Greenhouse gas emissions from agriculture - reduction options

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Introduction

Many people remain sceptical about climate change; these opinions range from not agreeing that climate change is real, those who agree that the climate is changing, but humans are not to blame, through to those who think that humans are mainly to blame. To move us forward, it is often useful to break down the issue as follows:

- The **Physical** impacts of a changing climate and how we will maintain a viable, profitable and sustainable agricultural industry into the long term future. This means managing a more variable climate in future.
- The **Policy** impacts of greenhouse gas emissions reduction targets set by governments and international agreements. Examples of this are the Carbon Pollution Reduction Scheme, the National Renewable Energy Target, the Kyoto Protocol and now the Copenhagen Accord.
- 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, can all have an impact on how farmers market their products.

For those who are sceptical about the physical impacts of climate change, it is now clear that the Policy and Peripheral impacts need to be managed. It is important, therefore, for farmers to remain abreast of the facts when it comes to the physical, policy and peripheral 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.

Combining the 3 'P's above, it is now clear that there will be a significant challenge to increase food production by 70% by 2050 to meet world food demand, while also reducing greenhouse gas emissions. Therefore, it is important to point out that 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 Department of Climate Change's annual inventory (Figure 1), agriculture emitted around 16% of Australia's total greenhouse gas emissions in 2008, being the dominant source of both methane (58% of all methane is agriculture) and nitrous oxide (76% of all nitrous oxide comes from agriculture). Enteric methane is the largest single source of emissions, contributing 65.3% of agricultural emissions (9.6% of national emissions), with nitrous oxide from soils contributing 17% (2.5% of national emissions). Livestock contribute around 70% of total agricultural emissions or 11% of national emissions. These Livestock emissions are mainly from enteric fermentation, being methane produced from microbial digestion of forages in cattle and sheep.

Cropping, pastures and soils contribute another 17% 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 (between 0.1 and 1 t CO_2e/ha[1]). However, even though the total loss of greenhouse gasses from cropping systems is small on a per hectare basis, the vast number of hectares cropped nationally adds up to a significant total emission from the cropping industry.

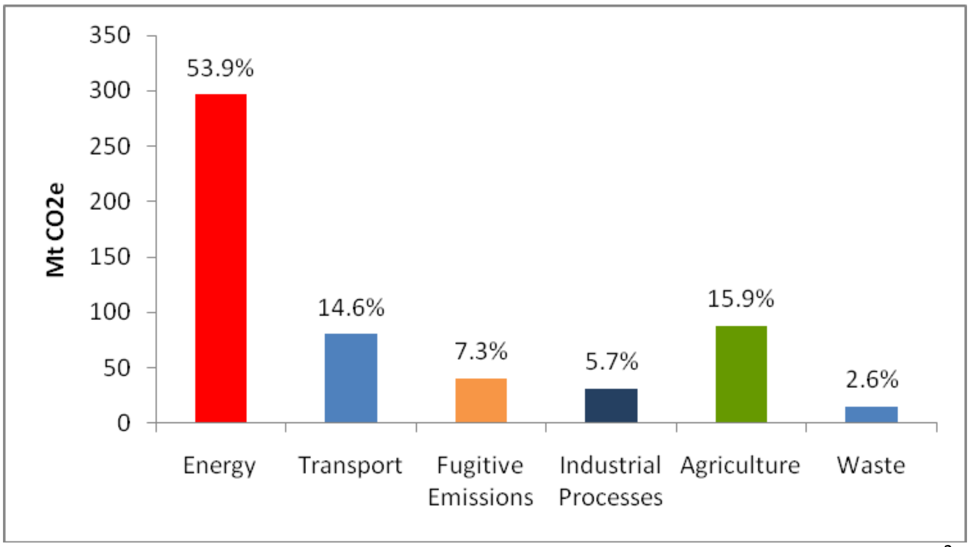

Figure 1. Australia's net greenhouse gas emissions by sector in 2008 (DCC 2010[2])

