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Greenhouse Gas Emissions and the Australian Red Meat Industry

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Introduction

Australia is one of the worlds leading producers of beef, mutton and lamb, with over 27 M head of cattle and 100 M head of sheep nationally, 878 K of the cattle being finished in feedlots. In 2004-5 the gross value of beef production was estimated around $7.7 billion and sheep and lamb production estimated at $1.86 billion in 2004-5. In 2004-5 there were 75,427 cattle and 46,178 sheep and lamb properties. These industries represent a substantial part of the Australian economy and a vital part of maintaining rural infrastructure in Australia.

The Bureau of Meteorology reported that 2005 was the hottest year on record and the January to May period in 2005 was the second driest on record. In January NSW experienced its warmest month ever recorded, with Victoria experiencing its 3rd warmest January since State-wide records began in 1950. The U.N.'s World Meteorological Organization reported that 9 of the 10 hottest years on record have occurred since 1994. With the last 4 years being part of the 5 hottest years on record, and atmospheric carbon dioxide levels at their highest ever known, it appears that our climate is changing. There is now increasing evidence that greenhouse gas emissions, from the burning of fossil fuels, land clearing and agricultural activities, have contributed to this process of global warming and climate change, and this represents one of the greatest challenges to future sustainable development.

The Australian continent differs from continents like Africa and North America, in that there were no large ruminant herds roaming the rangelands over 200 years ago. Due to the introduction of commercial farming systems, nitrogen fertiliser and livestock, the greenhouse emissions profile of Australia has changed dramatically over the past 200 years; these changes are therefore considered anthropogenic and thus part of Greenhouse emissions accounting and an integral component of any national greenhouse abatement strategy.

While it is imperative that the agricultural industries remain profitable, viable and internationally competitive, there is also an expectation on land managers to contribute where they can to minimise their environmental footprint.

Background

Under the Kyoto protocol the Australian government has agreed to conduct an annual National Greenhouse Gas Inventory (NGGI) to audit and report on greenhouse gas emissions from defined sectors of the economy. A summary of the most recent NGGI audit is presented in Figure 1 below, showing that the majority of greenhouse gas emissions are sourced from the Stationary Energy sector. However, the Agricultural Sector is reported to contribute 17.7% of Australia’s national net greenhouse gas emissions.

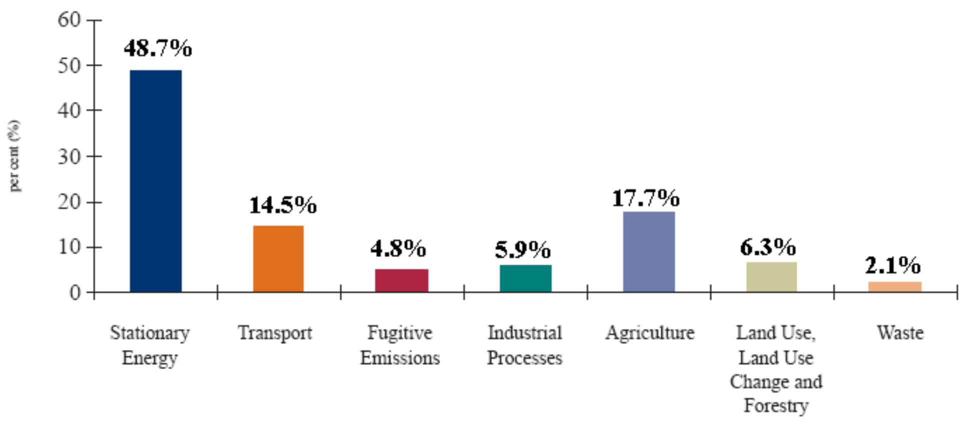

Figure 1. Sectoral greenhouse gas contributions in Australia for 2003 (NGGI 2005).

Gasses emitted from agricultural production

The main greenhouse gasses emitted from agricultural production in Australia are carbon dioxide, methane and nitrous oxide. In the 2003 NGGI, 68% of all methane and 77% of all nitrous oxide emitted nationally is attributed to the agricultural sector.

Methane and nitrous oxide are particularly potent greenhouse gasses with global warming potentials of 21 and 310 times that of carbon dioxide, respectively; all greenhouse gas emissions are multiplied by their global warming potentials to report emissions on a common carbon dioxide equivalents (CO_2e) basis.

a) Carbon dioxide

Carbon dioxide is mainly emitted through energy and fuel consumption on farm, being usually <10% of total on-farm emissions. In the NGGI these emissions are attributed to the transport or stationary energy sector and are not included in the agricultural sector in Figure 1.

Carbon fluxes from the cultivation of soils and land clearing is potentially massive, but changes in these stocks are slow and are not reported in inventories (eg Figure 2) as they are difficult to quantify.

The prescribed burning of rangelands in Australia is an important source of both methane and nitrous oxide emission. However, there is some contention that in the absence of prescribed burning, fuel loads would build and natural wildfires would eventually burn the area anyway.

b) Methane

> Methane is mainly lost from rumen fermentation and to a lesser extent from burning of rangeland and waste management.

In the rumen a group of microbes called methanogens are responsible for producing methane, utilising surplus hydrogen in the rumen to reduce carbon dioxide to produce methane. The methane produced is then largely belched and breathed out by the animal. However, as methane gas is a high energy source, this represents a significant loss of energy from the production system that can and should be redirected back into production. The key is therefore to provide another mechanism for reducing hydrogen levels in the rumen, otherwise normal digestion will be adversely affected and the energy savings will not be realised in improved production.

Methane emissions from rumen fermentation makes up more than 66% of total emissions from the agricultural sector (Figure 2) and are usually > 75% of on-farm greenhouse gas emissions from red-meat production systems in Australia.

c) Nitrous oxide

> Any agricultural activity that inefficiently supplies N to the soil-plant system can lead to large losses of N through a number of loss processes, including nitrous oxide.

