# The Carbon Challenge for Mixed Enterprise Farms

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## Abstract

As part of its climate change policy the Australian government has introduced a Mandatory Renewable Energy Target (MRET) scheme and is also attempting to introduce a Carbon Pollution Reduction Scheme (CPRS). Using as a case study a main agricultural region of Australia, this paper examines how farming systems in this region may be affected by the medium term policy settings of these two schemes. A bio-economic model of the region's farming systems is developed and used to assess the schemes' impacts on the nature and profitability of the farming systems. Results show a range of profit and enterprise impacts across the range of farming systems. Farms as providers of biomass for electricity generation and small users of electricity are liable to benefit from the MRET scheme, with the extent of benefit depending on the price offered for biomass. By contrast, the CPRS is liable to more profoundly affect farming systems, especially if agriculture is included in the scheme. The impacts of the CPRS on agriculture are mostly conditional on: the amount of free permits allocated to agriculture, the value of trees as carbon sinks, the extent of pass-through of CPRS-related costs onto agriculture and emission permit prices. Dependent on these factors, farm profits can increase by up to 20 percent or decrease by over 30 percent, relative to the 'no CPRS' or 'business-as-usual' case. If agriculture is covered by the CPRS, and emission permits and tree growth rates are sufficiently high then optimal farm plans typically involve a combination of reduced livestock numbers, the planting of permanent stands of trees on marginal farmland and other changes to the enterprise mix on farms that reduce emissions.

**Keywords**: agriculture, greenhouse gases, economic modelling, sequestration

## 1. Introduction

A range of national and international initiatives are being formulated to curb emissions of greenhouse gases in order to reduce the prospect of dangerous climate change. Australia's commitment to reduce emissions includes implementing a Mandatory Renewable Energy Target (MRET) scheme and adopting a Carbon Pollution Reduction Scheme (CPRS), the latter being proposed to commence in 2011.

On August 19 the Australian Parliament passed the Renewable Energy (Electricity) Amendment Bill 2009 and the Renewable Energy (Electricity) (Charge) Amendment Bill 2009. These bills require the Mandatory Renewable Energy Target (MRET) scheme to ensure that 20 per cent of Australia's electricity generation will be based on renewable sources by 2020. This scheme will increase the supply of renewable energy fourfold and mean that in ten years time the amount of electricity coming from renewable sources like biomass, solar, wind and geothermal will be around the same as all of Australia's current household electricity use. Broadacre agriculture is likely to have a role in the MRET scheme through provision of biomass that will replace some coal in the generation or co-generation of electricity.

The CPRS, by contrast, impacts more broadly than electricity generation through its emissions trading system that will use carbon permits to regulate greenhouse gas emissions from many sectors. As outlined in its White Paper (Commonwealth of Australia 2008) the CPRS would ensure a national commitment to a minimum unconditional reduction in emissions by 5 per cent below 2000 levels by 2020 (projected to be a 27 per cent reduction in per capita terms). A further 15 per cent reduction below 2000 levels by 2020 (projected to be a 34 per cent reduction in per capita terms) was conditional on global agreements that would signal substantial restraint on global emissions. In May 2009, however, the Australian government announced it would raise its longer term target for emisions reduction to be 25 per cent below 2000 levels by 2020, if the world agreed to an ambitious global deal to stabilise levels of CO2 equivalent in the atmosphere at 450 parts per million or lower (Department of Climate Change 2009a). Moreover, although it was initially agreed that sufficient emission permits would be allocated to ensure trades of permits at commencement would be around AUD$20 (Garnaut 2008), this was revised such that permits would cost $10 per tonne of $CO_2$ -e in 2011-12, with a transition to full market trading from 1 July 2012.[1] In May 2009 the Australian government also increased the potential assistance available to emissions intensive trade exposed industries.

Under the proposed CPRS (Commonwealth of Australia 2008), the decision on whether to include agriculture in the scheme will be announced in 2013. If the decision is made to include agriculture then it would be included in 2015 at the earliest.

In my experience, not many farmers nor farm management consultants seem to be aware of the impacts of agriculture's exclusion from the scheme. Even if agriculture is not a direct participant in the scheme other sectors covered by the scheme, such as electricity generators and bulk fuel distributors, will pass on their higher business costs to users of their goods and services, including agriculture. Farmers who use inputs whose prices are raised through the operation of the CPRS will face higher costs of production and potentially lesser profits (Keogh and Thompson 2008).

The preliminary investigation by Keogh and Thompson (2008) of the CPRS impacts on different types of agricultural businesses in Australia concluded that "under a Medium emission price scenario[2], the CPRS will potentially result in a 5–10 percent reduction in average broadacre farm cash margins relative to a business-as-usual scenario, with the impact much greater under higher emission price scenarios" (p. 25). They also forecast that if agriculture becomes covered by the CPRS then there would be a "100 percent reduction in farm cash margins relative to business-as-usual even in the short term, for broadacre farm enterprises involving ruminant livestock" (p. 25). They note however, that if farm businesses are granted emissions intensive trade exposed status and thereby receive 90 percent of required emission permits free, then the negative impact of the CPRS is substantially less, causing farm cash margins to be reduced by between 10 and 20 percent for most broadacre farm enterprises, relative to business-as-usual.

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[1] By illustration, the Department of Climate Change (2009b) suggests that in 2012-13 the permit price could be $29 per tonne. This price is based on DCC's estimation of world carbon price in 2012-13.

[2] The medium scenario commences with a price of $30/tonne CO2-e in 2010, which increases by 6.5% per annum to reach $106 by 2030.

Keogh and Thompson (2008) admitted that their analysis of farm-level impacts of the CPRS was preliminary and underpinned by several assumptions and limitations. For example, their analysis excluded the possibility of on-farm sequestration activity to offset emissions and neither was there any opportunity for the farm's emissions to be lessened through altering enterprise mix, input use or production technology. These were serious deficiencies potentially leading to an over-statement of the impacts of the CPRS at the farm-level.

Tulloh *et al.* (2009) examined various CPRS scenarios for a range of Australian agricultural industries. Their analysis assumed that only electricity, fuel and freight prices would increase because of the CPRS. They did not allow for any economy-wide changes in the cost of labour or capital that may occur due to the CPRS. They estimated that at 2015, if agriculture was covered by the CPRS then farm cash incomes would reduce by between 8.5 to 13 percent for the mixed livestock-crops industry; by 5.7 to 9.3 percent for the wheat and other crops industry, and by 12.2 to 16.7 percent for the sheep industry, depending on cost pass-through assumptions. These authors did not report on the extent of profit reductions. The farm-level impacts of the CPRS they reported were greater than the impacts earlier reported by Ford *et al*. (2009) who suggested that 'Once agriculture is included in the CPRS, the short to medium-term (to 2020) effects of the scheme on Australian agricultural activity levels and costs are projected to be relatively small.' (p. 28).

