Greenhouse gas emissions on New Zealand farms

A companion guide to the climate change seminar series for rural professionals

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Organising partners

With thanks to the following individuals for their expert input to the content:

- Journeaux Economics: Phil Journeaux
- AgResearch: Cecile de Klein, Robyn Dynes, Stewart Ledgard
- Groundtruth: John-Paul Praat, Peter Handford
- Manaaki Whenua: David Whitehead, Paul Mudge
- NZAGRC: Harry Clark, Greg Lambert, Andy Reisinger, Sinead Leahy, Laura Kearney
- Te Uru Rākau/Forestry New Zealand: Emily Geck
- University of Waikato: Louis Schipper

Overview

New Zealand's food and fibre sector contributed $56.2 billion in export revenue in 2022/23 and accounted for 81.8% of trade. It contributed 10.7% of GDP and 13.8% of employment. It also contributed half of our reported greenhouse gas emissions.

In line with our international obligations under the United Nations Paris Agreement, the Government is taking active steps to move New Zealand towards lowered greenhouse gas emissions and greater resilience to a changing climate. Government are working towards pricing agricultural emissions by 2030 at the latest. Agricultural markets and financiers are increasingly looking for emission reductions through their supply chains.

The challenge is significant, and mitigations need to be tailored to each farm.

Access to science-based information is critical for helping New Zealand farmers and growers, and the rural professionals that support them, understand the complexities of agricultural greenhouse gas emissions, what they mean on farm and what actions can be taken to manage them.

That’s what this booklet aims to do. It accompanies the information presented at the ‘Greenhouse Gas Emissions on New Zealand Farms’ seminar series run by the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), Journeaux Economics and the New Zealand Institute of Primary Industry Management (NZIPIM).

We are grateful to the Ministry for Primary Industries for funding support.

For more information on agriculture and climate change, see www.agmatters.nz

Dr Harry Clark, NZAGRC

Phil Journeaux, Journeaux Economics

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Setting the scene

Why climate change matters

Earth's atmosphere is heating up, associated with increasing concentrations of greenhouse gases. Significant changes to the climate are affecting our natural environment, primary sector, infrastructure and built environment, as well as human health.

Impacts of a warming climate

Globally

- Earth's average temperature has increased by about 1°C since humans started using fossil fuels. Most of the warming has occurred since the mid-1980s, with 19 of the warmest years on record occurring since 2000.
- The polar ice caps have melted faster in the last 20 years than at any other time in the last 10,000 years, and most glaciers around the world are retreating.
- The sea level has risen by about 21-24cm since scientific records began in 1880, and the rate of rise has increased in recent decades. In 2020, global sea levels set a new record high - 91.3mm above 1993 levels.
- There has been a 30% increase in ocean acidity in the last 250 years and scientists are predicting a 200% increase by 2100.
- There is a new pattern of more extreme weather across the globe – extreme heat, more intense precipitation, stronger hurricanes and other storms, more frequent floods and droughts.

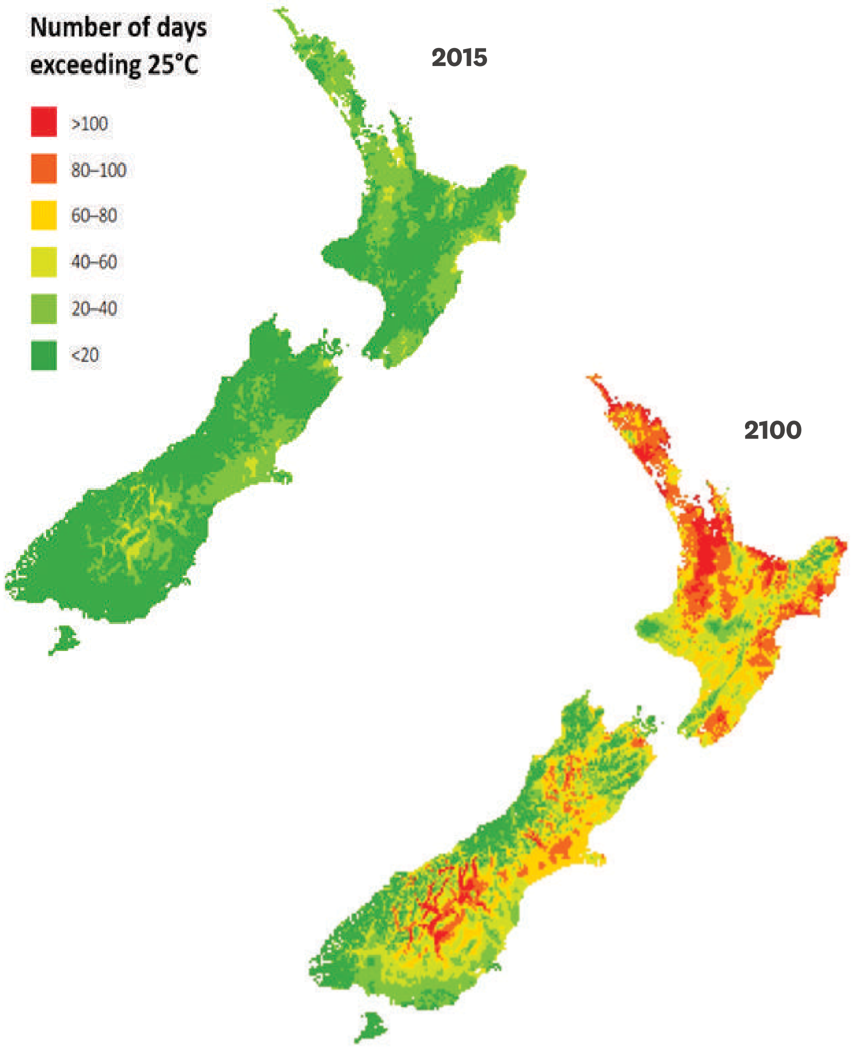
In New Zealand

- Temperatures are about 1.1°C hotter than they were a century ago, with seven of the eight hottest years on record occurring since 2013.
- Sea levels have risen 14–22cm since the early 1900s and are continuing to rise at a rate of 2.4mm each year.
- Our glaciers have lost 25% of their ice in the past 40 years and are melting seven times faster than they were 20 years ago.
- The country is experiencing fewer frost days and more warm days. Some locations are also experiencing drier soils and altered precipitation patterns.
- More intense weather events (droughts and storms) have occurred in many parts of the country in the last few years, and at unexpected times of the year.
- $800m in storm costs since 2015 (excluding the costs of Cyclones Hale and Gabrielle).

In the future

As New Zealand's climate changes, it might not be possible to farm in the same way as we can now. A couple of degrees of warming might not seem much, but it can have a big effect on pasture and crop growth and on pests, diseases and animal welfare. Here are some projections:

- Many places will see more than 80 days per year above 25°C by 2100, which will have a significant impact on ryegrass growth (it prefers temperatures of 5-18°C) and animal performance (see Figure 1).
- Winter and spring very likely to have increased rainfall in the west of the North and South Islands and be drier in the east.
- Summer is likely to be wetter in the east of both islands, while the west and central North Island will be drier.
- All areas are likely to get more very extreme rainfall, especially shorter, more intense events.
- Increased drought frequency in many regions of New Zealand (see Figure 2), and farmers in dry areas can expect up to 10% more drought days by 2040.



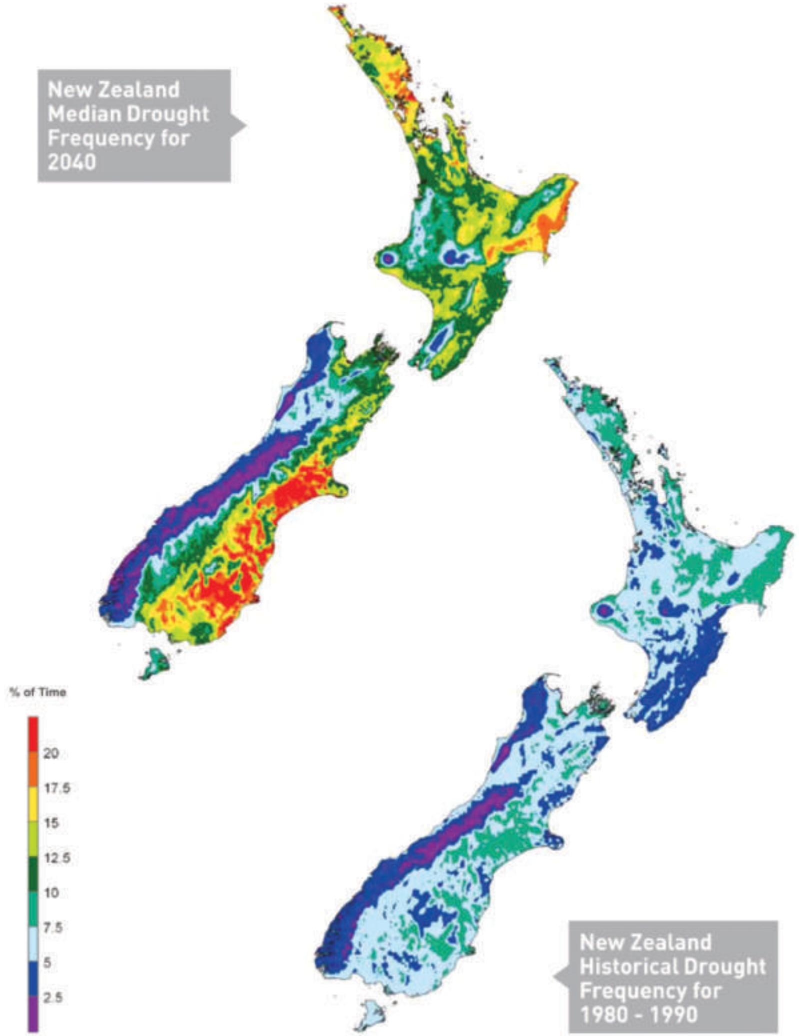


Figure 1: Number of days >25°C predicted to increase

Source: Royal Society of New Zealand (2016)

Figure 2: NZ median drought frequency for 1980/90 and 2040

Source: Royal Society of New Zealand (2016)

Some alternative views

It has been argued by some that the climate isn't warming, or that any observed warming is a result of natural climate variation and not emissions of greenhouse gases such as carbon dioxide, methane and nitrous oxide.

Within the agricultural sector, some have argued that methane doesn't matter or that methane and nitrous oxide make an insignificant contribution and should not be targeted in any national framework for reducing emissions.

Still others argue that increased carbon dioxide is actually good for the planet.

But there is strong evidence that the climate is changing, as outlined on the preceding pages and in Figure 3, which shows the increase in the global average temperature from 1850 until 2021.

Figure 4 shows the increase in global carbon dioxide levels - now at their highest in 650,000 years. Over the past 171 years, human activities have raised atmospheric concentrations of carbon dioxide by 48% above the pre-industrial levels found in 1850. This is more than what had happened naturally over a 200,000 year period.

Figure 5 illustrates that warming is associated with increasing levels of greenhouse gases and is not the result of natural climate variation. It shows the modelled atmospheric temperature anomalies, (which are driven in the model by atmospheric greenhouse gas concentrations), from 1850 to 2020, compared to the observed or actual warming.

Finally, the series of graphs in Figure 6 show that methane (CH_4) does matter when it comes to limiting global warming. The graphs depict alternative scenarios for achieving the goal of limiting warming to well below 2°C – based on different combinations of limiting carbon dioxide and methane.

The default scenario is the dark green line, which shows that, even with the expected decline in methane, net global carbon dioxide emissions need to go **negative** by 2080. That is, carbon dioxide emissions need to be physically removed from the atmosphere by 2080 in order to reduce warming to below 2°C. This is technically very challenging.

If methane is held constant (pale green line), then even more carbon dioxide needs to be removed to ensure that warming is limited. In other words, carbon dioxide needs to go negative by 2060.

If methane is reduced (brown line), then carbon dioxide emissions still need to reach net zero but don't need to go significantly below zero by the end of the century, and those reductions can be achieved at a slower and more manageable pace.

However, in contrast to carbon dioxide emissions, in none of these simulations do methane emissions need to go to zero. For more on methane, see pages 26-27 and 34-38.

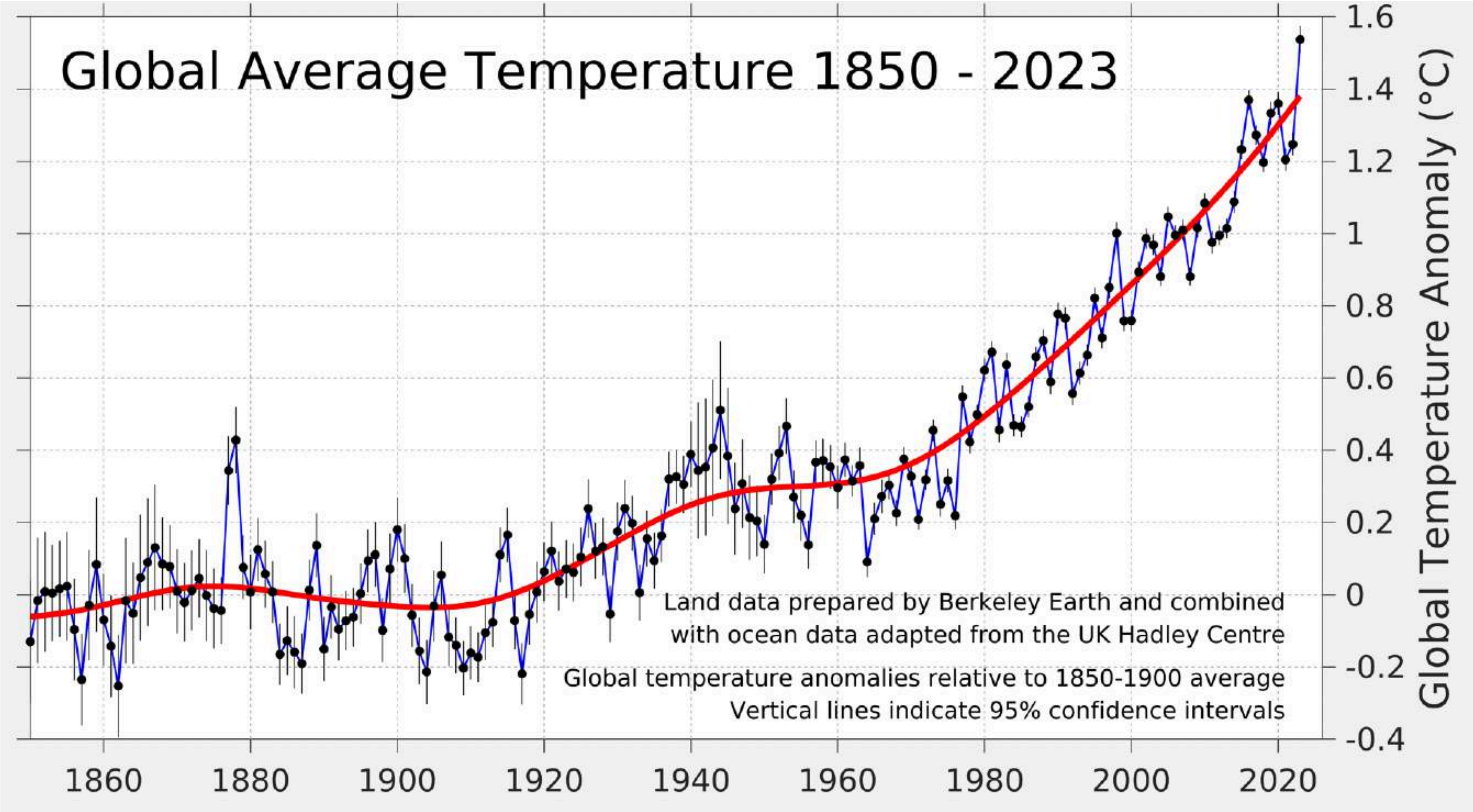


Figure 3: Global Average Temperature 1850-2023

Source: Global Temperature Report for 2023, www.berkeleyearth.org

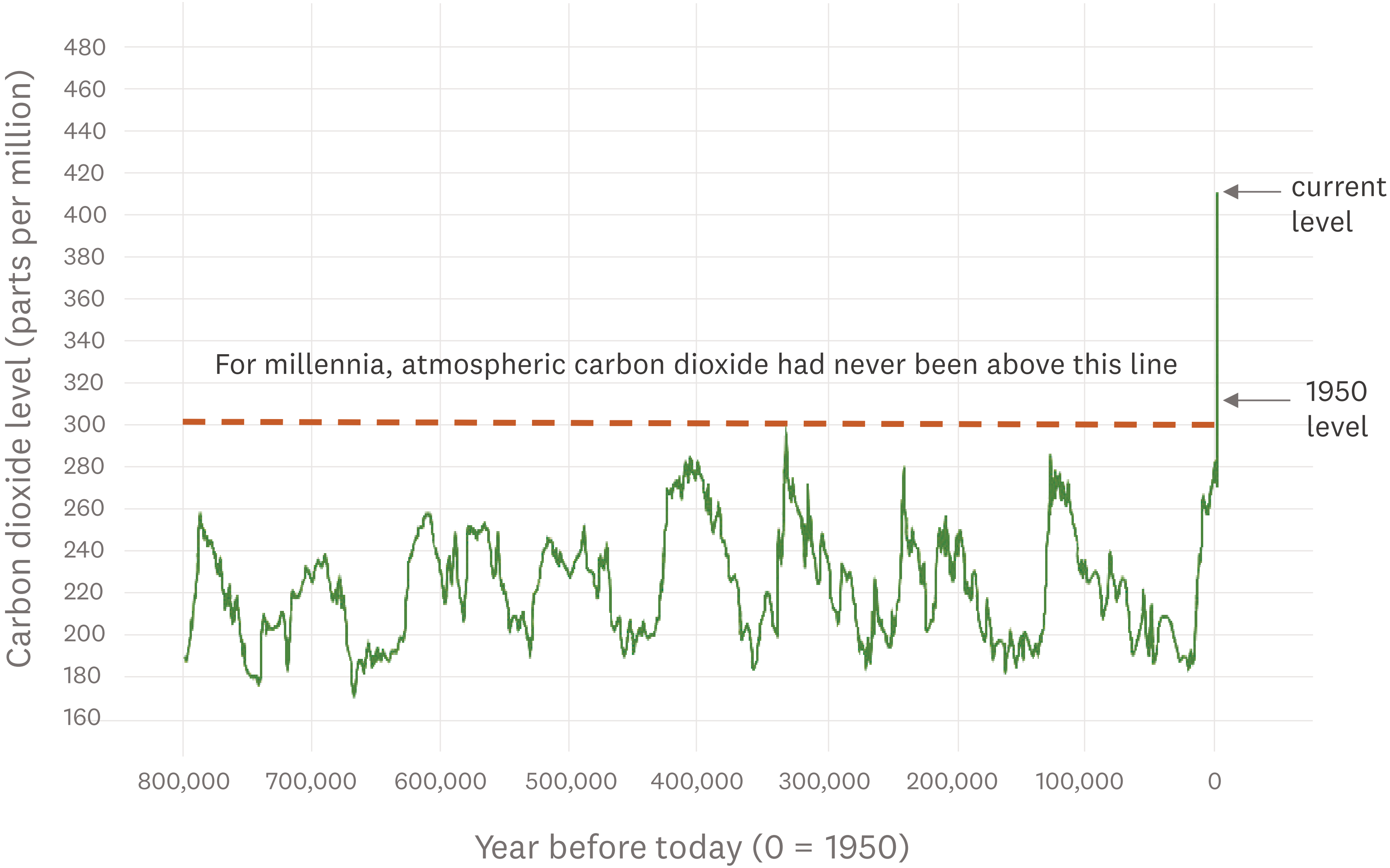


Figure 4: Global carbon dioxide levels over time

Source: climate.nasa.gov

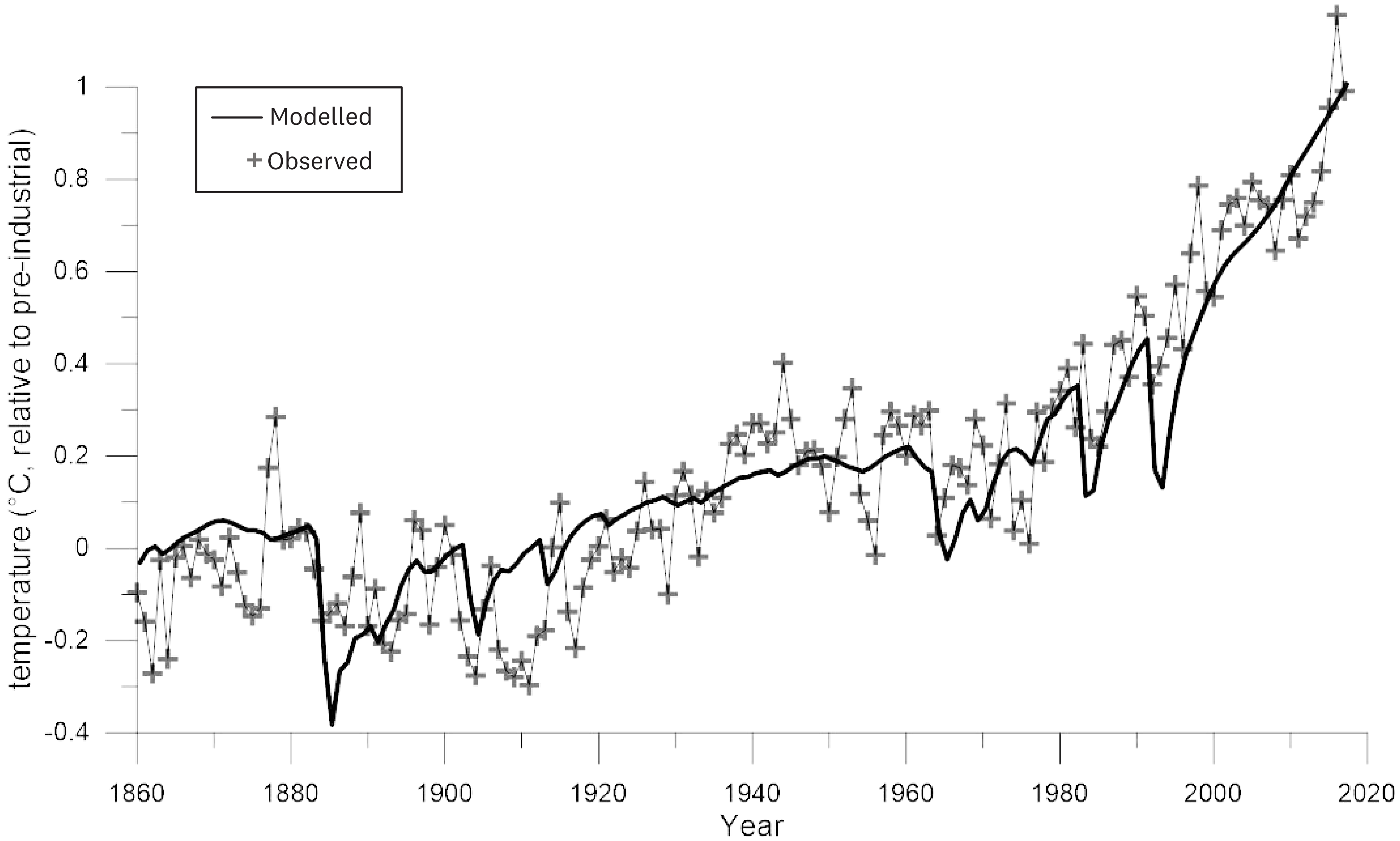


Figure 5: Modelled and observed temperatures

Source: Reisinger, A. and Clark, H. (2017). How much do direct livestock emissions actually contribute to global warming? Global Change Biology 24(4). https://doi.org/10.1111/gcb.13975

