



australian commodities

september quarter **07.3**

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ABARE project 1163 ❧

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ISSN 1321-7844

abare

climate change

issues and challenges for Australian agriculture and forestry

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- » *In Australia, the agriculture sector accounted for just under 60 per cent of total methane emissions, 84 per cent of total nitrous oxide emissions and 17 per cent of overall greenhouse gas emissions in 2005.*
- » *Adaptive responses in the agriculture and forestry sectors will be important for maintaining productivity growth and international competitiveness in response to climate change impacts and new policy environments.*
- » *Reduced land clearing and expansion of forestry areas are important in reducing growth in Australia's greenhouse gas emissions and increasing terrestrial carbon sequestration.*
- » *While progress is being made in resolving measurement and compliance issues associated with including agriculture and land use in the proposed domestic emissions trading scheme, these sectors have a considerable opportunity for early involvement in the scheme as providers of offsets.*
- » *Incorporating agriculture and land use sector emission permits or offset obligations in the proposed emissions trading scheme will be a challenge. Alternative approaches that place emissions reporting obligations downstream at the point of processing of farm products warrant consideration.*
- » *Preliminary analysis indicates that the indirect impacts of potential carbon pricing on on-farm costs are likely to be modest given that the shares of emission intensive farm inputs in total farm costs are relatively low.*
- » *There is a growing need for research into the biophysical and economic impacts of climate change, and into alternative adaptation and mitigation options and their cost effectiveness.*

introduction

There is consensus in the global scientific community that the climate has been changing and will continue to change (IPCC 2007). Current literature indicates that human induced increases in the atmospheric concentration of greenhouse gases will continue to drive changes in climate across Australia for the foreseeable future (PMSEIC 2007). Agriculture and forestry are two important sectors in the Australian economy that are likely to be affected directly and indirectly by both climate change and climate change response policies.

In this article, the potential impacts of climate change and climate change mitigation and adaptation responses in the agriculture and forestry sectors are discussed. Opportuni-

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ties and challenges in incorporating these sectors in a domestic emissions trading scheme are also explored.

agriculture and forestry – emission sources and sinks

The agriculture and forestry sectors play an important role in the makeup of Australia's greenhouse gas emissions profile through their role as both major emissions sources and sinks (table 1). In 2005, the agriculture sector accounted for about 17 per cent of Australia's greenhouse gas emissions or 87.9 million tonnes of carbon dioxide equivalent (Mt CO₂-eq) (NGGI 2007). The sector contributed just under 60 per cent of Australia's methane emissions and 84 per cent of Australia's nitrous oxide emissions in 2005 (NGGI 2007). Agriculture and forestry also contribute considerable amounts of carbon dioxide through the use of fossil fuels and electricity that are allocated to the stationary energy and transport sectors. Reduced land clearing and expansion of forestry areas are important sinks. In 2005 net emissions from land use change and forestry were -3.2 Mt CO₂-eq (NGGI 2007).

Key sources of emissions in the agriculture sector include enteric fermentation in livestock, manure management systems, agricultural soils, rice cultivation and burning of agricultural residues and savannas. Emissions from these sources are projected to reach 101.2 Mt CO₂-eq by 2020 under existing policy measures (table 2; AGO 2006a). Emissions

1 net historical agricultural and forestry emissions, by greenhouse gas

	1990				2000				2005			
	CO ₂	CH ₄	N ₂ O	total	CO ₂	CH ₄	N ₂ O	total	CO ₂	CH ₄	N ₂ O	total
	Mt CO ₂ -eq				Mt CO ₂ -eq				Mt CO ₂ -eq			
agriculture												
enteric fermentation	-	63.9	-	63.9	-	60.4	-	60.4	-	58.7	-	58.7
manure management	-	1.5	0.5	2.1	-	2.0	1.3	3.3	-	1.9	1.5	3.4
rice cultivation	-	0.5	-	0.5	-	0.7	-	0.7	-	0.2	-	0.2
agricultural soils	-	-	14.4	14.4	-	-	17.4	17.4	-	-	16.6	16.6
prescribed burning of savannas	-	4.6	2.0	6.6	-	9.3	4.0	13.2	-	6.1	2.6	8.7
field burning of agricultural residues	-	0.2	0.1	0.3	-	0.3	0.1	0.4	-	0.2	0.1	0.4
total	-	70.7	17.0	87.7	-	72.7	22.8	95.5	-	67.2	20.7	87.9
land use, land use change and forestry (LULUCF)												
forest land	-44.8	1.5	0.4	-42.8	-48.9	0.7	0.2	-47.9	-52.8	1.0	0.3	-51.5
cropland	13.2	0.7	0.2	14.1	2.5	0.6	0.2	3.3	-5.2	0.5	0.1	-4.6
grassland	111.4	2.7	0.7	114.8	59.7	1.4	0.4	61.5	56.2	1.3	0.4	57.8
other - harvested wood products	-4.4	-	-	-4.4	-4.3	-	-	-4.3	-5.0	-	-	-5.0
total LULUCF	75.4	4.9	1.3	81.6	9.1	2.8	0.8	12.6	-6.8	2.8	0.8	-3.2
total agriculture and LULUCF	75.4	75.7	18.3	169.3	9.1	75.5	23.6	108.1	-6.8	70.0	21.5	84.7
Australia's total greenhouse gas emissions ^a	355.1	119.0	20.2	499.9	361.5	118.6	26.3	510.2	377.4	113.9	24.6	522.2

CO₂ = carbon dioxide; CH₄ = methane; N₂O = nitrous oxide; HFCs = hydrofluorocarbons; PFCs = perfluorocarbons; SF₆ = sulfur hexafluoride.

^a Total emissions include high global warming potential gases (HFCs, PFCs, SF₆).

Source: NGGI (2007).

from the agriculture sector are heavily influenced by the size of the cattle herd, with cattle accounting for just under half of agricultural emissions (NGGI 2007).

Mitigation and the expansion of carbon sinks through terrestrial sequestration are key opportunities to reduce growth in Australia's greenhouse gas emissions from these sectors. The forestry industry plays a vital role in the sequestration of carbon. Terrestrial sequestration in the forestry sector can be increased through enhanced management of existing forestry land, new forestry plantations, the establishment of forested areas on agricultural land and regrowth of native vegetation where appropriate. Assuming no change in existing policy measures, the sequestration of carbon in the forestry sector is expected to decrease to about 39 Mt CO₂-eq by 2020 (table 2), a reduction of 25 per cent compared with 2005 (AGO 2006b).

impacts of climate change

Long term human induced climate change is expected to be evident in both a change in average rainfall and temperature, as well as changes in the severity and frequency of extreme weather and climatic events, such as droughts, floods, frosts and heat waves (IPCC 2007).

