REDUCING NEW ZEALAND'S AGRICULTURAL GREENHOUSE GASES:

WHAT WE ARE DOING

EDITION 2: AUGUST 2016

NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

PGgRc PASTORAL GREENHOUSE GAS RESEARCH CONSORTIUM

WORKING TOGETHER

CURRENT SITUATION

Farming is becoming more efficient and emissions per unit of product are falling but absolute emissions remain above 1990 levels.

New Zealand is unusual among developed countries, with its strong agricultural base and a high proportion of its electricity generation coming from renewables. As a result, agriculture is the largest contributing sector to New Zealand's greenhouse gas emissions (49%[1] in 2014, compared with an OECD average of about 12%). On a global scale, however, this country's total emissions are small: New Zealand produces less than 0.2% of total global greenhouse gas emissions, and about 0.6% of total global agriculture emissions.

New Zealand farmers are already part of the solution to limit climate change. On average, greenhouse gas emissions per unit of meat or milk on farm produced have dropped by about 1% per year for at least the past 20 years. In technical terms, the 'emissions intensity' (emissions per unit of product) has decreased, because farming has become more efficient. Improved animal genetics and management, combined with better grassland management and feeding practices mean that farms are using resources more efficiently to increase their outputs.

However, New Zealand's total agricultural greenhouse gas emissions have increased, by about 15% in 2014 relative to 1990 levels, because overall agricultural production has grown substantially in response to international demand. Yet without efficiency improvements, total greenhouse gas emissions from agriculture would have increased by almost 40% over this period to deliver the same amount of product.

These changes in overall production and efficiency have not always occurred smoothly. For example, during the severe droughts of 2006-2009, total agricultural emissions fell as farmers culled breeding stock, particularly in the sheep sector, and production per animal was reduced.

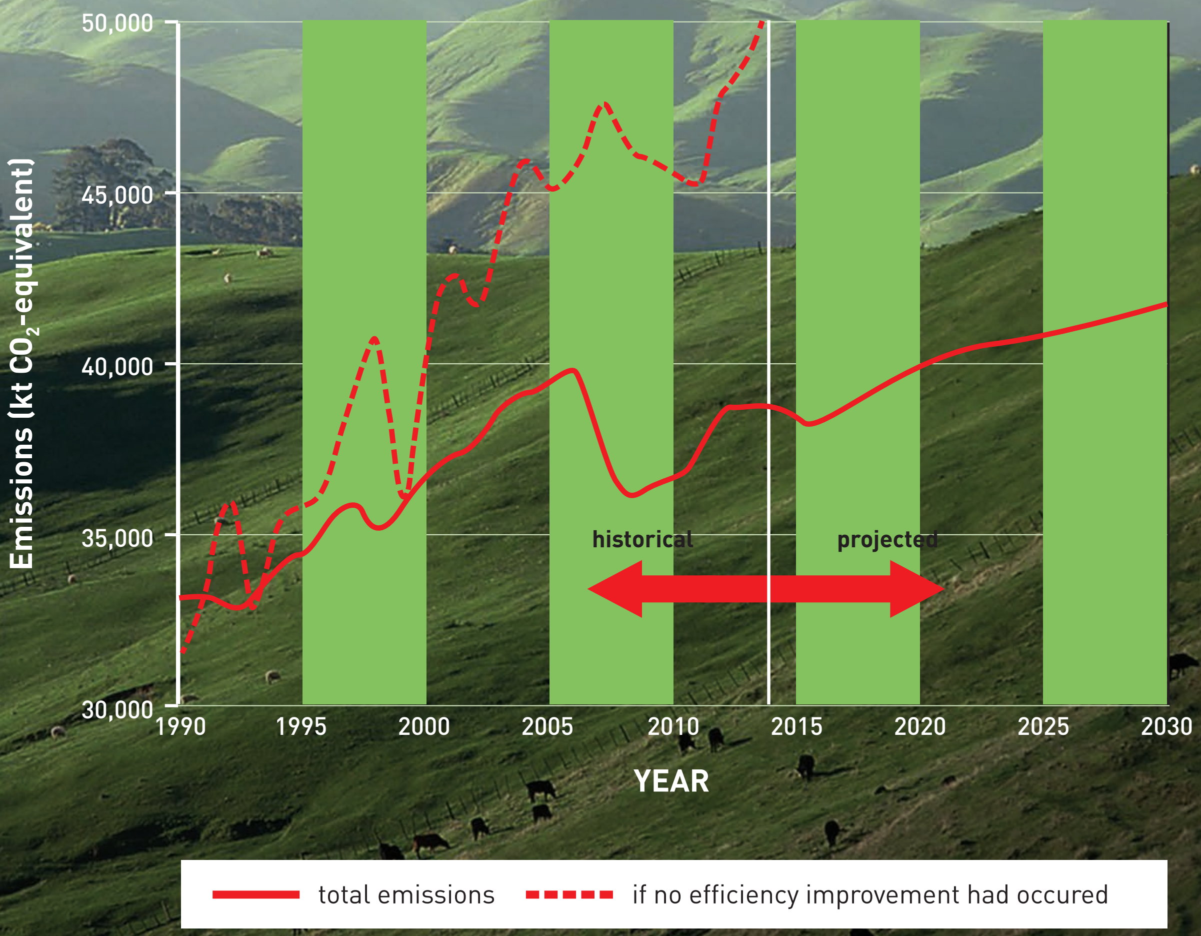
[1]Emissions of methane and nitrous oxide, the most important greenhouse gases from agriculture, are expressed in CO_2-equivalents (CO_2-eq), usually by the kilotonne (kt). These are obtained by multiplying emissions with the Global Warming Potential, which reflects the total warming effect of an emission over the next 100 years. Specific values used in this fact sheet are those used in international reporting 2013-2020.