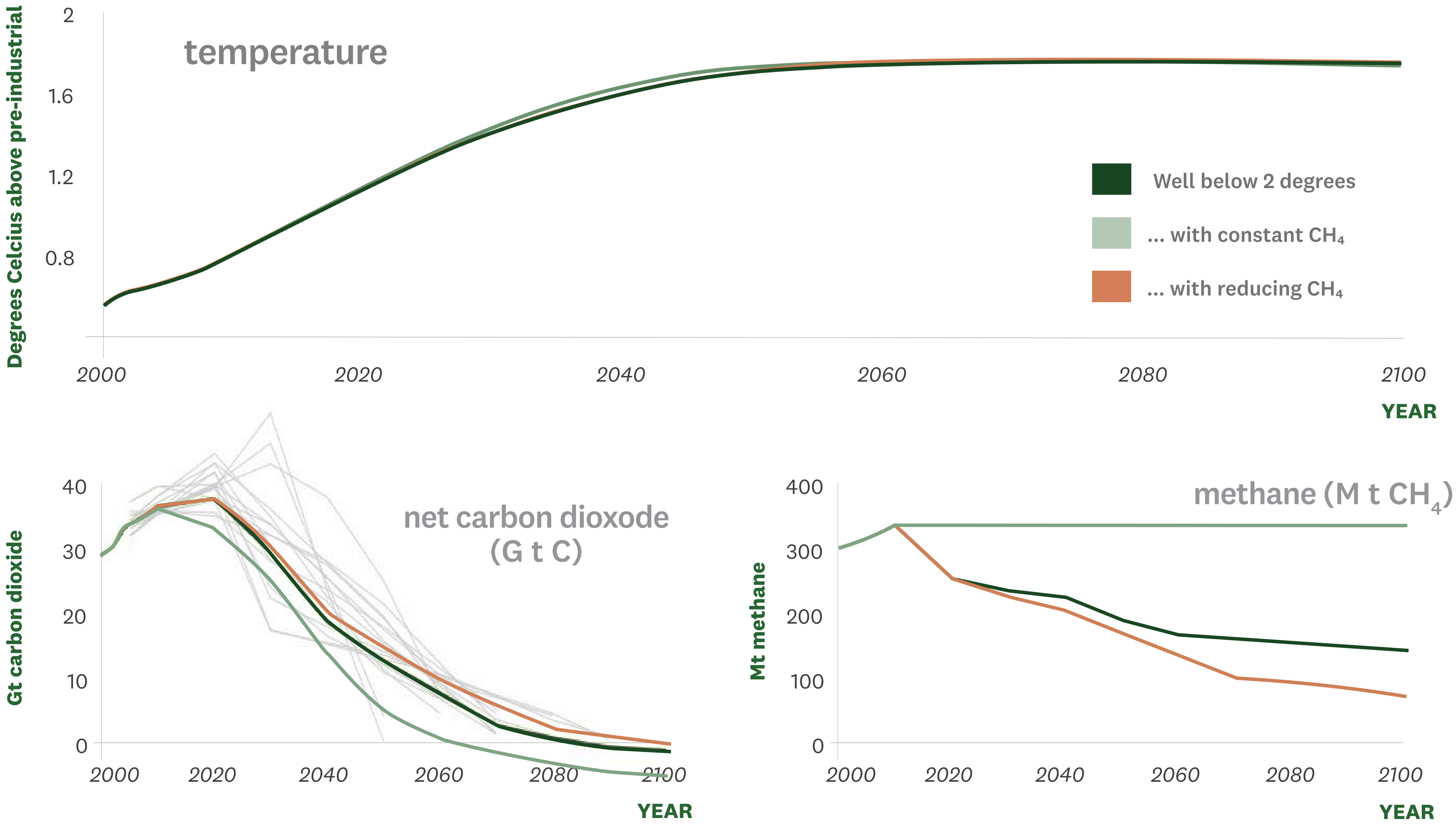


Figure 6: Three alternative scenarios for global emissions of carbon dioxide and methane that limit the temperature rise to 2°C

Source: Reisinger, A. (2018). The contribution of methane emissions from New Zealand livestock to global warming. A report to the Parliamentary Commissioner for the Environment.

New Zealand's greenhouse gas emissions

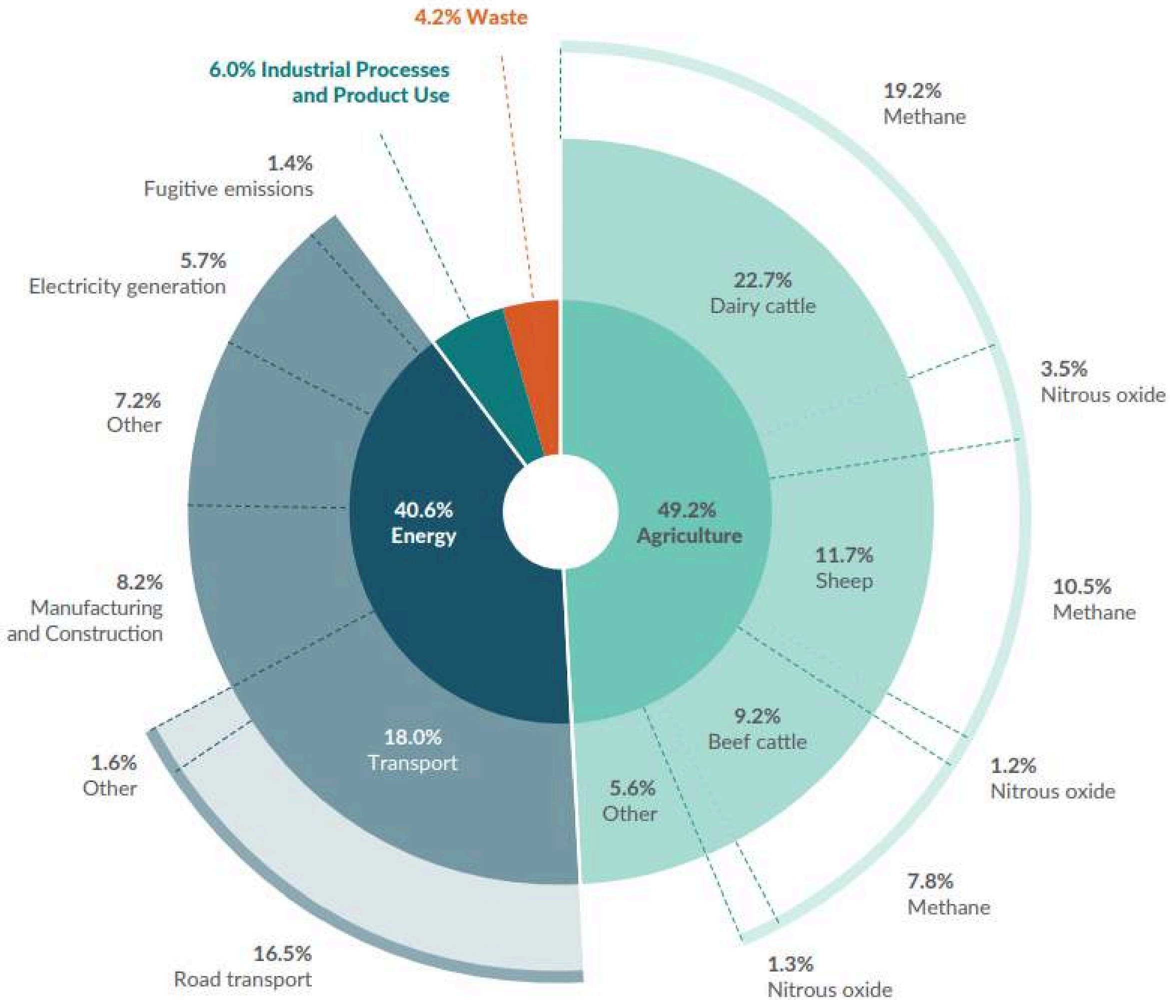
New Zealand's emissions profile is unique. Globally, carbon dioxide is the main greenhouse gas but in New Zealand in 2020, the agriculture sector contributed half of our total reported carbon dioxide equivalent (CO_2-e) emissions (see Figures 7 and 8), with methane from ruminant livestock the main contributor. The energy sector is the second largest emitter in New Zealand, mostly from transport.

This information is reported each year in the New Zealand Greenhouse Gas Inventory, the official annual estimate of all human-generated greenhouse gas emissions and removals in New Zealand. In 2020, New Zealand's gross emissions were 76,800 kilotonnes of carbon dioxide equivalent (Mt CO_2-e), comprising 45% carbon dioxide, 43% methane, 10% nitrous oxide and 2% fluorinated gases. This represents a 19% increase in emissions since 1990 (which is when international reporting obligations for greenhouse gas emissions began). The next inventory update will be provided in April 2024, for emissions from the 2022 year.

Overall, our emissions are small at just 0.17% of global gross emissions (22nd among developed countries). However, our per capita emissions are the sixth highest in the world.

Agriculture's dominance in New Zealand's emissions profile sets us apart from other developed countries, where carbon dioxide emissions from the energy and transport sectors are much higher (Figure 8). Our profile reflects our strong pastoral production base (contributing $56.2 billion in export revenue in 2022/23) and the use of renewable energy to generate most of our electricity.

In 2021, 81.4% of New Zealand's reported agricultural emissions was enteric methane from ruminant animals. A further 16.3% of agricultural emissions was nitrous oxide, largely (98%) from the nitrogen in animal urine and dung, with a smaller amount from the use of synthetic fertilisers. The remainder of agricultural emissions in 2021 were mostly methane from manure management (4.4%) and carbon dioxide from fertiliser, lime and dolomite.



Note: Percentages in the graph may not add up to 100 due to rounding.

Figure 7: Breakdown of emissions by sector (Agriculture, Energy, Industrial Processes and Product Use, and Waste), and sub-category, and greenhouse gas by type.

Source: New Zealand Greenhouse Gas Inventory 1990-2021, published April 2023
https://environment.govt.nz/publications/new-zealands-greenhouse-gas-inventory-19902021-snapshot/

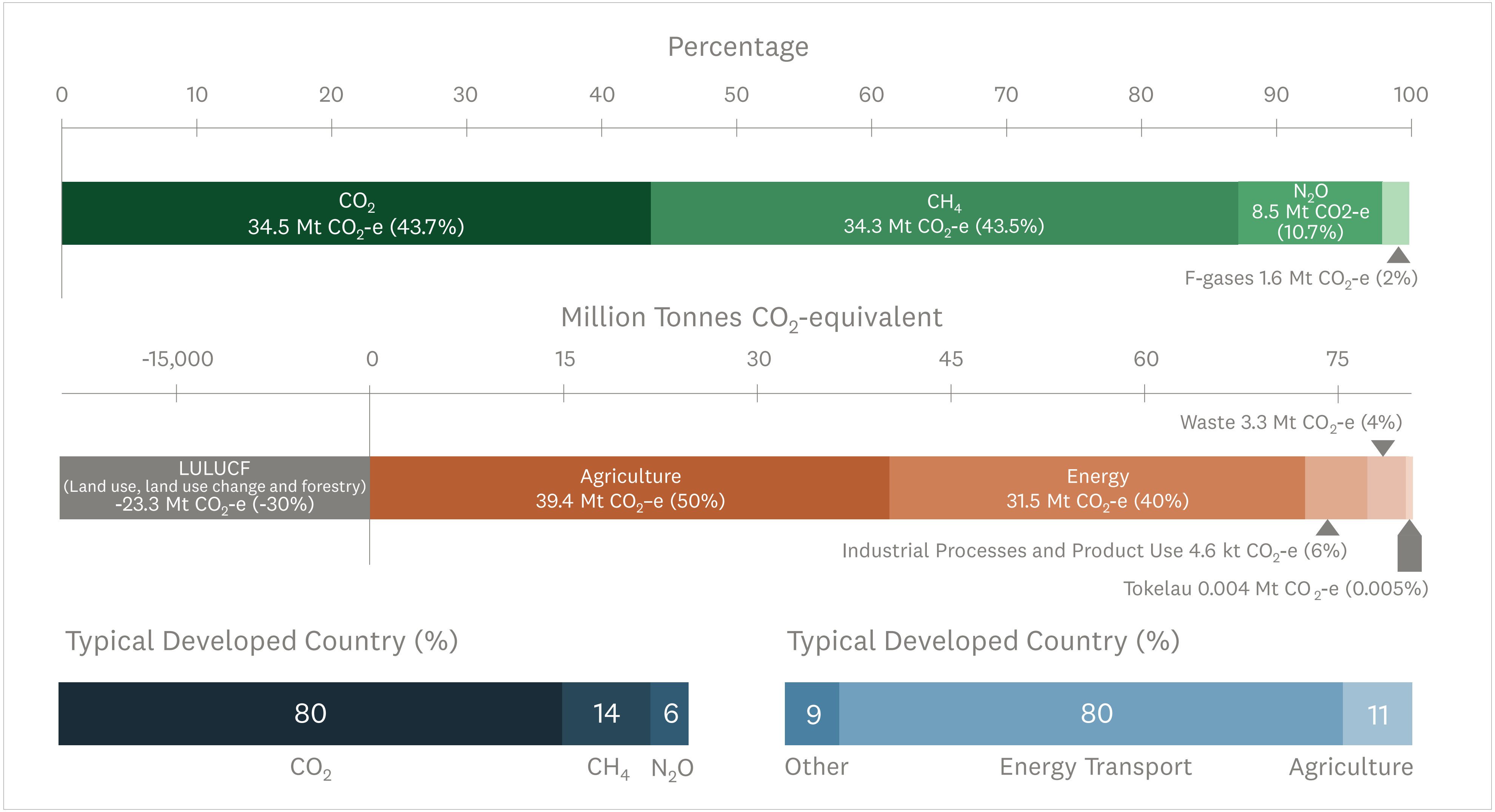


Figure 8: Comparing New Zealand's percentage emissions to that of a typical developed country

Source: New Zealand Greenhouse Gas Inventory 1990-2020, published April 2022

How are agricultural emissions changing?

New Zealand's estimated carbon dioxide equivalent agricultural emissions have risen by about 17% since 1990 (see Figure 9). Emissions from the dairy sector have more than doubled over that period. Although emissions per kilogram of milk have decreased (see Absolute Emissions vs. Emissions Intensity on pages 19 - 21), the dairy sector is producing much more milk than before[1] (although from fewer cows)[2].

A 50% reduction in the number of sheep and a 25% reduction in the number of beef cattle have led to sheep and beef emissions decreasing by about a third since 1990[3]. At the same time, the sector has made significant productivity gains, for example the average weight of a lamb carcass was 19kg in 2021 whereas it was 14.4kg in 1990. Similarly, in 1990 average ewe lambing was 100% whereas it is now 132 lambs born per 100 ewes.

Since 1990, there has also been a seven-fold increase in nitrogen fertiliser use, largely due to the intensification of dairy farm systems in combination with an increased area in dairying[4].

[1] In 1990/91, the milk solids processed in New Zealand was 599 million kgs. In 2020/21, that had increased to 1.947 billion kgs, which was also 2.7% more than the 2019/20 season. Average milk production per cow also increased by 3.1% from 2019/20 to 397kg milk solids - the highest on record (LIC & DairyNZ, New Zealand Dairy Statistics 2020-21).

[2] In 2020/21, there were 4.9 million milking cows in New Zealand, a small decrease of 0.36% from the previous season and down significantly from the peak cow numbers in 2014/15, which were over 5 million.

[3] Beef + Lamb New Zealand 2021 Annual Report

[4] Fertiliser Association website

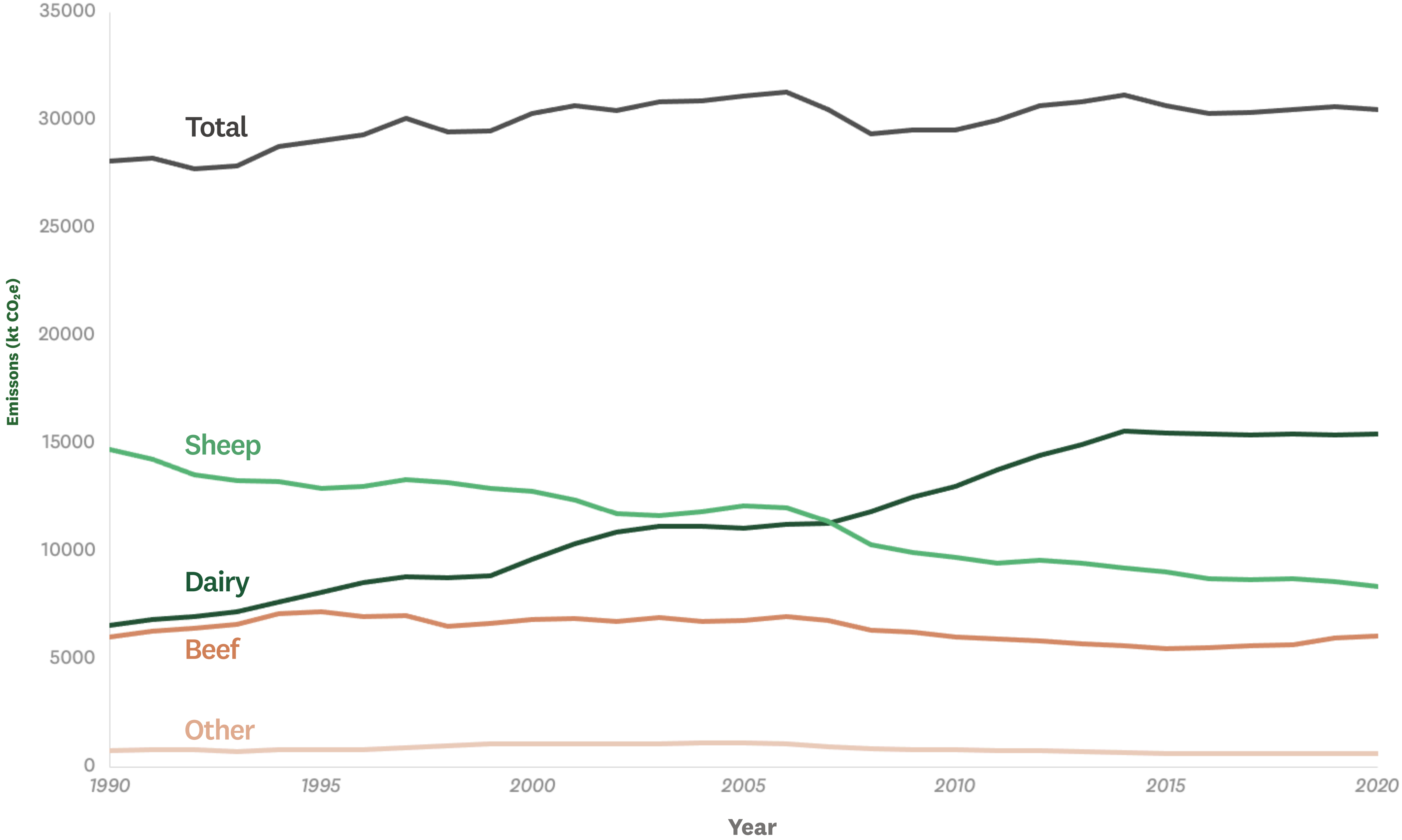


Figure 9: New Zealand's agricultural methane emissions (1990-2020)

Source: NZAGRC (2023) - source data from the New Zealand Greenhouse Gas Inventory 1990-2020

Absolute emissions vs. emissions intensity

Emissions intensity is the volume of emissions produced per unit of product. Absolute emissions are the total emissions produced by an enterprise or entity. Reducing emissions intensity means that fewer carbon dioxide equivalent (CO_2-e) emissions are being created per unit of product, but if there is an increase in the units produced, then there can still be an increase in absolute/total emissions, as illustrated in Figures 10 and 11.

Over the last 25 years or so, New Zealand farmers have markedly improved the efficiency of their farming operations. In dairy, this has been driven by an increased milk yield per cow and for sheep through increased reproductive efficiency and higher lamb growth rates and carcass weights. This has collectively reduced emissions intensity by about 20%. Without these changes, current agricultural emissions would have been 40% higher. However, simply focusing on emissions intensity is not enough. New Zealand’s international and domestic reduction targets (see pages 22-24) focus on absolute emissions, meaning that reductions in farm-level emissions need to be accounted for and reported in the same way.