Australia's climate is changing; the continent has warmed and so have the oceans around Australia (PMSEIC 2007). Rainfall across Australia continues to be dominated by variability across regions, seasons and years. The changes in the level and variability of temperature and rainfall have important implications for agriculture and forestry and other related sectors of the economy.

biophysical impacts

Climate change is likely to affect agricultural productivity through increased average temperatures, changed rainfall patterns and increased climate variability (AGO 2007). There may also be indirect impacts through changes in the incidence of pests and diseases and increased rates of soil erosion and degradation. The effect of changes in climate on agricultural productivity is likely to vary across different crop and livestock industries. For instance, crop production is likely to be affected directly by changes in average rainfall and temperatures, and by possible changes in distribution of rainfall during the year. The productivity of certain livestock industries will be influenced by the changes in the quantity and quality of available pasture, as well as by the direct effects of temperature changes and the increased likelihood of greater extreme temperatures (Adams, Hurd and Reilly 1999).

The projected changes in weather and climate extremes in Australia in the medium to long term include: an increasing number of hot days and nights; warm spells and heat waves; a rise in drought affected areas; and an increase in intense tropical cyclone activity

2 net historical and projected agricultural and forestry emissions

	1990	2000	2005	2010	2020
	Mt CO ₂ -eq				
agriculture					
enteric fermentation	63.9	60.4	58.7	63.7	68.9
manure management	2.1	3.3	3.4	3.3	3.5
rice cultivation	0.5	0.7	0.2	0.4	0.3
agricultural soils	14.4	17.4	16.6	16.8	17.2
prescribed burning of savannas	6.6	13.2	8.7	11.1	11.1
field burning of agricultural residues	0.3	0.4	0.4	0.3	0.3
total	87.7	95.5	87.9	95.6	101.2
land use, land use change and forestry (LULUCF)					
forest land	-42.8	-47.9	-51.5	-43.1	-38.8
other land use change	124.5	60.5	48.2	44.5	44.5
total LULUCF	81.6	12.6	-3.2	1.4	5.7
total agriculture and LULUCF	169.3	108.1	84.7	97.0	107.0

Source: AGO (2006a,b,c) and NGGI (2007).

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(PMSEIC 2007). The frequency of rainfall events in Australia is also likely to decline and the amount of rainfall that falls as extreme rainfall may increase. There is expected to be considerable regional variability in these impacts. The implications of these projected changes to climate extremes for the agriculture and forestry sectors are summarised in table 3.

economic impacts

Current understanding of the direct and indirect economic impacts of climate change on a broad range of agricultural activities is incomplete. This mainly reflects large information gaps on the interrelationships between long term climate change and various economic activities.

3 implications of extreme weather events for the agriculture and forestry sectors

phenomenon	direction of trend	implications
hot days and nights	↑	Moderate increase in crop yields in north eastern Australia. In cooler Australian climates, warming likely to allow alternative crop varieties to be grown. Less cold stress likely to reduce lamb mortality. Increase in potential distribution of exotic weeds and native woody species. Productivity of exotic softwood and native hardwood plantations likely to increase, although amount of increase will be limited by projected increase in temperature and reductions in rainfall. Temperate fruits and nuts production negatively affected.
warm spells and heat waves	↑	Significant crop yield reductions in south western Australia, compounded by reductions in rainfall. Increased heat stress on livestock. Impacts of cattle tick on the Australian beef industry likely to increase and move southwards. Reduced grape quality and value. Queensland fruit fly may become a significant risk to southern Australia.
drought affected areas	↑	Cropping in southern Australia becoming nonviable at the dry margins if rainfall is reduced substantially. Increased vulnerability of agriculture in south west and inland Australia. Waterlogging, soil acidification, soil erosion and dryland salinity likely to be exacerbated. Increase in potential distribution of exotic weeds and native woody species. 20 per cent reduction in rainfall likely to reduce pasture growth by an average of 15 per cent and live weight gain in cattle by 12 per cent. Land degradation; lower yields/crop damage and failure; livestock deaths.
intense tropical cyclone activity	↑	Damage to crops and trees.
heavy precipitation events	↑	Damage to crops, soil erosion, inability to cultivate land, waterlogging of soils.
rising sea levels	↑	Salinisation of irrigation and well water, estuaries and freshwater systems in some coastal regions.

Source: PMSEIC (2007), tables 2-4.

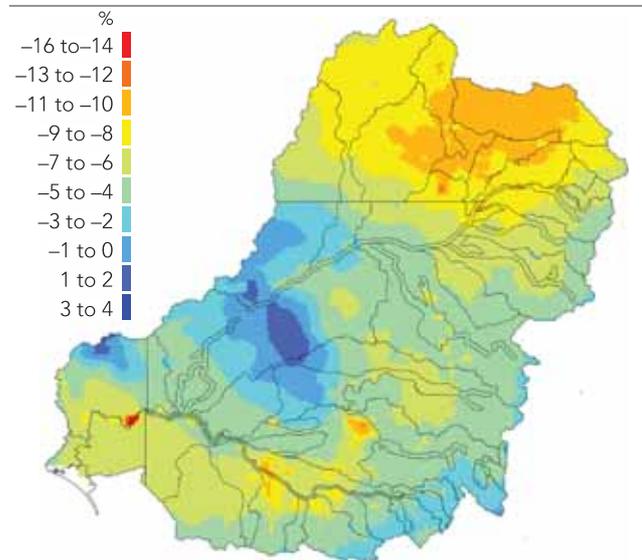
A key example of a climate related event that has major economic consequences is drought. For instance, it is estimated that the 2002-03 and 2006-07 droughts reduced economic growth in Australia by around 1.0 and 0.75 percentage points respectively from what would otherwise have been achieved (Penm 2003; Penm and Glyde 2007).

One of the important agricultural producing areas in Australia that is likely to be adversely affected by climate change is the Murray Darling Basin (MDB). The basin is the catchment for Australia's two largest river systems, the Murray and Darling rivers and their tributaries. Situated in the south east of Australia, the basin covers an area in excess of one million square kilometres or about 14 per cent of the country's total land area (MDBC 2007). The basin is Australia's most important agricultural region, accounting for nearly 52 per cent of the annual national gross value of agricultural production in 2001. The basin's 2.2 million hectares of irrigated agriculture is particularly important and represents about 75 per cent of Australia's total irrigation area (MDBC 2005).

According to a recent CSIRO study, climate change is a major risk to the basin's water resources (CSIRO 2006). Recent experience suggests that an apparently increasing frequency of extreme events, such as extended droughts, may seriously threaten the ecological systems and the economic viability of resource use systems in the basin. Reductions in rainfall in the basin are likely to be associated with reductions in runoff (map 1; PMSEIC 2007, p. 19) and losses in agricultural production (Adamson, Mallawaarachchi and Quiggin 2007). Runoff falls by about 2-3 per cent for every 1 per cent fall in rainfall. This implies that runoff reduces by a factor of two to three when compared with rainfall. Hence, small reductions in rainfall can produce much larger reductions in runoff, potentially compounding water resources problems (PMSEIC 2007).

