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Low Emission Farming Systems:
A whole-farm analysis of the potential impacts of greenhouse policy

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Abstract

The Australian government is introducing a Carbon Pollution Reduction Scheme in 2010, as part of its climate change policy. After 2015 agriculture may be covered by this scheme. This paper examines how different broadacre farming systems may be affected by the policy settings of this scheme. Using the bio-economic farming systems model MIDAS (Model of an Integrated Dryland Agricultural System) the impacts of the Carbon Pollution Reduction Scheme on the profitability of different broadacre farming systems in the southwest of Australia are investigated. Results show a range of profit and enterprise impacts across the various farm types. In a scenario where agriculture is not covered by the scheme, reductions in profit range from 7 to 12 percent, attributable to more expensive 'covered' inputs such as fuel and fertiliser; and farmers reduce their use of expensive energy inputs such as chemicals and fertilisers. In a covered scenario profits decline by 15 to 25 percent of 'business-as-usual' profit and optimal farm plans involve a combination of reduced livestock numbers, the introduction of permanent woody perennial plantations on marginal lands and other changes to the farm enterprise mix to reduce emissions.

Keywords: agriculture, greenhouse gases, economic modelling, abatement

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 Carbon Pollution Reduction Scheme (CPRS) in 2010. The scheme involves an emissions trading system using carbon permits to regulate greenhouse gas emissions. It has been recommended that sufficient permits are allocated in the beginning to ensure initial trades of permits are around AUD$20 (Garnaut 2008).

The Australian government's CPRS Green and White Papers (Commonwealth of Australia 2008) outline that agriculture will not be covered by the scheme when it is implemented in 2010.

However, it is possible that it will become a direct participant in the scheme after 2015. A final decision will be made regarding this in 2013 (Department of Climate Change 2008, Commonwealth of Australia 2008). Even if agriculture does not become a direct participant in the scheme other sectors covered by the scheme, including 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). Should agriculture become covered by the scheme and thereby need to account for its emissions, then farmers would consider options such as switching to lower emission production systems and offsetting emissions.

A preliminary investigation by Keogh and Thompson (2008) of different types of agricultural businesses in Australia concludes that "under a Medium emission price scenario[1], 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 (EITE) 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.

Keogh and Thompson (2008) admit that their analysis of farm-level impacts of the CPRS is preliminary and underpinned by several assumptions and limitations. For example, their analysis excludes the possibility of on-farm sequestration activity to offset emissions and neither is there any opportunity for the farm's emissions to be lessened through altering enterprise mix, input use or production technology. These are serious deficiencies potentially leading to an over-statement of the impacts of the CPRS at the farm-level. Accordingly, there is a need for additional modelling that better describes the responses of farm businesses to the CPRS.

[1] 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.

This research paper seeks to provide such modelling and analysis by using broadacre farming in Western Australia as an illustration of how mixed enterprise farming systems might reduce and/or offset their emissions in response to the CPRS, depending on whether or not agriculture is a covered sector within the CPRS.

The paper proceeds 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 optimal 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 wheatbelt 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.

