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Land Use Opportunities for Aotearoa

FACT SHEET

SCION

Greenhouse Gas Impacts from Forestry

Steve Wakelin
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Greenhouse Gas Impacts from Forestry

OVERVIEW

The greenhouse gas impacts of a land use include the direct emissions of greenhouse gases arising from the land use, uptake of CO_2 through photosynthesis by vegetation, and in the case of primary industry activities, the direct and indirect emissions associated with the upstream and downstream supply-chain.

Some landowners may be interested in quantifying emissions as part of product Life Cycle Analysis or carbon foot-printing, or with a view to determining how to achieve "net zero" or "carbon neutral" status at the property or enterprise level. These schemes each have their own protocols for determining which emissions must be included. Landowners will also be interested in determining any emissions that may be subject to a liability under a current or future emission pricing scheme, together with any uptake of CO_2 that may be eligible for rewards. In the case of new plantation forests, net carbon sequestration in biomass by growing forests typically far outweighs any emissions. The purpose of this document is to provide an indicative summary of the "sinks and sources' of greenhouse gases in forestry systems, and to indicate which are reported or accounted for under:

- Paris Agreement accounting towards New Zealand's 2030 target.
- The New Zealand Emissions Trading Scheme (ETS).
- The He Waka Eke Noa farm emission pricing scheme, as proposed in May 2022.

When the sources and sinks are summed over a typical radiata pine rotation, the stock change in the forest dominates (Figure 1) - even when sequestration is only included until the long-term average carbon stock as defined in the ETS Regulations is reached (16 years for radiata pine here, see Wakelin (2023)).

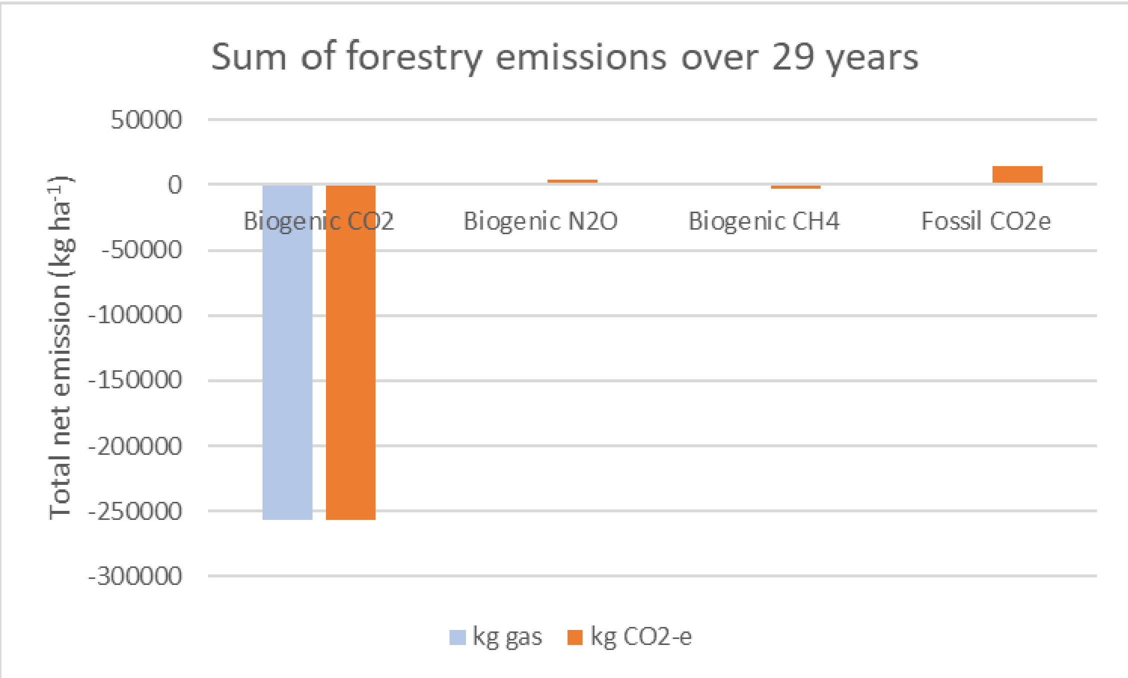

Figure 1. Sum of per hectare net forestry emissions, by gas and after conversion to CO_2e, over 29 years (sequestration follows NZ ETS accounting approach adopted from January 2023, accounting for sequestration until the assumed long-term average stock is reached, set at age 16).

