Climate change abatement and farm profitability analyses across agricultural environments

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Abstract

Management practices that reduce greenhouse gas emissions from farms or increase on-farm carbon storage can contribute to climate change mitigation. Farmers, however, are only likely to adopt new management practices if they contribute to farm profitability. We use the Agricultural Production Systems sIMulator (APSIM) to simulate how different cropping practices contribute to greenhouse gas abatement at case study farms in different grain growing regions across Australia. The APSIM simulations were subsequently used to calculate farm gross margins and conduct whole-farm economic modelling to estimate the costs of abatement under different management practices. Integrating detailed biophysical and economic analyses enables us to demonstrate the difference in potential to reduce greenhouse gas emissions across agricultural environments. We show this for two case study farms in different grain growing regions, where we found both positive and negative relationships between greenhouse gas abatement and profitability for the management practices. This diversity in potential to reduce greenhouse gas emissions across agricultural environments must be recognised in order to understand the role agriculture can play in climate change mitigation, and understand the implications of any potential future changes to include the industry in carbon pricing policies.

Keywords: Whole-farm economics, APSIM, nitrous oxide, carbon sequestration, climate change mitigation, grain farms

JEL-codes: Q12, Q54

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1. Introduction

The Australian agricultural industry is responsible for 15-16 percent of national greenhouse gas (GHG) emissions (Department of the Environment, 2013, 2015). Given the contribution of agriculture to national emissions, the industry is expected to contribute to emissions reduction efforts. Anticipated financial benefit has been identified as an important driver for farmers to adopt new practices (Cary and Wilkinson, 1997; Frost, 2000; Maybery et al., 2005; Pannell et al., 2006) and, more specifically, new low GHG emissions practices (Morgan et al., 2015). Therefore, as long as emissions reductions are voluntary, the economics of abatement is likely to be important in farmers' decisions to adopt or not adopt management practices that contribute to GHG emission reductions. Equally, any potential future decisions to mandate agriculture in emissions reduction policies (e.g. carbon pricing policies) will need to be informed by the economic impacts of abatement.

Increasingly, studies to understand the biophysical and economic potential of agricultural GHG abatement in the Australian environment have modelled potential options for farmers to reduce GHG emissions under carbon pricing policies. Further, they have determined the relative cost of a range of abatement options (based on reductions in farm profit) or determined the supply of abatement that is possible under different carbon prices. A carbon price of $23 per tonne of carbon dioxide equivalents (CO_2-e) was implemented in Australia from July 2012 to July 2014. Though agriculture was not legislated in the carbon price policy, studies have modelled the impact of this carbon price and a range of GHG abatement practices on farm profitability (e.g. Kragt et al., 2012; Thamo et al., 2013). Based on modelled reductions in profitability Kragt *et al.* (2012) estimate that the carbon price would need to be higher than $23 per tonne of CO_2-e and more like $80 per tonne CO_2-e to incentivise farmers to change their stubble management and sequester carbon in cropping soils in Western Australia. Likewise, Barton *et al.* (2014a) estimate that West Australian grain farmers would require a carbon price of $93 per tonne CO_2-e to grow legumes in rotations as a GHG abatement option. Studies including forestry as a GHG abatement option tend to estimate lower carbon prices for economic viability than studies that exclude forestry. Paul *et al.* (2013) conclude that the carbon price required for economic viability of biodiverse tree plantings on marginal agricultural land is generally lower than $18 per tonne CO_2-e. We look to answer similar questions to those of the studies described above, but with some different considerations in our analysis.

In terms of scope, we note two distinguishing features of existing studies. The first feature is the greenhouse gases included in the analysis. It appears that many studies focus on the economics of abatement for only one greenhouse gas. For example, Kragt *et al.* (2012) and Grace *et al.* (2010) consider the economics of abatement in broadacre cropping and mixed crop-livestock systems focussing specifically on soil carbon sequestration as a means of abatement. The second feature is the location, or agricultural environment, covered by the analysis. Many studies have looked at one or similar environments. For example, the same studies listed above, Kragt *et al.* (2012) and Grace *et al.* (2010), look at carbon sequestration in only the central wheatbelt of Western Australia and only the cropping region of south-eastern Australia, respectively.

