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Greenhouse Gas Research, Mitigation Options & Policy Developments for Agriculture

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Introduction

Recent surveys[1] show that around 60% of urban people 'believe' the science of climate change and human influence, compared to less than 30% of rural people. Regardless of belief, current government policy means that some impacts on rural communities will be unavoidable. It is helpful to break down the issue as follows:

- The **physical** impacts of a changing climate and how we will maintain a viable, profitable and sustainable dairy industry long term. The reality is that most farmers don't manage for what may happen in 50 years time, but do manage climate variability on a daily basis.
- The **policy** impacts of greenhouse gas emissions, where it is now clear we will face an emissions constrained future policy environment. Examples of this are the carbon price being set by government and the Carbon Farming Initiative[2]
- The **peripheral** impacts associated with climate change, where issues like carbon foot printing of food products, the changing demands of environmentally concerned consumers and carbon trading may all have an impact on how farmers market their products.

Not agreeing with the physical impacts or causes of climate change does not change the fact that there will be policy and peripheral impacts that need to be managed. It is important, therefore, for farmers to remain abreast of the facts when it comes to these impacts of climate change, and understand how to strategically adjust their business to maximise the opportunities and minimise the threats of this new operating environment.

It is also clear that, globally, agriculture now faces the significant challenge of increasing food production by 70% by 2050 to meet world food demand, while also reducing greenhouse gas emissions. Importantly then, the research and reduction options presented here aim at improving productivity and efficiency of farming systems while also reducing unnecessary greenhouse gas and other emissions (i.e. more output for less input and less loss to the environment).

What is agriculture contributing to the problem?

According to the federal Department of Climate Change and Energy Efficiency's annual inventory (Figure 1), agriculture emitted around 15% of Australia's total greenhouse gas emissions in 2009. It was the dominant source of both methane (57% of all methane is agriculture) and nitrous oxide (73% of all nitrous oxide comes from agriculture).

Enteric methane – produced from microbial digestion of forages in cattle and sheep – is the largest single source of emissions, contributing 64.6% of agricultural emissions and 9.7% of national emissions, while nitrous oxide from soils contributes 16.7% and 2.5%, respectively. Livestock contribute around 73% of total agricultural emissions and 11% of national emissions, with methane from enteric fermentation the dominant source.

Cropping, pastures and soils contribute another 12.5% of total agricultural emissions mainly as nitrous oxide from the application of fertilisers and the use of nitrogen fixing crops and pastures (Figure 2). Other emissions sources include the field burning of agricultural residues (primarily stubble burning of wheat crops and sugar cane prior to harvest) and the prescribed burning of savannas and grasslands.

Greenhouse gas emissions from livestock systems are orders of magnitude higher than from cropping systems, as enteric methane losses from livestock are relatively high, whereas cropping systems mainly lose nitrous oxide from fertiliser and legumes.

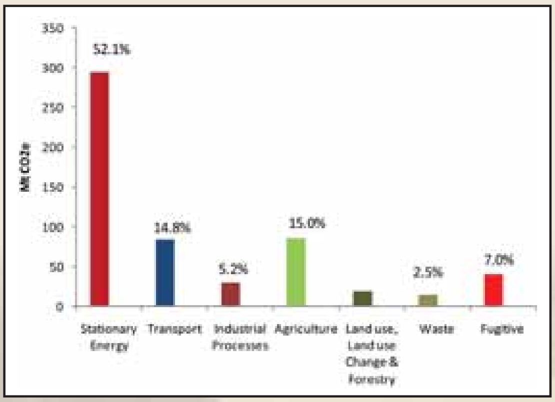

Figure 1. *Australia's net greenhouse gas emissions by sector in 2009 (DCCEE 2011)*

