Department of Primary Industries

Enteric methane research

A summary of current knowledge and research

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Enteric methane research: A summary of current knowledge and research

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Cover

Enteric methane is emitted mainly through an animal's mouth as burps and belches. Some is also emitted while the animal is chewing its cud, and some through the lungs. A small amount is also produced in the intestine and emitted through the rectum as flatulence. Photo: NSW DPI

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Foreword

This booklet aims to bring producers and advisors up to date with enteric methane research in Australia, with a focus on research for NSW cattle and sheep industries conducted by NSW Department of Primary Industries (NSW DPI). It provides a snapshot of current research into potential ways producers might incorporate mitigation of enteric emissions within a productivity focus in the future.

Cattle and sheep are ruminants, possessing a rumen in which microorganisms ferment and break down ingested feed and produce methane which is belched out of the animal's mouth. This gives grazing livestock a unique ability to produce high quality protein from high fibre feeds, but in doing so they also contribute to global greenhouse gas emissions by emitting enteric methane (CH_4). Although methane has a global warming potential 25 times that of carbon dioxide (CO_2), it has a comparatively short lifetime in the atmosphere. Accordingly, strategies to reduce methane emissions provide an opportunity to arrest the rate of anthropogenic global warming more rapidly than strategies focussed on reduction of carbon dioxide emissions alone.

Ruminant livestock industries face multiple challenges. They need to increase edible protein production to meet anticipated demand, adapt to environmental change and, at the same time, reduce their impact on the environment.

As part of Australia's research effort to reduce the impact of agriculture on greenhouse gas emissions, NSW DPI, together with other research organisations and universities, is exploring ways to both reduce enteric emissions and improve livestock productivity. NSW DPI's major research focus is selective breeding of productive animals with low methane emissions, but we are also exploring other mitigation strategies and methane prediction models to help producers understand the interactions between emissions reduction and productivity.

Agriculture is an important industry for the future (we all have to eat) and has the potential to provide long-lived carbon offsets for carbon-polluting industries. Although agriculture is not currently part of any emissions trading scheme, agricultural offsets such as sequestration of carbon in vegetation and soil, and reduction in methane from livestock, are encouraged through the Australian Government Carbon Farming Initiative, and already being used in some countries to provide credits for other industries.

Current research into methods to reduce the carbon footprint of agriculture will provide useful technologies for future carbon emission reduction schemes. Globally there is increasing discussion about the need for humans to eat less meat from ruminants and to reduce ruminant numbers and methane emissions. Research to reduce methane emissions from livestock will lay the foundations for effective strategies for greenhouse gas mitigation in the future and help allay some of these concerns.

Hutton Oddy
NSW DPI
October 2014

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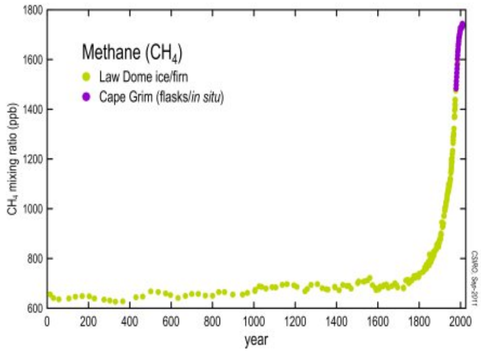
1. Introduction to enteric methane

What is methane?

Methane is a colourless, odourless gas released into the atmosphere from many sources (see Table 1), and is the main constituent of natural gas. Methane is the second most abundant greenhouse gas (GHG) after carbon dioxide (CO_2), accounting for 14 per cent of global emissions (Global Methane Initiative 2011).

Each methane molecule comprises one carbon (C) and four hydrogen (H) atoms, hence its chemical formula CH_4. In 1750 the concentration of methane in the Earth's atmosphere was estimated to be 700 parts per billion (ppb). Since industrialisation, methane concentrations have increased to around 1760 ppb (CSIRO 2013) (See Figure 1).

Figure 1. Global average abundance of methane calculated from ice cores (green) and air sampling at Cape Grim off Tasmania (purple) (CSIRO 2013)



Methane's global warming potential

Global warming potential (GWP) indicates the amount of heat trapped per mass of gas and the time the gas remains in the atmosphere. It is expressed relative to carbon dioxide which has a GWP of 1. GWP is used to convert the impact of different greenhouse gases into a single metric, carbon dioxide-equivalent (CO_2-e). In broad terms, multiplying a mass of a particular gas by its GWP gives the mass of carbon dioxide emissions that would produce the same warming effect over a 100 year period.

Methane is more efficient at trapping heat than carbon dioxide so has a higher GWP. The GWP of methane is currently 25. In 2013 the IPCC 5th Assessment Report (Mhyre et al 2013) recommended that the GWP of methane be raised to 34 to include climate-carbon feedbacks in their calculations. The IPCC and national carbon accounting systems will continue to use a GWP of 25 in calculations until 2018.

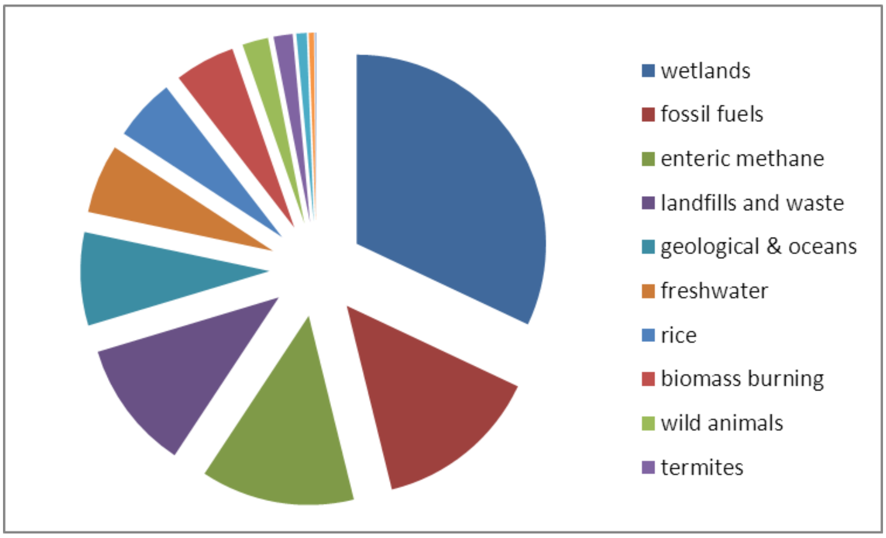
Sources of methane

Methane is emitted from both human-related activities and natural sources (see Table 1). In the first decade of this century, human activities were the cause of 50-65 per cent of global methane emissions (Ciais et al 2013). The main natural source of methane is wetland emissions. As global temperatures rise, a greater proportion of the total methane emissions will come from release of long term methane stored as gas hydrates and in permafrost.

