Forest Reference Level for Pre-1990 Natural Forests under the Paris Agreement

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Report information sheet

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Executive summary

The problem

A Forest Reference Level (FRL) is required for accounting for pre-1990 forests under the Paris Agreement. The Planted Forest component is based on a projection of net emissions under business-as-usual management, as defined for the 2000-2009 reference period. This is ultimately created through simulating harvesting and replanting in the Ministry for the Environment's Calculation and Reporting Application (CRA). The natural forest component of the FRL is calculated separately and integrated into the overall FRL. It should be based on the data used in national greenhouse gas inventory reporting and will also be calculated in the CRA.

This project

This report describes the data and approach used to establish the Forest Reference Level of expected net emissions from New Zealand's natural forests during the Paris Agreement compliance period from 2021-2030.

Key results

The pre-1990 natural forest FRL value of -1,399,534 t CO_2 $year^{-1}$ reported here represents the average annual net emission from these forests from 2021 to 2030. In this case carbon uptake in pre-1990 Regenerating natural forests outweighs the small loss of carbon from pre-1990 Tall natural forests, and smaller emissions from soil (due to land use change) and wildfires. The carbon stock changes per hectare for the two natural forest strata were calculated from analysis of data from the LUCAS natural forest inventory and are not statistically different from zero in either case.

Implications of results for the client

The Pre-1990 Natural Forest FRL is one component within the overall Pre-1990 Forest Reference Level for Paris Agreement accounting. It is combined with pre-1990 Planted Forest FRL, based on projected changes in the stock within pre-1990 planted forests and the HWPs produced from them after 2012.

Further work

It is recommended that:

• Estimates of carbon stock changes should be re-calculated when the third measurement cycle of the natural forest inventory is complete, and the results incorporated in both greenhouse gas inventory reporting and the FRL (through a Technical Correction).

• The background level of natural disturbance for use in accounting under the Paris Agreement should be reviewed. In the interim the value derived for Kyoto Protocol accounting can be used.

• A review of the emissions from harvesting in pre-1990 natural forests and the end uses and lifespans of the resulting HWPs be undertaken, particularly if there are indications that production is increasing over the compliance period.

Forest Reference Level for Pre-1990 Natural Forests under the Paris Agreement

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Introduction

The Paris Agreement is the global agreement on climate change adopted by Parties under the United Nations Framework Convention on Climate Change (UNFCCC) on 12 December 2015. Under the Paris Agreement New Zealand has committed in our Nationally Determined Contribution to reduce greenhouse gas emissions to 50 percent below gross emission levels in 2005 by 2030.

New Zealand has indicated that it will apply a modified version of Kyoto Protocol accounting rules to estimate and report its net emissions.[1] For net emissions from pre-1990 forests, this means that accounting will be against a Forest Reference Level (FRL), which defines expected net emissions during the 2021-2030 compliance period based on the assumption of a continuation of business-as-usual management practiced during the 2000-2009 reference period.

The Planted Forest component of the FRL is based on a projection of net emissions assuming the management and harvesting practices employed during the reference period. This is ultimately created through simulating harvesting, replanting and deforestation in the LUCAS Calculation and Reporting Application (CRA). The natural forest component of the FRL is calculated separately and integrated into the overall FRL. In both cases the FRL should be based on the data used in national greenhouse gas inventory reporting and calculated in the CRA, as used for reporting.

This report describes the data and approach used to establish the Reference Level of expected net emissions from New Zealand's natural forests during the Paris Agreement compliance period from 2021-2030.

Materials and methods

Scope

There are no mandatory guidelines for the preparation of a Forest Reference Level. There is an expectation that the approach will be consistent with IPCC guidance on greenhouse gas inventory reporting (IPCC 2006, IPCC 2014, IPCC 2019). Under the "activity-based" Kyoto Protocol accounting rules adopted by New Zealand, all managed forests first established before 1 January 1990 should be accounted for against the FRL. Natural forests established onto land that was not forest land as at 31 December 1989 (i.e. post-1989 natural forests) are accounted for separately.

The FRL applies to both pre-1990 planted forests and pre-1990 natural forests as defined in New Zealand's greenhouse gas inventory. New Zealand considers all of its planted and natural forests to be managed (MFE 2024).

Principles

Principles for New Zealand's pre-1990 natural forest FRL are:

1. FRL should reflect business-as-usual practices in natural forests during a reference period ending before 2010. The period 2000-2009 was initially adopted by the European Union (Forsell et al. 2018).
2. The methodology should be able to reproduce greenhouse gas inventory reporting from 2000 to 2020.
3. FRL should be based on the methods and LUCAS data used for New Zealand's greenhouse gas inventory reporting.

[1] https://unfccc.int/sites/default/files/NDC/2022-06/New%20Zealand%20NDC%20November%202021.pdf

European Union approach to developing the NF RFL

The key methodological steps described in the European Union approach to FRL development (Forsell et al.,2018) are based on earlier work by Grassi and Pilli (2017):

1. Stratify the area of *Forest remaining Forest*[2] based on national circumstances. Strata should be characterised by specific management objectives and practices.

2. Identify and stratify the forest management practices for each stratum during the reference period. These should be quantifiable criteria, e.g. the age, diameter or volume at which thinning or harvesting occurs, and monitored over time to document changes.

3. Project the evolution of *Forest remaining Forest* [for New Zealand, pre-1990 natural forest] area. Here it would be assumed that the deforestation rate over the reference period continues.

