



Garnaut
CLIMATE CHANGE
REVIEW UPDATE 2011

4

Transforming rural land use

Update Paper 4



Garnaut

CLIMATE CHANGE REVIEW UPDATE 2011

© Commonwealth of Australia 2011

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from the Commonwealth. Requests and enquiries concerning reproduction and rights should be addressed to the Commonwealth Copyright Administration, Attorney General's Department, National Circuit, Barton ACT 2600 or posted at www.ag.gov.au/cca

Publication and general enquiries to the Garnaut Climate Change Review – Update 2011 can be directed to:

Garnaut Climate Change Review – Update 2011
GPO Box 854
CANBERRA ACT 2601

Tel: 02 6159 7868
Email: garnautreview@climatechange.gov.au

IMPORTANT NOTICE

This publication is produced for general information only and does not represent a statement of the policy of the Commonwealth of Australia or indicate a commitment to a particular policy or course of action. The views expressed in this paper are those of the author and do not necessarily reflect those of the Commonwealth of Australia. The Commonwealth of Australia and all persons acting for the Commonwealth of Australia preparing this publication accept no liability for the accuracy, completeness or reliability of or inferences from the material contained in this publication, or for any action as a result of any person's or group's interpretations, deductions, conclusions or actions in relying on this material. Before any action or decision is taken on the basis of this material the reader should obtain appropriate independent advice.

Garnaut Climate Change Review – Update 2011

Update Paper four:

Transforming rural land use

Ross Garnaut

www.garnautreview.org.au

TRANSFORMING RURAL LAND USE

Key points

- The land sectors will be greatly affected both by climate change and its mitigation. Science-based knowledge and flexibility of production systems will be the keys to success in this new world, as they have been throughout the history of Australian farming.
- The rural sector is a major source of emissions, but at the same time holds tremendous opportunities to play a significant role in Australia's mitigation effort.
 - These opportunities could also significantly improve the economic prospects for Australian farmers.
- Emissions from the land sector account for 20 per cent of Australian emissions (2008) and around 26 per cent of global emissions (2005).
 - The natural processes of biosequestration must be central to any ambitious global effort to meet targets for limiting temperature increase, and are the only known channel for actually reducing concentrations after emissions targets have been exceeded.
- Improvements to emissions estimation methods and mechanisms for monitoring permanence of sequestration remain critical requirements for further developing and realising mitigation strategies in rural Australia.
- The development of international frameworks needs to accommodate greater incentives for countries to reduce emissions and increase biosequestration across a broader range of land management activities.
 - Australia can define best practice on accounting approaches and emissions management by adopting domestic mitigation measures with broad coverage and full recognition of co-benefits.
- Movement toward comprehensive coverage of all land sectors under a carbon pricing mechanism would yield economic and environmental benefits.
- The Government's proposed Carbon Farming Initiative will break new and productive ground for offset schemes in Australia and internationally. However, there is a case for:
 - reconsideration of the 'financial additionality' requirement of the scheme; and
 - establishing a link between the Carbon Farming Initiative and an emission trading scheme.
 - This could involve allowing businesses covered under the scheme to purchase Kyoto offsets directly to meet part of their emissions liability and the scheme regulator purchasing non-Kyoto offsets.
- While offset schemes, and a carbon price, will provide incentives for increased biosequestration activities, they should be supported by other incentives and regulatory safeguards to help encourage co-benefits, such as for biodiversity.
- Our understanding of the feasibility and potential scale of a range of biosequestration and emission reduction options in Australia's land sectors has improved since 2008, and work since then has confirmed the potential identified in the Review.
- The high food prices before the Great Crash of 2008, and the return to record levels in 2010 and the first months of 2011, is an early taste of the world of climate change and its mitigation. This represents opportunities for Australian farmers to maintain production and profitability despite climate change, as well as a challenge for global development.

Table of contents

1. Introduction.....	5
1.1 The 2008 Garnaut Climate Change Review on rural mitigation	7
2. The international climate change framework.....	9
3. The transition to a carbon pricing mechanism for land sectors in Australia	11
3.1 Coverage of the land sectors under a carbon price	11
4. Encouraging co-benefits and avoiding perverse incentives	17
5. How big are the opportunities?	22
5.1 Deforestation	26
5.2 Enteric fermentation emissions from livestock	26
5.3 Soils: cropping and pasture lands.....	28
5.4 Soils and vegetation: rangelands.....	32
5.5 Reducing emissions from savanna burning	33
5.6 Removal by post-1990 forest plantations.....	34
5.7 Removal by pre-1990 eucalypt forests	34
5.8 Carbon forest plantings.....	35
5.9 Bioenergy	36
5.10 Other options: manure management, rice production, and feral animal management	38
5.11 Research and development needs	38
6. Land use, water management and forestry.....	40
7. Food security	42
7.1 Global food security	42
7.2 Australian food and farmers' security.....	46
8. Conclusion	48
Appendix 1: International climate change frameworks and the land sectors	58

List of figures, tables and boxes

Box 1: Rural Australia and climate change.....	6
Box 2: The carbon cycle.....	7
Box 3: Offset schemes: domestic and international.....	12
Box 4: Agriculture and other co-benefits.....	18
Box 5: Linking climate change adaptation and mitigation through biodiversity benefits of biosequestration incentives.....	19
Box 6: Government support for natural resource management: price based schemes.....	21
Box 7: Centrefarm and the Central Land Council.....	22
Box 8: CSIRO 2009 Analysis of emissions reduction and biosequestration opportunities.....	23
Box 9: Biochar.....	30
Box 10: Western Arnhem Land fire abatement project.....	33
Box 11: Bioenergy demonstration project.....	37
Box 12: Australia’s contribution to international forest monitoring.....	40
Table 1: Summary of findings from CSIRO assessment of land sector mitigation options indentified in the 2008 Garnaut Review.....	24
Table 2: Potential for emissions per annum reduction and/or removal from Australia’s agriculture, forestry and other land sectors.....	25
Table 3: Sheep and cattle numbers and emissions 1990 and 2008.....	26
Table 4: Impact of carbon price on cost of meat production.....	27
Table 5: Summary of management options for sequestering carbon in agriculture	31
Figure 1: Australian real retail prices for meat 1960 to 2009.....	28
Figure 2: Australian per capita consumption of meat 1960 to 2009.....	28
Figure 3: Volume of wood harvested in plantation forests, 1997-98 to 2008-09.....	34
Figure 4: UN food price index.....	43
Figure 5: Australian farmers’ terms of trade and the prices received and paid indexes 1961 to 2011 (real).....	47
Figure 6: Australian farmers’ terms of trade and the prices received and paid indexes 1998 to 2011 (nominal).....	47
Figure 7: Emissions and removals from cropland, forest land and grassland 1990 to 2008.....	59

1. Introduction

Australia has always been a country of climate extremes. The health of Australian farming will continue to depend on effective management of weather and climate uncertainty (refer Box 1). It is increasingly clear that the world is moving towards more rapid and severe climate change (Steffen 2009). The science is telling us that climate change will be associated with significant warming, which will change optimal planting and harvesting times and the crops, cultivars and animal types that do well in each region. It will reduce water run-off even if there is no general effect on rainfall, and so reduce water available from rivers and streams for irrigation. It is likely to increase the intensity of extreme events: heatwaves and associated bushfires; cyclones in tropical regions; episodes of exceptionally high rainfall; and drought. The impacts of accelerating climate change will intensify the climatic challenge to rural Australia. The scientific evidence is considered in Update Paper five (*The science of climate change*). Land use planning will need to identify the range of future climate change risks and to consider how best to take these into account. Increasingly, farmers will need to understand and actively manage these risks to ensure the success of their activities in a changing climate.

All of these effects of climate change are likely to be significant, even if there is strong global mitigation from now, directed at holding the increase in global average temperature below 2°C above pre-industrial levels. Any delay or failure in global mitigation will increase these effects—severely if there is substantial delay or substantial failure. Mitigation will have a cost in rural Australia, including an opportunity cost to conventional rural production. The costs will be moderate if mitigation is implemented efficiently, but high if implemented crudely. The benefit to rural Australia of Australia playing its proportionate and necessary part in an effective global mitigation effort is the avoidance of the worst of the high costs of unmitigated climate change. There are also some special opportunities for the Australian rural sector in biosequestration, encouraged by the pricing of carbon.

It is likely that food and fibre prices will rise relative to other goods and services, after many years of decline (refer Section 7)—and much more in a world of climate change. The change could be large. Inefficient regulatory requirements in the European Union and the United States have already increased considerably the global prices of grains and agricultural oils. Extreme climatic events have also contributed to higher prices of agricultural commodities in the early twenty first century, notably in the current and recent years. Forest product prices, on the other hand, may fall as incentives for carbon sequestration encourage resources into higher levels of production.

The carbon emissions from the land sector in Australia are associated with agriculture and forestry as well as traditional management by Indigenous Australians and nature conservation. The land sectors are sources of several greenhouse gases, including carbon dioxide, methane and nitrous oxide. They also provide biosequestration, which is the removal of atmospheric carbon dioxide through biological processes such as photosynthesis in plants.

The land sectors are a significant part of Australia's emissions profile, because of our large land area and agricultural and forestry production relative to population. The agriculture, forestry and other land use sectors contributed around 20 per cent of total annual emissions in Australia's most recent Kyoto Protocol accounts (DCCEE 2010a). Globally, the land sectors account for around 26 per cent of emissions (Herzog 2009).

The national profile of emission reduction and biosequestration opportunities in rural Australia has risen since 2008, partly as a result of discussion of the 2008 Garnaut Climate Change Review (the Review). New opportunities to increase farm incomes through various carbon sequestration activities are set to coincide with the introduction of other changes in the incentives structure of Australian farming, including some support for biodiversity and some restraints on the use of water. Australian farming in future will involve a complex optimisation of income from conventional sales of farm produce (probably at higher prices than anticipated in the past) and from credits from ecosystem services, including carbon and biodiversity, within a wider range of constraints on water use and on carbon emissions. This is a world in which many Australian farmers can do well, so long as Australia remains at the forefront of the applied biological sciences, and remains flexible in the face of changing patterns of opportunity, and so long as climate change is held within manageable bounds.

Box 1: Rural Australia and climate change

The resilience of rural Australia has been tested by recent severe weather events. The drought from 1997 to 2009 was the driest period in south-eastern Australia in 110 years (CSIRO 2010). Most irrigators in the southern part of the Murray-Darling Basin received substantially lower water allocations during this drought. Adaptation responses have included trading water for high value uses and improving farm management practices (Sanders et al. 2010). Another response has been to change land use—between 2005-06 and 2007-08, the area of irrigated land in the Murray-Darling Basin fell 42 per cent, from more than 1.6 million hectares to less than one million hectares (Sanders et al. 2010).

Early estimates by the Australian Bureau of Agricultural and Resource Economics and Sciences of the impacts of flooding in eastern Australia during the summer of 2010-11 show large losses: 15 to 20 per cent of grain sorghum plantings in southern Queensland; 7 per cent of total Australian cotton plantings; and around \$225 million worth of fruit and vegetables in Queensland (ABARES 2011a).

Southwestern Australia, which generates the large majority of Western Australia's farm and pastoral production, has been experiencing steadily declining rainfall as well as stress from rising temperatures for several decades. The south-west of Western Australia had its driest year on record in 2010, which resulted in record low inflows to Perth region water storages (Smith and Timbal 2010). Western Australia's harvest of winter crops was 43 per cent lower than the previous year (ABARES 2011b).

The 2008 Review drew attention to the high level of disagreement between models in the projected changes in local rainfall levels. This was noted as a significant area of uncertainty in the Review's modelling of impacts. In the Review 'wet' and 'dry' as well as mainstream rainfall scenarios were the subjects of detailed modelling.

The climate models are weak in relation to the regional distribution of rainfall: there is much we do not know. While the worldwide effects of global warming are likely to include increased total precipitation, one expectation is that weather systems that bring rain in temperate latitudes will move towards the poles. This is likely to make drying the main influence in temperate latitudes where most Australians live and most of the farm value produced. The drying in the southwest of Australia is likely to be more clear-cut and affected less by other climatic influences than in the southeast of Australia.

There is no consensus on future changes in rainfall across much of Australia, except for southwest Western Australia. In the southwest, the dry conditions associated with the southerly shift of the westerly winds that bring rain in the winter half of the year are not expected to be modified by changes in other weather patterns associated with climate change (Garnaut Review Update 2011, Update Paper five *The science of climate change* [forthcoming]). The relationship between local rainfall and atmospheric temperature is complex, as local rainfall patterns are highly sensitive to the amount of water available for evaporation, the local topography and land cover and atmospheric and ocean circulation patterns.

The Government's proposed offset program, the Carbon Farming Initiative, is a good step towards providing the necessary incentive for mitigation in land sectors and, once a carbon price is in place, has the potential to provide large scale abatement at low cost. However, there are some aspects of the scheme that require further consideration. One of these is the requirement for 'financial additionality'. Another is establishing a link between the Carbon Farming Initiative and an emission trading scheme. This could involve allowing businesses covered under the scheme to purchase Kyoto offsets directly to meet part of their emissions liability as well as the scheme regulator purchasing non-Kyoto offsets.

The relaxation of the requirement of financial additionality and the linking of an emission trading scheme with the Carbon Farming Initiative would be large steps towards an Australian commitment to accounting for all land sector emissions.

This paper discusses the current international climate change framework and incentives for countries to adopt mitigation policies in the land sectors. The paper then focuses on Australia's current policy framework for encouraging mitigation through changes in land use, including the Government's proposed Carbon Farming Initiative, and on the potential contribution of biosequestration in mitigation. Finally, the paper provides an updated assessment of the emissions reduction and biosequestration options discussed in Chapter 22 of the Review and an overview of related land use, water management and forestry issues. Some emerging or potential mitigation options not considered in detail in the earlier Review are also briefly discussed.

Box 2: The carbon cycle

Life on earth has developed around a number of ecological processes, including a carbon cycle. The process of photosynthesis is at the heart of the carbon cycle: the process through which algae and plants absorb solar energy and carbon dioxide from the atmosphere, and convert them into oxygen (which is returned to the atmosphere) and organic compounds in living organisms. Part of the carbon remains within the organisms—the terrestrial and marine plants and algae—for as long as they are alive. Part is embedded in soils or in other ways in other terrestrial locations or is absorbed into the oceans or deposited on the ocean floor.

Some of the embedded and deposited carbon is locked out of the atmosphere for long periods in forms that humans have used as fuels—the fossil fuels: coal, oil, gas, and hydro-carbons embedded in sands and shale. When coal, oil and gas are used as fuels, the combustion that releases energy for human use re-combines the carbon with oxygen, and returns the carbon to the atmosphere as carbon dioxide.

The carbon cycle has made the earth habitable for animals and eventually for humans by converting a carbonic into an oxygen-rich atmosphere. This conversion was essential for the respiration that is integral to animal life. It also cooled the earth to an extent that enabled the emergence of human civilisation. Humans increase the amount of carbon dioxide in the atmosphere by destroying plants or changing soils in ways that release carbon, by burning fossil fuels, by husbanding and expanding the numbers of ruminant animals and their methane emissions, or in other, quantitatively less important ways. They can contribute to a reduction of carbon dioxide in the atmosphere by activity that leads to an increase in the carbon density of forests or woodlands or pastures or soils.

So the distinctive contribution of changes in land use to reducing carbon dioxide concentrations in the atmosphere is through the process of photosynthesis, so long as it is accompanied by steps to ensure that the hydro-carbons absorbed into living tissue are permanently kept out of the atmosphere.

The permanent (or, at least, long term) retention on land or in the seas of the algae and plant (and indirectly animal) products of photosynthesis is the mechanism through which the earth's carbonic atmosphere was made suitable for animal life and eventually human civilisation. It is the proven and at this stage the most likely process for actually reducing the concentrations of carbon dioxide in the atmosphere if ever human society judges that the concentrations of greenhouse gases have risen to levels that introduce unacceptable risks of dangerous climate change.

The world will be able to go further—perhaps much further—with mitigating the risks of dangerous climate change, and at lower costs, if reducing emissions and increasing sequestration associated with changes in land use is an important part of the mitigation effort.

1.1 The 2008 Garnaut Climate Change Review on rural mitigation

The Review said that biosequestration and greenhouse gas emissions reduction options in Australia's land sectors had large potential to lower the costs of reducing national emissions and to transform the economic prospects for rural Australia. It concluded that full realisation of this potential required comprehensive carbon accounting in relation to land use, and a determined policy and research effort. Since the Review, mitigation opportunities in the land sector have been assessed in greater detail. The

potential positive and negative implications of large-scale mitigation for rural communities and industries and Australia's land, water and biodiversity have received much attention.

The Review's economic modelling found that with unmitigated climate change, emissions from agriculture would increase substantially with rising production, before declining due to the negative effects of climate change on agricultural output. With mitigation directed at stabilisation at 550 ppm of carbon dioxide equivalent, there would be progressive reductions in the volume of emissions per unit of production, so that production levels could grow substantially while emissions in 2100 were similar to 2005 levels¹.

The economic analysis showed that forestry (timber plantations and carbon forests) would also be highly responsive to a carbon price, and would sequester a considerable quantity of carbon at low cost. Forests would increase significantly in the first part of the century before being constrained by rising land prices and competition with higher-value agricultural uses. Other constraints on expansion of forests include restrictions for conservation reasons, regional capacity constraints in timber processing, and landholder concerns to protect the traditional use of agricultural land.

The Review said that an emissions trading scheme would be the lowest-cost approach to reducing greenhouse gas emissions in Australia, so long as it was designed and implemented well, and that part of the revenue which it generated was used to provide support for research, development and commercialisation of low-emissions technologies. The Review proposed the following approach for the land sectors in an emissions trading scheme.

- Those undertaking reforestation should be allowed to decide for themselves whether they wished to be covered by the scheme. If they received credit for net removal of emissions from the atmosphere, they would have to accept liability for emissions.
- Those undertaking deforestation should be liable for resulting emissions.
- There should be full coverage of the agriculture, forestry and other land use sector, based on full carbon accounting once issues regarding emissions measurement, estimation and administration are resolved.
- Other complementary policies should encourage mitigation in the agricultural sector until it is covered under the scheme.

The Review proposed measures to encourage emissions reductions in sectors which were recognised under international rules but which were not covered by an Australian emissions trading scheme. Such reductions would attract domestic offset credits, which could be sold to firms that were liable under the emissions trading system, who would use them to meet their obligations.

The Review also looked more speculatively at a range of other potential opportunities to reduce emissions and increase carbon sequestration. These opportunities had previously received comparatively little attention in Australia and internationally. This assessment concluded that there were major emission reduction and carbon sequestration opportunities, which had the potential to reduce the cost of mitigation in Australia to well below that indicated by the formal modelling. This potential would only be realised if there were changes in the focus of policy, program and research efforts. Choices by farmers and other landholders on adopting various mitigation options would be influenced by the nature of their land, the price and availability of water, carbon prices, the development of new markets, proximity to markets, and prices of commodities and inputs.

¹ See figure 22.4 in Garnaut (2008)

The opportunities identified in 2008 included:

- Reducing deforestation;
- Reducing emissions from livestock;
- Improving soil carbon and reducing fertiliser emissions in cropping and pasture lands;
- Restoring degraded woodlands;
- Reducing emissions from savanna burning;
- Biosequestration in post-1990 forest plantations;
- Biosequestration in pre-1990 eucalypt forests;
- Biosequestration in forests planted to sequester carbon; and
- Biofuel production especially in locations that do not compete directly for land that is highly productive for food (with algae having especially attractive features as a source for biofuels in Australia).

Section 5 provides a more detailed discussion of each of these options.

2. The international climate change framework

Australia's emissions accounts under the Kyoto Protocol cover major sources of methane and nitrous oxide emissions from agriculture, as well as emissions and carbon sequestration (also termed removals) in deforestation and new forests (DCCEE 2010a). Australia's Land Use, Land Use Change and Forestry (Changing Land Use) accounts do not include carbon dioxide emissions and removals related to vegetation and soils across large areas of agricultural and forest lands. As allowed under the Kyoto Protocol (refer Appendix 1), Australia chose not to include these emissions and removals in its accounts for the first Kyoto commitment period because there were risks of emissions from natural causes such as drought and bushfires.

Excluding some Changing Land Use emissions does mitigate the risk that emissions resulting from bushfires and droughts will cause Australia to overshoot emission reductions targets. However, the Review placed greater weight on the opposite problem: if certain emissions are not recognised in accounts, their removal from the atmosphere cannot count toward emissions reductions obligations. This reduces the incentive to reduce emissions or to sequester carbon. Australia should continue to advocate international movement towards comprehensive monitoring, reporting and recognition of all emissions related to land use.

To ensure recognition of emissions reductions from all activities, any new international framework needs to provide greater incentives for countries to reduce emissions and increase biosequestration across a broader range of land management activities. A more comprehensive framework needs to recognise real mitigation action while finding reasonable and principled ways of managing risks associated with liability for emissions that are not caused by human activity.

The Government's priorities in the negotiations on rules to account for emissions and removals from Changing Land Use for the second Kyoto commitment period have been to simplify the rules, improve ways of comparing the mitigation efforts of different countries, and avoid countries having to account for emissions losses due to natural events (DCCEE 2010b). These negotiations are continuing, as are the separate discussions on the future treatment of agriculture emissions. The negotiations in Cancun in 2010 made progress on some issues, including agreement that approaches to dealing with natural events beyond a country's control (termed 'force majeure') for the second Kyoto Protocol commitment period would be considered (IISD 2010). The current Kyoto Protocol rules assume that carbon in harvested wood products is emitted at the time of harvest, rather than recognising that carbon remains stored, in some cases for many years. New approaches, including allowing countries to recognise carbon stored in different wood products consumed domestically and exported, were discussed in Cancun (UNFCCC 2010). Australia, appropriately, supports the new approaches.

