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Agricultural greenhouse gas emissions

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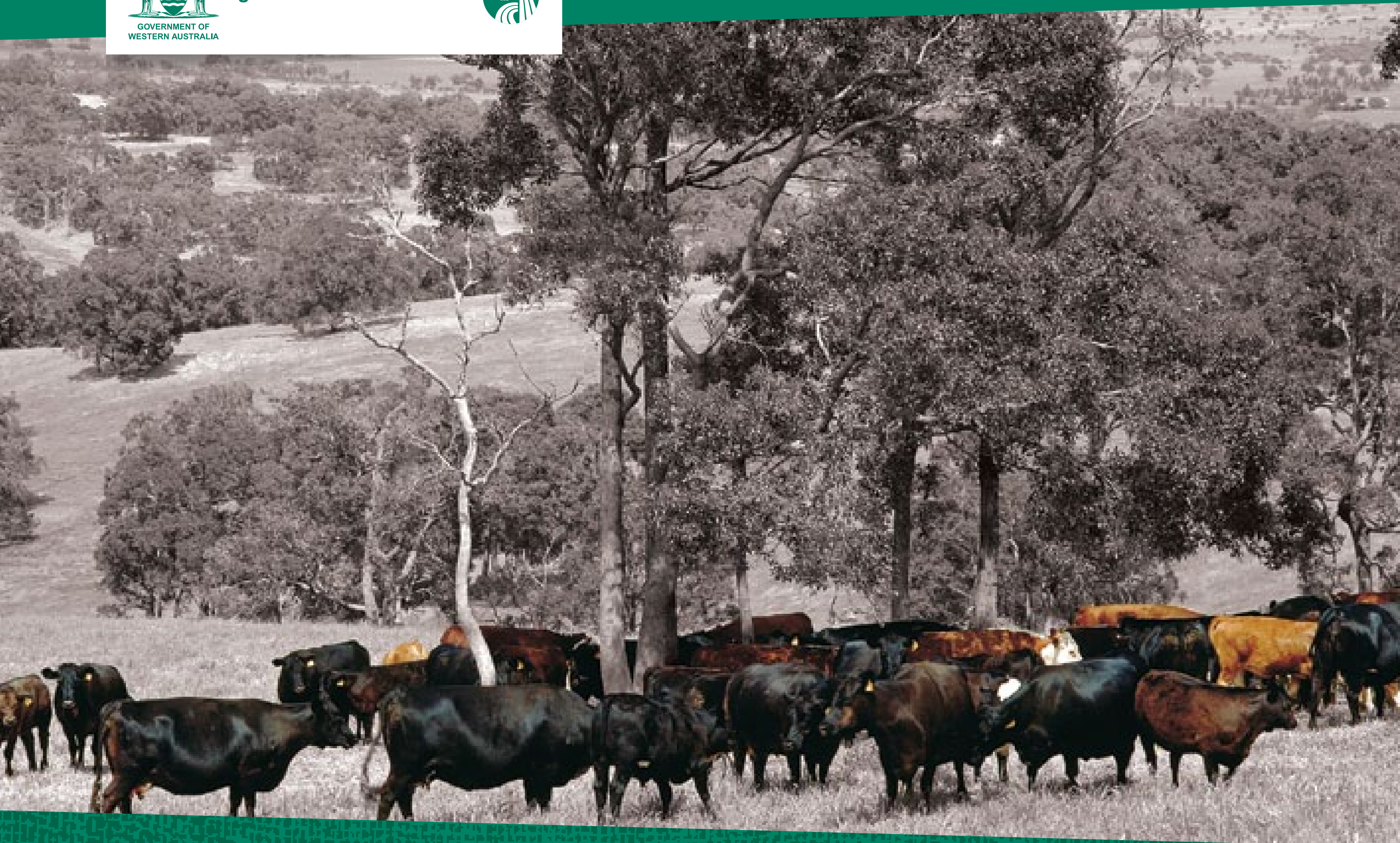

Agricultural Greenhouse Gas Emissions

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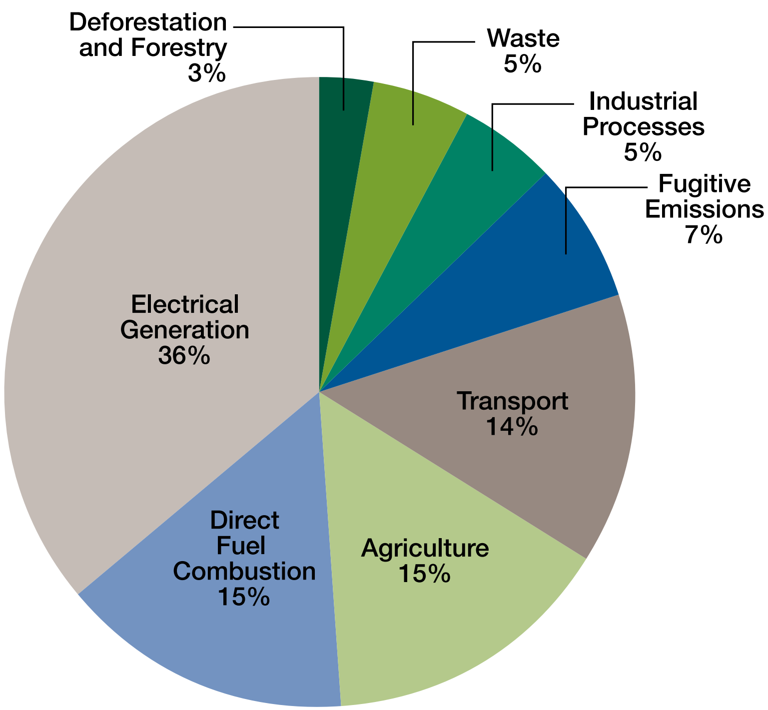
The Issue

Agriculture contributes 15.5 per cent of Australia's emissions (Figure 1), largely due to methane, from ruminant livestock digestion, nitrous oxide from soils and carbon dioxide from fossil fuel use (Australian National Greenhouse Accounts 2011; ABARES 2011). This bulletin identifies current ways to reduce greenhouse gas emissions from Australian agriculture.

