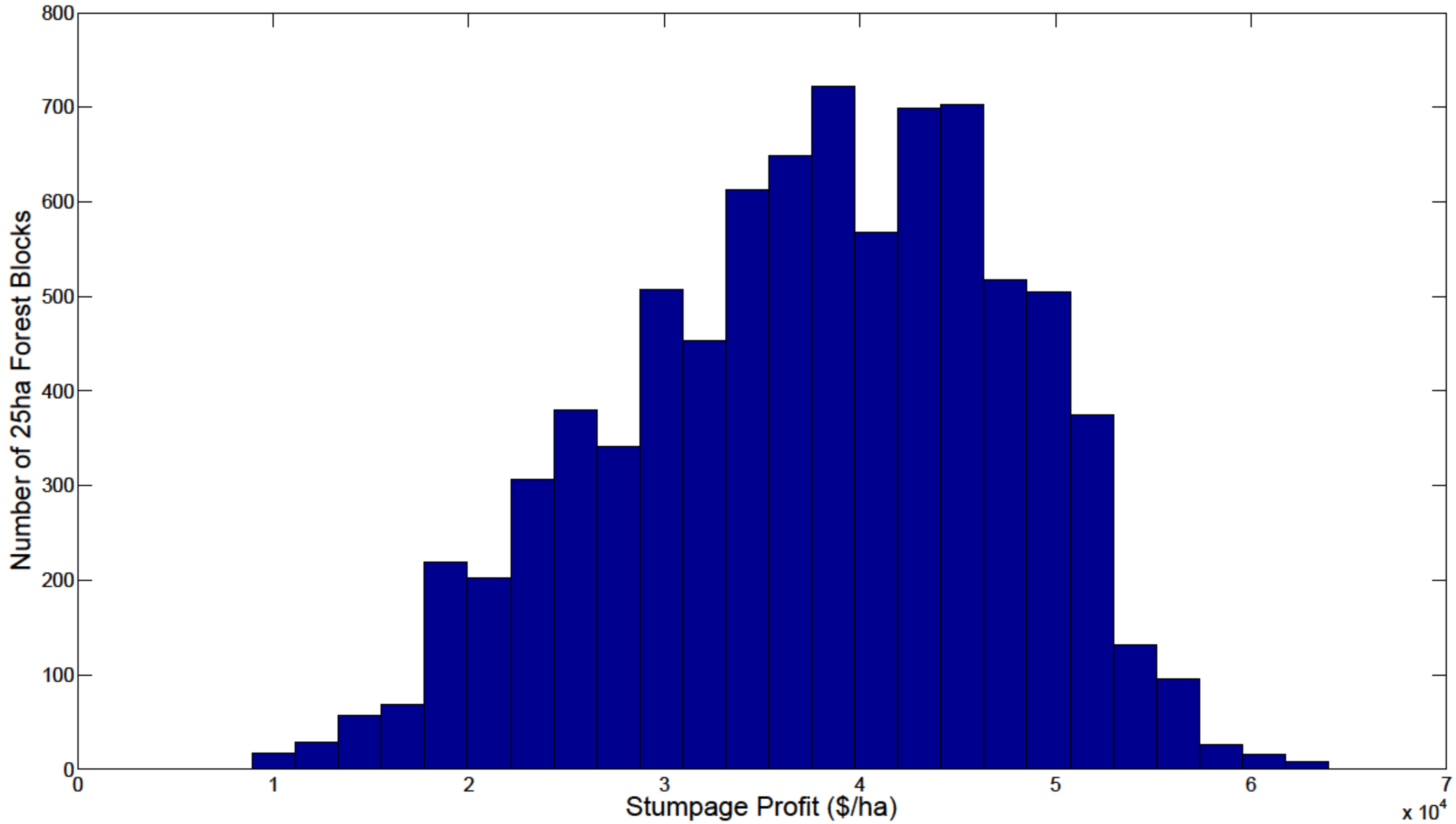


Figure 12: Stumpage Profit Map for 2030 for Pre-90 Forest ($/ha)