A future international framework that emerges from the existing Kyoto Protocol approach is likely to contain complexities and compromises. However, based on the recent agreement to consider a broader range of approaches, there is some prospect that modified Kyoto rules, if adopted, could strengthen international recognition for Australia and other countries adopting a wider range of land-based mitigation actions.

For example, the elective Kyoto Protocol category of forest management has been a focus of international negotiations on the accounting framework. Forest management covers native forests that are under active management (for example, harvesting for wood products) and plantations established before 1990. In Australia, forests under active management comprise only a small proportion of the total forest area.

The negotiations on forest management are seeking to improve the transparency and fairness of the rules so that more countries have an incentive to include this category of emissions in their commitments, and to increase forest biosequestration and reduce emissions. The discussions are focussed on dealing with natural events and setting an emissions baseline² (UNFCCC 2010). Proposals have been put forward to set baselines using reference levels—a proposal whereby countries would accept a baseline level of forest management emissions or removals based on historic or projected levels. Each country would then receive credits for net removals that are better than the reference level, and would be liable if net removals fell below the reference level. The Cancun negotiations in December 2010 agreed on steps for examining this proposal during 2011.

Australia is exposed to risks of greater damage from climate change than any other developed country. Australia also seems to have greater opportunities relative to population for low-cost mitigation in the land sector than any other country. Each of these interests argues for Australia doing what it can to encourage more comprehensive accounting for emissions within the international system. Australia could advance its interests by itself adopting more comprehensive accounting at an early date. This would provide a model for the productive evolution of a global system that provides for appropriately expanded coverage of emissions. To the extent that Australia's leadership on this issue was influential, it would directly increase opportunities for economically and environmentally productive international trade in emissions entitlements—a means for lowering costs and expanding ambition of mitigation in Australia and in the world as a whole.

It is desirable—and probably necessary for achievement of the world's mitigation objectives—for the international rules eventually to incorporate comprehensive accounting for all greenhouse gas emissions and sequestration in the land sector. The complexity around the issues of accounting for natural events and setting emissions baselines—and, it must be said, old fashioned political economy pressures in the developed countries—mean that international outcomes are difficult to achieve and in any case take a considerable time. While the current framework has flaws, it also addresses many complex issues, and a number of elements will provide a starting point for improved approaches. Australia's innovation with domestic mechanisms that encourage abatement both within and outside the current Kyoto Protocol rules (as proposed for the Government's Carbon Farming Initiative—explored in detail in Section 3), can demonstrate globally the potential role of land sectors in mitigation. There is also an opportunity to apply more comprehensive approaches to land use sequestration within regional agreements involving neighbouring developing countries in which land sector emissions are especially important.

² Baseline emissions refer to the production of greenhouse gases that have occurred in the past and which are being produced prior to the introduction of any strategies to reduce emissions. The baseline measurement is determined over a set period of time, typically one year. This historical or projected measurement acts as a benchmark to evaluate the success of subsequent efforts to reduce emissions. Without knowledge of baseline emissions, it is impossible to reliably judge the success of any remediation efforts

3. The transition to a carbon pricing mechanism for land sectors in Australia

Following the decision in 2010 to delay the introduction of the Carbon Pollution Reduction Scheme, the Government committed to establish the Carbon Farming Initiative, a legislated offset program targeted for commencement from July 2011 (DCCEE 2010c). The Government is taking the proposed scheme forward alongside the Multi-Party Climate Change Committee's consideration of options for the introduction of a carbon price. The Government released a proposal for a carbon price mechanism on 24 February 2011. Under the proposal, emissions from sources covered under the Carbon Farming Initiative would be excluded from coverage under the carbon pricing mechanism (MPCCC 2011). Credits for reductions in emissions that count towards Australia's Kyoto Protocol target could be used in the mechanism, or alternative funding arrangements could be adopted for the land sector.

This section briefly discusses the issue of coverage of the land sectors under a carbon pricing mechanism. It also discusses the Government's proposed Carbon Farming Initiative and its potential to encourage greater mitigation in the land sectors. Different mitigation policy approaches and carbon-pricing regimes are considered in Update Paper six (*Carbon pricing and reducing Australia's emissions*). Paper six will also discuss principles for investment of revenue from the national carbon price mechanism. It will consider the allocation of funding to biosequestration in the context of the requirement that the carbon pricing scheme should be neutral in its effects on Australian Government budget outcomes. This discussion will be embodied in an assessment of long-term potential for sequestration and long-term impacts on Australian Government revenue, expenditure and taxation.

3.1 Coverage of the land sectors under a carbon price

Eventual movement toward full coverage of the land sectors under a carbon pricing mechanism would help to reduce the cost and raise the ambition of mitigation for Australia. Resolution of accounting rules and estimation issues will open up greater opportunities for emission reductions and biosequestration in the land sectors.

The case for allowing voluntary coverage of reforestation from commencement of a carbon price remains strong. However, coverage of agriculture remains a challenge because the large number of entities raises the costs of establishing the points of obligation close to the points where producers make the decisions that determine emissions (Ancev 2011). There are similar challenges for coverage of deforestation. Investment in innovation and good scheme design can help to solve these difficulties over time.

The fact that some agricultural businesses must compete with those in countries that do not include coverage of agriculture in their emissions accounts, means that Australian farmers could be disadvantaged if forced to adopt practices that made it more expensive or difficult for them to compete internationally. This is the general problem of the trade-exposed industries, but one that is particularly challenging in this sector. The problem is more acute in this sector than in manufacturing or mining, where other countries are applying substantial and costly constraints on emissions (see Update paper two [*Progress towards effective global action on climate change*]). To date only New Zealand has committed to including agriculture in an emissions trading scheme, with obligations commencing from 2015, although the current review of the New Zealand's Emissions Trading Scheme could lead to changes in policy including on the inclusion of agriculture (NZ Ministry for the Environment 2010). Nevertheless, New Zealand's commitment is significant for Australian farmers, as New Zealand is Australia's main competitor in domestic and most international markets for meat, dairy products, wool and temperate horticultural products.

It is strongly in Australian farmers' interests that carbon constraints are applied in transparent ways to farm products in all developed countries, including Australia. Australian (and New Zealand) temperate animal products do not require the emissions-intensive winter heating that is common in the developed countries of the Northern Hemisphere (Garnaut 2008). Comprehensive global pricing of emissions would allow this important source of comparative advantage for Australian agriculture in a carbon-constrained world to generate commercial value.

In addition to the distortions associated with the commercial negation of Australia's natural emissions advantages over European, North American, Japanese and Korean producers, the exclusion of agriculture from a general carbon pricing scheme is the source of important domestic distortions. There are likely to be limits on agricultural producers' securing full value for emissions reductions and sequestration while the sector is covered only by offsets. This may be seen as a powerful reason for seeking inclusion if land-related abatement turns out to be a major source of income for farmers.

The Review recommended that the land sectors initially be brought within incentives to reduce emissions through offsets, and brought fully into full coverage within an emissions trading scheme once issues regarding emissions measurement, estimation and administration were resolved. The administration and measurement issues in these industries with many small enterprises remain reasons why early coverage by a carbon pricing scheme is not desirable. These issues could be reviewed in about 2015. The review would examine experience with measuring and administering offsets for land-based emissions within the Carbon Farming Initiative, It would also consider the extent of participation in sale of offsets within the Carbon Farming Initiative, developments in New Zealand and other producers of temperate farm products, and experience with the use of principled approaches to assistance for trade exposed emissions-intensive industries.

The date for inclusion of New Zealand agriculture is a good time for review of whether circumstances have changed in Australia.

Carbon Farming Initiative

The Carbon Farming Initiative is an important first step to encouraging abatement in the rural sector. It will provide an incentive for reduction and sequestration of emissions in Australia's land sectors. It will provide valuable lessons in Australia and internationally on the administration of land sector incentives. It will also lead to 'learning-by-doing' improvements in technologies applied to emissions reduction and sequestration in the land sector. The Government's proposed design provides substantial encouragement of new emission reduction and biosequestration while constraining the risks of giving credit for activities that do not deliver real abatement. Experience with the associated mitigation options and reporting methods will be useful in testing coverage design options prior to any transition to full coverage.

Under the Government's proposed Carbon Farming Initiative, landholders will be able to submit projects for approval on a voluntary basis. Landholders will be able to sell offset credits from a range of approved activities, so long as legal obligations such as periodic reporting are met. The new scheme covers emissions reductions and biosequestration in agriculture, forestry, other land uses and landfill waste deposited before 1 July 2011 (DCCEE 2010c). This coverage is likely to break new ground for offset schemes not only in Australia, but internationally. Of all established schemes, only the Alberta Offsets Scheme in Canada covers a broad range of emissions offsets from agriculture (DCCEE 2010c, refer also Box 4).

Box 3: Offset Schemes: Domestic and International

Emissions offset mechanisms have been established internationally and in Australia. Examples include the Clean Development Mechanism; the Alberta offset credit system, and the New South Wales and Australian Capital Territory Greenhouse Gas Reduction Scheme (Kollmuss et al. 2008).

Offset schemes can encourage emission reductions that assist in lowering overall costs of mitigation. They can also help to develop human and institutional capacity for reducing emissions in uncovered sectors (Kollmuss et al. 2008). On the other hand, poorly designed and implemented offset schemes can allow abatement to be credited where there are no real reductions in emissions. Regulatory mechanisms to limit these risks are necessary, but can result in administrative complexity and significant compliance costs (Australian Government 2008). Given the importance of the land sectors to Australia's mitigation effort, it is strongly in our interest to have a scheme that recognises and does as much as possible to break free from the weaknesses of earlier offset schemes such as the Clean Development Mechanism (Garnaut 2008; Calford et al. 2010).

Under the Carbon Farming Initiative, it is proposed that offset credits from biosequestration will be based on the net emissions or removals each year as measured against a baseline. The baseline represents the emissions that would have occurred in the absence of the incentive provided by the Carbon Farming Initiative. It is important that the setting of baselines should not disadvantage early adopters. The Government has acknowledged this issue in consultation papers on the Carbon Farming Initiative.

The quantity of emissions and sequestration will vary with natural disturbances or changes in land use, but also with the normal ebb and flow of business activity. For example, when forests are grown for harvest, carbon sequestration occurs until harvesting takes place. There is then a loss of carbon followed by further carbon sequestration in new growth. Unnecessary and unproductive transactions costs could be avoided by averaging the emissions and removals for each forest stand over time, and issuing credits and requiring acquittal of liabilities on this basis. The Government has proposed adopting an averaging approach for the Carbon Farming Initiative (DCCEE 2010c).

The Government's proposed Carbon Farming Initiative design applies a common framework for crediting abatement that would count toward Australia's Kyoto Protocol target, and non-Kyoto abatement. This approach would provide for broad coverage and, depending on the opportunities to obtain a significant price for abatement, could encourage greater mitigation than an approach that applies different rules to Kyoto and non-Kyoto abatement. It avoids landholders having to interpret Kyoto Protocol rules and provide evidence of, for example, areas of vegetation that met Kyoto forest criteria in 1990. This is a sound approach.

One possible example of the benefits of this approach could be in the semi-arid regions that have been a focus of extensive land clearing in recent decades. In these areas, native vegetation on individual properties can comprise a mix of forest and non-forest vegetation under Australia's criteria for defining forests under the Kyoto Protocol (refer Appendix 1). Part of the clearing of such vegetation will be deforestation and part will not. The Carbon Farming Initiative could allow management of the area as a whole for biosequestration, without requiring separation into Kyoto and non-Kyoto areas. The onus would be on the Government to determine areas of Kyoto and non-Kyoto land. Datasets developed through the Government's National Carbon Accounting System for preparing Australia's Changing Land Use emissions accounts would assist the determination.

This proposed common framework for the treatment of Kyoto and non-Kyoto land areas is the starting point for encouraging mitigation activity beyond the limited coverage of Australia's Kyoto Protocol accounts. The Government proposes that Kyoto and non-Kyoto abatement, while recognised under a common framework for offset project management purposes, would be separately identified. Credits could be sold in Australia or overseas. Kyoto-compliant credits could potentially be purchased by parties with emissions obligations that count towards Kyoto Protocol targets.

The proposed scheme incorporates integrity standards commonly adopted in offset schemes to ensure that credits represent genuine abatement that can be recognised as counteracting emissions produced elsewhere. The main standards deal with additionality³, permanence, leakage, measurement and verification (DCCEE 2010c).

Under the proposed Carbon Farming Initiative, activities would not be considered additional if they were financially viable without a carbon price, had already been funded under government programs, or were required under regulation. Under some approaches, determining additionality requires development of a baseline of emissions that would have occurred without the proposed project. In most cases, there will be information about activities that have been supported by government funding or carried out to meet regulatory requirements. This abatement would not be new abatement and would therefore fail the additionality test. Financial additionality is a much more complex issue.

³ A common requirement of offset schemes is that abatement must be additional, that is, it would not have occurred in the absence of the offset incentive.

Permanence is a critical issue. Unlike other emissions reductions, the abatement achieved through biosequestration can be reversed by events that are natural as well as by human action. While permanence can never be guaranteed, the risks of unplanned release of emissions can be reduced through good system design and good management practices. In addition, new insurance products are emerging that are applicable to carbon forests (for example, Insurance Facilitators 2009). These may offer forest growers risk management options that complement the management of risks to permanence proposed within the Carbon Farming Initiative.

The Government proposes a rigorous but flexible approach to dealing with permanence. Participants wishing to change land use must relinquish credits. A proportion of credits from biosequestration projects would be withheld, as a form of insurance against losses (DCCEE 2010c). Where unintended losses occur, credits would not have to be relinquished as long as the project was re-established. New credits would not be issued until the previous levels of accumulated sequestration had been reached.

This approach to permanence is consistent with Australia's current position on an improved accounting treatment for natural disturbance in international negotiations. Australia's position is that countries' national carbon accounts should not be penalised for emissions due to natural disturbance, and equally should not include the benefit of carbon sequestration in new growth on land affected by the natural disturbance. This approach is sound in principle. There is some risk that old levels of sequestration would never be restored after a major natural event. This risk has to be balanced against the certainty that opportunities for biosequestration will not be utilised if landholders have no incentive to do so.

Leakage occurs when an abatement activity results in emissions at another time or elsewhere. Leakage would be dealt with in the Carbon Farming Initiative by requiring reporting of increases in emissions that are directly attributable to a project and deducting that amount from credits issued. Some leakage will be unavoidable under an offsets scheme. This is a major reason why the use of offsets should be seen as transitional to full coverage.

Accurate measurement of emissions and sequestration is essential to the integrity of an offsets scheme in the land sector. The proposed Carbon Farming Initiative would require offset projects to use estimation methods that are consistent over time. Independent auditing of reported abatement estimates would be required.

To this end, the Department of Climate Change and Energy Efficiency is developing offset methodologies for some broadly applicable activities (DCCEE 2011). The Government has also announced that Regional Landcare Facilitators will assist in providing information and advice about the scheme to landholders (DAFF 2011). Clear rules and efficient administrative processes will be necessary for enabling participation.

The level of participation in the Carbon Farming Initiative is likely to grow gradually, as landholders gain an understanding of the scheme requirements and the opportunities and risks. Carbon forestry and reducing emissions from manure which are technically straightforward and have low costs could represent the bulk of early activity. Development of offset methodologies for options that have greater uncertainties in measurement and emissions reduction pathways may take a number of years.

There may be little activity if credits can only be sold into voluntary markets. Until the scheme is under way and firm market prices established some landholders may perceive risks of participation to be higher than the value of the offset credit (Gowen et al. 2010). They may shy away from the risk of future changes in scheme rules. If prices for credits are below the fixed carbon price, as they are likely to be to the extent that sales of credits are confined to the voluntary markets, they may judge it prudent to withhold participation in the scheme until the realisation of their sequestration opportunities attracts a more rewarding price.

Two aspects of the Government's proposed Carbon Farming Initiative warrant further consideration:

- relaxing the requirements for financial additionality; and
- the linking of an emissions trading scheme to the Carbon Farming Initiative.

Financial additionality involves evaluating whether a project would have been economically feasible in the absence of the income generated by the carbon offset. If it is judged that the project would have proceeded without the sequestration, it fails the financial additionality test.

Assessing financial additionality is highly subjective. This introduces uncertainty, and opportunities for distortion. It will often be the case that there are multiple motives for changes that sequester carbon. What matters is that the sequestration is new and is real.

Agriculture and forestry interests have been concerned that activities undertaken with a genuine intent of reducing emissions may not be eligible because they may also be profitable. There are concerns that penalising such activities because they deliver other good outcomes such as productivity gains would be counterproductive to the objective of reducing emissions (refer for example NFF [2011]). I see merit in these concerns, and problems with the subjective nature of assessments of financial additionality.

The Government has proposed mechanisms to simplify assessment of additionality. The primary proposal is to develop a list of activities that can be determined to be additional because they would not commonly be undertaken in defined circumstances. Such activities could include tree planting for environmental purposes, or installing equipment to capture and flare methane from waste in intensive livestock production systems. Activities that may be profitable in some locations or for some landholders may be determined to be additional in other situations where there are barriers to adoption. Such barriers might include capital costs of purchasing new equipment, or a lack of information on how to adopt low-emissions management practices in particular production systems or environmental conditions. Proponents of projects involving activities already deemed to be additional would not be required to submit evidence of additionality. These proposed simplifications would help limit costs of participation in the scheme and avoid duplication of effort in determining additionality for a range of activities.

However, it is likely that a range of activities that would produce genuine abatement would not meet the proposed financial additionality tests. For example, improving livestock feeding and fertiliser management practices can increase productivity as well as reducing emissions, so that adoption does not depend only on a carbon price. There is genuine abatement if emissions are reduced, whatever the motivation of the decisions that caused them. It is recommended that the financial additionality requirements be removed. This would avoid distortions, reduce ambiguities and costs of scheme implementation, and encourage genuine abatement.

The Government proposes that Kyoto and non-Kyoto abatement, while recognised under a common framework for offset project management purposes, would be separately identified. Credits could be sold in Australia or overseas. Kyoto-compliant credits could be sold to firms with emissions obligations that count towards Kyoto Protocol targets.

Once a carbon price is in place in Australia, liable parties could purchase Kyoto compliant offsets approved under the Carbon Farming Initiative. Liable parties could use these offsets to help meet their obligations. Prices for these offsets would be expected to settle near (a bit below) the general carbon price, with any difference reflecting transaction costs.

Under the Government's proposal, both Kyoto and non-Kyoto credits from the Carbon Farming Initiative could be sold in voluntary markets. The current demand for offsets in voluntary markets is low, and can be expected to fall once a carbon price is in place. For the new arrangements to encourage genuine sequestration through activities that are not recognised in the Kyoto agreements, the providers of offsets would need to be able to sell legitimate non-Kyoto credits to liable firms or to the regulatory authority.

The manner in which a fixed price emission trading scheme is linked to the Carbon Farming Initiative scheme requires careful consideration. There are two possibilities. One is to allow liable entities to purchase offsets directly. Another is for the regulatory authority to purchase credits, funded by a proportion of revenue from sale of emissions permits. Update Paper six (*Carbon pricing and reducing Australia's emissions*) will explore the fiscal and environmental implications of each of these possibilities.

Concerns have been expressed that the opportunities for low-cost sequestration in the land sector may be so large that the purchase of Kyoto credits at low prices by liable parties would reduce excessively the pressure on liable entities in other sectors to reduce emissions.

Is this a real cause for concern? The scheme may reveal large opportunities for low-cost abatement in the land sector (see section 5). Only time and experience with incentives for sequestration will tell. However, it is unlikely that the price for offsets would be pushed significantly below the fixed price proposed by the Australian Government for the early years of carbon pricing in Australia (see the statement by the Prime Minister on 24 February, 2011 [MPCCC 2011]). It is therefore unlikely to reduce pressure for reductions in emissions by liable entities under the carbon pricing scheme: they would face the same prices for emissions as they would in the absence of the Carbon Farming Initiative.

There are two reasons to expect the price of offsets to remain close to the fixed price in the early years of carbon pricing. First, it will take some time for possible participants in the Carbon Farming Initiative to learn about the possibilities and to integrate the opportunities into farm and land management systems. Second, there would be competitive pressure for liable entities to offer prices close to the fixed carbon price until the obligations of liable firms were being met entirely from offsets. This would require the utilisation of about one half of the immense annual ‘technical potential’ for both Kyoto-compliant and non-Kyoto sequestration identified speculatively in Chapter 22 of the Review and subsequently broadly confirmed by detailed new research by the CSIRO. As discussed in Section 5, it is unlikely that even a mature Carbon Farming Initiative would be able to realise anything like this proportion of the ‘technical potential’, even if opportunities for sale of offsets to liable entities were extended to non-Kyoto activities.

That is not to say that there would be no problems with the unlimited sale of Kyoto offsets to liable entities under the Carbon Farming Initiative. Sales of offsets to liable entities would reduce the number of permits purchased from the regulatory authorities, and therefore the Government revenue from sale of permits. This claim on potential revenue is open-ended and potentially large. It may challenge the requirement of budget neutrality that is an important premise of current discussions of a carbon pricing scheme.

This open-ended risk to budget neutrality could be removed by placing a limit on the proportion of a liable entity’s obligations that could be met by acquitting offsets. When the limit had been reached, offset prices would fall. This would introduce a real possibility that pressure on liable entities in other sectors to reduce emissions would be significantly reduced.

This issue would be removed if the regulatory authority purchased credits at the general price within a fixed price regime, and placed the limit not on the proportion of a liable entity’s obligations that could be met through the purchase of offsets, but on the maximum amount of carbon pricing revenue that would be allocated to the purchase of offsets. If the limit to the fiscal commitments were in danger of being breached in some future period, the regulatory authority would need to announce a reduction in the unit price at which credits would be purchased during that period. Such an announcement would drive the price of offsets below the price of carbon in the carbon pricing scheme. Alternatively, the regulatory authority could announce the amount of revenue that it was prepared to commit to purchase of offsets, and conduct a Dutch tender until the fiscal commitment has been exhausted.

