Greenhouse gas emissions on New Zealand farms

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

August 2021

NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

Agriculture & Investment Services
Ministry for Primary Industries
Manatū Ahu Matua

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Overview

New Zealand's agriculture[1] sector contributes one fifth of our GDP, generates one in 10 jobs and produces 75% of our merchandise exports. It also contributes nearly half our reported greenhouse gas emissions. In 2019, the majority of agricultural emissions were methane (77%) and nitrous oxide (20%).

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. The primary sector is committed to playing its part. Work is underway in a five-year partnership with Government and Iwi/Māori known as He Waka Eke Noa, which aims to reduce agricultural greenhouse gas emissions.

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), AgFirst 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

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'Agriculture' is used in this booklet to refer to pastoral, arable and horticulture production.

Contents

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, and 2020 the warmest year yet.
- 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 24cm since scientific records began in 1880, and the rate of rise has increased in recent decades. From 2018-2019, global sea level rose 6.1mm.
- 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°C hotter than they were a century ago, with six of the eight hottest years on record occurring since 2013.
- Sea levels have risen 14–22cm since the early 1900s.
- 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.

Implications for freshwater

- Increased runoff in the south and west of the South Island.
- Reduced runoff in the north east of the South Island and in the east and north of the North Island.
- Annual flows increase 5-10% in eastward rivers with headwaters in Southern Alps (winter/spring).
- Increased drought frequency in many regions of New Zealand (see Figure 1).

These impacts are set to continue.

As our climate changes, it might not be possible to farm in the same way or the same places as we can now. A couple of degrees of warming might not seem much, but it can have a big effect on crop and pasture growth, and on pests and diseases. 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 (which prefers temperatures of 5-18°C) and animal performance (see Figure 2).
- Annual average rainfall is expected to decrease in the north-eastern South Island and northern and eastern North Island and increase in other parts of New Zealand.
- Farmers in dry areas can expect up to 10% more drought days by 2040.

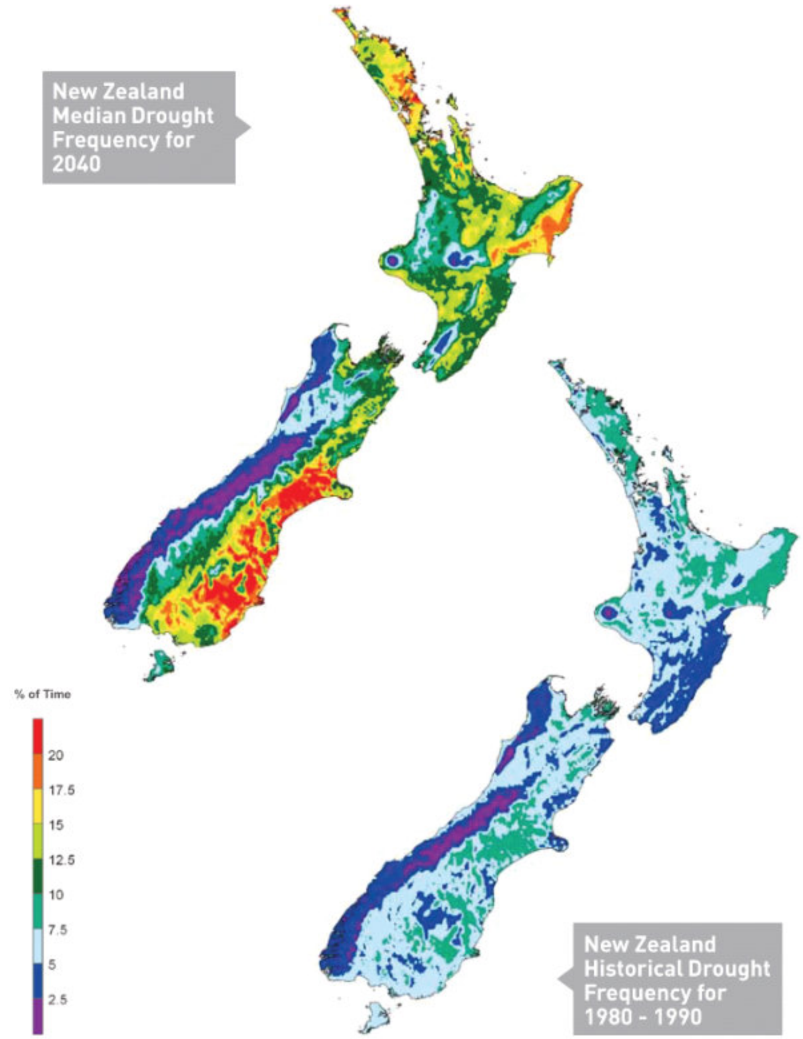


Figure 1: NZ median drought frequency for 1980/90 and 2040

Source: Royal Society of New Zealand (2016)

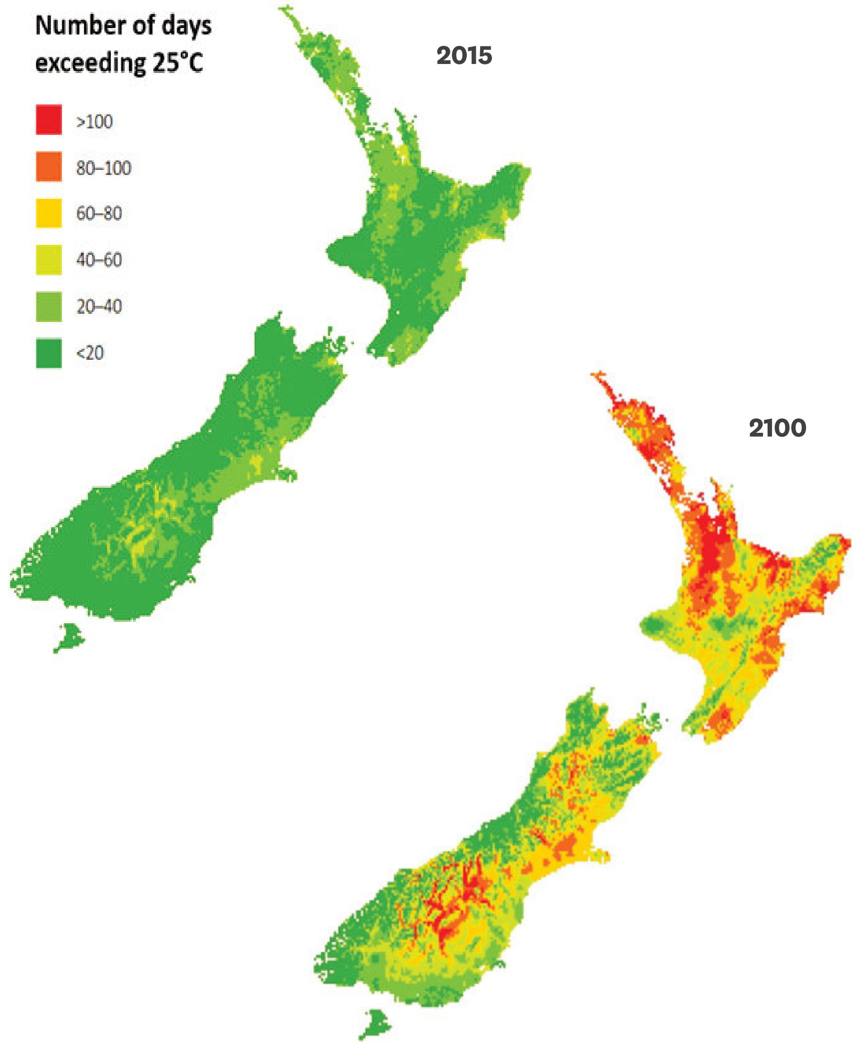


Figure 2: Number of days >25°C predicted to increase

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 2018.

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).

