Potential Scrub Changes and Its Spatial Allocation under the New Zealand Emission Trading System

Suzi Kerr, William Power and Wei Zhang

Motu Working Paper [Enter Number (Office Use)]
Motu Economic and Public Policy Research

16/01/2009

Contents

Table of figures

Table of tables

1 Introduction

1.1 Background and motivation

Efforts are being exerted globally to curb the green house gas emission. New Zealand has been committed to Kyoto Protocol to reduce its greenhouse gas emissions back to 1990 levels, on average, over the period 2008 to 2012. The New Zealand Trading Scheme has been developed to ensure meeting the international obligation while maintaining economic sustainability. It provides a flexible way of reducing the carbon footprint of New Zealanders at minimum cost and helps put New Zealand on the path to a sustainable future (Kerr and Sweet (2008)).

Industry sectors will be introduced into the emissions trading scheme gradually over a period of five years, starting in 2008. The plantation forestry industry will be the first sector entering the NZETS. The emissions trading scheme has been designed to encourage new planting and better management of forest estate. The New Zealand Units (NZUs)[1] are entitled to post-1989 forest land and owners of pre-1990 forest land in the emissions trading scheme.

The reward to the post-1989 forest land will create incentives for the landowners to revert their land uses that has been developed between 1990 to 2000 back to indigenous forest or scrub, which is a preparation stage for developing forest. The indigenous reversion is seen as an important mitigation option for those who suffer continuous profit loss in their current land uses.

The question is that for a given price of NZU how much land is likely to enter the NZETS as indigenous reversion and where it will mostly like to occur. We use the first version of Land Use in Rural New Zealand model (LURNZ) (Hendy et al (2007)) to simulate land use changes with or without NZETS to find out the source and amount of land that will enter NZETS as indigenous reversion from 2008 to 2015. Using the marginal map and ownership map provided by Landcare Research, we identify the geographical locations of the possible reverting land. Finally, we allocate the amount of reverting land according to their land quality.

---

[1] The definitions of “post-1989 forest land”, “pre-1990 forest land” and “New Zealand Units” can be found in http://www.climatechange.govt.nz/glossary.html

1.2 Land use theory embedded in LURNZ

We assume that landowners solve a dynamic optimisation problem and choose the land use that brings them the highest net present value of expected utility (Stavins and Jaffe (1990)). Based on this, we assume that landowners care about expected net returns, conversion costs from one use to another, and relative uncertainty. For simplicity, here we discuss the static optimisation problem.

At any point in time, returns per hectare to a particular land use on a farm are given by:

$$R = py - w'x \quad ,$$

where p is the output price, y is the yield per hectare, w is a vector of input prices, and x is a vector of input quantities. Landowners choose y^*, the optimal yield, to maximise their net future returns where y^* is constrained by the potential yield (or more technically the 'production function').

Potential yield depends on production technologies and the available inputs, which include land. Because land is heterogeneous, potential yield varies across space. The variation is driven by the variation of the natural capital of the land, where natural capital includes a mix of land characteristics such as soil type, climate, topography, altitude, and access to water. The variation in natural capital means it is possible to produce high yields on some pieces of land while no production is possible on others. In general, the better the natural capital of the land the more that can be potentially produced and vice versa.

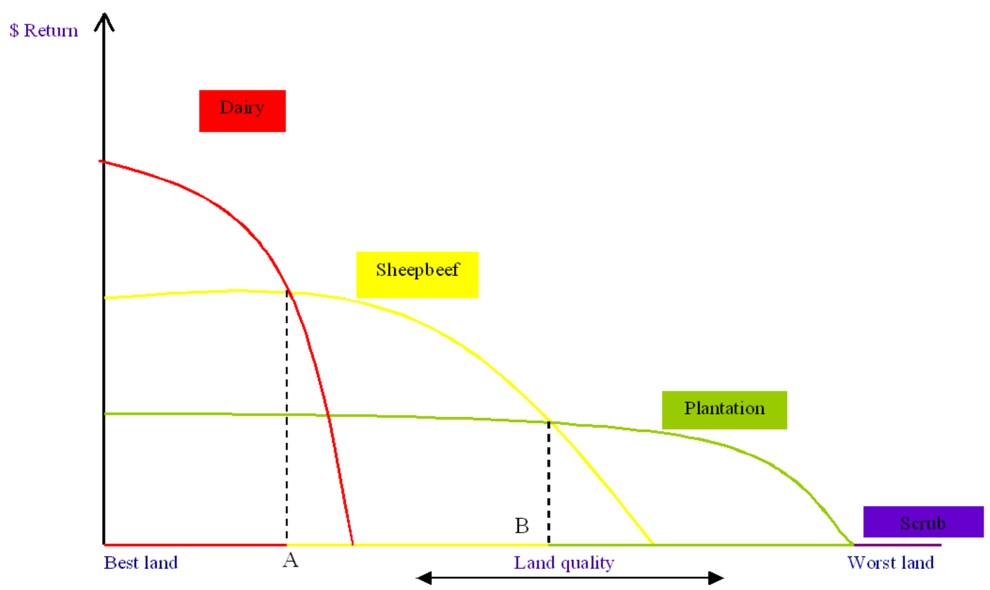
The optimal yield, y^*, will be less than or equal to the potential yield. Like potential yield, y^* will depend on production technologies and the available inputs. But y^* also depends on input prices w. y* and x^* will be jointly determined. The cost of production is then $c = w'x^*$ and net returns are $R = p'y^* - w'x^*$.

Optimal yields and costs are jointly determined by the mix of natural capital and socioeconomic characteristics, which we refer to jointly as 'land quality'. The socio-economic characteristics of land include availability of local infrastructure, services, and information/support networks. For a given yield, the better the land quality, the lower the costs. The better is the quality of land and the lower are the costs, the higher is the yield chosen.

Thus spatial variation in land quality also drives spatial variation in optimal returns. Figure 1 illustrates the hypothesised heuristic relationship between optimal returns and land quality along one-dimension, land quality. The real relationships are multi-dimensional. The y-axis indicates the expected return to the landowner from each hectare of land. The x-axis represents land quality, moving from the ‘best’ land on the left, to the ‘worst’ land on the right. Each curve represents the optimal return on land of that land quality from one particular use. According to our model, the landowner will choose the land use that will give the highest return. At the point where each curve intersects we can drop a line to the horizontal axis to indicate the transition point from one land use to another in terms of land quality.

For example, point A in Figure 1 indicates a transition point between dairy and sheep-beef farms. On a land parcel of this land quality the returns to dairy and sheep-beef would be the same, so a farmer on this type of land would be indifferent between dairy and sheep/beef. Slightly to the left of point A, the land quality is better, the returns to dairy would be higher than the returns to sheep/beef, and so a farmer would choose dairying as the optimal land use. Slightly to the right, the land quality is worse and sheep-beef would give the highest returns. Point B illustrates another transition point, this time between sheep-beef and forestry.

Figure 1 Economic returns and land use

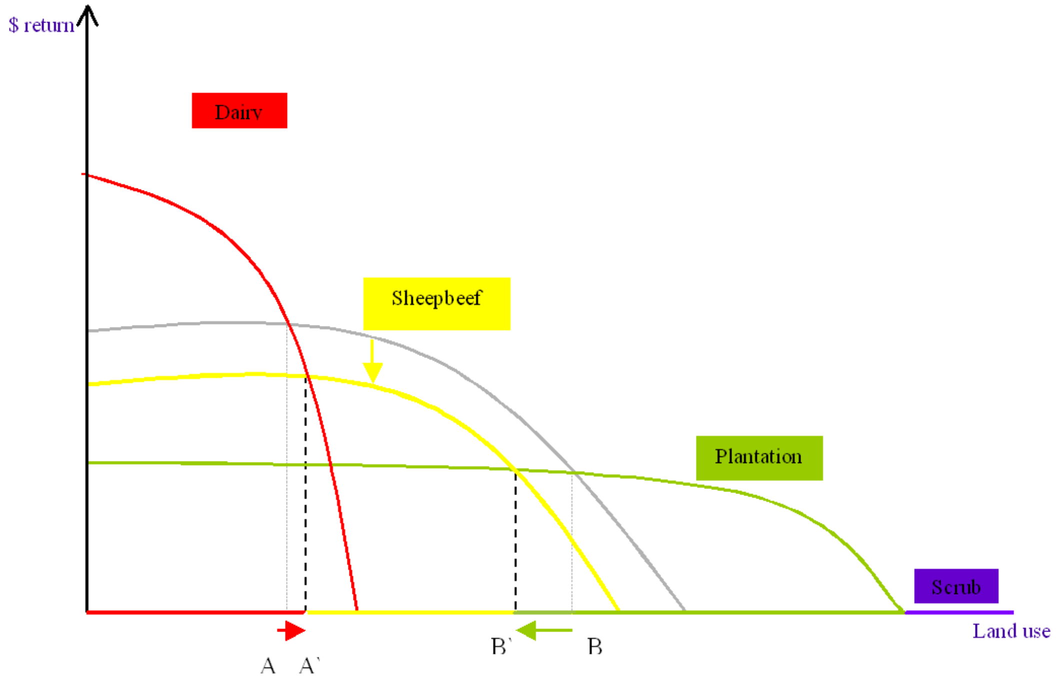


If prices, production technologies, or costs change, the optimal returns functions will change. The points of intersection between the different curves will shift, and the optimal land use will change for land parcels that are near transition points. [2]

Marginal land parcels are parcels that lie close to the transition points. **Figure 2** illustrates the effect of a reduction in the output price for sheep-beef farming on the potential returns curves shown in Figure 1. The transition between sheep-beef and forestry, which previously occurred on land with quality at point B, would shift to the left. Now forestry would be the optimal choice on the better land of quality between point B and point B'. Marginal land lies between these points.