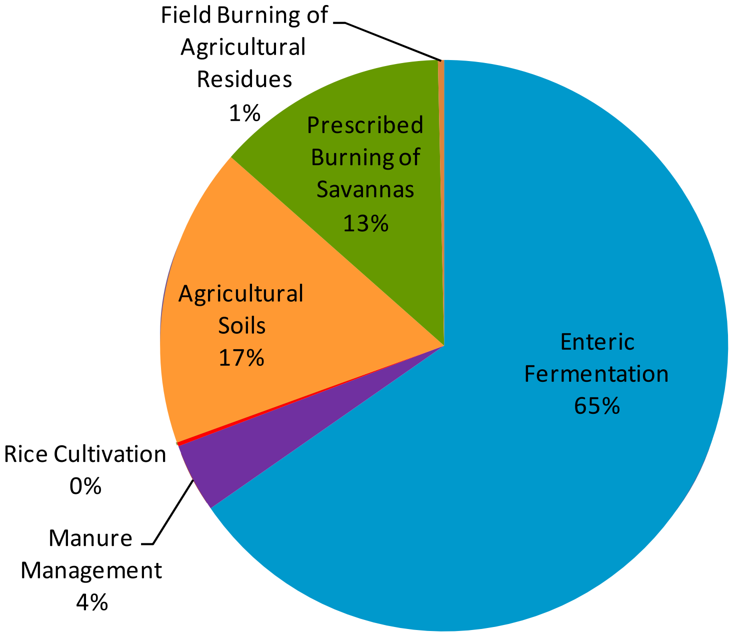

Figure 2. Sources of agricultural emissions in Australia in 2008 (DCC 2010[2]).

[1] CO_2e = Carbon dioxide equivalents. Methane and nitrous oxide emissions are converted into these standardised units by multiplying by 25 and 297 respectively.

[2] DCC (2010) National Inventory Report 2008 – Volume 1. The Australian Government Submission to the UN Framework Convention on Climate Change May 2010. Department of Climate Change, GPO Box 854, Canberra, ACT 2601 p. 297. www.climatechange.gov.au

Likely Policy Impacts
Late in 2009 the federal government announced that it will 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).

However, instead of a liability for on-farm emissions, these changes could well present a new income stream for farmers through trading of carbon offsets[3]. It is important for the agricultural sector to understand the potential implications of these, so that their representatives can constructively engage with the Federal government in this development.

At this stage it appears there are 2 ways in which agriculture may be able to participate in these new voluntary offset markets:

1. ***Carbon Farming Initiative (CFI)***

The Federal government recently announced the CFI as a replacement for agriculture being excluded from the CPRS. The CFI will be legislated through parliament in autumn 2011 and proposes 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.

The CFI includes recognition of offsets from Kyoto sinks (carbon stored in reforestation and afforestation) and real reductions in Kyoto sources (methane and nitrous oxide). Examples of these mitigation options are discussed later in this article.

2. ***The National Carbon Offset Standard (NCOS)***[4]

This provides a framework for the development of standards for offsets that would not have been eligible under the CPRS (non-Kyoto compliant sources and sinks), with methods and offsets submitted by proponents to the Domestic Offset Integrity Committee for approval, against the NCOS.

These offsets are likely to include soil carbon sequestration, carbon in managed forests (established before 1990), non-forest revegetation (eg. shrubs that don't meet strict Kyoto forest definitions) and biochar.

For both the CFI and NCOS, emissions and removals will be estimated using a prescribed methodology such as the National Carbon Accounting Toolbox[5]. However, many of the methods required for estimating real reductions in methane and nitrous oxide are not yet available.

[3] **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.
[4] http://www.climatechange.gov.au/en/government/initiatives/national-carbon-offset-standard.aspx
[5] http://www.climatechange.gov.au/government/initiatives/ncat/ncat-toolbox-cd.aspx

Enteric methane

Within the agricultural sector, methane is predominantly sourced from enteric fermentation in ruminants. The methane produced is then 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.

Table 1. Typical ranges in methane emissions from 3 classes of ruminants, energy lost as methane, with an estimate of effective annual grazing days lost.