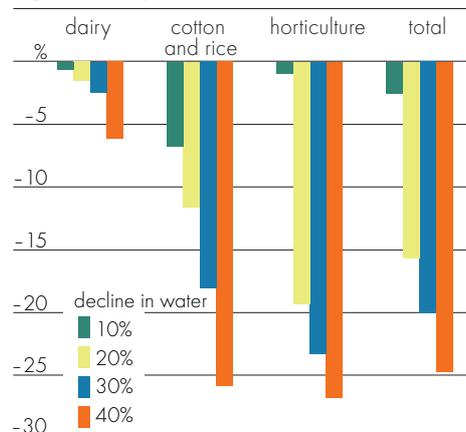
Reduced water availability in the Murray Darling Basin region associated with reduced rainfall from climate change could potentially have adverse economic impacts on irrigated agriculture in the region. According to preliminary ABARE analysis of the most extreme illustrative scenario considered (a 40 per cent decline in runoff in the basin), irrigated

map 1 **projected changes in median runoff in the Murray Darling Basin, 2030**



Based on simulations with a simple hydrological model (CSIRO), using 12 different global climate model patterns, three climate sensitivities and three emissions scenarios. Source: PMSEIC (2007, p. 19).

fig A **impacts of reduced water in the Murray Darling Basin** percentage change in irrigated farm output, relative to the reference case, 2001-02



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agricultural production in the region is estimated to fall by around 25 per cent relative to what would otherwise be (figure A). The greatest reduction in output is estimated to occur in perennial horticultural crops such as grapes, citrus and stonefruits.

In general, the impact of climate variability and climate change on the future availability of water resources for agricultural, human and environmental use will be influenced by a number of factors. These include rainfall pattern, pattern of water use, policy regimes relating to allocation of urban, rural and environmental water, inter and intraregional water trade, and the status of water infrastructure and catchment characteristics.

responding to climate change

There are two key ways of responding to climate change. The first is to adapt to the changes and the second is to try to reduce climate change through mitigation measures, which include emissions abatement and sequestration. The right balance between these activities is found by equating the marginal costs of adaptation, abatement and sequestration. By spreading effort across adaptation and mitigation activities, the costs of responding to climate change can be minimised.

Adaptation measures are changes in practices, processes and/or capital stocks that aim to reduce the adverse impacts of an anticipated or actual change in the operating environment and take advantage of any opportunities that may arise. Adaptation provides opportunities to manage risks and adjust economic activity to reduce vulnerability and improve business certainty (COAG 2007). Adaptation to changes in the operating environment (for example, in climatic conditions, input and output prices, and domestic and international agricultural and trade policies) has been a key feature of the evolution of Australian agriculture. The projected scope and extent of potential changes in precipitation, temperature, frosts and extreme weather events throughout Australia as part of a long term change in climate indicate that the agriculture sector will need to continue to adapt.

It is important to recognise that historically the Australian agriculture sector has adjusted and adapted continuously to external drivers such as changes in the natural resource base, including climate variability and climate change. Such adaptation has been achieved predominantly through productivity improvements induced by technological changes, changes to farm management practices and more market oriented domestic policy reforms.

Mitigation of the impacts of climate change involves human intervention to reduce the sources or enhance the sinks of greenhouse gases. Mitigation opportunities in agriculture and forestry range from improving animal and plant productivity to developing natural carbon sinks, such as in forestry and soils.

In general, a portfolio of measures will be required to respond effectively to climate change. These measures may include collaborative efforts with industry on research and development; the introduction of performance and emissions standards; measures to enhance capacity building and technological assistance within and between industries; and the use of economic instruments, such as emissions trading. Approaches will vary depending on the circumstances and capacities of different industries.

It is important to recognise that in responding to climate change, the agricultural and forestry sectors are in a unique position to play a central role in contributing to emission offsets and reducing the overall cost to the economy.

adapting to climate change

Effective climate change adaptation in the agricultural and forestry sectors requires identifying the relevant adaptation options, understanding the overall benefits of chosen adaptation measures and helping the sectors to enhance their adaptive capacity in relevant areas.

adaptation options

There are many adaptation options and strategies available to the agriculture sector to respond to climate change. Some of these can be considered autonomous responses that occur during the course of normal business operations in response to realised climate events or trends. These generally involve the implementation of existing technologies or knowledge (IPCC 2007). Planned adaptations on the other hand are mainly strategic responses in anticipation of expected changes. Planned adaptation generally involves enhancing adaptive capacity by developing new technologies, processes or infrastructure or making changes to the policy environment to strengthen conditions for effective adaptation (IPCC 2007). A range of broad adaptation options in the agriculture and forestry sectors are summarised in box 1.

The optimal use of different adaptation options from an economic and social perspective will depend on the costs and benefits of adaptation activities relative to 'doing nothing'. The use of particular adaptation options will be influenced by a range of factors, including the extent and timing of climatic changes, current degree of industry profitability, current enterprise mix, regional location, access to capital and new technologies, degree of risk aversion, access to and expected impacts of alternative nonfarming activities, changes in input and output prices and changes in domestic and international agricultural policies. Farmers' adaptive capacity will also be influenced by their level of education and training, diversity of on- and off-farm income sources, and levels of income (Nelson et al. 2005; Brooks and Adger 2005).

overall benefits of adaptation

ABARE analysis indicates that the uptake of adaptation measures (in response to climatic changes) to improve agricultural productivity can reduce the projected economic impacts of climate change by about half in selected agricultural regions in Australia. The extent to which farmers adapt, however, will depend on the relative costs of adapting and not adapting. In table 4, the projected impacts of adaptation on key economic and production variables are presented for two case study regions in Australia – the central western slopes and plains of New South Wales and the northern and eastern Western Australian wheat belt.

4 change in key economic variables assuming a decline in average rainfall, with and without adaptation, relative to business as usual

	New South Wales region		Western Australia region	
	no adaptation %	with adaptation %	no adaptation %	with adaptation %
gross regional product	-1.1	-0.5	-6.5	-3.3
wheat production	-6.8	-3.4	-13.4	-6.7
beef production	-0.9	-0.5	na	na
wool and sheep meat production	-2.1	-1.1	-5.2	-2.6

na Not applicable.

Source: Heyhoe et al. (2007).

box 1 climate change adaptation options in agriculture and forestry

cropping and horticulture

- alter the variety or species planted to those with more appropriate thermal time and vernalisation requirements and/or with increased resistance to heat, frosts or drought
- alter application times and amount of fertiliser or irrigated water to maintain growth and quality
- alter timing and location of cropping activities
- enhance water efficiency by using zero tillage, retaining crop residues and changing planting patterns
- in lower rainfall areas, enhance water management by implementing or expanding water harvesting technologies and acting to conserve soil moisture; in higher rainfall areas, improve water management to prevent waterlogging, erosion and nutrient leaching
- enhance pest, disease and weed management practices through integrated pest and pathogen management and using more pest and disease resistant varieties
- reduce potential for soil erosion by retaining stubble, reducing fallow times, etc

livestock

- adapt annual production cycle to better match feed production
- alter pasture rotations and modify grazing times
- alter forage and animal species or breeds
- provide supplementary feeding
- provide alternative housing infrastructure – for example, winter housing or increased shading
- change or improve feed concentrates

planted forests

- change management intensity, harvesting patterns, and rotation periods as appropriate
- select a variety of species
- manage landscape to reduce fire risk
- undertake prescribed burning to reduce vulnerability to fire damage

sectorwide

- use seasonal forecasting to reduce production risk
- diversify farm income by integrating other farming activities or increasing off-farm income
- move to alternative income sources outside of agriculture
- minimise high input costs in high risk areas or time periods
- have emergency response plans in place for fire, flood, hail and heavy rain etc
- offset increased costs of managing climate change by reducing other costs
- use financial risk management tools or options to manage risk – for example, futures contracts, water trading, carbon offsets, income stabilisation, insurance
- spread risk through multiple holdings in different climatic regions
- increase resilience of land systems through landcare and stewardship initiatives.

