Ministry for the Environment
Manatū Mō Te Taiao

Land Use, Land-use Change and Forestry Sector

Greenhouse Gas Emission Projections for the First Commitment Period of the Kyoto Protocol from LULUCF Activities under Article 3.3

Results, Data and Methodology

2012 Report

New Zealand Government

This report may be cited as:
Ministry for the Environment. 2012. *Land Use, Land-use Change and Forestry Sector Greenhouse Gas Emission Projections for the First Commitment Period of the Kyoto Protocol from LULUCF Activities under Article 3.3: Results, Data and Methodology*. Wellington: Ministry for the Environment.

Published in April 2012 by the
Ministry for the Environment
Manatū Mō Te Taiao
PO Box 10362, Wellington 6143, New Zealand

ISBN: 978-0-478-37280-9 (electronic)

Publication number: ME 1091

This document is available on the Ministry for the Environment's website:
www.mfe.govt.nz

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Introduction

This report provides projections of carbon dioxide equivalent gas removals and emissions from New Zealand's Land Use, Land-use Change and Forestry (LULUCF) sector under Article 3.3 of the Kyoto Protocol (figure 1). The projections include post-1989 afforestation, reforestation and deforestation activities, and pre-1990 planted forest and natural forest[1] deforestation.

The projections cover the first commitment period (CP1) of the Kyoto Protocol (2008–2012).

Net removals by the LULUCF sector (that is, removals by post-1989 forests minus emissions from deforestation of all forest) for CP1 are projected to be between 58.5 and 102.0 million tonnes of carbon dioxide equivalent. Net removals for the most likely scenario are projected to be 85.8 million tonnes, 3.0 million tonnes higher than the 2011 most likely scenario projection of 82.8 million tonnes (a 3.7 per cent increase).

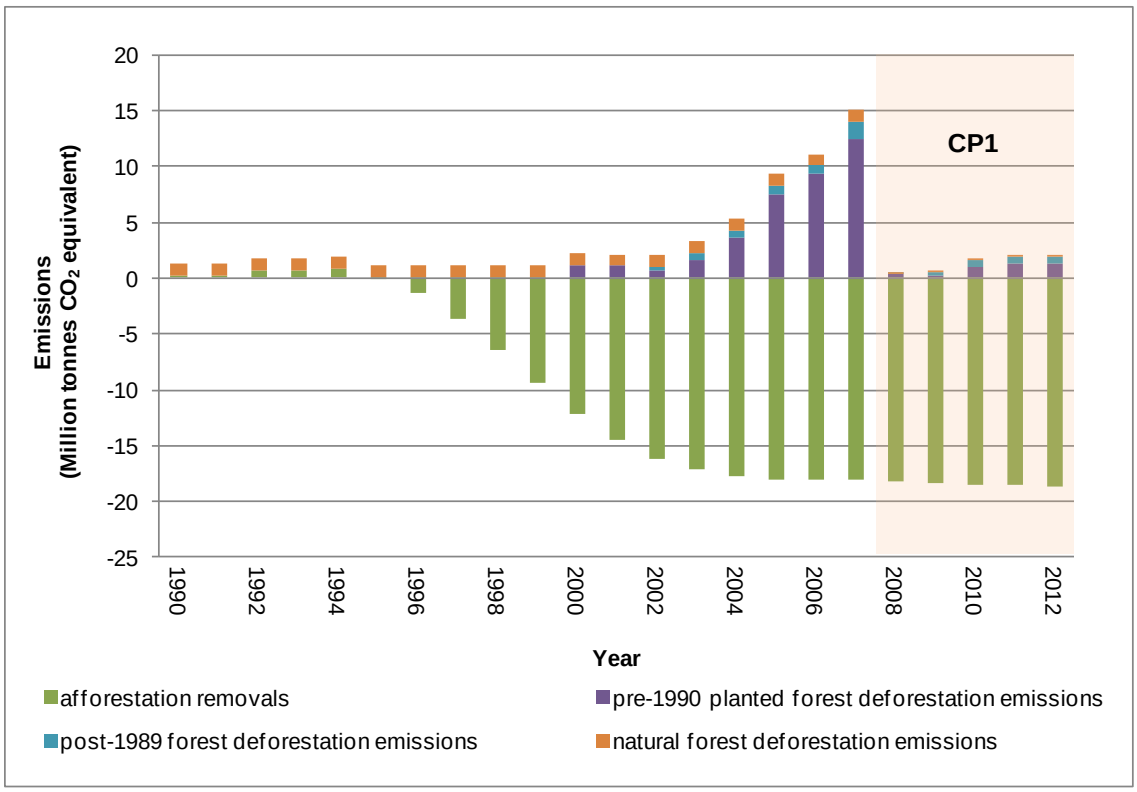
This increase is due to a new yield table for post-1989 forests, a new approach for estimating the change in soil carbon stock associated with land-use change, and new estimates of deforestation from mapping of land-use change by the Land Use and Carbon Analysis System (LUCAS) completed for 2008, 2009 and 2010.

The uncertainty in this estimate is mainly due to gaps in information about future activities and scientific knowledge. Uncertainty has been incorporated into the LULUCF projections through the use of scenarios that represent maximum, most likely, and minimum emissions (termed **'upper emissions'**, **'most likely'**, and **'lower emissions'**). Measurement error and uncertainty about the accuracy of these estimates are expected to be further reduced over the next few years as information from the LUCAS programme is gathered.

However, until the LUCAS forest plots are all measured and the forests have been mapped at the end of the commitment period, the LULUCF projections are likely to remain the least certain of all sectors in the Net Position report.

[1] Natural forest ecosystems comprise a range of indigenous and some naturalised exotic species.