The methods suggested for avoiding risks to budget neutrality both have costs in arbitrarily reducing incentives for legitimate abatement in the land sector. It is likely to be some years before the prudent limits of offset purchases would be reached. Reasonable limits during a transition period may reduce anxieties without undermining the genuine abatement effort.

If there were an emissions trading scheme with an emissions reduction target, there would seem to be no cause for concern and no need to limit sales of Kyoto-compliant offsets so long as the sequestration that earns credits is genuine, and so long as the target has been set appropriately.

So far we have been talking only of Kyoto-compliant offsets. Some of the most exciting opportunities for genuine abatement in the Australian land sector relate to activities that are not currently recognised within Australia’s Kyoto commitments. It is possible that developments within the international mitigation regime will render the distinction between Kyoto and non-Kyoto credits redundant. As discussed in Update Paper two (*Progress towards effective global action on climate change*), there may be no successor to the Kyoto Protocol, and we may for a while live in a world in which most countries of

significant size make major contributions to mitigation, but according to their own rules. In such a world, Australia's interest in keeping open the possibility of eventual effective agreement would be served by rigorous commitment to environmentally valid accounting for emissions in its domestic system, going beyond the old Kyoto framework where this improves the rules.

Abatement in the area that would be covered by non-Kyoto credits is genuine abatement (subject to rigorous measurement and administration), and belongs in sound Australian and international regimes. I recommend that non-Kyoto credits be purchased by the regulatory authority at a small discount to the carbon price (so as not to create an advantage over Kyoto credits, which would be discounted for transactions costs). To be confident of avoiding risks to budget neutrality, there would need to be a limit on the regulatory authority's expenditure on non-Kyoto credits.

The treatment of the Carbon Farming Initiative credits will interact with and have large implications for general carbon pricing. The interactions, affecting prices and volumes for credits under the Carbon Farming Initiative, will be explored in Update Paper six (*Carbon pricing and reducing Australia's emissions*).

4. Encouraging co-benefits and avoiding perverse incentives

Large-scale changes in land use through biosequestration can have benefits in addition to climate change mitigation. These include enhancing the resilience of biodiversity against climate change or other changes in the environment, providing opportunities for Indigenous livelihoods, and simply expanding the sources of income available to landholders in rural Australia (refer Boxes 4 to 7).

However, there are also potential negative impacts from broad scale biosequestration. For example, there are concerns in the agricultural sector and broader community that a carbon price could make forest establishment financially more attractive on large areas of productive agricultural land, with flow-on effects for food security and rural communities and negative effects on water resources. There have also been concerns about the potential for adverse impacts on biodiversity through expansion of monoculture (single-species) forests and clearing of native vegetation for forest establishment. The development of mechanisms for valuing biodiversity and principles for achieving co-benefits could substantially reduce the potential negative impacts of biosequestration.

Just as greenhouse gas emissions without a carbon price represent a market failure, the decline in Australia's biodiversity can also be attributed at least in part to a failure to correct through public policy the market's failure to value the natural estate. For example, the recent Henry tax review pointed to the important role government can have in purchasing biodiversity outcomes through management agreement payments to providers of carbon-sink forests for the additional costs of planting and maintaining biodiverse forests in perpetuity (Commonwealth of Australia 2010).

This failure, combined with the vulnerability of Australian ecosystems to climate change (Steffen et al. 2009) (refer Box 5), provides a strong basis for introducing incentives to encourage biodiversity co-benefits from biosequestration activities. In other words, the carbon price incentive for biosequestration should be accompanied by complementary biodiversity conservation incentive mechanisms so that increased biosequestration can help and not damage biodiversity.

Box 4 Agricultural and other co-benefits

Forest growing can provide a range of environmental benefits, and can be readily integrated with agriculture. Farm forestry, windbreaks and revegetation are widely adopted now, to protect and improve biodiversity and water quality, to arrest erosion, or to improve conditions for livestock. Revegetation on hills and lower productivity areas and along gullies and fence lines can provide these benefits without removing more productive areas from farming. Tree planting on farms has been shown to increase agricultural productivity, for example through reduced animal losses in cold weather and protection from soil erosion (GHD Hassall 2010). Mallee rows as well as bluegum and pine plantations can provide habitat for native fauna on cleared farmland and extend corridors between remnant vegetation (Smith undated; Loyn et al. 2009).

For example, mallee trees have been planted in rows across around 13,000 hectares in the Western Australian wheatbelt since the 1990s, mainly to help reduce land degradation (FFI CRC 2010). When planted on about 10 per cent of a farm, they also provide shelter and wildlife habitat, without competing with adjoining annual crops. The above-ground parts of mallees can be harvested repeatedly as they regenerate from roots after harvesting. This has led to the development of bioenergy production systems using mallee biomass.

CSIRO analysis has assessed the potential for carbon forest plantings on agricultural land in South Australia. At a carbon price of \$20 per tonne of carbon dioxide, large-scale forest establishment could deliver substantial carbon sequestration, improve the income of the state's agricultural sector by around 20 per cent, or \$1 billion annually, and help to improve water quality and biodiversity and to reduce land degradation (Crossman et al. 2010). This is after loss of some livestock production.

A recent economic analysis found that by 2026 an area of 163,200 hectares of mallee plantings in Western Australia, New South Wales and Victoria could be supplying two 8 megawatt bio-electricity plants and supporting co-firing in existing coal-fired power stations (FFI CRC 2010). Related analysis found that the revenue from sale of biomass and carbon sequestration in tree roots could improve farm profitability (Bartle and Abadi 2010). The tree growing, harvesting, transporting and processing operations at this scale would provide wider regional economic benefits. Further discussion of bioenergy opportunities can be found later in this paper.

Market mechanisms are likely to encourage biodiversity co-benefits at lowest costs (OECD 2010). For example, auction programs can reveal the price private landholders will accept to conserve and restore ecosystems (refer Box 6). Landholders make bids based on the costs of management actions, and bids are assessed against cost and environmental benefit criteria. Landholders whose bids deliver best value for money are offered contracts and then receive periodic payments. Biodiversity value for money would be enhanced if landowners were also claiming carbon sequestration credits. Regional natural resource management bodies, not-for-profit organisations and private brokers and advisers could support the uptake of incentives for multiple benefits and working with landholders to assist participation.

Getting value for money from biosequestration incentives depends on being able to deal with the risk that sequestered carbon could be lost or that a biosequestration activity will cause emissions elsewhere (leakage). As is the case with carbon sequestration, the success of market mechanisms for biodiversity will depend on being able to ensure that biodiversity benefits will be sustained over time. Incentives for biodiversity will need to deal with risks of loss, for example from fire or deliberate clearing.

There is increasing private philanthropic interest in encouraging biodiversity but Government is likely to remain the major source of funds to purchase biodiversity. Separate but complementary incentives for carbon and other ecosystem services will allow the respective benefits to be sold in separate markets, with landowners selling into both and taking decisions that maximise total incomes and benefits to themselves.

Box 5: Linking climate change adaptation and mitigation through biodiversity benefits of biosequestration incentives

Land clearing, the introduction of new plants and animals, redirection of waterways and other landscape modifications since European settlement have caused extinctions and changed Australian ecosystems. Around 50 vertebrate species and a similar number of plant species have become extinct in the last 220 years. Australia's record over this period for mammalian extinction is worse than any other country (Steffen et al. 2009). At least 1,700 species and ecological communities are said to be at risk of extinction (DSEWPac 2010).

Climate change is a major additional stressor on biodiversity in Australia. With unmitigated climate change, it would be likely to become an overwhelmingly important stressor in the course of this century. Climate change affects ecosystems and biodiversity by shifting, reducing and eliminating natural habitats. Many Australian species of flora and fauna are at risk from climate change because of their restricted geographic and climatic range. Where ecosystems and species have low tolerance for change, altered climatic conditions can trigger irreversible outcomes such as species extinction.

The Commonwealth, State and Territory Governments have adopted a range of policies to help protect and enhance biodiversity in a changing climate. Australia's biodiversity conservation strategy 2010-2030 provides a guiding framework for conserving biodiversity and building ecosystem resilience over the coming decades (NRMMC 2010a).

Positive incentive mechanisms include grants, revolving funds, voluntary covenanting, tax concessions, offsets and auctions. Programs for covenanting land to help secure biodiversity conservation have been in place for some time. In addition, regulation prohibits actions that would cause species loss and ecosystem decline, such as clearing of certain native grasslands with high conservation value. Governments have commonly used grant schemes to pay land managers for biodiversity conservation. Quantity-based market mechanisms, such as offsets for clearing of native vegetation, are also being adopted. Under these mechanisms, landholders and developers may be allowed to clear native vegetation where they protect or enhance an area of vegetation of comparable value somewhere else. Examples include Ecofund (Queensland), Bushbroker (Victoria) and BioBanking (New South Wales).

Adopting a carbon price will correct the negative externality associated with greenhouse gas emissions, including those from the land sectors. However, while providing an incentive for biosequestration, a carbon price may or may not lead to improvements in biodiversity or other ecosystem services. While establishing or restoring a native forest or woodland might support a rich and diverse ecosystem, the mass planting of a single species of tree would not. Forest growers could favour carbon forests comprising a single species over biodiverse forests because lower establishment costs and higher carbon sequestration rates can make them more profitable. For example, simulations conducted for agricultural regions of South Australia suggest that at a carbon price of \$10 per tonne of carbon dioxide, higher carbon sequestration rates in single species plantings would lead to profits being \$7 per hectare higher than with biodiverse plantings (Crossman et al. in press).

Additional incentives need to be developed specifically to encourage the conservation of biodiversity and ecosystem services. This is separate from climate change mitigation policy, but the interaction of incentives to reduce greenhouse gas emissions (the carbon price) and incentives for biodiversity may enhance both the carbon sequestration and the biodiversity effects.

In the face of rapid and severe climate change, it is also necessary to assist the adaptation of many natural systems. Land-based activities to assist the abatement of greenhouse gas emissions can also provide opportunities to enhance the resilience of biodiversity in a changing climate and highlight the important interactions between biodiversity and other objectives of climate change mitigation and adaptation policy.

Complementary markets will need to be carefully designed to limit complexity, transaction costs and any incompatibilities between carbon and biodiversity programs that may hinder participation. Existing biodiversity conservation incentives may need to be adjusted, and particular attention should be given to complementarity during design of new mechanisms. For example, carbon sequestration rights established under state and territory legislation (in line with their constitutional responsibility for land management) and obligations to maintain sequestered carbon under an emissions offset scheme will interact with the measurement, contracts and covenants used in other ecosystem services markets. Clarity of property rights of different ecosystem services and the development of robust monitoring and reporting frameworks are important in the design of instruments for expanding supply of ecosystem services (see OECD [2010] for further elaboration of key principles for enhancing the environmental and cost effectiveness of ecosystem service incentives).

The achievement of complementarity and consistency between carbon and ecosystem services programmes will require collaboration between the Australian, State and Territory Governments. Governments are currently working on a method to assess co-benefits of mitigation activities, which could be adopted for use in voluntary public reporting of co-benefits from offset projects under the proposed Carbon Farming Initiative (DCCEE 2010c). Over time, just as carbon accounts are needed for carbon markets, further development of ecosystem services markets will require more comprehensive systems of environmental accounts that can deal with the complexity of natural systems. Valuable work on methods for valuing ecosystem services, including through payments for biodiversity benefits, is progressing in Australia and internationally (see Stoneham et al. [2009], TEEB [2010], UNEP [2011] and OECD [2010]).

Co-benefits may include the enhancement of the livelihoods of Indigenous Australians. One example is income generation from land management activities including forestry, while improved management of savanna fires (refer section 5.5) provides an important example in northern Australia.

Initiatives such as Centrefarm (refer Box 7) and the Western Arnhem Land Fire Abatement Project (refer Box 10) help to establish new patterns of economic life that support cultural and social developments that are valued by people who are participating in them. A carbon price could provide additional incentive to take up these opportunities.

Box 6: Government support for natural resource management: price based schemes

Natural resource management networks and programs have been established in Australia to conserve our natural environments. With climate change, additional efforts will be required to build the resilience of the Australian environment. This can be achieved by reducing existing non-climatic stressors, such as land-use change, over-allocation of water, and pollution (Howden et al. 2003). Similarly, expanding the existing system of land reservation and exploring new methods for engaging private landholders will facilitate species migration, encourage conservation and promote resilience (Garnaut 2008, Chapter 15). For example, the Queensland Government has established the Carbon Accumulation Through Ecosystem Recovery information system to encourage landholders to manage regrowth for carbon sequestration and potentially participate in carbon markets (DERM 2009). Up to 14.8 million hectares of previously cleared land with woody regrowth have been identified as suitable for ecosystem restoration and biosequestration in Queensland (Fensham and Guymer 2009).

Price-based approaches such as auctions are likely to provide the most cost-effective incentive mechanisms for the protection of biodiversity and ecosystem services. They reveal the price private landholders will accept to conserve and restore ecosystems. They incorporate methods of comparing the environmental benefits of different activities (Edwards and Eigenraam 2011). In auctions, landholders make bids based on the costs of management actions, and bids are assessed against cost and environmental benefit criteria. Landholders whose bids deliver best value for money are offered contracts and then receive periodic payments.

Pilot auction-based programs such as the BushTender program in Victoria have been successful in expanding conservation activities across private land at lower costs to government than other forms of financial incentive (DSE 2008). Other auction-based programs include NatureAssist (Queensland), EcoTender (Victoria) and Environmental Stewardship (Commonwealth). Some programs target single outcomes, such as biodiversity conservation, while others encourage multiple benefits, including water quality and carbon sequestration.

The Victorian Department of Sustainability and Environment's EcoTender program is an auction-based environmental market designed to procure multiple environmental benefits in ways that secures the lowest possible costs. The design of EcoTender makes use of the fact that environmental goods and services (such as biodiversity conservation and improved water quality) are often produced by the same actions in the landscape. The underlying aim of EcoTender is to achieve an efficient allocation of land amongst various uses. It has been implemented successfully in three regions of Victoria—Corangamite, Port Phillip and West Gippsland, with successful bids from more than 150 landholders covering around 1,800 hectares (DSE 2011). The Department has demonstrated that purchasing these outcomes together can lead to significantly lower costs for government than programs which focus on a single outcome. Modelling utilising EcoTender results suggests that this gain can vary between 3 and 32 per cent (Edwards and Eigenraam 2011).

One of the multiple benefits 'co-produced' by revegetation actions is carbon sequestration. Recognising this, the EcoTender program is exploring mechanisms for linking auction-based ecosystem services markets with carbon sequestration markets. This approach allows government to purchase the non-carbon benefits of sequestration activities alongside the purchase by a third-party (which could be the regulator or a private participant in the national carbon pricing scheme). It also allows participating landholders flexibility to choose which services to sell in different markets, and early findings are that landholders are willing to engage in separate markets for co-produced carbon and other benefits.

Box 7: Centrefarm and the Central Land Council

Centrefarm Aboriginal Horticulture Limited was established by Aboriginal landowners in Central Australia and works in collaboration with the Central Land Council in the commercial development of Aboriginal land. Centrefarm is promoting the development of a conservation economy based on using natural resources in a sustainable manner for the benefit of Traditional Owners and the regional economy.

Relevant projects include the Aboriginal Carbon Fund, a not-for-profit company registered in September 2010 to buy and sell carbon credits generated on Aboriginal lands by Aboriginal people in Australia. When a domestic emissions trading scheme is in place, the fund will be able to trade in this commodity.

Centrefarm is also hosting the National Indigenous Climate Change (NICC) forum in Alice Springs (30-31 March 2011). This forum will bring together Indigenous, corporate and government leaders from across the nation to contribute to developing the NICC opportunities roadmap. It will discuss opportunities for sustainable economic development of Aboriginal lands through carbon sequestration (e.g. planting trees) and carbon abatement (e.g. fire management) and the potential of these and other activities to enhance regional economies in rural and remote areas.

Further information is available from: <http://centrefarm.com/11-conservation-economy.html>.

5. How big are the opportunities?

The Update's assessment of the land sector mitigation options that were outlined in the Review, draws heavily on a recent detailed report by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) following a major piece of research commissioned by the Queensland Government (refer Box 8). The findings of recent studies support the Review's assessment that there is large potential for reducing emissions and expanding biosequestration in rural Australia (refer to Tables 1 and 2).

The quantitative estimates from the CSIRO 2009 report indicate the potential scale of mitigation, rather than forecasts of outcomes. Significant uncertainty remains around how much of the identified technical potential can be realised. For example, the practical limitations, such as the willingness of farmers to change land use practices over large areas, or the economic constraints on establishing timber plantations a long distance from processing facilities, are not taken into account in estimates of technical potential. It is not realistic to expect that all or even most of the technical potential will be realised.

The realisation of mitigation opportunities will require significant investment in research and development and in many cases a high carbon price. The establishment of an offset scheme such as the Carbon Farming Initiative and eventual comprehensive coverage of the land sectors under a carbon pricing mechanism would allow the economic potential of biosequestration to be tested.

For all the qualifications about uncertainty, the land sectors could make a large contribution to the reduction in Australia emissions. The CSIRO's assessment indicates that technical potential is about twice the total level of current Australian emissions. The realisation of a small percentage of that potential would make a significant difference.

Box 8: CSIRO 2009 analysis of emissions reduction and biosequestration opportunities

At the request of the Queensland Premier's Council on Climate Change, CSIRO conducted an assessment of the land sector mitigation options identified by the Review. The CSIRO report, *An analysis of greenhouse gas mitigation and carbon biosequestration opportunities from rural land use*, was published in 2009. The assessment included consideration of implementation issues, risks, and interactions between mitigation options (including overlaps between options).

In addition to estimates of technical mitigation potential for Australia with a focus on Queensland, CSIRO provided estimates for Queensland's attainable abatement. Attainable abatement was the level that could be achieved with concerted efforts to adopt new technologies and management practices, adjust policies and alter land management priorities. These estimates were not translated to national estimates, but provide important insights into the constraints on realising theoretical or technical potential. Table 1 compares the estimates on mitigation options potential from the 2008 Review and the CSIRO study. Table 2 describes the options as considered by the Review.

The Review identified the largest mitigation opportunities to be restoring degraded rangelands and mulga country, establishing forests for carbon sequestration on agricultural land, and biosequestration in pre-1990 eucalypt forests. Using a different classification that assigned some opportunities to different categories than those used by the Review, the CSIRO analysis also identified rangeland restoration and carbon forest establishment as having significant potential. It found that pre-1990 eucalypt forests also had good potential, but presented a lower estimate than the Review. CSIRO found that post-1990 timber plantations have the greatest technical potential, while noting that the levels identified would require very large increases in plantation establishment rates.

For some options, CSIRO's assessment differed substantially from that of the Review. For example, two of the largest differences were CSIRO's findings that rangelands offered much lower technical potential than that indicated by the Review and that forests established for biodiversity and carbon had much greater potential. Reasons for these differences include changes made by CSIRO to the definition and scope of options, as well as assumptions on carbon sequestration rates and the periods for which future abatement was estimated. For example, CSIRO estimates for carbon forests took into account biodiversity benefits in addition to carbon sequestration, which made larger areas of forest establishment economically viable.

Considered as a whole, the quantitative estimates of the Review and the CSIRO assessment indicate aggregate annual abatement potential of a similar order over coming decades. This comparison confirms that there is a large technical mitigation potential based on contributions from a range of options covering most major agriculture and forestry land uses and other managed land systems.

Table 1: Summary of findings from CSIRO assessment of land sector mitigation options identified in the 2008 Garnaut Review (Note there are significant differences in categories used in the two assessments)

Option	Garnaut (2008) (Mt CO ₂ -e / year) [#]	CSIRO (2009) (Mt CO ₂ -e / year)
	National Potential	National Potential
AGRICULTURE		
Rehabilitate overgrazed rangelands, restoring soil and vegetation carbon-balance	286	100*
<i>Rehabilitate mulga lands, restoring soil and vegetation carbon balance (subset of rangelands)</i>	250	20*
Mitigation of emissions from savanna burning (Kyoto-compliant gases)**	5	13*
Build soil carbon storage and mitigate nitrous oxide emissions from cropped land (land use change not considered)	68	25*
Reduce livestock enteric emissions and structural change in industry**	16	26
Greenhouse gas sequestration/mitigation for agriculture (accounting for overlap of options)		164
FORESTRY		
Change land use to carbon forestry (primary goal is carbon sequestration)	143	750*
<i>Biodiversity – Implement biodiversity plantings as carbon sink (primary goal is promotion of native biodiversity; subset of carbon forestry)</i>	<i>Not estimated</i>	350
<i>Carbon storage in post-1990 (primary goal is commercial biomass harvest; competes for resources with carbon forestry)</i>	50	400
Increase carbon banks pre-1990 eucalypt forests	136	47*
Carbon positive management of regrowth vegetation and remnant forest (reduce land clearing)	63	56
Greenhouse gas sequestration from forestry (accounting for overlap of options)		853
BIOENERGY**		
Substitution of fossil fuels with biofuel/bioelectricity from first generation biomass resources	44 (mix of 1 st and 2nd generation resources)	Not estimated
Substitution of fossil fuels with biofuel/bioelectricity from second generation biomass resources		Not estimated
Stabilise organic carbon in biochar and store in soil (sugar cane biomass only; competes for resources with second generation biomass)	Not estimated	9
Greenhouse gas sequestration / mitigation for bioenergy (accounting for overlap options)		Not estimated

Mt CO₂-e per year equals million tonnes carbon dioxide equivalent per year

* Where estimates are significantly different between the 2008 Review and this study, the reason is often definitional and related to the area of land, however in some instances the estimated carbon sequestration rates also varied.