Table 1. Sources of methane (Ciais et al 2013)

Natural sources	Tg/yr*	Human activities	Tg/yr*
wetlands	217	fossil fuel production	96
geological (incl oceans)	54	enteric fermentation from livestock	89
freshwater	40	landfills, livestock manure & sewage	75
wild animals	15	rice cultivation	36
termites	11	biomass burning	35
gas hydrates	6	Total	331
wildfires	3		
Permafrost	1		
Total	347	*1 Teragram (Tg) = 1million tonnes	

Figure 2. Global sources of methane (Ciais et al 2013)



Agricultural methane

Sources of agricultural methane are:

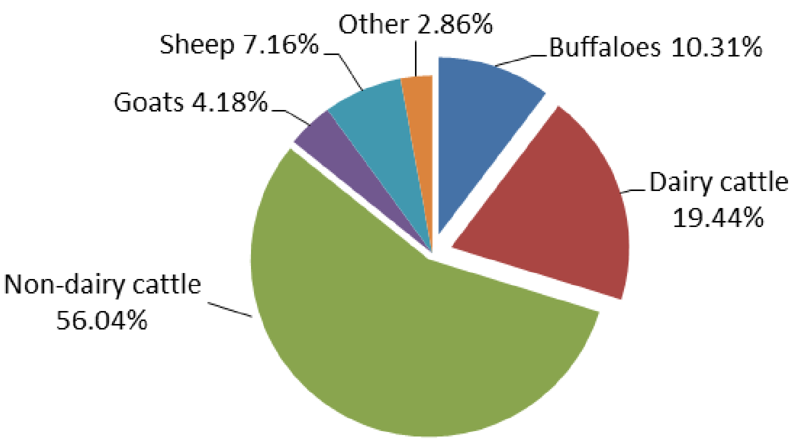
- enteric methane from ruminant animals
- animal manure
- biomass burning
- rice cultivation.

In 2012 Australia's agricultural methane emissions totalled 67.1 Mt CO_2-e. Australia's total greenhouse gas emissions were 543.6 Mt CO_2-e (Department of the Environment 2014a).

Enteric methane

The word enteric means 'related to the intestine' and is derived from the Greek word *enteron* meaning 'gut'. Enteric methane is a byproduct of the digestive process in ruminant animals such as cattle, sheep, goats, deer, buffalo, and camels (Figure 3). The digestive system of these animals includes a forestomach (mainly the rumen) which contains bacteria, protozoa and fungi to ferment and break down plant matter eaten by the animal (see page 5). Methane is a by-product of the fermentation process and most of it is emitted through an animal's mouth as burps and belches. Some is also emitted while the animal is chewing its cud, and some through the lungs. A small amount is also produced in the intestine and emitted through the rectum as flatulence.

Figure 3. Contribution of different animal species and cattle types to global livestock enteric methane emissions (from Pickering et al 2013)



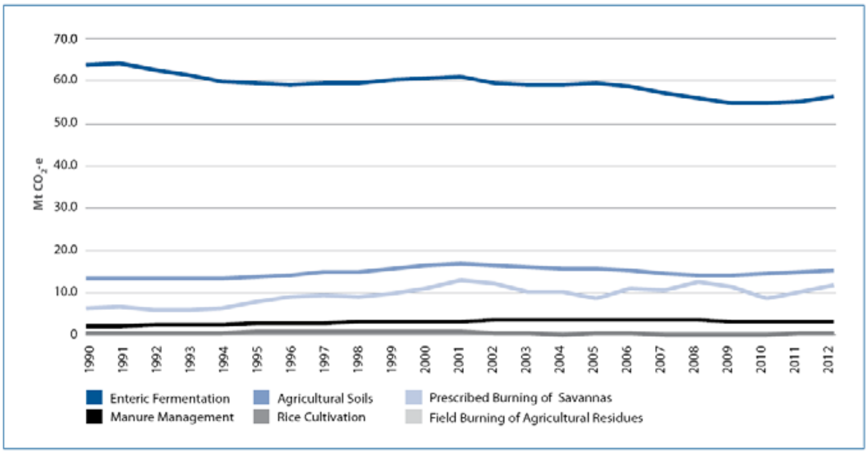
Enteric methane in Australia

Enteric fermentation from livestock is the main source of agricultural emissions in Australia (see Table 2). Enteric emissions dropped in the first decade this century due to the drop in livestock numbers during the Millennium Drought (Figure 4).

Table 2: Australia's agricultural emissions (Gg CO2-e*) in 2012 (Department of the Environment 2014a)

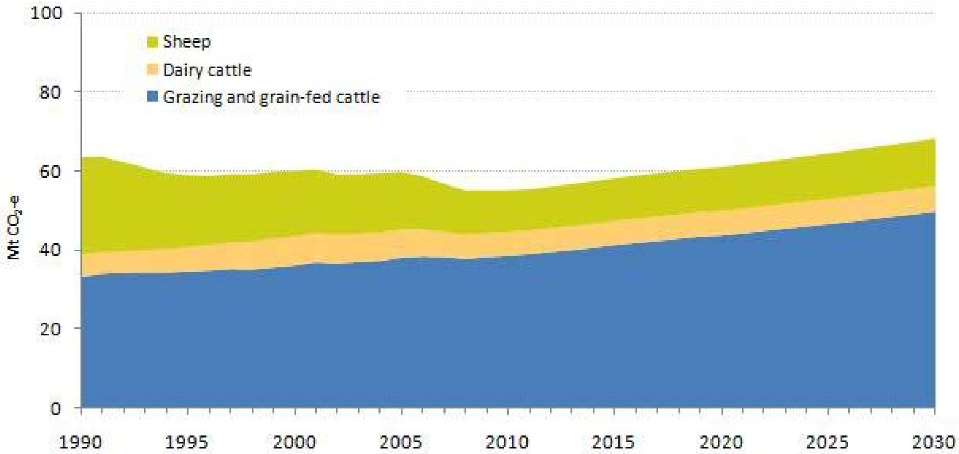
Agricultural emission	Methane CH_4	Nitrous oxide N2O	Total
Enteric fermentation	56,216	NA	56,216
Agricultural soils	NA	15,295	15,295
Prescribed burning of savannas	8,454	3,261	11,715
Manure management	1,676	1,545	3,221
Rice cultivation	478	NA	478
Field burning of agricultural residues	298	137	435
TOTAL	67,123	20,238	87,361
*1 Gigagram (Gg) = 1000 tonnes			

Figure 4. Enteric methane is the main source of agricultural emissions in Australia (Department of the Environment 2014a).



Sources of enteric methane in Australia

Figure 5. Past and projected enteric methane emitted by Australian sheep and cattle (Department of Climate Change and Energy Efficiency 2011).



Cattle account for around 80 per cent of Australia's livestock enteric methane emissions (grazing cattle 66 per cent, dairy cattle 11 per cent and feedlot cattle three per cent). Sheep account for almost 20 per cent. Similar proportions are expected in 2020, with sheep emissions dropping to around 18 per cent and cattle increasing to 82 per cent mainly due to increase in grazing cattle numbers (Department of Climate Change and Energy Efficiency 2011). The key driver of agricultural emissions projections is the size of the livestock herd, which is strongly driven by export demand and climate conditions. Increased export demand could increase the national herd and hence emissions. On the other hand, more frequent and severe droughts could decrease livestock numbers, leading to lower emissions. Overall projections are for increased enteric methane emissions.