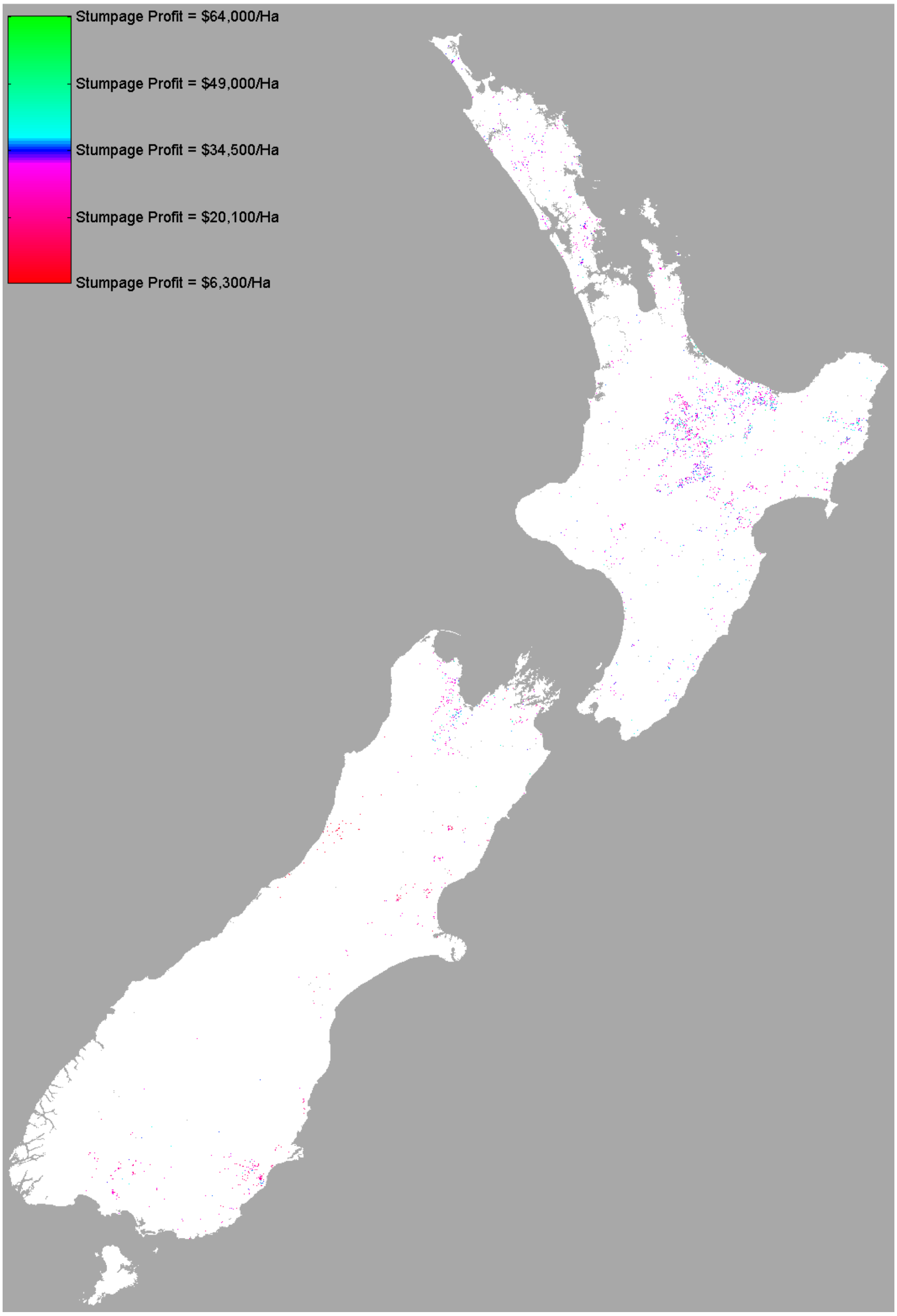


Figure 13: Stumpage Profit Map for 2030 for Post-89 Forest ($/ha)