Sources: Government of South Australia (2007); Smit and Skinner (2002); AGO (2007); IPCC (2007); PMSEIC (2007).

enhancing the capacity for adaptation in the agriculture and forestry sectors

There is a continuing need to improve the adaptive capacity of the agriculture and natural resource sectors of the economy in response to climate variability and climate change (PMSIEC 2007). Enhancing the capacity to adapt can occur at a farm, regional and national level. Governments have a key role in ensuring that the institutional, financial and general policy environment supports rather than stifles adaptation. It is important that productivity improvements, adaptation and structural adjustment continue to occur in the agriculture and natural resource sectors in the Australian economy into the future.

Government funding and support for research and development into alternative agricultural production technologies or varieties, such as more climate tolerant crops and livestock, will also be important for identifying efficient adaptation options.

Governments also have a key role to play in providing information on potential regional climate change impacts and in identifying and supporting possible response policies. The development and maintenance of key public infrastructure vulnerable to climate change relating to water storage, public lands and transport and storage will also be key to enhancing the adaptive capacity of regional communities.

Another challenge for governments and agricultural industry stakeholders is to deal with the uncertainties and manage the risks relating to the nature and extent of future climatic changes and potential mitigation and adaptation policies. Further research and the development of policies and farm management approaches that are flexible enough to deal effectively with a range of potential uncertainties will help with this (Heyhoe et al. 2007).

In Australia, federal, state and territory governments are aiming to address the issue of adaptation through the Council of Australian Governments (COAG) process and with the use of the National Climate Change Adaptation Framework. These initiatives, including the National Agriculture and Climate Change Action Plan (NACCAP), aim to strengthen knowledge of, and responses to, climate change vulnerabilities, impacts and adaptation and enhance Australia's adaptive capacity across a range of regions and sectors. The Australian Government has also announced funding of about \$165 million to develop an Australian Centre for Climate Change Adaptation and a CSIRO National Research Flagship on Climate Adaptation. This funding is designed to support and accelerate practical action on adaptation across the economy.

mitigation measures in the agriculture and forestry sectors

A range of technologies and management practices that can potentially reduce emissions in the agricultural and forestry sectors are discussed below. The need to undertake further research to better understand the cost of mitigation is also explored.

mitigation of livestock emissions – waste management

Liquid and slurry manure management systems used in intensive livestock farming such as dairy and pig farms are a primary source of methane emissions from livestock waste because of anaerobic storage conditions (EPA 2006). The installation of anaerobic digesters allows the methane emissions to be captured and used as an energy source to produce electricity, heat or hot water (Beach et al. 2006). As well as limiting the emissions of methane, anaerobic digesters can also assist in treating and stabilising waste and controlling odour (EPA 2006; Beach et al. 2006).

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The installation of anaerobic digesters will involve a range of capital and labour costs. However, the extent of these costs depends on the type (whether it includes an electricity or heat generator) and scale of the digester (EPA 2006). Livestock yields are not expected to be altered with the installation of anaerobic digesters. However, cost offsets can be generated from heat or electricity generation.

Efficient dry manure management can also reduce emissions from livestock waste. If manure is composted under aerobic conditions, methane emissions associated with anaerobic degradation can be reduced. If the resulting fertiliser is also used as a substitute for commercially produced fertiliser, nitrous oxide emissions may also be reduced (CHEMinfo et al. 1998).

mitigation in livestock management – enteric fermentation

Emissions from enteric fermentation in livestock depend on the type, size, age and productivity of the animal and the type and digestibility of the feed used (Lucas et al. 2007). Improving the feed conversion efficiency of livestock can reduce methane emissions per unit of product. Methane emissions can be reduced in a number of ways – altering animal diets, changing intensive grazing management and using more productive breeding practices and animal types (EPA 2006; ACG 2006; Beach et al. 2006; EPA 1999). Although these mitigation actions generally involve additional costs in the form of materials and labour, many of these practices will increase yields and reduce emissions as a result of increased production and feed efficiency. The scope of mitigating livestock emissions in Australia may be more limited than in other countries because of the greater use of grazing in extensive rather than intensive conditions.

mitigation in cropping

Nitrous oxide is emitted from soils during the processes of nitrification and denitrification. Activities that add nitrogen to the soil, such as applications of fertiliser, manure or sewage sludge, planting nitrogen fixing crops, retaining crop residues and cultivating organic soils may increase nitrous oxide emissions from soils (EPA 2006).

Options for reducing nitrous oxide and soil carbon emissions include more efficient use of fertilisers such as using nitrogen inhibitors and split fertilisation or switching to minimum tillage practices (EPA 2006; Beach et al. 2006).

mitigation in forestry

The forestry sector is a net sequester of carbon. However, the sector does produce greenhouse gas emissions through its use of fertilisers and fuels. In addition to increasing reforestation and afforestation and reducing deforestation, emissions could be reduced through more efficient or reduced fertiliser use and energy efficiency improvements in harvesting and processing.

There is significant potential to use forest products and residues for the production of bioenergy in some instances. Forest residues from the harvesting of commercial forests, thinnings that have no other market, and sawmill residues could all be used for the production of bioenergy (Raison 2006). Currently about 50 per cent of biomass from forestry is left on the forest floor as waste (NAFI 2007). It is estimated that about 14–16 million cubic metres a year of forest waste products is available from harvested Australian forests (Raison 2006). Forest residues could potentially be converted to electricity through co-firing, bioenergy plants or small scale gasification (Raison 2006).

potential costs of mitigation measures

While these technical possibilities exist, the overall efficiency of using these approaches needs to be carefully analysed to ascertain overall costs and benefits in the light of changing energy, transport and material costs over the medium to long term.

Some mitigation in the agriculture sector could be achieved at no or minimum cost to farmers. These are known as 'win-win' or 'no regrets' abatement opportunities because they both reduce emissions and provide cost savings or increased revenue to the farmer. For example, switching to best management practices such as minimum tillage, more efficient fertiliser use and improved grazing regimes will lower costs or increase yields while simultaneously reducing emissions in most cases (ACG 2006; EPA 2006).

A lack of knowledge and limited incentives to change farm management practices were found to be the major barriers preventing farmers from undertaking no regrets abatement action or the uptake of best management practices (Lucas et al. 2007). Beach et al. (2006) also suggest that farmers may not adopt certain mitigation options that appear to bring cost savings because there may be additional costs or adoption barriers to undertaking such options.

There is limited detailed information available about the extent of win-win or no regrets abatement options in Australia. Furthermore, adequate analysis has not been done on the scope or cost of specific abatement opportunities in Australia. Abatement potentials and costs can also vary greatly between regions and across enterprises. More research needs to be undertaken in this area to better understand the cost of abatement for Australian agriculture (ACG 2006).

emissions trading issues

In this section, a range of key emissions trading related issues, including options for reducing the overall cost of abatement, approaches to including agriculture in emission trading and the research needs to facilitate such approaches, are analysed.

