Short term effects of moderate carbon prices on land use in the New Zealand emissions trading system:
LURNZ-climate land use change simulations

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Abstract
The New Zealand Emissions Trading Scheme (NZ ETS) was introduced through the Climate Change Response Act in September 2008 and remains in force. To date only the forestry sector is directly affected by the NZ ETS but once it is fully implemented (2015) it will cover all sources and gases including agricultural emissions. Using the Land Use in Rural New Zealand model (LURNZ, hereafter), we simulate rural land use changes that could be driven by the NZETS in order that we can explore their potential implications for emissions and removals (sequestration) and rural incomes and land values. This paper documents our simulation methods and presents short term (up to 2015) simulations for moderate prices ($25 New Zealand dollars per tonne of Co2-eqv) where our current modelling techniques are most robust.

Contents

1 Introduction

The New Zealand Emissions Trading Scheme (NZ ETS) was legislated through the Climate Change Response Act in September 2008 and remains in force. To date only the forestry sector is directly affected by the NZ ETS but once it is fully implemented it will cover all sources and gases including agricultural emissions. The Government made substantive amendments to the NZ ETS in December 2009. The key amendments of interest for agriculture are delaying the entry of the agriculture sector from January 2013 to 2015, and allocating significant levels of free units on the basis of agricultural output.

Using the Land Use in Rural New Zealand model (LURNZ, hereafter), we simulate rural land use changes that could be driven by the NZETS in order that we can explore their potential implications for emissions and removals(sequestration) and rural incomes and land values. This paper documents our simulation methods and presents short term (up to 2015) simulations for moderate prices ($25 New Zealand dollars per tonne of Co2-eqv) where our current modelling techniques are most robust.

The development of LURNZ began in 2002, initially motivated by the need to understand the drivers of both forest sinks and methane and nitrous oxide emissions, and to inform debate on appropriate domestic and international rules relating to these in climate policy. It can also be used in analysis of water quality, biodiversity or water management policies.

LURNZ models land use spatially and dynamically based on econometric estimates of land-use change. It also simulates the profitability and hence distributional implications of different economic scenarios over time and space (e.g. Kerr and Zhang 2009 and Sinclair et al 2010). LURNZ currently models 4 types of rural land-use: dairy, sheep-beef, plantation and scrub (native forest), and treats land-use in horticulture and other animal farming, the conservation land and urban areas as exogenous. Hendy, Kerr and Baisden (2007) provide a detailed description of the two core modules of the first version of LURNZ - the land-use change module and the land-use change allocation module. It also documents the key datasets constructed to estimate these modules. The estimation of the land use change module is documented in (Kerr and Hendy, 2004) using data from 1974 to 2002. (Kerr and Ren, 2009) use updated data, 1974 to 2008, and two different Producer Subsidy Equivalent (PSE) estimates (Tyler and Lattimore, 1990) and (Anderson et al, 2007) to adjust the raw commodity price data for the effects of the 1980s reforms to re-estimate the regression models. A third module of land-use intensity simulates dairy and sheep-beef stocking rates, and fertiliser usage (Hendy and Kerr, 2006).

LURNZ-climate incorporates two additional modules. The first translates climate policy scenarios into price changes that alter land uses (described in this paper); the second, the greenhouse gas (GHG) emissions module, simulates GHG emissions/sequestration patterns and trajectories from all four land-uses (Hendy and Kerr, 2005).

This paper explains in detail how LURNZ-climate simulates changes in land-use shares over time and in response to different climate policy scenarios, and presents preliminary results. The methods section describes how the land-use change module works, explains how forestry price and hence new planting and replanting and dairy and sheep/beef prices are altered in response to climate policy and describes how the scrub price response is modelled; the results section presents and discusses simulation results; and the last section summarizes the key findings and future directions.

2 Methods

The core of the land-use change module is a system of regression equations that estimate land-use area/share responses to commodity prices (Kerr and Ren, 2009).

Gradual adjustment; constraints; time series; need to constrain. Better to think of these as calibration – not confident about estimates. Kerr and Ren provide several sets of coefficients. We use the set presented in Table 1. and Table 2.

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Table 1 Long run coefficients with dairy and sheep-beef commodity price adjusted using Producer Subsidy Equivalent from (Anderson et al, 2007);

	Dairy	Sheepbeef	Plantation	Scrub
logDairyPrice	0.0139916***	-0.0108554	-0.0031361	c
	(0.0039278)	(0.0074449)	(0.0068722)	--
logSBPrice	c	c	c	c
	--	--	--	--
logPlantationPrice	c	c	0.0199372***	-0.0199372***
	--	--	(0.006271)	(0.006271)
Other land	c	-0.9235489***	-0.0764511	c
	--	(0.0653362)	(0.0653362)	--
Interest rate	-0.0009812***	-0.0010946*	-0.0005375	0.0026133***
	(0.0002072)	(0.0005577)	(0.0004364)	(0.0004475)
Year	0.0016637***	-0.0020029***	0.0028275***	-0.0024883***
	(8.48e-05)	(0.0002937)	(0.000257)	(0.0001816)
constant	-0.0215613	0.819453***	-0.14000783*	0.3421865***
	(0.0259252)	(0.0492813)	(0.0727517)	(0.0615997)

Note: standard errors are in brackets. "c" indicates that the coefficients is constrained to zero. *** means coefficients are significant at 1% level, ** means significant at 5% level and * means significant at 10% level.