Animal Class	Av. Liveweight (kg)	Methane (kg/hd/year)	MJ methane lost / hd/day	Av Daily Energy requirement (MJ/ hd/day)	Effective annual grazing days lost
Mature ewe	48	10 to 13	1.5 to 2.0	13	43 to 55
Beef steer	470	50 to 90	7.6 to 13.6	83	33 to 60
Lactating dairy cow	550	91 to 146	13.6 to 22.1	203	25 to 40

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 direct (from fertiliser, dung, urine etc) or from indirect sources. These 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 is 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 nitrous oxide. Currently 40 to 60% of the N inputs into cropping and grazing systems can be lost to the environment – some of which is 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 produced is achievable with current technology, many of which will continue to improve production efficiency while also reducing methane losses.

<u>Animal numbers</u>

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, reduce energy demand for pregnancy and reduce replacement rates and therefore reducing on-farm methane emissions.

<u>Animal breeding</u>

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.

<u>Diet and nutrition management</u>

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

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. Therefore ensuring a high quality pasture (i.e. ryegrass rather than fog grass) will cause cows to eat more, produce more, but produce 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 with higher proportions of forage legumes in the diet, partly due to lower fibre content, faster rate of passage and, in some cases, the presence of condensed tannins.

Improving forage quality tends to increase the amount of feed consumed, increasing energy available for animal growth and production. Therefore, improving diet quality can result in better animal performance as well as reducing methane production, as measured by a reduction in methane emissions per unit of animal product. However, overall farm-level methane emissions may remain the same or increase if stocking rate is 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 through fertiliser applications for grain production elsewhere; but on balance this would still reduce total greenhouse gas emissions.

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 10–25% may be achievable through the addition of dietary oils to the diets of ruminants. Examples of these higher oil supplements could be whole cotton seed, cold-pressed canola, hominy meal, grape marc, micro-algae etc.

Some secondary plant compounds, such as tannins, have been shown to reduce methane production by 10–30%. 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, with only a 4% loss in pasture growth from dairy farming systems, when managed with strategic N fertiliser inputs, relative 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. The BMPs presented below are entirely consistent with current industry best practice for overall N efficiency and thus present a win-win opportunity.

Fertiliser Management
- **N Source**: Nitrate N sources may result in greater denitrification and leaching than ammonia-based sources of N (eg. urea), if applied under cold, wet and waterlogged conditions, but could lose high amounts of ammonia gas if top-dressed under warmer and windy conditions, especially on alkaline soils. Urea is also currently the cheapest straight source of N and DAP the cheapest mixed source of N.
- Strategies like incorporation, timing with weather or irrigation and applying 2 to 3 days before grazing can all reduce the ammonia volatilised.
- **Match crop 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 fertiliser 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. 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 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 60–90%, with pasture yield increases of 0–36%, depending on sol type and climate. A commercially available spray is available in Australia and New Zealand 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.

Crop and Pasture management

- **Reduce fallow**: During the fallow period the soil continues to break down organic soil N into nitrate through mineralisation (followed by nitrification) but there is no crop to utilise this nitrate; as a result this nitrate is susceptible to nitrate leaching and denitrification loss during summer storms.
- **Cover crops**: Where possible use cover crops to use residual nitrate N in soil such as in cotton cropping.
- **Plant breeding**: This is obviously a larger-term option. For example, a ryegrass plant 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 creates conditions for future runoff from rainfall, waterlogging for denitrification 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**: Transient salinity, sodicity and acidity all restrict the ability of crops to effectively utilise soil nitrogen. Nitrogen inputs should be reduced to reflect the true yield capacity of crops 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.

- **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 a tillage operation breaks 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 water logging.
- **Incorporating stubble** stores the N in decaying plant material in the soil, which is then slowly released into the soil through mineralisation, thus being less vulnerable to loss.
- **Irrigation and drainage**: Irrigation aims to maintain the soil above wilting point and below field capacity, the soil moisture zone that maximises nitrous oxide loss. 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**: The more compact a soil, the more anaerobic it becomes, 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 adoption of greenhouse specific management practice is not likely to be a high priority for the farming community as there are currently no policy drivers or market incentives for adoption of these practices. However, the physical, policy and peripheral impacts of climate change are likely to impact on agriculture in an increasingly emissions constrained future operating environment.

Fortunately, significant 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, meet world food demand, while also reducing the emissions per unit of food produced.

Literature sources:

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