Report of the Biological Emissions Reference Group (BERG)

Membership of the Biological Emissions Reference Group (BERG)

Publication information

This is the final report of the Biological Emissions Reference Group, and synthesises its research.

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Disclaimer

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The Biological Emissions Reference Group

The Biological Emissions Reference Group (BERG) was established in June 2016. The aim was to bring together agricultural sector organisations and Government agencies to build a portfolio of evidence covering:

- Opportunities to reduce biological greenhouse gas emissions from New Zealand agriculture (methane and nitrous oxide), both today and in the future; and
- The costs and benefits of these mitigation opportunities, and any barriers to their use.

The BERG's objectives are to:

- Increase industry, government, and public understanding of the current and future sources and drivers of biological emissions, and the potential to mitigate these;
- Build an agreed and robust understanding of what can be done to reduce biological emissions, and the costs and opportunities of doing so; and
- Build trust and confidence between New Zealand's primary industries and Government agencies.

What is not in scope?

The BERG does not have a mandate to develop policy or to make recommendations about policy. However, as part of building a portfolio of evidence, the group has commissioned analysis to estimate the costs and barriers of hypothetical policy options.

We have not commissioned any analysis about what agriculture's contribution to a domestic emission target could be, based on the science relating to the warming impact of methane as a short-lived gas.

Purpose of this report

This document summarises the findings of the research and analysis commissioned.

Foreword

Climate change stands out as one of the most significant challenges of our time. Along with most other nations, New Zealand has signed up to take ambitious steps to address global climate change, and to adapt to the effects of a warming world.

How biological emissions from agriculture are treated within domestic policy has long been a topic of much debate. Many farmers have also been asking what more they can do to reduce their emissions, prepare for any changes markets may require of them, and reduce their exposure to any future emission price. Farmers don't just want to safeguard their businesses; they are also aware of the need to uphold New Zealand's reputation as an environmentally sustainable nation. Many have already taken steps to reduce their emissions.

As a new initiative, the primary sector and government came together in June 2016 and formed the Biological Emissions Reference Group, to further develop our understanding of the opportunities to reduce biological emissions from agriculture. We wanted to understand the costs and benefits of these opportunities, and any barriers to their use.

Collaboration and agreement have been the hallmarks of how we have operated as a group. We are unanimous that robust information is the basis for sound, effective and enduring climate policy. We recognise that our respective organisations may take different views on the range of decisions to be made in light of this information. We therefore do not provide policy advice.

Our research and analyses were commissioned from a range of leading experts, employing a wide range of disciplines. Our aim at all times was to focus on evidence. We acknowledge upfront that we have not asked all the questions.

We believe this information will complement other analyses in this area, including work by the Productivity Commission, the Parliamentary Commissioner for the Environment, and the Interim Climate Change Committee. We are pleased to note that others have already used this analysis.

We hope this report will help New Zealand's land users, researchers, innovators, decision-makers, policy makers, and advisors at all levels understand where we can potentially focus our collective efforts to reduce biological emissions from agriculture, as well as help the agriculture sector and government work together to successfully transition New Zealand towards a low-emissions future.

Acknowledgements

We are grateful for the contribution of all involved. Our first thanks go out to AgResearch, Manaaki Whenua – Landcare Research, the New Zealand Agricultural Greenhouse Gas Research Centre, Beca Group, AgFirst, and Motu – as well as to many peer reviewers and others who contributed to each project. Our thanks also extend to past and current BERG members, previous working group co-chairs Kara Lok and Chris Kerr, and to our current working group co-chairs Dr Philip Wiles and Victoria Lamb, for the leadership they have shown throughout.

Governance members of the Biological Emissions Reference Group

December 2018

Part 1: Executive Summary and key findings

Executive summary

Before 2016, conversations about what mitigations are available to farmers, and what the costs of these actions were, were missing context and robust, relevant data. In response, the members of the Biological Emissions Reference Group (BERG) made a collective commitment to invest in an evidence base that would enable better conversations and inform future decisions. We set out to provide a greater understanding of the issues through analysis, without bias.

Our Terms of Reference intentionally exclude developing policy advice or providing recommendations. However we did commission analysis to estimate the costs and barriers of hypothetical policy options to reduce emissions. The analysis did not consider how biogenic methane emissions from agriculture could be treated within a domestic emissions target.

It is important to note that much of the commissioned research relies upon the use of models. While these provide us with a view of possible options for emissions reduction, and have some general consistent themes, there are always limitations in using models due to the assumptions they make, and uncertainty in future forecasting. Acknowledging this, reading these results requires careful interpretation and caution, and the results should not be used to drive policy.

Pages 18 to 50 summarise the approach and key findings about each piece of analysis.

Key findings

The key findings from the independent analysis commissioned by the BERG, and existing research summarised by the BERG are:

What drives farmers' decision making in relation to climate change

1. A survey[2] found:
    - **64% believe New Zealand agriculture should reduce its greenhouse gas emissions** to help combat global climate change;
    - 98% did not know the greenhouse gas emission rates from their farm;
    - 97% of farmers, when asked to estimate greenhouse gas emission rates from an average farm, underestimated the amount; and
    - **42% of farmers were not aware of mitigation strategies** that could reduce greenhouse emissions from agriculture, other than planting trees.
2. Three overarching factors influence farmers' decisions in terms of adoption of emission mitigation interventions. **Decisions are influenced by practical aspects of implementation** and fit with broader objectives; **personal factors including trust in advice**, available time, education level, environmental attitudes, risk appetite, and overall well-being; and **peers' attitudes and actions**.

Potential for mitigating emissions now

3. Modelling suggests that if there was widespread adoption of currently available mitigation options (mainly farm management practices) an up to about 10% reduction in absolute biological emissions from pasture-based livestock is possible. **However, the ability of farmers to implement such practices varies widely, and while some farmers might achieve such reductions without significant negative impacts on profitability, for others the impact could be large.**[3] A greater than 10% reduction in absolute biological emissions will likely require a combination of on-farm mitigation and land-use change.
4. One piece of analysis considered the likely adoption of currently available mitigation options on-farm if emissions were priced. This analysis shows that **farmers are likely to adopt several currently available**

2 The survey was of 68 mainly sheep, beef and dairy farmers.

3 Actual economic outcomes for each farmer will depend on a range of factors, including how mitigation options are implemented, skill levels, differences between farm systems, and other economic indicators.

mitigation options such as improving productivity per animal, going to once-a-day milking, and planting trees on marginal land if emissions are priced, and the rate of adoption increases with higher prices. The modelling found that irrespective of the emission price, if dairy farmers are able to reduce stocking rate and increase productivity per animal, this is the most adopted option. In reality, there are various barriers stopping all farmers from adopting this option.

5. We wanted to understand whether changes to farm management practices and/or land use targeting water quality improvements would also have a beneficial impact on overall emissions. A summary of two existing studies indicated that **changes already in place by some councils to meet existing Resource Management Act requirements for freshwater management could reduce agricultural greenhouse gas emissions by up to 4%**. If land-use change to forestry is also considered, the reports suggest that up to 800,000 hectares of trees could be planted as a result of the Freshwater NPS – the carbon sequestration potential of these trees could be equivalent to approximately 14% of agricultural emissions.

Potential for mitigating emissions in the future

6. If successfully commercialised, methane-reducing technologies (which are in varying stages of development) have the potential to significantly reduce biological emissions from agriculture. The NZAGRC and a group of sector subject-matter experts provided qualitative assessments of the likelihood of having different technologies being available in both 2030 and 2050. Of two of the more talked about potential technologies, the authors had:
    - ***Low confidence*** that a methane vaccine will be available by 2030, and ***medium-high*** confidence that one will be available by 2050. The efficacy of a vaccine is unknown at this stage but the **authors assumed a potential to deliver a 30% reduction in biogenic methane** based on the proven efficacy of methane inhibitors
    - ***Medium-high confidence*** that a methane inhibitor for grazing systems that can deliver a **10 to 30% reduction in biogenic methane will be available by 2030,** and ***high confidence*** **that one will deliver between a 30-50% reduction by 2050.**

7. Modelling indicated that **when all mitigation options[4] assessed by the NZAGRC are combined into packages, and assuming various rates of adoption of each practice by farmers, overall biological emissions in the future could potentially be reduced between 10-21% by 2030, and by 22-48% in 2050**, relative to MPI baseline projections.

Estimating biological emissions from agriculture

8. **OVERSEER[5] is a suitable tool for estimating biological emissions on farms**. Its calculations are supported by current scientific understanding, are consistent with the National Greenhouse Gas Inventory, and can be used for different farming systems[6] and management practices. This work did not assess the suitability of OVERSEER as a regulatory tool for biological emissions.

9. Many currently available mitigation options can be captured in New Zealand's National Inventory so they can contribute to New Zealand meeting its international climate targets. **Many mitigation options could be accounted for without requiring any changes**, although some options may require changes to the National Inventory's data, assumptions, or methodologies. If new technologies such as methane vaccines are developed, these could also be included in the Inventory.

10. The majority of vegetation found on-farm (for example small woodlots and shelterbelts) which currently do not meet the requirement for crediting via the New Zealand Emissions Trading Scheme have the potential to sequester carbon. Three case-study farms indicate that sequestration by current and planned vegetation has the potential to account for about **0–2.5% of current gross livestock emissions on intensive lowland sheep and dairy farms, and about 5–20% on a hill country sheep and beef farm**. There would be challenges in realising this potential.

4 An exhaustive list of these options can be found at page 27

5 OVERSEER is a software tool, developed in New Zealand, that has been in use for many years and helps land users estimate nutrient inputs and outputs, as long-term annual averages. As part of the nutrient cycle, it estimates greenhouse emissions.

6 The report assessed dairy, sheep, beef and deer farms; it did not assess horticulture operations.

11. Increasing soil-carbon stocks is often cited as a way to offset biological emissions. High soil carbon content also offers soil health and water management benefits. New Zealand's climate means our soils are relatively high in carbon, compared to countries such as Australia. It is therefore **relatively difficult to increase our carbon stock further to offset biological emissions**. Soil carbon is challenging to measure and monitor at scale, and while stocks can take a long time to build up, they can **be lost very quickly through circumstances outside of farmers' control** (such as droughts).

Possible implications of scenarios for land-use change

12. Modelling considered what land-use changes would be required to meet a range of pre-determined targets for biological emissions, and what the flow-on impacts might be. In some scenarios it was also assumed breakthrough methane technologies were available, and increases in horticulture occurred. Noting the limitations and assumptions of the modelling, it found that it was possible to meet all targets **although a 2030 target was harder to meet, due to the lack of time to change land use**.

13. Increases in forestry and horticulture were common across all scenarios modelled. A larger incentive is needed to drive enough forestry conversions to meet a 2030 target than the 2050 target. A very large **increase in horticulture or a breakthrough in methane mitigation technologies made meeting these targets easier**, although there are a range of barriers to both of these things happening.

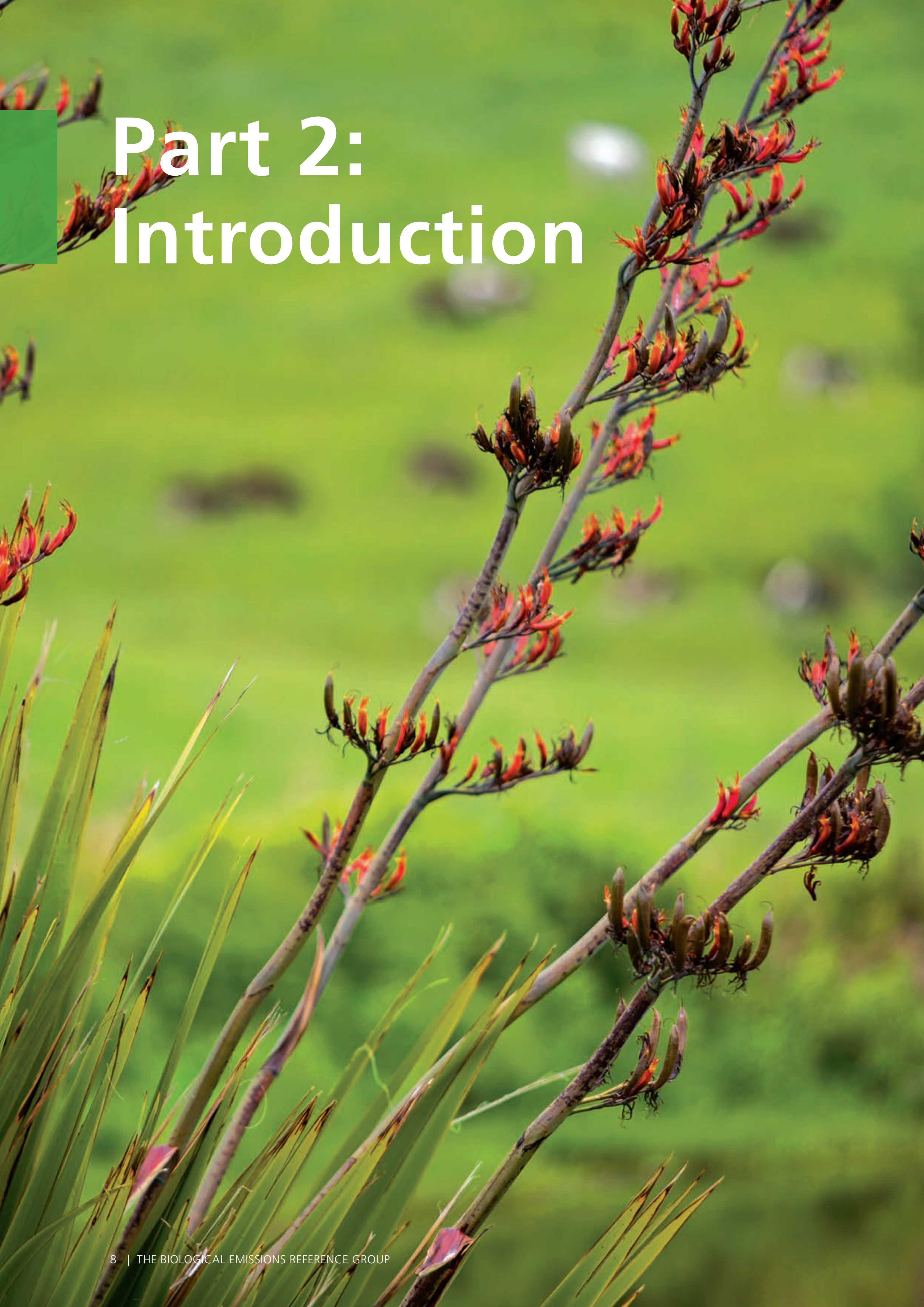
The costs and barriers of potential policy options

14. Although providing advice or recommendations is out of scope, we wanted to understand the possible administrative costs and barriers associated with a range of hypothetical policy options. The analysis identified **various barriers to adoption across most options, although all could likely be overcome through Government or sector assistance**.

15. Of the options assessed, pricing agricultural emissions at an on-farm point of obligation has the highest annual administration costs, with the agricultural sectors bearing the majority of these costs. It was also found that these **costs could be reduced significantly if ways can be found to**:

    - **Allow farmers to estimate on-farm biological emissions without engaging a certified nutrient management advisor; and**
    - **If a method can be found to reduce the brokerage fees farmers face in procuring emissions trading units.**

Part 2: Introduction



Biological Emissions Reference Group Report 2018 – An Introduction

This document summarises the findings of research projects commissioned by the Biological Emissions Reference Group (BERG) between 2016 and 2018.