- *Biogenic CO_2* – sum of sequestration for 16 years, *less* soil C loss over 20 years, less one-off loss of pre-afforestation biomass C, *less* CO_2 emissions from urea and lime (see Table 2). In this demonstration, long-term carbon storage in products and the substitution benefits from using wood products are ignored.
- *Biogenic N_2O* – sums all N_2O sources (very small until converted to CO_2-e).
- *Biogenic CH_4* – also small until converted to CO_2e. Shown as a net sink because soil methane consumption is likely to exceed any planted forest emissions.
- *Fossil CO_2e* – value chain fossil fuel emissions from nursery to mill/port gate, in kg CO_2e only.

Although the sequestration here is only credited for the first 16 years of the first rotation, it still takes another 16 rotations (almost 500 years in total) for this gain to be offset by the ongoing emissions shown in Figure 1. The inclusion of wood processing and export shipping emissions would shorten this time period, while the inclusion of benefits from substituting for more fossil fuel intensive products would lengthen it. Carbon storage of wood products in service significantly increases the long-term average carbon stock and hence increases the net biogenic CO_2 emissions shown in Figure 1 by ~50-80%.

Assessing the net GHG impacts of a land use change to forestry also requires the emissions avoided by replacing the previous land use to be taken into account, such as livestock methane emissions and N_2O emissions from greater use of fertilisers.

Note that Figure 1 shows *average* emissions across all plantation forests, with these averages being based on the current mix of sites and tree species. Averages include forests that are not subject to burning or fertiliser application. A stand that does receive nitrogen fertiliser will have greater than average emissions, just as a forest affected by a forest fire will have greater emissions than the "average" forest.

Optimal fertiliser application may differ for alternative species in terms of the timing and nutrient quantity and mix, but differences in overall net emissions will be more strongly driven by differences in sequestration rates over the lifetime of the forest.

TABLES

The following tables summarise potential biomass carbon stock changes and greenhouse gas emissions associated with afforestation and ongoing forest management. Emissions of CO_2, CH_4 and N_2O are based on the sources and methods identified for mandatory reporting under the United Nations Framework Convention on Climate Change (UNFCCC) (IPCC2006, 2019). Further details are provided in the Appendix.

Note these additional comments on the data tables that follow:

- **Table 1. Net sequestration – forest carbon stock changes**

  This table relates to the impact of *afforestation*. Forests must meet eligibility requirements to contribute to accounting in the ETS, He Waka Eke Noa or the Paris Agreement (e.g. forests must have been first established on land that was unforested at the end of 1989, with a minimum size of 1 ha, minimum height potential 5 m, minimum width 30m, and minimum tree canopy cover 30%).

  Other farm vegetation could also contribute to net carbon sequestration and the total carbon stock, although the rate of accumulation and maximum carbon stock are likely to be much greater for forests. Actual sequestration by ETS-eligible forests may differ from the ETS Standard Carbon tables shown here.[1]

  Deforestation and the clearance of non-forest vegetation also results in emissions, but only biomass loss from the clearance of vegetation for the purposes of afforestation is shown in Table 1.

- **Table 2. Greenhouse gas emissions from forests**

  These emissions are mainly associated with the use of synthetic nitrogen fertiliser, lime and dolomite. Fertiliser application in forestry is at a relatively low level compared with other land uses. In 2019 only 0.4% of the total application of these products to agricultural land was on farm type "forestry" (Agricultural Production Survey data). For an overview of fertiliser in forestry, see https://www.nzfoa.org.nz/resources/file-libraries-resources/environment/factsheets/682-fertiliser-use-in-plantation-forests/file.

  Emissions associated with harvest residues are included in the table based on the calculations used for agricultural crops, although forest land emissions from this source are not covered by the guidance for national greenhouse gas inventory reporting under the UNFCCC.

  Detailed methodologies for agricultural greenhouse gas emissions can be found in Pickering et al (2022).

[1] see Emissions Trading Scheme Standard Carbon Tables (ETS Lookup tables) - Datasets - Whitiwhiti Ora: Land Use Opportunities.

- **Table 3. Other sinks and sources of greenhouse gases in forests**

  These indicative estimates are provided to give a sense of their likely order-of-magnitude.

  Methane - Current work at Scion is aiming to better understand the forest methane cycle, which is not included in annual greenhouse gas inventory reporting under the UNFCCC.

  Fires - Emissions from wildfires and prescribed burning on forest land are included in the annual greenhouse gas inventory, but affect a very small proportion of the estate each year. Much greater areas of grassland and shrubland are burned annually, and greenhouse gas emissions from these sources are included in the annual greenhouse gas inventory.

  Fossil fuels - All primary production sector land uses will incur greenhouse gas emissions through management activities or the operation of product supply chains. Fossil fuel emissions for forestry are concentrated in the year of harvesting and are therefore low when averaged over the full rotation. They are not explicitly captured by the ETS or He Waka Eke Noa proposal, but the carbon charge applied to fuel use will be part of the cost of production.

