TRANSFORMING RURAL LAND USE

22

Key points

Rural Australia faces pressures for structural change from both climate change and its mitigation.

Effective mitigation would greatly improve the prospects for Australian agriculture, at a time when international demand growth in the Platinum Age is expanding opportunities.

Choices for landowners will include production of conventional commodities, soil carbon, bioenergy, second-generation biofuels, wood or carbon plantations, and conservation forests.

There is considerable potential for biosequestration in rural Australia. The realisation of this potential requires comprehensive emissions accounting.

The realisation of a substantial part of the biosequestration potential of rural Australia would greatly reduce the costs of mitigation in Australia. It would favourably transform the economic prospects of large parts of remote rural Australia.

Full utilisation of biosequestration could play a significant role in the global mitigation effort. This is an area where Australia has much to contribute to the international system.

Land-use change—the alteration of management practices on a certain type of land cover—has the capacity to transform Australia's, and to a lesser extent the global, mitigation effort. Outside Australia, it is of powerful significance for Australia's immediate neighbours, Indonesia, Papua New Guinea and the other countries of Southeast Asia and the South Pacific. Getting the incentive structures right at home and abroad to realise the enormous potential for biosequestration is a major challenge, and potentially Australia's most important contribution to the global mitigation effort.

This chapter looks more speculatively at some future possibilities that have been given an unreasonably small place in Australian and international discussions of mitigation.

Climate change and climate change mitigation will bring about major structural change in the agriculture, forestry and other land use sectors. With effective global action, climate change mitigation would become the more important force for change. A rising carbon price will alter the cost of land management practices and commodities, depending on their emissions profiles.

On the other hand, without mitigation, and in the next few decades in any case, projected temperature increases and decreased rainfall in some important centres of Australian agriculture are likely to reduce water availability. This will particularly affect industries that rely on irrigation and those that are currently operating near the margins of profitable cultivation. In the longer term, land managers will respond to these dual challenges by pursuing new opportunities in carbon removal (or sequestration), energy production from biomass and low-emissions livestock production. Such opportunities could significantly lower the economy-wide cost of the emissions trading scheme—far below those suggested in the Review's modelling of the costs of mitigation.

Agriculture and forestry will experience the effects of climate change differently, and their prospects for adaptation and emissions mitigation also differ. While these sectors warrant separate consideration, they are inextricably linked. Both provide products and services based on natural systems. The issues they face can be relevant to a single landowner or business. They sometimes compete with each other for land and water. Indeed, the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) incorporate emissions from what is known as the 'agriculture, forestry and other land use sector' into a single reporting framework. As many of the overarching issues relate to these interactions, agriculture, forestry and other land use are considered together in this chapter.

22.1 Drivers of a transformation towards lower emissions

22.1.1 Existing pressures on the agriculture and forestry sectors

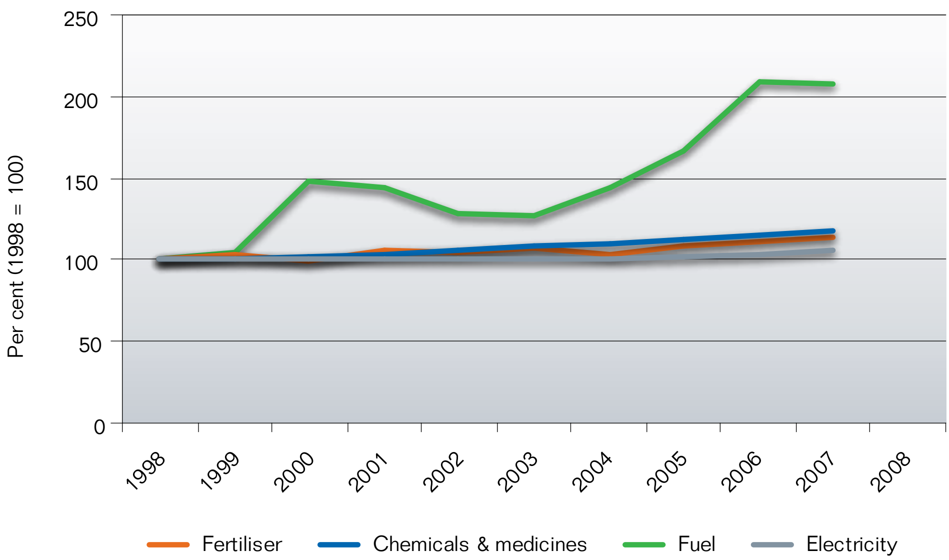
At the end of the 20th century, several factors coincided to place pressure on most Australian agricultural industries. A long period of relatively low real prices for agricultural products was continuing, while costs of established patterns of cultivation were rising. Environmental limits to production came to the fore in the form of dryland and irrigated salinity, soil acidification, soil fertility and structural decline, soil erosion, and increasingly stressed water systems. Governments responded by introducing regulations and establishing environmental markets. The most notable was the 1995 cap and trade system for water, which enabled high-value uses to compete for water in the Murray-Darling Basin. This competition has led to moves away from water-intensive agriculture in some areas. Further reforms to the existing water allocation systems will be implemented in the near future, increasing the impetus for change.

Over the last two decades, agricultural subsectors have been increasingly deregulated, including the dairy industry in the 1980s, the pork industry in the 1990s and the sugar industry in a series of steps. The increase in competition has affected local communities as the geographic location of production and employment has shifted.

Since 2000, several factors have acted in concert to increase commodity prices received by Australian producers. Incomes in developing countries are rising rapidly, leading to higher consumer demand for meat, dairy products and oil seeds. This growth in demand for animal products has increased demand for grain and oilseeds for stockfeed (ABARE 2006). With growth in major developing economies expected to continue for the foreseeable future, a continuation of this strong demand is likely. A series of droughts in Australia and drought and flood in other grain-producing regions of the world have placed further upward pressure on prices. Distortionary biofuels policies in North America and Europe have also contributed to increases in food prices. Some governments have responded to increased food prices by restricting food exports, setting limits on food prices, or both (von Braun 2008). Such controls have exacerbated global price increases and volatility in the rest of the world, and placed stress on developing countries that are dependent on imports.

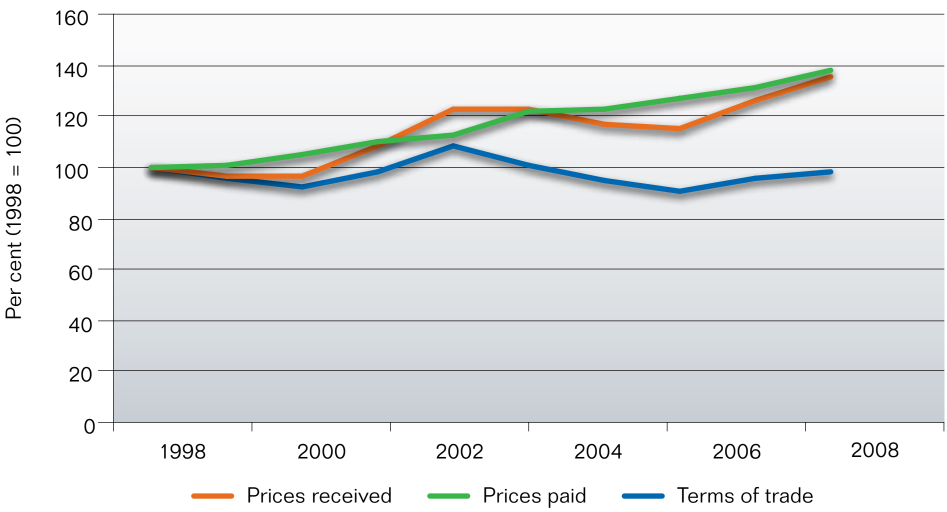
Higher costs for agricultural inputs, particularly for fuel, fertiliser and chemicals, have been observed in recent years, driven primarily by high global prices for petroleum and higher demand for these inputs (Figure 22.1). After a long period in which average farm sales prices fell relative to costs, through the early 21st century, the increase in the cost of inputs has almost been matched by an increase in prices received (Figure 22.2). So far in 2008, a large price increase in farm goods has improved farmers' terms of trade.

Figure 22.1 Prices paid by Australian farmers, 1998–2007



Source: ABARE (2008a).

Figure 22.2 Australian farmers' terms of trade, 1998–2007



Source: ABARE (2008a).

22.1.2 Effects of climate change on food demand and supply

Effects on global food supply and demand

Even with 550 ppm global mitigation, a global average temperature increase of 2.5°C above 1990 levels is the median equilibrium outcome. Temperature increases of between 1°C and 3°C above 1990 levels, and increases in carbon dioxide concentration and rainfall, are associated with an increased potential for global food production, but above this range potential production is expected to decrease relative to current levels (IPCC 2007: 274). The melting of glaciers, leading to sea-level rise, and changes in river flow and monsoon rainfall, are likely to severely affect agricultural production, particularly in Asia. South Asia, sub-Saharan Africa and Australia have been identified as having agricultural sectors that are especially vulnerable to the impacts of climate change.