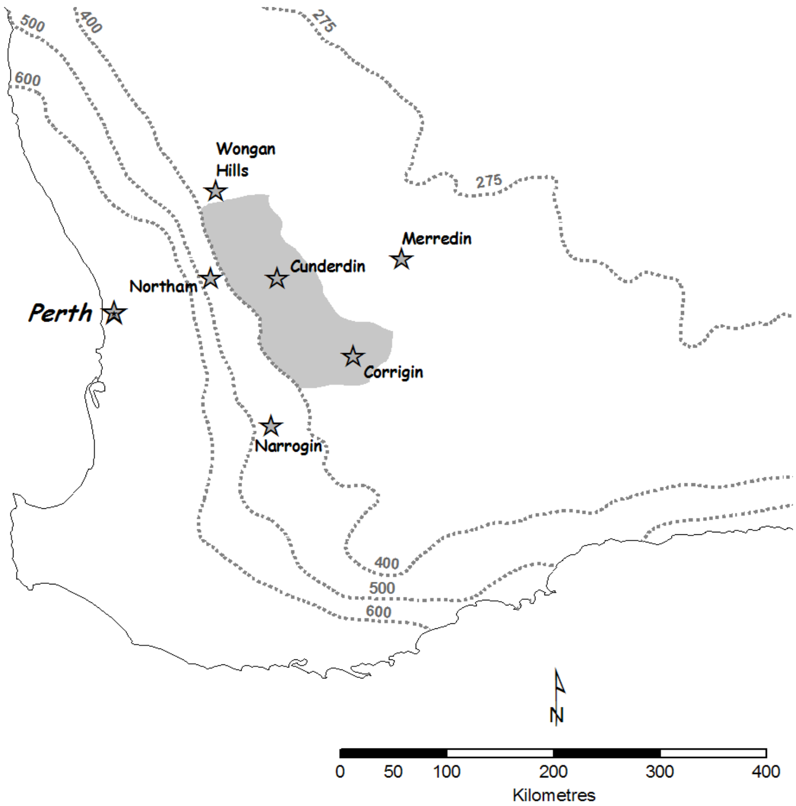

Figure 1 Map of the region represented by the Central Wheatbelt MIDAS model

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 10th 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. 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) and Gibson *et al.* (2008).

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

2.2 Inclusion of emissions and CPRS impacts in MIDAS

The most recent version of MIDAS was amended to consider 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; and fuel emissions produced during crop establishment, harvest, chemical and fertiliser application. All emissions are expressed as carbon dioxide equivalents (CO_2-e) and are based on National Greenhouse Accounting equations. Carbon storage options encompass the growing of non-commercial trees on the different LMUs. 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).

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. The price paid for permits is a direct expression of the costs associated with the scheme.

The main assumption of the formulae used is that the combustion of one litre of diesel produces 2.7 kilograms of CO_2 (Department of Climate Change 2008). Therefore, for each $10 increment in the price of emission permits, fuel will rise by 2.7 cents per litre. Another assumption is the price of diesel itself. In this study the diesel price has been set at a forecast 2009/2010 price of $1.90 per litre. Other assumptions consider how farm input prices will increase due to the rise in energy prices attributable to the introduction of the CPRS. A simple flow-on cost factor based chiefly on fuel costs was employed (see Table 2). This was the same approach taken by Keogh and Thompson (2008). For example, if fuel prices were to rise by 10 percent, then chemical costs are expected to increase by 5 percent (that is, 50 percent of 10 percent).

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

Farm input	Flow-on cost factor
Chemical	0.50
Contract harvesting	0.50
Contract seeding	0.50
Electricity	1
Fertiliser (Nitrogen)	0.75
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 three key scenarios regarding agriculture and the CPRS. The scenarios are:

1. A ‘business-as-usual’ case. This assumes the CPRS is not introduced and so provides a base for comparing all other variants of an introduced CPRS.

2. Agriculture not covered by the CPRS and with emission permit prices at \$20, \$40 and \$60 per tonne of CO_2-e. This allows for assessment of indirect flow-on costs to agricultural producers in the absence of them being accountable for their own emissions. These emission permit prices were selected as they represent possible starting, mid and high points of indicative emission price trajectories such as reported by Garnaut (2008) and the Australian Government (2008) (see Figure 2).