Figure 1: Emissions from the LULUCF sector under Article 3.3 of the Kyoto Protocol (million tonnes carbon dioxide equivalent)



Notes: The signs for removals are negative (-) and for emissions positive (+).

Emissions and removals estimates for 1990 to 2010 are based on LUCAS data. Estimates for 2011 and 2012 are based on planted forest deforestation projections from the Deforestation Intentions Survey (Manley, 2012), forecast future afforestation, and estimates of natural forest deforestation based on historical trends.

The increase in emissions resulting from deforestation before 2008 can be largely attributed to the anticipation that government climate policies would require forest land owners to pay for deforestation emissions from the start of 2008.

Background

This report provides projections of carbon dioxide equivalent removals and emissions from New Zealand's Land Use, Land-use Change and Forestry (LULUCF) sector under Article 3.3 of the Kyoto Protocol for the period 2008 to 2012. The projections cover land subject to Article 3.3 of the Kyoto Protocol, that is, afforestation, reforestation and deforestation[2] activities occurring since 1990. For the first commitment period (CP1) New Zealand elected not to account for Article 3.4 of the Kyoto Protocol, which covers additional LULUCF activities (eg, forest management of pre-1990 planted forests and natural forests).

Three key factors are used to estimate these projections:

- estimated (1990–2010) and forecast (2011–2012) area of post-1989 forest
- estimated (1990–2010) and forecast (2011–2012) area of deforestation of post-1989 forest, pre-1990 planted forest, and natural forests
- biomass and soil carbon stock changes following afforestation and deforestation.

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

A key aspect of this report is the inclusion of new data generated for the Land Use and Carbon Analysis System (LUCAS). Data collection as part of the LUCAS programme will be carried out for the duration of CP1, therefore, the projections are based on the best information available as at January 2012. LUCAS data used in this report includes the area of afforestation of post-1989 forest, area of deforestation, and estimates of biomass and soil carbon.

A more detailed explanation of the LUCAS data used is reported in the LULUCF and Kyoto Protocol chapters of the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

Land-use change 1990–2010

Estimates of afforestation and deforestation areas from 1990 to 2010 are based upon:

- afforestation from 1990 to 2010, estimated based on the LUCAS mapped area of post-1989 forest and the National Exotic Forest Description (NEFD) as at 1 April 2010 (Ministry of Agriculture and Forestry, 2011).
- mapped deforestation from 1990 to 2010 based on the LUCAS mapped area with information on the age profile of deforested forests from the 2008 Deforestation Survey (Manley, 2009) and unpublished work by Scion.

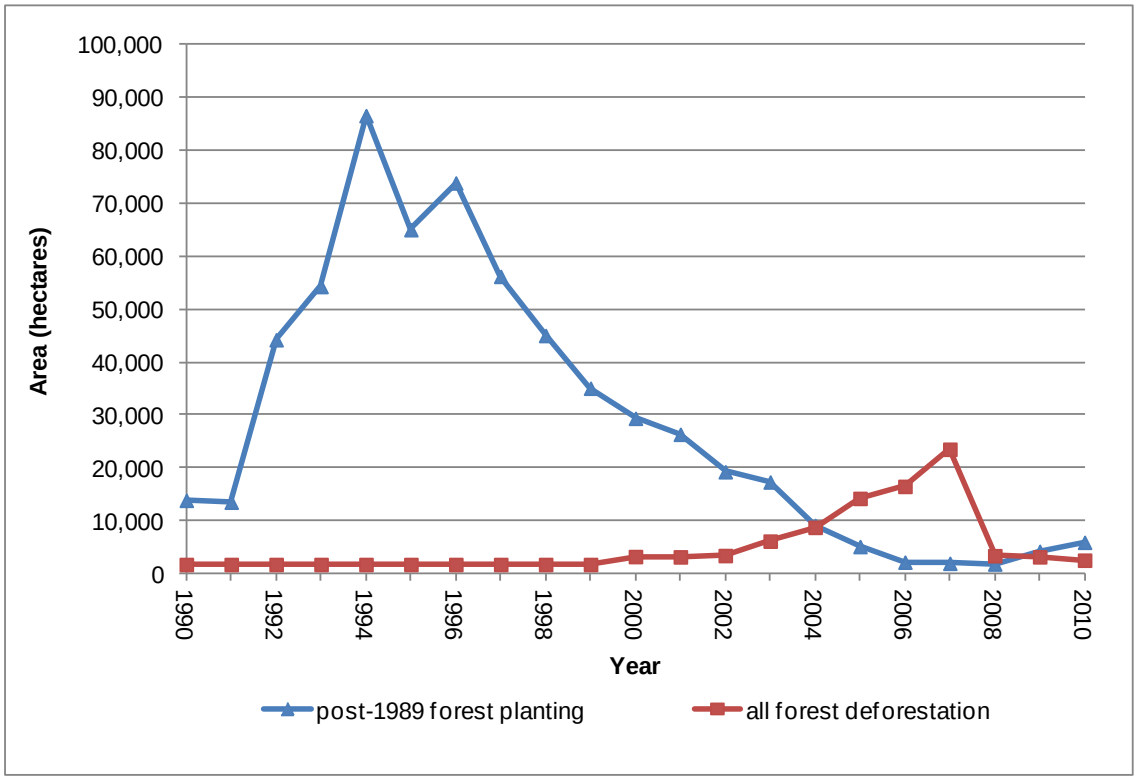
From these sources it is estimated there are approximately 593,821 hectares of post-1989 forest remaining in 2010. The planting profile, based on forestry statistics (Ministry of Agriculture and Forestry, 2010), indicates that planting of post-1989 forest peaked at 86,000 hectares during 1994 and declined until 2008 (figure 2).