Similarly, the transition between sheep-beef and dairy, which previously occurred on the land quality at point A, would shift to the right to point A'. Now, dairy would be the optimal choice on the lower quality land between point A and point A'. The transition points between optimal land uses will alter in terms of land quality. The optimal use of marginal land will change.

Figure 2 Changes in optimal land use



[2] The ordering of land quality depends on production technologies and costs. Changes in these could alter the ordinal relationship between the varying qualities of land. Land quality is not related to output price. A change in output price will monotonically transform the potential returns curves; it will shift the potential returns curves up or down and change the slope of the curves, but the slope will remain negative. We model policies as price changes, so we can assume that the ordinal relationship between the varying qualities of land does not change.

2 Methodology

2.1 Simulation in the Land Use in Rural New Zealand model (LURNZ)

LURNZ, developed by Motu, is a dynamic partial equilibrium model that predicts land-use change based on a micro-economic theoretical model where landowners choose land use to maximise future expected utility to their land (Hendy et al (2007)). For each land use – dairy, sheep-beef, plantation forest and scrub, the coefficients of response to prices and interest rates were estimated econometrically from historical data (Kerr et al (2007)).The first version of this model is designed to consider any policies that can be modelled as a commodity price or interest rate shock. The effect of the New Zealand Emission Trading Scheme (NZETS) resembles a commodity price shock in the first version of LURNZ. The table below summarizes the coefficient values that we used in the first version of LURNZ to simulate land use changes.

Table 1 Coefficient values for the long-term model Equation (1)

	Dairy	Sheep-beef	Plantation	Scrub
other_share	-0.08578	-0.44417	-0.02788	-0.44216
dairy_logp	0.01988	-0.01567	0.00684	-0.01105
sheepbeef_logp	-0.00079	0.01951	-0.00166	-0.01706
plantation_logp	0.00000	0.04229	0.00252	-0.04481
interest_5y	-0.00124	0.00123	-0.00034	0.00035
year	0.00172	-0.00238	0.00324	-0.00257
cons	-0.03336	0.26217	-0.02048	0.79167

We slightly modified the first version of LURNZ model to fit the simulation purpose in this paper. First, we use only the LURNZ long-term model to simulate land use change from 2007 to 2015 because we focus on long-term land uses not the transition path. Second, we constrain the response of dairy to log prices to be zero.[3] Third, we develop a relationship between the scrub price and land-use changes.

The long-term model in the first version of LURNZ is:

[3] It was insignificant and of the 'wrong' sign.

$$s_i = \alpha_i + \beta_i OL + \sum_j \gamma_{ij} \log p_j + \delta_{1i} r + \delta_{2i} time \quad \forall i \quad \textbf{(1)}$$

For each of the four land uses, i, we assume that the share of rural land in use i, S_i, depends linearly on a constant, the share of 1974 rural land not used for the four major land uses, *OL* (to account for changes in total rural land) the output prices for each of the major land uses (milk solids from dairy land, a weighted average of lamb, mutton, wool and beef price and log prices), p_j, and the nominal interest rate r. Kerr and Hendy (2004) documents details of the estimation of Equation 1.

As scrub does not produce any valuable commodity, Equation 1 omits the "scrub price" from the model. However, if the ETS starts to reward scrub owners for the amount of carbon sequestered, there will be a price for scrub and the price may cause changes in land use. Because historically there has never been a scrub price, the relationships between the shrub price and the other three land uses have to be estimated non-econometrically.

We modelled a reward for scrub by assuming that the dairy, sheep-beef and plantation land will respond to a price on scrub in the same way that scrub responds to a change in the return to these land uses. As the dairy industry has been highly profitable in the past 10 years (Ministry of Agriculture and Forestry (2007)), we assume that dairy land will not respond to a reward for scrub. In addition, we believe that under the NZETS, no plantation land will revert to scrub.[4] Therefore, we constrain the plantation land's response to scrub price to be zero. For sheep-beef land, we model the change in response to a reward to scrub in the following way.

$$\text{Change in shrubland share} = \gamma_{ij} \Delta \ln(\text{price SB}) \qquad (2)$$

where γ_{ij} is the coefficient in Equation (1) when i = scrub and j =sheep-beef commodity price.

Given,

[4] We do not model the response of plantation forestry to rewards for carbon sequestration directly but assume it does not affect the land that is likely to revert to scrub.

$$\Delta \ln(x)_{x \to x+\Delta x} = \ln(x + \Delta x) - \ln(x) \approx \frac{\Delta x}{x} \tag{3}$$

(2) and (3) imply

$$\text{Change in shrubland share} \approx \beta_1 \frac{\Delta \text{price SB}}{\text{price SB in 2007}} \tag{4}$$

$$\frac{\Delta \text{price SB}}{\text{price SB in 2007}} \approx \frac{\Delta \text{revenue per ha SB}}{\text{revenue per ha SB in 2007}} \tag{5}$$

Assuming that the intensity of production is relatively inelastic. By assuming that the sheep-beef land will respond to a price on scrub in the same way that scrub responds to a change in the price of sheep-beef land (Slutsky symmetry), we have

$$\begin{aligned} \text{Change in SB share} &\approx \gamma_{ij} \left(\frac{\Delta \text{revenue per ha shrubland}}{\text{revenue per ha SB in 2007}} \right) \\ &\approx \left(\frac{\gamma_{ij}}{\text{revenue per ha SB in 2007}} \right) \Delta \text{revenue per ha shrubland} \end{aligned} \tag{6}$$

A constraint on total land area in New Zealand combined with (6) implies:

$$\text{Scrub share} \approx \left(\frac{\gamma_{ij}}{\text{revenue per ha SB in 2007}} \right) \text{revenue per ha scrub} \tag{7}$$

The last coefficient – the sheep-beef land's response to scrub price (per ha) is estimated by

$$\frac{\gamma_{ij}}{\text{revenue per ha SB in 2007}} \tag{8}$$

where the revenue per hectare for sheep-beef land is calculated from the farm data provided by Meat and Wool Ltd; the national average of revenue per hectare is around $71.

Table 2 Coefficient values for the long-term model Equation (1)

	Dairy	Sheep-beef	Plantation	Scrub
scrub_price	0	-0.00023922	0	0.00023922

For the scrub price, we assume that landowners receive value equivalent to three tonnes of New Zealand units per year per ha. This smoothes out their cashflow even though actual carbon sequestration rates vary considerably across the years. This could correspond either to the government offering a stable flow of credits or to a private calculation by a landowner without a credit constraint. This figure takes into account several factors:

- A carbon sequestration yield curve from Landcare Research[5] combined with a sigmoidal evolution of forest cover. We assumed that it takes 10 years to reach canopy cover (see Hendy and Kerr (2005))
- The likely upward bias of this yield curve if used as a national average curve given that it was developed based on East Cape mānuka/kānuka forest

We used the version 1 of LURNZ to do two simulations. The first simulation (reference case) simulates land use changes in absence of NZETS. In the second simulation, we assume that government solely rewards for scrub reversions under NZETS. The result from these two simulations give us net changes in all land uses and separates response to ETS from the reference case.

2.2 Spatially allocating land use change in response to ETS

2.2.1 Step 1 Define land use transitions

To geographically allocate changes we need to transform these net changes into gross transitions between specific land uses. For guidance on this we draw both on our underlying theory (refer to picture) and also satellite data on actual transitions between 1996 and 2002.

Table 3 Net land use changes from 1996 to 2002 (Land Cover Database - LCDB), in hectare

Land cover type	Pasture	Plantation	Scrub
1996 areas	13537377	1901855	9029150
2002 areas	13412406	2041206	9007081
Change 1996-2002	-124971	139351	-22069

[5] www.landcareresearch.co.nz/research/globalchange/carbon_calc/carboncalc.aspx

Table 4 Land cover transitions from 1996 to 2002 (LCDB map), in hectares

		New land cover		
		Pasture	Plantation	Scrub
Initial land cover	**Pasture**	-	122674	508
	Plantation	721	-	680
	Scrub	4380	18720	-

Note: the sum of inflow and outflow for each land use may not equal to the figure in Table 3 because we ignore the land inflow and outflow from horticulture, urban and non-productive area.

