Potential for forestry on highly erodible land in New Zealand

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Abstract

Potential CO_2 sequestration from new forests planted in New Zealand was estimated assuming a planting rate of 50,000 ha per year. An analysis of erosion-prone Kyoto-compliant land revealed that an area of 1.3 million ha was available for planting. 26 years of planting were assumed, and sequestration was assessed at an estate level for 60 years following the first plantings. Six different combinations of species and silvicultural regimes were compared. If the entire area was planted in radiata pine and left to grow, then for some years total sequestration rates approached New Zealand's total gross greenhouse gas emissions and forests could render the nation greenhouse gas neutral. At the other extreme, either planting indigenous species or planting radiata pine destined for harvest with an appearance grade regime would result in considerably lower, but still very useful, levels of CO_2 sequestration. In all scenarios, sequestration levels varied a great deal across years of simulation, and this variation should be taken into account if sequestration of CO_2 by new forests is employed as a means to help New Zealand meet its climate change mitigation commitments.

Introduction

New Zealand has enormous potential to use forests to sequester CO_2 as part of its contribution to mitigating climate change. This report sets out the results of an analysis requested by the Green Party of New Zealand to examine the carbon sequestration potential of a range of alternative afforestation strategies. Erosion-prone land was chosen as a target because re-establishing forest greatly reduces the likelihood of further erosion (Marden, 2012; Marden, Herzig, & Basher, 2014), and such land is often relatively unproductive as farmland. The report was delivered in August 2015.

Method

We used Geographic Information System layers describing land titles,[1] Land Use Capability classes from the New Zealand Land Resource Inventory,[2] and Erosion Susceptibility Classes (ESC) defined in a study by Bloomberg et al. (2011). Erosion susceptibility classes are shown in Figure 1. We also created a mask that provided estimates of 'Kyoto compliant' land, i.e. land that is not currently in forest but that could reasonably be planted in forest. This was based on the LCDB v4.0 dataset.[3] The classes that were explicitly included in our analysis were:

- Gorse and/or broom
- High-producing exotic grassland
- Low-producing exotic grassland
- Short-rotation cropland
- Landslides.

In addition, broad radiata pine productivity classes were conservatively defined by mean annual rainfall and mean annual temperature. Temperature and water are the prime determinants of productivity identified in previous studies (Palmer et al., 2010). Land was allocated into four productivity categories: unsuitable for radiata pine; low productivity; medium productivity; and highly productive.

The potential productivity categories are shown in Figure 2.

Table 1 summarises land that is either highly or extremely erodible (based on ESC values of 'high' or 'very high') and that might be planted in carbon forests by productivity classes. Approximately 1.3 million ha are available in low, medium or high-productivity categories, or 5% of New Zealand's land area. Areas shown are in hectares. Most of the erodible land was in Land Use Capability classes VI to VIII, with the majority in class VII.

The areas identified as erodible and available for planting are shown in Figure 3.

[1]https://data.linz.govt.nz/layer/804-nz-property-titles/
[2]https://lris.scinfo.org.nz/layer/76-nzlri-land-use-capability/
[3]https://lris.scinfo.org.nz/layer/412-lcdb-v40-deprecated/