BERG membership and Terms of Reference

The working group members are subject-matter experts from the respective organisations. A governance group comprising senior leadership from all of the member organisations has overseen the process. Ministry for Primary Industries (MPI) has provided secretariat functions, and has led the procurement processes for research and the compilation of this synthesis report.

It is important to note that while two government Ministries are core members, the BERG is not a group appointed by Ministers.

For Terms of Reference see www.mpi.govt.nz/biological-emissions-reference-group.

Structure of this synthesis report

As already noted, this report intends to make available at a high level the findings from the research projects commissioned, in summarised form, without bias. The structure of this document reflects this.

Part 3: The New Zealand context – relevant background information.

Part 4: Summaries of research and analyses – provides a more fulsome summary of each piece of research including the methodologies, who was involved, assumptions, and key findings that were delivered.

The BERG's high-level collective 'out-takes' from the information are provided separately as **Concluding remarks.** These are not intended to be directive, but offer observations and insights from the Group's perspectives, as a set of possible responses to the body of evidence that has been collected, and what the next steps might be.

What analysis was commissioned?

An initial set of questions was identified as a basis for research that would be appropriate to both inform government decisions regarding agriculture and climate change, and provide better information for farmers and sector groups.

The working group agreed to the analysis commissioned, the scope and assumptions for each piece of analysis, and approved the suppliers who undertook the work. Each piece of completed analysis was also independently peer-reviewed.

Funding was provided by BERG members, based on each organisation's capacity and the relevance of the work to their sector and stakeholders.

This synthesis report also includes summaries of some existing research that the BERG did not commission, but was included here given relevance of the work.

Table 1: The analysis and lead supplier

Topics and analysis	Supplier
Climate change, and farmer decision making	
What drives farmer decision-making in relation to decreasing biological emissions, and climate change?	AgFirst
Potential for mitigating emissions	
What mitigation actions could be implemented on-farm now?	New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC)
What mitigation actions could be implemented in the future?	NZAGRC
What are the climate co-benefits from freshwater policy?	Collated by BERG
Estimating biological emissions from agriculture	
Can you estimate on-farm emissions, and will methods for on-farm estimates be consistent with the National Greenhouse Gas (GHG) inventory?	AgResearch
Can currently available mitigation actions help New Zealand meet international targets?	MPI
What are the carbon sequestration offset opportunities from on-farm vegetation which does not meet the current New Zealand Emissions Trading Scheme criteria?	Manaaki Whenua – Landcare Research
What are the offset opportunities from soil carbon?	Collated by BERG
Possible implications of changing land use	
Can land-use change be a mitigation option for climate change?	Motu Economic and Public Policy Research
Assessing the nationwide economic impacts of farm-level biological greenhouse gas emission mitigation options	Manaaki Whenua – Landcare Research
The costs and barriers of potential policy options	
What are the administrative costs and barriers of potential policy options to reduce biological emissions from agriculture?	Beca

The use of models in our research and analyses

Some of the research and analyses commissioned by the BERG used models to forecast hypothetical outcomes of future scenarios around addressing biological emissions. Models are useful in helping consider intended and unintended impacts of different paths that could be chosen, but should not be considered decision-making tools on their own.

No single model can give us an exact snapshot of all challenges and all benefits. None provides us with a crystal ball into an unknown future – especially when considering the rates of technological change and innovation.

In other words, the modelled findings summarised here signpost what could happen if a certain combination of choices were made *within certain timeframes and under certain conditions* – and as such the results need to be interpreted with care. What will actually happen will depend on our individual and collective actions, and events that, here in 2018, can neither be foreseen nor lie within our control.

The modelling tested:

- The potential of currently available mitigation options;
- How adoption of these options might change under different emission prices, and the resulting impacts on both on-farm profitability and the wider economy;
- What mitigation options might be available in the future, and what the potential of these options be might be; and
- How land use might change to meet specific sector mitigation targets, and how the change required to meet them differs when we assume different scenarios.

Key assumptions and limitations

Each piece of analysis provides a range of different insights. The summaries of each piece of analysis includes the most important assumptions (see pages 18-50). These assumptions do not reflect the BERG's preferences or views on the most likely or desirable outcome.

Motu's analysis modelled land-use change to meet a range of land sector specific emissions targets (high and low, and including New Zealand's current 2030 and 2050 emissions targets[1]). The modelling used various scenarios including assumptions that there will be large increases in horticulture, and availability of a breakthrough mitigation technology. The targets were not chosen because they are optimal, or expected outcomes, but to consider what actions would be needed to meet them.

Manaaki Whenua – Landcare Research's analysis considered how land users might adopt currently available mitigations under various emission prices in both 2030 and 2050, and what the impacts on on-farm profitability and the wider economy might be. Unlike Motu's analysis, the carbon prices were predetermined and not worked out by the model.

The results of this modelling are highly contingent on what on-farm mitigation options are assumed to be available, at what scale and over what time, and their effect on emissions and profitability. These were provided as an input to the model, drawing on NZAGRC work for sheep and beef farms, and independent analysis by DairyNZ for dairy farms.

1 New Zealand's current 2030 target is to reduce emissions to 30 per cent below 2005 levels. New Zealand's current 2050 target is to reduce emissions to 50 per cent below 1990 levels.

This modelling provides insights into the type of currently available mitigation activities that farmers might be expected to adopt at different emission prices. However, it does not consider the potential impact of future technologies .

To understand the possible impacts on farm profitability from on-farm mitigation, this case assumed no ability to change land use. In essence this means that we have assumed that farms continue to operate even under the most extreme scenario, when high emission prices make their farms unprofitable (in reality, some livestock farmers would almost certainly have ceased operating or changed land use in this scenario).

NZAGRC's analysis of currently available mitigation options looked at the effect on individual farms' productivity and profit, but did not perform a detailed economic analysis. Some of these assumptions have informed other work, namely Manaaki Whenua – Landcare Research's research (above).

Different assumptions were used in the NZAGRC and Manaaki Whenua – Landcare Research analysis to model the effects of the same mitigations. For example, different assumptions were used around increasing productivity per animal, when stocking rate decreases. Although different assumptions have been used, these provide useful insights into a range of possible outcomes.

Conclusion

Modelling can be useful when considering the potential costs, opportunities, risks and benefits of different approaches to reducing biological emissions– for farmers, businesses, policymakers, and communities.

While the summaries set out in this report provide an indication of what could happen, the results need to be interpreted with care. There are many variables and uncertainties that can neither be modelled nor predicted. The results should therefore not be viewed as forecasts, predictions, or recommendations.

Applications of this research and analysis

The timing of this research has been important, being concurrent with the development of policy, particularly options for a new 2050 emissions target.

The BERG has previously shared (at draft stage) some of the analysis summarised in this report with the following groups, who in some cases have publicly cited findings:

- The Productivity Commission's inquiry into a low-emission economy;
- The Prime Minister's Chief Science Advisor's report on agriculture and climate change;
- The Parliamentary Commissioner for the Environment's staff; and
- The secretariat of the Interim Climate Change Committee.

Access to reports

Each of the full reports have been published and are available online at www.mpi.govt.nz/biological-emissions-reference-group.

Part 3: The New Zealand context

New Zealand's response to climate change

As part of this country's obligations under the Paris Agreement, the New Zealand Government has already set a target to reduce greenhouse gas emissions by 30% below 2005 levels by 2030 ('the 2030 target'). This target includes all greenhouse gases (carbon dioxide, methane and nitrous oxide), and extends to all sectors of the economy, including, for the first time, the agriculture sector.

The stakes are high. Beyond 2030 it is clear that New Zealand, alongside the rest of the world, must continue transitioning to a low-emission economy to avoid the risks associated with an increasing average global temperature.

A huge amount of work is underway to lay the ground for this major transition. During 2018, the Government consulted on proposals for a Zero Carbon Bill, which, if passed, will put a 2050 target in place to further reduce emissions. Among other things, the Bill proposes an independent Climate Change Commission. An Interim Climate Change Committee is meanwhile amassing evidence and analysis on key issues for domestic climate change policy, in particular agriculture and renewable electricity.

Activity doesn't end there. The New Zealand Productivity Commission recently released a report on options to transition to a low-emission economy, while at the same time continuing to grow income and well-being.[7] The Parliamentary Commissioner for the Environment is following up the office's earlier examination of the science of agricultural greenhouse gases, including the merits of potential policy options.

Agriculture and New Zealand's climate-change story

Agriculture remains the backbone of the New Zealand economy, a significant contributor to national and rural economies and communities. In June 2018, total export revenue from agriculture[8] and horticulture[9] reached $31 billion (approximately 74% of total primary sector export revenue).[10]

Agriculture also contributes to domestic greenhouse gas emissions. Methane and nitrous oxide – by products of land use and known as 'biological emissions' – make up nearly half of our emissions (figure 1). Most come from ruminant animals (mostly sheep and cattle - figures 2 and 3) and, to a lesser extent, from on-farm use of fertilisers and lime (figure 4).

Agriculture therefore stands to play an important role in transitioning to a low-emissions economy. New Zealand can't ignore domestic biological emissions if we are going to meet our commitments to the Paris Agreement.

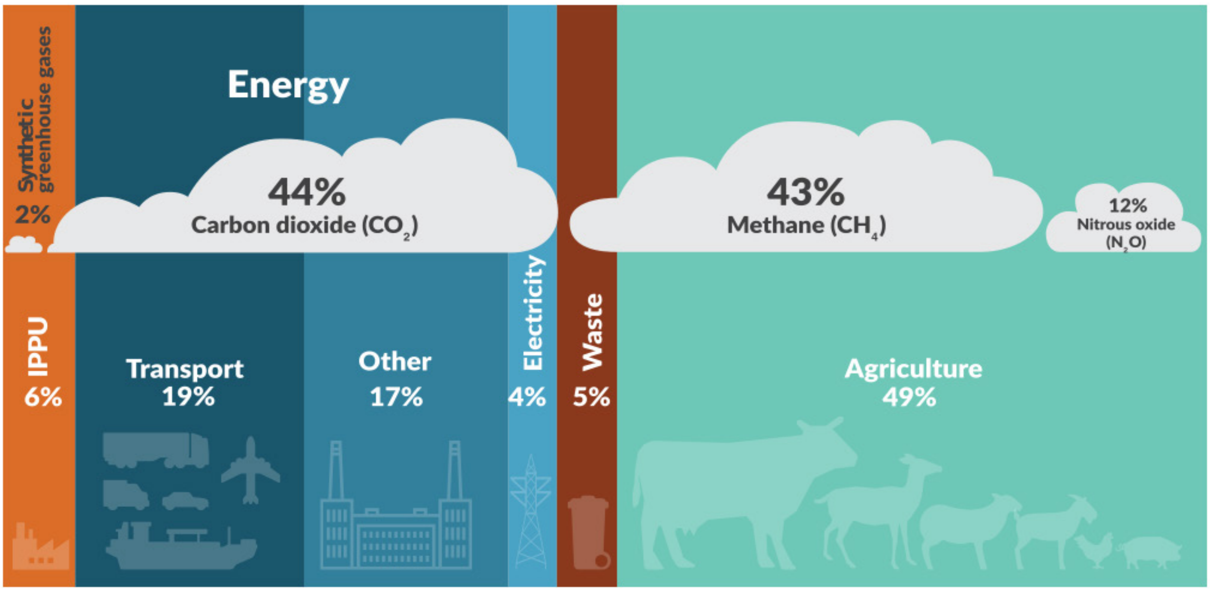
Some progress on reducing biological emissions has been made. Between 1990 and 2017, sheep and beef farmers became more efficient at delivering their products while producing 30% fewer emissions. They worked to improve on-farm practices such as feed and nutrition, animal genetics, reproduction rates and pasture management, and increased their use of technology and information.[11]

7 https://www.productivity.govt.nz/inquiry-content/3254?stage=4
8 Dairy, meat (excludes seafood), and wool exports
9 Wine, fruit, and vegetable exports (excludes arable)
10 Ministry for Primary Industries (September 2018), Situation and Outlook for Primary Industries
11 Climate Change and Agriculture: Understanding the biological greenhouse gases (2016), Parliamentary Commission for the Environment. https://www.pce.parliament.nz/publications/climate-change-and-agriculture-understanding-the-biological-greenhouse-gases

Solid progress was recorded. Without these improvements, agricultural emissions would have risen by almost 40%. Instead, they grew by just 16% and, since 2005, have remained relatively constant, although their source has changed. Most notably, emissions from sheep have declined, while dairy emissions have risen (figure 5).

If current positive trends continue through to 2030, total biological emissions are projected to decrease slightly, to 14% above 1990 levels.

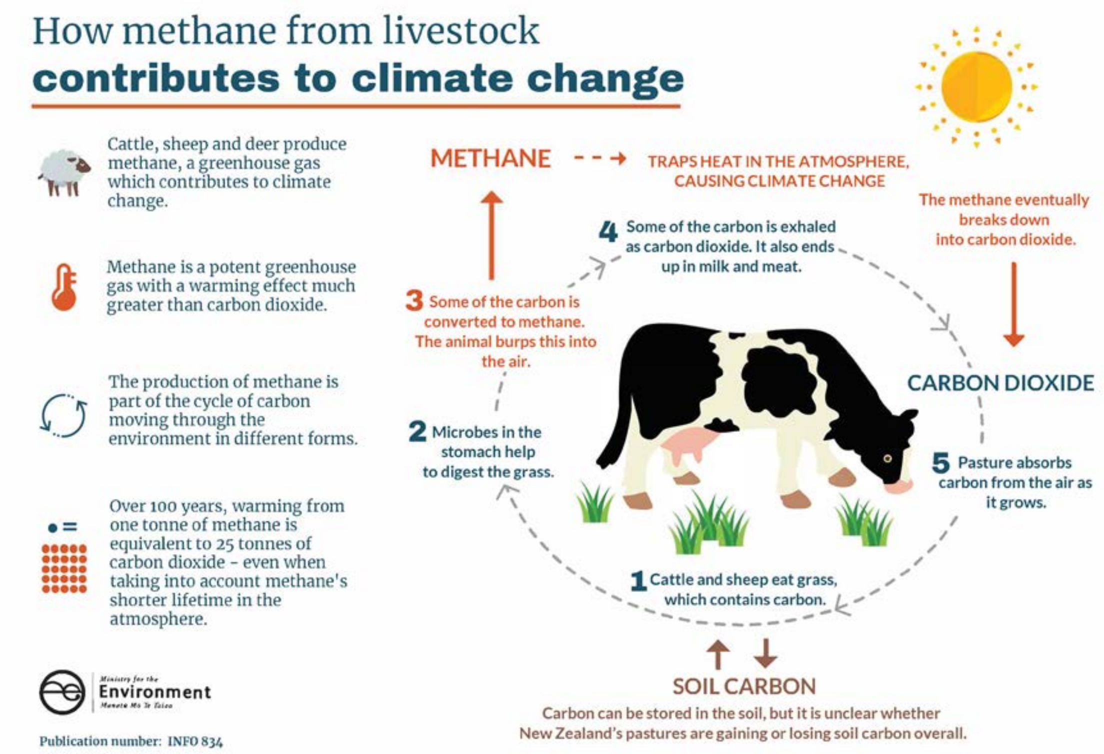
Figure 1: New Zealand's sources of greenhouse gas emissions[12]