Table 3 and Table 4 present the land use change and transaction information derived from Land Cover Data Base map in 1996 and 2002 (Hendy et al (2007)). It shows that

- Pasture area decreases by 1% of 1996 level. The majority of the loss goes to plantation forest. There is a small inflow from scrub followed by a tiny amount from plantation forestry.
- Plantation area increases by 7% of 1996 level. Pasture land fuelled most of the increase while there were tiny losses to pasture and scrub.
- Scrub area decreased by 0.02% of 1996 level. Most scrub changed to plantation forest with a tiny amount to pasture.

Figure 4 shows that the pasture decrease is made up of an increase in dairy and a large fall in sheep-beef land and that the net changes from 1996 – 2002 are representative of longer-term trends. We therefore assume that there is no movement out of dairy in the reference case and that only sheep-beef land transitions into dairy.

Figure 3 Assumptions about land use transitions 2002 - 2015 in reference case (no NZETS)

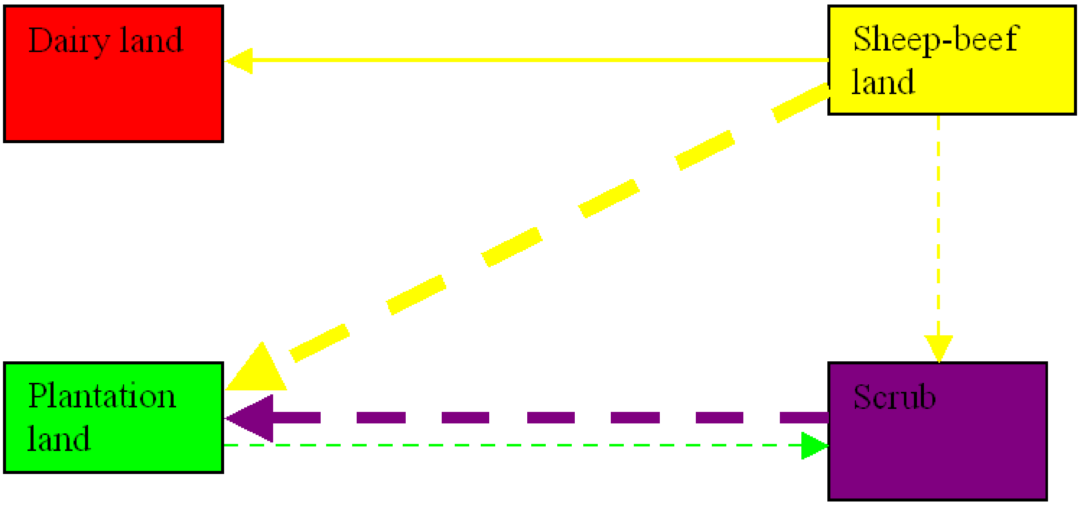


Figure 3 shows assumption about land use transitions from 2002 to 2015 in the reference case. We split pasture land into dairy and sheep-beef land and assume that the former is of better quality than the later. The dashed lines represent relatively lower quality land than the solid ones, while the fatter lines denote larger quantities than the thinner ones.

The second simulation simulates land use change when New Zealand government rewards scrub reversion from 2008 (the NZETS case). In this case, we expect to see low quality sheep-beef land transition into scrub. We assume that no other land use transitions are affected by the ETS.

The next step will be to identify the geographical location of the sheep-beef land that is eligible (under NZETS) for reward after reverting to scrub.

2.2.2 Step 2: locating sheep-beef that can be rewarded

From the sub-section above, we have estimated the amount of sheep-beef land that will revert to scrub due to a positive change in the scrub price. This section will explain how to identify the geographical location of the sheep-beef lands that can be rewarded. These are defined by:

- Sheep beef land
- Capable of regenerating to forest (as defined by Kyoto)
- On marginal erosion-prone lands
- Privately owned so land use decisions can be made

Because sheep beef land has steadily contracted since 1990, we assume that all current sheep beef land was not forested in 1990 and hence is eligible for Kyoto rewards. Landcare Research (Shepherd et al (2008)) has provided two GIS maps. One map shows the geographical location of marginal erosion-prone land that could potentially regenerate. The second map shows the ownership of New Zealand land. We overlap the two maps provided by Landcare research with a map identifying sheep-beef land.

Our spatial allocation rule to select land within this subset (private marginal sheep beef land that can revert) is based purely on an assumption that farmers will retire their least productive land. We are unable to predict the idiosyncratic characteristics of individual landowners that will lead some to retire land that is not of such bad quality either because they find native bush attractive and believe it will add to the value of their property, or because they are personally committed to environmental goals. These factors could lead to more, smaller patches of regeneration on the poor land within more highly productive areas – even potentially within dairy farms where farmers may also need to create riparian boundaries for water quality reasons. Because we use a 25 ha grid we assume that the regeneration occurs on a reasonable scale so do not worry about the transaction costs associated with claiming a reward.

3 Data

3.1 Data for the simulation of land use changes

We have used the first version of LURNZ model to simulate land use changes. The source data for the model is documented in Hendy et al (2007).

3.2 Data for the spatial allocation of new scrub

We need several GIS maps to identify the geographical location of the new scrub. These maps are raster maps with 25 ha pixels (500 meters length × 500 meters width).

We use Agribase Enhanced LCDB2 map to identify the location of sheep-beef land in New Zealand. The marginal land map and ownership map provided by Landcare Research gives the information of where the marginal grassland is and who owns them. The land quality map, which derived by first nest sorting the Land Use Capability map (LUC) and then the Pastoral productivity map, ranks each pixel of land by its quality. The details of all GIS maps information are documented in the Appendix.

4 Results

4.1 Land use changes simulated from LURNZ

With a price of $25 per NZU, the simulation results are presented below.

Figure 4 shows the land use changes for dairy, sheep-beef, plantation and scrub from 1974 to 2015 under reference case (in absence of NZEST). The land areas from 1974 to 2002 are collected from Statistics New Zealand while the ones from 2002 to 2015 are simulated by the version 1 of LURNZ. In absence of NZETS, our model predicts that the land use path will follow the historical pattern closely. Dairy and plantation area will increase gradually while sheep-beef and scrub area will be the fuel for their increase.

Table 5 Land use changes from 2007 to 2015 for three modelled scenarios

Land use	Scenario	Land area (000's ha)		Change in land area	
		2007	2015	%	000's ha
Dairy	S1	1462	1646	13	184
	S2	1462	1646	13	184
Sheep/Beef	S1	6878	6654	−3	−223
	S2	6878	6431	−6	−447
Plantation	S1	1451	1776	22	326
	S2	1451	1776	22	326
Scrub	S1	1188	901	−24	−287
	S2	1188	1125	−5	−63

Table 5 summarizes the results from the two simulations (with and without NZETS). Both scrub and sheep-beef land areas are predicted to fall in the reference case. The NZETS exacerbates the decline in sheep/beef and reduces the decline in shrubland.

Our results suggest a substantial increase in scrub relative to the reference case (Table 6). The reference case predicts a net loss of around 223 000 ha of scrub

(Table 5). Applying the NZETS policy almost reverses that net effect. Because the shrubland that is lost in the reference case is most likely to be converting to plantation forestry, these losses are unaffected by the NZETS scenario. The response to the shrubland policy must involve new shrubland on land that is currently sheep/beef (and is hence likely to be eligible for the NZETS). Around 447 000 ha of sheep/beef land is predicted to shift to shrubland between 2007 and 2015.

Table 6 Policy-induced changes in scrub area

Land use	Scenario	Land area (000's ha)		Change from reference case	
		2007	2015	%	000's ha
Scrub	S1	1188	901	0	0
	S2	1188	1125	25	224

To put these results in perspectie we show the time series history and reference case for each of the four LURNZ private land uses (Figure 4) and the effect of an ETS payment on scrub (Figure 5). Although the latter reverses the decline in scrub, this is only temporary – further increases (reductions in net decrease) would require that the carbon price continues to rise faster than the returns on sheep-beef land and that scrub is able to compete with forestry for this very marginal land.

Figure 4 Historical and simulated land use in New Zealand from 1974 to 2015: reference case.