This research paper complements these few studies on the farm-level impacts of the CPRS by using bioeconomic farm modelling that firstly captures farm level emissions and the likely cost imposts associated with the CPRS; secondly farm-level enterprise switching is permissible and thirdly emission reduction and offset activity is allowed. Unlike previous studies this paper reports impacts on farm profits rather than solely reporting cost or income changes. This study also reports the initial possible impacts of the recently announced new targets of the MRET scheme. A broadare farming region in south-western Australia is used a case study to illustrate both schemes' impacts.

The paper is structured as follows. The next section outlines the farm modelling approach and scenarios modelled. Then the results are presented and discussed. In the final section a set of conclusions is presented.

## 2. Methods

### 2.1 Farm modelling

This research uses a current version of the whole-farm bioeconomic model MIDAS (Model of an Integrated Dryland Agricultural System), originally developed in the mid-1980s (Kingwell and Pannell 1987) but subsequently revised and applied to other farming regions (Kingwell 2002; O'Connell *et al.* 2006; Gibson *et al.* 2008; Kopke *et al.* 2008). The model utilises mathematical programming to determine profit-maximising strategies for management of farming enterprises. Mathematical programming models have three components (i) an objective function (ii) alternative activities for attaining the objective and (iii) activity constraints (Kingwell and Pannell 1987).

MIDAS is a steady-state optimisation model that assumes an average weather-year, with the model's objective function being maximisation of the net return to capital and management invested in the farming enterprise. Net return is attained by deducting all operating costs, overhead costs, depreciation and opportunity costs associated with farm assets (exclusive of land) from production receipts. The several hundred activities in MIDAS include alternative rotations on each of eight soil classes (S1-S8), crop sowing opportunities, feed supply and feed utilisation by different livestock classes, yield penalties for delays to sowing, cash flow recording, and machinery and overhead expenditures. Constraints include resource restrictions such as availability of land, labour and capital plus various logical constraints and transfer rows.

The model jointly takes into account the biological, managerial, financial and technical aspects of a dryland farming system. One of the major strenghts of MIDAS is its ability to address a range of whole-farm issues (Pannell 1996). The MIDAS model used in this paper represents a typical

2000 hectare farm in the central grainbelt of Western Australia (see Figure 1). The types and areas of the various land management units that comprise the farm are listed in Table 1.

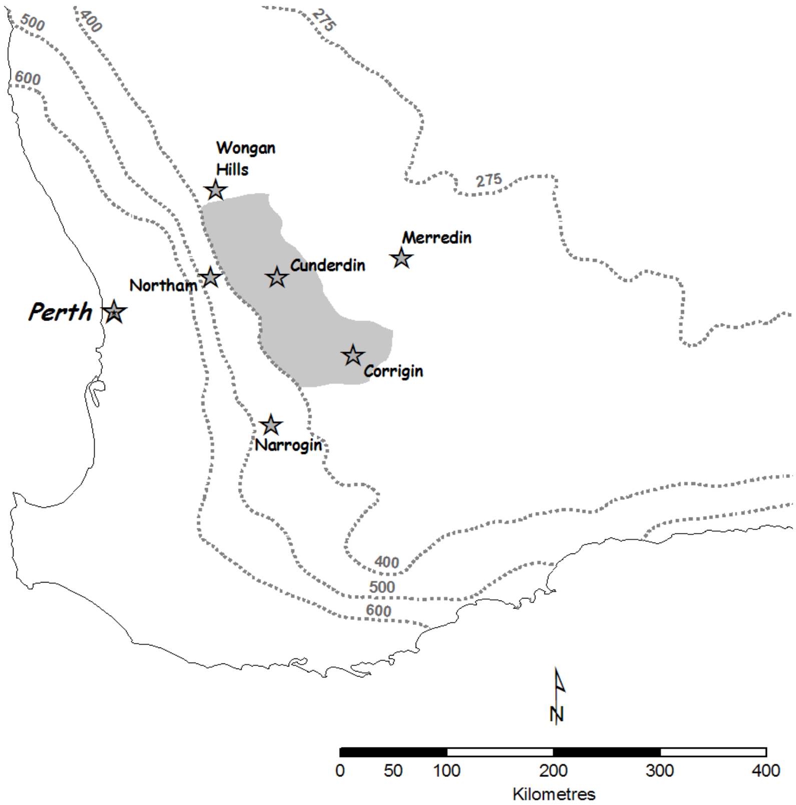


**Figure 1** Map of the region represented by the Central Wheatbelt MIDAS model

The farming region (Figure 1) receives medium rainfall, an average of 350-400 mm annually, with the majority of it falling over Winter/Spring (May-October). The weather is characteristic of a Mediterranean climate with long, hot and dry summers and cool, wet winters. In the model the break of season in the region occurs on the 10$^{th}$ May. A typical farm in the central wheatbelt engages in a mixture of cropping and livestock enterprises. In MIDAS the crops grown include wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), oats (*Avena sativa*), triticale (*Triticale hexaploide*), lupins (*Lupinus angustifolius*), canola (*Brassica napus*), field peas (*Pisum sativum*), and faba beans (*Vicia faba*). These are grown in rotation with lucerne and the pasture specie *French serradella* cv. Cadiz. Sheep on the farm are produced for wool and meat and are mostly Merino breeds.

**Table 1** Land management units (LMU) in the MIDAS model

| LMU | Name | Dominant soil type | Area (ha) |
|---|---|---|---|
| S1 | Poor sands | Deep pale sand | 140 |
| S2 | Average sandplain | Deep yellow sand | 210 |
| S3 | Good sandplain | Yellow gradational loamy sand | 350 |
| S4 | Shallow duplex soil | Sandy loam over clay | 210 |
| S5 | Medium heavy | Rocky red/brown loamy sand/sandy loam; Brownish grey granitic loamy sand | 200 |
| S6 | Heavy valley floors | Red/brown sandy loam over clay; Red and grey clay valley floor | 200 |
| S7 | Sandy surfaced valley | Deep sandy surfaced valley; shallow sandy-surfaced valley floor | 300 |
| S8 | Deep duplex soils | Loamy sand over clay | 390 |

For further detail of the MIDAS model the reader is referred to Kingwell and Pannell (1987), who describe the early version of the model. Later versions are described by Kingwell *et al.* (1995), Kingwell (2002), O'Connell *et al.* (2006), Kopke *et al.* (2008), Gibson *et al.* (2008) and Doole *et al*. (2009).

