New Zealand Agricultural and Resource Economics Society (Inc.)

Estimating and projecting flows of greenhouse gases for New Zealand agriculture and planted forests

Darran Austin
Ministry of Agriculture and Forestry, Innovation and Research Policy Group
e-mail: darran.austin@maf.govt.nz

Rosa Rivas Palma
Ministry of Agriculture and Forestry, Innovation and Research Policy Group
e-mail: rosa.rivas@maf.govt.nz

Paper presented at the 2009 NZARES Conference
Tahuna Conference Centre – Nelson, New Zealand. August 27-28, 2009.

Estimating and projecting flows of greenhouse gases for New Zealand agriculture and planted forests

Darran Austin and Rosa Rivas Palma
Ministry of Agriculture and Forestry
Innovation and Research Policy Group
darran.austin@maf.govt.nz, rosa.rivas@maf.govt.nz

Summary

New Zealand is atypical among the Annex I parties within the Kyoto Protocol with agriculture forming a large part of greenhouse gas emissions and planted forests sequestering large amounts of carbon.

This presentation will summarise the methods and data used to estimate flows of greenhouse gases within agriculture and planted forests in New Zealand's National Inventory Report submission to the United Nations Framework Convention on Climate Change last April. 2009 projections for the first commitment period of the Kyoto Protocol (2008-2012) will also be presented and discussed.

Keywords: greenhouse gas emissions; agriculture; planted forests

1 Introduction

New Zealand is one of the countries that has ratified the Climate Change Convention to address climate change that took effect in 1994, and is committed to monitor the trends of human induced greenhouse gas emissions. As an Annex I party, New Zealand agreed a non-binding agreement to reduce greenhouse gas emissions to 1990 levels. In 2002 New Zealand ratified its commitment to the Kyoto Protocol that commits Annex I parties to stronger and specific commitments to reduce greenhouse gas emissions (MfE, 2009b).

A high proportion of New Zealand's emissions are from agriculture (48% of total emissions) followed by energy (43% of total emissions) (both excluding LULUCF). This profile gives New Zealand a unique profile amongst Annex I countries, which agriculture emissions range between 2 and 16% of their total emissions (excluding LULUCF). Under the LULUCF sector, net removals (deducting emissions) are estimated to be approximately 35% of the national greenhouse gas emissions in 2007.

The Ministry of Agriculture and Forestry currently leads the agriculture sector greenhouse gas reporting and contributes to the Land use, land use change and forestry (LULUCF) sector with planted forests data and analysis. Ongoing research is developed to improve and refine the calculation of emissions.

The Agriculture and LULUCF Net Position sections included in this paper have been extracted from MAF's contribution to the Net Position report (MfE, 2009a) and prepared by a number of contributors.

2 Greenhouse gas reporting background

New Zealand reports annual emissions and removals of greenhouse gases (GHG) as part of its commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol in the National Inventory Report (NIR).

The NIR is compiled according to Good Practice Guidance prescribed by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 1997, 2000, 2003).The NIR includes emissions and removals of 6 direct GHG: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perflurocarbons (PFCs) and sulphur hexafluoride (SF_6). These GHGs are accounted under the Kyoto Protocol. Other indirect gases (carbon monoxide (CO), sulphur dioxide (SO_2), oxides of nitrogen (NOx) and non-methane volatile organic compounds (NMVOCs)) are also included in the NIR. The six sectors are included in the NIR are: Energy, Industrial processes, Solvent and other product use, Agriculture, Land use, land use change and forestry (LULUCF) and Waste.

The Net Position report is a projected balance of Kyoto Protocol units annually updated for domestic purposes. A Kyoto Protocol unit is equivalent to one tonne of GHG emissions or removals converted to CO_2 by their global warming potential. The

Net Position report uses the best available information for the projections, and includes projections for the same sectors as those included in the NIR.

The Ministry for the Environment (MfE) is the New Zealand entity responsible for the NIR compilation and submission to the United Nations. MfE also compiles the Net Position projections and report. MfE coordinates the development of both reports with other government agencies.

The Ministry of Agriculture and Forestry (MAF) has taken the sector lead in the compilation of the Agriculture sector in the last NIR submission and provides input in the compilation of the NIR LULUCF sector. MAF leads the Agriculture and Forestry sectors reporting for the Net Position Projections

3 Agriculture

3.1 Agriculture GHG inventory

The New Zealand Agricultural Inventory is reported following the United Nations Framework Convention on Climate Change (UNFCCC, 2006). The agriculture sector made up 48.2 % of New Zealand's total emissions in 2007. The key sources of emissions for New Zealand agriculture are methane from enteric fermentation, nitrous oxide from agricultural soils and both methane and nitrous oxide from manure management (Table 1).

Table 1: Agriculture summary of emissions (Gg CO_2-e)

Agriculture	CH_4	N_2O	Total
A. Enteric Fermentation	23,326.38		23,326.38
B. Manure Management	729.10	57.96	787.06
C. Rice Cultivation	NO		NO
D. Agricultural Soils	NE,NO	12,298.07	12,298.07
E. Prescribed Burning of Savannas	0.88	0.16	1.04
F. Field Burning of Agricultural Residues	13.16	4.31	17.47
G. Other	NO	NO	NO
Total	**24,069.51**	**12,360.49**	**36,430.00**

Source: Ministry for the Environment (2009b).
Notes:
1. IE (included elsewhere), NA (not applicable), NE (not estimated), NO (not occurring) are notation keys used in the common reporting format tables for the inventory.
2. The signs for removals are negative (-) and for emissions positive (+)

There are four main animal sources which contribute to the majority of the agricultural emissions. These are dairy, beef, sheep and deer. For these sources a more complex (than IPCC defaults) Tier Two calculation is carried out on estimating emissions. For other species, a Tier One (IPCC default) process is used.

For the four main animal sources emissions are calculated using population and productivity data. The productivity data is used to estimate the dry matter intake of the animals. From this methane produced through enteric fermentation, and methane and nitrous oxide produced from manure management and manure and fertiliser application to the soil can be calculated. There are many processes involved in the formation of nitrous oxide from animal manure and fertiliser application to the soil, including nitrification and denitrification. These processes along with indirect processes such as leaching and ammonium volatilisation contribute directly and indirectly to the nitrous oxide emissions.

Other than livestock, there are other smaller sources which contribute to total agricultural emissions. This included field burning of agricultural soils and prescribed burning of savannah. Due to their small contribution to the total agricultural emissions these are calculated using IPCC default methods.

Although sheep numbers have dropped dramatically since 1990, agricultural emissions have continued to rise. The drop in sheep population has been counterbalanced by an increase in dairy and deer numbers, an increase in fertiliser usage, while beef has remained static. Also, due to an increase in animal productivity since 1990, total sheep production has not dropped as much as the drop in populations numbers may indicate should have occurred. These two factors have meant that the fall in sheep numbers has not resulted in a drop in emissions.

3.2 Agriculture Net Position projections

These projections are based on:

(1) the methodologies used in the National Greenhouse Gas Inventory submitted to the United Nations Framework Convention on Climate Change (UNFCCC) annually, and
(2) econometric and physical models developed by the New Zealand Ministry of Agriculture and Forestry (MAF). The inventory methodology conforms to the Good Practice Guidance methodologies developed by the Intergovernmental Panel on Climate Change and adopted by the UNFCCC.

Projections are driven by future estimates of:

- annual animal numbers and animal performance data (milk yield, weights) by species (beef cattle, dairy cattle, deer and sheep) obtained from MAF's Pastoral Supply Response Model (PSRM);
- annual nitrogen fertiliser use obtained from MAF's Nitrogen Demand Model;
- annual emissions estimated using the agriculture GHG tier two inventory model.

Two further scenarios of projected emissions for each year in First Commitment Period (hereafter CP1) have also been produced that represent the upper and lower bounds of projected emissions. These present emission estimates using the 95 percent confidence intervals for the upper and lower bounds of animal numbers, animal performance, and nitrogen fertiliser use.

3.2.1 Changes in methodology since last year's assessment

There have been several significant improvements in the methodology used in this year's projections. They consist of the improvement of the PSRM which was used to forecast animal numbers and performance data, the incorporation of the agriculture GHG tier two inventory model (hereafter inventory model) (Clark et al, 2003) which is currently used to estimate New Zealand's emissions for the National Inventory reported to the UNFCCC. Emission factors have been updated to reflect improved understanding of agricultural ammonia (NH_3), nitric oxide and nitrogen dioxide (collectively referred to as NO_x) emissions under New Zealand conditions. These gases influence measured agricultural emissions as they are an indirect route for nitrous oxide (N_2O) formation.

MAF's PSRM has been improved to include a land use forecast component as well as new variables that feed into the inventory model (e.g milk yield, liveweights). The key outputs of the model are forecasts of animal numbers (which are driven by changes in land use and stocking rates) and animal performance, which are subsequently used as inputs into the inventory model. Animal performance projections are driven by past performances, weather conditions as well as farmgate prices. The new land use component allows for simulations of movements between different land use categories under a constrained total land capacity. It also allows for the inclusion of some land use assumptions used in the Land Use, Land Use Change and Forestry (LULUCF) sector. Exogenous shocks to the model are farmgate prices, net farm incomes, and weather conditions. MAF's Nitrogen Demand Model has also been updated.

Use of the inventory model is the second major methodological change. The ability of the PRSM to predict both animal population and performance makes it possible to use the full inventory model to obtain projections. In the past the PSRM projected animal numbers only and these were combined with projections of GHG emissions per animal. These projections were obtained from regression analysis of the time series of emissions per animal from 1990 to the present. Values reported in the Net Position Report are now consistent with how they are derived in New Zealand's National Inventory. Also, estimates for every year of CP1 can now be obtained rather than projecting the 2010 emissions and multiplying by 5 to obtain the total emissions over the 2008-2012 period.