The Australian Government has announced that a domestic emissions trading system will be introduced no later than 2012 as the primary mechanism for achieving a sustained reduction in emissions. The Prime Ministerial Task Group on Emissions Trading has indicated a threshold of 25 kt CO₂-eq a year to represent the size of facilities that could potentially be covered by an emissions trading scheme (PMTGET 2007). Initially, non-energy related emissions from the agriculture and forestry sectors will be excluded from the scheme. According to PMTGET (2007), agriculture and land use will initially be excluded from the proposed domestic emissions trading scheme for four key reasons:

- » the reliability of standard emissions estimation at facility level is generally low for agricultural practices and moderate for forestry
- » the large number of disperse emission measurement points
- » high measurement and transactions costs per tonne of emissions and
- » greater need for development of improved and more cost effective emissions measurement methodologies.

However, these sectors are likely to be brought into the proposed emissions trading scheme as practical issues relating to measurement uncertainties and compliance costs are resolved. The agriculture and forestry sectors will likely be able to participate in the scheme from its inception by generating offsets for use in the scheme. It is important that action is taken now to ensure that these sectors are able to take advantage of any opportunities presented through participation and to address any challenges.

5 illustrative impacts of hypothetical Australian greenhouse gas abatement scenarios using emissions trading to 2030 (only Australia abating)

	scenario A all sectors (other than land use change and forestry)	scenario B as for scenario A but natural gas, iron and steel, nonferrous metals and agriculture shielded	scenario B* as for scenario A but natural gas, iron and steel and nonferrous metals shielded
coverage			
carbon price in Australia (2006A\$/tCO ₂ -eq in 2030)	\$15	\$31	\$21
Australian emissions (CO ₂ -eq) relative to the reference case in 2030	-12%	-12%	-12%
impact on Australian GDP relative to the reference case in 2030	-0.7%	-1.1%	-0.8%
carbon leakage per unit of Australian abatement in 2030	12.8%	3.6%	5.0%

Source: ABARE analysis in PMTGET (2007, p. 172).

emissions trading – reducing the cost of abatement

If emission abatement costs are to be minimised, it is desirable that the coverage of the proposed domestic emissions trading scheme be as wide as possible. ‘Excluded’ emission sources force a higher level of abatement effort onto the ‘included’ sources and the incremental costs of further abatement tend to increase with the level of abatement (Hinchy, Fisher and Graham 1998). For example, shielding trade-exposed industries (including

box 2 indirect impact of emissions trading and opportunities to improve energy efficiency in the agriculture sector

The indirect and initial impact of the proposed domestic emissions trading scheme is likely to flow on to the agriculture sector through increases in the on-farm costs of energy and emissions intensive inputs – for example, fuels, energy, fertilisers and other farm chemicals – and also through increases in transport related costs.

The magnitude of these indirect costs on farm incomes will depend on the cost share of these inputs in total farm costs, the carbon price and the extent to which cost increases are passed on to farmers. Given that the shares of emission intensive farm inputs in total farm costs are relatively low, the indirect impacts of carbon pricing on on-farm costs are likely to be modest in the short term (as shown in the table below). Hence, unless the increases in farm costs are substantial, the incentive to improve efficiency in these areas is also relatively low. If the agriculture sector is included in the proposed emissions trading scheme as practical measurement issues are resolved, there will also be an explicit cost for its own emissions – the direct cost.

selected farm expenses’ shares of total farm costs

	2002-03	2003-04	2004-05	2005-06	2006-07
	%	%	%	%	%
chemicals	6	6	6	6	5
fertiliser	7	6	6	6	5
fuel and lubricants	5	6	6	7	7
other expenses	82	82	82	81	83

Source: ABARE (2007, p. 234).

agriculture) has the effect of redistributing the abatement burden to the nonshielded sectors within Australia.

Illustrative analysis undertaken by ABARE for the PMTGET indicate that shielding trade-exposed sectors could roughly double the estimated carbon price required to achieve the same level of abatement and lead to an additional 0.4 percentage point reduction in gross domestic product relative to what would otherwise be (table 5). The exact effects are dependent on the specific industries shielded – for example, including agriculture significantly reduces the gross domestic product impact of meeting a given emissions target.

The possible impacts of the indirect costs of an emissions trading scheme on the agriculture sector are discussed in box 2.

steps to including the agriculture sector in emissions trading

To date, agricultural activities have not been included in any emissions trading scheme except as a source for offsets. The Canadian offsets system includes emission reductions from agricultural activities, such as switching to low till cultivation as an offset project whose credits can be sold (Government of Canada 2005). The emissions trading scheme that is being developed in New Zealand is likely to include agriculture from 2013 (New Zealand Ministry for the Environment 2007).

There are two major areas of uncertainty relevant to the inclusion of agriculture in an emissions trading scheme. First, information about emission levels, abatement potentials and costs is deficient. Second, measurement and verification of emissions from agriculture are costly and complex.

There is limited information and analysis on the extent to which emissions from Australian agriculture can be reduced in an economically efficient manner. In many cases the estimates of marginal cost of abatement from Australian agriculture are not available (LWA 2007).

The costs of monitoring and reporting greenhouse gas emissions in the agriculture sector are currently high because of the specific nature of the sector. In Australia, the sector is comprised of approximately 130 000 geographically dispersed enterprises (ABS 2006) and emission sources vary widely in terms of size, time, location and nature. As discussed previously, agricultural production systems emit multiple greenhouse gases and emissions are site specific and influenced by a variety of factors including production type, species and climate, generally making measurement difficult and expensive.

Resolving measurement and compliance issues should be a priority. Accurate emissions monitoring and reporting is important to ensure Australia's compliance with international standards; to provide emitters with correct abatement incentives; and to ensure the integrity of an emissions trading scheme. Because stakeholder incomes would be affected by emission (and emission abatement) measurements, and as emissions trading would involve legally enforceable contracts, accurate monitoring and reporting would be essential for the effective operation of a trading system. Furthermore, if Australia's emissions trading scheme is to provide an example to other countries or be linked to international schemes, then emissions monitoring and the scheme must be robust and reliable.

abatement incentives

Determining emission levels or permit holdings on the basis of the estimated average emissions released from different farming activities creates incentive problems (Hinchy et al. 1998). If there is no scope for adjusting emission factors to account for lower emissions

per animal or hectare, an emissions trading scheme using average emission factors will provide inefficient incentives to farmers to reduce emissions.

The challenge in an emissions trading scheme is to link emission permit obligations to actual emission or abatement levels (ACG 2006). To provide an efficient incentive to reduce emissions per animal or per hectare of crop, emission factors would be required on an individual basis. However, to differentiate between farms, detailed information would be required that only the farmer could accurately report, which provides an incentive to inaccurately report activities. In this context, it is interesting to note the alternative approaches being discussed. For example, according to NZIER (2007), an alternative approach would be to place emission reporting obligations downstream at the point of processing of farm products, such as slaughter houses and dairy factories (box 3).