** These options will be continuous in their sequestration/mitigation while other options will saturate overtime.

Table 2: Potential for emissions per annum reduction and/or removal from Australia's agriculture, forestry and other land use sectors (reproduced from the 2008 Garnaut Review)

Process	Potential	Key assumptions
Land clearing (deforestation)	Emissions reduction potential of 63 Mt CO ₂ -e per year on an ongoing basis	Land clearing ceases (resulting in zero emissions from deforestation).
Enteric emissions from livestock	Emissions reduction estimated at 16 Mt CO ₂ -e per year on an ongoing basis	Based on either deployment of anti-methanogen technology for ruminant livestock, or shifting of meat production from a minority proportion (7 million cattle and 36 million sheep) of ruminant livestock by kangaroos.
Removal by soil—cropped land	Removal potential of 68 Mt CO ₂ -e per year for 20–50 years	Conservative management changes assumed (e.g. conservation tillage), not pasture cropping. Changed practices implemented on all cropped land (38 million hectares).
Removal by soil— high-volume grazing land	Removal potential of 286 Mt CO ₂ -e per year for 20–50 years	Based on the Chicago Climate Exchange for changed practices to rehabilitate previously degraded rangelands. Changed practices implemented on all grazing land (358 million hectares).
Restoration of mulga country	Up to 250 Mt CO ₂ -e per year for several decades	Comprehensive restoration of degraded, low- value grazing country in arid Australia.
Nitrous oxide emissions from soil	Reduction potential of 0.3 Mt CO ₂ -e per year for 20–50 years	Improved fertiliser management practised on all agricultural soils.
Reduction in emissions from savanna burning	Reduction of 5 Mt CO ₂ -e per year on an ongoing basis	Assumes annual emissions from savanna fires are 10 Mt (average from period 1990–2006). Complete reduction of savanna fire is not desirable or feasible; a 50% reduction is assumed, through management.
Removal by post- 1990 forests	Emissions removal potential of 50 Mt CO ₂ -e by 2020	Assumes Australia will have around 2 million hectares of Kyoto-compliant (post-1990) plantations (including wood production plantations and specific carbon plantations) by 2020.
Removal by pre- 1990 eucalypt forests	Emissions removal potential equivalent to 136 Mt CO ₂ -e per year (on average) for 100 years	Current carbon stocks in logged forests are about 40% below carrying capacity. Timber harvesting and other human disturbances cease in study area (14.5 million ha). Landscape growth potential has not been degraded by land use activities.
Carbon farming (plantations)	Emissions removal potential of 143 Mt CO ₂ -e per year for 20 years	Using 9.1 million ha of land where returns would be more than \$100 per ha per year better than current land use, with water interception less than 150 mm per year and permit price of \$20 per tonne CO ₂ -e.
Biofuel production	Up to 44 Mt CO ₂ -e per year on an ongoing basis	Replacement of all fossil fuel diesel with biodiesel. More than 550,000 hectares required for production (cultivating algae as a feedstock) or more than 10 million hectares (using other plants).

Sources: Garnaut (2008).

5.1 Deforestation

Deforestation is undertaken for agricultural purposes, as well as for mining, urban development and infrastructure such as roads and powerlines. The Australian Government's methods for estimating emissions from deforestation are well established, reflecting the significance of deforestation emissions for Australia's Kyoto Protocol target (DCCEE 2010d).

Since 1990, there have been large reductions in deforestation rates, and therefore emissions, due to economic, technological and climatic factors as well as government regulation (DCCEE 2010e). In regions such as semi-arid Queensland, where there has been extensive clearing for livestock grazing since the middle of last century, regrowth of woody vegetation following clearing is common. Landholders clear regrowth once it has grown to an extent that reduces livestock productivity (Fensham and Guymer 2009). Since 1990, the amount of clearing of regrowth has increased relative to the area of first-time clearing (DCCEE 2010e).

CSIRO (2009) estimates potential emissions reductions at 56 million tonnes carbon dioxide equivalent per year from 2010 to 2050 through a combination of a significant reduction in deforestation, increased carbon sequestration through reduced clearing of regrowth vegetation, and a smaller contribution from vegetation offsets. Vegetation offsets are where state governments permit land clearing on the condition that another area of vegetation is conserved to counterbalance impacts on biodiversity or other values.

The greatest opportunities for reducing deforestation and for maintaining and promoting regrowth are in Queensland, and, to a lesser extent, in New South Wales (DCCEE 2010f).

CSIRO's analyses indicate that either a carbon price and/or an offset credit at around \$15 - \$25 would encourage landholders to retain native vegetation that may otherwise be cleared. Landholders would make decisions based on carbon price levels, possible impacts on agricultural production and ecosystems, and risks of loss of stored carbon (for example, due to fire or drought and the impacts of climate change). In some instances, decisions will also be influenced by the need to adapt to climate change.

Long-term retention of vegetation would be necessary to maintain the benefits of avoided emissions and biosequestration. Decisions by landholders on long-term commitments would involve weighing the financial benefits of long-term retention of vegetation against impacts on the flexibility to change land use. Some landholders may choose to proceed with clearing until carbon prices are higher given the loss of private land value from long-term commitments to retaining vegetation (ClimateWorks Australia 2010).

5.2 Enteric fermentation emissions from livestock

Microbial fermentation during digestion of feed by cattle and sheep (the main ruminant livestock in Australia) produces methane emissions. Enteric fermentation emissions account for about 10 per cent of total national emissions. These emissions have declined by 13 per cent since 1990, largely because of a fall in sheep numbers due to the combined effects of the extensive drought and a fall in the price of wool relative to other agricultural produce (DCCEE 2010a). The reduction in emissions from sheep has been partially offset by an increase in emissions from cattle (Table 3).

Table 3: Sheep and cattle numbers and emissions, 1990 and 2008

	Number of animals (million)		Emissions (Mt CO ₂)-e	
	1990	2008	1990	2008
Sheep	174	77	25	11
Cattle	25	27	39	44

Source: DCCEE 2010g.

Several mitigation options are available. These include changes in animal breeding, diet and management.

Improved husbandry in the beef cattle and dairy industries over the past two decades to achieve commercial objectives has incidentally reduced emissions per unit of output (Henry and Eckard 2009; MLA 2010). These developments could go further, and would be encouraged by a mechanism that rewarded reducing methane emissions. For example, there are opportunities in animal breeding, extending the period between calving in dairy cows, improving pasture quality and earlier finishing of beef cattle in feedlots (Eckard et al. 2010). Australian research suggests that native fodder plants could reduce methane emissions compared to introduced pastures (Nicholls 2010). In addition, trials using algae as a feed supplement have shown a reduction in methane emissions (Sustainability Matters 2009).

In general, dietary supplements have the potential to reduce methane emissions, particularly in intensive systems such as feedlots and dairies where they can be provided daily (Henry et al. In prep). Some are already in use, while others are at present too costly or compromise productivity (Eckard et al. 2010). The commercial attraction of supplements would be improved with further research and development and by financial incentives for emissions reduction.

In extensive livestock enterprises such as those in Northern Australia, some mitigation options including the provision of feed supplements are difficult to adopt because livestock cannot be closely managed. However, breeding to increase the efficiency with which feed is utilised could be viable. Recent research indicates that there is potential to improve herd breeding performance (Henry et al. 2010).

Technologies such as vaccinations, biocontrols and chemical inhibitors which lower emissions are not commercially feasible on a large scale at this stage but they may become so in the future.

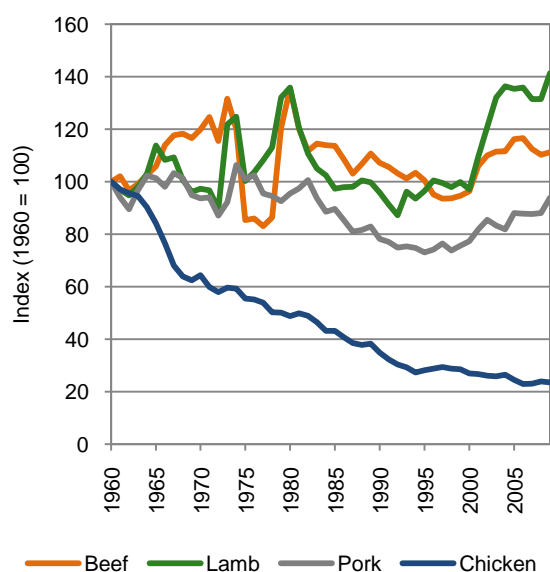
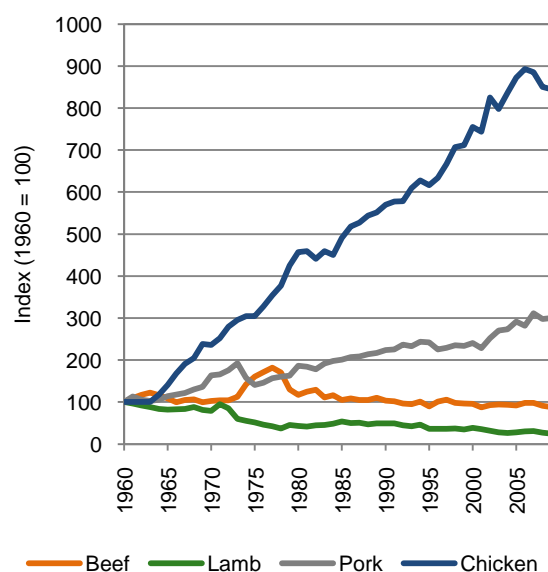
Meat consumption patterns in Australia have been highly responsive to changes in price and supply conditions (Figures 1 and 2). Per capita consumption of various types of meat has varied inversely with relative prices. If livestock emissions were covered by an emission trading scheme, and in the absence of cost-effective mitigation options, the carbon price would increase the costs of sheep and cattle production. The modelling for the 2008 Review showed that this would not be a major factor early in the life of a carbon pricing scheme that covered livestock emissions, but may significantly influence patterns of consumption at the higher emissions prices that would prevail late in the twenty first century. Since the price of carbon will make up a relatively small part of the total cost of meat, at least in the short to medium term (see Table 4), there is likely to be only a modest impact on meat prices and consumption in the early years of carbon pricing.

Improving emissions estimation methods to allow assessment of the impacts of emissions reduction options will be essential for further developing and realising mitigation strategies for ruminant livestock (CSIRO 2009; Henry et al. 2011).

Table 4: Impact of carbon price on cost of meat production

Commodity	kg CO ₂ -e emitted per kg of produce	Cost increase at \$40/t permit price (\$/kg)	2009 retail prices (\$/kg)	Price increase at \$40/t permit price (%)
Lamb	16.8	0.67	13.90	4.8
Beef	24.0	0.96	16.14	5.9
Pork	4.1	0.16	13.63	1.2
Chicken	0.8	0.03	5.49	0.5

Source: Garnaut 2008, ABARES 2010

Figure 1: Australian real retail prices for meat, 1960 to 2009**Figure 2: Australian per capita consumption of meat, 1960 to 2009**

Data are for calendar years from 1960 to 2009. Nominal data are deflated by the ABS Consumer Price Index, annualised for the matching calendar year, to produce real data. Data for retail meat prices prior to 1980 are not publicly available. Sources: ABARE (2000), ABARES (2010, 2011c, 2011d), ABS (2011).

5.3 Soils: cropping and pasture lands

Compared to northern hemisphere soils, many Australian soils naturally have low soil carbon levels due to their old, weathered nature and the effects of a warm and dry climate (Sanderman et al. 2010).⁴ Large losses of soil carbon have occurred since the conversion of native vegetation to agricultural land started in the 1800s (Grace et al. 2010).

Australian farmers over recent decades have adopted practices which reduce soil disturbance, and reduce losses of soil carbon (Sanderman et al. 2010). There has been progressive adoption of no-till and conservation farming practices, to reduce production costs and land degradation in cropping systems. Adoption levels for these practices have reached 90 per cent in many regions, and there have been rapid increases in the last 5 to 10 years in some regions where adoption had previously been relatively low (Llewellyn and D'Emden 2010).

The rate of loss of soil carbon can be reduced or the amount of organic carbon in soils increased by the promotion of more plant growth, and by adding organic matter from offsite sources (Sanderman et al. 2010). The potential for increasing soil carbon levels in soils at any location will depend on soil type, water and nutrient availability, temperature and land management history (Baldock et al. 2011). Where agricultural production is maintained, research suggests that improved management may be able to build soil carbon up to 75 per cent of that present under natural conditions (Lal 1999).

Nitrogen fertiliser application increases plant growth, but also results in emissions of nitrous oxide. These emissions can be reduced through management practices that match the rate and timing of fertiliser application to plant needs. The use of fertiliser formulations that limit conversion of inorganic nitrogen to nitrous oxide has not been cost-effective to date, but remains a potential option for significantly reducing nitrous oxide emissions in future (Eckard et al. 2010).

⁴ This section of the Update considers the potential for building soil carbon and reducing nitrous oxide emissions from soils across cropping and pasture lands other than the rangelands, which are considered separately.

CSIRO estimated that building soil carbon, combined with nitrous oxide emission reductions, on cropped land had a national technical mitigation potential of 25 million tonnes of carbon dioxide equivalent per year from 2010 to 2050 (CSIRO 2009). This assessment assumed adoption of practices to improve crop productivity and reduce tillage across 20 million hectares of annually cropped soils.

Some of the features and opportunities regarding the carbon sequestration potential of land use and management practices in cropping and pasture land are summarised below (Sanderman et al. 2010).

- Improved management of cropland, including adoption of practices such as enhanced rotations, no-till and stubble retention, has on average resulted in a relative gain of 0.7 to 1.1 tonnes of carbon dioxide per hectare per year compared to conventional management across a range of Australian soils. In some cases this gain represents a reduced loss of soil carbon, rather than an increase in soil carbon, because the soil carbon content is still responding to the initial cultivation of soil that was previously under native vegetation.
- Carbon sequestration rates on cropland are generally at their highest within the first 5 to 10 years after beneficial changes in management practice. The rate of increase in soil carbon then declines, and there may be minimal gains after 40 years.
- The more limited evidence for pasture improvements, including fertilising, liming, irrigation and sowing of more productive grass varieties, indicates relative gains of 0.4 to 1.1 tonnes of carbon dioxide per hectare per year. Converting cultivated land to permanent pasture has produced gains of 1.1 to 2.2 tonnes of carbon dioxide per hectare per year.
- Adding large amounts of organic materials (e.g. manure and green wastes), maximising pasture phases in mixed cropping systems and shifting from annual to perennial species in permanent pastures appear to have relatively large mitigation potential. There may be practical constraints to widespread adoption of some of these options, although a carbon price could improve their commercial contribution.
- Changes in land use, such as converting cropping land to permanent pasture or retiring and restoring degraded land, could also provide significant abatement.

There are considerable uncertainties surrounding these opportunities. For example, few studies have tracked the effects of management changes on soil carbon levels over an extended period. This introduces uncertainties about the effects of management practices on observed changes (Sanderman et al. 2010). Table 5 provides an indication of current levels of confidence around the mitigation potential of different options for sequestering carbon in agricultural soils.

There are also risks that increases in soil carbon can be reversed, for example in drought. Drought caused a significant spike in national emissions from croplands during 2002 and 2003 (DCCEE 2010d).

Nevertheless growing awareness of the climate change mitigation benefits of soil carbon sequestration has given impetus to the adoption of a wider range of new soil management practices and technologies that could benefit soil health, and which are being adopted widely for other reasons. One example is the use of a lignite-based fertiliser (Ignite Energy Resources 2010), which assists in absorption of carbon beyond that supplied by the lignite. Another is the sowing of cereal crops into existing perennial pasture in higher rainfall areas to allow optimal combinations of grazing and crop production. These and other emerging options are the subject of ongoing research.

There is also considerable interest in the potential for incorporating biochar into soils to increase soil carbon (refer to Box 9). Recent studies have confirmed earlier indications that some types of biochar can significantly increase crop yields, and some are stable in soil for decades, although these qualities vary with the feedstocks and production processes used (Keenan & Cleugh 2011). Crop yield responses to addition of biochar are also variable, ranging from a 30 per cent reduction to 200 per cent increase, and can vary with soil type (Keenan & Cleugh 2011).

Box 9: Biochar

Biochar can be produced from sources including wood, agricultural crop residues and green waste and gas produced in its creation can be used to generate electricity or converted to liquid fuels. Biochar has greater stability than the material from which it is made, and can therefore provide a long-term carbon store. It can be added to soils, and may improve soil fertility, which could in turn provide biosequestration benefits through enhanced plant growth.

The mitigation potential of biochar production and application in conjunction with bioenergy generation, and possibly waste management, depends on life-cycle emissions from changes in land use, the production, transport and storage of biochar, and displacement of fossil fuel emissions. Research into biochar has expanded greatly since the Review (Keenan & Cleugh 2011).

The economic viability of biochar production and application depends on the costs of feedstock and pyrolysis, the impact on crop yield and fertiliser requirements, and the returns from renewable energy and a carbon price (Keenan & Cleugh 2011).

While early results of biochar research are promising, there is a need for further work on potential benefits and other impacts. For example, biochar can bind to agrochemicals and nutrients, which could have negative effects in agricultural systems (Keenan & Cleugh 2011). Sustainable sourcing of feedstocks will also be important.

The costs of improving soil carbon levels depend on the types of change in land use and practice adopted. They vary with regions and production systems. In some cases they are amply justified by commercial benefits independently of a carbon price. In others, carbon pricing incentives will get them over the line that divides the commercially attractive from the unprofitable. In any case, a carbon incentive will accelerate the rate of adoption of practices that increase soil carbon. A recent study tested the effects of carbon prices on rates of adoption of conservation tillage in the southern region of the grains industry, and found that a carbon price of around \$54 per tonne of carbon dioxide equivalent could stimulate a transition from conventional tillage to no-till at a level that would realise 33 per cent of the region's carbon sequestration potential from increasing carbon in soils over 20 years (Grace et al. 2010).

Any incentives for soil carbon sequestration will need eventually to be embodied in comprehensive emissions pricing to avoid suboptimal outcomes. For example, if ruminant livestock emissions associated with converting cropland to permanent pasture were not covered by a scheme, inclusion of soil carbon may be rewarded excessively for its contribution to reducing greenhouse gas emissions. This underlines the importance of moving eventually to coverage of land use emissions in a carbon pricing scheme.

Recognising gains in soil carbon due to management actions requires the estimation of changes over time. Soil carbon levels may vary significantly at the paddock scale, and over time, and intensive sampling and analysis of soils to obtain highly accurate measurements reflecting this variability is currently not economic. Modelling can be used for estimation, where it is supported by representative management data and systems to verify reported estimates (Sanderman et al. 2010).

Soil carbon models are in use in Australia, including for national greenhouse gas emissions reporting, and research to obtain new data to support estimation is under way. However, further work will be required to develop methodologies that can, at reasonable cost, quantify levels of soil carbon and greenhouse gas emissions from soils, and the effects of management actions on emissions and removals (Baldock et al. 2011).

Table 5: Summary of management options for sequestering carbon in agricultural

Management	Soil organic carbon benefit ^a	Confidence ^b	Justification
1. Shifts within an existing cropping/mixed system			
a. Maximising efficiencies 1) Water-use 2) Nutrient-use	0/+	L	Yield and efficiency increases do not necessarily translate to increased carbon return to soil
b. Increased productivity 1) Irrigation 2) Fertilisation	0/+	L	Potential trade-off between increased carbon return to soil and increased decomposition rates
c. Stubble management 1) Eliminate burning/grazing	+	M	Greater carbon return to the soil should increase soil organic carbon stocks
d. Tillage 1) Reduced tillage 2) Direct drilling	0 0/+	M M	1) Reduced tillage has shown little soil organic carbon benefit 2) Direct drilling reduces erosion and destruction of soil structure thus slowing decomposition rates. However, surface residues decompose, with only a minor contribution to soil organic carbon pool
e. Rotation 1) Eliminate fallow with cover crop 2) Increase proportion of pasture to crops 3) Pasture cropping	+ +/++ ++	M H M	1) Losses continue during fallow without any new carbon inputs—cover crops mitigate this 2) Pastures generally return more carbon to soil than crops 3) Pasture cropping increases carbon return with the benefits of perennial grasses (listed below), but studies are lacking
f. Organic matter and other offsite additions	++/+++	H	Direct input of carbon, often in a more stable form, into the soil; additional stimulation of plant productivity (see above)
2. Shifts within an existing pastoral system			
a. Increased productivity 1) Irrigation 2) Fertilisation	0/+	L	Potential trade-off between increased carbon return to soil and increased decomposition rates
b. Rotational grazing	+	L	Increased productivity, including root turnover and incorporation of residues by trampling, but field evidence is lacking
c. Shift to perennial species	++	M	Plants can utilise water throughout the year, with increased below ground allocation. There are few studies to date
3. Shift to different system			
a. Conventional to organic farming system	0/+/++	L	Likely to be highly variable depending on the specifics of the organic system (e.g. manuring, cover crops)
b. Cropping to pasture system	+/++	M	Generally greater carbon 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 carbon gains

^a Qualitative assessment of the soil organic carbon 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) Source: Sanderman et al. 2010.

5.4 Soils and vegetation: rangelands

Arid and semi-arid rangelands, which include grasslands, shrublands and woodlands, make up about 70 per cent of Australia's land mass, or about 550 million hectares (Garnaut 2008). Rainfall in these rangeland areas varies widely and is highly variable.

Over many years, marginal sheep and cattle grazing has caused considerable degradation of some rangelands, including shrublands and woodlands dominated by mulga (*Acacia aneura*).

The most likely way in which rangelands will be rehabilitated is through reducing grazing intensity. Other possible ways to rehabilitate rangelands and increase carbon levels include introducing or re-establishing palatable shrubs such as saltbush, tagasaste or other perennial shrubs, and fire management (Sanderman et al. 2010; CSIRO 2009).

Recent studies have indicated substantial, but widely differing, technical mitigation potential from rehabilitating degraded rangelands. Most studies apply similar sequestration rates of less than one tonne of carbon dioxide per hectare per year through rangeland rehabilitation. The differences in technical potential arise primarily from differences in the land area considered by each study. Some of the differences in area derive mainly from differences in definition.

