Australian Government

AUSTRALIAN NATIONAL GREENHOUSE ACCOUNTS

Australian Land Use, Land Use Change and Forestry Emissions Projections to 2030

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1. SUMMARY OF KEY PROJECTIONS RESULTS

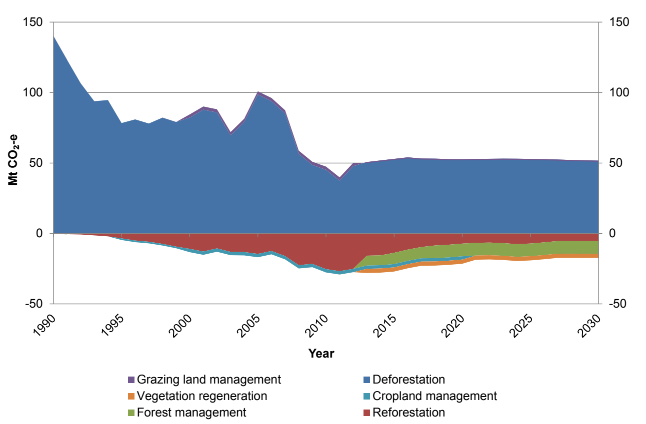
In Australia, the land sector contributes about 25% of total human-induced or anthropogenic greenhouse gas emissions to the annual national inventory through activities such as land clearing and forest management. The removal of carbon dioxide from the atmosphere by forests and other vegetation also provides an important carbon sink.

This document reports projected emissions from the land sector designed to reflect the expected state of the national greenhouse gas inventory for the period 2013-2030 applying the internationally agreed accounting and emissions estimation rules of the Kyoto Protocol.

Figure 1 shows net emissions and removals from the Land Use, Land Use Change and Forestry (LULUCF) sector for the period 1990 to 2030. Emissions from 1990 to 2011 are based on actual values, while emissions from 2011 to 2030 are projections for a baseline scenario that does not include effects of the carbon price or Carbon Farming Initiative (CFI).

Projected emissions and removals from CFI projects corresponding to the LULUCF activities are provided for different carbon price policy scenarios in the *Climate Change Mitigation Scenarios Modelling Report* (Treasury et al, 2013).

Figure 1:
LULUCF emissions trends, 1990 to 2030



Source: DIICCSRTE estimates.

LULUCF emissions have declined significantly over the period 1990 to 2011 due largely to declines in land clearing and removals from *afforestation/reforestation*. From 2013, emissions due to land clearing are expected to stabilise while removals associated with *reforestation* are expected to decline. The additional land activities *forest management*, *cropland management* and *grazing land management* are included in the accounting framework at the start of the second commitment period of the Kyoto Protocol in 2013.

Deforestation emissions are estimated to average 47 Mt CO_2-e per year over the first commitment period (2008–2012). *Deforestation* emissions are expected to rise to 53 Mt CO_2-e by 2020, reflecting recent improvements in economic conditions in the farm sector and, inter alia, changes to land clearing regulations by state governments.

Removals from *afforestation/reforestation* activities are projected to average 24.2 Mt CO_2-e a year over the first commitment period. In the baseline scenario, net removals are expected to be 7.2 Mt CO_2-e by 2020. This is due to declining average removal rates because of increasing average age of the post-1990 plantation estate, the conversion of plantation forests to agricultural land uses and the cessation of the harvest sub-rule, which only applied to the first commitment period.

Net credits generated from *forest management* activities are projected to be 9 Mt CO_2-e by 2020. Over recent years, harvesting in the native forest sector has reached historically low levels. This decline has been associated with changes in supply factors such as the creation of forest reserves and increasing supply from plantations (particularly those established after 1990) and demand factors including changes to the international price of harvested wood products and the value of the Australian dollar as well as shifts in demand patterns, especially between Japan and China.

Net credits generated by *cropland management* and *grazing land management* activities are estimated to be 3 Mt CO_2-e a year over the second commitment period.

2. INTRODUCTION

In Australia, the land sector contributes about 25% of total human-induced or anthropogenic greenhouse gas emissions to the annual national inventory through activities such as land clearing and forest management. The removal of carbon dioxide from the atmosphere by forests and other vegetation also provides an important carbon sink.

This document reports projected emissions from the land sector designed to reflect the expected state of the national greenhouse gas inventory for the period 2013-2030 applying the internationally agreed accounting and emissions estimation rules.

The international classification - land use, land use change and forestry (LULUCF) - includes carbon dioxide emissions and removals from the land. This report complements the report on projected emissions from the Agriculture sector, where non-carbon dioxide emissions, sometimes from the same human activities, are reported.

This report utilises rules for how the greenhouse gas emissions and removals from the land should count towards a country's emissions reduction commitment. These rules were agreed under the Kyoto Protocol, which provides an appropriate and internationally recognised system of land sector accounting rules to support tracking towards emission reduction commitments.

The commitments agreed under the Kyoto Protocol are designed to limit anthropogenic or human-induced greenhouse gas emissions. The Kyoto rules focus, therefore, on defining certain human activities which draw land into the accounting framework. Some of the land sector activities are mandatory, meaning that all countries with Kyoto Protocol commitments must include them in calculating their annual greenhouse gas emissions and removals. This list for the first commitment period, 2008-2012, included the forestry activities of *afforestation*, *reforestation* and *deforestation* and, in practice, drew about one per cent of Australia's land mass into the accounting framework.

In December 2012, Australia signed up to a second commitment period under the Kyoto Protocol, to run from 2013 to 2020. *Forest management* has been added to the list of mandatory activities for this period.

Other land sector activities are voluntary, meaning countries can decide whether to include them in the accounting towards their Kyoto Protocol commitment. The Australian Government subsequently announced it will include the *cropland management*, *grazing land management*, and *revegetation* activities so that, for the second period, virtually the whole land mass will enter into the accounting framework.

This report presents projections of greenhouse gas emissions and removals from these LULUCF activities.

The 2013 projections include estimates of emissions and removals from the additional land-based activities for the first time. As such, these projections estimates can be expected to be refined over time as more data become available, as experience is gained, and as inventory measurement methodologies for these subsectors are enhanced in future years.

Table 1:
LULUCF activities

Subsector	Activity Definition
Deforestation	The direct, human-induced removal of forest cover and replacement with pasture, crops or other uses since 1 January, 1990.
Reforestation/afforestation	The establishment of new forests by direct human action on land not forested as at 1 January, 1990 (*afforestation* and *reforestation*).
Forest management	A system of practices for stewardship and use of forestland aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.
Grazing land management	The system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced.
Cropland management	The system of practices on land on which agricultural crops are grown, and on land that is set aside or temporarily not being used for crop production.
Revegetation	A direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of *afforestation* and *reforestation*.

Source: DIICCSRTE 2013.

Some important new accounting rules were agreed for the second commitment period, which allowed parties to reach agreement on the mandatory inclusion of *forest management*.

First, net emissions from forests are to be compared with net emissions from a forest management reference level, which takes account of the underlying growth dynamics of forests and policies in place at 2009.

Second, countries will be able to exclude from their accounting the emissions, and subsequent sequestration, from significant natural disturbances beyond human control such as bushfire.

Third, emissions from the harvested wood product pool from forests will be included and estimated to reflect the use and degradation of products over time. The previous rules that applied to harvest wood products, known as the harvest sub-rule, applied for the first commitment period. Under this rule, debits resulting from harvesting during the first commitment period only following *afforestation* and *reforestation* were offset against credits accounted for on that land.

2.1 Core projections methodology

Australia's forests extend over 106 million hectares. Only a relatively small portion of these forests are managed for commercial timber so that, when Australia's national inventory was first being developed, there were few measurements available on the amount of biomass in forests and little monitoring of forest cover change.

It is not economically feasible or logistically practical to address these data gaps over such a large area with the use of direct emissions estimation methods alone e.g. field sampling or lidar sensors. Given these circumstances, the design of Australia's national inventory system for the land sector relied heavily on the application of 25 metre grid resolution satellite data to assess land use change. This data is input to a modelling framework, the Full Carbon Accounting Model (FullCAM), which estimates the biomass of vegetation on lands across Australia, the carbon stored in above and below ground vegetation and soil, and emissions resulting from land management activities.

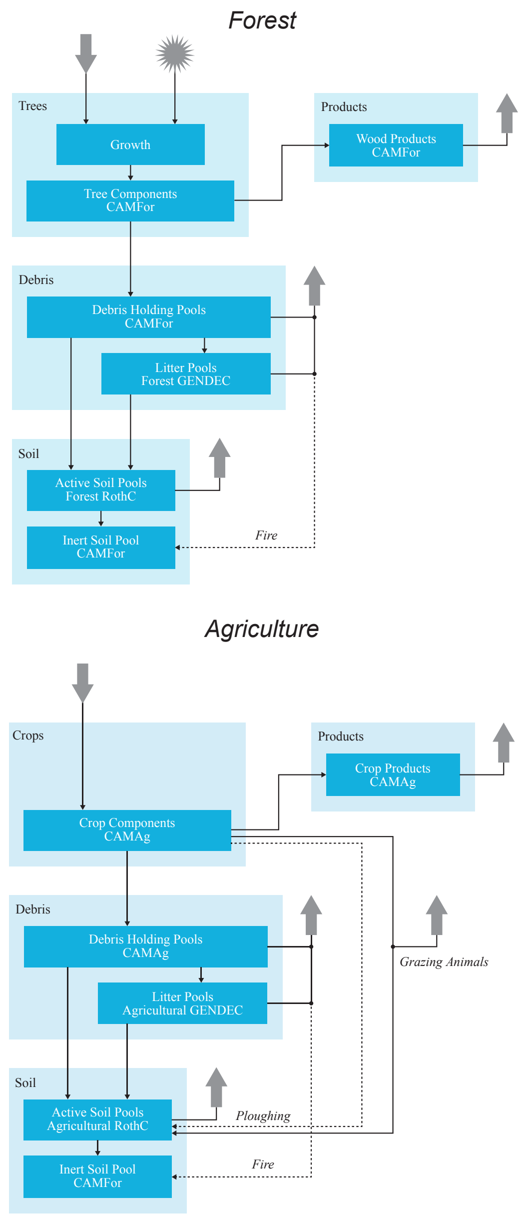
The initial priority for the development of the system was to support the estimation of emissions from land use change, which is a key category for Australia in terms of both total emissions and overall trend. Currently, the development of the system is increasingly concentrated on the enhancement of the estimation processes for other sources and sinks in the land sector, like croplands and grazing lands, requiring the development of new measurement protocols, the acquisition of new data sets and the implementation of new estimation techniques.