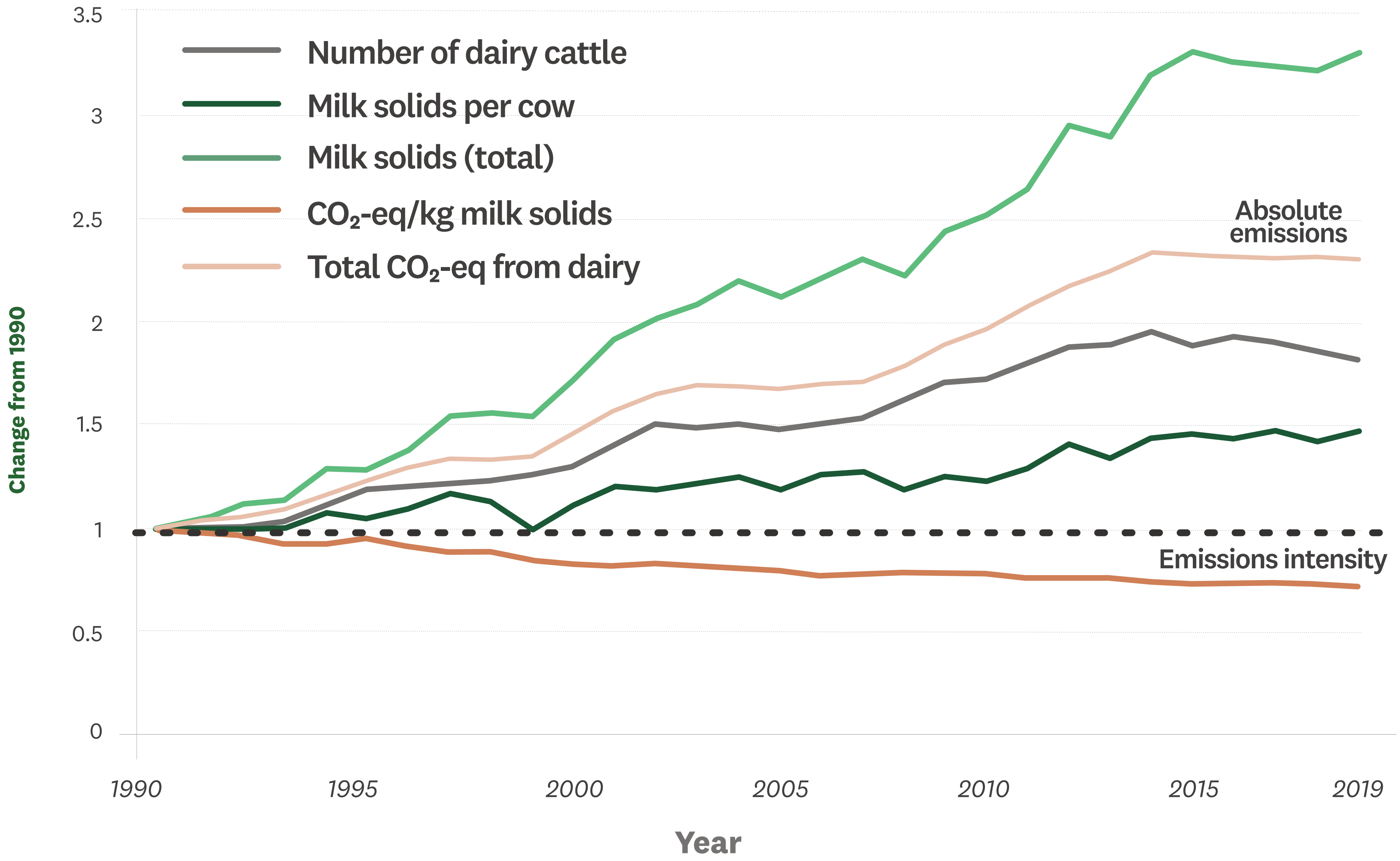


Figure 10: Changes in dairy greenhouse gas emissions intensity and absolute emissions (1990-2019)

Source: NZAGRC, with data sourced from the New Zealand Greenhouse Gas Inventory 1990-2019, DairyNZ and Statistics New Zealand

Figure 11: Total New Zealand agricultural emissions 1990-2016 (solid line) and two hypothetical scenarios with (a) identical increase in food production but no improvements in animal performance (i.e. a further increase in animal numbers to achieve the additional production (dashed brown line)), and (b) an identical improvement in animal performance but no increase in food production (i.e. a reduction in animal numbers to match the improved animal performance (dashed green line)).

Source: NZAGRC

Agricultural greenhouse gases and policy

International commitments

The Paris Agreement was adopted under the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 and commits all participating countries to act on climate change.

The purpose of the Paris Agreement is to:

- Keep the global average temperature well below 2°C above pre-industrial levels, while pursuing efforts to limit the temperature increase to 1.5°C
- Strengthen the ability of countries to deal with the impacts of climate change
- Make sure that financial flows support the development of low carbon and climate-resilient economies

New Zealand ratified the Paris Agreement in 2016. This commits us to having an emissions reduction target and regularly updating progress towards it. We must also report on our emissions and how we're tracking towards our target, provide financial support to assist developing countries and plan for adaptation.

Under the Paris Agreement, New Zealand has committed to reducing carbon dioxide equivalent emissions to 50% below 2005 levels from 2020 to 2030. In UN lingo, this is known as our 'Nationally Determined Contribution' or NDC. Examples of other countries' commitments are shown in Table 1.

Figure 12 then shows how the collective global efforts stacks up against the Paris Agreement's goal of limiting warming to 1.5°C. The Climate Action Tracker (CAT) shows that global temperatures could still be 2.7*C warmer by 2100 based on current levels of government action, indicating that much more needs to be done.

Table 1: Examples of other countries' commitments under the Paris Agreement

Country	Paris Agreement commitment
New Zealand	50% below 2005 levels by 2030
Australia	43% below 2005 levels by 2030
Brazil	50% below 2005 levels by 2025
Canada	40-45% below 2005 levels by 2030
France	47.5% below 2005 levels by 2030
Ireland	42% below 2005 levels by 2030
Netherlands	48% below 2005 levels by 2030
United Kingdom	68% below 1990 levels by 2030
United States	50-52% below 2005 levels in 2030

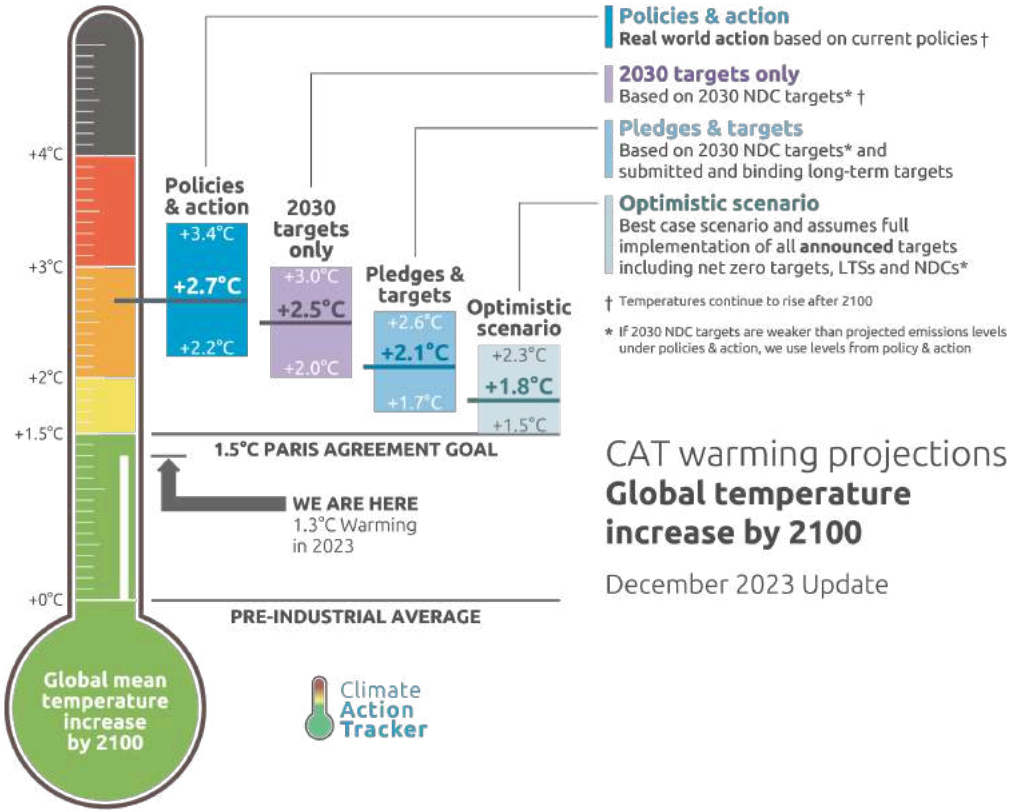


Figure 12: Climate Action Tracker (CAT) warming projections: global temperature increase by 2100 - as of December 2023

Source: https://climateactiontracker.org/global/cat-thermometer/

Agriculture in the Paris Agreement

Agriculture is mentioned in the UNFCCC Paris Agreement in two places:

1. ***In the 'preamble' or non-binding part of the treaty, where "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change" are recognised; and***
2. ***In Article 2, where the Agreement seeks to increase "the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production".***

Domestic commitments

A credible, long-term greenhouse gas reduction target is an important part of ensuring that New Zealand can meet its international commitments and make a smooth transition to a low emissions future.

This is achieved through the Climate Change Response (Zero Carbon) Amendment Act 2019 (also known as the Zero Carbon Act), which was passed into law in 2019. It provides a framework for New Zealand to:

- Contribute to the global effort under the Paris Agreement; and
- Prepare for, and adapt to, the effects of climate change.

The legislation puts in place long-term targets for reducing New Zealand's greenhouse gas emissions:

- Carbon dioxide and nitrous oxide (the 'long-lived' gases) are to reduce to net zero by 2050
- Methane emissions are to reduce to 10% below 2017 levels by 2030, and 24-47% below 2017 levels by 2050.

This is the first time there have been different targets for different gases in New Zealand, recognising the different warming effect of methane in the atmosphere.

As well as the targets, the legislation:

- Establishes a Climate Change Commission (see next page); and
- Requires the Government to have:
    - Three five-yearly emissions 'budgets'[5] in place as stepping stones towards the 2050 targets
    - An Emissions Reduction Plan (ERP) that describes how New Zealand will meet the current emissions budget and make progress towards the 2050 targets
    - A national adaptation plan to ensure New Zealand builds climate resilience

After considering advice from the Climate Change Commission, the Government released its first ERP in May 2022. This establishes three emissions budgets to 2035 (see Table 2) and contains strategies, policies and actions for the first budget. At the time the Government also announced $2.9 billion to support the initiatives in the ERP, including nearly $339 million to accelerate the development of high-impact technologies and practices for reducing agricultural greenhouse gas emissions.

Table 2: Emissions budgets out to 2035 (Mt CO_2-e)

	First emissions budget 2022-2025	Second emissions budget 2025-2030	Third emissions budget 2030-2035
All gases, net (AR5)	290	305	240
Annual average	72.5	61.0	48.0

[5] An emissions budget is a set quantity of emissions allowed during a defined period of time.

Climate Change Commission

The Climate Change Commission – He Pou a Rangi – was established in November 2019. Its purpose is to provide independent evidence-based advice to successive governments on New Zealand's greenhouse gas emissions and the potential impacts and effects of climate change. It also monitors and reviews progress towards the country's goals for reducing emissions and adapting to a changing climate.

In December 2023, following extensive public consultation, the Commission released its latest package of advice to the Government covering the second and third emissions budgets, and a wide range of other issues, including advancing the agricultural pricing mechanism and enhancing agricultural extension services.

The Commission has a number of other pieces of work underway, including providing advice on aspects of the Emissions Trading Scheme (see page 29-30) and the Government's pricing of agricultural greenhouse gas emissions (see page 31-33), and reviewing the 2050 targets (this is due in December 2024). It will also monitor progress against the Government's Emissions Reduction Plan and how the National Adaptation Plan is implemented and will deliver the next National Climate Change Risk Assessment (due in 2026).

For more, see www.climatecommission.govt.nz

Other drivers at play

There are a range of commercial factors also starting to play a role. For New Zealand, market access through trade agreements are essential for our economy, and climate change issues are becoming a component of these. Consequently, processing and marketing companies in New Zealand are responding to these signals and are starting to place requirements on suppliers to manage their emissions. Similarly, the financial institutions are implementing loans aligned with emission reductions (and other environmental targets) through lowered interest rates.

Fonterra

- Net zero by 2050; 50% reduction in Scope 1&2 by 2030 from a 2018 base year and 30% intensity reduction in Scope FLAG 1&3 from a 2018 base year

Danone

- Net zero by 2050; Reduce absolute Scope FLAG 1&3 emissions from Forest, Land and Agriculture 30.3% by 2030 from a 2020 base year

Tesco

- Reduce absolute Scope FLAG 3 emissions 39% by 2032, using a 2019 base year
- Net zero across total emissions footprint by 2050, including supply chain and products

Nestle

- 20% emissions reductions by 2025
- 50% emissions reductions by 2030
- Net zero emissions by 2050 at the latest

Mars

- Net zero by 2050; Reduce Scope FLAG 1&3 by 45.5% by 2030 from a 2015 base year

Kellogg Company

- Reduce absolute Scope 3 emissions 20% by 2030 from a 2015 base year

Unilever

- Reduce absolute Scope 3 emissions 20% by 2030 from a 2015 base year

McDonalds

- Net zero by 2050; Reduce absolute Scope 3 FLAG GHG emissions 16% by 2030 from a 2018 base year

Rabobank

- Net zero financed emissions by 2050

Why is there a different target for methane?

Methane is a powerful but relatively short-lived greenhouse gas. A methane emission disappears from the atmosphere quite quickly. About 63% of it disappears after about 12 years and the rest within 50 years of the emission occurring.

However, the warming caused by methane is not as short-lived. The warming from an emission of methane today will still be felt several centuries from now as the climate absorbs and redistributes the heat trapped while the methane is still in the atmosphere (see the grey shaded area in Figure 13).

Figure 14 compares the warming effect of methane with the warming effect of carbon dioxide. This type of comparison is called 'Global Warming Potential' (see page 28). In this comparison, one tonne of methane traps approximately 30 times more heat than a tonne of carbon dioxide over a 100-year period. However, carbon dioxide causes sustained warming for thousands of years. Similarly, nitrous oxide is a long-lived gas that also causes sustained warming for several centuries.

If methane is emitted at a constant rate, methane concentrations will stabilise within about 50 years as each new emission simply replaces a previous emission that is decaying naturally. Therefore, because the atmosphere does not accumulate methane, emissions do not have to go to zero. However, if methane emissions continue at or near their current rates, they will keep the Earth a lot warmer than it would be without those ongoing emissions. The less methane we emit in the future, the less we will contribute to global warming (Intergovernmental Panel on Climate Change (2018), *Special Report on Global Warming of 1.5°C*).

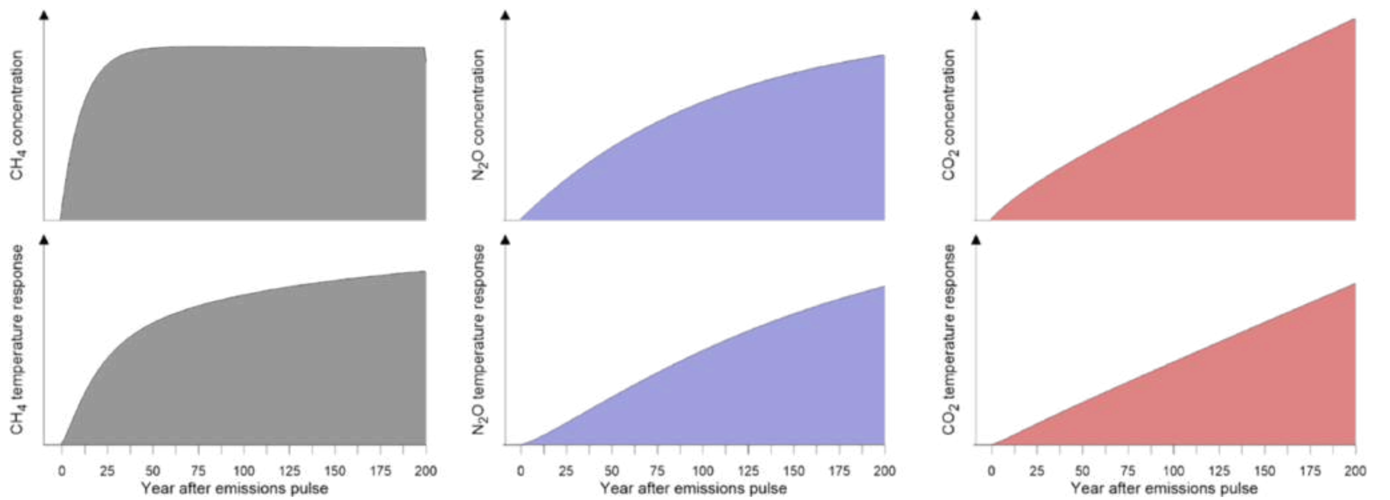


Figure 13: Different gases have different warming effects

Source: Based on Reisinger, A. (2018). The contribution of methane emissions from New Zealand livestock to global warming. A report to the Parliamentary Commissioner for the Environment.

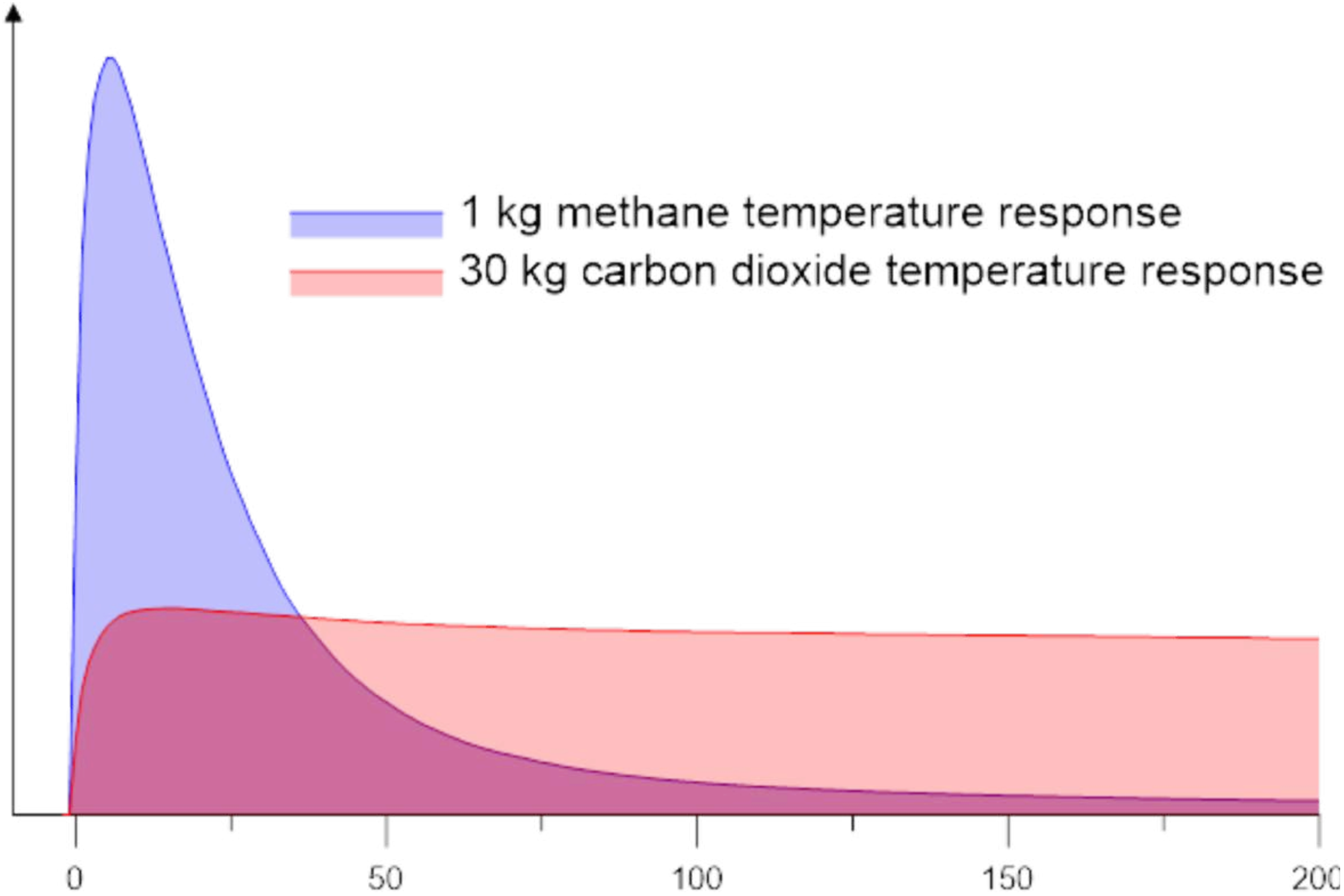


Figure 14: Warming effect of methane vs. carbon dioxide

Source: Based on Reisinger, A. (2018). The contribution of methane emissions from New Zealand livestock to global warming. A report to the Parliamentary Commissioner for the Environment.

Global Warming Potential

Different greenhouse gases can have different effects on the Earth's warming. A range of methods (known as 'metrics') have been developed over the years to compare the climate impacts of the gases, using a common currency.

The Global Warming Potential (GWP) metric averages the warming effect of an emission pulse over a given timeframe, e.g. 20, 50 or 100 years. By doing this, it indicates the ability of the gas in question to trap extra heat in the atmosphere relative to carbon dioxide. It is usually expressed as 'carbon dioxide equivalent' or CO_2-e. The most common timeframe is 100 years, which is known as 'GWP100'. It is used extensively for national and international reporting of emissions and by countries for target-setting and for pricing schemes. It is also used at the product level for greenhouse gas footprinting.

GWP (GWP 'star') has received attention in recent years. It compares the warming coming from continuous emissions of a short-lived, non-CO_2 gas (e.g. methane) with the warming coming from a one-off emission pulse of carbon dioxide.*

GWP100 compares the warming with and without an emission, whereas GWP looks at the change in warming coming from a time series of emissions. GWP values are always positive as they reflect emissions. However, GWP* values can be zero, negative or positive, as the metric is designed to directly compare warming at different points in time, not emissions at different points in time. Zero and negative GWP* values do not imply there is no warming, rather that there is less warming at one point in time compared to the warming that occurred at a previous time point.*

GWP can provide a better estimate of the warming coming from continuous emissions of short-lived gases like methane. However, the metric is very difficult to apply at a farm scale, in part because it requires around 20 years of historical data to work properly (otherwise it's erratic).*

The New Zealand Emissions Trading Scheme

The Emissions Trading Scheme (ETS) is the Government's main tool for reducing greenhouse gas emissions. It was established in 2008 to put a price on emissions, creating a financial incentive for businesses to reduce their emissions and landowners to earn money by planting forests that absorb carbon dioxide as the trees grow.

One emission unit, the New Zealand Unit (NZU), represents one metric tonne of carbon dioxide. The way the ETS works is shown in Figure 15.

The ETS was intended to be an 'all sectors, all gases' scheme. However, agriculture is not currently included other than for reporting purposes, meaning carbon dioxide is the only gas with surrender obligations.

Some changes were made to the ETS in 2020, which include:

- A cap on total emissions covered by the scheme that declines over time, in line with the Government's emissions budgets and the 2050 targets.
- Auctioning introduced in 2021 to allow the Government to sell NZUs from within the cap.
- Establishment of controls to prevent unacceptably high or low prices, which were updated in 2023:

Cost Containment Pricing ($/NZU)

	Current	Dec 2023	2024	2025	2026	2027	2028
Tier 1	$82	$173	$184	$194	$205	$215	$226
Tier 2		$216	$230	$243	$256	$269	$283
Floor price	$33	$60	$64	$68	$72	$75	$79

- Phase-out of industrial allocation from 2021 at a rate of 1% per year until 2030, 2% per year from 2030-2040, and 3% per year from 2040-2050.
- Changes to improve forestry's participation.