Table 1. Net Sequestration – Forest Carbon Stock Changes

		Avg	Min	Max	Paris Agreement target	NZ ETS	He Waka Eke Noa[2]
		kg CO_2 ha^{-1} $year^{-1}$					
Pre-afforestation biomass C loss	One-off loss of biomass in vegetation cleared. (min assumes low-producing grassland is converted; max assumes grassland with woody biomass is converted; avg is weighted average 2012-21)	7750 Year 0 only	10512 Year 0 only	47850 Year 0 only	✓	✗	✗
Biomass C uptake; biomass C decay (net biomass uptake)	Uptake of CO_2 in eligible above-ground and below-ground biomass via photosynthesis; release of CO_2 from dead wood and litter (e.g. from leaf fall, pruning, thinning, harvest residues). Varies by site, species and management. Sequestration estimates shown are for annual sequestration from the ETS Standard carbon tables, based on averaging accounting. Shown for comparability up to age 16 (when the long-term stock for radiata pine is assumed to be reached in the ETS) for radiata (avg), indigenous forest (min) and exotic hardwoods (max.). Alternative values to age 23 (for indigenous) and age 12 (for exotic hardwoods), using the crediting period defined for those species groups in the ETS Regulations. Actual sequestration rates may be significantly different from the ETS standard carbon tables, and the rate varies over the rotation.	-20100 annual to age 16 (radiata)	-6800 annual to age 16 (natives) -8400 annual to age 23 (natives)	-27200 annual to age 16 (hard-wood) -26700 annual to age 12 (hard-wood)	✓	✓	✓
Soil organic carbon	Change in the carbon stock of mineral soil organic carbon pool (over 20 years only). Depends on previous land use, using steady-state values assumed in the NZ GHG inventory.	2343 annual to age 20	1157 annual to age 20	2578 annual to age 20	✓	✗	✗
Soil organic carbon - drainage	Change in the carbon stock of organic soil organic carbon pool (annual – IPCC default value for loss from converted organic soils – applies to drained organic soils only)	9800			✓	✗	✗
Wood products	Change in the carbon stock of harvested wood products. Under the averaging accounting approach, this could add 50-80% to the long-term average carbon storage in the forest.	Varies. Service life for wood products ranges from 0 (e.g. fuel) to > 100 years.			✓ (In service only)	✗	✗

[2] As proposed in May 2022 (mandatory for GST-registered business that apply at least 40 tonnes of synthetic nitrogen fertiliser annually and/or have > 550 stock units and/or 50 dairy cattle).

Table 2. Greenhouse gas emissions from forests (not converted to CO_2-equivalent)

		Avg	Min	Max	Paris Agreement target	NZ ETS	He Waka Eke Noa
		kg GHG ha^{-1} $year^{-1}$					
N_2O from N fertiliser	Direct emissions of N_2O from fertilisation including urea. Average based on Agricultural Production Survey data on fertiliser applied to farm type "Forestry". Maximum assumes 200 kg N-urea/ha applied during a 28-year rotation.	0.007	0	0.066	✓	✗	✓
CO_2 from urea	Direct emissions of CO_2 from urea fertilisation. Based on Agricultural Production Survey data on fertiliser applied to farm type "Forestry", ignoring urease inhibitor. Maximum assumes 200 kg N-urea/ha applied during a 28-year rotation.	0.9	0	11.4	✓	✗	✓
CO_2 from lime and dolomite	Direct emissions of CO_2 from application of lime and dolomite. Based on Agricultural Production Survey data on fertiliser applied to farm type "Forestry".	1.2	0		✓	✗	✗
N_2O from soil C loss	Direct emissions of N_2O from disturbance associated with land use conversion (over 20 years). Depends on previous land use, assuming the steady state carbon stocks applied in New Zealand's national greenhouse gas inventory.	0.67 annual for 20 years	0.33 annual for 20 years	0.74 annual for 20 years	✓	✗	✗
N_2O from drained organic soils	Emissions of N_2O from drained organic soils in forests. (not estimated).				✓	✗	✗
N_2O from harvest residues	Direct emissions of N_2O from harvest residues (indicative, based on N content of end-of-rotation residues divided by length of rotation).	0.3			✗	✗	✗
N_2O from residue leaching	Indirect emissions of N_2O from harvest residues (indicative, assuming leaching fraction used for crops.	0.02			✗	✗	✗
N_2O from fertiliser leaching & residues	Indirect emissions of N_2O from fertiliser leaching and volatilisation. Average based on Agricultural Production Survey data on fertiliser applied to farm type "Forestry". Maximum assumes 200 kg N-urea/ha applied during a 28-year rotation.	0.002	0	0.020	✓	✗	✗