Figure 1. Australian fossil carbon emission profile based on 2009 emissions (from Australian National Greenhouse Accounts, 2011). Emissions are mainly from coal and natural gas burning for electricity generation, and petroleum products in the transport sector. Methane and carbon dioxide also escape into the atmosphere when coal is mined and gas is produced.



The enhanced greenhouse gas effect refers to the rise of the equilibrium temperature at the Earth's surface. This occurs as a result of humans releasing greenhouse gases from fossil fuel use or altering agricultural and natural systems and so increasing these gases in the atmosphere above pre-industrial levels. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the major gases responsible for this enhanced greenhouse effect (Eckard and Armstrong 2009). Each greenhouse gas has a different capacity to cause greenhouse warming. This capacity is measured in carbon dioxide equivalents (CO_2-e) and depends on the lifetime of the gas and its ability to trap heat in the atmosphere. For example, during a 100 year time frame, one tonne of methane is equivalent in warming potential to 21 tonnes of carbon dioxide, and one tonne of nitrous oxide is equivalent to 310 tonnes of carbon dioxide (ABARES 2011; Crutzen 1981) (see box 1 for glossary of greenhouse gases).

Methane and nitrous oxide are the two main gases from agriculture which contribute substantially to the Australian total greenhouse gas emissions. In 2009, agriculture produced an estimated 84.7 million tonnes (mt) of equivalent carbon dioxide (CO_2-e) emissions. The sector is the dominant national source of both methane and nitrous oxide accounting for 65.3 mt CO_2-e (57.9 per cent) and 19.5 mt CO_2-e (74.5 per cent), respectively of the net national emissions (see table 1 for breakdown of greenhouse gas sources) (Australian National Greenhouse Accounts 2011).

Box 1. Glossary of greenhouse gases

Methane

Methane is a natural by-product of wetland rice paddy farming, ruminant digestion and anaerobic decomposition of biological material, and has a global warming potential 21 times that of carbon dioxide. Animals produce methane as a by-product of fermentative digestion in the rumen and hind gut. Methane is largely released through the animals' mouths (ABARES 2011). The amount of methane produced by the ruminant livestock industry can be from 250 – 500L/animal/day (Jones *et al* 2009). Efforts to lower emissions from animal production systems are considered important for achieving long term domestic emissions targets and moderating their impact on climate change.

Nitrous oxide

Nitrous oxide emissions account for about ten per cent of global greenhouse gas emissions, with 90 per cent of these emissions derived from agricultural practices (Smith *et al* 2007). Nitrous oxide in soils is produced largely by the microbial process of denitrification and to a lesser extent by nitrification. Nitrification is an aerobic process that oxidises ammonium (NH_4^+) to nitrate (NO_3^-), with N_2O as a by-product, whereas dissimilatory nitrate reduction (denitrification) is an anaerobic process that reduces NO_3 – to nitrogen gas (N_2), with N_2O as an obligatory intermediate (de Klein and Eckard, 2008). As a consequence of its high global warming potential, nitrous oxide emissions from land can have a large bearing on the assessment of greenhouse gases from cropping systems (Australian National Greenhouse Accounts 2011). Nitrous oxide has also been implicated as an increasing contributor to ozone depletion, with potential negative consequences for the recovery of the ozone hole over Antarctica (de Laat and van Weele 2011)

Box 1. Glossary of greenhouse gases (continued)

Carbon dioxide

The National Greenhouse Gas Inventory does not include carbon dioxide emissions from farm machinery in the agriculture sector. Carbon dioxide is included in this report as studies have found carbon dioxide emissions produced by fossil fuels account for a large proportion of pre-farm greenhouse gas emissions and also a small proportion of on-farm and post farm emissions (Barton *et al* 2008a).

Sources and sinks of agricultural greenhouse gases

Emissions of methane and nitrous oxide are produced when living and dead biomass is consumed, decays or is burnt under low oxygen conditions. The amounts of these emissions are modified by human activities including cultivation, addition of fertilisers, deliberate burning, flooding and by the introduction of ruminant animals (Australian National Greenhouse Accounts 2011).

The sources of agriculture emissions used in the Australian National Greenhouse Accounts (2011) are:

- Enteric fermentation in livestock – emissions associated with microbial fermentation during digestion of feed by ruminant (mostly cattle and sheep) and some non-ruminant domestic livestock.
- Manure management – emissions associated with the decomposition of animal wastes held in manure management systems.
- Rice cultivation – methane emissions from anaerobic decay of plant and other organic material when rice fields are flooded.
- Agricultural soils – emissions associated with the application of fertilisers, crop residues and animal wastes to agricultural lands, and the use of biological nitrogen (N) fixing crops and pastures.
- Prescribed burning of savannas – emissions associated with the burning of tropical savannah and temperate grasslands for pasture management, fuel reduction, and prevention of wildfires.
- Field burning of agricultural residues – emissions from field burning of cereal and other crop stubble, and emissions from burning sugar cane prior to harvest.
- Recent research also indicates that organic matter rich in nitrogen which is sourced from agricultural land, and which then enters warm anaerobic conditions in tropical deep waters, can be converted to nitrous oxide in significant quantities (Purvaja *et al*., 2008).

Table 1. Australian agriculture sector carbon dioxide equivalent emissions (CO_2-e) for 2009 (from Australian National Greenhouse Accounts, 2011).

Greenhouse gas source and sink categories	CO_2-e emissions (Mt)			
	Carbon dioxide	Methane	Nitrous oxide	Total
Enteric fermentation	NA	54.7	NA	54.7
Manure management	NA	1.8	1.6	3.3
Rice cultivation	NA	0.05	NA	0.05
Agricultural soils	NA	NA	14.2	14.2
Prescribed burning of savannas	NA	8.5	3.6	12.1
Field burning of agricultural residues	NA	0.2	0.1	0.3
Total	NA	65.2	19.5	84.7

Greenhouse gas emissions from livestock systems are significantly 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_2-e/ha). 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 (Eckard *et al* 2010).

Beef cattle are a large source of methane

Ideas on how to estimate your on-farm greenhouse gas emissions are given below. Box 2 includes the type of calculation tools available, and Box 3 outlines examples from a hypothetical farm in Merredin. The amount of greenhouse gases emitted from different crops, the amount of fuel used and carbon emitted from different tillage practices are estimated.

