What carbon farming activities are farmers likely to adopt? A best-worst scaling survey

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Highlights

- We survey farmers to determine their willingness to adopt carbon farming practices
- Farmers are most likely to adopt practices that support production objectives
- Farmers consider improved soil quality as the most important benefit from carbon farming
- Best-Worst Scaling revealed preferences for retaining stubble and no-till cropping
- Policy uncertainty is a barrier to farmers' participating in carbon farming policy programs

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Abstract

Transferring carbon from the atmosphere into terrestrial sinks through carbon sequestration practices (so-called 'carbon farming') has been proposed as an important component in Australia's efforts to mitigate greenhouse gas emissions. We use a Best-Worst Scaling survey to determine which carbon sequestration practices farmers would be most and least likely to adopt, and what factors were most important in any potential adoption decision. The survey was distributed to dryland cropping and mixed crop-livestock farmers in Western Australia. Farmers ranked improved soil quality and reduced soil erosion as the most important potential co-benefits of carbon farming. Factors discouraging farmers from participating in carbon farming contracts were policy and carbon price uncertainty and the uncertain impact of carbon farming practices on productivity and profitability. Farmers had strong preferences for stubble retention and no-till cropping practices as carbon farming strategies. The practices that farmers preferred least were applying biochar and planting trees. Farm and farmer characteristics, including (lack of) awareness of carbon farming policies and opinions about climate change, influence the potential willingness to adopt different carbon farming practices. Given recent policy uncertainty and farmer preferences revealed in this study, it is important to communicate potential co-benefits (rather than opportunities to earn compensation or carbon credits) to increase farmers' engagement in carbon sequestration activities.

Keywords

Climate change mitigation, best worst ranking, stated preferences, broadacre farming systems, Australia

1. Introduction

To limit the potential impacts of climate change, the Australian government has set national greenhouse gas (GHG) emissions reduction targets. The current reduction target (updated in August 2015) is 26-28 percent below 2005 emissions by 2030 (Department of the Environment, 2015a). The Australian agricultural industry is responsible for 15-16 percent of national emissions (Department of the Environment, 2015b). As such, the industry is expected to contribute to national efforts towards emissions reductions.

Carbon farming is one way for farmers to reduce greenhouse gas emissions. 'Carbon farming' refers to a range of land use and land management practices designed to reduce emissions from farming activities, or sequester carbon in natural sinks such as soil and vegetation (Smith et al., 2008). In Australia, there are policies in place that include incentives to stimulate the adoption of carbon farming practices by landholders. The initial policy, the Carbon Farming Initiative (CFI), was introduced in 2011 (Parliament of the Commonwealth of Australia, 2011). For a two year period between July 2012 and July 2014 the initiative was working alongside a carbon price. The carbon price (indirectly) provided a value for carbon sequestration or GHG emissions reductions achieved by farmers. In December 2014, the CFI was merged into the new policy framework: the Emissions Reduction Fund (ERF, Parliament of the Commonwealth of Australia, 2014). The ERF operates as a reverse auction scheme. Under this scheme, farmers are invited to submit project bids that specify the carbon farming practices they are willing to undertake, and the required price per tonne of emissions reductions or sequestration to undertake the practice(s). The government purchase the lowest cost projects. For the CFI and ERF to be successful in mitigating climate change, it is imperative that farmers propose projects to participate in the scheme. Proposed projects must follow specific guidelines to ensure emissions reductions are measureable and verifiable. Under the ERF, the guidelines for projects are referred to as 'methods'. Some carbon farming practices that are covered by these methods include: reforestation of cleared lands; protecting native vegetation from being cleared; sequestering soil carbon in grazing systems; reducing emissions from livestock through changes in feed; and reducing emissions through improved fire management in northern savanna regions.¹

The public benefits of carbon farming, such as greenhouse gas mitigation and potential positive impacts on biodiversity and hydrology, are important (Macintosh, 2013). Several studies have estimated the nonmarket values that society derives from farmers participating in environmental stewardship and conservation activities. For example, Rodríguez-Entrena *et al.* (2014) found that individuals have a positive willingness to pay (WTP) for erosion reduction and biodiversity benefits from carbon farming in Andalusian olive groves. Glenk and Colombo (2011) estimated WTP values for biodiversity benefits from implementing a soil carbon sequestration program in Scotland. Their estimates ranged between GBP 4 and GBP 41 for an "improvement of farmland bird habitat", which was used as a proxy for biodiversity values. In a study on co-benefits from carbon offsets in the aviation industry, MacKerron *et al.* (2009) also found positive WTP values for a "conservation and biodiversity" benefit.