Hinchy et al. (1998) argue that much lower monitoring and enforcement costs would be incurred by applying policy measures at the point of sale of final farm products. However, the price signal passed to producers would be highly inaccurate since emissions associated with different types of the final product sold would vary markedly according to the method of production. If appropriate emission price signals are to be passed to producers it would be necessary to apply policy measures at the farm level. However, this could significantly increase monitoring costs.

The cost effectiveness of applying different policy measures to agriculture is an issue needing further research.

box 3 placing emission reporting obligations downstream – the case of emissions from livestock

The issue of emission reporting obligations is challenging for the agriculture sector given the dispersed nature of operations and potential high transaction costs. Several solutions proposed in New Zealand are described below.

In an emission trading scheme, placing emission reporting obligations upstream on individual farms would entail substantial transaction costs. This is because of the number of farms involved, the likely reluctance of farmers to take on additional costs and the scope for subverting the monitoring by shifting or misreporting stock numbers.

An alternative that may not overcome the current measurement difficulties but would require fewer parties to be involved would be to place emission reporting obligations downstream at the point of processing of farm products, such as at slaughterhouses and dairy factories. Under this approach, farm level emissions would be estimated based on throughput in each accounting period.

The ratio between livestock slaughtered and livestock in the paddocks (and emitting) can vary between seasons depending on restocking and destocking cycles. Hence, some form of system for calibrating the emissions per unit of production in a slaughterhouse with actual livestock numbers would be needed to make downstream allocation to slaughterhouses viable.

For dairying, the measurement problem might be made somewhat easier if the number of dairy animals of various kinds on each farm supplying each dairy factory were recorded and the emissions estimate for each factory was based on this measure and not on milk or milk solid deliveries to the dairy factory.

Source: NZIER (2007).

opportunities for carbon offsets

The uptake of carbon offsets in an emission trading system is likely to be influenced by a range of factors, including the availability of different carbon offsets and their potential co-benefits, cost drivers of offsets and any measurement difficulties associated with specific offsets.

There is a growing recognition of the importance of carbon offsets from the agriculture and forestry sectors, particularly in providing opportunities for early involvement of these sectors in the proposed domestic emissions trading scheme (PMTGET 2007). There is evidence to suggest that the marginal cost of abatement through carbon sequestration, particularly in forestry, may be comparable to other abatement options such as fuel switching or energy efficiency (Stavins and Richards 2005).

Carbon offsets may be generated in the agriculture and forestry sectors by expanding forestry areas (new forests plus regrowth of old forests), revegetating farmland (regeneration of native trees and shrubs) and protecting existing native trees and shrubs. About 70 per cent of forest plantations are located on private and leasehold land in Australia, and while plantations make up only around 1 per cent of the forest estate, plantations expanded by an average of 70 000 hectares a year between 1995 and 2005 (BRS 2007). Present arrangements for recognising the carbon sequestered in aboveground sinks such as forest plantations require the carbon stock to be maintained for a period of a hundred years (GGAS 2007).

The agriculture sector may also generate offsets through a range of agricultural management practices, including stubble retention, grazing management and conservation or minimum tillage practices, in order to build up carbon stocks in agricultural soils (M Keogh 2007). However, there are still large gaps in scientific and technical knowledge of soil carbon. For example, the capacity of Australian soils to sequester carbon for an extended period is still unknown. These issues need to be resolved, and a robust soil carbon accounting methodology developed before the development of an appropriate system for recognising carbon stored in soils is considered.

win-win opportunities

There is recognition that some of the offsets in agriculture and forestry may provide other 'win-win' opportunities through spillover benefits. For example, as well as providing a carbon offset, on-farm vegetation management could provide several other private and social benefits, including shelter for livestock and crops, reducing the incidence of salinity and waterlogging and conserving biodiversity.

Similarly, preventing or reducing deforestation, creating new carbon sink forests and implementing more effective land management practices also have the potential to contribute to more sustainable natural resource management and improved environmental outcomes.

According to the PMTGET (2007), there needs to be a long term commitment to such approaches. This is because such approaches generally take considerable time to deliver maximum carbon abatement and other environmental benefits. Hence, undertaking low cost measures to reduce deforestation and promote carbon sinks, both domestically and internationally, should be an immediate priority. Early development of carbon sink forests would also provide an avenue to help firms develop familiarity with any offset credit schemes and assist in achieving least cost abatement when the proposed domestic emissions trading scheme commences (PMTGET 2007, p. 83).

box 4 **cost drivers of forestry offsets**

tree species and forestry practices

Sequestration rates can vary considerably depending on the tree species used, the age of the trees and the geographic location or region. Although the sequestration trajectories of different forest species can vary in their timing and peak carbon flow levels, they share a pattern of initially rising rates of carbon sequestration followed by gradually declining rates.

opportunity cost of land

The opportunity cost of land used to sequester carbon reflects the net economic benefits that are forgone by diverting land from other uses. Some studies have assumed no opportunity cost of land. According to Manley, van Kooten and Smolak (2003) the average cost of carbon sequestration estimates for the United States were greater by 2–3.5 times in studies that took the opportunity cost of land into account relative to what would otherwise be. It is important to recognise that the opportunity cost of agricultural land tends to reflect the effects of any explicit or implicit farm support measures, which are generally capitalised into land values.

forest management

Following the establishment of a forestry project, there are generally ongoing maintenance costs, including those associated with application of fertiliser, thinning, security, fire management and other activities that are essential to ensure that expected carbon sequestration yields are realised.

disposal of biomass

Carbon flows into forests can be halted or even reversed by harvest, conversion to alternative uses or fire. The disposal of biomass can have significant effects on carbon flows as well as the financial flows linked with timber harvest. Inclusion of the financial flows linked to timber harvest in a carbon sequestration program would substantially reduce the marginal cost of carbon sequestration. At the extreme, some carbon sequestration programs may pay for themselves in the form of forestry products. In such cases the carbon benefits would be a 'costless' bonus often referred to as 'no regrets' mitigation options.

relevant prices

Pricing assumptions for agricultural and forest products could also influence the cost of carbon sequestration. For example, on land that can be used for either agricultural or forest production, a rise in expected future agricultural product prices (relative to forest product prices) would increase the opportunity cost of land used for forests and thereby drive up the relative costs of carbon sequestration.

discount rates

Given the long time horizons relevant to carbon sequestration activities in forestry, discount rates could also influence the cost of sequestration (net present value). Discount rates could influence the economic tradeoff between forgone future forest revenues and the immediate windfall that would result from harvesting a forest now. As the discount rate increases, immediate harvesting becomes more attractive. The rotation period of the forestry plantation may also be responsive to changes in the discount rate. The extent of the response will depend on the range of discount rates considered and the sensitivity of the value of standing timber (stumpage values) to changes in the rotation period.

policy instruments

The design of policies aimed to encourage carbon sequestration (such as subsidies, taxes, tax credits, offset schemes etc) may have substantial effects on the costs of sequestration. Any policy instrument aimed at encouraging carbon sequestration is generally most cost effective if they are outcomes based. This means focusing on actual increases in carbon sequestration rather than, for example, practices that might be more or less correlated with increased sequestration. Outcomes based policies maximise the incentive for individuals to innovate and select practices that maximise sequestration based on individual circumstances.