CSIRO estimated that rehabilitating 200 million hectares of overgrazed rangelands could have a technical potential to sequester 100 million tonnes per annum of carbon dioxide between 2010 and 2050 (CSIRO 2009). Of this total, mitigation of 20 million tonnes per annum from 2010 to 2050 could occur through restoring 75 million hectares of degraded mulga country.

Another study estimated that reducing grazing pressure on 11.2 million hectares of mulga land in Queensland could sequester up to 10 million tonnes of carbon dioxide per year in vegetation and soils (Witt et al. 2009). Other estimates indicate much smaller gains per hectare, with considerable regional differences (Sanderman et al. 2010).

The level of abatement achievable in rangelands will be limited by rainfall and soil characteristics, and is closely related to natural events. Severe droughts in northern Australia early in the twentieth century and in the 1990s caused extensive tree death (Fensham et al. 2009). Severe fires have caused tree death across a large area of woodland in southern Western Australia, and have been a major cause of a reduction in carbon stocks (Berry et al. 2010).

During the past decade, as a result of natural events, rangelands have fluctuated between being a large emissions source and a large sink (see Appendix 1).

Overall, the recent detailed assessments suggest considerable technical potential for rehabilitating grazed rangelands to build carbon levels in vegetation and soils, if there is ongoing adoption of changes in management practice across large areas. However, all of these estimates are based on limited knowledge of the current carbon status of Australia's diverse rangeland ecosystems. CSIRO's assessment is that the directions of change in carbon levels and responses to rehabilitation cannot yet be reliably assessed (CSIRO 2009). Responses may vary in different rangeland ecosystems and in some cases, livestock grazing has been linked to increases in woody vegetation, which could mean an increase in total carbon rather than a loss.

Nevertheless rangeland rehabilitation could provide significant economic opportunities especially in remote Australia. Net farm cash incomes for northern Australia's extensive beef production systems averaged less than four dollars per hectare in recent years (ABARE 2010a). A carbon credit price of less than \$20 may make sequestration more valuable than the associated loss of revenue from livestock in many isolated locations.

Reducing stocking rates in over-grazed areas could also over time allow both biosequestration and livestock production benefits, by improving land productivity and allowing for higher performance from individual animals (Burrows et al. 2010). Risks of carbon losses could be managed through fire management, averaging of net emissions or removals over a number of years to allow for inter-annual variability, and insuring against carbon losses.

5.5 Reducing emissions from savanna burning

Tropical savannas cover the northern third of Australia and are largely owned and managed by Indigenous Australians. They include grasslands and woodlands and are used by Indigenous peoples for traditional purposes, and for grazing and conservation (CSIRO 2009). There is some overlap between areas generally described as savannas and rangelands in Australia. Fires are common in savannas especially in the late dry season, when fuel loads are highest and have dried out. Strategic burning earlier in the dry season can help reduce fuel loads so that late dry season fires are smaller and less intense. Intense, hot fires late in the season burn more completely, and damage trees and native fauna in ways that controlled early season burning does not.

Savanna burning is the major source of emissions in the Northern Territory. Only non-carbon dioxide (mainly methane and nitrous oxide) emissions from savanna burning are included in Kyoto Protocol accounting and while emissions have declined since 2001, they are heavily influenced by climate factors from year to year (DCCEE 2010d).

Improved management of savanna fires was estimated by CSIRO to have the technical potential to reduce emissions by 13 million tonnes of carbon dioxide equivalent per year, or around 90 per cent from current levels, between 2010 and 2050 (CSIRO 2009).

Another assessment of abatement options on Indigenous land estimated that strategic fire management had the potential to reduce emissions by 2.6 million tonnes per year (Heckbert et al. 2008). While the cost of implementing the Western Arnhem Land Fire Abatement project (refer Box 10) has been estimated at between \$7 and \$30 per tonne of carbon dioxide equivalent (Whitehead et al. 2009). Commercial viability will vary across regions and depend on the carbon price (Heckbert et al. 2008).

Box 10: Western Arnhem Land fire abatement project

The Western Arnhem Land Fire Abatement project, which applies strategic fire management practices across 28,000 square kilometres, has demonstrated the feasibility of reducing the extent of late dry season fires and therefore overall area burnt and greenhouse gas emissions (CSIRO 2009, Whitehead et al. 2009). The project is conducted as a partnership between Darwin Liquefied Natural Gas, the Northern Territory Government, the Northern Land Council and Indigenous landowners and organisations. It provides abatement that is used to offset some of the emissions from a liquefied natural gas plant in Darwin. Annual emissions reductions of 145,000 tonnes CO₂-e have been reported.

Improved savanna fire management is also likely to provide biodiversity benefits (Woinarski et al. 2009). And it can provide regional economic benefits with a suitable carbon price (CSIRO 2009) and employment opportunities for Indigenous Australians that fit into patterns of life for people moving 'back to country' (Heckbert et al. 2008). Four large-scale fire management projects involving Indigenous land managers are under way in Western Australia, the Northern Territory and Queensland (Australian Government 2010b).

Strategic fire management needs to be undertaken across large areas to achieve significant emissions reductions. Significant resourcing and institutional capacity are required to enable sustained fire management practices across large areas, some of which may be inaccessible.

As the characteristics of savanna ecosystems vary across northern Australia, the emissions characteristics and management approaches required are also likely to vary. Research is required to understand these differences. There are also some uncertainties in estimates of emissions from savanna burning and the effects of changed management practice. For example, seasonal changes in combustion efficiency could affect methane emission levels and therefore the effectiveness of management practices (Russell-Smith et al. 2009). Research to improve emissions estimates is in progress.

5.6 Removal by post-1990 forest plantations

Australia's plantation forest estate has expanded significantly since 1990. An average of about 64,000 hectares per annum was established from 2002 to 2008. Within this average, there was a decline from 72,000 hectares in 2008 to 50,000 hectares in 2009 (Gavran and Parsons 2010).

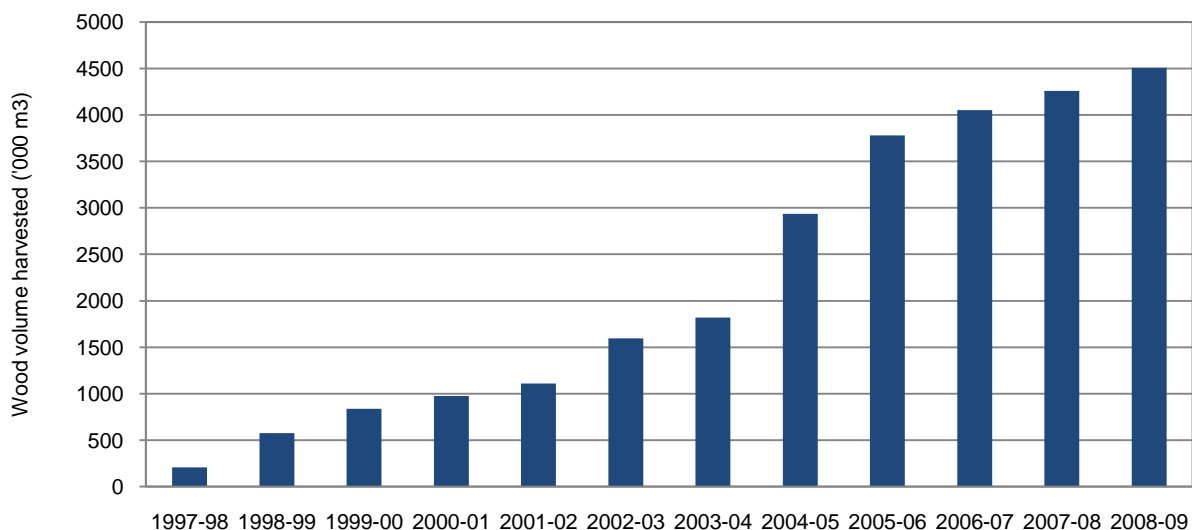
CSIRO assessed the technical abatement potential of post 1990 plantations to be 400 million tonnes of carbon dioxide equivalent per year between 2010 and 2050, with a carbon price of \$20 per tonne and an average carbon sequestration rate of 9 tonnes per hectare per year.

CSIRO cautions that this estimate needs to be considered as an upper bound once market demand, processing capacity and transport costs are taken into account. Other constraints on expansion include landholder willingness to convert agricultural land to forest, regulatory restrictions on forest establishment, transaction costs of carbon market participation, and impacts of climate change on land productivity for forestry.

Growing native tree species on low productivity land for carbon sequestration, wood products, including timber, and biomass for energy could address some of these constraints. Research suggests that there are some prospects for growing low rainfall plantation eucalypt species (ALRTIG 2009).

Accounting for emissions and removals in forestry should recognise carbon stored in harvested wood products, rather than assuming it is emitted at the time of harvest as required under Kyoto Protocol rules. The growing volume of wood now being harvested in the large areas of new plantations established in the late 1990s and early 2000s provides an indication of Australia's harvested wood products pool (refer Figure 3). This is an area in which it would be wise for Australia to develop standards based on rigorous assessments of genuine sequestration, and to apply them domestically in advance of international agreement.

Figure 3: Volume of wood harvested in plantation forests, 1997-98 to 2008-09



Source: ABARE-BRS 2010

5.7 Removal by pre-1990 eucalypt forests

The area of forests and wooded lands per person in Australia greatly exceeds that of other developed countries (Garnaut 2008). Native forests cover around 147 million hectares, or almost 20 per cent of Australia, including 23 million hectares held in conservation reserves and 9.4 million hectares of public land where timber production is permitted (BRS 2010). The remaining area comprises public land used for other purposes, and privately owned land. The area of native forest harvested has declined over time, and totalled about 114,000 hectares in 2008 (DCCEE 2010d).

There is limited information on carbon sequestration in native forests, and current estimates are subject to significant uncertainties (CSIRO 2009). Taking these uncertainties into account, CSIRO estimated that if native forest harvesting were to cease, there is a technical potential for abatement of 47 million tonnes of carbon dioxide each year from 2010 to 2050 (CSIRO 2009).

More comprehensive carbon accounting could open up opportunities for carbon markets to provide a source of revenue for forest managers. Emissions reductions and biosequestration in harvested native forests could be achieved through reducing the area harvested, or potentially through changes in harvesting practice. Forests that are subject to minimal human influence are likely to be either mature or regrowing following fire or other natural disturbance, and therefore provide limited opportunity for active management to increase carbon storage.

Management of harvested and other native forests for mitigation purposes will need to take into account risks of fire or other natural events causing emissions. An analysis of carbon stocks on publicly managed forest and other land in Victoria found that harvesting causes greater reductions than wildfire at particular locations, but wildfire has a larger effect overall because it is more widespread (Norris et al. 2010).

Harvesting of native forests in Tasmania, particularly in areas considered to have high conservation value, has been contentious for many years. Governments, forest industries and conservation organisations are working through the details of a proposed agreement that could see a substantial reduction in native forest harvesting on public lands in Tasmania, commencing with a moratorium on logging of high conservation value forests. If the agreement proceeds, it could deliver mitigation benefits, the extent of which would depend on the balance of plantation forests and other native forests in the compensating increase in wood supply from elsewhere.

Realising mitigation opportunities for native forests will require further investment in data collection and estimation methods. Some work in this area is under way (DCCEE 2010d; Keith et al. 2010).

5.8 Carbon forest plantings

Carbon forest plantings are grown for the purpose of biosequestration, and are a relatively new activity. They include plantings of mixed native species as well as single species such as mallees, and are often designed to provide other benefits for biodiversity, natural resource management and farm productivity. Plantings may be established in blocks, widely spaced rows or in ways designed to provide specific environmental benefits, for example along stream banks or as corridors for native species. Australian companies currently managing new forest plantings to provide emission offsets commonly use locally native species (Dargusch et al. 2010).

As carbon prices rise, establishing forests in regions with lower rainfall and lower land values becomes economically viable (Burns et al. 2009). Carbon plantings are more likely to be suited to these growing conditions than timber plantations. With a carbon price of \$20 per tonne CO₂-e and incentives for biodiversity benefits, establishing biodiverse carbon forests could have a technical biosequestration potential of 350 million tonnes carbon dioxide equivalent per year between 2010 and 2050 (CSIRO 2009). At a large scale of activity, some carbon forest establishment could replace growing of forests for wood production.

In recent years at least 20 businesses and not-for-profit organisations have been reported as offering carbon forest offsets in Australia (Carbon Offset Guide Australia 2010). Recently announced agreements between carbon forest growers and companies with large emissions profiles, for extensive plantings to offset energy emissions indicate expanding capacity and readiness in the carbon forest industry ahead of a carbon price (GHD Hassall 2010). For example, CO₂ Group Limited has established 16,500 hectares of mallee eucalypts on farmland between 2004 and 2010 (CO₂ Group Limited 2010), and Carbon Conscious Ltd has established 6,000 hectares of mallees in 2010 on land that is now unprofitable for agriculture in the northern Western Australia wheat belt (Balsarini pers. comm.).

Rates of carbon forest establishment will be influenced by cost and returns, which will be subject to the carbon price, establishment and maintenance costs, carbon sequestration rates and any opportunity cost of forgone agricultural production. Opportunity costs will be minimal or non-existent where carbon

plantings are integrated within existing agricultural land use and do not displace agricultural production, or where they are established on land that is unproductive for agriculture. At any given carbon price, decisions to invest in large-scale carbon forest establishment would have to take into account a margin for risks such as fire and drought, and uncertainties in carbon sequestration rates in future decades. While plantings of native species may recover from fire, high fire risks could be a significant constraint (GHD Hassall 2010).

Carbon forest establishment will also be subject to a number of the constraints applying to plantations. One significant difference is that carbon forests can be grown across a wider range of climate zones and land types, including locations where agricultural production is marginal and plantations would not succeed. This allows opportunities for diversifying incomes and allows carbon forests to be dispersed across landscapes. The location of carbon forests is also not constrained by requirements for harvesting including transport access and distance to processing facilities, and ongoing management costs are lower than for plantations.

Unlike timber plantations, for which there is a long history of measurement, environmental or carbon plantings may comprise multiple species, could be established across a wider range of growing conditions and are subject to varying levels of management. As a consequence, carbon sequestration estimates are less well developed. Given the potential of carbon plantings to provide substantial low-cost abatement, attention should be given to improving estimates.

5.9 Bioenergy

Using bioenergy (liquid biofuel, electricity and heat) instead of energy derived from fossil fuels can deliver mitigation benefits if emissions over the lifecycle of production of the biomass feedstock and energy are lower than for fossil fuels. First-generation (current) biofuels include ethanol produced from material such as sugar cane and sorghum, and biodiesel produced from sources including cooking oils and oilseed crops. Biofuel can also be produced through gasification of biomass. Biofuel production supplies less than one per cent of Australia's total transport fuels (O'Connell et al. 2009). Biomass feedstocks for heat and electricity in Australia currently comprise by-products or residues from agriculture and forestry production systems. The major feedstocks for heat and electricity are bagasse (sugar cane waste) and wood and wood waste (ABARE 2010b). Biomass energy contributes around one per cent of Australia's total electricity generation (O'Connell et al. 2009).

First-generation bioenergy production has been limited to date, and second-generation technologies using resources that do not have a large effect on food production offer greater potential for significant expansion of bioenergy production. Second-generation technologies could use lignocellulosic (woody) biomass from plants grown on less productive land, as well as algae, oil seed trees, sugar cane, cereals, forestry residues and grasses (CSIRO 2009; Stucley 2010). Realising the potential will require development of cost-effective biomass and energy production systems suited to Australian conditions (Stucley 2010). Biomass electricity is financially competitive with other renewable technologies where the fuel costs can be kept relatively low (ATSE forthcoming). Unlike some other prospective low emissions technologies, current industry estimates do not envision significant potential for capital cost reductions or significant increases in the scale of operation for power generation using biomass only (ATSE forthcoming). There are opportunities for biomass to be used with coal in power generation to lower emissions.

The use of planted mallee eucalypts as a biomass source for energy and other products has been investigated for a number of years, and has been demonstrated in a pilot bioenergy plant in Western Australia. Unlike some agricultural sources of biofuels, the ratio of energy output in biomass to energy inputs in production is highly positive (Bartle and Abadi 2010). Commercial viability of growing mallees for bioenergy would be enhanced by innovation to reduce growing, harvesting and transport costs. Cost reductions of 50 per cent are expected within ten years (FFI CRC 2010). Bioenergy production could also use a combination of biomass sources (refer Box 11).

Subject to constraints such as proximity to processing locations, growing forests for bioenergy production can improve on mitigation benefits of forests grown only for carbon sequestration. A CSIRO simulation found that the combined mitigation from carbon sequestration (allowing for losses from harvesting) and bioenergy production from a short-rotation plantation could be three times that of an unharvested forest covering the same areas (CSIRO 2009).

These combined mitigation benefits could allow for productive land use in regions, such as the northern Western Australia wheat belt, where declining rainfall has made crop production marginal or uneconomic. Use of low productivity land for biomass production would limit any negative impacts on food production and water availability, and could provide a new source of regional income.

Algae can be grown for use as a feedstock to produce biofuel or electricity, providing emissions mitigation through displacing fossil fuels. Large volumes of biomass can be produced from relatively small areas of lake or sea water, including on saline land not suited to agriculture. Augmented carbon dioxide supplies are necessary for high levels of production, and can be obtained from the exhausts of fossil fuel combustion in fossil fuel electricity generation facilities (CSIRO 2009) or the blast furnaces of steel mills. Some life cycle analysis suggests that algal biodiesel could be produced competitively with fossil diesel (Campbell et al. 2009). Commercial biodiesel production from algae will require further work to develop cost-effective large-scale cultivation and harvesting systems (Mata et al. 2010). Research and development activity in this field has increased since the Review, and a number of pilot plants are in development (see for example MBD Energy Ltd 2011; Algae.Tec 2011). Globally, there are prospects for commercialising algal biofuel production on a large scale within around five years (CMT 2011).

Pongamia trees produce seeds containing significant amounts of oil that can be used to produce biodiesel, and can grow in areas that are marginal for conventional agriculture. There is a need for further research into varieties, yield, harvesting and processing, and fuel testing (Stucley 2010). Another species, *Jatropha curcus*, is proving to be attractive in bio-fuel development in other countries. In Australia, its highly invasive properties have caused it to be declared a noxious weed and a prohibited import.

The appropriate incentives to biofuel production are a carbon price and fiscal support for research, development and commercialisation of new technologies. Mandatory requirements to use biofuels can be costly and have large negative effects on food production and prices for small environmental benefits.

Box 11: Bioenergy demonstration project

A bioenergy demonstration plant currently under construction will use new Australian pyrolysis (heating without oxygen) technology to produce biogas for electricity generation and biochar for application on cropland.

The demonstration plant is located on a 25,000 hectare wheat farm at Kalannie, in a low rainfall area of the Western Australian wheatbelt. Wheat straw and plantation mallee biomass from the farm will be used as feedstock for the pyrolysis plant. When fully operational, the plant is expected to produce three megawatts of dispatchable (on demand) electricity and 10,000 tonnes of high quality biochar per year. The biochar will be added to soils on the farm. Results from field trials suggest that high quality biochar can increase wheat productivity.

Initial life cycle analysis indicates net abatement of at least 60,000 tonnes CO₂-e per year through carbon sequestration and displacement of fossil energy. The overall abatement cost has been estimated at less than \$10 per tonne of carbon dioxide. Feasibility studies suggest a long run marginal cost of generation at or under \$100 per megawatt hour. If successful, the demonstration plant could be followed by establishment of further plants with capacity ranging from two to 20 megawatts in regional Australia.

Source: Burgess (pers. comm.).

5.10 Other options: manure management, rice production, and feral animal management

There are other opportunities for reducing emissions from manure management, rice production and feral animal management but they are likely to offer relatively small emissions reductions. A carbon price could encourage greater uptake of these opportunities.

Decomposition of animal wastes held in manure management systems in intensive livestock production enterprises such as cattle feedlots, dairies and piggeries produce methane and nitrous oxide emissions and contributes about four per cent of emissions from agriculture (DCCEE 2010a).

Options for reducing emissions from manure in cattle feedlots include altering nutrition, more frequent pen cleaning, turning compost piles, application of urea inhibitors and capturing methane for flaring or conversion into energy. Methane can be captured using covered anaerobic lagoons or anaerobic digesters (RIRDC 2008). Captured methane can be flared, converting it to carbon dioxide, which has a lower global warming potential than methane, or used to generate electricity. High capital costs are a constraint to take-up of these technologies, particularly for smaller farms. Some larger farms as well as abattoirs are installing these technologies.

Flooding of fields during rice production results in anaerobic decay of plant and other organic material, which results in methane emissions. Rice production represented about half a per cent of total Australian emissions, but fell to tiny levels when irrigation allocations fell in the drought (less than 50,000 tonnes of carbon dioxide equivalent in 2008). Rice production is irrigated, and reduced water allocations due to drought caused the area of production to decline from 115,000 hectares to 2,200 hectares in 2008 (DCCEE 2010g). Emissions can be reduced through improving water management or using rice varieties with reduced methane production (Calford et al. 2010).

Australia has large populations of feral animals, including camels and goats, which are ruminant animals and therefore produce methane emissions. Feral animals cause significant economic and environmental damage. Management of feral animal populations is complex and expensive, and eradication is unlikely. Sustained population reductions would be necessary to achieve any significant mitigation benefit.

There are currently over one million feral camels in Australia and the population is projected to double in the next decade (NRMMCb 2010). There is some camel harvesting, but returns from the sale of meat do not cover costs (NRMMCb 2010). However, the economic benefits of reduced grazing competition, infrastructure damage and greenhouse gas emissions could outweigh the costs of camel population reductions (Drucker et al. 2010). The Australian Government has committed funding for a control program aiming to significantly reduce the population. Recognition and reward of emissions effect would add to the incentives for control of camel numbers.