4. Project the future carbon gains and losses in each pool and stratum.

   4.1. Forest increment is calculated by the continuation of the management practices described in step 2.

   4.2 Estimation of carbon losses due to harvesting, which requires:

   a) Calculation of the *biomass available for wood supply* during the reference period ($BAWS_{RP}$). In their example, if Norway spruce is typically harvested between 80-140 years of age, the BAWS is the biomass available in this age range.

   b) Documentation of the harvest volumes during the reference period (H_{RP}).

   c) Calculation of the average harvest fraction over the reference period as HF_{RP} = mean H_{RP} / mean $BAWS_{RP}$. This is calculated for each stratum.
   The HF_{RP} is a proxy that captures the impact of all constraints (markets, policies, owners' behaviours, accessibility etc) on wood volumes during the reference period.

   d) Calculation of the expected evolution of the biomass available for wood supply in the compliance period, based on the age class distribution and growth rates.

   e) Calculation of the future harvest during the compliance period by multiplying the mean harvest fraction over the reference period by the expected biomass available.

5. Estimate projected HWP pool stock changes by applying the same HWP category proportions as during the reference period.

The most important component of a production forest FRL is the projected level of harvesting, which has a major influence on net emissions. This is reflected in the EU approach outlined above, which pays particular attention to defining business-as-usual harvesting practices during the reference period and using this as the basis for projecting harvesting during the compliance period, as captured in the FRL. However, harvesting is not part of the usual management of most of New Zealand's pre-1990 natural forests, where natural disturbances have a much greater role in driving net emissions.

The steps above were followed as described in the following section to derive a FRL for pre-1990 natural forests in New Zealand. In essence the FRL is based on:

- areas of pre-1990 natural forests by strata, and
- estimates of the expected average net stock change per hectare annually from 2021-2030 by strata, assuming that the management applied in the reference period continues.

[2] Note that the EU proposed to use a "land-based" rather than "activity-based" approach in line with greenhouse gas inventory reporting, so the pre-1990 (Forest Management) and post-1989 (Afforestation/Reforestation) distinction made under the Kyoto Protocol is not used. In New Zealand's case, it would be Forest Management area (i.e. pre-1990 Natural Forest area)

Developing a FRL for New Zealand's Natural Forests

1. Stratify the area of *Pre-1990 Natural Forest* based on national circumstances.

New Zealand's pre-1990 natural forest area has been mapped in two strata, Tall forest and Regenerating forest, based on forest classes mapped in version 5 of the Land Cover Database (LCDB5; Thompson et al. 2003, Landcare Research 2019). Table 1 provides the area of each of these strata from 1990 to 2022.

Table 1. Strata of pre-1990 Natural Forests and their area in New Zealand* (MFE, 2024)

	Area (kha)		
	Tall	**Regenerating**	**Total**
1990	6689.453	1124.330	7813.783
1991	6688.609	1122.011	7810.620
1992	6687.766	1119.692	7807.457
1993	6686.922	1117.372	7804.294
1994	6686.078	1115.053	7801.131
1995	6685.234	1112.734	7797.968
1996	6684.391	1110.414	7794.805
1997	6683.547	1108.095	7791.642
1998	6682.703	1105.776	7788.479
1999	6681.860	1103.456	7785.316
2000	6681.016	1101.137	7782.153
2001	6680.172	1098.818	7778.990
2002	6679.328	1096.498	7775.827
2003	6678.479	1094.179	7772.658
2004	6677.635	1091.860	7769.495
2005	6676.791	1089.541	7766.332
2006	6675.947	1087.221	7763.169
2007	6675.104	1084.902	7760.006
2008	6674.868	1084.493	7759.361
2009	6674.026	1083.022	7757.048
2010	6673.260	1082.042	7755.302
2011	6672.761	1081.620	7754.382
2012	6672.263	1081.096	7753.359
2013	6671.838	1080.430	7752.268
2014	6671.501	1080.231	7751.732
2015	6670.959	1079.852	7750.811
2016	6670.519	1079.568	7750.086
2017	6670.263	1079.279	7749.542
2018	6670.028	1078.895	7748.923
2019	6669.756	1078.504	7748.260
2020	6669.503	1078.150	7747.653
2021	6669.250	1077.764	7747.014
2022	6668.997	1077.378	7746.375

* Areas from 2008-2022 exclude 27.4 ha of pre-1990 forest land that had been deforested after 1989 and then converted to pre-1990 natural forest. This land is accounted for as Deforestation land.

Tall forest is made up of two LCDB classes:
1. Indigenous forest: tall forest dominated by indigenous conifer, broadleaved or beech species.
2. Broadleaved indigenous hardwoods: lowland scrub communities dominated by indigenous mixed broadleaved shrubs.

Regenerating forest consists of all other areas of pre-1990 natural forest that fall outside the two LCDB classes above. They generally represent forests regenerating from previous disturbances.

Within these two strata different forest types can be identified, and classification by region or ownership could also be made. In practice reporting has been confined to the two classes – Tall and Regenerating – because:

- Management objectives and practices for most natural forest is similar, whether in private or public ownership and regardless of forest type, with very little harvesting.
- The plot network used to estimate carbon stocks and stock changes is not dense enough to allow statistically significant differences in sequestration rates to be detected for smaller strata, given that carbon stock changes are small relative to the size of the pool.

There is little information that would allow stratification according to management objectives and practices. The large area of indigenous forest in New Zealand is principally managed for its role in protecting and regulating soil, biodiversity, water flows and quality, and for recreation and scenic values. Over 5 million ha of pre-1990 natural forests are management by the Department of Conservation for conservation of biodiversity, with another 100,000-200,000 ha of privately owned forest under conservation covenants (FAO 2020). In contrast, only 50,000-100,000 (~1%) of state and privately-owned indigenous forest is available for timber production (FAO 2020). While all forests in New Zealand are considered to be managed in the context of UNFCCC reporting (MFE 2024), management involving active silviculture and harvesting is only applied to a very small proportion of the area of natural forests, and net emissions in these forests are largely driven by natural processes.