3. Agriculture being covered by the CPRS and receiving ‘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.

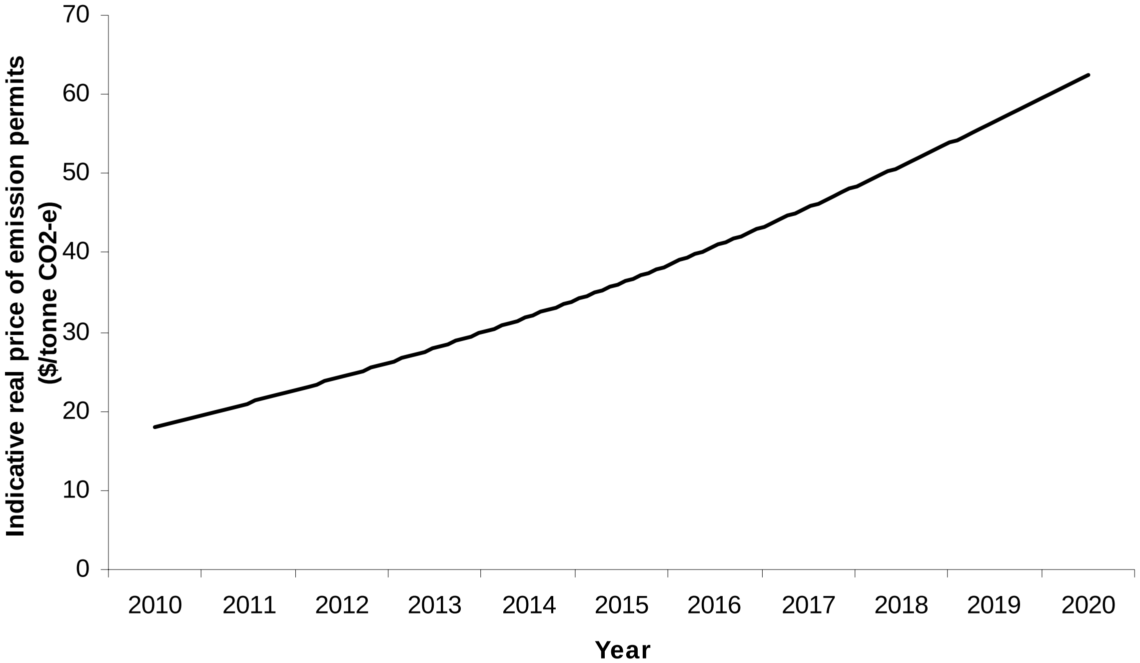

Figure 2 An indicative real price emission price trajectory associated with the emissions trading scheme (Garnaut 2008, Australian Government 2008)

3. Results and discussion

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

This study has indicated that greenhouse gas emissions from farming systems in the south-west of Australia are primarily comprised of emissions from sheep (see Figure 3). As the amount of land allocated to cropping activities increases, as opposed to running livestock, the quantity of emissions significantly decreases.

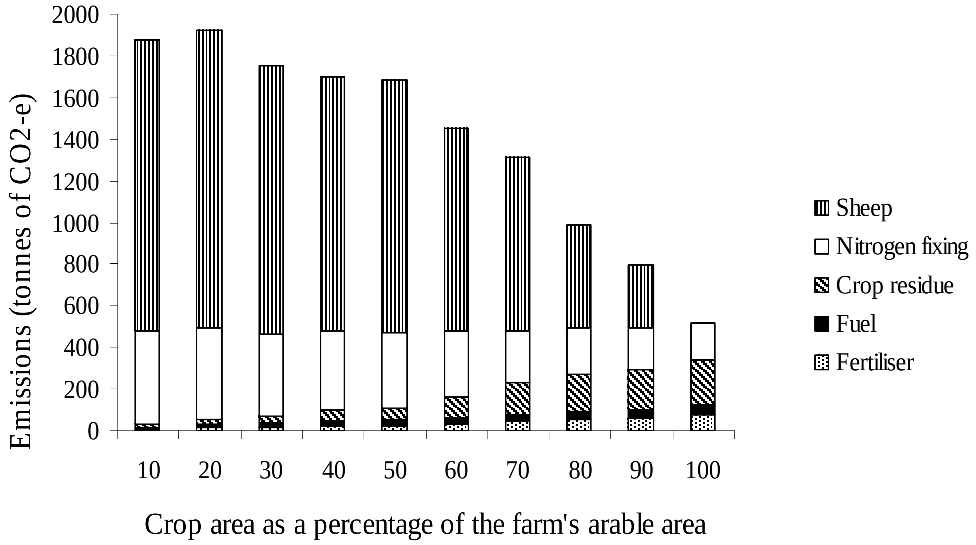

Figure 3: Annual emissions (tonnes of CO_2-e) arising from farming systems depending on the percentage of arable farmland allocated to cropping

In a business-as-usual scenario, a farmer in the central wheatbelt of WA who allocates 50 percent of their land (1000 hectares) to cropping enterprises and the rest to running livestock (6873 sheep on 1000 hectares) will emit a total of approximately 1680 tonnes of carbon dioxide equivalent annually. Sheep are responsible for more than 70 percent of total emissions in this farming enterprise mix. The other major contributor is emissions from nitrogen fixing crops, accounting for approximately 21 percent of total emissions. The main nitrogen fixing crops here are leguminous pasture (768 hectares) and lucerne (232 hectares), used to support livestock.

A farm allocating more land to cropping enterprises, for example 90 percent (1800 hectares), will emit approximately 792 tonnes of CO_2-e annually. This enterprise mix carries 1673 sheep, accounting for approximately 38 percent of total emissions. As the allocation of land to cropping increases there is a resultant decrease in emissions from sheep and nitrogen fixing crops. This is due to the greater use of fuel and fertiliser involved with growing cereal crops.

In the absence of the CPRS the optimal farm plan, in terms of maximum farm profit, is to allocate 70 percent of land (1400 hectares) to cropping activities and the other 30 percent (600 hectares) to running livestock. This results in an annual farm profit of $96K, and greenhouse gas emissions of 1309 tonnes of CO_2-e. Farmers in the central wheatbelt of WA typically allocate between 50 to 80 percent of their land to cropping activities.