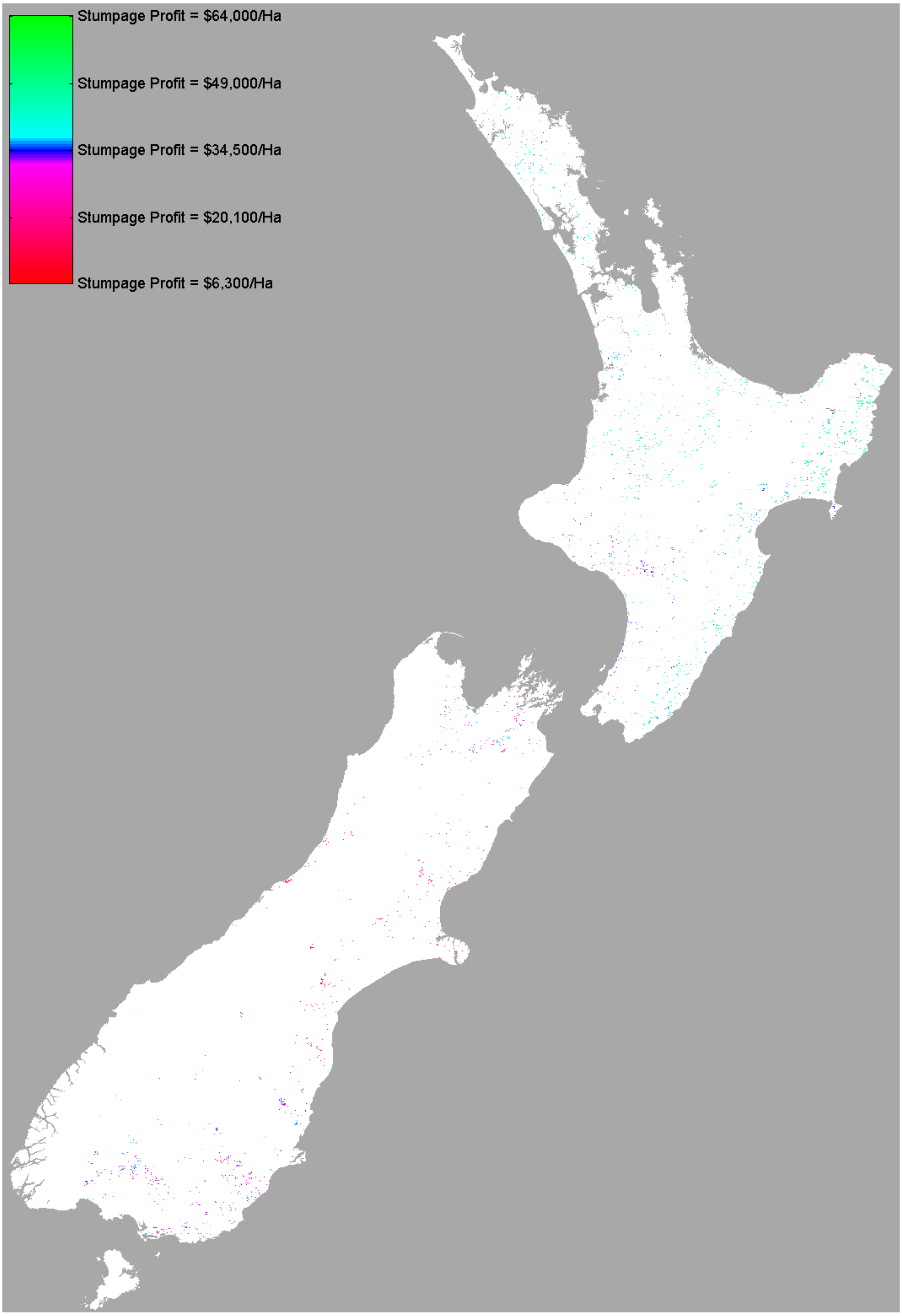


Figure 14: NPV Map for 2013 Pre-90 Forest ($/ha) – 