The abatement challenge for Australian Agriculture

Richard Eckard, Greenhouse in Agriculture
The University of Melbourne and Department of Primary Industries, Victoria.

Introduction

According to the National Greenhouse Gas Inventory (NGGI 2007) the agricultural sector contributes around 16% of national greenhouse gas emissions (Figure 1). The main greenhouse gases emitted from agriculture include methane lost during rumen digestion (enteric) and nitrous oxide lost from nitrogen fertilisers, animal excreta and soils (Figure 1). Agriculture accounts for 60% and 85% of Australia's total methane and nitrous oxide emissions, respectively (NGGI 2007), both potent greenhouse gases. While most of the methane lost from agricultural systems comes from rumen fermentation (Figure 1), it is estimated that nitrogen fertiliser is responsible for 16% of nitrous oxide emissions from agriculture with 21% derived from nitrogen in animal excreta. The indirect emissions, related to agriculture's use of transport and stationary energy account for around 11% of national emissions, but are attributed to the stationary energy and transport sectors in Figure 1.

Policy context in Australia

While Australia has signed the Kyoto Protocol it has not been ratified into law, unlike the EU and New Zealand, for example, where they now have binding emission reduction targets. However, by 2012 Australia is likely to have implemented a National Emissions Trading Scheme (NETS). At this initial stage it is proposed that a cap on emissions will not apply to the agricultural sector, but this sector will be able to trade offsets eg. tree plantings, to other sectors. In the USA a number of states are planning emissions trading schemes, while the Clean Air Act[1] will in future require reporting of emissions from agriculture. Closer to home, New Zealand is considering an emissions reporting system for the agricultural sector. In addition to the above, most States in Australia are drafting Climate Change bills that will target reductions in greenhouse gas emissions. Clearly the agricultural sector will be expected to play a role in any abatement towards targeted reductions.

