How much forestry would be needed to offset warming from agricultural methane?

Summary document

October 2022

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

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Why did the Parliamentary Commissioner for the Environment write the note?

1

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New Zealand's emissions reduction targets for 2050 were enshrined in legislation in 2019. In my view, the rationale behind having a net target for long-lived greenhouse gases and a gross target for biogenic methane was never satisfactorily explained. Why should emitters of carbon dioxide in the fossil fuel-based economy have access to New Zealand's limited supply of forestry offsets to assist them in meeting their emissions reduction target, but not emitters of livestock methane in the land-based economy?

Forests remove carbon dioxide from the atmosphere, not methane. But if forest offsetting works by creating a cooling effect to compensate for warming from emissions occurring elsewhere, then it should be possible – at least in theory – to use forestry to offset the warming from any greenhouse gas. This includes biogenic methane produced from plant or animal sources.

To test the feasibility of this idea, I commissioned Professor Dave Frame and Dr Nathanael Melia to calculate what area of forest would be required to offset livestock methane emissions using a warming-based approach.[1] Their results and some worked examples at the national level are outlined in the note.

There are no recommendations in the note. My aim in publishing it is simply to lay out what can and cannot be credibly claimed with respect to offsetting methane from livestock, in the hope it will help foster a better-informed debate should New Zealand's 2050 target for biogenic methane be reviewed in future.

1 Frame and Melia, 2022. A copy of this report is available on the PCE website, pce.parliament.nz.

How much methane is being emitted by livestock in New Zealand?

New Zealand's herds of livestock are currently emitting around 1.2 million tonnes of methane each year. Livestock methane accounts for 91% of biogenic methane emissions and 89% of total methane emissions.

Over the past two decades, methane emissions from dairy cattle have increased, while emissions from sheep, beef and deer have decreased. The net result is that total livestock methane emissions have remained basically constant since around the year 2000.