We expand on existing studies in two ways. Firstly, by assessing the whole-farm economic implications of abatement practices that can sequester soil organic carbon (SOC) or/and reduce nitrous oxide (N_2O) emissions. This is motivated by evidence for increased N_2O emissions from soils with higher carbon content (Barton et al., 2014b) and the potential for 'leakage' of emissions when only considering one GHG. 'Leakage' can occur if the emissions of one GHG increase as a result of efforts to reduce emissions of another GHG. Secondly, we expand on previous studies by conducting a whole-farm economic analysis of GHG abatement in a range of agricultural environments. We use the biophysical simulation model APSIM, which has been tested in many different environments in Australia (e.g. Huth *et al.,* 2010; Kragt *et al.,* 2012; Nash *et al.,* 2013), to predict changes in SOC stocks or N_2O emissions in various Australian grain growing regions. APSIM output is integrated with an economic analysis that is straightforward enough to be readily calibrated for other case study farms. A multi-environment analysis is important because any policy to incentivise emissions reductions will encompass different agricultural environments with different GHG abatement potentials. We provide results for two case study farms to demonstrate the importance of integrating detailed biophysical and economic modelling to understand the potential for the Australian grains industry to contribute to greenhouse gas reductions.

2. Methods

2.1 Scenarios

Options for broadacre cropping farms to reduce greenhouse gas emissions whilst continuing to grow crops (i.e. not engaging in forestry or native vegetation management) include: adding organic matter to the soil; changing nitrogen fertiliser management; and increasing cropping intensity (Dalal et al., 2003; Lal, 2004; Sanderman et al., 2010; Schlesinger, 1999; Smith et al., 2008; West and Post, 2002). We developed scenarios that include practices that have the potential to mitigate greenhouse gas emissions by increasing SOC sequestration or reducing N_2O emissions (Table 1). These practices included retaining stubble instead of burning it (Scenarios 2, 5-10); modifying nitrogen fertiliser rates

(Scenarios 3-6); adding organic matter as manure (Scenario 7), increased cropping intensity (Scenarios 8 and 10), and improved pasture (Scenarios 9 and 10). These scenarios were modelled for case study farms in agricultural environments that varied in: annual rainfall, temperature, soil types, cropping systems and management requirements.

Table 1. Scenario descriptions

No.	Name	Management practice description
1	Burn	Stubble burnt, bare summer fallow
2	No Burn	Stubble retained, bare summer fallow
3	Burn+N	Stubble burnt + 25 % extra N fertiliser
4	Burn-N	Stubble burnt - 25% less N fertiliser
5	No Burn+N	Stubble retained, bare fallow + 25 % extra N fertiliser
6	No Burn-N	Stubble retained, bare fallow - 25% less N fertiliser
7	Feedlot manure[1]	Stubble retained, bare fallow + feedlot manure
8	Summer crop[2]	Stubble retained + summer crop
9	ImprPasture[3]	Stubble retained, bare fallow + improved pasture
10	8&9Combination[2,3]	Stubble retained + opportunistic summer crop + improved pasture

[1] Feedlot manure (water content 20%; carbon fraction 0.4; C:N ratio 20:1) applied at 5 Mg ha^{-1} each five years; [2] Summer crop is a cowpea; [3]Applied only where there is a chemical fallow or 'weedy' pasture phase in the crop rotation

2.2 Biophysical modelling

Baseline farming practices and alternative, greenhouse gas abatement practices were simulated using the Agricultural Production Systems Simulator (APSIM; Holzworth et al., 2014). The APSIM model was used to predict crop yield, N_2O emissions and changes in SOC for each scenario (Table 1) on each soil type. APSIM 7.5 was parameterised with the relevant climate data (Jeffrey et al., 2001), soil properties and management practices described in Table 1. APSIM was configured with modules for soil nitrogen (APSIM-SoilN; Probert et al. 1998; Thorburn et al. 2010), soil water (APSIM-SoilWat; Probert et al. 1998), soil temperature (APSIM-SoilTemp2, following Campbell, 1985), residue (APSIM-SurfaceOM; Probert et al., 1998; Thorburn et al., 2001), and crop growth. APSIM-SoilN and APSIM-SoilWat were parameterised with representative local soils that were included in the APSIM soil toolbox.

Crops were modelled using default parameters for commonly used local varieties or, where these were not available, for varieties that produced comparable yield. Crop management information (e.g. plant density, sowing depth and sowing window) were provided by collaborating farmers, farmer groups and consultants.