The lack of active management has also limited the need for quantitative assessment of standing volume and biomass. As a result, there is little available nationally representative data before the implementation of the LUCAS Natural Forest inventory developed to meet Kyoto Protocol reporting requirements, and little data regarding business-as-usual management practices that may affect carbon stocks and stock changes. At a national level it is expected that the impacts of any harvesting will be captured in national stock change estimates from the forest inventory to the extent that sampling on the 8km grid and access permission for field inventory teams allows this. More intensive sampling would probably be required to make robust estimates of stocks and stock changes on natural forest land that is subject to harvesting.

2. Identify and stratify the forest management practices for each stratum during the reference period.

The intention of this step in the EU approach is to provide quantifiable criteria that define business-as-usual activities, particularly thinning and harvesting practices. These criteria include the tree or stand age, diameter or volume used to schedule interventions. As noted above, these activities are not drivers for net emissions by pre-1990 natural forests in New Zealand, as the area likely to be affected is small.

There are other management interventions that may alter carbon stocks in these forests, including:

- pest control (particularly control of invasive browsing pests)
- livestock grazing or exclusion
- weed control
- supplementary planting
- provision of infrastructure for recreation and tourism.

Previous work (Easdale and Burrows 2021) suggests that the ability to detect changes in carbon stocks due to activity such as pest control may be limited over the compliance period (2021-2030). It would also be difficult to identify both the extent of these management interventions during the reference period and their impact on carbon stocks, in order to support any later claim against the

FRL arising from improved management. There is ongoing research in this area which could later support stratification by management practices that positively or negatively affect carbon stocks. Stratification could later be made on this basis, requiring a technical correction to the FRL.

3. Project the evolution of *Pre-1990 Natural Forest* area.

Two options are provided by Forsell et al. (2018) for projecting the evolution of natural forest area:

a) Assume constant area of managed land, or
b) Account for projected gains and losses of forest area.

In both cases technical corrections (IPCC 2014) are required to ensure the FRL area matches the actual areas reported, so the end result will be the same. The advantage in projecting area changes is that future technical corrections due to area adjustments should be smaller.

Future mapping improvements that change the area of pre-1990 natural forests would apply to the whole time series for both greenhouse gas inventory reporting and the FRL, requiring a technical correction to the FRL (IPCC 2014). These adjustments will ensure the area used in the FRL is consistent with the area used in reporting. Other gains and losses of area do not necessarily imply that a technical correction is needed.

Gains of pre-1990 Natural Forest area

Pre-1990 natural forest can increase in area from two sources:
1. Conversion of non-forest land to pre-1990 natural forest
2. Conversion of pre-1990 planted forest to pre-1990 natural forest.

New natural forests on land converted from non-forest land uses or from post-1989 planted forests will normally be classed as post-1989 natural forests and, accordingly, will be accounted for outside the FRL. Land that is instead converted from non-forest land into pre-1990 forest land must have undergone multiple land use changes previously including deforestation. This land is reported in the greenhouse gas inventory as pre-1990 forest land but for accounting it should remain as Deforestation land (IPCC 2014). This means it is not included in the FRL.

Land converted from pre-1990 planted forest to pre-1990 natural forest has different implications for accounting depending on when it was converted:

- Conversion before 2002 - All soil carbon stock changes are complete before 2021, so are not included in FRL. Ongoing biomass stock changes are included in the FRL because the area is natural forest during the reference period.
- Conversion 2002-2009 – All ongoing net stock changes occurring in 2021-2030 are included in the FRL.
- Conversion 2010-2030 – these conversions are not considered to be business-as-usual, so net emissions from conversion in these years are not included in the initial FRL, and not included via a technical correction. Soil carbon change would be compared against a baseline of no soil carbon change (i.e. land area is assumed to stay as planted forest instead), so are accounted for in full. Biomass stock change (based on the new area of natural forest) would be compared against stock changes in the planted forest FRL, assuming that the converted area remained as planted forest instead.

According to the land use change estimates reported in the greenhouse gas inventory for 2024, most of the gain in pre-1990 natural forest since 2000 has been from pre-1990 planted forest. Pre-1990 natural forest only gained an average of 2.8 ha per year from non-forest land uses over the reference period (MFE 2024; Appendix Table A1). This increased to 34.2 ha annually from 2010 to 2020, mainly from Grassland with woody biomass. For recent years (2017-2020), the inventory estimates show an annual gain of 10 ha from high- and low-producing grassland combined. These areas should be accounted for as Deforestation land, rather than as part of the pre-1990 FRL.

A total of 1,216 ha of pre-1990 planted forest was converted to pre-1990 natural forest between 2002 and 2009, and these areas will still be emitting CO_2 and N_2O due to soil carbon loss during the compliance period. These emissions should be included in the FRL.

Losses of pre-1990 Natural Forest area

Area can be lost from pre-1990 Natural Forest in two ways:
1. Deforestation (conversion to a non-forest land use)
2. Conversion to pre-1990 planted forest (referred to as “overplanting”).

Forsell et al (2018) state that for projections of deforestation, the average annual loss from 2000 to 2016 should be used. However, the 2016 data was chosen simply because this allowed all data available at that time to be used. Given that a technical correction will be required anyway, all available historical data should be used to project deforestation over the 2021-2030 period as this is likely to give the most accurate prediction of future land use change.

Deforestation emissions do not form part of the FRL under activity-based accounting: any deforestation that occurs during the compliance period will be accounted for in full and require a technical correction to the FRL to ensure that pre-1990 natural forest area is consistent between reporting and the FRL.

Table 2 provides the annual deforestation rate in pre-1990 natural forest area from the 2024 greenhouse gas inventory submission (MFE 2024). This excludes area converted to planted forest (which is not deforestation). The ten-year average from 2011-2020 used for projections from 2021 is also provided.