Source: Ministry for the Environment

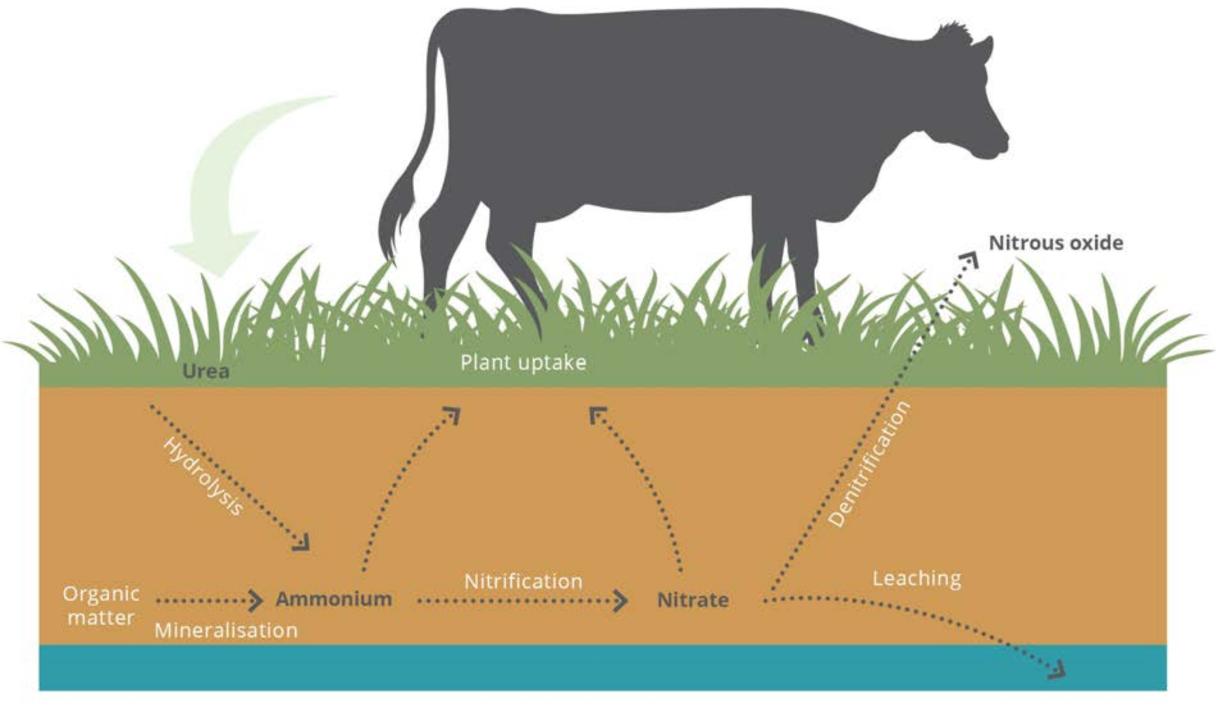
12 The percentages for different emissions shown in figure 1 total 101% due to rounding.

Figure 2: How methane from livestock contributes to climate change



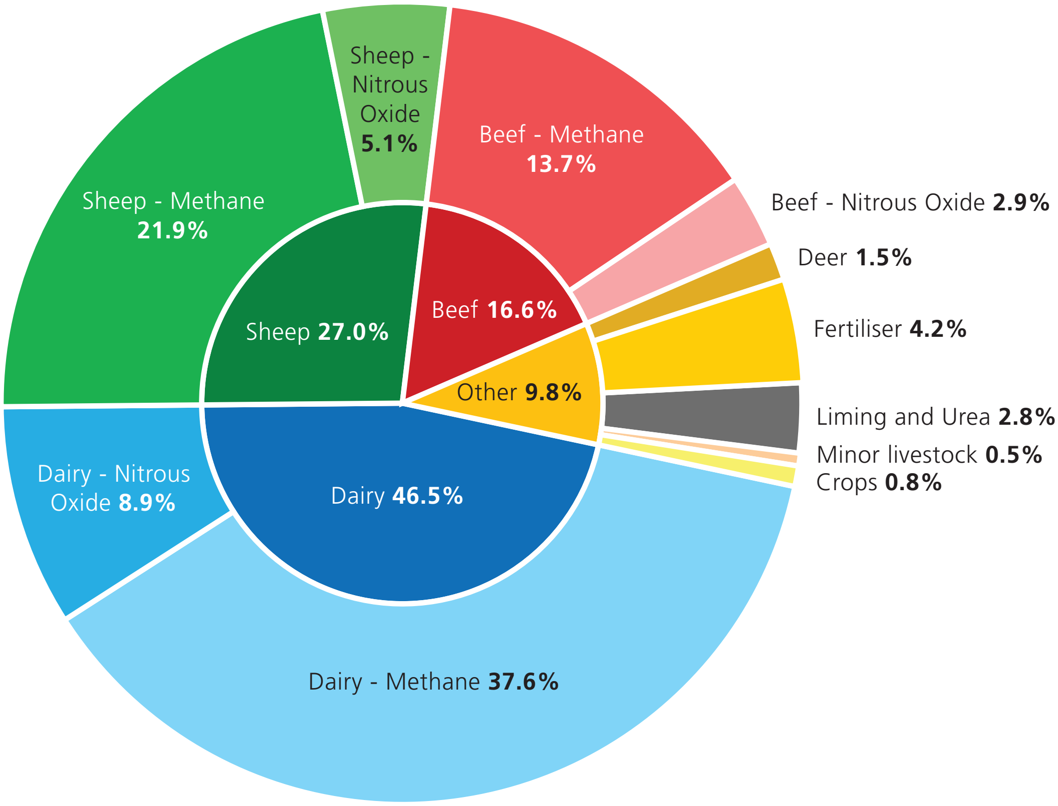
Source: Ministry for the Environment

Figure 3: How nitrous oxide is produced



Source: DairyNZ

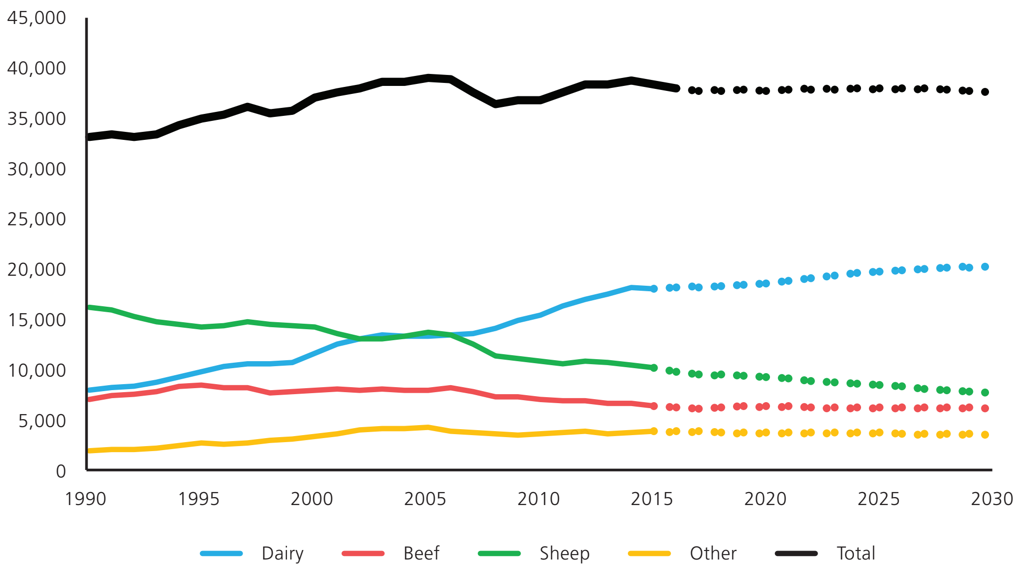
Figure 4: Profile of domestic biological emissions, showing relative contributions of industry and gas (2016)



Source: Ministry for the Environment

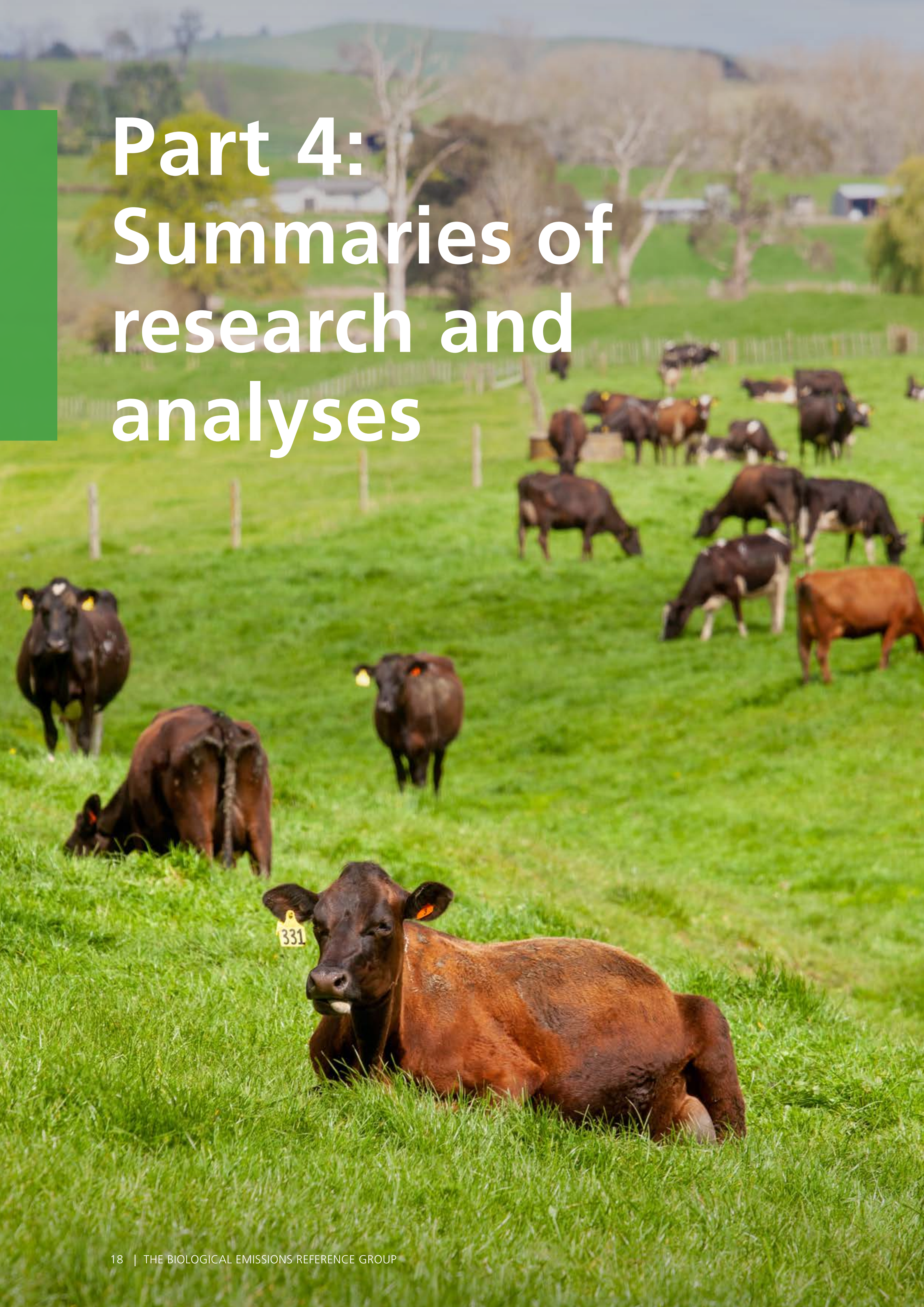
Note: National Inventory figures are published two years behind the current calendar year (for example, the 2018 Inventory has figures up to 2016).

Figure 5: New Zealand's actual and projected emissions 1990-2015, Ministry for Primary Industries



Note: National Inventory figures are published two years behind the current calendar year (for example, the 2018 Inventory has figures up to 2016).

Part 4: Summaries of research and analyses



4.1 Climate change, and farmer decision making

What drives farmers' decisions about decreasing biological emissions, and climate change?

Purpose

Reducing biological emissions is a challenge facing all New Zealanders. Existing research[13] shows that even when the costs of adopting new practices are zero or negative, barriers to changing behaviours remain.

Approach

AgFirst investigated and discussed the social and behavioural barriers to farmers adopting practices to mitigate biological emissions.

The analysis was undertaken in three parts:

(i) A literature review on farmer behaviour and decision-making, particularly regarding climate change and greenhouse gas mitigations;

(ii) Interviews with sector experts regarding farmer behaviour and decision-making, particularly about climate change and greenhouse gas mitigations; and

(iii) A survey of farmers to gauge general awareness of the issue.

Key findings

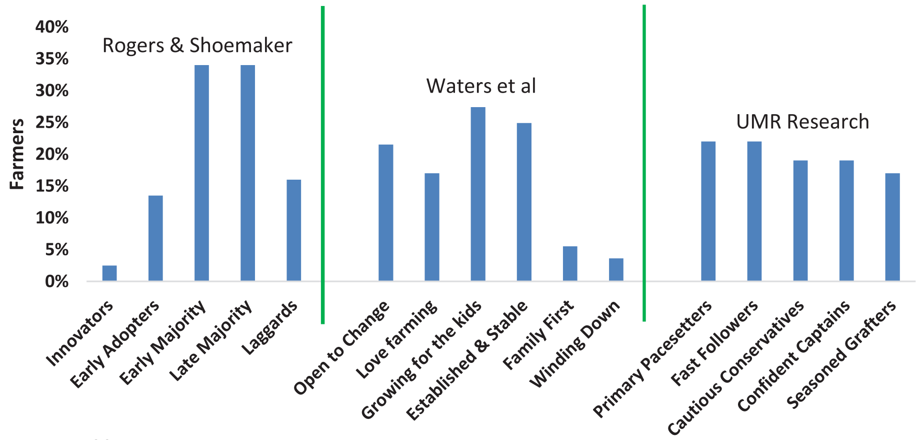
The literature indicates that many things influence farmer behaviour, and may prevent them from addressing environmental issues such as emissions. These barriers include:

- Lack of information and institutional support;
- New ways of doing things not being compatible with existing practice;
- Complexity of changes;
- Difficulties with access to finance;
- Land tenure issues; and
- Personal characteristics, such as age and lack of confidence.

The literature review also found a large diversity of attitudes and drivers within the farming sector, shown in figure 6. This compares the outcomes of three studies which grouped farmers based on their attitudes and behaviours.

13 https://motu.nz/our-work/environment-and-resources/agricultural-economics/no-cost-barriers/barriers-to-adoption-of-no-cost-options-for-mitigation-of-agricultural-emissions-a-typology/

Figure 6: Three studies into farmers' attitudes and behaviours



Source: AgFirst report, page 29

The following three factors influence farmers' adoption of mitigation interventions:

1. The intervention itself:
   a. Ease of trialling on-farm;
   b. Benefits relative to current practice. These may be economic, or may include such factors as reducing risk or the time required;
   c. Compatibility with current systems;
   d. Connection to broader objectives; and
   e. Visibility of results.
2. Personal factors: These include how much time farmers have available, their level of education, and their attitude towards the environment in general and those providing the advice in particular. Farmers' sense of well-being, past successes and failures, and their approach to risk or fear of failure also have a bearing.
3. Broader societal influences: These include acceptance of mitigation practices by their peers, and family circumstances in how the farm is run.

In order to take action to mitigate biological emissions, farmers need to understand the issues, how these inter-relate with their farm systems and profitability, and the complexity of how all of this fits together. Two things are important to changing behaviours: demonstrating clear links between environmental and economic benefits, and ensuring practical options are available.