Each scenario was simulated over a 100 year period. Because crop yields and changes in SOC are sensitive to initial conditions, each combination was run for 10 different starting years in case cyclical patterns occurred in the climate data. The 10 starting years were 1906 to 1915 (i.e. the simulation periods were 1906-2005 to 1915-2014). The results from the 10 starting years were then averaged to give results for one 100 year simulation period.

To compare net greenhouse gas abatement from sequestered SOC and changed N_2O emissions, values were converted to the common unit of carbon dioxide equivalents (CO_{2}-e; IPCC, 2013). Greenhouse gases included in the calculations were limited to on-farm changes in (a) carbon dioxide associated with sequestration of SOC (0.0-0.3 m), and (b) emissions of N_2O. Changes in N_2O emissions were converted to CO_{2}-e using a conversion factor of 298 (IPCC, 2013). The CO_{2}-e of sequestered SOC was calculated using a conversion factor of 3.67 (IPCC, 2013). The net GHG abatement, also referred to as the net change in global warming potential, reported in this paper is the sum of CO_{2}-e values derived from each alternative practice (Scenarios 2-10 or 3-10, Table 1) compared to the emissions from the baseline scenario (Scenario 1 or 2, Table 1).

2.3 Economic analyses

We use a gross margin and whole-farm economic analysis to compare the profitability of current farm management practices to each of the alternative GHG abatement practices. This analysis allows us to identify the costs and benefits (if any) associated with changing farm management to mitigate greenhouse gas emissions.

2.3.1 Gross margins

The gross margin is the difference between revenue and cost before accounting for fixed costs. In our model this is crop revenue less the costs directly associated with grain production (the variable costs). To calculate crop revenue, APSIM simulated yields were multiplied by the five-year-average farm-gate price for the relevant grain. A gross margin (GM in $\$\cdot ha^{-1}\cdot yr^{-1}$) is calculated for each soil type *i* and crop *j* on a farm in a given year (equation 1).

$$GM_{ij} = (crop\ yield_{ij}\ x\ crop\ price_j) - VC_j \qquad (1)$$

The variable costs VC_j for each crop *j* include: seed, fertiliser, chemicals, machinery maintenance and repairs, fuel, lime, gypsum, manure, freight, contractors, casual labour and crop insurance. All variable costs correspond to the inputs used in the APSIM modelling and/or are based on common practices for each case study area.

To allow comparisons of gross margins across rotations, we calculate the average annual gross margin for each rotation (e.g., rather than a four year rotation having different annual GMs, corresponding to different crops, we have one average GM for each of the four years). This procedure represents that a farmer compares the profitability of a rotation as a whole, rather than each individual crop in a rotation.

2.3.2 Operating profits

The operating profit OP_n of a farm n measures profitability at the whole-farm scale, and is equal to total revenue minus total cost. Revenue is generated by crop sales: $yield_{ij}$ x $price_j$. Total cost includes the variable costs VC_j (outlined in the previous section) plus operating, or fixed, costs. Operating costs OC_n are incurred regardless of whether a crop is grown. They include overheads (electricity and phone bills, insurance, advisory and accounting services, administration expenses etc.), the farmer's income, machinery costs, and other capital expenditure.

To calculate the annual OP_n we first calculate the whole-farm gross margins by multiplying each GM_{ij} by the area of each soil type i and crop j, and summing over all soil types and crops:

$$Farm\ GM = \sum_{i=1}^{I}\sum_{j=1}^{J} area_{ij} \times \left[\left(yield_{ij} \times price_j\right) - VC_j\right] \quad (2)$$

Where $area_{ij}$ is the area in hectares of each soil type i and crop j on the farm in a given year. Operating profit is calculated by subtracting OC_n from the farm GM:

$$OP_n = \sum_{i=1}^{I}\sum_{j=1}^{J} area_{ij} \times \left[\left(yield_{ij} \times price_j\right) - VC_j\right] - OC_n \quad (3)$$

The operating profit, OP captures the capacity of the farm to generate profits from cropping under different GHG abatement scenarios. OP is also known as 'earnings before interest and tax' in accounting. The earnings before interest and tax are a useful metric to compare the costs and benefits of GHG abatement practices across farms that operate in different tax environments and have different financing strategies (and thus incur different interest). Operating profit has been a popular metric to assess the cost-effectiveness of greenhouse gas abatement (e.g. Adler et al., 2013; Adler et al., 2015; Doole, 2014; Vibart et al., 2015).