CURRENT SITUATION

Historical and projected future greenhouse gas emissions from agriculture in New Zealand.

The following graph provides an overview of New Zealand's actual and projected agricultural greenhouse gas emissions from 1990 to 2030.

The solid red line shows greenhouse gas emissions from agriculture in the past (1990-2014) and projected for the future, including changes in production and on-farm efficiency gains. The dotted red line shows where emissions would have been in 1990-2014 if farmers had increased their production but had not made any efficiency gains.



Sources: New Zealand's Greenhouse Gas Inventory 1990-2014[2] and New Zealand's second biennial report under the United Nations Framework Convention on Climate Change[3]

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[2]www.mfe.govt.nz/publications/climate-change/new-zealand-greenhouse-gas-inventory-1990-2014
[3] www.mfe.govt.nz/publications/climate-change/nz-second-biennial-report-under-unfccc

TRENDS IN AGRICULTURE PRODUCTION AND EFFICIENCY

Collectively, dairy, beef and sheep generate more than 97% of all agricultural greenhouse gas emissions in New Zealand. Changes in emissions since 1990 are characterised by increasing dairy emissions, which more doubled during this period, falling sheep emissions, down more than 30%, and approximately constant beef emissions.

These trends in absolute emission reflect changes in animal numbers as well as changes in the production efficiency within each sector. They hold important clues as to how farmers can further reduce their emissions per unit of product.

DAIRY

In 1990, New Zealand had 3.44 million dairy cattle. By 2014, that number was 6.45 million, and total milk production almost tripled over this period. The efficiency of milk production increased through improved pasture management (including more targeted use of fertilizers and irrigation), increased use of supplements and continued improvement of genetic merit of animals. As a result, the average cow produced 256 kilograms of milk solids per year in 1990 but 364 kilograms in 2014. The more milk a cow produces, the more of the feed it consumes and emissions it generates goes directly towards milk production rather than simply maintaining the mature animal. As a result of this increasing productivity per animal, the average emissions per kg of milk solids produced in New Zealand dropped by about 19% between 1990 and 2014.

SHEEP

Sheep numbers dropped from 57.9 million in 1990 to 31.3 million in 2014, but New Zealand today produces almost as much lamb meat as in 1990. Improved pasture production, optimized stocking rates, increased hogget mating and increased genetic merit of sheep have resulted in higher lambing percentages and increased lamb weights at slaughter. As a result, far fewer ewes are need to produce the same amount of lamb meat every year, and the emissions intensity of lamb production was about 33% lower in 2014 than it was in 1990.

BEEF

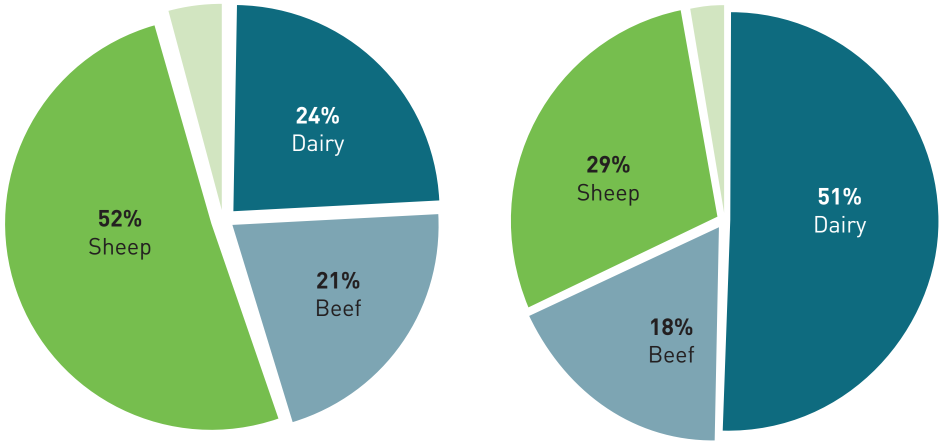
Beef cattle numbers also dropped, though less dramatically than sheep – from 4.59 million in 1990 to 3.73 million in 2014. Yet total beef production increased by almost 20%. This is because beef animals now gain weight faster due to better feeding and management of animals and better genetics, so they are heavier by the time of slaughter. In addition, farmers use fewer breeding beef cows, and more dairy-bred cattle and surplus culled cows to make up an increasing proportion of the beef produced. These efficiency gains[4] have reduced the emissions intensity of beef by about 23% from 1990 to 2014.

FERTILISER

Nitrogen-based fertiliser enhances pasture growth but also generates emissions of the powerful greenhouse gas nitrous oxide. Fertiliser use grew strongly from 1990 to about 2004, and has since grown more slowly as fertiliser application has become more targeted and efficient. Emissions due to fertiliser in this fact sheet are allocated to the dairy, beef, sheep sectors based on their estimated fertiliser use since definitive data are not available.

[4]In the New Zealand emissions inventory, emissions from culled dairy cattle used for meat production are counted towards dairy, not beef emissions. This accounting convention does not change overall emissions, but it does result in a relatively lower emissions intensity of beef production than if emissions from culled dairy animals were counted towards the beef sector.