The importance of working with farmers

Overcoming these diverse barriers requires a multifaceted approach, including incentives, either regulatory or price. However, incentives on their own will not be enough. To effectively change behaviour, incentives need to be accompanied by a programme that includes:

- Actively involving farmers in its design. It is important to reflect the world view of farmers, including an understanding of why they may not readily adopt alternative technology and management practices.
- Targeting 'early adopters'. The adoption of innovations varies across a population. There are 'innovators', 'early adopters', 'early majority', 'late majority' and 'laggards'. While innovators are important, research indicates that early adopters are more influential on the rest of the population and should therefore be the focus for early contact.
- Using a combination of mass media and discussion groups. Using mass media helps trigger innovators to act, but is less effective in persuading other groups. The greatest level of adoption occurs when advisors

work one-to-one with farmers. Discussion groups are a halfway house between these approaches, where local farmers meet regularly with an advisor to look at individual farms and discuss farming systems and associated issues.

- Using trusted advisors. Farmers are more likely to take advice from those who are closer to their business (friends and family). It is important to support networks that enable trusted and respected farmers to interact with other farmers.
- Delivering the programme within the context of the farm management system as a whole. Any advice on reducing emissions must tie in with existing systems and profitability.

The BERG points to consistent farmer feedback through this research and generally, that any approach for managing on-farm emissions should:

- Provide clarity and certainty;
- Be co-developed with stakeholders; and
- Adopt an integrated approach with other environmental considerations such as water, biodiversity and soil conservation.

Results from AgFirst's survey of farmers confirm that, in general, understanding of biological emissions and potential adaptations can be improved. Some of the questions and results are shown in table 2.

For example, a total of 98% of farmers didn't know the level of greenhouse gas emissions for their own farm, and 97% underestimated the amount of carbon dioxide equivalent emitted by the average farm. When asked if they believe the agricultural sector should reduce biological emissions to help combat global climate change, 64% agreed.

As to the information, support and systems they may need to help manage a future cost on greenhouse gases, farmer's responses included their desire for proof of need, for better understanding of their options to reduce or offset emissions, and for certainty on greenhouse gas prices. The assistance sought included funding, education on soil science, and technology to reduce methane from rumen digestion.

Table 2: Some of the questions and responses to AgFirst's farmer survey

Question 1:	Do you know the level of greenhouse gas emissions for your farm? 2% yes – 98% no
Question 2:	Do you believe that New Zealand agriculture should reduce its greenhouse gas emissions to help combat global climate change? 64% yes – 36% no
Question 3:	Other than planting trees, are you aware of mitigation strategies that would reduce your greenhouse gas emissions? 58% yes – 42% no Other mitigation strategies mentioned included: use of biofuels, reduced stocking rates, no-tillage for cropping, and fewer cattle.
Question 4:	What would you estimate the amount of carbon dioxide equivalent the average farm is emitting? The majority (97%) underestimated this, with 82% estimating fewer than 1,000 tonnes CO_2e1/year. The average farm emits about 1,900–2,000 tonnes CO_2e/year.
Question 7:	What information, support or systems do you need to help you manage a future cost on greenhouse gases? Many of the comments reflected the need to understand greenhouse gas emissions, the options to reduce or offset emissions, and the costs and benefits involved, as well as the need for good scientific information and new technologies.

4.2 Potential for mitigating emissions

What mitigation options could be implemented on-farm now?

Purpose

This research was commissioned to identify the availability, effectiveness and viability of existing options to reduce biological emissions on-farm.

Approach

New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) used models to explore a range of possible mitigation options based on currently available farm technologies and practices. These options can either improve or decrease production and/or profit, and sometimes have other benefits, such as improving water quality.

The modelling used hypothetical average farm systems for dairy, sheep and beef across several regions, to explore the production and profitability implications of applying currently available mitigation options. Deer farm systems were evaluated in less detail, due to a lack of data. Horticulture and arable farming were only summarised, as their contribution to biological emissions levels is relatively small.

While the analysis considered the economic implication of possible mitigation options on-farm, it did not perform a detailed economic analysis at a regional or national level. Their results have nevertheless informed other work commissioned by the BERG, including an analysis of the economic impacts of reducing on-farm emissions, albeit with different assumptions about the costs of mitigation options for dairy farms.

Key findings

A range of options to reduce emissions from pasture-based livestock systems exist, but the reductions that can be achieved without significant reductions in profitability are limited. These options can be grouped into three broad areas:

- Improving the productivity and efficiency of farm systems;
- Reducing emissions (by changing feed); and
- Reducing the amount of feed eaten by reducing livestock numbers.

A variety of mitigation options exist across the sector that collectively reduce biological emissions by 5–10% without necessarily reducing on-farm profitability. Actual economic outcomes for each farmer will depend on a range of factors, including how mitigation options are implemented, skill level required to implement these options, farm systems, commodity prices and emission prices (if changed).

Land use change is generally required to achieve a reduction of more than 10%.

Dairy

Individual mitigation options (other than on-farm forestry) have the potential to reduce absolute biological emissions by approximately 2–10%. Each intervention has widely varying implications for profitability.

Improving productivity per animal, while reducing stocking rates, has the potential to consistently reduce greenhouse gas emissions by up to 10% and could increase farm profitability. However, achieving the modelled outcomes depends significantly on farmer skills and base farm systems. If stocking rates are reduced but performance per animal increases less than modelled in this report or not at all, the approach could reduce profitability. The fact that only a limited fraction of farmers have followed this approach to date points to important barriers to its more widespread adoption. The approach is generally more profitable if milk pay-outs are lower.

Once-a-day milking could reduce total production and emissions but maintain profitability if reduced labour costs balance a reduction in total milk production. In this case, this approach would reduce emissions by 6–7%. The effect on profitability depends strongly on pay-outs for milk solids and reductions in labour costs. In addition the effect on production, emissions and profitability is likely to change over time, as farms adapt to once-a-day milking and adjust the genetic make-up of their herd.

Low protein supplementary feeds, removing nitrogen fertiliser, and removing summer crops can also reduce emissions by up to approximately 5%. These may be economically viable in some regions but not all. Their feasibility will depend strongly on base farm characteristics and the level of management expertise. Off-farm emissions associated with low-protein feed also need to be considered.

On-farm forestry can achieve the biggest emissions reductions (3–96%), depending on the percentage of land planted (the analysis modelled an area between 10–30%). However, these options are also by far the most expensive (with implied carbon costs in excess of \$100–\$600/tonne CO_2e). The most viable options are where forests are planted only on marginal land and not for harvest, which depends heavily on individual farm configurations and has a more limited mitigation potential of up to 10% of emissions.

In addition, planting trees can reduce flexibility in farm operations. Options involving on-farm forestry also depend strongly on whether all carbon sequestered by growing trees is accounted for, or only the carbon that remains in between harvest and re-planting cycles.[14]

Sheep and beef

Because management in the sheep and beef sector is less intensive than dairying, options to reduce emissions are more limited. Some options may enable minor reductions while increasing profitability, but depend heavily on farmer skill levels and access to resources.

Reducing stocking rates while improving productivity per animal can reduce emissions by 2–5% and increase profitability by 16–28%. Without concurrent productivity improvements, reduced stocking rates would lead to significant reductions in profitability (from 4% on the North Island hill country farm, to 26% for the South Island intensive system, with implied carbon costs of mitigation of \$60–\$200/tonne CO_2e). Achieving the modelled productivity improvements depends heavily on farmer skills and access to training and resources.

Replacing breeding beef cows on hill country farms with surplus bulls and steers from the dairy herd can result in 1–4% emission reductions and greater than 10% reductions in emission intensity. This could also lift profitability by more than 50%. Possible barriers to this option include the need for infrastructure improvements and farmer skills to work with bulls, as well as challenges to maintain pasture quality.

Integrating forestry into farm operations can offset emissions by more than 100%, especially if the land is planted for permanent forest. The costs of mitigation through forestry depend on the approach, but the implied carbon costs of on-farm forestry range from \$10–\$45/tonne CO_2e.

Variation within the sector means the introduction of forestry can improve profitability on a proportion of farms. However, the opportunity cost of the reduced flexibility in land use is likely to be a barrier to widespread adoption, especially if there is uncertainty about future carbon prices. Increased skills are also required to intensify the remaining pastoral land to minimise overall costs.

14 https://www.mpi.govt.nz/news-and-resources/consultations/a-better-ets-for-forestry

Other measures, such as changing the sheep/cattle or male/female ratios, or removing nitrogen fertiliser inputs, generally result in minor to negligible emission reductions. Some mitigation actions, such as forestry, are highly sensitive to commodity prices, whereas bull beef production appears less sensitive to payment schedules.

Deer

Reductions in stocking rates with reduced input costs appear to decrease emissions by about 10%, and increase profitability by 4% if farmers achieve a concurrent increased performance per animal. In this case, profitability increases were driven by cost reduction rather than increased productivity.

Eliminating nitrogen fertiliser use has a negligible effect on emissions, as well as profitability. As nitrogen fertiliser is often applied for tactical reasons, removing it can increase variability of returns and a farmer's ability to achieve consistent pasture production.

Ranging between 8–37%, on-farm forestry offers the most significant emission reductions, depending on the species of tree and duration planted. However, profitability drops to between 6–11% and it is generally more costly than for sheep and beef systems, even if limiting planting to marginal land only. The implied carbon costs are $39–$129/tonne CO_2e.

Horticulture and arable cropping

Emissions from dedicated cropping and horticulture constitute less than 3% of New Zealand's biological emissions. Emissions from domestic horticulture systems were assessed for the main commodities of kiwifruit, apples, and viticulture. For arable land use, the assessment mainly focussed on wheat and other grains, maize, and ryegrass seed production.

Options exist to reduce emissions in horticulture and arable cropping but are limited, given the low use of nitrogen. Mitigation options are somewhat greater for cropping given its heavier reliance on fertiliser, but are still limited.

Collectively, these approaches have been estimated by others to be able to reduce emissions from horticulture and arable cropping by up to 15–20%. Their impact on profitability is small, or even positive, but the evidence base for this, and their practical implementation, is more limited than for livestock options. They can also expose farmers to risks from climate and market variability.

Crop lands typically have lower soil carbon storage than pasture or forest lands, and soil carbon can continue to decrease. Low or no-till farming, and crop residue management have been shown elsewhere to enhance soil carbon storage, but the evidence is more limited in New Zealand.

What mitigation options could be implemented in the future?

Purpose

A number of mitigation options may become available in the future, which have the potential to considerably reduce on-farm biological emissions. Both the government and agricultural sectors have invested in research and development of these potential new technologies. However, much uncertainty still exists about whether they will actually come to fruition, and if so, whether they can be applied nationally, what they will cost, and whether they will be effective.

Approach

The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) was commissioned to lead an assessment of the likelihood of different mitigation technologies being available in the future, and what potential these might have to reduce on-farm biological emissions. Some options are available already, although their efficacy or scale of adoption could still change. These were also included in the report.

As part of this activity, a group of technical experts from participating organisations within the BERG was assembled to determine how realistic it is that any of the possible mitigation options will be available to farmers in the future. They considered the potential effectiveness of each option, how widely it might be adopted, and what might encourage or hinder uptake.

Key assumptions

The authors looked at how much each option might reduce biological emissions below baseline projections. For this, they used the National Inventory tool and MPI's baseline projections to 2030, extended out to 2050.

Only potential on-farm mitigation options within an existing land use were considered. Included here were actions to increase carbon sequestration, but only where this did not compromise existing livestock production. Mitigation options that relied on land use change, either between different livestock systems or away from livestock entirely, were not included.

The report explored the following mitigation options:

Methane inhibitors	Methane vaccine
Breeding low-emission animals	Low-emission feeds
Nitrification and urease inhibitors	Reduced nitrogen fertiliser use
Increasing performance of individual animals	Enhanced manure management
De-intensifying dairy systems	Once-a-day milking
Removing breeding beef cows	Increased tree planting (without negatively affecting production)

Some options are proven and are already being implemented by farmers; others are under active research and are yet to reach proof of concept.

Caveat

Absolute reductions in biological emissions by 2030 and 2050 will depend on changes in animal numbers and total production. Predictions of numbers and production have greatly varied in recent years, and some Government predictions used here differ from the expectations of industry. If future baseline emissions turn out higher than assumed, more mitigation effort will be needed to achieve the same absolute emissions by 2030 or 2050 (and vice versa).

Key findings

The mitigation options with the greatest potential are not yet commercially available

The mitigation approaches with the largest potential impact on emissions, e.g. methane inhibitors and vaccines, nitrification inhibitors, and genetically modified ryegrass, are not yet commercially available. Some have proof of concept (e.g. a methane inhibitor for feedlot animals), or proven benefits (e.g. nitrification inhibitors). Others are at various stages of development. An example of the latter is genetically modified ryegrass, which exists, but its efficacy in reducing emissions is yet to be demonstrated. Similarly, a methane vaccine is in development but is yet to demonstrate an effect in live animals. Bringing such options to market suitable for use on-farm will require further development, with timelines of 5–20 years, and uncertain outcomes.

We can have different degrees of confidence that some novel technologies will be developed

The report looked at the likelihood that novel technologies will be available in the future. By way of example, table 3 summarises the authors' assessment of two of the most discussed possible mitigation options.

Table 3: The likelihood of two potential future mitigation options

Mitigation	Likelihood	Possible mitigation potential
Methane vaccine	Low confidence that it will be available by 2030 Medium-high confidence by 2050	30% reduction possible in both 2030 and 2050
Methane inhibitor	In-shed feeding (twice a day): • High confidence that it will be available by 2020[15] Extensive grazing systems (slow-release): • Medium-high confidence it will be available by 2025 • High confidence by 2050	5% efficacy in 2020, rising to 30% by 2030 10-30% efficacy in 2030, rising to 30-50% by 2050

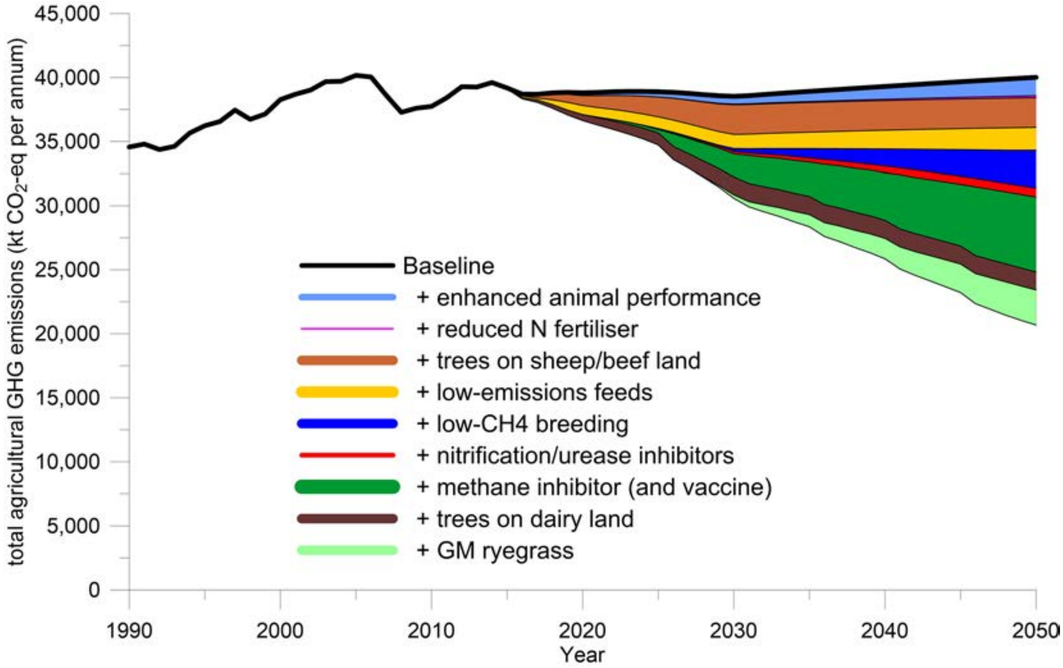
'Packages' of mitigation options have greater potential than adopting a single measure

It is unlikely that a large shift in overall emissions can be achieved with a single mitigation option. However, when individual options are combined into mitigation 'packages', the analysis estimated that biological emissions can be reduced by 10–21% in 2030, and by 22–48% in 2050, relative to the MPI baseline projections.[16] For example, figure 7 (sourced from the report) shows one scenario that estimates the cumulative effects for one package of possible interventions for dairy, sheep and beef, assuming the highest efficacy and adoption rates. The actual mitigation potential and adoption rates of options are as yet uncertain, and will also depend on policy incentives. Lower rates of adoption, or lower mitigation of individual options, will result in lesser total mitigation.