Why we need to reduce enteric methane

1. It is otherwise predicted to increase and has a larger global warming potential (GWP) than carbon dioxide.
2. It currently accounts for 64 per cent of Australia's agricultural GHG emissions but can be targeted for reduction by research.
3. It represents a loss of feed energy so, if reduced, will improve livestock productivity.

Enteric methane and the Carbon Farming Initiative (CFI)

The Carbon Farming Initiative (CFI) allows farmers and other land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land. Participants can generate carbon credits by setting up a project under an approved CFI methodology determination, which sets out the rules for the activity. At the time of writing there were two endorsed methodologies for enteric methane: *Reducing greenhouse gas emissions by feeding dietary additives to milking cows* (ComLaw 2013 and Department of the Environment 2014b) and *Reducing greenhouse gas emissions by feeding nitrates to beef cattle* (ComLaw 2014). Further CFI methodologies are under development.

Dietary additives methodology

The methodology involves feeding dairy cows selected high fat feed supplements which result in lower methane emissions. The supplements are canola meal, cold-pressed canola meal, hominy meal, brewer's grain and dried distiller's grain, which are the by-products of other agricultural production processes (ComLaw 2013).

Feeding nitrates methodology

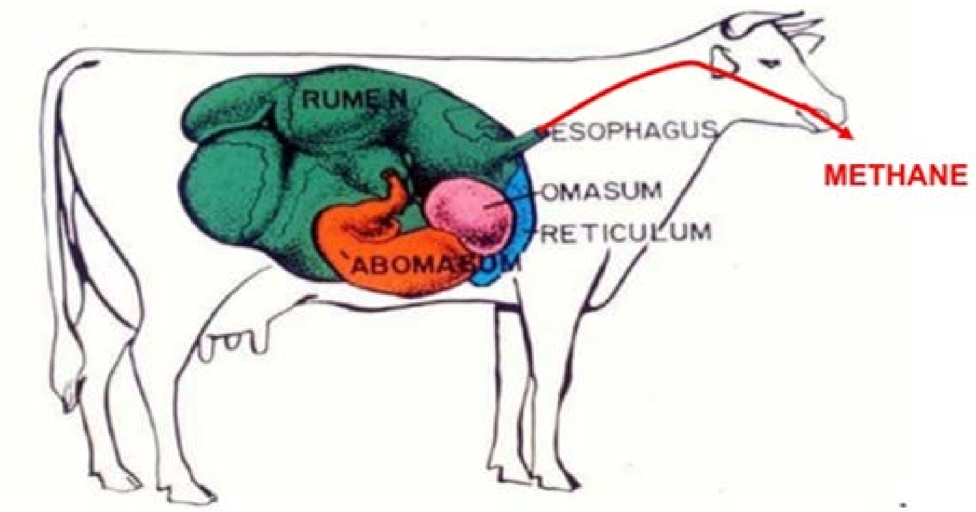
This methodology involves providing nitrate lick blocks to beef cattle that had previously been fed urea (ComLaw 2014).

It remains to be seen whether the financial incentive of carbon trading to reduce enteric emissions will be sufficient to drive changes in farming practice.

2. How the rumen works

The rumen is the first and largest of four digestive chambers in ruminant animals. Food eaten by the animal first passes into the **reticulum**, a small pouch separated from the rumen by a ridge of tissue. Its lining has a raised honeycomb-like pattern covered with small projections known as papillae, and is sold as tripe. Heavy or dense feed and foreign objects settle here.

Figure 6. The ruminant digestive system (Herd 2011)



The rumen and reticulum are very close in structure and function and can be considered as one organ. The rumen's internal surface is also covered with papillae, which increase the surface area and allow better absorption of digested nutrients.

In the **rumen**, microorganisms (mainly bacteria, protozoa and fungi) ferment and break down ingested feed. The mix of undigested feed particles and soluble components, including saliva and microbial biomass, is known as 'digesta'. It is regurgitated back through the reticulum to the mouth as 'cud' and chewed again (rumination). The reticulum and rumen are quite muscular and move digesta around by ordered contractions. In cattle, the reticulum and rumen hold 50-120L of digesta.

Methane is a byproduct of the microbial fermentation in the rumen and most of it is emitted through the animal's mouth as belches and burps (eructation). Some is also emitted while the animal is chewing its cud, and some through the lungs.

Ruminated digesta, which is about 90 per cent water, moves on to the **omasum** where much of the water is absorbed. Digesta leaving the omasum for the abomasum typically contains 50-70 per cent water.

The **abomasum**, equivalent to the human stomach, secretes large amounts of hydrochloric acid in the region adjacent to the omasum to acidify the digesta from a pH ~6.5 to 2.5. This kills many of the rumen microbes, and starts the process of digestion in the small intestine.

The small intestine secretes alkaline bile which aids absorption of fats (as complexes with bile acids), amino acids and starch (after breakdown to glucose).

Undigested feed and materials secreted in the small intestine are further digested in the caecum (between the small and larger intestines) and provide 10-15 per cent of the animal's energy supply. A small percentage of methane is also produced here and emitted through the rectum as flatulence. The large intestine absorbs water and minerals, and all remaining material is excreted through the rectum.

Ruminants derive between 60-70 per cent of their energy from short chain (volatile) fatty acids produced from rumen and caecal fermentation of cellulose and hemicellulose in feed. The balance of energy available is from fats (some of which are made in the rumen), amino acids, and starch that escapes rumen fermentation. Some 70-80 per cent of the amino acids are derived from digestion in the small intestine of the microorganisms produced in the rumen. Starch only becomes available if livestock are fed large amounts of grain.

The adaptations of the ruminants to derive much of their nutrient supply from cellulose and hemicellulose (which are almost indigestible by humans, pigs and chickens, and less digestible by horses) has provided them with a unique ability to thrive in an ecological niche that other species cannot. In so doing they have expanded the range of grasslands on the planet. From the perspective of a ruminant, the production of a small amount of methane (typically eight per cent of total ingested energy) is a small price to pay to out-compete other species of animals in a grasslands-dominated environment. Domesticating ruminants about 10,000 years ago provided humans with the ability to utilise sunlight for food, fibre, hides and work that would otherwise not be accessible to us.

3. Total emissions and emissions intensity

It is important to know the difference between total emissions and emissions intensity as both terms are used but they are not interchangeable. Both are expressed as tonnes of carbon dioxide equivalent (t CO_2-e) but the scale varies. Total emissions are expressed as t CO_2-e, while emissions intensity is expressed as t CO_2-e /unit product.

Total emissions

Total emissions are emissions from a given unit such as a country district, a farm , a hectare or an animal, and the term is mostly applied at the enterprise/farm level. A grazing farm's total emissions are affected by a number of factors, including climate, soils, animals and pasture.

Emissions intensity

Emissions intensity is the quantity of emissions produced per unit of agricultural product such as saleable carcass weight, milk solids or fleece weight. Improved management practices that result in more animal growth for the same amount of pasture reduce emissions intensity because there are fewer emissions per kg of carcass weight or fleece weight.

Emissions intensity is the preferred measurement for agriculture because it links emissions reduction to production efficiency and productivity, and is able to be marketed in those terms. However, Australia's national target is to reduce total emissions, so the Carbon Farming Initiative is focussed on reducing total farm emissions.