The use of the inventory model to forecast emissions for every year in CP1 enables the most up to date information available to be incorporated into the projection, reducing the uncertainty bounds determined for the 2008 emissions forecast. Preliminary data from the 2008 agricultural production survey were used for animal population numbers. This data relates to the last half of 2007 and the first half of 2008 and therefore only animal numbers for the last 6 months of 2008 needed to be forecast. Without this data, the entire year plus 6 months of 2007 would need to be forecast. Estimates of animal performance for the 2008/09 production season were made using production data up to January 2009. Therefore the estimates on performance data for the calendar year 2008 were based on actual data rather than forecasts.

Nitrous oxide is one of the six greenhouse gases whose emissions are estimated for New Zealand's National Inventory. It is produced by both direct emissions from nitrogen (N) and indirectly where other N forms are first formed before being converting to N_2O. One such indirect path is where NH_3 gas and other NOx are first produced. These gases are then re-deposited on land surfaces elsewhere before being converted to N_2O. The major source of NZ's N_2O emissions comes from N excreted by livestock. In order to estimate the indirect contribution to N_2O of N excreted by livestock via NH_3 and NO_x gases, a factor called $Frac_{gasm}$ is used. This represents the proportion of N which is excreted by livestock and is released into the atmosphere as NH_3 and NOx. Currently New Zealand uses the IPCC default value of 0.2 for $Frac_{gasm}$. A MAF contracted report (Sherlock et al., 2008) reviewed the relevant studies on $Frac_{gasm}$ from livestock excreted-N, and found that New Zealand could halve the $Frac_{gasm}$ value to 0.1. This report was internationally peer reviewed. The lower values for $Frac_{gasm}$ has been used and this accounts for 3.8 Mt CO_2-e.

Reduction of nitrous oxide emissions due to application of a nitrification inhibitor has also been incorporated and accounts for a further 0.3 Mt CO_2-e. The application of the nitrification inhibitor dicyandiamide (DCD) to dairy pastures has been shown to reduce nitrous oxide emissions from fertiliser and animal excreted nitrogen on pasture over a five month period in winter. Nitrate leaching is also reduced. A report contracted by MAF on the use of DCD (Clough et al, 2008) developed the methodology for the quantification of the reduced nitrous oxide emissions.

3.2.2 Projected animal numbers and nitrogen fertiliser use forecasts

Agricultural commodity prices

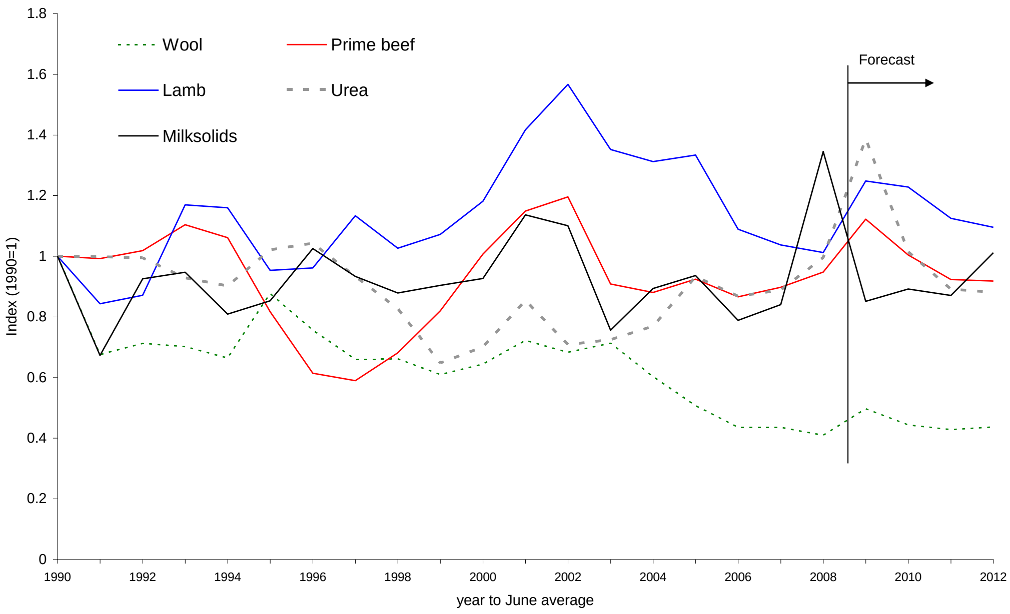
Future numbers of dairy cattle, beef cattle, sheep and deer are driven by changes in land use and stocking rates. Land use changes are modelled using expected changes in farm incomes. Stocking rates are modelled using expected changes in farm-gate prices, animal performance, and weather conditions. MAF estimates key farm-gate prices based on international price movements and the Treasury's assumptions on the future exchange rate and inflation, as published in their 2008 December fiscal and economic update. Figure 1 illustrates MAF's current expectations for key farmgate prices to 2012 in real terms.

In spring 2008, the global financial crises unfolded. The crisis has seen international prices for many commodities receding from their previous high levels and the New Zealand dollar depreciated rapidly against all major trading partners. The New Zealand trade weighted index fell 28 percent for February 2009, year on year. The significant currency depreciation means New Zealand dollar farmgate prices will increase unless there is a severe fall in international price, as is the case with dairy prices (see Figure 1).

New Zealand dairy prices fell quite spectacularly with very rapid falls in international dairy prices from the peaks of the dairy boom (since August 2008). The average milksolid payout is expected to significantly decline from the peak in the 2007/08 season leading to slower growth in the dairy sector over CP1.

International meat prices followed a different trajectory to dairy; meat prices were poor during the commodity boom but have recently improved due to specific supply constraints. New Zealand meat prices are expected to strengthen over CP1 encouraging a partial recovery in sheep and beef numbers from the drought induced de-stocking of 2008.

Figure 1: Past and expected changes to key inflation adjusted farm-gate prices



Animal number forecasts

Since the 2008 net position report, the scale and consequences of the 2008 nationwide drought has become more apparent. The preliminary agricultural production survey results, released on the 10th of February 2009, provide a comprehensive quantitative description of the drought's impact. Sheep numbers fell by 12 percent, beef numbers fell by 6 percent, and deer numbers fell by 13 percent. Dairy numbers increased by 6 percent.

Over CP1, dairy numbers are expected to be lower than last year's forecasts due to lower payouts. Projections of sheep and beef numbers, on the other hand, improved from last year's forecasts due to higher prices at farm gate.

Table 2: Animal numbers projections for most likely scenario (000)

Year end 30 June	Beef cattle	Dairy cattle	Deer	Sheep
1990	4593	3441	976	57852
2008 [1]	4119	5563	1213	33894
2009 [2]	4213	5582	1371	35589
2010 [2]	4367	5645	1432	36330
2011 [2]	4377	5713	1386	36920
2012 [2]	4402	5746	1385	37243

[1] 2008 is provisional data from the Agricultural Production Survey
[2] Projected numbers from MAF's PSRM

<u>Nitrogen fertiliser usage forecasts</u>

The application of nitrogen fertiliser rises in line with improvements in farmgate pastoral output prices, especially the milksolids price, and tends to fall with increases in the price of the fertiliser itself (see Austin *et al*, 2006). The most likely forecast for nitrogen fertiliser use for 2010 is 317,844 tonnes, which is lower than the 2008 forecast of 396,967 tonnes. This difference is largely attributed to lower dairy payouts and higher fertiliser prices over CP1.

Table 3: Projections of nitrogen fertiliser usage for most likely scenario (tonnes)

Year end 30 June	N fertiliser use
1990	59265
2008 [1]	349157
2009 [2]	349993
2010 [2]	317844
2011 [2]	297418
2012 [2]	330418

[1] 2008 is provisional data from FertResearch
[2] Projected data from MAF's Nitrogen Demand Model

3.2.3 Animal performance forecasts

With genetic improvement and better pasture utilization, productivity of New Zealand sheep, cattle and deer has increased. This has resulted in increasing amounts of pasture per animal being consumed and consequently more methane and nitrogen in urine and dung being produced. While in years of drought such as 2008/09 animal performance typically dips, the underlying upwards trend is robust and expected to continue in the foreseeable future. In MAF's PSRM model animal performance is modelled as a function of a linear trend of past performance, days of soil moisture deficit and, where statistically significant, farmgate price. Table 4 shows four examples of the performance statistics which are obtained from the PSRM.

Table 4: Example of some of the animal performance data obtained from the Pastoral Supply Response Model.

30 June year end	Total dairy milk yields (million litres/year)	Beef bull slaughter weight (kg)	Lamb slaughter weights (kg)	Breeding stag slaughter weight (kg)
1990	2746	275.1	14.1	51.5
2008 [1]	3538	299.3	16.5	56.8
2009 [2]	3744	308.7	17.6	58.4
2010 [2]	3872	313.3	18.0	59.9
2011 [2]	3934	319.6	18.0	61.0
2012 [2]	3996	321.5	18.2	61.3

[1] 2008 is data from LIC New Zealand Dairy Stats, and estimate of slaughter weight using MAF slaughter stats