### 2.2 Inclusion of emissions and responses to the CPRS and MRET schemes

The most recent version of MIDAS was amended to consider farm input cost and forecast price conditions for 2009, and to include greenhouse gas emissions from farm activities and carbon storage options. Greenhouse gas emissions include those generated by livestock through enteric fermentation and animal waste; fertiliser emissions; nitrogen fixing crop emissions; crop residue emissions. Fuel emissions produced during crop establishment, harvest, chemical and fertiliser application and fuel emissions associated with farm product and farm input transport are assumed to have an off-farm point of obligation and the cost of those emissions is assumed to be fully imbedded in the cost of fuel. All farm-level emissions are expressed as carbon dioxide equivalents ($CO_2$-e) and are based on Australia's National Greenhouse Accounting equations, adjusted where warranted for regionally-specific, scientifically verified differences. For example, Biswas *et al.* (2008) have used field experimentation and compiled data for nitrous oxide emissions in the study region and shown these emissions are appreciably different from international default values.

Carbon storage options encompass the growing of non-commercial trees on the different LMUs and, for the MRET scheme, the planting of mallees (*Eucalyptus kochii*, *Eucalyptus polybractea* and *Eucalyptus loxophleba*) as biomass for electricity generation. Currently trees are the only carbon storage option in MIDAS because they meet the internationally recognised standards for environmental integrity of representing abatement that is additional, permanent, measurable and verifiable (Department of Prime Minister and Cabinet 2007). The price range for biomass was based on public statements by the region's electricity generator regarding their response to the MRET scheme and from information supplied by a bioenergy analyst (Amir Abadi, *pers comm*.). This price range, expressed in 2009 dollar terms, is indicative of prices likely to be paid over the next decade for biomass.

Representing the CPRS in MIDAS involved building in the higher prices producers will pay for inputs made more expensive by the operation of the scheme. It firstly concerned identifying all the farm's major inputs, then developing formulae to reflect how the prices of those inputs are affected by the scheme and its associated emission permit price. Many farm input prices will be affected directly or indirectly by the scheme, via the price of emission permits. Figure 2 shows an indicative real price emission price trajectory associated with the CPRS as outlined by Garnaut (2008) and the Australian Government (2008).

It needs noting that the earliest that agriculture will be included in the CPRS is in 2015. Further, at the outset of the scheme much transitional assistance is available to lessen any immediate impacts of the scheme. For example, the White Paper (Australian Government, 2008) and in draft legislation for the CPRS, farmers will receive a fuel credit for the first three years of the scheme to offset the increase in fuel prices attributable to the scheme. Haulage transport used by farmers will also receive a fuel credit for the first year of the scheme. However, in the medium term emission costs associated with fuel use will not attract compensation payments. Hence, in the medium term fuel costs and goods and services dependent on fuel will become more expensive. By contrast fertilisers and chemicals may not become more expensive. Although fertiliser and chemical manufacture is energy intensive, only local producers of fertilisers and chemicals will face higher input costs due to the scheme's operation. By contrast, international producers who export to Australia are unlikely to face the same input cost increases and therefore domestic producers will have little ability to charge more for fertilisers to recover their additional costs attributable to the CPRS.

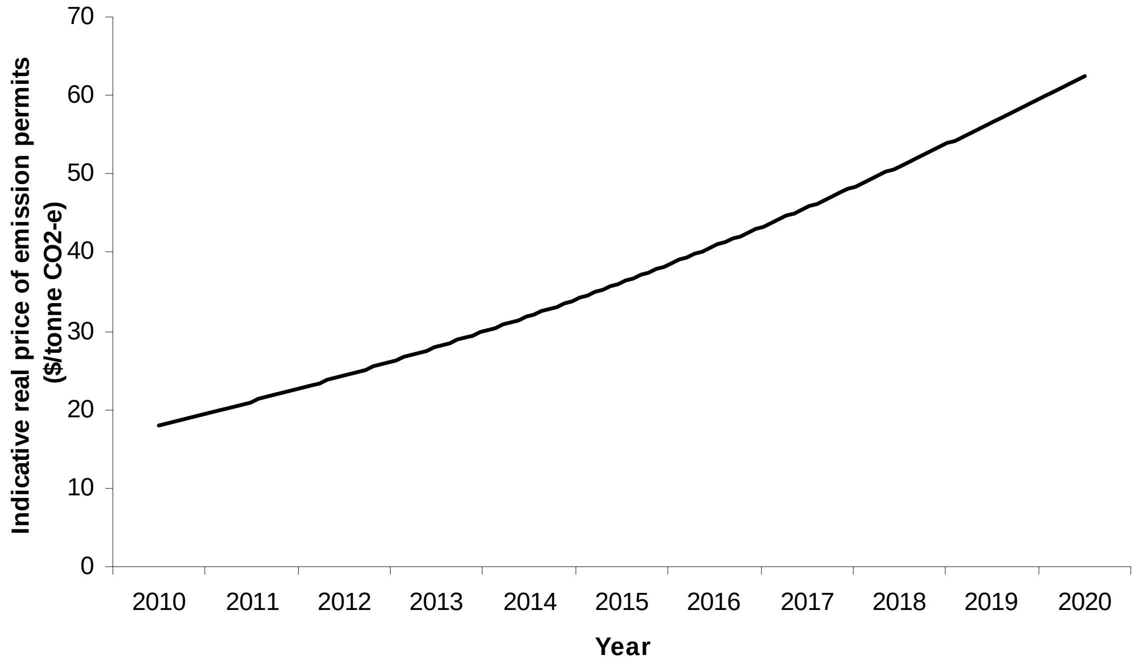


**Figure 2** An indicative real price emission price trajectory associated with the CPRS (Garnaut 2008, Australian Government 2008)

In modelling the medium term (i.e. after 2015) farm cost increases attributable to the CPRS the approach used by Keogh and Thompson (2008) is adopted in this study. They considered the likely fuel component of various goods and services used by farm businesses and related fuel price increases attributable to the CPRS to how prices of these goods and services may change. They assumed that combustion of one litre of diesel produces 2.7 kilograms of $CO_2$ (Department of Climate Change 2008) and therefore, for each $10 increment in the price of emission permits, the price of fuel would rise by 2.7 cents per litre. Keogh and Thompson (2008) also used a simple flow-on cost factor based mostly on fuel costs (see Table 2). For example, if in 2015 fuel prices increased by 8.1 cents per litre or approximately 5 percent (assuming the farm price of fuel was then around $1.5), then chemical costs are expected to increase by 1.25 percent (that is, 25 percent of 5 percent).