Domestic food production in many developing countries will be at immediate risk of reductions in agricultural productivity due to crop failure, livestock loss, severe weather events and new patterns of pests and diseases (FAO 2007). Climate change could disrupt ocean currents, which would have serious ramifications for the availability of fish, a major protein source.

Farmers in developing countries are less able to adapt to and effectively manage these risks due to the higher proportion of small-scale and subsistence farms, poorly developed infrastructure and lesser access to capital and technology.

These impacts, together with the considerable increases in population and food demand expected in developing countries, will lead to an increase in global food prices.

Effects on domestic food supply

In Australia, some agricultural industry subsectors will be more vulnerable than others to climate change impacts (see Table 22.1). Enterprises already close to the edge of the ideal climatic range for their dominant agricultural activity will be particularly at risk.

Changes to local climate and water availability will be key determinants of where agricultural production occurs and what is produced. Climate change is expected to reduce yields for many crops and place upward pressure on Australian food prices (Quiggin 2007). Climate change impacts will also drive a range of adaptation measures.

Table 22.1 Vulnerability of Australia's agricultural industry to the biophysical impacts of climate change, by subsector

Industry subsector	Vulnerability to biophysical impacts of climate change
Sheep (dryland)	High
Sheep (irrigated)	Very high
Grain (dryland)	High
Grain (irrigated)	Very high
Beef cattle (dryland)	High
Dairy cattle (irrigated)	Very high
Pigs (intensive)	Low
Poultry (intensive)	Low
Other (horticulture & viticulture)	Moderate (high for wine quality)
Forestry	Moderate
Fisheries	High for some species, but largely unknown

Note: Vulnerability is a measure of impacts (exposure + sensitivity) and adaptive capacity (see also Figure 6.1).

22.1.3 Drivers introduced by climate change mitigation

Existing mitigation policies

In Australia, emissions mitigation has been pursued for several years, particularly in the forestry sector, as many existing mitigation policies and agreements recognise and provide credit for carbon removal by forests. Land clearing has slowed significantly since 1990, primarily due to regulatory controls.

Forests and plantations established after 1990 accounted for net removal of about 23 Mt CO_2-e in 2006, and will make an important contribution towards meeting Australia's commitment under the Kyoto Protocol.

Mitigation through forest sinks has been encouraged by demand for emissions reduction certificates or offset credits under a number of domestic programs, including the New South Wales Greenhouse Gas Reduction Scheme, the West Australian Government's requirement for some project approvals to involve carbon offsetting, and the Commonwealth-administered Greenhouse Friendly program.

At the same time, there has been increasing interest in a range of low- to negative-cost emissions reduction activities in the agriculture sector, which generally also provide productivity benefits, such as fertiliser management.

It is important that an emissions trading scheme with comprehensive coverage replaces and expands incentives for mitigation in the agriculture and forestry sectors. For activities not included in the scheme, other policies will be required to drive mitigation.

An emissions trading scheme

When it is introduced by the Commonwealth Government, an emissions trading scheme will be the primary instrument driving emissions mitigation in Australia. The effect of the scheme on the agriculture and forestry sectors will depend on several factors:

- rules for their coverage or inclusion under the scheme
- direct and indirect emissions intensities
- availability and cost of mitigation options
- availability of alternatives for commodity production.

In relation to the treatment of forestry and agriculture under an emissions trading scheme, the Review proposes the following approach:

- Those undertaking reforestation should be allowed to opt in for coverage (that is, liability for emissions and credit for net removal from the atmosphere) from scheme commencement.
- 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.
- Policies should apply to the agriculture sector to drive mitigation until it is covered under the scheme.

The over-riding idea should be one of providing incentives for net sequestration within a comprehensive carbon accounting framework.

Full coverage of the agriculture, forestry and other land use sector would involve accounting for all greenhouse gas emissions and removal on managed land, including soil carbon, forests and wooded lands (regardless of the date of establishment) and life-cycle emissions from, and carbon storage by, harvested wood products. The 2006 IPCC Inventory Guidelines provide a useful framework for the development of a comprehensive approach to accounting. However, emissions reported do not necessarily have to align exactly with emissions liabilities or credits under an emissions trading scheme.

The mitigation policy modelled by the Review (Chapter 11) does not reflect this emissions trading scheme design. Consequently, the analysis in the following section and in Chapter 11 cannot be taken as a reflection of what would occur under the Review's recommended emissions trading scheme design. They take account of only a small part of Australia's biosequestration potential.

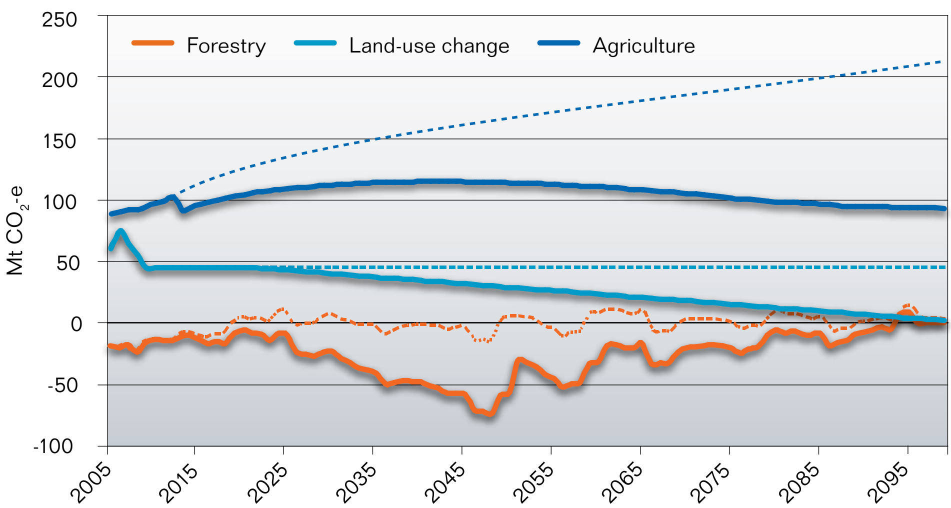
22.2 Economic modelling results: a possible future?

The modelling presented in Chapter 11 considered possible outcomes for Australia's economy without mitigation, and also considered the impacts of an emissions trading scheme under three technology assumptions: 'standard', 'backstop' and 'enhanced'. The focus of this section is on the transition for the agriculture and forestry sectors in Australia in a world with effective global action on mitigating emissions (stabilisation at 550 ppm CO_2-e or 450 ppm CO_2-e under standard technology assumptions). It does not take into account some of the large opportunities for biosequestration discussed later in this chapter. It reflects continuing application of current Kyoto Protocol rules as adopted by Australia—including Australia's decision so far not to opt in to the more expansive coverage of Article 3.4 of the Kyoto Protocol, and relevant clauses of the Marrakesh Accords.

22.2.1 Overview of emissions outcomes

Projected non-combustion emissions from agriculture, forestry and land-use change for the no-mitigation and 550 standard technology scenarios are presented in Figure 22.3.

Figure 22.3 Non-combustion emissions for agriculture, forestry and land-use change for the no-mitigation and 550 standard technology scenarios



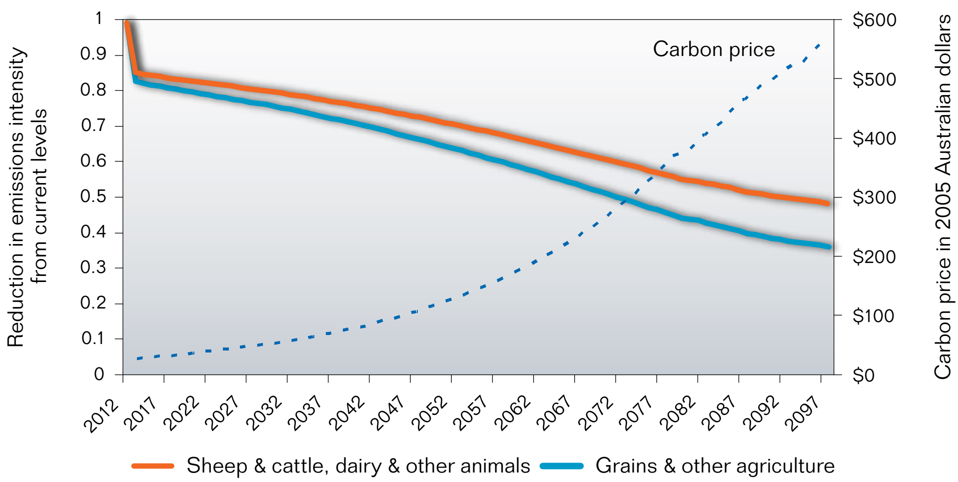
Note: These results were generated using MMRF. Emissions under no mitigation are shown with the dashed lines. Emissions from fuel combustion in the agriculture and forestry sectors, such as the on-farm use of petrol and diesel in farm machinery, are not included.