Petersen *et al*. (2003) used the MIDAS model to examine greenhouse gas emissions from livestock dominant farming systems in the great southern area of 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 was from sheep. Flugge and Schilizzi (2005) also estimated emissions from the great southern area of WA with the MIDAS model, and found that the average farm emitted 1762 tonnes of CO_2-e annually. Estimates of emissions from a typical farming system in the eastern wheatbelt of WA were 1930 tonnes of CO_2-e (Flugge and Schilizzi 2005). The amount of emissions from these farming systems in the great southern and central wheatbelt are about the same, however emission estimates in this study are lower than these. This is principally due to more crop dominant farm plans currently being optimal, given the high prices for grains relative to livestock.

3.2 Agriculture uncovered — introduction of the CPRS

When the CPRS is introduced in 2010 the agricultural sector will not be covered by the scheme, however the sector will still be affected by the scheme. Those sectors or businesses who are covered will pass on some (or all) of their costs from the operation of the scheme to consumers of their goods and services. The implication for agriculture is that farmers will experience higher farm input costs, referred to in this study as the flow-on costs as discussed in the methods section.

In a business-as-usual scenario the most profit is made when farm businesses allocate between 50 and 80 percent of their arable land to cropping enterprises (see Figure 4). This is the same case in an uncovered CPRS scenario, however the nature of the optimal farm plan shifts to 60 percent of land (1200 hectares) being devoted to cropping and the rest to livestock (see Figure 4). This optimal allocation holds for emission permit prices of $20, $40 and $60.

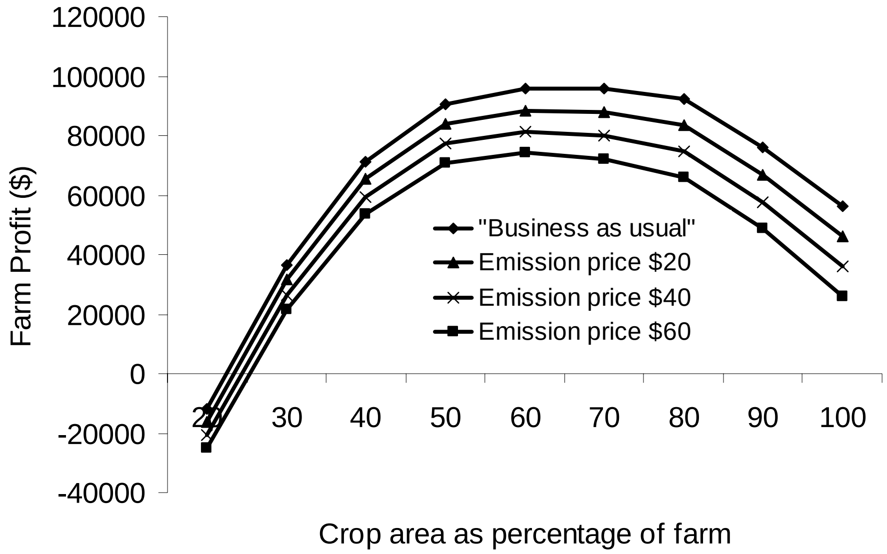

Figure 4 The effect of a range of emission permit prices (tonnes of CO_2-e) on farm profit ($)

Under the scenario whereby agriculture is not covered by the CPRS, farm businesses that are more crop dominant will experience greater economic losses. A farming system allocating 90 percent of its arable area to cropping activities, under a $20 emission price, experiences a $9236 decrease in farm profit (from a business-as-usual scenario). A farm allocating 70 percent to cropping faces a profit reduction of $8023, whilst a 50 percent cropping enterprise experiences a reduction of $6601. These losses roughly double under the $40 emission permit price, and triple under the $60 price. Moreover, as the emission price increases there is a slight shift in the optimal farm plan downwards from 70 percent cropping.

The greater cost impacts for producers specialising in cropping operations is due to their greater reliance on energy and energy-dependent inputs. There are relatively large flow-on cost factors associated with fertiliser and chemicals. Hence, farmers operating highly crop dominant farming systems are likely to be most affected by the scheme, at least during its phase where agriculture is uncovered. Table 3 expresses the loss of farm profit as a percentage of business-as-usual profit. A recommendation from Garnaut for the CPRS is that farmers be compensated for any increases in their fuel costs attributable to the scheme. The government intends to adopt this recommendation so the profit reductions in Table 3 overstate the initial impact to agriculture being an uncovered industry. However assuming this compensation is wound back, then this analysis indicates the likely impact on farm businesses.