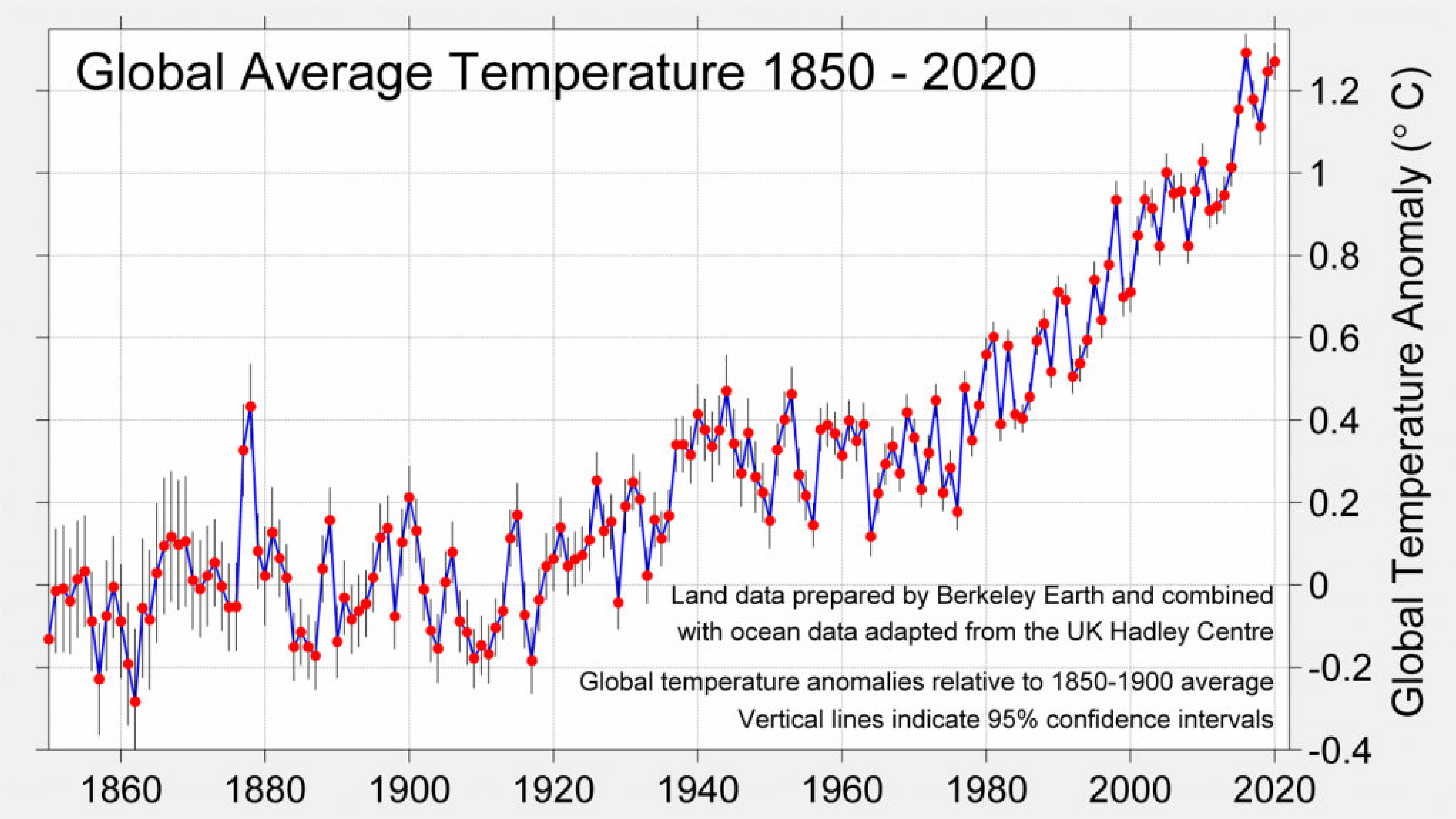


Figure 3: Global Average Temperature 1850-2020

Source: Global Temperature Report for 2020, www.berkeleyearth.org

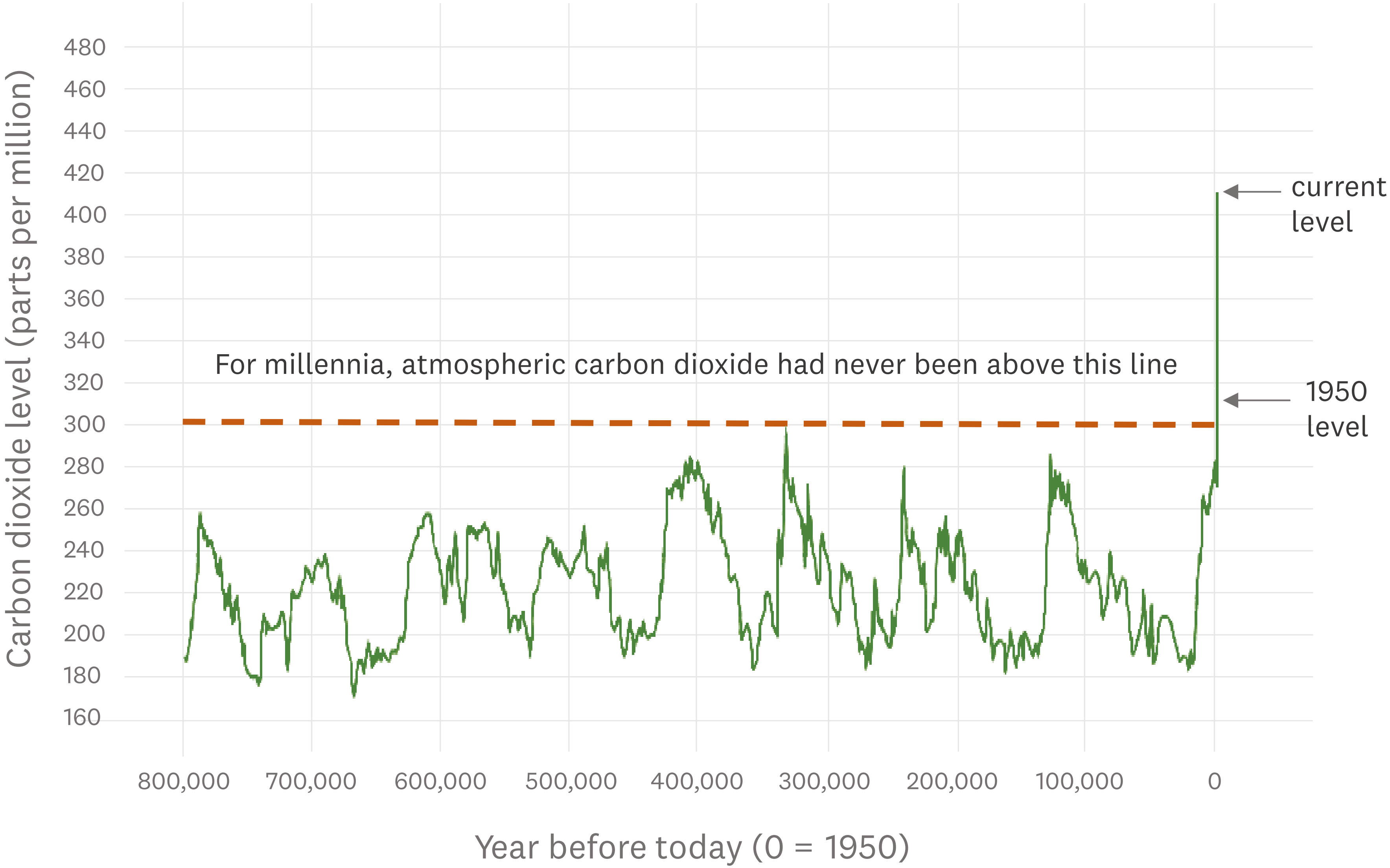


Figure 4: Global carbon dioxide levels over time

Source: climate.nasa.gov

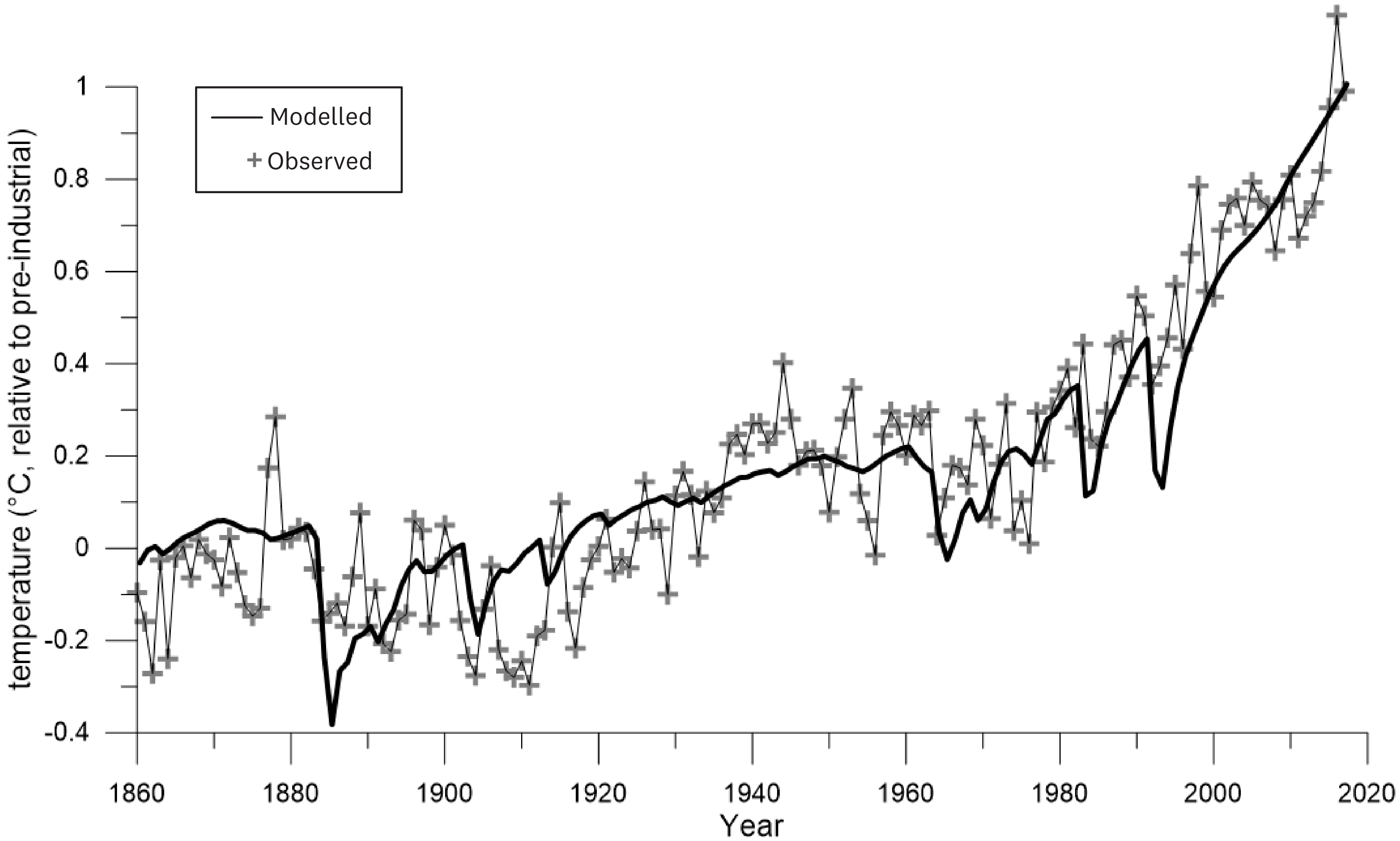


Figure 5: Modelled and observed temperatures

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

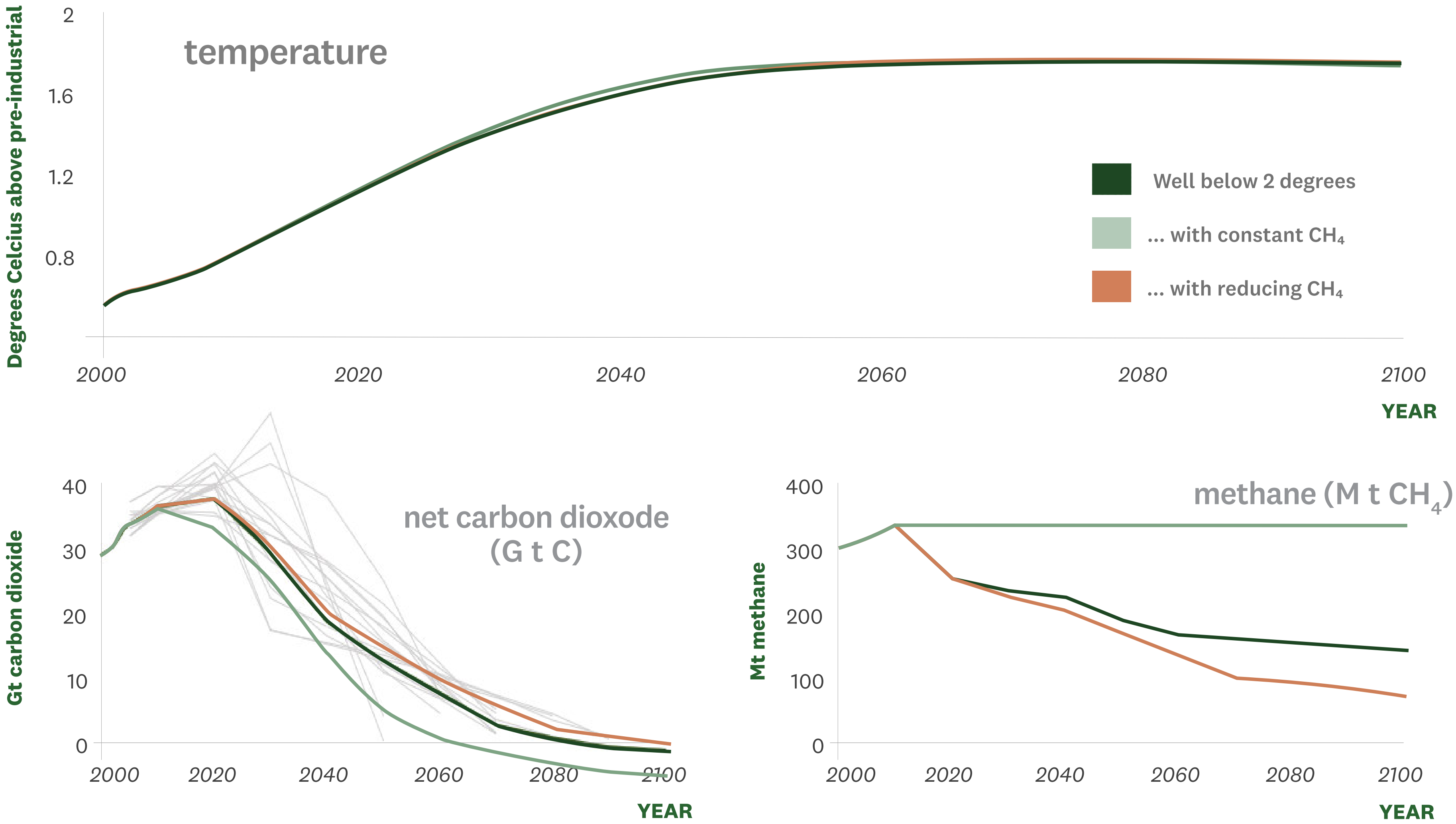


Figure 6: Three alternative scenarios for global emissions of carbon dioxide and methane that limit the temperature rise to 2°C

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

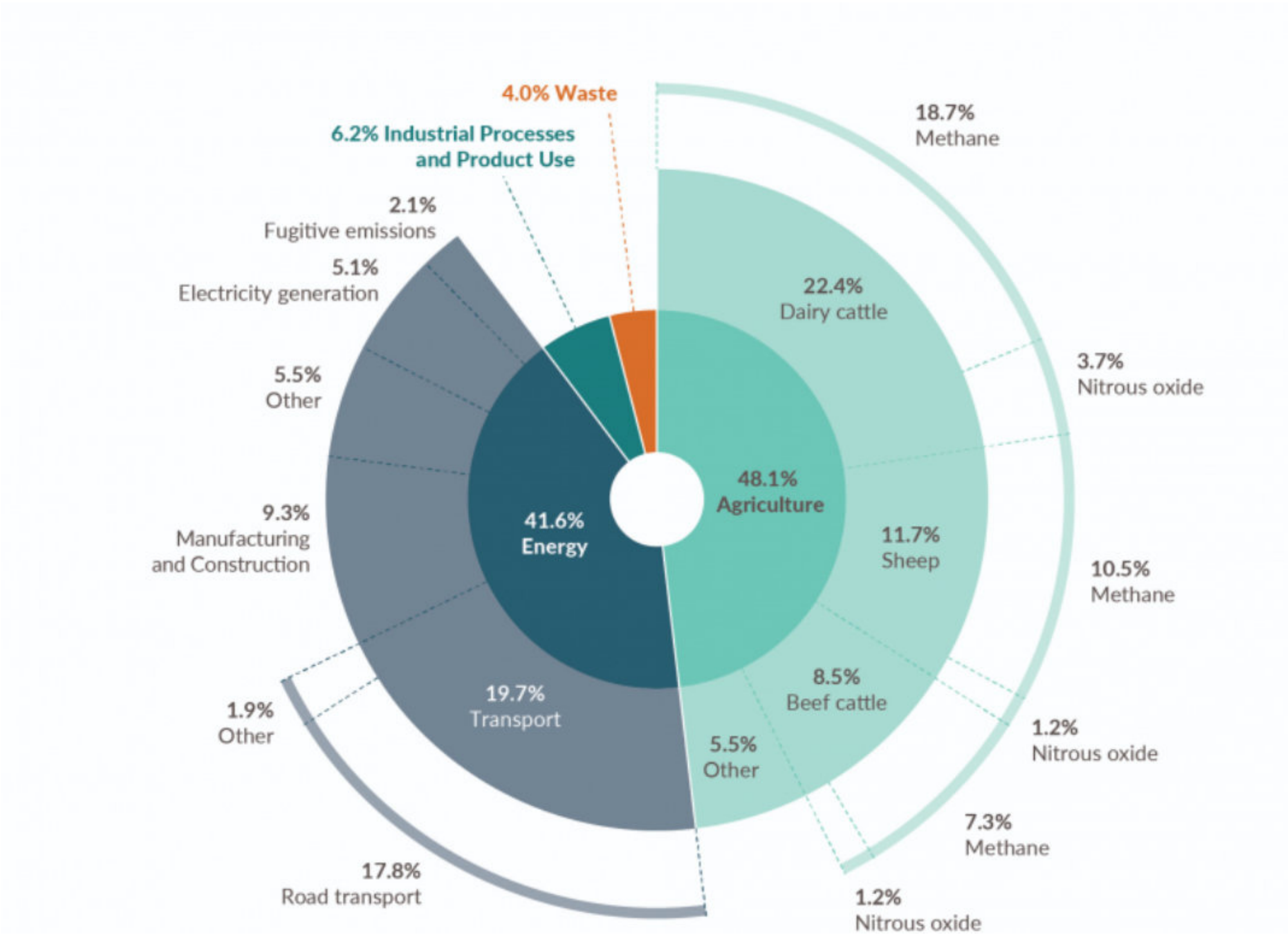
New Zealand's emissions profile is unique. Globally, carbon dioxide is the main greenhouse gas but in New Zealand in 2019, the agriculture sector contributed almost half of our total reported carbon dioxide equivalent (CO_2-e) emissions (see Figures 7 and 8), with methane from ruminant livestock the 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 2019, New Zealand's gross emissions were 82.3 million tonnes of carbon dioxide equivalent (Mt CO_2-e), comprising 46% carbon dioxide, 42% methane, 10% nitrous oxide and 2% fluorinated gases. This represents a 26% 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 2022, for emissions from the 2020 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 33% of New Zealand's total export revenue) and the use of renewable energy to generate most of our electricity.

In 2019, 73% of New Zealand's reported agricultural emissions was enteric methane from ruminant animals. A further 20% of agricultural emissions was nitrous oxide, largely from the nitrogen in animal urine and dung, with a smaller amount from the use of synthetic fertilisers. The remainder of agricultural emissions in 2019 were mostly methane from manure management (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 1990-2019, published April 2021
https://environment.govt.nz/publications/new-zealands-greenhouse-gas-inventory-1990-2019-snapshot/key-findings-of-the-2021-inventory/

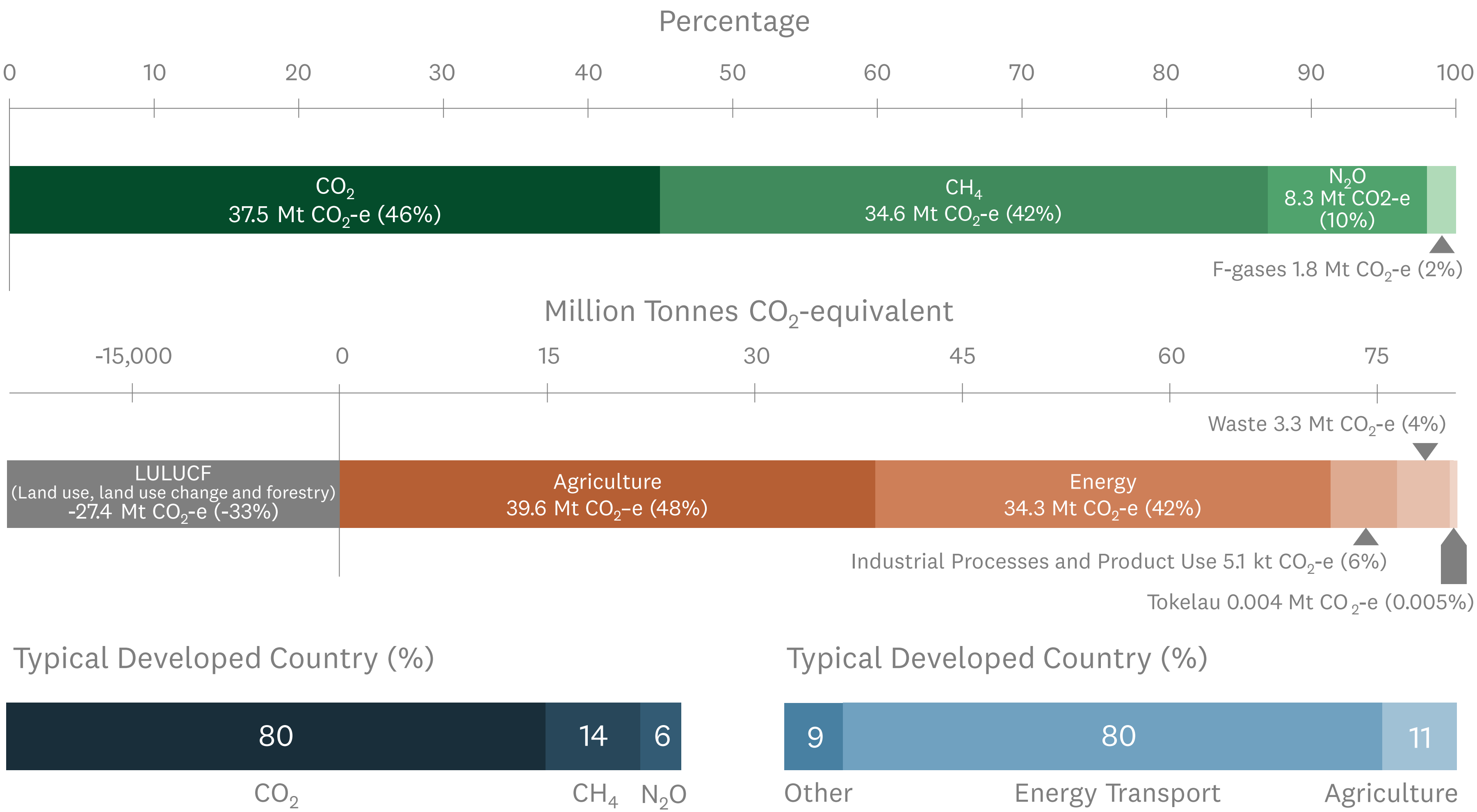


Figure 8: Comparing New Zealand's percentage emissions to that of a typical developed country

Source: New Zealand Greenhouse Gas Inventory 1990-2018, published April 2021

How are agricultural emissions changing?

New Zealand's estimated carbon dioxide equivalent agricultural emissions have risen by about 17% since 1990 (see Figure 9 and 10). 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 20 - 22), the dairy sector is producing much more milk than before[2] (although from fewer cows)[3].

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[4]. Due to the increase in individual animal productivity and more integration between the beef and dairy sectors, lamb production has reduced by only 8% while beef production has increased 46%. These trends show that reductions in greenhouse gas emissions do not necessarily mean a reduction in product volume, let alone profits.

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[5].

However, Figure 10 also shows how difficult it is to predict how agricultural emissions will change. This graph presents historical and projected agricultural emissions, based on four successive Government reports[6]. Assumptions for agricultural climate policy are identical in all four reports, but non-climate and market assumptions differ.

[2] Since 1990-1991, the milk solids processed in New Zealand has increased from 599 million kgs to 1.9 billion kgs, 0.6% more than the previous season. Average milk production per cow also increased from 381kg MS in 2018/19 to 385 kg MS in 2019/20 (LIC & DairyNZ Statistics 2019-2020).

[3] In 2019/20, there were 4.921 million milking cows in New Zealand, a 0.5% decrease on the previous season and down significantly from the peak cow numbers in 2014/15, which were over 5 million.

[4] Beef + Lamb New Zealand 2020 Annual Report

[5] Fertiliser Association website

[6] National Communications and Biennial Update Reports are required from countries are part of the United Nations climate change reporting framework. New Zealand submits a 'BUR' every two years, presenting our progress towards our international climate change commitments and emissions reduction targets, historical and projected emissions trends, and policies and measures in place to support New Zealand's climate change efforts.