7% discount rate

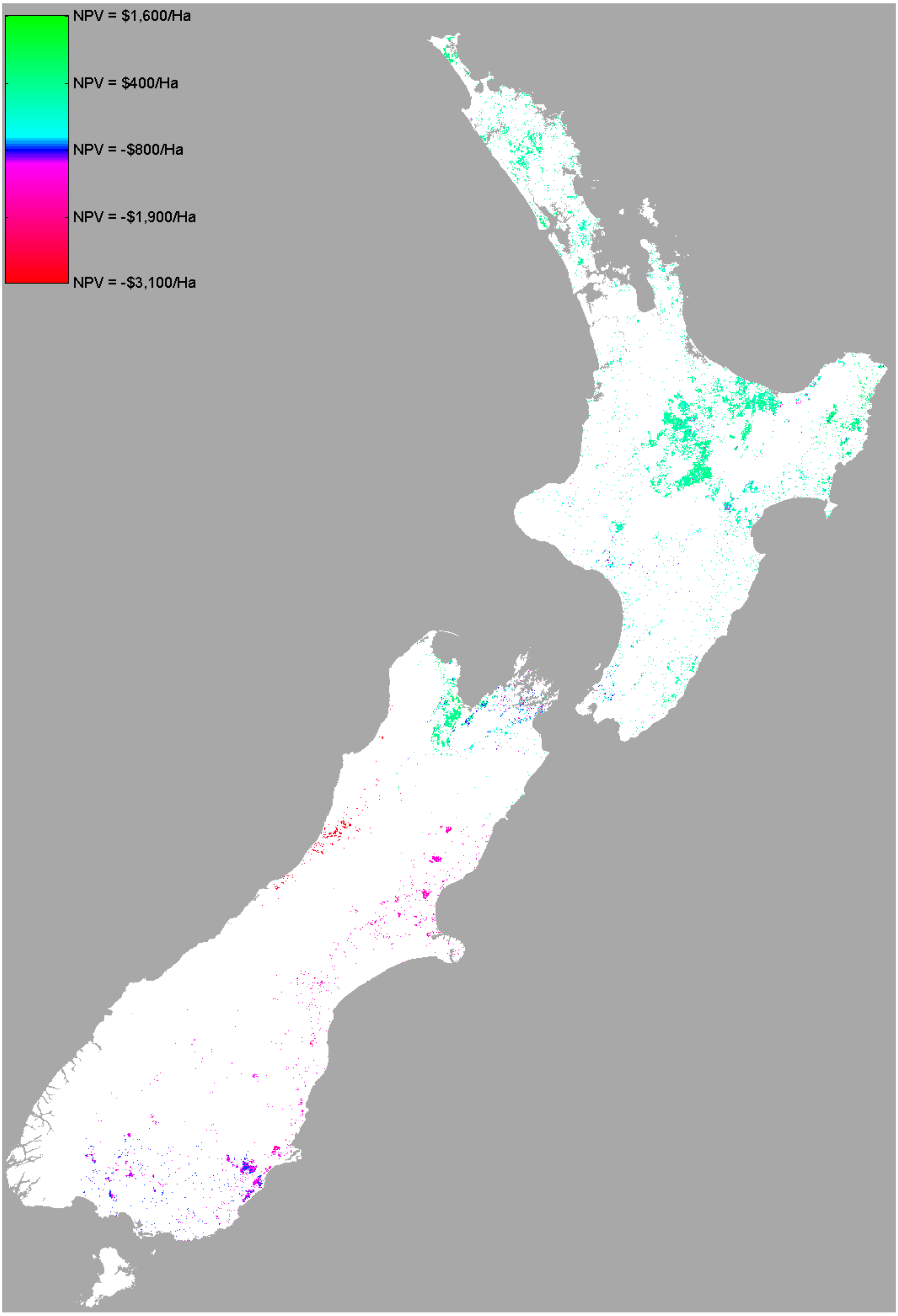


Figure 15: NPV Map for 2013 Post-89 Forest ($/ha) – 7 % discount rate

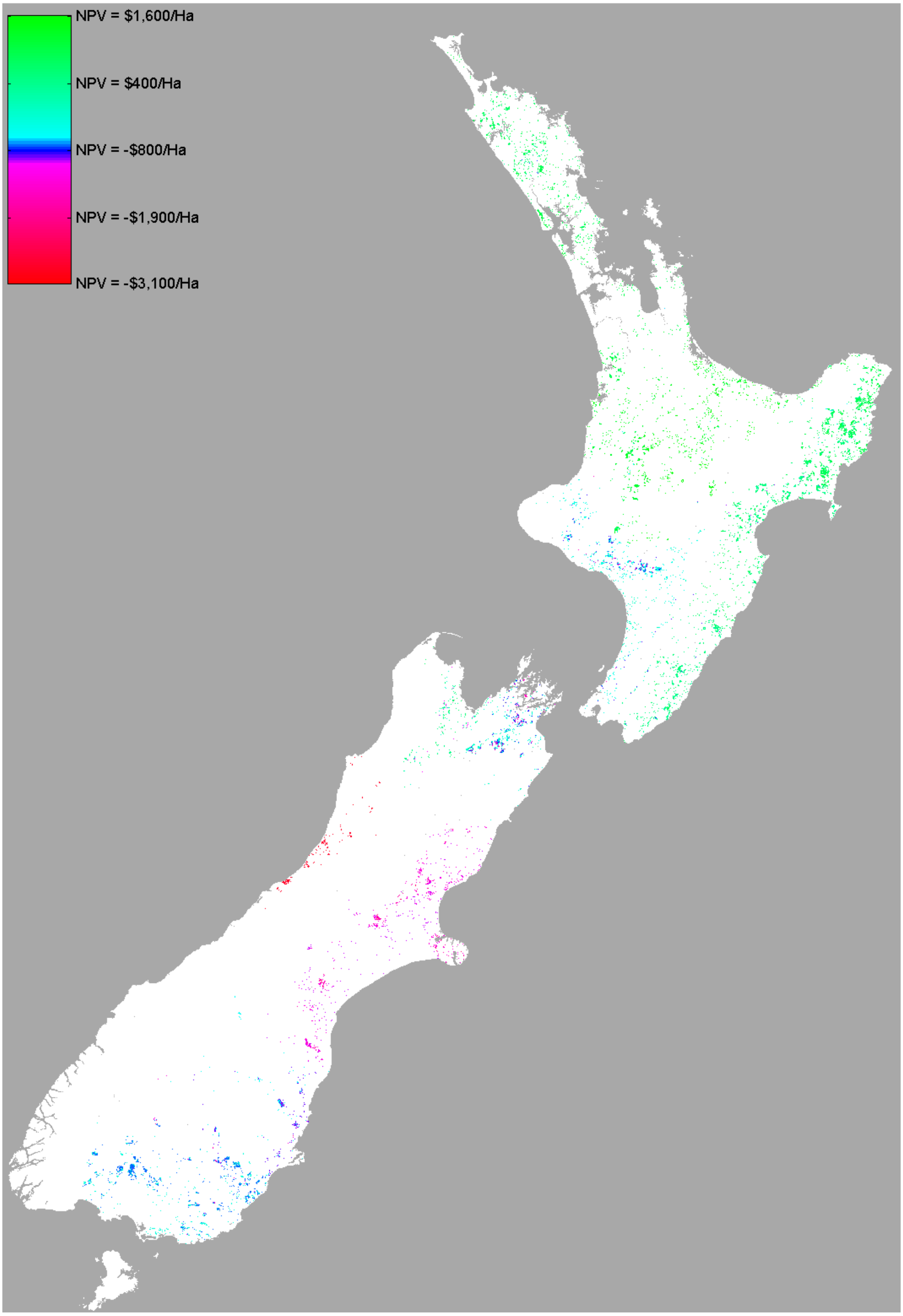


Figure 16: IRR Map for 2013 Pre-90 