[2] Emissions from deforestation of all forest types are included under Article 3.3 of the Kyoto Protocol.

Since 2008, the area of post-1989 forest has been increasing. This increase is largely attributable to the Afforestation Grants Scheme. It is estimated 1,900 hectares of new post-1989 forest was planted in 2008, with a further 4,300 hectares planted in 2009, and 6,000 hectares planted in 2010.

An estimated 106,906 hectares of all forest types[3] in New Zealand was deforested between 1990 and 2010, with deforestation peaking in 2007 at an estimated 23,560 hectares. The majority (72 per cent) of this deforestation being pre-1990 planted forest. Better returns from alternative land uses are the main driver for the conversion of planted forest land to other land uses. Deforestation before 2008 was also impacted by the anticipation that government climate policies would require forest land owners to pay for deforestation emissions from the start of 2008. Since then, total deforestation has decreased to an estimated 2,616 hectares in 2010 (figure 2).

Figure 2: Estimated post-1989 forest planting and all forest deforestation for the LULUCF sector for the period 1990–2010 (hectares)



Source: Ministry for the Environment, 2012.

Deforestation between 2008 and 2010 has been mapped by LUCAS. A combination of data sources were used to identify the location and timing of deforestation after 1 January 2008.

At the end of 2010, high resolution imagery (10m) was acquired for the four areas identified as those most actively undergoing land-use change. Where destocking was detected these areas were flown with a light aircraft and aerial photos taken to help identify if the destocking was associated with deforestation or harvesting. Areas of deforestation reported under the New Zealand Emissions Trading Scheme (ETS) were also used as evidence of land-use change. An estimate of the area of 2010 deforestation for the least active areas was made based on the

[3] Includes all forest: post-1989 forest, pre-1990 planted forest, and natural forest.

proportions found in each region from the 2008–2009 deforestation mapping exercise which was carried out across the whole of New Zealand. During 2012 the less active areas of New Zealand will be mapped using the same process as carried out during 2010.

Areas of unstocked forest which were unable to be distinguished as either harvested or deforested were flagged for tracking for four years from the date of clearing. If those areas are not replanted within four years they will be deemed to be deforested at the date of forest clearing.[4]

Analysis of land-use change has estimated that from 1990 to 2010 the majority of the area converted to post-1989 forest (afforestation) was from grassland (99 per cent). Also, most of the deforested areas of both post-1989 and pre-1990 planted forest were converted to grassland subcategories (98 per cent).

Carbon density estimates

The yield tables and carbon stock values used in the 2012 projections were developed for the 2010 Greenhouse Gas Inventory[5] (Ministry for the Environment, 2012). They are described in this section.

The **post-1989 forest** carbon yield table was calculated from LUCAS field inventory data and airborne laser scanning (Light Detection and Ranging – LiDAR) measurements. This yield table was used to estimate removals of existing post-1989 forest and future afforestation, and emissions from post-1989 forest deforestation.

Unless the actual age of deforestation is known, areas of post-1989 forest deforested are attributed the carbon value of the area weighted average age of the forest estate for each year (for example, the carbon value from the yield table at the estate average age of 13 is used for 2008 deforestation).

Carbon stocks were estimated from the plot data using the Forest Carbon Predictor (version 3) (Beets and Kimberley, 2011). Regression models were developed with LiDAR metrics providing good predictions of forest carbon (tonnes of carbon per hectare) at the plot scale. Post-1989 forest yield tables based on ground data were adjusted in a standard double-sampling routine using the LiDAR regression to increase the precision of the carbon estimate (Stephens et al, 2012).

The **pre-1990 planted forests** carbon yield table is derived from a national plot based inventory system using the Forest Carbon Predictor (version 3) in a similar manner to the post-1989 forests. This yield table was used to estimate emissions from pre-1990 planted forest deforestation. Unless the actual age of the deforested area is known, deforestation of pre-1990 planted forest is assumed to occur at age 28, the average age of pre-1990 planted forest harvesting (Ministry of Agriculture and Forestry, 2011).

Natural forest deforestation emissions were based on the analysis of the first full round of measurements of natural forest LUCAS plots (Beets et al, 2009). The analysis of the LUCAS

[4] Section 4.2.3.2, IPCC Good Practice Guidance for LULUCF, IPCC, 2003

[5] For more information see http://www.mfe.govt.nz/publications/climate/new-zealand-greenhouse-gas-inventory/index.html.

land-use maps and Ecosat vegetation maps have estimated that approximately 88 per cent of natural forest deforestation occurs in immature natural forest (regenerating areas that meet the forest definition) with the remaining 12 per cent being in mature natural forest.

Soil organic carbon stock estimates used to estimate changes in soil carbon following afforestation and deforestation were based on Tier 1 IPCC defaults as used in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012). Estimation of change in soil carbon with change in land use is calculated based on the differences in equilibrium soil carbon values between the initial and final land use, with the change occurring in a linear manner over a 20 year period (IPCC default; IPCC, 2003). The change in carbon is then multiplied by the area of land-use change mapped.

Modelling process

As with the LULUCF section of the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012), the LUCAS Calculation and Reporting Application (CRA) has been used to determine projected emissions and removals for afforestation and deforestation, for Article 3.3 of the Kyoto Protocol. For estimating carbon stocks and change for post-1989 forest, the CRA uses a growth simulation method as used in previous net position reports. The CRA tracks post-1989 forest areas through time and generates annual estimates of carbon stock by multiplying the area at a given age by the carbon yields per hectare for that age.