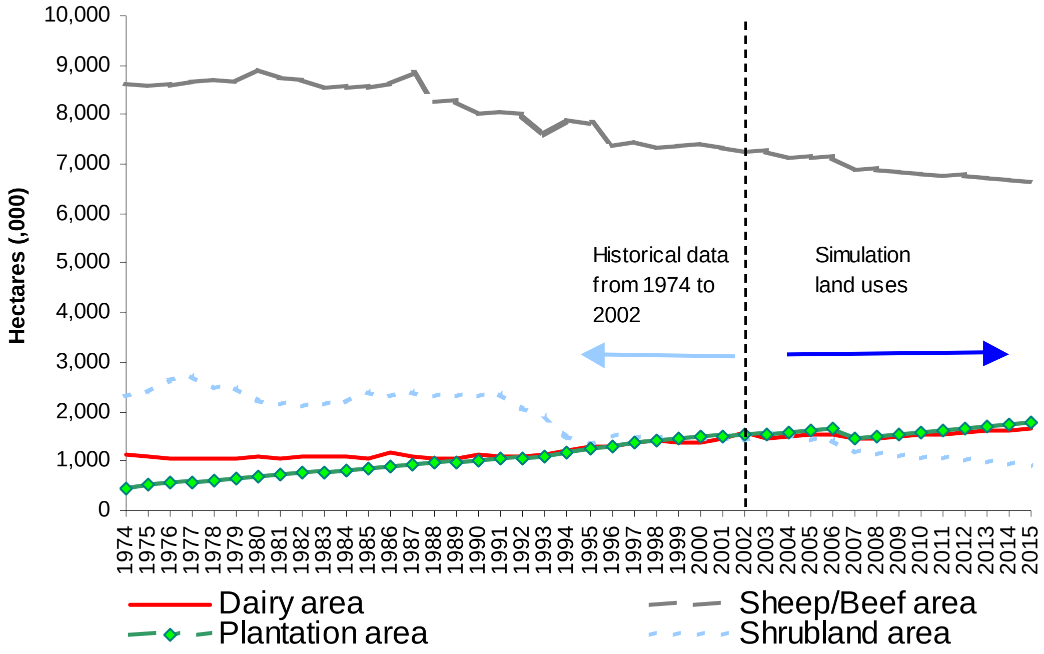
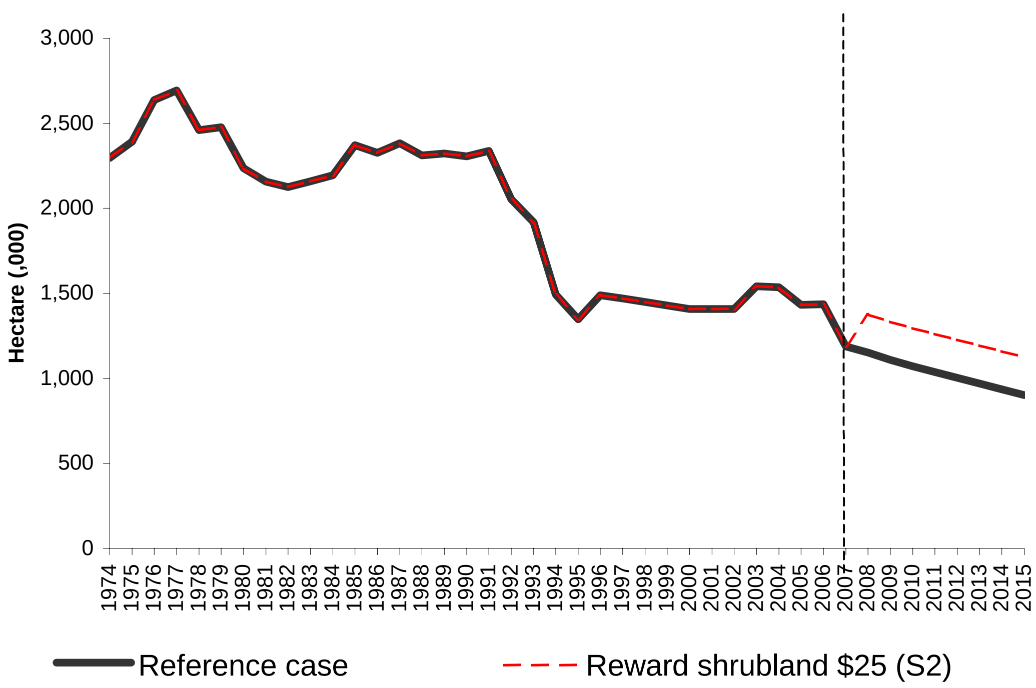


Figure 5 Scrub area on private land under different scenarios given $25 CO_2 price



4.2 Identifying geographical location of new scrub

Once we had an estimate of the likely area of regeneration in response to the shrubland price we explored where this would be likely to occur. We used the Agribase Enhanced LCDB2 map to create a map of land use, which includes the sheep-beef. We then used the two maps created by Landcare Research – ownership and areas of potential change from marginal grass land – to identify potential areas for new shrubland in response to the NZETS. These are private sheep/beef farms with land that can potentially revert to gorse, indigenous broadleaved shrubland and other indigenous.

We then ranked each 25-ha pixel of land in these categories from best to worst land using a nested-sort where land is first sorted by Land Use Capability class and then, within each class, by the value of a pasture productivity variable (Baisden 2006). Figures 7 and 8 show the areas that are most likely to revert in blue, and those that could revert but are not on the least productive land in red.

The spatial allocation rule we used is based purely on an assumption that farmers will retire their least productive land. Because we used a 25 ha grid we already assume that the regeneration occurs on a reasonable scale. This reduces the likelihood that transaction costs would make it necessary to have several patches of regeneration on the same property. We are unable to predict the idiosyncratic characteristics of individual landowners that will lead some to retire land that is not of such bad quality either because they find native bush attractive and believe it will add to the value of their property, or because they are personally committed to environmental goals. These factors could lead to more, smaller patches of regeneration on the poor land within more highly productive areas – even potentially within dairy farms where farmers may also need to create riparian boundaries for water quality reasons.

Our predictions suggest that the introduction of an ETS will result in the creation of c. 447 000 ha of new shrubland. Most of this will be in the North Island, and most on private (as opposed to Māori) land (Table 7). However, the biggest area for likely shrubland reversion is the East Cape, where there is a large proportion of Māori land. Public land is not expected to respond to the ETS directly. Unless transaction costs are low, and there are acceptable ways of minimising risks (e.g.

loss of carbon stock) and maintaining options for future land use change, we may be overpredicting responsiveness to change in these areas, at least in the short term.

Table 7 Area (ha) and ownership of non-public land predicted to revert to scrub and eventually indigenous forest as a result of the introduction of an ETS.

Ownership	North Island	South Island	Total
Māori	24 825	0	24 825
Private	286 075	136 000	422 075
Total	310 900	136 000	446 900

Figure 6 Likely scrub regeneration on privately owned land in the North Island. Areas most likely to revert (New scrub) are shown in blue; those that could revert but are not on the least productive land (Potential scrub) is shown in red.