With the 550 standard technology scenario, non-combustion emissions from all three sources are lower than under the no-mitigation scenario; however, agricultural emissions still increase slowly to around 30 per cent above 2005 levels by mid-century, before declining to 5 per cent above 2005 levels in 2100.

By 2100, in the 550 standard technology scenario, the agriculture sector is responsible for more than 41 per cent of total Australian emissions and is by far the largest source of emissions under the standard technology scenarios. The agriculture sector as a whole has a lower known technological and economic potential to reduce emissions intensity than other sectors of the economy. There is currently a lack of well-quantified and well-costed mitigation methods available to agriculture. While the modelling exercise allows reductions in emissions intensity, it does not identify individual mitigation methods and technologies. Rather, an assumed marginal abatement cost curve was used (US EPA 2003, 2006).

Known and expected opportunities account for the mitigation observed in the agriculture sector, and emissions intensity progressively falls throughout the century (Figure 22.4). The cost of this was attributed to the subsector through a marginal abatement cost curve. Following the literature, emissions intensity is assumed to improve more rapidly for grains and other agriculture than for the animal subsector, reflecting greater potential for mitigation at a given carbon price. The level of aggregation of subsectors in the MMRF model means that low-emissions agricultural products are not individually identified. However, the marginal abatement cost curves have been developed to broadly reflect the potential for substitution of high-emissions with low-emissions agricultural products.

Figure 22.4 Change in emissions intensity over time in response to carbon price, 550 standard technology scenario, 2006–2100



Note: These results were generated using MMRF.

The rate of emissions intensity improvement in the agricultural sector in the first half of the 21st century under the 550 standard technology scenario reflects the limited mitigation options available at the prevailing carbon price. As the carbon price increases, it becomes efficient to reduce agricultural emissions further. After 2050, the higher carbon price leads to emissions reductions that would require a widespread change in agricultural practices and/or consumer tastes, or the implementation of new technologies. By 2100, output from the sector is almost four times larger than in 2005, but agricultural emissions are just above 2005 levels and emissions intensity levels have decreased by more than half relative to current levels.

A scenario was run through the model assuming emissions reductions from forestry activities were not eligible under the global emissions trading scheme. To achieve the same level of mitigation without forestry activities, the carbon price is consistently 30 per cent higher than when forestry activities are included and when standard technology assumptions are used. The higher carbon price leads to higher gross world product costs. In Australia, GNP in 2100 is half a percentage point lower in 2100 when forestry is not included, compared to the same mitigation scenario where it is included. This sensitivity illustrates the potential impact of excluding forestry activities from emissions accounting. It also demonstrates how the availability of large, low cost sources of mitigation can reduce the global costs of mitigation policy. Such sources could include soil carbon or biochar, or a new technology to reduce emissions from livestock.

If new, low-cost mitigation options emerge for the agriculture sector, there will be greater reductions in the agriculture and forestry sectors' emissions, at a lower cost than the model predicts. An alternative, lower-emissions future for the agriculture and forestry sectors is described in section 22.3.

22.2.2 Productivity and macroeconomic effects on agriculture and forestry

After 2050 the benefits of mitigation (avoided climate change) start to become evident when the 550 standard technology scenario is compared to the no-mitigation scenario. With unmitigated climate change, all agricultural subsectors experience a reduction in output by the end of the century as temperatures increase and water availability decreases as a result of climate change. Water-intensive or water-dependent industries such as grain, farm dairy and horticulture are particularly affected.

Under the 550 standard technology scenario, a large proportion of climate change impacts are avoided. Those sectors that benefit more from the avoided impacts of climate change, and are affected less by rising carbon prices, show higher levels of output in 2100 than in the no-mitigation scenario.

The forestry sector, which includes environmental plantings, is stimulated by the introduction of an emissions trading scheme. Demand for offset credits (from carbon removals) increases demand for forestry output, which include logging and services associated with plantations, in the 550 standard technology scenario. The forestry sector increases by more than 20 times by 2100 and its share of overall activity more than doubles relative to 2005 levels.

While activity in the agriculture sector increases by 2100, agriculture has a falling share of total output. The composition of the agriculture sector changes: output from sheep and cattle, grains and dairy decreases relative to the no-mitigation scenario, while the share of other animal products and other agriculture, including horticulture, increases.

22.2.3 Changes to production of livestock and other animals

The sheep and cattle industries are highly emissions intensive, and there are currently limited opportunities for the reduction of methane emissions. Other meat products, such as pork and chicken, are less emissions intensive. While the model allows for substitution between existing meat products in response to the carbon price, there is no explicit consideration of alternative sources of animal protein that are not currently widely consumed, such as kangaroo meat.

In response to a carbon price on the agricultural sector, households move away from meat and meat products because of the higher price of these commodities under an emissions trading scheme. Households also move away from beef and lamb towards less emissions-intensive meat, such as chicken and pork. A similar pattern of change is observed in Australia's export of meat and meat products under the mitigation scenarios.

While output in the sheep and cattle industries is reduced in comparison to the no-mitigation scenario, real production in the 550 standard technology scenario still increases by around 150 per cent from current levels by 2100.

22.2.4 Land use, land-use change and forestry

Modelling land use, land-use change and forestry emissions is complex and difficult, and the results should be seen as a guide only to the possible implications of the forestry sector's response to a carbon price.

The forestry sector responds to the carbon price by establishing new plantations. In the modelling, three types of forestry activity were assumed to be available—softwood and hardwood timber plantations and environmental (carbon sequestration) plantations. All types have establishment costs, but carbon plantings do not have transport or harvesting costs.

The forestry modelling for Australia was incorporated into MMRF (see Box 11.1). The analysis took in land currently used for all forestry and agricultural activities, including minimally adjusted pastures used for livestock production in remote areas of Australia. The extent of new land dedicated to forestry is determined by the relative value of forestry activities compared to the value of agricultural activities competing for the land.

The model did not explicitly consider possible restrictions on forestry expansion for conservation reasons, the potentially negative environmental impacts of forestry expansion (such as reduced water runoff), the potential implications arising from climate change, or regional capacity constraints in timber processing or other factors leading to landholder resistance to land conversion. However, there are assumed restrictions on potential take-up rates, which may limit the potential increase in forestry activity.

Forestry experiences a significant change between the no-mitigation and effective global mitigation scenarios. Under the no-mitigation scenario, emissions from forestry rise over the study period, to the point where it is a net source of emissions in some years (Figure 22.3). By contrast, under the 550 standard technology scenario forestry is consistently an emissions sink, with removal from the atmosphere increasing particularly after the late 2020s, and reaching almost 60 Mt CO_2-e in 2050.

The fluctuations in forestry emissions are due to assumptions regarding harvesting periods for timber plantations and the maturing of environmental plantations. Carbon plantations are assumed to reach maturity after 45 years, after which no further carbon removal occurs. After 2050 in the 550 standard technology scenario, net sequestration from forestry activities declines and approaches zero by 2100.

After 2050, few new plantations are established due to rising land prices and competition with higher-value agricultural uses. By the end of the century, just over half of the new land under forestry is dedicated to carbon plantings.

Far more land goes to forest sinks in the 450 standard technology scenario; this reflects the higher carbon price. In the 450 scenario, higher carbon prices are reached earlier in the century when land values are lower, so that forestry activities, especially carbon plantations, are more competitive.

In the Review's modelling, land use and land-use change emissions—for instance, a liability for landowners for emissions from clearance, or the opportunity costs of reduced clearance—were not included. Rather, land use and land-use change emissions are imposed in the models. Land use emissions for Australia largely represent emissions from clearing of regrowth as part of agricultural management—rather than clearing for new land. In the no-mitigation scenario, emissions from land clearing were assumed to remain at 44 Mt CO_2-e per year throughout the modelling period, based on a simple extrapolation from projections in the most recent national emission projections (DCC 2008c). Under the modelled policy scenarios, clearing emissions are assumed to decline in a linear fashion in response to the carbon price, to 28 Mt CO_2-e by 2050 and reaching zero by 2100.

22.2.5 Biofuels and bioenergy

The modelling exercise assumed that the emissions intensity of fuels such as petrol and diesel would decrease over time through an increase in the share of biofuels. However, the potential impacts of increased domestic demand for first-generation biofuels is not reflected in competition between different uses of land. Due to the difficulty in making predictions about second-generation biofuel technologies and costs, the modelling did not include any progress in these technologies under a carbon price. If domestic production of bioenergy were to increase, there could be greater competition for land that is currently assigned in the model to food or forestry production.