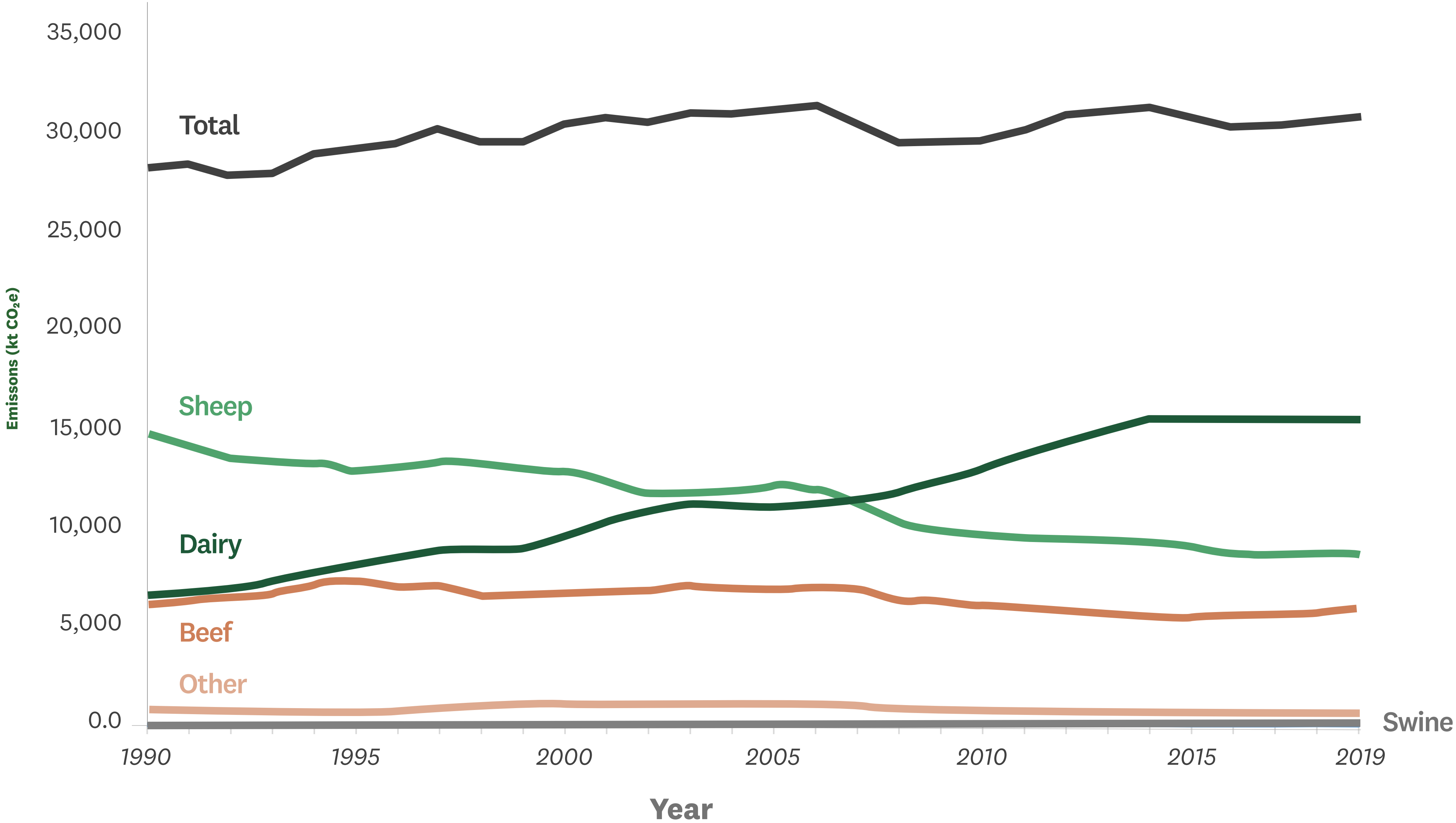


Figure 9: New Zealand's agricultural methane emissions (1990-2019)

Source: NZAGRC (2021) - source data from the New Zealand Greenhouse Gas Inventory 1990-2019

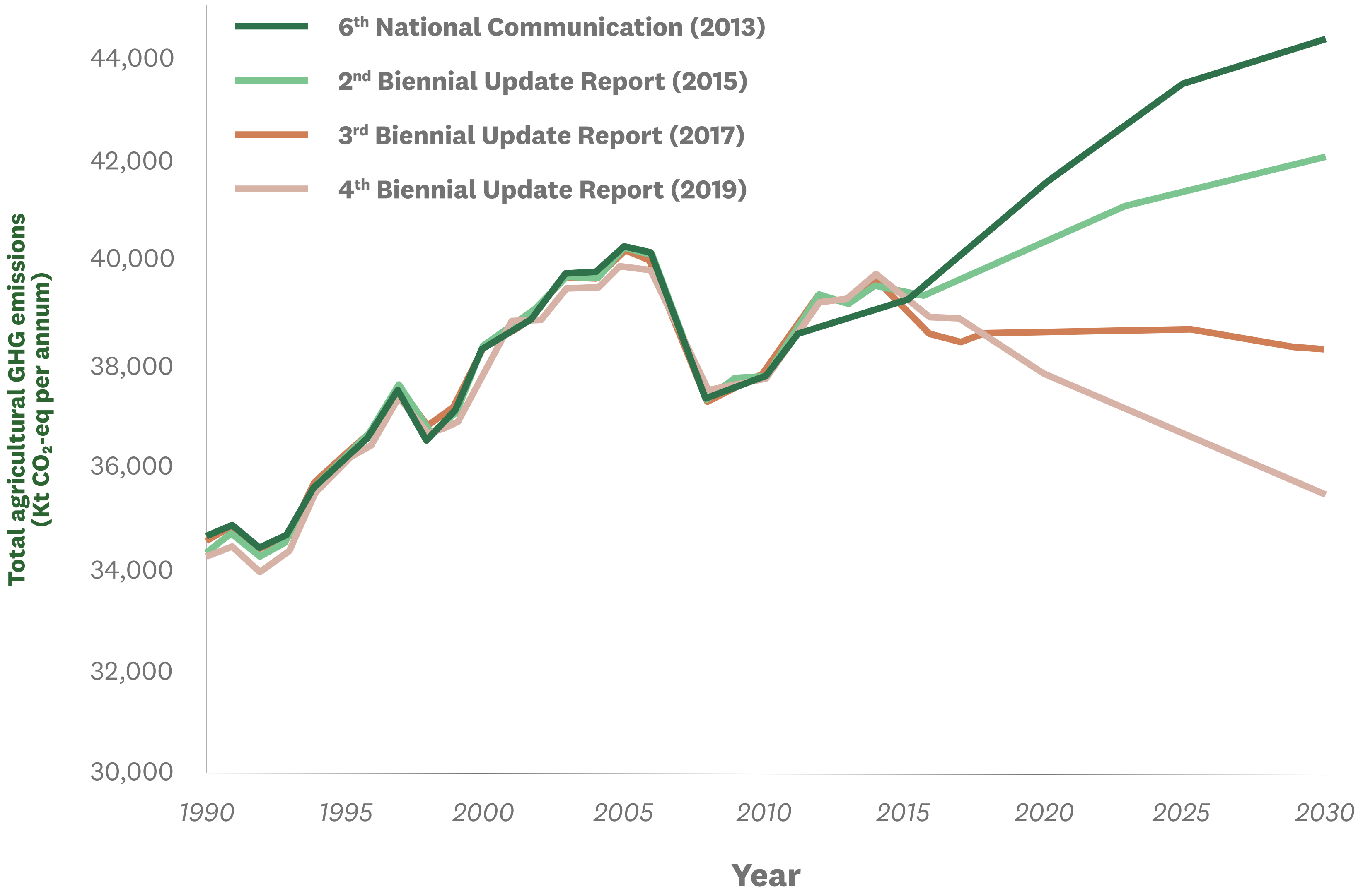


Figure 10: New Zealand's historical and projected agricultural emissions from 1990 out to 2030

Updated from: Reisinger, A. et al (2018). Future options to reduce biological GHG emissions on-farm: critical assumptions and national scale impact. A report to the Biological Emissions Reference Group.

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 11 and 12.

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 23-25) focus on absolute emissions, meaning that reductions in farm-level emissions need to be accounted for and reported in the same way.

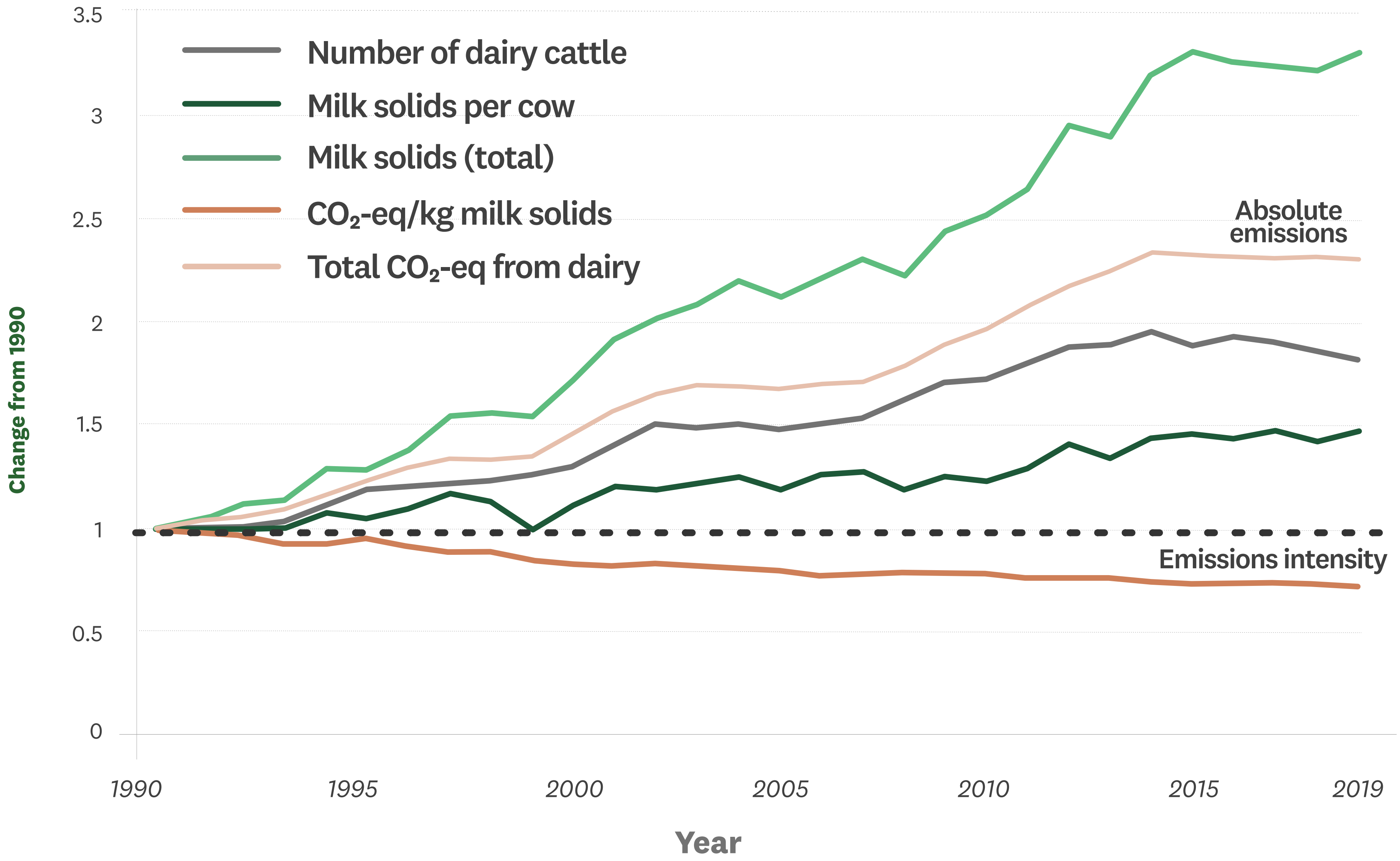


Figure 11: Changes in dairy greenhouse gas emissions intensity and absolute emissions (1990-2019)

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

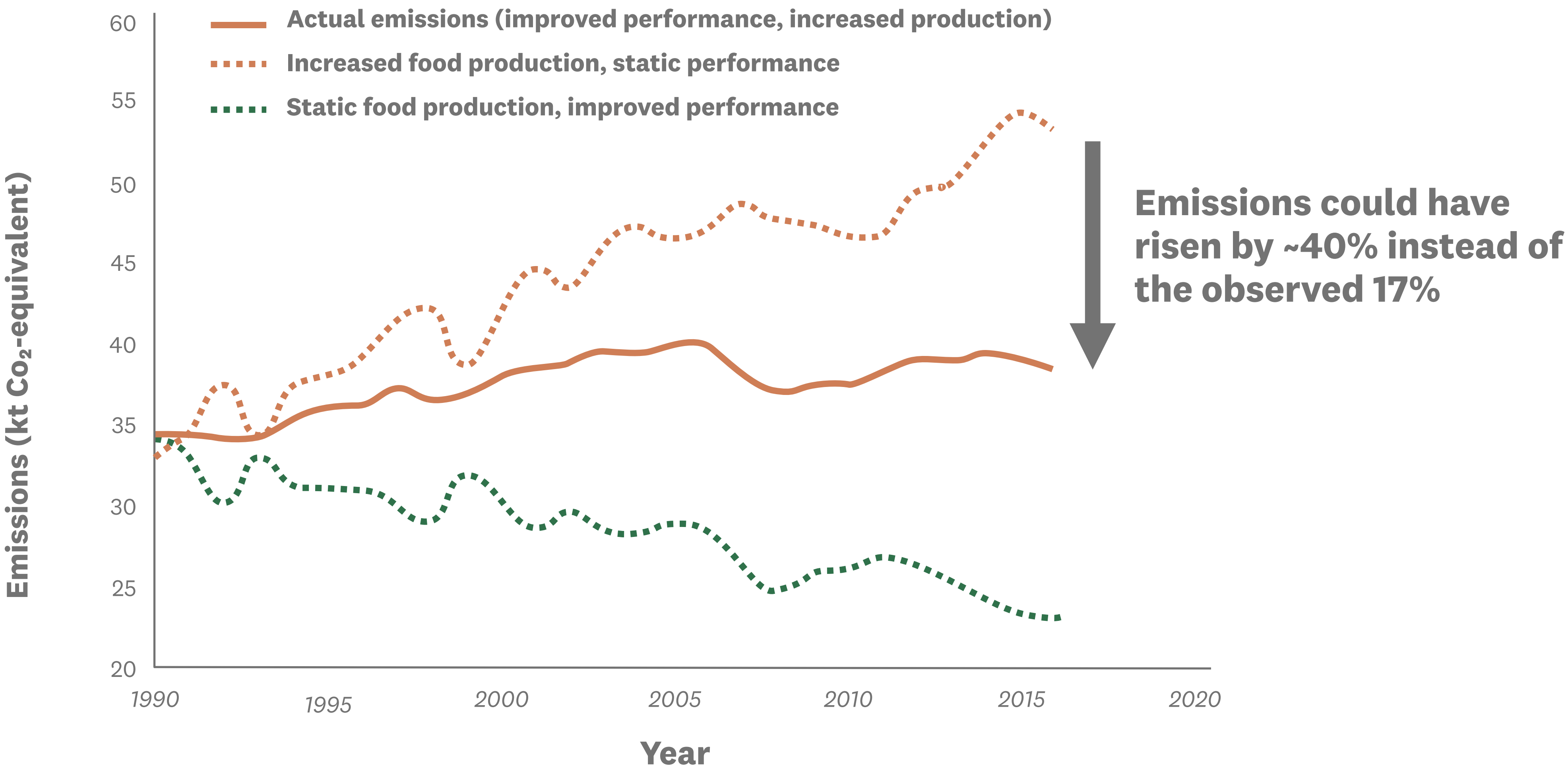


Figure 12: Total New Zealand agricultural emissions 1990-2016 (solid line) and two hypothetical scenarios with (a) identical increase in food production but no improvements in animal performance (i.e. a further increase in animal numbers to achieve the additional production (dashed brown line)), and (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 is the latest global agreement on climate change. It 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 30% below 2005 levels (or 11% below 1990 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 13 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 2.4*C warmer by 2100 based on countries' pledges and targets, 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	30% below 2005 levels by 2030
Australia	26-28% below 2005 levels by 2030
Brazil	37% below 2005 levels by 2025
Canada	40-45% below 2005 levels by 2030
France	37% below 2005 levels by 2030
Ireland	30% below 2005 levels by 2030
Netherlands	36% below 2005 levels by 2030
United Kingdom	37% below 2005 levels by 2030
United States	50-52% below 2005 levels in 2030

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".*

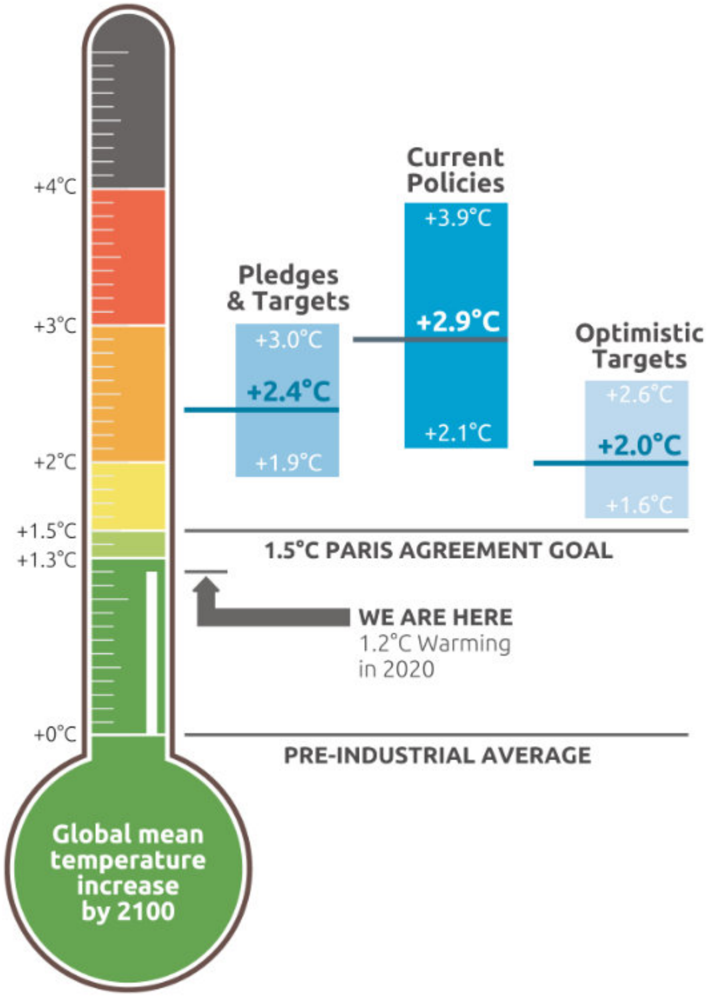


Figure 13: Climate Action Tracker (CAT) warming projections: global temperature increase by 2100 - as of May 2021

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

Domestic commitments

A credible long-term greenhouse gas emissions 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.

In November 2019, following extensive consultation, the Climate Change Response (Zero Carbon) Amendment Act was passed into law, putting in place new national 2050 targets:

- Carbon dioxide and nitrous oxide emissions (the 'long-lived' gases) to reduce to net zero by 2050
- Methane emissions to be reduced 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 (for more, see Figures 6 and 14-15).

This legislation is often referred to as the Zero Carbon Act but is actually an amendment of the climate change legislation that has been in place in New Zealand since 2002. The Act also introduced a system of emissions 'budgets' to act as stepping stones toward the 2050 targets, and specific requirements for the Government on adaptation.

Importantly, the Act also sets up an independent Climate Change Commission to advise successive Governments on mitigation and adaptation, monitor progress towards the 2050 targets, and advise on emissions budgets. The Commission also has responsibilities for monitoring progress regarding reducing agricultural greenhouse gas emissions - for more on this, see page 30-31.

In June 2021, the Commission released its first package of advice to the Government in a report called 'Ināia Tonu Nei: a low emissions future for Aotearoa'. Its advice addressed three main areas:

1. The levels of the first three emissions budgets, advising the total amount of emissions allowed in New Zealand over five-year periods to 2035 - charting a course towards meeting the 2050 targets.
2. Direction on the policies and strategies that the Government could employ to meet the first emissions budget.
3. Advice on the Paris Agreement NDC and the eventual reduction in biogenic methane, as requested by the Minister of Climate Change.

It is now over to the Government to consider this advice in deciding the specific policies that will form New Zealand's emissions reduction plan and to set the first three emissions budgets. These decisions must be in place by the end of 2021.

For more, see www.climatecommission.govt.nz

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 14).