5.11 Research and development needs

Numerous recent assessments of land-based mitigation options in Australia provide detailed recommendations for further research covering data collection, estimation methods, technical development of management practices and technologies, social and economic analysis, and monitoring and reporting. It has been demonstrated that this sector should be a major focus of expanded public support for research, development and commercialisation of low-emissions technologies. This has the potential to generate large returns in terms of reductions in costs and expansion of ambition in mitigation. It would incidentally nurture a major new source of income for Australia's regional economies.

Mitigation incentives can only work in the land sectors if the effects of management actions on emissions and removals, can be measured and rewarded. The challenge in the land sector with its numerous small enterprises is to reduce measurement costs to reasonable levels. The objective should be to develop estimation methods that can track emissions and removals, and changes due to management actions (and natural events), at reasonable costs, and at levels of certainty sufficient for recognition under carbon pricing mechanisms and international rules.

Australia's diverse natural systems and primary industries, and the large influence that a highly variable climate has on emissions, makes measurement difficult. The Government's National Carbon Accounting System, which uses remote sensing and ecosystem modelling supported by field data, provides good estimation capability for deforestation and plantation forests (DCCEE 2010d). In contrast, the data on emissions and removals in native forests is limited and information for rangelands is in some areas insufficient to allow reliable assessment of changes in emissions.

Research, development and extension in emissions estimation and management have gained momentum since 2008. For example, the Australian Government's Climate Change Research Program is supporting national programs of research into reducing methane and nitrous oxide from livestock and crop production, soil carbon measurement and management, and biochar (DAFF 2010). Rural research and development corporations, state government agencies, CSIRO and universities are all undertaking research in these fields. The Climate Change Research Strategy for Primary Industries provides an avenue for research coordination and collaboration. In relation to bioenergy, a new biofuels research centre will focus on second generation biofuels and food security issues (Gillard 2010). A number of demonstration and prototype commercial second generation biofuel plants are operating or under construction (Stuckey 2010).

This increase in momentum is, however, building on a low base. Overcoming the significant gaps requires a major increase in the level of funding, commitments to long term funding to allow research to capture the time lags and variability in natural systems, and better coordination of research.

Delivery of mitigation incentives should be accompanied by information and other support for adoption. Land managers already adopt management practices and technologies that help reduce emissions and sequester carbon. The motives have included agricultural productivity gains and land rehabilitation. However, levels of adoption of innovations already available to raise productivity seem to underutilise the opportunity (Hogan and Morris 2010; Sheng et al. 2011). Barriers to adoption of new technologies or practices include resistance to changing established practices, significant initial costs (e.g. purchase of new machinery for conservation tillage), lack of access to information, uncertainty about possible changes in mitigation policy and programs, and concerns about impacts on property values and management flexibility.

The Government's Australia's Farming Future program and the proposed Carbon Farming Initiative include work programs to assist understanding of mitigation opportunities and support adoption. Information and guidance for landholders will be most effective where mitigation benefits are linked to practical land management approaches and to enhancement of farm productivity.

To help realise the potential mitigation contribution from the land sector, some of the carbon price revenue should be directed toward further developing the measurement and estimation capabilities needed to enable comprehensive accounting. Australia is supporting development of carbon estimation capabilities in developing countries (refer Box 12), and could make a large contribution to the global mitigation effort by extending this work. Part of the funds allocated to research, development and commercialisation of new technologies should be directed to sequestration in the land sector.

Investing carbon price revenue in innovation will deliver important advantages for Australia in achieving cost-effective mitigation across a range of sectors, and is considered in Update Paper seven (*Low emissions technology and the innovation challenge*).

Box 12: Australia's contribution to international forest monitoring

Reducing emissions from deforestation and forest degradation in developing countries (REDD+) can make a major contribution to global mitigation, at relatively low cost (Garnaut 2008).

Accurate monitoring of changes in forest cover and estimation of emissions and removals will be essential to make sure emissions reductions are real and verifiable and that protection of one area of forest does not simply result in clearing of another. Developing countries need assistance in establishing sound forest carbon monitoring systems that use data from satellite remote sensing and on-ground sources together with emissions accounting methods.

The Australian Government's National Carbon Accounting System uses satellite remote sensing and on-ground validation to track changes in forest cover and ecosystem modelling to estimate emissions in land systems. Australia is sharing its expertise and technologies to assist international efforts to help developing countries establish forest carbon monitoring systems.

Australia is working directly with Indonesia and Papua New Guinea to help them develop national carbon accounting systems for tracking emissions from forests.

In partnership with the Clinton Climate Initiative, Australia is supporting other countries including Guyana, Tanzania, Kenya and Cambodia in developing national forest carbon measurement systems. This support includes providing high-quality, low-cost forest carbon data to enable verification of reductions in deforestation and forest degradation.

Australia together with Canada, Japan and Norway is leading a program of work under the international Group on Earth Observations organisation that is supporting countries setting up national forest monitoring systems. This includes facilitating access to satellite imagery and other data, providing analysis and prediction tools, and supporting national forest carbon tracking systems. Observation systems are expected to be in operation from 2013 onward (GEO 2010).

To assist developing countries in our region, Australia is installing a ground receiving station for satellite data and procuring archived historical data to allow analysis of forest cover and emissions trends over time.

Further information is available from:
www.climatechange.gov.au/government/initiatives/international-forest-carbon-initiative.aspx

6. Land use, water management and forestry

The realisation of a substantial proportion of Australia's mitigation potential will involve changes in land and water management practices. The type and scale of change will be influenced by carbon prices, rural commodity prices, infrastructure development and government policy specifically on water management and land use. Adaptation to climate change will also play a part. Some climate change adaptation responses to achieve and maintain agricultural productivity and diversify farm income in a changing climate will also contribute to emissions reduction. For example, improving the efficiency of irrigation systems in response to reduced water availability may also help to reduce emissions of nitrous oxide from soils. Some activities that have mitigation as a motive will assist with adaptation to climate change—for example, increased carbon in soils which assists in water retention; and woodland conservation, which may increase resilience in the face of warming and changed rainfall.

There are also potential negative effects of mitigation on other values through their effects on water and land use. Plantations and carbon forests have been the subject of much recent public discussion and analysis. Concerns over potential negative impacts have focussed on competition for agricultural land and pressure on food production, water availability and biodiversity (Wentworth Group 2009).

Competition between forestry and agriculture will depend on relative returns (including the effects of any carbon price), as well as other socio-economic factors, climatic and other environmental constraints, and institutional factors such as land use regulation (GHD Hassall 2010).

Most new commercial timber plantations are likely to be attracted to locations at which rainfall and soils are also highly suitable for agriculture, and where processing facilities and markets are not far away. In contrast, carbon forests are not harvested, so they can be located further inland and are largely established in lower rainfall areas (GHD Hassall 2010). Carbon forests can grow successfully in less productive and more isolated areas, which could limit any potential negative impacts. A recent study identified 11 Australian companies whose primary business is managing new forest plantings to provide emission offsets. All of these companies establish forests more than 200 kilometres away from port facilities in semi-arid regions (Dargusch et al. 2010).

In most states, plantation forest establishment on agricultural land requires planning approval (GHD Hassall 2010). Some planning regulations prohibit plantations in certain locations, and in others conditions may be placed on the area planted. In Tasmania for example, plantation establishment on 'prime agricultural land' is restricted (Tasmanian Government 2009). Consideration of impacts on priority agricultural areas is also required in Western Australia (GHD Hassall 2010).

In our market economy, farmers and other landowners should be free to use their land as they judge best for themselves unless there are good reasons for the community as a whole to constrain private choices. Carbon pricing will cause farmers to substitute some sequestration activities for conventional farming simply because it is profitable to do so. There is nothing wrong with that. The regulation of land use decisions on private land would only be warranted if land use change threatened major disruption to established patterns of life for others, and where the accumulation of effects of this kind forced welfare-reducing changes in the opportunities for others to an extent that total incomes and opportunities were substantially diminished. Where the new activities make fewer demands on local labour and services, their replacement of traditional activities may threaten the viability of local communities or of services that are necessary to established farm activities. These situations will probably be rare; they can be managed through zoning of land use where they are present. Decisions on whether to constrain changes in land use through the withholding of planning approvals are best made at a local level. The overall aim of policy and planning should be to achieve a balance between agricultural and forestry land uses that is appropriate in each local community.

The newer activity of carbon forest plantings has to date not been subject to explicit approval requirements. However, some existing approvals processes, for example those for timber plantations, may be applicable (GHD Hassall 2010). As carbon forestry has expanded in recent years, more attention has been focussed on ensuring that this activity does not have negative impacts on land use and the environment. For example, the Queensland Government is proposing to restrict the establishment of carbon forests that could not be legally cleared or harvested, and large scale plantations, on highly productive cropping land (DERM 2010).

One particular concern about expanding forests has been the reductions in the amount of water available for other uses. Water use by large-scale plantations can reduce streamflow and groundwater resources (FWPA 2009). The impacts in each catchment depend on factors such as climate, soils, the proportion of the catchment planted to forests, planting type, and location in the catchment (Marcar et al. 2010). Changes in rainfall due to climate change could exacerbate negative impacts. Impacts on water availability are greatest in high rainfall areas.

Negative environmental externalities associated with a large switch in land use toward production forestry can be corrected through the creation of market-based instruments for other ecosystem services. The National Water Initiative recognises that a number of land use change activities, including large scale plantation forestry, have the potential to intercept significant volumes of surface and groundwater now and into the future (NWC 2004). The National Water Initiative requires that signatory governments take into account significant interception activities in water systems by 2011. However, only limited progress has been made in addressing these commitments (NWC 2009). In the National Water Commission's 2009 assessment of the implementation of the National Water Initiative, South Australia was the only jurisdiction that had in place a process for regulating the water interception impacts of commercial forestry plantations. With the potential for expanded forest establishment in

response to a carbon price, greater progress toward implementation is warranted to help avoid negative impacts on water resources.

Carbon forests could also have negative impacts on water availability if planted over large areas in high rainfall locations. However, in inland regions where carbon plantings and woodland regeneration are more likely, the impacts on water yield are much lower (Polglase et al. 2008).

With the potential for land-based climate change mitigation activities in response to a carbon price, there is a need for more integrated, landscape-scale assessment and planning to help maximise benefits and limit risks of negative regional impacts. Integration needs to encompass land use planning, environmental and natural resource management, and involve primary industries and regional communities. The relevant area for planning and coordination will often be the catchment area of a river system. As suggested in a recent report to the Prime Minister's Science, Engineering and Innovation Council, interdisciplinary research and analysis will be required to inform integrated approaches to landscape planning and management (PMSEIC 2010).

All tiers of government are involved in planning and regulation of land and water use and environmental monitoring. New types of land use and management associated with climate change mitigation are likely to add to existing complexities in land use planning. Greater collaboration and foresight across all levels of government in implementing their responsibilities would be beneficial in helping to realise the benefits of land sector mitigation for national emissions reductions and regional Australia.

There are roles for regulation, as well as market-based approaches, in helping to avoid unintended negative impacts. As new mitigation activities such as carbon forest establishment and rehabilitation of rangelands and woodlands continue to develop, it will be important to assess whether such activities could have negative impacts on other ecosystem services, for example on water supplies. Any new constraints on such activities should only be applied where there is clear potential for negative impacts, rather than simply transferring approaches based on high rainfall areas.

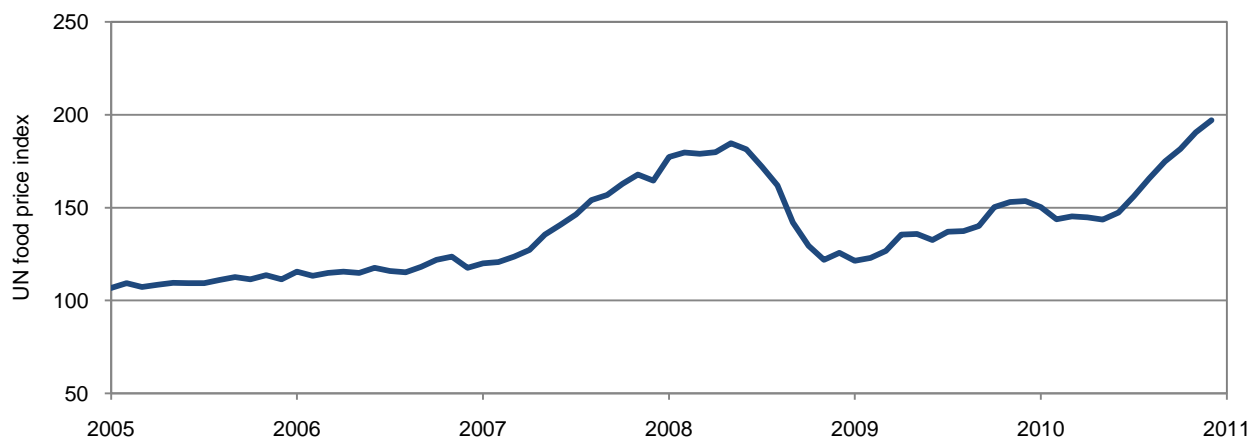
7. Food security

7.1 Global food security

Global food security has received considerable attention since a large spike in world food prices in 2008. Between 2006 and 2008, the year of the Review, global food prices rose by 60 per cent (FAO 2011a). The spike is estimated to have increased by 100 million the number of people considered to be "food insecure" (Fischer et al. 2009). Demonstrations and riots occurred in over 30 countries across the Middle East, Africa, Asia and Latin America, and in Haiti food riots led to the toppling of the Prime Minister (Hendrix et al. 2009).

Global food prices eased following the Great Crash of 2008. The easing was brief. Global food prices again surged in 2010. As shown in Figure 4, the Food and Agriculture Organisation of the United Nations' food price index surpassed the 2008 peak in December 2010, to reach the highest level in the history of the index (FAO 2011b). Food prices have risen to new heights in the first months of 2011. There are fears of new pressures on grain and oilseed prices in February and early March 2011, as persistent and severe drought in the North China Plain leads China to increase imports (The Economist 2011). In India, too, food imports are rising to meet increasing demand, and prices in the early part of 2011 are more than 17 per cent higher than in 2009 (Bajas 2011). The food price outlook for 2011 is problematic (FAO 2011a).

Beyond the economic and climatic circumstances in the largest developing countries, there has been upward pressure on grain prices from an unusual range of other severe climatic events affecting global agriculture: dry conditions in the United States; floods in Australia, Canada, Pakistan and Brazil; dry conditions in Argentina; and high temperatures, drought and wildfires in Russia. Once world grain prices started to rise strongly, the increase was exacerbated by a number of countries, most importantly Russia, seeking to enhance their own food security by restricting exports of grain (Sheales and Gunning-Trant 2009).

Figure 4: UN Food Price Index

Source: FAO (2011c).

Large increases in the production of biofuels driven by government mandates, particularly in the United States and Europe, have also contributed to food price increases through recent years. In the United States, around 25 per cent of the corn crop is now used to produce biofuel, while in Europe nearly 40 per cent of canola is used for biofuels (Sheales and Gunning-Trant 2009). Demand for biofuels is estimated to have accounted for 60 per cent of the global change in demand for wheat and coarse grains between 2005 and 2007 (Headey et al. 2009). According to a recent study, setting a global biofuels target of 10 per cent of transport fuel would lead to the number of people at risk of hunger rising by 15 per cent, while only delivering significant emissions benefits after 30 to 50 years (Fischer et al. 2009).

The recent succession of extreme weather events and the large losses of food production with which they have been associated—with Russia in 2010 being particularly dramatic—have focussed attention on the pressure that future climate change is likely to have on world food production and food security. A major study of the effects of climate change by the International Food Policy Research Institute and made available as an advance copy in December 2010, based on what I consider to be optimistic assumptions of emissions in the absence of effective mitigation, estimates that prices for wheat, rice and maize in 2050 would be up to 23.1 per cent, 19.8 per cent and 32.2 per cent higher respectively in 2050 than they would have been without further climate change beyond 2000 (Nelson et al. 2010).⁵

The International Food Policy Research Institute study is worth a closer look, as it brings together the range of major influences that will challenge global food security through the remainder of the twenty first century. But let us first examine the large forces that are beginning to challenge the relatively benign trends in the balance between global supply and demand for food that have existed since the beginnings of the 'green revolution' in India in the 1960s.

Food relative to other prices fell through most of the twentieth century. There had been pessimism in the early 1960s about whether the acceleration in population growth that characterised the early years of the second half of the twentieth century would overwhelm growth in food production. This was one spur to greatly increased public investment in agricultural research in the large developing countries, which joined traditionally high investments in research in the developed countries. Food supplies easily outran rapidly growing population in the last third of the twentieth century. The Malthusian race between population and humanity's capacity to increase food production was being won by humanity. The relative price of food fluctuated around an apparently entrenched downward trend. The number of

⁵ Note that these are IFPRI's baseline estimates

people living in extreme poverty (living on less than one United States dollar per day) fell steadily, and encouraged the development of the United Nations' ambitious "millennial goals" for accelerated reduction in the number of the world's poor and hungry people. Most important of all, the spreading of modern economic development into the large developing countries in the last decades of the twentieth century and the commitment of the Chinese Government to radical fertility control policies from the beginning of the reform period in 1980 saw a rapid reduction in fertility rates and population growth. The last of these developments promised permanent victory of food supplies over population.

Humanity took these favourable developments into the twenty first century. For the first time since the spread of the fruits of modern medical science throughout the world in the nineteenth century, it was possible to look forward to a time when global population would stabilise and then fall.

The early twenty first century saw an acceleration of economic growth over a large part of the developing world. I have called this period of sustained rapid growth in output and incomes the Platinum Age. It has been led by the most populous developing countries, first of all China and then India and Indonesia, but is by no means confined to them.

Modern economic growth was built on a revolution in science and technology and economic institutions, and in ideas about social and political organisation. This fulfilment of the 'industrial revolution', eventually in the twentieth century, released from poverty, ignorance and insecurity most people in the developed countries that are a relatively small portion of the global population. The Platinum Age represents the extension of the influence of those beneficial forces into the homelands of the majority of humanity.

The scale of the transformation of the global economy that comes with the Platinum Age greatly exceeds the transformation that accompanied world economic growth in the period before the Platinum Age.

The Platinum Age has taken us into a new, different and bigger Malthusian race. The pressure of modern economic activity on the earth's natural resources and environment grows far more rapidly and on a much larger scale than anything in earlier history. At the same time, rapid economic growth and higher living standards are doing three things that hold out prospects for humanity's success: the Platinum Age is reinforcing the continued reduction in fertility and population growth; it is widening access to the knowledge and technology that can break the link between growth in living standards and pressure on natural resources and the environment; and it is lifting much of humanity rapidly towards the conditions in which concern for environmental amenity rises in priority alongside consumption of goods and services.

Humanity won the old Malthusian race in the twentieth century. This new Malthusian race is between humanity's increased pressure on the natural environment, and the capacity and will to break the nexus between high and rising material standards of living and pressure on the natural environment. An optimistic forward view of this new Malthusian race suggests that it will be a close run thing.

Climate change is just one of the points of vulnerability of the natural environment in the twenty first century. But it seems at this stage to be the one that has by far the greatest potential to trip up humanity in the great race.

The study by the International Food Policy Research Institute brings the elements in the new Malthusian race together in a major exercise in economic modelling. No economic model foretells the future. It is no better and no worse than the many assumptions that are fed into it. Those assumptions necessarily extend into issues about which there is great uncertainty. But done well—and the International Food Policy Research Institute does this work well—economic modelling of this kind can spell out the implications of the future of assumptions drawn from the best scientific and economic knowledge available.

The International Food Policy Research Institute (IFPRI) takes as a starting point the latest of the standard demographic projections that are updated periodically by the United Nations. As discussed in Update Paper three (*Global emissions trends*), there is not a great deal of leeway for variations in world population to 2030. Most of the people who will be alive in 2030 have already been born. However, variations in fertility can have much larger effects on global population if our horizon is 2050—the first

horizon of the IFPRI economic modelling. From 6.9 billion today, the number of humanity will have risen to somewhere in the range 10.4 billion (called the pessimistic case) and 7.9 billion (called the optimistic case) by 2050. The central or baseline case is 9.1 billion.

The low population case largely derives from rapid growth in economic output per person (3.2 per cent per annum, compared with 2.9 per cent per annum in the 1990s, the decade that preceded the Platinum Age). The high population case is derived from low growth of economic output per person (to 0.9 per cent per annum).

In my view, something closer to the optimistic than the baseline case would be likely to emerge from the acceleration of economic growth in the early twenty first century—if we were able to expel the spectre of climate change. But Nelson, Rosegrant and their colleagues at IFPRI have judged otherwise, and take a case of lower economic growth and higher population as their baseline. That is consistent with their adoption of emissions growth scenarios (the B1 and A1B scenarios that were discussed in the Review and which will be revisited in Update Paper five (*The science of climate change*)). I consider these to be conservative representations of the near-term realities in the absence of effective global mitigation and climate change. Caution has its place in analysis, so long as we remember that it is there.

Incidentally, the IFPRI modelling, like that of the Review, focuses on what the science has assessed to be the most likely climatic response to increased concentrations in the atmosphere. This is another point of conservatism, as it was in the modelling for the Review. In truth, there is uncertainty around these most likely outcomes. Things may turn out to be better or worse. The worst outcomes could be catastrophic, and early. Few people would think that these possibilities were balanced by similar probabilities that outcomes may be more benign.

Without climate change, in IFPRI's baseline scenario, humanity stays in front and there are fewer hungry people but the world falls behind (more hungry people) in the pessimistic case. In the optimistic case—more or less my view of the Platinum Age without climate change—humanity with its falling population has the food security race won by 2050.

Higher food prices introduce special policy challenges for feeding adequately the world's people. The relatively wealthy people of the world—and as we move through the twenty first century these include most of the people of China and Indonesia and more and more people in India—can buy the food that they want even if prices are high. Many poor people in poorer countries cannot. The food security of many poor people in poorer countries will depend on the effectiveness of domestic and international public interventions of various kinds.