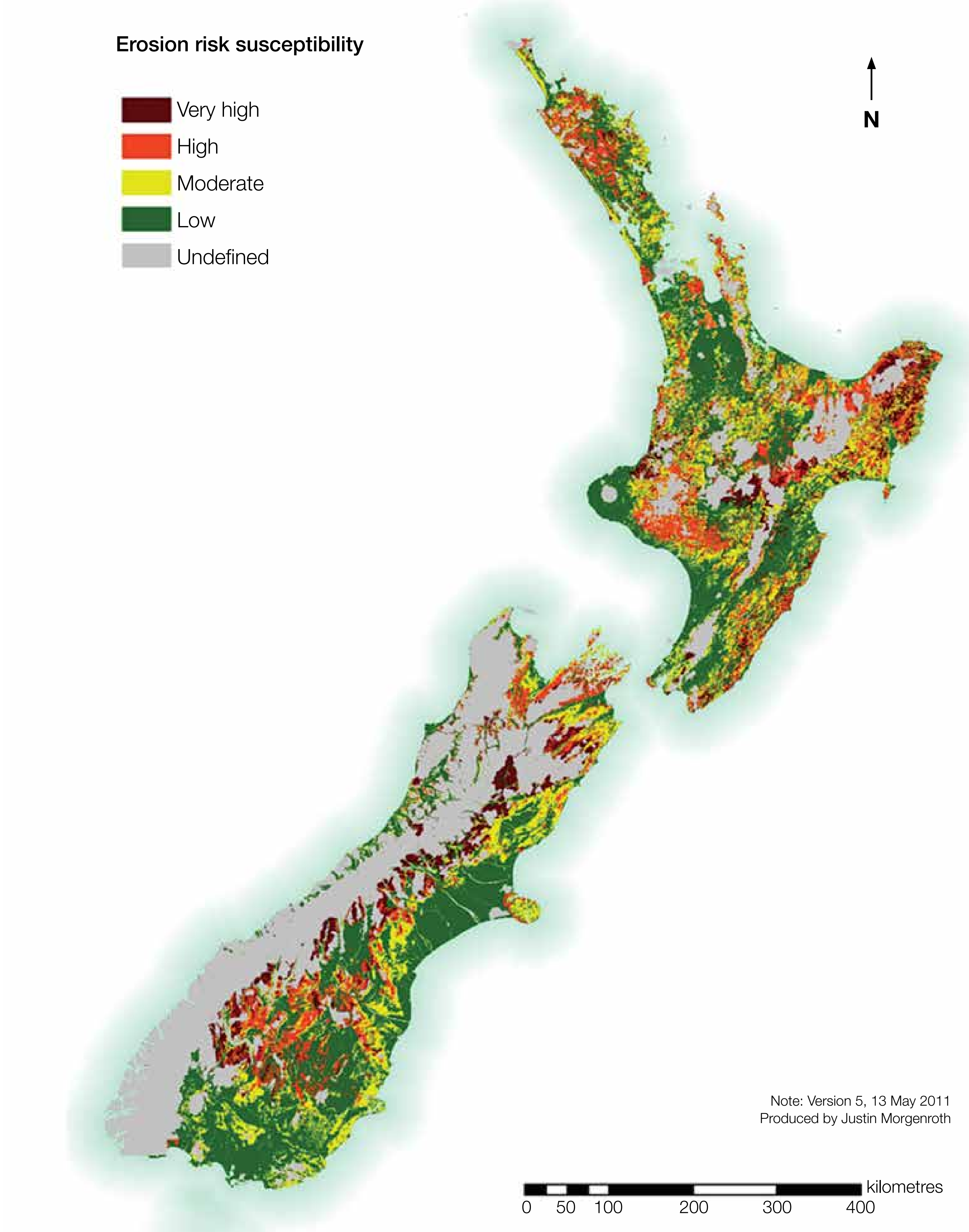

Figure 1: Erosion susceptibility classes (ESC) by Bloomberg et al., 2011

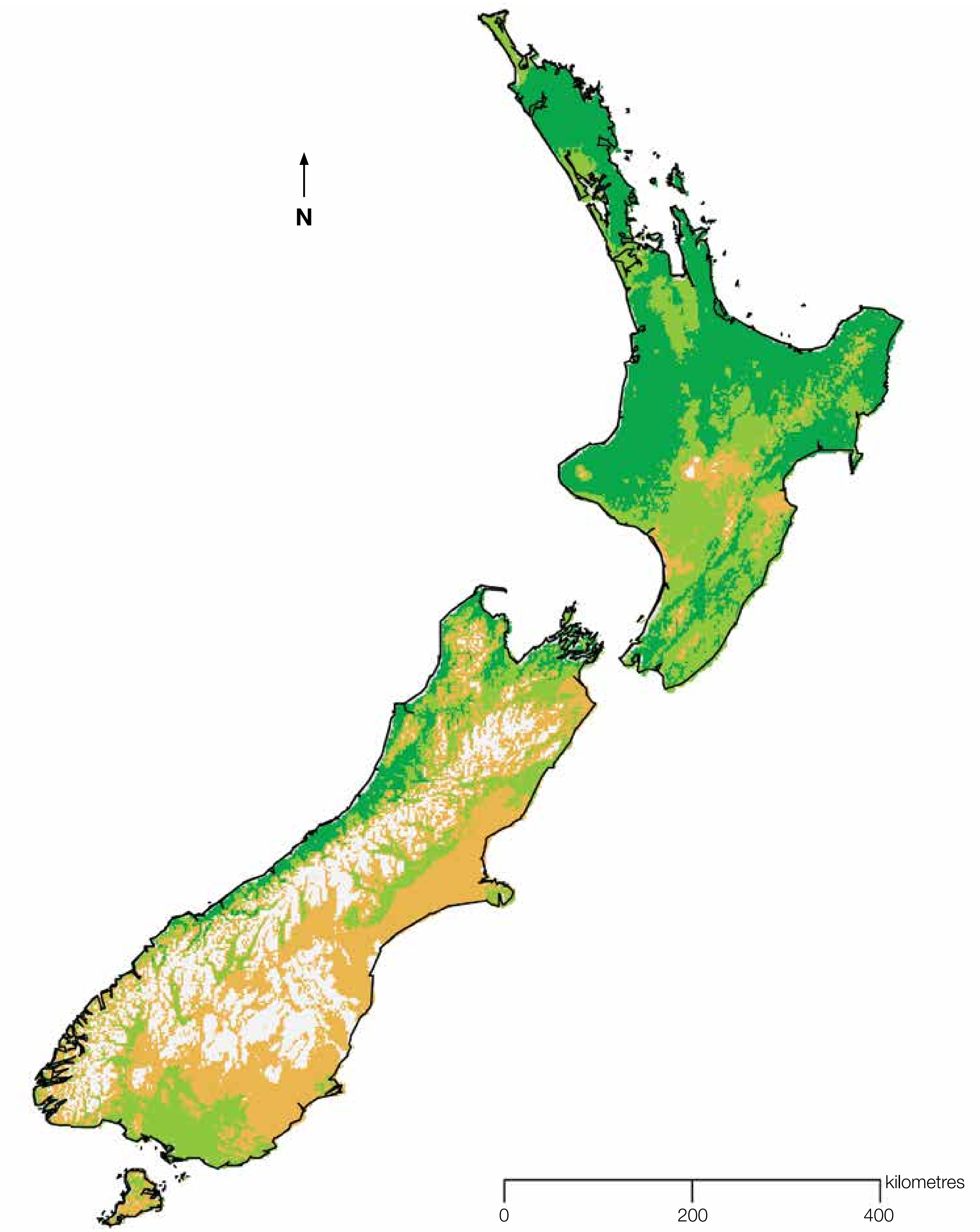

Figure 2: Potential productivity categories for radiata pine in NZ defined by rainfall and temperature. Green=highly productive, light green=moderately productive, brown=low productivity and white=unsuitable

Table 1: Provisional summaries of highly erodible land available for planting (ha)

Threatened environment class (see Table 2)	Productivity class			Total
	Low	Medium	High	
0	89	39	27	155
1	51,457	112,189	34,435	198,081
2	34,545	97,540	129,380	261,465
3	22,914	59,242	98,758	180,914
4	87,952	38,753	72,864	199,569
5	38,508	9,429	38,038	85,975
6	131,892	65,396	188,505	385,793
Total	367,357	382,588	562,007	1,311,952

Three points in the landscape were selected that were roughly representative of average conditions in the low, medium and high-productivity classes shown in Figure 2. 'Forecaster' software created by Scion Research as a successor to 'Standpak' (West, 1997) was used to run the 300 Index model (Kimberley, West, Dean, & Knowles, 2005) at each location for a silvicultural regime that comprised planting 1,000 radiata pine stems/ha and leaving them to grow. It was also used as a regime that is considered typical in pruned crops of radiata pine, with three pruning lifts and low final crop stockings in the range of 300 stems/ha after early thinning to waste. Model C_Change (Beets, Robertson, Ford-Robertson, Gordon, & Maclaren, 1999) was employed to estimate CO_2 sequestration in these regimes. Simulations of plant and leave regime options for radiata pine were adjusted downwards for the following reasons:

- Data employed for creating the growth and yield model we used did not cover long-rotation plant and leave options, and so the model was extrapolating for that option
- Estimation of carbon contents of large trees was based on a tiny dataset
- Examination of model outputs suggested that the growth and yield model may have been underestimating tree death from competition during the simulation period
- The adjusted model brought data more into line with published data (Woollons & Manley, 2012) we do have over long rotations, and so we know the values can be achieved.