**Table 2** Flow-on cost factors for various farm inputs (based on Keogh and Thompson (2008)).

| Farm input | Flow-on cost factor |
|---|---|
| Chemical | 0.25 |
| Contract harvesting | 0.50 |
| Contract seeding | 0.50 |
| Electricity | 1 |
| Fertiliser (Nitrogen) | 0.25 |
| Fertiliser (Other) | 0.25 |
| Fuel | 1 |
| Grain handling | 0.30 |
| Hired labour | 0.20 |
| Professional fees | 0.10 |
| Repairs and maintenance | 0.20 |
| Shearing | 0.20 |
| Sheep work | 0.20 |
| Shire rates | 0.10 |
| Transport | 0.25 |

### 2.3 Scenarios for agriculture and the CPRS

This study examines four key scenarios regarding agriculture and the CPRS and the MRET scheme. The scenarios are:

1. A 'business-as-usual' case. This assumes the MRET scheme is in place yet the CPRS is not introduced and so provides a base for comparing all other variants of an introduced CPRS.
2. Agriculture is not included in the CPRS and after 2015 (in 2009 dollar terms) a range of emission permit prices ($20 to $50 per tonne of $CO_2$-e) is possible. This range of emission permit prices represents various indicative emission price trajectories such as reported by Garnaut (2008) and the Australian Government (2008). The MRET scheme is assumed to be in operation.
3. Agriculture is part of the CPRS and receives 'free' permits for 90, 75 and 50 percent of its 'business-as-usual' emissions. These levels were chosen because should agriculture become a covered industry they will more than likely be considered 'emissions intensive and trade exposed', and be given access to 'free' permits. Although the amount of free

permits is currently an unresolved CPRS design rule, it could initially be as high as 90 percent of business-as-usual emissions. The MRET scheme is assumed to be in place.

## 3. Results and discussion

### 3.1 Business-as-usual - greenhouse gas emissions and farm profit

The MIDAS model is representative of farming systems in a region of the south-west of Australia (see Figure 1). The greenhouse gas emissions from these farming systems, as identified by the farm modelling, primarily comprise emissions from sheep (see Figure 3), depending on the farm's enterprise mix. As the amount of land allocated to cropping activities increases, as opposed to running sheep, the quantity of emissions significantly decreases.

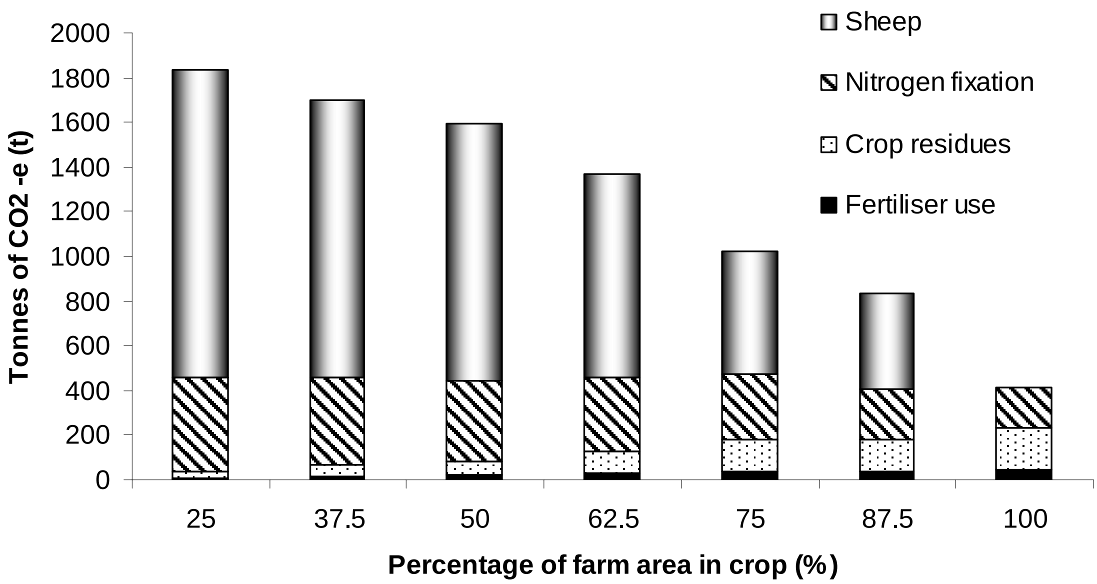


**Figure 3:** Annual emissions (tonnes of $CO_2$-e) arising from farming systems depending on the percentage of arable farmland allocated to cropping

The annual profits generated by different farming systems that operate under the 'business-as-usual' scenario are shown in Figure 4. A plateau region of profitability occurs where 45 to 75 percent of the farm's arable area is committed to cropping; noting that the representative farm comprises eight different soil types.