Nitrous oxide is primarily produced in soil by micro-organisms through incomplete denitrification of nitrate into nitrogen gas, and to a lesser extent, through the nitrification of ammonium into nitrate (see Figure 4). This process is maximised in warm, acidic, anaerobic (wet) soil conditions with large amounts of nitrate and available carbon present.

Nitrous oxide losses are mainly from soils disturbance, nitrogen fertiliser, animal excreta and manure management systems, and to a lesser extent from crop and rangeland burning.

Nitrous oxide emissions from grazing systems range from about 0.2 kg N/ha as nitrous oxide (93 kg/ha per year CO_2e) under extensive conditions, through to about 6 to 11 kg nitrous oxide-N/ha (2.9-5.3 t/ha CO_2e) from an intensive grazed dairy pasture, where fertiliser is applied at rates from 0 to 200 kg N/ha. Nitrous oxide emissions from legume-based pastures may be in the order of 1 to 2 kg N/ha, and similar losses are likely when these pastures are terminated for cropping.

Nitrogen fertiliser is not commonly applied to pastures used for red-meat production and consequently nitrous oxide emissions from this source would be extremely low. Most of the nitrogen lost from grazing is through the inefficient recycling of nitrogen through urine. Nitrous oxide emissions make up 19% of total greenhouse emissions from the agricultural sector (Figure 2), and within red-meat production systems are usually < 20% of total on-farm emissions.

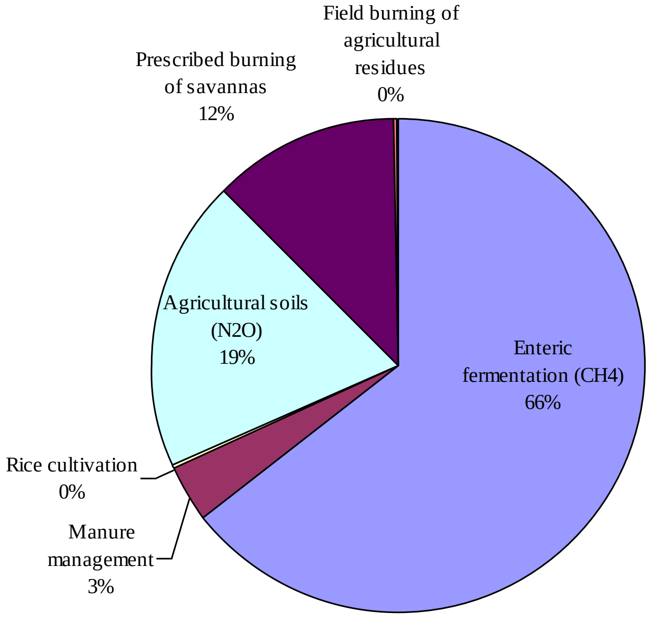

Figure 2. Greenhouse gas emissions from the agricultural sector in 2003. All gasses expressed as carbon dioxide equivalents (CO_2e) (NGGI 2005).

Greenhouse emissions from the Australian livestock industries

Within the livestock industries, beef cattle are the largest emitting sector followed by the sheep industry (Figure 3). These trends are largely driven by animal numbers, as can be seen by the decline in emissions from sheep between 1990 and 2002, closely following trends in the national sheep numbers. However, within the livestock classes dairy cattle are the largest individual emitters of both nitrous oxide (due to the higher protein intake and excretal loss of nitrogen) and methane, losing between 90 and 150 kg methane/hd/y (enough to power a 6-cylinder car for 1000 km). Beef cattle emit between 50 and 90 kg methane/hd/y, while sheep lose between 10 and 13 kg methane/hd/y.

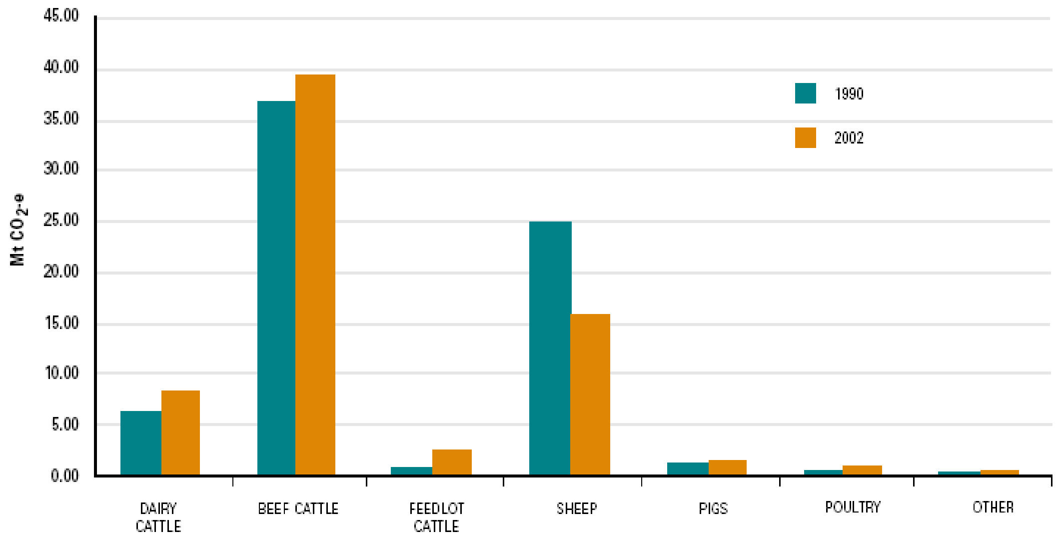

Figure 3. Greenhouse gas emissions from livestock classes in Australia in 1990 and 2002 (NGGI 2005).

Uncertainty in emission estimates

In the NGGI there is an inherent uncertainty associated with estimates of greenhouse emissions. Uncertainties associated with agricultural estimates are high as:

- most of the research on methane and nitrous oxide loss are based on studies conducted in the northern hemisphere; their direct application to Australian agriculture is questionable and requires local research before industries can be held accountable for their emissions;
- national inventories rely accuracy of input data like animal numbers and nitrogen fertiliser use, and
- biological systems are inherently variable and by definition and national inventory method can only integrate and approximate using available data.