Forest ($/ha)

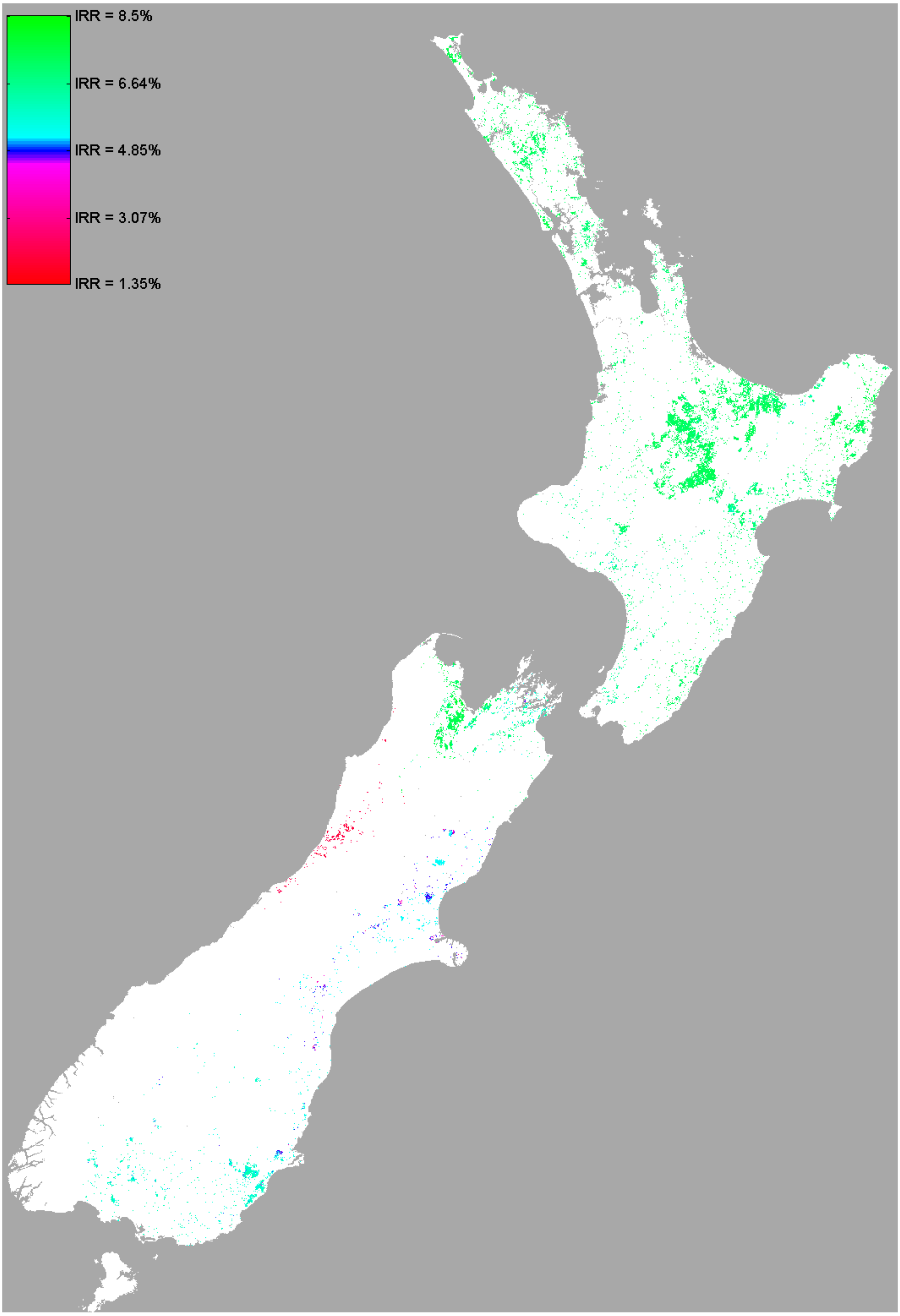
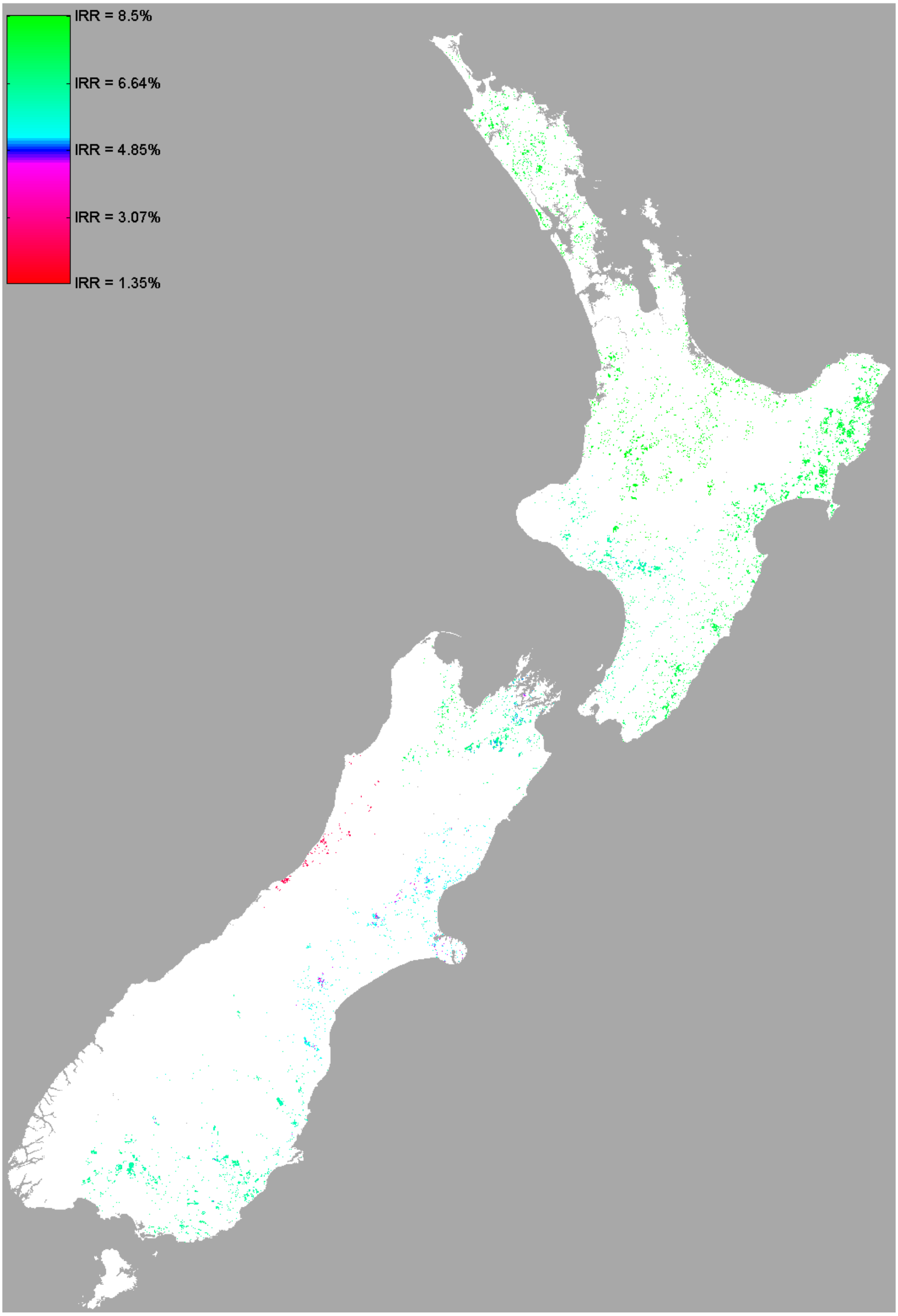


Figure 17: IRR Map for 2013 Post-89 Forest ($/ha)



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