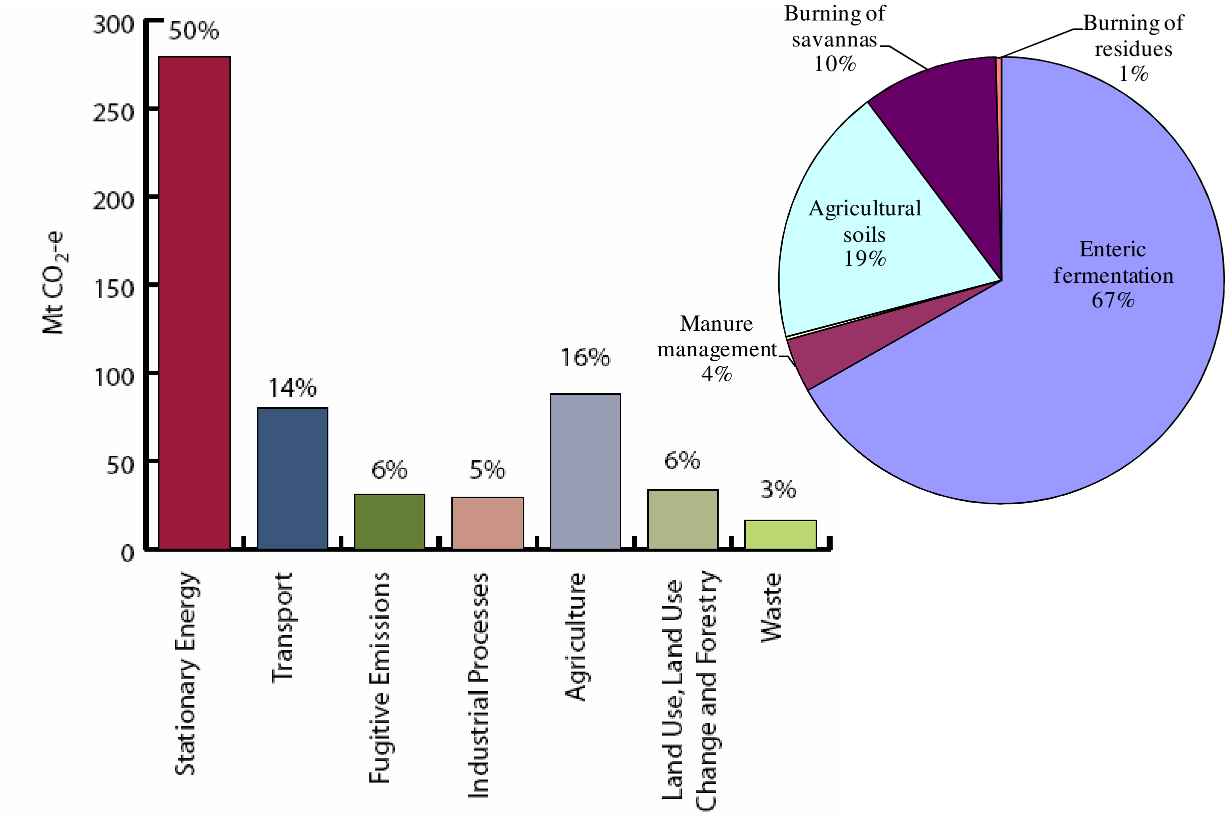

Figure 1. Australian national sectoral greenhouse gas emissions (left) and the apportionment of emissions within the agricultural sector (right), according to the 2005 NGGI (2007).

[1] http://www.epa.gov/air/caa/

Enteric methane

Methane is a significant greenhouse gas with 23 times the global warming potential of carbon dioxide. Within the agricultural sector, methane is predominantly sourced from enteric fermentation in ruminants (Figure 1). 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 (see Table 1), 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.

Table 1. Typical level of methane produced from enteric fermentation in the rumen of domestic livestock and relative measures of animal production or energy lost as a result.

Animal Class	Methane (kg/year)	Equivalent grazing days of energy lost per animal	Potential km driven in 6-cylinder LPG car
Mature ewe	10 to 13	41 to 53	90 to 116
Beef steer	50 to 90	32 to 57	450 to 800
Dairy cow	90 to 146	24 to 38	800 to 1350

A number of potential strategies for methane abatement have been identified (Figure 2), with most of these options currently being addressed by researchers either in Australia or New Zealand.