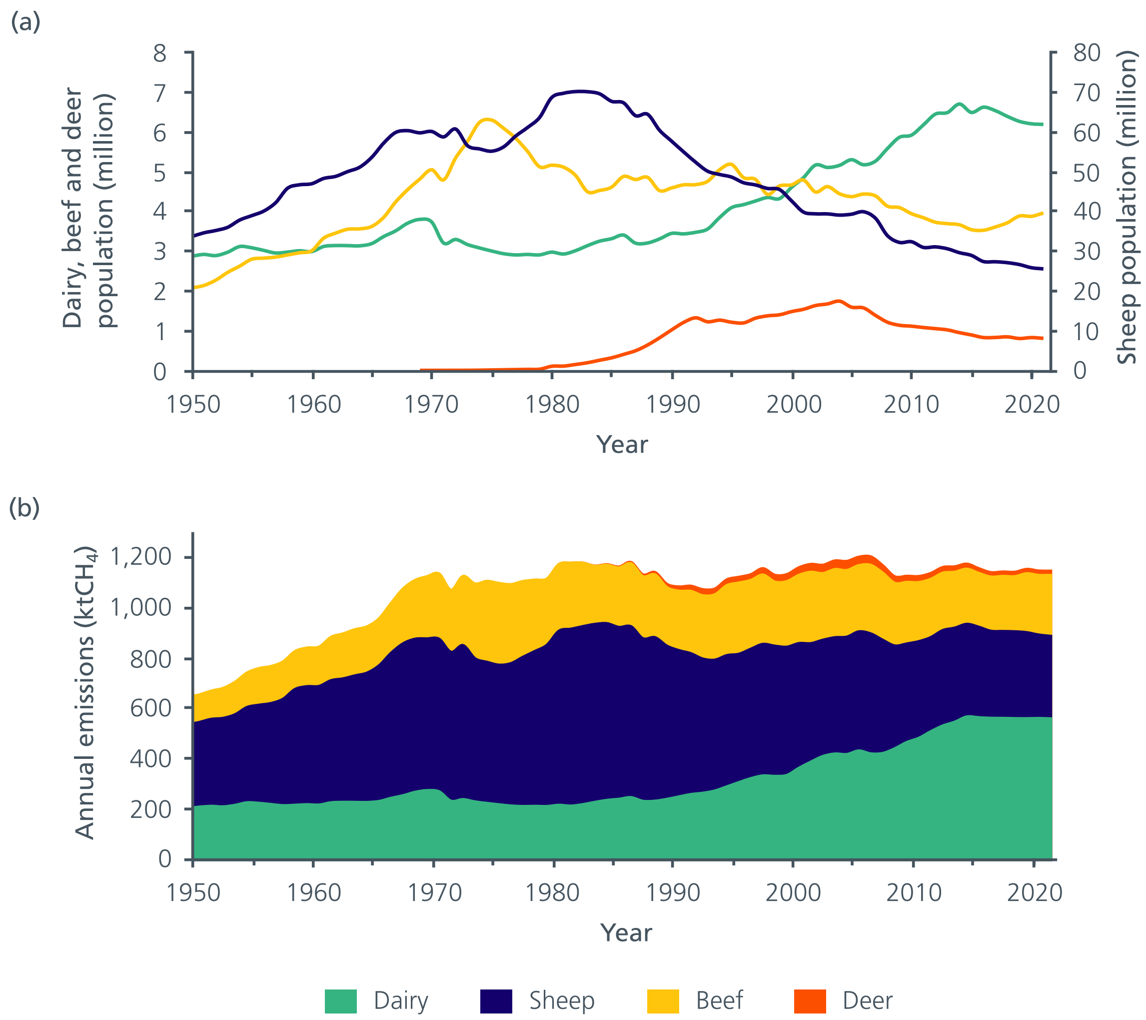

Figure 1: Livestock numbers (a) and livestock methane emissions (b) between 1950 and 2021. The charts begin in 1950 because this is the first year that disaggregated statistics for dairy cattle and beef cattle are available.

How much warming is currently being caused by New Zealand's livestock methane emissions?

There is a lot of genuine confusion about how much warming is being caused by the methane emissions from New Zealand's livestock. This occurs among both those calling for more stringent cuts to biogenic methane emissions, and those advocating the opposite on the basis that we do not need to worry about methane if its warming contribution is stable.

It is an unequivocal fact that a one-off emission of methane has a strong but relatively short-lived heating effect on the climate compared with carbon dioxide. While most of the warming occurs within the first few decades after a one-off emission, there is also a small but long-lived tail of lingering warming.

Every herd of ruminants – even a herd that is constant or decreasing in size over time – emits methane. These ongoing methane emissions keep the planet warmer than it would otherwise have been in the absence of that herd. The warming from a herd of constant size will eventually stabilise (after more than a century). But a herd with a stable warming contribution is still a herd that is warming the planet.

The methane emissions to date from New Zealand's livestock are currently keeping the planet around 0.0015 °C warmer than it would otherwise have been if our herds of ruminants did not exist. This is sometimes called marginal warming.

For comparison, New Zealand's fossil carbon dioxide emissions and nitrous oxide emissions since 1850 are currently elevating the temperature of the planet by around 0.0009 °C and around 0.0004 °C, respectively. (These warming contributions are dwarfed by the ongoing warming effect from the clearing of primary native forests in the past, which released massive volumes of carbon dioxide into the atmosphere.)

Livestock methane therefore accounts for around 55% of New Zealand's current warming contribution from past emissions of fossil carbon dioxide, agricultural nitrous oxide and livestock methane since 1850 (excluding the effect of historical deforestation).

Because methane decays relatively quickly in the atmosphere, almost all of the methane emitted before 1990 has now disappeared. Most of the warming occurring today from livestock methane is therefore due to methane emitted since 1990. By contrast, roughly half of the current warming from fossil carbon dioxide emissions is a legacy effect of carbon dioxide emitted before 1990.

How much warming is already locked in due to past emissions?

Regardless of how much future emissions are reduced, some warming is already 'locked in' as an inescapable consequence of past emissions.