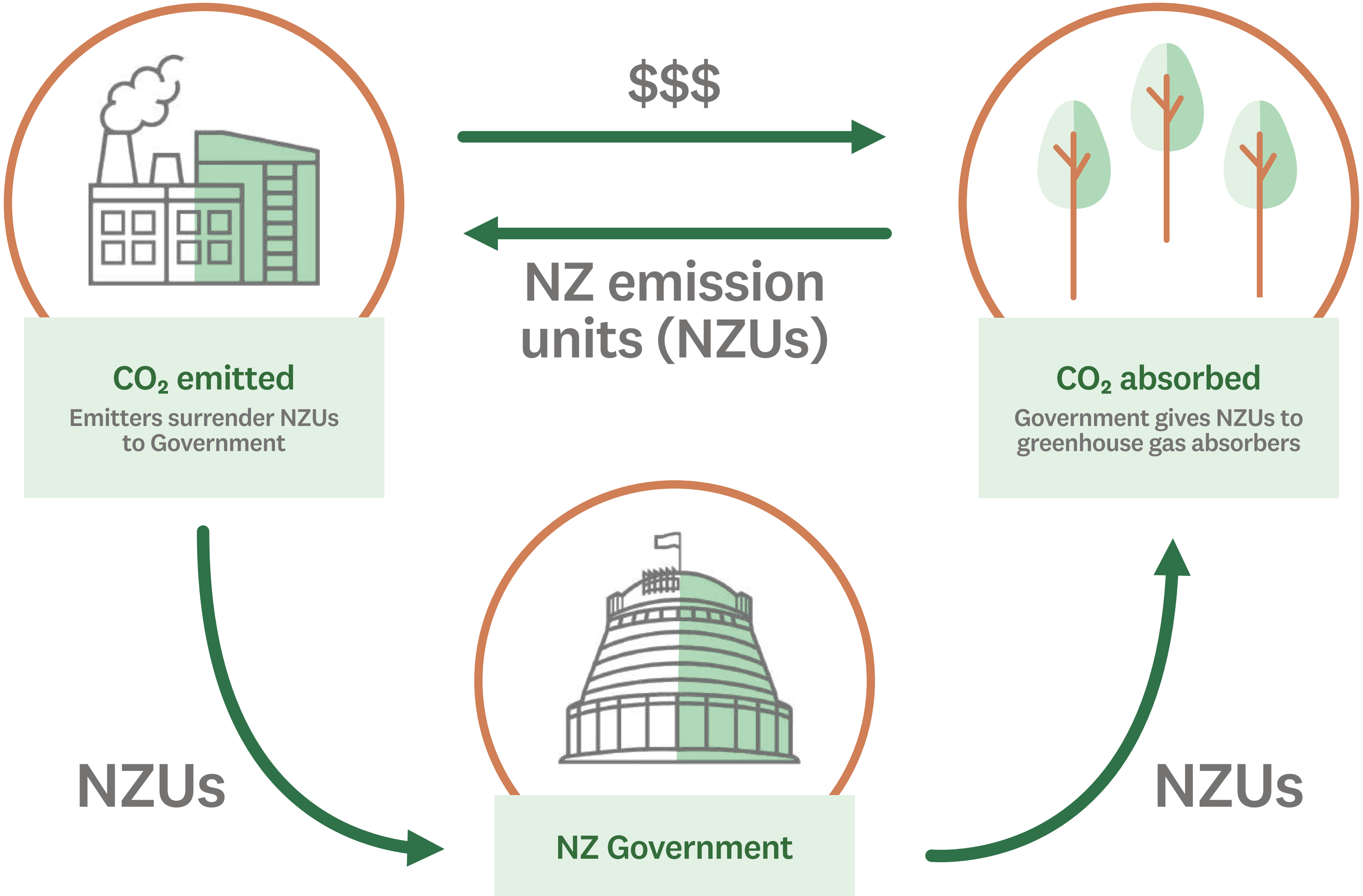


Figure 15: How the ETS works

Pricing agricultural greenhouse gas emissions

He Waka Eke Noa

In October 2019, following widespread consultation, the Government announced 'He Waka Eke Noa'[6] – a five-year partnership between Government, industry and Māori to reduce agricultural greenhouse gas emissions.

The partnership's main focus was to develop a farm-level pricing mechanism for agricultural greenhouse gas emissions as an alternative to pricing via the ETS. The partnership was also charged with targets for all farmers and growers to:

- Know their annual on-farm agricultural greenhouse gas emissions by December 2022; and
- Have a written plan in place for managing their emissions by December 2024.

[6] Translating to 'We're all in this together'

Developing the pricing scheme

In late May 2022, following extended consultation on a range of pricing options, the He Waka Eke Noa partnership reported back to Government, recommending a farm-level split-gas levy. Key features included:

- Farmers calculate their short- and long-lived gas emissions through a single centralised calculator (or through existing tools/software that are linked to the calculator).
- Calculated on-farm emissions determine the levy cost rather than the use of national averages.
- Recognition of reduced emissions from on-farm efficiencies and mitigations as they become available.
- Incentives are provided for uptake of actions to reduce emissions.
- A split-gas approach applies different levy rates to short- and long-lived gas emissions.
- On-farm sequestration is recognised, which could offset the cost of the levy.
- Levy revenue is invested in research, development and extension, including a dedicated fund for Māori landowners.
- A System Oversight Board with expertise and representation from the primary sector would work closely with an Independent Māori Board to provide recommendations on the levy rates and prices and set the strategy for use of levy revenue.
- Levy rates should be set as low as possible to drive emissions reductions, while maintaining a profitable primary sector.

In parallel, the Government had requested the Climate Change Commission to provide advice on the He Waka Eke Noa recommendations. The Commission's report was published in July 2022. It agreed with many of the partnership's recommendations, including – importantly – that a farm-level pricing scheme outside the ETS was the best approach to pricing agricultural emissions in the long term. However, there were several areas of difference in the Commission's advice:

- A high price should be used to drive behaviour change, with output-based assistance to moderate the impacts of that price.
- Nitrogen fertiliser emissions should be included in the ETS at the processor level and before 2025.
- Non-ETS sequestration through on-farm vegetation should not be included in the farm-level pricing scheme. Instead, it should be recognised in a separate scheme that could then reward a range of other benefits e.g. biodiversity and freshwater.

The Government opened a public consultation process during October and November 2022 to gather views on the way forwards for pricing emissions at the farm level, drawing on the He Waka Eke Noa recommendations and the Commission's advice. On 21 December 2022, the Government released its final report on the pricing scheme. Key features include:

- A farm-level split-gas levy for agricultural emissions that would price emissions from methane and nitrous oxide (including from fertiliser) from January 2025 (this date may be adjusted to later in 2025 to better align with farm accounting systems).

- Emissions thresholds set to determine participation in the scheme (equivalent to ~200 tonnes CO_2-e per year):
    - 550 stock units (sheep, cattle, deer, calculated on a weighted annual average basis); or
    - 50 dairy cattle; or
    - Applying over 40 tonnes of nitrogen through fertiliser.
- Reporting can be done at either the individual farm level or via a collective. If the latter, they would still need to be a GST-registered, legally recognised entity.
- A five-year price pathway for both methane and nitrous oxide would be established from 2025, providing certainty out to 2030. This would be reviewed after three years.
- Emissions levy to be set at the lowest price possible to achieve outcomes, with the revenue raised used to incentivise behaviour change.
- Incentive payments would be used to make the uptake of mitigation technologies and practices more cost-effective.
- Sequestration payments for eligible on-farm vegetation will also be an interim part of the farm-level pricing scheme until such time that further vegetation categories can be included in the National Inventory and ETS.
- Oversight of the pricing system would include the Commission and an Oversight Board with representation from the agriculture sector and Māori.
- Ministers would be responsible for setting and updating the levy prices.

Further detail is being worked through by the Government.

For more information, see the Government's report: https://environment.govt.nz/publications/pricing-agricultural-emissions-report-under-section-215-of-the-climate-change-response-act-2002/

For an assessment of the potential financial impacts of the farm-level pricing scheme, see page 56-60 of this booklet.

A common statement

Some commentators argue that reducing New Zealand's emissions is perverse.

They say that if we reduce production here with a price on agricultural greenhouse gas emissions, other – less efficient – producers will increase their production and total global emissions will go up. This is often referred to as 'emissions leakage'.

But it's not quite as simple as that:

- *Many of our competitors produce similar emissions per unit of product*
- *Many of our competitors have national mitigation targets to meet – if they expand their agricultural production, emissions must reduce somewhere else in their economy*
- *Our competitors in the developed world also face constraints on production*
- *The 95% free allocation means that the incentive to reduce production is low*
- *There is scope to maintain production and reduce greenhouse gas emissions*

He Waka Eke Noa milestones

As noted on page 32, the He Waka Eke Noa partnership was tasked with several key milestones as a means of supporting farmers towards farm-level emissions pricing. These are outlined in the table below, along with an indication of progress towards their achievement.

Milestone	Progress
By 31 December 2022, “all farms” must hold a documented annual total of their on-farm greenhouse gas emissions	As of 31 December 2022, 81% of farms held a documented annual total of on-farm greenhouse gas emissions.
By 1 January 2024, a pilot of a farm-level accounting and reporting system must be completed across a range of farm types	In development, pending further details from the Government on the pricing scheme.
By 1 January 2025, all farms must be using a farm-level accounting and reporting system for 2024 agricultural greenhouse gas emissions	In development, pending delivery of the pilot, conclusion of relevant government legislative processes etc.
By 1 January 2025, all farms must have a written plan in place to measure and manage their greenhouse gas emissions	Being monitored. As of 31 December 2022, 42% of farms had a written plan in place.

He Waka Eke Noa has now been disbanded. The new Government has announced that it will develop tools farmers need to reduce emissions before introducing an on-farm emissions pricing system, by 2030 at the latest.

The science

Where do livestock emissions come from?

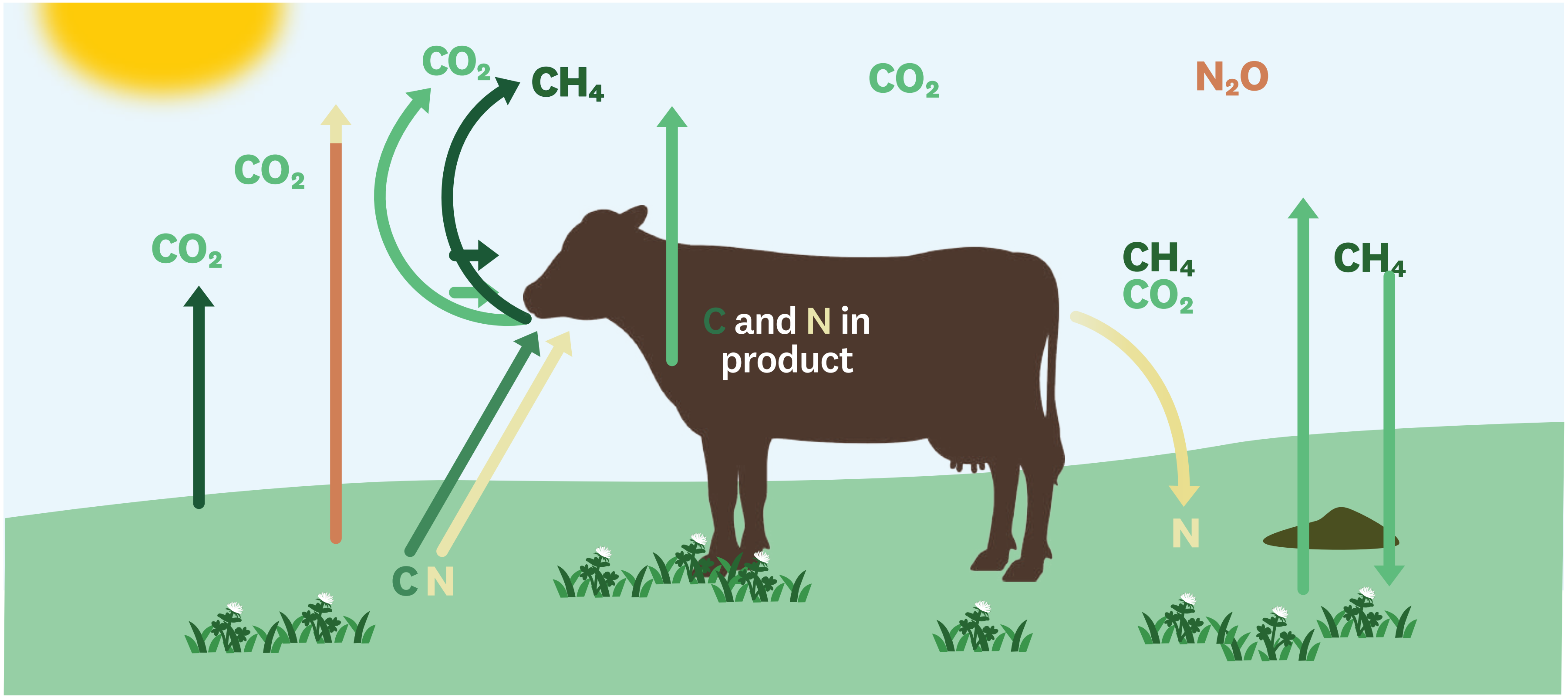


Figure 16: Greenhouse gas emissions from ruminant animals

Source: NZAGRC

Figure 16 shows that:

- Livestock are neither a source nor a sink of carbon dioxide (CO_2)
- Livestock are a source of methane (CH_4)
- Livestock are a source of nitrous oxide (N_2O) and cause a permanent loss of nitrogen (N)

Figure 17 shows the percentage of agricultural greenhouse gas emissions from livestock sources and non-livestock sources (synthetic fertiliser).

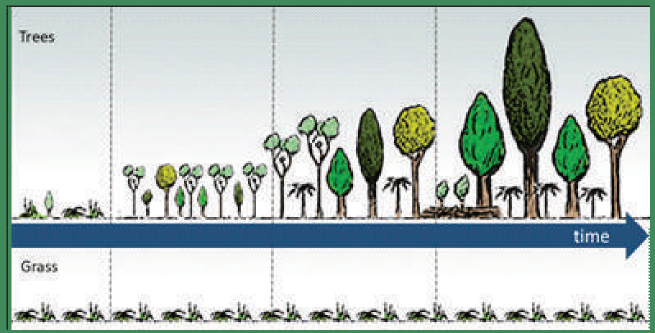
Livestock greenhouse gas emissions (methane and nitrous oxide) are part of the carbon and nitrogen cycles. The carbon in atmospheric carbon dioxide cycles through plants, then the soil and/or animals that eat the plants. Most re-enters the atmosphere in the form of carbon dioxide.

Plants remove carbon dioxide via photosynthesis and return it by respiration. Soils absorb carbon dioxide and return it to the atmosphere when soil micro-organisms use litter, dead roots and manure as their food source (for more information on soil carbon, see pages 77-82). Humans who eat plant and animal products containing carbon return it as carbon dioxide to the atmosphere via respiration.

However, micro-organisms found in the rumen of animals use plants as their food source and convert some of it to methane, which the animal mostly belches out. Methane contains the same amount of carbon as carbon dioxide but behaves very differently in the atmosphere. Although it is a shorter-lived gas (most decaying back into carbon dioxide after about 12 years) while it is in the atmosphere it has a greater warming effect. This means that while the cycle is still ‘carbon neutral’, it is not greenhouse gas or warming neutral. For more on the impact of methane in the atmosphere, see Figures 6 and 13-14.

Why don’t we count the carbon stored in grass?

Grass removes carbon dioxide from the atmosphere as it grows but returns it to the atmosphere when it is harvested and utilised. Trees do exactly the same. However, the interval between growing/harvesting grass is weeks, whereas trees are harvested after decades or centuries – or not at all. The same quantity of carbon is stored in grass at the start and end of each year. The quantity of carbon in a tree increases year on year, while the tree grows – as shown in the illustration.



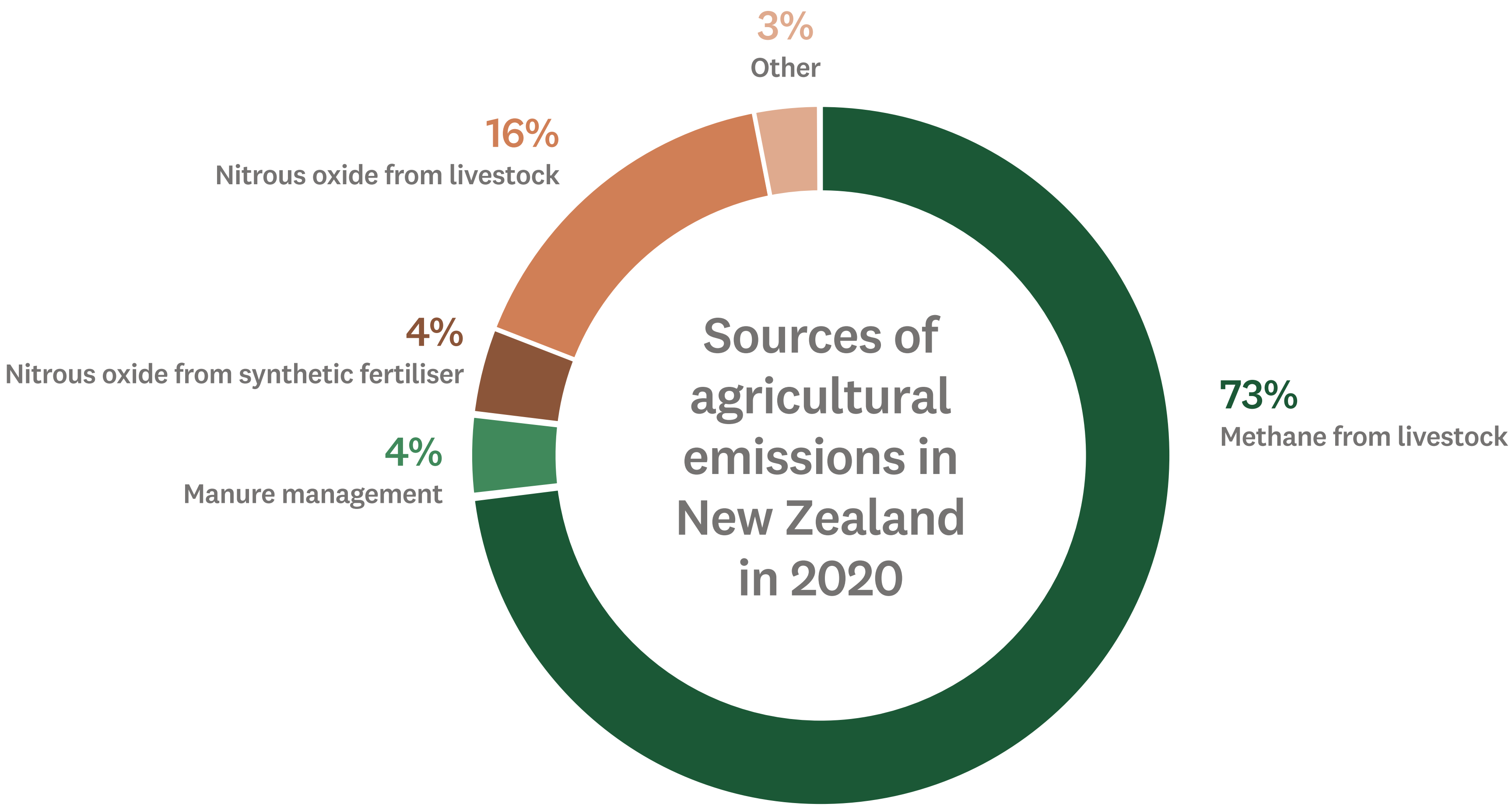


Figure 17: Sources of agricultural emissions in New Zealand in 2020

Source: NZAGRC, New Zealand Greenhouse Gas Inventory 1990-2020

Methane

How is methane produced?

Methane has several sources, including wetlands, landfills, forest fires, agriculture and fossil fuel extraction. In New Zealand, the largest proportion (approximately 95% of total methane) is belched out by livestock. This is known as ‘enteric methane’.

Methane production naturally occurs in all ruminant animals, e.g. deer, sheep, cows, buffalo etc. These animals have four-chambered stomachs, the largest of which is known as the rumen. The rumen acts as a fermentation vat where a complex and highly adapted community of microbes anaerobically breaks down the feed into smaller compounds, including methane. This is then released into the atmosphere when the animal burps.

Methane is also produced from animal manure. A small amount is released when it is deposited directly onto pasture. It is released in greater quantities when manure is stored – essentially following a similar process to that when it is generated in the rumen (anaerobic decomposition of organic material by a community of microbes). Methane emissions from stored waste is very low in New Zealand because of our pasture-based systems (6-7% of dairy wastes, close to zero for other animals).

What influences how much methane is produced by an individual animal?

The amount of methane produced by an individual animal is directly linked to how much it eats (see Figure 18). Generally, between 21 -22 grams of methane is produced per kilogram of dry matter eaten by a forage-fed animal in New Zealand. Emissions increase as the quantity of feed increases.

The average dairy cattle beast produces approximately 98 kg of methane per year, the average beef cattle beast produces approximately 61 kg per year, the average deer approximately 25kg and the average sheep approximately 13 kg per year.

Some individual feeds result in lower emissions, when fed as sole feeds, e.g. forage rape produces around 30% less methane per kilogram eaten and cereal grain around 50% less methane.

Methane emissions per unit of intake for different diets are relatively constant. That is, large changes in diet are needed to affect emissions (e.g. >60% fodder beet). Some additives reduce emissions (e.g. lipids, monensin, essential oils, garlic), but the effect is small and variable.

Variation between animals in emissions per unit of intake is linked to rumen size, rate of passage and microbial community structure.