15 The report's authors made this assessment in 2017. Availability of an inhibitor would be dependent on whether it would be subject to regulatory requirements under the Agricultural Compounds and Veterinary Medicines Act 1997, and Hazardous Substances and New Organisms Act 1996.

16 This equates to about 12-24% below 2005 levels by 2030, and 9-40% below 1990 levels by 2050.

Figure 7: An example of the cumulative effects for a future package of interventions for dairy, sheep and beef



Note: These numbers are based on the most ambitious assumptions about the mitigation potential relating to different options, and farmer uptake of these options.

Table 4: A summary of estimated emissions reductions by different mitigation packages

Mitigation package	Comment	2030 (relative to 2005)	2050 (relative to 1990)
Baseline	Based on MPI projections, and extended in this report to 2050	- 4.1%	+ 15.8 %
Full package	All options except dairy de-intensification approaches	- 14% (low) - 24% (high)	- 10% (low) - 40% (high)
Sectoral packages	Dairy de-intensification package	- 9% (low) - 16% (high)	- 2% (low) - 17% (high)
	Sheep/beef package	- 8% (low) - 12% (high)	+ 8% (low) ± 0% (high)
Alternative full package	Dairy de-intensification plus sheep/ beef package	- 12% (low) - 24% (high)	- 9% (low) - 33% (high)

Drivers and barriers to adoption

Mitigation options that affect nitrous oxide (N_2O) emissions will have strong drivers when they also benefit water quality and nutrient discharges, such as reducing the use of fertiliser and applying nitrification and urease inhibitors. Potentially, these mitigation actions also include dairy de-intensification, low-emission feeds, and animal breeding. How much water quality can drive the uptake of such mitigation options will vary strongly between catchments.

Challenges lie not only in development of the technology, but also in the regulatory settings and market responses, both domestic and international. Even where there is high or very high confidence that a technology will become available, market responses and/or overseas regulatory barriers can remove it as a viable option locally. The nitrification inhibitor dicyandiamide (DCD) is a case in point. Work to ensure the market acceptability of novel mitigation technologies is therefore vital to securing their potential.

How widely and how fast farmers can adopt mitigation actions will vary. Dairy farms tend to have more mitigation options available, together with differences in high- and low-input dairy systems. Uptake will also be affected by:

- Farmers' capability, willingness to take risks, and access to skilled labour;
- Availability of relevant information, skilled advisors, and finance; and
- The extent to which markets dictate farm practices.

Some options may be impossible on individual farms, even though they may be considered possible in general for that farm type, and vice versa.

Conclusions

The report notes that in the absence of novel technologies, the overall potential to reduce on-farm biological emissions is more limited. Ongoing investment in research into novel mitigation options is therefore critical, to allow the sector to contribute to more ambitious mitigation goals without having to resort to costly offset mechanisms, or substantial land-use change.

Overall, regardless of the specific direction taken, further changes in farm systems are required to achieve efficient mitigation. This means farmers need to adapt as the impacts of a warming world become a reality, as climate and associated policies engage, and as global markets respond to both.

The report also says that further investment into extension will be required, to help farmers put in place changes to management systems required by the new options. Investment in monitoring tools and accounting approaches is also needed to ensure measurement of positive actions by farmers.

What are the climate co-benefits from freshwater policy?

Purpose

The National Policy Statement for Freshwater Management (Freshwater NPS) first came into effect in 2011[17]. It requires regional councils and unitary authorities to consult with local communities to establish objectives for the state of freshwater bodies in their regions, and set enforceable limits on resource use to achieve them. Methods (both regulatory and non-regulatory) must be implemented to meet those targets within a specified time frame.

17 It was updated and replaced in 2014, with a further update in 2017. See http://www.mfe.govt.nz/fresh-water/national-policy-statement/about-nps for more information.

The BERG's aim was to understand the benefits that arise from changing management practices and, in some cases land use, to meet water quality limits that may also apply to mitigating emissions from farms.

Approach

No specific research was commissioned, because MPI had separately commissioned two reports on the issue, the contents of which remain current. The reports, from AgResearch and Motu/Manaaki Whenua - Landcare Research, assess the possible impacts of the Freshwater NPS on New Zealand's land-based emissions.

While the reports use different methodologies, a synthesis of their findings shows they are broadly consistent.[18]

Key findings

The reports show that the Freshwater National Policy Statement policies already implemented (or likely to be implemented) by regional councils and unitary authorities have the potential to provide a moderate reduction of agricultural emissions (0.5–4%), through changes in farming practices, such as reduced fertiliser use and optimised stocking rates.

When land-use change to forestry is also considered, the reductions are even greater, as summarised in table 5. The reports estimate that up to 800,000 ha. of trees could be planted as a direct result of the Freshwater NPS. Those trees can sequester up to 5.4 million tonnes of carbon dioxide equivalent (Mt CO_2e[19]), equivalent to 14% of current agricultural greenhouse gas emissions. The reduced stock numbers due to this land-use change can reduce biological emissions by another 1.2 Mt CO_2e.

The reports assumed partial uptake across national water catchments, based on information available at the time. These co-benefits are likely to increase over time as more regional councils and unitary authorities develop and implement their Freshwater NPS policies. Actual emission reductions will depend on the limits imposed, and the extent to which different mitigation measures are implemented.

Table 5: Summary of potential reductions in agricultural emissions due to the Freshwater NPS

Reductions in agricultural emissions (excluding land use change to forestry)	0.2 – 1.7 Mt CO_2e (from 0.5% – 4% of agricultural emissions)
If land-use change to forestry is included:	
Reductions in agricultural greenhouse gas emissions	Up to an additional 1.2 Mt CO_2e (3% of agricultural emissions)
Forest sequestration of greenhouse gas emissions	Up to an additional 5.4 Mt CO_2e (14% of agricultural emissions)
Total potential greenhouse gas benefit	**Up to 8.3 Mt CO_2e (21% of agricultural emissions)**

18 Shepherd M, Daigneault A, Clothier B, Devantier B, Elliott S, Greenhalgh S, Harrison D, Hock B, Kerr S, Lou E, Lucci G, Mackay A, Monaghan R, Müller K, Murphy L, Payn T, Timar L, Vibart R, Wadhwa S, Wakelin S. 2016. New Zealand's freshwater reforms: what are the potential impacts on Greenhouse Gas emissions? A synthesis of results from two independent studies. MPI Technical Paper No: 2017/21

19 'Mt CO_2e' is a metric measure used to compare the emissions from different greenhouse gases based on their global warming potential. It allows the comparison of 'apples with apples'. The carbon dioxide equivalent (CO_2e) for a gas is derived by multiplying the tonnes of the gas by its global warming potential.

4.3 Estimating biological emissions from agriculture

Can you estimate on-farm emissions, and will methods for on-farm estimates be consistent with New Zealand's National Greenhouse Gas Inventory?

Background

It is not possible to directly measure biological emissions, either at a national or farm scale.

It is therefore necessary to use mathematical models to estimate emissions, based on our understanding of biological processes (for example, in the rumen, or when nitrogen is applied to soil). These models are founded on decades of international and, where appropriate, New Zealand-specific science.

The New Zealand Agricultural Greenhouse Gas Inventory (hereafter the National Inventory[20]) uses this science to estimate annual average national emissions.

Overseer Limited[21] farm management software draws on the same science to estimate annual average farm-scale emissions. The model is known as OVERSEER® Nutrient Budgets (OVERSEER®), and is the subject of the research commissioned by the BERG and summarised below. In 2019, a new version OverseerFM, replaces OVERSEER®, while retaining the same underlying farm system modelling. Notwithstanding this change, the report commissioned by the BERG and its recommendations remain relevant and entirely consistent, because the underlying farm-system modelling used by OverseerFM remains the same.

OverseerFM has already implemented some of those recommendations, and will continue to incorporate new science and upgrades to the model.

Purpose

OVERSEER® helps users estimate nutrient inputs and outputs, as long-term annual averages. As part of the nutrient cycle, it estimates greenhouse emissions. The model can also be used to estimate the impact of different farm management scenarios on a farm's nutrient load, including emissions and options to mitigate them.

To address freshwater quality limits and comply with the Government's National Policy Statement for Freshwater Management 2014 (Freshwater NPS), some regional councils and unitary authorities already require farmers to use OVERSEER® for farm-scale reporting or to meet farm-scale nutrient loss limits. Participating farms can generate greenhouse gas emissions reports with little additional cost or effort.

Recognising that OVERSEER® is already used in a regulatory context, the BERG sought an assessment of:

(a) Its suitability for estimating on-farm greenhouse gas emissions;

(b) How well OVERSEER® aligns to the National Inventory; and

(c) Options for systems and processes for incorporating changes and updates to OVERSEER® and the Inventory to ensure ongoing alignment and consistency.

This work did not assess or comment on the suitability of OVERSEER® as a regulatory tool for biological emissions.

20 The National Greenhouse Gas Inventory is the official annual estimate of all human-generated greenhouse gas emissions and removals that have occurred in New Zealand since 1990. It measures New Zealand's progress against obligations under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

21 Overseer was developed in the 1980s, and is refined and peer reviewed as new science becomes available. The Overseer model is owned in equal shares by the Ministry for Primary Industries (MPI), AgResearch Limited, and the Fertiliser Association of New Zealand (FANZ). In turn, Overseer Limited is owned in equal ordinary shares by FANZ and AgResearch. MPI has equal voting rights alongside the shareholders.

Approach

The BERG commissioned AgResearch to undertake this work. Its assessment focused on the main source of biological greenhouse gas emissions: enteric methane (CH_4) and nitrous oxide (N_2O) from dairy, sheep, beef, and deer livestock systems.

AgResearch further examined the findings of a 2015 comparison between the National Inventory method, and the version of OVERSEER® operating at that time. It repeated the analysis, using an updated version of the software.

The evaluation used case-study examples for the energy requirements of dairy cows. In the case of nitrous oxide emissions, case studies of pastoral farms for dairy, sheep, beef and deer on a range of moderately well-drained soils across the country were used. Case-study examples also assessed nitrous oxide emissions for irrigated dairy farms on contrasting soils.

Key findings

Overall, OVERSEER® software is a suitable measuring tool for estimating farm-scale emissions. Its calculations are supported by current scientific understanding, and it can accommodate different farm systems and management practices.

Estimates from OVERSEER® are generally consistent with those modelled by the National Greenhouse Gas Inventory. Small variations exist, but this is expected as the models operate at different scales. OVERSEER® estimates farm averages, while the National Inventory estimates national averages.

To ensure that OVERSEER® and the National Inventory remain aligned, and to ensure ongoing confidence that OVERSEER® is representative of farm-scale greenhouse gas emissions, the AgResearch report recommends that:

- A small working group be commissioned to undertake a full assessment of all energy, feed intake, and greenhouse gas emissions equations, and how these are applied in OVERSEER®;
- The equations, and how they are applied, be evaluated for all domestic farming systems – i.e. dairy, sheep, beef, deer, horticulture, and arable farming;
- 'Annual average' emission factors[22] be set as the default option for calculating nitrous oxide emissions in OVERSEER®, and all emission factors used be the same as those in the National Inventory;
- 'Farm specific' and 'annual average, seasonally adjusted' emission factors be disabled until the methods used to derive these options are reviewed, and experts are satisfied that the spatial and/or temporal information they are based on is robust enough to justify their use;
- The rationale behind the choice of equations and parameters for estimating energy, feed intake, and greenhouse gas emissions be fully documented in technical manuals;
- A calibration data set be developed to validate the calculations in OVERSEER® for estimating dry-matter intake, nitrogen intake and excretion, for apportioning annual nitrous oxide emissions across the months, and for determining nitrous oxide emissions based on soil moisture and temperature; and
- Overseer Limited and MPI's National Inventory team ensure ongoing alignment between OVERSEER® and the Inventory, and the agreed approach be formally implemented.

The BERG notes that the review identified the need for a working group to be established to ensure ongoing alignment between OVERSEER® and the National Inventory model, and to ensure reviews of relevant published research are conducted regularly. The BERG anticipates these processes will enable any new mitigations to be incorporated consistently into OVERSEER® and the National Inventory model, as the science becomes available.

22 'Emissions factors' are used to transform data on activities that cause greenhouse gas emissions (such as using fuel) into estimates of actual emissions. For example, multiplying a known quantity of fuel by a specific fuel 'emission factor' provides an estimate of the actual emissions that using that amount of fuel would cause.

Supporting science will be needed to ensure robust modelling along with the necessary calibration and validation of data for new mitigations. A time lag may exist between new mitigations becoming available and being incorporated into the models.

Can currently available mitigation actions help New Zealand meet international targets?

Purpose

On-farm reductions in biological emissions will only contribute to New Zealand meeting its international targets if they can be included in the country's emission reports. These reports, prepared in line with United Nations guidelines, are recognised by the international community. They are captured in the National Inventory.

Approach

The MPI agricultural inventory team assessed how difficult it would be for the National Inventory to include the on-farm mitigation options covered in chapters B1 and B2 of this report.

Key findings:

Dairy

Several proposed mitigation options available for dairy farming can be accounted for without requiring any changes to the National Inventory's data, assumptions, or methodologies:

- Lowering stocking rates and increasing production per cow;
- Increasing forestry, while also increasing stocking rates and/or the intensity of the farm system;
- Switching to once-a-day milking;
- Cutting or reducing nitrogen fertiliser inputs;
- Removing summer cropping; and
- Planting trees on marginal land.

A further possible mitigation option – feeding low-nitrogen supplements (grown either off-farm or on-farm) – would require new data and other minor changes to the National Inventory methodology. MPI is currently collecting data on the types and amounts of supplemental feed used in dairying (and the sheep and beef industries), so this can be included in future inventories.

Sheep and beef

The following proposed mitigation actions available for sheep and beef can be accounted for in the National Inventory without requiring any changes to its data, assumptions, or methodologies:

- Increasing forestry, either large-scale or on marginal land;
- Removing breeding beef cows; and
- Decreasing stocking rates, while increasing productivity on intensive sheep and beef farms.

Can future mitigation technologies be included in the National Inventory?

To incorporate the effect of advanced mitigation technologies such as methane vaccines or inhibitors, changes to the National Inventory methodology will be needed. The Deputy Director General (Policy and Trade) of MPI can approve changes, following advice from the Agriculture Inventory Advisory Panel, an independent group of experts.

To recommend a change, the Panel will need to be confident that:

- The proposed change improves the accuracy of the National Inventory;
- The change is backed up by robust science and research, which demonstrates that the new technology has an effect on emissions from actual farms. Ideally, the research will be published in a reputable, peer-reviewed scientific journal;
- Data is auditable or able to be verified by a secondary data source; and
- The change will be accepted by external expert reviewers (selected by the UNFCCC).