[2] Projected data from MAF's Pastoral Supply Response Model

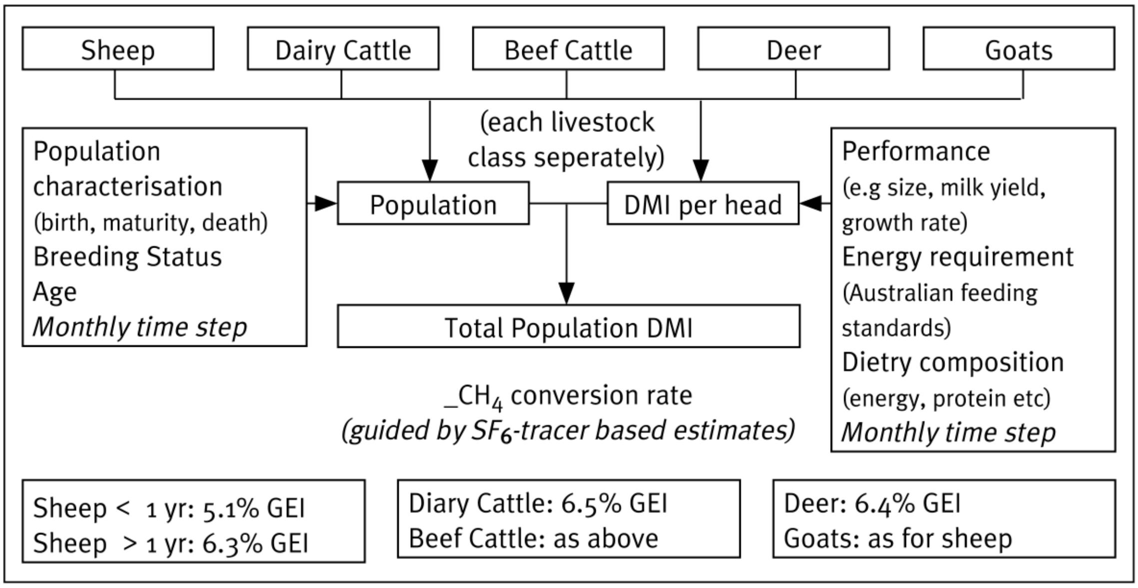
3.2.4 Development of greenhouse gas emission projections: most likely scenario

Projections of enteric methane emissions

Projections of enteric methane emissions for beef, dairy, deer and sheep for each year in CP1 were calculated by running actual data and forecast data from MAF's PSRM through the agriculture GHG tier two inventory model.

The inventory model determines animal feed intakes in monthly time steps for different age classes of each animal species. These are based on the mean national animal performance data derived from national statistics relevant to each species. For example, dairy cattle inputs include: animal liveweight, total milk production and milk fat and protein percentages. For each animal species, an empirical relationship has been derived for the amount of enteric methane produced per unit of feed intake. These relationships have been developed in New Zealand for deer, beef and dairy cattle, and sheep, using the sulphur hexafluoride (SF_6) technique that enables estimation of methane emissions under practical farming situations. The estimated annual methane emissions per animal take into account changes in animal performance over time. Since individual animal performance has been increasing over time (e.g. milk yields per cow have risen by approximately 25 percent since 1990), feed intake and methane emissions per animal have also increased.

Figure 2: Model for deriving ruminant methane emissions (Clark *et al*, 2003)



*GEI = Gross energy intake

Carbon dioxide equivalents from this enteric methane emission from each main source are shown in Table 5. Methane emissions from enteric fermentation on a per animal bases is shown in Table 6. An overview of the inventory model is shown in Figure 2.

Table 5: Projections of enteric methane emissions from each main source for the most likely scenario and the 1990 baseline (reported in Mt CO_2-e)

Calendar year	Beef cattle	Dairy cattle	Deer	Sheep	Total enteric methane emissions*
1990 baseline**	4.89	5.01	0.38	11.28	21.82
2008 [1]	4.93	9.08	0.58	7.95	22.60
2009 [2]	5.1	9.42	0.64	8.19	23.41
2010 [2]	5.37	9.6	0.68	8.49	24.19
2011 [2]	5.5	9.78	0.67	8.71	24.72
2012 [2]	5.56	9.92	0.67	8.89	25.11

*Total enteric methane emissions also include emissions from other animal species (goats, horses, pigs, and poultry) for which projections are discussed later.

**1990 values include all new science and methodologies and therefore are not identical to the 1990 assigned amount

[1] Estimated emissions

[2] Projected emissions using the Inventory Model

Table 6: Methane emissions from enteric fermentation per animal for 1990 baseline, 2008 estimate and projected most likely scenario values for 2009 – 2012 (kg CH_4/head/annum)

Calendar year	Beef cattle	Dairy cattle	Deer	Sheep
1990 baseline*	50.74	69.35	18.76	9.28
2008 [1]	56.97	77.73	22.72	11.17
2009 [2]	57.62	80.36	22.07	10.96
2010 [2]	58.55	80.96	22.61	11.12
2011 [2]	59.83	81.48	23.12	11.24
2012 [2]	60.19	82.19	23.13	11.37

*1990 values include all new science and methodologies and therefore are not identical to the 1990 assigned amount

[1] Estimated emissions

[2] Projected emissions using the Inventory Model

Methane emissions from ruminant animal waste

Methane emissions also arise from animal faecal material. This includes material deposited on pasture and, in the case of lactating dairy cows, from animal faecal material collected and treated in waste management systems. The projected waste methane emissions for beef, dairy, deer, and sheep for each year in CP1 were derived by running actual data and forecast data from MAF's PSRM through the agriculture GHG tier two inventory model. Carbon dioxide equivalents from animal waste methane emission from each main source are shown in Table 7. Methane emissions from animal waste on a per animal bases is shown in Table 8.

Table 7: Projections of animal waste methane emissions for the most likely scenario and the 1990 baseline (reported in Mt CO_2-e)

Calendar Year	Beef cattle	Dairy cattle	Deer	Sheep	Total waste methane emissions*
1990 baseline**	0.06	0.21	0.004	0.11	0.58
2008 [1]	0.06	0.39	0.01	0.08	0.53
2009 [2]	0.06	0.4	0.01	0.08	0.55
2010 [2]	0.07	0.41	0.01	0.08	0.56
2011 [2]	0.07	0.41	0.01	0.09	0.57
2012 [2]	0.07	0.42	0.01	0.09	0.58

* Total waste methane emissions also include emissions from other animal species (goats, horses, pigs, and poultry) for which projections are discussed later.

**1990 values include all new science and methodologies and therefore are not identical to the 1990 assigned amount

[1] Estimated emissions

[2] Projected emissions using the Inventory Model

Table 8: Methane emissions from waste per animal for 1990 baseline, 2008 estimate and projected most likely scenario values for 2009 – 2012 in kg CH_4/head/annum

Calendar year	Beef cattle	Dairy cattle	Deer	Sheep
1990 baseline*	0.62	2.89	0.17	0.09
2008 [1]	0.70	3.32	0.21	0.11
2009 [2]	0.71	3.41	0.20	0.11
2010 [2]	0.72	3.43	0.21	0.11
2011 [2]	0.73	3.45	0.21	0.11
2012 [2]	0.73	3.49	0.21	0.11

*1990 values include all new science and methodologies and therefore are not identical to the 1990 assigned amount

[1] Estimated emissions

[2] Projected emissions using the Inventory Model

Projections of nitrous oxide emissions

Nitrous oxide emissions are derived from animal nitrogen output and synthetic nitrogen fertiliser use. Animal nitrogen output is a function of animal feed intake and the nitrogen content of the diet minus any nitrogen stored in animal product (meat, milk etc). Models developed by Clark *et al* (2003) for estimating monthly feed intake also estimate nitrogen output per animal. Projections of nitrous oxide emissions for beef, dairy, deer, and sheep for each year in CP1 were derived by running actual data and forecast data from MAF's PSRM through the agriculture GHG tier two inventory model. Projections of emissions from nitrogen fertiliser use were projected using forecasts of nitrogen use and emission factors that are currently used in National Inventory calculations. (Table 9)

Table 9: Projections of nitrous oxide emissions for each major nitrogen source for the most likely scenario and the 1990 baseline (reported in Mt CO_2-e)

Calendar year	Dung and urine from beef cattle	Dung and urine from dairy cattle	Dung and urine from deer	Dung and urine from sheep	Emission from N fertiliser use	Total nitrous oxide emissions *
1990 baseline**	1.87	2.22	0.15	4.53	0.34	9.4
2008 [1]	1.88	3.90	0.23	3.23	2.00	11.51
2009 [2]	1.94	4.02	0.25	3.43	2.00	11.92
2010 [2]	2.05	4.08	0.27	3.55	1.82	12.05
2011 [2]	2.10	4.14	0.26	3.66	1.70	12.15
2012 [2]	2.13	4.19	0.26	3.74	1.89	12.49

* Total nitrous oxide emissions also include emissions from other animal species (goats, horses, pigs, and poultry), N-fixing crops, crop residues and emissions from burning of savannah and field burning of agricultural residues.

**1990 values include all new science and methodologies and therefore are not identical to the 1990 assigned amount

[1] Estimated emissions

[2] Projected emissions using the Inventory Model

Table 10: Nitrogen output per animal for 1990 baseline, 2008 estimate and projected most likely scenario values for 2009 – 2012 (kg N/head/annum).