The modelling framework provided by FullCAM for the estimation of emissions from the land sector is illustrated in Figure 2. The exchanges of carbon, loss and uptake between the terrestrial biological system and the atmosphere are accounted for in the full/closed cycle mass balance model which includes all biomass, litter and soil pools.

Projections

The projections of the key variables across the land sector are prepared through economic models that link observed human activity to economic conditions and to the physical properties and responsiveness of the land. For this purpose, a reduced form, tier 2 version of the FullCAM model (DIICCSRTE, 2013) is applied, explained in more detail in this report.

Figure 2:
The FullCAM model pool structure



Source: *National Inventory Report 2011*, vol 2, p.102 (DIICCSRTE, 2013).

3. SECTORAL EMISSIONS PROJECTIONS

3.1 Deforestation

3.1.1 The national inventory

Land clearing is an important contributor to Australia's total net greenhouse gas emissions. Carbon dioxide and other greenhouse gases are released when vegetation is burned or left to decay, and as soil carbon declines over time following a clearing event.

Deforestation emissions accounted for around 7% of Australia's net emissions of 563.1 Mt CO_2-e reported under the Kyoto Protocol in 2011.

Areas subject to land clearing are detected using US Geological Survey satellite imagery and geographic information systems (GIS) utilising information, systems and services provided by GeoScience Australia, the CSIRO Mathematical and Information Sciences and a number of private contractors. When an area of forest clearing is detected from changes in satellite images from one year to the next, the cause is determined from fine-scale images and cross-referencing national data sources on land use. This provides a spatially explicit picture of how much human-induced land clearing occurs each year, and where it happens.

The application of a consistent data set over a time series, dating back to 1972, is important for the system as the effects on emissions from land use change are typically long lasting. Site history can be critical, for example, a current *deforestation* event will generate fewer emissions if the forest cleared is secondary forest (regrowth after previous clearing) rather than a primary forest.

The inventory system integrates the spatially referenced data with the FullCAM model to estimate carbon stock changes and emissions from changes in land use and management practices (DIICSRTE, 2013). The model applies equations reported in Richards and Brack (2004), Brack et al. (2006) and Waterworth et al. (2007) for the estimation of forest carbon stocks and requires significant data inputs in relation to climate, soil and management practices.

Climate data from the Bureau of Meteorology for rainfall, minimum and maximum temperature, evaporation and solar radiation are processed each year by researchers at the Australian National University to generate monthly climate surfaces (maps) at 1 km resolution.

Soil carbon data is taken from the Australian Soil Resources Information System (ASRIS), prepared by the CSIRO. Grass and cropland yield estimates are prepared by CSIRO modellers at the Land and Water Division.

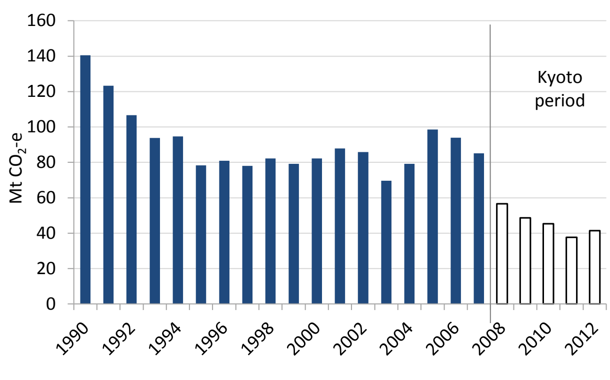
Land use (e.g. crop or pasture type) and management practices (e.g. tillage, use of fire and grazing intensity) information is drawn from Australia's National Forest Inventory and from the land use mapping program of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) which assigns a land use type to the land.

The fundamental analytic unit of FullCAM is the land cover change grid (25 m x 25 m) derived from the satellite remote sensing program. The first time a land clearing event is detected for a pixel from one satellite image to the next, in the time series dating back to 1972, the modelling of that pixel commences. The emissions profile generated by the land clearing event will last many years as dead organic matter decays and soil carbon is released over time.

3.1.2 How much clearing?

Emissions from *deforestation* declined by 41% between 1990 and 2000 (Figure 3) along with declining rates of land clearing, principally in response to economic conditions in the farm sector. *Deforestation* emissions declined further in the period 2000-2010 due to further decreases in land clearing reflecting, at least in part, regulatory changes in domestic vegetation management frameworks. By 2010, *deforestation* emissions had declined by 68% compared with emissions in 1990 (Figure 3).

Figure 3:
Net emissions from deforestation, calendar year, 1990-2012

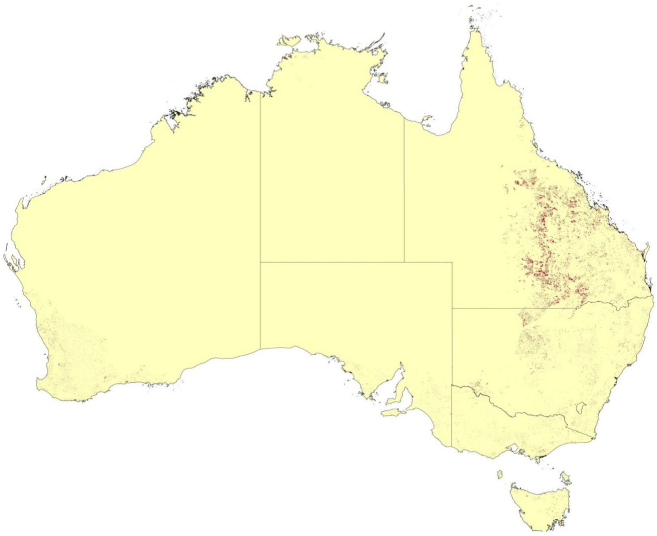


Source: *DIICCSRTE estimates, December 2012 Quarterly Update.*

3.1.3 Where does land clearing occur?

During the period 1990-2011, land clearing occurred predominantly in Queensland and New South Wales and to a lesser extent in Western Australia. The locations of land clearing events detected between 1990 and 2011 are displayed in Figure 4 and Table 2 (page 7).

Figure 4:
Location (in red) of land clearing events detected between 1990 and 2011, which are included in the *deforestation* account.



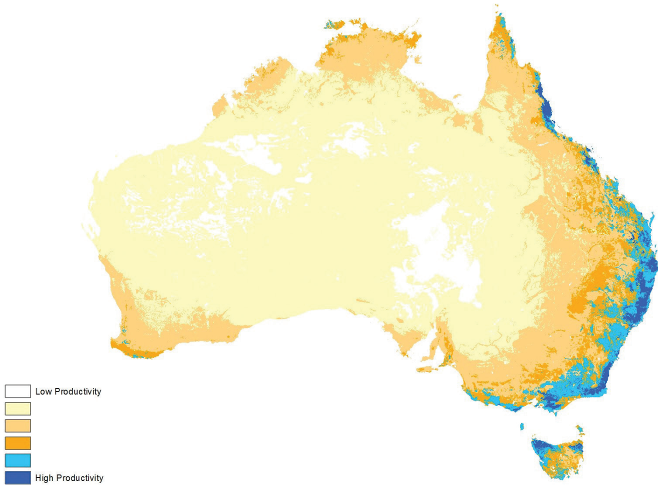
Source: *DIICCSRTE estimates.*

3.1.4 Emissions associated with land clearing

Emissions from land clearing are estimated using FullCAM equations relating biomass estimated to be present on the site to national data sets of soil quality and climate variables in a 'forest productivity index'. The effect of these equations may be demonstrated in Figure 5, which shows the resulting map of the index across Australia indicating estimated plant productivity and forest mass at each location.

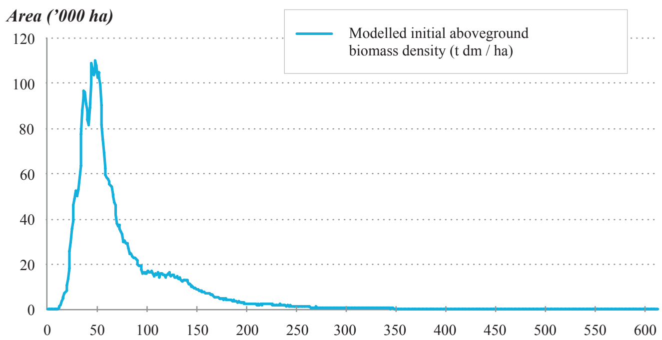
The estimated biomass at the sites where clearing has occurred can be illustrated in Figure 6, which shows a frequency distribution of the modelling results, expressed as the area in the *deforestation* account (in thousands of hectares) at every value of the modelled initial above ground biomass density (in tonnes of dry matter per hectare, t dm/ha).

Figure 5:
Map of the forest productivity index across Australia, which measures plant productivity and forest growth at each location based on variables such as rainfall, temperature and soil type.



Source: Derived from data in the National Inventory Report 2009, described in vol. 2, appendix 7.A. For more information on the forest productivity index, see: Kesteven, J. et al (2004), Developing a National Forest Productivity Model, NCAS Technical Report No. 23, Australian Greenhouse Office.

Figure 6:
Distribution of modelled initial above ground biomass density across Australia's Kyoto deforestation account.



Source: *DIICCSRTE estimates.*

The modelled estimates cover a large range of values. Most estimates are quite low, between around 25 and 85 t dm/ha, as most clearing since 1990 has occurred in areas of relatively sparse forest cover. However, the distribution also has a long tail extending to much higher values, as well as a 'bulge' around 100 to 160 t dm/ha. This is due to clearing events detected in high-productivity areas, where the model predicts higher initial above ground biomass densities. The lowest value in the distribution is 7 t dm/ha, and the highest value is 647 t dm/ha. The model does not predict any initial above ground biomass densities outside this range for these areas.