Policy assumptions

Emissions Trading Scheme

These projections incorporate the impacts of the Climate Change Response (Moderated Emissions Trading) Amendment Act enacted on 7 December 2009. Forestry became the first sector to enter the scheme with obligations and entitlements applying retrospectively from 1 January 2008. The Kyoto Protocol creates a distinction between forests established before and after 1 January 1990 and the ETS maintains that distinction, and therefore includes different rules for 'pre-1990 forest' and 'post-1989 forest'.

In summary, the main outcomes of the legislation on New Zealand forestry are:

- Owners of post-1989 forest land (or those with a registered interest in the forest on the land) may voluntarily become Participants in the ETS, and in doing so are entitled to receive New Zealand Units for the increase in carbon stocks in their forests from 1 January 2008. The owners of post-1989 forest will have to surrender units if the carbon stocks in their registered forest area fall below a previously reported level (for example, due to harvesting or fire). However, surrender liabilities for specified areas of land are capped at the amount of units previously received by the Participant for those areas
- The Crown is in the process of transferring approximately 19 million New Zealand Units in CP1 to owners of pre-1990 planted forests. The allocation to eligible pre-1990 forest owners is in recognition of the potential loss in value of their land as a result of the introduction of the ETS
- Eligible pre-1990 forest landowners may also apply for an exemption. The 50 hectares and tree weed exemptions are available to land owners to exempt pre-1990 forest land from the ETS. The exemption applies to the land, and means that the land use can be changed at any time without generating liabilities under the ETS. Non-exempt owners of pre-1990 planted forest who deforest more than 2 hectares per commitment period will be required to surrender New Zealand or Kyoto Units to cover deforestation emissions.

These projections exclude any future changes to legislation that may result from the 2011 review of the ETS (Emissions Trading Scheme Review Panel, 2011). Any changes to forestry legislation resulting from the review will be included in subsequent projections.

Afforestation schemes

The afforestation scenarios include new planting under the government afforestation schemes established to encourage new planting. These schemes are briefly described below:

The Afforestation Grants Scheme (AGS) is a contestable fund set up to encourage the establishment of new forests. It is part of the Government's package of climate change initiatives and offers an alternative to the Emissions Trading Scheme (Forestry) as a way to encourage greater levels of greenhouse gas absorption by increasing the area of Kyoto-compliant new forest in New Zealand.

The AGS began in 2008/09 and operates through a tendered public grant pool and a fixed regional grant pool, with funding ending in 2012/13. Some 3,247 hectares were planted in the first two years of operation, and a further 9,255 hectares have been, or are expected to be, approved for planting in 2010/11, 2011/12 and 2012/13.

The Permanent Forest Sink Initiative (PFSI) promotes the establishment of permanent forests on previously non-forest land. It offers land owners of permanent forests established after 1 January 1990 the opportunity to earn Kyoto Protocol compliant emission units (Assigned Amount Units) for the carbon sequestered by their forests since 1 January 2008. As of February 2012, 41 PFSI covenants covering 10,758 hectares were registered.

The East Coast Forestry Project (ECFP) was established because the Government considered it important to address the wide-scale erosion problem in the Gisborne district. Since 1992, MAF has provided funding to landholders to prevent and control erosion. The ECFP grant can be used to control erosion on the worst eroding or erosion-prone land in the district. By July 2011 around 35,550 hectares had been established in erosion control treatments and a further 5,745 hectares approved for establishment over the next few years.

Projected emissions and removals

Sector summary

Net removals from the LULUCF sector under Article 3.3 of the Kyoto Protocol are projected to be between 58.5 and 102.0 million tonnes of carbon dioxide equivalent gas (CO_2-e). This range is based on the upper and lower emission scenarios respectively. Net removals for the **most likely** scenario are projected to be 85.8 million tonnes CO_2-e (table 1). This is an increase of around 3.0 million tonnes over CP1 compared with the 2011 projection of 82.8 million tonnes (3.7 per cent increase).

Table 1 provides a breakdown of the major contributing factors on which the removals and emissions projections are based. The calculation of removals and emissions depends on several key factors and uncertainty around those factors. These are described in the following sections.

Table 1: Projected removals and emissions from the LULUCF sector under Article 3.3 of the Kyoto Protocol (million tonnes carbon dioxide equivalent) during CP1 (2008–2012)

Contributing factor		2012 projections			2011 projections
		Upper emissions scenario	Most likely scenario	Lower emissions scenario	Most likely scenario
Afforestation removals ($Mt\ CO_2$)	Estimated post-1989 forest (1990 to 2010)	-73.9	-92.7	-110.6	-89.6
	Future afforestation (2011 and 2012)	-0.01	0.5	1.2	0.3
	Total afforestation	-73.9	-92.2	-109.4	-89.3
Deforestation emissions ($Mt\ CO_2$)	Post-1989 forest	5.2	1.6	1.8	2.3
	Pre-1990 planted forest	9.7	4.6	5.4	4.0
	Natural forest	0.4	0.3	0.2	0.2
	Total deforestation	15.4	6.4	7.5	6.6
Net removals (removals less deforestation emissions) ($Mt\ CO_2$)		**-58.5**	**-85.8**	**-102.0**	**-82.8**

Notes: Deforestation emissions include biomass emissions from the deforestation event, biomass removals of the land use after deforestation, and soil carbon change with deforestation.

Afforestation includes the biomass emissions of the land use before afforestation, soil carbon change, and growth of new forest.

All forest biomass carbon is emitted instantaneously in the year of a deforestation activity taking place. However, soil carbon changes associated with deforestation are estimated to occur over a 20 year period, the IPCC default (IPCC, 2003).