The estimated uncertainty in enteric methane emissions ranges from –5.1% to +5.9% and –52% to +110% for nitrous oxide from *agricultural soils*. The uncertainty in estimated cattle numbers was the most significant contributor to the overall uncertainty in enteric methane, while the uncertainty for nitrous oxide emissions is due to lack of local research data and inherent spatial and temporal variability in emissions; the latter can only be addressed through a dynamic process-based model, or at a minimum, the use of spatially and industry-specific emission factors, developed from representative research conducted in Australia.

Recent measurements of methane emissions from sheep on high-quality pastures and cattle on grain diets in Australia show that the inventory procedure produces accurate estimates of methane emission rates. However, further work is needed to reduce uncertainties relating to feed intakes, methane emissions from sheep on low-quality pasture, methane emissions from beef cattle, and emissions from manure under a range of conditions; however, these are largely government research priorities.

Potential abatement Actions for the Australian red-meat industry

Wherever possible research into greenhouse gas emissions and abatement should explore potential synergy with other industry objectives. For example, the planting of trees for carbon credits should include an assessment the biodiversity and salinity benefits that may accrue.

> *As there are current no economic or policy drivers for the adoption of greenhouse gas abatement on farm, the initial focus of any investment by MLA should be on exploring win-win outcomes, where overall farm profit or efficiency can also be*

Extension and communication

The level of knowledge and understanding of greenhouse gas emissions and climate change amongst the farming community is highly variable. Many farmers perceive this as a new threat or unnecessary impost on their enterprise.

> There is a need to more fully understand the attitudes and level of knowledge of red-meat producers in Australia, and identify the potential barriers to adoption of management changes for greenhouse abatement and adoption of strategies to adapt to a changing climate.

State governments have reduced their investment in formal extension services to the extent that farmer source most of their information from non-government sources. There is a need, therefore, to identify these sources in order to effectively communicate research outcomes to various groups of red-meat producers in Australia; this priority is not specific to greenhouse emissions.

Australian agriculture promotes a “Clean and Green” production image and there is increasing pressure to demonstrate that this claim can be substantiated. However, it is not clear if this pressure is actually being demanded by the consumer, international markets or is being driven locally through perception. With respect to ‘greenhouse friendly’ production systems there is also speculation that Australia not having ratified the Kyoto protocol this may be used as a potential trade barrier in future, and for that reason Australian agriculture may need to be able to demonstrate its greenhouse credentials. There is a real need for the red-meat industries to understand if these issues are real, imminent or just perceived.

Specific Action for MLA

1.1: Commission market research to understand the demands, expectations and perceptions of export markets to greenhouse friendly production systems.

1.2: Commission market research to understand the attitudes, perceptions, communication needs and barriers to adoption or greenhouse best practice in the farming community.

1.3: Based on the outcomes of 1.1 and 1.2 above, commission a targeted extension and communication program to address key education and communication needs identified.

Specific Action for Farmers:

Remain current with the latest reliable information on greenhouse gas emissions, climate change, sequestration opportunities and associated market expectations from un-biased sources.

Whole Farm Systems and Life Cycle Assessment

A comprehensive analysis of mitigation measures ideally has to take the total net effect of all greenhouse gas emissions into account, since action to mitigate greenhouse gas emissions at one point in the production chain may lead to higher emissions at a subsequent point. A simple example here is that, one strategy to reduce methane emissions from temperate pasture would be to improve forage quality through applying more nitrogen fertiliser, with the unintended consequence of increasing total greenhouse gas emissions through the production of a more powerful greenhouse gas, nitrous oxide.

In developing GHG abatement measures research needs to take into account the whole farm system and the life cycle impacts of any abatement measures, to ensure that there are no other unintended production and/or environmental consequences elsewhere in the production system.

Specific action for MLA

2.1: Where feasible, all investments in greenhouse abatement technologies need to include an assessment of the whole-of-production-system impacts and a life-cycle assessment of the measures, before they are extended to the farming community.

2.2: Whole farm systems modelling needs to include the capacity to predict relative changes in enteric methane and nitrous oxide emissions, along with carbon fluxes.

Nitrous oxide

An illustration of the nitrogen cycling in an agricultural system is provide in Figure 4, showing the many pathways through which nitrogen can cycle and be lost from the soil-plant-animal system. Nitrogen is an inherently leaky element and livestock production systems are very inefficient in converting nitrogen into animal produce. Grazing systems may convert between 15 and 60% of total nitrogen inputs into animal produce, demonstrating a large range in efficiencies and room for improvement.

Nitrogen is very inefficiently cycled livestock production systems, with large leaching and gaseous losses from urine deposition.

As nitrogen fertiliser is not commonly applied to pastures and rangeland used for red-meat production in Australia, emissions of nitrous oxide from this source are not considered significant. The main input of nitrogen into these grazing systems, and therefore by implication the potential for nitrous oxide loss through dung and particularly urine, would be through biological nitrogen fixation from legumes. Pastures with excessive legume content (>25 to 30%) will result in a high nitrogen to energy ratio in the animal, expending energy to metabolise surplus nitrogen and excreting high nitrogen in the urine. However, given the clear benefits, it is both impractical and unacceptable to consider reducing legumes in grazing systems.

The NGGI also accounts for nitrous oxide emissions resulting from soil disturbance i.e the enhanced emission from a production system relative to its pristine state. While most intensive pastures were established on cleared land, these pasture and rangeland systems are seldom disturbed and thus these enhanced emissions are both low and provide limited potential for further abatement.