Table 2:
Land clearing areas, 1990-2011, rates of forest conversion ('Con') and reclearing ('RC') (kha)

Year	Australia		NSW		QLD		WA		Other [a]	
	Con.	RC	Con.	RC	Con.	RC	Con.	RC	Con.	RC
1990	442.5	157.9	65.6	45.6	308.4	85.4	43.5	14.3	25.1	12.6
1991	306.5	151.5	52.6	49.8	212.4	80.5	23.5	10.7	17.9	10.6
1992	268.9	141.0	35.7	36.3	199.3	84.2	16.9	8.7	17.0	11.8
1993	276.0	171.8	36.0	41.6	208.1	107.6	17.9	10.0	14.1	12.7
1994	249.4	151.5	32.4	37.4	185.7	92.2	16.9	9.2	14.4	12.8
1995	207.2	139.2	25.0	38.2	155.2	78.3	15.6	11.8	11.4	10.8
1996	225.4	157.5	27.9	44.7	167.7	87.2	17.4	13.5	12.3	12.1
1997	206.3	143.8	25.6	41.0	153.7	79.7	15.8	12.2	11.3	11.0
1998	219.2	166.1	24.7	50.9	174.1	92.2	9.9	9.0	10.5	13.9
1999	226.1	171.5	25.1	52.4	180.1	95.0	10.0	9.3	11.0	14.9
2000	238.2	174.3	21.0	44.1	196.1	105.0	12.8	13.7	8.4	11.6
2001	249.5	183.0	21.9	45.8	204.4	109.3	14.2	15.5	9.1	12.5
2002	194.8	172.5	19.1	42.0	150.2	95.6	15.6	19.6	9.9	15.3
2003	188.0	185.9	19.7	44.4	140.5	102.6	16.8	21.6	11.0	17.3
2004	248.8	263.2	32.2	76.2	183.5	133.9	18.1	26.4	15.0	26.8
2005	240.6	274.0	23.7	59.4	178.3	138.6	18.1	33.9	20.5	42.0
2006	225.2	310.4	30.0	92.6	157.6	133.9	20.1	44.2	17.6	39.8
2007	165.2	237.7	22.6	64.3	114.0	107.3	15.5	37.5	13.1	28.6
2008	123.5	204.5	19.9	60.3	76.8	82.9	13.6	34.5	13.4	26.9
2009	109.1	206.7	20.2	65.9	60.8	71.4	13.2	38.2	14.9	31.1
2010	86.2	166.4	17.2	57.1	45.0	57.5	13.6	23.9	10.5	28.0
2011	63.5	117.5	15.8	39.0	33.3	44.1	7.8	16.0	6.6	18.5

[a] Other denotes the sum of the Northern Territory, South Australia, Tasmania and Victoria.

Note: The sum of conversion and reclearing reported here is greater than land areas reported in Table 7.2 of the *National Inventory Report 2011*. This is because Table 7.2 includes conversion and only that portion of reclearing that occurs on land that was initially clear (in 1972), has regrown and then was cleared.Table 7.2 does not include reclearing events on land that is already in the account.

The mean of the distribution occurs at 80 t dm/ha. This represents the modelled average above ground biomass density prior to first-time clearing in areas within the Kyoto deforestation account. The median is 59 t dm/ha, which is lower than the mean due to the effect of relatively infrequent units of land with high modelled initial biomass densities.

The results reflect an estimate of the long-term average above ground biomass density that was present in these areas prior to the first clearing event. This can then be used to assist in the calculation of net emissions or carbon stocks.

3.1.5 Re-clearing cycles

Not all land cleared is first time clearing. Clearing also occurs on land where vegetation is managed by repeated re-clearing for livestock grazing or other agricultural purposes.

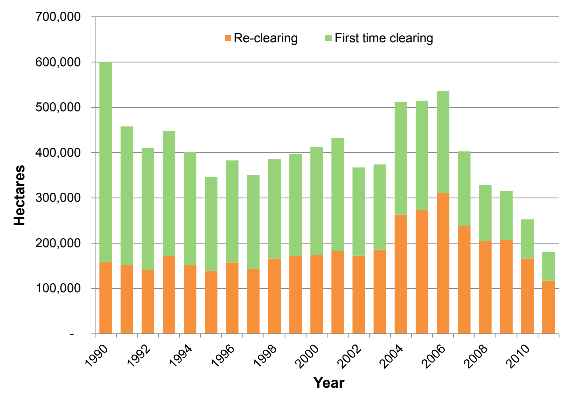
Figure 7 (page 8) demonstrates the area subject to re-clearing events has remained relatively steady while there have been strong declines in the area subject to first-time clearing over this period.

Emissions from re-clearing of regenerated forests are typically lower than from first-time clearing, since regenerated forests may not yet have reached their long-term average biomass densities.

In the national inventory, these effects of regrowing forests are modelled using FullCAM using equations reported in DIICCSRTE (2013) and, earlier, in Richards and Brack (2004), Brack et al. (2006) and Waterworth et al. (2007).

Typical values of biomass for areas of re-cleared land are 22 tonnes per hectare in woodlands (88% of clearing); 49 tonnes per hectare in open forest (10% of clearing); and 64 tonnes per hectare of biomass in closed forests (2% of clearing).

Figure 7:
Confirmed *deforestation* on *afforestation/reforestation* lands



Source: *DIICCSRTE estimates.*

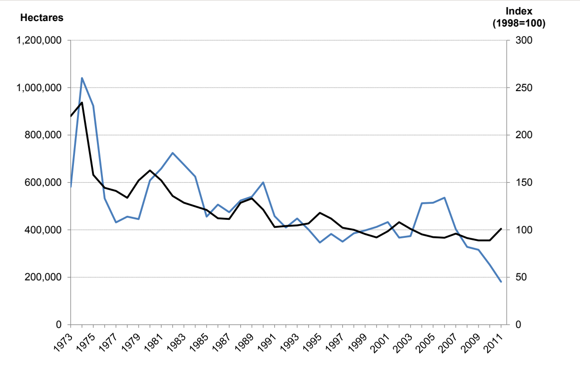
3.1.6 Drivers of land clearing

For farmers and other managers, economic considerations are an important driver of land clearing. When the prices of agricultural products, for example beef, are high, land managers have an increased incentive to clear land and expand production.

The *farmers' terms of trade* is a key indicator of economic conditions in the agriculture sector. It is defined as the ratio of an index of prices received by farmers to an index of prices paid by farmers. Prices received include agricultural products such as beef, and prices paid include inputs such as fertiliser and diesel. The *farmers' terms of trade* increase if either the price of an agricultural product rises, or the price of an input falls.

Figure 8 shows the *farmers' terms of trade* in Australia and the annual area of cleared land between 1973 and 2011. The land clearing areas are the sum of the area of first-time clearing and re-clearing.

Figure 8:
Land clearing and farmers' terms of trade, Australia, 1973-2011



Source: Land clearing: DIICCSRTE data used in the National Inventory Report 2011. Farmers' terms of trade: ABARES, Australian Commodity Statistics 2013, vol.3 no.1, March.

As illustrated in Figure 8, there is a strong relationship between the *farmers' terms of trade* and land clearing. The data also indicate a lag of approximately one year in the relationship. Typically, an increase (or decrease) in the *farmers' terms of trade* is followed by a corresponding increase (or decrease) in land clearing around one year later. A linear least squares regression using yearly percentage changes in the land clearing area and the *farmers' terms of trade* from 1974 to 2009, with a lag of one year, confirms that this relationship is statistically significant at the 1% significance level (R^2 = 0.34).

The national trends also reflect to a certain extent the effects of domestic regulatory changes. In 2004, for example, the Queensland Government passed amendments to vegetation management regulations which imposed certain restrictions on clearing from 2007 onwards. The effects of this policy change can likely be seen in the drop in land clearing from 2007 onwards as well as the temporary increase immediately prior to the drop, between 2004 and 2006, as the introduction of the new regulations was anticipated. Unlike most previous large shifts in the rate of land clearing, the recent shifts in 2004 and from 2007 onwards were not accompanied by significant changes in the *farmers' terms of trade* (Figure 8).

The Queensland Government recently passed *The Vegetation Management Framework Amendment Act 2013*, which will return aspects of the vegetation management framework to the conditions that applied prior to 2009. In particular, land managers are less likely than previously to require a permit to undertake land clearing activity. To the extent that there may be some unmet demand in the sector to increase the area of land under production, regulatory reform could be expected to put some upward pressure on clearing activity.

Rainfall is another important factor that influences the rate of land clearing. Forest regrowth occurs faster during times with high rainfall, resulting in landowners needing to re-clear land sooner. During times of drought, landowners may clear additional vegetation to provide emergency fodder for stock. These climatic effects could also be expected to affect rates of observed clearing independently of changes in the *farmers' terms of trade*.

3.1.7 Deforestation of Afforestation and Reforestation lands

An additional source of *deforestation* relates to decisions to not replant previously harvested forests. In particular, land that had been classified as *afforestation/reforestation* land, if not replanted or regenerated after harvest, qualify as deforestation land. Land that is eventually re-planted is considered to be temporarily destocked land and remains classified as forest land.

Remote sensing of *afforestation/reforestation* lands for re-plantings is undertaken to identify additional sources of *deforestation*. As new data are added to the time-series the certainty that *deforestation* and *afforestation/reforestation* occurred increases. This results in a small recalculation of these accounts (<4%) each year.

The general rate of regeneration of plantation estates in Australia has been reported in the *Australia's State of the Forests Report 2008* (Montreal Process Implementation Group for Australia, 2008). This reported data for the period 2000-2006 shows regeneration rates for plantations at around 93% for Tasmania and 98-100% for South Australia. These regeneration rates apply to all plantations in the state, including lands that do not meet the requirements to be included as *afforestation/reforestation*. High regeneration rates have normally been expected in Australia's plantation estates.

As indicated above, re-establishment rates are subject to more uncertainty in Australia given the current economic conditions in the industry. During the recent period, several major players including companies that built their business around Management Investment Schemes exited the market, which is the likely cause of reduced planting rates in the last few years. Consequently, the rate of re-establishment of harvested areas is projected to fall for the next few years.