How long will these changes take?

National Inventory figures are published two years behind the current calendar year (for example, the 2018 Inventory has emissions figures up to 2016). New mitigation technology could potentially be included in the National Inventory under this regime, assuming that published, peer-reviewed research on the effect of the technology is available, along with robust data on its uptake. For example, if a new technology is applied in 2020, the BERG expects it can be incorporated from 2022.

What carbon sequestration offset opportunities from on-farm vegetation do not meet current New Zealand Emissions Trading Scheme (NZ ETS) criteria?

Purpose

When discussing climate change with farmers, one of the first questions they ask is: *"Why don't the other trees and practices on our farms count in the NZ ETS, or towards mitigation efforts?"*

Part of the problem here is a widespread lack of understanding about how much carbon is sequestered from on-farm activities that do not meet the NZ ETS's current criteria for 'forest land'[23]. While a number of studies have been done on the potential of riparian strips to sequester carbon, serious gaps remain in information about the potential for additional net revenue (or liability) for landowners, if other currently ineligible activities were included in a carbon accounting or offsetting scheme.

Approach

Manaaki Whenua - Landcare Research, in collaboration with SCION, the National Institute of Water and Atmospheric Research (NIWA), and AgResearch, reviewed the carbon sequestration potential of on-farm vegetation not currently captured under the NZ ETS or the National Inventory. Included here were wetlands, riparian strips, pole plantings, shelter belts, small woodlots[24], and revegetating retired land.

The analysis was limited to currently available literature and information sources. With the exception of wetlands, only the biomass sources and sinks were included. This is because of uncertainty about how soil's

23 The NZ ETS defines 'forest land' as land greater than 1 hectare, on which the tree species reach a height of at least 5 metres, and there is greater than 30 per cent canopy cover. Forest land can also be land with the potential to reach these parameters under its current management. http://www.mfe.govt.nz/climate-change/state-of-our-atmosphere-and-climate/measuring-greenhouse-gas-emissions/measuring, retrieved 26 August 2018.

24 Under the NZ ETS, woodlots qualify as forests only if they meet the thresholds used for New Zealand's National Greenhouse Gas Inventory:
i. Tree species capable of reaching 5 metres height in situ (United Nations Framework Convention on Climate Change (UNFCCC)minimum: 2–5 m)
ii. 30% canopy cover (UNFCCC minimum 10–30%)
iii. 30 metre minimum width
iv. 1 hectare minimum area (UNFCCC minimum 0.05–1 ha.)

organic carbon stocks change in response to on-farm activities of this kind. The study did not assess or comment on the devolution of such activities under the NZ ETS, or whether New Zealand can gain credits for them internationally. Neither was there an analysis of the potential to increase the carbon capture and storage capabilities of agricultural soils.

Key findings

Estimating on-farm carbon sequestration is a highly complex task. Significant gaps exist in the data and in knowledge of estimates of actual carbon stocks, vegetation-specific emission factors, potential sequestration rates and their variability, and how long-lived different carbon sinks are.

The review's overall conclusion was that the majority of the on-farm non-NZ ETS vegetation types investigated have the potential to sequester carbon. They are widespread and common across New Zealand farmland, and their management follows accepted practices.

New activities can contribute to offsetting on-farm emissions in some cases, and provide additional environmental benefits at both the farm and national scale. Targeted national initiatives can aim to remove significant barriers.

Measurements conducted on three case-study farms indicate that sequestration by current and planned vegetation can account for about 0–2.5% of current gross livestock emissions on intensive lowland sheep and dairy farms, and about 5–20% on a hill country sheep and beef farm.

Opportunities

Table 6 shows that among the existing on-farm vegetation types considered, small woodlots and shelter belts offer the highest sequestration rates (all figures are approximate). Next best are riparian strips and pole plantings, while natural wetlands and retired land offer the lowest rates.

Potential exists to increase carbon sinks: new small woodlots, riparian belts, and pole plantings, if sufficient areas can be permanently set aside. Wetlands have some potential as sinks, but are complex to measure and will require further research, particularly constructed wetlands. Existing shelter belts have limited potential.

Table 6: Approximate rates of carbon sequestration by different vegetation types

On-farm vegetation type	Approximate range of sequestration rates (t·CO_2e·ha–1·yr–1)	Potential new carbon sinks nationally (Mt·CO_2e·yr–1)
Small woodlots	6.5–26.3	1.0 (if established on 0.4% of agricultural land, until they mature about 2050)
Shelter belts	6.5–26.3	Limited
Riparian strips	0–5.28	0.72 (if planted 10 m wide with a significant number of trees, on 50% of New Zealand streams and rivers)
Pole plantings	2.0	---
Wetlands	0–2.0	0.06 (if agricultural land is retained in peat mires)
Revegetating non-ETS compliant retired land	0–0.47	-

As a point of reference, Pinus radiata sequesters 18.4-28.8 tonnes of CO_2 equivalent per hectare per year (t· CO_2e·ha–1·yr–1)on average over a 28-year planting cycle. Over the same period, indigenous forests sequester 8.7 t· CO_2e·ha–1·yr–1.

Challenges

Carbon sink benefits are of a temporary nature, with a finite lifetime that ends when vegetation growth reaches maturity. As with production forestry, small woodlots, pole plantings, riparian plantings, and shelter belts have finite lifetimes and must be replanted. In most cases this lifetime is 20–30 years, with natural wetlands and retired land potentially extending beyond 50 years. Native species have longer carbon accumulation timeframes, but annual accumulation rates are lower.

In the same way, carbon stocks stored in existing forests, peat mires, and soils only create an offset benefit when there is a net increase in stocks. While these carbon sinks are temporary, the many other benefits such as water purification, shelter, and erosion control, are ongoing.

Nor is much known about the *potential* carbon sinks covered in this report. Large gaps exist in our knowledge of their ability to sequester carbon and emissions factors. These gaps will need to be addressed before it is possible to include such areas more accurately in the UNFCCC reporting, or when accounting for domestic climate change targets. Developing suitable emission factors for retired land, for example, is a major undertaking because of the wide range of ecosystems that fall into this category, and the associated likely low-growth rates.

Possible next steps to improve knowledge

The findings for the on-farm vegetation types should be considered in relation to the likelihood of their being adopted as an expanded, additional, significant new carbon-offset sink on farms, beyond business-as-usual land use.

The report provides more clarity around the potential sequestration occurring on farms. However, before farmers consider increasing the potential for their land to sequester carbon, they need to understand the cost-benefit ratio of producing carbon units versus livestock units. The authors recommend further analysis to consider the area of land required to offset typical farm emissions.

More work is also required to accurately quantify the spatial extent of on-farm activities, sequestration rates of different vegetation and wetland types, and the longevities of sinks.

What are the offset opportunities from soil carbon?

Purpose

Increasing soil carbon stocks is often cited as a possible way to offset biological emissions.

This topic remains an active focus of research, summarised recently by Schipper et al. (2017).[25] The BERG decided it was more useful to assess existing research rather than commission new work.

Approach

MPI analysed existing research to assess whether increasing soil-carbon levels is a viable way to offset emissions.

25 Schipper LA, Mudge PL, Kirschbaum MUF, Hedley CB, Golubiewski NE, Smaill SJ & Kelliher FM (2017): A review of soil carbon change in New Zealand's grazed grasslands, New Zealand Journal of Agricultural Research, DOI: 10.1080/00288233.2017.1284134.

Key findings

While high carbon content offers soil health and water management benefits, New Zealand's climate means our soils are comparatively high in carbon compared to countries like Australia. Soil carbon is therefore unlikely to provide an additional significant carbon sink. Soil carbon is also difficult to measure and monitor. Carbon takes time to build up in the soil, and can be lost quickly through land management practices such as cultivation, and through events such as drought that lie beyond a farmer's control.

Current data shows that domestic soils are relatively high in carbon content compared with other countries. But because impacts are complex to assess, it is unclear whether New Zealand as a whole is gaining or losing soil carbon.

Recent studies indicate parts of the hill country are gaining soil carbon, while some pockets of specific soils on flat land appear to be losing It. Irrigating land appears to cause a loss of soil carbon, with further investigation required (Mudge et al. 2017), (Parfitt et al. 2014).[26]

Furthermore, organic soils (such as peat) are different to mineral soils. When drained for agricultural use and exposed to oxygen, organic soils decompose and become an ongoing source of carbon dioxide, methane and nitrous oxide emissions (Schipper et al. 2017). Such emissions persist if the soil remains drained, or as long as organic matter remains within it. While this only affects 0.03% of New Zealand's land area, its carbon emissions are four times as much as from mineral soils.

Changes in the amount of mineral soil organic carbon caused by changes in high-level land use (e.g. moving from forest cover to pasture) are currently recognised in national greenhouse gas reporting. Mid-level land-use changes (e.g. shifting from non-dairy to dairy farming) may be captured at a basic level. However, not enough robust evidence exists to incorporate the impacts that different on-farm land management practices may have, i.e. tillage and no-tillage cropping.

There is a lack of farm-based tools to estimate soil carbon levels or to identify what can be done to enhance soil carbon or prevent its loss. The long-term nature of changes to soil carbon stocks means that significant improvements to the monitoring system used to report on domestic greenhouse gas emissions will require several decades of data.

26 Mudge PL, Kelliher FM, Knight T, O'Connell D, Fraser S, Schipper LA 2017. Irrigating grazed pasture decreases soil carbon and nitrogen stocks. Global Change Biology 23: 945–954.

Parfitt RL, Stevenson BA, Ross C, Fraser S. 2014. Changes in pH, bicarbonate-extractable-P, carbon and nitrogen in soils under pasture over 7 to 27 years. New Zealand Journal of Agricultural Research. 57:216–227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4.4 Possible implications of scenarios for land use change

Can land-use change be a mitigation option for climate change?

Purpose

This report explored three scenarios of changes in land use to achieve different biological emission targets and their impacts on the economy at a national scale. It also considered some social impacts that could arise as a result.

Approach

The BERG commissioned Motu, with input from Infometrics, to consider three land sector mitigation targets:

- Reference: with no additional emission-reduction mitigation targets over and above the existing NZ ETS;
- Low-ambition target: 15% net emissions reduction by 2030; 25% by 2050; and
- High-ambition target: 30% net emissions reduction by 2030; 50% by 2050.

The following land-use change scenarios were assessed, using the Land Use in Rural New Zealand (LURNZ) model:

- A. Reference: No expansion of horticulture and no increase in on-farm mitigation, with reductions achieved through increase in forestry;
- B. Growing horticulture: 20% expansion of horticultural land by 2030, and 40% by 2050, and no increase in on-farm mitigation, with reductions achieved through increase in forestry;
- C. Horticultural transformation: 100% expansion of horticultural land (500,000 ha.) by 2030, and 200% (1 million ha.) by 2050, with remaining reductions achieved through increase in forestry;
- D. Mitigation technology breakthrough in 2030: Reduces dairy emissions by 30%, sheep and beef by 20%, with remaining reductions achieved through increase in forestry.

How did the modelling work?

Three economic models were used in this analysis. Land-use change projections were created using the LURNZ model and the New Zealand Forestry and Agricultural Regional Model (NZFARM). The outputs were then used in a Computable General Equilibrium (CGE) model called ESSAM to estimate wider economic impacts.

In the case of the NZFARM modelling, land-use changes towards arable and horticulture are driven from within the model. With the LURNZ modelling, it is assumed there will be more horticulture, without modelling what caused it.

Both the LURNZ and NZFARM land-use models adopt a common reference scenario for land-use patterns in future years. They then shift land uses from high-emission uses towards lower-emission uses in a way that optimises profit, until the target is met. Both share a common reference case for land use in 2012, 2030 and 2050.

Caveat

Reading these results requires careful interpretation and caution. While the scenarios used in the modelling of the low- and high-ambition targets are possible, they are not necessarily expected or guaranteed. Nor should they be used to drive policy, as many other land-use pathways are equally plausible.

For example, the combined footprint of cropping, vegetables, orchards and viticulture is currently approximately 500,000 ha. and the combined area of orchards and viticulture is currently approximately 80,000 ha. In the Motu modelling, the expansion of horticulture was assumed to relate to the expansion of orchards and viticulture. The modelled high-horticulture scenario at 1 million ha. represents a 200% increase in the combined horticulture and arable area, but a 1,150% increase in the area of orchards and viticulture, if this land use alone provides for the expansion. Regulatory, market, institutional, and behavioural barriers are likely to hinder expansion of this magnitude.

Furthermore, the analysis does not provide insight into who should bear the costs of any changes in land use to meet such targets.

Key findings

In the case of both high- and low-ambition targets, achieving desired reductions by 2030 is harder to achieve than those for 2050. This is because the rate of emission reduction required is much faster between 2018 and 2030, than that between 2030 and 2050.

A larger incentive is therefore needed to drive enough forestry conversions to meet the 2030 target than the 2050 target. Accordingly, for the high-ambition target of a 30% reduction in emissions by 2030 and 50% by 2050, the carbon price for the 2030 target ($80/tonne) is higher than the 2050 target ($62/tonne). This falls to $50/tonne in the breakthrough methane mitigation technology scenario and the high horticulture scenario (as fewer emissions are generated).

Modelled land-use change and emissions reductions

Both models require a large increase in forestry planting rates to meet the targets in all scenarios:

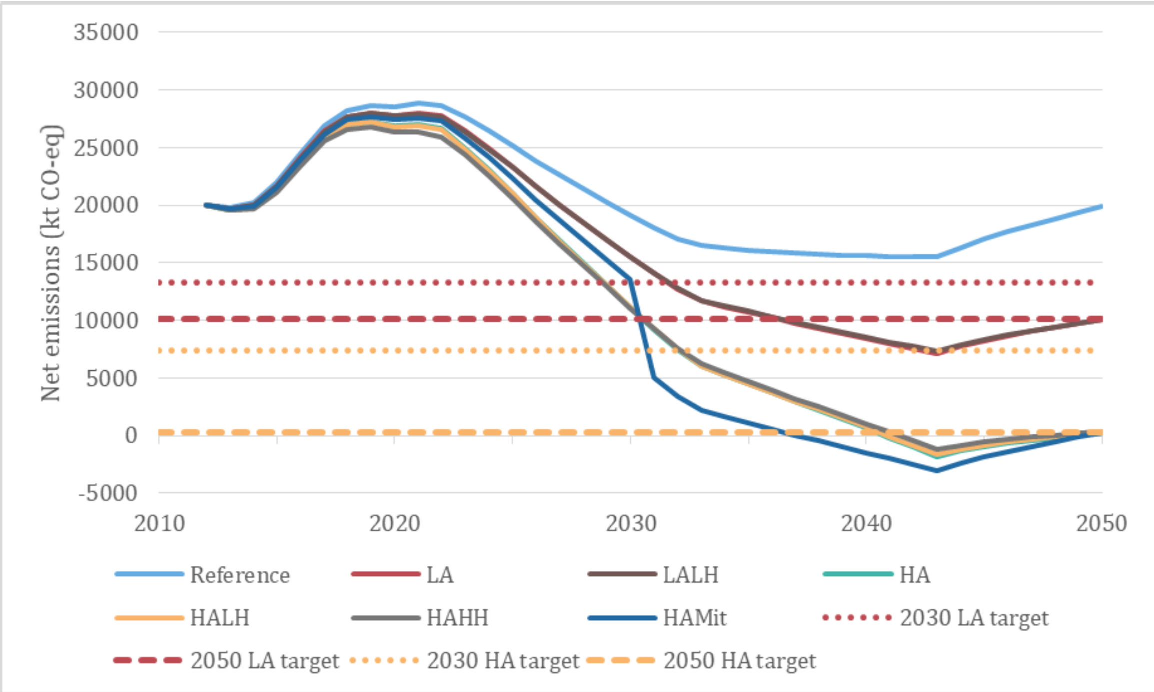
- Under LURNZ, the high-ambition scenario requires planting rates to double by 2050, compared to the reference scenario (29,000 ha. versus 58,000 ha.). Under NZFARM, planting increases by 39%.
- When the LURNZ model is applied to scenarios, the increase in forest area is lowered significantly where there is a large expansion in horticulture, or a new livestock mitigation technology becomes available. The land that changes use in scenario D is quite different to that under the NZFARM model, which leads to quite different implications for dairy, relative to sheep and beef.
- When the LURNZ model is applied to scenarios, higher levels of horticulture expansion early on result in a lower emission price. This results in less land-use change to forestry. The overall result is fewer biological emissions and less forest sequestration.