In addition, C yields for the plant and leave options were further reduced to allow for attrition of whole stands after 30 years. Nevertheless, estimates of sequestration for the radiata pine plant and leave regimes remain highly uncertain.

Sources estimating sequestration rates for native species were consulted (there is an excellent summary at http://maxa.maf.govt.nz/forestry/pfsi/carbon-sequestration-rates.htm). Yield tables of carbon sequestration for typical native species were created that mirrored the tables for radiata pine but with a slower development. The mean sequestration rates used for native species ranged from 3.8 to 9.1 tonnes of CO_2 $ha^{-1}year^{-1}$ depending on site type. Figure 4 shows the accumulated CO_2 over 60 years for each option.

Yield tables over 60 years were created for the following options:

- Plant and leave the entire area in radiata pine at a planting rate of 50,000 ha/year over 26 years
- Plant at the same rate but prune, thin and harvest all of it at an appropriate time, then replant
- A 50:50 mixture 1 and 2
- Plant the total area in native forest at 50,000 ha/year
- A 50:50 mixture of 1 and 4 with 1 confined to the three least threatened environments
- A 50:50 mixture of 3 and 4 with 3 confined to the three least threatened environments.

Results

Figure 5 shows annual sequestration rates for the six simulated scenarios. As a reference, New Zealand typically emits approximately 80 million tonnes of CO_2-e per year.

Sequestration rates for the six scenarios summarised in tabular form are available from the authors.

Table 2: Threatened environment classes in New Zealand

Threatened class	Threatened class description
0	No data
1	Acutely threatened
2	Chronically threatened
3	At risk
4	Critically under-protected
5	Under-protected
6	Less reduced and better protected

Source: https://lris.scinfo.org.nz/layer/288-threatened-environments-classification-2012/