¹ See www.environment.gov.au/climate-change/emissions-reduction-fund/methods for a list of all approved methods under the ERF.

Given the potential to deliver public benefits, it is not surprising that the policy interest in carbon farming is high. But, participation in carbon farming and emissions abatement policies is voluntary. So, what is in it for the farmer? There exists a rich literature on farmers' adoption of environmental management or conservation farming practices (e.g. Barr and Cary, 2000; Knowler and Bradshaw, 2007; Pannell et al., 2006). Factors that are important in farmers' decisions to change agricultural management practices include the (monetary and non-monetary) investment costs of the new practice, the impacts of the new practice on farm profitability, whether the practice 'fits' in the current farming system, the farmer's financial situation and personal values, the social context in which the farmer operates, as well as the public co-benefits generated by adopting the practice (Pannell et al., 2006; Kragt et al., 2014; Morgan et al., 2015). Generally, if new practices fit these criteria and provide (or are perceived to provide) private production benefits, farmers will adopt them (Morgan et al., 2015; Page and Bellotti, 2015). Carbon sequestration in agricultural soils can help to improve soil structure, reduce erosion, increase soil moisture retention and plant available water, and improve nutrient storing capacity (Desjardins et al., 2005; Lal, 2004). These changes can have a positive impact on agricultural yields (Kragt et al., 2012). Likewise, returning land to native vegetation can contribute to reduced salinity, improved water quality, and improved habitat provision for native plants and animals (George et al., 2012; Perring et al., 2012; Bradshaw et al., 2013). So, do farmers know of these potential benefits of carbon farming and are they using them as a motivator to adopt new management practices?

Despite the Australian government's interests in carbon farming, and the likely benefits of adoption, there have been few studies that have investigated whether farmers are willing to participate in carbon farming, and none that have looked specifically at the likelihood of Australian farmers adopting carbon sequestration practices within the context of the CFI and ERF, relatively unique policies. In this study we use a best-worst scaling survey to determine what carbon farming practices broadacre farmers are most likely to adopt. The focus of our research is on dryland cropping and mixed crop-livestock farmers, who form a significant part (28 percent) of Australia's farming community (Australian Bureau of Statistics, 2012). We also aim to identify the co-benefits and other factors that motivate or discourage farmers from adopting carbon farming practices.

The following section describes the best-worst scaling method. This is followed by a description of the survey design, sampling procedure, and modelling approach in Section 3. Results of the survey and best-worst scaling models are presented in Section 4. In the concluding section (Section 5), we discuss the findings in light of the CFI and ERF policy frameworks and develop recommendations for further work.

2. The best-worst scaling method

Best-worst scaling (BWS) is a survey-based, stated preference technique that presents respondents with sets of alternatives from which a respondent chooses his or her 'superior' and 'inferior' options (Finn and Louviere, 1992). The choice task is repeated over a number of sets that contain different

combinations of the elements², as per an experimental design. The repetition of varied choice sets and the choice task provides information to calculate the preference scores of each respondent (Jones et al., 2013). The likelihood of choosing an option is relative to the other options presented in the choice sets. It is expected that the most preferred options will be chosen as 'superior' more often than the other options and a least favoured option will be chosen more often as the 'inferior' option compared to the other alternatives.

An advantage of BWS is that choosing only a best and worst option from a set is often easier for respondents than ranking all the elements simultaneously. Another advantage is that the results typically show a greater discrimination between elements compared to alternative ranking techniques such as the Likert Scale (Finn and Louviere, 1992; Jones et al., 2013). Furthermore, other ranking techniques such as paired comparisons can be inadequate when the respondent is indifferent between the options or dislikes both options (Bateman et al., 2002).

Applications of BWS have been in food policy, food quality, health policy, transport and agricultural contexts (e.g. Coltman et al., 2010; Cross et al., 2012; Erdem et al., 2012; Glenk et al., 2014; Jones et al., 2013; Lee et al., 2007; Marti, 2012). The BWS technique has been used twice previously in agricultural GHG emissions mitigation studies. Jones *et al.* (2013) used BWS to elicit expert and farmer opinion on the relative effectiveness and practicality of practices to reduce GHG emissions from sheep farms in Wales. Glenk *et al.* (2014) used a BWS survey to rank 20 different greenhouse gas mitigation strategies for Scottish dairy farms to determine how current levels of adoption affected the perceived impacts of mitigation practices on farm performance. The authors found that current adoption rates significantly affected farmers' evaluation of potential carbon farming practices (Glenk et al., 2014). Our study is the first to use BWS to understand farmers' preferences to adopt carbon farming practices at the same time as a policy (the CFI) is in operation to incentive the adoption of a sub-set of the practices.