Calendar year	Beef cattle	Dairy cattle	Deer	Sheep
1990 baseline*	65.51	103.87	24.88	12.61
2008 [1]	73.45	114.14	30.18	15.33
2009 [2]	74.29	117.56	29.29	15.53
2010 [2]	75.61	118.18	30.03	15.75
2011 [2]	77.31	118.87	30.71	15.95
2012 [2]	77.81	119.80	30.71	16.17

*1990 values include all new science and methodologies and therefore are not identical to the 1990 assigned amount

[1] Estimated emissions

[2] Projected emissions using the Inventory Model

Other animal species and greenhouse gas sources

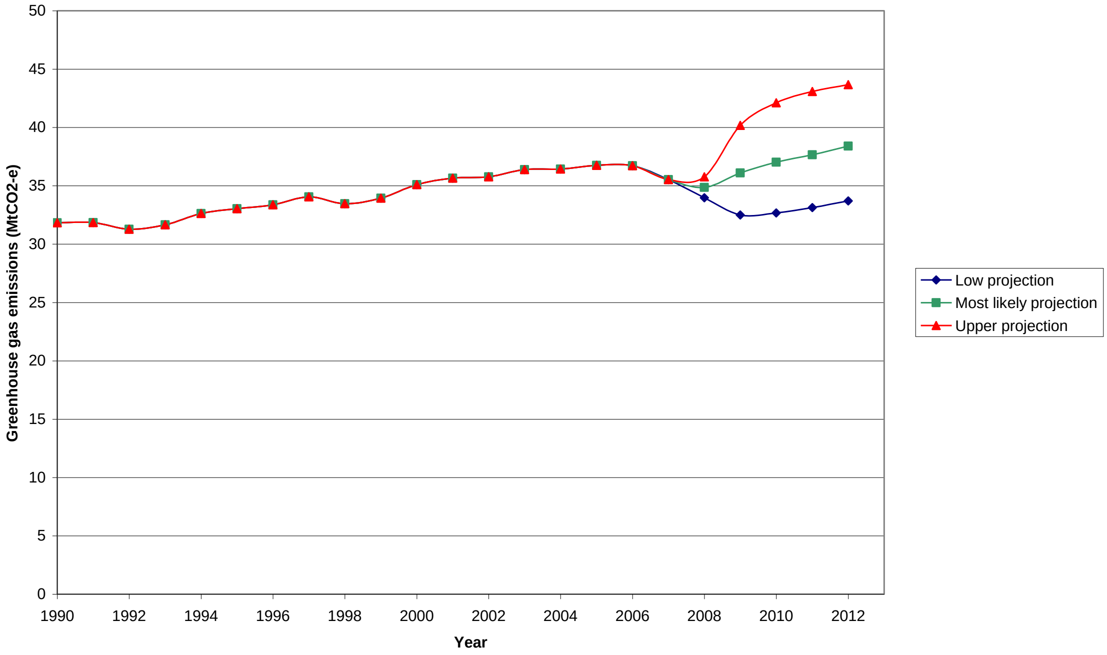
Methane and nitrous oxide emissions of minor animal species present in the national inventory i.e. goats, horses, pigs, and poultry and nitrous oxide emissions from crop stubble burning, savannah burning and nitrogen fixing crops were forecast based on a rolling three year average method from their actual level of production in 2008. As these sources made up only 1.5 percent of total agricultural emissions in 2007 (0.55 $MtCO_2$-e), the impact of even large changes in any of these small emission sources on the total national emissions profile would be small.

3.2.5 Development of lower and upper scenarios

Two further scenarios were developed: a lower and higher scenario. The higher scenario combined the *upper* 95 percent confidence interval values for animal numbers, animal performance and nitrogen fertiliser use. The lower scenario combined the *lower* 95 percent confidence interval values. These two scenarios estimate the values of the upper and lower bounds of future projected emissions at the 95 percent confidence level.

These calculations attempt to provide a range, with a specified probability, within which future reported emissions estimates should lie. It takes into account the uncertainty around the prediction of the forecasts used to determine the emissions, for example future animal numbers and performance levels. Predictions assume current science and do not account for any future changes in science or methodology.

Figure 3: Projected emissions over CP1



Animal numbers and nitrogen fertiliser usage

Table 11: Projections of animal numbers (000) and nitrogen fertiliser usage (tonnes) for low and high scenarios

Year end June	**Beef cattle**		**Dairy cattle**		**Deer**		**Sheep**		**N fertiliser use**	
	Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
2009	3,950	4,475	5,483	5,682	1,141	1,602	29,944	41,723	266,928	447,996
2010	4,116	4,618	5,472	5,818	1,197	1,667	30,087	43,036	219,721	432,873
2011	4,125	4,628	5,518	5,909	1,141	1,632	30,449	43,826	208,050	420,236
2012	4,151	4,652	5,542	5,950	1,140	1,631	30,665	44,240	229,631	478,333

Enteric methane emissions

Lower and upper estimates of enteric methane emissions were obtained from running the inventory model with the lower and upper estimates of animal numbers and performances. This gives a lower and upper bound for projected enteric methane emissions at the 95 percent confidence level (Table 12).

Table 12: Projections of enteric methane emissions for the main livestock industries for the lower and upper scenarios (Mt CO_2-e)

Calendar year	**Beef cattle**		**Dairy cattle**		**Deer**		**Sheep**	
	Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
2008	4.82	5.04	8.85	9.31	0.56	0.59	7.68	8.23
2009	4.63	5.59	8.94	9.93	0.52	0.76	7.16	9.59
2010	4.86	5.90	8.96	10.28	0.54	0.83	7.22	10.28
2011	4.97	6.05	9.04	10.56	0.53	0.83	7.41	10.60
2012	5.03	6.12	9.14	10.76	0.53	0.83	7.58	10.86

Nitrous oxide emissions

Lower and upper estimates of nitrous oxide emissions were obtained from running the inventory model with the lower and higher estimates of animal numbers and performances. Emissions from nitrogen fertiliser were projected using lower and higher estimates of nitrogen use. This gives an upper and lower bound for projected nitrous oxide emissions at the 95 percent confidence level (Table 13).

Table 13: Projections of nitrous oxide emissions from the main nitrogen sources for lower and higher scenarios (Mt CO_2-e)

Calendar year	Dung and urine from beef cattle		Dung and urine from dairy cattle		Dung and urine from deer		Dung and urine from sheep		Emissions from N fertiliser use	
	Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
2008	1.84	1.92	3.80	3.91	0.22	0.23	3.12	3.34	2.00	2.00
2009	1.76	2.13	3.81	4.05	0.21	0.30	2.89	3.92	1.53	2.56
2010	1.85	2.26	3.81	4.12	0.21	0.33	2.91	4.22	1.26	2.48
2011	1.89	2.32	3.84	4.19	0.21	0.32	2.99	4.35	1.19	2.41
2012	1.92	2.35	3.87	4.24	0.21	0.33	3.06	4.46	1.31	2.74

3.2.6 Overall assumptions and limitations of the projections

All the above projections need to be assessed within the inherent uncertainties of biological systems. Climate shocks such as droughts, and the economic conditions which are largely driven by overseas markets, can rapidly change the circumstances under which the agricultural industry operate over the next few years.

Uncertainty in projections of animal populations and animal performances and of the science underlying measurement methods all attribute to the uncertainty in projections of total emissions.

Emission mitigation technologies such as nitrification inhibitor DCD and improvements in the science behind measuring agricultural emissions ($Frac_{gasm}$) have been incorporated into emission projections. New mitigation technologies and further refinements of measurement methods will bring further changes to these projections.

Adoption of mitigation technologies may be counter-balanced by greater increases in emissions from increases in animal numbers and further improvements in animal productivity growth. Past data on animal productivity growth were used to derive the best fit projection equations for future changes. However, animal performances remained largely dependent on future improvements in technologies and management practices.

4 Land Use, Land Use Change and Forestry (LULUCF)

4.1 LULUCF GHG inventory background

LULUCF GHG inventory reporting follows the United Nations Framework Convention on Climate Change (UNFCCC, 2006).

Carbon dioxide emissions and removals in the LULUCF sector are driven by uptake from vegetation, emissions from harvest production forests, and decomposition of organic material. Non-carbon emissions are generated from nitrification and denitrification (nitrous oxide, N_2O) and the burning of organic matter (N_2O, methane (CH_4), carbon monoxide (CO), other oxides of nitrogen (NO_x) and non- CH_4 volatile organic compounds (NMVOC).

The LULUCF GHG inventory includes six land use categories as defined in *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003):

- Forest land – all land with woody vegetation consistent with defined national thresholds. It could be sub-divided into ecosystem type. It also includes areas of vegetation that currently fall below, but are expected to reach the defined national thresholds. New Zealand's categories are Planted and Natural forests.

- Cropland – arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for forest land category, and are consistent with national definitions. New Zealand's categories are Annual and Perennial croplands.

- Grassland – rangelands and pasture land that are not considered as cropland. It also includes systems with vegetation that fall below the defined national threshold in the forest land category and are not expected to reach or exceed this threshold without human intervention. New Zealand's categories include High producing and low-producing grassland.

- Wetlands – land that is covered or saturated by water for all or part of the year (e.g. peat land) and that does not fall into the forest land, cropland, grassland or settlements categories. Natural rivers and lakes are unmanaged subdivisions of wetlands.

- Settlements – all developed land, including transportation infrastructure and human settlements unless they are already included under other categories. This should be consistent with the selection of national definitions.

- Other land – bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. This should be consistent with the selection of national definitions.

New Zealand uses a combination of IPCC defined Tier 1 and Tier 2 methods for reporting removals and emissions from the LULUCF sector. Tier 1 methodologies usually use activity data that are spatially coarse. Tier 2 methodologies can use the same approach as Tier 1 but applies country specific emission factors and activity data for the most important land uses or activities. Tier 2 can also country-specific methodologies based on national data (IPCC, 2003).

The Tier 1 approach used in the inventory is based on a simple land use change matrix based on the existing land cover maps (Land Cover Databases 1 and 2) which reflect land use in 1997 and 2002 respectively. The land types in these maps were re-classified to reflect IPCC land category definitions (except planted forests). The changes in land use between 1997 and 2002 were calculated and extrapolated to calculate land use change trends from 1990 to 1997 and 2002 to the corresponding reporting year. A Tier 2 modelling approach using New Zealand specific data has been used to estimate removals and emissions in planted forests, excluding soils. (MfE, 2009b).

In 2007, net removals (deducting emissions) from the LULUCF sector were estimated in 23,836 Gg CO_2-e. Forest land contributed 24,527.9 Gg CO_2-e net removals (Table 14).