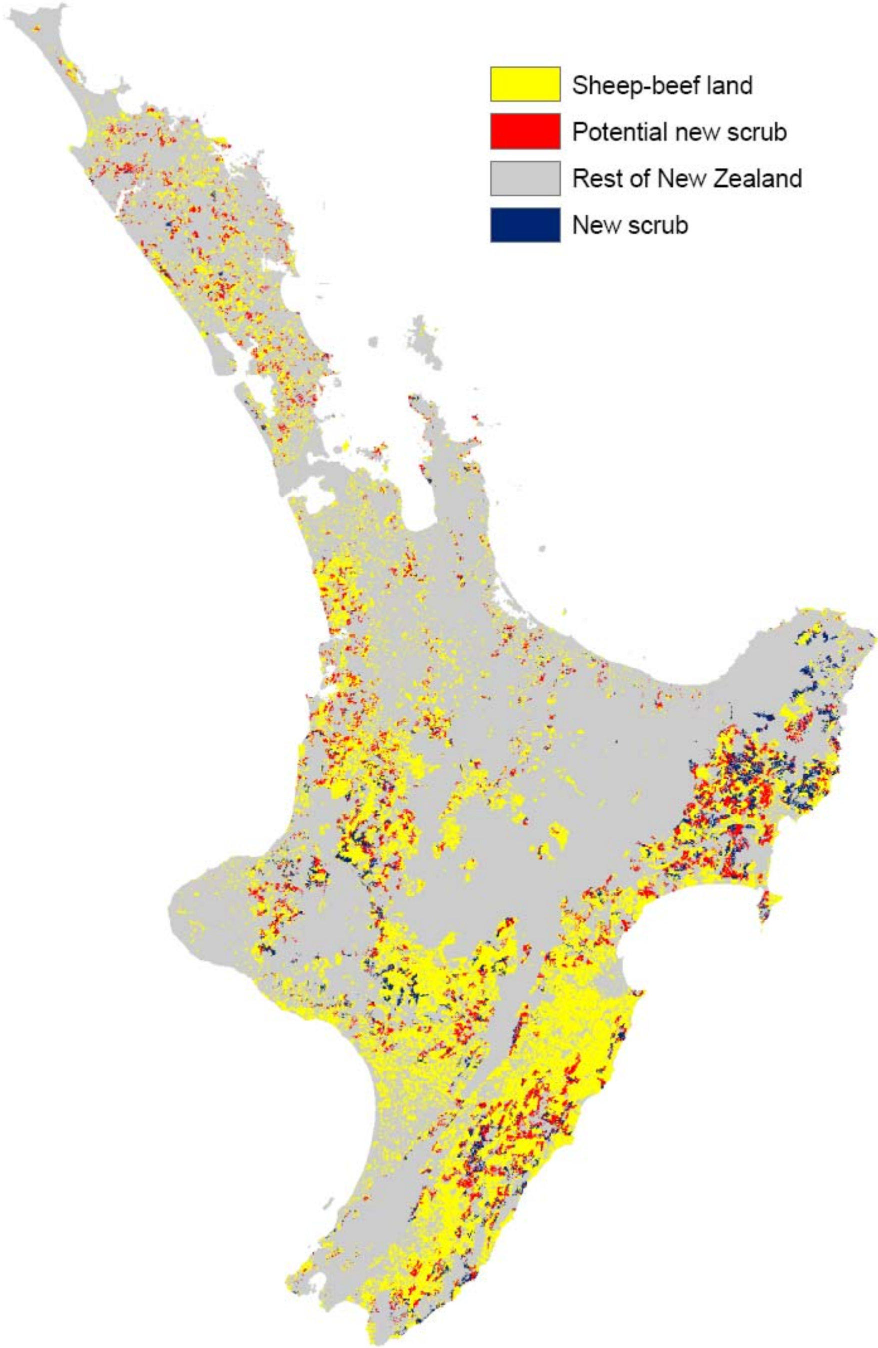
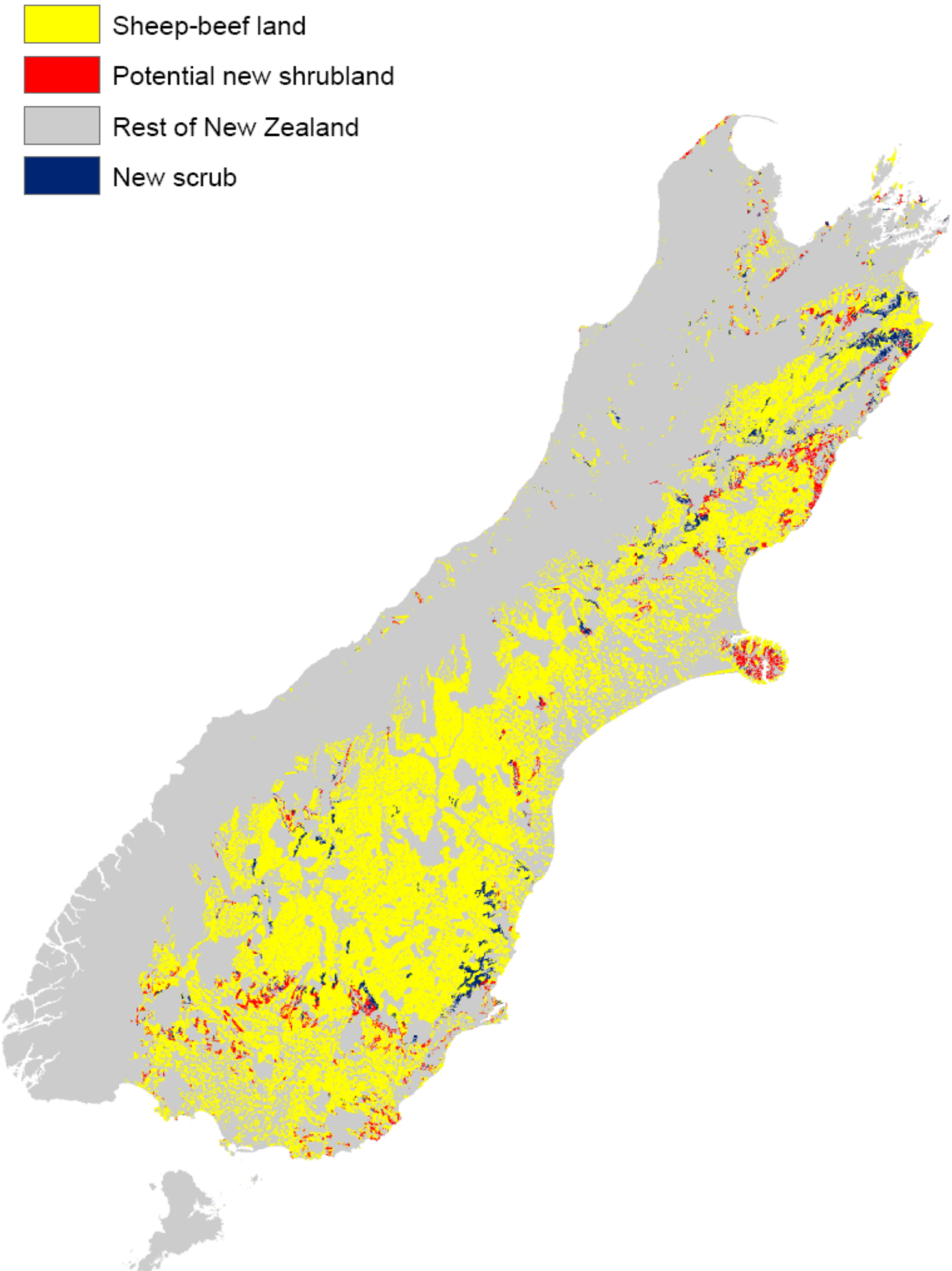


Figure 7 Likely scrub regeneration on privately owned land in the South Island. Areas most likely to revert (New scrub) are shown in blue; those that could revert but are not on the least productive land (Potential scrub) is shown in red.



4.3 Caveats

There are several reasons to interpret these results with caution. First, we need to assume symmetry between the response of sheep-beef land to a scrub price (reward to regeneration) and scrub to a sheep-beef price. While this is plausible, we have no evidence of actual responses to rewards for regeneration on any scale.

Second, the results are estimated from historical relationships between land use and prices. This assumes that farmers will interpret a regulatory reward in the same way that they respond to a change in a market price. If the reward has different risk characteristics or if it involves transaction costs, responses may well differ. Case study research suggests that some Māori land owners may find it difficult to coordinate to make a decision to allow regeneration, in part because of concerns about future liability and being 'locked in' to a given land use. Other farmers are also concerned about loss of options particularly when the long-term returns to native regeneration seem highly uncertain. Indigenous reversion may also be seen as more attractive than plantation forestry when landowners cannot afford the capital outlay associated with new plantations.

Third, historically, at a national level both scrub and sheep-beef land has been in fairly steady decline. This means we have estimated our responses over a period where scrub has been declining and have applied those results to simulate an increase in scrub. It is not clear that the factors that cause a decline in scrub are completely symmetrical with those that cause increase.

All three reasons suggest that the level of response may be lower than simulated. We do not simulate the effects of a $50 carbon charge because we believe this is too far outside the sampling range of the model we used here to make those results robust.

5 Conclusion

Under the New Zealand Emission Trading System, post-1989 forestry land in New Zealand is eligible to be rewarded for a reversion from their previous usages to scrub. By assuming a price of $25 dollars per New Zealand Unit reward starting from 2008, we use the Land Use in Rural New Zealand (LURNZ) model to simulate the amount of land use changes for dairy, sheep-beef, plantation and scrub from 2008 to 2015 with and without the NZETS. After identifying the source and amount of land area that will revert to scrub from the 2 simulations, we geographically locate the new scrub based on the productivity and eligibility of the land. The results show that there will be 447,000 hectares of new scrub, of which most will be located in the North Island and 6% are in Maori land.

Appendix

Agribase enhanced LCDB2 map

Agribase is a national spatial farm database. It was originally developed by MAF Quality Management (now AgriQuality New Zealand Ltd) to provide core information to be used during major animal health emergencies such as a foot-and-mouth disease (FMD) epidemic. Development of the system began in late 1988 and national data capture began in earnest in 1993.

In Agribase, farms are the primary objects. Farms are the management units that utilise New Zealand's rural land on a day-to-day basis (irrespective of who owns or indeed pays rates on the land). Each farm has a unique farm identifier (the *farm_id*) and the types of information stored include:

- Name and address (contact details) of the key personnel on the farm
- Homestead and gate locations as GPS coordinates
- Dominant farm type (see Table 1 below)
- Total farm size
- Animal numbers by livestock class
- Planted areas of crops / orchards / vineyards (including exotic and native forests)

The New Zealand Land Cover Database[6] (LCDB) is a Crown database that translates satellite images of New Zealand into information on the different types of land cover that exist on the ground. This information can be used, over time, to monitor and report on the changes to the state of our environment and provide the basis for better resource management decisions, more efficient use of natural resources and improved environmental management.