3.1.8 Key assumptions and activity data

Projections of emissions are undertaken using a reduced form (tier 2) version of the FullCAM model, as described by DIICCSRTE (2013).

In particular, the emissions projections for land clearing for agriculture were modelled from estimated relationships between areas of land clearing activity and movements in the *farmers' terms of trade*. Projections of the *farmers' terms of trade* for the period 2013-2016 are from ABARES (2013) and held constant thereafter, assuming these values reflect long term equilibrium prices (Table 3).

The projection assumes normal seasonal conditions.

Additionally, as discussed above, recent regulatory reforms could be expected to place upward pressure on clearing activity. These regulatory effects, inter alia, have been modelled by rebasing the modelling start point for the simulation to reflect 2010 clearing levels after a short transition period.

Table 3:
Farmers' terms of trade (index), 1971 to 2030

Year		Year		Year	
1971	171.6	1991	102.9	2011	96.7
1972	175.3	1992	104.1	2012	94.4
1973	219.9	1993	104.7	2013	95.0
1974	234.3	1994	106.8	2014	92.6
1975	158.0	1995	118.0	2015	89.1
1976	144.3	1996	111.8	2016	87.7
1977	141.1	1997	102.2	2017	87.5
1978	133.8	1998	100.0	2018	87.0
1979	152.1	1999	95.6	2019	87.0
1980	162.7	2000	92.0	2020	87.0
1981	152.2	2001	98.5	2021	87.0
1982	135.7	2002	108.1	2022	87.0
1983	128.6	2003	101.1	2023	87.0
1984	124.8	2004	95.3	2024	87.0
1985	121.0	2005	92.3	2025	87.0
1986	112.2	2006	91.7	2026	87.0
1987	111.5	2007	96.0	2027	87.0
1988	128.5	2008	91.4	2028	87.0
1989	133.2	2009	88.9	2029	87.0
1990	121.3	2010	88.8	2030	87.0

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2013).

3.1.9 Projection results

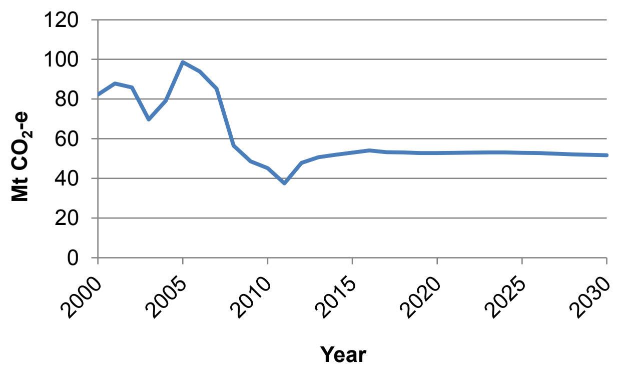
By 2015, *deforestation* emissions are estimated to rise by around 20% from 2011 levels reflecting changes in the *farmers' terms of trade* and regulatory and other effects. Without the carbon price and CFI, *deforestation* emissions are expected to equilibrate at 52 Mt CO_2-e by 2020 (16 Mt CO_2-e above the 2011 level) (Table 4).

Table 4:
Deforestation emissions, 2008-2030

Year	Mt CO_2-e
2008-2012	47
2013-2020	52
2021-2030	51

Source: *DIICCSRTE estimates.*

Figure 9:
Deforestation emissions, 2000-2030



Source: *DIICCSRTE estimates.*

3.2 Afforestation/Reforestation

3.2.1 The national inventory

The emissions and removals from *afforestation/reforestation* are estimated using the spatially explicit FullCAM modelling system (DIICCSRTE, 2013, Appendix 7.B and 7.D). The modelling methods and calibration were published in peer reviewed literature (Waterworth et al, 2007; Waterworth and Richards, 2008).

Plantations commonly produce more biomass than native forest systems in Australia, at least in the short to medium term (15-40 years). These growth differences are driven by factors such as nutrient addition, reduction in insect herbivory associated with the use of non-endemic species or through control of pests, and species specific site matching and management.

The plantations model takes into account the age, plantation type, management and site conditions to estimate emissions and removals. The native forest regrowth model is supplemented to include functions that represent Type 1 and Type 2 growth responses (Snowdon and Waring, 1984) and the impact of using non-endemic species (DIICCSRTE 2013, Appendix 7.G). Type 1 management practices advance or retard stand development (effectively age) but do not increase underlying site productivity over the life of the rotation (e.g. weed control at establishment). Type 2 treatments increase (or decrease) a site's carrying capacity in the longer term (e.g. phosphorus application).

As the carbon increment estimates are based on above ground biomass, there is a need to correct for the increment in below ground biomass (roots) to provide an estimate of total live biomass. FullCAM calculates the partitioning using an empirical approach derived from expansion factors reported in Snowdon et al. (2000) and Mokany et al. (2006). This method allows allocation to vary between sites and species within set ranges based on age, site productivity and level of stand development.

Studies of the carbon fractions of above and below ground biomass components for Australian vegetation were used to provide the parameters for the carbon fractions of tree components in the model (Gifford, 2000a and 2000b).

A comprehensive database of the plantation management practices used in Australia since 1970 has been implemented for each tree species within each region and then spatially and temporally referenced to link to information on site productivity and previous land-use.

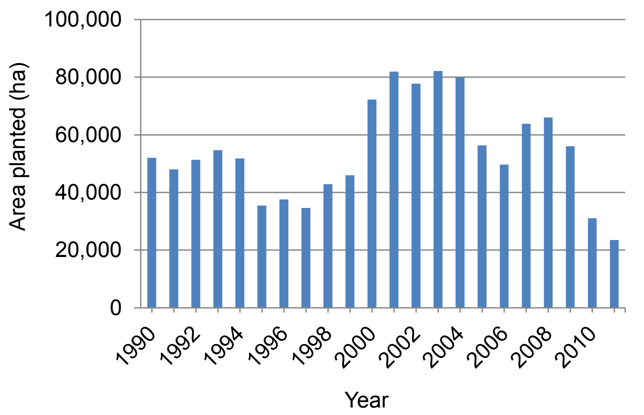
The turnover rate of leaves and fine roots affects both the amount of fine litter on the forest floor and subsequently most of the contribution to soil carbon. Soil carbon is estimated using the fully spatially explicit approach described in DIICCSRTE (2013), Appendix 7.B, with some modifications to the base input data to suit the modelling for post-1990 plantations.

3.2.2 Drivers of emissions and removals

The *afforestation/reforestation* classification includes forests established since 1 January, 1990 due to direct human-induced activity on land that was clear of forest on 31 December, 1989.

Due to the framework of the *reforestation* classification (only new forest areas since 1990), the key driver of *reforestation* removals is the rate of plantation establishment (Figure 10).

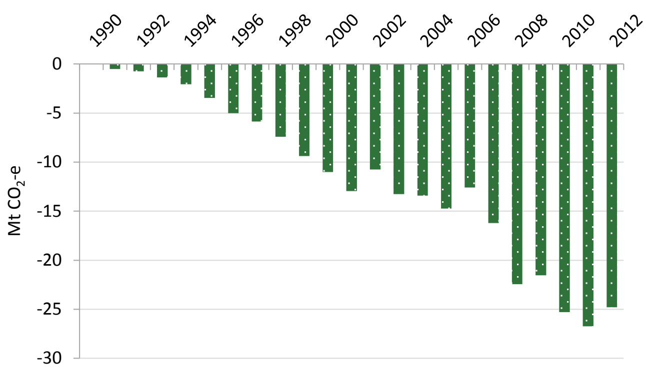
Figure 10:
Annual area of reforestation 1990-2011



Source: *DIICCSRTE estimates.*

Key elements of the trend reflect the large expansion of plantation forestry during 1990-2005, partly in response to incentives for plantation establishment such as the taxation treatment of Managed Investment Schemes[1]. In 2011, however, the annual rate of plantation establishment was the lowest since 1990. This may have been caused by economic conditions for forest products, including the historically high value of the Australian currency in 2010-2011, which made it more challenging to export plantation products overseas. Several major players, including companies that built their business around Management Investment Schemes, left the plantation forestry industry and this may have resulted in a reduction of plantation establishment.

Figure 11:
Net emissions from afforestation and reforestation, calendar year, 1990-2012



Source: *DIICCSRTE estimates, December 2012 Quarterly Update.*

Over the period 2000-2010, the annual rate of commercial plantation establishment declined from 55,000 ha/yr in 2000 to 25,000 ha/yr in 2010. However, national aggregate removals were highest in the period 2010/11 due to the lag of several years between planting and the maximum rate of removals by newly established plantations. In the last two years, however, net removals have reached a turning point and have begun to diminish as the trees planted in early years pass their maximum growth rates and as new planting rates decline.

3.2.3 Key assumptions and activity data

Activity data levels have been prepared using expert judgement based on history and relevant evidence. Planting rates are assumed to average 11,660 ha per year until 2020.

Projections of emissions are undertaken using a reduced form (tier 2) version of the FullCAM model, as described by DIICCSRTE (2013). The tier 2 model is based on a series of 46 plot files drawn from within the tier 3 modelling framework. The selected plot files are representative of the most common species and management regimes within each state and National Plantation Inventory (NPI) region. The area represented in each NPI region by each plot was determined from the land sector remote sensing program.

3.2.4 Projection results

Removals from ***reforestation*** activities are estimated to average 24.2 Mt CO_2-e a year over the first commitment period. By 2020 removals are expected to decline to 10.2 Mt CO_2-e. This is due to declining average removal rates due to the increasing average age of the post-1990 plantation estate and the conversion of plantation forests to agricultural land uses.

The new international rules such as the cessation of the harvest sub-rule for ***reforestation*** activities from 2013 means that the time series is not strictly comparable between 2008-12 and 2013 onwards.