Table 14: LULUCF summary of emissions and removals (Gg CO_2-e)

Land Use, Land-Use Change and Forestry	CO_2	CH_4	N_2O	Total
A. Forest Land	-24,565.23	33.89	3.44	-24,527.90
B. Cropland	-520.99	NA,NO	10.71	-510.28
C. Grassland	1,032.61	28.21	2.86	1,063.68
D. Wetlands	0.72	IE,NE,NO	IE,NE,NO	0.72
E. Settlements	97.16	NE	NE	97.16
F. Other Land	40.61	NE	NE	40.61
G. Other	IE,NE	IE,NE	IE,NE	IE,NE
Total	**-23,915.12**	**62.10**	**17.01**	**-23,836.01**

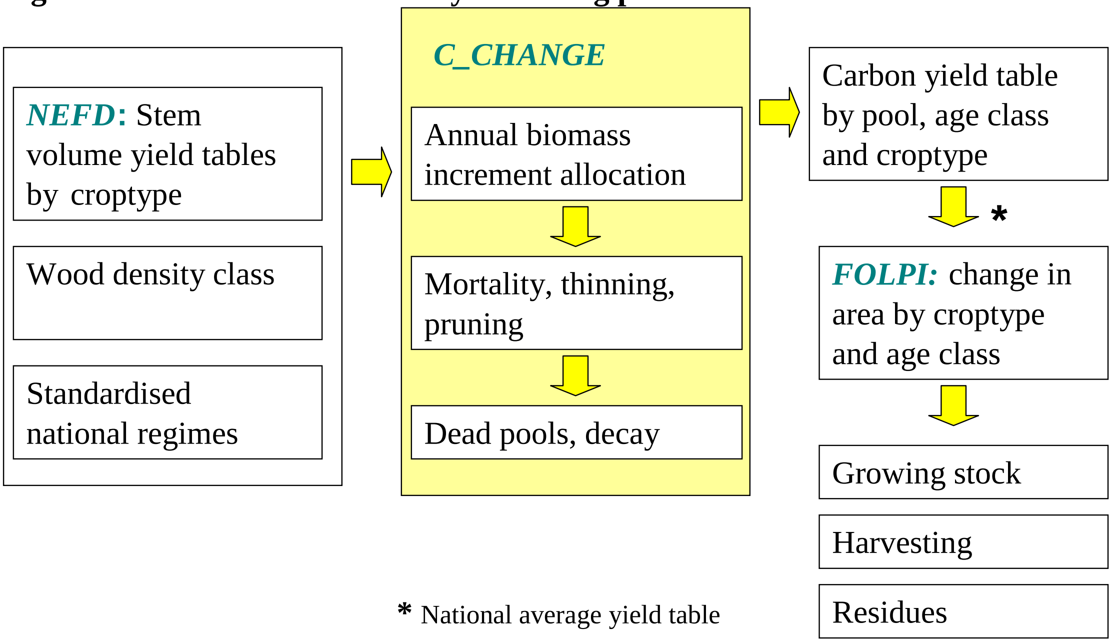
Source: Ministry for the Environment (2009b)
Notes:
3. IE (included elsewhere), NA (not applicable), NE (not estimated), NO (not occurring) are notation keys used in the common reporting format tables for the inventory.
4. The signs for removals are negative (-) and for emissions positive (+)

4.1.1 Methodology used for planted forests

This model is based on data from the National Exotic Forest Description (NEFD). The NEFD database has planted forest areas by year of planting. The data is aggregated at a crop type level (defined by region, species and forest management regime). Stem volume yield tables have been prepared based on these NEFD croptypes (MoF, 1996), from which a national carbon yield table has been derived.

The C_Change model developed by Scion (formerly Forest Research Institute) is used to predict biomass pools, based on the NEFD stem volume yield tables, wood density classes for regions and species and forest management regime details. The forest estate modelling system, FOLPI, to combine the yield information with national areas by age class, allowing the planted forest estate to be simulated over a 98 year period from 1980 (Wakelin, 2008). These outputs were reported in the inventory for the 1990-2007 time series.

Figure 4: Planted forest inventory modelling process



Source: Wakelin (2008)

4.1.2 Land Use and Carbon Analysis System (LUCAS)

The Land Use and Carbon Analysis System (LUCAS) project aims to develop a robust and comprehensive data gathering, data management, analysis and reporting system consistent with IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry. LUCAS is designed to provide appropriate data to meet UNFCCC and Kyoto Protocol (Article 3.3.) LULUCF sector reporting, as well as support and underpin New Zealand climate change policy development through to 2012 and beyond.

Data collection has three main components: Forests (natural and planted), soils, and land use mapping. LUCAS uses a network of permanent plots that have been established in planted forests (pre-1990 and post-89) and natural forests. The data to be collected from these plots will cover all the carbon pools needed for LULUCF reporting (above-ground biomass, below-ground biomass, dead wood, litter, and soil) as identified by IPCC.

Historic soil plots have been established in different land uses: grassland, natural forest, shrubland, planted forest, cropland, pasture-planted forests paired sites, shrubland regenerating in pasture paired sites. Results from plots will provide information for modelling soil carbon change associated with land use change.

LUCAS will derive land use changes from wall-to-wall mapping of New Zealand at 1990, 2008 and 2012.

LUCAS has a purpose-built database to store and manipulate all data used to calculate carbon stock changes in the LULUCF sector. The LUCAS Calculating and Reporting application is under development (MfE, 2009b). When the LUCAS data and applications are available, these will be used in the GHG inventory.

4.2 LULUCF Net Position

Under the terms of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), New Zealand has agreed to take responsibility for its greenhouse gas emissions in Commitment Period One (CP1: 2008–2012).

As forests grow they remove carbon dioxide (CO_2) from the atmosphere (removals). Under the Kyoto Protocol, parties must account for CO_2 emissions and removals by forests established on non-forested land after 31 December 1989 (post-1989 planted forests). Net removals can be used to offset greenhouse gas emissions from other sectors.

The Net Position report provides projections of CO_2 removals and emissions from New Zealand's Land Use, Land-use Change and Forestry (LULUCF) sector, presently limited under the Kyoto Protocol to post-1989 afforestation, reforestation and deforestation. These projections only cover Kyoto-compliant planted forests.

The six key factors used to estimate these projections are:

- the estimated area of post-1989 planted forests (Kyoto forest area)
- forecast afforestation rates
- forecast deforestation rates of planted forests
- post-1989 planted forest growth rates based on a preliminary analysis of Land Use and Carbon Analysis System (LUCAS) forest inventory measurements
- the proportion of exotic forest area planted since 1 January 1990 that may be "ineligible Kyoto forests" (over-planted onto land which was already defined as forest as at 1 January 1990)
- the potential loss of soil carbon following afforestation of grassland.

Assumptions around the likelihood of these factors in the future provide the range of values for the **upper**, **most likely**, and **lower emissions** scenarios.

4.2.1 Forestry trends and drivers affecting forecasts

Forecasts are greatly influenced by recent historic and prevailing conditions. This section briefly summarises the economic and policy environment the New Zealand forest sector has been operating in.

From 2004 until mid-2008 the New Zealand forestry sector faced a high exchange rate, increasing costs (particularly shipping costs), increasing international competition and changing international markets – all of which impacted negatively on forest-growing profitability. More recently international demand for forestry products has fallen sharply, with lumber exports badly affected by the global economic situation. The domestic forest products market is also forecast to slow further during 2009.

Better returns from alternative land uses, and the greater separation of forest ownership and forest land ownership, have led to the conversion of forest land to other land uses. The area of deforestation accelerated in anticipation that Government climate policy would require forest land owners to pay for deforestation emissions from the start of 2008. A survey of forest owners undertaken between December 2008 and February 2009 indicates that intentions for future land use changes between 2008 and 2020 is forecast to be in the range of 29,000 to 90,000 hectares.

The results of these changes and the perceptions about forestry's future profitability have resulted in:

- a major decline in the rate of afforestation: from an annual average of 38,000 hectares over the last 30 years, to around 2,000 hectares per years in 2007 and 2008. These are the lowest levels of afforestation recorded since 1945.
- forest land being converted to other land uses, particularly dairy farming. It was estimated that approximately 20,000 hectares were deforested in the year ended December 2007, before the Emission Trading Scheme (ETS) legislation was enacted (Manley, 2009). Estimated deforestation for the year ended 2008 under current ETS policy was approximately 3,000 hectares.

4.2.2 Modelling methodology

This report provides scenario-based forecasts (projections) of CO_2 removals and emissions for the LULUCF sector for the period 2008 to 2012. The projections are based on information available as at February 2009 and only cover planted forests.

These forecasts are derived from data and assumptions provided by the Ministry of Agriculture and Forestry (MAF) and the Ministry for the Environment (MfE). The modelling was undertaken by Scion (formerly the New Zealand Forest Research Institute). The underpinning science incorporated in the forest carbon models used in these projections, together with scientific assumptions, come from work carried out by New Zealand's Crown Research Institutes, predominantly Scion and Landcare Research.

Scientific uncertainty, information gaps and the range of possible future outcomes (such as future afforestation and deforestation rates) are reflected in a scenario-based analysis. The scenarios represent the circumstances expected to result in the maximum, most likely and minimum emissions (termed the "**upper emissions"**, "**most likely"** and "**lower emissions"** scenarios). The scenarios include the likely ranges of the major contributing factors that influence planted forest LULUCF sector removals and emissions, based on the current economic conditions, policy settings, land-use statistics, and scientific knowledge. More detailed information on these factors are contained in the section on Model assumptions.

The projected post-1989 planted forest removals were calculated using LUCAS field inventory data collected from 273 sample sites. At each sample site 4 sample plots were measured. The sample sites were located on a 4*4km grid laid across New Zealand with sample sites established where the grid intersected with post-1989 planted forest. Because there are still a number of outstanding measurement issues the analysis must be regarded as preliminary at this stage.

The removals calculation methodology used in these projections is based on the design intended to be used by the LUCAS Calculation and Reporting Application. This largely replaces the previous approach used to project CP1 CO_2 removals, which was based on data from the National Exotic Forest Description and models developed for UNFCCC reporting in the early 1990s.

Carbon stocks were estimated from the plot data using an empirical forest growth model – the 300 Index model (Kimberley et al., 2005) and the carbon allocation model C_Change (Beets et al., 1999). The 300 Index model uses the LUCAS inventory data to estimate stem volume growth from establishment to a future harvest age. The C_Change model uses the 300 Index generated stem volumes along with forest management information to estimate forest carbon stocks.
A model that links the 300 Index and C_Change has been developed in Microsoft Excel; this model is called "Forest Carbon Predictor" (Version 2.1).