Table 2. Annual deforestation rate by Pre-1990 Natural Forest strata (MFE 2024)

	Tall forest (ha)	**Regenerating (ha)**	**Total (ha)**
1990-2008 (annual avg.)	509.98	1281.02	1791.00
2009	798.75	1732.31	2531.06
2010	734.94	1243.64	1978.58
2011	467.00	684.95	1151.95
2012	467.08	794.08	1261.16
2013	423.54	829.39	1252.93
2014	335.77	347.36	683.13
2015	540.32	527.71	1068.03
2016	438.89	433.19	872.08
2017	242.51	248.19	490.70
2018	221.15	343.01	564.16
2019	258.27	350.28	608.55
2020	239.04	313.63	552.67
2021	239.49	335.64	575.13
2022	239.49	335.64	575.13
Annual avg. 2011-2020	*363.36*	*487.18*	*850.54*

Additional area can be lost from pre-1990 natural forest land through conversion to pre-1990 planted forest land (overplanting, rather than deforestation). This affected 25,519 ha from 1990 to 2009 (Appendix Table A2). This land will be included as planted forest within the FRL. Area lost to pre-1990 planted forest from pre-1990 natural forest after 2009 is treated as a change in management, so it stays in the FRL as natural forest without requiring a technical correction.

There are also potential land use transitions *within* the natural forest land category. It is possible for Tall forest to transition into Regenerating forest, and vice versa. However, Regenerating forest types mapped in LCDB5 are unlikely to have transitioned to a Tall forest type by 2030. Tall forests

could transition to Regenerating forest through disturbance events. This can be assessed when LCDB6 is available. For the reference period it can be assumed that these transitions did not occur. In principle, transitions between strata are not allowed within a FRL, as this would normally be regarded as a change in management.

Deforestation was modelled to 2030 for New Zealand's planted forest FRL but increases in pre-1990 planted forest area were not included. If this approach is also used for pre-1990 natural forest FRL, then the pre-1990 natural forest area would be held constant as at the end of 2009 (after removing any Deforestation land), other than any deforestation projected to 2030.

For the pre-1990 natural forest FRL component, the area as at 2009 (Table 1) is used as the base area. Areas from 2010 to 2020 in Table 1 are replaced by applying actual deforestation areas in Table 2. This means that no gains in natural forest area occur after 2009 (e.g. areas converted from planted forest to natural forest after 2009 are not included in the natural forest component of the FRL. The average deforestation rate over the ten-year period 2011-2020 (Table 2) assumed to continue annually from 2021-2030. The pre-1990 natural forest areas included in the FRL therefore include land that was pre-1990 natural forest during the 2000-2009 reference period but has since been converted to planted forest, but exclude any land converted to pre-1990 natural forest after 2009 (Table 3).

Table 3. Pre-1990 natural forest area assumed over the 2021-2030 Paris Agreement compliance period

	Tall forest (kha)	Regenerating (kha)	Total area (kha)
2021	6669.294	1076.420	7745.714
2022	6668.931	1075.932	7744.863
2023	6668.567	1075.445	7744.013
2024	6668.204	1074.958	7743.162
2025	6667.841	1074.471	7742.312
2026	6667.477	1073.984	7741.461
2027	6667.114	1073.497	7740.611
2028	6666.751	1073.009	7739.760
2029	6666.387	1072.522	7738.910
2030	6666.024	1072.035	7738.059

In summary, the areas used in the pre-1990 Forest Reference Level for natural forests (Table 3) comprise:

- Pre-1990 natural forest area as at the end of 2009:
  - *including* pre-1990 natural forest land that had been converted from pre-1990 planted forest *before* 2010
  - *excluding* 27.4 ha of pre-1990 natural forest established after a post-1989 deforestation event (which is therefore accounted for as Deforestation land rather than included in the FRL).
  - *ignoring* conversion of pre-1990 natural forest to pre-1990 planted forest *after* 2009 (as these areas remain as pre-1990 natural forest in the FRL)
  - *including* actual deforestation from 2010 to 2020 and projected deforestation from 2021-2030 based on the ten-year average deforestation rate from 2011-2020 in Table 2 (850.5 ha $year^{-1}$ in total).

4. Project the future carbon gains and losses in each pool and stratum.

There are two parts to this step in the EU approach:
1. Determining forest carbon increment.
2. Estimating forest carbon losses due to the continuation of harvest practices.

Net Stock Changes in Pre-1990 Natural Forest strata

Estimates of net carbon stocks and stock changes in New Zealand's pre-1990 natural forests are obtained through the LUCAS Natural Forest Inventory, administered by the Ministry for the Environment (MfE 2023a).

Data has been analysed for the first two complete cycles of the pre-1990 Natural Forest Inventory and for part of the third cycle. Measurement of the third cycle is expected to be completed in 2024 with analysis of these data expected to be completed in 2025 (Table 4).

Table 4. Pre-1990 Natural Forest Inventory measurement cycles

Cycle	Measurement start & end-year	Mid-point	Plots measured (to Dec 2022)	Mean time between measurements
C1	2002 - 2007	2004	1,028	
C2	2009 - 2014	2012	923	C1 to C2: 7.7 years
C3	2014 – 2024 (expected)	2019	662	C2 to C3: 5.7 years (to Dec 2022)

The published analysis covers the first two cycles only (Paul et al 2021). This analysis has formed the basis for the National Inventory Report (NIR) submitted in 2023 (1990-2021 inventory, MFE 2023) and the 2024 NIR submission (MFE 2024). However, for these NIR submissions the published values in Paul et al. (2021) were re-stratified using the mapped Tall and Regenerating forest classes from LCDB5 to assign carbon values to mapped strata, rather than to forest types based on plant species composition within plots (which was the method followed by Paul et al 2021).

An unpublished report reanalysed the first two cycles and included available measurements from the third cycle as of mid-2020 (Paul and Wakelin 2023). Of the 1,028 plots measured in C1, about half (545) had been measured three times by December 2023. Another 47 plots were added for the first time in Cycle 3. However, because the measurement cycle is incomplete, only the stock change estimates from Cycle 1 to Cycle 2 have been reported in the greenhouse gas inventory.