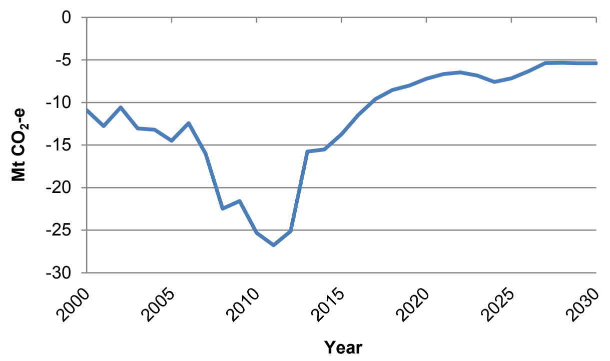
Table 5:
Reforestation net emissions, 2008-12, 2020, 2030

Year	Mt CO_2-e
2008-2012	-24.2
2020	-7.2
2030	-5.4

Source: *DIICCSRTE estimates.*

[1] Managed Investment Schemes were established by the *Income Tax Assessment Act 1997 (Cwlth)*. For more information, see: http://www.comlaw.gov.au/Details/C2013C00367

Figure 12:
Reforestation net emissions, 2000-2030



Source: *DIICCSRTE estimates, December 2012 Quarterly Update.*

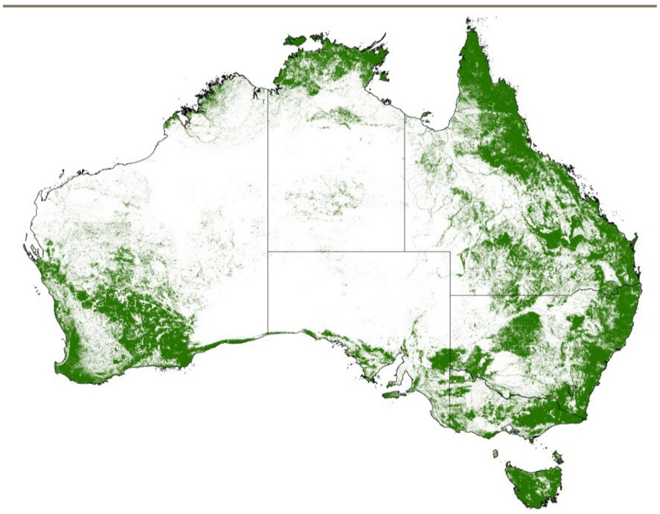
3.3 Forest Management

For the first commitment period of the Kyoto Protocol, 2008-2012, Australia's Kyoto Protocol inventory included emissions and removals from *afforestation/reforestation* and *deforestation* activities only. For the second commitment period, 2013-2020, the inventory will also include estimates of the emissions and removals from *forest management*.

3.3.1 The national inventory

Australia's land area of 769 million hectares incorporates a forest area of 108 million hectares. Native forests make up 106 million hectares while the remaining approximately 2 million hectares are plantations (Figure 13). Anthropogenic emissions and removals due to the management of Australia's forests are primarily the result of management activities and practices related to the production of wood and wood products.

Figure 13:
Forest area in Australia

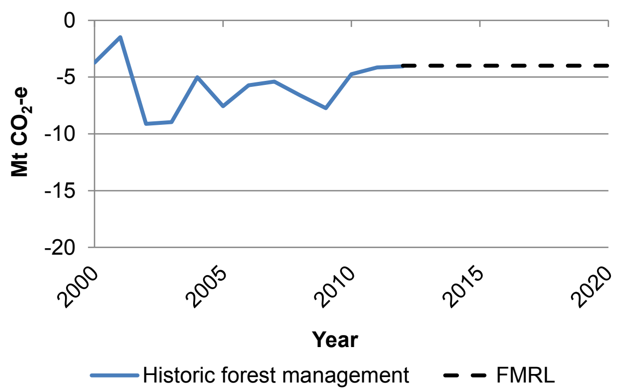


Source: *DIICCSRTE estimates.*

For the second commitment period, emissions accounting for *forest management* will be on the basis of a projected reference level. The reference level is a projection of emissions from *forest management* activities policies as at December 2009. Credits will be issued if actual net emission outcomes achieved over 2013-2020 are less than net emissions in the reference level. This treatment of the projected reference level is designed to identify enhancements to sinks or reductions in emissions that are the result of policies and changes in management actions introduced after 2009 relative to the reference level.

The emissions/removals for *forest management* land follow a stable trend with some inter-annual variation from 2000 through to the period covered by the forest management reference level (2013-2020) (Figure 14). On average, over the period 2013-2020, Australia's Forest Management Reference Level is projected to be -4 Mt CO_2-e per year (Figure 14).

Figure 14:
Historic Forest Management emissions and the Forest Management Reference Level (FMRL) (2013-2020)



Source: *DIICCSRTE estimates.*

3.3.2 Forest management lands

Forest management lands have been defined as those forests that are managed under a system of practices that include: forest harvesting; silvicultural practices; and the protection of natural resources within the areas of land available for harvest. Forests included under this definition are:

- Multiple Use Forests (Australia's State of the Forests Report, 2008); and
- Plantations established prior to 1990 (that is, those plantations that do not qualify for *afforestation/reforestation*).

Forest management activities (harvesting and silvicultural practices) also occur on privately managed native forest land. As the management intent on these lands is largely unknown, to ensure balanced and complete accounting for emissions and removals from forest management activities, harvesting on these lands since 1990 has been identified and included under *forest management*.

Forest management includes all timber production areas. The approach provides a clearly delineated and verifiable basis for monitoring and measuring changes in carbon stocks from Forest Management activities in the period to 2020. In 2011, the area of land that met the definition of *forest management* was 10.6 million hectares (Table 6).

Table 6:
Forest management land area[2]

Forest classification	Area (M ha)
Multiple Use Forests[3]	9.41
Private harvested native forests	0.39
Pre-1990 plantations	0.82
Total	10.6

Source: *DIICCSRTE estimates.*

Australia's native forests are dominated by *eucalypts* (78%), followed by *acacias* (7%) and *melaleucas* (5%). The distribution of forest types is mainly determined by climate and soil properties. Other factors, especially fire frequency and intensity, are also important.

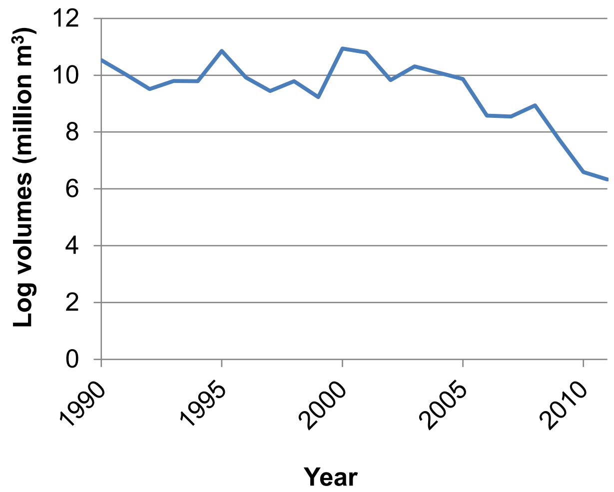
The treatment of natural disturbances for *forest management* has been an important consideration. A natural disturbance provision has been included with the *forest management* accounting rules that helps to manage the non-anthropogenic effects on emissions on *forest management* lands, such as the effects of extreme climatic conditions. The natural disturbance provision allows inventory compilers to exclude both the high emission events from natural disturbances such as wildfire, and the subsequent removals, as long as the process is consistent with certain technical accounting rules and does not generate an expectation of the creation of net credits or debits.

3.3.3 Drivers of emissions and removals

The key driver of emissions and removals on *forest management* land is forest harvesting and subsequent forest regrowth. Rates of log volumes removals from native forest have historically been ranged between 9-11 million cubic metres (M m^3) per year (Figure 15). In the period after 2009, the rates of log volumes removed have been outside of this historic range at 6.5 M m^3/year (Figure 15).

The decline in native forest harvesting has been associated with changes in supply factors such as increasing supply from plantations (particularly those established after 1990). Demand factors such as the international price of harvested wood products, the value of the Australian dollar and shifts in demand patterns, especially between Japan and China, have also contributed to the decline in harvesting.

Figure 15:
Log volumes removed from native forests



Source: *Australian Forest and Wood Products Statistics, March and June quarters, 2012.*

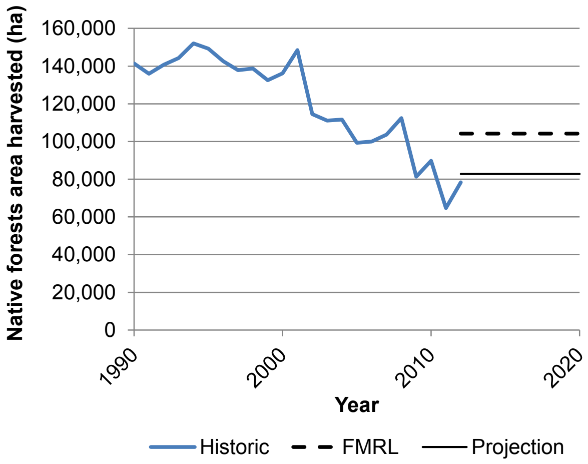
3.3.4 Key assumptions and activity data

The rate of forest harvesting each year (hectares per year) is used as the key independent variable in the *forest management* projections model. The assumption for this projection is that harvesting in native forests remains at current levels. Given the large number of factors that influence harvest rates, this is an assumption that will need to be carefully reviewed over time as new information on demand and supply factors emerge.

[2] The area of land falling into the Forest Management classification can increase over time due to the re-classification of land tenure (e.g. Multiple Use Forests) or additional areas of privately owned native forests become subject to forest management activities. Under the Kyoto Protocol reporting framework *forest management* land can be re-classified as *deforestation* if *deforestation* is observed to occur.

[3] This is the area of Multiple Use Forests in which wood production is an objective.

Figure 16:
Historic native forest harvest areas in Australia and the harvest areas applied in the construction of the forest management reference level (FMRL) and the current projection



Source: *DIICCSRTE estimates.*

As the forest management reference level is locked, based on harvest rates experienced between 2003-2009, and declines in market conditions occur in the years since 2009, the native forest harvest rates projected in this scenario are on average lower than those used for the calculation of the forest management reference level. The difference is 21,500 ha per year.

The harvesting rates for pre-1990 plantations are determined by the standard rotation lengths for each species. There is some potential for small variation around the rotation lengths that reflect economic, and other management decisions, however, in general the rotation length will not vary substantially.