The change in carbon stock (tonnes C/ha) from 1 January 2008 to 31 December 2012 has been predicted for each LUCAS plot using the Forest Carbon Predictor. From this the average change in carbon stock per hectare was calculated, and multiplied by the estimated total post-1989 planted forest area based on national afforestation statistics collected by MAF. This gives the total forecast change in carbon stock over the commitment period, which is then converted to CO_2-equivalents.

The scenarios modelled included uncertainty around total afforested area, and the adjustment of forest areas to deduct ineligible forest areas planted onto existing forest land (ie, shrubland that met New Zealand's forest definition). In the latter case, the over-planted proportion was removed from the calculations.

The spreadsheet simulation model described in previous Net Position Reports was still used as a cross check on the Forest Carbon Predictor model forecasts and also to provide estimates of projected removals from post-2007 afforestation, soil carbon, and deforestation.

4.2.3 Model assumptions

Kyoto forest area

Kyoto forest areas have been estimated from national afforestation statistics collected by MAF. These statistics are based on a combination of:

- An annual survey of the number of planting stock sold by forest nurseries (Eyre, 1995). From this survey national estimates of total planting, restocking and new planting are calculated. This survey has been in operation since 1992 and the methodology used was reviewed in 2003 (Manley et al, 2003).
- The National Exotic Forest Description (NEFD) database. The NEFD data is maintained through an annual census of major forest growers and a biennial survey of forest owners with 40 hectares of forest or more. Since the mid-1990's much of the afforestation that has occurred has been by smaller-scale forest owners, many of them new entrants to forest growing. Obtaining complete statistics from these small-scale owners (using postal survey methods) has been problematic.

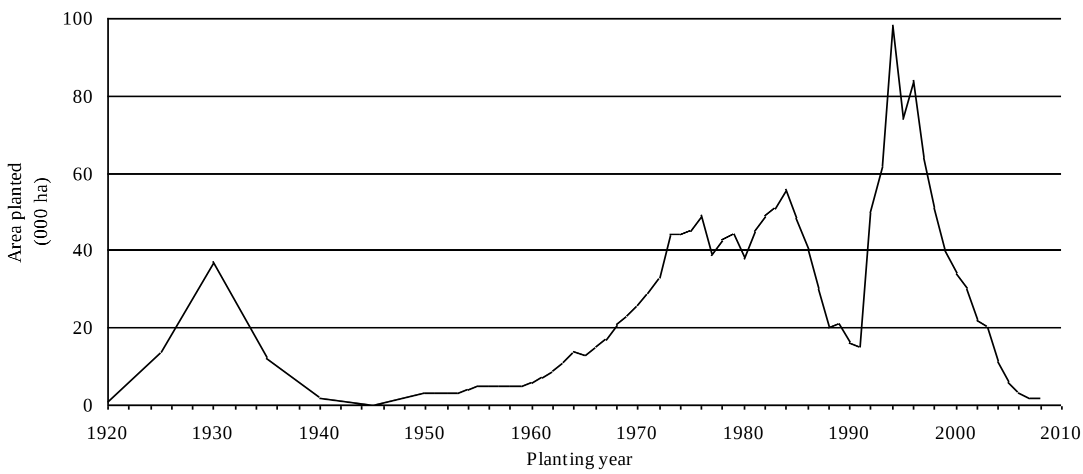
- Statistics New Zealand estimates of afforestation from the Agricultural Production Survey.
- A small reduction in area to allow for known deforestation of post-1989 planted forest area.

In developing regional wood availability forecasts which are based on NEFD forest areas, the small-scale owner's areas were reduced by 15 percent. This was done because small-scale owner's areas are often reported on a gross area rather than the actual net stocked area basis. For that reason the uncertainty range used for the post-1989 afforestation area (much of which is owned by small-scale owners) was set to ±15 percent.

Future afforestation of exotic planted forests

The average new planting rate over the last 30 years has been 38,000 hectares per year. In the period 1992 to 1998 new planting rates were high, averaging 69,000 hectares per year. Since then new planting has declined to around 2,000 ha in 2008.

Figure 5: New forest planting, 1920–2008



Source: National Exotic Forest Description (MAF, 2008)

Table 15 shows the afforestation rates used in the 2009 net position projections.

Table 15: Future plantation afforestation (hectares)

Calendar year	Upper emissions scenario	Most likely scenario	Lower emissions scenario
2008	0	2,000	2,700
2009	0	2,000	4,000
2010	0	2,000	5,200
2011	0	2,000	6,500
2012	0	2,000	17,900
Average (2008–2012)	0	2,000	7,300

The **most likely** scenario assumes annual afforestation of 2,000 hectares per year during CP1, based on current afforestation levels.

The **upper emissions** scenario assumes no further afforestation occurs after 2007. This assumption is the same as last year's projections (worst-case scenario).

The **lower emissions** scenario assumes average afforestation of 7,300 hectares per year between 2008 and 2012. These rates are based on the projected afforestation rates estimated by Cairns et al. (2008) at a carbon price of $25 per tonne ($CO_2$ equivalent). Afforestation areas include 1,500 per year afforested through the Afforestation Grant Scheme (AGS). This scheme is currently scheduled to run until 2012. The balance of the area is attributable to the ETS.

Afforestation rates may increase once the forestry schemes (Forestry ETS, Permanent Forest Sinks Initiative (PFSI) and AGS) are fully implemented. There are currently only a small number of participants that have registered in these schemes. However, it is expected that when national climate change policy is fully defined and international carbon market trading is more established, afforestation rates would increase in time. The **lower emissions** scenario takes into account this assumption of increased future afforestation rates, compared with current trends (as at February 2009).

As previously noted, the impact of future afforestation on the amount of CO_2 removed in CP1, is very limited. However, these forests will remove increasing amounts of CO_2 as the forests mature, resulting in larger removals in future commitment periods.

Future deforestation

Since 2004, a clear trend has emerged of not replanting all forest after harvesting and in a number of cases even immature forest has been converted to pasture. These land use changes have been driven by changing commodity prices between forest products and those from competing land uses, particularly diary farming. New Zealand has traditionally had dynamic land-use change that is responsive to price signals, so these changes in land use are not unusual. However, prior to 2002 almost all forest was replanted after harvest.

It has been estimated that approximately 20,000 hectares of plantation forests were deforested in the year ended December 2007 (Manley, 2009). The latest Deforestation Intentions Survey forecast deforestation under three scenarios (Manley, 2009):

a. ETS policy (with deforestation liabilities accruing to the forest owner)
b. Amended ETS policy (offset planting required[1]; no deforestation liabilities for forest owners)
c. No ETS (no deforestation liabilities for forest owners)

The survey results indicated that deforestation between 2008 and 2012 would be approximately 13,000, 27,000 and 34,000 hectares for each scenario respectively. In previous surveys, it was assumed that all deforestation was of pre-1990 planted forest. In this year's deforestation intentions survey forest owners also provided new information on the areas of immature and mature trees that are intended to be deforested. This has allowed a more refined forecast of deforestation emissions. For all the deforestation scenarios it was assumed that 6,000 hectares of immature post-1989 planted forest would be deforested, with the remainder being pre-1990 planted forest.

All deforestation of pre-1990 planted forest is assumed to be mature radiata pine (28-year-old), releasing approximately 800 tonnes of CO_2 per hectare. Deforestation from post-1989 planted forest was assumed to release approximately 280 tonnes of CO_2 per hectare, assuming an average age of 12 years (based on expert opinion).

Deforestation estimates do not include indigenous forest or shrubland that meets New Zealand's adopted Kyoto forest thresholds, as there are currently insufficient national statistics available on the area cleared of either indigenous forest or shrubland (that meets the forest definition). A Landcare Research report provided estimates for indigenous forest and scrub area cleared between 1989/90 and 1996/97, using visual interpretation of ground cover from satellite images (Stephens et al, 2001). Although a complete coverage for New Zealand was not achieved because of insufficient cloud-free images, it was estimated that around 0.03 percent of the total area of indigenous forest and 0.05 per cent of the total area of scrub were cleared between 1990 and 1996.

However, it is considered that under current legislation no significant deforestation of indigenous forest is likely. Until improved national mapping of forest area and change is available through the LUCAS programme, the actual level of indigenous forest and shrubland clearance remains unknown.

Growth rates

Forest growth rates used in this report were based on a preliminary analysis of the data collected from LUCAS sample plots established in post-1989 planted forests.

---

[1] Under this proposal, an area of planted exotic forest land would not be considered deforested if an "equivalent area of forest" was established elsewhere.

These new growth rates replace the NEFD-based yield table used in previous Net Position Reports. The preliminary results from the LUCAS plots indicate that post-1989 planted forests have a higher biomass per unit area compared with the NEFD data. This difference seems to be a result of post-1989 planted forests owned by small-scale foresters having received less intensive forest management and so have higher stockings than those managed by large-scale forest owners. In addition much of the post-1989 planted forest is established on former farm sites, which are likely to be more fertile than traditional forestry sites.

The estimates of the removals of Kyoto forests for the **most likely** scenario were calculated by projecting the carbon stock gain during the commitment period for each plot. Each plot was modelled individually using standardised forest management decision rules (Paul et al, 2009).

The **lower emissions** scenario assumes no silviculture occurs in post-1989 planted forests during CP1 (therefore more forest biomass and removals).

The **upper emissions** scenario was defined by a 10% reduction in the average carbon stock increase. This represents the lower end of the sampling error for the most likely estimate (6%), with additional allowance made for modelling error and greater losses due to wind damage or disease than are assumed by the growth model.