22.3 An alternative future

There are major opportunities to reduce emissions and increase greenhouse gas removal in the agriculture, forestry and other land use sectors. Not all of these are incorporated in the modelling results. Some combination of them could reduce radically the cost of mitigation in Australia and transform the economic prospects of rural Australia, especially of remote areas. Options include reducing emissions from major sources (sheep and cattle), and carbon dioxide removal in forests, other types of vegetation and soil. Producing biomass as a feedstock for biofuels and other forms of energy could also reduce emissions. These biosequestration activities appear to offer the largest emissions reduction potential.

These sectors could reduce emissions and exposure to an emissions price through other means too—improved management of manure, changed methods of rice cultivation and reduced fuel and electricity consumption are all promising options. However, because these options are likely to offer relatively small emissions reduction benefits, they are not considered in this chapter.

Land managers will choose among mitigation options depending on the nature of their land, the price and availability of water, carbon prices, and the development of new markets (for example, for biofuels). For some commodities, proximity to markets and commodity and input prices will also determine patterns of production. Estimates of some technical potential for emissions reduction and removal in the agriculture, forestry and other land use sector are summarised in Table 22.2 and Box 22.2. It is recognised that these potentials are calculated in a context of uncertainty and will in many cases not be easy to realise without substantial investments in proving and developing the systems. Further, since some of the identified processes overlap, their mitigation potential is not intended to be aggregated. Rather, they are listed to provide a broad sense of the mitigation possibility if policy, program and research efforts were more heavily focused on endeavours that recognised the integration of climate change mitigation with the management of agriculture, forests and other land use issues.

Table 22.2 Potential for emissions per annum reduction and/or removal from Australia's agriculture, forestry and other land use sectors

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.

Table 22.2 Potential for emissions per annum reduction and/or removal from Australia's agriculture, forestry and other land use sectors *(continued)*

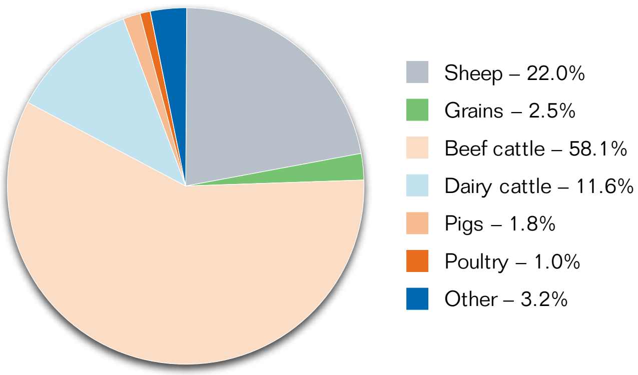
Process	Potential	Key assumptions
Removal by soil—cropped land	Removal potential of 68 Mt CO_2-e per year for 20–50 years	Conservative management changes assumed (e.g. conservation tillage), not pasture cropping. Changed practices implemented on all cropped land (38 million ha).
Removal by soil—high-volume 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 ha).
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 ha 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 ha required for production (cultivating algae as a feedstock) or more than 10 million ha (using other plants).

Sources: Beeton (pers. comm.); Chicago Climate Exchange (2008); DCC (2008a); de Klein & Eckhard (2008); Grace et al. (2004); IPCC (2006); Mackey et al. (2008); NAFI & TPA (2007); Chan (unpublished); Polglase et al. (2008); Russell-Smith et al. (2004); Wilson & Edwards (2008).

22.3.1 Livestock production

In Australia, enteric fermentation emissions from livestock (mainly sheep and cattle) account for about 67 per cent of agricultural emissions (DCC 2008b). Cattle and sheep production also accounts for a significant proportion of emissions from agricultural soils, and beef production is responsible for some emissions from savanna fire and land clearing. Agricultural emissions, allocated by subsector and not including emissions due to land clearing, are presented in Figure 22.5.

Figure 22.5 Contribution to Australia's agricultural emissions, by subsector, 2005



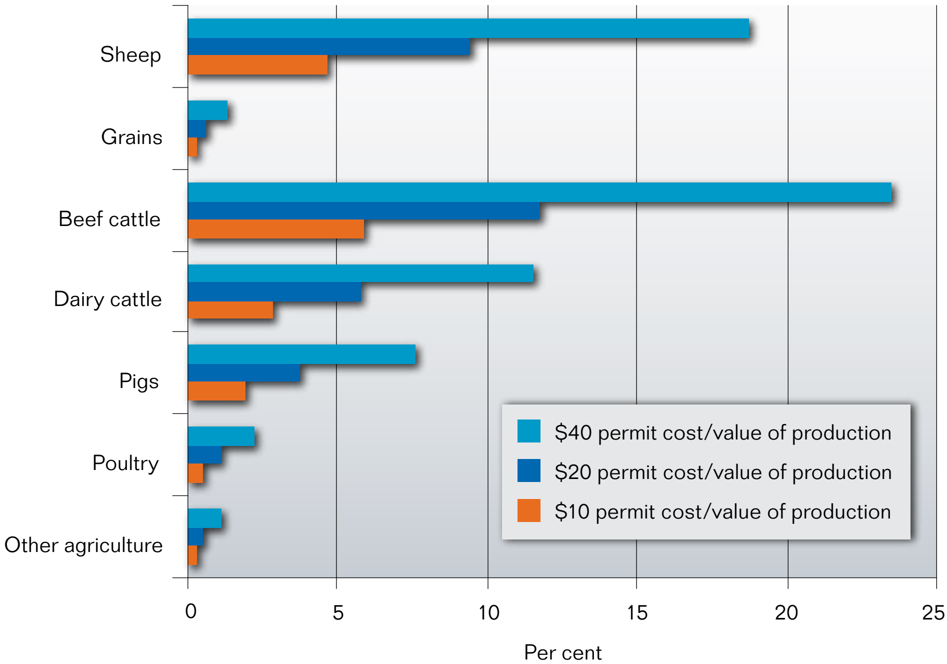
Source: DCC (2008d).

Figure 22.6 shows the ratio of total emissions permit costs to the value of production by subsector in the agricultural industry for a range of permit prices. Clearly, among the agricultural subsectors, a carbon price will affect cattle and sheep producers most heavily.

Over time, increasing permit prices will encourage reduced use of energy and emissions-intensive inputs and drive mitigation of livestock emissions. Current options for the mitigation of methane emissions include:[1]

- **Practices to increase productivity**—Breeding pattern manipulation, better location of watering points and greater use of products that promote growth can all increase productivity without increasing food consumption and resultant emissions (Eckhard 2008; Howden & Reyenga 1999). These activities are already widely practised.
- **Nutritional management**—The addition of monesin, dietary fats and lipids can reduce ruminant emissions by 20 to 40 per cent (Beauchemin et al. 2008; Howden & Reyenga 1999). Nitrous oxide emissions from livestock can also be reduced through dietary changes (Miller et al. 2001; van Groenigen et al. 2005). These options are technically feasible, but are generally not yet cost effective.
- **Vaccination, biocontrols and chemical inhibitors**—Trials of immunisation on sheep found methane emissions reductions of almost 8 per cent (Wright et al. 2004). This is a longer-term category—it may be decades before this is feasible on a large scale.

Figure 22.6 Ratio of emissions permit costs to value of production, by subsector, 2005



Note: Emissions due to land clearing have not been attributed to the agricultural subsectors responsible. Includes indirect emissions from purchase of electricity, does not include transport.

Sources: DCC (2008d); ABS (2008).

The effectiveness of these mitigation options may be limited and research and development is likely to continue for some time.[2] To the extent that there were no cost-effective mitigation options, under an emissions trading scheme methane-emitting livestock producers would be required to purchase permits for their emissions, which would lead to an increase in costs of sheep and cattle production. In the short to medium term, the impact on meat prices and consumption may not be large, given that global demand is expected to remain strong and permit prices will be a relatively small component of the cost of animal products (see Table 22.3).

According to the Australian Bureau of Agricultural and Resource Economics (ABARE) (2008b), since 1960:

- real retail prices for beef have remained roughly steady, as has per capita consumption
- lamb prices have increased by about 30 per cent and per capita consumption has fallen by 70 per cent
- pork prices have fallen by about 10 per cent and consumption has nearly tripled
- poultry meat prices have fallen by more than 75 per cent and there has been an almost ninefold increase in per capita consumption.