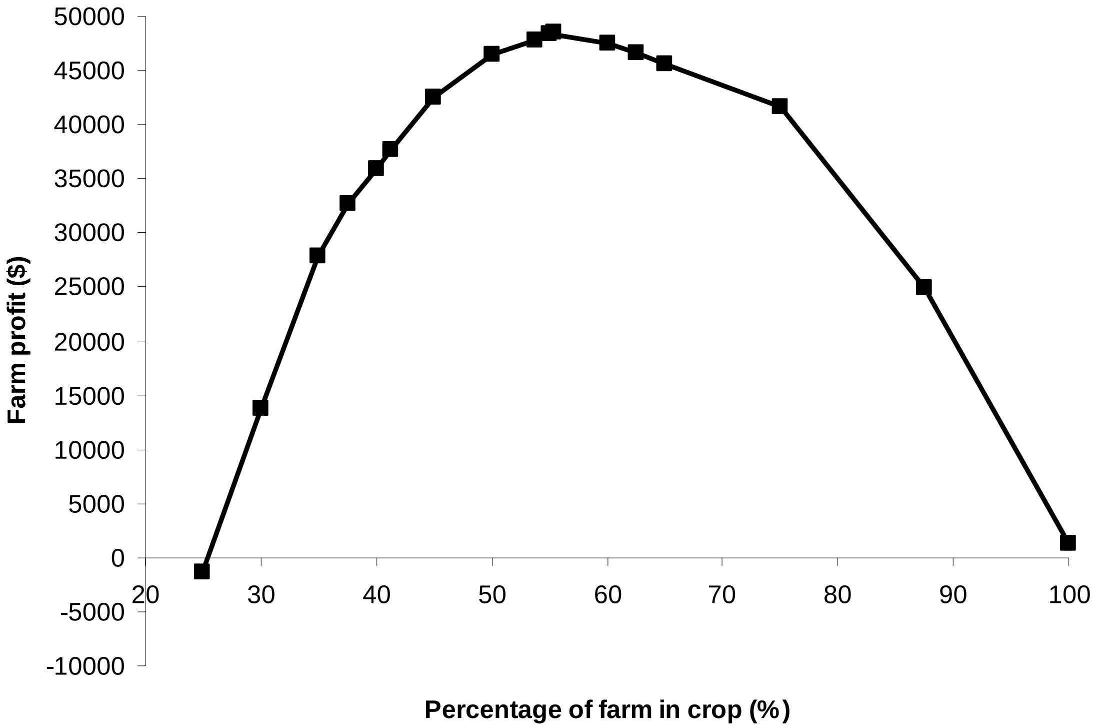


**Figure 4:** Farm profit for different farming systems based on the proportion of the farm's arable area devoted to cropping; assuming no CPRS and with the MRET scheme in place

In a business-as-usual scenario, a farming system based on 50 percent of arable land (1000 hectares) being in crop and the rest devoted to sheep production (6026 WGDSE[3]) emits approximately 1593 tonnes of $CO_2$ –e annually.  Sheep are responsible for more than 70 percent of the emissions in this farm's enterprise mix. The other major contributor is emissions from nitrogen fixing crops (field peas and lupins) and leguminous pastures that account for over 20 percent of total emissions. The main nitrogen fixing crops and pastures are clover, medic and serradella pastures (788 hectares), lucerne (232 hectares), lupins (73 hectares) and alternative legume crops such as field peas (232 hectares).

A farm allocating more land to crop enterprises, for example 87.5 percent (1750 hectares) of the arable area being devoted to crops, will emit 835 tonnes of $CO_2$-e annually. This enterprise mix carries 2212 sheep that account for over half of total emissions. As the allocation of land to

[3] WGDES refers to winter grazed dry stock equivalents

cropping increases there is a resultant decrease in emissions from sheep and nitrogen fixing pastures.

The optimal farming system in the business-as-usual scenario is an allocation of 56 percent of land (1110 hectares) to cropping enterprises and the remainder to pasture production for running sheep. This results in an annual farm profit of $49K and greenhouse gas emissions of 1563 tonnes of $CO_2$-e. Farmers in this region currently typically allocate between 50 to 70 percent of their land to cropping activities (BankWest 2007).

Petersen *et al*. (2003) used a version of the MIDAS model to examine greenhouse gas emissions from livestock dominant farming systems in the high rainfall great southern area of Western Australia (WA). A farming enterprise of 1000 hectares, with 15 percent of land cropped, emitted 1745 tonnes of $CO_2$-e annually, of which the vast majority came from sheep. Flugge and Schilizzi (2005) also estimated emissions from the same region and found that the average farm emitted 1762 tonnes of $CO_2$-e annually. They also estimated emissions from a typical farming system in the low rainfall eastern wheatbelt of WA to be 1930 tonnes of $CO_2$-e (Flugge and Schilizzi 2005). The amount of emissions from these farming systems in different regions are about the same, however emission estimates in this study of a medium rainfall region (450 to 550 mm of annual rainfall) are slightly lower. This is principally due to more crop dominant farm plans currently being optimal in this region, given the greater relative profitability of grain production.

The business-as-usual scenario in Figure 4 includes the MRET scheme being in place which means that the biomass price is likely to be around $25 per tonne. As shown in Figure 5, the optimal farm plan excludes mallee plantings. Only when the biomass price is $27 per tonne do mallee plantings enter the optimal farm plan, and even then only small areas on the poorest of soils are allocated to mallees. Hence the impact of the MRET scheme on farming systems in the region may be minor and so the main focus of farm activity will remain in traditional agricultural pursuits rather than being a source of biomass for renewable energy for electricity generation.

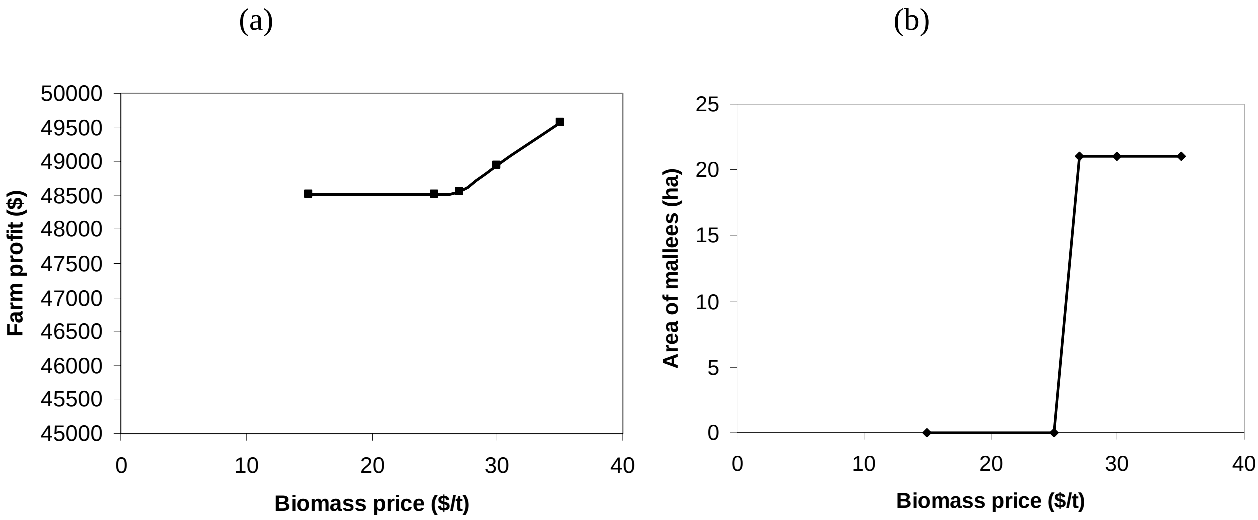


**Figure 5:** (a) Optimal farm profit with changes in the price of biomass
(b) Area of mallees selected in optimal farm plans at different biomass prices

### 3.2 Agriculture uncovered — introduction of the CPRS

If the CPRS is introduced in 2011 with specifications as in the current draft legislation, then the agricultural sector will not initially be included or covered by the scheme. However agriculture will still be affected by the scheme. Sectors or businesses that are covered will pass on some or all of their costs associated with the scheme to consumers of their goods and services, including farmers. The implication for agriculture is that farmers will experience some higher farm input costs, referred to in this study as the flow-on costs as discussed previously in the methods section.