Box 2. Estimating on-farm Carbon emissions

A number of on-line tools exist to estimate greenhouse gas emissions (Table 2). These estimates are based on methodology provided by the National Greenhouse Gas Inventory. These methods were used as they are approved by the International Panel for Climate Change (IPCC) and are currently the only recognised methods for estimation of on-farm emissions. It is important to note that estimated emissions may be very different to measured emissions (see Box 3).

Table 2. Current tools available for calculating on-farm greenhouse gas emissions.

Tool	Applications	Source
Farm Gas Calculator	Estimates annual greenhouse gas emissions at individual activity level or whole farm Examines financial impacts of different greenhouse mitigation options	Australian Farm Institute www.farminstitute.org.au
Grains Greenhouse Accounting framework Dairy Greenhouse Accounting framework Sheep Greenhouse Accounting framework Beef Greenhouse Accounting framework	Estimates greenhouse gas emissions for grain, dairy, sheep and beef producing systems based on methodology provided by the National Greenhouse Gas Inventory.	Greenhouse in Agriculture (University of Melbourne/DPI Victoria) www.greenhouse.unimelb.edu.au
Dairy Greenhouse Gas Abatement Calculator	Looks at herd, soil, feeding management and farm intensification	Dairying for Tomorrow (Dairy Australia) www.dairyingfortomorrow.com
Farm Fuel Calculator	Estimates the amount of CO_2 and total carbon produced by farm vehicles	Department of Agriculture and Food, Western Australia www.agric.wa.gov.au
Carbon Toolkits in Agriculture Network	Information on tools, related news and resources	Department of Primary Industries, Victoria www.dpi.vic.gov.au/agriculture

Box 3. Emission estimates from cropping practices

Greenhouse gas emissions from a number of hypothetical crops located in Merredin Western Australia (WA) were estimated using the Grains Greenhouse Accounting framework. The Farm Fuel Calculator was used to estimate the total amount of carbon produced by farm vehicles (Table 3). From Table 3, the highest greenhouse gas *estimated* was produced through the application of fertiliser in cereal crops and from N_2 fixation from legume crops whereas *measured* results show that the majority of carbon produced in farming systems comes from fuel (in wheat production).

Please note that the numbers in Table 3 are estimates, and not actual values. Research has found using international emission factors to estimate nitrous oxide emissions from the WA grain belt is not appropriate due to differences in nitrogen (N) fertiliser management, soil types and climate, and factors demonstrated to influence annual agriculture nitrous oxide emissions (Stehfest and Bouwman 2006). Studies in WA, have found the international default value for soil nitrous oxide emissions over estimated measured greenhouse gas by 52 per cent in wheat (Barton *et al*., 2008a) and were 50 times greater than actual nitrous oxide emissions associated with growing and converting canola for biodiesel production and the burning of biodiesel (Farm Weekly 2011). A University of Western Australia (UWA) five year study looking at paddock based greenhouse emissions in WA wheat growth has changed the Australian nitrous oxide emissions standards used from one per cent of N fertiliser (IPCC values) to 0.1 per cent (Department of Climate Change and Energy Efficiency values) for Australian grain growers (Farm Weekly 2011). The values reported in Table 3 are from the Grains Greenhouse Accounting framework which is using IPCC values.

Soil nitrous oxide emissions are relatively low in the winter growing season, but increase markedly following summer rain. Different crop rotations can have a significant impact on nitrous oxide emissions following rainfall in summer and the effect is also likely to be influenced by factors such as soil type and rainfall amount and timing. Two National Adaptation and Mitigation Initiative (NAMI) projects[1] measured nitrous oxide emissions from trial sites located at the UWA Ridgefield Farm at Pingelly and the Department of Agriculture and Food Western Australia (DAFWA) Dry Land Institute at Merredin. Nitrous oxide emissions were relatively low and were of a similar order to those reported for Western Australia by Barton *et al*. (2008b). Nitrous oxide emissions at Merredin were mostly below detection levels. At Pingelly nitrous oxide emissions in the subsequent wheat crop did not increase after fallow compared with continuous winter cropping. Rather, these emissions appeared to be impacted by the current (2011) crop management (seeding and fertilisation) and rainfall. (Flower *et al*., 2012)

Assumptions – Merredin is a 'non-leaching' area according to the Grains Greenhouse Accounting Framework, and so no nitrous oxide emissions have been estimated for leaching or run-off. All crops (apart from lucerne) had 10 per cent stubble burnt (Llewellyn and D'Emden, 2009). Potential yields for 2011 were calculated using the Potential Yield Calculator[2]. Nitrogen rates were calculated using 45 units of nitrogen per tonne for cereals, 60 units per tonne for canola (B. Bowden pers comm.). Fallow was field peas which were either green manure (gm) (ploughed into ground) or brown manure (bm) (chemically killed – four spray passes (as four has been shown to be the number of sprays required to effectively kill weeds and keep a bare fallow). * measured amounts from Barton *et al*., 2008a from wheat produced on 0.43 hectares and delivered to port.

1 More information about NAMI can be found at web address http://www.agric.wa.gov.au/search for climate change

2 Potential Yield Calculator is developed by DAFWA www.agric.wa.gov.au/search decision support tools

Box 3. Emission estimates from cropping practices (continued)

Table 3. Estimated methane, nitrous oxide and carbon dioxide (from fuel) for different hypothetical farming systems in Merredin, WA using the Grains Greenhouse Accounting Framework and the Farm Fuel Calculator, values are expressed as kg/ha CO_2-e.