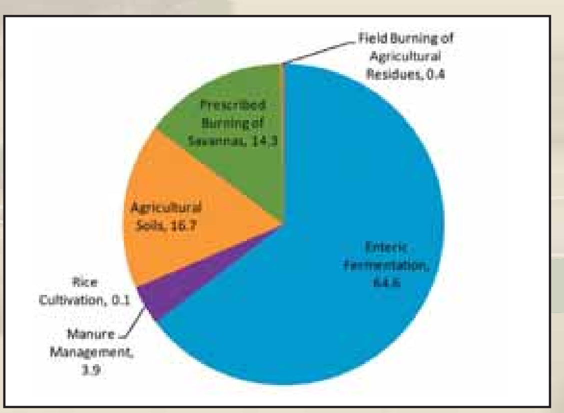

Figure 2. *Sources of agricultural emissions in Australia in 2009 (DCCEE 2011)*

Carbon Farming Initiative

Late in 2009 the federal government announced that it would exclude agricultural emissions from any future emissions trading scheme. However, there is an expectation that agriculture will contribute to reducing Australia's greenhouse gas emissions given it has the second highest emissions profile (Figure 1).

Instead of a liability for on-farm emissions, the government has proposed the **Carbon Farming Initiative (CFI)**[4] as a ***voluntary*** incentive based approach, allowing farmers a new source of revenue through trading of carbon offsets[5]. The CFI is currently before parliament and is anticipated to start late in 2011. All offsets rewarded under the CFI will have to be passed by a Domestic Offset Integrity Committee to ensure they meet the appropriate standards of integrity.

These standards of integrity include issues like:

- **Additionality -** the action must be additional to what farmers would have done;
- **Permanence -** if carbon stored in soil or trees is claimed as an offset, it needs to stay there for at least 100 years;
- **Leakage -** the action should not generate increased emissions somewhere else that equal those reduced on farm e.g. you cannot just move replacement heifers to the farm next door.

The CFI includes recognition of offsets from:

- Kyoto sinks e.g. carbon stored in reforestation and afforestation;
- Kyoto sources e.g. real reductions in methane and nitrous oxide;
- Non-Kyoto sinks e.g. soil carbon, managed forests, revegetation

The buyers of the Kyoto offset credits will be those with an obligation under the carbon price e.g. a power station may find it cheaper to buy credits from farmers than to install low emissions turbine.

The buyers of the non-Kyoto credits will most likely be more altruistic e.g. a legal firm wanting to brand themselves as carbon neutral, or an airline offering these as offsets on flights. Obviously the Kyoto offsets will attract a higher price than the non-Kyoto offsets.

The National Carbon Offset Standard (NCOS)[6] is a framework for the development of standards for these CFI offsets. All methods and projects submitted by proponents will need to follow the NCOS framework to demonstrate how these offsets will be measured, reported and verified. These projects are then submitted to the Domestic Offset Integrity Committee for approval.

Methodologies may be developed by private proponents and government agencies. The Department of Climate Change and Energy Efficiency[7] and the Department of Agriculture, Fisheries and Forestry[8] are working with industry to develop offset methodologies, including reforestation, forest management and avoided deforestation; savanna fire management; landfill gas recovery; manure management; management of methane from livestock; and soil carbon and biochar. Technical working groups comprising representatives of expert and practitioner groups are being established by the departments to review current scientific knowledge, determine any requirements for additional research and finalise methodologies. These methodologies are expected to be approved and rolled out progressively in 2011.

Enteric Methane

The methane produced by fermentation in the rumen is largely belched and breathed out by the animal. However, as methane gas is a high energy source (see Table 1), this represents a significant loss of energy from the production system (8 to 10% of gross energy intake is lost as methane), some of which can and should be redirected back into production.

Animal Class	Av. Liveweight (kg)	Methane (kg/hd/year)	Energy lost as methane (MJ/hd/day)	Effective annual grazing days lost
Mature ewe	48	6 to 10	0.9 to 1.5	26 to43
Beef steer	470	50 to 90	7.6 to 13.6	33 to 60
Lactating dairy cow	550	91 to 146	13.6 to 22.1	25 to 40

Table 1: *Typical ranges in methane emissions, energy lost as methane and effective annual grazing days lost from three classes of ruminants.*

Nitrous Oxide

Nitrous oxide is primarily lost from agricultural soils as a result of cultivation, legumes, nitrogen (N) fertilisers and animal excreta. These emissions can be either direct (from fertiliser, dung, urine, etc.) or indirect emissions. Indirect nitrous oxide emissions assume that some of the ammonia volatilised and the nitrate leached becomes nitrous oxide in subsequent off-site processes and thus contributes further to total nitrous oxide emissions.