Source: Stavins and Richards (2005).

It is important to recognise that these different types of carbon offsets need to meet 'additionality' and 'permanency' requirements for them to become eligible for any formal greenhouse gas abatement scheme. To meet the additionality requirement a particular project or activity must generate an emissions offset that actually creates additional reductions in emissions than would otherwise have occurred under a 'business as usual' scenario. The permanency requirement entails ensuring that the project or activity results in permanent sequestration of carbon.

factors influencing offsets

The cost of achieving a given carbon offset, particularly in the forestry sector, is likely to be influenced by a range of factors. These include biophysical factors, such as tree species, forestry practices, geographic location, and carbon yield patterns. Other factors that could influence the efficiency of carbon sequestration in the forestry sector include the opportunity cost of land, availability of water, forest management practices, the disposal of forest products and related biomass, and the policy instruments used to achieve carbon sequestration (box 4).

As discussed in box 4, the amount of carbon that can be sequestered in forests is influenced by region and tree species. In general, however, carbon yield patterns in the forestry sector represent a pattern of initially rising rates of carbon sequestration followed by generally declining rates (figure B). In Australia, forestry sequestration potentials range from about 23.6 tonnes of carbon dioxide per hectare a year in tall, dense eucalypt forests that are less than ten years old to about 0.7 tonnes of carbon dioxide per hectare a year in mature, medium density forests (NGGIC 2006).

Empirical estimates of the costs of carbon sequestration are sparse. According to Stavins and Richards (2005) the marginal cost of carbon sequestration in the US forestry sector ranges from about US\$7.50 to US\$22.50 a tonne of CO₂ equivalent (in 1997 US dollars). Offset prices in Australia are discussed in box 5.

offsets in an emissions trading scheme

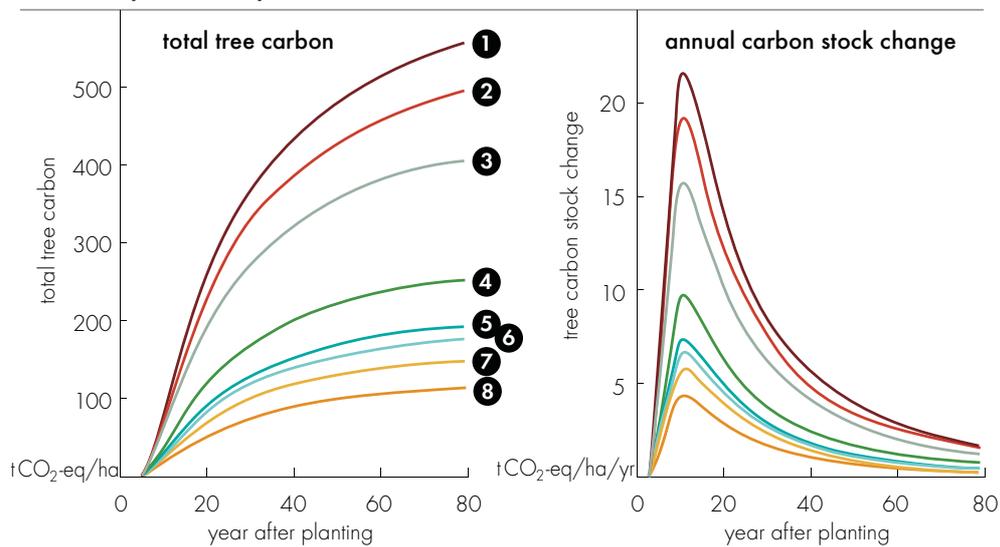
It has been argued that the scope for emission offsets from agriculture has gone largely unexplored, and there is little comprehensive information on the supply of low cost abatement opportunities in the sector (ACG 2006). The ability of the agriculture and forestry sectors to act as sources of emission offsets can considerably reduce total abatement costs to the economy.

In the proposed domestic emissions trading scheme in Australia, offsets from the agriculture and forestry sectors have a potentially important role to play through their capacity to reduce the total cost of meeting a given abatement target. Given current understanding of the proposed scheme, inclusion of offsets from the agriculture and forestry sectors will assist in preparing these sectors for eventual inclusion in the scheme. Furthermore, it could also provide an early mover advantage if international schemes eventuate in the future (PMTGET 2007).

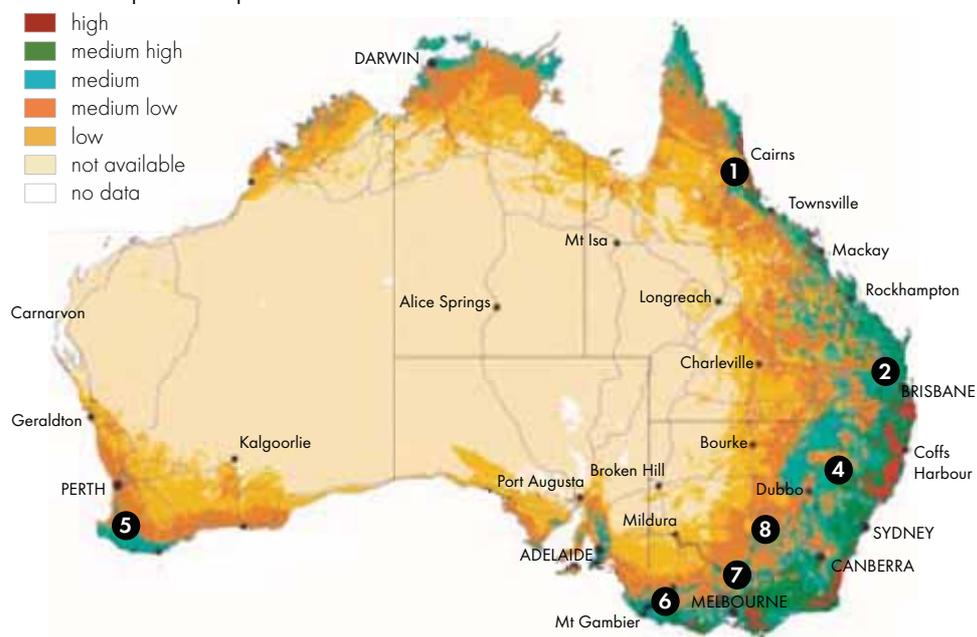
Including offsets in an emissions trading scheme presents additional measurement and reporting issues. Regulators need to ensure that offsets comply with additionality and permanency requirements. Satisfying the additionality requirement can be difficult because 'business as usual' emissions can never be known with certainty (NETT 2006). The permanency requirement presents problems because some projects may plan on being permanent but fail after the offset credits have been granted – for example, forest projects that are destroyed or harvested. In these cases, under the New South Wales Greenhouse Gas

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fig B mixed species environmental plantings on sites with differing carbon sequestration potential



carbon sequestration potential



Note: Examples of total tree carbon (t CO₂-eq/ha) and annual carbon stock change (t CO₂-eq/ha/yr) in mixed species environmental plantings on sites with differing carbon sequestration potential. Coloured lines and numbering correspond to the numbered locations on the map of Australia. The examples represent modelled tree biomass estimates (and not total onsite carbon mass) derived from the National Carbon Accounting Toolbox. Source: AGO (2006d).