Table 2 Short run coefficients with dairy and sheep-beef commodity price adjusted using Producer Subsidy Equivalent from(Anderson et al, 2007)

	Dairy	Sheepbeef	new.plant	Re.plantation	Scrub
logDairyPrice	0.0073689**	-0.0067503*	-0.0006186	c	c

	(0.0031658)	(0.0032938)	(0.001003)	--	--
logSBPrice	-0.0063639*	0.0084217**	c	-0.0020578	c
	(0.003227)	(0.0036565)	--	(0.0019423)	--
logPlantationPrice	-0.0009766	c	0.0039458***	0.0023426	-0.0053117
	(0.0024837)	--	(0.001)	(0.0020573)	(0.0031686)
dOther land	c	-0.5454655***	c	-0.0308414	-0.423693***
	--	(0.1370728)	--	(0.0656773)	(0.1369616)
Interest rate	5.69e-05	-9.63e-05	-0.0001045	0.0001356	0
	(0.0001533)	(0.0002938)	(6.24e-05)	(0.000119)	(0.0002812)
lagError dairy	-0.4052063***	c	c	0.0473351	0.3578712**
	(0.1258837)	--	--	(0.1029357)	(0.1539526)
lagError sheepbeef	0.0382319	-0.1730418**	0.047285**	c	0.0875249
	(0.0492019)	(0.0824717)	(0.0183374)	--	(0.0820378)
lagError plantation	c	c	c	-0.0436923	0.0436923
	--	--	--	(0.0809123)	(0.0809123)
constant	0.005428	-0.0146023	-0.030897***	-0.0106354	0.0507066
	(0.0221942)	(0.020782)	(0.0097332)	(0.0213843)	(0.0301365)

Note: standard errors are in brackets. "c" indicates that the coefficients is constrained to zero. *** means coefficients are significant at 1% level, ** means significant at 5% level and * means significant at 10% level.

We model changes in commodity prices as a result of climate policy and hence changes in the returns to each land use. For a given price of a tonne of Co2-eqv, LURNZ calculates how much the price of a unit of product from each land use will change. These new prices can then be used in the land use change equations to simulate the impact of each scenario.

Evaluating the impact of carbon charging on the dairy and sheep-beef sectors is relatively straightforward. The production cycle is short and the carbon charge could pass onto products almost instantaneously. On the other hand, the impact is difficult to assess for the forestry and scrub sector. Lengthy production cycles, uncertainties in carbon price and forest management could all contribute to the difficulty for the former (See for example Meade et al 2009). For the scrub sector, not only is there no scientifically based set of carbon yield tables for the scrub sector such as exists for forestry, but also there is no way to estimate statistical relationships between scrub price and land-uses because scrub was never priced before. This section explains first how we estimate the changes in sheep/beef and dairy returns and then how we address the challenges in the forestry and scrub sector.

2.1 Modelling the impact of climate policy on agricultural returns in LURNZ

This is the simplest simulation. We estimate historical emissions per unit output and then project these forward (see Zhang and Kerr 2010). In each policy scenario where the agricultural sector is included in the emissions trading system we lower the price of our two agricultural commodities, milk solids and meat by the estimated emissions times the GHG price.

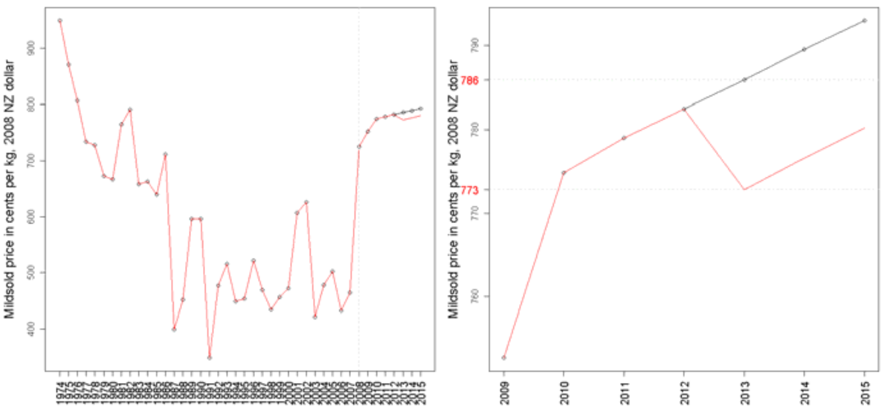
Zhang and Kerr (2010) models two sources of emissions – livestock emissions and fertiliser induced emissions. For the first source, they estimate a trend function for emissions per kilogram of milksolid produced and sheep-beef product produced respectively. Fertiliser induced emissions per unit of dairy and sheep-beef output account only a fraction of total emissions per output so we only use the latest estimates as a proxy for future values. The impact of ETS on dairy and sheep-beef product prices are formulated as

$$\text{Impact on milksolid price(Year)} = (e^{23.63-0.011*\text{Year}} + 0.8)*2.5 \quad (1)$$

$$\text{Impact on sheep-beef price(Year)} = (e^{24.56-0.011*\text{Year}} + 0.3)*2.5 \quad (2)$$