The IFPRI authors note that feeding the world's larger population in the first half of the twenty first century was going to be a challenge in the best of circumstances. The strong growth in grain yields that was associated with the 'green revolution' came to an end late in the twentieth century (see also *The Economist* [2011]). Climate change is not the best of circumstances. They note that "The first decade of the 21st century has seen several harbingers of a troubled future for food security" (Nelson et al. 2010, p xv). The deceleration in growth of farm product yields, continued growth in population, and rising incomes leading to increased effective demand for higher quality and more resource-intensive foods in large developing countries has reversed the twentieth century decline in the relative prices of foods. The IFPRI authors say that climate change will make food production harder because of higher temperatures, shifting seasons, more frequent and extreme weather events, flooding and drought.

The higher food prices with climate change are driven mainly by lower yields. Wheat yields with climate change in developed countries are 4.2 per cent lower in 2050 and 14.3 per cent lower in 2080, and in developing countries are 4.1 per cent lower in 2050 and 18.6 per cent lower in 2080. Incidentally, declines in production are disproportionately large in Australia, deriving from lower yields and contraction of planted areas.

With climate change, the number of malnourished children in the world rises by 10 per cent above what it would otherwise have been in 2050 in the optimistic and 9 per cent (from a higher base) in the pessimistic case.

The IFPRI authors conclude that good policy and innovative production responses could significantly alleviate the pressures of climate change early in the twenty first century. The most important elements in an effective adaptive response would be the maintenance of good policy for broad-based sustainable development; large increases in investment including public investment in agricultural research to raise productivity; global free trade in food; and decisive early action on adaptation to and mitigation of climate change. The list does not look much easier than policies to hold climate change within moderate bounds.

The IFPRI authors comment that the effects of unmitigated climate change from 2050 to 2080 would possibly be unmanageable.

7.2 Australian food and farmers' security

People with good incomes can afford to meet their food needs even when food prices are high, and whether or not their own country produces food. People in Singapore and Hong Kong probably have as much or more fundamental food security than any in the world. They buy large quantities of the best quality food from almost all of the substantial food producing countries.

A sound economy generating income security provides the first pillar of food security.

Australia is rich enough for all Australians to have incomes that are adequate to purchase their essential needs for good food if policy is set with that objective in mind. It is difficult now to imagine circumstances in which Australians face shortages of food.

Difficult... until we imagine other countries closing their food markets and banning exports as food prices rise under the influence of difficult climatic conditions. We were given a foretaste of that possibility with the bans on grain exports in many countries during the price spike of 2008, and with the Russian bans on wheat exports in the 2010 drought and wildfires.

An open, rules-based international trading economy, built around maintaining free trade in agricultural as well as other products, is the second pillar of food security. A sound economy and a sound international trading system built around principles of free trade are usually enough to guarantee food security.

The high global food prices of 2008 and 2010-11 affect Australians, but are not a fundamental threat to food security. The high agricultural prices of recent times, and which can be expected to rise further in future even with effective climate change mitigation, and further still in its absence, are a boon to Australian farmers.

The real prices received by Australian farmers declined substantially in the second half of the twentieth century (see Figure 5), while the real prices paid for inputs remained roughly constant. This resulted in a substantial decline in Australian farmers' terms of trade. The long-term decline in Australian farmers' terms of trade precipitated a substantial fall in the real net value of farm production in the 1980s and 1990s, compared to the 1960s and 1970s. (The real net value of Australian farm production was higher in the decade to 2011, following favourable conditions in the early 2000s. In the latter part of the decade, it resumed its downward movement despite more favourable trends in the terms of trade, under the influence of prolonged drought) (ABARES 2010).

At the time of the Review in 2008, the prices received by Australian farmers had risen substantially following rapid increases in global food prices. This happened despite the extraordinarily high Australian dollar exchange rate during the first stage of the current resources boom, prior to the Great Crash of 2008. That part of the increase in prices that was not negated by the resources boom's high exchange rate was largely absorbed by higher costs—which were themselves pushed strongly upwards by the resources boom. After the release of the Review in 2008, prices fell from their peak, in line with the moderation in global food prices (refer Figure 6). Data released by the Australian Bureau of Agricultural and Resource Economics and Sciences in March 2011 show a strong increase in the prices received by Australian farmers. The latest forecast for 2010-11 represents an upward revision on the previous forecast, released in December 2010, of over 6 per cent. Current prices are above these levels, and the ABARE forecasts will be exceeded unless prices fall back during the year.

Figure 5: Australian farmers' terms of trade, and the prices received and paid indexes, 1961 to 2011 (real)

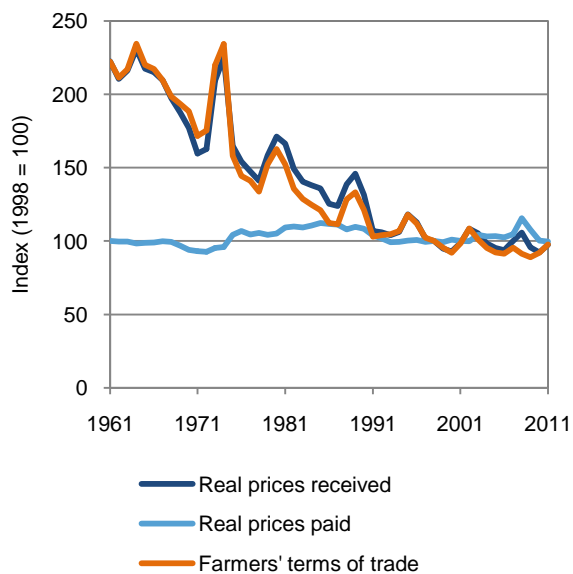
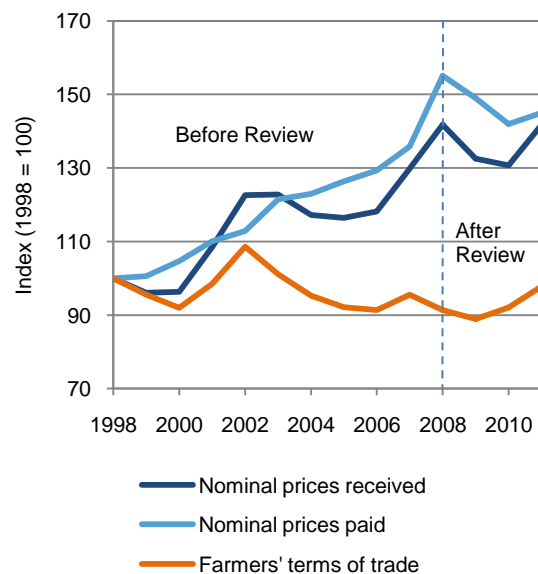


Figure 6: Australian farmers' terms of trade, and the prices received and paid indexes, 1998 to 2011 (nominal)



Data are for financial years from 1960-61 to 2010-11. Nominal data are deflated by the ABS Consumer Price Index, annualised for the matching financial year, to produce real data. Data for the 2010-11 financial year are ABARES forecasts. Real data for 2010-11 are deflated by the Australian Treasury's Consumer Price Index inflation forecast for 2010-11 of 2.75 per cent. Sources: ABARE (2000, 2005), ABARES (2011c), ABS (2011), Australian Government (2010a).

It may not seem remarkable that Australian farmers' terms of trade have been roughly maintained through the last decade. In truth, the change in trend is of historic significance. The huge appreciation of the Australian dollar during the resources boom has crushed the international competitiveness of the services and manufacturing sectors, and in old circumstances would have been expected to have had a similar effect on the farm sector. This effect would have been exacerbated if the long-term fall in global agricultural prices that reduced Australian farmers' terms of trade by more than half between 1950 and 2000 had continued into the early twenty first century.

The reversal of the long term downward trend in global agricultural prices in the early twentieth century has been powerful enough not only to end the long term decline in farmers' terms of trade, but to do this in circumstances in which the unprecedented appreciation of the real exchange rate could have been expected separately to have placed farmers' terms of trade under great downward pressure.

As the IFPRI modelling shows, in the absence of climate change, global food prices and with them Australian farmers' terms of trade could be expected to rise over the next half century.

With climate change, the outlook is more complex, and problematic. World agricultural production will be affected adversely by warming, by more variable weather, and by more intense extreme climatic events. That will raise global food prices. That in itself would help Australian incomes. But Australian food production would be affected more than most, and most Australian farmers would be battling to maintain the production that would allow them to take advantage of higher prices.

The twenty first century is likely to provide large opportunity for Australian farmers with effective global mitigation. It is likely to be deeply problematic without effective global mitigation. The Australian rural economy has an immense interest in the success of global mitigation.

Farmers are naturally anxious about the costs that they will bear as part of a proportionate Australian contribution to strong and effective global mitigation. Like all Australians, and more than most, they will contribute through higher costs of fuel and transport. Like all Australians, they will be beneficiaries of adjustments to tax and social security that emerge from the allocation of revenue from carbon pricing.

The rural community, like all Australians, will be intensely interested in the detail of the allocation of increased costs and tax cuts associated with the introduction of carbon pricing.

Australian farmers have no interest in failure of global mitigation—this is the circumstance that would deny them the opportunity profitably to expand production and exports in a period of rising global prices.

It has already been observed that Australian farming would do well in a world of comprehensive global carbon pricing. Northern Hemisphere producers of temperate farm products are more emissions-intensive, and there would be some tendency for market shares of Australia and New Zealand to expand.

We will probably have to live through an extended period of transition to global carbon pricing. An initial period in which farmers can take advantage of the sale of genuine abatement whether or not it complies with Kyoto rules would provide potentially large opportunities for augmenting rural incomes. We will only learn how large by introducing the opportunity and observing what use is made of it. If 10 per cent of the technical potential identified speculatively in the Review and identified by the CSIRO in 2009 after a large research effort came eventually to be utilised, and rewarded at the general carbon price, the addition to rural incomes would be similar to the recent contribution of the wool industry—not what it was, but far from trivial.

So the world of the twenty first century with Australia playing its part in an effective global mitigation effort—and providing incentives for land-related sequestration at the general carbon price—would be a good world for Australian farming.

Many Australian farmers managed to stay afloat and some to prosper during the long decline in the farm terms of trade in the second half of the twentieth century. Those who remain in farming today have revealed in high degree the capacity for innovation based on advanced knowledge, sound management and flexibility in the face of changing opportunity. These same qualities will provide a basis for great success in times of expanded opportunity.

If there is no effective global mitigation, success will also require a large measure of good fortune at the farm level. At the national level, Australia would depend on imports for food security from time to time, and perhaps much of the time. We would depend on an open global trading system not only for export income, as we do now, but for food security. We may have no choice but to make the most of such a world. But both food security and farmers' income security make it a choice to avoid if we can.

8. Conclusion

The land sector is greatly affected by climate change and has a large part to play in its mitigation. This is true for the world as a whole. It is more powerfully true in Australia than in any other developed country.

The international rules developed within the Kyoto process overlook many potentially important areas of land sector mitigation. The omissions are especially important in Australia. Australia has a major role to play in developing alternative and economically and environmentally more efficient rules governing incentives for mitigation in the land sector. Demonstration of their suitability in Australia can lead to their adoption in other countries, including our developing country neighbours with their large forestry sectors.

The land sector, especially through biosequestration, has immense technical potential for reduction and absorption of emissions. The realisation of a small proportion of that potential through providing incentives commensurate with its mitigation contribution would transform the Australian mitigation effort, it would also greatly expand the economic prospects of rural Australia.

We are a long way from knowing how much of the technical potential can be realised economically. The proposed Carbon Farming Initiative provides substantial opportunities to bring out the potential and define the extent to which it is economically relevant; it does this by providing for the emergence of an offsets market for land sector abatement.

The Review Update suggests two modifications of the Initiative, to expand its contribution to revealing the land sector's abatement potential. One is to remove the 'financial additionality' test. The other is to allow businesses covered under the scheme to purchase Kyoto offsets directly to meet part of their emissions liability and the scheme regulator to purchase non-Kyoto offsets.

It is essential to ensure that the abatement that is supported by the Initiative is genuine, and permanent. The rules being developed by the Government give priority to these necessary conditions.

There is much to be learned about measurement of land-sector emissions, about technologies to reduce emissions in the sector, and about the rules and institutions that should encourage genuine abatement and avoid false abatement in the sector. Australia has a major role to play in the development of knowledge on all of these things, for use by itself and by the international community. Part of the revenues from carbon pricing should be allocated to research and development in these areas, and to commercialisation of relevant low-emissions technology.

An offsets program is likely to run into various problems over the long time. It should be seen as transitional to full inclusion of the land sector in a comprehensive carbon pricing scheme. Completion of the transition would allow the removal of constraints on sale of abatement from the land sector at the general carbon price. There would be large advantages for the Australian farm sector in global transition to full coverage of the land sector.

There is increasing recognition of the importance of biodiversity and biodiversity resilience in Australia, and that it will become more important with climate change. Biodiversity should be supported independently of greenhouse mitigation. The encouragement of complementary development of support for carbon abatement and biodiversity, with funds being drawn from separate pools for the same project where the project makes dual contributions, would help to ensure that the potential for carbon and biodiversity efforts to assist each other is realised. In these circumstances, support for biosequestration in the land sector can provide for co-benefits for biodiversity. Other co-benefits from support for land sector mitigation relate to Indigenous income opportunity in rural areas, and more generally rural income opportunity.

The world has entered a challenging period of rising food prices in the twenty first century, after a long period of decline. This presents problems for global food security. These challenges can be met, so long as the higher food prices are not compounded by the effects of weakly mitigated or unmitigated climate change.

In themselves, higher food prices represent opportunities for the Australian rural sector. The Australian rural sector is set to do well in these new circumstances if the world is effective in mitigating climate change. In the absence of effective global mitigation—in which Australia will have to play its proportionate part—the twenty first century will be deeply problematic for global and even Australian food security, and for the income security of rural Australia.

References

ABARE (Australian Bureau of Agricultural and Resource Economics), 2000, *Australian commodity statistics 2000*, ABARE, Canberra.

ABARE, 2005, *Australian commodity statistics 2005*, ABARES, Canberra.

ABARE, 2010a, *Australian beef: financial performance of beef cattle producing farms, 2007-08 to 2009-10*, ABARE, Canberra.

ABARE, 2010b, *Energy in Australia*, ABARE, Canberra.

ABARE-BRS (Bureau of Rural Sciences), 2010, *Australian forest and wood products statistics: March and June quarters 2010*, ABARE-BRS, Canberra.

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) 2010, *Australian commodity statistics 2010*, ABARES, Canberra.

ABARES, 2011a, *ABARES special report 21 January 2011: The impact of recent flood events on commodities*, <http://adl.brs.gov.au/data/warehouse/pe_abares99001773/Floods_on_commodities_2011_REPORT.doc>.

ABARES, 2011b, *Australian crop report, 15 February 2011*, ABARES, Canberra.

ABARES, 2011c, *Australian commodities March quarter 2011*, ABARES, Canberra.

ABARES, 2011d, Unpublished data provided to the Garnaut Climate Change review – Update 2011.

ABS (Australian Bureau of Statistics), 2011, *Consumer price index, Australia, December quarter 2010*, Cat. No. 6401.0, ABS, Canberra.

Algae.Tec, 2011, *Advanced biofuels company Algae.Tec lists on ASX today*, ASX press release, <<http://algaetec.com.au/wp-content/uploads/2011/01/Press-release.pdf>>

ALRTIG (Australian Low Rainfall Tree Improvement Group), 2009, *Australian Low Rainfall Tree Improvement Group: metadata from measures of hardwood tree improvement trials in Southern Australia*, Rural Industries Research and Development Corporation, Canberra.

Ancev, T., 2011, 'Policy considerations for mandating agriculture in a greenhouse gas emissions trading scheme', *Applied Economic Perspectives and Policy*, DOI:10.1093/aep/11/1/ppq031.

ATSE (Australian Academy of Technological Sciences and Engineering) forthcoming report on a comparison between current and previous costs for a range of new power generating technologies, prepared for the Garnaut Climate Change review – Update 2011.

Australian Government, 2008, *Carbon Pollution Reduction Scheme: Australia's low pollution future, white paper, Volume 1*, Australian Government, Canberra.

Australian Government, 2010a, *Mid-year economic and fiscal outlook 2010-11*, Australian Government, Canberra.

Australian Government, 2010b, *Caring for our Country 2008-2009 report card: outcome information sheet*, <www.nrm.gov.au/me/report-cards/2008-09/npa/info-sheets/npa-north-remote-4.html>.

Bajas, V., 2011, *Galloping growth, and hunger in India*, New York Times, 11 February 2011, <www.nytimes.com/2011/02/12/business/global/12food.html?_r=1>.

Baldock, J.A., McKenzie, N. & McBratney, A., 2011, *Soils and climate change: potential implications and future research for Australian agriculture*, National Climate Change Research Strategy for Primary Industries 2011 conference handbook.

- Bartle, J. & Abadi, A., 2010, 'Toward sustainable production of second generation bioenergy Feedstocks', *Energy Fuels* 24:2-9.
- Berry, S., Keith, H., Mackey, B., Brookhouse, M. & Jonson, J., 2010, *Green carbon: the role of natural forests in carbon storage Part 2. Biomass carbon stocks in the Great Western Woodlands*, Australian National University, Canberra.
- BRS, 2010, *Australia's forests at a glance*, BRS, Canberra.
- Burns, K., VEDI, J., Heyhoe, E. & Ahammad, H., 2009, *Opportunities for forestry under the Carbon Pollution Reduction Scheme (CPRS): an examination of some key factors*, ABARE, Canberra.
- Burrows, W.H., Orr, D.M., Hendricksen, R.E., Rutherford, M.T., Myles, D.J., Back, P.V. and Gowen, R., 2010, 'Impacts of grazing management options on pasture and animal productivity in a *Heteropogon contortus* (black speargrass) pasture in central Queensland. 4. Animal production', *Animal Production Science* 50: 284-292.
- Calford, E.M., Gurney, A., Heyhoe, E. & Ahammad, H., 2010, *The effects of an emissions offsets scheme on Australian agriculture*, ABARE, Canberra.
- Campbell, P.K., Beer, T. & Batten, D., 2010, *Greenhouse gas sequestration by algae – energy and greenhouse gas life cycle studies*, CSIRO, Aspendale.
- Carbon Offset Guide Australia, 2010, <www.carbonoffsetguide.com.au>.
- ClimateWorks Australia, 2010, *Low carbon growth plan for Australia*, ClimateWorks Australia, Clayton, Victoria.
- CMT (Centre for Management Technology), 2011, *Algae status report: how far are we from commercialization?*, CMT, Singapore.
- CO2 Group Limited, 2010, *CO2 Group Limited Annual Report 2010*, CO2 Group, Australia.
- Commonwealth of Australia, 2010, *Australia's future tax system review*, Commonwealth of Australia.
- Crossman, N.D, Bryan, B.A & Summers, D.M., in press, 'Carbon payments and low cost conservation', *Conservation Biology*.
- Crossman, N.D., Summers, D.M. & Bryan, B.A., 2010, *Opportunities and threats for South Australia's agricultural landscapes from reforestation under a carbon market*, CSIRO client report.
- CSIRO (Commonwealth Scientific and Industrial Research Organisation), 2009, *An analysis of greenhouse gas mitigation and carbon biosequestration opportunities from rural land use*, CSIRO, St Lucia, Queensland.
- CSIRO, 2010, *Climate variability and change in south-eastern Australia: a synthesis of findings from Phase 1 of the South Eastern Australian Climate Initiative (SEACI)*, CSIRO.
- DAFF (Department of Agriculture, Fisheries and Forestry), 2010, *Climate Change Research Program*, <www.daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research>.
- DAFF, 2011, *Carbon Farming Initiative*, <www.daff.gov.au/climatechange/cfi#biocharcapacitybuilding>.
- Dargusch, P., Harrison, S. & Herbohn, J., 2010, 'How carbon markets have influenced change in the Australian forest industries', *Australian Forestry* 73(3): 165-184.
- DCCEE (Department of Climate Change and Energy Efficiency), 2010a, *National Greenhouse Gas Inventory - Kyoto Protocol Accounting Framework*, DCCEE, Canberra.

DCCEE, 2010b, *Land Use, Land-Use Change and Forestry*, <www.climatechange.gov.au/government/international/lulucf.aspx>.

DCCEE, 2010c, *Design of the Carbon Farming Initiative: consultation paper*, <www.climatechange.gov.au/government/submissions/carbon-farming-initiative.aspx>

DCCEE, 2010d, *National inventory report 2008*, DCCEE, Canberra.

DCCEE, 2010e, *Submission to the Senate Finance and Public Administration Committee inquiry into native vegetation laws, greenhouse gas abatement and climate change measures*, <www.aph.gov.au/senate/committee/fapa_ctte/climate_change/submissions.htm>.

DCCEE, 2010f, *State and territory greenhouse gas inventories 2008*, DCCEE, Canberra.

DCCEE, 2010g, *Australian greenhouse emissions information system*, <<http://ageis.climatechange.gov.au/>>.

DCCEE, 2011, *Carbon Farming Initiative*, <www.climatechange.gov.au/government/initiatives/carbon-farming-initiative.aspx>.

DERM (Department of Environment and Resource Management), 2009, *Identifying the Carbon Potential of Native Vegetation*, Fact Sheet, <www.climatechange.qld.gov.au/pdf/factsheets/5primind-n3.pdf>.

DERM, 2010, *Protecting Queensland's strategic cropping land: A policy framework*, DERM, Queensland.

Drucker, A.G., Edwards, G.B. & Saalfeld, W.K., 2010, 'Economics of Camel Control in Central Australia', *The Rangeland Journal*, 32(1):117-127.

DSE (Department of Sustainability and Environment) 2008, *BushTender: Rethinking investment for native vegetation outcomes. The application of auctions for securing private land management agreements*, DSE, East Melbourne.

DSE, 2011, unpublished information provided to the Garnaut Climate Change review – Update 2011.

DSEWPac (Department of Sustainability, Environment, Water, Population and Communities), 2010, *Species profile and threats (SPRAT) database*, <www.environment.gov.au/biodiversity/threatened>.