The 2012 projections assume an age of deforestation for post-1989 forest using the area weighted average age of the post-1989 forest estate in each year unless the actual age of the deforested area is known (for example, the carbon value from the yield table at the average age of 13 is used for 2008 deforestation).

The 2012 projections assume deforestation of pre-1990 forest at age 28 throughout CP1, unless the actual age of the deforested area is known.

Totals may not add due to rounding.

Post-1989 forest area

Incorporation of data from the New Zealand ETS and Pre-1990 Forest Land Allocation Plan has decreased the estimated gross[6] post-1989 forest area by approximately 1,856 hectares compared to the 2011 projections. The post-1989 forest area established between 1990 and 2007 is now estimated to be 598,949 hectares. A further 12,200 hectares of post-1989 forest are estimated to be planted between 2008 and 2010 based on statistics from the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2011). Afforestation under the most likely scenario is projected to be 24,000 hectares from 2011 to 2012, resulting in a total estimated post-1989 forest planting from 1990 to 2012 of 635,149 hectares.

Based on the mapping methodology described in Dymond et al, (2008), LUCAS estimated the accuracy of the post-1989 forest area from 1990 to 2007 was within ± 7 per cent. This uncertainty range is used for the upper and lower scenarios in these projections for the post-1989 forest area between 1990 and 2007. The 2009 National Exotic Forest Description (NEFD) uncertainty factor of 5 per cent was applied to the lower and upper scenarios for the 2008 to 2010 afforestation rates.

Table 2 shows the post-1989 forest planting rates used in the 2012 Net Position projections.

The **upper emissions scenario** is based on:

- 7 per cent reduction in the area of post-1989 forest from 1990 to 2007 based on LUCAS mapping accuracy
- a decrease in the area of post-1989 forest of 5 per cent between 2008 and 2010 based on the confidence limits in the estimates of the NEFD
- the NEFD provisional planting estimate for post-1989 forest planting in 2011of 12,000 hectares
- forecast low levels of afforestation for 2012.

The **most likely scenario** is based on:

- the area of post-1989 forest for 1990 to 2007 from LUCAS
- the area of post-1989 forest for 2008, 2009 and 2010 as reported in the NEFD
- the NEFD provisional planting estimate for post-1989 forest planting in 2011 of 12,000 hectares
- A similar rate continuing for 2012.

The **lower emissions scenario** is based on:

- 7 per cent increase in the area of post-1989 forest from 1990 to 2007 based on the LUCAS mapping accuracy
- An increase in the area of post-1989 forest of 5 per cent between 2008 and 2010 based on the confidence limits in the estimates from the NEFD
- Similar levels of afforestation rates to the most likely scenario.

[6] The gross estimate of post-1989 forest area includes all post-1989 forest planting since 1990 and excludes the reduction in post-1989 forest area due to deforestation.

Table 2: Post-1989 forest planting since 1990 and future afforestation (hectares)

Period	2012 projections			2011 projections
	Upper emissions	Most likely	Lower emissions	Most likely
1990–2007	557,022	598,949	640,875	600,805
2008	1,805	1,900	1,995	1,900
2009	4,085	4,300	4,515	4,000
2010	5,700	6,000	6,300	6,000
2011	12,000	12,000	12,000	8,000
2012	6,000	12,000	13,000	10,000
Total	586,612	635,149	678,685	630,705

Notes: Table 2 only refers to new planting of post-1989 forest and therefore excludes the reduction in the post-1989 forest area due to deforestation.

The calendar year 2007 refers to the LUCAS land-use mapping as at 1 January 2008.

1990–2010 estimates for afforestation given the most likely scenario are as reported in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

The 2011 projections used the provisional NEFD afforestation for 2009, which has been updated with the final estimate in these projections.

The 2012 projections use the provisional NEFD afforestation for 2010, as in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

Totals may not add due to rounding.

The area of post-1989 planted forest afforestation estimated for 2011 and 2012 is 12,000 hectares for each year. This is an increase of 6,000 hectares over that estimated for 2010. Gross removals from future afforestation have limited impact in CP1, as young trees sequester only a small amount of carbon for the first few years following establishment. There is also a loss of carbon following forest establishment as the previous vegetation cover is lost before planting and there are changes in soil carbon associated with the land-use change. The impact of the removals from these forests will increase over time and have a more tangible impact in the future.

Previous land-use areas and carbon stock values before afforestation were based on the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012) with the same proportions as seen between 2008 and 2010 assumed to occur through the remainder of the CP1 (table 3).

Table 3: Percentage of previous land use before afforestation used through CP1 and the related carbon stock (t C ha^{-1})

Land-use subcategory	Per cent of land use before afforestation through CP1	Carbon stock used to calculate emissions
Grassland with woody biomass	14	29.0
Grassland – high producing	20	6.8
Grassland – low producing	65	3.1
Other land	1	0.0

Source: Ministry for the Environment, 2012.

Post-1989 forest carbon

Post-1989 forest growth rates for the **most likely** scenario were based on the LUCAS carbon yield table as used in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012). The **lower emissions** and **upper emissions** scenarios were defined by ± 10.2 per cent change in carbon stock, based on the uncertainty estimates in biomass accumulation rates.

The incorporation of a new carbon yield table for post-1989 forests in this year's report has caused the greatest change in removals from those reported in the 2011 Net Position report. While the total volume in the yield table used for the 2012 report is lower, the trajectory of the new yield table is steeper for the older aged forests (the annual growth is greater). This coincides with a large area planted in the mid-1990s. This results in a greater change in post-1989 forest carbon stocks over the CP1 than was previously reported.