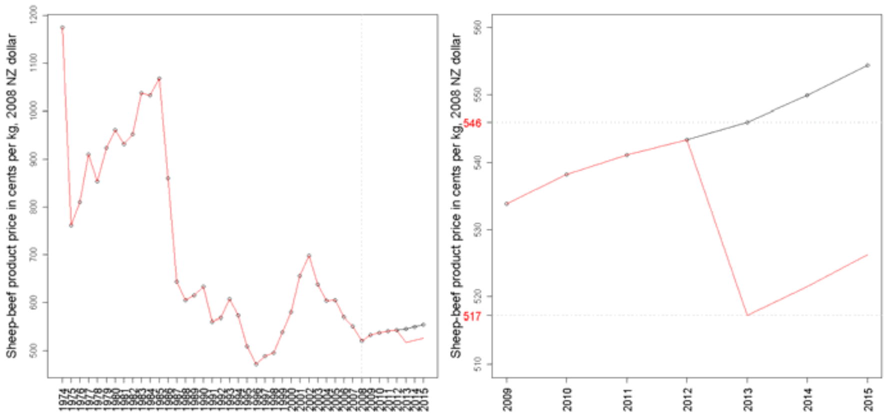
The impact on dairy and sheep-beef product prices are primarily driven by livestock emissions (the exponential function), and affected fractionally by fertiliser induced emissions (0.8 kg and 0.3 kg of CO_2-eqv emitted from producing one kg of milksolid and sheep-beef products respectively). 2.5 cents is the price of a kg of CO_2-eqv. The estimated impacts can be directly added to price data which are measured in cents per kilogram.

Figure 1 Milksolid price before and after the implementation of ETS



We assume the agriculture sector enters the ETS in 2013 when it will start to affect dairy and sheep-beef product prices. Figure 1 plots the historical and projected (from 2008 onward) milksolid price measured in cents per kg from 1974 to 2015 (hollow dots), as well as the simulated price after the impact of ETS (red line). The right panel zooms in from year 2009 to 2015, and shows that the ETS would cause a 2% fall (on average) in predicted dairy prices from 2013 to 2015. Using data over X years to 2008, Kerr and Zhang (2010) shows that the profit, measured by earnings before income and tax, of an average dairy farm would have dropped 20% given a price of $25 per tonne of CO2-eqv.

Figure 2 Sheep-beef product price before and after the implementation of ETS



The predicted 5% decrease in the sheep-beef product price after the ETS only shows what would happen to farms' revenues. The ETS will also have negative impacts on the farms' costs such as increase in electricity costs and fuel costs. Using data over X years to 2008, Kerr and Zhang (2010) shows that the profit, measured by earnings before income and tax, of an average sheep-beef farm would have dropped 50% given a price of $25 per tonne of CO_2-eqv, and become financially nonviable when the price doubles.

2.2 Modelling the impact of carbon price on forestry returns in LURNZ

Estimating the impact of carbon prices on forestry returns is less straightforward in the forest sector because of the long investment period, normal rotation length of 25 to 32 years, combined with uncertainty in carbon and log prices and variations in forest management.

Two independent studies ((Maclaren et al, 2008) and (James A.Turner et al, 2008)) have explored possible impacts of the ETS on the New Zealand forestry sector in terms of investment decisions, new planting rates and harvest decision. Both studies find that the ETS would increase the land expectation value (LEV) significantly regardless of species and regimes, and would increase new planting rates.

In LURNZ commodity prices for the forestry sector are measured as cents per cubic meters of log. We translate the carbon reward for sequestration (liability for harvest/deforestation) into an increase (decrease) in the log price that reflects the gain (loss) from the ETS. The net credits valued at the end of the first rotation (to be consistent with the timing of forestry returns from timber) are:

$$Credit = \frac{\sum_{t=0}^{62} P_{Co2}(1+g)^t OC[Y(t+1) - Y(t)](1+r)^{Hage-t}}{National\ average\ volume\ per\ ha} \qquad (3)$$

where

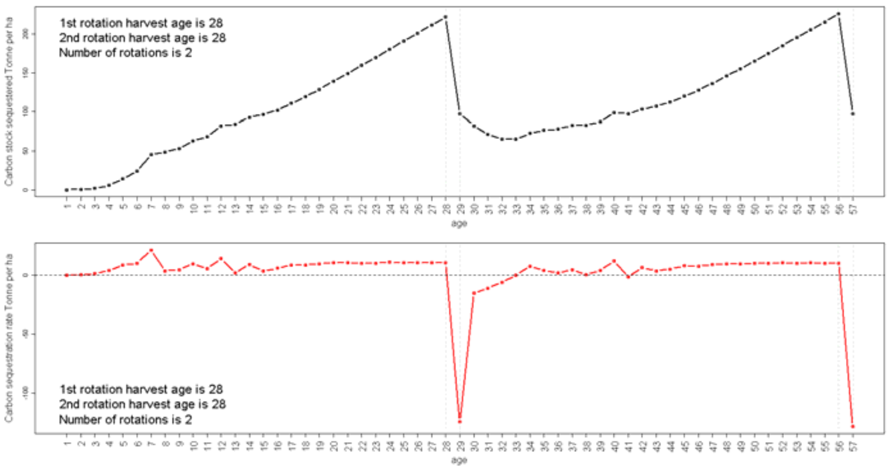
- P_{CO2} is the price of a tonne of Co2-eqv

- *g* is the growth rate of P_{CO2}
- *Y(t)* is the carbon stock sequestered at age t
- *r* is the discount rate
- *OC* is the C to Co2 converter -- 3.667,
- *Hage* is harvest age, which is assumed to be 28 years[1]
- *National average volume per ha* is set at 465 m^3 per ha[2], which measures the average volume of logs sold from a hectare of forest

This calculates the future value (at the year of first harvest) of the first two rotations of a newly established forest. For simplicity we do not consider the very small value of carbon in later rotations. We have not yet introduced uncertainty in either forestry or carbon returns or allowed the harvest age to vary.