3. Survey design

In this study, we used a 'Case 1' BWS to identify what carbon farming practices farmers in the case study region would be 'most likely' and 'least likely' to adopt (Finn and Louviere, 1992; Flynn and Marley, 2012)³. The survey was designed to gather information about the respondent, their farm business, attitudes toward climate change and preferences for carbon farming practices. We identified a range of carbon farming practices through a review of literature and interviews with experts in broadacre agriculture. Nine carbon sequestration practices, shown in Table 1, were selected for the mixed crop-livestock and cropping-only farmers BWS surveys. Of the practices included in the BWS choice sets, planting trees and establishing areas of native vegetation were approved CFI methods at the time the survey was administered.

² Sometimes also referred to as 'objects' or 'items'. In this paper we use the term 'element' to indicate the nine carbon farming practices available to respondents. We use the term 'option' to indicate the choice alternatives in one choice set.

³ Flynn and Marley (2012) describe three types of BWS including Case 1 (the object case). The interested reader is referred to Flynn and Marley (2012) for further information about Case 1 BWS and other BWS approaches.

Table 1. Carbon farming practices used in best-worst scaling choice sets

For cropping-only farmers	For mixed crop-livestock farmers
Adopt no-till cropping practices	Adopt no-till cropping practices
Apply biochar	Apply biochar
Apply mulch to bare soil	Apply mulch to bare soil
Establish areas of native vegetation	Increase the area dedicated to pasture (by decreasing area dedicated to crops)
Inter-crop with perennial pastures	Inter-crop with perennial pastures
Plant perennial pastures	Plant perennial pastures
Plant tree belts	Plant tree belts
Plant trees for harvest (e.g. oil mallee)	Implement rotational grazing
Retain stubble after crop harvest	Retain stubble after crop harvest

Note: Establishing areas of native vegetation, planting trees for harvest, and planting tree belts were approved practices for participation in the Carbon Farming Initiative at the time the survey was distributed (providing specific criteria were met and a specific methodology was used to conduct the practice).

The survey consisted of four parts. The first part of the survey contained socio-demographic questions and questions about the respondent's farm size and type of farming system (e.g. mixed crop-livestock or cropping-only). The second part of the survey investigated farmers' opinions about climate change and attitudes towards carbon farming. The BWS choice questions were presented in the third part of the survey. Farmers were asked to think about carbon farming practices that they could adopt on their farm. We defined carbon farming as "practices that have the potential to capture (sequester) carbon in soils or vegetation for long periods of time". Each choice set presented six possible practices from which the respondent was asked to choose the one practice that they would be most likely to adopt, and the one practice they would be least likely to adopt. The BWS choice sets were constructed using a Balanced Incomplete Block Design (Street and Street, 1987). Each respondent was shown 12 choice sets, containing six of the nine possible practices in different combinations. An example choice set is shown in Figure 1.

[PLEASE INSERT FIGURE 1 ABOUT HERE, SIZE = 1.5 COLUMNS WIDE]

In the last section of the survey, information was gathered on the reasons for, or barriers to, adopting carbon farming practices, and opinions about current carbon farming policies. Respondents were also asked to rank (from 1-6) several "co-benefits" of carbon farming in order of importance to their decision to adopt carbon farming practices. The co-benefits presented to farmers were: improving soil quality, reducing soil erosion, enhancing biodiversity on farm, selling carbon credits, improving landscape appearance and greenhouse gas mitigation/carbon storage.

3.1 Survey administration

The survey was programmed in the survey software Qualtrics (Qualtrics, 2013), and distributed online to farmers in the northern wheatbelt area of Western Australia (Figure 2). The online survey link was distributed via email by three farmer groups: Liebe Group, Mingenew Irwin Group, and the North East Farming Futures Group. These groups have approximately 630 farm business members, and cover an area of about 1.8 million hectares (GGA, 2015). An online distribution method was chosen for a number of reasons, including to eliminate interviewer bias (Bateman and Mawby, 2004), ease of access to an email database from the grower groups, ease of data collection, and demonstrated success in surveying specialised groups with online surveys (e.g. Rogers, 2013). The survey responses were collected between 3 August and 2 September 2013.