Figure 15 compares the warming effect of methane with the warming effect of carbon dioxide. This type of comparison is called 'Global Warming Potential' (see side bar). 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*).

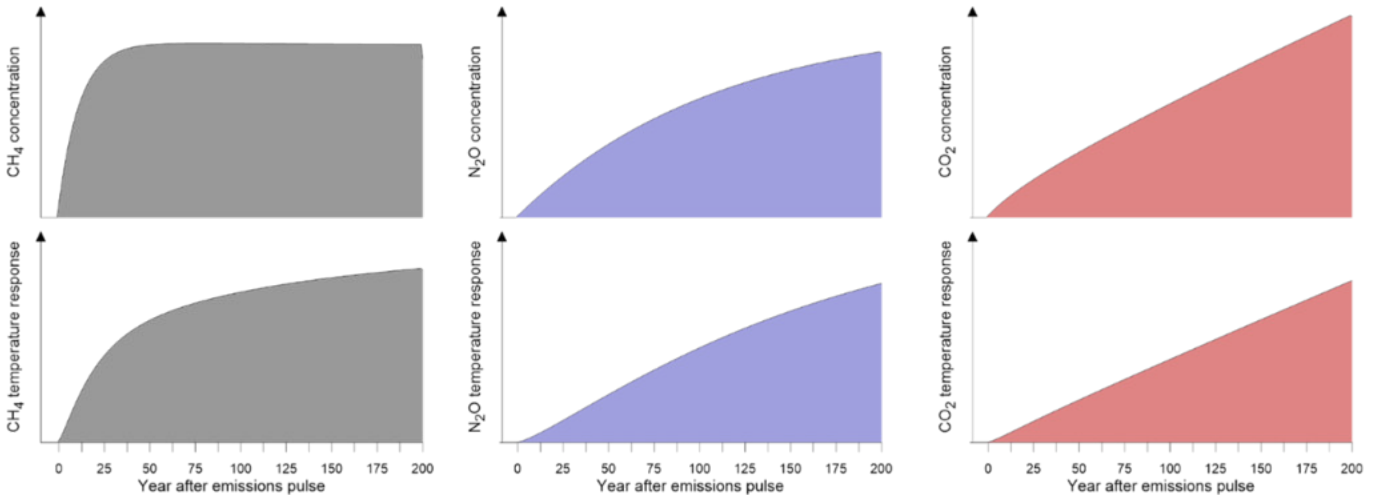


Figure 14: Different gases have different warming effects

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.

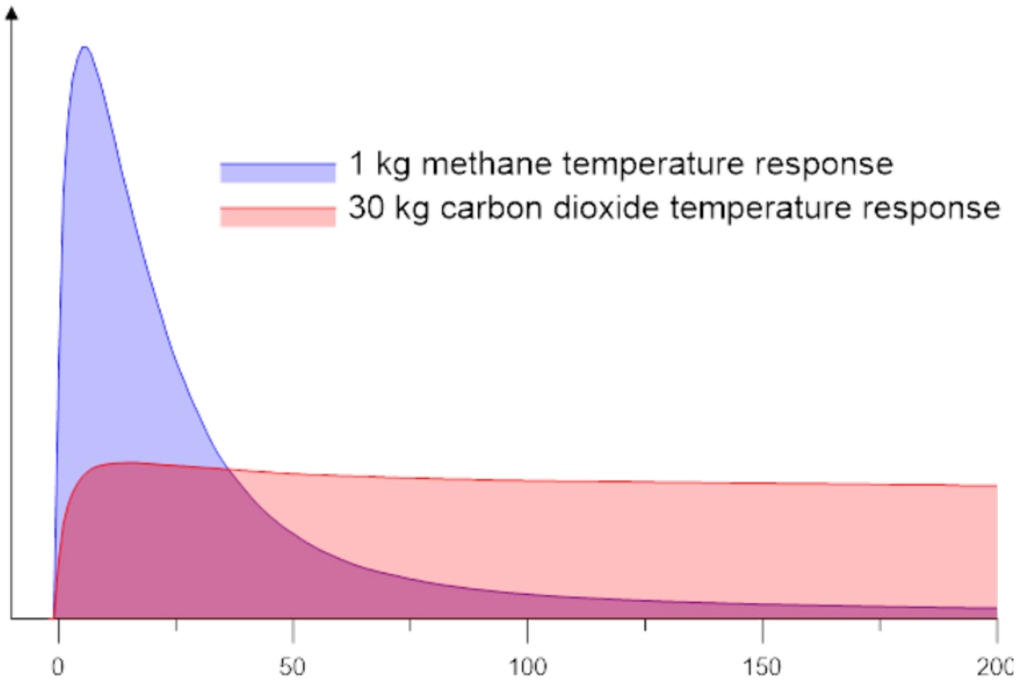


Figure 15: Warming effect of methane vs. carbon dioxide

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

There are different 'metrics' or ways of equating different gases into a common unit, allowing for comparison. Global Warming Potential (GWP) is used internationally and indicates the ability of a greenhouse gas to trap heat in the atmosphere over time (most commonly 100 years) relative to carbon dioxide. It is usually expressed as carbon dioxide equivalent or CO_2-e.

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 16.

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.

The ETS was reformed in 2020 to strengthen its effectiveness. The main changes included:

- A cap on total emissions covered by the scheme that declines over time, in line with progressive emissions budgets and the 2050 targets
- Auctioning introduced from 2021 to allow the Government to sell NZUs from within the cap
- Establishment of controls to prevent unacceptably high or low prices:
    - Price floor of $20/NZU, which will increase by 2% for each subsequent year.
    - Cost containment reserve (price ceiling) triggered if the unit price reaches $50, which would release more NZUs into an auction to ease demand. This will increase by 2% for each subsequent year, based on forecast annual inflation.
- 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

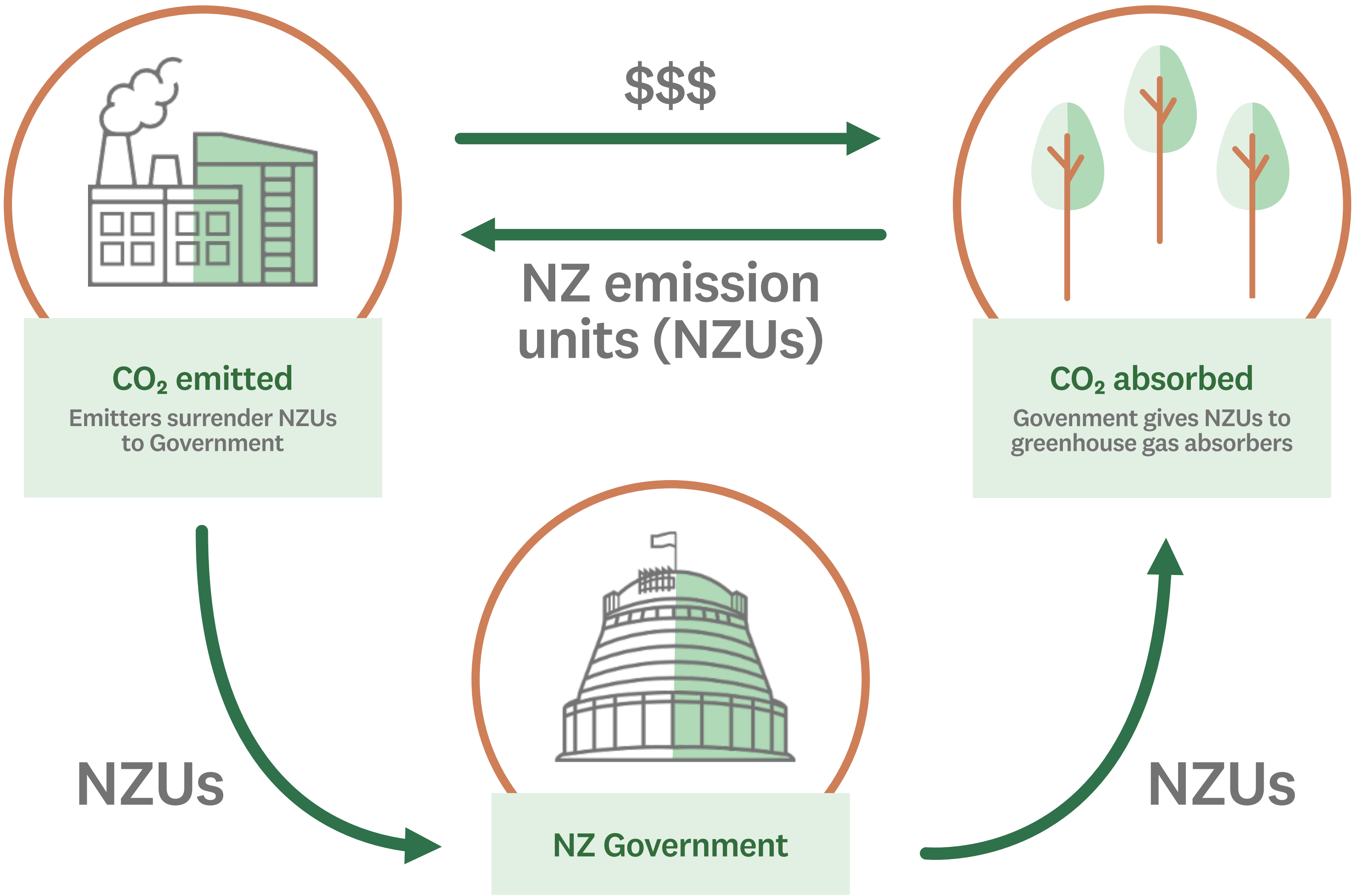


Figure 16: How the ETS works

He Waka Eke Noa

How will the primary sector meet the methane and nitrous oxide targets if those gases aren't priced in the ETS?

In 2018 and 2019, the Government consulted widely on how agricultural greenhouse gas emissions should be treated. In October 2019, 'He Waka Eke Noa'[7] was announced – a five-year partnership between Government, industry and Māori to reduce agricultural greenhouse gas emissions. This will see the development of a framework to equip farmers and growers to reduce emissions and adapt to a changing climate.

At the centre of the partnership is the development of a pricing mechanism for agricultural greenhouse gases that will apply from 2025. A substantial work programme is underway to develop that mechanism and associated support for farmers. Joint industry/government/Māori working groups are developing:

- A Farm Plan approach
- Criteria, methodologies and definitions for on-farm emissions reporting
- A simple, cost-effective programme that recognises on-farm sequestration
- A farm-level pricing mechanism
- A supporting programme of extension and innovation/research activities and ways to recognise early adopters

Key milestones for He Waka Eke Noa have been legislated in the same piece of legislation that introduced the ETS improvements (see table 2).

Table 2: He Waka Eke Noa milestones

Deadline	Action
1 January 2021	Guidance issued on how to measure and manage agricultural greenhouse gas emissions through farm planning
31 December 2021	25% of all farmers and growers must know their annual total on-farm greenhouse gas emissions and have a written plan to manage emissions
31 December 2022	100% of all farmers and growers must know their annual total on-farm greenhouse gas emissions
31 December 2023	Completion of a pilot project testing a system for farm-level emissions accounting and reporting
31 December 2024	100% of all farmers and growers must have a written plan to measure and manage emissions
1 January 2025	All New Zealand farms using the farm-level accounting and reporting system for 2024 agricultural greenhouse gas emissions

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

For the purposes of the milestones in Table 2, the He Waka Eke Noa partnership has defined a farm as being "anything over 80ha, or a dairy farm with a milk supply number, or a cattle feedlot as defined in the freshwater policy". The partnership has also noted that smaller farms may be included in the future. This will be decided as part of developing the pricing mechanism.

The partnership will report to Government in April 2022 with recommendations for the pricing mechanism and system for recognising on-farm sequestration. Then, by December 2022, the Ministers for Climate Change and Agriculture will put forward a report outlining a system to put a price on emissions from agricultural activities as an alternative to the ETS. The Ministers' report must detail:

- How those emissions would be priced and accounted for
- Which activities and participants would be included
- The methodologies for calculating emissions and removals (sequestration)
- What assistance (if any) would be given to participants - e.g. allocation of units
- How methane emissions would be treated relative to other greenhouse gas emissions, including whether, how and what type of removals would be recognised
- What information participants would have to provide and how that information would be used, shared or made publicly available
- How participants and industry groups would be engaged in designing, implementing and operating the system
- Who would be responsible for administering it
- What legislative amendments might be required

As part of preparing their report, the legislation also directs the Ministers to have sought advice from the Climate Change Commission about what assistance, if any, should be given to participants.

If milestones aren't being met, Government can bring agriculture into the ETS at the processor level before 2025. If the farm-level pricing mechanism isn't ready for implementation by 2025, agriculture will come into the ETS at the processor level.

For more information on the point of obligation for agricultural greenhouse gas emissions, see pages 64-67.

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*

Notes

The science

Where do livestock emissions come from?

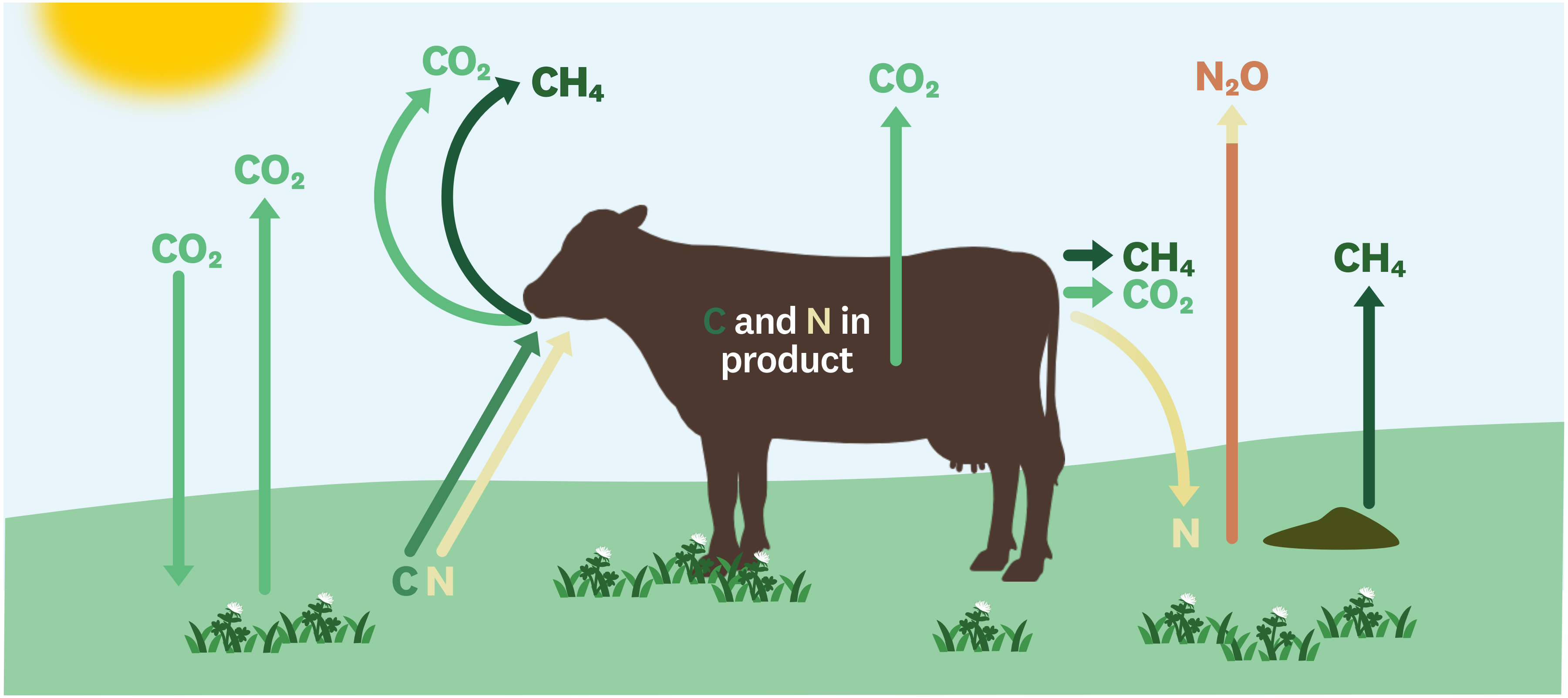


Figure 17: Greenhouse gas emissions from ruminant animals

Source: NZAGRC

Figure 17 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 18 shows the percentage of agricultural greenhouse gas emissions from livestock sources and non-livestock sources (synthetic fertiliser).

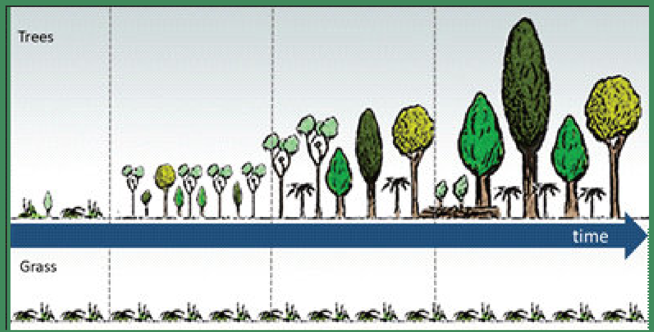
Livestock greenhouse gas emissions (methane and nitrous oxide) are part of the carbon and nitrogen cycles. The carbon in atmospheric carbon dioxide cycles through plants, then the soil and/or animals that eat the plants. Most re-enters the atmosphere in the form of carbon dioxide.

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 85-90). 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 14-15.

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.