Table 22.3 Impact of emissions permit prices on cost of meat production

Commodity	Kg CO_2-e emitted per kg of produce[a]	Cost increase at $40/t permit price ($/kg)	2006 retail prices ($/kg)	Price increase at $40/t permit price (%)
Lamb & mutton[b]	16.8	0.67	12.20	5.5
Beef & veal	24.0	0.96	15.38	6.2
Pork	4.1	0.16	11.87	1.3
Poultry meat[c]	0.8	0.03	3.16	0.9

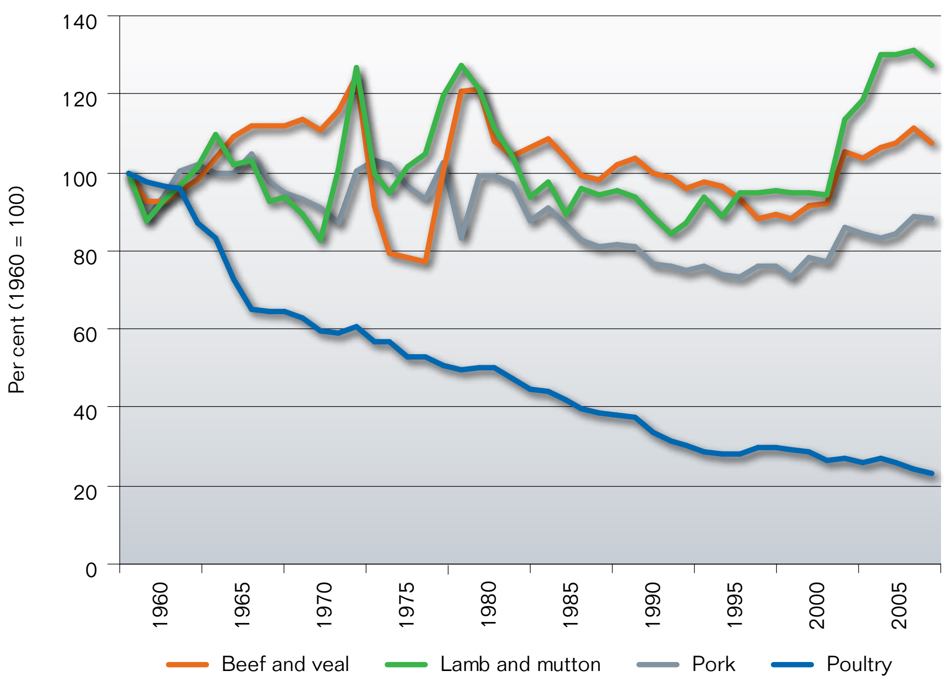
a This does not take into account any emissions resulting from deforestation, which are largely attributable to the beef cattle industry.

b Emissions from sheep production were allocated between sheep meat and wool in proportion to the gross value added by each commodity.

c Emissions from poultry production were allocated between poultry meat and eggs in proportion to the gross value added by each commodity.

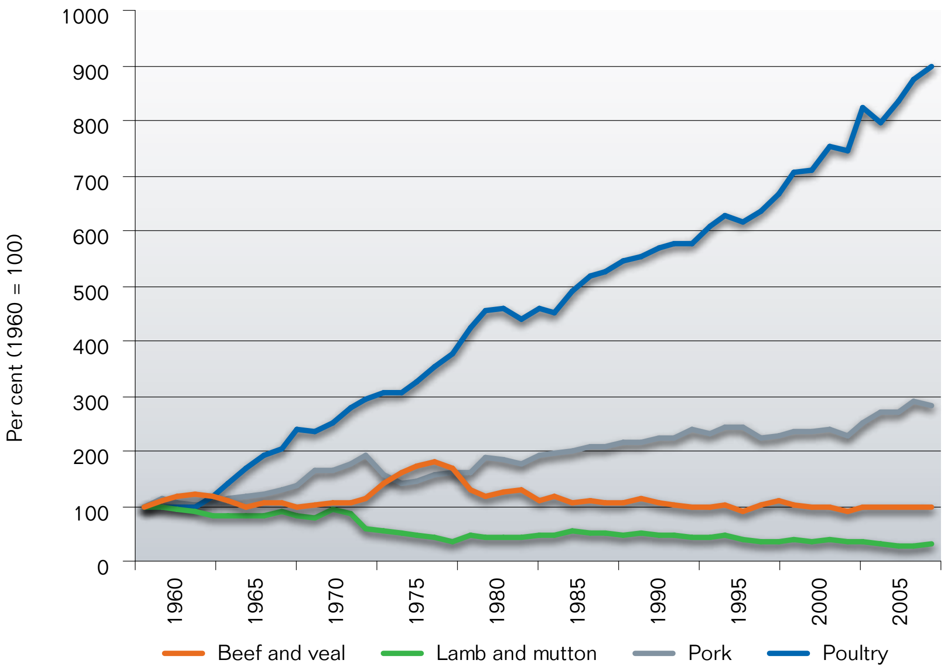
The ABARE data suggest that, over time, consumption patterns in Australian households are highly responsive to changes both in price and conditions of supply (see figures 22.7 and 22.8). Australian consumer preferences have changed over time, and will continue to change into the future.

Figure 22.7 Australian real retail prices for meat, 1960–2006



Source: ABARE (2008b).

Figure 22.8 Australian per capita consumption of meat, 1960–2006



Source: ABARE (2008b).

As permit prices increase, higher prices for some meats are likely to lead to further changes in consumption patterns.

Sheep and cattle production is highly vulnerable to the biophysical impacts of climate change, such as water scarcity (see Table 22.1). This factor, combined with increased costs for methane emissions, could hasten a transition toward greater production and consumption of lower-emissions forms of meat, such as chicken, fish and pork. Demand for these products is projected to remain strong.

Australian marsupials emit negligible amounts of methane from enteric fermentation (Klieve & Ouwerkerk 2007). This could be a source of international comparative advantage for Australia in livestock production. For most of Australia's human history—around 60 000 years—kangaroo was the main source of meat.[3] It could again become important. However, there are some significant barriers to this change, including livestock and farm management issues, consumer resistance and the gradual nature of change in food tastes.

Edwards and Wilson (2008) have modelled the potential for kangaroos to replace sheep and cattle for meat production in Australia's rangelands, where kangaroos are already harvested. They conclude that by 2020 beef cattle and sheep numbers in the rangelands could be reduced by 7 million and 36 million respectively, and that this would create the opportunity for an increase in kangaroo numbers from 34 million today to 240 million by 2020. They estimate that meat production from 175 million kangaroos would be sufficient to replace the forgone lamb and beef meat production, and that meat production from kangaroos would become more profitable than cattle and sheep when emissions permit prices exceed $40 per tonne CO_2-e. The net reduction in greenhouse gas emissions would be about 16 Mt CO_2-e per year.

22.3.2 Soil management

Carbon dioxide removal by soil

Atmospheric carbon dioxide is removed from the atmosphere by plants and transferred to soil through active plant roots or the decomposition of plant and animal matter.

Soil carbon is both a source and a sink of greenhouse gases. Soil carbon can be restored and increased through active management of the biological system. It can be affected by employing conservation tillage; increasing the use of mulch, compost and manure; and changing the vegetation cover on soil. Soil carbon can be built with the use of further soil additives, including calcium-bearing silicates (Engineering and Physical Sciences Research Council 2008) and biochar (see section 22.3.4). Tests are now being conducted using lignite as a catalyst for accumulation of soil carbon (LawrieCo 2008).

Soil carbon can be lost—for example, as a result of land clearing, erosion or drought (Lal 2004). Soil carbon built up by conventional cropping with reduced tillage (such as 'zero-till' methods) may only affect soil close to the surface, and is often returned to the atmosphere within months (J. Baldock 2008, pers. comm.; Lal 2004; Chan unpublished). By contrast, carbon dioxide removed by actively growing roots of living plants and stored in soil humus can provide long-term storage. Increased soil microbe activity associated with increased vegetation is essential for soil carbon sequestration. This promotes plant availability of soil minerals and other nutrients, improves soil structure and humus content, increases water retention and increases oxygen respiration to the atmosphere (Jones 2008; Parr & Sullivan 2005; Post & Kwon 2000).

All things being equal, the potential for removal of carbon by soil is in the following order (least to greatest): degraded soils and desertified ecosystems, cropland, grazing lands, forest lands[4] and permanent crops. Some estimates are available for the removal potential of soil (Table 22.4).

There are other benefits from building soil carbon. It increases oxygen and retention of moisture when combined with other nutrients and minerals, leading to improved soil health (Grace et al. 2004; Jones 2007; Lal 2007; Wentworth Group of Concerned Scientists 2008). As a result, a number of Australian land managers are already making on-farm changes to build soil carbon (Jones et al. 2008). Australia is well positioned to further increase carbon dioxide removal by soil, due to the sheer size of its land mass and the ability of its farming sector to adopt new management practices.