Table 3. Other sinks and sources of greenhouse gases in forests

		Avg	Paris Agreement target	NZ ETS	He Waka Eke Noa
		kg GHG ha^{-1} $year^{-1}$			
CH_4 emissions	Trees can emit small quantities of CH_4, especially in flooded forests or when old and decaying, which are not conditions associated with plantation forests. Estimates for pine forests in non-tropical regions suggest that emissions from planted forests in New Zealand would be low.	~0.01	✘	✘	✘
CH_4 uptake by forest soils	CH_4 is taken up by microorganisms in forest soils.	~4-6	✘	✘	✘
CH_4, N_2O, from biomass burning	Emissions of non-CO_2 (CH_4, N_2O) through biomass burning (prescribed and wildfires). Mean rate 1990-2021 for CH_4; 2011-2021 for N_2O.	0.45 CH_4 0.05 N_2O	✓	✘	✘
Value chain emissions	Value chain fossil fuel emissions from the nursery to the mill gate/port have been estimated as about 20 kg CO_2-e m^{-3} of logs harvested, which equates to about 0.5 t CO_2-e ha^{-1} $year^{-1}$ over a rotation.	~500	✓ (Energy sector)	(Captured in fuel charges)	(Captured in fuel charges)

Appendix – Sources of information in the tables

Table 1. Net sequestration – forest carbon stock changes

- Biomass and soil carbon loss associated with afforestation – based on emission factors in MFE (2023). Average loss was based on weighting by the proportions of previous land uses converted to post-1989 planted forest, averaged over 2012-2021 (MFE 2023). Minimum and Maximum estimates assumed 100% of whichever grassland sub-category produced the lowest or highest loss respectively.

Table A1. Weighted pre-afforestation land use soil and biomass carbon (used for average)

Pre-afforestation land use	Proportion %	Steady-state soil C t C ha^{-1}	Biomass C t C ha^{-1}
Grassland with woody biomass	15.64	98.23	13.05
High-producing grassland	10.96	105.34	6.345
Low-producing grassland	73.40	105.98	2.867
Weighted		**104.7**	**4.84**
Post-1989 planted forest		91.92	

- Sequestration – from ETS Standard Carbon Tables – see Wakelin (2023): Emissions Trading Scheme Standard Carbon Tables (ETS Lookup tables) - Datasets - Whitiwhiti Ora: Land Use Opportunities.

Table 2. Greenhouse gas emissions from forests

- Fertiliser, lime and dolomite emissions – based on Agricultural Production Survey data (Table A2) and emission assumptions in MFE (2023).

Table A2. Annual fertiliser application to farm type *Forestry* *

Year	A030100. Forestry area	Urease inhibitor (coated urea for example SustaiN, N-Protect)**	Other Urea	Di-ammonium phosphate (DAP)	Ammonium sulphate (SOA)	Super-phosphate	Potassium chloride (muriate of potash) and/or potassium sulphate	Dolomite (from all sources)	Lime (from all sources)
	ha	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
2017	1,481,794	579	578	677	357	4,052	340	65	5,512
2018	1,463,994	S	S	883	S	S	S	12	S
2019	1,497,061	932	772	817	409	4,170	289	46	5,150
2020	1,473,615	690	S	S	224	3,968	429	31	2,667
2021		Not available due to data errors							
2022	1,623,581	2,316	762	821	410	5,537	1,219	26	7,244

* This excludes woodlots on farms that are classified under their predominant use e.g. sheep and beef farming. Rates were calculated (tonnes applied per ha of forestry each year) then averaged over the time series where data is available.

** Urea amounts were combined and emissions were not adjusted for inhibitors.
S = data suppressed to preserve confidentiality

- Direct N_2O loss associated with soil carbon loss – indicative based on assumed mix of pre-afforestation land uses as in Table 1 for soil carbon loss, and emission assumptions in MFE (2023).

- Direct and Indirect N_2O emissions from harvest residues – indicative value based on N content in post-harvest residues as modelled in NuBalM (Smaill et al 2011), annualised by dividing by the rotation length. Uses crop emission factors in MFE (2023).

Table 3. Other sinks and sources of greenhouse gases in forests

- CH_4 emissions from upland pine trees – rate reported in Covey and Megonigal (2019).

- CH_4 uptake by forest soils – range for New Zealand plantation forests reported in Saggar et al (2008).

- Biomass burning – CH_4 emissions derived from annual emissions of CH_4 from biomass burning on forest land reported for planted forests in MFE (2023) for 1990-2021, divided by annual plantation forest estimates from the National Exotic Forest Description (MPI 2023). N_2O emission rates per hectare from biomass burning were averaged for 2011-2021.

- Value chain emissions are indicative based on Sandilands et al. (2008).

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