The survey was pre-tested with farmers from the North East Farming Futures group in Western Australia. We asked a series of questions about the survey structure, length, and the carbon farming practices included in the choice sets. Based on the feedback, we removed some questions, included definitions of some terms and made the instructions for completing the BWS sets easier to interpret.

[PLEASE INSERT FIGURE 2 ABOUT HERE, SIZE = ONE COLUMN WIDE]

3.2 Data analysis

We use a parametric approach to analyse the BWS data. This approach is theoretically founded in Random Utility Theory, which states that consumer i chooses option j that maximises their utility (welfare), U_{ij} (Manski, 1977). The statistical model underlying BWS assumes that the relative choice probability of a given pair of elements is proportional to the distance between the two attribute levels on the latent utility scale U_{ij} (Flynn et al., 2007). Latent utility is composed of a deterministic component V_{ij} , which can be observed through individuals' choices, and a stochastic, unobserved, error component ε_{ij} :

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad j = 1, 2, \dots, J \quad (1)$$

Our model explains utility V_{ij} as a linearly additive function of the elements X_j (carbon farming practices) and interactions between the elements and individual socio-demographic characteristics ($Z_i X_j$):

$$V_{ij} = \beta_j \cdot X_j + \beta_{ij} \cdot (Z_i \cdot X_j) \quad (2)$$

Including socio-demographic variables in the model allows us to predict how individual characteristics influence preferences for the carbon farming practices included in the choice sets.

Following a conventional approach in best-worst scaling (e.g. Glenk et al., 2014; Lancsar and Louviere, 2008), we assumed a sequential choice process.⁴ The probability that option n is selected as the best option from the set of J alternatives in the choice set is given by:

$$Pr_{in_1} = \frac{\exp[\mu V_{in_1}]}{\sum_{j=1}^J \exp[\mu V_{ij}]} \quad J = 1, 2, \dots, 6 \quad (3)$$

Where μ is a scale parameter that is inversely proportional to the variance of the error term, typically normalised to one to enable estimation. The probability that option n is selected as the worst option from the remaining J alternatives is conditional on the choice of the best option:

$$Pr_{in_2|n_1} = \frac{\exp[-\mu V_{in_2}]}{\sum_{j=1}^J \exp[-\mu V_{ij}]} \quad J = 1, 2, \dots, 5 \quad (4)$$

The probability of selecting n_1 as best and n_2 as worst is given by:

$$Pr_{i,n_1,n_2} = Pr_{in_1} \cdot Pr_{in_2|n_1} \quad (5)$$

Which is analysed using a conditional logit regression model in Stata 13. Burge *et al.* (2011) explain that estimates from such conditional logit models are consistent, but that the standard errors need to be corrected to accommodate the non-independence of the data; i.e. there are relationships within choices made by the same respondent. To account for this panel nature of the data, we adjust the standard errors of our model using a sandwich estimator (Train, 2003, page 205). The sandwich estimator corrects the standard errors by clustering on the respondent's ID (Burge et al., 2011; Daly and Hess, 2011).

4. Results

4.1 Sample characteristics

A total of 43 survey responses were collected from individuals who manage a farm business. The median age of the respondents was 40 years old. This is younger than the median age (53) of Australian farmers in 2012 (Australian Bureau of Statistics, 2012). Most farmers (70 percent) identified as mixed crop-livestock farmers and the remaining 30 percent identified as cropping-only farmers. Most respondents (80 percent) said the farm was their only source of income (Table 2). Average farm size for mixed crop-livestock farmers was 7,100 ha (range 2,000 to 18,220) and for cropping-only farmers was 6,900 ha (range 2,000 to 23,500). Farms of this size are common in the low to medium rainfall zones in Western Australia (Planfarm, 2014). The mean area of cropped land per farm was 4,300 hectares and the mean area of pasture for livestock was 840 hectares. Crops grown by our respondents are common in the northern wheatbelt of Western Australia and include wheat, barley and canola, and in some areas, lupins.

⁴ In our choice sets, the 'best' choice was presented on the left and the 'worst' choice on the right. Given that English language readers typically read from left to right (e.g. Tanzer and Hof, 2011) it is reasonable (and most common in BWS analysis) to assume that respondents first make their best choice, followed by their worst choice.