The primary difference between the gross margin analysis and the whole-farm economic analysis is the treatment of fixed farming costs. The whole-farm economic analysis captures whether the adoption of a GHG abatement practice requires a change in fixed costs structure compared to the current practice (for example by purchasing new equipment). Accounting for fixed costs allows us to compare the costs of adopting GHG abatement practices on farms with different capital infrastructure. This comparison is important if we attempt to assess the effectiveness of different national policy schemes (e.g. carbon prices) that are likely to affect these systems.

2.3.3 Economic data collection

Data to populate the economic modelling were collected from a range of sources, including collaborating farmers, and were checked with researchers, consultants and farmers in the study areas. Crop prices are area-specific and vary from year-to-year, thus, the model was populated using the average 2010-2014 farm-gate crop prices for our case study regions (Appendix 1). The variable costs were based on the costs included in standard gross margin-templates that farmers or consultants in the study regions typically use. For variable costs dependent on APSIM simulations, e.g. fertiliser, we parameterise the model with the price per unit of fertiliser (Appendix 1). For variable costs not dependent on APSIM simulations such as chemicals, lime or gypsum and freight, the price per unit and required quantity were based on feedback from farmers in the region. The operating costs (fixed costs) are based on average-annual farm expenditure on overheads, farm manager wages, and machinery and capital improvements. These operating costs were collected from farm surveys, machinery guides and farm records from the case study areas (Appendix 1).

2.4 Case study regions

The Australian Grain Research and Development Corporation (GRDC) distinguishes three main grain growing regions in Australia: western (south-west of Western Australia), southern (southern New South Wales, Victoria, South Australia and Tasmania), and northern (Queensland and northern New South Wales). The conditions vary greatly within and across these regions. We demonstrate our modelling approach for a grain farm in the northern wheatbelt of Western Australia (WA) and the Wimmera district of Victoria (VIC). These grain growing regions experience different climate conditions and have different soil types and thus are likely to exhibit different GHG abatement potentials. The case study farms also vary in their baseline practices.

The case study farms are briefly characterised as:

1. Dalwallinu (WA)
   Farm size = 6,000 hectares
   Climate = Mediterranean climate, winter-dominant average annual rainfall of 358 mm yr^{-1}
   Soils = sands and sandy loams
   Crops = canola, wheat, barley, lupins
   Baseline practice = Scenario 1 or 2 (Table 1)

2. Wimmera (VIC)
   Farm size = 2,300 hectares
   Climate = Temperate climate, winter-dominant average annual rainfall of 447 mm yr^{-1}
   Soils = clays
   Crops = canola, wheat, barley, chickpeas, faba beans, oaten hay
   Baseline practice = Scenario 2 (Table 1)

3. Results

The gross margin and whole-farm economic analyses allow for profitability comparisons across greenhouse gas abatement scenarios. The comparison of interest is between the baseline (current practices) and each alternative practice at the case study farms. The results, for the Dalwallinu and Wimmera farms, indicate that profitability gains are possible for a subset of the greenhouse gas abatement practices. In the literature, these are sometimes referred to as 'no-regrets' or 'win-win' greenhouse gas abatement options. For the Dalwallinu farm, win-win practices are: retaining stubble, retaining stubble and adding 25 percent extra nitrogen fertiliser, and retaining stubble and replacing weedy pasture phases with improved pasture (top-left quadrant of Figure 1(a) and Figure 1(c)). For the Wimmera farm, replacing a winter fallow with an improved pasture can achieve improved profitability at the same time as GHG abatement (top-left quadrant of Figure 1(b) and Figure 1(d)).