In a business-as-usual scenario the most profit is made when farm businesses allocate between 45 and 75 percent of their arable land to cropping enterprises (Figure 4). This is roughly the same case in a CPRS scenario where agriculture is not covered and the permit price is $25 or $35 per tonne of $CO_2$ –e (Figure 6). The CPRS does cause some farm inputs to be slightly more expensive which lowers farm profit in crop dominant farming systems, when the permit price is $25 tonne of $CO_2$ –e. Cropping enterprises depend more on inputs made more expensive by the CPRS and therefore are slightly relatively disadvantaged. However, at higher permit prices such as $35 per tonne of $CO_2$ –e it becomes lucrative for farmers to allocate some of their poor quality land to trees for carbon sequestration. The low opportunity cost of this land for agriculture is such that its best use is as permanent reforestation that yields income as carbon offsets. The optimal enterprise mix under the CPRS, with agriculture not covered but sequestration activity allowed, generates a farm profit that is about 30 percent greater than the business-as-usual scenario when the permit price is $35 per tonne of $CO_2$ –e. However, if the permit price is $25 of $CO_2$ –e then the profit difference between optimal farm plans is such that the farm is about 4 percent worse off when compared to the business-as-usual scenario.

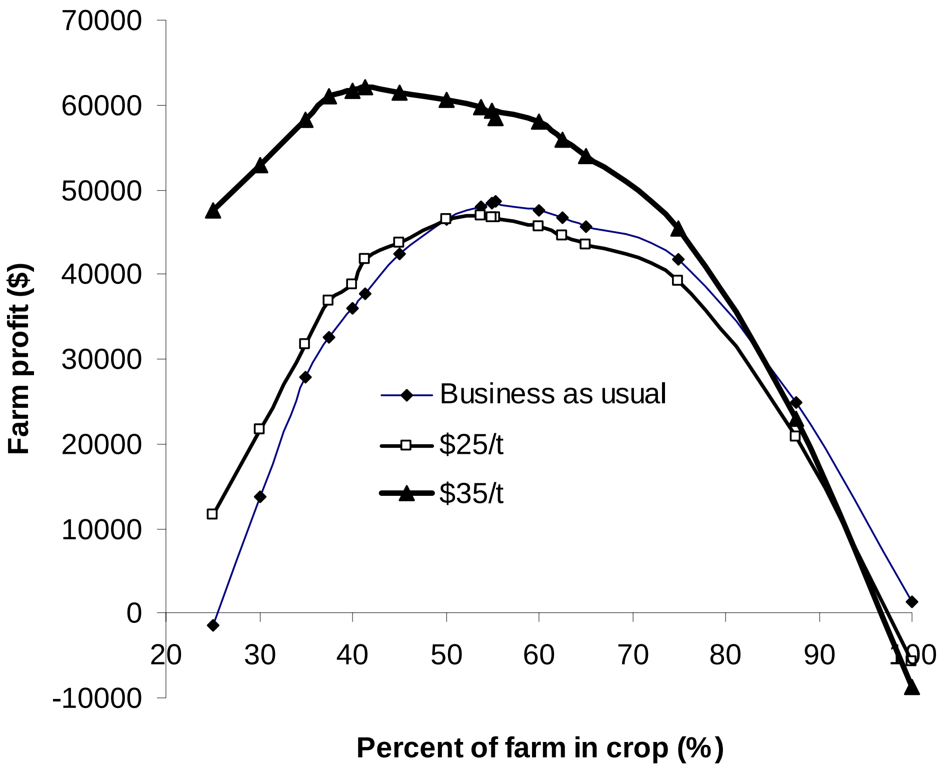


**Figure 6:** The effect of the CPRS (given permit prices of $25 or $35 per tonnes of $CO_2$-e) on farm profit ($) when agriculture is not covered by the CPRS

When the permit price is $35 per tonne of $CO_2$ –e then the optimal farm plan includes 430 hectares of poor quality land being committed to reforestation generating an equivalent annual revenue that equates to an annual sequestration of 2758 tonnes of $CO_2$ –e. Note the revenue calculation assumes tree growth is a non-symmetrical sigmoidal growth pattern, estimated following Yin *et al*. (2003) and drawing on tree growth data at a site in the study region (Justin

Jonson, *pers comm*.). A further assumption is a price trajectory for permits such as outlined in Figure 2. Having soils suited to tree growing yet displaying a low opportunity cost for agriculture ensures that the representative farm benefits from the introduction of the CPRS only through profiting from carbon sequestration if the permit price is sufficiently high.

Preliminary modelling by Keogh and Thompson (2008), on the potential impacts of the CPRS on Australian agriculture, suggests that energy-dependent farming enterprises will suffer greater farm profit reductions in an uncovered scenario. Their findings are similar to those in this study for permit prices of $25 or less. However, Keogh and Thompson ignore any possibility of income from sequestration activity and do not account for land quality differences. Accordingly, they overstate the likely impact of the CPRS scenario where agriculture is not covered by the scheme. Keogh and Thompson findings are based on i) modelling a single 'average' Australian farm, ii) only reporting cash profit and so ignoring depreciation and some overhead expenses, iii) not considering different land qualities and different profitabilities of enterprises on different soil types and, iv) not allowing for any economising regarding the impacts of the CPRS through changes in inputs and enterprises. These restrictions are not applicable to the analysis reported here.

### 3.3 Agriculture covered — reducing and/or abating greenhouse gas emissions

For the scenario where after 2015 agriculture is assumed to be covered by (i.e. included in) the CPRS then farmers have four main options: (i) reduce emissions by making changes to the farm's enterprise mix, in this case it is more than likely that changes will be made to the amount of livestock carried due to their high emission levels, (ii) abate emissions through the use of offsets (e.g. by planting trees), (iii) purchase emission permits and (iv) sell 'free' permits not required by the farm business.

Assuming that the model farm receives free permits equivalent to half its annual emissions based on the optimal farm plan in the business-as-usual scenario, then the impact on the farm business is very dependent on the price of emission permits and tree growth rates. Profits from different farming systems when permits are $25 or $35 per tonne of $CO_2$ –e are contrasted against the business-as-usual scenario in Figure 7.