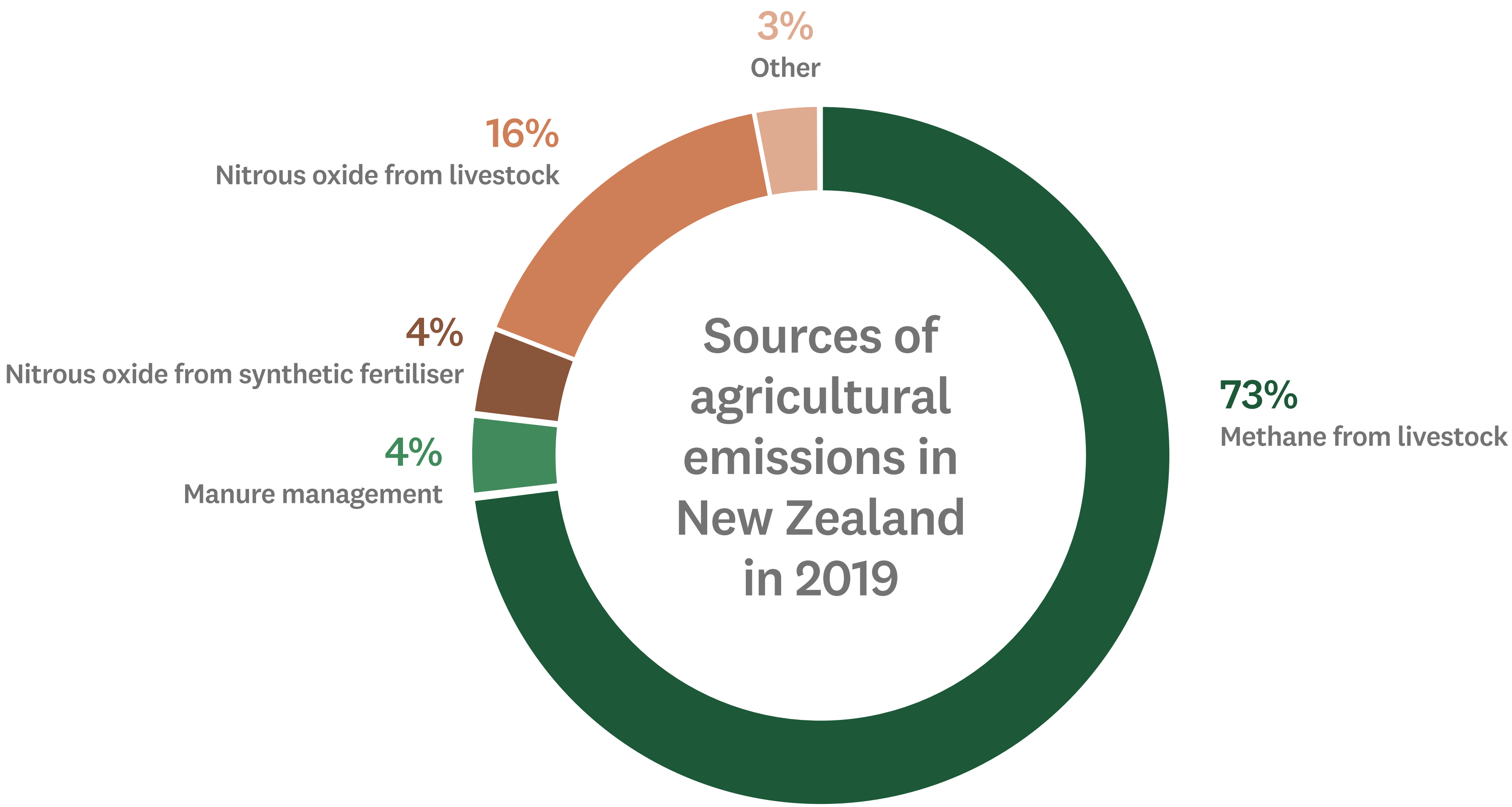


Figure 18: Sources of agricultural emissions in New Zealand in 2019

Source: NZAGRC, New Zealand Greenhouse Gas Inventory 1990-2019

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 19). 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.

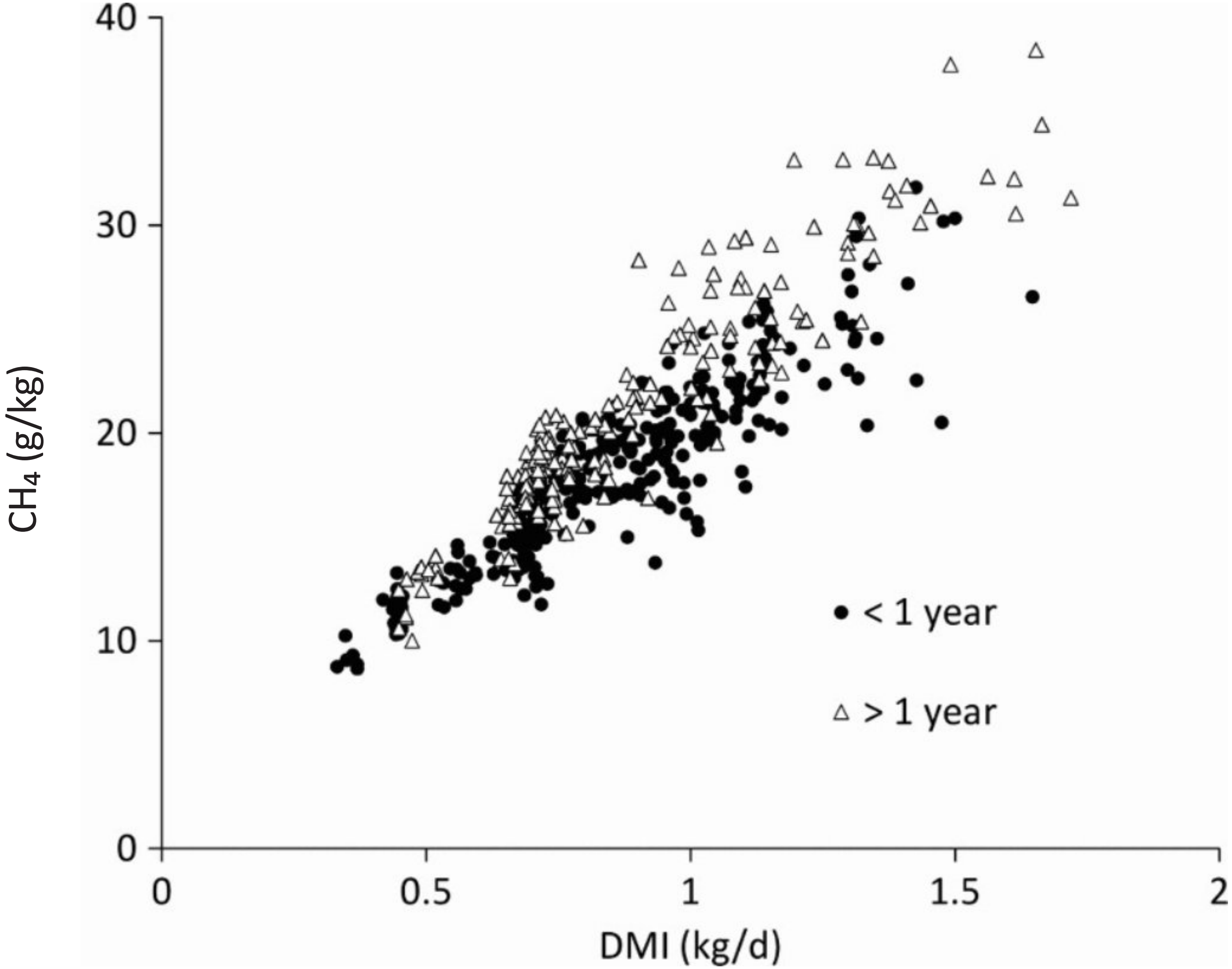


Figure 19: The amount of methane produced is directly linked to Dry Matter Intake in sheep

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 13.8% of New Zealand's total greenhouse gas emissions in 2018, the largest source of which comes from livestock urine and dung.

Figure 20 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 the 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 21). 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.

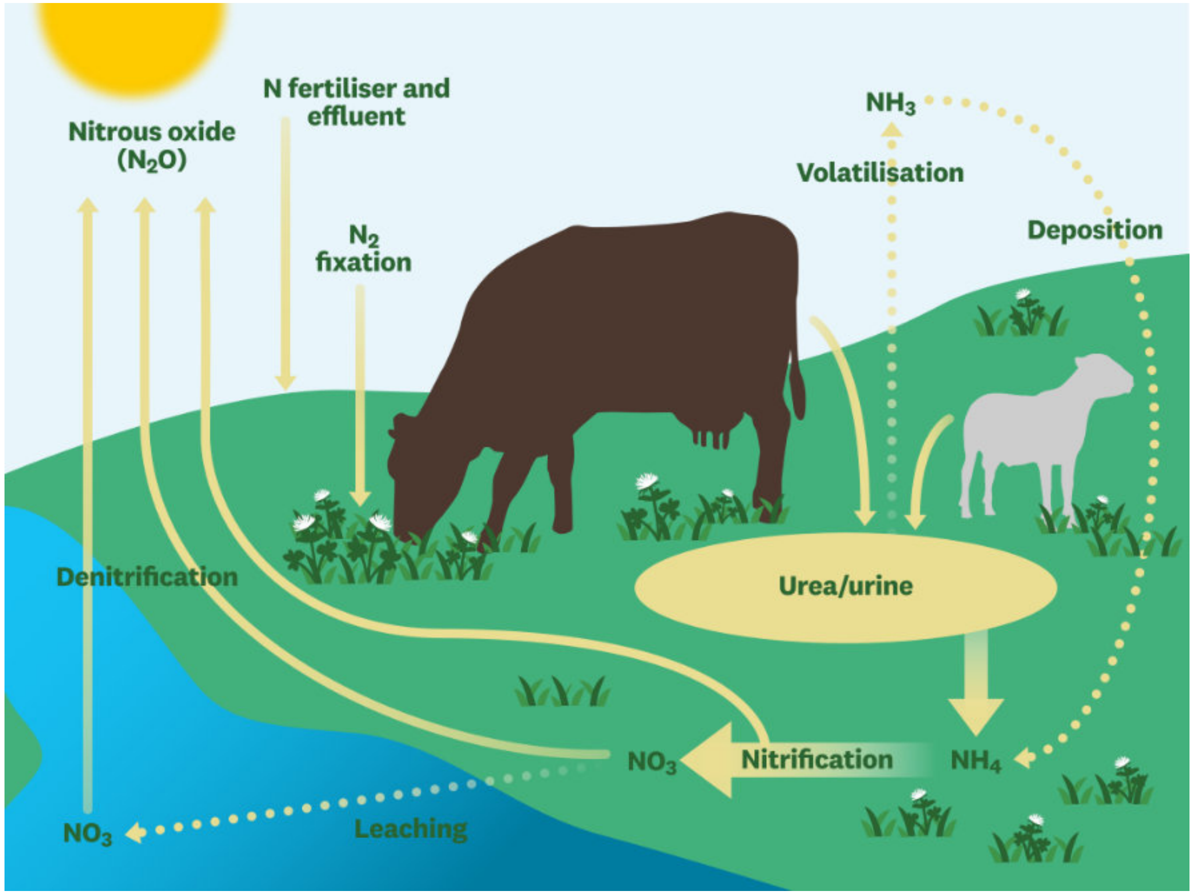


Figure 20: Nitrogen cycle on a farm

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.

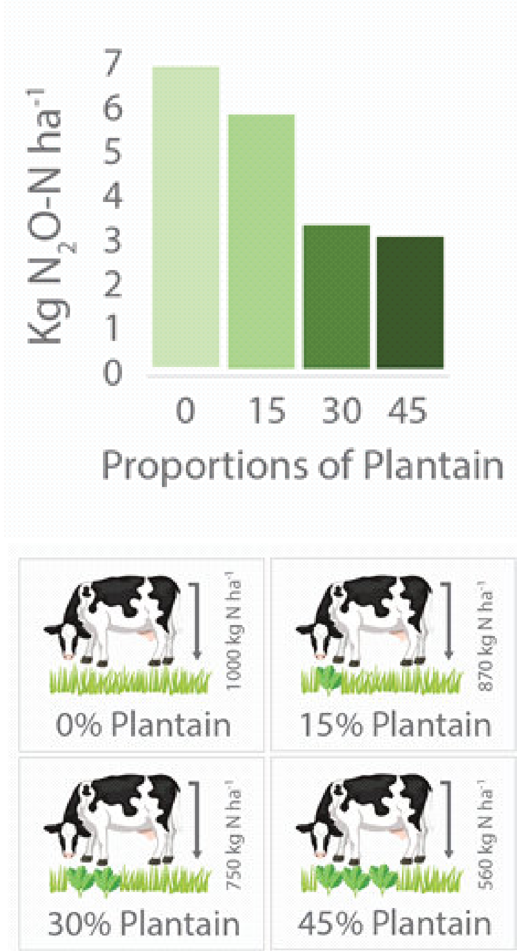


Figure 21: Plantain's potential impact on nitrous oxide emissions

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
- 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 48-62. 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 91-93.

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	2-3 years	10%?
Low methane emitting cattle	>5 years	10%?
Low N excreting cattle	Now, in theory	??
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	?	?
Animal devices (e.g. methane destruction)	?	?

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 low methane emitting sheep. Emissions differ by approximately 20% between low-emitting and high-emitting flocks (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 3-NOP 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. In the absence of significant co-benefits for animal performance, adoption of methane inhibitors will depend on cost and therefore climate policy incentives or consumer demand.

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. 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.

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.

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
8.8	14.2	23.6	19.6	30.7

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'[8], and forestry profitability based on the Forecaster Calculator[9].

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 two dairy farms and two sheep and beef farms.

For more on OverseerFM and Farmax, see the Tools section on pages 91-93.

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

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

Dairy farm
Case studies

Table 5 provides a summary of modelling work done on a number of 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.

The following pages then present the modelling results for two dairy farm case studies.

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

		Change in GHG	Change in EBIT
Reduce stocking rate by 10%	Farm 1	-6%	12%
	Farm 2	-7%	-4%
	Farm 3	-8%	-3%
	Farm 4	-3%	14%
Replace N fertiliser with bought-in feed		-11%	-18%
In-shed feeding with increased cow numbers		11%	12%
In-shed feeding, no increase in cows		10%	9%
Grow maize instead of buying in PK		-4%	0%
Limit N fertiliser to 100kgN/ha		-5%	-12%
Shift to once-a-day milking		3%	21%

Dairy farm
Case study 1

Farm Statistics

Total area (ha)	161
Effective area (ha)	161
Cows milked	425
Heifers	99
Farm system	3
Milk solids/ha	851
Cows/ha	2.7
N fertiliser applied (kg/ha)	59
Supplementary feed bought in (tonnes DM)	272

Scenarios

Thirteen scenarios were modelled, as shown below/over the page. These were developed via discussion with the farm owners/managers.

Scenario		Description
1	Base farm	Current existing farm system
2	Reduce cow numbers 10% - no improvement in productivity	Cow numbers were reduced by 10%, with no change in per cow production. Bought-in supplements were also proportionally reduced
3	Reduce cow numbers 10% - improve productivity	Cow numbers were reduced by 10%, with per cow production improved as much as possible within existing feed supplies
4	Reduce cow numbers 15% - improve productivity	Cow numbers were reduced by 15%, with per cow production improved as much as possible within existing feed supplies

Scenarios continued

	Scenario	Description
5	Reduce replacement rate	The theory was that improved animal health and animal husbandry results in a reduction in deaths and an improvement in in-calf rates. The result being that less replacements can be reared. For the case study farm, this meant a reduction in replacement heifers run, from 101 to 65.
6	No nitrogen fertiliser	All nitrogen fertiliser applied was eliminated. Base N usage was 59kgN/ha. To compensate for this cow numbers were reduced by 5% and per cow production held at the base level.
7	No bought-in supplementary feed	All bought-in supplement was eliminated. Total base bought-in supplement was 392 tonnes DM. To compensate, cow numbers were reduced by 10% and per cow production held at the base level.
8	No N fertiliser, no bought-in supplement	All nitrogen fertiliser and bought-in supplement were eliminated. To compensate, cow numbers were reduced by 15% and per cow production held at the base level.
9	10% of farm in pines	10% of the farm (16ha) was planted in pines. The intent was to use the forestry as a carbon offset in order to meet the 2030 targets. To compensate, cow numbers were reduced by 10% and per cow production held at the base level.
10	10% of farm in pines, reduce SR 10%	This was similar to Scenario (9), with cow numbers reduced further as a means to increase per animal production to help offset the drop in profitability. This resulted in a 19% reduction in cow numbers, with per cow production improved as much as possible within existing feed supplies
11	31% of farm in pines	31% of the farm (50ha) was planted in pines in order to make the farm carbon-neutral by offsetting with forestry. To compensate, cow numbers were reduced by 32% and per cow production held at the base level.
12	10% of farm in gold kiwifruit	The farm is suitable for growing kiwifruit, which is grown on surrounding blocks. This scenario saw 10% of the farm (16ha) planted in gold kiwifruit. To compensate, cow numbers were reduced by 10% and per cow production held at the base level.
13	24ha pines, reduce SR 16%, differential offset	15% of the farm (24ha) was planted in pines, with the resultant carbon sequestration differentially attributed to offsetting methane and nitrous oxide, in order to achieve the 2050 targets. To compensate, cow numbers were reduced by 16% and per cow production held at the base level.

Results

The results shown below demonstrate that it is possible to achieve a reduction in greenhouse gas emissions at the same time as increasing profits (EBITDA) – see highlighted rows.

		Total property net CO_2e (T/ha)	Total GHG % change from Base	EBITDA % change from Base	(kg N/ha/yr)	% Change in N from Base
1	Base model	8.4			37	
2	Reduce cow numbers 10% - no improvement in productivity	7.7	-8%	-35%	36	-3%
3	Reduce cow numbers 10% - improve productivity	7.9	-6%	33%	35	-5%
4	Reduce cow numbers 15% - improve productivity	7.5	-10%	38%	35	-5%
5	Reduce replacement rate	8.3	-1%	12%	37	0%
6	No nitrogen fertiliser	7.8	-7%	-5%	32	-14%
7	No bought-in supplementary feed	7.6	-10%	-21%	34	-8%
8	No N fertiliser, no bought-in supplement	7	-17%	-16%	30	-19%
9	10% of farm in pines	5.6	-33%	-7%	35	-5%
10	10% of farm in pines, reduce SR 19%	5.1	-39%	11%	34	-8%
11	31% of farm in pines	-0.3	-103%	-55%	28	-24%
12	10% of farm in gold kiwifruit	7.7	-9%	211%	36	-3%
13	24ha pines, reduce SR 16%, differential offset	4.1	-51%	-30%	34	-8%

Dairy farm
Case study 2

This case study wasn't included in the presentation but provides helpful additional detail for understanding how different scenarios play out on different farms.