4.2 Opinions about climate change and carbon farming

We hypothesise that individual respondent's opinions about climate change and carbon farming policies may affect their preferences towards adopting carbon farming practices. In Table 2, we show the results of questions that aimed to capture respondents' opinions, experience and attitude toward climate change and climate change mitigation. Overall, 91 percent of farmers in our sample agreed with the statements "I believe climate change is occurring..." and the majority of these respondents agreed that climate change is (at least partly) caused by human activities (*CC opinion*; Table 2). This finding is in line with views found amongst the wider Australian population (Leviston et al., 2014). More than 60 percent of the survey respondents stated that they were experiencing impacts from climate change (*Experiencing CC*; Table 2). These respondents reported that they were experiencing decreased annual rainfall, prolonged and more pronounced drought events, higher average temperatures, shorter growing seasons, more extreme rainfall events, and a delayed start to the traditional growing season. About two-fifths of cropping-only farmers (38 percent) and more than half of the mixed crop-livestock farmers (57 percent) indicated that they had already changed their farm management in the past ten years to increase carbon sequestration. Changed farming practices that were identified include: minimum tillage, stubble retention, fewer fallow periods, fencing of remnant vegetation and trialling new vegetative species. Many of these practices are likely to have been adopted before the introduction of the CFI (e.g. Llewellyn and D'Emden, 2010). Therefore, awareness of the CFI (*Aware of CFI*; Table 2) has not necessarily affected the adoption of carbon farming practices.

Table 2. Socio-demographic characteristics of the sample

Variable	Response levels	Mixed crop-livestock (percent)	Cropping-only (percent)
<i>Area (hectares)</i>	Average farm area (continuous variable)	7123	6908
<i>Age (Respondents' age in years)</i>	18 to 34 years	30	30
	35 to 44 years	10	46
	45 to 54 years	20	8
	55 to 64 years	37	8
	65 years and above	3	8
<i>Only source of income (0 / 1)</i>	Farm business is main source of income = 1	73	92
	Income is supplemented by other incomes / Farm not my main source of income = 0	27	8
<i>Know others (0 / 1)</i>	Know someone who is currently undertaking carbon farming practices = 1	57	54
	(otherwise = 0)	43	46
<i>Aware of CFI (0 / 1)</i>	Aware of the CFI = 1	40	38
	(otherwise = 0)	60	62
<i>Appropriate (0/1)</i>	Believe changes in farm practices are an appropriate way to reduce Australia's GHG emissions =1	33	23
	I am unsure or do not believe changes in farm practices are an appropriate way to reduce Australia's GHG emissions = 0	67	77
<i>CC Opinion (-1/0/1)</i>	I don't believe climate change is occurring/ I am not sure if climate change is occurring or not = -1	6	15
	I believe climate change is occurring and it is caused by natural fluctuations in the Earth's temperature = 0	37	39
	I believe climate change is occurring and it is partly caused by human activities/ I believe climate change is occurring and it is a result of human activities =1	57	46
<i>Experiencing CC (0/1)</i>	I believe my farm business is experiencing the impacts of climate change =1	63	62
	I am unsure or do not believe my farm business is experiencing the impacts of climate change = 0	37	38
<i>Already changed practices (0/1)</i>	I have changed my farm management in the past 10 years to increase carbon storage in vegetation and/or soils = 1	57	38
	I have <u>not</u> changed my farm management in the past 10 years to increase carbon storage in vegetation and/or soils = 0	43	62
<i>Policies are encouraging (-1/0/1)</i>	The carbon farming policies will <u>not</u> help to encourage farmers to sequester carbon on their land = -1	16	46
	I am unsure whether the carbon farming policies will help to encourage farmers to sequester carbon on their land = 0	57	46
	The carbon farming policies will help to encourage farmers to sequester carbon on their land = 1	27	8

Note: Variable names used in column 1 are repeated in Table 3 and Table 4 when presenting regression results using these socio-demographic factors.

4.3 Important co-benefits and barriers to carbon farming practice adoption

Farmers were asked to rank the importance of six carbon farming co-benefits in their decision to adopt carbon farming practices (from 1 = most important to 6 = least important, Figure 3). There was no difference between the ranking given by mixed crop-livestock farmers and cropping-only farmers (chi-square value of 4.81, p-value of 0.439). Improving soil quality by sequestering carbon was ranked as the most important benefit (relative to the other potential benefits presented) by 73 percent of mixed crop-livestock farmers and by 77 percent of cropping-only farmers. The opportunity to mitigate emissions and to sell carbon credits did not appear to be important benefits of carbon farming from the farmers' perspective. Improved soil quality may thus drive a farmer's decision, with any GHG mitigation that might be achieved as a spin-off (auxiliary) benefit.