However, for many of the land cover classes, only broad inferences on possible land use can be made. These include the extensive grass and tussock covered areas of New Zealand, and the other horticultural classes. There simply was not enough spatial resolution in the imagery to derive actual land use. It therefore requires access to additional data sources to provide information on the true land use within

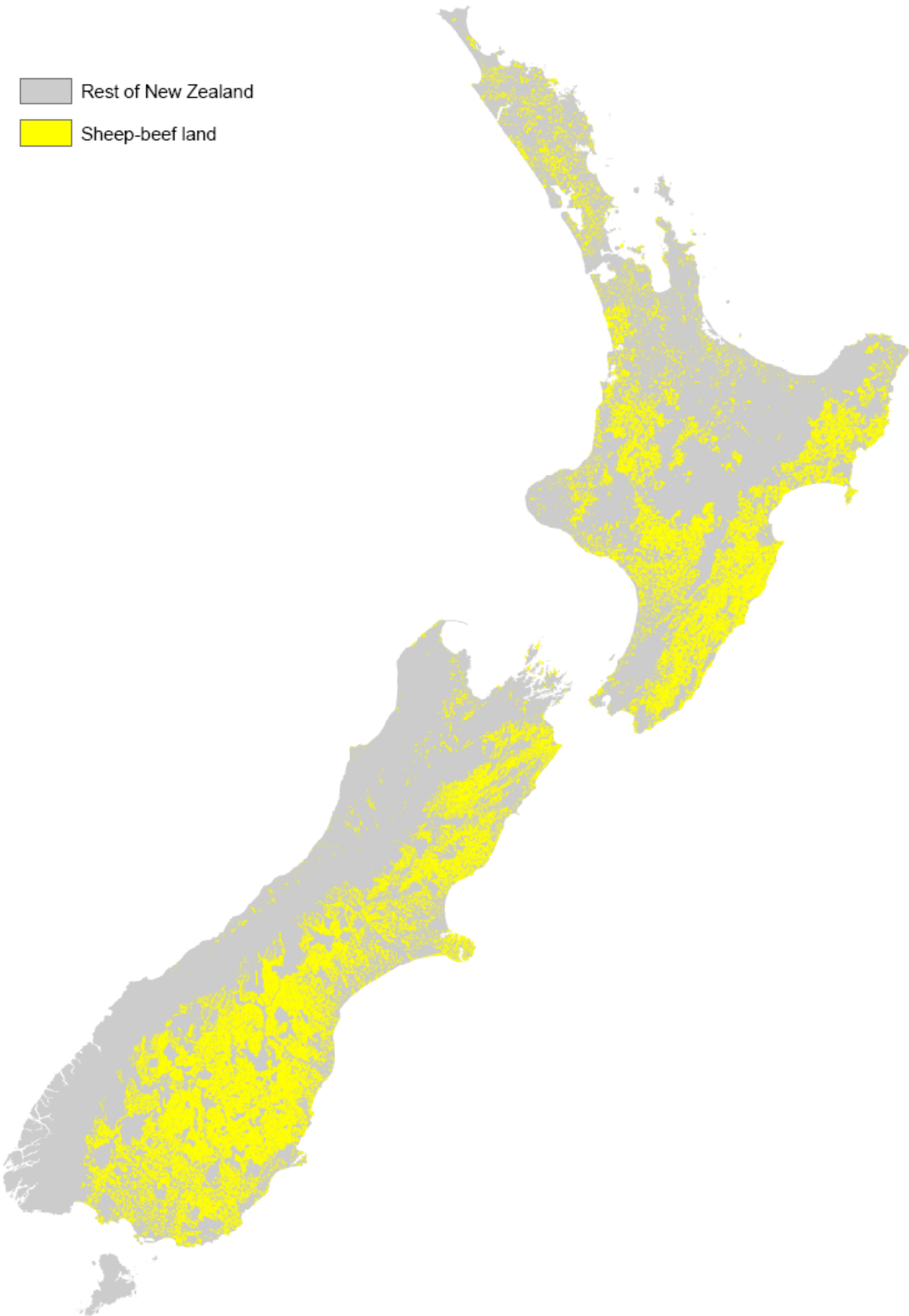
[6] For more information, http://www.mfe.govt.nz/issues/land/land-cover-dbase/classes.html

these class polygons. The Agribase enhanced LCDB2 map has utilized AgriBase, a land-based register of farms and orchards owned and maintained by AgriQuality Limited, to embed real land use information within the LCDB2 map.

The enhanced LCDB2 map enables distinguishing the 4 types of land uses LURNZ – dairy, sheep-beef, plantation and scrub. As the potential new scrub is assumed to come from sheep-beef land, the map helps to identify the geographical location of those land areas. The categories named "BEF", "SHP" and "SNB" (beef farm, sheep farm and sheep-beef mixed farm) in the Agribase enhanced LCDB2 map database are classified as sheep-beef farm. ion of sheep-beef land in 2002.

Figure 8 shows the geographical location of sheep-beef land in 2002.

Figure 8 sheep-beef land in New Zealand 2002



Marginal land map

The marginal land map is provided by Landcare Research Ltd[7] as a GIS shape file. This map contains information on the geographical location for marginal grasslands that are able to revert to gorse, indigenous broadleaved scrub and other indigenous vegetation types.

Table 8 Marginal map information provided by the shape file

[7] For more information, http://www.landcareresearch.co.nz/

Variable	Description
y_gorse	Marginal land with potential seed sources to allow natural reversion to gorse
y_indig_bl	Marginal land with potential seed sources to allow natural reversion to indigenous broadleaved scrub
y_indig_for	Marginal land with potential seed sources to allow natural reversion to indigenous forest
y_man_kan	Marginal land with potential seed sources to allow natural reversion to manuka/kanuka
y_noss	Marginal land with no potential seed sources to allow natural reversion to any of the above
“NA”	Where there is no value, we assume they are mountain tops and not able to revert to scrub

Table 8 summarizes the marginal land information provided by the shape file. For each shape in the original map, there is one corresponding variable name attached. The shapes with variable names “y_gorse”, “y_indigo_bl” and “y_indigo_for” are identified as revertible land while others are classified as non-revertible land. Figure 9 presents the geographical location of revertible land that is coloured by red whereas the grey colour marks the land that is not revertible.

Figure 9 Revertible land in New Zealand

Ownership map

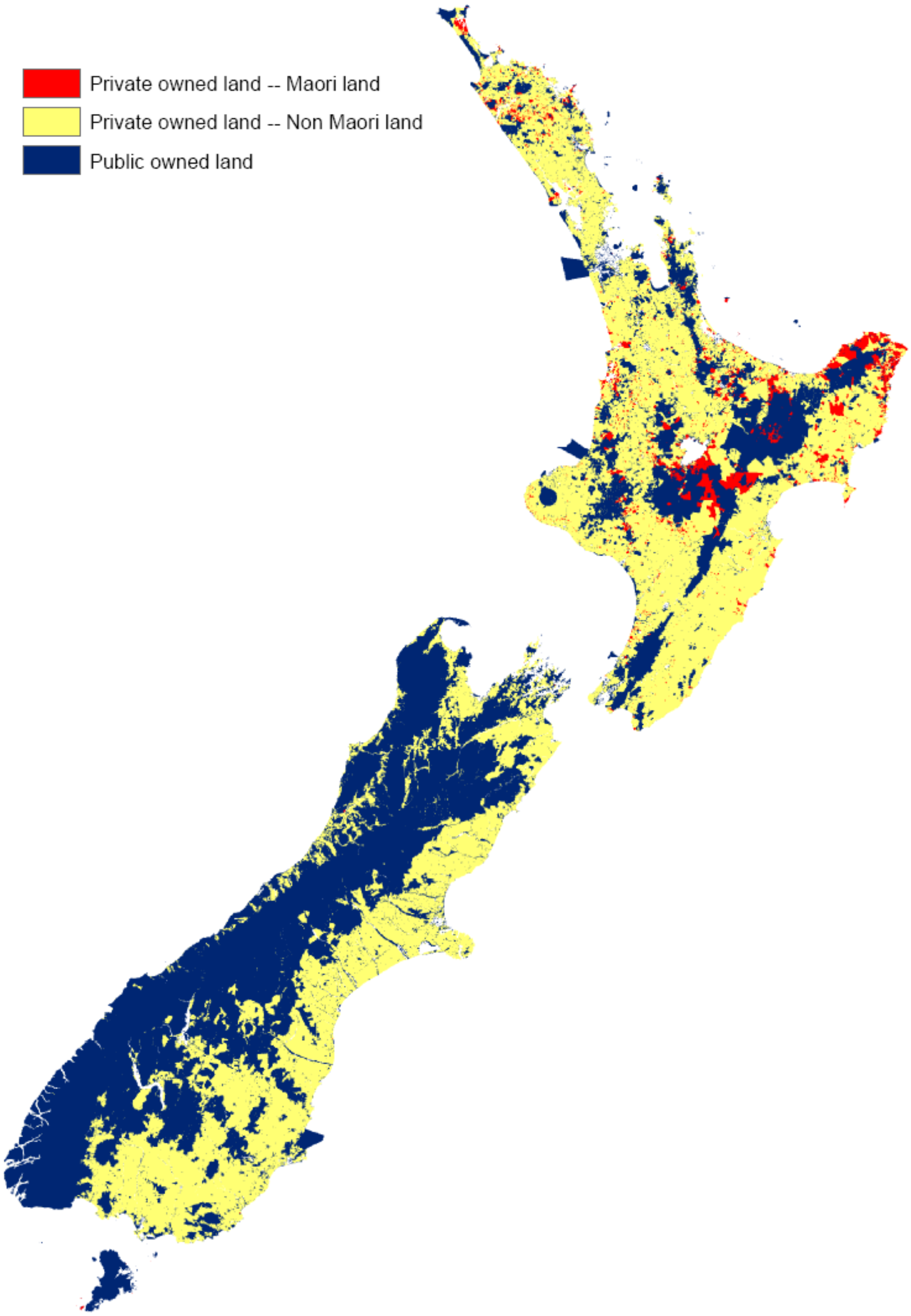
Ownership map is also provided by Landcare Research Ltd as a GIS shape file. This map contains land ownership information across New Zealand. Table 9 summarizes the ownership information and categorizes variables into “Private Maori land”, “Private Non-Maori land” and “Public owned land” groups.