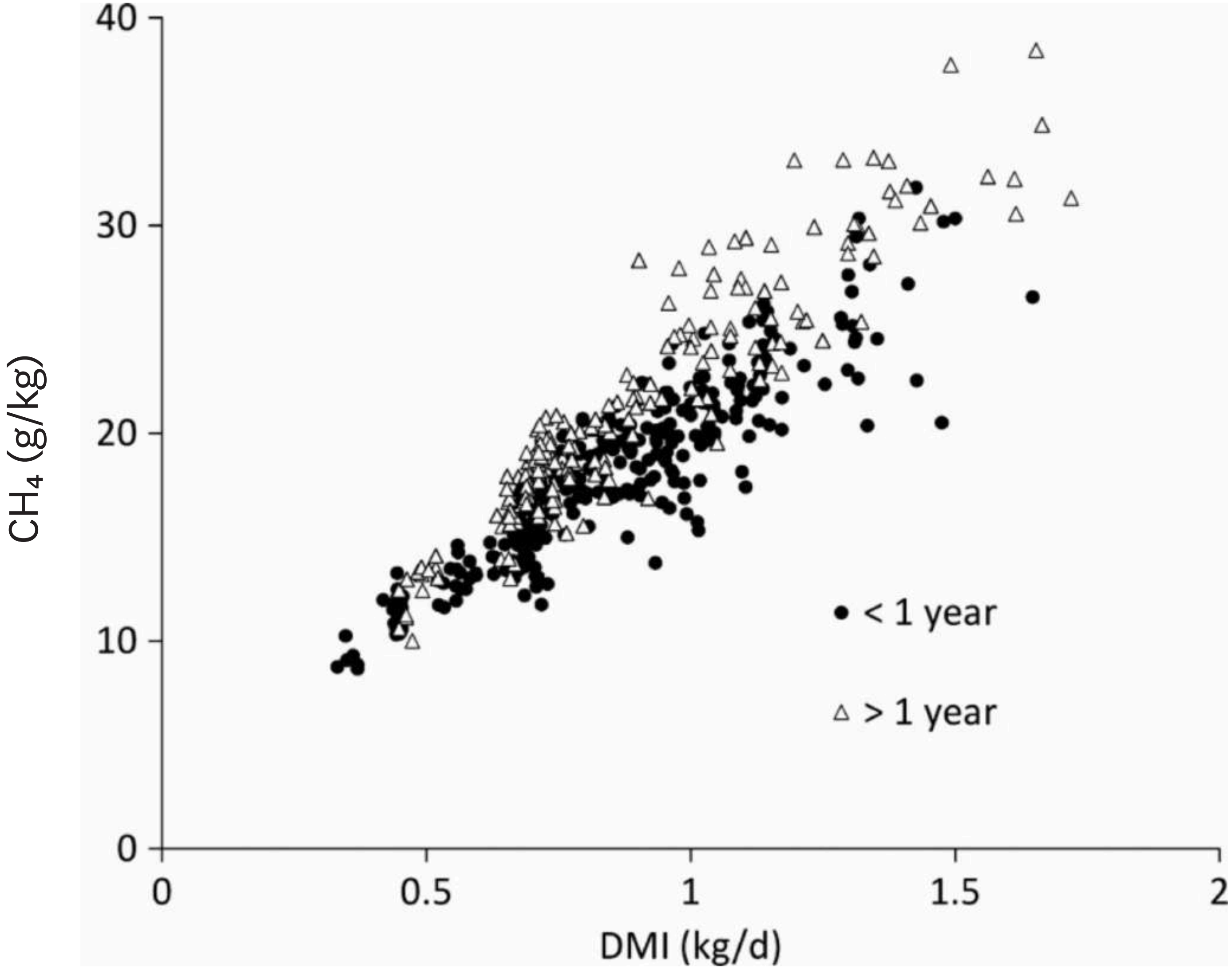


Figure 18: The amount of methane produced is directly linked to Dry Matter Intake in sheep

Source: Muetzel, S. and Clark, H. (2015) Methane emissions from sheep fed fresh pasture. In New Zealand Journal of Agricultural Research, 58 (4).

Nitrous oxide

Where does nitrous oxide come from?

Nitrous oxide is emitted into the atmosphere when naturally occurring microbes act on nitrogen introduced to the soil via dung, urine and fertiliser. Nitrous oxide accounted for 8.8% of New Zealand's total greenhouse gas emissions in 2021, the largest source of which comes from livestock urine and dung.

Figure 19 shows how nitrous oxide emissions are produced as part of the nitrogen cycle. Ruminant animals eat pasture or crops that are rich in nitrogen. However, they only use a fraction of it to support their own growth and productivity – the rest simply passes out the other end in urine and dung, which creates very concentrated patches of nitrogen in the soil. Complex microbial communities transform nitrogen into a form that plants can use. But not all of it is taken up by plant roots. Some sits in the soil as nitrate, which can leach or run off in rainwater or irrigation. Different microbes transform some into nitrous oxide which is emitted into the atmosphere.

What influences how much nitrous oxide is produced on a farm?

Nitrous oxide emissions depend on the total amount of nitrogen going through a farm via feed or fertiliser. Some feeds, e.g. maize and fodder beet, have a lower nitrogen concentration meaning less nitrogen is excreted onto pastures and nitrous oxide emissions are reduced.

Plantain is currently generating interest. It has been shown to reduce nitrogen concentration in urine and create soil microbial conditions that reduce the production of nitrous oxide under some circumstances (see Figure 20). However, it does require a significant proportion in the diet to achieve a noticeable effect. Research is ongoing to better understand how and under what circumstances plantain affects nitrous oxide emissions.

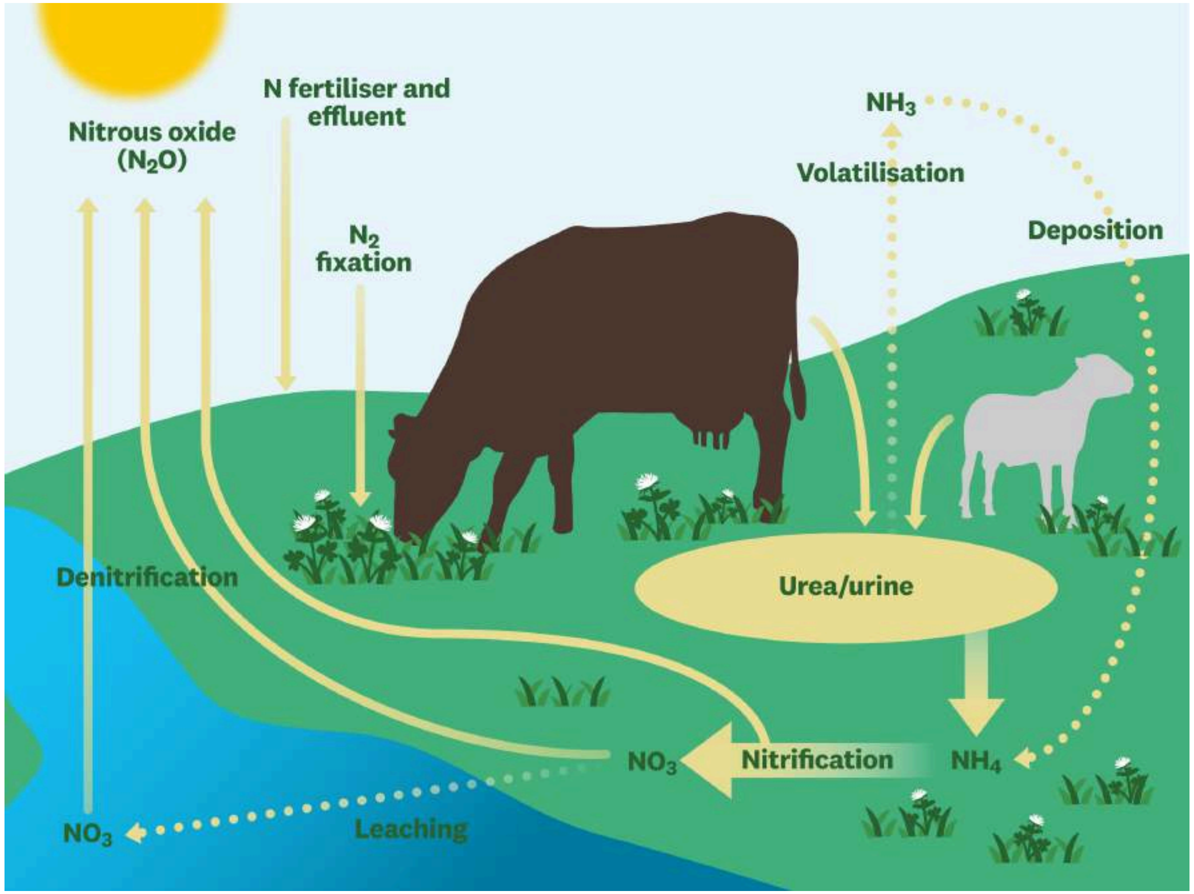


Figure 19: Nitrogen cycle on a farm

Source: de Klein, CAM, Pinares-Patiño, CS and Waghorn, GC. 2008. Greenhouse gas emissions. In Environmental Impacts of Pasture-based Farming, Edited by: RW, McDowell. 1–32.

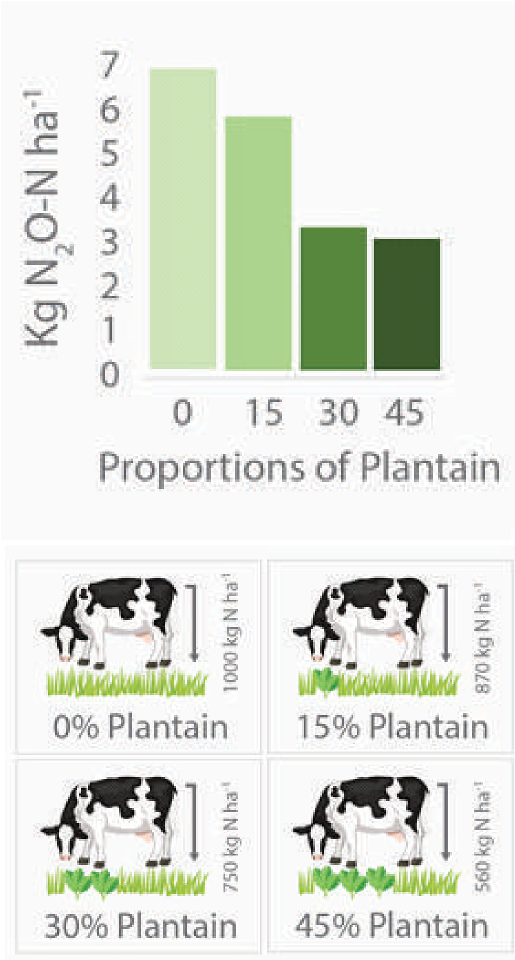


Figure 20: Plantain's potential impact on nitrous oxide emissions

Source: Simon, P. et al (2019). The efficacy of Plantago lanceolata for mitigating nitrous oxide emissions from cattle urine patches. Science of the Total Environment 691.

Mitigation options

Current options

Agricultural greenhouse gas emissions are closely linked to total feed intake and the amount of nitrogen deposited on the land either through animal manure or fertiliser. Mitigation options currently available to New Zealand farmers and growers include:

- Further increasing animal productivity and farm efficiency
- Additional technologies that directly reduce emissions
- Constraints on total production, e.g. from freshwater regulations
- Shifting to lower greenhouse gas emitting land uses, e.g. cropping and horticulture, forestry

Studies suggest that this limited list of on-farm practices could reduce emissions on some farms by up to 10% while still maintaining profitability. This is illustrated in the modelling case studies presented on pages 48-50. However, it is important to note that every farm will have a unique emissions profile and there is no 'one size fits all' solution.

The critical first step is to find out what your farm's emissions are. For more on this, see the Tools section on pages 83-84.

New technologies

Table 3 summarises the main technologies being researched, their timeframe and potential for reducing greenhouse gas emissions (‘maximum efficacy’).

The mitigation options that could have the largest potential impact on agricultural greenhouse gas emissions are not commercially available yet, e.g. methane vaccine or inhibitors. These options are being actively researched but have uncertain end outcomes in some cases and will require time to bring them to market suitable for New Zealand farming systems. Challenges lie not only in the development of the technology but also regulatory settings and domestic as well as international market responses. Ongoing investment in science and commercialisation pathways will be essential, as will work to ensure the technologies are acceptable in markets.

Table 3: Timeframe and efficacy of new/novel technologies

Technology	When available	Maximum efficacy
Low methane emitting sheep	1-2 years	10%?
Low methane emitting cattle	>5 years	10%?
Methane vaccine	>10 years	30%?
Methane inhibitors	2-5 years	30+%
Nitrification inhibitors	3-5 years	50+%
Low emission feeds (forage rape, fodder beet, plantain)	Available now	?
Novel low emitting feeds/additives (e.g. GM ryegrass, seaweed, phage)	?	?
Direct-fed microbials (DFMs) e.g. Kowbucha	?	?
Animal devices (e.g. methane destruction)	?	?
Manure management (e.g. Ecopond)	Available now	>70% (depends)

Breeding low-emitting livestock

Sheep vary naturally in the amount of methane they produce per kg of dry matter consumed. This trait has been shown to be heritable and thus enables the breeding of lower methane emitting sheep. Emissions differ by approximately 20% between the lowest and highest emitting animals (so the low emitting flock would be 10% better than an "average" flock) after three generations without adverse effects on major production traits and some indications of positive correlations. Following industry trials, the low methane trait is expected to be available to sheep farmers in New Zealand within the two years.

Cattle show similar potential for breeding strategies, but commercialisation is less advanced due to the higher cost of measuring low-emitting animals. Research is underway to develop proxy indicators (e.g. in milk, rumen microbial profiles) to enable cheap and rapid identification of low-emitting animals.

Low nitrogen (N) sires are available through industry. Bulls with negative breeding values for milk urea nitrogen (MUN) are expected to reduce MUN in their daughters thereby reducing the amount of nitrogen excreted in cow urine. With less nitrogen expected in urine patches this is theorised to reduce the production of nitrous oxide emissions. However, there is currently no empirical evidence to demonstrate a reduction in nitrous oxide emissions from low N sires.

Methane vaccine

Vaccination against rumen methanogens is expected to have broad applicability globally and could be practical and cost-effective even in extensive systems. Research into a methane vaccine remains in the development phase and has not yet been demonstrated in live animals. However, all major components of a vaccine chain have been demonstrated: genome sequencing of methanogens has identified targets that stimulate antibody production, antibodies can be created by host animals and detected in saliva and the rumen, and those antibodies have been shown to suppress pure methanogen cultures in vitro. The in vivo efficacy of a vaccine is necessarily speculative but a reduction of 30% is considered plausible given the efficacy of methane inhibitors. Commercial availability of a vaccine is estimated to take 7-10 years after demonstration of a prototype.

Methane inhibitors

A methane inhibitor is a chemical compound that suppresses the activity of methanogens in the rumen. Inhibitors could be delivered as a feed additive or as a bolus (a small capsule containing the active compound, inserted into the rumen). 3-Nitrooxypropanol (3-NOP) has been shown to consistently reduce methane emissions by around 30% in Total Mixed Ration (TMR) farm systems without compromising animal productivity and is expected to be commercially available in some countries within the next two years. 3-NOP has limited applicability in grazing systems as it decays within a few hours in the rumen, but its applicability could be extended to most dairy systems via slow-release formulations. Research is also progressing in the use of inhibitors in young ruminants to stimulate lifetime reductions, and on other inhibitors with longer rumen lifetimes and low dosage rates to allow bolus delivery. These developments could increase the utility of methane inhibitors beyond TMR systems into grazing systems.

Nitrification inhibitors

Nitrification inhibitors are chemical compounds that inhibit the formation of nitrate in the soil, and thus the potential for nitrous oxide production. Researchers in New Zealand are seeking new nitrification inhibitors that have wide availability, are low cost, and have a low risk of residues in food products. A suite of promising compounds has been identified and testing has begun to deliver proof of concept in the field. Researchers are also investigating ways in which these inhibitors can be practically delivered.

Low emission feeds

Research has shown that some alternative feeds can reduce emissions of methane and/or nitrous oxide if fed to ruminants as a sufficient proportion of the diet. Supplementary feeds relevant to New Zealand that have been shown to reduce the amount of methane produced by an animal per unit of feed eaten include forage rape, plantain and fodder beet. Research has also shown that some plant species, for example plantain can affect the amount of nitrogen excreted by grazing animals, and/or influence the soil microbial processes that result in nitrous oxide emissions. Research is still on-going to quantify and validate the impact these feeds have on greenhouse gas emissions.

Animal devices

Industry is developing wearable devices for livestock that reduce methane production at an individual animal level. Devices are intended to be fitted over the animal's snout, capturing exhaled methane and using a special catalytic converter to turn it into a combination of carbon dioxide and water vapour. Work is currently focused on pilot trials to demonstrate proof of concept and practicality.

Manure management

Manure collection and storage provides farms, particularly dairy farms, with an important capacity to recycle valuable nutrients to the land for future plant uptake, and to manage risks to freshwater quality. Most manure management options are well established in principle (examples include bio-digestors and flaring) and available internationally now. However, the cost-effectiveness and practicalities of many of the technologies are challenging in New Zealand's pastoral systems. Recently, Ravensdown has developed the EcoPond effluent treatment system with research demonstrating that it can reduce methane emissions from the dairy effluent ponds by up to 99%. The technology works by addition of a poly-ferric sulphate compound which is thought to affect methane production via several mechanisms: (i) increased microbial competition for organic matter substrate due to the addition of sulphate and ferric ions; (ii) direct inhibition of methanogens due to sulphide and ferric ions; and (iii) anaerobic oxidation of methane.

Novel low emitting feeds/additives

Seaweed

Algae of the genus Asparagopsis have been shown to reduce ruminant methane emissions by 20-98%, although the persistence of this effect over multiple seasons remains unclear. The role of bromoform and bromochloromethane as active ingredients in Asparagopsis raises challenges from a regulatory and market acceptability perspective, given that both substances are confirmed animal carcinogens and probable/possible human carcinogens. Animal trials have detected residues in urine and milk but no detrimental effects on meat quality. There are also open questions regarding palatability to livestock, animal health and the ability to produce and supply seaweed at large scale especially to extensively grazed livestock.

Genetically modified ryegrass

Researchers have developed a genetically modified ryegrass which has a higher lipid content. In vitro testing and modelling suggest that a genetically modified ryegrass with higher lipid content could potentially lead to a reduction in greenhouse gas emissions. Work is on-going to confirm efficacy. Other research is also looking at the potential of modifying other relevant plant species.

Direct-fed microbials (DFMs)

DFMs refer to any type of live microbe-based feed additive. The term 'DFM' and 'probiotic' are often used interchangeably in animal nutrition. On-farm DFMs are typically used as a feed supplement to promote growth and improve health of young animals and improve the health and performance of older ruminants. Literature on the use of DFMs to reduce methane production in ruminants is limited. However, research is on-going. Kowbucha is a DFM product being developed by Fonterra. Early work suggests that calves emit up to 20% less methane when they receive Kowbucha. The Kowbucha powder is blended into a milk-like drink which is then fed to the calves. Trials are ongoing to confirm its efficacy.

Notes

On-farm economics

Average farm emissions

Farm-level modelling has enabled us to work out the average emissions for a New Zealand farm.

Average dairy farm

9.6 tonnes agricultural greenhouse gas emissions per hectare per year

Range: 3.1-18.8 tonnes/ha/year

Average sheep and beef farm

3.6 tonnes agricultural greenhouse gas emissions per hectare per year

Range: 0.16-7.1 tonnes/ha/year

These figures are considered very good by international standards. The wide ranges suggest there is room to improve on some farms. Table 4 compares the intensity of emissions associated with different livestock products.

Table 4: Intensity of emissions expressed as kg CO_2-e/kg product

Milk solids	Beef	Sheep meat	Goat meat	Venison
8.76	14.2	23.57	19.56	30.7

Total emissions

The price on emissions is based on the total emissions from a farm, for example:

- Average dairy farm: 155 ha x 9.6 tonnes/ha = 1,488 tonnes CO_2e
- Average sheep and beef farm: 695 ha x 3.6 tonnes/ha = 2,502 tonnes CO_2e

As from 18 April 2024, the National Inventory will update emission factors to AR5 levels. This means that the average farm's biological GHG emissions will increase by ~+7%.

Drivers of on-farm emissions

As outlined in the science section of this booklet, there are three main drivers of on-farm emissions:

1. Dry matter eaten – a direct correlation with methane emissions and strong correlation with nitrous oxide
2. Protein (nitrogen) content of the feed
3. Amount of nitrogen fertiliser used

Essentially, these three things underpin the mitigation 'toolbox' that farmers can currently use, outside of land use change.

Farm-level modelling

Modelling is a helpful way of testing the impact of different changes to land use and/or an existing farm system on a farm's greenhouse gas emissions and profitability. This is undertaken via a combination of:

Farmax

This is a farm systems model that allows modelling of changes in the farm system and shows whether a given system is feasible and the impact on profitability.

OverseerFM

This is a nutrient budget model. The input data is transferred from Farmax to determine greenhouse gas and nutrient emissions.

Forestry

Carbon sequestration rates are determined from the MPI 'Look-up Tables'[7], and forestry profitability based on the Forecaster Calculator[8].

Spreadsheeting

Excel is used to collage the above information, enabling comparison of the impacts of the various scenarios modelled.

The following pages provide examples of the results of modelling different greenhouse gas mitigation options on dairy and sheep and beef farms.

For more on OverseerFM and Farmax, see the Tools section on pages 83-84.

[7] https://www.mpi.govt.nz/forestry/forestry-resources/

[8] https://www.nzffa.org.nz/farm-forestry-model/the-essentials/inventory-and-decision-support-software/forecaster-calculator/

Dairy farm Modelling

Table 5 provides a summary of modelling work done on three case study dairy farms and illustrates the impact of the various changes in farm system, on both greenhouse gas emissions and farm profitability. It also illustrates the variation in outcomes on different farms for the same system change.

Table 5: Summary of dairy farm modelling of greenhouse gas emissions scenarios and impact on profit (EBIT)

	Farm 1			Farm 2			Farm 3		
	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)
Reduce SR 10% - no productivity improvement	-8%	-35%	-3%	-11%	-18%	-9%	-10%	-17%	-11%
Reduce SR 10% - improve productivity	-6%	33%	-5%	-6%	7%	-11%	-4%	0%	-5%
Take out all Nitrogen Fertiliser	-7%	-5%	-14%	-16%	-7%	-26%			
Take out 1/2 Nitrogen Fertiliser							-3%	-1%	-8%
Take out bought-in supplements	-10%	-21%	-8%	-6%	-1%	-7%	-7%	-1%	0%
Plant 10% of farm in Gold Kiwifruit	-9%	211%	-3%						
Plant 13% of farm in Green Kiwifruit	-10%	130%	-11%						
Plant 10% of farm in pine trees	-39%	-7%	-5%	-31%	-8%	-7%			
Plant 30% of farm in pine trees	-106%	-55%	-24%	-100%	-34%	-20%			

Sheep and beef farm Modelling

Table 6 provides a summary of modelling work done on three case study sheep and beef farms and illustrates the impact of the various changes in farm system, on both greenhouse gas emissions and farm profitability. It also illustrates the variation in outcomes on different farms for the same system change.