Nitrous oxide emissions from the red-meat industry are therefore mainly sourced from urine (estimated at 1.2×10^9 tonnes CO_2e from beef cattle and 1.1×10^9 tonnes CO_2e from sheep nationally) and to a lesser extent from dung (estimated at 0.73×10^9 tonnes CO_2e from beef cattle and 0.44×10^9 tonnes CO_2e from sheep nationally) deposited in the field, or in manure management systems in the case of feedlots.

Nitrous oxide emissions, being mainly the result of an anaerobic microbial process in the soil called denitrification (see Figure 4), can also be exacerbated by soil compaction and poor drainage. Stock management that results in a high stocking density (camping) in areas of the paddock will therefore lead to a concentration of dung and urine deposition, together with increased soil compaction, leading to a nitrous oxide emissions hotspot (and potentially high ammonia volatilisation and nitrate leaching). Improving drainage and preventing soil compaction can reduce nitrous oxide emission by around 3% each.

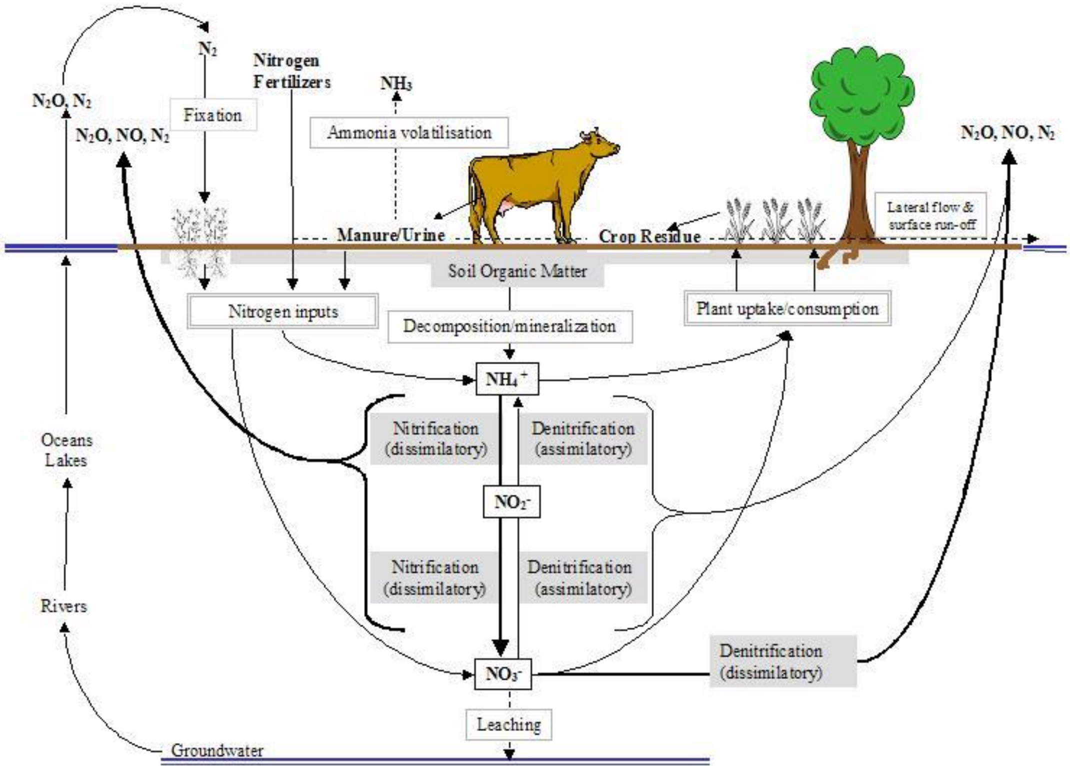

Figure 4. The nitrogen cycle highlighting potential sources of nitrous oxide.

Manipulating the diet of animals can significantly influence the amount of nitrogen excreted in urine. For example, feeding cattle protein that resists degradation in the rumen and high starch diets can result in less nitrogen being excreted in the urine, reduced ammonia volatilisation, and less nitrous oxide emission. Research has shown up to a 24% reduction in urinary nitrogen loss is possible.

Breeding forage cultivars that provide an energy-to-protein ratio more in keeping with the animal's needs could improve nitrogen efficiency. Again cows fed grasses high in water soluble carbohydrate may excrete 24% less nitrogen than those fed normal diets.

Although limited in where it can be implemented, one strategy for improving overall nitrogen efficiency, would be keeping stock on feed-pads during the wet season (particularly the winter rainfall regions), so that excreta can be collected and utilised as fertiliser later in the year. This strategy will also reduce pasture damage. Through this strategy it is estimated that nitrous oxide emission from excreta could be reduced by as much as 25% and nitrate leaching by 40%.

If it is assumed that the effects are additive, and that the reductions achieved experimentally could be realised in a practical farming situation, there is the potential for nitrous oxide emission to be reduced from the sheep, dairy cattle, and beef cattle sectors by 16%, 28% and 25% respectively. It is accepted that these estimates of abatement potential will be subject to considerable variation, and that reductions of this order are unlikely to be achieved in a farm situation. However, the strategies discussed above will not only reduce nitrous oxide emissions, but will improve the efficiency of nitrogen economy and overall production efficiency.

Abatement strategy to reduce nitrous oxide emissions
Invest in actions aimed at improving the overall efficiency of nitrogen cycling in red-meat production systems.

Specific action for farmers to reduce nitrous oxide emissions
- Minimise camping to improve nitrogen redistribution on the property.
- Avoid soil compaction through hoof compaction, particularly in seasonally wet areas.
- Manage pastures to maintain a reasonable, but not excessive (>30%) legume content.
- In feedlot systems, ensure that the energy to protein ratio is optimised for production benefit.
- In regions of heavy winter rainfall, consider using stand-off areas limiting stock access time to pasture to reduce pasture damage, soil compaction and nitrogen losses. However, to ensure efficiency of nitrogen use, the animal waste from the stand-off area would need to be spread back evenly on the pasture later in the season.