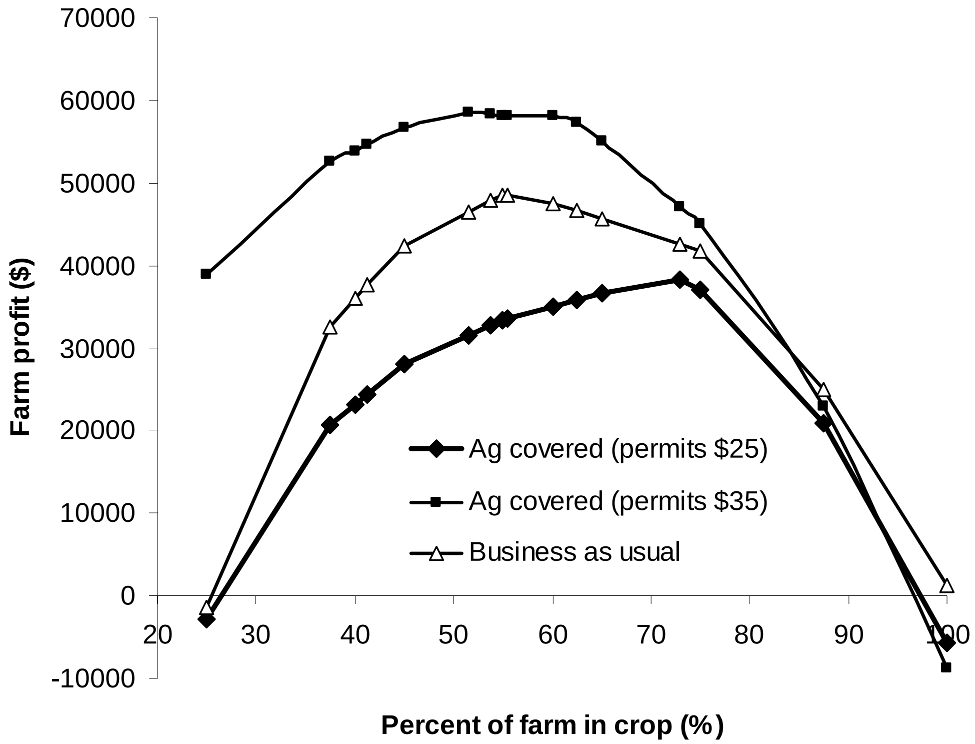


**Figure 7:** The effect of the CPRS (given permit prices of $25 or $35 per tonnes of $CO_2$-e) on farm profit ($) when agriculture is covered by the CPRS and receives free permits equivalent to 782 tonnes of $CO_2$ –e (50% of emissions generated by the optimal farm plan in a business-as-usual scenario)

When the permit price is $25 per tonne of $CO_2$ –e then the optimal farm plan shifts from 56 percent of the farm being in crop, carrying 5820 sheep, planting no trees and generating $48.5K of annual profit (the business-as-usual optimal plan) to a plan involving 73 percent of the farm being in crop, carrying only 2215 sheep, planting 175 hectares of trees and generating $38.2K of annual profit. Annual profit declines by 21 percent in this case when the permit price is $25 per tonne of $CO_2$ –e. By contrast if the permit price increases to $35 per tonne of $CO_2$ –e then the optimal farm plan shifts from one as outlined above to a farm plan where 52 percent of the farm is in crop, 2277 sheep are carried, 605 hectares of trees are planted and $58.5K of annual profit is generated (or 21 percent more than the business-as-usual scenario).

The reason why farm profit may decrease or increase if agriculture is covered by the CPRS is due a few factors including: (i) the amount of free permits, (ii) the price of permits and (iii) the relative profitability of cropping, livestock and tree-based carbon sequestration on the various soil types on the farm. For the farm as modelled, the CPRS unleashes land use competition between grazing and tree-based carbon sequestration on the farm’s poorer soils and at higher prices of permits the preferred more profitable use of this land is for carbon sequestration. At low prices for permits the poorer soils generate far less income through sequestration. Furthermore, although the lower prices for permits is less of a tax on livestock, nonetheless the imposition of the permits shifts the relative profitability of the enterprise mix on the farm away from sheep toward cropping that entails fewer emissions. The net result at the lower price for permits is a reduction in farm profit.

These findings of losses or profits from the introduction of the CPRS mirror the tension in debate among some farmer groups where the CPRS is viewed as a livestock tax that will decimate the sheep industry whereas others see the CPRS as offering farmers a diversification option to make money through provision of forestry offsets on their marginal land. In reality, both views are valid and their veracity depends on the design features of the CPRS, and important issues such as the opportunity cost of agriculture on marginal land, tree growth rates and emission permit prices.

The modelling results show that trees initially are planted on low profitability land (mostly on soil type 1 and then on soil types 2 and 7; see Table 1). Soil type 1, for example, is a deep pale sand, fairly infertile and normally used for permanent pasture. The requirement for the farm to restrict, offset or pay for its emissions causes the more profitable use of the more marginal land to be for carbon sequestration rather than as a feed source for grazing sheep.

Some of the other land use changes that result from the CPRS covering agriculture, at least for the model farm, are listed in Table 3. As the amount of free permits increases then in general the optimal farm plans change and become more profitable, characterised by more sheep, a larger area of pasture, a lesser area planted to crops and trees and a lesser area of legume crops. As the price of permits increases then tree planting for carbon sequestration becomes a preferred activity on some soil types and the area in trees increases causing a reduction in the area allocated to other enterprises.

**Table 3** Key characteristics of optimal farm plans under different assumptions when agriculture is included in the CPRS

| Permit Price ($/t $CO_2$-e) | Free Permits[a] (t) | Crop area (ha) | Sheep Nos (dse) | Tree Area (ha) | Pasture area (ha) | Alternative legume crops (ha) | Farm profit ($'000) |
|---|---|---|---|---|---|---|---|
| 25 | 1407 | 1074 | 5117 | 175 | 751 | 237 | 46.8 |
| 25 | 1172 | 1191 | 4126 | 175 | 635 | 270 | 44.4 |
| 25 | 782 | 1458 | 2215 | 175 | 367 | 303 | 38.2 |
| 35 | 1407 | 826 | 5050 | 430 | 745 | 150 | 62.1 |
| 35 | 1172 | 806 | 4307 | 555 | 640 | 152 | 61.5 |
| 35 | 782 | 1032 | 2277 | 605 | 363 | 152 | 58.5 |

[a] The three levels of free permits correspond to 90, 75 and 50 percent respectively of the emissions of the optimal farm plan in the business-as-usual scenario

The greater role for trees is a product of their growth rate. If, for example, rather than using the *in situ* measures of growth rates, default growth rates in the National Carbon Accounting Toolbox (NCAT) are used then tree planting plays a much-reduced role and the effects of the CPRS on the representative farm are far more adverse than suggested thus far in this paper. By illustration, Table 4 lists the optimal farm plan characteristics when NCAT default values for tree growth in the region are used and indicates the absence of tree plantings and the large declines in farm profit, relative to the business-as-usual case, that characterise these plans.