For centuries to come, past fossil carbon dioxide emissions will continue to keep the planet warmer than it would otherwise have been had this carbon remained locked up in fossil reservoirs and not been injected into the atmosphere.

By contrast, because the atmospheric lifetime of methane is short, most of the warming from methane emitted before 2020 will be gone by 2050. But as long as there are still herds of livestock burping methane, some level of warming will continue to be sustained into the future.

How much warming these herds will contribute during the second half of this century therefore largely depends on the actions taken or not taken to reduce livestock methane emissions between now and 2050.

What is additional warming?

Confusion arises because the term 'warming' is also sometimes used to refer to the change in warming relative to a reference level, such as the 1990 level. If warming has increased since the reference level, this is 'additional warming' relative to the reference level.

The change in warming relative to a reference level can vary significantly depending on the reference level used. For example, the additional warming from New Zealand's livestock methane emissions is currently around 0.0015 °C relative to the 1850 level, around 0.0007 °C relative to the 1950 level, and around 0.0002 °C relative to the 1990 level.

It is therefore always important to state the reference level whenever the term 'additional warming' is used. Additional to *what* level?

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5

Does reducing livestock methane emissions cause cooling?

The short answer is it depends on what you mean by cooling.

A herd of livestock is like a heater in a room. If turned on and left at the same setting, the temperature of the room will in time stabilise at a higher level.

Once the temperature of the room has stabilised, the heater is still causing warming – that is, the temperature of the room is still being kept higher than it would otherwise have been if the heater were off.

If the heater is turned down to a lower setting, the temperature of the room will decrease. The room is now cooler than it was before the heater was turned down. But the heater is still causing warming in the sense that the room remains warmer than it would otherwise have been in the absence of the heater.

For the purposes of this note, the language used is that reducing livestock numbers reduces the level of warming associated with that herd.

What reduction in warming could be achieved by reducing future emissions?

The level of warming New Zealand seeks to justify from its emissions of biogenic methane and long-lived greenhouse gases is not a matter of science but an economic, social and political choice.

Parliament has legislated targets to reduce biogenic methane emissions by 10% by 2030 and 24–47% by 2050 relative to the 2017 level. Reducing livestock methane emissions by 24–47% by 2050 would reduce their contribution to warming to below the current level by the second half of this century.

The size of New Zealand's contribution to warming from future emissions will be mainly determined by the following four 'dials':

(a) Future annual emissions of livestock methane. Turning down future annual emissions will turn down the warming from this source within a few decades.

(b) Cumulative fossil carbon dioxide emissions. Warming from fossil carbon dioxide emissions will keep going up until annual emissions are turned down to zero.

(c) Cumulative agricultural nitrous oxide emissions. Like fossil carbon dioxide, warming from agricultural nitrous oxide emissions will continue to rise so long as annual emissions remain above zero.

(d) Use of offsets such as carbon dioxide removals by forests. Offsets can be used to compensate for some or all of the warming from (a), (b) and (c). However, there are limitations and risks associated with their use.

All four dials will need to be used if New Zealand is to meet its climate change mitigation obligations under the Paris Agreement. In addition to turning down carbon dioxide and nitrous oxide emissions, turning down livestock methane emissions would significantly reduce the contribution to warming from New Zealand's future emissions.

In the Climate Change Commission's 'demonstration path', gross carbon dioxide and nitrous oxide emissions are reduced by 78% and 28% by 2050 respectively, relative to the 2019 level.

If gross carbon dioxide and nitrous oxide emissions were to follow this path and livestock methane emissions were reduced by 47% by 2050 then kept at this level, the warming from livestock methane emitted from 2020 onwards would account for around three quarters of the warming from all future emissions by the end of the century.

Reducing livestock methane emissions could have real economic and social impacts on people and ways of life. A fine balance needs to be struck between having regard to economic and social dislocation and finding a position that New Zealand can defend in international climate change negotiations, while remaining competitive in global food markets with growing consumer demand for low-emissions products.