Figure 10 presents the geographical location for the 3 specified groups in Table 9, where “Private Maori land” is marked with red colure, “Private Non-Maori land” is marked by yellow colure and “Public owned land” is in dark blue.

Table 9 Ownership information provided by the shape file

Ownership	Variable
Private Maori land	"Maori Reserve" "Maori Land Cover" "Maori Reserve and Maori Land Cover"
Private Non-Maori land	"QEII" "Transpower" "Private Reserve" "LINZ pastoral lease" "Landcorp" "none"
Public owned land	"Reserve" "DOC" "Local Govt" "DOC and QEII" "Reserve and Maori Land Cover" "Public Reserve" "DOC and Maori Land Cover" "DOC_unprotected land of interest to DOC" "DOC and LINZ pastoral lease" "Local Govt and LINZ" "LINZ and Min of Defence" "Local Govt and LINZ and Min of Defence" "Min of Defence" "DOC and Min of Defence" "DOC_protected other" "LINZ and Landcorp"

Figure 10 Land by ownership in New Zealand



Land use capacity map

Landcare Research developed a GIS database that classifies land based on its limitations for productive use measured by climate and geology. This classification, referred to as Land Use Capability (LUC), gives an indication of what uses the land is capable of supporting in the long term.

To make the classification, areas of land that are essentially homogeneous in rock type, soil unit, and slope were identified; these areas were defined as homogeneous polygons. Experts then intuitively assessed each polygon in the database using aerial photographs, existing information (e.g. soil information) and additional fieldwork Froude (1999)(Froude, 1999). They based their assessment on physical characteristics, which, in addition to rock type, soil type, slope group, included erosion, vegetation, and climate information, past land-use effects, and the potential for erosion.

Each polygon was classified on a discrete scale from 1 to 8, with class 1 land being the best for sustained agricultural production and class 8 being land with severely limited uses (Froude, 1999); each class is described in Table 10. Classes 1 to 4 are suitable for cultivation. Classes 5 to 7 are not suitable for cultivation, but may be better suited to farming or forestry. Class 8 is not suitable for any productive use (Environment Waikato, 2005).

Table 10 Descriptions of the LUC Classes

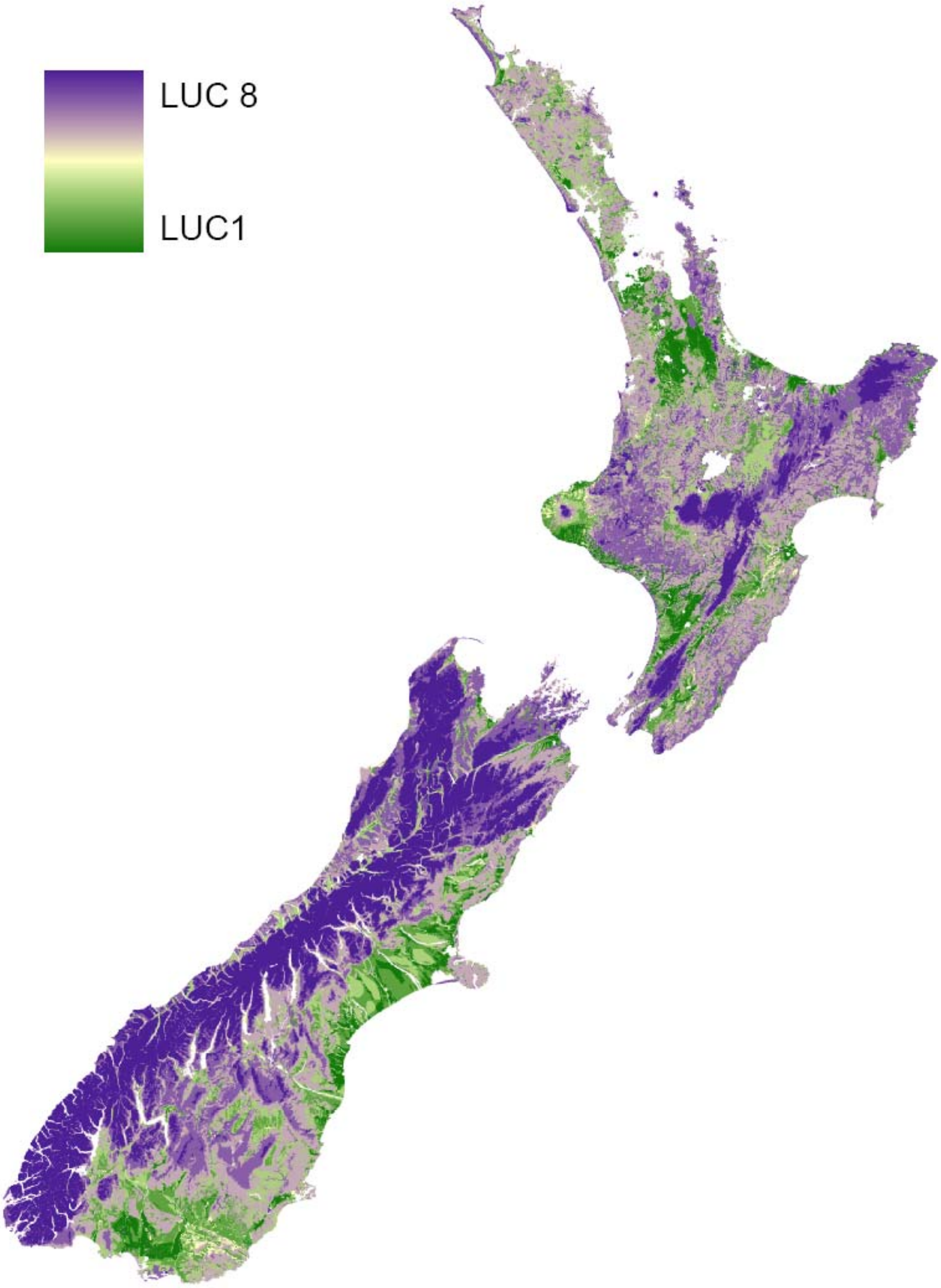
LUC Class	Description
1	Good multi-use land, flat to very gently sloping, deep, easily worked soil, negligible risk of erosion.
2	Flat to gently rolling land with slight physical limitations, may be used for cultivated cropping, horticulture, pastoral farming or forestry.
3	Land with moderate physical limitations for cultivation; may be used for cultivated cropping, horticulture, pastoral farming or forestry.
4	Land with severe physical limitation for cultivation; constraints on the choice of crops able to be grown; may require intensive soil and water conservation treatment and careful management practices.
5	Too many limitations to be cultivated for cropping. Negligible to slight erosion risk under pastoral or forestry use. Typically stony, wet or sloping land with high quality, stable soils. Where slopes prevent cultivation, some horticulture may be suitable.
6	Moderate limitations for pastoral use. Suitable for forestry.
7	Severe limitations for pastoral use. Suitable for forestry.
8	Severe physical limitations; not suitable for any form of cropping, pastoral or production forestry use; only suitable for watershed protection.
Source: Environment Waikato (2006)	

The database consists of about 100,000 polygons, with the minimum polygon resolution equal to 25 hectares and average polygon size approximately equal to 300 hectares Leathwick et al (2002). The database covers the North and South Island and inshore islands, but excludes Stewart Island. The database began in

1973 and new information is added when it comes available (Froude, 1999). We acquired it in May 2003.