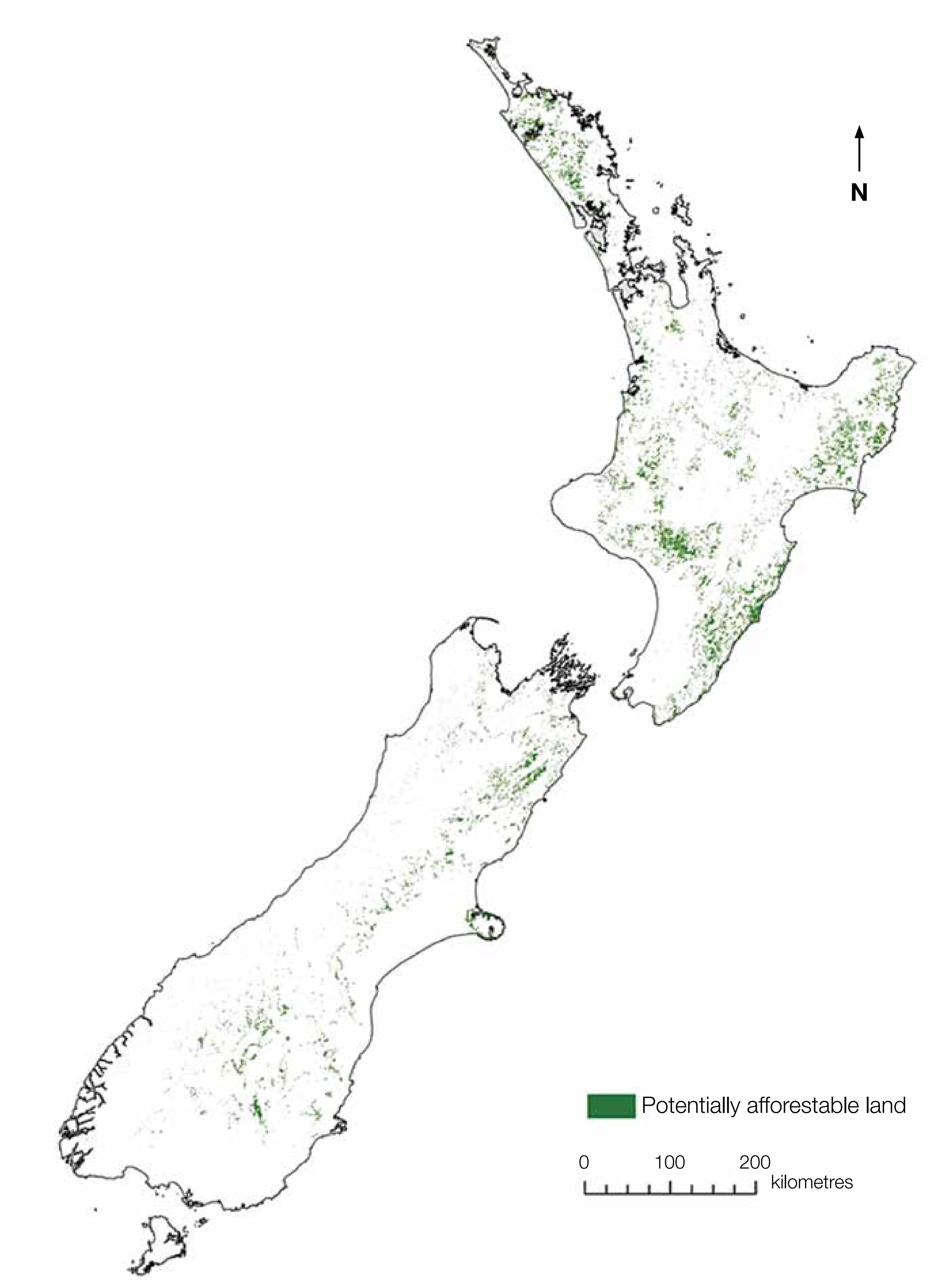

Figure 3: Areas that were available for afforestation and also judged to be at high or very high risk of erosion

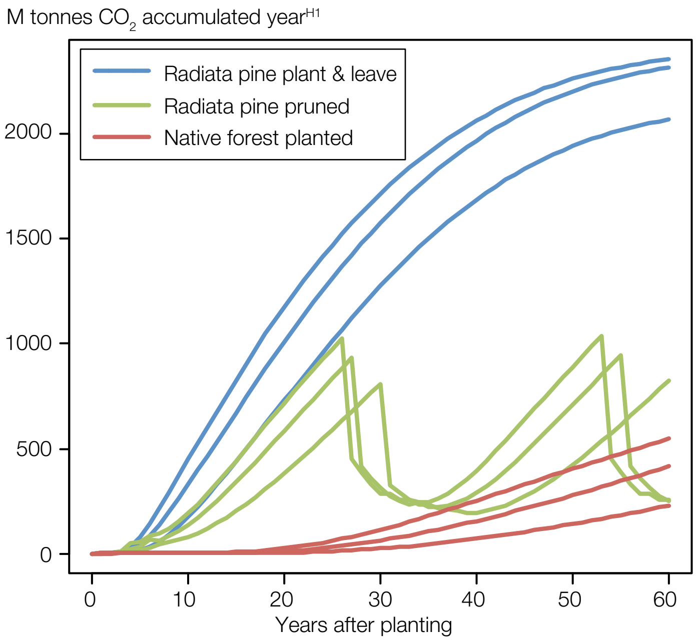

Figure 4: CO_2 accumulated over 60 years for each option simulated, with three lines representing high, medium and low productivity. Plant and leave options have been adjusted downwards from the original simulation, but they are still the most uncertain projections

Why radiata pine?

Radiata pine was chosen for the following reasons:

- It grows rapidly and sequesters C at a much higher rate than native species
- We are experts at producing seedlings for this species and they are cheap
- It will grow on a wide range of sites and we understand how to establish it on diverse sites, despite its sensitivity to shade and frost
- It is not a high-country wilding risk. It is very intolerant of both shade and frost, and would only seed naturally on moist lowland areas where adjacent land was not intensively grazed (Ledgard, 2008). Generally lowland areas are intensively grazed
- On warm, moist sites, either medium or high-productivity categories, it would act as a nurse crop for native forest, and the C reservoirs we establish would ultimately change to become native forest so long as seed sources were available in the local vicinity (Forbes, Norton, & Carswell, 2015a, 2015b) (Figure 6)
- Studies suggest that radiata pine will continue to sequester carbon for up to 100 years on some sites (Woollons & Manley, 2012), but we have assumed 60 in this analysis. This means that the forests would remain as sinks for some considerable time.