Eckard, R.J., Grainger, C. & de Klein, C.A.M., 2010, 'Options for the abatement of methane and nitrous oxide from ruminant production: a review', *Livestock Science* 130:47-56.

The Economist, 2011, "Grim reaping A lack of rain in China threatens to send wheat prices even higher", 26 February 2011.

Edwards, C. & Eigenraam, M., 2011, *An empirical examination of the gains in cost-effectiveness from the use of multiple environmental outcome conservation tenders*, Australian Agricultural and Resource Economics Society 2011 conference paper.

FAO (Food and Agriculture Organization of the United Nations), 2011a, <*FAO Initiative on Soaring Food Prices*, <www.fao.org/isfp/background/en/>.

FAO, 2011b, *Global Food Price Monitor, 3 February 2011*, <www.fao.org/giews/english/gfpm/GFPM_01_2011.pdf>.

FAO, 2011c, *Monthly Food Price Indices, February 2011*, <www.fao.org/fileadmin/templates/worldfood/Reports_and_docs/Food_price_indices_data.xls>.

Fensham, R.J., Fairfax, R.J. & Ward, D.P., 2009, 'Drought-induced tree death in savanna', *Global Change Biology* 15: 380-387, doi: 10.1111/j.1365-2486.2008.01718.x.

- Fensham, R.J. & Guymer, G.P., 2009, 'Carbon accumulation through ecosystem recovery', *Environmental Science & Policy* 12: 367-372.
- FFI CRC (Future Farm Industries Cooperative Research Centre), 2010, *Energy tree crops: renewable energy from biomass could be the driver to large scale adoption of woody crops and to structural improvements to dryland agricultural systems in Australia*, FFI CRC, Western Australia.
- Fischer, G., Hizsnyik, E., Prieler, S., Shah, M. & van Velthuizen, H., 2009, *Biofuels and food security*, OPEC Fund for International Development, Vienna.
- FWPA (Forests and Wood Products Australia), 2009, *The impacts of plantations and native forests on water security: review and scientific assessment of regional issues and research needs*, FWPA, Melbourne.
- Garnaut, R., 2008, *The Garnaut climate change review: final report*, Cambridge University Press, Melbourne.
- Gavran, M. & Parsons, M., 2010, *Australia's Plantations 2010 Inventory Update*, National Forest Inventory, Bureau of Rural Sciences, Canberra.
- GEO (Group on Earth Observations), 2010, *Forest carbon tracking, taking care of our forests*, <www.geo-fct.org/home/fct-initiative-brochure>.
- GHD Hassall, 2010, *The impacts of greenhouse mitigation policies on the demand for agricultural land*, research report, Australian Farm Institute, Surry Hills.
- Gillard, J., 2010, letter to T Windsor MP regarding agreement on 7 September 2010 to form government.
- Gowen, R., Rolfe, J. & Donaghy, P., 2010, *Productivity tradeoffs and synergies for grazing lands in Central Queensland to generate carbon offsets*, Australian Agricultural and Resource Economics Society 2010 conference paper, <<http://purl.umn.edu/59082>>.
- Grace, P.R., Antle, J., Ogle, S., Paustian, K. & Basso, B., 2010, 'Soil carbon sequestration rates and associated economic costs for farming systems of south-eastern Australia', *Australian Journal of Soil Research*, 48: 720-729.
- Green, D., Jackson, S. & Morrison, J., 2009 (eds), *Risks from climate change to Indigenous communities in the tropical north of Australia*. A scoping study for the Australian Government Department of Climate Change, the Western Australian Department of the Environment and Conservation and the Northern Territory Department of Natural Resources.
- Headey, D., Malaiyandi, S. & Fan, S., 2009, *Navigating the Perfect Storm: Reflections on the Food, Energy, and Financial Crises*, International Food Policy Research Institute, <www.ifpri.org/sites/default/files/publications/ifpridp00889.pdf>.
- Heckbert, S., Davies, J., Cook, G., Mclvor, J., Bastin, G. & Liedloff, A., 2008, *Land management for emissions offsets on Indigenous lands*, CSIRO Sustainable Ecosystems, Townsville.
- Hendrix, C., Haggard, S. & Magaloni, B., 2009, *Grievance and Opportunity: Food Prices, Political Regime, and Protest*, International Studies Association convention, <http://cshendrix.files.wordpress.com/2009/06/magahaggahendrix_isa.pdf>.
- Henry, B., Charmley, E., Eckard, R., Gaughan, J. & Hegarty, R., in prep., *Livestock production in a changing climate*, National Climate Change Research Strategy for Primary Industries 2011 conference paper.
- Henry, B. & Eckard, R., 2009, 'Greenhouse gas emissions in livestock production systems', *Tropical Grasslands*, 43: 232-238.

Herzog, T., 2009, *World greenhouse gas emissions in 2005*, WRI working paper, World Resources Institute, <http://pdf.wri.org/working_papers/world_greenhouse_gas_emissions_2005.pdf>.

Hogan, L. & Morris, P., 2010, *Agricultural and Food Policy Choices in Australia*, Australian Bureau of Agricultural and Resource Economics and Science – Bureau of Rural Sciences, Canberra.

Howden, M., Hughes, L., Dunlop, M., Zethoven, I., Hilbert, D. & Chilcott, C. 2003, *Climate change impacts on biodiversity in Australia*, outcomes of a workshop sponsored by the Biological Diversity Advisory Committee, 1–2 October 2002, Commonwealth of Australia, Canberra.

Ignite Energy Resources 2010, *Lignite based BioLogic fertiliser CO₂ sequestration – replacing chemical fertiliser*, <www.igniteer.com/pdfs/Investor_Presentation_May_3_2010.ppt>.

IISD (International Institute for Sustainable Development), 2010, *Earth Negotiations Bulletin*, Volume 12 Number 498, <www.iisd.ca/climate/cop16/compilation.pdf>.

Insurance Facilitators, 2009, *Carbon*, <www.if.net.au/public/carbon.html>.

Keenan, T.D. & Cleugh, H., 2011, *Climate science update for the Garnaut Review*, CAWCR Technical Report No. 036, 2011.

Keith, H., Mackey, B., Berry, S., Lindenmayer, D. & Gibbons, P., 2010, 'Estimating Carbon Carrying Capacity in Natural Forest Ecosystems Across Heterogeneous Landscapes: Addressing Sources of Error', *Global Change Biology*, 16(11): 2971-2989.

Kollmuss, K., Lazarus, M., Lee, C. & Polycarp, C., 2008, *A review of offset programs: trading systems, funds, protocols, standards and retailers*, Research Report, Stockholm Environment Institute, Sweden.

Lal, R., 1999, 'Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effects', *Progress in Environmental Science* 1: 307-326.

Llewellyn, R.S., D'Emden, F.H., 2010, *Adoption of no-till cropping practices in Australian grain growing regions*, Grains Research and Development Corporation, Canberra.

Loyn, R., McNabb, E., Macak, P. & Cheers, G., 2009, *Fauna in eucalypt and pine plantations in the Green Triangle of south-eastern South Australia and south-western Victoria*, Arthur Rylah Institute for Environmental research, Department of Sustainability and Environment, Heidelberg.

Marcar, N., Theiveyanathan, T., Roxburgh, S., Gilfedder, M., Littleboy, M., Almeida, A., Christy, B., Barlow, K., Crawford, D. & Benyon, R., 2010, *Methodology to assess site-specific impacts of plantations on catchment water yields*, CSIRO.

Mata, T.M., Martins, A.A. & Caetano, N.S., 2010, 'Microalgae for biodiesel production and other applications: a review', *Renewable and sustainable energy reviews* 14: 217-232.

MBD Energy Ltd, 2011, *Algal synthesis technology boosted by government funding*, media release, 8 July 2010, <www.mbdenergy.com/catalogue/c5/p246/cp4>.

MLA (Meat and Livestock Australia), 2010, *Australian cattle industry cuts emissions by 6.5% per kg of beef produced*, media release, <www.mla.com.au/About-the-red-meat-industry/About-MLA/Media/Media-releases/Australian-cattle-industry-cuts-emissions-by-6-point-5-per-cent-per-kg-of-beef-produced>.

MPCCC (Multi-Party Climate Change Committee), 2011, *Carbon Price Mechanism*, <www.climatechange.gov.au/government/initiatives/multi-party-committee.aspx>.

NAFI (National Association of Forest Industries), 2009, *Forestry Key to Meeting CPRS Targets*, media release, <www.nafi.com.au/userfiles/media1/Forestry%20key%20to%20meeting%20CPRS%20targets%20030609.pdf>.

NAFI 2010, *Australian climate change policy: forestry and land use*, presentation, United Nations Climate Change Conference, 3 December 2010, Cancun, Mexico, <[www.nafi.com.au/userfiles/publication/Cancun%202010%20-%20Australian%20forest%20policy%20\(NAFI\).pdf](http://www.nafi.com.au/userfiles/publication/Cancun%202010%20-%20Australian%20forest%20policy%20(NAFI).pdf)>.

Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T.B., Ringler, C., Msangi, S. & You, L., 2010, *Food security, farming, and climate change to 2050: scenarios, results, policy options*, International Food Policy Research Institute, Washington.

NFF (National Farmers' Federation), 2011, *Design of the Carbon Farming Initiative*, NFF Submission to the Department of Climate Change and Energy Efficiency, NFF, Canberra.

New Zealand Ministry for the Environment, 2010, *The NZ Emissions Trading Scheme*, accessed 20 December 2010, <www.climatechange.govt.nz/emissions-trading-scheme/about>.

Nicholls, K, 2010, 'Perennial shrubs support productive pastures', *Focus on perennials*, issue 14, December 2010, FFI CRC, Western Australia.

Norris, J, Arnold, S. & Fairman, T., 2010, 'An indicative estimate of carbon stocks on Victoria's publicly managed land using the FullCAM carbon accounting model', *Australian Forestry* 73(4): 209-219.

NRMMC (Natural Resource Management Ministerial Council), 2010a, *Australia's biodiversity conservation strategy 2010-2030*, Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra.

NRMMC, 2010b, *National feral camel action plan: A national strategy for the management of feral camels in Australia*, NRMMC.

NWC (National Water Commission) 2004, *Intergovernmental Agreement on a National Water Initiative*, <www.nwc.gov.au/resources/documents/Intergovernmental-Agreement-on-a-national-water-initiative.pdf>. NWC, Canberra.

NWC, 2009, *Australian Water Reform 2009: Second biennial assessment of progress in implementation of the National Water Initiative, September 2009*, NWC, Canberra.

O'Connell, D., Braid, A., Raison, J. & Handberg, K., 2009, *Sustainable production of bioenergy: a review of global bioenergy sustainability frameworks and assessment systems*, Rural Industries Research and Development Corporation, Canberra.

OECD (Organisation for Economic Cooperation and Development), 2010, *Paying for biodiversity: enhancing the cost-effectiveness of payments for ecosystem services (PES)*, OECD, Paris.

PMSEIC (Prime Minister's Science, Engineering and Innovation Council), 2010, *Challenges at the energy-water-carbon-intersections*, PMSEIC, Canberra.

Polglase, P., Paul, K., Hawkins, C., Siggins, A., Turner, J., Booth, T., Crawford, D., Jovanovic, T., Hobbs, T., Opie, K., Almeida, A. & Carter, J., 2008, *Regional Opportunities for Agroforestry Systems in Australia: A report for the RIRDC/L&WA/FWPA/MDBC Joint Venture Agroforestry Program*, RIRDC, Canberra.

RIRDC (Rural Industries Research and Development Corporation), 2008, *Using methane in intensive livestock industries*, RIRDC, Canberra.

Russell-Smith, J., Murphy, B.P., Meyer, M.C.P., Cook, G.D., Maier, S.W., Edwards, A.C., Schatz, J. & Brocklehurst P., 2009, *Improving estimates of savanna burning emissions for greenhouse accounting in northern Australia: limitations, challenges and applications*, in Russell-Smith, J., Whitehead, P., Cooke, G.D., 2009 (eds), *Culture, ecology and economy of fire management in north Australian savannas: rekindling the Wurrk tradition*, CSIRO, Collingwood.

Sanderman, J., Farquharson, R. & Baldock, J., 2010, *Soil carbon sequestration potential: a review for Australian agriculture*, report prepared for the Department of Climate Change and Energy Efficiency, CSIRO.

Sanders, O., Goesch, T., Hughes, N., 2010, *Adapting to Water Scarcity*, 10.5, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Sheales, T. & Gunning-Trant, C., 2009, *Global food security and Australia*, ABARE, Canberra.

Sheng, Y., Zhao, S. & Nossal, K., 2011, *Productivity and farm size in Australian agriculture: reinvestigating the returns to scale*, Australian Agricultural and Resource Economics Society 2011 conference paper.

Smith, I. & Timbal, B., 2010, 'Links between tropical indices and southern Australia rainfall', *International Journal of Climatology*, DOI: 10.1002/joc.2251.

Smith, P., undated, *Biodiversity benefits of oil mallees*, <www.futurefarmcra.com.au/documents/BiodiversitybenefitsofOilMallees_000.pdf>.

Steffen, W., 2009. *Climate Change 2009: Faster change and more serious risks*. Prepared for the Australian Government Department of Climate Change.

Steffen, W., Burbridge, A., Hughes, L., Kitching, R., Lindenmayer, D., Musgrave, W., Stafford-Smith, M. & Werner, P. 2009, *Australia's biodiversity and climate change*, a report to the Natural Resource Management Ministerial Council commissioned by the Australian Government, CSIRO Publishing.

Stoneham, G., Eigenraam, M. & Bain, D. 2009, *Creating environmental accounts for diffuse-source environmental problems*, paper prepared for the London Group on Environmental Accounting Workshop, Canberra, Australia, 1 May 2009.

Stucley, C., 2010, *Overview of bioenergy in Australia*, Rural Industries Research and Development Corporation, Canberra.

Sustainability matters, 2009, *Algal synthesiser offers renewed hope of rapid CO2 emissions reduction*, <www.sustainabilitymatters.net.au/articles/37285-Algal-synthesiser-offers-renewed-hope-of-rapid-CO2-emissions-reduction>.

Tasmanian Government, 2009, *State policy on the protection of agricultural land 2009*, Tasmanian Government.

TEEB (The Economics of Ecosystems and Biodiversity), 2010, *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB*, <www.teebweb.org/TEEBSynthesisReport/tabid/29410/Default.aspx>.

Tulloch, C., Ahammad, H., Mi, R. & Ford, M., 2009, *Effects of the Carbon Pollution Reduction Scheme on the economic value of farm production*, ABARE, Canberra.

UNEP (United Nations Environment Programme), 2011, *Towards a green economy: pathways to sustainable development and poverty eradication - a synthesis for policy makers*, <www.unep.org/greeneconomy>.

UNFCCC (United Nations Framework Convention on Climate Change), 2010, *Ad hoc working group on further commitments for Annex I Parties under the Kyoto Protocol, fifteenth session, agenda item 3: consideration of further commitments for Annex I Parties under the Kyoto Protocol, revised proposal by the Chair, FCCC/KP/AWG/2010/CRP.4/Rev.4* <unfccc.int/resource/docs/2010/awg15/eng/crp04r04.pdf>.

Wentworth Group of Concerned Scientists, 2009, *Optimising carbon in the Australian landscape: how to guide the terrestrial carbon market to deliver multiple economic and environmental benefits*, Wentworth Group of Concerned Scientists, Sydney.

Whitehead, P.J., Purdon, P., Cooke, P.M., Russell-Smith, J., Sutton, S., 2009, *The West Arnhem Land Fire Abatement (WALFA) project: the institutional environment and its implications*, in Russell-Smith, J., Whitehead, P., Cooke, G.D., 2009 (eds), *Culture, ecology and economy of fire management in north Australian savannas: rekindling the Wurrk tradition*, CSIRO, Collingwood.

Witt, G.B., Noël, M.V., Bird, M.I. & Beeton, R.J.S., 2009, *Investigating long-term grazing exclosures for the assessment of carbon sequestration and biodiversity restoration potential of the mulga lands*, final report for the Department of the Environment, Water, Heritage and the Arts, University of Queensland.

Woinarski, J.C.Z., Russell-Smith, J., Andersen, A.N. & Brennan, K., 2009, *Fire management and biodiversity of the western Arnhem Land plateau*, in Russell-Smith, J., Whitehead, P., Cooke, G.D., 2009 (eds), *Culture, ecology and economy of fire management in north Australian savannas: rekindling the Wurrk tradition*, CSIRO, Collingwood.

Appendix 1: International climate change frameworks and the land sectors

Australia prepares annual greenhouse gas inventories under the rules of the United Nations Framework Convention on Climate Change (UN Framework Convention) and the Kyoto Protocol, as outlined below. While common estimation methods are used for both inventories, and reporting of agriculture emissions is the same in both, reporting of Land Use Land Use Change and Forestry (Changing Land Use) emissions under the UN Framework Convention is more comprehensive than for Australia's Kyoto Protocol accounts.

Kyoto Protocol

Agriculture

Accounting for agriculture emissions is based on activities that cause emissions. It covers only non-carbon dioxide emissions, mainly methane and nitrous oxide. The sources of agriculture emissions 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 while 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-fixing crops and pastures
- prescribed burning of savannas—emissions associated with the burning of tropical savanna and temperate grasslands for pasture management, fuel reduction, and prevention of wildfires
- field burning of agricultural residues—emissions from field burning of cereals, sugar cane and crop stubble.

Agriculture emissions totalled 87 million tonnes carbon dioxide equivalent in 2008, or 16 per cent of national emissions. Emissions in 1990 were very similar (DCCEE 2010a).

Enteric fermentation emissions account for two thirds of Australia's agriculture emissions, or about 10 per cent of total national emissions (DCCEE 2010a). Enteric fermentation emissions declined by 13 per cent between 1990 and 2008, due largely to a fall in sheep numbers of more than 50 per cent (DCCEE 2010a). Beef cattle are the major contributor (80 per cent), followed by sheep and dairy cattle.

Of the other sources, agricultural soils contributed around 17 per cent of agricultural emissions in 2008, followed by savanna burning at 16 per cent, manure management at 4 per cent, and rice cultivation and field burning of agricultural residues, which produced minor emissions.

Changing Land Use

Mandatory Changing Land Use accounting categories are afforestation, reforestation and deforestation. Afforestation and reforestation are described as forests established by direct human action on land that was clear of forest on 31 December 1989. Deforestation is the direct human-induced conversion of land that was forested on to non-forested land. A forest comprises trees with a potential height of at least two metres and crown cover of at least 20 per cent, in patches greater than 0.2 hectare in area.

Once lands are brought into the Kyoto Protocol accounts following afforestation, reforestation and deforestation, emissions and removals on those lands are included in annual accounts.

Afforestation and reforestation represented a sink of 23 million tonnes carbon dioxide equivalent in 2008. Removals have progressively increased since 1990 as forest establishment has expanded. Deforestation declined from 132 million tonnes carbon dioxide equivalent in 1990 to 50 million tonnes carbon dioxide equivalent in 2008.

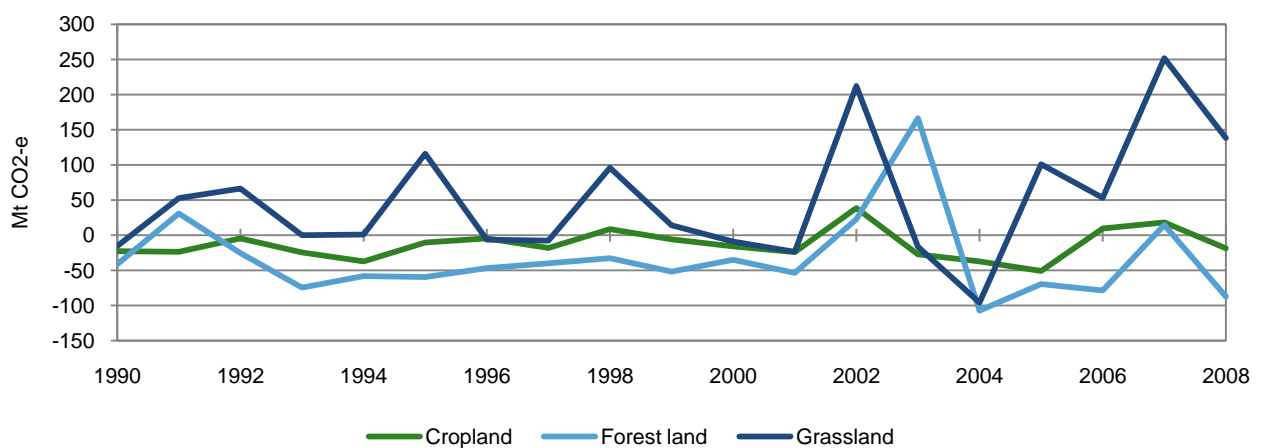
Countries could also elect to include any or all of the voluntary activities Forest Management, Cropland Management, Grazing Land Management and Revegetation in accounting against their emissions targets for the first commitment period. Australia did not elect to include any of these activities in its accounts, because of risks of losses due to fire and drought.

UN Framework Convention

The UN Framework Convention reporting framework for Changing Land Use covers much more land than the area included in Australia's Kyoto Protocol accounts. Whereas the Kyoto Protocol accounts cover only lands on which there has been a deliberate change in land use, reporting under the UN Framework Convention covers all forest land, cropland and grassland. The grassland category includes woody vegetation such as shrubs and sparse trees that do not meet criteria for a forest. Reporting of emissions for these categories in Australia's UN Framework Convention inventory represents about 75 per cent of the total land area (DCCEE 2010d).

Emissions and removals on these lands are heavily influenced by climatic factors. Annual emissions and removals since 1990 are shown in Figure 7. These estimates do not include forests established on non-forest land since 1990 or land converted from forest land to cropland or grassland since 1990, i.e. they cover land that has remained under the same land use since prior to 1990.

Figure 7: Emissions and removals from cropland, forest land and grassland, 1990 to 2008



Source: DCCEE 2010d.

www.garnautreview.org.au