3.3.5 Projections results

Over this period, economic conditions in the forest sector are assumed to remain subdued.

Consequently, *forest management* emissions remain at low levels due to continued historically low harvesting rates in native forests.

The results of the analysis indicate average abatement of approximately 8 Mt CO_2-e per year for *forest management* in the period 2013-2020 (Table 8).

Table 7:
Native forest harvest rates, 2000-2020

Year	Forest Management Reference level ('000 Ha)	Projected Forest Management ('000 Ha)
2000	136,206	136,206
2001	148,557	148,557
2002	114,504	114,504
2003	111,090	111,090
2004	111,620	111,620
2005	99,363	99,363
2006	99,977	99,977
2007	103,686	103,686
2008	112,433	112,433
2009	81,387	81,387
2010	89,748	89,748
2011	64,697	64,697
2012	78,294	78,294
2013	104,258	82,841
2014	104,258	82,841
2015	104,258	82,841
2016	104,258	82,841
2017	104,258	82,841
2018	104,258	82,841
2019	104,258	82,841
2020	104,258	82,841

Source: *DIICCSRTE estimates.*

Table 8:
Forest Management net emissions relative to reference level

Year	Emissions relative to reference level (Mt CO_2-e)
2013	-7
2014	-7
2015	-8
2016	-8
2017	-8
2018	-9
2019	-9
2020	-9

Source: *DIICCSRTE estimates.*

3.4 Cropland Management

As described in the introduction to this report, for the first commitment period of the Kyoto Protocol, the national inventory incorporated estimates of emissions for the mandatory land management activities of *deforestation* and *afforestation/reforestation* only. For the second period, the Government decided to account net emissions from *cropland management*, *grazing land management* and *revegetation* activities.

Cropland management is the system of practices on land on which agricultural crops are grown and on land that is set-aside or temporarily not being used for crop production.

The cropland category includes continuous cropping lands, lands which are cropped in rotation with pastures, as well as lands with woody perennial crops such as orchards or olive groves.

Accounting for *cropland management* requires a comparison of net emissions/removals in 1990 against net emissions/removals in the commitment period. Under the international rules, accounting for *cropland management* will only make a contribution towards meeting the target if, during the commitment period, net emissions are lower or net removals are higher than they were in the 1990 base year.

Emissions and removals from all land sector activities are to be estimated using methods consistent with guidance published by the 2013 Intergovernmental Panel on Climate Change (IPCC), including the *Revised Supplementary Methods and Good Practice Guidance for LULUCF Arising from the Kyoto Protocol* (forthcoming) and the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The methods that may be used for estimating carbon stock changes range from simple IPCC default tier 1 methods through to complex tier 3 modelling systems.

Recent changes to the international rules and guidance help to minimise the risk associated with accounting for these activities in the second commitment period by providing new tools to address the white noise of emissions from non-anthropogenic causes.

The IPCC 2013 *supplementary methods* (forthcoming) notes that the estimation of the impact of human activities and their trends over time is the main purpose of national greenhouse gas inventories. The *supplementary methods* make further explicit recognition that the effects of inter-annual climate variability and natural disturbance on emissions can be large enough to mask the signal of human activities, and that this is undesirable. Parties are advised to implement methods to minimise the impact of interannual variability on reported estimates and a number of examples are provided on how to achieve this.

One example is the approach that makes explicit impacts of land management changes on cropland emissions. Two time series of emissions and removals are calculated in which only management practices differ. This isolates the impact of human activity on emissions as the two time series include the same climate and natural disturbance data, and so background variability in emissions resulting from these sources is removed when the difference between the two time series is taken. This makes the estimate of soil carbon emissions analogous to how emissions of nitrous oxide from fertiliser application are already calculated.

This approach reduces the risks associated with having an unusually "wet" base year or "dry" condition during the commitment period. It provides greater consistency between Parties as it brings the higher tier methods into alignment with the tier 1 and tier 2 methods by controlling for the impacts of changes in management practices without the white noise associated with climate variability.

Other approaches identified by the IPCC, which may be used to manage inter-annual variability in emissions and isolate the impacts of changes in human activities, include:

- the exclusion of specified volatile pools from reporting, for example plant biomass from herbaceous and annual crops;
- measurement intervals for biomass of 5 years or longer rather than annual intervals;
- the *supplementary guidance* advises that a measurement interval should be chosen which does not make estimates susceptible to the impacts of annual fluctuations in weather. It also recognises that in some cases, for example soil carbon, a longer interval may be required to detect stock changes that are not the result of annual climate effects;
- the use of environmental data averaged over 5 or 10 years as an input to complex models, rather than annual data;
- the use of longer term averages of emissions and removals to represent the base year if climatic conditions were anomalous in 1990; and
- development of biomass growth rate functions from measurements of periodic growth as these represent average growth rates and are therefore influenced little by short-term fluctuations in environmental conditions (i.e. the application of tier 1 or 2 methods).

The *supplementary methods* provide for the development of additional approaches by countries as appropriate for national circumstances and advises that it is good practice to report on how inter-annual variation is addressed in inventory estimates.

3.4.1 Drivers of emissions and removals

Carbon dioxide emissions and removals from croplands are primarily the result of changes in the quantity of organic carbon stored in soils and in the biomass of woody crops including orchards and vineyards.

Changes in management practices affect soil carbon stocks over a long period (assumed by the IPCC to be 20 years). Consequently, changes in management practices observed between 1990 and 2010 will continue to have effects on soil carbon stocks if maintained at current levels.

Management practices that could be expected to affect the rate of loss of soil carbon include:

- tillage techniques;
- tillage frequency and intensity;
- crop type and rotation (including pasture leys);
- stubble management;
- fertiliser application;
- irrigation;
- green manures (particularly legume crops);
- soil ameliorants (application of manure, compost or biochar); and;
- burning practices.

Widespread changes in farming practices across Australia's agricultural lands in the period since 1990 have tended to slow the rate of soil carbon loss from cropland soils. In particular, there has been a significant shift towards low tillage techniques since the late 1980s. The estimates of net emissions from cropland management are based on activity data collated from ABS statistics, which provide data on changes in agricultural management practices since 1990.

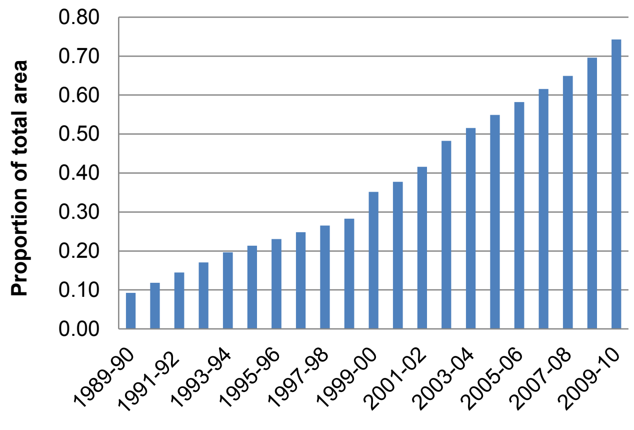
As shown in Figure 17, the area of cropland under minimum tillage practice increased from 9% of the total area in 1990 to 74% in 2010.

3.4.2 Activity data

The projection focuses on the effects of minimum tillage management practices. Management practices are assumed to remain constant for the projection period at rates observed in 2010 (Table 9).

Normal seasonal conditions are assumed.

Figure 17:
Proportion of total cropland area subject to no-till management, 1990–2010



Source: *DIICCSRTE estimates.*

Table 9:
Proportion of cropland areas managed using minimum tillage practices: 1990-2010

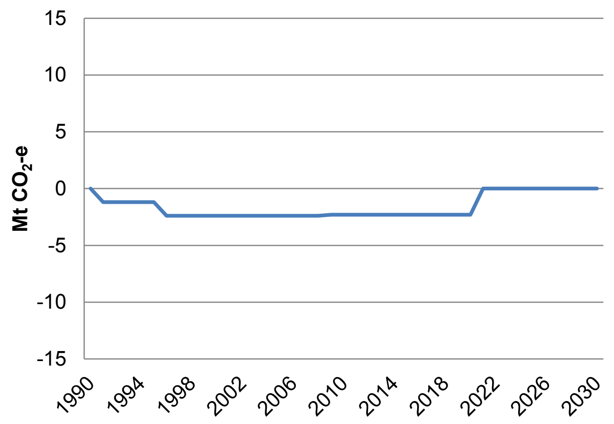
Year	Proportion	Year	Proportion
1989-90	0.09	2005-06	0.58
1990-91	0.12	2006-07	0.62
1991-92	0.14	2007-08	0.65
1992-93	0.17	2008-09	0.70
1993-94	0.20	2009-10	0.74
1994-95	0.21	2010-11	0.74
1995-96	0.23	2011-12	0.74
1996-97	0.25	2012-13	0.74
1997-98	0.27	2013-14	0.74
1998-99	0.28	2014-15	0.74
1999-00	0.35	2015-16	0.74
2000-01	0.38	2016-17	0.74
2001-02	0.42	2017-18	0.74
2002-03	0.48	2018-19	0.74
2003-04	0.52	2019-20	0.74
2004-05	0.55		

Source: *DIICCSRTE estimates.*

3.4.3 Projection results

Figure 18 provides the history and projections for net emissions from the *cropland management* activity. The activity is projected to generate net credits in the second commitment period because the rate of loss of soil carbon stocks is lower in the projection period than in the base year 1990. Projected net credits decrease somewhat in the period 2021–2030 because it has been assumed that there has been no additional change in policy or in management practices after 2010. Consequently, the projected *cropland management* estimates are the result of the ongoing effect of management practices already in place by 2010.

Figure 18:
Cropland Management net emissions, 1990-2030, relative to 1990 base year



Source: *DIICCSRTE estimates.*

Table 10:
Cropland Management, net credits (Mt CO_2-e per year)

Time Period	Net Credits	Total credits counted towards commitment each year	Additional Information
2008 - 2012	2.4	0.0	Activity not elected in CP1
2013 - 2020	2.3	2.3	Activity elected for CP2
2021 - 2030	-0.01	-0.01	Assuming continuation of KP rules

Source: *DIICCSRTE estimates.*

3.5 Grazing Land Management

Grazing land management is the system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced.