TRENDS IN AGRICULTURE PRODUCTION AND EFFICIENCY

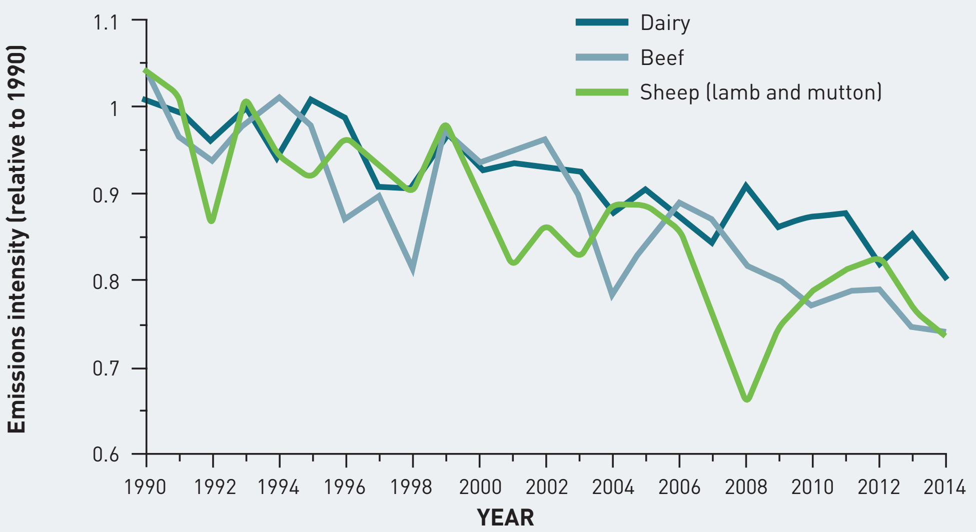


1990
Total: 34,351 kt CO_2-eq

2014
Total: 39,585 kt CO_2-eq

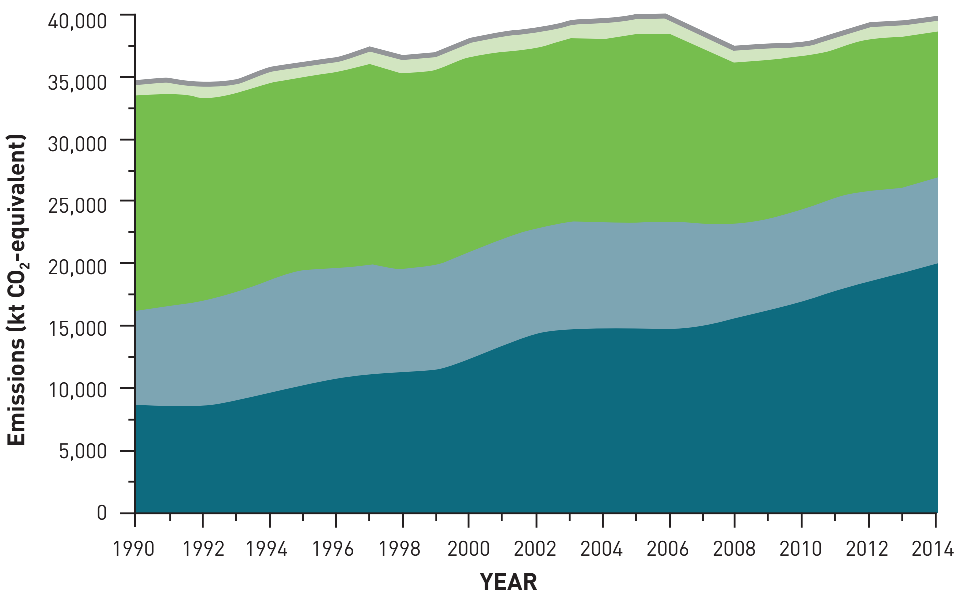
Relative contributions of key agricultural sectors to total agricultural emissions from 1990 to 2014[5].

Source: New Zealand's Greenhouse Gas Inventory 1990-2014.



New Zealand's agricultural greenhouse gases emissions intensity by agricultural sub-sector including nitrogen fertiliser use (1990-2014)[5].

Source: New Zealand's Greenhouse Gas Inventory 1990-2014.



New Zealand's total greenhouse gas emissions by agricultural sub-sector including nitrogen fertiliser use (1990-2014)[5].

- Dairy
- Beef
- Sheep (lamb and mutton)
- Other
- Total

Source: New Zealand's Greenhouse Gas Inventory 1990-2014.

[5]Fertiliser emissions are included in each sector based on estimated use.

FUTURE PROSPECTS FOR EMISSIONS TRENDS

One hundred and ninety two countries are party to the United Nations Framework Convention on Climate Change.

New Zealand has agreed to take responsibility for cutting its greenhouse gas emissions to an emissions target level 5% below 1990 levels by 2020, and set an intended target of 30% below 2005 levels by 2030 (approximately 11% below 1990 levels) subject to confirmation as part of a new global agreement on climate change. The government also gazetted a long-term aspirational target of reducing net emissions by 50% by the year 2050, relative to 1990 levels, or take responsibility for excess emissions.

As a responsible global citizen, and because our biological systems and economic interests benefit from a stable climate, New Zealand can be expected to contribute its fair share to the global effort to reduce greenhouse gas emissions and the risks from climate change. Retailers in high-value markets increasingly seek reassurance that producers are managing not only food safety but also their carbon footprint responsibly. Furthermore, actions to limit emissions often have other benefits, such as improved productivity or water quality.