Direct nitrous oxide emissions are primarily formed through denitrification; a microbial conversion of nitrate to nitrous oxide. This process is maximised in warm, anaerobic (wet) soil conditions with large amounts of nitrate and available carbon present. To a lesser extent, some nitrous oxide can be produced when soil ammonium is converted to nitrate in a process called nitrification.

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 as nitrous oxide. Currently 40 to 60% of the N inputs into cropping and grazing systems can be lost to the environment – some as nitrous oxide. Clearly there is room to improve this efficiency.

Thus the loss of methane and nitrous oxide not only potentially contributes to our changing climate, but also present an opportunity for efficiency gains in Australian agricultural production systems.

Best Management Practices

Enteric Methane

From the work conducted to date and the reviews of published literature, an abatement of 20 to 40% of methane emitted is achievable with current technologies, many of which will continue to improve production efficiency while also reducing methane losses.

Animal Numbers

Methane emissions from a farm depend on the number of animals and the emissions per head. By improving health, genetic and nutritional management production will improve the productivity and fertility of the herd and increase weaning rate with flow-on effects to lower total methane emissions from the herd.

Through earlier finishing of beef cattle in feedlots, slaughter weights are achieved at younger ages, with reduced lifetime emissions per animal, and thus proportionately fewer animals producing methane. Strategies such as extended lactation in dairy cows, where cows calve every 18 months rather than annually, reduces replacement rates and therefore the number of stock producing methane.

Animal Breeding

Selection for genetic lines of sheep and cattle that have lower methane emissions (both in absolute terms and as a function of productivity i.e. feed conversion efficiency) has the potential to be an effective long term and economically sound approach to reducing methane emissions from livestock. Measurements suggest that animal breeding could achieve a reduction of 10–20% in methane production from dry matter during digestion.

Diet and Nutrition Management

Methane-producing rumen microbes (methanogens) thrive on fibrous feeds (e.g. mature pasture, tropical grass and hays). These lower digestibility diets ferment to a near-neutral pH producing large amounts of hydrogen gas which the microbes require to produce methane. In contrast, cereal grain concentrates ferment to produce little hydrogen gas and a highly acidic rumen, both of which are restrictive to methanogens.

Forage quality can be improved through feeding forages with lower fibre and higher soluble carbohydrates, changing from C4 tropical grasses to (mostly temperate) C3 species, or grazing less mature pastures. Ensuring a high quality pasture (i.e. ryegrass rather than fog grass) will cause cows to eat more, resulting in higher production but less methane per unit of output. Thus providing animals with the best combination of pasture quality and concentrate feeding will effectively reduce methane emissions from the herd. Methane emissions are also commonly lower when the diet is made up of a higher proportion of legumes, due to lower fibre content, faster rate of passage and, in some cases, the presence of condensed tannins.

Improvements in forage quality will reduce methane produced per unit product, but overall farm methane emissions may remain the same or even rise if feed intake or stocking rate are increased to take advantage of the improved forage availability. Adding more grain to the diet can also result in an increase in nitrous oxide emissions elsewhere, through fertiliser applications for grain production. However on balance this would still reduce total greenhouse gas emissions, as the reduction in methane is larger than the emissions from grain production.

Dietary Supplements

In intensive livestock production systems, dietary supplements have the potential to profitably reduce methane emissions, with many strategies already available for implementation on-farm. For every 1% increase in total oil in the diet, average methane emissions can be reduced by 3.5%. Reductions of 10 to 25% may be achievable through the addition of dietary oils to the diets of ruminants in summer. Examples of these higher oil supplements include whole cotton seed, cold-pressed canola, hominy meal, grape marc and micro-algae.

Some secondary plant compounds such as tannins, have been shown to reduce methane production by 10 to 30%. These compounds act through a direct toxicity effect on methanogens, but may reduce dry matter intake depending on how they are fed. An added bonus of feeding tannins is that they can also reduce the loss of excess dietary N through urine; this should then reduce nitrous oxide losses as well.