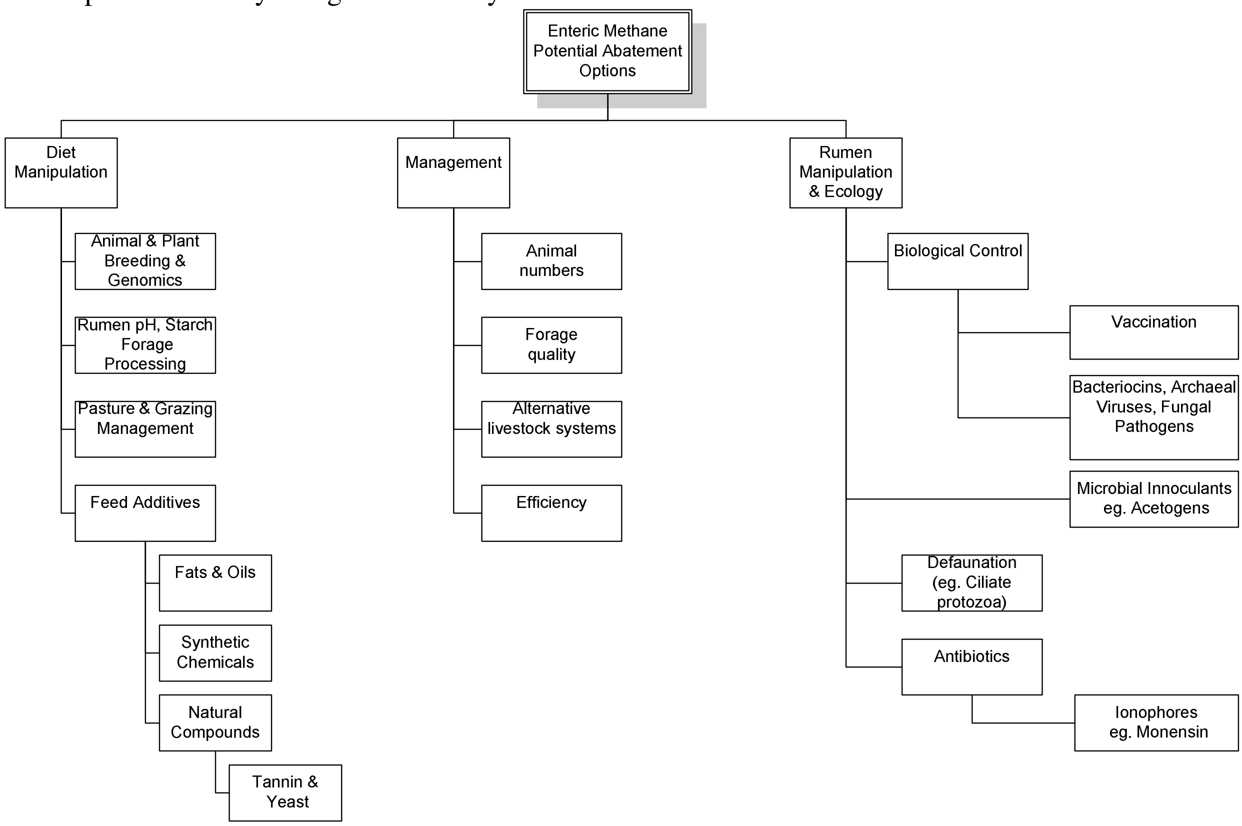

Figure 2. Potential options for enteric methane abatement from ruminants (Eckard 2002).

Diet manipulation and management

Research in New Zealand has identified differences in methane emissions between individual animals, indicating that breeding for more efficient animals may result in 10 to 20% less methane (Waghorn *et al.* 2007). Research by the CRC for Greenhouse Accounting has also demonstrated that diet quality affects methane production, with animals on high quality spring pasture producing up to 37% less methane than those on poor quality summer pasture (Eckard *et al.* 2000). Minimising the number of animals on the farm through earlier finishing (eg. improved feeding) or reducing unproductive animal numbers (eg. through extended lactation) also improves both the profitability and reduces unnecessary methane emissions.

A review currently in press (Beauchemin *et al.* 2007) shows that for every 1% increase in dietary oils, up to a maximum of 6% in the diet of ruminants, methane emissions will be reduced by 6%. Recent research by scientists in DPI Victoria, has also shown that dietary oils (eg. whole cotton seed) fed to dairy cattle on summer pastures can reduce methane emissions by 12%, while profitably increasing milk solids by 16% (Grainger *et al.* 2007a). Likewise feeding tannin extracts from the black wattle to dairy cows on lush spring pasture was shown to reduce methane emissions by up to 29%, while also reducing urinary nitrogen excretion by up to 59% (Grainger *et al.* 2007b, c); the latter could be significant in reducing the nitrous oxide and nitrate leaching from grazing systems.

Longer-term research options for methane abatement

A number of the methane abatement options shown in Figure 2, while likely to deliver higher and sustainable abatement, may require 5 to 20 years research and development before being available to the farming community. These strategies include those listed in Figure 2 under rumen manipulation and ecology, as well as plant and animal breeding and genomics. Many of these options are being addressed by research teams in Australia and New Zealand.

Nitrous oxide

Nitrous oxide is a significant greenhouse gas with 297 times the global warming potential of carbon dioxide. The exponential increase in the use of nitrogen fertilisers in Australia over the past 25 years has resulted in a corresponding increase in nitrous oxide emissions attributed to agricultural production. Nitrous oxide is primarily lost from agricultural soils as a result of cultivation, legumes, fertilisers and animal excreta all contributing to excess mineral nitrogen in the soil.

Agricultural systems are relatively inefficient in their use of nitrogen, with between 20 to 60% of nitrogen inputs typically being lost from cropping and grazing systems through a range of loss processes. This wide range of losses indicates room for efficiency improvements which also typically mean less nitrous oxide emissions. Research has now clearly shown that the rate, source / formulation, timing and placement of nitrogen fertiliser are all important management factors affecting nitrous oxide emissions.

Nitrous oxide is mainly formed through denitrification; a process maximised in warm, anaerobic (wet) soil conditions with large amounts of nitrate and available carbon present. Nitrification can also be a minor source of nitrous oxide in drier soils. Any agricultural activity that inefficiently supplies nitrogen to the soil-plant system can therefore lead to large losses of nitrogen through a number of loss processes, including nitrous oxide.

Nitrous oxide emission factors

Research conducted by the CRC for Greenhouse Accounting concluded that nitrous oxide emissions from nitrogen fertiliser, applied to irrigated dairy pastures, maize and cotton and dryland winter wheat, appear much lower than average emission factors from northern hemisphere studies.

The default emission factor, recommended by the Intergovernmental Panel on Climate Change (IPCC) for national emissions reporting, assumed that 1.25% of all nitrogen fertiliser applied was lost as nitrous oxide. The calculation of this default emission factor relied heavily on research conducted in the Northern Hemisphere where agricultural systems and environmental conditions are dissimilar to those in Australia. Revised and industry-based emission factors published by the CRC for Greenhouse

Accounting, are listed in Table 2. These low emission factors reflect a combination of the climate and soils specific to Australian agriculture, but also demonstrated that the application of best management practices for nitrogen fertiliser can reduce nitrous oxide emissions (Galbally *et al.* 2005).