Examples

The examples below show how different production systems can result in the same emissions intensity, despite varying in their total emissions.

Example A: Standard milk production

A herd of 200 dairy cows produces 4000 litres of milk per head per annum. Each cow emits 165 kg enteric methane per year.

Total milk: 200 cows x 4000 litres = 800,000 litres

Total emissions: 200 cows x 165kg methane = 33,000kg methane

Emissions intensity: 33,000 kg methane/800,000 litres of milk = 41.25 g methane per litre of milk

Example B: Increased production per head

A combination of improved genetics and management result in an increase of milk production to 6000 litres of milk per annum. However, each cow will produce more methane per day because it eats more and produces on average 220kg methane per annum.

Total milk: 200 cows x 6000 litres = 1,200,000 litres

Total emissions: 200 cows x 220kg methane = 44,000 kg methane

Emissions intensity: 44,000 kg methane/1,200,000 litres of milk = 36.7 g methane per litre of milk.

This scenario thus results in more milk and more methane, but lower emissions intensity than Example A.

Example C: Increased production and fewer cows

The producer may choose to milk fewer high producing cows to produce the same amount of milk. In this case 135 high producing cows could produce the same amount of milk as 200 lower-producing cows.

Total milk: 135 cows x 6000 litres = 810,000 litres

Total emissions: 135 cows x 220kg methane = 29,700 kg methane

Emissions intensity: 29,700 kg methane/810,000 litres of milk = 36.7 g methane per litre of milk

This scenario results in the same production and emissions intensity as Example A, but with less methane and lower operating costs due to fewer cows.

Example C shows a net reduction in total emissions of methane and a net reduction in the cost of production to the producer. Most producers would aim to maximise productivity per head, but if payments were capped or uncertain they might prefer to produce more to minimise their risk.

4. Management options to reduce enteric methane

Currently, best practice management for production efficiency and profit will give the best outcome for methane abatement for any particular farming system. Making any changes to reduce enteric methane requires analysis of the impacts on productivity and profit. Farms that are already well managed have few options to reduce enteric methane without significant changes to farming or feeding systems.

Potential options to reduce enteric methane depend on the enterprise and include

- improved animal management
- improved pasture management
- feed supplements
- animal breeding
- rumen manipulation.

A. Animal management

Figure 7. Maximising breeding productivity per animal will reduce emissions intensity. Photo: NSW DPI

Changing animal management practices on existing pastures to maximise productivity can make substantial differences to emissions intensity (ie emissions per unit of product).

Improve animal production genetics

Improving production traits such as growth rate, carcass weight and wool production through genetics will contribute significantly to improving emissions intensity.

Reduce stock numbers

Methane emissions are highly correlated with the total population of ruminant animals. Australia's enteric emission declined between 1990 and 2010 due largely to a reduction in sheep numbers, but are now increasing due to good seasons and overseas demand, and are projected to increase further by 2020. Culling low fertility breeding stock is important. Unless numbers of production animals (females) are reduced, there is unlikely to be a real reduction in methane emissions.

Remove production impediments

Producers can help their animals maximise feed energy by eliminating parasites and nutrient deficiencies. This is a best management practice for all livestock producers.

Maximise reproductive efficiency

Practices that maximise breeding productivity per animal and hence improve emissions intensity include earlier mating, improved nutrition and genetics to increase progeny/mother and reduce time to slaughter, and delaying of ewe/cow culling by one year.

Finish animals faster

Finishing animals more quickly before slaughter means fewer days between birth and slaughter, so fewer emissions per animal.

Breed low methane-emitting animals

Research to date suggests there may be sire variation in methane yield of their progeny and work is continuing in this field (see page 16).

The producer's dilemma: Total emissions or emissions intensity?

The primary drivers of enteric methane emissions are feed intake, and fermentation of that feed in the rumen. In general, management practices that increase the proportion of feed used to produce meat, milk or wool rather than maintain the animal, reduce the amount of methane per unit of animal product produced (emissions intensity). Higher animal productivity generates the same amount of animal product with fewer methane emissions, so producers can run fewer animals more intensively on a smaller area of land. More intensive production provides flexibility to control emissions, improve profitability and make areas of the farm available for other uses.

However, increasing feed intake will always lead to an increase in total methane production unless the total number of animals is reduced. Dairy industries throughout the developed world have consistently increased productivity per head over the past 60 years, resulting in more production from fewer cows and a lower output of methane per unit of milk produced (Capper 2011).

Higher productivity may encourage some producers to carry more animals, which would counter any emission reductions. Choices about balancing emission reduction targets with farm productivity targets depend on producers' financial and philosophical priorities and are also influenced by government policy.

B. Pasture management

Figure 8. Younger grasses are more digestible than mature or senescing plants, so produce less methane. Photo NSW DPI

Ruminant animals can digest fibrous feeds that monogastric animals (pigs, chickens, humans) cannot thrive on. Ruminants have co-evolved with micro-organisms that digest the fibre and make the nutrients available as short chain fatty acids and microbial protein. The byproduct of this activity is the production of methane in ruminants' forestomachs. The amount of methane exhaled or belched depends largely on the total amount and digestibility of the feed eaten. Digestibility is a function of the feed's fibre, carbohydrate, protein and oil content. Fibre makes feed less digestible; carbohydrate, protein and oil make it more digestible. Research has found significant variation in plants' potential for suppressing methane, depending on cultivar, season, location and plant part. The effects of methane suppression by plants appear to be immediate, persistent and maintained when potent plants are included as part of a mixed diet. Several forages with potential for various livestock production zones have been identified for further research but are not yet commonly used in pastures.

Graze on younger grasses

Grasses in the earlier growth phase are more digestible than mature or senescing plants.

Graze at the optimal time

Ideally, plants should be grazed so that stock eat higher quality forage without increasing feed intake, and there is opportunity for high quality pasture regrowth following each grazing event. Very long pasture rest periods result in stock grazing feed with very low digestibility which will increase their methane output.

Use fertilisers to improve pasture quality

Pasture improvement can enable the same amount of pasture to be generated from a smaller area. Matching fertiliser to plant nutrient requirements can also lead to increase in legume persistence.

Synchronise pasture availability with the breeding cycle

This will match pasture to livestock production requirements and maximise pasture use efficiency in times of high pasture production.

Supplement with grains

In general, animals fed on diets rich in cereal grains such as barley, maize or wheat yield less methane than animals grazed on pasture, reflecting the high load of fermentable energy in grain. Feeding wheat rather than maize or barley to dairy cows can also reduce enteric methane. However, feeding grains to animals is expensive, can promote acidosis which in extreme cases can be fatal, and takes food out of the human supply chain. The cost and practicality of grain feeding mean it is mostly confined to intensive industries such as dairy and feedlots, so will have only a minor impact on national enteric methane emissions.

C. Feed supplements

Figure 9. A number of feed supplements have been examined for their impact on methane emissions. Photo NSW DPI.