Before 2002 there was no national, representative sampling of biomass in natural forests in New Zealand, so there are no estimates of stock change during the 2000-2009 reference period or earlier. It is therefore necessary to use the stock change from Cycle 1 to Cycle 2 to represent the change during the 2000-2009 reference period and assume a continuation of this rate for the FRL. This is consistent with the approach taken for greenhouse gas inventory reporting. A Technical Correction to the FRL will be required when Cycle 3 measurements are complete, and the assumptions used in greenhouse gas inventory reporting should then be changed to maintain consistency.

Table 5 provides the plot analysis based on reassigning plots to the Tall and Regenerating strata based on the 2008 map from the 2019 LCDB5 release. Only plots measured in both Cycle 1 and Cycle 2 were included, and the carbon stocks and stock change are calculated using the sum of the sub-pools rather than the total values from the plot data. Changes were not statistically different from zero. These annual stock changes are applied to the areas in Table 3.

Table 5. Annual stock change rate (negative = a gain): ~2004 to 2012 (C1 to C2)

Source	Pre-1990 natural forest sub-category	C1 to C2		
		No. of plots	Change in stocks tC ha^{-1} yr^{-1}	
Derived from Paul et al (2021) after remapping	Tall	815	0.0115	± 0.194
	Regenerating	93	-0.427	± 0.510

Source: MFE Carbon Sequestration Team, prepared for 2024 GHG inventory submission

Soil carbon

Soil carbon stocks in mineral and organic soils are not included in the stock estimates derived from the LUCAS plot network. The greenhouse gas inventory assumes that soil carbon stocks are stable under a constant land use – currently management activities within forest land are not considered to have a net impact of soil carbon stocks (MFE 2023a). The FRL should be based on the same assumptions (Table 6).

Table 6. Steady-state land use mineral soil organic carbon stocks (Table A3.2.6, MFE 2023b)

Land Use	Steady state carbon SOC stock (t C ha-1)	95% confidence intervals (CI)	
Pre-1990 natural forest	92.25	84.99	99.51
Pre-1990 planted forest	92.44	81.12	103.77
Post-1989 planted forest	91.92	82.40	101.44
Post-1989 natural forest	91.92	82.40	101.44
Grassland with woody biomass	98.23	91.02	105.43
High producing grassland	105.34	99.21	111.47
Low-producing grassland	105.98		

Land use change can result in mineral soil carbon stock changes (and potentially associated N_2O emissions). These are modelled over the IPCC default period of 20 years in New Zealand's greenhouse gas inventory, so during the reference period there can be emissions resulting from land use changes into pre-1990 natural forests that occurred from 1981-2009. These are not attributable to business-as-usual management practices but are essentially a legacy age class effect. Net emissions associated with land use change before 2010 should be the same in both the FRL and reporting, so no accounting quantity arises.

During the compliance period, there will be reporting of soil carbon changes associated with land use change into pre-1990 natural forest from 2002 onward, because of the 20-year transition period assumed. This will include land use change from 2021-2030. Soil carbon changes associated with land use change into pre-1990 natural forest before 2010 will be included in the FRL, unless they are on land previously deforested, as discussed previously. Net emissions from conversions into pre-1990 natural forest after 2009 will form part of the emissions that are accounted against the FRL.

As outlined in the previous section, projections of gains in pre-1990 planted forest area are not required and were not made for the planted forest FRL, so are not included here. Gains in area between 2002 and 2009 will still be affecting soil carbon stocks and associated nitrous oxide emissions between 2021 and 2028 due to the 20-year transition period. Area gains in 2000 and 2001 will have already reached steady-state soil carbon stocks. The relevant areas and the corresponding annual soil C stock change over 20 years are given in Table 6. In all cases, the source land use steady-state soil carbon stock was higher so there is a loss of soil carbon associated with conversion to pre-1990 natural forest.

The land converted from planted forest in Table 7 was natural forest in 2009 so is included as part of the Forest Reference Level, with associated soil CO_2 and N_2O emissions. However, the land converted from the grassland categories must have undergone deforestation previously (or it would be classed as post-1989 natural forest), so the associated emissions would be reported under Deforestation land, and therefore excluded from the FRL.

Table 7. Area gain contributing to soil CO_2 and N_2O emissions during 2021-2030

Source land use	Soil C loss (t C ha^{-1} year^{-1}) *	Annual gain in area (ha)							
		2002	2003	2004	2005	2006	2007	2008	2009
Pre-1990 planted forest	0.0095	81	81	81	81	81	81	365	365
High producing grassland	0.6545	0	0	0	0	0	0	5	5
Low-producing grassland	0.6865	0	0	0	0	0	0	4	4
Grassland with woody biomass	0.2990	0	0	0	0	0	0	5	5

* annual loss of soil carbon over 20 years due to land use change

Drainage of pre-1990 natural forest organic soils does not occur, so no emissions are estimated from organic soils within natural forests (MFE 2023b p80).

Harvesting carbon losses

MPI roundwood removals data shows that from 2000-2009, natural forests provided 0.18% of New Zealand's annual roundwood production on average (36,000 m3 per year), with a strong downward trend over the period. For the 2010 to 2018 period, production was more stable at an average of 18,000 m3 per year (Figure 1), or 0.07% of total roundwood removals.