Scrub decreases in scenario C because roughly half of new-planted forest area will come from scrub. Using the LURNZ model, scrub emissions show essentially the inverse pattern to forestry emissions, but the emissions do not reverse as plantation forests begin to be harvested. This contributes to the increase in net land-sector emissions that begins in the mid-2040s.

Both models show that the area used for sheep and beef farming declines compared with scenario A, but at a marginally higher rate relative to 2002-2012. This is driven by lower net revenue from sheep and beef land compared to dairy (and horticultural land uses in NZFARM). This land is therefore more readily converted to forestry, especially marginal or less productive sheep and beef land. Under LURNZ, the larger horticultural expansion leads to a disproportionate reduction in emissions relative to the other changes. A likely explanation is that horticultural expansion occurs on areas of high class and versatile land of good quality, which is currently used for intensive sheep and beef farming.

In the NZFARM model, the dairy area declines relative to the reference case (scenario A), with some conversion to horticulture. Emissions from dairy only reduce compared to 2012 levels in one case: where the high-ambition, high horticulture targets are applied. Introduction of a methane vaccine (scenario D) has a dramatic effect on the sector as it is assumed that it will be taken up by 100% of ruminant livestock at the same time. In reality, the uptake is unlikely to be this rapid or widespread. (Methane vaccine costings have not been included in the analysis.)

Figure 8: Net additional land sector emissions across all scenarios, compared to all targets



Impact on GDP

- The NZFARM model shows small impacts on New Zealand's net revenue. Losses in the dairy, sheep and beef sectors are mostly offset by increased revenue from forestry and, to a lesser extent, horticulture.
- The CGE results suggest a small positive effect on the economy. This increase largely results from a change in the terms of trade as New Zealand moves towards the more profitable horticultural sector by expanding international markets.
- Importantly, the report notes that for these results to occur, there must be a market for the new mix of products at prices that achieve a similar level of current profitability. It also points out that significant changes in training, community demographics, and local infrastructure are also required to enable large shifts towards horticulture.

Output

- Where the high-ambition targets are applied to scenario C, gross output for horticulture and arable crops expands by 212%, while it declines for sheep and beef, and dairy (13% and 28% respectively). These changes are smaller in other scenarios as the shift to more horticulture is less marked.

Employment

Overall it appears that the issue is not about total employment, but rather a training, retraining, and education issue.

- In scenario A, total employment in the agricultural sectors in 2050 is 86,500 full-time equivalents. This jumps to 136,900 full-time equivalents in the high-ambition, high-horticulture scenario. This represents a significant increase, one that will be difficult to achieve without an equivalent rise in the pool of suitable labour. It is therefore unlikely to occur without significant investment or policy change.

- Employment losses in pastoral agriculture may be more than offset by the projected expansion in horticulture. The fact that seasonal work represents a major proportion of horticultural employment means rapid expansion would bring its own challenges. In short, a change of this magnitude brings significant social impact(s).

Profitability

Under all mitigation scenarios, the NZFARM model shows that the reduction in net land-use revenues in the pastoral sector is mostly offset by the increase in net revenue from horticulture and forestry.

Social and local community impacts

The analysis suggests:

- Large employment and migration effects can be more heavily felt and have permanent effects in some of New Zealand's isolated communities; and
- Positive shocks (such as an expansion of horticulture), with resulting higher land values and employment demand, can also create significant changes within communities.

Assessing the nationwide economic impacts of farm-level biological emission mitigation options

Purpose

Farmers face a range of complex choices when considering options to reduce on-farm emissions, and the possible impacts these may have on profitability. The aim of this modelling is to determine whether on-farm emission reduction could achieve reduction targets without land-use change, and the influence of the NZ ETS price on the uptake of on-farm mitigation.

Approach

The BERG commissioned Manaaki Whenua - Landcare Research, with input from Infometrics, to:

- Assess the adoption of mitigation actions under different emission prices, and what barriers may prevent their adoption;
- Estimate the mitigation potential of the various options;
- Estimate the subsequent economic impacts, such as changes in profitability; and
- Estimate the wider national impacts on gross domestic product (GDP), terms of trade, employment, and real gross national disposable income.

A mixture of quantitative (economic modelling) and qualitative analysis was used. The following economic models were used:

- NZFARM: this simulated the uptake of different mitigation options, and the impacts on profitability under different emission prices.
- ESSAM: the results from NZFARM were fed into this model to simulate the wider, macroeconomic impacts.

Manaaki Whenua - Landcare Research also used Dairy New Zealand and Reisenger et al. (2018) estimates of mitigations on dairy, sheep and beef farms, calculated using Farmax and Overseer respectively.

A qualitative ecosystem services assessment was used to consider the possible environmental co-benefits or costs that weren't captured by modelling.

Key assumptions

The BERG agreed with the assumptions used here by Manaaki Whenua - Landcare Research. This includes the following emission prices set for 2030 and 2050, for four different scenarios (table 7).

Table 7: Four scenarios of prices for greenhouse gas emissions produced on farms, for 2012, 2030 and 2050.

Years	Carbon sequestration reward $/t CO_2	GHG price scenarios for on-farm emissions			
		GHG1 $/t CO_2	GHG2 $/t CO_2	GHG3 $/t CO_2	GHG4 $/t CO_2
2012	$5.00	$15.00	$25.00	$50.00	$100.00
2030	$26.26	$20.25	$33.75	$67.5	$135.00
2050	$37.35	$28.73	$47.88	$96.77	$191.54

The BERG and Manaaki Whenua - Landcare Research also agreed which currently available mitigation options would be used in the analysis. Mitigation options for dairy included:

Output approach: reducing greenhouse gas emissions that includes a combination of changes in use of fertiliser and supplementary feed, and change in stocking rate;

- Reducing different inputs (feed and nitrogen fertiliser);
- Reducing stocking rate;
- Changing to once-a-day milking; and
- Planting forestry on-farm.

In the case of dairy, two separate modelling runs were carried out:

- Analysis I: assessing the impacts of both reducing stocking rate and maintaining milk production per cow; and
- Analysis II: assessing reducing stocking rate and increasing milk production per cow.

Each mitigation option had various levels of stock reductions: 5%, 10%, 15%, and 20%.

Mitigation actions modelled for sheep and beef farms were:

- Reduce stocking rate and maintain productivity;
- Replace breeding cows with surplus dairy animals; and
- On-farm forestry planting.

Caveats

Because the report is based on modelled assumptions, the BERG advises it should be read with caution. A number of caveats are raised.

1. Many of the scenarios describe a complex future. Wide-scale adoption of the mitigation practices considered will require considerable time and effort to improve on-farm capability (including skills and infrastructure). The analysis does not quantify this effort.
2. The analysis did not consider land-use change as a mitigation option, except for allowing up to 20% of pastoral land to be planted in forestry, with the amount converted depending on the price of emissions. (The implications of changing land use to mitigate emissions is separately considered).
3. The analysis assumes that even if farms become unprofitable due to prolonged periods of negative or low profits, farmers continue to operate and do not shift to another land use. This is not uncommon in the sector, although clearly continued financial losses are not sustainable. In reality, when faced with high emission prices, dairy, sheep and beef farmers may consider either changing land use or exiting the industry, rather than adopting unprofitable mitigation options.
4. Different emission prices were used for rewarding carbon sequestration from forestry, compared to the prices applied to agricultural greenhouse gas emissions.
5. Finally, as this analysis extends to 2050, there is inevitable uncertainty associated with future commodity prices, levels of productivity, changes in farmer behaviour, and their decisions and adoption of mitigation options. As timeframes move further from the present, the certainty of the modelling reduces.

Key findings

Predicting adoption of mitigation options and flow-on effects

In general, the modelling suggests farmers will adopt several mitigation options when emissions are priced, and the rate of adoption increases with higher prices. At higher prices, the adoption of some dairy mitigation options increase, such as reduced fertiliser use, change in supplementary feed use, and reduced stocking rate.

Where only on-farm mitigation options are available, none of the scenarios can achieve the high-ambition emission target of 30% at 2030, and 50% at 2050. The model achieves the low-ambition target of 15% at 2030 and 25% at 2050, but with significant reduction in farm profits.

For dairy

Analysis I shows that, in order to maximise profits, the dairy sector will adopt a range of different mitigation options to reduce the costs of pricing biological emissions.

In Analysis II, on the other hand, the predominant mitigation option taken up is reducing cow numbers and increasing milk production per cow. This option has a smaller impact on profits compared to others. Caveat #1 must, however, be applied here: capability barriers may prevent the widespread adoption of mitigation options that increase productivity. The analysis doesn't quantify this.

Analysis II also shows some adoption of reducing inputs, once-a-day milking and the partial planting of forestry.

For sheep and beef

For the sheep and beef sector, most emission reductions are already achieved at low prices. At all emission prices in both 2030 and 2050, planting forestry is the most commonly adopted mitigation option, followed by reducing stocking rates (while maintaining production), and removing breeding cows.

Although removing breeding cows is more profitable than other options, there is little opportunity for large increases in its use as the removal of breeding cows has already largely occurred.

Mitigation potential

Across the sector, biological emissions reduced as follows, depending on the emission prices modelled:

- Analysis I: from 12% – 20% in 2030, and 12% – 25% in 2050.
- Analysis II: from 19% – 24% in 2030, and 19% – 26% in 2050.

For dairy

The impacts from the dairy sector reduced as follows, depending on prices modelled:

- Analysis I: from 1% – 9% in 2030, and 2% – 15% in 2050.
- Analysis II: from 18% – 19% in both 2030 and 2050.

The greater mitigation potential in Analysis II comes from the greater adoption of options overall, in particular the large uptake of reducing cow numbers while maintaining profitability.

For sheep and beef

The corresponding reduction in emissions from the sheep and beef sector is 21% – 29% in 2030, and 20% – 34% in 2050, depending on the emission prices.

Impact on profits

Across the sector, profits reduced as follows, depending on the greenhouse gas prices modelled:

- Analysis I: from 6% – 47% in 2030, and from 8% – 61% in 2050.
- Analysis II: from 5% – 44% in 2030, and from 7% – 57% in 2050.

The analysis shows marked decreases in profits when the greenhouse gas price is modelled as higher but the available mitigation options do not increase the profitability of the livestock sectors.

However, caveat #3 must be applied here. In reality we can expect that when faced with such high emission prices, dairy, sheep and beef farmers may consider changing land use rather than adopting mitigation options that are not profitable.

For dairy

In Analysis I, depending on the price of emissions, profits decreased between 9% and 70% in 2030, and 14% and 98% in 2050.

The impacts on profits are not as pronounced in Analysis II, with profits decreasing between 7% and 59% in 2030, and 11% and 84% in 2050, depending on the price of emissions. This difference in profitability is again driven by the large uptake of the mitigation option that reduces cow numbers while increasing per-cow milk production.

For sheep and beef

Modelling shows sheep and beef sector profits decreased between 9% and 89% in 2030, and between 15% and 123% in 2050, as emissions prices increased. As with the dairy sector, the reduction in profits as the prices increase comes from the low profitability (or even losses) of some types of sheep and beef farm systems in certain areas. Once again, caveat #3 applies: farmers may change land uses or exit the industry during prolonged periods of negative or low profits. The analysis did not consider this option.

Macroeconomic impacts

The analysis considered the macroeconomic effects on the wider economy of the lowest and highest emissions prices in 2050, for both Analysis I and II. The key results for Analysis I are shown in table 8.

Table 8: Macroeconomic effects in 2050 of the lowest and highest emissions prices, as modelled for Analysis I

Indicators	GHG1 (\$28.73/tonne CO_2)	GHG4 (\$191.54/tonne CO_2)
	% change on associated reference case	
Emissions price	**\$28.73**	**\$191.54**
Private consumption	0.0%	0.4%
Exports	–0.5%	–2.3%
Imports	–0.1%	–0.3%
GDP	–0.1%	–0.2%
RGNDI[28]	0.0%	0.3%
Terms of trade	**0.4%**	**2.0%**
Real wage rate	**–0.2%**	**–1.0%**
	CO_2e (Mt)	
Gross emissions	–5.2	–15.1
Agricultural CH_4 & N_2O	–5.1	–12.5

In 2050, under the lowest emission price only minor macroeconomic effects are projected to occur.

The modelling also considered the possible impacts on gross output and employment in 2050. The key results are shown in table 8. The output of all agricultural sectors contracts as a result of emissions being priced. Employment decreases in all pastoral agriculture sectors, especially under the highest emission price in 2050. In contrast, the forestry industry experiences modest growth.

Table 9: Changes in gross output and employment in agriculture and forestry in 2050, relative to the reference case for Analysis I

Land uses	% change on respective reference case			
	GHG1 (\$28.73/tonne CO_2)		GHG4 (\$191.54/tonne CO_2)	
	Output	Employment	Output	Employment
Horticulture	–0.9%	–0.7%	–4.9%	–4.2%
Sheep and beef	–2.5%	–1.9%	–12.7%	–10.4%
Dairy	–1.8%	–1.6%	–9.2%	–8.4%
Other farming	–1.3%	–1.0%	–6.9%	–5.7%
Forestry	0.2%	0.4%	1.6%	1.9%

4.5 Possible costs and barriers of potential policy options

What are the administrative costs and barriers of potential policy options to reduce biological emissions from agriculture?

Purpose

This assessment estimates the administration costs for a number of hypothetical policy scenarios, as well as any barriers to their implementation and management.

Approach

Beca Group considered the costs and barriers of the following hypothetical policy scenarios:

- Price-based scenarios:
  - Emissions trading obligations for biological emissions: 'Processor point of obligation';
  - Emissions trading obligations for biological emissions: 'On-farm point of obligation'; and
  - Price based incentives: 'Payment for low emissions technologies'.
- Non-price-based scenarios:
  - Regulated biological emission limits (for example, biological emissions per ha. limit).
  - Regulated use of emission mitigation technologies (for example, compulsory use of methanogen vaccine).
  - Government-industry agreement in which agricultural sector organisations support farmers to undertake biological emission reduction activities.

Assessing the merits of the different scenarios was out of scope because the BERG does not have a mandate to provide policy recommendations.

This assessment was founded on engagement with government and agricultural sector stakeholders, supported by desktop research. A workshop identified the scenarios for assessment.

Caveats

Beca Group's estimate of the administration costs associated with each option includes the costs of organisations implementing or complying with each scenario, but does not include costs related to undertaking mitigation activities.

Beca Group's analysis was based on the current version of Overseer. Overseer's new product OverseerFM will likely help reduce the costs and barriers outlined here.