Plant breeding may in future offer opportunities to increase oil and tannin levels in existing pastures and forages.

Rumen Manipulation

Manipulating microbial populations in the rumen through chemical means, by introducing competitive or predatory microbes, or through vaccination approaches can reduce methane production. Many of these techniques are in the early stages of research in terms of a practical and cost-effective method of abatement and are thus not generally available.

Nitrous Oxide

While actual nitrous oxide emissions are relatively small, the abatement potential can be significant through improved fertiliser, soil and animal management. By managing the rate, source, timing and placement of N fertiliser, nitrous oxide losses can be significantly reduced. A recent study showed a potential 80% reduction in emissions of nitrous oxide, accompanied by only a 4% loss in pasture growth, from dairy farming systems that were managed with strategic N fertiliser inputs compared to N applied after every grazing rotation.

From our research to date, the following BMPs are likely to both improve overall N efficiency and reduce nitrous oxide losses. These BMPs are entirely consistent with current industry best practice for overall N efficiency and thus present a win-win opportunity.

Fertiliser and Manure Management

- **N source:** Nitrate N sources may result in greater denitrification and leaching than ammonia-based sources of N (e.g. urea), if applied under cold, wet and waterlogged conditions. However urea can lose some ammonia gas if top-dressed in summer with windy conditions. Urea is still the cheapest pure source of N and di-ammonium phosphate (DAP) the cheapest mixed source of N.
- **Timing:** Strategies like timing applications with rainfall or irrigation, and applying two to three days before grazing in summer can all reduce the amount of ammonia volatilised.
- **Match demand:** Only apply N when crop or pasture is actively growing and can utilise the N, and only apply the highest recommended rates when no other limiting factors are restricting yield potential.
- **Avoid excessive nitrogen rates:** For actively growing pastures, do not apply above 50 to 60 kg N/ha in any single application and do not apply N closer than 21 (30 kg N/ha in spring) to 28 (50 kg N/ha) days apart, as this will increase N losses dramatically.

- **Warm and waterlogged soils:** Avoid high N rates on waterlogged soils, particularly if soil temperatures are high, as this will maximise denitrification losses.

Coated / Treated Fertilisers

There are a number of formulations and coatings that can be applied to N fertilisers that will eliminate nitrous oxide losses directly from fertiliser. These products do increase the unit cost of the N fertiliser and the producer will need weigh the costs against the likely reduction in N loss. However, these fertilisers are likely to become more commonplace with an increasingly emissions-constrained future, particularly if the added cost can be met through the sale of offset reductions in nitrous oxide. Examples include:

- **Controlled-release:** A range of polymer-coated/impregnated fertiliser products are available, releasing their N according to the predicted crop growth pattern. Controlled release fertilisers are usually prills of fertiliser encapsulated in a polymer or oil-based coating. The polymer coating controls the rate of release by allowing the fertiliser to pass through the coating over time. Release is often controlled by the thickness or type of polymer used and soil conditions (often referred to as biodegradable resin-coated slow release fertilisers, or methylene-urea polymers).
- **Slow release fertilisers** work by changing the chemical composition or mixing the fertiliser to reducing its solubility. The key difference between controlled and slow release technologies may appear semantics, but are used strongly in marketing in that one product actual controls the release pattern and timing, while the other is merely a constant, but slower release of the nutrient.
- **Nitrification inhibitors:** Nitrification inhibitors can be provided as a coating or spray that inhibits the conversion of ammonia to nitrate in the soil, thus reducing the chance of both nitrate leaching and denitrification loss. Applied as a spray, nitrification inhibitors can also be effective in reducing nitrous oxide emissions from animal urine by 60 to 90%, with pasture yield increases of 0 to 36%, depending on soil type and climate. A commercial spray is available in New Zealand (and soon in Australia) for reducing nitrous oxide losses from urine deposition on pastures.
- **Urease inhibitor** - coated fertiliser products are also readily available for situations where high ammonia loss from urea may be otherwise unavoidable.