Table 2. Nitrous oxide emission factors (EF) from four agricultural systems in Australia (Galbally *et al,* 2005). Annual application rates of fertiliser nitrogen (N) in kg/ha are listed with the treatments.

Site	**Crop**	**Treatment**	**EF (%)**
Griffith, NSW	Irrigated maize	Stubble burning 300N	2.8
		Stubble retention 300N	1.6
Kyabram, VIC	Irrigated dairy pasture	Urine 1000N	0.4-0.5
		Urea 150N	0.4-0.5
Rutherglen, VIC	Rainfed wheat	Conventional cultivation 83N/ Direct drilling 83N	0.05-0.1
Narrabri, NSW	Irrigated Cotton (C) in rotation with vetch (V) and wheat (W)	CC 100N	0.03
		CC 200N	0.24
		WVC 100N	0.39
		WVC 200N	0.51
		WVC 300N	2.47
		WC 100N	0.09
		WC 200N	0.26

EF = average annual % of nitrogen inputs assumed lost as nitrous oxide

The 2005 NGGI now includes a series of revised emission factors that are more industry-specific and appropriate to Australian climate and soils (Table 3). While this is only a reduction in 'estimated' emissions, the relative contribution of nitrogen fertiliser use in agriculture to total greenhouse gas emissions has also been reduced.

Table 3. Revised industry-specific nitrous oxide emission factors (EF) included in the Australian NGGI (2007)

Production System	**EF (%)**
Non-irrigated crop	0.3
Non-irrigated pasture	0.4
Irrigated pasture	0.4
Cotton	0.5
Sugarcane	1.25
Irrigated crop	2.1
Horticulture vegetables	2.1

Managing urinary nitrogen losses

In intensive grazing systems, ruminants commonly excrete 75 to 80% of all the nitrogen they ingest from pasture. With urine being predominantly urea, the effective nitrogen content in a typical dairy cow urine patch can be >1000 kg nitrogen/ha equivalent within the patch. It is not surprising therefore that, of the nitrogen excreted in urine, 40 to 60% is lost either through ammonia volatilisation, nitrate leaching or denitrification (including nitrous oxide) (de Klein and Eckard, 2007).

Nitrification and urease inhibitors have been commercially available from the major fertiliser companies for many years, but these products have historically not been adopted widely due to their relatively high cost. The emergence of emissions trading and greenhouse gas abatement targets is likely to change the economics of these products in the marketplace.

Extensive research has now been conducted in New Zealand using nitrification inhibitors (eg. dicyandiamide - DCD) as an abatement strategy to reduce urinary nitrogen losses from grazing systems. This research has shown DCD sprayed onto grazed pasture can reduce nitrous oxide emissions by between 60 and 80%, with increased pasture production of 15 to 25% possible (de Klein and Eckard, 2007). More recent research in New Zealand has also suggested that certain nitrification inhibitors can be passed out in the urine, thereby applying the inhibitor at the source of the excess nitrogen. Based on this evidence the New Zealand government is now considering including recognition of the use of nitrification inhibitors in their NGGI, a move that will certainly increase the adoption and use of these products by farmers.

Other strategies identified for reducing urinary nitrogen losses include adding tannin in the diet (to bind surplus protein in the rumen), balancing protein to energy ratios in the diet (ensuring more efficient use of dietary nitrogen), feeding salts to increase water intake (diluting and spreading urine over a greater area) and grazing management (eg. feed pads with urine collection) (de Klein and Eckard, 2007). However, most of these strategies still require further research before specific abatement can be claimed.

Production of Biofuels

Another role that agriculture can play in providing abatement of greenhouse gas emissions is through the production of biofuels. The Commonwealth and Victorian[2] governments currently have targets of 1% and 5% of Australia's total fuel sourced from biofuels by 2010, respectively.