At the moment, farmers can reduce their emissions intensity further by continuing to adopt good management practice and making additional efficiency gains as fast as possible. However, increasing total agriculture production has outpaced reductions in emissions intensity and this trend will likely continue, given current growth targets and rising global demand for livestock products.

Since most of New Zealand's agricultural greenhouse gas emissions are related to production for export, there is an argument about where New Zealand should focus its efforts: reducing absolute emissions (which is not possible at present without limiting total production), or reducing emissions intensity without constraining production and absolute emissions.

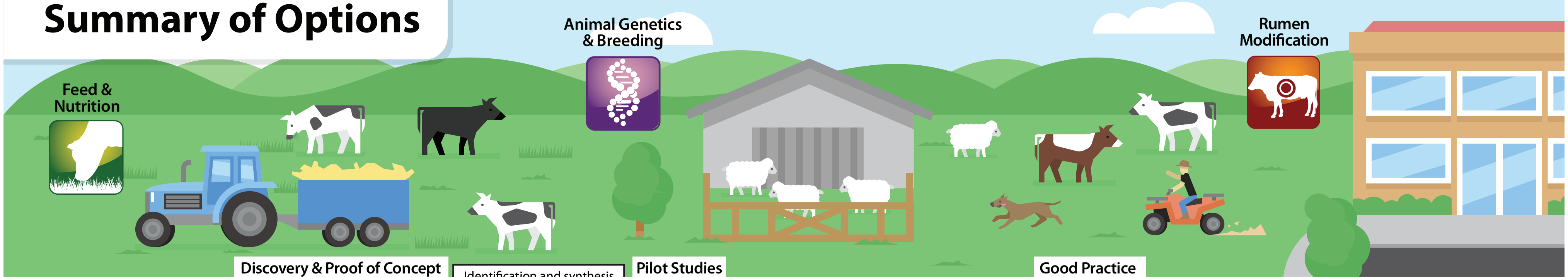
Government, industry and researchers are making a concerted effort to develop practical new tools to help reduce emissions intensity and total emissions without curtailing production. This effort is driven jointly by the government-funded New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) and the industry-led and jointly industry/government funded Pastoral Greenhouse Gas Research Consortium (PGgRc). This fact sheet summarises what farmers can do already and which future options look most promising.

'Good practice' measures are already available and many have already helped improve New Zealand farm performance. Their use could be extended to further reduce emissions per unit of meat or milk. The NZAGRC and PGgRc are funding research on new options consistent with New Zealand farming conditions. This research is at different levels of maturity: 'Pilot Studies' – technology/practice has been demonstrated in a small-scale setting, next step is up-scaling, commercial development and dissemination; 'Discovery & Proof of Concept' – the measure has been demonstrated only in experimental or laboratory settings, but some fundamental mechanisms may still be under investigation. This fact sheet focuses on the most promising options available today or within ten years.

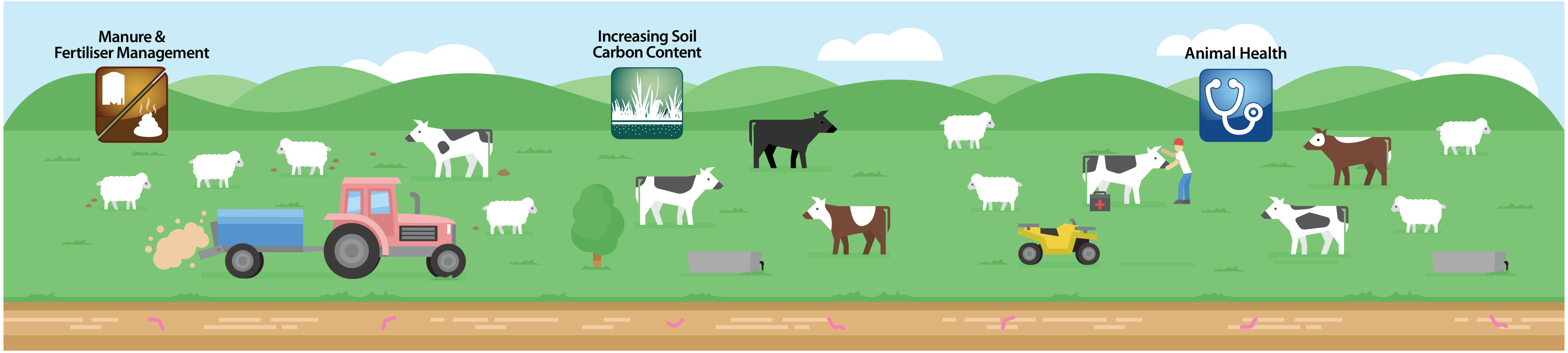
Increasing soil carbon is another method for reducing net GHG emissions, but it is equally important to identify and avoid new management practices that could result in carbon losses from soil. Because of New Zealand's high soil carbon levels, considerable uncertainty exists about the scope for any increases in soil carbon and research is at an early stage. This is therefore only treated briefly here, and discussed in more detail in a dedicated fact sheet on soil carbon[6].