Farm statistics

Total area (ha)	480
Effective milking platform area (ha)	234
Cows milked (peak)	592
Replacement heifers	198
Farm system	2/3
Milk solids/ha	706
Milk solids/cow	279
Cows/effective milking ha	2.6
N fertiliser applied (kg/ha)	113
Supplementary feed bought in (tonnes DM)	165

Scenarios

Ten scenarios were modelled for this farm, as shown below/over the page. These were developed via discussion with the farm owners/managers.

Scenario		Description
1	Base farm	Current existing farm system
2	Reduce cow numbers 10% - no improvement in productivity	Cow numbers were reduced by 10%, with no change in per cow production. Bought-in supplements were also proportionally reduced
3	Reduce cow numbers 10% - improve productivity	Cow numbers were reduced by 10%, with per cow production improved as much as possible within existing feed supplies
4	Reduce cow numbers 15% - improve productivity	Cow numbers were reduced by 15%, with per cow production improved as much as possible within existing feed supplies

Scenarios continued

Scenario		Description
5	No nitrogen fertiliser	All nitrogen fertiliser applied was eliminated. Base N usage was 113kgN/ha. To compensate for this cow numbers were reduced by 10% and per cow production held at the base level.
6	No bought-in supplementary feed	All bought-in supplement was eliminated. Total base bought-in supplement was 158 tonnes DM. To compensate, cow numbers were reduced by 5% and per cow production held at the base level.
7	No N fertiliser, no bought-in supplement	All nitrogen fertiliser and bought-in supplement were eliminated. To compensate, cow numbers were reduced by 15% and per cow production held at the base level.
8	10% of farm in pines	10% of the farm (23ha) was planted in pines. The intent was to use the forestry as a carbon offset in order to meet the 2030 targets. To compensate, cow numbers were reduced by 5% and per cow production held at the base level.
9	31% of farm in pines	31% of the farm (73ha) was planted in pines in order to make the farm carbon-neutral by offsetting with forestry. To compensate, cow numbers were reduced by 13% and per cow production held at the base level.
10	Reduce SR 15%, improve productivity, 40ha forest/offset differentially split	17% of the farm (40ha) was planted in pines, with the resultant carbon sequestration differentially attributed to offsetting methane and nitrous oxide, in order to achieve the 2050 targets. To compensate, cow numbers were reduced by 15% and per cow production improved as much as possible within existing feed supplies

Results

The results shown below demonstrate that it is possible to achieve a reduction in greenhouse gas emissions at the same time as increasing profits (EBITDA) – see highlighted rows.

	Scenario	Total property net CO_2e (T/ha)	Total GHG % change from Base	EBITDA % change from Base	(kg N/ha/yr)	% Change in N from Base
1	Base model	4.5			46	
2	Reduce cow numbers 10% - no improvement in productivity	4	-11%	-18%	42	-9%
3	Reduce cow numbers 10% - improve productivity	4.2	-6%	7%	41	-11%
4	Reduce cow numbers 15% - improve productivity	4.1	-9%	2%	41	-11%
5	No nitrogen fertiliser	3.8	-16%	-7%	34	-26%
6	No bought-in supplementary feed	4.2	-6%	-1%	43	-7%
7	No N fertiliser, No bought-in supplement	3.6	-20%	-10%	33	-28%
8	10% of effective area in pines	3.1	-31%	-8%	43	-7%
9	31% of effective area in pines	0	-100%	-34%	37	-20%
10	Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	2.1	-52%	4%	41	-11%

Sheep and beef farm
Case studies

Table 6 provides a summary of modelling work done on a number of 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.

The following pages then present the modelling results for two sheep and beef farm case studies.

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

		Change in GHG	Change in EBIT
All male progeny as bulls		-6%	12%
Convert to deer (finishing weaners)		0%	-19%
Shift to 50:50 sheep: beef		-10%	13%
Increase sheep : cattle ratio	Farm 1	-1%	0%
	Farm 2	1%	10%
	Farm 3	-1%	-20%
	Farm 4	0%	19%
Intensive lamb finishing		7%	22%
Increase lambing % (135 to 160)		0%	12%
Develop 100 ha techno beef unit		9%	33%
Replace breeding cows with finishing bulls & heifers		-8%	78%
Convert to dairy sheep		17%	68%

Sheep and beef farm
Case study 1

Farm statistics

Total area (ha)	1,435
Effective area (ha)	1,050
Pines (ha)	61
Native bush/riparian (ha)	324
Sheep stocking units	8,558
Cattle stocking units	3,858
Stocking unit/ha	11.8

Scenarios

Thirteen scenarios were modelled, as shown below/over the page. These were developed via discussion with the farm owners/managers.

Scenario		Description
1	Base	Current existing farm system
2	Forestry (plant 140ha)	An additional 140ha of pines planted. Sheep numbers reduced 11%, cattle reduced 10% to compensate. No improvement in animal productivity
3	Forestry (plant 300ha)	An additional 300ha of pines planted. Sheep and cattle numbers reduced 24% to compensate. No improvement in animal productivity
4	Forestry (plant 500ha)	An additional 500ha of pines planted. Sheep and cattle numbers reduced 41% to compensate. No improvement in animal productivity

Scenarios continued

	Scenario	Description
5	Decrease ewes 20% - increase lambing % and beef weights	Breeding ewe and replacement hoggets reduced by 20%. Lambing % increased from 127 to 160%, plus steers finished to 300kg carcass weight (CW).
6	Decrease stocking rate by 10% - no change in performance	Sheep and cattle numbers reduced by 10%. No change in per animal production.
7	Decrease stocking rate by 10% - change performance	As for scenario (6), but per animal production increased within existing feed supplies: Lambing % increased from 127 to 135%, lamb weights increased by 1.5kg CW, finishing cattle to 290kg CW
8	No breeding cows, finish bulls	Breeding cow herd eliminated and replaced with bull beef: 400 weaner bulls finished to 260kg CW at 18-20 months
9	Increase subdivisional fencing and improved water system	This was based on the study by Journeaux and van Reneen (2016) that showed an improvement in animal performance due to better subdivision and reticulated water on hill country. The scenario assumed an average improvement in performance relative to this study (lambing % improved to 135, and cattle weights increased by 20kg CW). A capital cost of $262,500 was capitalised into the EBITDA figure.
10	Forestry - plant natives to join Whenua Rahui areas	This assumed an area of 30ha was planted in native trees as a way of joining up existing Whenua Rahui areas.
11	Reduce replacement rates	This scenario assumed an improvement in animal health/animal husbandry such that death rates and dry animal rates decreased. This meant a lower replacement rate could be run; 20% down to 15% for sheep, 27% down to 20% for cattle
12	Decrease ewes 10%, no breeding cows - finish bulls, increased subdivision	This combined a number of the above scenarios; breeding ewe numbers were reduced 10% (lambing % increased to 140%), breeding cows were swapped for finishing bull beef (450 weaners finished to 300kg CW), and improved subdivision/water supply was installed
13	Decrease SR 10%, improved animal performance, +33ha pines, differential offset	This is the same scenario as (7), with the addition of an extra 33ha of pines (giving 82ha in total), with the carbon sequestered differentially distributed relative to methane and nitrous oxide emissions, so as to achieve the 2050 targets.

Results

The results shown below demonstrate that it is possible to achieve a reduction in greenhouse gas emissions at the same time as increasing profits (EBITDA) – see highlighted rows.

	Scenario	Gross CO_2e pastoral area (t/ha)	Total property net CO_2e (T/ha)	Total GHG % change from Base	EBITDA % change from Base
1	Base	3.3	2.5		
2	Forestry (plant 140ha)	2.9	-0.1	-105%	-15%/-14%*
3	Forestry (plant 300ha)	2.5	-3.1	-226%	-17%/6%*
4	Forestry (plant 500ha)	1.9	-6.9	-378%	-27%/24%*
5	Decrease ewe numbers 20% - increase lambing % and beef weights	3	2.2	-10%	22%
6	Decrease SR 10% - no change in performance	2.9	2.2	-13%	-17%
7	Decrease SR 10% - change performance	3	2.2	-12%	14%
8	No breeding cows, finish bulls	3.1	2.3	-6%	9%
9	Increase subdivisional fencing. Improve water system	3.3	2.5	2%	10%
10	Forestry - plant natives to join Whenua Rahui areas	3.2	2.3	-8%	-2%
11	Reduce replacement rates	3.2	2.5	-1%	3%
12	Decrease ewes 10%, no breeding cows - finish bulls, increase subdivision	3.1	2.4	-5%	62%
13	Decrease SR 10%, improve performance, +33ha pines, differential offset	3	1.7	-33%	16%

* if surplus carbon sold at $25/tonne CO_2-e

Sheep and beef farm
Case study 2

Farm statistics

Total area (ha)	894
Effective area (ha)	507
Pines (ha)	72
Native bush (ha)	315
Sheep stocking units	1,054
Cattle stocking units	4,637
Stocking unit/ha	11.2

Scenarios

Ten scenarios were modelled, as shown below/over the page. These were developed via discussion with the farm owners/managers.

	Scenario	Description
1	Base farm	Current existing farm system
2	Reduce stocking rate by 10% - no improvement in productivity	Breeding ewe and finishing cattle numbers reduced by 10%. No change in dairy grazer numbers. No change in per animal production.
3	Reduce stocking rate by 10% - improve productivity	As for scenario (2), but per animal production increased within existing feed supplies: Lambing % increased from 130 to 135%, finishing cattle weights increased by ~20kg CW
4	Eliminate N fertiliser #1 - reduce sheep	Nitrogen fertiliser applications (average of 39kgN/ha over 222 ha) was eliminated. Only sheep numbers were reduced (by 25%) to compensate for this, with no improvement in per animal production.

Scenarios continued

	Scenario	Description
5	Eliminate N fertiliser #2 - reduce sheep and cattle	As for scenario (4), but with both sheep and finishing cattle numbers reduced (by 10% each) to compensate. No change in dairy grazer numbers and no change in per animal production.
6	Forestry (plant additional 65ha)	The farm currently has 72 ha of pines, which could be eligible for the ETS. A further 65 ha was planted (giving 137ha in total), which would be sufficient for the farm to be carbon neutral via offsetting. Sheep & finishing cattle numbers were reduced by 26% to compensate, with no improvement in per animal performance.
7	Remove dairy grazers, finish bulls	All dairy grazers were removed, and replaced with a finishing bull beef regime: 600 100kg live weight (LW) weaners were purchased, and finished by 18-20 months of age at ~280 kg CW
8	Finish steers at 18-20 months	The cattle finishing regime concentrated on steers only; no heifers were purchased for finishing, instead 340 weaner steers were bought in and finished by 18-20 months at ~260kg CW. No change in dairy grazer numbers
9	Eliminate N fertiliser #3 - reduce sheep, no grazers, finish bulls	Nitrogen fertiliser applications were eliminated. Sheep numbers were reduced by 25%, dairy grazers were removed, and 500 weaner bulls finished to ~ 270/280 kg CW by 18-20 months
10	Reduce stocking rate by 10%, improve productivity, differentiate offset	This is the same scenario as (3), except the carbon credits generated by the existing 72ha was differentially used to offset methane and nitrous oxide in order to meet the 2050 ZCA targets

Results

The results shown below demonstrate that it is possible to achieve a reduction in greenhouse gas emissions at the same time as increasing profits (EBITDA) – see highlighted rows.

		Gross CO_2e pastoral area (t/ha)	Total property net CO_2e (T/ha)	Total GHG % change from Base	EBITDA % change from Base model
1	Base	3.5	1.8		
2	Reduce SR 10% - no improvement in productivity	3.4	1.7	-7%	-9%
3	Reduce SR 10% - improve productivity	3.4	1.7	-7%	-3%
4	Eliminate N fertiliser #1 - reduce sheep	3.4	1.6	-7%	-4%
5	Eliminate N fertiliser #2 - reduce sheep & cattle	3.4	1.6	-8%	-6%
6	Forestry (plant 65ha)	3.2	-0.1	-108%	-7%
7	Remove dairy grazers, finish bulls	3.3	1.6	-12%	29%
8	Finish steers at 18-20 months	3.7	2	10%	10%
9	Eliminate N fertiliser #3 - reduce sheep, no grazers, finish bulls	2.9	1.2	-33%	-4%
10	Reduce SR 10%, improve productivity, differentiate offset	3.4	1.7	-7%	-3%

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.agfirst.co.nz/wp-content/uploads/2020/09/Achieving-Zero-Carbon-Act-Reduction-Targets-on-Farm-AGF.pdf

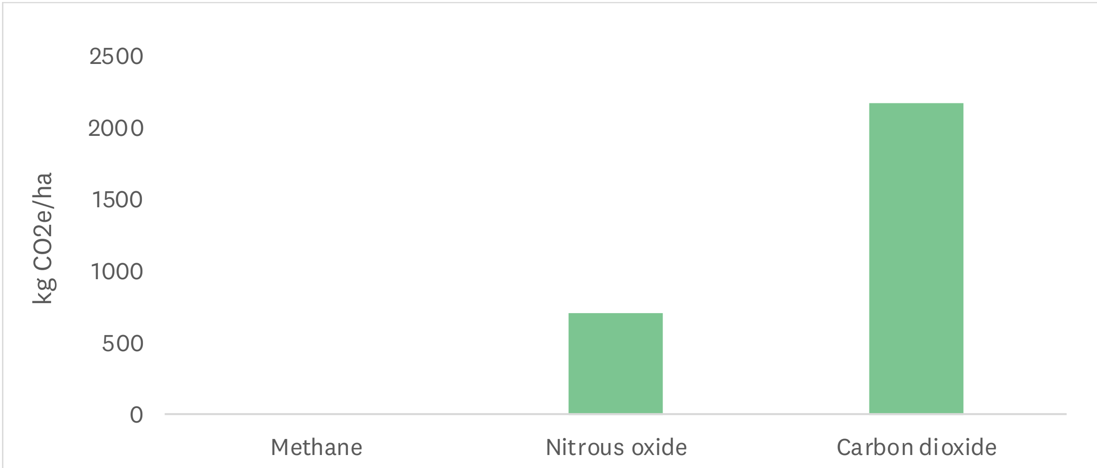
Arable farm modelling

For arable farms, the main greenhouse gas is nitrous oxide from 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.

	N	P	K	S
Fertiliser Input (kg/ha)	154	84	75	19

Nitrous oxide sourced mostly from N fertiliser

Carbon dioxide sources:	
Fuel	10%
Nitrogen fertiliser	17%
Fertiliser/lime	61%



Greenhouse Gas Output ($kgCO_2e/ha$)	
Methane	0
Nitrous oxide	701
Carbon dioxide	2162

Pricing agricultural greenhouse gas emissions

Where to set the 'point of obligation'

As outlined on pages 28-29, carrying out certain activities and industrial processes in New Zealand may create an obligation to report emissions and surrender New Zealand Units (NZUs) under the ETS – essentially facing a price for those emissions. (At the moment, a price only applies to carbon dioxide emissions).

Generally, the best place to set that point of obligation is where emissions can be monitored with reasonable accuracy, where compliance can be enforced at reasonable cost, and on entities who can influence emissions reductions.

The current ETS sets that point of obligation for carbon dioxide emissions as far upstream in the supply chain as possible. This means that most businesses in New Zealand are not required to be participants in the ETS. For example, for liquid fossil fuel (e.g. petrol), the point of obligation is set at the point that a fuel supplier takes fuel from the refinery or imports it. Private citizens, such as motorists, are not directly involved – although the cost of those emissions is passed on through the price of fuel at the pump.

As explained earlier in this booklet, agricultural greenhouse gas emissions are not currently priced as part of the ETS. As part of the He Waka Eke Noa process, these emissions will be priced from 2025 although decisions are still to be made as to where the point of obligation would sit (see pages 30-31).

If the point of obligation for livestock and/or fertiliser emissions sat at the processor level, processors would be likely to pass on the costs to farmers through reduced pay-outs/schedules for milk or meat or increased prices for fertiliser. Although this system is administratively simpler and cheaper, it provides little incentive for change. Farmers could only reduce their liability by reducing output (or inputs in the case of fertiliser), including changing land use. In contrast, a farm-level point of obligation means each farm's liability is directly related to its greenhouse gas emissions, and a wider range of mitigation options can be recognised.

Free allocation

As well as the point of obligation, the other decision that could be made is whether the ETS concept of 'industrial allocation' could be applied in any pricing mechanism for agricultural greenhouse gas emissions.

Industrial or 'free' allocation is the term used to describe an allocation of emissions without specific cost to businesses by the Government[10]. It is different to how the term 'allocation' may be used in water policy, where it can refer to a farm-specific limit for a water take or discharge.

In the ETS, industrial allocation is considered transitional assistance and was introduced to assist a small minority of eligible (non-agricultural) emission-intensive and trade-exposed industries whose international competitiveness might be affected. The intent was always to reduce the level of assistance over time through a well-signalled phase-out, for overall economic efficiency and equity reasons. As noted on page 28, the Government has already agreed to phase out industrial allocation in the ETS from 2021 at the following rate:

- 1% per year until 2030
- 2% per year from 2030-2040
- 3% per year from 2040-2050

Note that this phase-out will apply to the carbon dioxide emissions associated with nitrogen fertiliser as those emissions are already priced in the ETS.

The Government is yet to determine whether this type of allocation would be employed as part of pricing agricultural greenhouse gas emissions. More is expected to be known in late 2022 as the He Waka Eke Noa process advances and Ministers make their recommendations, including on what assistance (if any) is given to participants in the proposed pricing scheme (see page 31).

The impact of the point of obligation decision and the allocation decision on livestock and fertiliser emissions is shown in the following tables, with tables 7-11 relating to livestock emissions and tables 12-13 relating to nitrous oxide emissions from fertiliser.

Please note that the percentage liabilities shown are illustrative only and are based on the industrial allocation approach applied in the ETS.