[PLEASE INSERT FIGURE 3 ABOUT HERE, SIZE = 1.5 COLUMNS WIDE]

Farmers who had not changed their practices to increase carbon storage in vegetation and/or soils in the last 10 years (see Table 2) were also asked to nominate the three factors that have so far discouraged them from doing so. The most common barriers to adoption were: uncertainty about policies (66 percent), uncertainty about the possible practices and the potential effects of those on the farm business (61 percent), uncertainty about the price of carbon (57 percent) and the buyers in the carbon market (52 percent).

4.4 Preferences for carbon farming practice adoption

Responses to the BWS questions can be used to rank the 'willingness to adopt' carbon farming practices (relative to the other carbon farming practices presented in the BWS choice sets) for the aggregated survey sample. To assess whether the choices for different elements depend on the levels of other variables, we create new 'interaction variables' as per equation 2. Each socio-demographic and attitude variable (Table 2) was interacted with each of the nine carbon farming elements. The conditional logit models were estimated assuming a sequential best-worst choice model (equations 3-5)⁵ using "plant perennial pastures" as the reference item. A positive coefficient for an element thus indicates that the practice is preferred relative to planting perennial pastures, a negative coefficient indicates that the farmer is less willing to adopt the practice relative to planting perennial pastures.

4.4.1 Mixed crop-livestock farmers

The results from the conditional logit models for mixed crop-livestock farmers are provided in Table 3. When accounting for socio-demographic and attitudinal factors the practices that mixed crop-livestock farmers were most likely to adopt were retaining stubble and rotational grazing. There were no significant differences in the stated 'willingness to adopt' perennial pastures, no-till cropping and increasing the area dedicated to pasture. Inter-cropping with perennial pastures, applying mulch,

⁵ More complex random parameter models were also estimated but did not alter the main conclusions. Results from the RPL models are available upon request from the authors.

planting tree belts and applying biochar were less likely to be adopted (compared to perennial pastures) by mixed crop-livestock farmers. Mixed crop-livestock farmers who were aware of the CFI had lower than average 'willingness to adopt' scores for no-till cropping, and higher than average 'willingness to adopt' scores for applying mulch to soil (Table 3). Older farmers had a greater willingness to adopt no-till cropping, apply biochar and plant tree belts. However, those who knew other farmers who had implemented a carbon farming practice were less likely to plant tree belts compared to farmers that did not know other carbon farmers (Table 3).

Table 3. Conditional logit model estimates for the influence of socio-demographic variables on carbon farming adoption preferences of mixed crop-livestock farmers.

Carbon farming practice	Coefficient	St. Error^x	P value
Retain stubble after crop harvest	3.56	0.485	0.000
Implement rotational grazing	1.85	0.774	0.017
Adopt no-till cropping	0.10	0.903	0.916
Plant perennial pastures (reference practice)	0.00	-	-
Increase area dedicated to pasture	-0.54	0.344	0.119
Inter-crop with perennial pastures	-0.73	0.250	0.003
Apply mulch to bare soil	-1.92	0.459	0.000
Plant tree belts	-2.35	1.040	0.024
Apply biochar	-4.73	1.334	0.000
Interactions with SD variables	Interaction Coefficient	St. Error	P value
Retain stubble x Appropriate	-1.78	0.604	0.003
Implement rotational grazing x Age [†]	-0.04	0.016	0.011
Adopt no-till cropping x Age	0.05	0.019	0.004
Adopt no-till cropping x Aware of CFI	-1.74	0.813	0.010
Plant tree belts x Know others	-1.80	0.700	0.010
Apply mulch to bare soil x Aware of CFI	1.35	0.624	0.030
Plant tree belts x Age	0.06	0.022	0.011
Apply biochar x Age	0.04	0.024	0.085
Apply biochar x Area ('000s of hectares)	0.17	0.073	0.018
Number of observations [‡]	720		
Log likelihood	-785.29		
Pseudo R2	0.359		

Notes: Socio-demographic and attitudinal variables and their levels are defined in Table 2.

Adoption preferences are relative to adopting perennial pastures. ^x Standard errors were corrected for 30 clusters (respondents) to account for multiple choice observations per respondent. [†] For the regressions, the age variable was converted into a continuous variable using the mid-point of each category and 65 years for the top-category. [‡] The 30 farmers completed one best and one worst choice in each of the 12 choice sets, leading to 24 choice observations per respondent.