The LUC is part of a larger database that has been used primarily by regional councils as a basis for guiding soil management and other related functions (Froude, 1999). A number of councils have also used the LUC as a basis for rules within statutory plans. LUC provides well-tested and widely used information on where dairy, sheep/beef, and plantation forestry, are likely to be feasible and to be best suited.

Figure 11 Land Use Capacity map in New Zealand



Pastoral productivity map

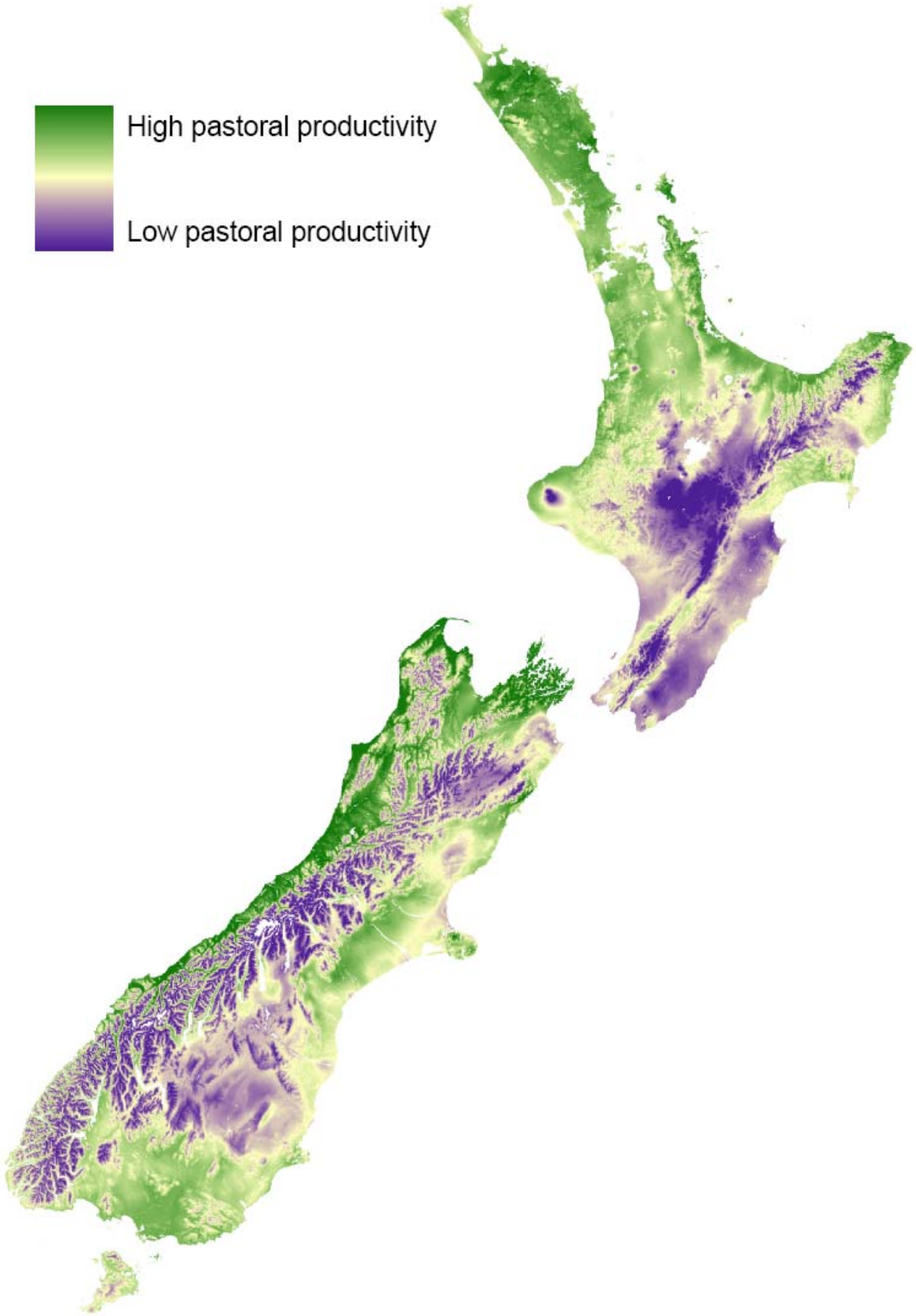
Baisden (2006) developed indices designed to estimate the biological productivity of land when used for pastoral and forestry production. He used a ‘Storie Index’ approach, where indices of co-limiting soil and climate factors are multiplied together to give a productivity index. The Storie Index approach has been actively in use in California for over 60 years and has been a useful tool for determining rural land values.

Indices that help describe spatial variation in biological productivity already exist in the Land Environments in New Zealand (LENZ) GIS database; an example is the LUC map. However, the average size of a polygon in the LENZ database is approximately equal to 300 hectares and thus the maps of these indices are not detailed enough to describe spatial variation within farms. Baisden's aim was to create indices that give greater spatial detail. He reinterpreted data layers from LENZ, to design productivity indices that give sensible results at 1 ha.

To create the indices, Baisden correlated soil and climate indices with recently updated Storie Index rating tables reported for parts of northern California, using areas that are suitably similar to New Zealand. Each of the underlying indices was measured as a percentage where 100% corresponds to no limitations. The indices were recalibrated against a map of average biological Net Primary Production (NPP) in New Zealand, derived from data from the NASA MODIS sensor averaged over the years 2000 to 2003. The process is described in detail in Baisden (2006).

The final Forestry Storie Index is the product of slope, soil water deficit, and drainage indices. The Agricultural Storie Index is the product of slope, soil moisture deficit, drainage, particle size, and growing-degree-day indices.

Figure 12 Pastoral productivity map in New Zealand


High pastoral productivity
Low pastoral productivity

References

Baisden, W. T. 2006. "Agricultural and Forest Productivity for Modelling Policy Scenarios: Evaluating Approaches for New Zealand Greenhouse Gas Mitigation", *Journal of the Royal Society of New Zealand,* 36:1, pp. 1-15.

Environment Waikato. 2006. "Managing Land and Soil," *Webpage* . Available online at http://www.ew.govt.nz/enviroinfo/land/management/index.htm.

Froude, Victoria. 1999. "Review of National Databases Relating to Land, Water and Biodiversity," *Webpage report prepared for the Ministry for the Environment's Environmental Performance Indicators Programme, Ref. TR89* . Available online at http://www.mfe.govt.nz/publications/ser/metadata/land-rep/index.html.

Hendy, Joanna and Suzi Kerr. 2005. "Greenhouse Gas Emission Factor Module: Land Use in Rural New Zealand - Climate Version 1," *Motu Working Paper 05-10,* Motu Economic and Public Policy Research, Wellington, NZ. Available online at http://www.motu.org.nz/working_papers.

Hendy, Joanna; Suzi Kerr and Troy Baisden. 2007. "The Land Use in Rural New Zealand Model Version 1 (LURNZv1): Model Description," *Motu Working Paper Motu Working Paper 07-07,* Motu Economic and Public Policy Research, Wellington, New Zealand. Available online at http://www.motu.org.nz/working_papers.

Kerr, Suzi and Joanna Hendy. 2004. "Drivers of Rural Land Use in New Zealand: Estimates From National Data," *Draft Motu Working Paper ,* Motu Economic and Public Policy Research, Wellington, NZ.

Kerr, Suzi; Joanna Hendy; Kelly Lock and Yun Liang. 2007. "Estimating the Drivers of Regional Rural Land Use Change in New Zealand," .

Kerr, Suzi and Andrew Sweet. 2008. "Inclusion of Agriculture and Forestry in a Domestic Emissions Trading Scheme: New Zealand's Experience to Date," *Motu Working Paper 08-04*. Available online at http://www.motu.org.nz/working_papers.

Leathwick, John; Fraser Morgan; Gareth Wilson; Daniel Rutledge; Malcolm McLeod and Kirsty Johnston. 2002. "Land Environments of New Zealand: a Technical Guide," Ministry for the Environment and Landcare Research, Wellington, NZ.

Ministry of Agriculture and Forestry. 2007. "Pastoral Monitoring Report 2007," *MAF report*. Available online at http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/farm-monitoring/2007/pastoral/full-report.pdf.

Shepherd, James D.; Anne M. Sutherland; Ian Payton; Suzi Kerr; Wei Zhang and William Power. 2008. "Nature and Scale of Eligible Post-1989 Non-Planted Forests," .

Stavins, Robert N. and Adam B. Jaffe. 1990. "Unintended Impacts of Public Investments on Private Decisions: The Depletion of Forested Wetlands", *American Economic Review,* 80:3, pp. 337-52. Available online at JSTOR.