[10] Note that there are different methods that can be used for farm-level and processor-level free allocation; the Government will decide on the method as part of the He Waka Eke Noa process. For more, see https://www.mfe.govt.nz/consultation/action-agricultural-emissions

Table 7: Point of obligation for farm-level GHG emissions at the processor level – impact on the beef schedule ($/kg)

	Price of carbon ($/t CO_2e)			
% Liability	$25	$30	$50	$100
5%	$0.02	$0.02	$0.04	$0.07
10%	$0.04	$0.04	$0.07	$0.14
50%	$0.18	$0.21	$0.36	$0.71
100%	$0.36	$0.43	$0.71	$1.42

Table 8: Point of obligation for farm-level GHG emissions at the processor level – impact on the sheep meat schedule ($/kg)

	Price of carbon ($/t CO_2e)			
% Liability	$25	$30	$50	$100
5%	$0.03	$0.04	$0.06	$0.12
10%	$0.06	$0.07	$0.12	$0.14
50%	$0.30	$0.35	$0.59	$1.18
100%	$0.59	$0.71	$1.18	$2.36

Table 9: Point of obligation for farm-level GHG emissions at the processor level – impact on the dairy pay-out ($/kgMS)

	Price of carbon ($/t CO_2e)			
% Liability	$25	$30	$50	$100
5%	$0.01	$0.01	$0.02	$0.04
10%	$0.02	$0.03	$0.04	$0.09
50%	$0.11	$0.13	$0.22	$0.44
100%	$0.22	$0.26	$0.44	$0.88

Table 10: Point of obligation for farm-level GHG emissions at the farm level – cost for average sheep and beef farm ($/ha)

	Price of carbon ($/t CO_2e)			
% Liability	$25	$30	$50	$100
5%	$5	$6	$9	$18
10%	$9	$11	$18	$37
50%	$46	$55	$92	$184
100%	$92	$110	$184	$367

Table 11: Point of obligation for farm-level GHG emissions at the farm level – cost for average dairy farm ($/ha)

	Price of carbon ($/t CO_2e)			
% Liability	$25	$30	$50	$100
5%	$12	$14	$24	$48
10%	$24	$29	$48	$96
50%	$120	$144	$240	$480
100%	$240	$288	$480	$960

Table 12: Price on fertiliser ($/tonne) – urea

	Carbon price ($/NZU)				
% Liability	$25	$50	$75	$100	$250
5%	$3	$6	$9	$12	$29
10%	$6	$12	$17	$23	$58
25%	$15	$29	$44	$58	$146
50%	$29	$58	$87	$117	$292
100%	$58	$117	$175	$233	$583

Table 13: Price on fertiliser ($/tonne) – lime

	Carbon price ($/NZU)				
% Liability	$25	$50	$75	$100	$250
5%	$0.55	$1.10	$1.65	$2.20	$5.50
10%	$1.10	$2.20	$3.30	$4.40	$11.00
25%	$2.75	$5.50	$8.25	$11.00	$27.50
50%	$5.50	$11.00	$16.50	$22.00	$55.00
100%	$11.00	$22.00	$33.00	$44.00	$110.00

Summary of on-farm emissions information

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.

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.

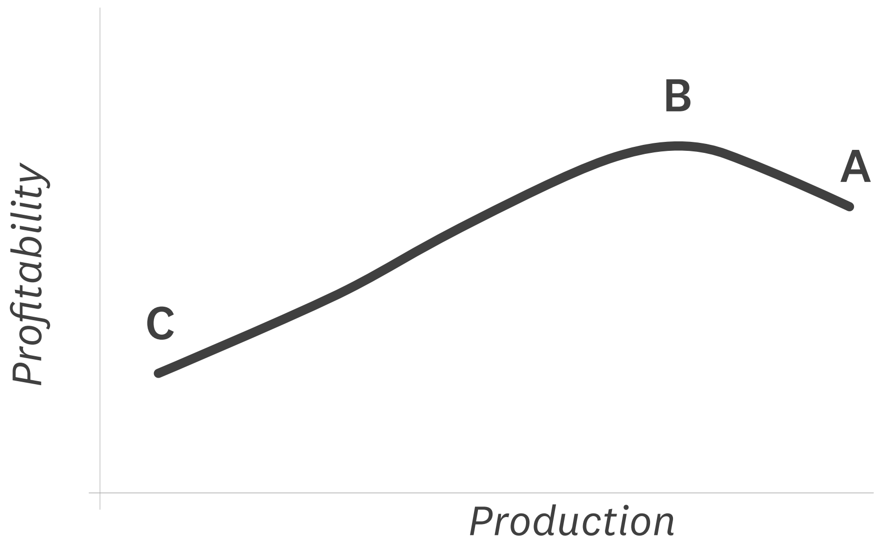
In theory, if stocking rate is reduced, then ‘surplus’ pasture results and there is the potential for a corresponding increase in per animal production.

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).



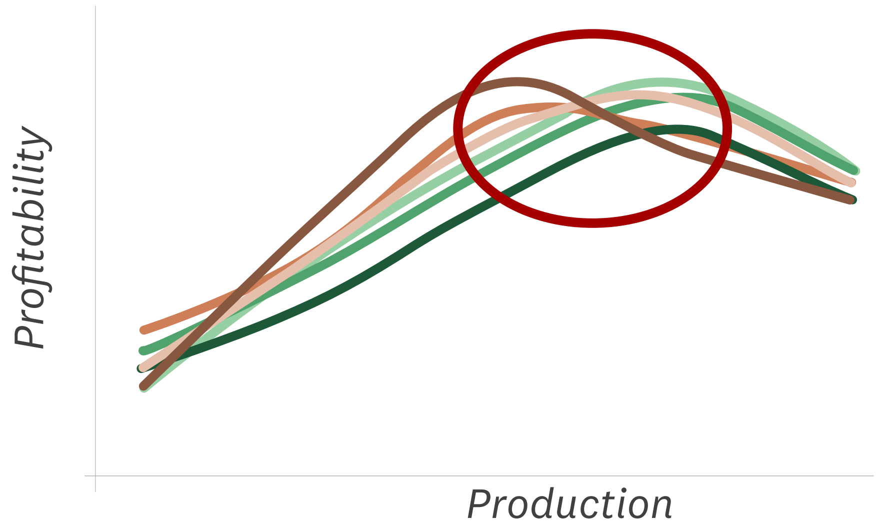


Figure 22: The challenges with reducing stocking rate

Notes

How can emissions be reduced?

For methane:

- Reduce stock numbers/increase efficiency
- Possibly plant trees for offsets, depending on what emerges from the He Waka Eke Noa workstream 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

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.

But, by 2025, 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.

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. Per the requirements in He Waka Eke Noa, all farmers and growers will have to know this by the end of 2022.

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.

Farmers should also get to grips with the basics of forestry as an offset, in particular that it is not a permanent solution and that getting expert 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 He Waka Eke Noa process
- Ensure that any greenhouse gas and water quality mitigations are coordinated

Notes

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, the He Waka Eke Noa partnership includes a workstream developing a simple, cost-effective programme for on-farm sequestration.

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[11] 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 oaks planted for erosion control

Poplars planted for erosion control

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

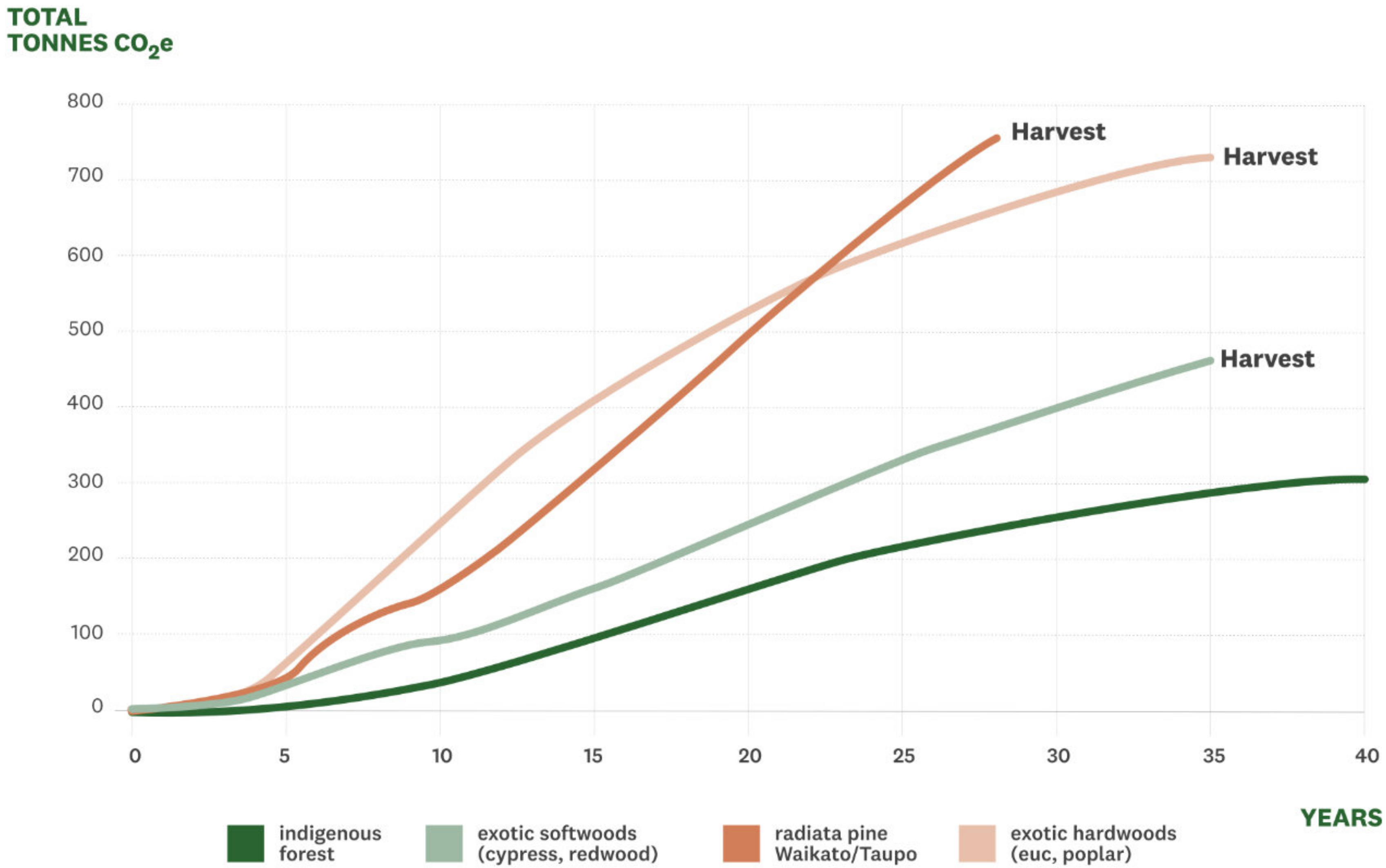


Figure 23: Rate of carbon accumulation over time by different species

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.

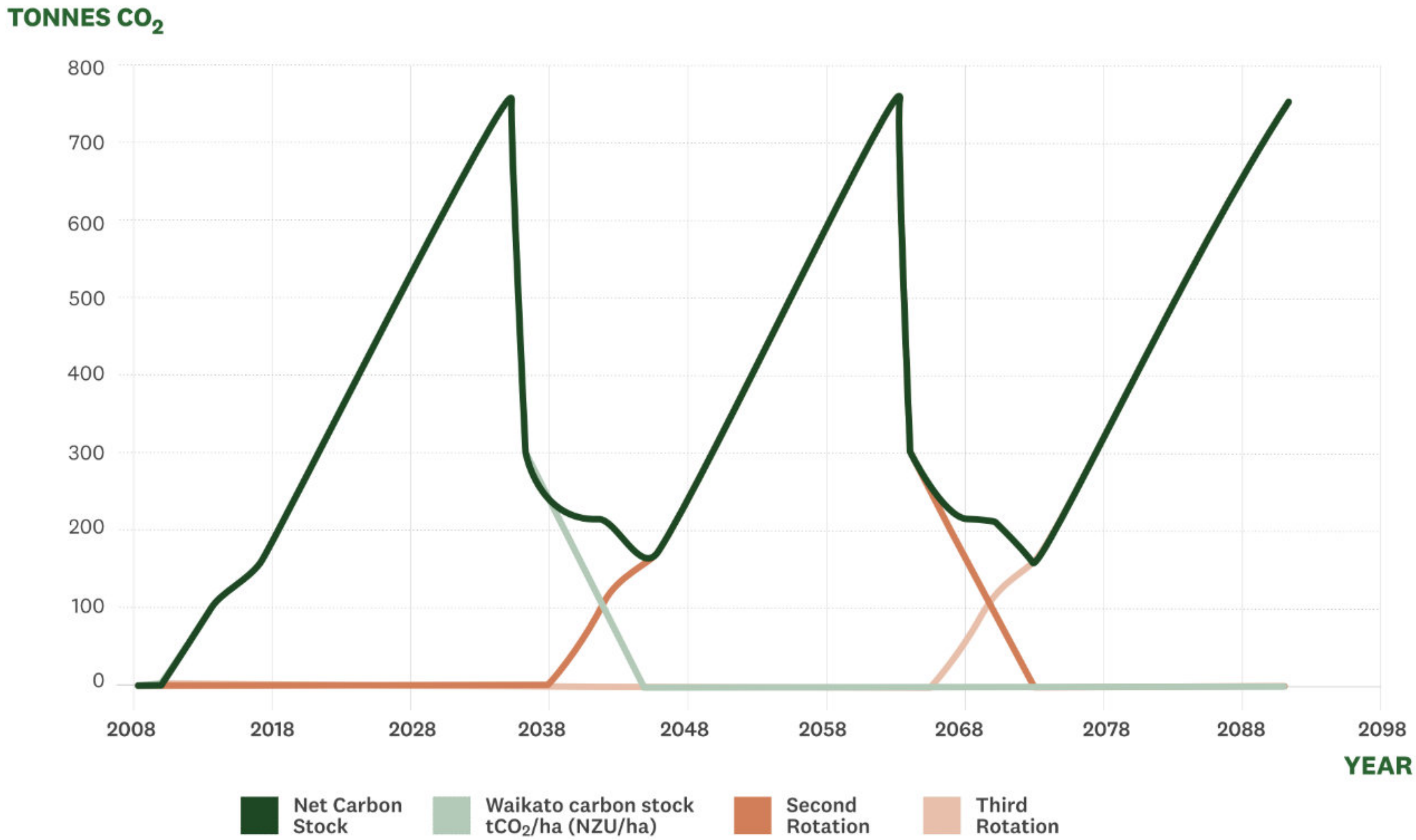


Figure 24: Total carbon associated with a 28-year harvest rotation of radiata pine

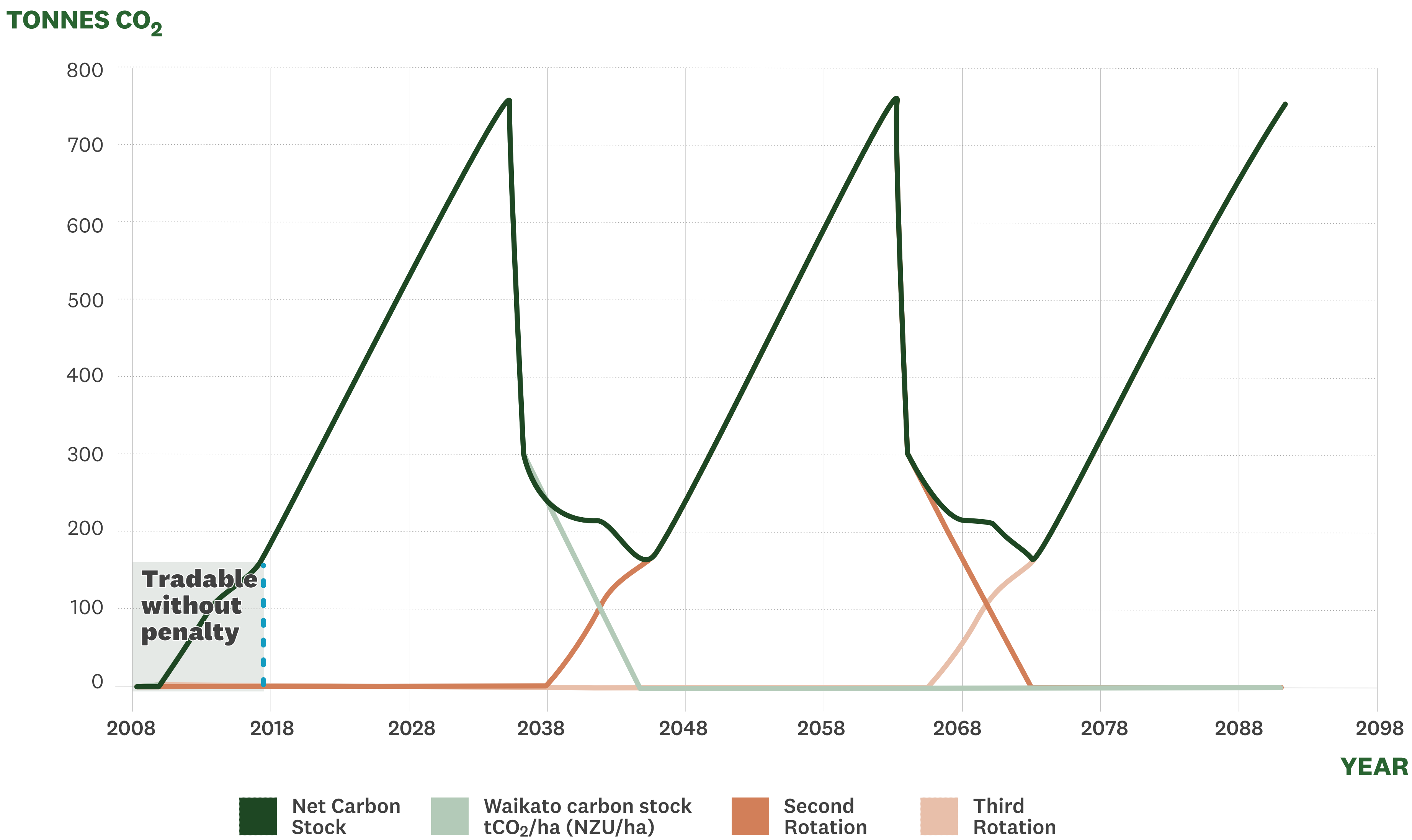


Figure 25: 'Safe carbon' associated with a 28-year harvest rotation of radiata pine

New way to earn carbon credits from 2023 - averaging accounting

The way ETS participants account for their carbon and earn NZUs from their forests will change in 2023.