Feed supplements are used to balance the ratio of protein, energy and fibre in the feed. A number of feed supplements have been examined for their impact on methane emissions (see below) including canola and sunflower oils, grape marc (a wine by-product of grape skins and seeds), spent brewer's grains, tannin extract (from black wattle) and marine algae (high oil content) (Meat and Livestock Australia 2014). Many supplements are still in the research phase, and unlikely to be used in extensive grazing due to limited supply, cost of manufacture and delivery, and difficulty in application. It is difficult to feed extensively grazed animals with the required amount of supplement at specified times. Producers are unlikely to use supplements unless there is positive economic impact on animal production.

Oils

Fats and oils change the fermentation process in the rumen, producing more propionic acid and less methane. This enables better digestion of lower quality feed during drier seasons, thereby reducing methane emissions and increasing productivity. Oil-rich feeds such as fuzzy cottonseed, brewers grain, cold-pressed canola or hominy meal are used widely in dairy and feedlots. Dietary oil has been found to reduce methane 3.5 per cent for every one per cent increase in dietary oil (Moate et al 2011). The Carbon Farming Initiative has endorsed a methodology to feed high fat supplements to dairy cows. The endorsed supplements are canola meal, cold-pressed canola meal, hominy meal, brewer's grain and dried distiller's grain (Department of the Environment 2014b).

Tannins

Tannins are natural plant compounds that have a toxic effect on methanogens in the rumen. Condensed tannins in some legumes also reduce the potential for bloat in cattle. However, tannins tend to suppress food intake and can affect production. Tannin-rich dried grape marc, a byproduct of wine production, has shown a 20 per cent reduction in enteric methane in dairy cattle, without decreasing feed intake or milk yield, or having adverse impacts on milk composition (Moate et al 2012). Further research is underway to establish commercial potential and define operating parameters.

Nitrate

Nitrate has potential to reduce emissions by competing for hydrogen from fermentation in the rumen, producing ammonia rather than methane. However, it can be toxic, so research is underway to develop safe feeding technologies and determine safe feeding quantities for different classes of livestock. The Carbon Farming Initiative has endorsed a methodology for nitrate lick blocks for beef cattle previously fed urea (ComLaw 2014).

D. Animal breeding

Figure 10. Research shows that there is sire variation in methane yield of progeny. Photo: NSW DPI.

In beef and sheep industries, more than 75 per cent of methane production is derived from breeding females. Most females are run extensively on pastures, handled only a few times each year and rarely fed supplements. However, a lasting increase in productivity has been achieved through traditional selective breeding. If we can measure methane emissions in individual animals it is potentially feasible to breed for reduced emissions. Research is currently underway to develop such methods. There are several feasible options for reducing emissions through breeding.

Breed animals with low net feed intake (NFI).

Net feed intake is a measure of feed efficiency and is the difference between the amount of feed eaten and that calculated to maintain weight and weight gain. Animals with low NFI eat less feed for the same production than those with high NFI. Because they eat a little less low NFI cattle produce a little less methane. Estimated breeding values for NFI are now in place for some beef cattle breeds, so producers can breed low NFI cattle.

Breed animals with low methane yield.

Animals vary in their methane yield (methane emissions per quantity of feed eaten). Research is currently underway into methane yield of sheep, beef cattle and dairy cattle. Results to date suggest there is sire variation in methane yield of their progeny. If there are genetic differences, it may be possible to breed future generations of cattle and sheep with low methane yield in addition to low NFI.

Breed animals with improved reproductive performance

The more progeny per ewe or cow, the less methane is produced per unit of product (eg number of lambs weaned or days to first oestrus in cattle).

It is anticipated that the strategies listed above will be additive, i.e. selection pressure can be placed on each trait and together they will contribute to reduced methane emissions.

E. Rumen manipulation

There is considerable research effort directed towards understanding the microbial ecology of the rumen and its influence on feed efficiency and productivity. Researchers hope to find microorganisms that can be inoculated to modify rumen function and reduce methane emissions. Research is in the early stages and it is unlikely that a novel treatment will emerge soon. It is also possible that vaccination against the methanogenic rumen microbes may be achievable. Research has demonstrated that it is possible to vaccinate animals against other classes of micro-organisms in the rumen, but it remains to be seen whether vaccination against methanogens can reduce methane emissions.

5. Enteric methane research in Australia

Since 2009 the Australian Government has funded three major research programs into enteric methane: A. Reducing Livestock Emissions Research Program (2009-12), B. National Livestock Methane Program (2012-15), and C. Filling the Research Gap Round 2 (2014-16).

A. Reducing Livestock Emissions Research Program (2009-2012) outcomes

The Reducing Livestock Emissions Research Program was managed by Meat and Livestock Australia (2014) and resulted in more accurate knowledge about methane emissions, possible levels of mitigation and production impacts of a range of management strategies.

Animal breeding

- It will be possible to identify sires whose progeny will produce less methane.

Feed supplements

- Dietary oil and grape marc have shown promising results as supplements for reducing methane.
- Nitrate supplements have consistently and rapidly reduced methane production, but further understanding of their potential toxicity is required.

Forages

- Several forages have been identified as being able to reduce enteric methane, but are not yet widely used, although chicory is used in some production systems.

Farm management

- The online FarmGAS calculator was developed and launched to allow producers to explore abatement options.

B. National Livestock Methane Program (2012-2015) projects

The National Livestock Methane Program, also coordinated by MLA, aims to develop practical on-farm options to reduce methane emissions from livestock, quantify the level of abatement achievable while increasing productivity, and provide the science to underpin methodologies developed under the Carbon Farming Initiative. It was funded by the Carbon Farming Futures Filling the Research Gap Round 1. A supplementary round of projects (2014-17) was funded in 2014 under Filling the Research Gap Round 2 (Department of Agriculture 2014a).

Animal breeding

- Genetic technologies to reduce methane emissions from Australian beef cattle (Lead- NSW DPI)

Feed supplements

- Understanding methane reducing tannins in enteric fermentation using grape marc as a model tannin source (Australian Wine Research Institute)
- Development of algae based functional foods for reducing enteric methane emissions from cattle (CSIRO)
- Supplementation with tea saponins and statins to reduce methane emissions from ruminants (CSIRO)
- Strategic science to develop dietary nitrate and defaunation as mitigation methodologies for grazing ruminants (University of New England)
- Practical and sustainable considerations for the mitigation of methane emissions in the northern Australian beef herd using nitrate supplements (Ridleys Agriproducts)

- Enteric methane mitigation strategies through manipulation of feeding systems for ruminant production in southern Australia (Victoria DPI)

Forages

- Impacts of leucaena plantations on greenhouse gas emissions and carbon sequestration in northern Australian cattle production systems (CSIRO)
- Best choice shrub and inter-row species for reducing emissions and emissions intensity (University of Western Australia)
- The mechanism of antimethanogenic effects of bioactive plants and products on methane production in the rumen (University of Western Australia).

Farm management

- Efficient livestock and low emissions from southern grazing systems (University of Western Australia)

Rumen manipulation

- Culture independent metagenomic approaches for understanding the functional metabolic potential of methanogen communities in ruminant livestock (CSIRO)
- Comparative analyses of rumen microbiomes to mitigate methane and improve feed utilisation (CSIRO)
- Measuring methane in the rumen under different production systems as a predictor of methane emissions (CSIRO)
- Development of gas selective membranes for intra ruminal capsules (RMIT)

Measurement

- Evaluation and optimisation of Greenfeed Emission Monitoring units for measuring methane emissions from sheep and cattle (UNE)

C. Filling the Research Gap Round 2 (2014-2016) projects

This further round of funding was made available under Carbon Farming Futures: Filling the Research Gap round 2 in 2014.