[6] NZAGRC-PGgRc fact sheet: Reducing New Zealand's agricultural greenhouse gas emissions: Soil carbon

Summary of Options



	Discovery & Proof of Concept	Pilot Studies	Good Practice
Feed & Nutrition	Incorporating low GHG traits into forage plants; Identification and synthesis of compounds from plants that can reduce methane and nitrous oxide	Low-methane feeds; Low-nitrogen feeds	Forage crops with improved energy values and lower nitrogen content; Improved forage quality
Animal Genetics & Breeding		Identification and selective breeding of low greenhouse gas animals	Good reproductive performance; High growth rate; High milk yield; Breeding high-value animals
Rumen Modification	Anti-methane vaccines; Methane inhibitors - grazing systems	Methane inhibitors - feedlot systems	
Manure & Fertiliser Management	Plant effects on nitrous oxide emissions mediated by soil	Enhanced low-N plant growth (e.g. gibberellins); Optimisation of grazing/housing options	Capturing biogas from anaerobic processes; Manure collection, storage and application; Urease inhibitors; Nitrification inhibitors; Optimised fertiliser use
Increasing Soil Carbon Content	Increased carbon supply to soil and / or increased stabilisation of soil carbon	Biochar on pasture	Maintaining carbon inputs to soil
Animal Health			Prevention, control and eradication of disease; Increasing productive lifetime of animals
Improved Farm Systems	Developing and demonstrating profitable, practical and low GHG emitting farm systems		



CURRENT GOOD PRACTICE OPTIONS TO LIMIT EMISSIONS GROWTH

Options to further enhance production efficiency

New Zealand already operates a highly efficient and productive pastoral system. Over the past 20 years, farmers have steadily improved feed and nutrition, animal genetics, pasture management, and animal health. These provide permanent, cumulative gains: globally, for instance, genetic improvement is estimated to account for an average 0.5-1% efficiency increase per animal per year. The best way to keep reducing New Zealand's greenhouse gas intensity is for farmers to continue to increase the production efficiency of their operations as much as possible, and as fast as possible.

DAIRY

The key elements underpinning reduced emissions intensity of milk are:

- increased genetic merit of cows
- improved grazing land management to maximise dry matter yield and quality
- enhanced use of supplementary feed to balance diets
- optimised nitrogen fertiliser use per animal
- improved animal health

These elements work together as a package. For example, greater genetic merit only translates into higher production per animal when the feed supply matches the animal's potential.

SHEEP

The key factors contributing to reductions in emissions intensity are:

- increased lambing percentage, so farmers can run fewer ewes for the same number of lambs
- faster growth rates for lambs, which means earlier slaughter or greater weight at slaughter

Both factors are connected to improved genetic merit of sheep and managing them such that their genetic potential is realised in practice.

BEEF

Improved feeding practices and genetic merit have resulted in faster growth and increased weight of animals at slaughter.

This is combined with changes in the beef herd structure, with fewer breeding and more finishing animals, and greater use of dairy cattle for beef production, a trend that is expected to continue especially as dairy animal numbers continue to increase.

By continuing to push these successful strategies, farmers could further reduce emissions intensity and constrain the expected growth in agricultural greenhouse gas emissions as overall animal production continues to increase.

CURRENT GOOD PRACTICE OPTIONS TO LIMIT EMISSIONS GROWTH

Options to reduce the growth in absolute emissions

Most of the additional currently available options to reduce the growth in absolute emissions are related to the dairy sector, which employs a greater diversity of management strategies and feed inputs than the almost entirely grazing-based sheep and beef sectors. The economic efficiency of those options will vary greatly between farms and farm systems and has not been assessed yet for New Zealand as a whole.

USE MORE LOW-NITROGEN FEED

New Zealand pasture-based diets provide more nitrogen to animals than necessary for their optimal growth and productivity. Livestock excrete this surplus nitrogen in their dung and urine, where it contributes to nitrate leaching and nitrous oxide emissions.

Dairy production in New Zealand is increasingly making use of supplementary feed to improve animal performance and balance year-to-year and seasonal variations in grass growth. Many of the supplementary feeds contain less nitrogen than normal pastures and thus could help reduce nitrous oxide emissions on farms. Feeds include domestically-grown supplementary feed, commonly maize silage, hay and silage, and imported supplements, such as palm kernel expeller (PKE). Whether increased use of supplementary feeds is viable depends on international milk prices and domestic environmental regulations.

If feeds are imported from overseas, care also needs to be taken to avoid 'pollution swapping' – where New Zealand could achieve emissions reductions and higher production by driving up emissions offshore – and to keep an eye on any biosecurity issues.

REDUCE NITROGEN FERTILISER USE

Another option is to use less nitrogen fertiliser per hectare or per animal. This requires careful management of nutrient flows, for example by using more purchased feed and/or growing forages with a higher yield per hectare, and optimising the use of animal manures.

Fertiliser use per animal increased throughout the 1990s and peaked around 2004, but has declined since while productivity per animal has continued to increase. There is reason to believe this can be pushed further without compromising production, although it may increase risk to farmers and require higher farm management skills. Reducing overall nitrogen fertiliser use would also help improve water quality.

CURRENT GOOD PRACTICE OPTIONS TO LIMIT EMISSIONS GROWTH

More options to reduce the growth in absolute emissions

MANAGE MANURE FROM HOUSED ANIMALS

Dairy production in New Zealand is intensifying; temporary housing is becoming more common to avoid pasture damage in wet weather, or to control nitrate leaching to waterways. Confinement of animals means that a greater proportion of dung and urine can be captured and treated before being spread back onto land. Farmers can avoid spreading manure when soils are wet and nitrous oxide emissions and nitrate leaching losses are high.