The two main biofuel products are bioethanol and biodiesel:

- ***Bioethanol*** can be produced from sugar cane and most grain crops (eg. wheat, barley, corn, sorghum), although it is mainly produced from wheat starch and sugar cane in Australia. More recently technology using ligno-cellulosic enzymes, although currently more expensive, mean that more fibrous grasses (eg. switchgrass in the USA) and even wood may be used to generate ethanol in future. Studies have shown that E10[3] (10% ethanol blended with petrol) delivers around a 1.7% to 5.1% greenhouse benefit for grain-fed ethanol and sugar cane, respectively.
- ***Biodiesel*** can be produced from most vegetable oils and animal fats (eg. canola, sunflower, palm oil, used oils, tallow, etc). Recent research has investigated quick growing algae that can produce oil suitable for biodiesel production from effluent[4] and from carbon dioxide from power plants[5]. Blending 20% biodiesel with diesel (B20[3]) delivers greenhouse gas reductions of 10 to 20% depending on the feedstock. Recycled vegetable oils offer the biggest saving and tallow the lowest saving in greenhouse gas emissions.

For crop farmers biofuels could mean new markets and alternative income streams, producing both the food and future energy for society, whereas for the dairy, poultry and feedlot industries higher grain prices due to biofuel production could threaten their future access to affordable feeds.

A significant issue for biofuel production in Australia is the vulnerability of agricultural production to drought. Biofuel production from agriculture would therefore need to be spread over a range of climatic zones and latitudes in order to spread the risk of drought affecting supply. It is also important to conduct a full Life Cycle Assessment[6] of biofuel production systems, to ensure that abatement is being achieved in each case. The utilisation of waste streams wherever possible will be an important component of achieving this.

---

[2] The Victorian Government biofuel target of 5% is currently an inspirational goal only.
[3] http://www.rirdc.gov.au/reports/EFM/07-071sum.html
[4] eg. http://www.scoop.co.nz/stories/SC0605/S00030.htm
[5] eg. http://www.unh.edu/p2/biodiesel/article_alge.html
[6] http://en.wikipedia.org/wiki/Life_cycle_assessment

Gaps in knowledge

One of the key gaps in information is a full Life Cycle Assessment[6] of a range of abatement options to ensure that reductions in one part of the supply chain do not stimulate higher emissions elsewhere. Typical examples of this would be a new oil-seeds industry emerging to supply dietary oils to reduce methane from animals; but incurring new nitrous oxide emissions during their production and carbon dioxide emissions during transportation. This type of "cradle to grave" analysis is also required for biofuel production. Together with the above Life Cycle Assessment should be a full 'current' and 'likely future' economic analysis of abatement options, as most of the research to date has only been presented using partial farm budgets to demonstrate their efficacy and economic benefit.

If the agricultural industries are expected to participate in emissions trading, then scientifically sound methods of verification will be needed before any abatement of methane and nitrous oxide can be claimed and traded. In addition, recognised abatement measures will need to be captured in any future NGGI methodology to reconcile traded abatement and offsets against the Australian national accounts. The National Carbon Accounting System (NCAS[7]) is being developed by the Australian Greenhouse Office to address this gap in the land-based and agricultural sector, while in New Zealand and more simple input: output model (OVERSEER[8]) is being developed for the agricultural sector. As an example of recognition of specific abatement actions, the New Zealand government is considering including nitrification inhibitor applications in their NGGI; this will require agreement on average abatement achievable, together with provision of data on areas (GPS locations), rates and timing of inhibitor applications.

Apart from the options discussed in this paper, a number of basic and applied research gaps still exist before the agricultural industries can be provided with comprehensive, scientifically sound, practical and economic options for the abatement of methane and nitrous oxide.

Issues and incentives for adoption

Significant research has occurred to improve our understanding of agricultural emissions but there are key issues around how any abatement options can be adopted by the agricultural industries. These could be either through legislative drivers, voluntary mechanisms, incentives, efficiency gains or a combination. To date the research has focused on win-win abatement options that are profitable in their own right, while also reducing emissions (eg. whole cotton seed producing profitable increases in milk solids, while also reducing methane emissions), thus providing a profit driver for adoption.

Emissions trading may also provide incentives for the agricultural industries to adopt abatement or sequestration practices through potential profit drivers. However, reliable and simple methods for verification of on-farm abatement are yet to be developed for use by the agricultural industries in Australia. However, where a climate change bill may target a 60% reduction in emissions by 2050 from all sectors of the economy, voluntary measures of abatement may not be adequate and further incentives or legislative options may need to be considered.

The abatement challenge for agriculture

There are over 130,000 farms in Australia, each with their own unique production systems and management approaches. In addition, greenhouse gas emissions from these farming systems are biological processes that are inherently variable. While it may be relatively easy to measure emissions from vehicles or power stations, it is far more challenging to measure emissions from millions of hectares of farmland and millions of head of livestock across the country.