Animal breeding

- Genetics to reduce methane emissions from Australian sheep (UNE)
- Host control of methane emissions from sheep (UWA)
- The trade-off between feed efficiency, methane and reproduction in sheep (Murdoch University)
- Novel strategies to breed dairy cattle for adaptation and reduced methane emissions (Dairy Futures Limited)

Forages

- Nitrate and sulphate rich shrubs to reduce methane and increase productivity (CSIRO)

Farm management

- Innovative livestock systems to adapt to climate change and reduce emissions (UWA)
- Impacts of Carbon Farming Initiative rumen-based methodologies on farm systems (UNE)

Rumen manipulation

- Maximising energy-yielding rumen pathways in response to methane inhibition (CSIRO)

Research coordination

- International coordination of the ruminant pangenome project (UWA)

6. NSW DPI enteric methane research

A. Genetic technologies to reduce methane emissions from Australian beef cattle (2012-15)

Figure 11. Breeding for low methane progeny at Trangie. Photo: NSW DPI

This three year project will run until 2015 to deliver genetic technologies for breeding cattle that naturally produce less methane. It follows on from the 2009-2012 project that investigated natural variation in methane emissions among progeny of Angus bulls.

Project objectives

- Determine underlying genetic variation in cattle, and heritability and genetic associations with other production traits.
- Develop new technology to allow cattle producers to identify low-methane bulls and use them with confidence.
- Implement industry recording of methane production by animals from major Australian breed societies.
- Methane emissions will be costed into the breeding values and profit indices used to describe the genetic merit of cattle in the national genetic evaluation system BREEDPLAN®.
- Divergent selection on methane production will be continued to reveal any unfavourable consequences.
- The selection lines also provide powerful demonstration that breeding for reduced methane is possible, and are a proven powerful design for the discovery of DNA markers with which to identify superior cattle.

Outputs

- New profit indices and breeding values to allow cattle producers to identify and purchase superior bulls whose offspring will have naturally lower methane emissions.
- Future elite sires from Australian cattle breeds ranked by estimated breeding values (EBV) for methane, and profit indices with methane costed. These bulls will be among the elite sires

used widely in artificial insemination through their breeds and will have a major impact on future genetic change in commercial cattle herds.

- Knowledge of the phenotypic and genetic relationships between methane production traits and other important production traits for inclusion in, and adjustment of, the BREEDPLAN® model for genetic variation.
- Increased accuracy of EBV for methane production traits using information from DNA data to help cattle producers select superior bulls whose offspring will have naturally lower methane emissions.

Outcome

Cattle producers are able to buy bulls to breed future generations with lower methane emissions.

More information

Herd et al 2013, Donoghue et al 2013

B. Natural variation in methane emissions among progeny of Angus bulls (2009-2012)

Figure 12. Low methane bull, Trangie. Photo: NSW DPI

This study investigated natural genetic variation in methane yield in Australian beef cattle.

Findings

- There was a large range in methane yield, with highest levels being almost three times the lowest levels.
- Methane production was positively correlated with bodyweight and dry matter intake.
- Cattle with higher bodyweights tended to have a lower methane yield.
- Sire was a significant effect for methane yield, indicating a naturally occurring genetic variation in methane yield

Future research

Test more cattle to estimate accurately the magnitude of genetic variation and trait heritability.

Implications

The Australian cattle population has sires that can be used to produce progeny with lower methane emissions relative to the amount of feed consumed.

More information

Herd et al 2011

C. Genetics to reduce methane emissions from Australian sheep (2012-16)

Figure 13. Variation in digestive function affects methane emissions in sheep. Photo: NSW DPI

Past research (Robinson et al 2014) has found that short term measurements of sheep methane emissions are moderately repeatable and appear to be heritable. This provides hope that a reliable low cost measurement protocol can be developed to screen animals for selection to breed low methane emitting sheep. NSW DPI is working with the project leader, University of New England, to establish a robust measurement protocol and then, with DAFWA and Murdoch University, will measure 3000 sheep from the industry resource flocks to establish genetic parameters for methane traits. The research will also establish initial relationships between methane and production traits necessary to include in any formulation of breeding values for methane.

More information

Robinson et al 2014

D. Host control of methane emissions from sheep (2013-16)

Figure 14. Sheep used in enteric methane trials, Armidale. Photo: NSW DPI

Past research has found that sheep with lower methane yield have smaller rumens and their digesta (fermenting feed) passes through the rumen more quickly. This project, led by University of Western Australia with partners NSW DPI, UNE, CSIRO, University of Queensland, AgResearch NZ and Utah State University, is studying the interaction between animal hosts and rumen microbial populations. The project will provide insights into the fundamental biology of rumen function and methane emissions in sheep and underpin the discovery of new tools for breeding low methane emitting sheep.

The genetics project is developing a robust standard operating procedure for measuring methane emissions from sheep. Outcomes will enable industry breeding values for methane emissions to be developed and will provide a pathway to participation in the Carbon Farming Initiative. Multiple tests under different environments are needed to better understand

- variation in emissions by individual animals (same animals while young and growing, when pregnant and lactating and again when dry)
- variation in emissions between animals
- extent of genetic variation in feed intake and methane emissions
- impact of different environments (abundant/scarce pasture conditions and respiration chamber measurements)
- sire x test batch interactions
- development of test protocols that can be applied to sheep in the field to facilitate development of genetic parameters including ASBVs
- relationship between methane emissions in different environments, changes in liveweight, feed intake and RFI.

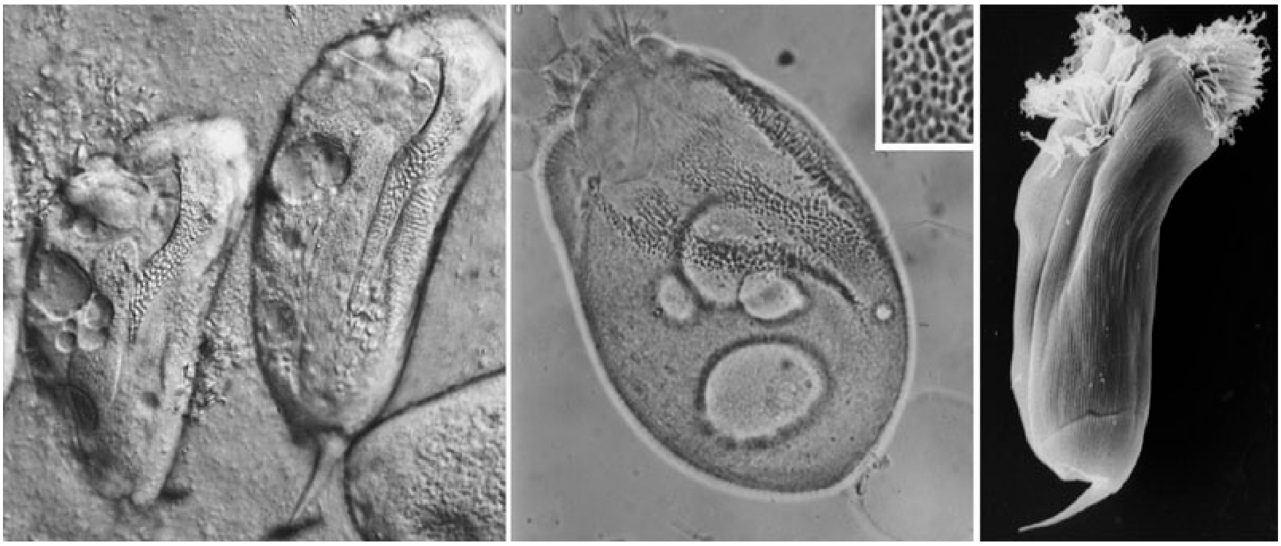
- relationship between methane yield and rumen microbiota
- how the host animal controls its internal environment (genomics of development of the rumen and its microbes)
- tools for genomic selection of sheep.