Table 6: Summary of sheep and beef farm modelling of greenhouse gas emissions scenarios and impact on profit (EBIT)

	Farm 1			Farm 2			Farm 3		
	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)
Decrease SR 10% - no change in performance	-13%	-17%	-8%	-7%	-9%	-6%	-6%	-41%	0%
Decrease SR 10% - change performance	-12%	14%	-8%	-7%	-3%	-6%	-3%	2%	0%
Dcr ewes 20% - incr lambing % and beef weights	-10%	22%	-8%						
No Breedng Cows, finish bulls	-6%	9%	-8%				-2%	61%	0%
Reduce replacement rates	-1%	3%	-8%						
Forestry (Plant 140ha - 13% of farm)	-105%	-15%	-8%						
Eliminate N Fertiliser - Reduce sheep & cattle				-8%	-6%	-6%			
Remove dairy grazers, finish bulls				-12%	29%	-11%			
Finish steers at 18-20 months				10%	10%	-6%			
Forestry (Plant 65ha - 13% of farm)				-108%	-7%	-6%			
No Breedng Cows, finish steers							-4%	33%	0%

Farm modelling
Summary

Overall, the dairy and sheep and beef modelling has shown that changes in farm systems can reduce agricultural greenhouse gas emissions, but that the impact is relatively limited e.g. 2-10% reduction.

While the impact on profitability can vary, and can be positive, in many of the scenarios modelled, it is negative. The key tool in the toolbox for livestock farmers at the moment is to reduce stocking rate, but per animal productivity needs to be improved in order to maintain profitability.

One of the main takeaways from this work is that every farm is different. The impacts of the mitigation strategies will vary from farm to farm and are influenced by a number of variables including the existing farm system, farmer values and priorities, the ease with which different management practices can be introduced etc.

For more on livestock farm modelling, have a look at: https://www.nzagrc.org.nz/publications/farm-systems-modelling-for-ghg-reduction-on-maori-owned-farms/

Arable farm modelling

For arable farms, the main greenhouse gas is nitrous oxide from synthetic nitrogen fertiliser use. While there are also carbon dioxide emissions, these are mainly from fuel and imbedded fertiliser, which are already priced under the ETS. Most arable farms also run some livestock, which adds methane emissions into the mix. The tables below show the average greenhouse gas emissions associated with arable farms, based on a study by FAR in 2021/22 and a Pioneer study in 2021/22 in the Waikato looking at maize production.

FAR Study (44 farms)	**Maximum**	**Minimum**	**Median**	**Mean**
Methane ($kgCO_2e/ha$)	6,888	0	1,196	1,709
Nitrous Oxide ($kgCO_2e/ha$)	3,219	679	1,401	1,389
CO2 ($kgCO_2e/ha$)	5,907	344	1,013	1,254
Biological (CH_4 + N_2O) ($kgCO_2e/ha$)	10,107	679	2,597	3,098

Waikato Maize (Pioneer)	**CH_4**	**N_2O**	**CO_2/N Fertiliser**	**Total**
Grain (8 farms)	57	1,684	295	2,036
Silage (12 farms)	1,327	1,480	313	3,120

Emission Intensity vs Gross Emissions

Some industries are targeting reductions in emission intensity. The issue that arises is that reductions in emission intensity may or may not be accompanied by reductions in total emissions.

Example: 400 cow herd producing 160,000kg MS (400/cow)

1. Breed high quality cows – produce more milk/kg DM (cows now producing 450/cow from same DM)
Result: Emission intensity reduces, gross emissions the same, profitability increases

2. Feed more DM as supplement or improved pasture utilisation. (cows producing 450/cow but from more DM)
Result: Emission intensity reduces, gross emissions increase, profitability varies

3. Reduce cow numbers (10%)/increase per cow production. Cows producing same total MS: 160,000 or 444/cow
Result: Emission intensity reduces, gross emissions reduce, profitability improves.

In all 3 scenarios emission intensity reduces, but in only 1 does gross emissions reduce. Caution is therefore needed if targeting emission intensity to also keep regard of what is happening to gross emissions.

Pasture quality

Pasture quality has an important role to play in on-farm emissions. Generally, the higher the quality of the feed (measured as megajoules of metabolisable energy per kilogram of dry matter), the greater the intake and the faster the growth.

The higher the growth rate, the greater the percentage of feed intake that goes into liveweight gain, and the sooner animals reach finishing weights. This has two key advantages: higher profit, and lower relative greenhouse gas emissions. This obviously provides a direct incentive for farmers to endeavour to maintain pasture quality to feed to livestock.

The importance of pasture quality is shown in Tables 9 and 10.

Table 9: Growing bulls from 300 to 600kg LW

Feed quality (MJME/ kg DM)	Bull LWG (kg/ day)	Weeks to finish	Feed efficiency (kg DM/kg LWG)	Feed Required (kg DM)	kg CH_4
9	0.40	113	20.4	6,123	129
10	0.98	44	10.7	3,209	67
11	1.47	29	8.0	2,423	51

Table 10: Post-weaning requirements for a 30kg LW lamb

	Post weaning liveweight gain (gm/day)					
	50	**100**	**150**	**200**	**250**	**300**
Daily energy requirement (MJME/day)	11	13	15	17	19	21
Daily dry matter requirement (kg DM/day)	1.0	1.2	1.4	1.5	1.7	1.9
Time for 1 kg carcass weight gain (days)	45	23	15	11	9	8
Total energy requirement (MJME)	495	299	225	187	171	168
Total dry matter requirement (kg DM)	45	27	20	17	16	15
kg CH_4	0.95	0.57	0.42	0.36	0.34	0.32

Reducing stocking rate

Reducing stocking rate has a direct impact on greenhouse gas emissions, particularly methane. However, the effectiveness of this strategy depends on the starting position of the farm (e.g. stocking rate/per animal production) and grazing management.

In theory, if stocking rate is reduced, then 'surplus' pasture results and there is the potential for a corresponding increase in per animal production.

If stocking rate is reduced and there is an increase in per animal production such that total production equates with the 'pre' or base level, the saving in greenhouse gas emissions is the maintenance cost of the animals removed, plus the marginal improvement in the efficiency of utilisation of dry matter by increasing per animal performance. Under this scenario, the farm is also probably making more money.

Reducing stocking rate is not always a straightforward practice to implement – it depends a lot on farmer expertise and skill.

A number of farms are operating beyond their optimum level. If they reduce stocking rates and/or feed inputs, they can effectively move back up the profitability curve, thereby improving profitability and reducing greenhouse gas emissions in tandem. In the top graph in Figure 22, this is illustrated by moving from A, where marginal costs (MC) are greater than marginal revenue (MR), to B, where MC = MR.

The challenge in achieving this is that the optimum 'sweet spot' (e.g. B), will vary both within and between years as costs and prices received vary. This means the profitability curve moves about, making it very difficult to optimise at any one point in time. Most farmers aim to operate close to optimum most of the time, but seldom ever exactly at the optimum point (as shown by the red circle in the graph).

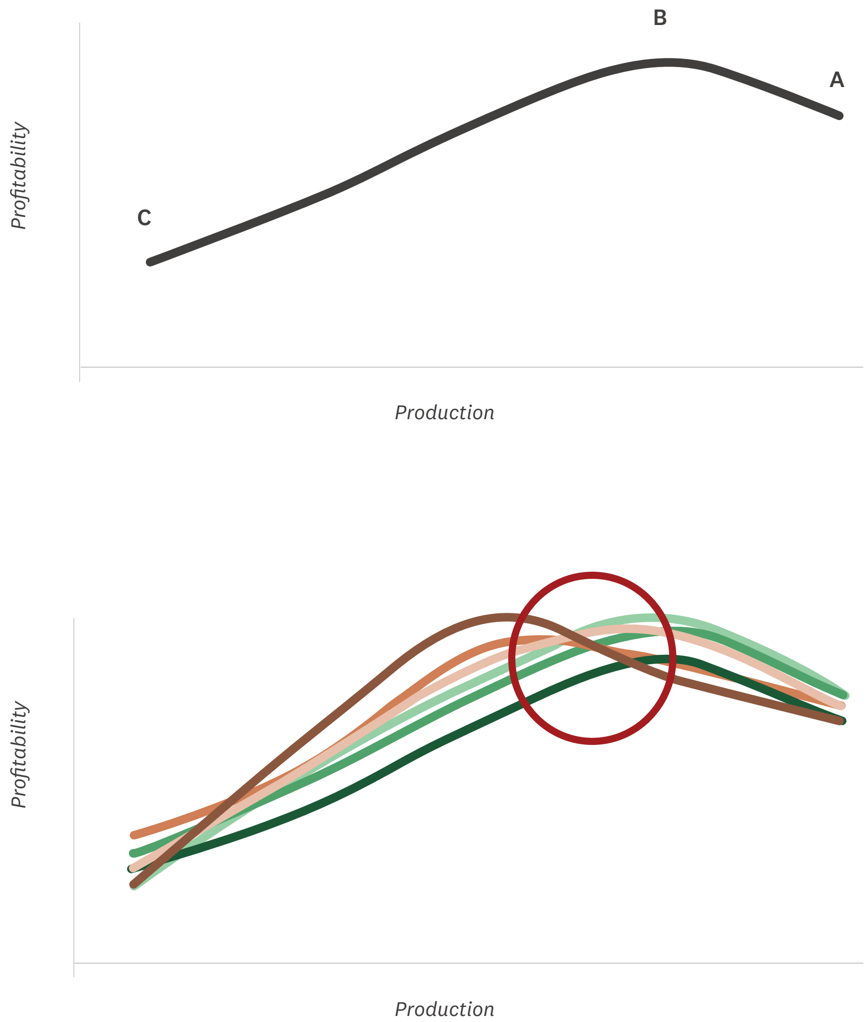


Figure 22: The challenges with reducing stocking rate

Potential impact of the farm-level pricing scheme

As outlined on pages 32-34, in late December 2022 the Government announced its high-level decisions on the farm-level pricing scheme. This drew on extensive development and consultation via the He Waka Eke Noa partnership, advice from the Climate Change Commission, and the Government's own consultation processes.

This section of the booklet is intended to show how the farm-level levy could apply. In the absence of further detail from the Government, it is based on example costs used in the He Waka Eke Noa recommended pricing scheme. Please note that this information represents estimates only and is subject to change.

A		B		I		C		$
The cost that each farm faces for their short-lived gas emissions (CH_4)	+	The cost that each farm faces for their long-lived gas emissions (N_2O)	-	The incentive discount for approved actions that reduce emissions	-	The value that each farm is rewarded for eligible on-farm sequestration	=	The total net cost where A, B, I and C are all netted off as dollar values
The weight of CH_4 gas emissions calculated (kg) multiplied by the price for CH_4 gas emissions ($/kg)		The weight of N_2O gas calculated (kg CO_2e) multiplied by the price for N_2O emissions ($/kg CO_2e)		Approved actions (practices or technologies) that have been clear and credible emissions reductions The incentive discount accounts for the implementation cost and the emissions reduced by each action		The area and category of eligible vegetation multiplied by the relevant sequestration rate/s in weight of long-lived gases (kg CO_2e) multiplied by the price for sequestration ($/kg CO_2e)		(**not** as gases through carbon equivalency metric)

Figure 21: He Waka Eke Noa farm-level split gas levy formula (A + B - I - C = $)

Understanding how pricing could apply

As noted on page 61, the Government has not yet announced details on the initial levy price for methane and nitrous oxide nor how the five-year price pathway would unfold. The report released in December 2022 states that, when setting the levy prices, primary consideration would be given to achieving emissions reductions in line with legislated targets and emissions budgets. The following additional factors would also be taken into account:

- Availability and cost of (current and future) on-farm mitigations
- Social, cultural and economic impacts on farmers and growers, regional communities, households and Māori agribusiness
- Best available scientific, mātauranga Māori and economic information
- Emissions leakage

The previous Government proposed that “relatively low, unique prices could be set initially” for both methane and nitrous oxide, based on the above. The planned five-year price pathway would include a review after three years with the ability to adjust the price in “special situations such as significant variance towards the emissions targets”.

The report also states that the price of nitrous oxide would be capped for the first five years at a level that the sector would be no worse off than if it had entered the ETS at this point.

The current Government has indicated that pricing will begin “no later than 2030”.

Working out the price – a hypothetical example

The lack of available detail on the pricing scheme means that it has not yet been possible to undertake farm-level economic modelling. However, modelling that was completed based on the pricing formula proposed by the He Waka Eke Noa partnership in May 2022 is still relevant for understanding the potential impacts at the farm level from pricing agricultural emissions.

As shown in Figure 21, the He Waka Eke Noa levy formula is A ($$CH_4$) + B ($$N_2O$) – I ($incentive payment) – C ($sequestration payment) = $ levy. To estimate the impact, the following prices were applied:

- A: Methane: He Waka Eke Noa maximum price of $0.11/kg CH_4 (at least until 2028). If this rose to around $0.17-0.35/kg by 2030, it would result in methane reductions of at least 4%. This is equivalent to $85/tonne of methane using CO_2e at 5% and $68-140/tonne CO_2e at 10% in 2030.
- B: Nitrous oxide: Indicative price in 2025 based on He Waka Eke Noa was given as $4.25/tonne CO_2e rising to $13.80/tonne/$CO_2$e in 2030. This is equivalent to $85/tonne of CO_2e at 5% and $138/tonne CO_2e at 10% in 2030.
- I: Incentive payment: This has not been included in the price modelling as it is not yet known which practices and technologies may qualify for an incentive payment.
- C: Sequestration payment (see also page 81-82): The He Waka Eke Noa treatment of sequestration was to link it to the ETS carbon price but discounted to reflect that only some vegetation types count towards national targets and their inclusion in the farm-level levy requires a lower burden of proof than the ETS. An indicative range could be around 75-90% of the ETS carbon price, e.g. a discount of around 10-25% could be applied to the ETS price.

To apply the A+B-I-C=$ formula, a farmer first needs to get their greenhouse gas and sequestration numbers from a greenhouse gas calculator like Overseer or Farmax. They need the numbers shown in Table 7.

Table 7: Numbers needed to estimate the farm-level levy for a hypothetical farm

	Tonnes CO_2e	Tonnes (methane)
A: Methane	2,000	80
B: Nitrous oxide	500	
C1: ETS sequestered carbon	250	
C2: Farm-level levy sequestered carbon	75	

There are several things to note about these numbers:

- **Methane:** All of the current calculators show the A and B numbers, albeit methane is shown in carbon dioxide equivalents (CO_2e). However, because He Waka Eke Noa proposes to price methane based on its weight, it will need to be converted back into kilograms of the gas emissions (divide by 25) in order to work out the levy price.
- **Sequestration:** The farm in Table 8 is assumed to have both an ETS-registered forest and a farm-level levy eligible forest, resulting in two sequestration streams (C1 and C2). The farm-level levy sequestered carbon will be given a value (yet to be set), which is credited against the gross emission levy shown below. Assuming this is not sufficient to cover the levy cost, then the ETS credits could be sold to pay for the remainder of the levy.
- **Incentive discount:** As noted on page 58, at the time of writing, there was insufficient information on the application of the incentive discount to include it in this worked example.

Translation of the figures in Table 7 into the He Waka Eke Noa formula of A+B-I-C = $ then looks like this (noting that methane has been converted into tonnes rather than kg):

A		B		$ (gross levy)
(80 T CH_4 x $110)	+	(500 T N_2O as CO_2e x $4.25)	=	$10,925

The farm-level levy sequestered carbon is then credited: 75 tonnes at an assumed $85/T x 75% = $4,781. This is deducted from the gross levy, leaving a residual price to pay of $6,208. This could then be covered by selling 73 tonnes of the ETS carbon at an assumed $75/T. The remaining ETS credits could then be carried forward to cover the levy in future years.

Impact of the levy on different farms

Table 8 shows an estimate of the impact of the farm-level levy on different farms around New Zealand. This is based on gross emissions and the prices originally indicated by He Waka Eke Noa in their recommendations report to Government in May 2022. These prices will change depending on how the Government sets the initial levy price and the price pathway.

Table 8: Estimate of farm-level levy, based on gross emissions and using He Waka Eke Noa pricing

Farm Type and Location	2025	2030 Low CH_4 Price	2030 High CH_4 Price
Waikato/BoP Dairy	$6,426 (5c/kgMS)	$12,450 (9c/kgMS)	$20,656 (15c/kgMS)
Canterbury Dairy	$13,120 (4c/kgMS)	$25,332 (7c/kgMS)	$41,940 (12c/kgMS)
NI Hill Country S&B	$7,757 ($1.54/SU)	$1,419 ($2.86/SU)	$24,776 ($4.92/SU)
SI Hill Country S&B	$11,675 ($1.52/SU)	$21,771 ($2.83/SU)	$37,291 ($4.86/SU)

Working out your A's & B's in Overseer

Overseer shows a more detailed breakdown of a farm's greenhouse gas emissions. It is important to ensure that the 'biological' emissions are counted for the levy, being methane and nitrous oxide emissions. The Government confirmed in December 2022 that carbon dioxide emissions from nitrogen fertiliser would be excluded from the farm-level levy. This is shown in the image below. These figures can be found in the greenhouse gas report page in Overseer.

Emissions by source

METHANE	ECO2/KG/HA/YR 10204
Enteric	9395
Dung	99
Effluent	709

N2O	ECO2/KG/HA/YR 2840
Excreta paddock	1930
Excreta effluent	16
N fertiliser	399
Crops	0
Indirect	494

Summary of on-farm emissions information

What should farmers do now?

At the moment, the critical first step for a farmer or grower is to identify what their on-farm (methane and nitrous oxide) emissions are and start benchmarking these against sector and farm-type averages. Having an understanding of farmer's emissions and a plan outlining current options to respond is a good place to start.

Farmers should also start to build their knowledge of the basic drivers of farm-level methane and nitrous oxide emissions as a precursor to understanding and developing:

- Farm system strategies for reducing their on-farm agricultural greenhouse gas emissions
- Land use change options
- Implications for business profitability

In this regard, it is also useful to know the greenhouse gas impact of any measures being considered for meeting freshwater regulations.

If there is potential for tree-planting on the farm, then it is worth getting to grips with the basics of forestry for offsetting. In particular, farmers need to understand that getting expert forestry advice is essential before business decisions are made.

Farmers should also stay attuned to what is happening in the wider sector around meeting the 2050 reduction targets.

Once that work is done, then the following actions could be considered:

- If there are mitigation options for a farm that will improve profitability while maintaining or reducing greenhouse gas emissions – proceed
- If the farmer is prepared to trade-off reduced profitability with improved environmental outcomes, then be aware of the costs and benefits of those trade-offs
- If forestry is presenting as a viable option, then proceed as soon as possible as this is a long-term exercise. However, get good – and specialist – advice first.
- If the sector-wide strategies/trends are likely to meet the Government's targets, then continue as is (e.g. finding out the annual on-farm emissions total, identifying mitigation options for inclusion in a written greenhouse gas management plan), but hold off on implementing actions to reduce emissions until more is known from the Government's process to develop the farm-level pricing scheme
- Ensure that any greenhouse gas and water quality mitigations are coordinated

How can emissions be reduced?

For methane:

- Reduce stock numbers/increase efficiency
- Possibly plant trees for offsets, depending on what emerges from the Government's work regarding on-farm sequestration – although farmers can already sell forestry credits into the ETS to gain financially
- Utilise low-emissions breeding traits for sheep (research on dairy cattle is underway)
- Wait for a vaccine or inhibitor to become commercially available

For nitrous oxide:

- Reduce stock numbers/increase efficiency
- Reduce nitrogen fertiliser input
- Plant trees to offset
- Wait for an inhibitor

What will farmers be asked to do in the future?

The short answer is "it depends on what happens at the sectoral level". The targets in the Zero Carbon legislation for methane and nitrous oxide are national targets and as yet, there has been no allocation within that, e.g. between the different sectors.

Nationally, legislation aimed at improving water quality may reduce dairy cow numbers in some areas. There may also be a shift from sheep and beef into forestry due to a higher carbon price, making the latter relatively more profitable. The more that happens at the sectoral level, the less individual farmers will need to do.

Under the current Government, by 2030, agricultural greenhouse gas emissions will be priced and everyone will have to be reporting their annual total on-farm greenhouse gas emissions via a dedicated accounting and reporting system and must have a written greenhouse gas management plan in place.

Forestry

Content prepared by John-Paul Praat and PeterHandford (Groundtruth), with input from Te Uru Rākau/Forestry New Zealand

Forestry and the ETS

The ETS provides a way for owners of newer forests to be rewarded for the carbon dioxide absorbed by their forests as they grow. There are two classes of forest in the ETS, which are treated differently depending on the year the forest was first established (i.e. planted or regenerated):

- '**Pre-1990' forests**: if the forest was established prior to 1 January 1989, it is considered part of New Zealand's baseline carbon storage and is not eligible to earn carbon credits (NZUs – see pages 28-29). Pre-1990 forests can be harvested and replanted without penalty. If the forest is converted to another land use, carbon credits will need to be paid for those emissions.
- **'Post-1989' forests**: if the forest was established after 31 December 1989, it can be registered with the ETS to earn NZUs. Any carbon credits claimed must be paid back if the forest is converted to another land use.

If the forest was established after 31 December 1989 and has not been registered with the ETS, then no carbon liability is payable if the forest is converted.

ETS 'forest' definition

The ETS has a specific definition for what a forest is, known as the 'forest land definition'. This is to differentiate between land managed as a forest and other trees in the landscape. The forest land definition is:

- Area of 1ha or greater
- Canopy width of at least 30m wide on average
- Vegetation (trees) must be able to reach 5m in height where they are growing
- Vegetation (tree canopy) must be able to cover more than 30% of each hectare

The current definition **excludes**:

- Shelterbelts
- Fruit trees and nut crops
- A forest of native (indigenous) species that existed before 1990

Note that wide-spaced poplar pole planting can be considered a forest if it will achieve >30% canopy cover in each hectare at maturity.

Small forest plantings and riparian strips are currently excluded from the ETS. However, as a result of the He Waka Eke Noa recommendations, the Government has agreed to establish an interim system that recognises on-farm sequestration as part of the farm-level pricing scheme. In the longer term, the Government is working towards amending the ETS and the National Greenhouse Gas Inventory to include new categories of scientifically valid on-farm sequestration (see also pages 31-33, 56-60 and 81-82).