Ineligible planting

Initial research has suggested that a proportion of the post-1989 exotic planting may have occurred on land that already met New Zealand's forest definition due to the presence of indigenous shrubland species that had already reached the Kyoto forest thresholds adopted by New Zealand. Under carbon accounting rules, such land does not qualify as Kyoto forest, as the land was already deemed to be forest land on 31st December 1990.

The estimated proportion of "ineligible" post-1989 planted forests used in the 2006, 2007, and 2008 LULUCF projections were 8 per cent (**lower emissions**), 16 per cent (**most likely**), and 21 per cent (**upper emissions**). The proportions for the **most likely** and **upper emissions** scenarios have been updated to 12 and 16 per cent respectively, based on a preliminary analysis of newly developed datasets of landcover at 1990 (Kirschbaum et al, 2009). These figures represent the best estimates currently available.

Table 16: Percentage of existing forest (shrubland) ineligible under the Kyoto Protocol

	Upper emissions scenario	Most likely scenario	Lower emissions scenario
Percentage of post-1989 forest planted into shrublands that could already have met New Zealand's Kyoto forest definition	16%	12%	8%

Confirmed estimates of ineligible post-1989 exotic forest planting will not be available until the LUCAS land-use mapping for the 1990 and 2008 years have been completed and undergone quality assurance. This will provide more definitive data.

Changes in soil carbon

Soil carbon values used in this report are based on the New Zealand Soil Carbon Monitoring System (Soil CMS) model and the soils dataset that will be used in LUCAS.

The Soil CMS model was developed for New Zealand conditions to meet Intergovernmental Panel on Climate Change (IPCC) reporting requirements. This model estimates soil carbon stocks and the forecast change in stock with land-use change (the stock change factor). The Soil CMS model has been determined to be appropriate for meeting soil carbon reporting requirements by an International Review Panel (Ministry for the Environment, 1999) and has been reported in a number of peer-reviewed international scientific publications (e.g. Scott et al, 2002, Tate et al, 2005). With the Soil CMS model, LUCAS uses the Historic Soils dataset which has been extracted from the National Soils Database and five other smaller soils datasets. Future refinements are planned including additional data collection to fill gaps in the current dataset and model refinements to reduce uncertainty.

Initial calculations from the Soil CMS model and Historic Soils dataset predicted a soil carbon loss of 18.4 t C/ha for afforestation. This is assumed to occur over the IPCC default transition period of twenty years. This estimate is assumed to be the **upper emissions** scenario for this year's projections, as it was in the 2008 projections. A review of national and international studies, and process-based modelling, by Kirschbaum et al (2009) – and the expert judgment of researchers and officials – indicated that this initial predicted carbon loss associated with afforestation may be overstated.

Attempts have been made recently to recalibrate the Soil CMS model in a way that better accounts for the broad differences in soil profiles between typical grassland and forest sites, by weighting apparently spatially auto correlated grassland data, and by rejecting grassland sites that are a long way from forest sites. Preliminary analyses based on these approaches indicate mean soil carbon losses of between 8 to 13 t C/ha with afforestation. Further refinement of the spatial auto correlation approach is underway. Based on expert judgement considering all evidence currently available, a soil carbon loss of 11 t C/ha with afforestation was used in the **most likely** scenario.

The **lower emissions** scenario assumes no soil carbon change following afforestation, as in the 2008 projections.

4.2.4 Projection results

Table 17 provides a breakdown of the major contributing factors on which the removals and emissions projections are based. Net removals from the LULUCF sector for the period 2008 to 2012 are projected to be between 46 and 108 Mt CO_2.

Net removals for the **most likely** scenario are projected to be 85 Mt CO_2 (compared to 67 Mt CO_2 in the previous year's projection).

Table 17: LULUCF projected carbon removals and emissions (Mt CO_2-e) during CP1: Comparison of the 2008 "Most likely" projection with the three 2009 scenarios

Contributing factor	**2009 projections**			**2008 projection (Most likely scenario)**
	Upper emissions scenario	**Most likely scenario**	**Lower emissions scenario**	
Removals based on afforestation only				
Post-1989 planted forest CO_2 removals (based on existing 664,000 ha)	109.7	109.7	109.7	95.5
Future afforestation (2008 to 2012): 0; 2,000; 7,300 ha/yr	0.0	0.1	0.2	0.2
Adjustment factors (assumptions see text)				
Area of Kyoto forest planted between 1990 and 2007 ± 15%	-16.5	0.0	16.5	0.0
Kyoto forest growth rates	-11.0	0.0	15.2	0.0
Ineligible afforestation	-17.5	-13.2	-8.8	–14.6
Soil carbon change with afforestation	-11.1	-6.6	0.0	–2.9
Mean removals estimated through Monte Carlo simulation	**70.2**	**92.3**	**115.4**	**84.1**
Emissions from deforestation[1,2,3]	-24.2	-7.3	-7.3	-16.9[4]
Removals less deforestation emissions	**46.0**	**85.0**	**108.1**	**67.2**

Notes:

1. The deforestation rates were based on the latest Deforestation Intentions survey results. The **most likely** and **lower emissions** scenarios have estimated deforestation emissions of -7.3 Mt CO_2. This is based on the "Current ETS policy" scenario with 13,000 hectares of deforestation in CP1. The **upper emissions** scenario is based on intended deforestation without an ETS and results in 34,000 hectares in CP1 (-24.2 Mt CO_2).
2. It has been assumed that all forest carbon is instantly emitted upon the deforestation activity taking place.
3. All scenarios include the deforestation of 6,000 hectares of post-1989 planted forest with emissions estimated at approximately 280 t CO_2 /ha (assuming an average age of 12 years).
4. The 2008 projections assumed all deforestation was pre-1990 planted forests and resulted in emissions of approximately 800 t CO_2/ha (28 years old trees). The most likely scenario did not assume all carbon was instantly emitted. Instead, it is assumed that harvesting residues left on site decayed over a 10 year period.
5. The signs for emissions are negative (-) and for **removals positive** (+)

4.2.5 Data limitations

There are acknowledged limitations in the data used in the LULUCF sector projections due to information gaps and scientific uncertainty. MfE commenced the implementation of LUCAS in 2005. LUCAS is being designed to provide more robust inventory data specifically for Kyoto carbon accounting purposes. This is a long-term and large-scale project that will not be fully operational until 2011. LUCAS uses a network of permanent plots across New Zealand's planted and natural forest. This permanent plot network along with national forest mapping has been designed to provide unbiased national estimates of carbon stocks and carbon stock change for New Zealand's forests.

Preliminary analysis of LUCAS sample plots in post-1989 planted forests was used in this report. LUCAS mapping products that will allow the estimation of post-1989 planted forest areas, and land use changes, are not currently complete. Until this information is available, other existing planted forest information such as the NEFD and the Land Cover Databases (LCDB's) will continue to be used for projecting CO_2 removals, even though these data sources were not designed for forest carbon accounting purposes and have known limitations.

The NEFD describes pre-1990 planted forests well (with ownership dominated by large-scale forest growers). NEFD information on plantation forests established by a large number of smaller-scale forest owners since 1992 is of poorer quality. Information on carbon stock changes in New Zealand's 6.5 million hectares of indigenous forest and 2.6 million hectares of shrubland remains scant (Ministry for the Environment, 2004).

4.2.6 Uncertainty analysis

A Monte Carlo analysis was carried out using @Risk software (Palisade Corporation), as in the 2008 projections. The ranges for afforestation factors in Table 17 were represented by triangular probability distributions, with the **upper emission** values set to the 97.5th percentile of the distribution and the **lower emissions** level set to the 2.5th percentile (except for future afforestation where the low value – associated with zero hectares of afforestation – was set as the distribution minimum). The uncertainty analysis used 10,000 iterations to derive the 95th percentile range for CO_2 removals of, which range from 70 to 115 Mt CO_2. Deforestation emissions were then deducted to give an uncertainty range of about 46 to 108 Mt CO_2 (Table C5).

4.2.7 Review of past projections

Since 2005, greenhouse gas projections have been subject to a number of reviews, the most comprehensive being two AEA Technology (United Kingdom) reviews (2005 and 2007). These reviews identified a number of improvements for producing future projections, most of which have been incorporated in the current report. The overall finding of the review of the 2005 projections was that "the methodologies employed to project emissions and sinks across the different sectors [are] generally sound and reasonable in their approach". AEA Technology noted the uncertainties are inherent in all countries' approaches to projecting future greenhouse gas emissions, and that it is "not uncommon" for projections to change on re-analysis. The reviewers recognised that many of their recommendations built upon improvements already in train. AEA Technology's key conclusions for the LULUCF sector review were:

- *methodologies and input assumptions are reasonable and the resulting removal and emission projections are of a good standard*
- *a single document should be produced for any future projection estimates that provides a detailed basis and sources for all calculations*
- *four key issues will require further consideration to minimise uncertainty in future projections:*
    1. *reasons and drivers for the downward trend in new forest planting*
    2. *the areas of post-1989 forest planting at a national scale into existing shrublands that meet the Kyoto Protocol definition of forest*
    3. *estimation of areas deforested and drivers for this process*
    4. *time patterns of loss of carbon soil after afforestation*
- *the New Zealand Carbon Accounting System (now called Land Use and Carbon Analysis System) will provide valuable data in assessing removals and emissions for land use land-use change and forestry.*

Of the four key issues above issues 1 and 3 have been addressed. For Issue 1, a report examining the financial returns from forestry and its relationship to forestry planting rates has been published (Horgan, 2007). This report is available on MAF's website. In respect to Issue 3, deforestation intentions surveys have been undertaken yearly since 2005 (Manley, 2005, 2006, 2008 and 2009), examining major forest owners' deforestation intentions and determining where deforestation is taking place and why. The survey results have been incorporated in the present projections. The 2006 and 2007 deforestation intention survey reports are available on the MAF website.