Key findings

Table 10 below shows Beca Group's estimate of the range of annual administration costs of the scenarios assessed, based on a sensitivity analysis.

Table 10: Estimated range of annual administration costs for each scenario

	Processor point of obligation	On-farm point of obligation	Payments for low-emissions teechnologies	Regulated biological emissions limits	Regulated use of mitigation technologies or practices	Government industry agreement
Low cost scenario	*No change*	$16,000,000	*No change*	$11,000,000	*No change*	*No change*
Central scenario	$2,700,000	$39,000,000	$3,600,000	$15,000,000	$1,300,000	$6,900,000
High cost scenario	*No change*	$61,000,000	*No change*	$32,000,000	*No change*	$16,000,000

The four key cost drivers were:

- Cost of engaging a certified nutrient management advisor, to support modelling of on-farm biological emissions;
- Brokerage costs if a point of obligation under the NZ ETS is at the farm level;
- Government administration costs of an on-farm point of obligation; and
- Costs associated with developing a Farm Environment Plan, if required.

The analysis concluded the sector will bear 78% of annual administration costs of agriculture being in the NZ ETS at an on-farm point of obligation. However, costs can be reduced significantly if ways can be found to:

- Allow farmers to estimate on-farm biological emissions without needing to engage a certified nutrient management advisor; and
- Reduce the brokerage fees farmers face in purchasing NZ ETS units.

Implementing each scenario delivers a range of potential barriers and limitations. Individually, each of these barriers can likely be overcome through Government or agricultural sector programmes or investment. No barriers were identified to prevent any scenario from being implemented.

An on-farm point-of-obligation scenario is likely to face the highest number of barriers to implementation. Beca Group estimated this scenario will likely require 50–100 extra certified nutrient management advisors than are currently employed by rural consultancies.

Part 5: Concluding Remarks

Concluding remarks

Before 2016, conversations about what mitigations are available to farmers were missing context and data. In response we formed this group and agreed on an approach to develop a robust evidence base.

Our terms of reference intentionally excluded developing policy advice or recommendations. We wanted to provide analysis, without bias, to inform future decisions and actions.

We believe we have achieved our objectives:

- We strengthened relationships between our primary sector leaders and government;
- We increased our understanding of biological emissions and how they can be reduced; and
- We clarified the biggest (known) opportunities, costs, and barriers.

Through this work the BERG members have developed positive working relationships, and enhanced our individual and collective understanding of each sector's priorities, goals, and challenges. This will support constructive policy discussions going forward.

One key outtake from the work is that farmers expect to contribute to New Zealand's emissions targets, but most are not aware of the greenhouse gas emissions profile of their farms, nor what mitigation options they can adopt (apart from on-farm forestry).

It's also fair to assume we can expect our primary production systems will see significant change over the next 10 to 30 years, including ongoing diversification in land use. This itself is not new – New Zealand has seen major changes in land use in the past.

Informing wider work on climate change

The agricultural sector members of BERG have already used this evidence base in their respective work on climate change, such as the Dairy Action for Climate Change.

MPI and MfE officials have used this analysis to inform their advice to Ministers on how biological emissions could be treated in a 2050 emissions target. It is also feeding into other MPI and MfE work on sustainable land use, and future research and development funding.

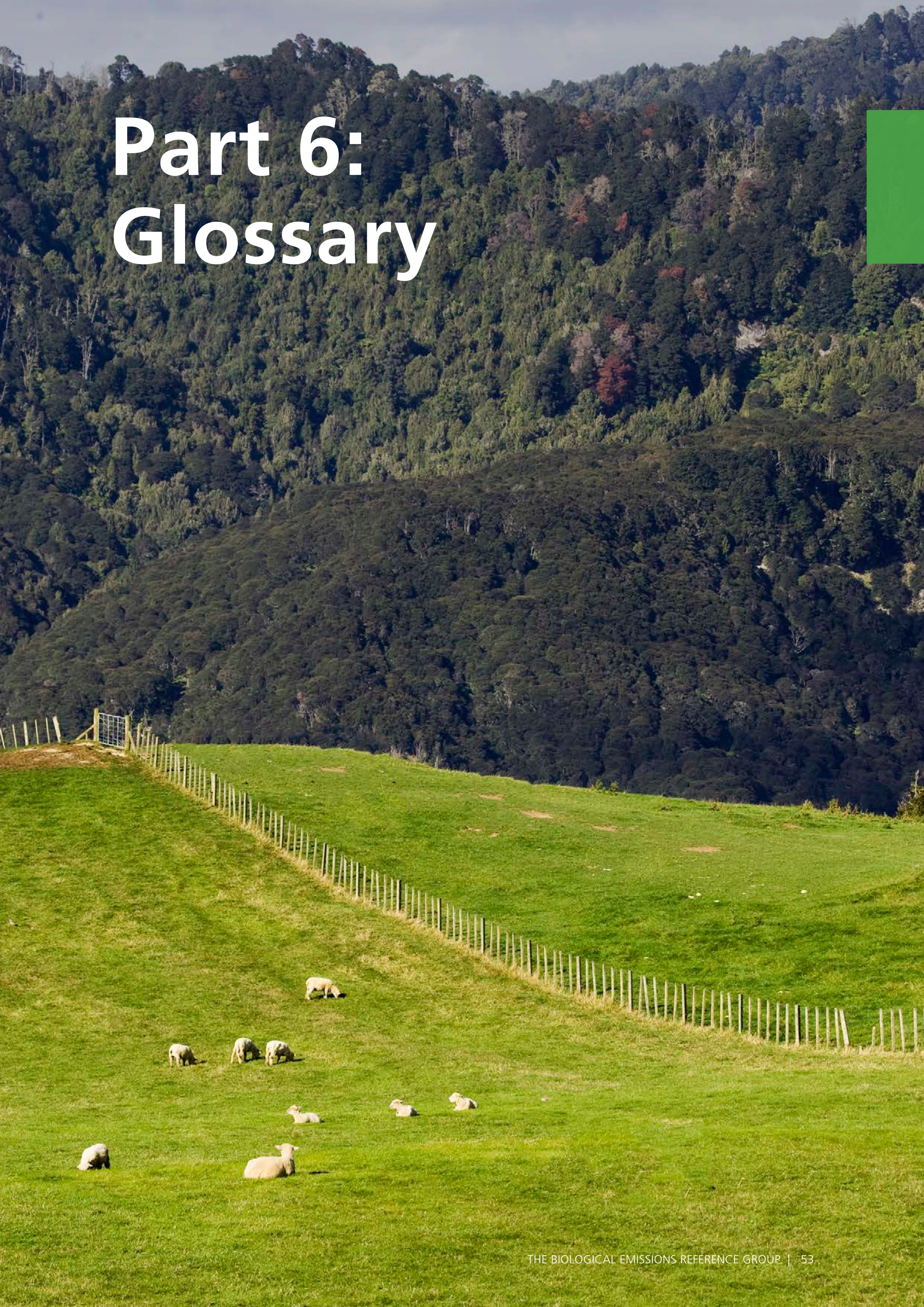
With BERG's permission, some of the analysis we commissioned has already been cited in the public domain, including by the Productivity Commission and the Chief Science Advisor to the Prime Minister.

Where to from here?

Overall, the findings from the analyses tell us that essentially, we need to continue to improve our farming practices to maintain our status among the most trusted food producers in the world.

The government and the agricultural sectors can create the conditions for this to happen by continuing to work together, supporting opportunities for fast gains in on-farm emission management, reducing the barriers to improving land management and land-use diversification, and ensuring our farmers have the information they need to make the best decisions for themselves, their communities and our environment.

Part 6: Glossary



Glossary

Agricultural emissions	*Greenhouse gas* emissions associated with agricultural production. Mostly represented by methane and nitrous oxide emissions from livestock, manure management, fertiliser use, and emissions from cropping activities and liming. It excludes fuel, energy, industrial and processor emissions associated with agriculture, as these are captured elsewhere.
Agriculture sector	Components of the primary industries such as livestock production (cattle, sheep, deer, goats, pigs and poultry) and horticulture (including vegetable production, orchards, viticulture and arable cropping). Excludes forestry, fisheries, and aquaculture.
Baseline projection	How the state of something (for example the economy) is expected to develop if existing trends are maintained. It provides a guide for expected change in the absence of any policy changes and allows modellers to then consider the divergence from this baseline if certain policies are implemented.
Biogenic methane	Methane which is produced by methanogen bacteria decomposing organic matter under low-oxygen conditions, such as the gut of ruminant animals (such as cows and sheep).
Biological emissions	Methane, nitrous oxide, and carbon dioxide emissions from biological systems used in primary production.
Carbon cycle	The natural and anthropogenic flow of carbon in its various forms (for example, as carbon dioxide) through the atmosphere, land, ocean, vegetation, and organisms and industrial processes.
Carbon sequestration	The natural or artificial process by which carbon dioxide is removed from the atmosphere and held long-term in a solid or liquid form (for example by trees or the ocean), and in certain cases can be used to offset carbon dioxide emissions from anthropogenic activities. Sometimes called a *carbon sink*.
Computable general equilibrium (CGE) model	A class of economic model that uses actual economic data to estimate how an economy might react to changes in external factors, such as policies or technology.
Carbon dioxide (CO_2)	A naturally occurring atmospheric gas consisting of a carbon atom bonded to two oxygen atoms. It is primarily produced by respiration, geological processes, as well as through the combustion of wood and fossil fuels. It is also considered the main *greenhouse gas* responsible for driving anthropogenic climate change, due to the combination of its longevity (lasting hundreds to thousands of years), effectiveness at trapping heat, and significant increase in concentration in the atmosphere since the mid-1700s.
Carbon dioxide equivalent (CO_2e)	A unit of measure commonly used to compare different *greenhouse gases* by taking into consideration their warming effect on the atmosphere relative to carbon dioxide.
Dry matter intake (DMI)	The weight of feed material consumed by livestock per day, excluding the moisture it contains.
Emission factor	A value used to transform data on activities that cause *greenhouse gas* emissions (such as using fuel) into estimates of actual emissions. For example multiplying a known quantity of fuel by a specific fuel 'emission factor' provides an estimate of the actual greenhouse gas emissions that using that amount of fuel would cause.
ESSAM	A type of computable general equilibrium (CGE) model. (see above)

FARMAX	A farm planning, budgeting, and decision-support tool that enables farmers to test the commercial and biological feasibility of different land-use scenarios.
Greenhouse gas (GHG)	A generic term for a gas which is effective at trapping heat that has been radiated from the Earth's surface. The major greenhouse gases are water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Each of these differ in their lifespan, warming effect, and concentration in the atmosphere.
Kyoto Protocol	An international treaty adopted in 1997 and entered into force in 2005, which legally binds those Parties that ratified it to reduce global greenhouse gas emissions, and provides a framework for emissions trading. It is a subsidiary agreement under the United Nations Framework Convention on Climate Change. The first commitment period covered 2008-2012, with the second covering 2013-2020. New Zealand's 2020 target is to reduce emissions by 5% below 1990 levels.
LURNZ model	Land use in rural New Zealand (LURNZ) is a model that simulates land-use changes. The model produces dynamic paths of rural land-use change, at a scale of 500m x 500m and maps of annual rural land use change across New Zealand.
Metabolisable energy	A measure of the energy value in feed of livestock, calculated as the amount of mega joules of metabolisable energy per kilogram of dry matter (MJ ME/kg DM).
Methane (CH_4)	An atmospheric gas consisting of a carbon atom bonded to four hydrogen atoms. It is short-lived, with a lifespan of about 12 years, but is 25 times more powerful than carbon dioxide at warming the atmosphere over a 100-year period. In New Zealand, most methane comes from belching by ruminant animals: sheep, cattle, and deer, and some from animal manure.
Methanogen	A microorganism that produces methane. Methanogens are found in the rumen of ruminant animals.
Methane inhibitors	Chemical substances which have the potential to supress methane production in the rumen by targeting specific enzymes utilised by methanogens for fundamental metabolic processes.
Methane vaccine	A substance that is currently in development. If developed, the vaccine would function by using antibodies to suppress methanogens in the rumen. This would reduce a ruminant's methane emissions.
Megatonne (Mt)	A unit of mass equal to 1,000,000 metric tons or 1,000,000,000 kilograms.
National Greenhouse Gas Inventory	New Zealand's official annual estimate of human-generated greenhouse gas emissions and removals that have occurred in New Zealand since 1990. The Inventory measures our progress against obligations under the United Nations Framework Convention on Climate Change agreement.
New Zealand Emissions Trading Scheme (NZ ETS)	The Government's main tool for reducing greenhouse gas emissions. It places a price on emissions from all sectors of the economy (except biological emissions from agriculture) in order to create a financial incentive for businesses to invest in technologies and practices that reduce emissions. It also encourages forest planting by allowing eligible foresters to earn emissions units as their trees grow and absorb carbon dioxide.
New Zealand Forestry and Agricultural Regional Model (NZFARM)	NZFARM is a comparative-static, partial equilibrium model of regional New Zealand land use that maximises rural income across a catchment, accounting for the environmental impacts of land use and land-use changes.

Nitrification inhibitor	A chemical compound which slows microbial activity of bacteria in the soil that convert ammonium-nitrogen to nitrate-nitrogen. It reduces loss of nitrous oxide to the atmosphere and nitrate leaching.
Nitrous oxide (N_2O)	An atmospheric gas consisting of two nitrogen atoms bonded to an oxygen atom. It is long-lived, with a lifespan of about 120 years, and 298 times more powerful than carbon dioxide at warming the atmosphere over a 100-year period. In New Zealand, most nitrous oxide is produced by the action of soil bacteria in urine patches from livestock. Smaller amounts come from dung deposited during grazing, stored manures spread back onto pasture, and from nitrogen fertiliser.
OVERSEER® Nutrient Budgets	OVERSEER is a farm-management decision-support tool which uses estimates of nutrient inputs to model nutrient outputs, as long-term annual averages. It can be used to estimate the impact of changes under different management scenarios, including emissions and options to mitigate them. OVERSEER Nutrient Budgets will be decommissioned in June 2019.
OverseerFM	OverseerFM is the new web-based software that was released in June 2018. It provides a more user-friendly interface and central data system that has significantly increased the efficiency in undertaking farm analysis.
Paris Agreement	A global agreement to take action on climate change, adopted by state parties in 2015 and entered into force in 2016, under the United Nations Framework Convention on Climate Change. The purpose is to keep the global average temperature well below 2°C above pre-industrial levels, strengthen the ability of countries to deal with the impacts of climate change, and make sure that financial flows support the development of low-carbon and climate-resilient economies. The commitment period covers 2021-2030. New Zealand's 2030 target is to reduce emissions by 30% below 2005 levels (equivalent to 11% below 1990 levels).
Riparian strips	Vegetated strip of land along the margins of a waterway including streams, lakes, and wetlands. They provide a buffer from some of the effects of surrounding land-use.
Rumen	The rumen forms the first chamber in the alimentary canal of ruminant animals. It serves as the primary site for microbial fermentation of ingested feed. Ruminant animals include sheep, cattle, goats and deer.
Unitary authorities	Local council authorities which also have the powers, duties and responsibilities of a regional council.
United Nations Framework Convention on Climate Change (UNFCCC)	An international treaty adopted in 1992 with the primary objective to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The state parties meet formally at the annual Conferences of the Parties to assess progress in dealing with climate change, and to negotiate emission-reduction targets through subsidiary protocols or agreements.
Urease inhibitor	Compounds added to urea or urea-containing fertilisers that can slow their conversion to ammonium, by blocking the activity of the enzyme urease.