Discussion

This report was produced in a short time and so we recommend further analysis, particularly a refinement of rates of sequestration on diverse land types. Our estimates of erodible land area available are also preliminary. However, the main inferences we draw from this analysis are valid:

- Forestry can make an enormous contribution to mitigating climate change, as previously identified by Watt et al., 2011, and
- An estate-level simulation of C sequestration arising from annual programmes of planting produces annual sequestration rates that vary enormously over time at a national level.

The extent of sequestration rate fluctuation would be highly dependent on the planting schedule. For this analysis we assumed that equivalent proportional areas of low, medium and high-productivity classes were planted each year and that 50,000 ha were planted each year for 26 years.

We chose to focus on erosion-prone land because its afforestation would require minimal reductions in livestock farming and would reduce damage from flood-related siltation on adjacent farmland (Marden, 2012; Marden et al., 2014). As shown in Figure 3, Kyoto-compliant, erosion-prone land frequently occurs in small fragments, and so many farmers could continue to farm on the rest of their farms while they earned revenue from carbon forestry on small sections of their properties.

It is likely that incentives to plant may result in some planting of land that is not highly prone to erosion, and so long as the price of carbon is well set then trade-offs between livestock farming and carbon forestry will be sensible.

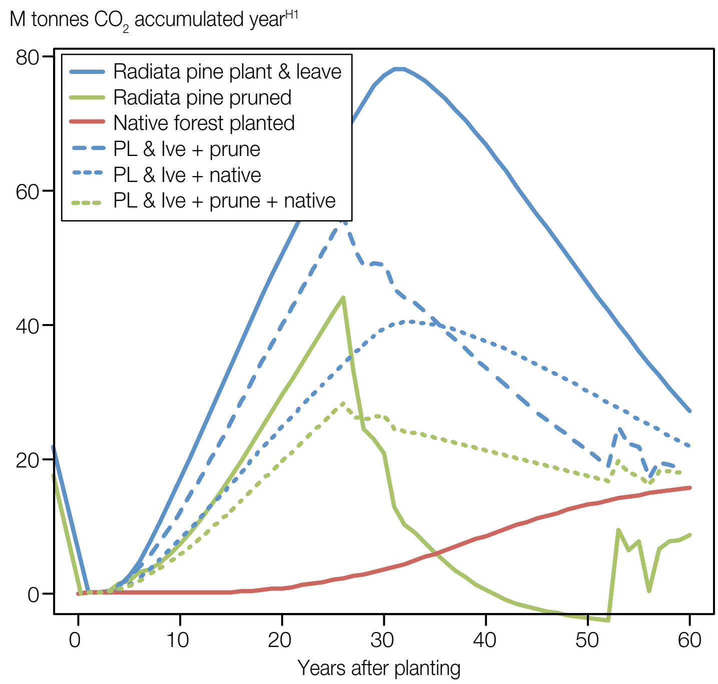

Figure 5: Sequestered CO_2 per annum for the six planting scenarios, with year=0 at the beginning of the establishment schedule of 50,000 ha year-1 for 26 years