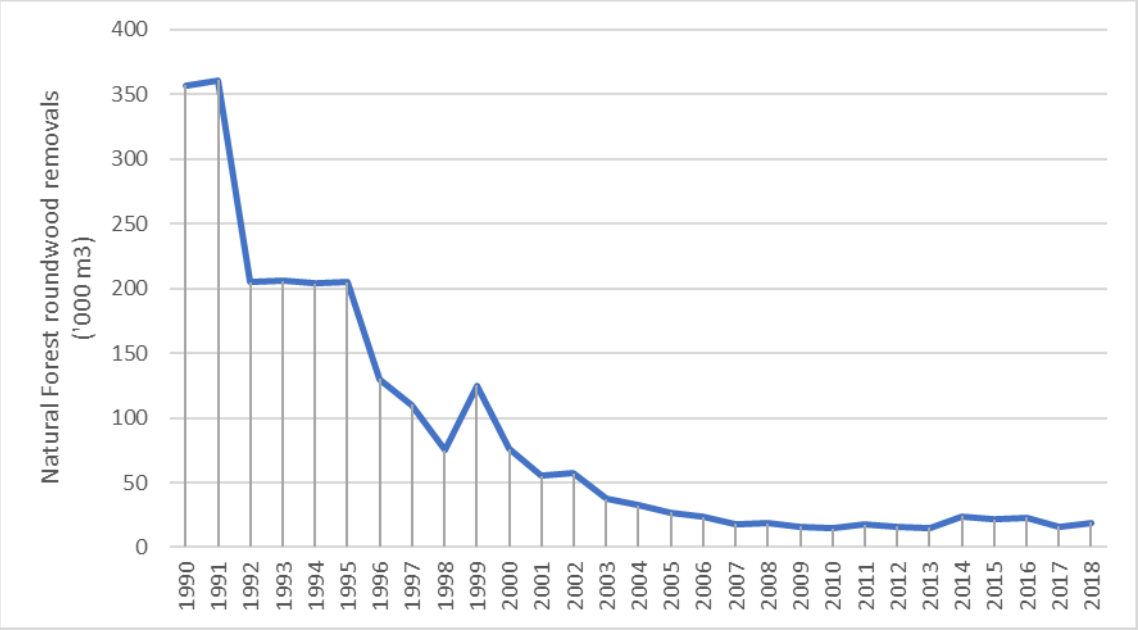

Figure 1. Roundwood removals from Natural Forests in New Zealand. (*MPI website: https://www.mpi.govt.nz/forestry/forest-industry-and-workforce/forestry-wood-processing-data/wood-processing-data/*)

No timber is legally harvested from natural forests in the publicly owned conservation estate other than in exceptional circumstances where legislation allows. Most other harvesting of natural forests is required by law to be undertaken on a sustainable basis, as required by the Forests Act 1949. The area of natural forest under Sustainable Forest Management (SFM) Plans and Permits is small, and only a small proportion of management plans are implemented to the point of timber extraction. In 2016, a total of 77,125 ha was covered by SFM Plans and Permits (about 1% of the total pre-1990 natural forest area), and less than half of the permitted volume was produced (Griffiths 2017).

It is assumed in the greenhouse gas inventory that the net stock changes derived from LUCAS plot measurement sufficiently describe the impact of management on carbon stocks in these forests. The same approach is taken in the FRL. If roundwood removals from these forests increase significantly during the compliance period, a separate stratum could be created and a Technical Correction made to explicitly incorporate harvest practices in the FRL

Other emissions

Nitrous oxide emissions that result from nitrogen mineralisation and immobilisation associated with soil carbon loss following land conversion are reported in the greenhouse gas inventory. New Zealand applies equations 11.2 and 11.8 from IPCC (2006) to estimate these emissions, and these have been used to calculate the emission values in Table 9c. Carbon lost from the soil (Table 7) is divided by the soil C:N ratio (15), an emission factor (EF_1 = 0.01) and the molecular ratio (44/28) to give the emission in tonnes of N_2O. These estimates are converted to carbon dioxide equivalents using the GWP factor of 265 from the 5th Assessment Report. As described above, the soil CO_2 and N_2O emissions from converting planted forest to natural forest before 2010 are included in the FRL, but emissions associated with conversions from grassland would be reported against Deforestation land instead.

Table 8. Wildfire emissions from natural forests (GWP CH_4 = 28, N_2O = 265).

	Wildfire Emissions		
	CH_4 (kt)	N_2O (kt)	CO_2-e (kt)
1990	0.02676	0.00158	1.16713
1991	0.01428	0.00084	0.62268
1992	0.00800	0.00047	0.34872
1993	0.00890	0.00052	0.38811
1994	0.01953	0.00115	0.85184
1995	0.02047	0.00121	0.89262
1996	0.03239	0.00191	1.41263
1997	0.05876	0.00346	2.56279
1998	0.03019	0.00178	1.31674
1999	0.00867	0.00051	0.37805
2000	0.01787	0.00105	0.77921
2001	0.01188	0.00070	0.51797
2002	0.01756	0.00103	0.76574
2003	0.01275	0.00075	0.55621
2004	0.01726	0.00102	0.75301
2005	0.02037	0.00120	0.88835
2006	0.02672	0.00157	1.16543
2007	0.01778	0.00105	0.77528
2008	0.09488	0.00559	4.13814
2009	0.07295	0.00430	3.18182

Wildfire emissions are also a minor component of net emissions in pre-1990 natural forests, and CO_2 emissions from wildfires are implicitly captured in the stock change data (see *Natural Disturbance Background Level* below). Non-CO_2 wildfire emissions (CH_4 and N_2O) expressed in carbon dioxide equivalents were obtained for 1990 to 2009 from CRA outputs for Natural Forest Wildfire (Table 8). These were divided by the reported area for pre-1990 natural forests (including pre-1990 natural forest on land accounted for as Deforestation land because it has been established on previously cleared pre-1990 forest land) to estimate emissions per hectare. The average rate of emissions per hectare over this period (mean of ratios; 0.000151 t CO_2-e ha^{-1}) was calculated and applied to the projected areas in 2021-2030 (Table 3) to estimate wildfire emissions for the compliance period. The longer period of 1990-2009 was used to calculate the average wildfire emissions because annual wildfire emissions are highly variable and dominated by sporadic very large events, and this pattern is unlikely to be represented well over a ten-year reference period.

New Zealand's activity data on nitrogen fertilisation are not currently disaggregated by land use, so are reported under the Agriculture sector.