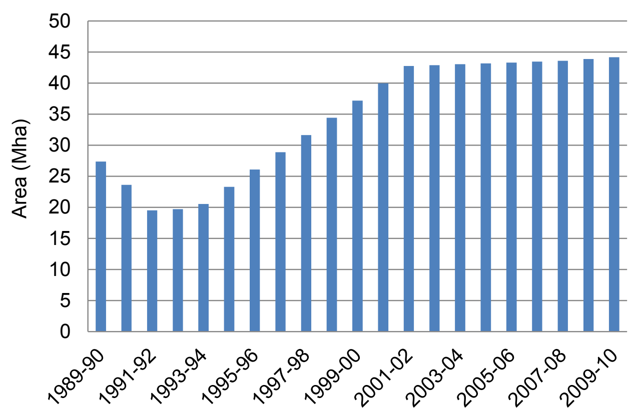
The area of land included under *grazing land management* is to be based on criteria established by individual Parties to the Kyoto Protocol as not all grasslands are grazed and grazing may occur on lands types other than grassland, such as forest and croplands. Lands may be included under *grazing land management* where growing of forage crops or livestock grazing is the most important activity on the area.

There are approximately 440 million hectares of grazing land in Australia, occurring across diverse climate, ecosystem and management systems. Pasture types and associated management intensities range from highly improved and sometimes irrigated pastures to extensive rangeland systems in the semi-arid and arid regions of Australia.

As explained in the *croplands management* section, anthropogenic emissions and removals from Australia's grazing lands result from changes in land management practices that affect the amount of carbon stored in live biomass and dead organic matter as well as the amount of residue, root and manure inputs to soil carbon. Identified management practices will focus on pasture improvement, fire management and woody shrub management.

Relevant land management practice across Australia's agricultural lands since 1990, which affect soil carbon stocks are documented with data from the Australian Bureau of Statistics. For example, there has been a significant increase in the area under improved pasture since the mid-1990s. In particular, the total area under pasture improved by fertiliser application has increased from 27 million hectares in 1990 to 44 million hectares in 2010 (Figure 19).

Figure 19:
Area of pasture fertilised, 1990-2010

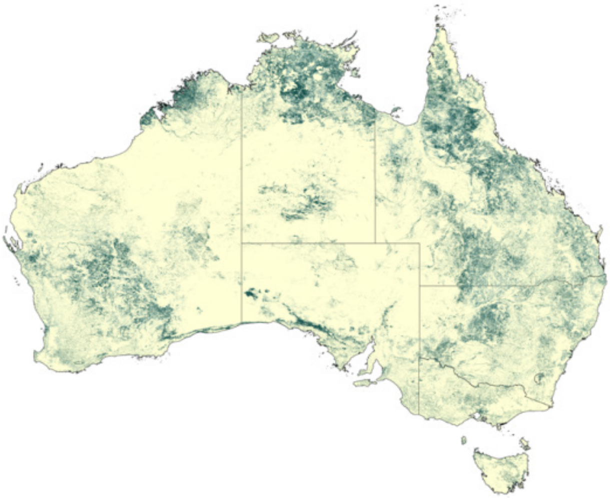


Source: *DIICCSRTE estimates.*

Other effects of management practices are monitored using remote sensing techniques.

Changes in the area of woody vegetation associated with changes in management practices will be monitored. Mapping of the extent, and change in extent in forest systems is now relatively straightforward using data from the Landsat satellite data archives.
Applying the techniques learned from the forest mapping, a national mapping program is currently underway to assess both the extent, and changes in extent, of sparse woody vegetation (shrub land) (Figure 20).

Figure 20:
Extent of sparse vegetation, 2002

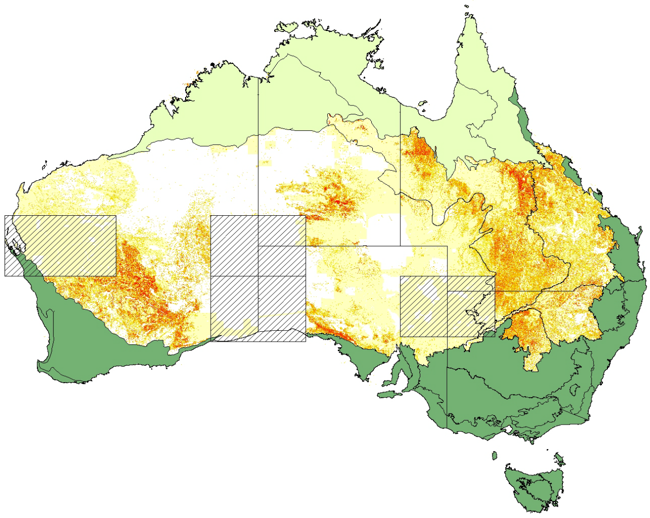


Source: *DIICCSRTE estimates.*

The national inventory system has made substantial progress toward mapping change in woody vegetation 1990–2006. Australia's forested areas, the northern savanna woodlands and the southern forested regions, are separated by a large grassland area which may also includes wetland or other lands (Figure 21). The black and white shaded grids in the grasslands area of Figure 21 indicate where sparse woody vegetation mapping is still in progress, to be completed over the coming months.

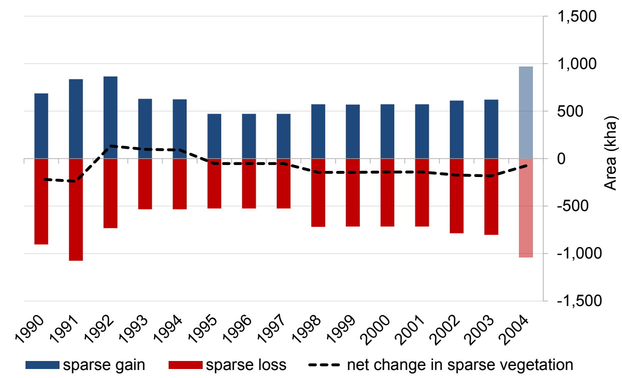
As shown in Figure 22, the total area of sparse woody vegetation has remained relatively constant over time with annual loss mirrored by annual gains. Preliminary estimates of emissions and removals associated with this annual area change suggest that annual net emissions from these vegetation types may approximate a steady state with relatively small variations over the longer term. A long-term shift in a particular direction would therefore be the result of a discrete change in management practice or land use as discussed above. For example, revegetation on a large area of grassland as the result of easing grazing pressure, could be expected to increase the sparse woody vegetation in the area and result in additional sequestration.

Figure 21:
Map showing the availability of sparse woody vegetation data derived from remote sensing data analysis for the years from 1990 to 2006



Source: *DIICCSRTE estimates.*

Figure 22:
Annual transitions between sparse vegetation and non-woody land [4]



Source: *DIICCSRTE estimates.*

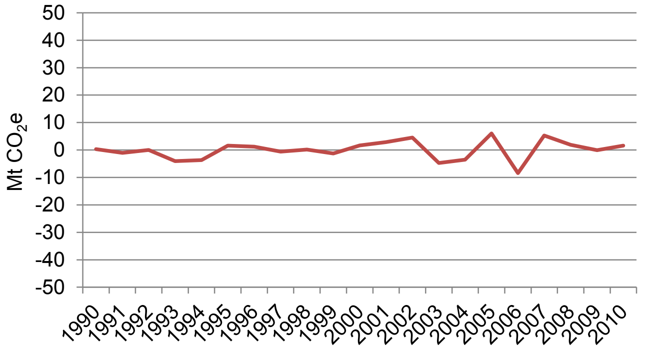
Savanna and other grassland ecosystems are burned by both wildfire and prescribed burning. Prescribed burning occurs for a number of reasons including pasture management, fuel reduction, and prevention of uncontrollable wildfires. Net carbon dioxide emissions resulting from prescribed fire and wildfire in these lands are estimated and reported as stock changes in the sparse woody vegetation. Thus, the estimates include both carbon emitted due to fire as well as carbon sequestered as vegetation regrows after burning. Non-carbon dioxide emissions from these fires are reported under the agriculture sector of the projections report and are not included here.

4 The results for 2005 change will be revised when areas of uncertain change are confirmed by additional years of data. Non woody areas include grasslands, wetlands and 'other' lands throughout Central Australia.

The long-term trend in net fire emissions from grazing lands, although variable, has been relatively constant over time (Figure 23) due to the offset of emissions from fire by subsequent carbon sequestration from the regrowth of woody vegetation.

In the short term, total emissions vary from a net source in years with relatively high fire activity to a net sink in periods of lower fire activity when sequestration by vegetation regrowth on areas burned in previous years has the largest effect on net emissions.

Figure 23:
Net emissions from fire in grassland remaining grassland



Source: *DIICCSRTE estimates.*

3.5.1 Key assumptions and activity data

ABS statistics publications provide evidence of changes in agricultural management practices since 1990 that affect net emissions from grazing lands. The impact of the increase in the area of improved pasture due to fertilizer since the mid-1980s on grazing land soil carbon stocks is expected to be approximately equal in the second commitment period and in the 1990 base year.

Annual activity data for the estimation of net emissions from fires and changes in the area of woody vegetation are collected from the inventory's remote sensing program, as described above.

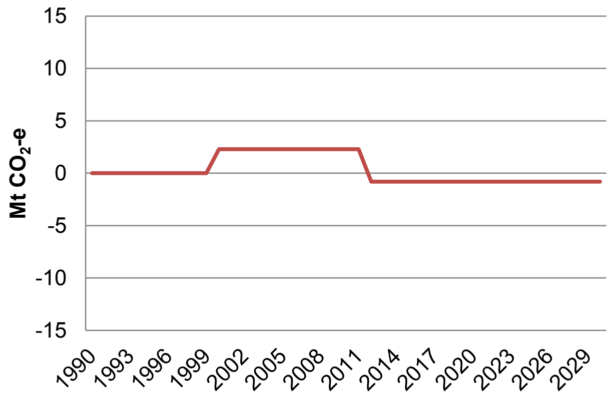
It is assumed that management practices are held constant throughout the projection period.