Table 22.4 Technical potential for CO_2 removal by soil—selected estimates

Activity	Location	Carbon dioxide removal estimate[a]	Source
Conservation and sustainable land management practices	Worldwide	3.3 Gt (± 1.1 Gt) CO_2 per year (for 50 years)	Lal (2004)
		1.6–3.2 Gt CO_2 per year (for 50 years)	Paustian et al. (2004)
Adoption of sustainable stocking rates, rotational grazing and seasonal use grazing practices	United States rangelands (previously degraded)	0.3–1.3 t CO_2 per ha per year	Chicago Climate Exchange (2008)
Zero till or minimum tillage	United States	0.5–1.5 t CO_2 per ha per year	Chicago Climate Exchange (2008)
Conservation tillage	Australia-wide	25% increase in carbon retained, compared to conventional tillage	Valzano et al. (2005)
Conservation tillage	South-eastern Australia	43.3-46.6 t CO_2 per ha over 20 years in high rainfall region (on average between 2.1 and 2.3 t per year)	Grace et al. (2004)
Changes in cropping practice	New South Wales	2 t CO_2 per ha per year	Chan (unpublished)
Sowing of crops into perennial pastures (growth of perennial grasses alongside crops)	Trial sites in New South Wales with good soils	5-10 t CO_2 per ha per year (up to 20–30 t under good conditions)	C. Jones (2008, pers. comm.)
Pasture cropping (pasture type: Rhodes, Lucerne, Siratro, Bambatsi)	Loam soil, 'northern agriculture region', Western Australia	5.2 t CO_2 per ha per year	T. Wiley (2008, pers. comm.)

a Soil carbon will eventually reach a new equilibrium, and carbon removals in soil will cease. Removals may continue for 20–50 years before a new equilibrium is reached.

Notes: Technical potential refers to what is physically possible and does not take into account the influence of emissions reporting requirements or cost effectiveness. Some units have been converted from original source data.

A range of biophysical, economic and social constraints must be overcome in order for this potential to be realised on a large scale, although it is already technically feasible. To be pursued on an optimal scale, carbon removal by soil would require recognition under an emissions trading scheme, a sufficient carbon price and potentially the assurance that those undertaking it will not be held liable for soil carbon emissions that result from non-anthropogenic release.[5]

The barriers to recognising carbon dioxide removal by soil could be overcome within decades, presenting soil carbon as a new commodity for landowners. Though the potential is not as great as in high-quality soil, removal by soil may offer an alternative to other forms of biosequestration in areas of low rainfall or scarce water supply.

Nitrous oxide emissions

Nitrous oxide emissions that result from soil management can be reduced through currently feasible activities—fertiliser management, soil and water management, and fertiliser additives (de Klein & Eckhard 2008). These mitigation activities can significantly reduce costs. Organic additives are low-emissions alternatives to conventional fertiliser that are already available. Further research and development may help to identify new biological products that are appropriate for fertiliser production, and could also improve the efficiency of chemical fertilisers (Hargrove 2008).

Nitrification inhibitors on fertiliser have been shown to reduce nitrous oxide emissions by up to around 80 per cent (de Klein & Eckhard 2008). Nitrification inhibitors for livestock also have potential, although data are limited (de Klein & Eckhard 2008; Whitehead 2008).

Building soil carbon may have implications for nitrous oxide and other emissions, for example increases that may arise from chemical fertilisers (Changsheng et al. 2005; Grace et al. 2004). There needs to be a comprehensive and robust carbon market, and a market for other environmental externalities (such as forms of pollution), to ensure sustainable decision making and to avoid suboptimal outcomes.

22.3.3 Plantations and production forests

Forests and plantations established after 1990 already contribute to reportable mitigation of Australia's emissions, consistent with the provisions of the Kyoto Protocol. In 2006, afforestation and reforestation accounted for net removal of about 23 Mt CO_2 from the atmosphere. This could increase to about 50 Mt CO_2 per year by 2020 (NAFI & TPA 2007).

The profitability of harvested forestry systems can be improved if carbon is included as an additional, saleable product. Analysis by Polglase et al. (2008) concludes that carbon payments could increase the profitability of hardwood and softwood sawlog systems, but not of pulpwood. Carbon revenue has a lower impact upon pulpwood production because rotation periods are relatively short and these systems have less opportunity to store carbon compared with longer rotation sawlog systems.

There will be significant financial opportunities for landholders who intend to maintain permanent forest cover. However, participation in the carbon market will also carry risks, especially for landholders who intend to change from forestry to another land use and, to a lesser degree, for those who intend to harvest their forests. Permits or credits generated as a growing forest removes carbon dioxide from the atmosphere will need to be surrendered when the forest is harvested.

There is scope to reduce the carbon liability incurred when trees are harvested if inventories, and the emissions trading scheme, recognise carbon stored in harvested wood products. The provisions of the Kyoto Protocol do not account for carbon in harvested wood products. However, the 2006 IPCC Inventory Guidelines provide detailed guidance on how to estimate the contribution of harvested wood products to emissions and removals. The approach requires estimation of emissions from the decay of all wood products in the 'products in use' pool and would be likely to result in an increase in Australia's reported greenhouse gas emissions (G. Richards 2008, pers. comm.).

There are flaws in the approach. This is an important issue that warrants further analysis and then international discussion. The objective should be to credit genuine, multiyear sequestration of carbon in harvested wood products.

A large switch in land use toward production forestry would have additional consequences that might be negative (such as impacts on water supply) or positive (for example, mitigating dryland salinity and assisting with habitat restoration), depending on the type of forestry and the land use it replaces. These externalities should be addressed through the creation of market-based instruments for other ecosystem services, such as water quantity and quality, biodiversity, air filtration, and abatement of salinity and erosion.

22.3.4 Biofuels

If a biofuel is to have environmental and economical value it must be produced sustainably and contain more energy than was used to produce it. The net reduction in emissions must be secured at a cost that is competitive with alternative mitigation opportunities. Perverse incentives allow production of some biofuels that do not meet these criteria (Oxburgh 2008). A poorly conceived biofuel production process could:

- produce less liquid fuel energy than is used in production
- over the life cycle of the process, emit the same quantity of greenhouse gases per unit of liquid fuel energy as fossil fuels
- place upward pressure on food prices through competition with food production for arable land.

Subsidies and mandated targets for biofuels distort the market. The correct way to support mitigation through biofuels involves placing a price on all greenhouse gases arising from the production process and the combustion of the biofuel. This is achieved through including inputs into and the use of biofuels comprehensively in the emissions trading scheme.

Global production of biofuels in 2005 amounted to roughly 1 per cent of total road transport fuel consumption (Doornbosch & Steenblik 2007). Satisfying the global demand for liquid fuels with current (first-generation) biofuel technologies would require about three-quarters of the world's agricultural land (Oxburgh 2008). First-generation biofuels can therefore never amount to more than a minor supplement. In the future, second-generation biofuels, using resources that are not applied to food production, will be valuable.

Box 22.1 Biofuel production methods

Biofuels are produced in three main ways: through fermentation (ethanol), extraction and chemical processing of oils (biodiesel), and gasification (syngas and biochar). Biodiesel has several advantages over ethanol, among them that it requires less energy for production (Durrett et al. 2008).

Ethanol accounts for more than 90 per cent of current global biofuel usage. It is produced by fermentation of material rich in sugar and starch, such as sugar cane, corn, sugar beets, potatoes, sorghum and cassava. Compared with gasoline, use of ethanol from Brazilian sugar cane is estimated to reduce emissions by 90 per cent, while use of corn ethanol yields an estimated emissions reduction of only 15 to 25 per cent (IEA 2007).

Biodiesel can be produced from vegetable oils, used cooking oils and animal fats. Oily seeds that can be used for biodiesel include palm oil, rape (canola), soy and sunflower. Oxburgh (2008) has noted that *jatropha curcas* can be used as a feedstock for biodiesel and is cultivated on marginal land in Southern Africa, India and Southeast Asia. An assessment of the costs and benefits of cultivating *jatropha curcas* in arid regions of Australia unsuitable for food production is warranted. Considerations would need to include the degree to which it presents a pest risk to Australian native fauna or habitat. In some parts of Australia *jatropha curcas* is a declared noxious weed and growing or importing it is illegal (Western Australia Department of Agriculture and Food 2007).

Gasification involves conversion of biomass into 'syngas'—a mixture of hydrogen, carbon monoxide and other gases. Syngas can be converted directly to electricity, hydrogen or other chemicals, including liquid fuels. The biochar left over after gasification is high in carbon. Biochar degrades very slowly and has been proposed for use as a fertiliser and to build soil carbon (J. Baldock 2008, pers. comm.; Johnson et al. 2007).

Biofuels can be produced using second-generation technologies from waste biomass, lignocellulosic materials or algae. Australian native trees offer a wide range of possibilities. Mallee eucalypts, for example, can be grown on marginal arid and semi-arid lands, including land that seems to be in the process of conversion out of wheat growing by the warming and drying of southeast Australia. The mallee green top can be harvested perennially as a biofuel feedstock. The growing of mallee can lessen dryland salinity and assist in habitat restoration without competing directly with fibre production from the forestry sector. Mallee also contributes directly to mitigation through storage of carbon in its massive root system.

Biofuel production using algae can be concentrated in terms of land use (see Table 22.5). Its essential requirement is energy from sunshine. Algae can absorb carbon dioxide from the atmosphere and thrive on concentrations of the gas from combustion wastes. They do particularly well in saline environments, which are abundant in Australia and have no alternative commercial uses.