Instead of accounting for the actual increases and decreases in carbon, participants will 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. For example, radiata pine forests will typically reach the average amount of carbon they will store over the long-term at around age 16-18.

Once the forest reaches its average carbon stock, it will stop earning NZUs. When it is harvested, the NZUs won't usually 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.

The finer details of averaging accounting are still being decided. This includes the calculation for the average age, how flexible averaging will be to different harvest times, and how second rotation forests will be treated. Decisions on these are expected in 2023.

Using averaging accounting:

- Until 31 December 2022, all newly registered forests will continue to use the existing "stock change" method for calculating carbon storage.
- Forests that are registered between 1 January 2019 and 31 December 2022 will 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.

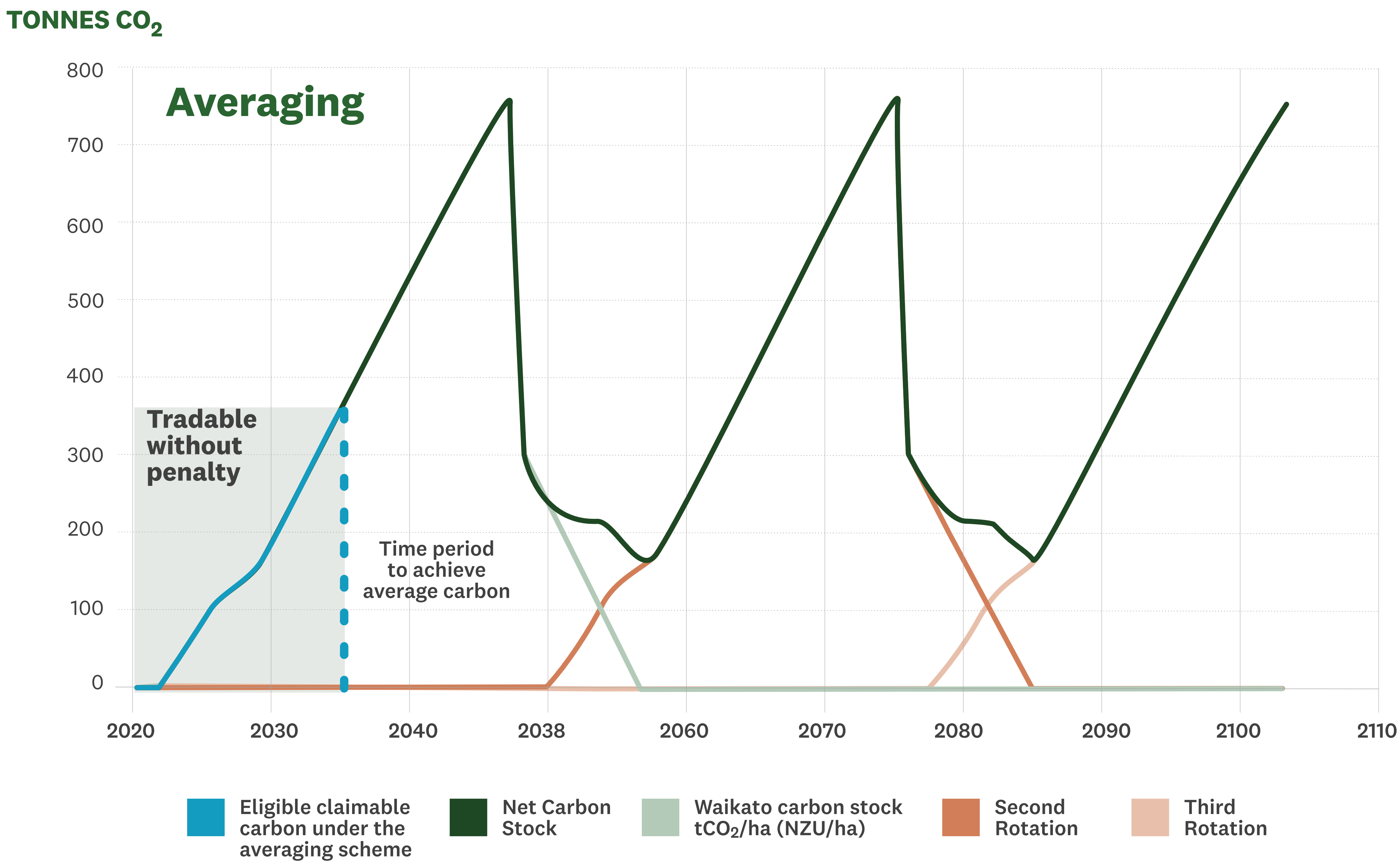


Figure 26: 'Average*' amount of carbon associated with a 28-year harvest rotation of radiata pine

*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 14.

Table 15 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 14: 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 15: Area of forestry required to offset, using the averaging scheme

% Offset:	5%	10%	25%	50%	100%
155 ha dairy farm	6.0	11.9	16.5	59.5	119.0
680 ha sheep & beef farm	9.8	19.6	23.0	97.9	195.8

Note that Table 15 is based on the national average Pinus radiata data. Regions and other species will vary. The average taken gives a 16-18 year offset.

Indigenous forestry

There are pros and cons when considering indigenous species for forestry offsetting. Indigenous species sequester around 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 14 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 16 shows a case study of a Hawkes Bay farm considering planting the property in pines for carbon farming – the strong returns are obvious. The case study in Table 17 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.

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.

Table 16: Case study – pines

	Sheep and beef farming	Forest for timber	Forest for timber & carbon @ $25/t	Forest for timber & carbon @ $50/t
EBIT/ annuity ($/ha)	$245	$292	$744	$1,196
IRR on investment	4.5%	7.9%	14.7%	24.3%

Table 17: Case study – indigenous forest (50 years)

	Carbon @ $25/tonne	Carbon @ $50/tonne
NPV	-$11,743	$-8,805
IRR	-1.4%	0.8%

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 18 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 18: 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}

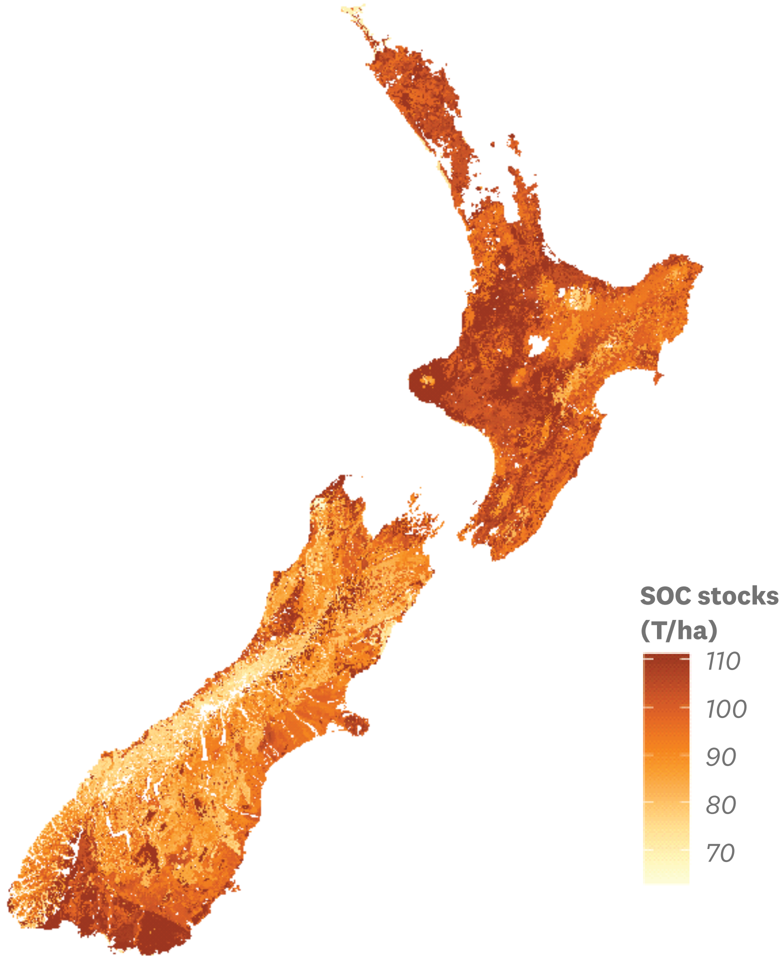


Figure 27: National soil carbon map

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.

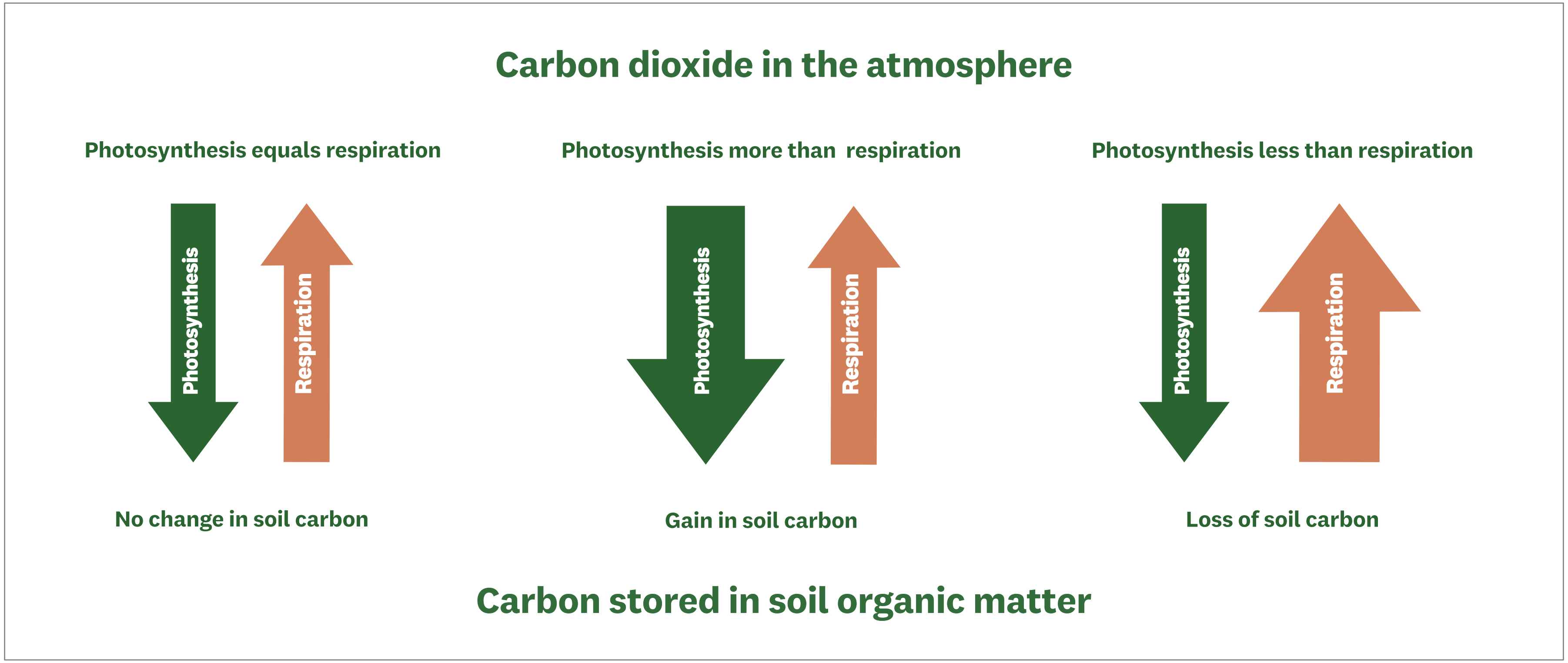


Figure 28: Changes in soil carbon

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.

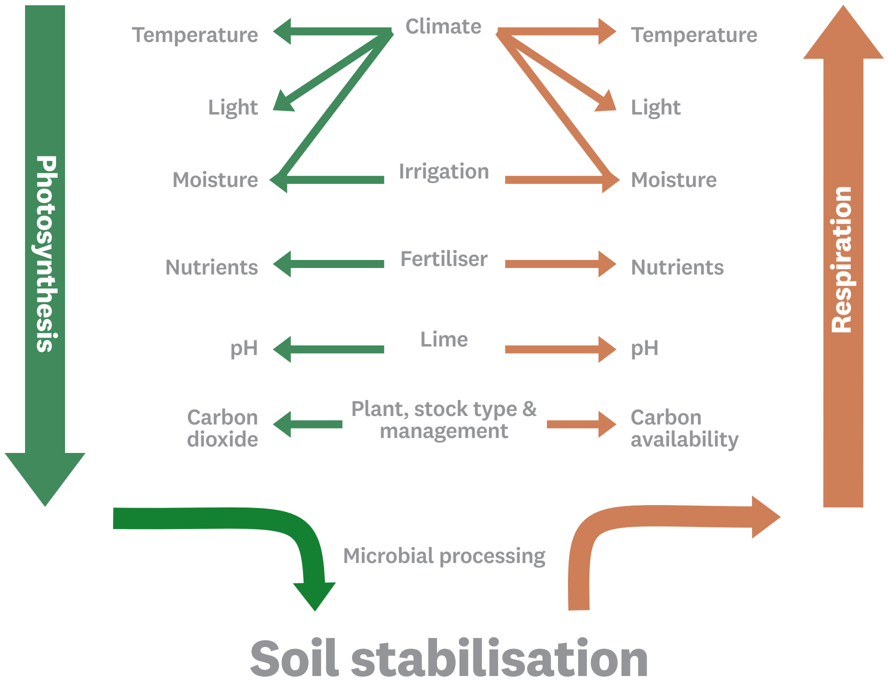


Figure 29: Effect of management practices on soil carbon

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.

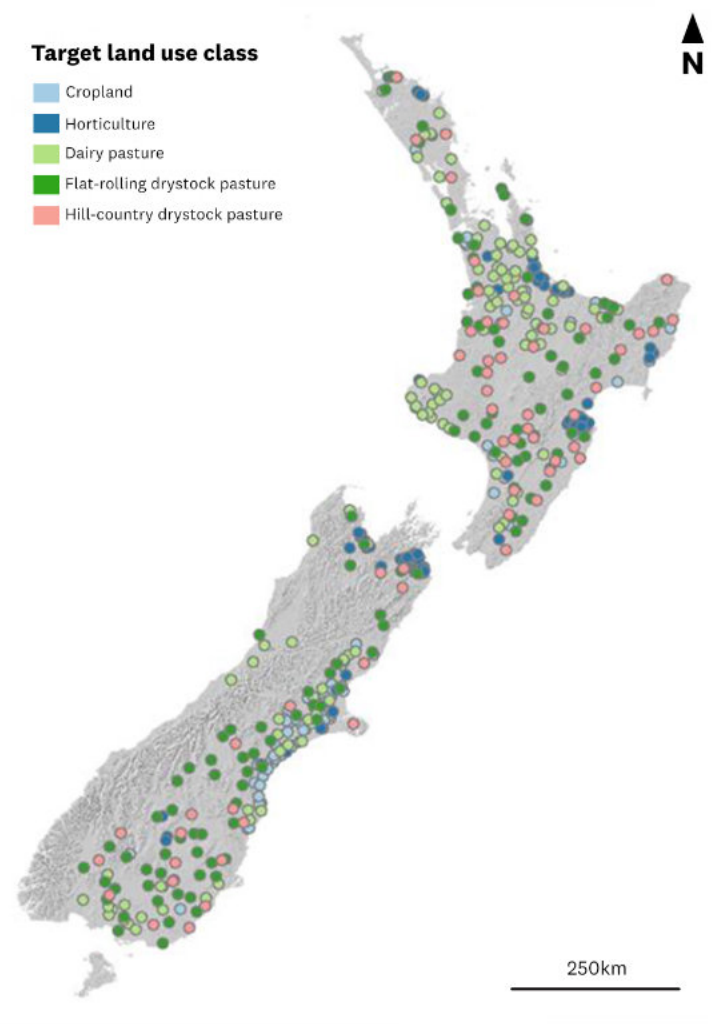


Figure 30: Sampling sites for the national soil carbon benchmarking and monitoring study

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 (see Figure 31). 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.

Current tools available or being developed include:

- The Lincoln University Farm Carbon Footprint Calculator is a simple tool requiring various inputs such as stock numbers, production and fertiliser/feed: www.lincoln.ac.nz/carboncalculator
- 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
- 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/publications/measuring-emissions-emission-factors-workbook-2020/
- 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

A process is underway in He Waka Eke Noa to assess the suitability of different tools for estimating a farm's greenhouse gas numbers. Ten of the tools in the list on this page have been assessed as part of that process. You can find out which ones on the Ag Matters website, as well as downloading a copy of the assessment reports. For more, see www.agmatters.nz/topics/know-your-number/

Simple and low cost, but highly averaged

Recognises productivity differences between farms

Complex and higher cost, but more farm specific

PRODUCT METHOD

Tonnes product (meat, milk solids, fertiliser) x emission factor

STOCK METHOD

Stock numbers x emission factor

SIMPLE SPECIFIC METHODS

Methods using a limited number of data points usually already recorded and collated by farmers. For example, combining stock numbers with production data and potentially other characteristics (e.g. age, weight)

COMPLEX SPECIFIC METHODS

Methods using multiple farm-specific data points.

Examples include the Agricultural Inventory Model (AIM) method and Overseer.

Farmers may require certified advisers to assist with calculations

Figure 31: Spectrum of greenhouse gas estimation tools

Notes

Sources of further information

Useful sources of climate change information in New Zealand

Ag Matters

A climate change website produced by the NZAGRC (with funding from MPI) 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

He Waka Eke Noa: Primary Sector Climate Action Partnership

The Government/industy/Māori partnership set up to develop a pricing mechanism for agricultural greenhouse gas emissions and associated support for farmers and growers.
See https://hewakaekenoa.nz/

Ministry for the Environment

Leads New Zealand's climate change programme. Their website contains in-depth international and national information, including the Paris Agreement, New Zealand's reduction targets, the Emissions Trading Scheme 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.iccc.mfe.govt.nz/what-we-do/agriculture/
- 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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NEW ZEALAND
AGRICULTURAL GREENHOUSE GAS
Research Centre

AGFIRST

nzipim
NZ Institute of
Primary Industry
Management