Specific action for MLA:
3.1: Research into the abatement of nitrous oxide emissions from nitrogen fertiliser applied to pastures is **NOT** a high priority for the MLA and should be addressed by the fertiliser, dairy and cropping industries.
3.2: A desktop review of the efficiency of nitrogen cycling in key grazing systems in Australia. This study should aim to highlight nitrogen inputs and outputs from a range of production systems, identifying the points of nitrogen loss and sources of inefficiency in the nitrogen cycle.
3.3: Following or combined with the action above, further research is required into options for reducing nitrogen losses from urine deposition, and therefore by implication nitrous oxide losses, perhaps as a joint investment between MLA, AWI and DA.
3.4: Where investments are made in breeding of forage varieties this should include a focus on improving the energy to protein ratios in these forages.

Methane

Enteric methane emissions are the largest greenhouse gas source emitted by the red-meat industry in Australia. However this is also the largest sectoral source of methane in Australia and is therefore unlikely to escape attention by policy makers or international bodies like the IPCC.

Reviews of available literature suggest that up to 50% abatement in enteric methane is achievable, with the majority of studies showing between 14 and 25% potential abatement. Studies have also demonstrated that strategies that provide an alternative sink for hydrogen in the rumen can redirect the energy back into production.

> The loss of methane from ruminants represents a loss of energy that can be redirected back into production. The key for research is to develop ways to doing this economically, thereby providing an incentive for adoption.

As the rumen is a complex environment, there are numerous potential strategies for reducing enteric methane emissions from ruminants as illustrated in Figure 5.

a) <u>Feed Management</u>

i) Plant breeding

The diet of the ruminant can have a marked affect on methane production and productivity. One strategy to increase production efficiency and reduce methane would be to breed higher quality forages, but also breed to increase certain natural plant chemicals.

Plant breeding programs should aim to improve plant carbohydrate to protein ratios, but also improve carbohydrate composition (increase starch and reduce structural carbohydrates). A number of forages contain small quantities of alkaloids that have been shown to reduce methane production and also reduce urinary nitrogen excretion (eg. tannin).

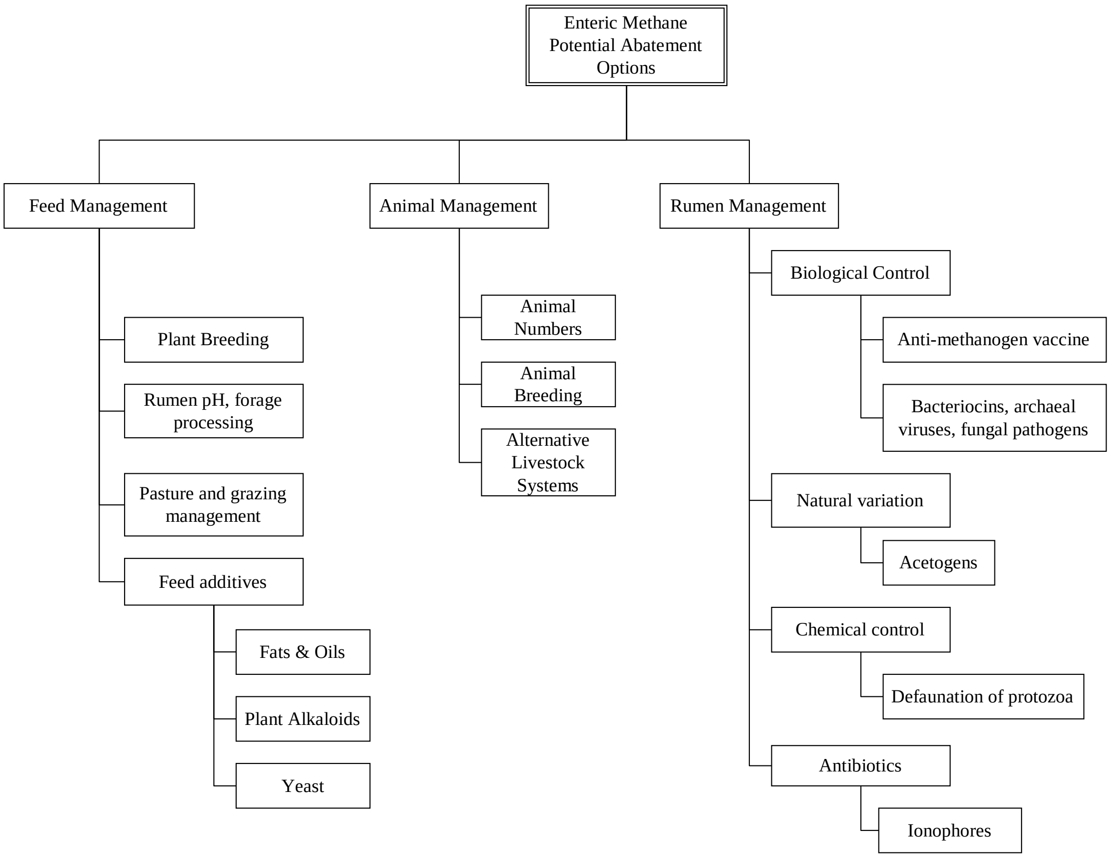

Figure 5. A flow chart of the options available for the abatement of enteric methane in ruminants.

Delivery by breeding into pasture plants is possible, but the time needed to get viable pasture swards established should not be underestimated.

ii) Rumen pH, forage processing and supplementary feeding

The proportion of gross energy lost as methane is generally higher on poorer quality roughage diets, relative to diets with higher concentrate feeding or where forages are pre-processed. This effect is largely attributed to higher propionate production and an acidic rumen being more hostile to methanogens. At high intakes, methane loss/unit of diet can be reduced 20-40 %.

iii) Pasture and grazing management

As discussed above, feeding animals on higher quality pasture will improve productivity and reduce methane losses. Pasture renovation, improved soil fertility and rotational grazing management can all impact on this.