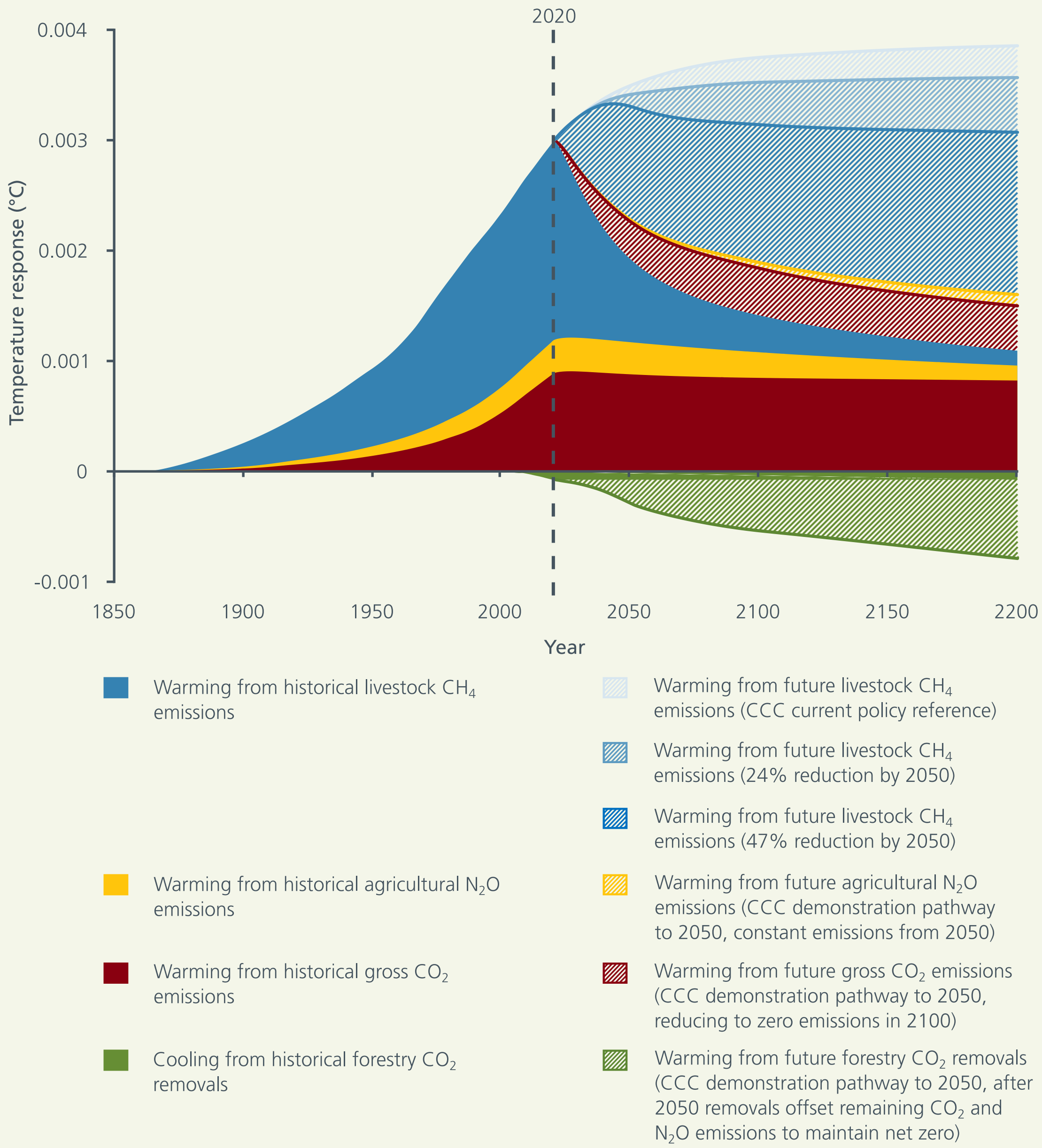

Figure 2: Warming from past emissions and illustrative pathways for future emissions. The solid shaded areas show the warming from past emissions – this warming is already 'locked in'. The hatched areas show the warming from future emissions that can potentially be avoided by reducing emissions. Deep, rapid and sustained reductions in gross emissions of livestock methane, fossil carbon dioxide and agricultural nitrous oxide will be needed – as well as enhanced carbon dioxide removals from forests – to minimise the warming from New Zealand's future emissions.