Crop	Potential yield (t/ha)	CH_4 from burning residues	N_2O from burning residues	N_2O crop residues returned	Indirect – N_2O ammonia loss	N_2O from fertiliser	N_2O from N_2 fixation	CO_2 from fuel	Fuel use (L)	Total kg/ha CO_2-e*
Wheat	1.8	4.5	1.3	33	39	118	0	35	6526	230.8
Canola	1.2	2.7	0.8	24	35	105	0	29	5327	196.5
Oats for hay	3.1	7	2.1	49	68	204	0	41	8118	371.1
Lupins	1.3	4.2	1.2	0	0	0	218	30	5680	253.4
Barley	2.2	5	1.5	35	48	144.5	0	37	6346	271
Fallow gm	1.6	5.2	1.6	0	0	0	268	42	8435	316.8
Fallow bm	1.6	5.2	1.6	0	0	0	268	16	3269	290.8
Lucerne	1	0	0	0	0	0	168	17	225	185
Wheat *	1	8	0	0	0	56	0	195	n/a	259

Table 3a. Fuel use and carbon emissions from different tillage practices from 1.8 t/ha wheat crop, using the Farm Fuel Calculator.

	No till	Disc plough	Cultivator	Scarifier
Fuel use (L/ha)	12	24	34	21
Carbon dioxide produced (kg/ha)	30	60	84	52

Notes – calculation was done assuming a conventional harvester, if a rotary harvester is used add a further 1.5L/ha of fuel and 3 kg/ha of carbon produced. Deep ripping would add 13.2 L/ha of fuel, and 34 kg/ha of carbon.

Options for on-farm mitigation

There are many options to reduce agricultural greenhouse gas emissions in a changing climate. Strategies include reducing emissions, increasing carbon sequestration and developing technologies to avoid fossil emissions. Each strategy varies in its current scientific and technological advancement, ability to mitigate greenhouse gases, ease of implementation, economic viability and effectiveness over time (ABARES 2011).

Reducing methane – livestock emissions

A reduction of 20 to 40 per cent of methane produced is achievable with current technology, many of which will continue to improve production efficiency while also reducing methane losses (Eckard *et al* 2010). This includes:

- 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 (Eckard *et al* 2010).
- Animal breeding – a genetic improvement program can achieve shorter finishing times by selecting bulls or rams for efficient feed conversion. Estimates suggests that over 25 years, it may be possible to reduce annual greenhouse gas emissions by approximately three per cent when herds are bred for increased feed efficiencies (Alford *et al* 2006).
- Diet and nutrition management – ensure pasture is of good quality and include perennial pastures (Jones 2009), this will cause cows to eat more, produce more, but produce less methane per unit of output. Therefore 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 (Eckard *et al* 2010).
- 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 one per cent increase in total oil in the diet, average methane emissions can be reduced by 3.5 per cent. Reductions of 10 to 25 per cent may be achievable through the addition of dietary oils to the diets of ruminants. 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 per cent (Eckard *et al* 2010).
- 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 (Eckard *et al* 2010).
- New forage plants – several alternative plant forages such as broccoli leaves and some Australian natives (tar bush, the golden wreath wattle and a number of salt bush species) have been shown to reduce methane emissions in laboratory experiments (DAFF 2011a). A recent study at the UWA shows that tar bush can reduce sheep methane emissions by one-third. Further research is planned to confirm these results under field conditions (UWA 2011).

Minimising nitrous oxide – fertiliser management

- Nitrate N sources (i.e., ammonium nitrate, potassium nitrate, calcium ammonium nitrate) may result in greater denitrification and leaching than ammonia based sources of nitrogen (ie, urea, di-ammonium phosphate DAP, ammonium sulphate) if applied under cold, wet and waterlogged (soils close to field capacity or above) conditions. However, ammonia based sources could lose high amounts of ammonia gas if top dressed under warmer and windy conditions, especially on alkaline soils (Eckard and Armstrong 2009).

Box 4. Coated/chemically treated fertilisers

There are a number of coatings that can be applied to nitrogen fertilisers that will eliminate nitrous oxide losses directly from fertiliser. However, these coatings have no effect on losses of nitrogen derived from legumes and urine. In the future it is likely that most nitrogen fertiliser sold will be in some form of controlled release or inhibited form. At this stage these products are too expensive to justify their commercial use in broad acre agriculture and require further research to evaluate performance under Australian conditions.

- Nitrification inhibitors – this coating inhibits the conversion of ammonia to nitrate in the soil, thus reducing the chance of both nitrate leaching and denitrification loss. An example of such a compound is dicyandiamide (DCD), proven effective in many studies (Eckard and Armstrong 2009).
- Controlled-release – a range of polymer-coated/impregnated fertiliser products are available, releasing their nitrogen according to the predicted crop growth pattern. This controlled release significantly improves fertiliser efficiency. However, if the onset of conditions favourable to denitrification coincides with nitrogen release from the coated fertilisers, denitrification may still result albeit at a lower rate than would have occurred using conventional forms of nitrogen fertiliser (Eckard and Armstrong 2009).
- Enhanced efficiency fertilisers (EEFs) – combine fertiliser and breakdown inhibitors. They are able to increase plant uptake of nitrogen and thereby reduce the loss of nutrients through leaching, runoff and as gases. They work by delaying the chemical process that nitrogen compounds go through to produce ammonium and nitrate, both precursors to nitrous oxide. EEFs can work well across a range of soil types. In some applications, the rate of nitrous oxide emissions can be reduced for up to 60 days (DAFF, 2011b).

- Match crop or pasture demand – incorporate fertiliser at the top of raised beds or ridges to avoid wet areas. Place fertiliser below the soil surface where possible to limit ammonia volatilisation (especially on alkaline soils). Apply nitrogen fertiliser based on a calculation of target yield and crop nitrogen requirement during the growing season (Eckard and Armstrong 2009).
- Avoid excessive nitrogen fertiliser rates. For pastures, do not apply above 50 to 60 kg nitrogen/ha in any single application and do not apply nitrogen closer than 21 (30 kg nitrogen/ha in spring) to 28 (50 kg nitrogen/ha) days apart, as this will increase nitrogen losses dramatically (Eckard and Armstrong 2009).
- Warm and waterlogged soils – avoid high nitrogen rates on waterlogged soils, particularly if soil temperatures are above 10°C, as this will increase denitrification losses. Denitrification is highest under anaerobic soil conditions, particularly when these conditions are coupled with warmer soil temperatures (Eckard and Armstrong 2009).