Soil carbon

Soil carbon values used in this report are based on IPCC defaults as given in Good Practice Guidance for LULUCF. These are the values used in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012). This is a change from last year's projections where estimates from the LUCAS Soil Carbon Monitoring System were used. This change is because improvements to make the LUCAS Soil Carbon Monitoring System acceptable to international reviewers are still ongoing.

Table 4 presents the equilibrium soil carbon stock estimates for each land-use subcategory. These are the soil carbon stocks under a constant land use. A change in land use generates a change in soil carbon stocks, and estimation of that change is calculated based on the differences in equilibrium soil carbon values for the respective land uses. It is assumed that the change in soil carbon stocks occurs in a linear fashion over a 20-year period (this is an IPCC default; IPCC, 2003). These are the values used for the **most likely** scenario.

Table 4: New Zealand's steady state soil carbon stock densities by land-use subcategories

Land-use class	Soil carbon stock density (t C ha^{-1})
Natural forest	92.59
Pre-90 planted forest	92.59
Post-89 planted forest	92.59
Grassland with woody biomass	92.59
High producing grassland	117.16
Low producing grassland	105.55
Perennial cropland	97.76
Annual cropland	59.82
Open water	0.00
Vegetated wetland	92.59
Settlements*	64.81
Other land	92.59

Source: Ministry for the Environment, 2012.

* The stock change factors for unimproved grassland with severe degradation were used in the absence of IPCC default stock change factors for settlements for this land use.

The **lower emissions** scenario uses the same stock values as the most likely scenario.

The **upper emissions** scenario uses the tier 2 methodology for estimating soil carbon stock density as used in the 2009 Greenhouse Gas Inventory (Ministry for the Environment, 2011).

Deforestation in post-1989 and pre-1990 planted forest

New Zealand assumes instant emissions of all biomass carbon at the time of deforestation, and soil carbon changes are modelled over a 20-year time period. This assumption is based on the majority of deforestation since 1990 being forest conversion to grassland, resulting in the rapid removal of all biomass as the land is prepared for farming. As such, only soil carbon changes associated with deforestation from 1990–2007 are accounted for within CP1.

All forest biomass carbon is emitted instantaneously in the year of a deforestation activity taking place.

The estimates of planted forest deforestation for 2008, 2009 and 2010 obtained through LUCAS mapping (Ministry for the Environment, 2012) have increased the projected area of deforestation compared to the estimates used in the 2011 projections (Table 5 and 6).

Deforestation projections for all plantation forests for 2011 and 2012 are sourced from a survey of forest owners undertaken between November and December 2011, which forecasts deforestation under three possible policy scenarios. The survey indicates that intentions for conversion of planted forest to other land uses in 2011 and 2012 are likely to be in the range of 5,000 to 14,000 hectares with around 80 per cent of the deforested land going into grassland for dairy farming (Manley, 2012). The split between pre-1990 planted forest and post-1989 forest deforestation was based on the proportion of these categories deforested between 2008 and 2010 in the LUCAS data.

For the 2012 projections, the **most likely** scenario is based on the LUCAS mapped estimates for deforestation for 2008 to 2010. The estimates of deforestation for 2011 and 2012 are based on the Deforestation Intentions Survey scenario "Emissions Trading Scheme legislation continues unchanged" (Manley, 2012).

The **upper emissions** scenario accounts for the uncertainty in the mapping of deforestation (the area of deforestation is increased by 7 per cent) for 1990 to 2008. The deforestation between 2008 and 2012 is based on the no Emissions Trading Scheme legislation scenario (this assumes the ETS is repealed and not replaced) (Manley, 2012).

The **lower emissions** scenario accounts for the uncertainly in the mapping (decrease of deforestation by 7 per cent) for 1990 to 2010, and assumes the same area of deforestation between 2008 and 2012 as the most likely scenario based on the fact that this covers area that has been confirmed as deforested and so is unlikely to have been underestimated.

Table 5: Estimated post-1989 forest deforestation since 1990 and future deforestation (hectares)

Calendar year	2012 Projections			2011 Projections
	Upper emissions	Most likely	Lower emissions	Most likely
1990–2007	15,391	14,384	13,378	14,384
2008	3,000	622	622	385
2009	3,000	1,101	1,101	734
2010	2,500	1,220	1,220	1,500
2011	3,500	1,500	1,500	1,750
2012	3,500	1,000	1,000	1,750
Total	30,891	19,827	18,820	20,503

Notes: The calendar year 2007 refers to the LUCAS land-use mapping as at 1 January 2008.

1990–2010 estimates for the most likely scenario are based on LUCAS land-use mapping, as reported in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

All forest biomass carbon is emitted instantaneously in the year of a deforestation activity taking place. As such, only soil carbon changes associated with deforestation from 1990–2007 are accounted for within CP1.

Totals may not add due to rounding.

Table 6: Estimated pre-1990 forest deforestation since 1990 (hectares)

Calendar year	2012 Projections			2011 Projections
	Upper emissions	Most likely	Lower emissions	Most likely
1990–2007	54,180	50,635	47,091	48,449
2008	3,000	1,926	1,926	552
2009	3,000	1,652	1,652	449
2010	2,500	1,157	1,157	1,500
2011	3,500	1,500	1,500	1,750
2012	3,500	1,000	1,000	1,750
Total	69,680	57,869	54,325	54,450

Notes: The calendar year 2007 refers to the LUCAS land-use mapping as at 1 January 2008.

1990–2010 estimates for the most likely scenario are based on LUCAS land-use mapping, as reported in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

All forest biomass carbon is emitted instantaneously in the year of a deforestation activity taking place. As such only soil carbon changes associated with deforestation from 1990–2007 are accounted for within CP1.

Totals may not add due to rounding.