3.5.2 Projections results

Figure 24 provides the history and projections for net emissions from the grazing land management activity. The activity varies from a small net source to a modest net sink, across the period.

Estimated abatement from grazing lands is projected to be modest given current policies and existing methods. New empirical data sources are expected to emerge for this activity over time. The methodologies and models necessary to fully implement this new activity, and the cropland management activity in the national inventory system, will be refined in future as this new scientific evidence becomes available.

Figure 24:
Grazing land management emissions 1990–2030, relative to 1990 base year



Source: *DIICCSRTE estimates.*

Table 11:
Grazing land management, net credits (Mt CO_2-e) emissions

Time Period	Net Credits	Total credits counted towards commitment each year	Additional Information
2008 - 2012	-2.3	0	Activity not elected in CP1
2013 - 2020	0.8	0.8	Activity elected for CP2
2021 - 2030	0.8	0.8	Assuming continuation of KP rules

Source: *DIICCSRTE estimates.*

3.5.3 Vegetation regeneration

For the second commitment period, total emissions from the LULUCF sector may include removals from land areas undergoing regeneration of vegetation in certain circumstances. In particular, where documentation can be provided to demonstrate that the growth of the vegetation is the result of a deliberate land management activity (or is 'directly human-induced').

A final classification system for these lands must be determined prior to April 2015, the first reporting date for the second commitment period under the Kyoto Protocol.

Under the Kyoto Protocol rules, Australia could choose to classify these lands as either *grazing land management* or *afforestation/reforestation*.

Where lands have been managed primarily for livestock grazing and the regeneration is not intended to change the land use, such lands could be considered part of the grazing management activity.

Alternatively, if the growth of the vegetation is the result of a land management decision to convert a grassland to forest, these lands may be considered to be *afforestation/ reforestation*.

In 2010, there were approximately 9 million hectares of land meeting the definition of vegetation regeneration as described above. The distribution of these lands across Australia's States and Territories is provided in Table 12.

Table 12:
Distribution of additional, cumulative *afforestation/ reforestation* lands, 2010

State/Territory	Area (ha)
New South Wales	2,347,836
Northern Territory	1,478,642
Queensland	2,496,829
South Australia	537,796
Tasmania	146,327
Victoria	376,292
Western Australia	1,652,278
Total	9,036,000

Source: DIICCSRTE (2013).

Preliminary result indicates that approximately 12.5% of the observed natural regeneration is associated with regions where land-clearing restrictions can limit the ability of landholders to maintain areas under production if forest regrowth occurs. Assuming 12.5% of 9.036 million hectares is directly human-induced, the rate of human-induced natural regeneration is approximately 55 000 ha per year over the period 1990-2010. Over the projection period, the removals associated with these areas are estimated to be 3 Mt CO_2 per year, equivalent to a growth rate of approximately 1.5 t CO_2 per hectare per year. This is a low rate of annual growth as this vegetation will be largely regenerating in water-limited environments in inland regions.

The removals from these lands has been added to the projected LULUCF emissions totals from 2013 onwards (Figure 1, page 2).

4. SENSITIVITY ANALYSIS

4.1 Deforestation

As described in the *methodology section*, emissions projections for *deforestation* were modelled from estimated relationships between areas of land clearing activity and movements in the *farmers' terms of trade*. The *farmers' terms of trade* are a measure of economic conditions in the farming sector, providing an indication of the incentives for landowners to clear land to expand agricultural production. Changes in the outlook for international commodity prices that affect the *farmers' terms of trade* can have a significant impact on land clearing and deforestation emissions.

Projections of the *farmers' terms of trade* are produced by ABARES (the central scenario). Two sensitivity scenarios were considered for the years 2012 to 2019. A high terms of trade scenario was modelled assuming a 30% increase on the central-price scenario, and a low terms of trade scenario modelled assuming a 30% decrease on the central-price scenario. Consistent with the central scenario, the change in government policies on land clearing is incorporated into all scenarios.

In the high and low scenarios, *deforestation* emissions stabilise at higher and lower levels over the longer term, respectively, compared to the central scenario (Figure 25 and Table 13).

The upper and lower bound of the sensitivity analysis are not perfectly symmetrical. This is due to soil carbon emissions, splicing methods and other adjustments.

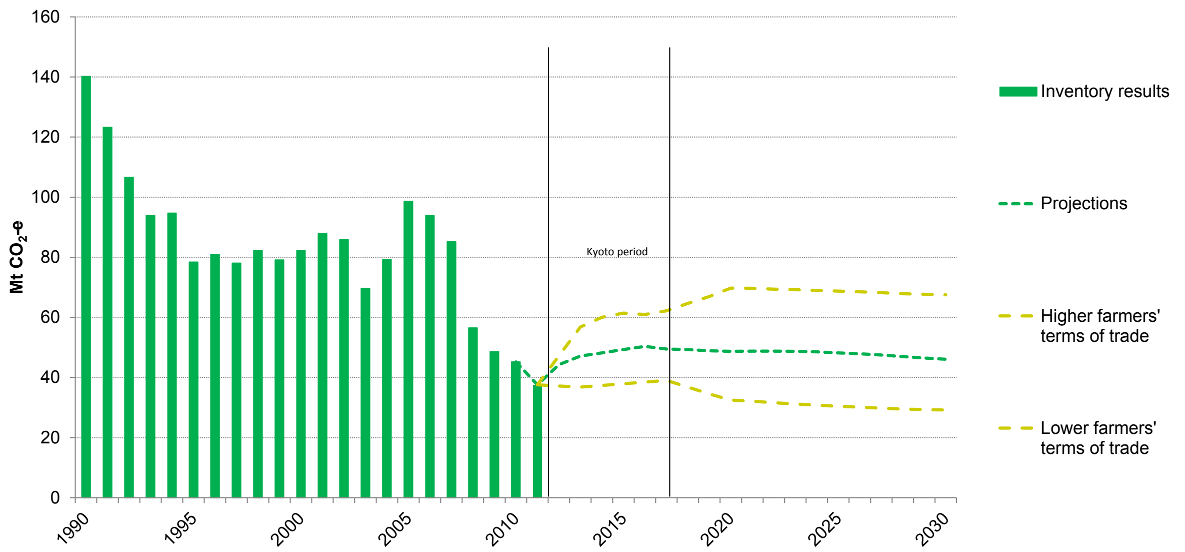
In addition to the *farmer's terms of trade*, *deforestation* emissions in the projection period will be impacted by state and federal regulatory changes and other factors as described in *section 3.1: Deforestation.*

Table 13:
Projected deforestation emissions under the sensitivity analysis and central scenarios

Scenario	2020 (Mt CO_2-e)	2030 (Mt CO_2-e)
High	69.73	67.5
Central	48.71	46.09
Low	32.49	29.2

Source: *DIICCSRTE estimates.*

Figure 25:
Deforestation emissions: sensitivity analysis



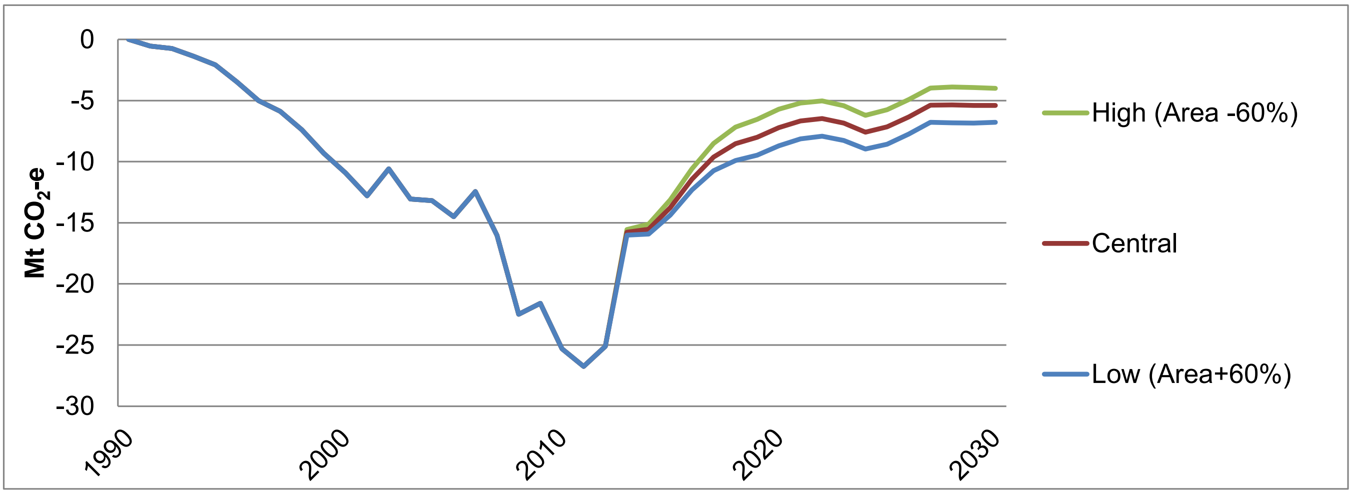
Source: *DIICCSRTE estimates.*

4.2 Reforestation

The key uncertainty in the reforestation projection is assumed planting rates. High and low scenarios were modelled assuming planting rates 60% lower (high emissions scenario) and 60% higher (low emissions scenario) than the central scenario (see *methodology section*). Consistent with the central scenario, the high and low sensitivity analyses have been reported as a five-year rolling average of the annual modelled data. The results are summarised in Figure 26 and Table 14.

There is a low level of sensitivity in the *reforestation* projection model to the high and low emissions scenarios. This is due to the soil carbon pool and the harvested wood product pool (after 2012) acting as a buffer to short term shifts in the plantation establishment rate.

Figure 26:
Reforestation emissions: sensitivity analysis



Source: *DIICCSRTE estimates.*

Table 14:
Projected reforestation emissions under the sensitivity analysis and central scenarios

Scenario	2020 (Mt CO_2-e)	2030 (Mt CO_2-e)
High (Area -60%)	-5.71	-4.01
Central	-7.21	-5.39
Low (Area +60%)	-8.71	-6.77

Source: *DIICCSRTE estimates.*

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