Forest and carbon management

Different species sequester carbon at different rates, as shown in Figure 23.

The Ministry for Primary Industries issues standardised 'look-up' tables[9] to assess carbon accumulation. Participants that have less than 100ha of registered forest use these tables to work out the carbon stored in their forest. Participants with 100ha or more must physically measure the carbon stock in their forests.

Wide-spaced planting for erosion control

Poplars planted for erosion control

[9]https://www.mpi.govt.nz/forestry/forestry-resources/

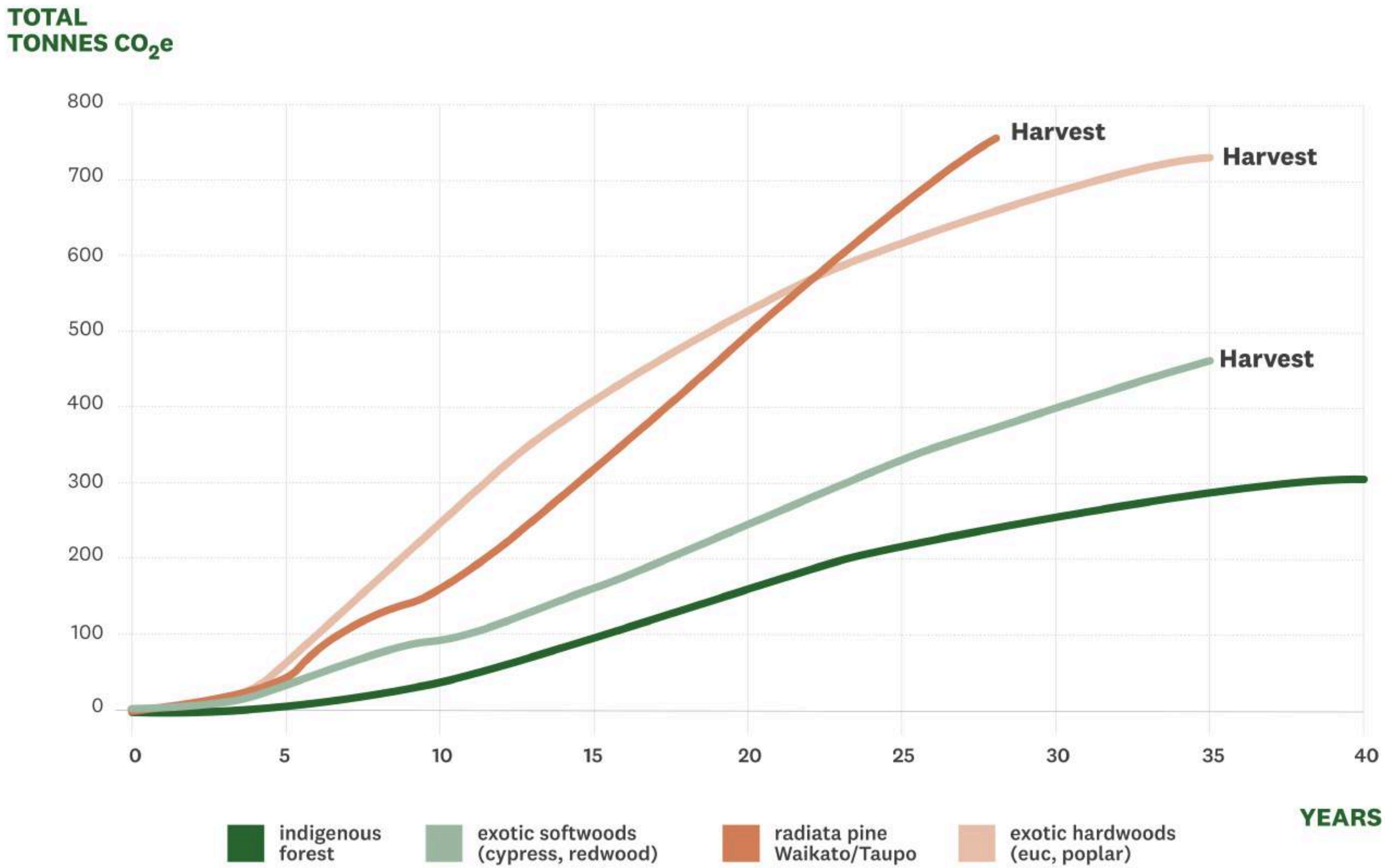


Figure 23: Rate of carbon accumulation over time by different species

Earning carbon credits

To earn carbon credits (NZUs), ETS participants must 'account' for the increases and decreases in carbon in their forests.

Currently, participants account for the short-term changes in the carbon stored in their forest (called "stock change" accounting). This follows the pattern shown in Figure 24.

As the forest grows and stores carbon, the participant earns NZUs (one NZU for every tonne of carbon dioxide removed from the atmosphere) from the Government that they can keep or sell on the carbon market.

When the trees are harvested, around 60-70% of the carbon leaves the land. The remaining carbon, tied up in the stumps, roots and slash, slowly decays away over a period of 10 years. NZUs need to be paid back to the Government to cover these emissions.

If the forest wasn't replanted, the carbon stock would eventually return to zero, and all the NZUs earned would need to be repaid.

If the forest is replanted, the new growth from the second rotation will overtake the decay from the previous rotation and the forest will begin earning NZUs again. This is usually about 8-10 years after harvest. Because the carbon stock in the forest doesn't return to zero, there is a portion of NZUs (sometimes called "low risk" or "tradeable without penalty" NZUs) that don't need to be paid back to the Government after harvest. This is shown in Figure 25. The number of low risk NZUs the forest earns depends on how old it was when it was registered and how quickly the forest was replanted after harvest.

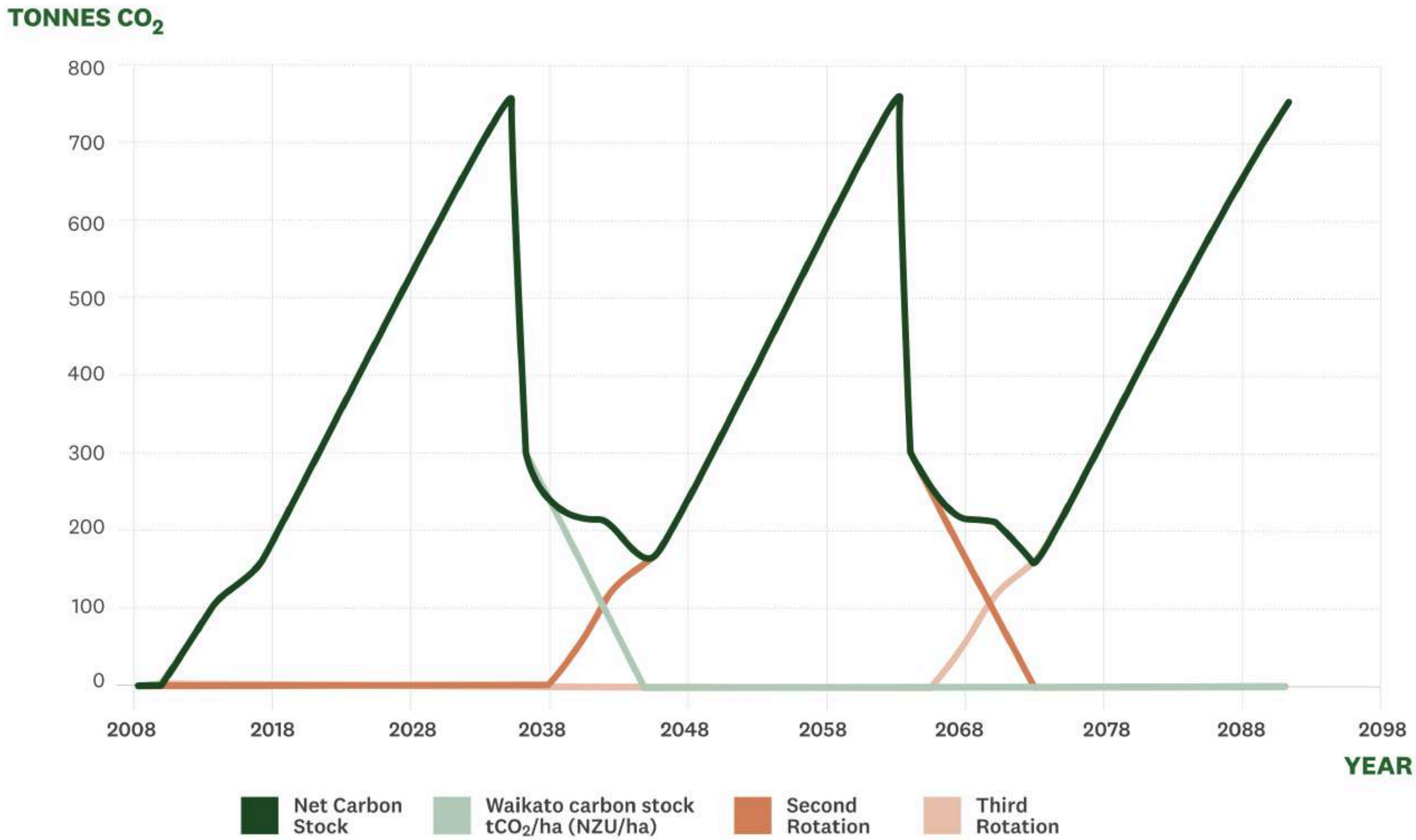


Figure 24: Total carbon associated with a 28-year harvest rotation of radiata pine

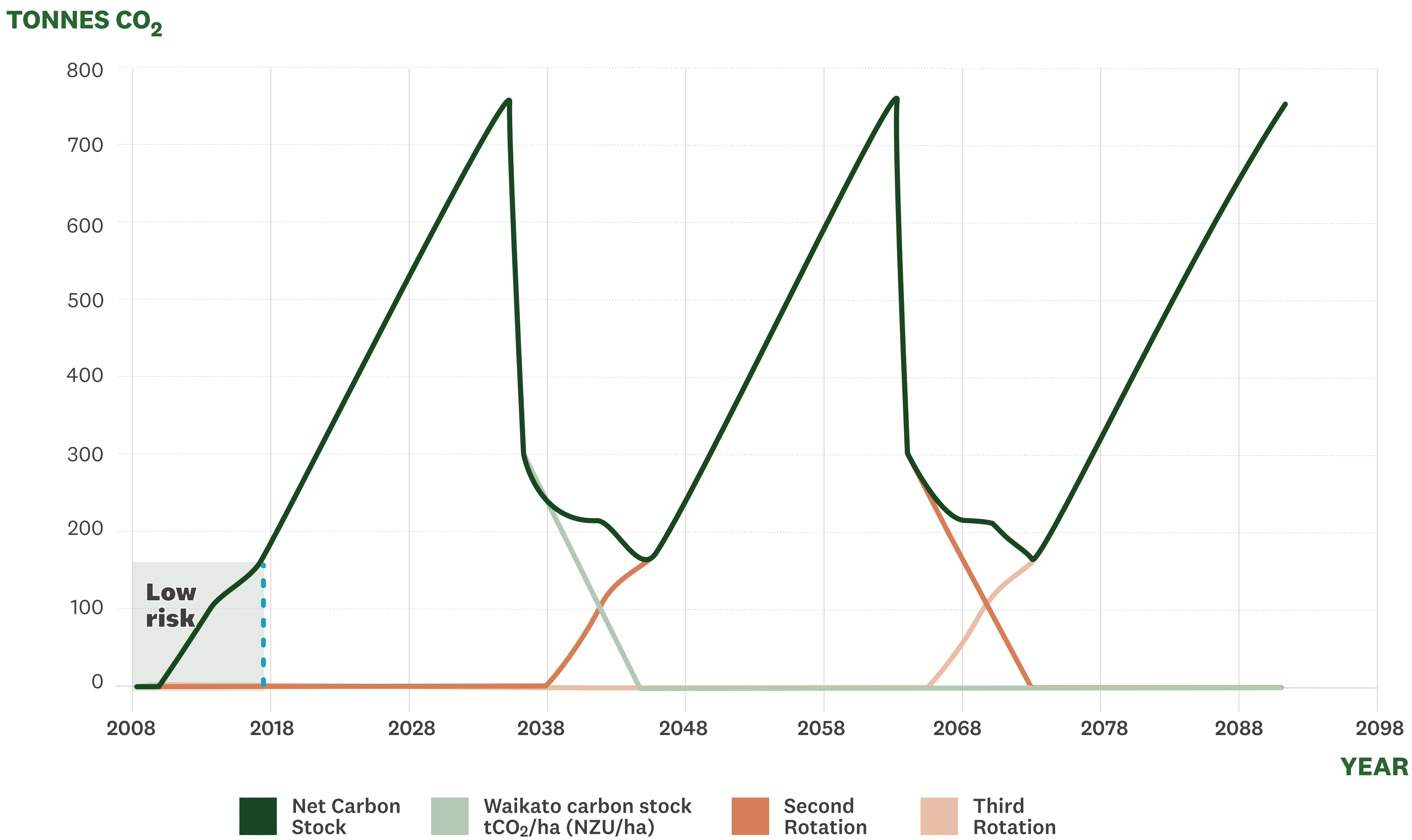


Figure 25: 'Safe carbon' associated with a 28-year harvest rotation of radiata pine

New way to earn carbon credits from 2023 - averaging accounting

The way ETS participants account for their carbon and earn NZUs from their forests changed as at 1 January 2023.

Instead of accounting for the actual increases and decreases in carbon, participants now account for the long-term average amount of carbon stored in the forest. This is illustrated by the shaded area in Figure 26.

Participants will earn NZUs on their first rotation until their forest reaches its average long-term carbon stock over several rotations of growth and harvest. The average carbon stock of a forest will depend on the species and when that type of forest is typically harvested. Table 11 shows the age that different tree species will typically reach the average amount of carbon they will store over the long term.

Once the forest reaches its average carbon stock, it will stop earning NZUs. When it is harvested, the NZUs won't need to be repaid to the Government. This means participants will earn more "low risk" NZUs and will only earn additional NZUs or need to pay NZUs back if the forest is harvested significantly earlier or later than is usual.

Using averaging accounting:

- Up to 31 December 2022, all newly registered forests continued to use the existing "stock change" method for calculating carbon storage.
- Forests that were registered between 1 January 2019 and 31 December 2022 have the option of switching to averaging accounting in 2023, through a special emissions return process.
- From 1 January 2023, averaging accounting must be used for all newly registered post-1989 forests, unless the forest is registered as a permanent forest activity.
- Forests registered before 1 January 2019 will continue to use stock change.

For more details on averaging, talk to a foresty/ETS consultant or Te Uru Rākau/Forestry New Zealand.

Table 11: Averaging ages (years)

Radiata pine	16
Douglas fir	26
Exotic softwoods	22
Exotic hardwoods	12
Indigenous	23

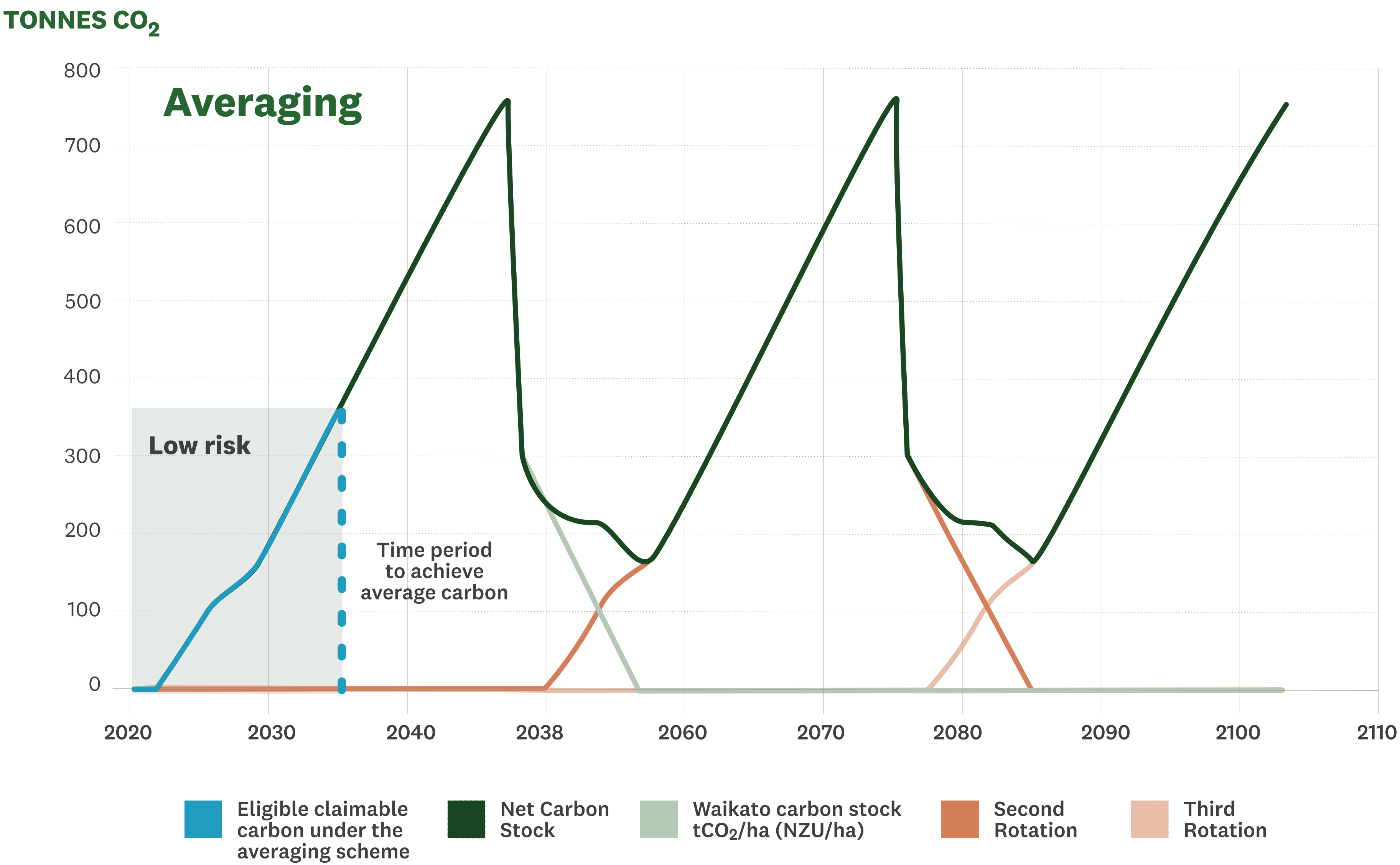


Figure 26: 'Average*' amount of carbon associated with a 28-year harvest rotation of radiata pine

*The averaging line in this figure is approximate.

Forestry is not a permanent solution for offsetting farm emissions

Key points to remember:

- The forest has to be replanted, otherwise the full amount of carbon that was claimed must be repaid; and
- The benefit of "low risk" NZUs only applies to newer rotation forests and permanent forests

Establishing a new forest and registering it in the ETS is a useful way to earn additional income from NZUs and the sale of timber or other forest products. The new forests can help mitigate some on-farm emissions, and the income used to pay for improvements that reduce net farm emissions.

However, solely using forestry to offset farm emissions may be difficult to achieve for the average farm. Rotational forests will offset emissions for a period of time, and then additional areas will need to be planted to continue offsetting and earning credits. Assuming no other mitigations are used, an ever-increasing area is required, as shown in Table 12.

Table 13 illustrates the area of forestry needed to offset the average farm's greenhouse gas emissions, depending on the percentage offset required and based on how the ETS averaging scheme might work.

Table 12: Replanting required under averaging approach, if used as the sole emissions offset

	Year 1	Year 17	Year 34	Year 51	Year 68
Plant (ha)	10	10	10	10	10
Total (ha)	10	20	30	40	50

Table 13: Area of forestry required to offset, using the averaging scheme

% Offset:	5%	10%	25%	50%	100%
155 ha dairy farm	3.7	7.4	18.5	37.2	74.4
695 ha sheep & beef farm	6.3	12.5	31.3	62.6	125.1

Note that Table 11 is based on the national average Pinus radiata data. Regions and other species will vary. The average taken gives a 16 year offset.

Indigenous forestry

There are pros and cons when considering indigenous species for forestry offsetting. Indigenous species sequester around 25-30% of carbon per year compared with pines. However, they sequester it for 200-300 years. Indigenous species can be very expensive to establish, e.g. $10,000-40,000/ha in comparison to pines at around $1,500/ha. But they also bring significant biodiversity benefits.

Permanent forestry

From January 2023, permanent indigenous or exotic forests can be registered in the ETS under the new 'permanent forest' category. Forests in this category will use the stock change approach and will earn NZUs for actual forest growth. The minimum term for the permanent category is 50 years, during which the forest cannot be clear-felled (although some limited harvesting is allowed as long as the forest does not drop below 30% canopy cover).

Once past the 50-year point, the forest can either remain as a permanent forest or can shift to the 'averaging' approach (see Figure 26).

Encouraging natural reversion can be a more cost-effective way to establish an indigenous forest. It can be registered in the ETS once there are enough forest species seedlings per hectare that it's likely the land will be able to meet the forest land definition at maturity.

Something to think about: Table 12 showed a farm that had planted 30ha of pines after 34 years. An alternative would be to simply plant 36ha of indigenous species at the outset – no more planting required for 200-300 years.

Carbon impact on forestry profitability

Table 14 shows a case study of a Hawke's Bay farm considering planting the property in pines for carbon farming – the strong returns are obvious. The case study in Table 15 uses indigenous species rather than pines. The Net Present Value (NPV) and Internal Rate of Return (IRR) are negative due to a combination of very high establishment costs for indigenous species and their very long/slow sequestration of carbon.

Table 14: Case study – pines (using Averaging Scheme)

	S&B farming	Forest for timber	Forest for timber & carbon @ $50/t	Forest for timber & carbon @ $65/t
Case Study #1 (IRR)	4.5%	7.9%	24.3%	30.0%
Case Study #2 (IRR)	2.8%	3.5%	6.9%	8.4%

Table 15: Case study - indigenous forest (50 years, $15k/ha establishment)

	Carbon @$50/tonne	Carbon @$65/tonne
NPV	-$15,827	-$14,272
IRR	-0.8%	0.1%

Transitioning from exotics to indigenous species

This approach depends on the economics of felling trees for timber. It has been suggested in areas where it may be impractical to harvest trees, e.g. if the farm is a long way from a port or mill or the cost of providing access is very high.

The idea is to plant pines as they sequester carbon rapidly but are not a ‘climax’ forest. A climax forest is one that will remain essentially unchanged in terms of species composition for as long as the site remains undisturbed.