But there are two key challenges:

- more research is needed to determine the potential nitrous oxide reduction from spreading manure at different times, compared to urine and dung being deposited directly
- storing manure generates methane from anaerobic ponds which may offset any reductions in nitrous oxide emissions. To make manure storage a mitigation option, the methane has to be captured and either flared or used to generate biogas. This can be costly; options and economic viability depend on the volume of manure treated

The optimal balance between grazing and housing, and tools for minimizing emissions from housed animals, will continue to evolve over the coming years and will also reflect other environmental goals such as reducing nitrate leaching.

MAINTAINING CARBON INPUTS TO SOILS

It has been difficult to demonstrate practices for New Zealand soils that reliably increase soil carbon, as the effectiveness of any management practice is highly dependent on climate and existing soil carbon stocks and management history.

Globally, one of the most robust good practices is to avoid overgrazing to ensure constant grass cover and production to continue carbon inputs to soil and to reduce erosion risk. Farmers can also reduce the risk of soil carbon losses by avoiding too intense disturbance of the plant/soil system such as frequent cultivation.

Overall in New Zealand, there is no consistent trend in soil carbon stocks in flat land. There is some evidence of increasing soil carbon stocks in hill country, but the reasons for this are not clear yet (it could simply reflect a slow recovery of top soils following the initial clearing of forests, or it could reflect improved management practices).

CURRENT GOOD PRACTICE OPTIONS TO LIMIT EMISSIONS GROWTH

HOW MUCH COULD DCD HELP REDUCE EMISSIONS?

Nitrification inhibitors slow the conversion of ammonium (NH_4+), deposited into the soil in the form of urine, to nitrate (NO_3), which leaches into waterways. Nitrous oxide (N_2O) is released into the atmosphere as part of this process. DCD (dicyandiamide) is a nitrification inhibitor that has proven to be effective in reducing nitrate leaching while boosting pasture growth. The NZAGRC has assessed DCD and a similar product, DMPP. Both were equally effective in reducing nitrous oxide emissions from urine patches in grazed pasture, with emissions reductions of about 60% under a range of conditions. However, DCD was taken off the New Zealand market after the discovery of residues in milk. Future options to meet international trade requirements are being considered. But nitrification inhibitors are not cost-effective if the only motivation for using them is to reduce greenhouse gas emissions. At an application cost between $100 and $250 per hectare, and given that DCD is effective only over a five-month period during winter, farmers would be spending more than $200 for every tonne of CO_2-equivalent emissions avoided. In some dairy catchments, however, nitrification inhibitors may be an important way to meet water quality requirements; emissions reductions would be a beneficial side effect.

A technologically similar option, but based on current evidence without any residues, is the use of urease inhibitors. These restrict the conversion of urea and urine to ammonium in the first place and are particularly effective in restricting emissions from applied N fertilisers. As they break down very quickly in the soil they are less effective in reducing emissions from urine patches where emissions can occur over a substantial period. The cost and benefits for New Zealand-specific climate and soil types, and pastoral farming systems, are not well-documented as yet.

PILOT STUDIES: OPTIONS THAT COULD BE 2-5 YEARS AWAY

New options for reducing total emissions may become available in the next few years, based on evidence from laboratory studies and small-scale animal trials. The critical challenge for those options is to commercialise them and ensure they are viable within New Zealand farming systems.

BREEDING LOW-EMITTING SHEEP AND CATTLE

Research has found that some animals emit less methane than others and that this trait is genetic and can be passed on to their offspring. This has been demonstrated clearly for sheep, and low-emission traits could be available in breeding indices by as early as 2017. Work on cattle began in 2015, and researchers hope that lessons learnt from the sheep programme will allow faster progress for cattle, so that the commercial availability of low-emitting cattle could be as little as five years away.

Based on data obtained to date, naturally low-emitting animals appear to be as productive as average animals, so there would be no direct financial penalty from selecting these sheep. There is still an opportunity cost, however, since adding this additional breeding trait lowers the rate of gain in achieving other breeding objectives. Dollar estimates of this opportunity cost are being explored, but specific policies or market premiums for 'climate-friendly' animals may be necessary to encourage widespread adoption of low-emitting sheep. Further work is also continuing to conclusively demonstrate in a range of practical situations that there is no production penalty associated with the low emission trait or any trade off with nitrous oxide emissions.

LOW METHANE FEEDS AND FEED ADDITIVES

Brassicas have been tested extensively in sheep in New Zealand and forage rape has consistently reduced methane emissions by 20-30% when fed as full diet. Limited work has been done with cattle but the results are also very encouraging. However, it appears that in some circumstances nitrous oxide emissions can increase considerably when brassicas are grazed, and implications for animal health of any increased use also need further study. If these issues can be overcome, greater use of forage rape may yield overall emissions reductions. Preliminary studies with fodder beet have shown reduction in methane when fed at >75% of the diet. However the consequences of feeding fodder beet at such high levels need to be studied further.