The remaining greenhouse gas practices can be separated into two categories: (1) those that do not provide greenhouse gas abatement relative to the current practices; and (2) those that were predicted to reduce greenhouse gas emissions but at a cost to operating profit. Practices that are predicted to reduce greenhouse gas emissions at a cost to profitability are plotted in the bottom-left quadrants in Figure 1. Generally, these practices provide more GHG abatement than profitable practices but are costly to implement. There are significant differences in the amount of abatement and the costs per unit of abatement between farms and scenarios (Figure 1). For example, summer cropping and the use of improved pastures (Scenario 10) is predicted to achieve the most abatement at the Dalwallinu and Wimmera farms. Average annual emissions reductions under Scenario 10 at Dalwallinu was predicted to be 0.49 tonnes of CO_2-e ha^{-1} yr^{-1} and at the Wimmera farm was predicted to be 1.94 tonnes of CO_2-e ha^{-1} yr^{-1}. The cost per tonne of CO_2-e abatement for Scenario 10 at the Dalwallinu farm is \$67 and at the Wimmera farm is \$44.

In this analysis the gross margin was always greater than the operating profit. This follows from the extra costs accounted for the in the calculation of the operating profit. However, we are most interested in the comparison in profitability between the baseline and the alternative practice. When making this comparison there is very little difference in the results generated using a gross margin calculation or the whole-farm analysis (Figure 1).

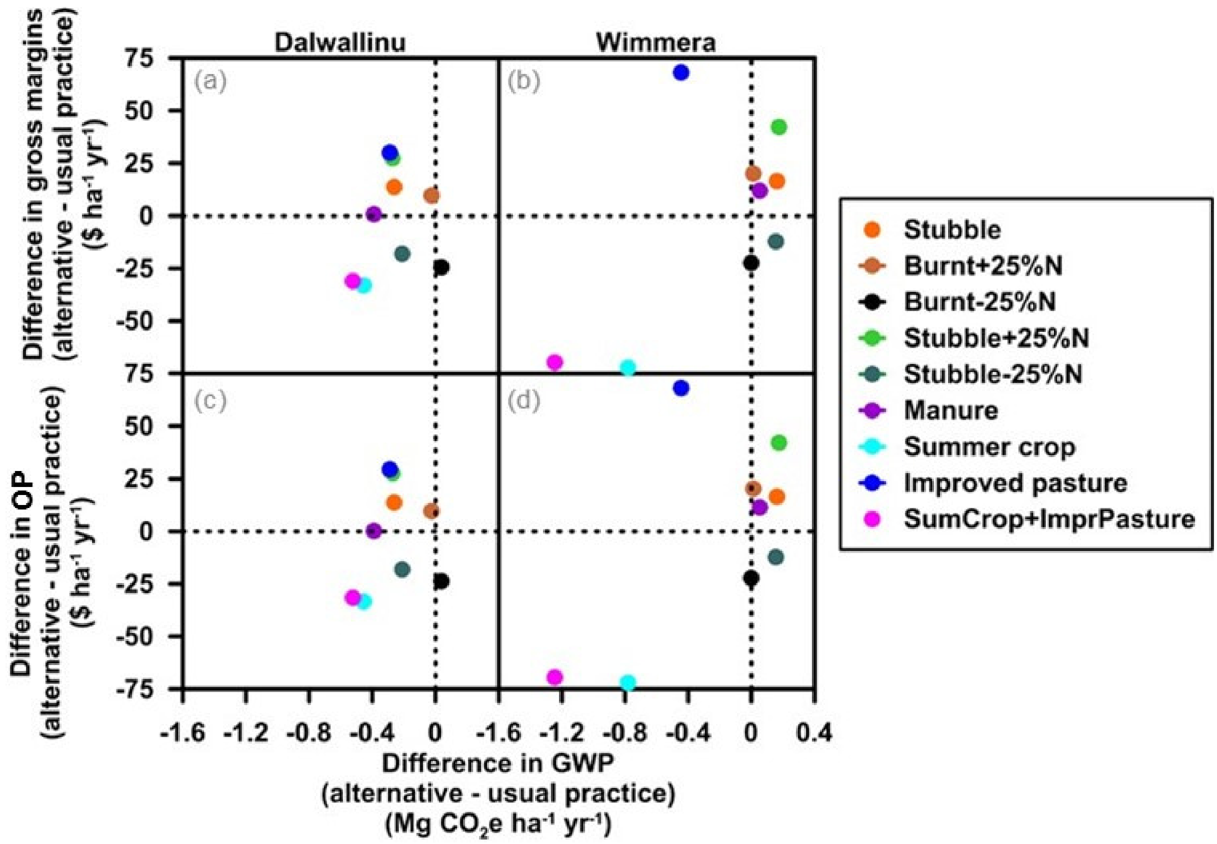

Figure 1. Difference between alternative scenarios and baseline values for net global warming potential (GWP) and profitability at the Dalwallinu and Wimmera case study farms. Data points are averages for a 100 year simulation period. Positive values represent an increase relative to the baseline scenarios.