As the total amount of methane produced from a farm is directly related to the number of animals, a faster turn-off and minimising non-productive animals on the property are two obvious management strategies to both improve profitability and reduce methane. The methane reduction achievable is directly correlated to the reduction in animal numbers.

iv) Feed additives

A wide range of feed additives have been shown in various studies to reduce methane. The dosages required would need to be small to suit slow-release capsule technologies, otherwise these options would be limited to feedlots.

- The organic acids **malate** and **fumarate**, while effective as alternative hydrogen acceptors and can potentially reduce methane by up to 35%, remain highly expensive and therefore unlikely to play a role in methane abatement.
- Addition of **unsaturated fatty acids** to the rumen will decrease methane emission. Their effect is twofold: the unsaturated fatty acids are a potential alternative sink for hydrogen, and large doses are toxic to rumen microorganisms but may depress digestion. It is the medium chain fatty acids (C10 – C21), which cause the greatest reduction in methane production and also the methanogen population. Methane abatement of up to 37% has been reported in various studies.
- Forages containing **condensed tannins** have been shown to reduce methane emissions by up to 16%, while also decreasing urinary nitrogen losses, thereby reducing potential nitrous oxide emissions as well. Condensed tannins occur naturally in forages like *Lotus* spp and in most Australian and African *Acacia* spp. A condensed tannin extract from *Acacia mearnsii* (Black Wattle) is commercially available at relatively low cost from the tanning industry.
- **Saponins** are natural compounds found in some plants. They consist of a sugar moiety (oligosaccharide chain) which is linked to sapogenin (a hydrophobic aglycone). The main commercial source of saponin used in human foods and in animal feeding is from the Yucca plant (*Yucca schidigera*, grown mainly in Mexico) and the *Quillaja saponaria* tree (hardwood tree grown in Chile). Saponins have antiprotozoal activity which could be beneficial for methane reduction, because up to 40% of methanogens are directly associated with rumen ciliate protozoa.

b) <u>Animal Management</u>

i) Animal numbers

Obviously a reduction in animal numbers will reduce methane emissions. This is evidenced in the changes in national emissions from sheep in the NGGI following the downturn in the wool price. This is not an acceptable solution as a stand-alone option. However, it may be possible to reduce methane by combining improvements in animal efficiency with lower livestock numbers.

ii) Animal breeding

There are two aspects of genetic improvement with respect to methane emission: genetic improvement in the efficiency of food conversion by the animals themselves; and the possibility that there are genetic differences between animals in the amount of methane they emit at the same feed intake.

In grazing systems there has been little direct selection for improved feed conversion efficiency, which is in contrast to the situation with pigs and poultry where huge gains have been made. There has, however, been considerable indirect selection for increased liveweight gain in fattening lambs and beef cattle.

Research in New Zealand has demonstrated up to 40% difference in methane emission between individual animals of the same breed and type. These differences may be linked to individual intakes, rumen volume, diet selection etc. However, little is know about the key attributes contributing to these differences and their persistence.

iii) Alternative livestock systems

While we have been good at reproducing European agriculture in Australia, we need to question the appropriateness of these production systems in the Australian context. As Kangaroos produce virtually no methane, and have a lower fat content in the meat, we should be asking ourselves if we are producing the right red-meat products in this country.

c) Rumen Management

Many suggestions have been made for manipulating the rumen microbial ecosystem to achieve methane reduction. These include targeting methanogens with microbial antibiotics, bacteriocins or phage, removing protozoa and developing alternative sinks for hydrogen such as acetogenic bacteria.

i) Biological control

- **Immunisation** of animals against methanogens has been attempted by CSIRO scientists, with a proof-of-concept experiment showing a 7.7% (ns) abatement in 30 sheep. This is a good concept as methanogens are antigenically distinct and an abatement of up to 20% is possible. It is also one of the better options for the extensive grazing industry. However, both the lead time and cost of the research is high.
- **Bacteriophages Bacteriocins, archaeal viruses, fungal pathogens -** A number of bacteria, viruses and fungi have been identified in the rumen that either directly attack methanogens, or produce compounds like bacteriocins (antibiotics, generally protein or peptide in nature). Potential biological control (pathogenic) organisms targeting rumen methanogens or the protozoa with which they associate, have not been researched nor are these organisms well understood.
- **Probiotics** are reputed to promote gut health and aid digestion although. Studies on *Aspergillus oryzae* and *Saccharomyces cerevisiae* have shown 50% and 10% reductions in methane, respectively. *In-vivo* studies in cattle and sheep have shown significant increases in digestibility and propionic acid production, both of which suggest that the product may be able to reduce methane emissions.
- **Acetogens -** There is another group of rumen microorganisms, the acetogenic bacteria, which have the capacity to convert hydrogen into acetate, one of the main nutrients of the ruminant animal. Acetogens do not compete well in the rumen compared to methanogens, so experiments are in progress to see if the microbial ecosystem can be manipulated to enhance acetogen activity. One strategy is to genetically modify acetogens so that they can compete more effectively in the rumen.

Development of mitigation technologies from research into biological control is well in the future because of the need to better understand the rumen microbial ecosystem.

ii) Chemical control

Many halogenated methane analogues such as chloroform, carbon tetrachloride, chloral hydrate, bromochloromethane and bromoethanesulphonic acid can be very potent methane inhibitors, reducing methane by up to 50%.

Up to 40% of methanogens cling to rumen ciliate protozoa, thus eliminating or suppressing protozoa may reduce methane by up to 50%. Options for reducing protozoal numbers include using defaunating agents like manoxol or teric. However, these protozoa are needed for fibre and microbial protein digestion, so sustainable abatement can only be achieved through selectively reducing protozoa.