Table 3 The change in farm profit (percentage of business-as-usual profit) experienced by three different enterprise mixes under a $20, $40 and $60 emission permit price

Enterprise mix	Business-as-usual profit	Emission price (per tonne CO_2-e)	Percentage change in profit
50 percent cropping	$90428	$20	-7
		$40	-15
		$60	-22
70 percent cropping	$96012	$20	-8
		$40	-17
		$60	-25
90 percent cropping	$76216	$20	-12
		$40	-24
		$60	-36

Preliminary modelling by Keogh and Thompson (2008), on the potential impacts of the CPRS on Australian agriculture, supports the finding that energy-dependent farming enterprises will suffer greater farm profit reductions in an uncovered scenario. For example; a farm enterprise similar to the 50 percent cropping enterprise mix in this study is estimated to have a profit reduction of $3534 from business-as-usual profit under a $20 emission permit price, and a farm similar to the 90 percent cropping enterprise mix faces a profit reduction of $4363. Although Keogh and Thompson’s profit reductions are roughly half the expected reductions in this study, it must be recognised that they i) model an ‘average’ Australian farm, ii) only report cash profit and so ignore depreciation and some overhead expenses, iii) do not consider different land qualities and different profitabilities of enterprises on different soil types, iv) do not allow for any economising regarding the impacts of the CPRS through changes in inputs and enterprises and v) exclude fuel emissions in any greenhouse emission calculations (assumed that fuel will be sourced from covered industries that have already accounted for these emissions).

3.2.1 Sensitivity analysis on assumed flow-on cost factors

Under an emission permit price of $20, increasing the flow-on cost factors by 20 percent resulted in farm profits being eroded by a maximum of 3.4 percent. For the optimal farm plan (60 percent cropped) this reduction was 1.2 percent, equivalent to approximately $1091. If flow-on cost factors are increased by 40 percent, farm profits are eroded by a maximum of 6.7 percent. For the optimal farm plan this reduction was 2.4 percent, or $2101.

Increasing the flow-on cost factors is a reflection of other scheme participants passing more of their costs back onto farmers. Should this transpire farm profits will be further reduced, particularly for those reliant on expensive energy-dependant inputs.

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

The possibility that agriculture may become a covered sector under the CPRS in 2015 makes it necessary to analyse how farming systems may respond to the requirement to lower emissions from their businesses. Farmers have three main options available i) to 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) to abate emissions through the use of offsets (e.g. by planting trees) and iii) to purchase emission permits.

In a covered scenario the optimal farm plan typically is to allocate 70 percent of land to cropping operations and the rest to running livestock. Hence, the nature of the farm business remains broadly the same as the optimal farm plan under a business-as-usual scenario. A 70 percent cropping enterprise farm in a business-as-usual scenario emits approximately 1309 tonnes of CO_2-e annually. If agricultural producers were granted an amount of free permits equivalent to 90 percent of business-as-usual emissions, then for this optimal farm plan, emission levels must be mitigated by approximately 131 tonnes.

In the situation where farmers are responsible for 10 percent of their emissions (because 90 percent of emissions have been accounted for with free permits), the least cost strategy for dealing with these emissions is to make relatively small changes to the enterprise mix (see Figure 5). This mainly involves reducing the number of sheep on the farm, and also small adjustments to the area of crop and pasture plant species grown. The least cost strategies at the $40 and $60 emission permit prices are exactly the same, however at the $20 permit price it is more cost-effective to make heavier reductions in livestock numbers than make other enterprise mix changes. This is due to a combination of the relatively low permit price and high free permit level.