How can livestock methane emissions be reduced?

Farmers can reduce livestock methane emissions by reducing livestock numbers through destocking or changing land use from pastoral agriculture to other land uses such as horticulture or forestry. Beyond this, there are currently limited options commercially available to most farmers for achieving more than incremental reductions in livestock methane emissions.

Research is being undertaken into technologies to reduce livestock methane emissions from farms, such as low-methane sheep and cattle, low-methane feeds, methane inhibitors and a methane vaccine. Accelerating the pace of this research should be a critical priority for New Zealand.

What role could forestry offsets play?

The purpose of offsetting is to soften the negative social, cultural and economic consequences of meeting gross emissions reduction targets. This enables more ambitious emissions reduction targets to be set and achieved.

Given the need to make deep reductions in all emissions, offsetting with trees should be a last resort that is used only when all practicable means of reducing emissions at source have been exhausted.

If forestry is used to offset livestock methane, it should only be used in addition to – not instead of – gross emissions reductions.

The Climate Change Response Act 2002 requires a reduction in biogenic methane emissions of 24–47% by 2050 relative to the 2017 level. Forestry offsets could be used to go beyond whatever minimum gross reduction within this range proves possible.

The existing architecture of the Climate Change Response Act does not allow forestry offsets to be counted towards national targets for biogenic methane. Therefore, changes to the architecture of the Act would be required if this were to be considered.

Image: Andrea Lightfoot, Unsplash

How much forestry would need to be planted to offset livestock methane?

The area of forest needed to offset the methane emissions from a herd of livestock depends on which method is used to define equivalence between carbon dioxide removals by forests and methane emissions from herds of livestock.

The conventional approach based on GWP_{100}

The conventional approach to greenhouse gas accounting is based on the 100-year global warming potential (GWP_{100}) metric. This approach converts quantities of different greenhouse gases into a common unit called 'tonnes of carbon dioxide equivalent', which enables them to be added and subtracted. It is based on how much heat each gas traps on average over a 100-year period compared to one tonne of carbon dioxide.

Using the conventional approach, annual emissions of livestock methane (in tonnes of carbon dioxide equivalent) are offset each year by an equivalent quantity of annual removals of carbon dioxide from forestry (in tonnes of carbon dioxide).

A new pine plantation forest generates annual removals during its first rotation until it reaches its long-term average carbon stock. This is reached after 16 years for a *Pinus radiata* forest on a 28-year rotation.

To ensure a sufficient flow of annual average carbon dioxide removals, this approach suggests that a relatively modest area of new pine plantation forest (around 0.1 hectares per cow for a dairy herd) would need to be planted initially. After 16 years, the forest would reach its long-term average carbon stock and another 0.1 hectares per cow of new forest would need to be planted elsewhere. This would be followed by another 0.1 hectares per cow in year 32, another 0.1 hectares per cow in year 48, and so on forever.

Each area of new pine plantation forest can be harvested and replanted but it must remain forest land indefinitely, or an equivalent area of forest must be planted elsewhere if the original forest land is deforested.

This approach roughly balances out warming and cooling on average over time. But it does not ensure that the cooling from the forest planting compensates for the warming from the herd at all points in time.

During the first century, the cooling effect of the forest planting is insufficient to compensate for the warming effect of the methane emissions. In the second century, as more and more forest continues to be planted, this is reversed and the cooling effect of the forest planting becomes greater than the warming effect of the methane emissions.

A warming-based approach based on GWP*

I was curious to know if a warming-based approach to offsetting methane with trees could be developed that would avoid over- or undercompensating over time for the warming effect of sustained methane emissions from a herd of livestock. I therefore commissioned Frame and Melia to calculate what area of forest would be required to achieve this.