Trials of the production of second-generation biofuels are already proceeding, although there are as yet no full-scale production facilities in operation. It could qualify for commercialisation support under the innovation proposals of Chapter 18, and will be encouraged by a rising carbon price. Commercial production of second-generation biofuels could reasonably be anticipated before 2020.

Table 22.5 Estimated oil yield per ha for biodiesel production

Biofuel feedstock	Estimated oil yield (litres per ha per annum)[a]
Cottonseed	200–400
Soybean	400–600
Sunflower	900–1100
Groundnut/peanut	1000–1200
Canola/rape	1100–1300
Jatropha curcas	1200–1400
Coconut	2200–2400
Palm	2400–2600
Algae	> 30 000[b]

a Yield numbers are subject to considerable geographic and temporal variation. In the cases of palm and coconut, yield numbers represent production from mature plants and do not reflect periods of lower production during plantation establishment.

b Theoretical calculation based on photosynthetic efficiency and growth potential.

Sources: Durrett et al. (2008); Hu et al. (2008).

22.3.5 Other forms of bioenergy

Biomass can be converted to other forms of energy, such as heat and electricity. Biomass could be the basis for 'negative emissions' energy if it is coupled with carbon capture and storage or secure storage of biochar. While biomass offers the only promising way of making clean liquid fuels for vehicles, there are other ways of generating electricity cleanly, so that biofuel is likely to be the early target of commercialisation (Oxburgh 2008).

Polglase et al. (2008) assessed the potential economic outcomes and environmental impacts across Australia of agroforestry for dedicated bioenergy and integrated tree processing (that is, integrated production of bioenergy, activated carbon and eucalyptus oil), based on various species of mallee and other eucalypts. They conclude that dedicated bioenergy and integrated tree processing systems are unlikely to be profitable unless they are close to processing facilities. This is due to the high cost of production (harvesting and transport) relative to the low product price for wood energy. Lehmann (2007) suggests that, in the United States, biochar production in conjunction with bioenergy from pyrolysis could become economically attractive at an emissions permit price above US$37 per tonne.

22.3.6 Environmental carbon plantings

Australia has large areas of land, much of which would be suitable for carbon plantings and revegetation (see Table 22.6).

Table 22.6 Area of selected land uses in Australia[a]

Land use	Area (million ha)
Agricultural land	425
Grazing land	358
Cropping land	38
Other agricultural purposes	2
Agriculturally unproductive	28
Forests and wooded lands	571
Plantation forests	2
Native forests	147
Wooded lands	422
Savanna[b]	190
Settlements	3

a Data are taken from a number of sources and some categories of land use classifications are overlapping (e.g. between wooded lands and grazing land, and also between those categories and savanna).

b Savanna is defined as biogeographic regions in northern Australia that are dominated by a wet–dry climate and have landscapes dominated by grasslands or woodlands, not forests (Tropical Savanna Cooperative Research Centre 2008).

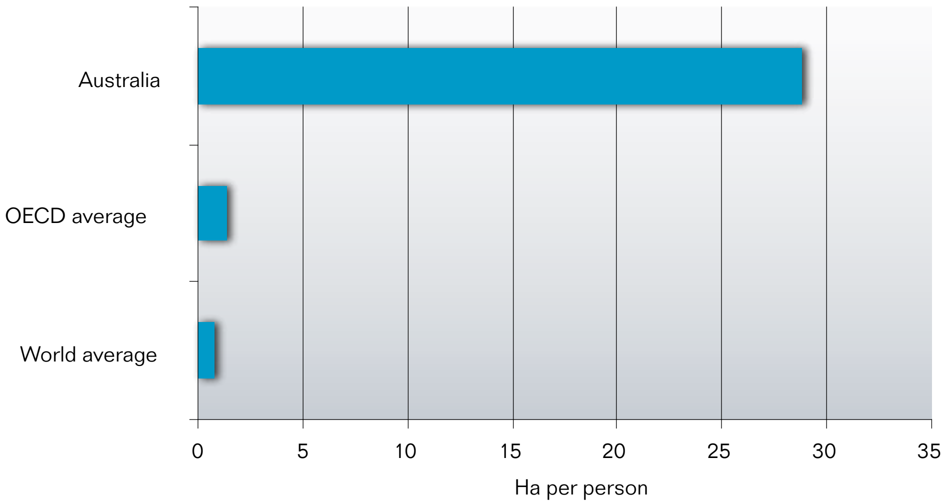
Sources: Gavran & Parsons (2008); DAFF (2008); ABS (2008); FAO (2008); Savanna Explorer (2008).

There are about 28.8 ha of forest and wooded land for every person in Australia (FAO 2008). This is the largest area of forest and wooded land per person among OECD countries and the second largest globally (see Figure 22.9).

In addition to land area, the amount of additional carbon dioxide that can be removed from the atmosphere by existing forests and woodlands and through revegetation of cleared lands is determined by the local climate, the fertility of the substrate, the characteristics of the plant species and the impact of land use history in reducing carbon stocks below the land's carrying capacity.

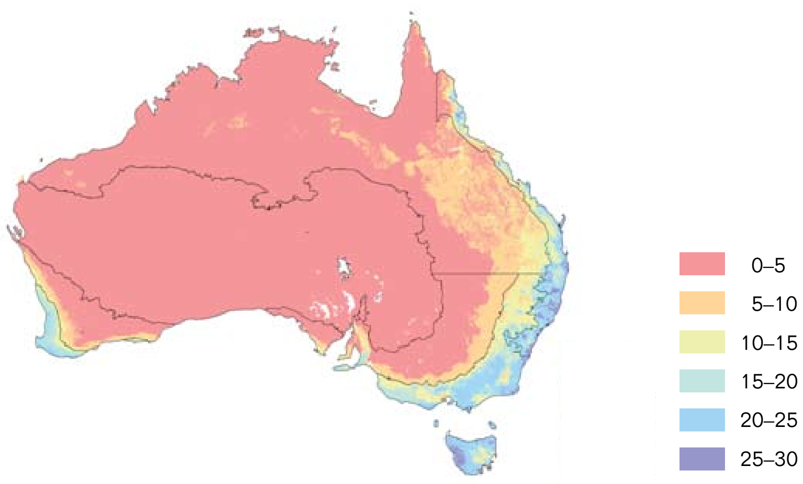
Polglase et al. (2008) have undertaken extensive analysis of the opportunities for carbon farming across Australia, taking account of climatic and soil suitability, species characteristics, the likely profitability of carbon farming compared with current land use and the potential impact on rainfall interception and biodiversity benefits. They modelled environmental plantings of mixed species with an open woodland structure, as well as monocultures of eucalypts and pines. Taking account of climatic and soil suitability, they find that there is about 200 million ha of land suitable for carbon plantings (see Figure 22.10) with potential revenue of up to $40 billion per year. This does not suggest that all land will be planted, rather it will depend on land availability, social attitudes, investment and farming models, and intersection with other policy (for example, on water and planning).

Figure 22.9 Per capita area of forested and wooded land, 2005



Source: FAO (2008).

Figure 22.10 Carbon removal potential for environmental plantings (tonnes CO_2-e per ha per year)



Source: Polglase et al. (2008).

Opportunities for profitable carbon farming have no harvesting or transportation costs and location is not constrained by proximity to processing facilities. Moreover, the carbon payment can be an annuity and financial returns are not delayed by years or decades until trees are harvested.

Polglase et al. (2008) found that carbon farming in Australia could remove about 143 Mt of carbon dioxide from the atmosphere annually, based on the following assumptions:

- There is a carbon price of $20 per tonne CO_2-e.
- Carbon farming would take place in areas where it would generate sales revenue of at least $100 per ha per year more than current land use.
- Carbon plantings would be restricted to areas where rainfall interception would be less than 150 mm per year.

A total of 9.1 million ha were identified as being suitable for carbon farming under these criteria and, compared with current land uses, the additional revenue that would be realised is estimated at $1.9 billion per year. The most significant opportunities are in south-eastern Australia (west of the Great Dividing Range and extending through Victoria and New South Wales up to the Queensland border), southern and south-eastern South Australia and parts of Tasmania and south-west Western Australia. (Polglase et al. note that their results are based on a particular set of assumptions in relation to variables that will differ across regions.)

22.3.7 Conservation forests

As provisions for carbon accounting become more comprehensive, carbon dioxide removal from the atmosphere could be a substantial new source of revenue for managers of national parks and forests set aside for conservation. However participation in carbon markets would also entail risks. Liability for emissions arising from fires would be the most significant risk, and would require management responses. Some but not most forests are already close to their carbon carrying capacity.

The IPCC default values for temperate forests are a carbon stock of 217 tonnes carbon per ha and net primary productivity of 7 tonnes of carbon per ha per year (IPCC 2000). However these IPCC estimates may be conservative, particularly for intact forests. Mackey et al. (2008) have shown that the stock of carbon for intact natural forests in south-eastern Australia is about 640 tonnes per ha, with an average net primary productivity of 12 tonnes per ha per year. They estimate that the eucalypt forests of south-eastern Australia could remove about 136 Mt CO_2-e per year (on average) for the next 100 years.