The first panel of Figure 3 shows the carbon stock while the second panel shows the carbon sequestration rate; both are measured in tonnes per hectare. The carbon yield table is from (Te Morenga and Wakelin, 2003) and is for a pruned forest.

Figure 3 Carbon stock sequestered and carbon sequestration rate measured by tonne per ha



We choose 'r' to be equal to 8% as default, and test various 'g' for a given initial $25 per tonne of Co2-eqv. The results are presented in Table 3.

Table 3 Credits earned under different Co2 price growth rates with an initial price of $25

Co2 price Growth rate	Credit $ per m^3 2008 price	Credit as a percent of average log price (1974 to 2008)
0	146.47	92%

[1] The harvesting data (page 11) from (Ministry of Agriculture and Forestry, 2008) indicates that the area-weighted average clearfell age of radiata pine is round 28 years

[2] The harvesting data (page 11) from (Ministry of Agriculture and Forestry, 2008) states that in the year ened 31 March 2007 1.79 million cubic meters radiata pine harvested and sold from clearfelling 38700 hectares of forest which calculates approximately 465 cubic meters per hectare

0.01	159.54	100%
0.02	173.47	108%
0.03	187.99	117%
0.04	202.52	127%
0.05	215.79	135%
0.06	225.29	141%
0.07	226.03	141%
0.08	208.45	130%
0.09	154.41	97%
0.1	30.07	19%
0.11	-226.86	-142%

Note: The last column is calculated by dividing the credit by the average log price from 1974 to 2008 -- $160 per m3 in 2008 NZ dollars.

Even though most carbon that is sequestered during the growth phase is released during harvest the carbon returns are considerable. The key driver is the carbon left on the land which means that there is always a positive carbon stock. Having g>0 has two effects. The dominant one is clearly that the carbon left on the land is more valuable. The other effect is that the liability is more expensive.

If the forester expects r<g he won't sell his credits as they accrue but hold them until they are needed for liability. This makes it more profitable than the formula suggests when g is greater than r (0.08). The market as a whole cannot be confident that r<g if there is banking unless g is risky (Hotelling). We have not yet modelled forester behaviour under carbon price risk. The sensitivity to our assumptions about g reltaive to r can be seen by varying g while it is less than r.

If r>g the forester will sell the credits as they accrue and buy them back to pay back the liability. In LURNZ, we choose to let r=8% and g=5%, which results, reading from Table 3, in $215 per m^3 of log earned from the carbon trading and a 135% increase in revenue relative to historical prices(this yields forest revenues that are still within the historical range).[3]

2.3 Modelling how rural land-use responds to scrub price changes relating to carbon rewards

2.3.1 Simulating land-use changes in response to scrub price changes

Privately owned scrub land does not generally generate economically valuable products. Therefore, by default, the price of products from scrub land has been zero

[3] This difference between g and r could be interpreted as a reflection of the higher risk associated with holding carbon credits.

historically. The relationship between 'scrub price' and rural land-use changes cannot be estimated econometrically.

We assume that each land use responds to scrub price the same way as scrub land responds to the commodity prices associated with each other land use (Slutsky symmetry) with the constraint that dairy land does not respond to the scrub price change because dairy returns are so high that scrub would never be viable on land that could be used for dairy farming (Shepherd et al, 2008)..

$$\text{Change in scrub share} = \beta_1 \Delta \ln(\text{price SB}) \quad (4)$$

$$\Delta \ln(x)_{x \to x+\Delta x} = \ln(x+\Delta x) - \ln(x) \approx \frac{\Delta x}{x} \quad (5)$$

(2) & (3) imply

$$\text{Change in scrub share} = \beta_1 \frac{\Delta \text{price SB}}{\text{price SB in 2007}} \quad (6)$$

$$\frac{\Delta \text{price SB}}{\text{price SB in 2007}} \approx \frac{\Delta \text{revenue per ha SB}}{\text{revenue per ha SB in 2007}} \quad (7)$$

(2) & (5) imply

$$\text{Change in scrub share} \approx \beta_1 \left(\frac{\Delta \text{revenue per ha SB}}{\text{revenue per ha SB in 2007}} \right) \quad (8)$$

Assumption: change in scrub share = - change in SB share

$$\text{Change in SB share} \approx -\beta_1 \left(\frac{\Delta \text{revenue per ha SB}}{\text{revenue per ha SB in 2007}} \right) \quad (9)$$

Symmetry argument: an increase of X $/ha in the scrub price revenue acts like a decrease of X $/ha in the SB return.

$$\begin{aligned} \text{Change in SB share} &\approx \beta_1 \left(\frac{\Delta \text{revenue per ha scrub}}{\text{revenue per ha SB in 2007}} \right) \\ &\approx \left(\frac{\beta_1}{\text{revenue per ha SB in 2007}} \right) \Delta \text{revenue per ha scrub} \end{aligned} \quad (10)$$