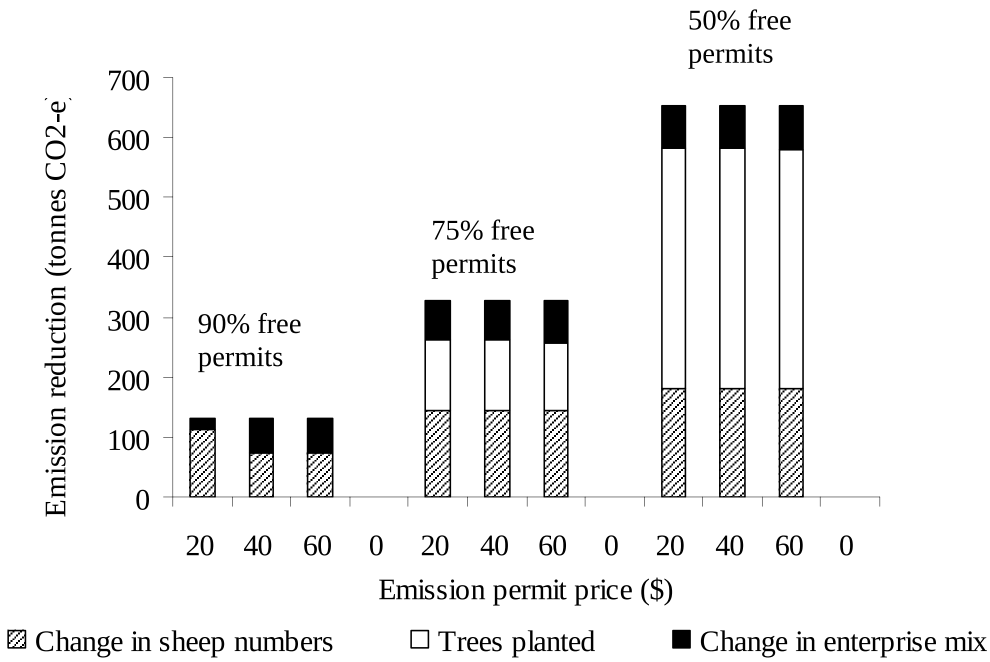

Figure 5 The least-cost strategies for reducing emissions not covered by the free permits for the profit-maximising farm plan of 70 percent cropping

In this analysis the abatement activity of planting trees to sequester carbon comes into the least cost strategy when free permits are provided for only 75 percent of business-as-usual emissions. Approximately 39 hectares of trees are planted in each permit price. This amount of trees sequesters around 117 tonnes of CO_2. The reduction of sheep on the farm and small adjustments to the area of crop and pasture plant species grown still feature as part of the least cost strategy for accounting for emissions.

When half of emission levels must be accounted for (only provision of 50 percent of free permits) the profit-maximising area of trees increases to approximately 133 hectares (401 tonnes of CO_2 sequestered). This equates to nearly 7 percent of farmland. Also, there is a greater reduction in the number of sheep on the farm. In this analysis the purchasing of permits to enable producers to go on running their businesses as usual is not selected as part of the least cost strategy for dealing with emissions.

All of the trees planted to sequester carbon are selected to be planted on low profitability land (soil type 1, see Table 1). This soil type is deep pale sand, fairly infertile and normally used for permanent pasture. The requirement for agriculture to restrict their emission levels causes the more profitable use of the land to be as a carbon sink rather than as a feed source for grazing sheep.

The cost to farm businesses in a covered scenario is detailed in Table 4. It shows the percentage change in profit from a business-as-usual scenario. In a covered scenario, if emission permit prices are around the projected price of $40 and producers are given access to a 90 percent level of free permits, then farmers could face profit reductions of between 15 to 25 percent of their business-as-usual profit.

Table 4 The percentage change in farm profit (from business-as-usual profit) experienced by three different enterprise mixes, at differing free permit allowances and emission permit prices

Emission Price	Free Allowance	50 percent cropping	70 percent cropping	90 percent cropping
$20	90%	-8	-9	-13
	75%	-13	-12	-15
	50%	-22	-18	-20
$40	90%	-15	-17	-25
	75%	-20	-20	-28
	50%	-31	-26	-33
$60	90%	-23	-25	-37
	75%	-27	-28	-40
	50%	-38	-34	-45

Petersen *et al.*(2003) used MIDAS to examine the role of commercial tree crops for greenhouse gas abatement in the south-west of Australia, and concluded that tree crop plantations are effective at reducing emissions from a predominately grazing farm system. This finding also holds for broadacre farms in the cental wheatbelt of WA.

Flugge and Abadi (2006) used MIDAS to analyse the viability of growing trees for the purpose of selling carbon credits in low and medium rainfall zones, and established that, at an expected carbon price of $15 per tonne, growing trees was viable in the medium rainfall region but not in the low rainfall region. Trees come into the optimal solution in this analysis at an emission permit price of $40, although this is due to the requirement to lower emission levels, not to be a viable enterprise in their own right.