The carbon credits from the pines can be claimed for 50-100 years, by which time the pines are falling over and indigenous species are coming through. The forest owner will need to manage this transition to indigenous species, but in theory they will eventually take over.

Value of forestry for offsetting

	Pastoral Area (ha)	Forest/ Horticulture Area (ha)	Total T CO2e/ Pastoral area	Farm-level levy		ETS forestry revenue		Net Levy		Levy as a % of total EBITDA	
				2025	2030	2025	2030	2025	2030	2025	2030
Sheep & Beef Farm base	2,921	0	8,285	$35,212	$114,336			$35,212	$114,336	6%	20%
Plant 294ha forest - Pines	2,627	294	7,937	$33,731	$109,527	$552,279	$896,641	-$518,548	-$787,114	-89%	-134%
Plant 294ha forest - Other Exotic Softwood	2,627	294	7,937	$33,731	$109,527	$319,872	$519,322	-$286,141	-$409,795	-54%	-77%
Plant 294ha forest - Natives	2,627	294	7,937	$33,731	$109,527	$162,435	$263,718	-$128,704	-$154,191	-46%	-55%
Dairy Farm base	155.1	0	2,027	$8,613	$27,966			$8,613	$27,966	1%	4%
Forestry - plant 15 ha in pines	140.1	15	1,806	$7,677	$24,927	$26,520	$43,056	-$18,843	-$18,129	-3%	-3%
Forestry - plant 15 ha in other exotic softwood	140.1	15	1,806	$7,677	$24,927	$16,320	$26,496	-$8,643	-$1,569	-1%	0%
Forestry - plant 15 ha in natives	140.1	15	1,806	$7,677	$24,927	$8,288	$13,455	-$611	$11,472	0%	2%

Sequestration in the farm-level pricing scheme

An important part of the He Waka Eke Noa recommendations to Government in May 2022 was recognition of existing and new eligible vegetation that encourages the right tree in the right place. He Waka Eke Noa recommended two broad categories be included in the farm-level pricing scheme: permanent vegetation and cyclical vegetation. This section provides further information on those two categories, noting that the Government is now considering how to include on-farm sequestration in the pricing scheme in the short term, alongside changes to the ETS in the longer term to include a broader range of vegetation types.

Permanent vegetation includes planted or regenerated indigenous vegetation that would not be harvested and is generally self-sustaining through self-seeding. The land must remain in permanent vegetation and not be cleared. Sub-categories include:

- Indigenous vegetation established before 1 January 2008
  - At least 0.25ha of land wholly or predominantly in vegetation, stock excluded
  - Vegetation types include gorse/broom (as a nursery crop for indigenous species if seed is present), manuka/kanuka, matagouri, mixed broadleaf/scrub such as swamp maire, five finger, coprosma, wineberry, lemonwood, cabbage trees, totara/kahikatea, old growth cut-over and beech
- Indigenous vegetation established on or after 1 January 2008
  - At least 0.25ha of land wholly or predominantly in indigenous woody vegetation either planted, regenerated or a combination, that was in pasture prior to 1 January 2008 (unless there is evidence of establishment between 1990-2008)
  - Declaration required that land was not in vegetation prior to 1 January 1990
  - For regenerating, a seed source needs to exist within 100m of the regenerating vegetation area
- ETS-eligible indigenous vegetation would be eligible to be entered into the system although the preference is that it be entered into the ETS instead
- Riparian vegetation established on or after 1 January 2008 (unless there is evidence of establishment between 1990 and 2008)
  - Plantings suited to margins and banks of waterways, including wetlands
  - Minimum of 1m from edge of bank
  - Predominantly woody vegetation including indigenous and/or mix of non-indigenous plants used for environmental benefit
  - Non-woody vegetation such as flax and toetoe are included but cannot be predominant species

Cyclical vegetation is defined as vegetation that is planted and may be felled and re-established. This kind of forest is not self-sustaining and needs to be replanted to ensure its continuation. It must be planted on or after 1 January 2008 (unless there is evidence of it being established between 1990-2008). Categories include:

- Perennial cropland e.g. orchard or vineyard greater than 0.25 ha
- Scattered forest
    - Minimum of 0.25ha for any area counted with minimum stocking rate of 15 stems per hectare
    - Not eligible if greater than 1ha and over 30% canopy cover at maturity and over 30m wide (e.g. once it meets the ETS criteria)
- Shelterbelts
    - One or more rows of trees planted on or after 1 January 2008 with a minimum linear canopy of 90%
    - Not eligible if greater than 1ha and over 30% canopy cover at maturity and over 30m wide (e.g. once it meets the ETS criteria)
- Woodlots/tree-lots
    - Up to 1ha and at least 0.25ha of tree species that have greater than 30% canopy cover

NOTE: ETS-eligible exotic forest would not be eligible for the sequestration payments in the farm-level pricing scheme. See pages 32-34 for more.

NOTE: The new Government's approach is "full recognition of on-farm carbon sequestration, including all forms of carbon capture and storage alongside trees, provided it is scientifically robust and demonstrated to be additional".

Soil carbon

Soil carbon
A brief introduction

There is considerable interest in the capacity of the soil to store carbon and reduce the amount of carbon dioxide in the atmosphere. Soil carbon is also considered important for maintaining soil health and resilience.

How is carbon stored in the soil?

Carbon in soil is bound up as organic matter and is typically greatest in the topsoil. It is derived mostly from plant roots plus non-grazed above-ground plant material (litter). As roots grow and die, they release carbon into the surrounding soil and micro-organisms decompose this released carbon and convert it into forms that are protected by the soil.

How much soil carbon do we have in New Zealand?

Currently available data indicate that carbon stocks in New Zealand agricultural soils are high compared to other countries - see Table 16 and Figure 27. There are several reasons for this:

- Our soils are young and human settlement has occurred comparatively recently.
- New Zealand has a temperate climate that mostly supports year-round plant growth, resulting in continuous inputs of carbon into our soils from plants.
- The chemical and physical properties of our soils mean they generally have a large capacity to protect carbon from loss.
- Our soils have generally been well managed with little intensive tillage and cropping—practices that have decreased soil carbon in many other countries.
- Most of our pastures are long-term perennial, meaning soils are rarely devoid of growing plants.
- A large proportion of our pastures are grazed by livestock, which recycle carbon in the form of dung.

From this high starting point, it's considerably harder to add to New Zealand's soil carbon stocks than in other countries.

Table 16: Average soil carbon stocks to 30cm

Location	Quantity
New Zealand	90 t C ha^{-1}
Australia	30 t C ha^{-1}
United States	45 t C ha^{-1}
Global	62 t C ha^{-1}

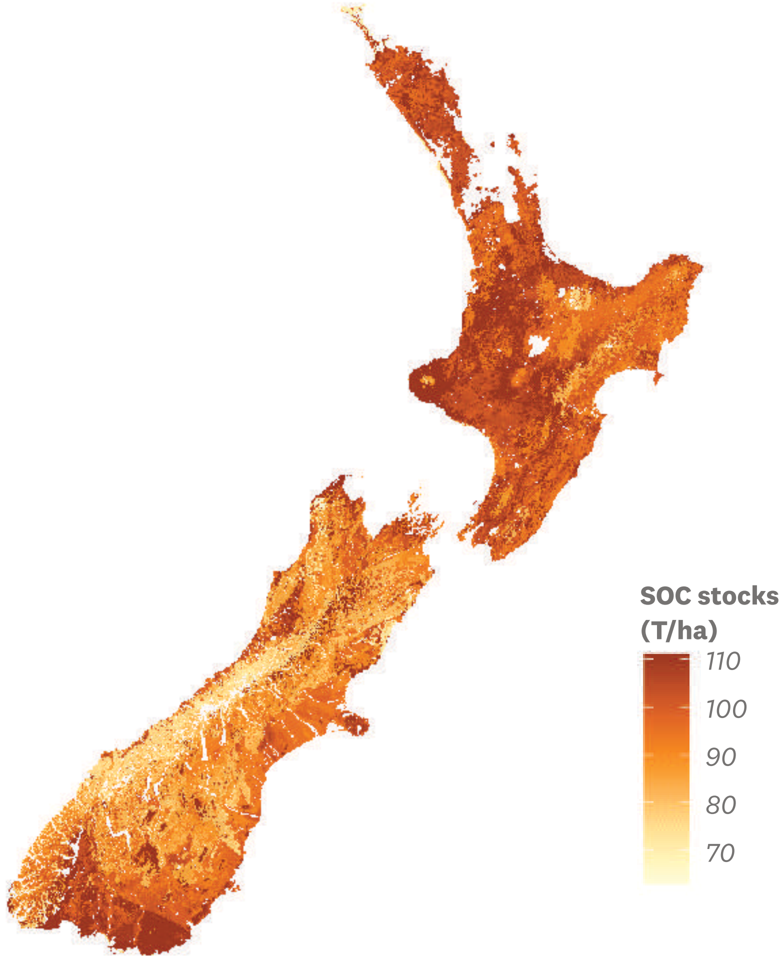


Figure 27: National soil carbon map

Source: Stephen McNeill, Manaaki Whenua and University of Waikato

What factors lead to soil carbon accumulation or loss?

Whether soil gains or loses carbon depends on the balance of photosynthesis by plants and respiration by the soil and plants, as shown in Figure 28. Photosynthesised carbon can also be exported in products like milk and meat and later converted to carbon dioxide after being consumed.

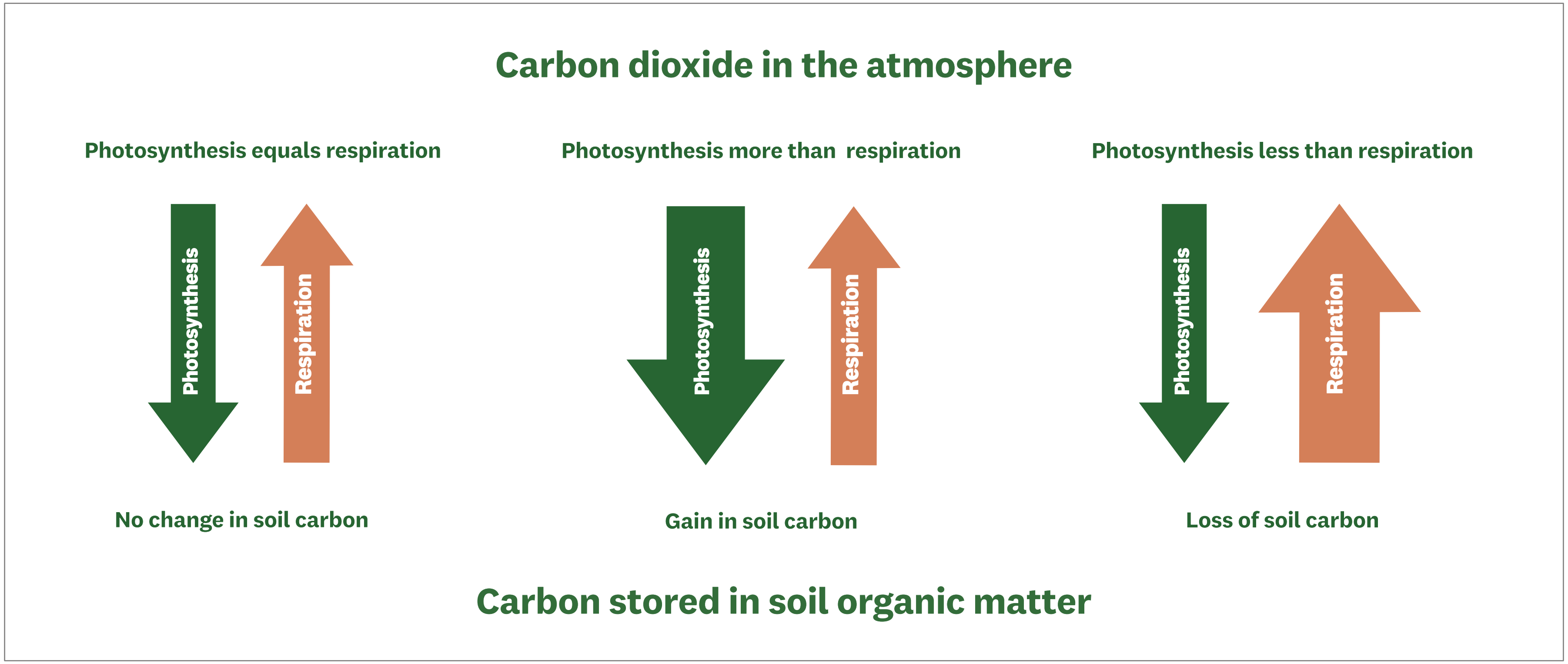


Figure 28: Changes in soil carbon

Effects of management practices on soil carbon

There are many factors that control the amount of carbon in the soil – see Figure 29. Many management practices alter the flow of carbon from the atmosphere to the soil as well as the flow back to the atmosphere. When you change one practice, you can end up altering rates in both directions, but it is the net effect that matters.

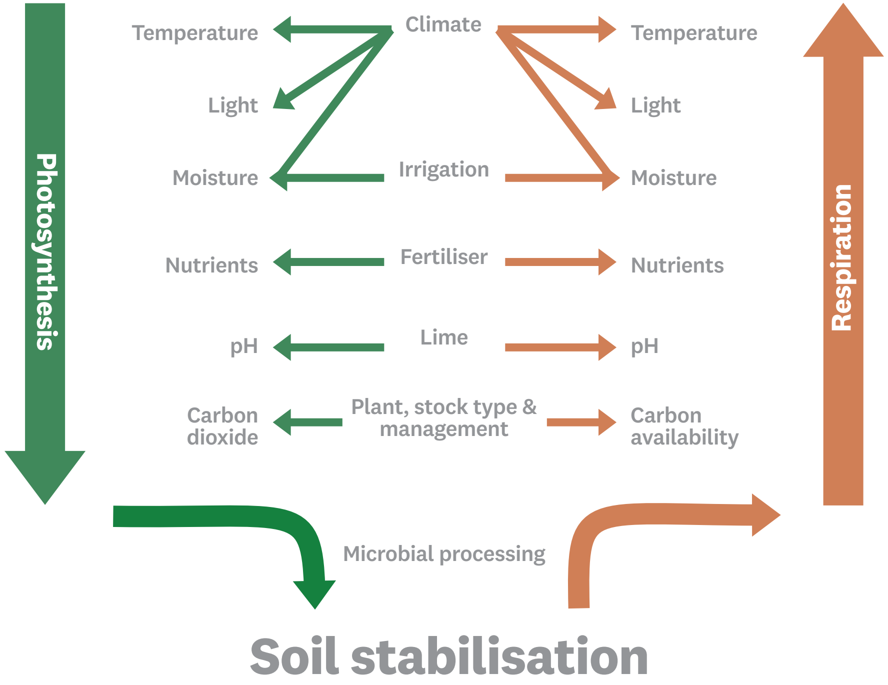


Figure 29: Effect of management practices on soil carbon

Is New Zealand soil carbon accumulating or being lost?

Science has shown that soil carbon levels under most New Zealand pasture on flat to rolling land are in a steady state, e.g. no change in the past two to three decades. The main exception to this is organic or peat soils, which can lose a significant amount of carbon for as long as they remain drained. There is also some evidence that soil carbon is increasing under hill country grazing.

In general, there is little evidence of grazing management practices in New Zealand that increase carbon by much, probably because carbon stocks in New Zealand soils are already high (see Figure 27). There are some management practices that result in carbon loss, e.g. leaving soils bare of growing plants for long periods and – surprisingly – irrigated pasture. While the reasons for this have not yet been determined, it is likely that irrigation stimulates respiration by soil microbes more than it increases photosynthesis by plants.

Monitoring changes in soil carbon

Long-term data is key to better understanding how New Zealand's agricultural soil carbon stocks are changing over time within different land uses and under different environmental conditions.

A comprehensive national study is underway to collect this data. About 500 farm sites will be sampled to a depth of 0.6m (see Figure 30). This sampling intensity has been statistically designed to detect a minimum change of 2 tonnes of carbon per hectare, should such a change occur within the broad land uses of: cropland, perennial horticulture, dairy, flat to rolling drystock and hill country drystock. These sites will be re-sampled through time from 2019-2030.

Strict site selection, sampling, analysis, storage and data management protocols will be followed to ensure results are robust, comparable and available. The data generated will help improve our estimates of carbon stocks within a land use and how stocks are likely to change when land use changes.

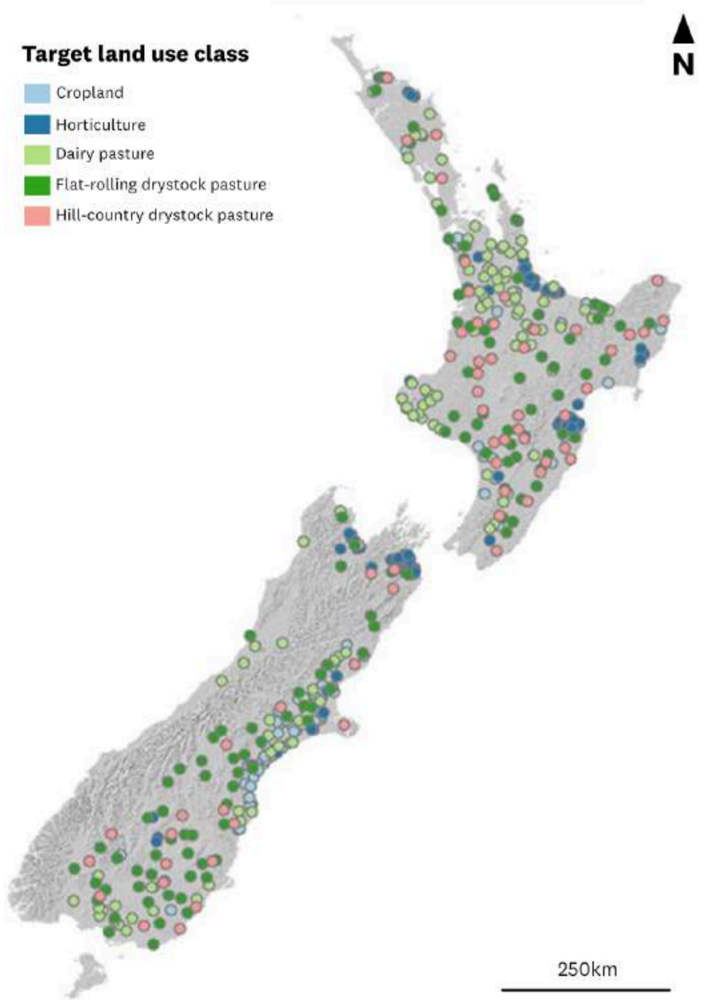


Figure 30: Sampling sites for the national soil carbon benchmarking and monitoring study

Source: Manaaki Whenua

Greenhouse gas estimation tools

What methods are available to estimate on-farm emissions?

There is a wide range of tools available for estimating on-farm agricultural greenhouse gas emissions. Which tool to use depends on the degree of detail required. The tools vary in complexity and cost, and improvements to their accuracy, usability and sensitivity are ongoing.

The He Waka Eke Noa partnership has evaluated the suitability of 12 tools for estimating a farm's greenhouse gas numbers. They include:

- OverseerFM is a software platform for modelling nutrient flows through a farm and includes a greenhouse gas component (see also page 47): www.overseer.org.nz
- Farmax is a software platform for modelling farm system efficiency and profitability and includes a greenhouse gas component (see also page 47): www.farmax.co.nz
- Fonterra is using the Agricultural Inventory Model (AIM) to provide estimates of on-farm emissions for all its suppliers. AIM underpins the New Zealand Greenhouse Gas Inventory.
- Beef + Lamb New Zealand has developed a 'GHG Calculator' - a free online tool for farmers to measure and report on-farm greenhouse gas emissions and sequestration, reflecting the individual farm's livestock and production systems: www.beeflambnz.com/ghg-calculator-info
- 'MyImprint Farm' is a proprietary model based on the New Zealand Greenhouse Gas Inventory. It can model farms that have sheep, beef, deer and dairy cattle and includes forestry: https://www.myimprint.nz/
- ProductionWise is a crop record keeping and decision support tool developed by the Foundation for Arable Research (FAR) that now generates greenhouse gas numbers for arable systems: www.productionwise.co.nz
- Horticulture New Zealand has a nitrous oxide emissions spreadsheet developed by (and available from) MPI for its growers
- The Ministry for the Environment has a spreadsheet calculator for New Zealand businesses, including farms, to work out their emissions: https://environment.govt.nz/what-you-can-do/agricultural-emissions-calculator/
- Alltech has a proprietary carbon footprint service ‘E-CO2’for businesses: www.alltech-e-co2.com
- Grazing Systems Limited operates the ‘Enviro-Economic Model’ (E2M) that is based on a linear-programming platform and can model whole farm systems including greenhouse gas emissions.
- 'PigGas' is a model developed by the pork industry to estimate emissions from piggeries.
- Toitū Envirocare offers a tool that builds on greenhouse gas data from OverseerFM to provide an ISO-certifiable carbon footprint of a farm: www.toitu.co.nz

MPI are currently working on a standardised methodology to be used in GHG calculators.

For more, see www.agmatters.nz/topics/know-your-number/

Sources of further information

Useful sources of climate change information in New Zealand

Ag Matters

A climate change website managed by the NZAGRC for farmers, growers and rural professionals. It provides science-based information on agricultural greenhouse gas emissions in New Zealand and ways they can be reduced. See www.agmatters.nz

NZAGRC

Coordinates New Zealand's research into on agricultural greenhouse gas emissions. For more information on the science in this area, including new mitigation options, see www.nzagrc.org.nz

Ministry for the Environment

Government department that leads New Zealand's climate change programme. Their website contains in-depth policy information and data and more. See https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/

Climate Change Commission

Provides independent evidence-based advice to successive Governments on climate change issues, see www.climatecommission.govt.nz

Te Uru Rākau/Forestry New Zealand

For information on forestry in the Emissions Trading Scheme, you can call a dedicated phone line 0800 CLIMATE (0800 25 46 28) or check out https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/

Other information

Useful documents with detailed analysis of agricultural greenhouse gas emissions include:

- The Interim Climate Change Committee 'Action on Agriculture' report and accompanying technical documents published in April 2019. See https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/interim-climate-change-committee-reports/
- Analytical reports produced in 2018 for the Ministry for Primary Industries' 'Biological Emissions Reference Group' (BERG). See www.mpi.govt.nz, keyword search 'BERG'

Industry websites also contain helpful information, such as Beef + Lamb NZ, DairyNZ, Deer Industry New Zealand, Foundation for Arable Research and Horticulture New Zealand.

If your question can't be answered by any of the above, please feel free to contact us at enquiry@nzagrc.org.nz.

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