4. Discussion

In this paper we describe our approach to integrated bio-economic modelling to predict GHG emissions, crop yield and farm profitability of different management practices on grain farms in different agricultural environments. This approach enables us to assess what GHG abatement practices can be implemented on a farm under varying climate or economic conditions. Using this approach we can provide insights into the costs faced by farmers if they were to adopt GHG abatement practices in the absence of policy help and provide insights into the compensation payments required to encourage the adoption of GHG abatement practices. Further, we can contribute empirical evidence to the debate about whether or not the cost of GHG abatement on grain farms is relatively high or relatively low in different locations, and relatively high or relatively low compared to other agricultural enterprises (e.g. livestock farming) and relatively high or relatively low compared to other industries. Such cost and relative cost information is important for decision-makers when considering whether to mandate emissions reductions for the sector or encourage emissions from the sector through voluntary policy programs (Ancev, 2011).

The results for two case study farms indicate a positive relationship between GHG abatement and profitability for a sub-set of the greenhouse gas abatement practices simulated. We find that retaining stubble, fewer fallow periods and improved nitrogen management could contribute to GHG abatement and improved profitability at our case study farms. If these practices are indeed profitable, have farmers already adopted them? If they have not already adopted them, what, other than profitability, could be hindering this process? Farmers' risk preferences, management requirements, irreversibility of investment, and a lack of required resources could be barriers to adoption (Ancev, 2011; McCarl and Schneider, 2000). Such barriers could prevent the adoption of some practices included in our scenarios. For example, summer cropping may require significant increases in farm labour and is likely to be an opportunistic venture for grain farmers in Western Australia and Victoria. Retention of crop stubble was an important practice for improving SOC sequestration, and hence achieving GHG abatement. However, stubble burning is an important tool for managing weeds and so other methods of weed control may need to be adopted when stubble is retained. Also, some abatement practices may require inputs that are not readily available in the local area. For example, feedlot manure may not be available in all regions, and the variable nature of manure may lead to different responses in SOC and yield and thus economics, than were obtained in this study (using constant quality parameters for manure).

The practices predicted to provide the highest level of abatement in our analysis tended to be costly to farm profitability. For the case study farms presented in this paper, summer cropping and summer cropping alongside the inclusion of improved pastures in the cropping rotation were predicted to provide the highest levels of abatement. Factors that reduced profits under summer cropping scenarios were decreased yields and increased input costs, such as, higher labour, seed, chemical, fuel and machinery costs (Appendix 1). Summer cropping at West Australian and Victorian farms can have a detrimental effect on the yields of the subsequent crop if soil water and nutrients are depleted in the summer cropping phase and not replenished before the following winter crop is planted (Robertson et al., 2005). For the Dalwallinu farm a move from baseline practices to retained stubble and summer cropping (scenario 8, scenario 10) reduced operating profits by \$32-33 ha^{-1} yr^{-1} and reduced emissions by 0.424-0.485 t CO_2-e ha^{-1} yr^{-1}. These results follow findings by Kragt *et al.* (2012) and Thamo *et al.* (2013) in a similar environment. Kragt *et al.* (2012) predicted a change in crop rotations from the profit-maximising rotation to a rotation that could maximise SOC sequestration would decrease profit by \$50 ha^{-1} yr^{-1} and increase carbon sequestration by 0.205 t CO_2-e ha^{-1} yr^{-1}.

The greenhouse gas abatement scenarios selected for inclusion in this analysis do not require structural changes to the farming system or the farm's enterprise mix. These scenarios represent management changes that farmers can make without forgoing the opportunity to grow grain. This is an important consideration given objectives to increase global food supply to keep up with growing demand from a growing population at the same time as reducing GHG emissions from agriculture. However, the relatively incremental nature of the management changes means that there are no significant differences in the operating costs (fixed costs) between scenarios. A consequence of this is that the relative profitability of the scenarios (compared to the baseline practices) are very similar from a gross margin and a whole-farm perspective. The only changes in fixed costs between scenarios were the inclusion of extra, or different, machinery (Appendix 1). Nevertheless, it is important to conduct the whole-farm analysis to capture these extra costs as changes to fixed costs are likely to be important in farmer decision making. If other scenarios were included, such as forestry options, we expect the importance of fixed costs to be greater. Our approach allows for such alternative scenarios to be readily included in the economic model.