4.4.2 Cropping-only farmers

When accounting for socio-demographic and attitudinal factors the practices that cropping-only farmers were most willing to adopt were retaining stubble, no-till cropping practices and applying mulch (Table 4). The practice that cropping-only farmers were least willing to adopt was planting trees for harvest. There were no significant differences in the farmers' stated willingness to plant perennial pastures, plant tree belts, inter-crop with perennial pastures, apply biochar or establish areas of native vegetation. Farmers who were already experiencing negative impacts of climate change had a higher 'willingness to adopt' score for planting trees for harvest compared to farmers who said they had not experienced any impacts of climate change. Cropping-only farmers who believed humans are at least partially contributing to climate change had higher than average 'willingness to adopt' scores for applying mulch,

adopting no-till cropping practices and planting tree belts. Cropping only farmers who were aware of the CFI were less willing to apply mulch and plant trees belts compared to farmers who were not aware of the CFI. Farmers who believed carbon farming is an appropriate way to reduce Australia's GHG emissions, had lower than average 'willingness to adopt' scores for applying mulch.

Table 4. Conditional logit model estimates for the influence of socio-demographic variables on carbon farming adoption preferences of *cropping-only* farmers.

Carbon farming practice	Coefficient	St. Error^x	P value
Retain stubble after crop harvest	4.24	0.513	0.000
Adopt no-till cropping	3.50	0.526	0.000
Apply mulch to bare soil	0.80	0.312	0.011
Plant tree belts	0.47	0.552	0.394
Plant perennial pastures (reference practice)	0.00	-	-
Inter-crop with perennial pastures	-0.08	0.384	0.835
Apply biochar	-0.97	0.549	0.079
Establish areas of native vegetation	-1.31	1.270	0.304
Plant trees for harvest	-1.57	0.577	0.006
Interaction with SD variables	Interaction coefficient	St. Error	P value
Adopt no-till cropping x CC Opinion	1.35	0.750	0.073
Establish areas of native veg x Area ('000s of hectares)	0.16	0.094	0.079
Apply mulch to bare soil x CC Opinion	0.80	0.416	0.053
Apply mulch to bare soil x Aware of the CFI	-1.48	0.539	0.006
Apply mulch to bare soil x Appropriate	-2.19	0.982	0.025
Plant tree belts x CC Opinion	1.00	0.295	0.001
Plant tree belts x Aware of the CFI	-1.05	0.468	0.025
Establish areas of native vegetation x Know others	1.96	1.126	0.083
Plant trees for harvest x Experiencing CC	1.94	1.042	0.063
Plant trees for harvest x Policies are encouraging	-3.67	0.917	0.000
Number of observations [‡]	312		
Log likelihood	-296.25		
Pseudo R2	0.442		

Notes: Socio-demographic and attitudinal variables and their levels are defined in Table 2. Adoption preferences are relative to adopting perennial pastures. ^x Standard errors were corrected for 13 clusters (respondents) to account for multiple choice observations per respondent. [‡] The 13 farmers completed one best and one worst choice in each of the in 12 choice sets, leading to 24 choice observations per respondent.

5. Discussion and conclusion

The carbon farming practice that was, overwhelmingly, preferred by both cropping and mixed crop-livestock farmers surveyed was retaining stubble after crop harvest. Alongside retaining stubble, mixed farmers stated a preference to implement rotational grazing. Both practices can provide improved grazing options for livestock, which form a significant part of the mixed crop-livestock farm business. Livestock grazing was allocated, on average 20 percent (range 6 to 65 percent) of farm area in the survey sample, a result in line with the average mixed crop-livestock farm in Western Australia (Kragt et al., 2012; Kragt and Robertson, 2014). Cropping-only farmers also indicated a high likelihood of adopting no-till cropping practices. The high preference for retaining stubble and no-till cropping are likely to reflect farmers' perceptions of the production co-benefits associated with these two practices. Both stubble retention and no-till cropping have been found to positively impact soil quality, which can subsequently have a positive impact on crop yield (Lal, 2004). The relationship between production benefits and likelihood of adoption is further confirmed by respondents ranking 'improved soil quality'

and 'reduced soil erosion' as the most important co-benefits to be derived from carbon farming. The willingness to adopt no-till and stubble retention could also be attributed to the ease with which these practices can be included into standard broadacre farming operations. In comparison, practices that do not readily fit within the existing farm enterprise mix (e.g. applying biochar) received lower scores in our study. Practices that require an even larger change to the farming system, such as establishing areas of native vegetation or tree plantings, were also often chosen as 'least likely to adopt' by respondents to our survey.