To reduce nitrogen loss through nitrous oxide emissions, apply fertiliser based on a calculated yield/biomass

Minimising nitrous oxide – Crop & Pasture management

- Reduce fallow – during the fallow period, soil continues to break down organic soil nitrogen into nitrate (mineralisation followed by nitrification) but there is no crop to utilise this nitrate and as a result this nitrate is susceptible to leaching and denitrification loss following heavy rainfall (Eckard and Armstrong 2009).
- Cover crops – where possible use non-leguminous cover crops to use residual nitrate nitrogen in soil such as in cotton cropping (Eckard and Armstrong 2009).
- Water use efficiency – use efficient soil and pasture management practices, including nutrition, to make the best use of water. Unused water if left in excess it creates conditions for future runoff from rainfall, water logging for denitrification or leaching of nitrates (Eckard and Armstrong 2009).
- Other nutrients – if there are other nutrients limiting the growth potential of the crop or pasture, nitrogen fertiliser use will be less efficient leading to greater loss potential (Eckard and Armstrong 2009).
- Subsoil limitations such as transient salinity, sodicity, acidity, restrict the ability of crops to effectively utilise soil nitrogen. Nitrogen inputs (from either fertiliser or legumes) should be reduced to reflect the true yield capacity of crops where subsoil limitations are present (Eckard and Armstrong 2009).
- Animal stocking rate – the higher the stocking rate the higher the volume of nitrogen 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 per cent of the nitrogen in a urine patch being lost to the environment. Higher stocking rate systems demand higher nitrogen input regime (either fertiliser or imported feed) and thus result in a higher nitrogen content excreted in urine. A urine patch from a 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; pugged soils tend to be more anaerobic due to hoof compaction leading to higher nitrous oxide losses (Eckard and Armstrong 2009).
- Plant breeding – a longer term strategy is breeding plants that are less nitrophylous i.e. a ryegrass plant that does not require as much nitrogen fertiliser, or plants with a deeper rooting system to extract nitrate from a greater volume of soil (Eckard and Armstrong 2009).

Minimising nitrous oxide – Soil management

- Manage cropping to protect soil structure – avoid burning crop residues after harvest and retain where practical (e.g. pruning's, stubble). Aim to build soil organic matter – for example through including legume pasture rotations, minimum tillage or adding composted material. Ensure continuous plant cover where possible (e.g. between growing seasons and between row crops) to utilise available nitrogen and avoid losses of nitrogen by leaching or denitrification during the fallow (DPI Victoria 2011).
- Reduced tillage – soil disturbance such as a tillage operation breaks up soil organic matter, stimulating greater mineralisation of organic nitrogen. This leads to nitrate becoming available in the soil at a greater rate following tillage and thus a greater loss potential. It also reduces soil structure, leading to poorer plant growth and greater potential for temporary water logging (Eckard and Armstrong 2009).
- Irrigation and drainage – irrigation aims to maintain the soil above wilting point and below field capacity. Poorly drained soils are anaerobic thus promoting denitrification of soil nitrate. If soil nitrate is in excess of crop growth, nitrous oxide loss can be high in both cases (Eckard and Armstrong 2009).

- Soil compaction – the more compact a soil is, 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, especially under wet conditions, in grazing systems (Eckard and Armstrong 2009).
- Liming – early research has found that applying lime to bare soils after significant summer/autumn rain can decrease nitrous oxide emissions if the soil was fertilised during winter cropping (DAFF, 2011b).

Minimising methane and nitrous oxide – reduce burning

In the WA wheatbelt, burning paddocks to control weeds is common practice (Llewellyn and D'Emden 2009). DAFWA research has shown that a windrow – concentrating crop residue into a narrow row, burns at a higher temperature for longer than spread stubble, improving weed kill. Burning a narrow windrow also reduces the percentage of paddock burnt, thereby reducing the area prone to wind erosion and effectively reducing greenhouse gas emissions (DAFWA 2011). The increase in other practices for weed control (e.g. the Harrington seed destructor, rolling crop stubble) is also effective in reducing the amount of greenhouse gas emitted by burning crop residues.

Reducing stubble burning on farms will reduce overall greenhouse gas emissions and also areas prone to wind erosion

Carbon sequestration

Soil organic carbon (SOC) plays a central role in the functioning of all soils including providing an energy source for biological processes, improving soil structure and buffering chemical reactions. Australian soils under rain fed farming, typically has SOC contents in the range of 0.7 – four per cent (Hoyle *et al* 2011). As a consequence of the loss of soil carbon in agricultural systems, many Australian soils now have a significant capacity to store additional carbon. Changing farming practices has the potential to reduce emissions of greenhouse gases while simultaneously increasing productivity, reducing input costs and producing wider natural resource management benefits (Wentworth Group of Concerned Scientists 2009).

One way to offset greenhouse gas emissions produced on farm is to increase total amount of carbon produced and stored in the soil. Any practice that increases the photosynthetic input of carbon and/or slows the return of stored carbon to carbon dioxide via respiration, fire or erosion will increase carbon reserves thereby ‘sequesting’ carbon or building carbon ‘sinks’ (Smith *et al* 2007). Soils have the ability to sequester carbon dioxide which means less carbon is released to the atmosphere. Carbon sequestration will help reduce greenhouse gas emissions from Australian agriculture, increase farm productivity and potentially create offsets under the Carbon Farming Initiative, providing new economic opportunities for landholders (DAFF 2011c). It is important to note that long term sequestration in soil carbon stores and forests is limited by their maximum potential to store carbon (saturation) and uncertainties about measurements and losses (ABARES 2011). However, if we could capture just 15 per cent of the biophysical capacity of the Australian landscape to store carbon, it would offset the equivalent of 25 per cent of Australia’s current annual greenhouse emissions for the next 40 years (Wentworth Group of Concerned Scientists, 2009). A primary challenge for farmers is to sustain a profitable farming system for the long term, which requires continued addition and maintenance of organic inputs (Hoyle, 2011). The following table gives a summary of the major management options for sequestering carbon in agricultural soils.

Table 4. Summary of major management options for sequestering carbon (C) in agricultural soils (from Sanderman *et al* 2010, or otherwise stated).