5. Estimate the HWP pool by applying the same HWP category proportions as during the reference period.

Harvested wood products (HWPs) from pre-1990 natural forests form a very small proportion of total production from New Zealand's forests (less than 0.1%) and are captured within the HWP pool from planted forests. No specific information on the end uses and lifespans of products made from these forests is currently used in greenhouse gas inventory reporting.

In the future it would be useful to review the likely extent of annual emissions resulting from harvesting in pre-1990 natural forests, conversion to HWPs and their end use and lifespans, and the extent to which this is captured in greenhouse gas inventory reporting and the FRL.

Natural disturbance accounting provision

Pre-1990 natural forests are subject to natural disturbances including extreme weather events, wildfires, pests and diseases and geological disturbances. The Kyoto Protocol introduced a natural disturbance accounting provision which allows emissions from disturbances that fall well outside historic levels to be excluded from accounting (IPCC 2014). New Zealand has declared a background level of zero between 1990 and 2009 for Kyoto Protocol accounting for disturbances other than fire. It was assumed that a low level of disturbance is captured implicitly in LUCAS forest inventory (MFE 2023a).

For wildfires, a background level for pre-1990 forests was calculated as 9.34 kt CO_2-e for the purposes of Kyoto Protocol accounting (MFE 2023a). This covers direct oxidation of biomass in wildfires in both pre-1990 planted and natural forests. This is included implicitly within the FRL and will be retained for the initial Paris Agreement FRL, pending further research to update this estimate.

Results

Pre-1990 Natural Forest Reference Level

The Forest Reference Level is expressed as the average annual net emission in tonnes CO_2-equivalent over the 2021-2030 period; in this case -1,399,534 t CO_2 $year^{-1}$ (Table 11), a net carbon sink.

Table 9 provides the forest area assumed in the FRL and the stock changes in the combined above-ground biomass, below-ground biomass, dead wood and litter pools, based on analysis of pre-1990 natural forest inventory plots.

Table 10 provides the emissions due to soil carbon loss (CO_2 and N_2O) as a result of past land use change. Non-CO_2 emissions (CH_4 and N_2O) from wildfire are also provided in carbon dioxide equivalents based on the 5th Assessment Report Global Warming Potentials.

Results are combined in Table 11. New Zealand's official natural forest FRL will be produced from the LUCAS Calculation and Reporting application managed by MfE.

Table 9. (a) Pre-1990 natural forest area by strata, (b) emissions in kt C, and (c) emissions in kt CO_2

(a) Area* (kha)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tall	6669.294	6668.931	6668.567	6668.204	6667.841	6667.477	6667.114	6666.751	6666.387	6666.024
Regenerating	1076.420	1075.932	1075.445	1074.958	1074.471	1073.984	1073.497	1073.009	1072.522	1072.035
Total	7745.714	7744.863	7744.013	7743.162	7742.312	7741.461	7740.611	7739.760	7738.910	7738.059

(b) Emission (kt C) (positive = emission)

											Annual average kt C		
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2021-25	2026-30	2021-30
Tall	76.697	76.693	76.689	76.684	76.680	76.676	76.672	76.668	76.663	76.659	76.689	76.668	76.678
Regenerating	-459.631	-459.423	-459.215	-459.007	-458.799	-458.591	-458.383	-458.175	-457.967	-457.759	-459.215	-458.175	-458.695
Total	-382.934	-382.730	-382.527	-382.323	-382.119	-381.915	-381.711	-381.507	-381.304	-381.100	-382.527	-381.507	-382.017

(c) Emission (kt CO_2) (positive = emission)

											Annual average kt CO_2		
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2021-25	2026-30	2021-30
Tall	281.222	281.207	281.191	281.176	281.161	281.145	281.130	281.115	281.099	281.084	281.191	281.115	281.153
Regenerating	-1685.314	-1684.552	-1683.789	-1683.026	-1682.263	-1681.501	-1680.738	-1679.975	-1679.212	-1678.450	-1683.789	-1679.975	-1681.882
Total	-1404.092	-1403.345	-1402.598	-1401.850	-1401.103	-1400.355	-1399.608	-1398.860	-1398.113	-1397.366	-1402.598	-1398.860	-1400.729

* Based on 2009 areas from MFE (2024) less 27.4 ha of pre-1990 natural forest on land accounted for as Deforestation land because it has been established on previously cleared pre-1990 forest land. Then actual deforestation to 2020 is applied and the average 2011-2020 deforestation rate is assumed from 2021-2030.

Table 10. Soil Carbon, HWP and non-CO_2 emissions (positive = emission)

(a) Soil carbon stock change: positive = emission

	2021	2022	2023	2024	2025	2026	2027	2028	2029*	2030*	Annual average 2021-25	Annual average 2026-30	Annual average 2021-30
t C	11.6	10.8	10.0	9.2	8.5	7.7	6.9	3.5	0.0	0.0	10.013	3.621	6.817
Kt CO_2	0.042	0.040	0.037	0.034	0.031	0.028	0.025	0.013	0.000	0.000	0.037	0.013	0.025

* only soil carbon loss for 20 years after land use change 2002-2009 included

(b) HWP net emission (kt CO_2)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Annual average 2021-25	Annual average 2026-30	Annual average 2021-30
HWP kt CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE			

IE – included elsewhere (with pre-1990 planted forests)

(c) Non-CO_2 emissions (Kt CO_2-e)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Annual average kt CO_2-e 2021-25	Annual average kt CO_2-e 2026-30	Annual average kt CO_2-e 2021-30
Wildfire	1.168	1.168	1.168	1.168	1.168	1.168	1.167	1.167	1.167	1.167	1.168	1.167	1.168
N_2O soil	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.000	0.000	0.003	0.001	0.002
Total	1.171	1.171	1.171	1.170	1.170	1.170	1.169	1.168	1.167	1.167	1.171	1.168	1.170