However, issues like adaptation by rumen microbes, host toxicity and suppression of digestion still need to be overcome, apart from the public perception of these chemicals being introduced into the food chain.

iii) Antibiotics

Commercial ionophores (eg. Monensin), Salinomycin and Avoparcin have been shown to enhance propionate production and some studies have shown methane abatement of 20 to 40%. There are, however, reports that the effect appears to be short-lived as the rumen microbes adapt to the antibiotic additive within two weeks. Methane abatement also appears far greater on TMR diets, with recent research on grass-based diets showing little or no methane reduction.

Abatement Strategy to reduce enteric methane emissions:

Develop breeding and feeding systems that reduce methane, while increasing production efficiency.

Specific action for farmers to reduce enteric methane losses:

- Pasture improvement to introduce a higher quality pasture will improve both productivity and reduce methane.
- Genetic improvements should continue to focus on efficiency gains and in particular use indicators of feed conversion efficiency.
- Apart from reducing unproductive animals, feeding animals on high quality forages and continual breeding for more efficient animals, there are no proven practical strategies available to economically reduce enteric methane loss from ruminants at this stage.

Action for MLA

4.1: Where investments are made in forage breeding, these should include attention to the plant quality attributes and natural plant chemicals where possible.

4.2: Consider co-investing with the dairy industry in quantifying the productivity benefits and greenhouse gas abatement of key feed additives like unsaturated fats, tannins and saponins.

4.3: Where investments are made in animal breeding, these should include feed conversion efficiency as a key criterion.

4.4: Further understanding is needed of the large differences that seem to exist between individual animals in methane emission.

4.5: A basic research programme to improve our general understanding of rumen ecology should be supported. This study should include more than just the methanogenic Archaea and associated ciliate protozoa.

Manure management

Both methane and nitrous oxide are emitted from stored manures, are usually less than 2% of total farm emissions on dairy farms in total, and only really relevant to the dairy and feedlot industries.

Carbon

The role of carbon credits in land management has been given considerable exposure in recent years. Although there is no national emissions trading system in Australia some speculative trades are occurring.

a) Carbon dioxide emissions

Carbon dioxide emissions from the red-meat industries would be largely from power consumption and diesel used in farm machinery. Relative to most other industries these emissions are insignificant and there is already extensive research being conducted world-wide into energy efficiency in electricity generation, alternative energy sources and fuel efficiency. The outcomes from these developments will automatically flow on to red-meat producers over time.

> Most carbon stocks in Australian soils are still in net decline post land clearing. Improved permanent pastures can reduce this rate of loss over decades.

b) Soil carbon

Soil carbon emissions typically occur after clearing of native vegetation for cropping and pasture, while some land management practices, such as establishment of permanent pasture and pasture improvement may increase soil carbon. One of the issues is that most soil carbon stocks in Australian agricultural soils are still in net decline post land clearing and most management practices are merely arresting the rate of decline, not actually sequestering carbon.

In Australia, grazing of rangelands is the most extensive land use, and changes in rangelands management could have a significant impact on the country's carbon balance. There is major sink potential in the reduction and reversal of rangelands degradation, but this may be difficult to achieve in practice.

While showing great potential for changes in carbon storage, achieving recognisable soil carbon sequestration is difficult under the current rules defined for carbon accounting and the timescales required to demonstrate change in soil carbon stores do not provide sufficient economic incentive for farmers at this stage.

c) Tree plantings

Most farmers would be aware of the potential value of tree plantings in providing carbon credits. However, farmers need to be made aware that planting trees just for their carbon credit value may not to be economic in its own right, and needs to be viewed as part of a package of benefits that include biodiversity, wildlife corridors, salinity management, shade and shelter etc.

Planting trees for their carbon credit value may not to be economic in its own right, but needs to be viewed as part of a package of benefits that include biodiversity, salinity management, shelter etc.

Producers will also need to be aware that other industries will be looking to the land-based sectors to offset their emissions. For example, if the proposed State based emissions trading scheme is established, even if just initially for the stationary energy sector, this sector may decide that it is more cost-effective to establish trees on agricultural land than to reduce their direct emissions from power generation. This may represent an opportunity for some farmers wishing to diversify, or may be a direct threat to agricultural land.

A plantation is likely to sequester between 1-10 tonnes of carbon per hectare per year over a 30 year period, although this figure may be greater in areas of high rainfall and lower on marginal land. The amount of carbon sequestered by a forest depends on site, age, stocking, management, and species characteristics. As an example, a 200 cow-calf operation on 300 ha (16 DSE/ha or 1.2 LSU/ha) would produce around 1000 t CO_2e per year and thus need to establish between 36 ha of a fast growing *Eucalyptus* species in an area receiving between 500 and 700 mm rainfall, to fully offset their farms total greenhouse gas emissions. Likewise a 2500 ewe-lamb operation on 350 ha (16 DSE/ha) would produce similar emissions and thus require the same amount of timber plantation (see Figure 6).

Abatement Strategy to increase carbon storage:

Promote management systems that minimise soil disturbance and maximise tree plantings on less productive or marginal land.

Specific action for farmers to increase carbon storage:

- Planting trees just for their carbon credit value may not to be economic in its own right, and needs to be viewed as part of a package of benefits that include biodiversity, wildlife corridors, salinity management, shade and shelter etc.
- When considering carbon sequestration projects, take professional advice and ensure that the advice is using methods accredited by the Australian Greenhouse Office; otherwise credits may not be recognised for trading purposes.