The lower growth rate of the trees, as specified by the NCAT default values, means that if they apply in practice, then in some situations it becomes preferable to buy permits than use farmland for sequestration. Moreover, the low rates of sequestration cause tree planting to be uneconomic and therefore farm incomes are not bolstered by allocating land to growing trees. In this situation the CPRS places farming at a disadvantage, needing to account for its emissions plus facing the consequences of pass-on effects from other sectors included in the CPRS.

**Table 4** Key characteristics of optimal farm plans under different assumptions when agriculture is included in the CPRS and NCAT default values for tree growth in the study region apply

| Permit Price ($/t $CO_2$-e) | Free Permits[a] (t) | Crop area (ha) | Sheep Nos (dse) | Tree Area (ha) | Pasture area (ha) | Alternative legume crops (ha) | Buy permits (t) | Farm profit ($'000) | Decline in profit relative to business-as-usual (%) |
|---|---|---|---|---|---|---|---|---|---|
| 25 | 1407 | 1183 | 5014 | 0 | 917 | 235 | 0 | 41.8 | 14.7 |
| 25 | 1172 | 1319 | 4051 | 0 | 681 | 282 | 0 | 38.2 | 22.0 |
| 25 | 782 | 1555 | 2374 | 0 | 445 | 303 | 58.4 | 31.4 | 35.9 |
| 35 | 1407 | 1183 | 5050 | 0 | 745 | 235 | 0 | 39.4 | 19.6 |
| 35 | 1172 | 1319 | 4307 | 0 | 640 | 282 | 0 | 35.7 | 27.1 |
| 35 | 782 | 1555 | 2277 | 0 | 363 | 303 | 53.4 | 28.2 | 42.4 |

[a] The three levels of free permits correspond to 90, 75 and 50 percent respectively of the emissions of the optimal farm plan in the business-as-usual scenario

In the study region about 90 percent of the grain production, all the wool and about two-thirds of the sheep-meat are exported and it is unlikely that the farmers in the region will receive any price compensation on these export markets for any higher production costs due to the CPRS. Hence, the cost imposts of the CPRS, in the absence of on-going free permit compensation, could mean large percentage reductions in farm profits, if farmers have no cost-effective offset options such as fast-growing trees on agriculturally marginal land.

Petersen *et al.*(2003) used MIDAS to examine the role of commercial tree crops for greenhouse gas abatement in a higher rainfall region of Western Australia (WA), and concluded that tree crop plantations were effective at reducing emissions from a predominately grazing farm system. This finding also holds for the current study region, based on *in situ* tree growth data.

Flugge and Abadi (2006) also used MIDAS to analyse the viability of growing trees for the purpose of selling carbon credits in low and high rainfall zones, and estimated that the price for emission permits needed to be at least $45 and $66 per tonne of CO2-e in the high rainfall and low rainfall regions respectively. In this analysis of a medium rainfall region, based on NCAT growth rates, trees begin to come into the optimal solution at an emission permit price of $50. If the *in situ* growth rate parameters are used then trees enter optimal solutions even at a permit price of $25 per tonne of CO2-e.

If the policy decision regarding the CPRS is that agriculture should not be covered by the scheme then emissions from broadacre farming systems as typified in this paper could, depending on emission permit prices and tree growth rates, actually increase due to the flow-through costs impacting more on cropping activities than sheep production. In other words, sheep production which is the main source of emissions could be made slightly relatively more profitable. Conversely, if the policy decision regarding the CPRS is that agriculture should be covered by the scheme then the livestock enterprise in broadacre farming will be disadvantaged. In both cases an enhanced role for carbon sequestration is possible, depending on tree growth rates.

## 4. Conclusion

This paper has assessed the farm-level implications of the newly announced Mandatory Renewable Energy Targets (MRET) scheme and the proposed Carbon Pollution Reduction Scheme (CPRS) on broadacre farming systems in a region of Western Australia. Three scenarios are considered: (i) business-as-usual where the MRET scheme is in place but not the CPRS, (ii) both the CPRS and MRET schemes are operating but agriculture is not included in the CPRS and (iii) both schemes apply with agriculture included in the CPRS.

In the second scenario farmers experience higher farm input costs as a consequence of the operation of the pass-through or cost-flow on consequences of the CPRS; with the size of this impost linked to the price of emission permits and the relative profitability of alternative farm enterprises. The growth rate of trees is shown to be important in determining the role and value of trees as carbon sinks in these farming systems.

In the third scenario in which agriculture is covered by the CPRS; if tree growth is poor and emission prices are high and free permits are only a small proportion of a farm's emissions then farm profits are liable to be greatly diminished. For example, profit reductions of between 15 to 40 percent of 'business-as-usual' profits are feasible. Profit reductions in an uncovered scenario are far less, at around 4 percent at an emission permit price of $25 per tonne of CO2-e. Hence, the profitability of some types of farm enterprise mix are potentially under threat from the introduction of the CPRS, and greenhouse and R&D policy needs to address this when finalising the design rules of the scheme. Farm modelling results identify that a portfolio of strategies is optimal in a farmer's response to the CPRS when agriculture is included. Strategies include reducing livestock numbers, planting trees (if economic) or buying emission permits and changing the mix of farm enterprises.

If agriculture becomes a covered industry in 2015 and is considered 'emissions intensive and trade exposed', and thus granted a high level of free permits to protect farm viability, then it may be necessary to find alternative methods to promote emissions reduction in agriculture. Similarly, if agriculture is not included in the CPRS there remains the need to lessen its emissions as agriculture remains an important source of Australia's emissions. Greenhouse gas emissions from agriculture account for 16.8 percent of national emissions (AGO 2007), and if energy and transport used by the industry are included, this figure increases to 23 percent (Hatfield-Dodds *et al.* 2007).

Most importantly, this study highlights the crucial need for further R&D into emission offset and reduction technologies for farming businesses. Due to livestock's emissions intensity, and the fact that livestock play an important role in the farming system, methane reduction technology is an area that could offer potential benefits. Selection of fast-growing provenances of trees is another potential rich vein of R&D.

A limitation of this research is the steady-state optimisation framework that underpins the MIDAS model, including its assumption of continuous average weather-year conditions. This means that the analysis represents a steady-state single period equilibrium, and does not account for variations in price, cost or climate conditions across weather-years and how they may affect farm management and farm profitability. Also, there are additional costs and issues associated with the CPRS that have not been captured in this analysis such as points of obligation and implementation, monitoring and compliance costs.

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