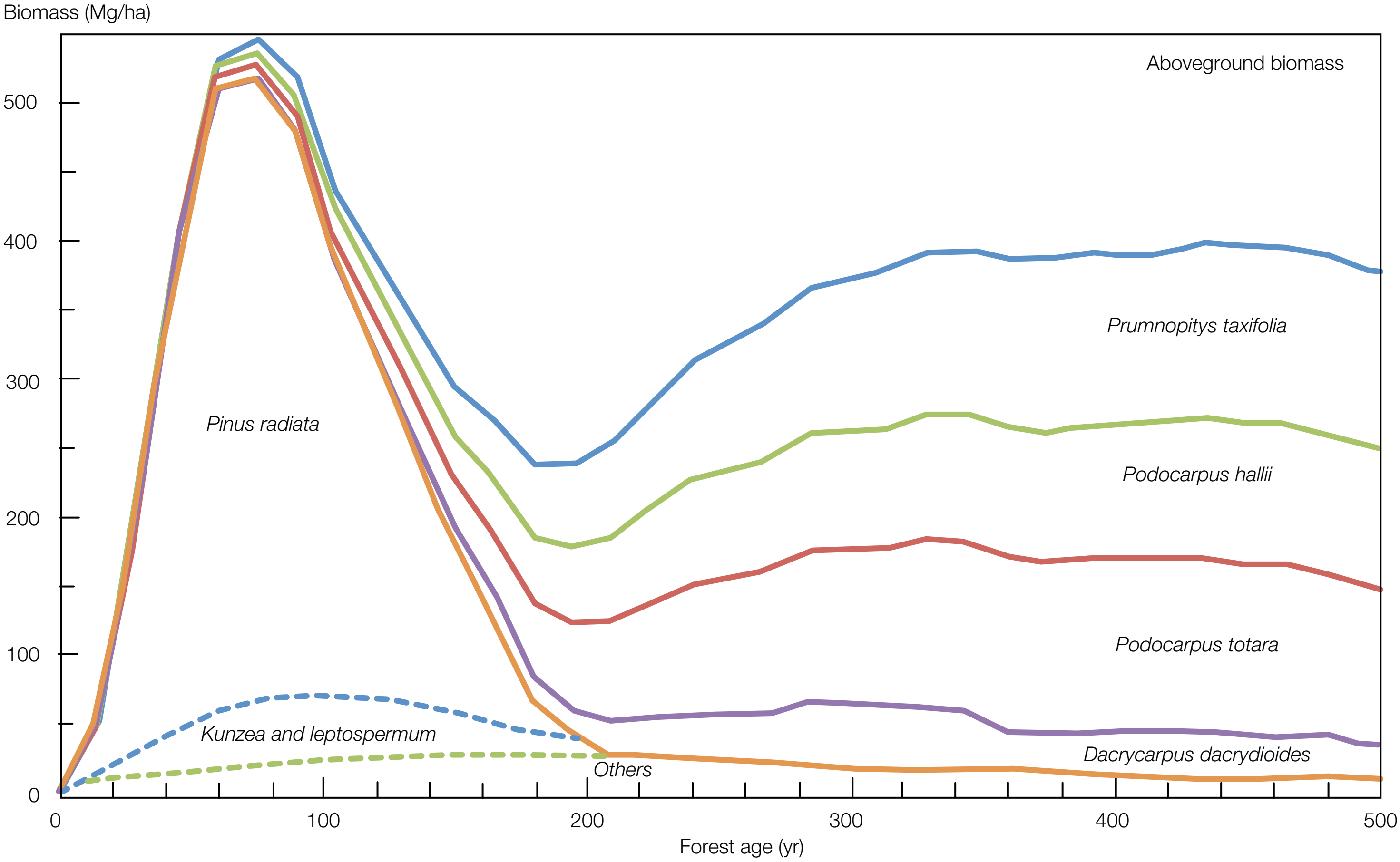

Figure 6: Forest biomass dynamics after introducing the exotic pine species *Pinus radiata* to the native species pool. Dynamics are modelled for a site near Christchurch, NZ. Species aboveground biomass is cumulative. '*Kunzea* and *Leptospermum*' include the early colonising species *K. ericoides* and *L. scoparium*. 'Others' include the species *Griselinia littoralis, Pittosporum eugenioides, Aristotelia serrata, Elaeocarpus hookerianus, Fuchsia ex-corticata, Nothofagusfusca* and *N. solandri var. solandri*. Source: Hall, 2001

If plant and leave regimes of radiata pine are selected, then a native forest understorey can be promoted by ensuring that there is a local seed source of native forest (Forbes et al., 2015a, 2015b). If local patches of native forest do not exist then they can be planted.

Our simulations suggest that in some years following initiation of the planting programme New Zealand could be completely greenhouse gas neutral. This would be even more frequent if sequestration from pre-existing Kyoto-compliant plantations was added to the total. Our international commitments do not require us to be fully greenhouse gas neutral within the timeframe simulated here, but it is gratifying to realise that we could achieve that milestone at a relatively low cost.

We expect that other options such as renewable energy production and reducing agricultural emissions will also be important elements of New Zealand's response to climate change. The final mix and extent of mitigation options will be determined by government policies and costs of alternatives.

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