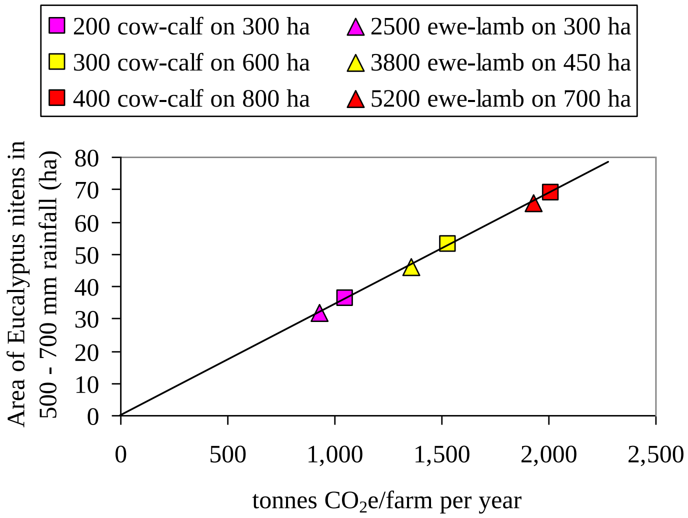

Figure 6. Examples of the area of a fast growing *Eucalyptus* species, grown in a high rainfall zone (500 – 700 mm), required to fully offset the annual total greenhouse gas emissions (t CO_2e/farm) from various beef and sheep production systems.

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Appendix I: Summary of abatement actions

Extension and Communication
1.1: Commission market research to understand the needs and perceptions of export markets to greenhouse friendly production systems. *1.2:* Commission market research to understand the attitudes, perceptions, communication needs and barriers to adoption in the farming community. *1.3:* Based on the outcomes of 1.1 and 1.2 above, commission a targeted extension and communication program to address key education and communication needs identified.
Whole Farm Systems and Life Cycle Assessment
2.1: Where feasible, all investments in greenhouse abatement technologies need to include an assessment of the whole-of-production-system impacts and a life-cycle assessment of the measures, before they are extended to the farming community. *2.2*: Whole farm systems modelling needs to include the capacity to predict relative changes in enteric methane and nitrous oxide emissions, along with carbon fluxes.
Nitrous Oxide Abatement
Abatement strategy to reduce nitrous oxide emissions: Invest in actions aimed at improving the overall efficiency of nitrogen cycling in red-meat production systems.
3.1: Research into the abatement of nitrous oxide emissions from nitrogen fertiliser applied to pastures is not a high priority for the MLA and should be addressed by the fertiliser, dairy and cropping industries. *3.2:* A desktop review of the efficiency of nitrogen cycling in key grazing systems in Australia. This study should aim to highlight nitrogen inputs and outputs from a range of production systems, identifying the points of nitrogen loss and sources of inefficiency in the nitrogen cycle. *3.3:* Following or combined with the action above, further research is required into options for reducing nitrogen losses from urine deposition, and therefore by implication nitrous oxide losses; perhaps a joint investment between MLA, AWI and DA. *3.4:* Where investments are made in breeding of forage varieties this should include a focus on improving the energy to protein ratios in these forages.
Enteric Methane Abatement
Abatement Strategy to reduce enteric methane emissions: Develop breeding and feeding systems that reduce methane, while increasing production efficiency.
4.1: Where investments are made in forage breeding, these should include attention to the plant quality and natural plant chemicals where possible. *4.2:* Consider co-investing with the dairy industry in quantifying the productivity benefits and greenhouse gas abatement of unsaturated fats, tannins and saponins. *4.3:* Where investments are made in animal breeding, these should include feed conversion efficiency as a key criterion. *4.4:* Further understanding is needed of the large differences that seem to exist between animals in methane emission. *4.5:* A basic research programme studying the ecology of the rumen Archaea should be supported. The aim should be two-fold: to identify opportunities for reducing methane synthesis; and to divert accumulated hydrogen into products that can be utilised by the animal.
Carbon
Abatement Strategy to increase carbon storage: Promote management systems that minimise soil disturbance and maximise tree plantings on unproductive land.

Appendix II. Summary of likely abatement achievable

Strategy/ action	Potential methane reduction
Enteric Methane	
Adding grain to a forage-based diet	Up to 5%
Increasing forage quality and legumes into pastures	Up to 10%
Feeding Malate or Fumarate	Up to 35%
Feeing polyunsaturated fats (sunflower, cotton seed, canola oil, palm oil)	20% (up to 37%)
Overall impact of forage processing and improving diet quality	20 to 40%
Reducing unproductive animal numbers	Proportional to animal numbers
Feeding condensed tannin	16%
Animal breeding and types	Up to 40%
Vaccination	7.7% (20% potential?)
Probiotics	10 to 50%
Chemical control (eg Chloroform)	Up to 50%
Antibiotics (eg Ionophores) on TMR diets	10 up to 40%
Nitrous Oxide	
Improving drainage and preventing soil compaction	3% each
Improving the quality of forages (eg. nitrogen to carbohydrate ratio)	24% less N lost in urine
Use of feedpads during wet season, with excretal collection and redistribution	25%
Feeding condensed tannin to reduce urinary N excretion	Not well quantified

Appendix III: Summary of Suggested Actions for Farmers

- Remain current with the latest reliable information on greenhouse gas emissions, climate change, sequestration opportunities and associated market expectations from un-biased sources.

Specific action for farmers to reduce nitrous oxide emissions

- Minimise camping to improve nitrogen redistribution on the property.
- Avoid soil compaction through hoof compaction, particularly in seasonally wet areas.
- Manage pastures to maintain a reasonable, but not excessive (>30%) legume content.
- In feedlot systems, ensure that the energy to protein ratio is optimised for production benefit.

Specific action for farmers to reduce enteric methane losses:

- Pasture improvement to introduce a higher quality pasture will improve both productivity and reduce methane.
- Genetic improvements should continue to focus on efficiency gains and in particular use indicators of feed conversion efficiency.
- Apart from reducing unproductive animals, feeding animals on high quality forages and continual breeding for more efficient animals, there are no proven practical strategies available to economically reduce enteric methane loss from ruminants at this stage.

Specific action for farmers to increase carbon storage:

- Planting trees just for their carbon credit value may not to be economic in its own right, and needs to be viewed as part of a package of benefits that include biodiversity, wildlife corridors, salinity management, shade and shelter etc.
- When considering carbon sequestration projects, take professional advice and ensure that the advice is using methods accredited by the Australian Greenhouse Office; otherwise credits may not be recognised for trading purposes.