Similarly:

$$\text{Change in plantation share} \approx \left(\frac{\beta_2}{\text{revenue per ha plantation in 2007}} \right) \Delta \text{revenue per ha scrub} \quad (11)$$

Implies:

$$\text{Change in scrub share} \approx \left(\frac{\beta_1}{\text{revenue per ha SB in 2007}} + \frac{\beta_2}{\text{revenue per ha plantation in 2007}} \right) \Delta \text{revenue per ha scrub} \quad (12)$$

2.3.2 Carbon sequestration in scrub/indigenous forest

Another difficulty is the lack of an accurate carbon yield table for scrub land. The rate of growth of scrub varies spatially and is poorly measured. We assume an average of 3 tonnes of Co2-eqv sequestered per hectare of scrub land per year. Although the Ministry of Agriculture and Forestry (2009) releases a carbon stock table for indigenous forest in New Zealand, we cannot utilize this information for lack of data on scrub ages. In any case, their current table simply makes the same assumption we do. Based on advice from Landcare Research we use Trotter et al, (2005) to calculate carbon sequestration in scrub land. The study estimates that mean net carbon accumulation rates for mânuka/kânuka shrubland are in the range 1.9 to 2.5 tonnes of carbon per ha per year when averaged over the active growth phase of about 40 years.

2.3.3 Scenario setup

We consider 8 possible scenarios including business as usual (see Table 4). We allow forestry and 'scrub' to be treated differently in policy but either include all or none of the agricultural(livestock) sector. Comparison of scenarios allows us to understand how the sectors interact.

Table 4 a summary of scenarios carried out in LURNZ

Scenario	Description
No ETS	There is no Emission trading system in New Zealand through out all simulation periods
Only Agri ETS	The agriculture sector enters EST from 2013, from when emissions from dairy and sheep-beef sections are liable to charges
Only Forest ETS	The forestry sector enters EST from 2010 (the actual year it happed in New Zealand is 2008). The owners of forests are entitled to the credit from carbon storage from planting and are liable from carbon emissions from harvesting and deforestation

Only Scrub ETS	The scrub sector enters EST from 2010 (assumed to be later than the forestry sector). The owners of scrub land are entitled to the credit from carbon storage from reversion and are liable to carbon emissions from clearance
Agri and forest ETS	Both agriculture and forest sectors enter the ETS at the years given above
Agri and scrub ETS	Both agriculture and scrub sectors enter the ETS at the years given above
Forest and scrub ETS	Both forest and scrub sectors enter the ETS at the years given above
Full ETS	Agriculture, forestry and scrub sectors enter the ETS at the years given above

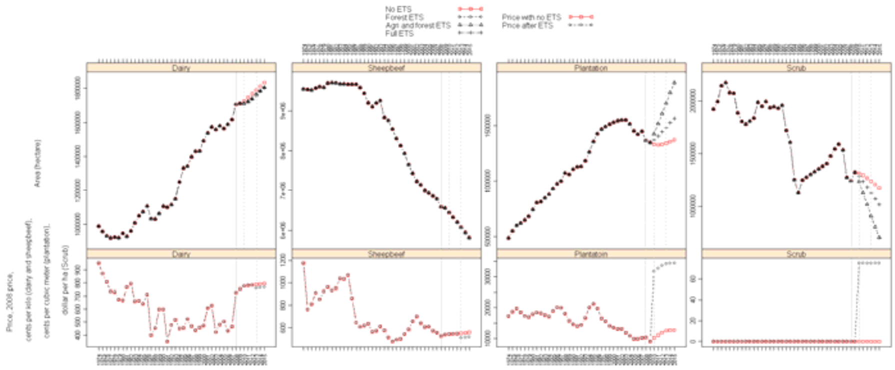
We assume the price of a tonne of Co2-eqv is $25 New Zealand dollars with the time horizon of simulations reaching out to year 2015. If a substantial high price or/and an long time horizon were chosen, there would be likely to be structural changes in the economy and in a system that is surely non-linear we are not able to identify those off recent history where prices haven't been in those ranges. For example at even $50 per tonne CO_2–e a lot of sheep-beef farms would be non-viable (Kerr and Zhang, 2010). We will expect them to change land use even though our model does not predict it. $25 per tonne is still in a price range we have some experience with.

3 Simulation results

We focus on comparing several scenarios against the "No ETS" baseline, which are either happening or very likely to happen in near feature. The selected scenarios are "Only forest ETS", "Agri and forest ETS" and "Full ETS". The reason for not including results on the "Forest and scrub ETS" scenario is that the simulation results from it are almost identical to those from "Full ETS" as "Agri ETS" has virtually no impact on all four land-uses. A full set of simulation results is presented in Table 5 and Table 6 in the Appendix.