22.3.8 Savanna

About a quarter of Australia is covered by savanna woodlands and grasslands, and much of this land is owned and managed by Indigenous Australians (Tropical Savanna Cooperative Research Centre 2008). The upgrading of savanna management has substantial mitigation potential, and would also have positive effects for biodiversity conservation and for Indigenous land managers.

Under its implementation of the Kyoto Protocol, Australia can only account for carbon dioxide removed on land that was cleared at 1 January 1990, and most savanna areas do not satisfy this provision. Future carbon accounting provisions should include all greenhouse gases removed by and emitted from managed lands.

This would provide significant revenue opportunities for land managers. It would also require the management of risks, especially if liability for emissions resulting from non-anthropogenic activities—such as fire and the effects of drought—were brought to account.

Savanna fires are the principal source of greenhouse gas emissions in the Northern Territory, and a significant source of Australia's agricultural emissions. Ignitions of savanna fires are frequently anthropogenic (Russell-Smith et al. 2004). Reducing savanna fires can significantly increase biosequestration and protect carbon stored in vegetation sinks. Actions to reduce the area burnt include seasonally targeted management strategies such as fire breaks, early and seasonal burning, and fuel reduction burns. For example, the West Arnhem Land Fire Abatement project, which applies traditional Indigenous burning practices to 28 000 km^2, has reduced annual emissions by an average of 145 000 tonnes CO_2-e over the three years of the project, at a cost of around $15 per tonne (excluding the cost of establishing the project) (Tropical Savanna Cooperative Research Centre 2008; Whitehead et al. in press).

Box 22.2 The potential for biosequestration in arid Australia

Australia has the largest area of woodlands and forest per capita among OECD countries. These vast areas have a large and varied potential for biosequestration. To date, the focus of Australia's biosequestration efforts has been on plantation forests, encouraged, and distorted, by transportation of the limited Kyoto rules into various Australian arrangements. However, Australia enjoys a potential international comparative advantage in carbon trading through its large areas of marginal pastoral country.

Arid and semi-arid rangelands currently make up about 70 per cent of Australia's land mass, or around 5.5 million km^2. Eighteen per cent of this area consists of chenopod shrublands, native tussock grasslands, and woodlands and shrublands that are dominated by mulga (*Acacia aneura*) in eastern Australia, within the 200 to 500 mm annual rainfall zone.

Considerable degradation of these rangelands has been caused by marginal sheep and cattle grazing. It is estimated that these rangelands could absorb at least half of Australia's current annual emissions or some 250 Mt for several decades. A carbon price of $20 per tonne would provide up to a tenfold increase in income for property holders in this region if current practices were replaced by land restoration through a strategic property management program. The mitigation gains are potentially so large that it is important for Australia to commence work on program design and implementation even before the issues of coverage, national and international, are fully resolved.[6]

22.4 Barriers and limits to a low-emissions future

22.4.1 Ability to estimate or measure emissions and removals

More reliable and cost-effective ways to measure or estimate net emissions are needed in the land use sector. Without reliable estimation, it is difficult to include the sector in an emissions trading scheme.

Estimation of emissions and removal by soils is particularly difficult. There are models—such as the Rothamsted soil carbon (RothC) and GRC-3 (DCC 2008a)—but actual samples often provide different results. Soil carbon is characterised by spatial, seasonal and annual variation. Sampling is intensive and costly, and data are limited. Emissions estimation is also difficult for nitrous oxide and native forests.

Resources should be directed, as a priority over the next few years, to overcoming gaps in emissions data and measurement issues for the agriculture, forestry and other land use sectors, in order to include all of the sector's emissions in accounting and potentially in an emissions trading scheme. In addition, training will be needed to ensure that Australia has the skills needed for monitoring and verification.

The same issues arise in relation to Australia's developing country neighbours. Australia has been helpful in sharing knowledge of carbon measurement techniques in Papua New Guinea, Indonesia and elsewhere. Extending this work can be a large Australian contribution to the global mitigation effort.

22.4.2 Emissions accounting rules

If emissions removal processes are not recognised in accounting protocols, they cannot assist in meeting emissions obligations—which reduces the incentive to pursue them.

Accounting should be as broad as possible in the land use sector, particularly if it is included in an emissions trading scheme. This would minimise the likelihood of perverse incentives. With incomplete coverage (for example, exclusion of emissions from deforestation), a carbon price could provide a financial incentive to clear land for biosequestration or bioenergy even though this could result in a net increase in emissions.

The accounting framework for Australia's emissions under the Kyoto Protocol is not comprehensive. The dampening effect this has on the take-up of biosequestration was evident in the Review's modelling results, which assumed continuation of existing emissions accounting rules. As new global emissions accounting methods are developed, alternative technologies and forms of biosequestration should be considered. Australia should advocate movement towards comprehensive monitoring, reporting and recognition of emissions from land use.

It is also important that Australia take full advantage of whatever international accounting rules are in place. The Marrakesh Accords (UNFCCC 2002) of the

Kyoto Protocol determined that any Annex I party (such as Australia), in addition to claiming emission reductions from afforestation, reforestation and deforestation (under Article 3.3 of the Protocol), could (under Article 3.4 of the Protocol) 'choose to account for anthropogenic greenhouse gas emissions by sources and removals by sinks … resulting from … revegetation, forest management, cropland management, and grazing land management'. Australia has opted not to account for emissions in these areas. While there are valid concerns about the impact of bushfires on emissions, and these need to be addressed, it is in Australia's interests to implement as wide-ranging a definition of human-induced greenhouse gas emissions as possible.

It will be important to account for all emissions—including those caused by natural processes—although it may not be appropriate to include all emissions in an emissions trading scheme. Clear rules will be needed about how non-anthropogenic emissions, such as those caused by drought and fire, might be managed.

The potential contribution of biosequestration, much of it at relatively low cost, to the mitigation task is immense. This is true for the world, and particularly true for Australia. Comprehensive emissions accounting as a basis for the emissions trading scheme's application to agriculture, forestry and related sectors could meet a major part of Australia's mitigation effort. The exclusion of comprehensive accounting from the modelling of the Review's costs of mitigation is a large source of conservatism in the estimates of the costs of mitigation in Australia.

22.4.3 The high cost of mitigation in the agriculture sector

The agriculture sector lacks cost-effective mitigation options for some major sources of emissions. Most methane abatement options are costly—for example, reducing emissions through nutritional management can result in higher costs for animal feed, farm labour and animal health. The biosequestration options, if properly accounted and rewarded, are quantitatively much more important in the mitigation story.

Nevertheless, there are promising research avenues for reductions in agricultural emissions. Large-scale, and widely shared, public good research in this area is warranted.

The transaction costs of full inclusion of agriculture in an emissions trading scheme would be high. There are around 130 000 agricultural establishments in Australia (ABS 2007), each with a diverse emissions profile. Inclusion of agriculture in an emissions trading scheme will involve a trade-off between accuracy and cost. Both will be significantly influenced by the threshold set for coverage and the point of obligation. There will be a large role for collective action among farmers, or private broking functions, to reduce the costs of individual farmers' interaction with an emissions trading scheme.

Notes

1 As discussed in section 22.2, not all of these mitigation options were assumed to be available in the modelling.

2 First, there are doubts about whether reductions from nutritional management and biological treatments persist over time (Guan et al. 2006; McAllister & Newbold 2008). Second, assuming these interventions reduce methane emissions, these savings could be offset or even exceeded by the indirect emissions involved in implementing the mitigation measure—for example, the cultivation and transport of high-quality feed (Beauchemin et al. 2008; Howden & Reyenga 1999).

3 Kangaroo meat is currently used for human consumption and pet food. By volume, total kangaroo meat production declined by about 22 per cent between 2002 and 2007. This was due to a reduction in harvest quotas necessitated by a decline in the kangaroo population under severe drought conditions. Over the same period the proportion of kangaroo meat used for human consumption increased from about 40 per cent to about 60 per cent, resulting in an increase in the value of kangaroo meat production of about 15 per cent in real terms (ABARE 2008b).

4 Australian research has found that converting land to forest (afforestation or reforestation) can have variable outcomes in terms of soil carbon (Guo & Gifford 2002; Paul et al. 2002).

5 Soil emissions resulting from drought or fire would be potentially large. It may be appropriate to consider rewarding and penalising landowners only for changes in emissions that result from anthropogenic activities (for example, changed practices). Government may also seek to avoid such liability and be reluctant to agree to reporting arrangements such as those set out under Article 3.4 of the Kyoto Protocol.

6 Based on information supplied by Professor Bob Beeton, Chair of the Commonwealth State of the Environment Committee.

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