More information

Oddy et al 2014, DAFWA 2014, Meat and Livestock Australia 2011, Alcock and Hegarty 2011, Hegarty et al 2010

E. Defaunation to reduce sheep and cattle enteric emissions

Figure 15. Rumen protozoa *Epidinium caudatum*. Images: Professor David N Furness, Keele University UK



Rumen defaunation is the removal of protozoa from the rumen. This project compared methane emissions from animals (mainly sheep) with and without protozoa. Protozoa don't produce methane but their activity in the rumen is believed to encourage growth and proliferation of methanogens (microorganisms that produce methane).

Findings

- Defaunation had no effect on sheep methane production irrespective of animal age, diet or protozoa removal method.
- Defaunation increased animal performance in many situations, which means methane emissions per product would be reduced.

More information

Bird et al 2008, Hegarty et al 2008

F. 'Trevenna' sheep production demonstration site

Figure 16. Sheep grazing on higher fertility pastures produced almost 30 per cent less methane. Photo: NSW DPI

This demonstration site in Armidale NSW (2010-2012) was established by the University of New England and NSW DPI to

- compare animal productivity and emissions on low and high productivity landscapes
- build up information about greenhouse gas flows in grazing systems.

Findings

- Sheep grazing on the higher fertility pastures produced almost 30 per cent less methane per kilogram live weight gained (ie reduced emissions intensity).
- Higher fertiliser soils had more green pasture, greater feed quality and energy content, and better digestibility, leading to increased weight gain and feed-use efficiency.
- Improving soil fertility and pasture quality improved the feed–conversion efficiency in livestock. This reduced methane emissions intensity. It also increased the carrying capacity of paddocks, but if more stock were added, total emissions would increase.
- Changing the way producers manage pastures, feed and soils can have multiple benefits for grazing enterprises. Less methane means less waste and improved production.

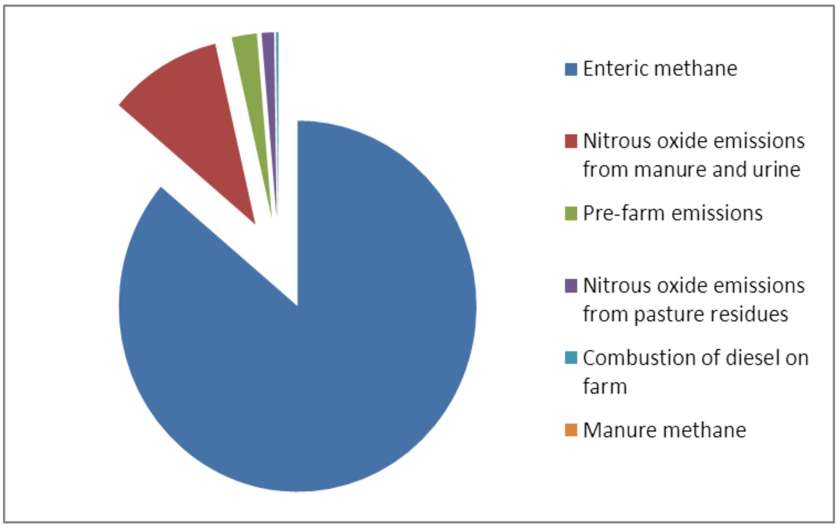
More information

McPhee M 2011, McPhee et al 2010, Powell et al 2011

G. Life Cycle Assessment (LCA) of livestock emissions

Life Cycle Assessment analyses the environmental impacts of a product's life cycle to identify potential points of improvement. This project calculated the LCA of wool and meat from a 1000ha Yass sheep enterprise. It measured all greenhouse gas emissions from the 4941 breeding ewes, annual outputs of 65.32 tonnes of 19 micron greasy wool and 147 tonnes of sheep meat as live weight from wethers and cull ewes, and 978 maiden ewes sold off-farm as replacement stock.

Figure 17. Greenhouse gas emissions (kg CO2-e) from the production of one kg of greasy wool and associated co-products at the farm gate in the Yass Region (Brock et al 2013).



Findings

- Emissions from the production of 19 micron wool were 24.9 kg CO_2-e per kg of greasy wool at the farm gate.
- Enteric methane (86 per cent of total) was the main emission.
- Methane emissions from manure were less than 15 per cent of the total.
- Nitrous oxide accounted for just over 11 per cent of total emissions (five per cent direct from manure and urine, five per cent indirectly from volatilisation and re-emission of manure and urine, and one per cent from decomposition of pasture residues).
- Only two per cent of total emissions were embodied in farm inputs, including fertiliser.
- The emissions profile varied according to the calculation method and assumptions used. Enteric methane production was calculated using five recognised methods and results were found to vary by 27 per cent.
- Calculated emissions for wool production changed substantially by changing the enterprise from wool to meat production (41 per cent decrease) and by changing wool price (29 per cent variability), fibre diameter (23 per cent variability) and fleece weight (11 per cent variability).

More information

Brock et al 2013

H. Use of modelling to account for enteric methane

This project aimed to develop a modelling framework to calculate reductions in enteric methane from on-farm mitigating activities.

Findings

Most models are too complex and input intensive to be used directly for emissions trading accounting.

It may be possible to use complex modelling to establish a likely mitigation effect, so that proponents only need to provide evidence of their actions rather than have to calculate the mitigation impact themselves.

Simplified models based on less intensive measures of enterprise activity are easier to use but there are risks in establishing a representative baseline.

A pasture-based model could be used to run enterprises with typical management and animal genotypes to generate a base line emissions profile. Alternate management strategies and genotypes could then be compared against the baseline to assess emissions profiles and production outcomes. Economic implications could be derived by comparing changes in costs with changes in economic output to determine the cost effectiveness of the mitigation strategy.

More information

Alcock and Hegarty 2011

7. Frequently asked questions about enteric methane

a. Why is reduction of enteric methane emissions important?

Enteric methane from ruminants, particularly cattle, contributes around 64 per cent of Australia's agricultural greenhouse gas emissions, so any reduction will help reduce national emissions. Methane has a higher global warming potential than carbon dioxide, but it also has a much shorter half-life, so reducing methane now will have a much faster impact on global warming potential in the future. There are additional potential benefits from reducing methane in terms of reduced waste of feed energy and improved efficiency of production, although these are likely to be small.