3.4 Optimal farm plans under different CPRS scenarios

As discussed earlier, in a business-as-usual scenario the optimal farm plan is to allocate 70 percent of farmland to cropping operations and the rest to running livestock. In an uncovered CPRS scenario, the optimal farm plan includes 60 percent of farmland in cropping. In a plausible covered CPRS scenario, where the emission permit price is $40 and 90 percent of free permits are allocated, the optimal farm plan is also 60 percent of arable land in crop.

Although the optimal allocation of land to cropping enterprises in different CPRS scenarios does not change significantly from the business-as-usual scenario, the profit reductions under each scenario does change. Profit reduction in an uncovered scenario is nearly 8 percent from business-as-usual profit, and in a covered scenario nearly 17 percent.

Figure 6 details the optimal area allocation of crop and pasture species, and sheep numbers, under the different CPRS scenarios. It shows the greenhouse gas emissions from each scenario before any reduction/abatement activity. The introduction of the CPRS, agriculture uncovered and covered, notably changes the composition of crop and pasture species grown and the number of sheep on the farm. There are fewer cereals grown, but more area of pasture and lucerne and more sheep. Sheep numbers increase by 19 percent from a business-as-usual scenario to an uncovered scenario (4644 and 5537 sheep respectively), and by 8 percent in a covered scenario (5036 sheep). The area of canola grown is significantly lower in CPRS scenarios, so too the area of lupins, especially in the covered scenario (area planted is down 46 percent from the business-as-usual scenario).

In the scenario where agriculture is uncovered these changes reflect the move away from energy and energy-dependant inputs. Livestock operations rely less on expensive farm inputs such as fertiliser, chemicals and machinery operations. The growing of canola requires high fertiliser use, thus the area planted decreases by 84 percent from a business-as-usual scenario.

When agriculture is covered and producers become responsible for their emissions, there is a move away from sheep, but not to levels lower than the business-as-usual scenario. Due to the high level of free permits (90 percent) the intent of the scheme is distorted, and the profit-maximising enterprise mix still contains many emissions from livestock. However, the fewer free permits farmers are given the more appropriate, in term of the CPRS policy, is the farmer's response in lowering net emissions. For example, at a $40 emission permit price but only a 75 percent level of free permits, the optimal farm plan runs 18 percent less sheep than the business-as-usual scenario.[2] The large reduction in area planted to lupins also reflects the move away from emission intensive activities, in this case reducing nitrous oxide emissions associated with lupin crops.

An interesting finding of this study is that, for the CPRS scenarios considered (excluding abatement activity), emissions from the farming system are actually greater than in a business-as-usual scenario (Figure 6). In the uncovered scenario 1463 tonnes of CO_2-e are produced and in a covered scenario where the permit price is $40, emissions are 1454 tonnes. However, when abatement/reduction activities are included in the covered scenario at the 90 percent free permit level, greenhouse emissions are equal to those in the business-as-usual scenario (1309 tonnes of CO_2-e). The implication is that as the Australian government works towards lowering greenhouse gas emissions from those industries covered by the CPRS, agriculture, whether covered or not, is likely to make little contribution towards achieving greenhouse reduction targets. Once again in the covered scenario this is due to the high level of free permits. By contrast, if free permits were at the 75 percent level, requiring producers to reduce 25 percent of their emissions, then emissions from the optimal farm plan after abatement would be 982 tonnes of CO_2-e.[3]

[2] The optimal farm plan in this situation ($40 emission permit price and 75 percent free permits) has shifted to 70 percent of the farm's arable area being in crop