Pasture Management

- **Plant breeding:** This is obviously a longer term option. Examples include ryegrass that does not require as much N fertiliser for similar yield, has a higher energy to protein ratio, or has a deeper rooting system to extract nitrate from a greater volume of soil.
- **Water use efficiency:** Use efficient soil and pasture management practices, including nutrition, to make the best use of available soil water. Excess soil water can lead to rainfall runoff, denitrification due to waterlogging or leaching of nitrates.
- **Other nutrients:** If there are other nutrients limiting the growth potential of the crop or pasture, N fertiliser use will be less efficient leading to greater loss potential.
- **Subsoil limitations:** Salinity, sodicity and acidity all restrict the ability of crops and pastures to effectively utilise soil nitrogen. Nitrogen inputs should be reduced to reflect the true yield capacity of crops and pastures where subsoil limitations are present.
- **Stocking rate:** The higher the stocking rate, the higher the volume of N deposited in dung and urine per unit area. Dung and especially urine are very inefficiently recycled in the soil plant system, with up to 60% of the N in a urine patch being lost to the environment. Higher stocking rate systems demand a higher N input regime (either fertiliser or imported feed) and thus result in a higher N content excreted in urine. A urine patch from dairy cow commonly contains between 800 and 1400 kg N/ha effective application rate within the patch. A higher stocking rate also leads to greater pugging (hoof compaction) of the soil; compacted soils tend to be more anaerobic leading to higher nitrous oxide losses (see below).
- **Ration balancing:** Balancing the energy to protein ratio in animal diets apportions less N to the urine and improves N conversion to animal product.

Soil Management

- **Reduced tillage:** Soil disturbance such as tillage operations break up soil organic matter, stimulating greater mineralisation of organic N. This leads to nitrate becoming available in the soil at a greater rate following tillage and thus greater potential loss. Cultivation also reduces soil structure, leading to poorer plant growth and greater potential for temporary waterlogging.
- **Irrigation and drainage:** Irrigation aims to maintain the soil above wilting point and below field capacity, which is the range in which nitrous oxide loss is highest. Poorly drained soils are anaerobic thus promoting denitrification of soil nitrate. In both cases, if soil nitrate is in excess of crop growth, nitrous oxide loss can be high.
- **Soil compaction:** Compact soils are more anaerobic leading to higher nitrous oxide loss through denitrification. Soil is commonly compacted through wheel traffic in cropping systems and through treading from animal hooves in grazing systems.

Conclusions

The Carbon Farming Initiative provides a financial incentive for farmers to reduce greenhouse gas emissions and store carbon in soils and trees. However, given that the system is both voluntary and proponent based, it is unlikely that many individual farmers will participate in their own right. It is far more likely that farmers will be offered opportunities to get involved through third party aggregators, like a dairy processor or fertiliser company, where the costs and administration can be more centralised.

Reductions in both methane and nitrous oxide can be achieved on-farm through the implementation of current BMPs that are entirely consistent with improving the efficiency of agricultural production. In the near future many of these practices could attract payments if traded as offsets. These BMPs therefore represent a clear win-win opportunity for farmers to improve efficiency and profitability, and contribute to meeting world food demand, while also reducing the emissions per unit of food produced.

References:

[1] http://www.daff.gov.au/climatechange/australias-farming-future

[2] http://www.climatechange.gov.au/government/submissions/carbon-farming-initiative.aspx

[3] http://ageis.climatechange.gov.au/

[4] http://www.climatechange.gov.au/en/government/initiatives/carbon-farming-initative.aspx

[5] **Carbon offsets** represent a reduction in greenhouse gases, or enhancement of greenhouse gas removal from the atmosphere by sinks such as soil carbon, relative to a business-as-usual baseline. Carbon offsets are tradable and often used to offset all or part of another entity's emissions.

[6] http://www.climatechange.gov.au/en/government/initiatives/national-carbon-offset-standard.aspx

[7] http://www.climatechange.gov.au/government/initiatives/carbon-farming-initative/methodology-development/methodology-guidelines.aspx

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For further information, articles and tools see:
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