Table 11. Combined pre-1990 natural forest net emissions (kt CO_2-e)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Annual average kt CO_2-e 2021-25	Annual average kt CO_2-e 2026-30	Annual average kt CO_2-e 2021-30
Biomass	-1404.092	-1403.345	-1402.598	-1401.850	-1401.103	-1400.355	-1399.608	-1398.860	-1398.113	-1397.366	-1402.598	-1398.860	-1400.729
Soil carbon	0.042	0.040	0.037	0.034	0.031	0.028	0.025	0.013	0.000	0.000	0.037	0.013	0.025
Non-CO_2	1.171	1.171	1.171	1.170	1.170	1.170	1.169	1.168	1.167	1.167	1.171	1.168	1.170
Total	-1402.879	-1402.134	-1401.390	-1400.646	-1399.902	-1399.157	-1398.413	-1397.679	-1396.946	-1396.198	-1401.390	-1397.679	-1399.534

Recommendations and conclusions

The Pre-1990 Natural Forest FRL is one component within the overall pre-1990 Forest Reference Level for Paris Agreement accounting. It is combined with pre-1990 planted forest FRL, based on projected changes in the stock within pre-1990 planted forests and the HWPs produced from them after 2012.

The pre-1990 natural forest FRL value of -1,399,534 t CO_2 $year^{-1}$ reported here represents the average annual net emissions from these forests from 2021 to 2030. In this case carbon uptake in pre-1990 Regenerating natural forests outweighs the small loss of carbon from pre-1990 Tall natural forests and smaller losses from the soil and wildfires. The carbon stock changes per hectare were calculated from analysis of data from the LUCAS natural forest inventory and are not statistically different from zero for either stratum.

It is recommended that:

- Estimates of carbon stock changes should be re-calculated when the third measurement cycle is complete, and the results incorporated in both greenhouse gas inventory reporting and the FRL (through a Technical Correction).

- The background level of natural disturbance for use in accounting under the Paris Agreement should be reviewed. In the interim the value derived for Kyoto Protocol accounting can be used.

- A review of the emissions from harvesting in pre-1990 natural forests and the end uses and lifespans of the resulting HWPs be undertaken, particularly if there are indications that production is increasing over the compliance period.

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Appendices

Table A1. Land Use Change to Pre-1990 Natural Forest (MFE 2024)

FROM>>	Pre-1990 natural forest	Pre-1990 planted forest	Post-1989 planted forest	Post-1989 natural forest	Annual cropland	Perennial cropland	High producing Grassland	Low producing Grassland	Grassland With woody biomass	Wetland - Open water	Wetland - Vegetated	Settlements	Other Land	TOTAL
	Hectares per year													
1990	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1991	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1992	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1993	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1994	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1995	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1996	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1997	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1998	0	81	0	0	0	0	0	0	0	0	0	0	0	81
1999	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2000	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2001	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2002	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2003	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2004	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2005	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2006	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2007	0	81	0	0	0	0	0	0	0	0	0	0	0	81
2008	0	365	0	0	0	0	5	4	5	0	0	0	0	379
2009	0	365	0	0	0	0	5	4	5	0	0	0	0	379
2010	0	365	0	0	0	0	5	4	5	0	0	0	0	379
2011	0	365	0	0	0	0	5	4	5	0	0	0	0	379
2012	0	365	0	0	0	0	5	4	12	0	0	0	0	386
2013	0	83	0	0	0	0	5	18	60	0	0	0	0	166
2014	0	83	0	0	0	0	5	3	60	0	0	0	0	151
2015	0	83	0	0	0	0	5	3	60	0	0	0	0	151
2016	0	83	0	0	0	0	5	3	60	0	0	0	0	151
2017	0	0	0	0	0	0	3	7	0	0	0	0	0	10
2018	0	0	0	0	0	0	3	7	0	0	0	0	0	10
2019	0	0	0	0	0	0	3	7	0	0	0	0	0	10
2020	0	0	0	0	0	0	3	7	0	0	0	0	0	10
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A2. Land Use Change from Pre-1990 Natural Forest (MFE 2024)

TO >>	Pre-1990 natural forest	Pre-1990 planted forest	Post-1989 planted forest	Post-1989 natural forest	Annual cropland	Perennial cropland	High producing Grassland	Low producing Grassland	Grassland With woody biomass	Wetland - Open water	Wetland - Vegetated	Settlements	Other Land	TOTAL
							Hectares per year							
1990		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1991		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1992		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1993		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1994		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1995		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1996		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1997		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1998		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
1999		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2000		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2001		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2002		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2003		1,408	0	0	1	3	568	905	317	5	0	22	22	3251
2004		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2005		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2006		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2007		1,401	0	0	1	3	568	905	317	5	0	22	22	3244
2008		147	0	0	0	0	282	317	239	0	0	11	15	1011
2009		147	0	0	0	0	644	800	983	5	5	13	82	2679
2010		147	0	0	3	0	469	512	862	0	0	14	119	2126
2011		147	0	0	0	0	228	314	475	0	0	0	135	1299
2012		147	0	0	0	0	152	340	618	0	3	7	141	1408
2013		5	0	0	3	0	226	496	415	0	0	8	104	1257
2014		5	0	0	6	0	159	245	216	0	0	2	55	688
2015		5	0	0	7	0	280	196	463	1	0	19	103	1074
2016		5	0	0	0	0	137	296	344	2	0	22	71	877
2017		64	0	0	0	0	108	158	203	2	0	5	14	554
2018		64	0	0	0	0	203	252	72	0	0	4	34	629
2019		64	0	0	0	2	115	174	260	1	0	6	51	673
2020		64	0	0	0	0	116	174	197	9	0	14	43	617
2021		64	0	0	0	0	145	201	177	0	0	8	43	638
2022		64	0	0	0	0	145	201	177	0	0	8	43	638