Our approach to model the biophysical and economic consequences of GHG abatement on grain farms has a number of advantages. It allows us to: (1) extend the analysis to multiple agricultural environments; (2) include multiple GHGs in the analysis and consider the trade-offs between them; (3) change parameter values with relative ease; and (4) account for whole-farm economic impacts that are likely to be important in farmers' decisions to adopt or not adopt GHG abatement practices. These advantages are important as we attempt to predict the cost of, and capacity for, abatement under ever-changing climate, economic and policy conditions. We believe that the approach has an appropriate balance of complexity and simplicity. It is sufficiently complex to account for a range of factors that influence GHG abatement and profitability and sufficiently simple to enable us to change parameter values and adapt the analysis for a different environment or economic scenario. A transparent simulation approach is also advantageous as it allows us to diagnose the key costs and drivers of profitability under different management practices and show our process and outputs to key stakeholders including farmers and policy-makers.

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Appendix 1. Economic parameters

Table A1. Crop prices for Dalwallinu and Wimmera case study farms. Prices are average farm gate price for 2010 – 2014.

Dalwallinu farm		**Wimmera farm**	
Canola	$480/t	Canola	$490/t
Wheat	$260/t	Wheat	$240/t
Barley	$230/t	Barley	$230/t
Lupins	$250/t	Chickpeas	$500/t
		Faba beans	$380/t
		Oaten hay	$145/t

Data from: Rural Solutions SA (2015) *Farm Gross Margin Guide 2015*. Available from: http://www.grdc.com.au/Resources/Publications/2015/02/2015-Farm-Gross-Margin-Guide;
DAFWA (2012) *Gross margins by region*, Department of Agriculture and Food Western Australia, South Perth

Table A2. Variable costs for Dalwallinu and Wimmera case study farms.

Dalwallinu farm		**Wimmera farm**	
Crop seed + seed treatment costs			
Canola	$12.32/ha	Canola	$30.00/ha
Wheat	$27.23/ha	Wheat	$21.60/ha
Barley	$23.73/ha	Barley	$28.80/ha
Lupins	$29.00/ha	Chickpeas	$75.02/ha
Improved pasture	$16.00/ha	Faba beans	$60.00/ha
(serradella)		Oaten hay	$23.40/ha
		Improved pasture (serradella)	$16.00/ha
Fuel (planting, spraying, harvesting etc)			
Seeding	$6.50/ha	Seeding	$6.50/ha
Top-up fertiliser	$1.30/ha	Top-up fertiliser	$1.30/ha
Spraying	$1.30/ha	Spraying	$1.30/ha
Harvesting*	$10.40/ha	Harvesting*	$10.40/ha
*Critical (minimum) yields to warrant harvest			
Canola	50 kg/ha	Canola	50 kg/ha
Wheat	100 kg/ha	Wheat	100 kg/ha
Barley	100 kg/ha	Barley	100 kg/ha
Lupins	100 kg/ha	Chickpeas	60 kg/ha
		Faba beans	60 kg/ha
		Oaten hay	0 kg/ha
Fertiliser			
Urea	$0.607/kg	Urea	$0.620/kg
DAP	$0.837/kg	MAP	$0.780/kg
Agstar Extra	$0.757/kg		
Sulphate of Ammonia	$0.320/kg		
Superphosphate	$0.358/kg		
Muriate of Potash	$0.716/kg		