Change in biomass carbon in the land use after deforestation have been included as part of the deforestation emissions. The land use after deforestation was based on LUCAS data, with the same proportions as seen between 2008 and 2010 assumed to occur through the remainder of the commitment period (Tables 7 and 8).

Table 7: Percentage of land use after post-1989 forest deforestation used through CP1 and carbon stock (t C ha^{-1})

Land-use subcategory	Per cent of land use after post-1989 forest deforestation through CP1	Biomass carbon stock used to calculate emissions (t C ha^{-1})
Grassland – high producing	10	6.8
Grassland – low producing	89	3.1
Other land	1	0

Source: Ministry for the Environment, 2012.

Table 8: Percentage of land use after pre-1990 planted forest deforestation used through CP1 and carbon stock (t C ha^{-1})

Land-use subcategory	Per cent of land use after pre-1990 planted forest deforestation through CP1	Biomass carbon stock used to calculate emissions (t C ha^{-1})
Grassland – high producing	14	6.8
Grassland – low producing	86	3.1
Other land	0.2	0

Source: Ministry for the Environment, 2012.

Note: Totals may not add due to rounding.

Deforestation in natural forests

Estimates of natural forest deforestation are based upon updated LUCAS mapping for 1990 to 2010. These estimates are slightly higher than the LUCAS estimates used in the 2011 projections, and have therefore increased the projected area of deforestation through CP1 (Table 9).

The LUCAS deforestation mapping estimates 919 hectares of natural forest was deforested during 2008, 506 hectares during 2009, and 204 hectares during 2010. The **most likely** scenario assumes the average deforestation between 2008 and 2010 will continue for the remainder of CP1 resulting in 2,757 hectares of total natural forest deforestation in CP1.

The **upper** emissions scenario is calculated using an adjustment to the area deforested based on the mapping uncertainty (±7 per cent).

The **lower** emissions scenario is calculated using an adjustment to the area deforested based on the mapping uncertainty (±7 per cent) for 1990 to 2007, actual areas of deforestation for 2008 to 2010, and the average area of deforestation from 2008 to 2010 continuing for the rest of the commitment period. Again the actual areas of deforestation are used for the lower emissions scenario as these are confirmed areas of deforestation.

For the 2011 projections, the natural forest deforestation area during CP1 was based on the annual average natural forest deforestation for 2008 and 2009 (498 ha/year), which resulted in a total of 2,491 hectares of natural forest deforestation during CP1.

Table 9: Estimated natural forest deforestation since 1990 (hectares)

Calendar year	2012 Projections			2011 Projections
	Upper emissions	Most likely	Lower emissions	Most likely
1990–2007	34,823	32,545	30,266	32,718
2008	983	919	919	535
2009	541	506	506	462
2010	257	240	240	498
2011	584	546	546	498
2012	584	546	546	498
Total	37,771	35,300	33,022	35,209

Notes: The calendar year 2007 refers to the LUCAS land-use mapping as at 1 January 2008.

1990 to 2010 estimates for the most likely scenario in the 2012 projections are based on LUCAS land use mapping as reported in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

All forest biomass carbon is emitted instantaneously in the year of a deforestation activity taking place. As such, only soil carbon changes associated with deforestation from 1990–2007 are accounted for within CP1.

Totals may not add due to rounding.

Along with the area of deforestation the **most likely** scenario uses the average carbon density for natural forest (179 t C ha^{-1}). This is calculated based on a weighted average carbon stock based on the relative proportions of regenerating natural forest (57.3 t C ha^{-1}) and mature natural forest (217.9 t C ha^{-1}) as used in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

The **upper** and **lower** emissions scenarios are calculated using an adjustment to the emission factor based on the calculated uncertainty in this figure (±3.6 per cent).

This is different to last year when the **upper emissions** scenario assumed that all of the natural forest deforestation was in mature natural forest (217.9 t C ha^{-1}) during CP1, whilst the **lower emissions** scenario assumed all natural forest deforestation occurs in regenerating natural forest (57.3 t C ha^{-1}) during CP1. Table 10 shows the assumptions used for the three scenarios.

Table 10: Basis for natural forest deforestation scenarios

Period	Upper emissions	Most likely	Lower emissions
1990–2007	7% increase in natural forest deforestation area. 3.6% increase in the national average carbon density for natural forest.	The average carbon density for natural forest of 179 t C ha^{-1} is used based on 88% of deforestation being regenerating natural forest (that meets the forest definition) (57.3 t C ha^{-1}) and 12% being mature natural forest (217.9 t C ha^{-1}). This is the same as used within the 2010 Greenhouse Gas Inventory.	7% decrease in the area of natural forest deforestation. 3.6% decrease in the national average carbon density for natural forest.
2008–2010	7% increase in natural forest deforestation area. 3.6% increase in the national average carbon density for natural forest.	Natural forest deforestation area based on the 2010 Greenhouse Gas Inventory. The average carbon density for natural forest of 179 t C ha^{-1} is used based on 88% of deforestation being regenerating natural forest (that meets the forest definition) (57.3 t C ha^{-1}) and 12% being mature natural forest (217.9 t C ha^{-1}). This is the same as used within the 2010 Greenhouse Gas Inventory.	Natural forest deforestation area based on the 2010 Greenhouse Gas Inventory. 3.6% decrease in the national average carbon density for natural forest.
2011–2012	7% increase in the average area of natural forest deforestation from 2008 to 2010 continues throughout 2011 and 2012. 3.6% increase in the national average carbon density for natural forest.	Average of 2008 to 2010 natural forest deforestation in this scenario continues throughout 2011 and 2012. The average carbon density for natural forest of 179 t C ha^{-1} is used based on 88% of deforestation being regenerating natural forest (that meets the forest definition) (57.3 t C ha^{-1}) and 12% being mature natural forest (217.9 t C ha^{-1}).	Average of 2008 to 2010 natural forest deforestation in this scenario continues throughout 2011 and 2012. 3.6% decrease in the national average carbon density for natural forest.