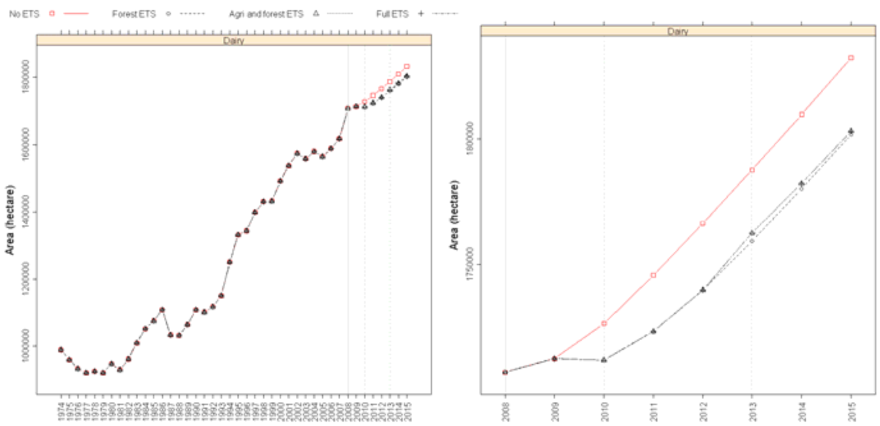
The first question is what the simulated dynamic path for each land-use type looks like. These are presented in the upper panel of Figure 4.

Figure 4 Simulated land-use paths for all land-uses under different scenarios



The baseline case (No ETS) is denoted by a red solid line marked with red hollow squares. Dairy area continues to expand. Forestry grows slowly and scrub and sheep/beef area continue to contract. These are driven by long term trends (productivity?) and also current and forecast prices: high dairy prices and relatively low forestry prices.

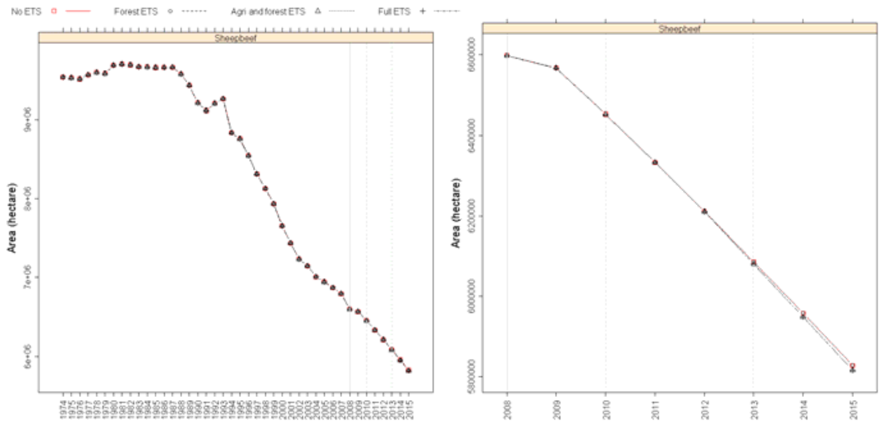
Figure 5 Historical and simulated dairy areas from 1974 to 2008 and from 2009 onwards under different ETS scenarios



Dairy area (Figure 5) has been increasing steadily since the beginning of the data (1974) apart from the drop from 1985 to 1986 (when agricultural subsidies were removed). From 2009 to 2015, the prediction era, it follows its historical tend. The simulation, from 2009 to 2015, shows that while the inclusion of the agriculture in the emissions trading system will have a relatively small effect, the implementation of the ETS in the forestry sector would have negative impacts on the level of dairy areas due to the steep rise in the effective log price (return to forestry). From 2013 onwards, the agriculture sector is assumed to enter the ETS. This has a slight positive effect on the level of dairy area. This is because some sheep-beef farms that are on good quality land change to dairy. The ETS dampens the sheep-beef farm profits more than it does dairy farms. The “full ETS” and “agri and forest

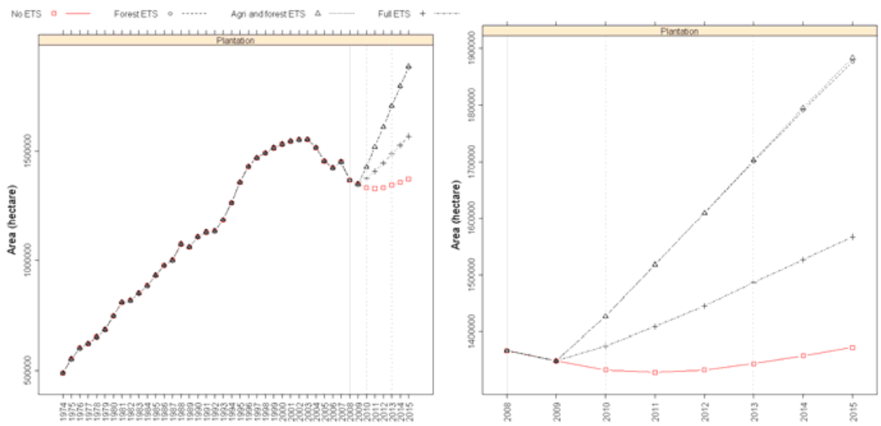
ETS" are effectively the same in this case for the dairy area is assumed to not respond to the price change in scrub sector.

Figure 6 Historical and simulated sheep-beef areas from 1974 to 2008 and from 2009 onwards under different ETS scenarios



Sheep-beef area (Figure 6) decreases pretty steadily from 1985 onwards, and the ETS scenarios have virtually no impact on it. This happens because we do not estimate any significant relationship between sheep/beef area and price (Table 1 and Table 2). Because the coefficient is in fact negative which we believe to be implausible we constrain it to equal zero.