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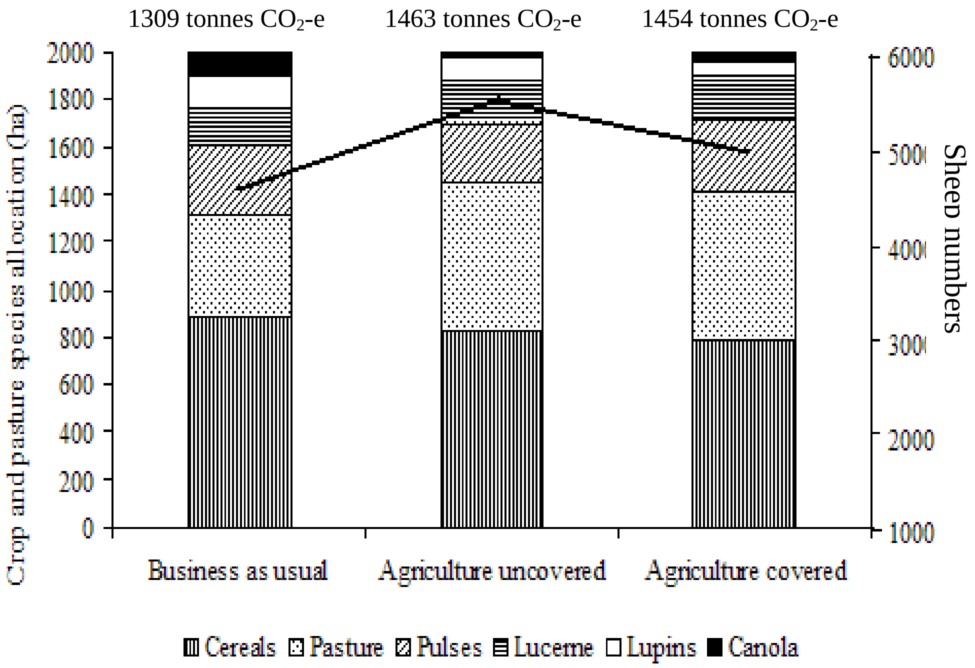

Figure 6 The area (ha) of crop and pasture species and sheep numbers under the optimal farm plan of a business-as-usual (70 percent cropping), uncovered (60 percent cropping at $20 emission permit price), and covered scenario (60 percent cropping at $40 emission permit price and 90 percent free permits). Also the tonnes of greenhouse gas emissions (CO_2-e) from these farming systems before any reduction/abatement activities.

4. Conclusion

This research has assessed the farm-level implications of introducing a Carbon Pollution Reduction Scheme (CPRS) to the broadacre farming systems in Western Australia. The purpose of this study is to increase our understanding of how mixed enterprise farming systems might reduce and/or offset their emissions in response to the CPRS and how farm profits might be affected. Two main scenarios were considered; an uncovered scenario where agricultural producers experience higher farm input costs as a consequence of the operation of the scheme, and a covered scenario where producers are directly accountable for their greenhouse emissions. Within each scenario changes to the nature of the farming enterprise, generated in response to the scheme, are determined along with the impacts on farm profitability.

A key finding is that if agriculture is a covered sector under the CPRS, then farmers could face severe reductions in profit, especially if the provision of free permits is limited. A plausible covered scenario for agriculture would see profit reductions of between 15 to 25 percent of 'business-as-usual' profit. Profit reductions in an uncovered scenario were also significant but less, being between 7 to 12 percent at an emission permit price of $20. Hence, the profitability of farming is under threat from the introduction of the CPRS, and greenhouse policy needs to address this when finalising the design rules of the scheme.

Another key finding concerns the twofold nature of free permits. Although a high level of free permits ensures the CPRS generates little impact on the profitability of farming, it distorts the primary intent of the CPRS by not signalling that emissions intensive activities are undesirable. Again, this has serious implications for the design rules of the scheme. If agriculture becomes a covered industry in 2015 and is considered 'emissions intensive and trade exposed', and thus granted a certain level of free permits, then it may be necessary to find alternative methods for compensation that promote emissions reduction while ensuring farm businesses remain viable.

Another finding concerns the way covered farming systems deal with the requirement to reduce and/or abate their greenhouse emissions. The most cost-effective strategies for reducing emissions from typical central wheatbelt farming systems in WA include reducing livestock numbers, planting trees and changing the mix of farm enterprises. Under the different levels of free permits used in this analysis (90, 75 and 50 percent) the purchasing of permits is not part of the profit-maximising strategy. Rather abatement via carbon sequestration in reforestation is a more cost-effective use of farm financial resources than purchase of permits.

Most importantly, this study highlights the crucial need for research and development 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 greatly contribute to lowering farm emission levels. In this study livestock are the major source of greenhouse emissions for the broadacre farming systems, as sheep still play an important economic role in the farming systems, even in a covered CPRS scenario when producers are responsible for farm emissions. In other words, sheep, albeit in reduced numbers in some situations, still form part of profit-maximising farm plans.

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 associated with the CPRS that have not been captured in this analysis such as implementation, monitoring and compliance costs.

From this research stems additional issues deserving further investigation, particularly once the design rules of the CPRS are finalised. For example, investigating changes in emission factors is needed. Biswas *et al.* (2008) have shown that regionally-specific data for nitrous oxide emissions are appreciably different from international default values. If such regionally specific emission factors could be applied to a region's farming systems then how different would be the impacts of the CPRS on the nature and profitability of different farming systems?

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