Because people have to eat, agriculture is an assured industry into the future and as such a potential source of long-lived carbon offsets for carbon-polluting industries. Although agriculture is not currently part of any emissions trading scheme, agricultural offsets such as sequestration of carbon in vegetation and soil, and reduction in methane from livestock, are already being used in some countries to provide credits for other industries. Current research into methods to reduce the carbon footprint of agriculture will provide useful technologies for future carbon trading schemes. Globally there is increasing discussion about the need for humans to eat less meat from ruminants and to reduce ruminant numbers and methane emissions (eg Ripple et al 2014). Research to reduce livestock emissions will help allay some of these concerns.

b. Why should producers have to reduce their methane emissions?

Reducing on-farm emissions of methane assists Australia to meet its international commitments to reduce greenhouse gases. Currently there is no legal requirement for producers to reduce methane emissions, but many management practices that reduce enteric methane also result in better farm productivity. Reducing enteric emissions can be seen as a public good objective but may become a private production objective if livestock GHG emissions are included in local or global carbon economies.

c. What is the difference between emissions intensity vs total emissions?

Total emissions is all the enteric methane produced by a given unit (eg herd, farm, enterprise). Emissions intensity is the enteric methane produced per unit of animal product (eg carcass weight, fleece weight). Management practices that increase the proportion of feed utilised for productive purposes (milk, meat or wool), rather than maintain the animal, all reduce emissions intensity.

d. Why can't producers be rewarded for improved emissions intensity?

The Australian government has committed to reducing total GHG emissions by five per cent by 2020. This can only be achieved by total reduction in GHG emissions. If intensity of GHG emissions can be improved (lower GHG emissions/unit product) this can contribute to a reduced total GHG emission only if the number of animals is reduced. This may be profitable in some circumstances. For intensive industries, eg dairy, it may be possible to both improve emissions intensity and reduce total GHG. For some extensive industries it may also be possible if enterprises are currently overstocked, and they adopt a policy of reducing stocking rate as a way to improve productivity.

e. Do agriculture and livestock contribute to climate change?

Agriculture and livestock both contribute greenhouse gases through human activity. Rising levels of greenhouse gases in the atmosphere are contributing to atmospheric warming which in turn is contributing to increased climate variability, increases in extreme weather, melting ice-caps and rising sea levels. Agriculture contributes 16 per cent of Australia's greenhouse gases from human activity, but enteric methane, particularly from cattle, is the most significant source of agricultural greenhouse gas emissions, so reducing enteric methane would help to reduce Australia's agricultural emissions.

f. What impact does forage quality have on methane emissions?

Forage quality has a major impact on methane production, being highest with low forage quality. Moving sheep from lower quality ryegrass to lucerne reduced emissions from 37 to 27 grams per sheep per day. Whole-farm modelling has found that improving pasture quality may well improve productivity and lower emission intensity per unit of product, but enables a higher stocking rate, resulting in higher emissions per hectare. (Eckard, Grainger and de Klein 2010)

g. My farm is part livestock, part cropping – what can I do?

If you want to reduce enteric methane emissions, you can increase the proportion of land area under cropping. Before doing this it would be prudent to re-evaluate the enterprise risk profile and your long term goals.

h. What is the more important emission, nitrous oxide or methane?

The CO_{2}-e of methane is 25; and nitrous oxide is 298, so the latter has a greater global warming impact than methane. Around 70-80 per cent of greenhouse gas emissions from a grazing animal are enteric methane, and 10-20 per cent are nitrous oxide emitted from microbial breakdown of urine patches and manure.

i. Do we know how to account for methane?

Nationally, Australia's national enteric methane emissions have been based on fixed feed intake-methane conversion rates based for each livestock category: ie pasture fed cattle(temperate and tropical), lot fed cattle, dairy cattle, sheep and pigs. An average conversion rate is used for remaining the small populations of other livestock types. Stock numbers are drawn from the Australian Bureau of Statistics databases. The conversion rates are also used in a variety of calculators to help landholders calculate on farm greenhouse gas emissions. Results of recent research into more accurate emissions measurement techniques, and into the amount and range of methane emissions from different animal systems will help update national inventory conversion factors and will open the way to more accurate on-farm calculations based on enterprise, and feed source quality and quantity. For more information on how enteric methane is accounted for, read the latest National Inventory Report from Australia's Greenhouse Gas Accounts, available on the Australian Government website.

j. What is the incentive to participate in emissions reduction?

Strategies to reduce enteric methane emissions can improve animal productivity. Depending on government policy, there may also be financial incentives to reduce emissions.

k. What is NSW DPI's role in reducing enteric methane emissions?

NSW DPI's role is to research and understand enteric methane emissions at system, farm and enterprise scale, and develop tools and information packages for delivery by public and private extension providers. This process requires collaboration between NSW DPI and potential extension providers and industry.

8. Glossary

Cud

Partly digested feed that is re-chewed by ruminant animals.

Defaunation

Removal of protozoa from the rumen of ruminants.

Digesta

The mix of undigested feed particles and soluble components, including saliva and microbial biomass, in the rumen which is regurgitated back to the mouth as 'cud' and chewed again (rumination).

Enteric

Related to the gut, derived from the Greek word *enteron* meaning 'gut'.

Enteric methane

Methane produced as a by-product of the digestion process in ruminant animals. It is emitted mainly through an animal's mouth as burps and belches. Some is also emitted while the animal is chewing its cud, and some through the lungs. A small amount is also produced in the intestine and emitted through the rectum as flatulence.

Genetics

The study of inheritance, or the way traits are passed down from one generation to another.

Genomics

The study of an organism's entire genome, focussed mainly on the positional mapping of genes, but particularly useful for determining the association of genes and gene networks with phenotype.

Genotype

Genetic makeup, as distinguished from physical appearance, of an organism (eg animal).

Global warming potential (GWP)

Indicates the amount of heat trapped per mass of gas and the time the gas remains in the atmosphere. It is expressed relative to carbon dioxide which has a GWP of 1.

Life Cycle Assessment

Analysis of the environmental impacts of a product's life cycle to identify potential points of improvement.

Methane

Colourless, odourless gas, abundant in the atmosphere and the main component of natural gas. Each molecule comprises one carbon and four hydrogen atoms, hence its chemical formula CH_4.

Methane emissions intensity

Amount of methane per unit of agricultural product produced eg enteric methane per kg of wool, per kg of meat, or per kg of milk solids.

Methane yield

Methane emissions per quantity of feed eaten.

Methanogen

Microorganisms that produce methane.

Net feed intake

A measure of feed efficiency, being the amount of feed eaten by an animal above or below its expected requirement to maintain weight and for weight gain.

Phenotype

Observable traits of a living organism (eg animal)

Rumen

The first and largest of four digestive chambers in ruminant animals where microorganisms (mainly bacteria, protozoa and fungi) ferment and break down ingested feed.

Ruminant

Animals with a rumen and so able to digest fibrous material.

Rumination

The digestive process of ruminants in which digested feed in the rumen is regurgitated for re-chewing before being re-digested.

Total methane emissions

The total quantity of methane produced by an entity, eg by an animal, farm, industry, state etc. expressed as kg methane per entity

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