Management	Soil Organic C benefit [a]	Conf. [b]	Justification
1. Shifts within an existing cropping/mixed systems			
a. Maximizing efficiencies 1. Water use 2. Nutrient use	0/+	L	Yield and efficiency increases do not necessarily translate to increased C return to soil
b. Increased productivity 1. Irrigation 2. Fertilisation	0/+	L	Potential trade-off between increased C return to soil and increased decomposition rates
c. Stubble management 1. Eliminate burning/grazing	+	M	Greater C return to the soil should increase SOC stocks. Also promotes water conservation (Hoyle *et al* 2011).
d. Tillage 1. Reduced tillage 2. Direct drilling	 0/+ 0/+	 M M	1. Reduced till has shown little SOC benefit. In theory reduced or zero tillage options will promote soil aggregation and provide greater physical protection of SOC (tillage is likely to result in continuing decline of SOC) (Hoyle *et al* 2011). 2. Direct drill reduces erosion and destruction of soil structure thus slowing decomposition rates, however surface residues decompose with only minor contribution to SOC pool
e. Rotation 1. Eliminate fallow with cover crop 2. Inc. proportion of pasture to crops 3. Pasture cropping	 + +/++ ++	 M H M	1. Losses continue during fallow without any C inputs – cover crops mitigate this. Reduced fallow periods also increase root biomass and decrease erosion (Hoyle *et al* 2011) 2. Pastures generally return more C to soil than crops. 3. Pasture cropping increases C return with the benefits of perennial grasses
f. Organic matter and offsite additions Biochar	++/+++ +	H M	Direct input of C, often in a more stable form, into the soil. Farmers may be able to regulate agricultural management to maximise organic inputs and retain them, but in some cases only an external source of organic matter to the soil will improve SOC (Hoyle *et al* 2011). Organic matter contributes to stabilising soil aggregates and pore structure as well as increasing C inputs (Hoyle *et al* 2011). As not all biochars have the same properties, how it stores carbon is variable, research is on-going (CSIRO 2011).

Management	Soil Organic C benefit [a]	Conf. [b]	Justification
2. Shifts within an existing pastoral system			
a. Increased productivity 1. Irrigation 2. Fertilisation	0/+	L	Potential trade-off between increased C return to soil and increased decomposition rates
b. rotational grazing	+	L	Increased productivity, inc. root turnover and incorporation of residues by trampling but lacking field evidence
c. Shift to perennial species	++	M	Introducing grass species with greater productivity or carbon allocation to deeper roots has been shown to increase soil carbon (Smith *et al* 2007). Early trials have shown that perennial grasses, including kikuyu grasses can increase soil carbon levels (DAFF 2011c).
3. Shift to different system			
a. Conventional to organic farming system	0/+/++	L	Likely highly variable depending on the specifics of the organic system (i.e. manuring, cover crops)
b. Cropping to pasture system	+/++	M	Generally greater C return to soil in pasture systems; will likely depend greatly upon the specifics of the switch
c. Retirement of land and restoration of degraded land	++ +++	H	Annual production, minus natural loss, is now returned to soil; active management to replant native species often results in large C gains

Notes: [a] Qualitative assessment of the SOC sequestration potential of a given management practice (0=nil, + = low, ++ = moderate, +++ = high). [b] Qualitative assessment of the confidence in this estimate of sequestration potential based on both theoretical and evidentiary lines (L = low, M = medium, H= high).

Reducing carbon dioxide emissions

Studies have shown carbon dioxide can account for a considerable proportion of on-farm greenhouse gas emissions (Barton *et al* 2008a). Therefore it is important to look at reducing greenhouse gas emissions from fossil fuels.

- Switch to alternative fuels such as LPG, natural gas, or Biofuels such as biodiesel from canola. Current research from DAFWA supports the viability of canola for biodiesel production in WA which also minimises greenhouse gas emissions (Farm Weekly 2011). Biofuels still release carbon dioxide upon combustion, but the carbon is of recent atmospheric origin (via photosynthesis), rather than from fossil carbon (Smith *et al* 2007).
- Improve the efficiency of fertiliser and chemical applications to help save on fuel consumption.
- Obtain energy from renewable sources such as solar panels and wind where possible.
- Survey and design paddocks to maximise operating efficiency including systems for controlling traffic.

The introduction of the carbon price will change Australia's electricity generation by encouraging investment in renewable energy like wind and solar power and the use of cleaner fuels like natural gas. The Government's Renewable Energy Target (RET) combined with the carbon price, will deliver around $20 billion of investment in renewable energy by 2020. It will mean that the equivalent of 20 per cent of Australia's energy will come from renewable sources by 2020 (Commonwealth of Australia, 2011).

The RET is designed to speed up the adoption of renewable energy technologies and help smooth the transition to a clean energy future. A great deal of the new investment is likely to be in regional and rural Australia. Investment supported by RET includes wind energy which is the fastest growing large-scale renewable energy source in Australia. The Clean Energy Council indicates that more than 9000 MW of large wind projects are proposed for development around the country. The RET has also encouraged significant deployment of small systems with around 300,000 solar panel systems supported under the RET since 2001 (Commonwealth of Australia, 2011).

Solar Power is an effective way of reducing carbon dioxide emissions (3892025 solar panels)

Box 5. Carbon Farming Initiative

Farmers and land managers will receive significant support to pursue climate change action on the land and enhance biodiversity through a suite of measures including Carbon Farming Initiative, Carbon Farming Futures program and a new Biodiversity Fund. Emissions from agriculture will not be subject to a carbon price (Commonwealth of Australia, 2011).

The Carbon farming initiative is a carbon offset scheme that will provide new economic opportunities for farmers and help the environment by reducing carbon pollution. Farmers and land managers will be able to generate credits that can then be sold to other businesses wanting to offset their own carbon pollution. Actions to reduce pollution or increase carbon storage can also increase the land sector's resilience to climate change, protect Australia's natural environment and improve long term farm productivity (Commonwealth of Australia, 2011).