A key challenge for abatement from the agricultural sector is therefore the auditing and validation of abatement actions. This will require an agreed and standardized, but also relatively simple auditing approach, to enable farmers to participate in any emissions trading associated with abatement. The Australian NCAS[7] and New Zealand OVERSEER[8] models are examples of such tools.

---

[7] www.greenhouse.gov.au/ncas/index.html
[8] http://www.agresearch.co.nz/overseerweb

To achieve abatement from the agricultural sector in Australia, we will therefore need further research on abatement options, modelling of whole farm systems and Life Cycle Assessment of abatement options, auditing tools to validate abatement and profit incentives for farmers to engage in emissions trading.

Acknowledgements
The Cooperative Research Centre for Greenhouse Accounting, was a partnership between DPI and DSE Victoria, the University of Melbourne, CSIRO Marine and Atmospheric Research, with collaborative partnerships with Queensland University of Technology, University of Western Australia, the University of Wollongong, Department of Agriculture and Food, Western Australia, Cotton Cooperative Research Centre and CSIRO Plant Industries. International collaborators included the Institute for Meteorology and Climate Research, Forschungszentrum Karlsruhe, Germany, Agriculture and Agri-Foods Canada, Dexcel and AgResearch New Zealand. Apart from funding from the above partners, the project was also been funded by the Australian Greenhouse Office, the Grains Research and Development Corporation, Dairy Australia Ltd, the Cotton Research and Development Corporation, Eli Lilly and the CRC for Greenhouse Accounting. Biofuel information was provided by David Griffin, DPI Victoria.

References:

Beauchemin KA, Kreuzer M, O'Mara FO, McAllister TA (2007) Nutritional management for enteric methane abatement: a review. Special Edition: Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference. *Australian Journal of Experimental Agriculture* (in press).

De Klein CAM and Eckard RJ (2007) Targeted Technologies for nitrous oxide abatement from Animal Agriculture. Special Edition: Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference. *Australian Journal of Experimental Agriculture* (in press).

Eckard RJ (2002) Methane abatement program for Australian livestock. Consultancy Report to the Science and Agriculture Team, The Australian Greenhouse Office, Canberra, August 2002. 12pp.

Eckard RJ, Dalley D, Crawford M (2000) Impacts of Potential Management Changes on Greenhouse Gas Emissions and Sequestration from Dairy Production Systems in Australia. In: "Management Options for Carbon Sequestration in Forest, Agricultural and Rangeland Ecosystems" Keenan R, Bugg AL and Ainslie H (eds), Workshop Proceedings, CRC for Greenhouse Accounting, 25 May 2000, ANU, Canberra. pp. 58-72. ISBN 0646404318.

Galbally I, Meyer C, Bentley S, Weeks I, Leuning R, Kelly K, Phillips F, Barker-Reid F, Gates W, Baigent R, Eckard R, Grace P (2005) A study of environmental and management drivers of non-CO2 greenhouse gas emissions in Australian agro-ecosystems. *Environmental Sciences June-September 2005*. 2(2-3):133-142.

Grainger C, Clarke T, Beauchemin KA, McGinn SM, Eckard RJ (2007a) Supplementation with whole cottonseed reduces methane emissions and increases milk production of dairy cows offered a forage diet supplemented with grain. Special Edition: Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference. *Australian Journal of Experimental Agriculture* (in press).

Grainger C, Clarke T, Auldist MJ, Beauchemin KA, McGinn SM, Eckard RJ (2007b) Use of *Acacia Mearnsii* tannins changes energy and nitrogen partitioning of dairy cows offered cut pasture supplemented with grain. Special Edition: Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference. *Australian Journal of Experimental Agriculture* (in press).

Grainger C, Auldist MJ, Clarke T, Beauchemin KA, McGinn SM, Eckard RJ (2007c) Use of *Acacia Mearnsii* tannins reduces methane emissions but decreases milk production of dairy cows offered pasture supplemented with grain. Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference, Christchurch, New Zealand, November 2007 (in press).

NGGI (2007) National Greenhouse Gas Inventory 2005, Australia's National Greenhouse Accounts. Australian Greenhouse Office, Department of Environment and Water Resources, Canberra. http://www.greenhouse.gov.au/inventory.

Waghorn GC, Woodward SL, Tavendale M, Clark DA (2007) Inconsistencies in rumen methane production – effects of forage composition and animal genotype. Special Edition: Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference *Australian Journal of Experimental Agriculture* (in press).