Table A2 (Cont.) Variable costs for Dalwallinu and Wimmera case study farms

Dalwallinu farm		**Wimmera farm**	
Chemicals			
Canola	$108.76/ha	Canola	$84.57/ha
Wheat	$72.40/ha	Wheat	$88.70/ha
Barley	$57.75/ha	Barley	$83.20/ha
Lupins	$47.50/ha	Chickpeas	$124.73/ha
Weedy pasture	$33.50/ha	Faba beans	$138.28/ha
Improved pasture	$45.00/ha	Oaten hay	$39.56/ha
Wheat after weedy pasture	$79.40/ha	Improved pasture	$45.00/ha
		Chemical fallow	$50.75/ha
Machinery repairs and maintenance			
Canola	$18.92/ha	Canola	$18.92/ha
Wheat	$12.44/ha	Wheat	$12.44/ha
Barley	$12.44/ha	Barley	$12.44/ha
Lupins	$16.43/ha	Chickpeas	$19.17/ha
Pasture	$10.00/ha	Faba beans	$19.74/ha
		Oaten hay	$7.05/ha
		Improved pasture	$10.00/ha
		Chemical fallow	$10.00/ha
Lime		**Gypsum**	
2 tonnes per hectare every 5 years		2.5 tonnes per hectare every 10 years	
Purchased, carted, spread	$122/ha	Purchased, carted, spread	$105/ha
Freight			
For fertiliser	$28/t	For fertiliser	$20/t
Manure			
Purchased, carted, spread	$44.50/ha	Purchased, carted, spread	$36.50/ha
5 tonnes applied every 5 years		5 tonnes applied every 5 years	
Summer crop (cowpea)			
Seed, chemicals, fertiliser	$47.40/ha	Seed, chemicals, fertiliser	$47.40/ha
Casual labour		**Contractor costs**	
$2100 per person, per week		Top-up fertiliser	$12/ha
		Spraying	$14/ha
		Windrowing	$35/ha
		Mowing hay	$42/ha
		Baling hay	$27/t
Crop insurance (cost per dollar of expected income)			
Canola	$0.012/$1	Canola	$0.012/$1
Wheat	$0.0085/$1	Wheat	$0.0085/$1
Barley	$0.0085/$1	Barley	$0.0085/$1
Lupins	$0.01/$1	Chickpeas	$0.01/$1
		Faba beans	$0.012/$1
		Oaten hay	$0.0025/$1

Data from: Rural Solutions SA (2015) *Farm Gross Margin Guide 2015*. Available from: http://www.grdc.com.au/Resources/Publications/2015/02/2015-Farm-Gross-Margin-Guide; DAFWA (2012) *Gross margins by region*, Department of Agriculture and Food Western Australia, South Perth; NSW DPI (2012) *Farm budgets and costs*. Available from: www.dpi.nsw.gov.au/agriculture/farm-business/budgets. Accessed 15/4/2015; Kondinin Group (2012) *Low cost, high quality pastures for cropping*, Farming Ahead, No. 242, March 2012; MIDAS Model: CWM2014 (2014) (Authors: S. Blennerhassett, A. Bathgate, E. Petersen, M. O'Connell, J. Young, F. Byrne, T. Thamo and R. Kingwell); Liebe group consultation meeting, 24 March 2015.

Table A3. Operating costs for Dalwallinu and Wimmera case study farms.

Dalwallinu farm		**Wimmera farm**	
Farm manager wage (per F.T.E)			
$80,000/yr		$80,000/yr	
Overheads:	$94,500/yr	**Overheads:**	$44,500/yr
Insurance		Insurance	
Telephone		Telephone	
Licences		Licences	
Shire rates		Shire rates	
Electricity		Electricity	
Accounting services		Accounting services	
Advisory services		Advisory services	
Administration expenses e.g. subscriptions		Administration expenses e.g. subscriptions	
Fuel (other than that used to manage crop directly)		Fuel (other than that used to manage crop directly)	
Capital costs	$28,500	**Capital costs**	$23,500
Fences		Fences	
Sheds		Sheds	
Field bins		Field bins	
Silos		Silos	
Workshop supplies		Workshop supplies	
Machinery (Scenarios are described in Table 1)			
Scenario 1-6	$104,560/yr	Scenario 1-6, 8-10	$100,800/yr
Scenario 7	$107,560/yr	Scenario 7	$101,900/yr
Scenario 8-10	$108,660/yr		

Data from: ABARES (2015) *AGSURF: farm survey data*. Available from: apps.daff.gov.au/AGSURF. Accessed 15/04/2015; NSW DPI (2012) *Farm budgets and costs*. Available from: www.dpi.nsw.gov.au/agriculture/farm-business/budgets. Accessed 15/4/2015; Agribenchmark (Agrarian Management) (2013) *Kellerberrin typical farm data*. http://www.agribenchmark.org/cash-crop/network.html