As New Zealand assumes all forest biomass carbon is emitted instantaneously in the year of a deforestation event taking place, only soil carbon changes associated with deforestation from 1990 to 2007 are accounted for within CP1. Given this there is no effect on CP1 emissions from adjusting the biomass carbon density for natural forest from 1990 to 2007 for the **lower** and **upper emission** scenarios.

Change in biomass and soil carbon from the land use following deforestation have been included as part of the deforestation emissions. The future land-use areas after deforestation are based on LUCAS data for 1990 to 2010 with the same proportion as observed through the first half of the commitment period continued for 2011 and 2012 (Table 11). The carbon stocks used to calculate emissions from land use after deforestation were based on values used in the 2010 Greenhouse Gas Inventory (Ministry for the Environment, 2012).

Table 11: Percentage of land use after natural forest deforestation used through CP1 and carbon stock (t C ha^{-1})

Land-use subcategory	Percent of land use after natural forest deforestation 2008-2012	Biomass carbon stock used to calculate emissions (t C ha^{-1})
Grassland – high producing	14	6.8
Grassland – low producing	82	3.1
Settlement	< 0.1	0
Other land	4	0

Source: Ministry for the Environment, 2012.

Changes to projections since 2011

Net removals from Article 3.3 of the Kyoto Protocol for LULUCF are projected to be 3.0 million tonnes carbon dioxide equivalent higher than projected in 2011. The main changes from the 2011 report are:

- An increase in net removals from post-1989 forest of around 3.0 million tonnes CO_2.[7] This is mostly due to revision of the post-1989 forest yield table. The yield table has been revised to use the latest version of the Forest Carbon Predictor (version 3). Version 3 contains new temperature dependent decay functions, and species specific growth trajectories and biomass adjustments which have changed the profile of the yield table. While the volumes in the new yield table are lower, the trajectory of growth in the new yield table, particularly over the period when new planting was high (mid-1990s), is steeper (the annual increase is greater) and this results in a greater change in post-1989 forest carbon stocks over the commitment period than was previously reported. The post-1989 forest yield table used for the 2011 report was based on Forest Carbon Predictor version 2.2.
- An increase in removals due to the change in soil carbon methodology of 1.9 million tonnes CO_2.[7] Changes have occurred where the change between steady state values estimated using the IPCC default values (Tier 1) are different to the change between values estimated using the NZ specific methodology (Tier 2), for instance with land-use change between grassland with woody biomass and post-1989 forest land. In the 2011 report, the soil carbon stock change associated with this land-use change was a loss of 9.46 t C ha^{-1}. In the 2012 report the soil carbon stock change is estimated as 0 t C ha^{-1}.
- Net emissions from afforestation in 2011 and 2012 are estimated to be 0.5 million tonnes compared to last year's projections of 0.3 million tonnes. This change is due to increased projections of afforestation for 2011 and 2012 based on the National Exotic Forest Description (NEFD) provisional planting estimate for 2011, and the change in methodology for estimating soil carbon change with land-use change which results in a lower estimate of emissions from soil with afforestation than used in the 2011 report.
- Deforestation emissions are projected to be 0.2 million tonnes lower than estimated in 2011. The inclusion of new mapping information on the area of deforestation for 2008 and 2009 has seen a rise in the emissions from deforestation of pre-1990 forests (0.58 million tonnes) and a decrease in the emissions from deforestation of post-1989 forests (0.74 million tonnes). The total area of deforestation during CP1 used in the 2011 report was 23,090 hectares, compared to 14,611 hectares used in this report.

[7] Recalculations to the post-1989 yield table, soil carbon methodology and deforestation areas are not cumulative as the change in deforestation area will affect how much land is subject to soil carbon changes. The figures stated here represent the effect of each change on the 2011 Net Position report in isolation. The total change between the 2011 net position and 2012 net position is projected to be 3.0 million tonnes carbon dioxide equivalent.

Future improvements and reporting

New Zealand's estimates and projections will progressively improve in accuracy and completeness during CP1 as a result of additional data collection for forest land and planned improvements under the LUCAS programme as outlined below:

- At the end of the first commitment period New Zealand will create a 2012 land-use map using high-resolution satellite data. This mapping will be used to make comparisons with the 2008 land-use map to identify land-use changes between 1 January 2008 and 31 December 2012. As part of the land-use mapping process, areas of forest destocking (both harvesting and deforestation) will be identified. These areas will be assessed for land-use change (deforestation) using oblique aerial photography taken from a light aircraft as was completed in previous years.
- Other ongoing mapping improvements include the integration of mapping information from the Emissions Trading Scheme and other Ministry of Agriculture and Forestry forestry schemes, and improvements to the 2008 land-use map based on the latest Land Cover Database (LCDB3).
- Remeasurement of the post-1989 forests has recently begun. This uses the same ground sampling method as used previously. The post-1989 yield table will be revised based on these measurements.
- Investigations are underway into species specific modelling. If this is found to be a feasible option within LUCAS it will be implemented over the next two years. This change will allow more accurate projections of emissions from both afforestation and deforestation.
- LUCAS is undertaking improvements to the Soils Carbon Monitoring System, including collection of soil carbon data for under-represented land uses, and refinements to the model. The results from these analyses will further improve the information to estimate soil carbon changes with afforestation and deforestation in future projections.

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