Other feeds or feed additives have also been shown to reduce methane production in animals in some studies. However this does not necessarily mean they will work under New Zealand conditions:

- there is strong evidence that *high cereal diets* can reduce methane emissions per unit of product; but cereal must make up at least 30-60% of the diet. This makes it unlikely to be cost-effective for New Zealand's pastoral grazing systems. It is also important to factor in the emissions generated to produce and transport the cereal feed
- *lipid supplementation* (fats such as tallow) appears to reduce emissions by up to 20% in some circumstances, but results from New Zealand studies have shown no decreases. This may be because New Zealand's pasture-based diets differ from the mixed diets used in overseas testing
- limited testing of New Zealand's largest imported feed, *PKE (palm kernel expeller)*, has found no effect on methane emissions
- diets containing maize silage, the most common non-pasture feed in the dairy industry, have also been found to have no consistent effect on methane emissions and the effect could depend on the percentage of silage in the diet
- *tannin-containing plants* reduce emissions generally but have poor agronomic characteristics
- *garlic and essential oils* (e.g. from sandalwood) added to feed have been found to reduce methane emissions in some trials but can taint milk and their very high costs rule currently them out as practical mitigation approaches
- some *biochemical substances*, including some antibiotics and growth promoters (e.g. monensin), have been shown to reduce methane emissions in intensive feedlot systems but they seem to have limited effects in pasture-based systems. There can also be strong market resistance to the use of such substances

PILOT STUDIES: OPTIONS THAT COULD BE 2-5 YEARS AWAY

METHANE INHIBITORS – FEEDLOT OPERATIONS

Researchers are looking for animal-safe compounds that would suppress the methane-producing microbes in the rumen and thus reduce overall methane emissions from animals, without side effects. An inhibitor suitable mainly for feedlot animals has been successfully tested in long-term trials overseas, where it has been shown to reduce methane emissions by 30%. This inhibitor is being developed by the Dutch company DSM, with commercial release planned by 2019. However, this inhibitor is unlikely to be effective in grazing systems as it relies on it being mixed in with cattle feed. Work is underway to develop inhibitors suitable for New Zealand grazing systems (see "Discovery & Proof of Concept").

LOW-NITROGEN FEEDS AND ENHANCED PLANT GROWTH AT LOWER NITROGEN LEVELS

Research to date has demonstrated that nitrification inhibitors are viable tools from an emissions and soil health perspective. While use of the commercial product DCD has been suspended, researchers are investigating whether some plants naturally produce nitrification inhibitors that could be promoted for more widespread use in New Zealand's pastures. Some plants also influence the balance and composition of urine and dung and thus could influence the emissions of nitrous oxide from pastures; the use of such plants could be promoted more widely if they show no negative effects on productivity.

Some substances promote plant growth without relying on high nitrogen inputs, such as the commercially-available natural plant hormone gibberellin. Currently available evidence, mainly from short-term trials, suggests that gibberellin could be used to maintain herbage production when nitrogen fertilizer use is reduced. Further work to confirm these initial findings and analyse the long-term effects of repeated gibberellin use is underway. For more information on gibberellins, see the dedicated NZAGRC-PGgRc factsheet[7].

BIOCHAR

There is good evidence that biochar (organic matter carbonised under controlled conditions) represents a very stable form of carbon, so it could be used to store more carbon in soils. Research has indicated that specific biochars could also help reduce nitrous oxide emissions although the specific mechanisms are not yet clear; other potential benefits for improving soil functions and reducing emissions from pastures are also being tested. However, the main challenge at present to any widespread use of biochar in a pastoral system remains its cost and the large area that would need to be covered, which makes this strategy not economically feasible for NZ farmers.

[7]NZAGRC-PGgRc fact sheet: Reducing New Zealand's agricultural greenhouse gas emissions: Gibberellins

DISCOVERY AND PROOF OF CONCEPT: OPTIONS MORE THAN 5 YEARS AWAY

Some key research supported by the NZAGRC and PGgRc is now at, or approaching, proof of concept stage; other research is still developing fundamental understanding to identify future options. Results from laboratory or experimental settings so far are promising, but scientists are attempting world firsts here and even after proof of concept has been obtained in an animal trial, it could take five years or more before the new technologies under development can be used widely.

METHANE INHIBITORS – GRAZING SYSTEMS

New Zealand's predominantly grazing system means that an inhibitor could at best be given twice daily (restricting its use to intensive dairy systems) or through a bolus (capsules that can be swallowed safely by the animal and release the inhibitor slowly over a time of days to months).

Many thousands of compounds have been screened and more than 100 target compounds have been analysed in the laboratory; the top five to ten compounds have been tested since 2014 in animal trials in New Zealand. Some have shown promising first results with methane reductions of 30% or more, albeit so far only in short-term trials of 2-16 days.

The key for New Zealand is to find inhibitors that are effective at low concentrations (for ease of administration) for pasture-based diets, are low cost, have low toxicity, carry no food safety risks and have no negative effects on productivity. While development of a suitable compound and release mechanism may be feasible sooner, ensuring that there are no residues or negative effects on productivity, and that the compound does not conflict with the expectations of New Zealand's key export markets will take more time. On current progress, the commercial availability of an inhibitor suitable for use on New Zealand farms is expected to take until 2023 or later.

METHANE VACCINES

New Zealand scientists are working to produce a vaccine that stimulates the animal to produce antibodies that suppress key methane-generating microbes in the rumen of livestock.

Prototype vaccines have demonstrated that they can generate antibodies that can alter the microbial populations and methane production in laboratory studies. Further trials are underway to demonstrate that these have an effect on methane emissions in both sheep and cattle. A vaccine would have to achieve a minimum 20% emissions reduction per animal, without reducing productivity, to be worthwhile developing.