Land sector activities under the Carbon Farming Initiative – land managers will be allowed to earn credits (generate income) from the following:

- Reforestation and revegetation
- Reduced methane emissions from livestock digestion
- Reduced fertiliser pollution
- Manure management
- Reduced pollution or increased carbon storage in agriculture soils (soil carbon)
- Savannah fire management
- Native forest protection
- Forest management
- Reduced pollution from burning stubble and crop residue
- Reduced pollution from rice cultivation

Challenges for Mitigation

Mitigating on farm greenhouse gas emissions has some big challenges. To be effective, any mitigation strategy must be scientifically sound, measurable, relatively easy to implement and economically viable, and must retain effectiveness over the long term (ABARES 2011). It is important to remember that there is no quick fix when it comes to mitigation, with animal breeding estimates suggesting that it might be 25 years until a reduction in greenhouse gas emissions are seen (Alford *et al* 2006).

Farming carbon for profit is viable in WA. A 2006 study found that at the then expected carbon price of $15/t CO_2-e (it is now $23 a tonne), growing trees for carbon is not a viable alternative for landholders in low rainfall regions (330 mm/year) due to low sequestration rates. In medium rainfall region (550 mm/year), growing trees for carbon and timber is a viable alternative (Flugge and Abadi 2006). A more recent study has found that it is better to increase soil organic carbon as a means of improving the farming system rather than to achieve an economic benefit from storing carbon (Hoyle and Bennett 2009).

Some mitigation practices may be technically and economically viable with extra incentives. For example, no-till practices (which are already incorporated in the majority of WA farming systems) that reduce production cost and increase productivity through improving soils may become cost effective (ABARES 2011). Targeted soil nutrient application and improved animal feed efficiency may also be attractive as they have the potential to reduce input costs (Smith *et al* 2007).

Conclusion

Greenhouse gas emissions from the agricultural sector can be reduced by implementing alternative management practices, increasing carbon sequestration and reducing fossil fuel emissions. The results from the various NAMI trials should also encourage mitigation in WA. The ABARES report (2011), research by Barton *et al* (2008a) and a joint project by DAFWA, UWA and Curtin University (Farm Weekly 2011), highlights the importance of life cycle assessment. Life cycle assessment is critical in assessing the whole farm impact and in ensuring the strategy does not increase emissions elsewhere in the production chain. For example, improving pasture quality (digestibility) may reduce methane emissions, but is likely to increase dry matter intake (Eckard *et al* 2010).

For farmers, an on farm life cycle assessment will help to identify optimal greenhouse gas mitigation strategies for each property and, when combined with economic analyses, will indicate the lowest cost path to greenhouse gas abatement. However, comprehensive life cycle analyses are not always possible, given the complexity of many farming systems. Table 5 has been provided to summarise the impacts of some mitigation options. The table also includes estimates of the confidence based on expert opinion that the practice can reduce overall net emissions at the site of adoption. Some of these practices also have indirect effects on ecosystems elsewhere. For example, increased productivity in existing croplands could avoid deforestation and its attendant emissions (Smith *et al* 2007). The potential to mitigate on farm greenhouse gas emissions is greatest where science is sure and easy to implement at low cost. Policy certainty and financial incentives, such as a carbon offset market, may also encourage mitigation activities by Australia's primary producers (ABARES 2011).

Table 5. Proposed measures for mitigating greenhouse gas emissions from agricultural ecosystems, their apparent effects on reducing emissions of individual gases where adopted (mitigated effect), and an estimate of scientific confidence that the proposed practice can reduce overall net emissions at the site of adoption, from Smith *et al.*, 2007.

Measure	Examples	Mitigative effects [a]			Net mitigation [b] (confidence)	
		CO_2	CH_4	N_2O	Agreement	Evidence
Cropland management	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management (irrigation, drainage)	+/-		+	*	*
	Agro-forestry	+		+/-	***	*
	Set-aside, land-use change	+	+	+	***	***
Grazing land management/ pasture improvement	Grazing intensity	+/-	+/-	+/-	*	*
	Increased productivity (e.g. fertilisation)	+		+/-	**	*
	Nutrient management	+		+/-	**	**
	Fire management	+	+	+/-	*	*
	Species introduction (including legumes)	+		+/-	*	**
Livestock management	Improved feeding practices		+	+	***	***
	Specific agents and dietary additives		+		**	***
	Longer term structural and management changes and animal breeding		+	+	**	*
Manure/biosolid management	Improved storage and handling		+	+/-	***	**
	Anaerobic digestion		+	+/-	***	*
	More efficient use as nutrient source	+		+	***	**
Bio-energy	Energy crops, solid, liquid, biogas, residues	+	+/-	+/-	***	**

Notes: [a] + denotes reduced emissions or enhanced removal (positive mitigated effect). – denotes increased emissions or suppressed removal (negative mitigated effects), +/– denotes uncertain or variable response, [b] a qualitative estimate of the confidence in describing the proposed practice as a measure for reducing net emissions of greenhouse gases, expressed as CO_2-e: agreement refers to the relative degree of consensus in the literature (the more asterisks, the higher the agreement); Evidence refers to the relative amount of data in support of the proposed effect (the more asterisks, the more evidence).

References

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) 2011 'Options for on-farm mitigation of greenhouse gases in Australia'. Science and Economic Insights Issue 3, viewed 20 September 2011, http://www.daff.gov.au/abare-brs/publications

Alford, AR, Hegarty, RS, Parnell, PF, Cacho, OJ, Herd, RM & Griffith, GR 2006 'The impact of breeding to reduce residual feed intake on enteric methane emissions from the Australian beef industry.' *Australian Journal of Experimental Agriculture* 46:813-820.

Australian National Greenhouse Accounts 2011 'National Inventory Report 2009: Accounting for the Kyoto Target December quarter 2010' Published by the Department of Climate Change and Energy Efficiency. April 2011, viewed 20 September 2011 http://www.climatechange.gov.au/publications/greenhouse-acctg/national-greenhouse-gas-inventory-2009.aspx

Barton, L, Biswas, W & Carter, D 2008a 'Global warming potential of wheat production in Western Australia : A life cycle assessment'. *Agribusiness Crop Updates, Farming Systems* 2008 pp 4-7

Barton, L., Kiese, R., Gatter, D., Butterbach-Bahl, K., Buck, R., Hinz, C., Murphy, D.V., 2008b. Nitrous oxide emissions from a cropped soil in a semi-arid climate. Global Change Biology Bioenergy 14, 177-192.