The implementation of a carbon farming practice on a neighbouring property could demonstrate success, as in the case of stubble retention and no-till cropping, but also failure. For example, whilst tree belts have positive impacts on soil carbon, there is evidence that trees compete with crops for water and nutrients, consequently reducing crop yields (Sudmeyer et al., 2012). If such negative impacts are demonstrated on neighbouring properties where tree belts have been planted, farmers may be less willing to also plant trees. We recommend that, to increase the adoption of carbon farming in Australia, the feasibility and profitability of changing practices be demonstrated clearly through farm trials or other extension programs. The CFI was initially accompanied by the Carbon Farming Futures program that funded research trials and extension to farmers, with the aim to demonstrate how carbon farming practices can be incorporated in profitable farming systems (DCCEE, 2011). Our results suggest that such programs will be essential to achieve more wide-spread adoption of carbon farming into the future.

We show that farmers' preferences for changed land management vary with their opinions about climate change and experience with the CFI. Whether farmers perceive to experience negative impacts of climate change, and their belief that humans are (at least partly) contributing to climate change, affects farmers' stated likelihood to adopt some of the carbon farming practices included in our research. Experiencing negative impacts of climate change had a positive influence on the preferences of cropping-only farmers to plant trees for harvest. This could be a result of the higher proportion of cropping-only farmers being located in the most marginal areas of the West Australian wheatbelt, which is experiencing the greatest impact of declining rainfall and increasing temperatures (Asseng and Pannell, 2013). In such marginal areas, carbon farming may well provide an alternative income source, rather than be seen as competing with traditional broadacre farming practices. These results are likely to be indicative for other grain growing regions in Mediterranean climate regions that have experienced similar negative impacts of climate change (such as drought-prone regions in Southern Australia, and Mediterranean farming regions in Spain or Portugal).

Awareness and understanding of the Carbon Farming Initiative had an impact on preferences. Cropping-only farmers aware of the policy were less likely to apply mulch and plant tree belts, than cropping-only farmers that were unaware of the policy. This is not desirable given the policy aims to encourage adoption of these practices. We further found that less than 35 percent of respondents agreed that carbon farming is an appropriate way to reduce Australia's GHG emissions. It appears that

farmers' willingness to adopt carbon farming practices may well be hindered by their attitudes and understanding of the policy framework.

It is interesting to note that the opportunity to generate carbon credits was not an important driver to adopt carbon farming practices for the farmers that were surveyed. This finding continues to support the common theme in the results, practices with demonstrable environmental co-benefits or benefits for farm productivity are most likely to be adopted and they are most likely to be adopted as a result of the private benefits they can provide. Practices that fit within the existing farming system are also more likely to be widely adopted relative to practices that require changes to the farm enterprise mix. If we aim to achieve widespread adoption of carbon farming practices, we require flexible policies that allow farmers to select the carbon farming practices that are most appropriate for their farm system and their management strategy (Jones et al., 2013). This may create a case for providing more information and extension services that target specific groups of farmers based on their farm enterprise mix and location. Furthermore, if the government wants to increase the farming community's support for carbon farming policies, it will be important to communicate the co-benefits from carbon farming and synergies with existing farm management practices, rather than highlighting the opportunity to earn carbon credits through a voluntary carbon offset market.

Policy uncertainty has continued since this survey was conducted. Under the newly introduced Emissions Reduction Fund, the government intends to purchase the lowest cost abatement through a reverse auction system. Logically, we will most likely see businesses with the capacity to implement new practices in a cost-effective manner and achieve credible emissions reductions to be the ones to participate in the scheme. The challenge for farmers looking to engage in the scheme is to know what carbon farming practices are able to deliver low cost abatement, and how much it will cost them to implement the necessary changes to their farm system. These unavoidable transaction costs will likely remain an obstacle to participation alongside the policy uncertainty. We have shown that production and profitability benefits are the major motivations for farmers to adopt carbon farming practices. Research is ongoing to determine the benefits of adopting climate change mitigation practices on broadacre cropping farms, and the cost effectiveness of carbon farming practices to achieve emissions mitigation.

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Figures

465

MOST likely to adopt	Carbon farming practice	LEAST likely to adopt
☐	Retain crop stubble after harvest	☐
☐	Apply biochar	☐
☐	Plant tree belts	☐
☐	Plant perennial pastures	☐
☐	Apply mulch to bare soil	☐
☐	Adopt no-till cropping	☐

466 Figure 1. An example of a best-worst scaling choice set used in this study

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Figure 2. Study region (shaded), northern wheatbelt of Western Australia

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Figure 3. Relative importance that farmers placed on six potential benefits of carbon farming. The box plot indicates the 25th, 50th and 75th percentiles and the standard deviation of the ranking position (1-6) for each benefit. The most important benefit is ranked as number 1.