The method they developed used a greenhouse gas metric called GWP*. The GWP* metric was developed to reflect more accurately how sustained methane emissions change the global average temperature over time. A warming-based approach to offsetting livestock methane with trees based on GWP* would ensure that offsetting has roughly the same temperature effect at all points in time as reducing emissions at source.

Using this method, Frame and Melia estimated the area of new pine plantation forest and the timing of the planting that would be required to achieve roughly the same temperature effect over time as reducing a herd of livestock by one animal. The headline results were that a one-off upfront planting of 0.6 hectares per animal for dairy cattle, 0.4 hectares per animal for beef cattle, 0.2 hectares per animal for deer, and 0.08 hectares per animal for sheep would be needed.

The new area of pine plantation forest can be harvested and replanted. These calculations assume a 30-year rotation. The area of forest required is lower if the forest is planted in a region with higher than average growth rates or if it has a longer rotation length than 30 years.

Comparing the two approaches

Over a 100-year period, the total area of pine plantation forest that needs to be planted to offset an ongoing flow of livestock methane emissions is similar using either the conventional approach or a warming-based approach. The main difference between them is the timing of the planting.

If a warming-based approach using GWP* is used, the area of new pine plantation forest that needs to be planted upfront is around five to six times larger area than the area required using the conventional approach based on GWP_{100}. The warming-based approach therefore delivers more climate change mitigation immediately, rather than some time next century. The area required under the warming-based approach is fixed and no further expansion of forest area is required following the initial planting.

By contrast, the planting is spread out more evenly over a 100-year period in the conventional approach. But after 100 years, the area of forest required continues to expand every 16 years for as long as the flow of livestock methane emissions continues.

Using a warming-based approach to offset livestock methane does not lock up land permanently like offsetting fossil carbon dioxide does. If the stream of livestock methane emissions being offset is reduced in future, the forest land can be used for something else.

How much forestry would be needed to offset New Zealand's national livestock methane emissions?

The answer to this question depends on what total net reduction in warming is being sought, and the extent to which it proves possible to reduce livestock methane emissions at source.

If the aim is to reduce gross emissions of livestock methane by 24–47% by 2050 relative to the 2017 level, the calculations in this note could be used to offset some or all of the warming from the remaining emissions.

Planting around 770,000 hectares of new pine plantation forest between now and 2050 would have a similar temperature effect as reducing gross methane emissions by a further 10%. This is equivalent to planting 26,000 hectares every year on average between now and 2050.

These numbers can be scaled up; a further 20% would require 1.5 million hectares (51,000 hectares per year), a further 30% would require 2.3 million hectares (77,000 hectares per year), and so on.

To put these numbers into perspective, there is currently around 9 million hectares of land being used for pastoral farming in New Zealand and around 1.7 million hectares of production forest. The highest annual planting rate since records began was 98,000 hectares in 1998.

The areas of new forest required would be even larger if native tree species were used because they have lower carbon dioxide sequestration rates per hectare than fast-growing *Pinus radiata.*

As for other types of on-farm vegetation, the proportion of warming from livestock methane that could be offset using riparian plantings, scattered forest fragments, shelterbelts and woodlots would likely be minimal at the national level. Further, it would be almost impossible to estimate accurately in the absence of data on specific species types and vegetation age classes.

Planting very large areas of forest to offset livestock methane emissions could have co-benefits in some places, but adverse economic, social, cultural and environmental impacts in others. The consequences would be highly place-specific and would depend on the type of forest being planted. If not done carefully, there is a real risk that the negative impacts of forest planting could outweigh the negative impacts of reducing gross emissions.

Forest offsetting is no easy fix for neutralising New Zealand's livestock methane emissions. Care would be needed to ensure the cure is not worse than the disease.

Reducing gross emissions of livestock methane to the greatest extent possible – in addition to reducing gross emissions of carbon dioxide and nitrous oxide – must be the top priority. We cannot simply plant our way out of this problem, just as we can't plant our way out of burning fossil fuels.

12

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