Issues 2 and 4 are expected to be informed by data and analysis undertaken within the LUCAS programme, though obtaining data for item 4 is very costly since changes are small and highly spatially variable. For further details on LUCAS see http://www.mfe.govt.nz/issues/climate/lucas/.

4.2.8 Summary of changes in the modelling approach used for the 2009 projections

During 2007 and 2008 forest inventory plots have been measured across the post-1989 planted forest estate. This is the first time this national forest inventory data has been available. In order to use this new data a revised approach used to forecast emissions and removals in this 2009 Net Position Report.

Previous approach: Simulation

Up until this year projected removals were calculated using a spreadsheet simulation model of the post-1989 planted forest estate. This previous approach used a carbon yield table derived from the National Exotic Forest Description (NEFD) yield tables. This national carbon yield table provides carbon stock estimates by age on a per hectare basis for the four forest biomass pools. All forest areas planted in the same year were modelled as a single forest area for that planting year. The model tracked these planted areas through time and generated annual estimates of carbon stock by multiplying the area at a given age by the carbon yields per hectare for that age. This approach is the same as that employed by routinely-used forest estate planning simulators, such as the Interactive Forest Simulator (IFS) (FRI, 1995, García 1981).

For each Net Position Report, the national average carbon yield table created for the most recent UNFCCC national planted forest carbon inventory has been used (Wakelin, 2008). In previous Net Position Reports, this national average carbon yield table was used to calculate both removals from existing planted forest and future afforestation, as well as emissions from all deforestation.

Revised approach

The modelling approach described above was still used to calculate removals associated with *future* afforestation. The only difference was that a specific post-1989 yield table was derived from the LUCAS plot data for this purpose. This yield table was also used to model deforestation of post-1989 planted forests. The latest NEFD-based national average carbon yield table used in the 2007 UNFCCC planted forest inventory (Wakelin 2008) was only used to model deforestation occurring in the pre-1990 planted forest.

Removals associated with the *existing* post-1989 planted forest as at January 2008 were not estimated using the previous simulation approach. Instead, these removals were calculated directly using the LUCAS plot data, total forest area and the LUCAS methodology described in more detail in the next section (LUCAS method).

There was no change in the way soil carbon changes were modelled.

Table 18 summarises the methods used for each contributing factor in the projections.

Table 18: Summary of the 2009 and previous modelling approaches and source of yield tables

Contributing factor	Previous approach		Revised approach	
	Methodology	Yield table	Methodology	Yield table
Post-1989 planted forests CO_2 removals	Simulation	NEFD-based national average	LUCAS method	Not required
Future afforestation removals	Simulation	NEFD-based national average	Simulation	Derived from LUCAS plots
Area of Kyoto forest planted between 1990 and 2007 ± 15%	Simulation	NEFD-based national average	LUCAS method	Not required
Kyoto forest growth rate – lower emissions	Simulation	300 Index model	LUCAS method with no future thinning	Not required
Kyoto forest growth rate – upper emissions	Simulation	NEFD-based national avg. minus 10%	LUCAS method minus 10%	Not required
Ineligible afforestation	Simulation	NEFD-based national average	LUCAS method	Not required
Soil carbon change with afforestation	Simulation	Soil carbon estimates	Simulation	Soil carbon estimates
Emissions from deforestation: Pre-1990 planted forests	Simulation	NEFD-based national average	Simulation	NEFD-based national average
Emissions from deforestation: Post-1989 planted forests	Not modelled[1]	Not required	Simulation	Derived from LUCAS plots

Notes:

1. In previous Net Position Reports, there was no information on the area of pre-1990 and post-1989 planted forest forecast to be deforested.

5 References

Austin D, Cao K, Rys G. (2006). Modelling Nitrogen Fertiliser Demand in New Zealand. Paper presented at the New Zealand Agricultural and Resource Economics Society conference, Nelson.

Beets PN, Robertson KA, Ford-Robertson JB, Gordon J, and Maclaren JP. (1999). Description and validation of C change: a model for simulating carbon content in managed Pinus radiata stands. New Zealand Journal of Forestry Science 29(3): pp. 409-427.

Cairns I, Livesey C and Twaddle D. (2008). Forestry Mitigation Response and Cost Curves. Internal report. Ministry for the Environment.

Clark H, Brookes I, Walcroft A. (2003). Enteric Methane Emissions for New Zealand Ruminants 1990–2001 Calculated Using an IPCC Tier Two Approach. Report prepared for the Ministry of Agriculture and Forestry by AgResearch Ltd.

Clough, T.J., Kelliher, F.M., Clark, H. and van der Weerden, T.J. (2008). Incorporation of the Nitrification Inhibitor DCD into New Zealand's 2009 National Inventory. Prepared for Ministry of Agriculture and Forestry, PO Box 2526, Wellington.

Eyre J. (1995). Predicting and Measuring New Planting from Nursery Surveys. New Zealand Journal of Forestry, August 1995, pp 45–46.

FRI (Forest Research Institute). (1995). IFS/FOLPI Database and Utilities, Interactive Forest Simulator Manual. FRI Software Series No 19.

García O. (1981). IFS, an Interactive Forest Simulator for Long Range Planning. New Zealand Journal of Forestry Science 11: 8–22.

Horgan G. (2007). Financial Returns and Forestry Planting Rates. Ministry of Agriculture and Forestry report.

Intergovernmental Panel on Climate Change (IPCC). (1997). *Revised 1996 IPCC Guidelines for National Greenhouse Inventories*. Houghton J.T., Meira Filho L.G., Lim B., Treanton K., Mamaty I., Bonduki Y., Griggs D.J. and Callander B.A. (Eds). IPCC/OECD/IEA, Paris, France.

Intergovernmental Panel on Climate Change (IPCC). (2000). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Penman J., Kruger D., Galbally I., Hiraishi T., Nyenzi B., Emmanuel S., Buendia L., Hoppaus R., Martinsen T., Meijer J., Miwa K., and Tanabe K. (Eds). IPCC/OECD/IEA/IGES, Hayama, Japan.

Intergovernmental Panel on Climate Change (IPCC). (2003). Good Practice Guidance for Land Use, Land Use Change and Forestry. Penman J., Gytarsky, M. Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. and Wagner, F. (Eds). IPCC/OECD/IEA/IGES, Hayama, Japan.

Kimberley, MO, West, GG Dean, MG, Knowles, LR. (2005). The 300 Index - a volume productivity index for radiata pine. New Zealand Journal of Forestry 50(2) 13-18.

Kirschbaum M, Trotter C, Wakelin S, Baisden T, Curtin D, Dymond J, Ghani A, Jones H, Deurer M, Arnold G, Beets P, Davis M, Hedley C, Peltzer D, Ross C, Schipper L, Sutherland A, Wang H, Beare M, Clothier B, Mason N and Ward M. (2009). Carbon stocks and changes in New Zealand's soils and forests, and implications of post-2012 accounting options for land-based emissions offsets and mitigation opportunities. Unpublished contract report prepared for the Ministry of Agriculture and Forestry.

Manley B, Somerville O, Turbitt M and Lane P. (2003). Review of new forest planting estimates. New Zealand Journal of Forestry 43 (3).

Manley B. (2005). 2005 Deforestation Survey. Canterprise, University of Canterbury.

Manley B. (2006). 2006 Deforestation Survey. Canterprise, University of Canterbury.

Manley B. (2008). 2007 Deforestation Survey. Canterprise, University of Canterbury.

Manley B. (2009). 2008 Deforestation Survey. Canterprise, University of Canterbury.

Ministry for the Environment (1999). International Review of New Zealand's Carbon Monitoring Project, ME 340, Wellington.

Ministry for the Environment (2009a). Net Position Report 2009: Projected balance of emissions units during the first commitment period of the Kyoto Protocol. http://www.mfe.govt.nz/publications/climate/net-position-report-2009/index.html

Ministry for the Environment (2009b). New Zealand's Greenhouse Gas Inventory 1990–2007. http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2009/index.html

Ministry of Forestry, 1996. National Exotic Forest Description Regional Yield Tables as at 1 April 1995. Edition 2. Ministry of Forestry, Wellington.

Ministry of Agriculture and Forestry (2008). A National Exotic Forest Description as at 1 April 2007.

Paul T, Andersen C, Kimberley M and Goulding C. (2009). Analysis of the 2007-2008 Planted forest Carbon Monitoring System Inventory data of post-1989 forests. Scion. Unpublished contract report prepared for the Ministry for the Environment.

Scott, NA, Tate KR, Giltrap DJ, Tattershall Smith C, Wilde RH, Newsome PFJ and Davis MR. (2002). Monitoring land-use change effects on soil carbon in New Zealand: quantifying baseline soil carbon stocks, Environmental Pollution, 116, S167-S186.

Sherlock, R, Jewell, P., and Clough, T. (2008). Review of the New Zealand Specific $Frac_{gasm}$ and $Frac_{gasf}$ Emission Factors. Prepared for Ministry of Agriculture and Forestry, PO Box 2526, Wellington.

Stephens P, Heke H, Sutherland A, Sheperd S and Pinkney T. (2001). Estimating Clearance of Indigenous Forest and Scrubland between 1898/90 and 1996/97. Landcare Research. Unpublished contract report prepared for the Ministry of Agriculture and Forestry.

Tate, KR, Wilde RH, Giltrap DJ, Baisden WT, Saggar S, Trustrum NA, Scott NA and Barton JP. (2005). Soil organic carbon stocks and flows in New Zealand: system development, measurement and modelling, Canadian Journal of Soil Science, 85, 481-491.

United Nations Framework Convention on Climate Change (UNFCCC) (2006). Updated UNFCCC reporting guidelines on annual inventories following incorporation of the provisions of decision 14/CP.11. 93 p.

Wakelin S. (2008). Carbon Inventory of New Zealand’s Planted Forests – Calculations revised in October 2008 for New Zealand’s 2007 Greenhouse Gas Inventory. Scion. Unpublished contract report prepared for the Ministry of Agriculture and Forestry.