Commonwealth of Australia 2011 'Securing a clean energy future. The Australian Government's Climate Change Plan. Licensed from the Commonwealth of Australia under a Creative Commons Attribution 3.0 Australia Licence, viewed 18 October 2011, http://www.cleanenergyfuture.gov.au/clean-energy-future/securing-a-clean-energy-future/.

Crutzen, PJ 1981 'Atmospheric chemical processes of the oxides of nitrogen including nitrous oxide'. In: Delwiche, CC (ed.) *Denitrification, Nitrification and Atmospheric Nitrous Oxide*. John Wiley and Sons New York 17-44.

CSIRO 2011 'Biochar for agronomic improvement and greenhouse gas mitigation' CSIRO Sustainable Agriculture Flagship, viewed 20 September 2011 http://www.csiro.au/resources/Biochar-agronomic-improvement.html

DAFF 2011a 'Reducing emissions from livestock fact sheet' Department of Agriculture, Fisheries and Forestry, viewed 19 September 2011, http://www.daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research/emissions_reduction2/reducing-emissions-livestock/fact-sheet

DAFF 2011b 'Reducing nitrous oxide emissions' Climate Change Research Program Department of Agriculture, Fisheries and Forestry, viewed 19 September 2011, http://www.daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research/emissions_reduction2/nitrous_oxide_research_program/fact-sheet-reducing-nitrous_oxide_emissions

DAFF 2011c 'Reducing greenhouse gas emissions using soil carbon' Climate Change Research Program Department of Agriculture, Fisheries and Forestry, viewed 19 September 2011, http://www.daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research/emissions_reduction2/reducing-emissions-livestock/fact-sheet-greenhouse

DAFWA 2011 'Weeds – integrated weed management – Tactic 1.1 Burning', Department of Agriculture and Food, WA, viewed 19 September 2011, http://www.agric.wa.gov.au/PC_93465.html?s=2075361928

De Klein, CAM & Eckard RJ 2008 Targeted technologies for nitrous oxide abatement from animal agriculture. *Aust. J. Exp. Agric*. 48: 14-20.

de Laat, ATJ & van Weele M 2011 The 2010 Antarctic ozone hole: observed reduction in ozone destruction by minor sudden stratospheric warmings. *Scientific Reports* 1:38

DPI Victoria 2011 Carbon and Emissions: soils Department of Primary Industries, Victoria website', viewed 27 September 2011 http://new.dpi.vic.gov.au/agriculture/farming-management/weather-climate/understanding-carbon-and-emissions/soils

Eckard, R & Armstrong, R 2009 'Grains Greenhouse Accounting Framework' viewed 19 September 2011, www.greenhouse.unimelb.edu.au/site/Tools.htm

Eckard, RJ, Grainger, C, & de Klein, CAM 2010 'Options for the abatement of methane and nitrous oxide from ruminant production: A review'. *Livestock Science* 130: 47–56

Farm Weekly 2011 'Biodiesel canola treads lightly on canola'. 18 August 2011, 22

Flower, K.C., Manalil, S., Riethmuller, G., Peek, C. and Pasqual, G. (2012). Previous fallow has no effect on soil nitrous oxide emissions in wheat but weedy fallow reduces yield. Paper published in GRDC Agribusiness Crop Updates. 28th February 2012, Pan Pacific Hotel, Perth Western Australia.

Flugge, F, & Abadi, A, 2006 'Farming carbon: an economic analysis of agroforestry for carbon sequestration and dryland salinity reduction in Western Australia'. *Agroforest Syst* 68:181–192

Hoyle, FC, Baldock, JC, & Murphy, DV, 2011 'Chapter 14 Soil Organic Carbon – Role in Rainfed Farming Systems. With Particular Reference to Australian Conditions. In: Tow, P, Cooper, I, Partridge, I, & Birch, C (eds). *Rainfed Farming Systems* Springer Science + Business Media 339-361

Hoyle, FC, & Bennett, A, 2009 'Soil organic carbon in WA agricultural soils'. *Agribusiness Crop Updates, Farming Systems* 2009 226 – 227

Jones, F 2009 'Seeking to reduce livestock greenhouse emissions' Department of Agriculture and Food, WA Factsheet 376

Jones, F, Phillips, F & Naylor, T 2009 'Greenhouse emissions from breeding beef cows selected for extremes in low and high net feed efficiency under a pasture grazing system'. Climate 21: Understanding climate change and how to manage it. Department of Agriculture and Food, WA. pp 20

Llewellyn, RS & D'Emden, F 2009 'Adoption of no-till cropping practices in Australian grain growing regions'. Report for SA No-till Farmers Association and CAAANZ June 2009 CSIRO

Purvaja, R, Ramesh, R, Ray, A,K, & Rixen T 2008. Nitrogen cycling: A review of the processes, transformations and fluxes in coastal ecosystems. Current Science 94 (11) 1419-1438.

Sanderman, J, Farquharson, R & Baldock, J 2010 'Soil Carbon Sequestration Potential : A review for Australian agriculture CSIRO, viewed 27 September 2011, http://www.csiro.au/files/files/pwiv.pdf

Smith, P, Martino, D, Cai, Z, Gwary, D, Janzen, H, Kumar, P, McCarl, B, Ogle, S, O'Mara, F, Rice, C, Scholes, B & Sirotenko, O 2007 'Agriculture' in 'Climate Change 2007: Mitigation', *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* in Metz, B, Davidson, OR, Bosch, PR, Dave, R & Meyer, LA (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY , USA, viewed 27 September 2011, http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch8.html

Stehfest, E & Bouwman, L 2006 'N_2O and NO emission from agricultural fields and soils under natural vegetation: Summarising available measurement data and modelling of global annual emissions' *Nutrient Cycling in Agroecosystems* 74, 207 – 228

UWA 2011 University of Western Australia website, viewed 19 September 2011, http://www.news.uwa.edu.au/201109143924/research/touch-tar-bush

Wentworth Group of Concerned Scientists 2009 'Optimising Carbon in the Australian Landscape. How to guide the terrestrial carbon marlets to deliever multiple and economic and environmental benefits, viewed 27 September 2011, http://www.wentworthgroup.org/blueprints/optimising-carbon-in-the-australian-landscape