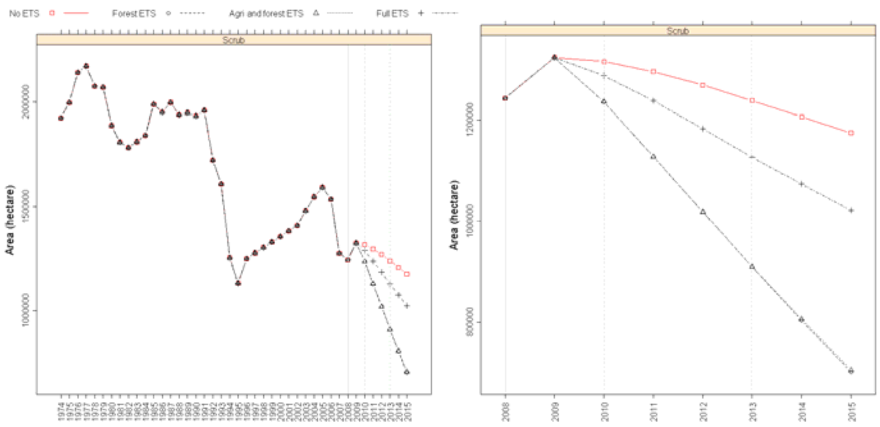
Figure 7 Historical and simulated plantation areas from 1974 to 2008 and from 2009 onwards under different ETS scenarios



Plantation area experienced a period of steady increase from 1974 to 2004, then dropped from 2005 to 2008. This fall was partly induced by anticipation of the emissions trading system which would impose liability for deforestation. It was also affected by low forestry prices. The model simulates that the rate of decline would slow and then be reversed and the area would slowly increase to 2008 levels by 2015 under the baseline.

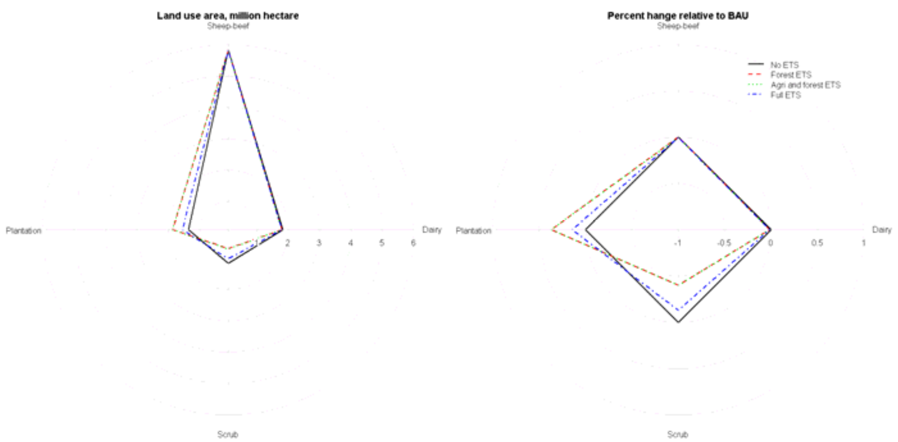
"Forest ETS" would boost the plantation area from 2010. "Full ETS" would also cause a increase in plantation area, although only half as effective as "Forest ETS" because the scrub sector competes with the forest sector. "Agri ETS" would increase the plantation slightly for it would force sheep-beef farms on low quality land to convert to forest land.

Figure 8 Historical and simulated scrub areas from 1974 to 2008 and from 2009 onwards under different ETS scenarios



The simulated scrub area from 2009 to 2015 almost mirrors the results for the forestry sector. Under the "Forest ETS" scenario, high quality scrub land would be converted to forest land because of the soaring financial benefits from planting trees. If scrub and forestry ETS were introduced together, less scrub land would be converted as it is assumed to generate a return of $75 dollars a year per hectare. The impact from "Agri ETS" is hardly visible. It helps to curb the decrease in the scrub area fractionally as sheep-beef farms or the parts of them on low quality land would be left to revert scrub.

Figure 9 Land-use comparison between scenarios at year 2015, area change and percentage change relative to the baseline case



Dynamic paths show how areas for each land-use type evolve through time and how they are affected jointly by price predictions, historical trends and relationships between each commodity price and each land-use type. A static comparison, on the other hand, shows how policies could change the structure of the four land-uses.

Figure 9 shows a static comparison between all scenarios at year 2015. The left panel shows the land-use area changes against the "No ETS" case marked by black solid line. The right panel presents the same information in terms of percentage changes relative to the baseline case. One feature of this simulation is that the trade-off between plantation area and scrub area. Both "Agri and forest ETS" and "All ETS" scenarios show an increase in plantation area contrasted with a decrease in scrub area. The dairy and sheep-beef area remain more or less constant.

4 Summary

This paper documents how the land use change module in LURNZ simulates land-use changes, the choice of parameter values and interpretation of results. It simulates land-use change under the New Zealand Emissions Trading System.

5 Appendix

5.1 Land-use simulation

Table 5 shows the area of simulated each 4 types of land-use under 8 different scenarios. The area is measured by hectare.