Another line of enquiry is the use of nanobeads, microscopic beads produced by bacteria, to carry enzymes than can suppress methane-generating microbes in the rumen. While still at the fundamental inquiry stage, such approaches hold promise because they offer new and additional ways of interrupting methane production in the rumen and that could be integrated with other technologies.

FURTHER DEVELOPMENT OF LOW-EMISSIONS FORAGES AND ACTIVE CHEMICAL COMPOUNDS

Wherever pilot studies identify plants that help lower greenhouse gas emissions, this offers two avenues for further development: the active compound that influences methane or nitrous oxide emissions could be isolated and produced commercially for use as a feed additive or the trait that generates the compound could be incorporated into other pasture species through plant breeding programmes. Both approaches would be expected to take significant time for development even after the active compound has been identified and its mode of action understood. Work is starting to identify naturally occurring nitrification inhibitors that could reduce nitrous oxide emissions without introducing new chemicals into the food chain.

It may also be possible to develop pasture species that requires less nitrogen in the first place. So far, research has identified a gene that could support the breeding of higher yielding ryegrass cultivars that do not need as much nitrogen and thus could further help reduce fertiliser inputs.

There is potential to incorporate such low greenhouse gas traits into pasture.

INTERACTIONS OF PLANTS AND SOIL MICROBES

Soil microbes play a crucial role in the transformation of dung, urine and fertiliser into undesired nitrate or nitrous oxide, or into beneficial or at least harmless forms of nitrogen. Research is underway in New Zealand and elsewhere to better understand how soil microbial communities differ depending on soil type, climate and pasture management, and to see if changes in management practice could promote those organisms that reduce or bypass environmentally negative outcomes. For example, some plants encourage microbial processes that reduce nitrate to inert and environmentally harmless nitrogen gas, and work is beginning to see if these properties can be enhanced and exploited through pasture management or forage breeding.

ENHANCING SOIL CARBON SINKS

If more carbon can be absorbed and kept in the soil, this could offset greenhouse gas emissions to the atmosphere. This is particularly challenging in New Zealand when soil carbon stocks are already high, and it is equally important to ensure any new management practices aimed at enhancing production do not result in carbon losses from soil. For many management practices, their long-term impact on soil carbon remains anecdotal and/or highly dependent on local conditions including management history. Research is testing the effect of a range of management practices at different sites, and is developing models and measurement techniques to understand and test options for different conditions and locations. Short term changes in carbon stocks are not necessarily a good indicator of the long-term potential for grasslands to store carbon, making long-term modelling essential to develop robust advice.

For more information on enhancing soil carbon sinks, see the dedicated NZAGRC-PGgRc factsheet[8].

[8]NZAGRC-PGgRc fact sheet: Reducing New Zealand's agricultural greenhouse gas emissions: Soil carbon

FUTURE OPTIONS: POTENTIAL TO REDUCE EMISSIONS

HOW MUCH DIFFERENCE COULD NEW TECHNOLOGIES MAKE?

Widespread adoption of an effective vaccine/inhibitor package, together with the breeding of low methane-emitting animals, could deliver large emissions reductions – substantially larger than all other mitigation options combined.

If successful, such a package could release New Zealand farmers from the current situation where even best practice efforts to reduce emissions intensity are not enough to reduce total emissions from agriculture.

Apart from low-emitting sheep, however, the effectiveness and long-term sustainability of the technologies still have to be demonstrated in real farm situations.

Adoption rates will have a big effect on the net emission reductions across the livestock sector. If an inhibitor reduces methane emissions by 30% but only 10% of farmers use it, total methane emissions would be reduced by only 3% (and total greenhouse gas emissions reduction would be even smaller because this option would not reduce nitrous oxide). So, the success of new technologies such as vaccines, inhibitors and low-emissions animals will also depend on how their adoption can be encouraged widely across New Zealand, including international market responses.

Ensuring new technologies meet all necessary regulatory requirements, such as no residues in milk or meat, will be a major test in the further development of these technologies.

PUTTING IT ALL TOGETHER: DEMONSTRATING INTEGRATED FARM SYSTEMS

Farms are complex operations, and changes in one part of the system can affect production and emissions in other parts.

It is crucial to understand how individual options to reduce emissions fit into the overall farm system and farming practice: their impact on farm profitability and production, their implications for other environmental and social goals, and not least whether they are consistent with how farming in New Zealand is seen and marketed overseas.

Many good practice options are already an integral part of New Zealand farming. New approaches will need to undergo careful testing and evaluation to ensure they can be used and will be viable for New Zealand farming systems and meet market requirements.

The NZAGRC and PGgRc have partnered with industry to identify and demonstrate the greenhouse gas impacts of current and potential future farming practices, and to show how the results of the various research streams can be brought together into integrated systems on the farm.[9]

For more information about our work and to download other NZAGRC-PGgRc factsheets in the reducing New Zealand's agricultural greenhouse gas emissions series, visit www.nzagrc.org.nz and www.pggrc.co.nz

[9]NZAGRC-PGgRc fact sheet: Reducing New Zealand's agricultural greenhouse gas emissions: Efficiency in the whole farm system

WORKING TOGETHER

There is more information on our websites, or contact us:

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Note on statistics: The NZ greenhouse gas emissions data cited here are for 2014, issued by the Ministry for the Environment in May 2016 (Publication reference ME 1239). All developed countries are required to use international guidelines that set the inventory year 15 months behind the calendar year for official greenhouse gas statistics.

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