Abatement Scheme (GGAS) the project proponent must surrender credits to account for the lost carbon (NETT 2006).

Offsets in the agriculture sector face similar measurement difficulties to emission sources as they are small and dispersed sites. It is likely that the transaction costs faced by small scale landholders associated with providing an offset will prevent their participation in the offsets market. Use of a manager or broker to handle the measurement, reporting and legal requirements could, however, achieve economies of scale to make offsets a viable option for farmers (AGO 2005a). A national framework on carbon sequestration needs to be developed for defining, trading, certifying and quantifying carbon sequestration (AGO 2002). Currently, each state has different laws on carbon sequestration, which increases transaction costs across the nation (AGO 2005b).

Establishing a baseline for a projected emissions profile (or the emissions that would occur without policy intervention) against which reductions by abatement activities could be determined is a challenging task for incorporating agriculture in an emissions trading scheme. A related challenging task would be the way to address eligibility or otherwise of

box 5 **Australia's offsets markets**

In Australia there are a number of developing markets for carbon offsets. These markets have been established to meet the requirements of the New South Wales Greenhouse Gas Abatement Scheme (GGAS) and the Greenhouse Friendly (GHF) program, or in response to other commercial concerns. Offsets in these markets are created through a variety of projects, including biosequestration, energy efficiency and renewable energy. Offset providers may adhere to varying standards or to none. In Australia, offset providers are accredited by GGAS, GHF or under the Mandatory Renewable Energy Target. They may also adhere to various international standards (Ribón and Scott 2007). Alternatively, providers may not certify their offsets or may develop their own standards.

NGACs (NSW Greenhouse Abatement Certificates) are traded by registered companies on the GGAS Registry. Only registered users can own certificates and only companies that are accredited can create certificates. In 2006, 595 307 carbon sequestration certificates were created in the registry (GGAS Registry 2007). Each certificate represents sequestration of 1 tonne of carbon dioxide equivalent. Abatement from GHF approved projects can be used by GHF members to offset emissions associated with their certified product or service (Brill 2006).

Prices of offsets differ between markets and over time for a number of reasons, including the different characteristics of the offsets, supply of offsets and certification issues. In Australia, providers of biosequestration offsets charge about A\$9-13 a tonne of carbon dioxide (tCO₂), while providers of energy efficiency and renewable energy oriented offsets charge about A\$20-40/tCO₂ (Ribón and Scott 2007). This compares with A\$10/tCO₂-eq in the EU Emissions Trading Scheme (B Keogh 2007).

estimates of recent offset prices

market	price A\$/tCO ₂ -eq
Greenhouse Friendly program – Australia	6.00
NSW Greenhouse Gas Abatement Scheme	12.00
European Union Emissions Trading Scheme	10.13
Chicago Climate Exchange	5.75

Source: B Keogh (2007).

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prebaseline abatement or offset activities. In this context it is important to note that various industries and firms have already undertaken a range of abatement and offset related activities through, for example, improvements in energy efficiency and use of less emission intensive inputs. These industries and firms would have undertaken such early action voluntarily on the basis it made good economic sense or in response to specific government programs, triple bottom line concerns or in anticipation of future regulation.

PMTGET (2007) does not consider that credits should be provided for abatement activity undertaken before any policy announcement. Crediting previous abatement and/or offsets action requires introducing criteria that are in some sense arbitrary (even in cases where abatement is verified using established frameworks). Furthermore, crediting for previous abatement and/or offset activities could produce a windfall gain for some firms that have already been compensated or who would have undertaken these abatement activities for economic gain. This would also transfer greater adjustment to any cap onto other firms in the system (PMTGET 2007).

Ideally, offsets should comply with established internationally recognised frameworks. This would make establishing international linkages easier and offsets would be credible in the international community. Transaction costs would be lower because procedures already established could be applied and it would be simpler for companies in multiple jurisdictions (NETT 2006).

concluding comments

The agriculture and forestry sectors are vulnerable to the potential negative impacts of future climatic changes. However, there are technologies and risk management options that can help these sectors respond to the future challenges of climatic change and maintain high levels of productivity growth.

Implementation of the proposed emissions trading scheme in Australia would present a number of opportunities and challenges to the agriculture and forestry sectors. These sectors should ensure that they are positioned to take advantage of these opportunities, including through the provision of emissions offsets.

In order to maintain and enhance the productivity and international competitiveness of Australia's agriculture and forestry sectors, further research and development is required in the following areas: identifying potential future climate changes and its impacts; adaptation and mitigation measures; and emissions monitoring and reporting. Industry and government partnerships will be particularly important in this context. Governments will also have a key role to play in maintaining policy environments that are conducive to appropriate adaptation and mitigation responses in industry and that minimise the cost of any responses to climate change.

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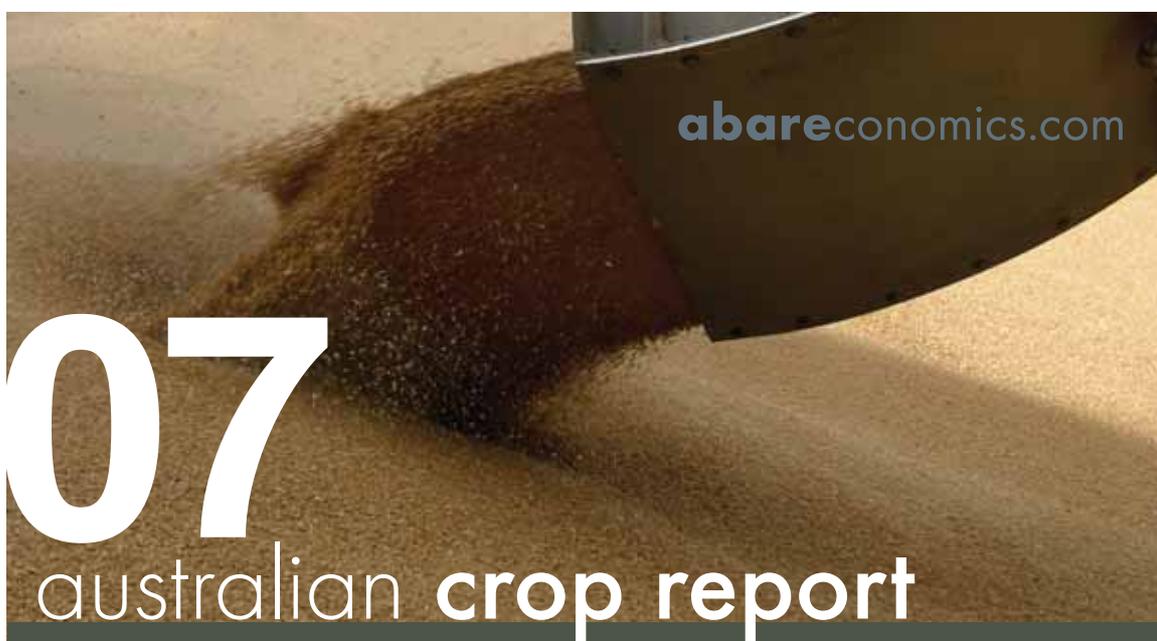
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