Table 5 Land use for difference scenarios measured by hectare

Dairy								
	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	1712572	1712572	1712572	1712572	1712572	1712572	1712572	1712572
2010	1726516	1726516	1712053	1712053	1726516	1726516	1712053	1712053
2011	1745715	1745715	1723422	1723422	1745715	1745715	1723422	1723422
2012	1766214	1766214	1739873	1739873	1766214	1766214	1739873	1739873
2013	1787532	1790737	1762383	1759178	1787532	1790737	1759178	1762383
2014	1809477	1811585	1782148	1780041	1809477	1811585	1780041	1782148
2015	1831820	1833105	1803025	1801740	1831820	1833105	1801740	1803025
Sheep-beef								

	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	6567090	6567090	6567090	6567090	6567090	6567090	6567090	6567090
2010	6453100	6453100	6453100	6453100	6453100	6453100	6453100	6453100
2011	6334072	6334072	6334072	6334072	6334072	6334072	6334072	6334072
2012	6211401	6211401	6211401	6211401	6211401	6211401	6211401	6211401
2013	6085816	6080215	6080215	6085816	6085816	6080215	6085816	6080215
2014	5958070	5948739	5948739	5958070	5958070	5948739	5958070	5948739
2015	5828643	5816282	5816282	5828643	5828643	5816282	5828643	5816282

Plantation								
	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	1349052	1349052	1349052	1349052	1349052	1349052	1349052	1349052
2010	1333321	1333321	1426447	1426447	1281793	1281793	1374918	1374918
2011	1328761	1328761	1518194	1518194	1219505	1219505	1408938	1408938
2012	1333331	1333331	1609873	1609873	1168870	1168870	1445412	1445412
2013	1344272	1346668	1703237	1700841	1127018	1129414	1483587	1485983
2014	1358052	1362739	1794652	1789966	1090311	1094998	1522225	1526911
2015	1372897	1379526	1883339	1876709	1056875	1063505	1560688	1567317

Scrub								
	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	1322839	1322839	1322839	1322839	1322839	1322839	1322839	1322839
2010	1314690	1314690	1236029	1236029	1366218	1366218	1287557	1287557
2011	1295154	1295154	1128018	1128018	1404410	1404410	1237273	1237273
2012	1268832	1268832	1018635	1018635	1433293	1433293	1183096	1183096
2013	1238234	1238234	910024.4	910024.4	1455488	1455488	1127279	1127279
2014	1206331	1208868	806397.8	803860.5	1474072	1476609	1071601	1074139
2015	1174646	1179093	705368.5	700921.6	1490667	1495114	1016943	1021390

Table 6 presents the percentage change of simulated land-use of each type from each scenario against the "No ETS" case, which is derived from Table 5.

Table 6 Land use change as a percentage relative to the base line case (NO ETS) for difference scenarios

Dairy

	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	0.00%	0.00%	-0.84%	-0.84%	0.00%	0.00%	-0.84%	-0.84%
2011	0.00%	0.00%	-1.28%	-1.28%	0.00%	0.00%	-1.28%	-1.28%
2012	0.00%	0.00%	-1.49%	-1.49%	0.00%	0.00%	-1.49%	-1.49%
2013	0.00%	0.18%	-1.41%	-1.59%	0.00%	0.18%	-1.59%	-1.41%
2014	0.00%	0.12%	-1.51%	-1.63%	0.00%	0.12%	-1.63%	-1.51%
2015	0.00%	0.07%	-1.57%	-1.64%	0.00%	0.07%	-1.64%	-1.57%
Sheep-beef								
	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2011	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2012	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2013	0.00%	-0.09%	-0.09%	0.00%	0.00%	-0.09%	0.00%	-0.09%
2014	0.00%	-0.16%	-0.16%	0.00%	0.00%	-0.16%	0.00%	-0.16%
2015	0.00%	-0.21%	-0.21%	0.00%	0.00%	-0.21%	0.00%	-0.21%
Plantation								
	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	0.00%	0.00%	6.98%	6.98%	-3.86%	-3.86%	3.12%	3.12%
2011	0.00%	0.00%	14.26%	14.26%	-8.22%	-8.22%	6.03%	6.03%
2012	0.00%	0.00%	20.74%	20.74%	-12.33%	-12.33%	8.41%	8.41%
2013	0.00%	0.18%	26.70%	26.53%	-16.16%	-15.98%	10.36%	10.54%
2014	0.00%	0.35%	32.15%	31.80%	-19.72%	-19.37%	12.09%	12.43%
2015	0.00%	0.48%	37.18%	36.70%	-23.02%	-22.54%	13.68%	14.16%
Scrub								
	No ETS	Agri ETS	Agri and forest ETS	Forest ETS	Scrub ETS	Agri and scrub ETS	Forest and scrub ETS	Full ETS
2009	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	0.00%	0.00%	-5.98%	-5.98%	3.92%	3.92%	-2.06%	-2.06%
2011	0.00%	0.00%	-12.90%	-12.90%	8.44%	8.44%	-4.47%	-4.47%
2012	0.00%	0.00%	-19.72%	-19.72%	12.96%	12.96%	-6.76%	-6.76%

2013	0.00%	0.00%	-26.51%	-26.51%	17.55%	17.55%	-8.96%	-8.96%
2014	0.00%	0.21%	-33.15%	-33.36%	22.19%	22.40%	-11.17%	-10.96%
2015	0.00%	0.38%	-39.95%	-40.33%	26.90%	27.28%	-13.43%	-13.05%

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