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Motivations and barriers for Western Australian broad-acre farmers to adopt carbon farming

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ABSTRACT

Carbon farming policies aim to contribute to climate change mitigation, but their success strongly depends on whether landholders actually adopt desired practices or participate in offered programs. The Australian Government's Carbon Farming Initiative and Emissions Reduction Fund policies were designed to incentivise the adoption of carbon farming practices. Although these policies have been active since December 2011, farmer engagement has been limited, and net emissions reductions low as a result. We surveyed broad-acre farmers in the Western Australian wheatbelt to explore their drivers and barriers to adopting carbon farming practices and participating in carbon farming policy programs. Drivers of adoption included knowledge and perception of co-benefits (for yield, productivity, and the environment), knowing another adopter, and believing that changes to farm management are an appropriate method to reduce Australia's greenhouse gas emissions. Barriers to adoption included lack of information, uncertainty and costs. The key barrier to participation was policy and political uncertainty. The determinants of adoption and participation that we identify in our study offer important insights into how to best ensure the success of Australia's land sector-based climate change policies. We conclude that, to increase landholder engagement, the co-benefits and climate change benefits of carbon farming practices must be actively promoted, and additional information is needed about the costs associated with adoption. Information diffusion is best achieved if it actively leverages landholder social networks. Finally, our results indicate that landholder buy-in to carbon farming could be greatly enhanced by achieving more continuity in Australian climate change policies and politics.

1. Introduction

Carbon farming programs aim to combat climate change by encouraging land managers to adopt 'carbon farming practices'. These practices may involve either sequestering carbon in soils/vegetation, or reducing emissions. To sequester carbon in vegetation, land managers can plant trees, protect remnant vegetation, restore native vegetation or reforest degraded lands (Evans et al., 2015; Polglase et al., 2013; van Kooten et al., 1999). Sequestration in soil can involve adopting minimum or no-till cropping, retaining crop residues, or increasing the amount of land under pasture relative to crop (e.g. Grace et al., 2010; Kragt et al., 2012; Sanderman et al., 2010). To achieve emissions reductions, farmers may change fertiliser management, implement savannah/crop residue burning regimes, and manure management; or reduce methane emissions from livestock and rice production (Howden and O'Leary, 1997; Thornton and Herrero, 2010).

Technical assessments show considerable (global) potential for such changed agricultural practices to mitigate climate change, and at low costs (Canadell and Schulze, 2014; Crossman and Bryan, 2009; Evans et al., 2015; Lal, 2004). This has increased political optimism about the potential for the agricultural sector to abate greenhouse gas emissions. In Australia, for example, the conservative Liberal-National coalition proposed that the agriculture/land sectors could, by 2020, sequester at least 150 million tonnes of CO_2 equivalents (CO_2e) in agricultural soils annually for a price of $10 per tonne of CO_2e (The Coalition, 2010). In 2011, the Australian Government introduced a package of climate change mitigation policies that included the Carbon Farming Initiative (CFI; Parliament of the Commonwealth of Australia, 2011). The CFI allowed farmers and other land managers to earn carbon credits through approved sequestration or emissions reductions activities (DCCEE, 2012). Farmers and land managers could then sell the carbon credits in the voluntary carbon offset market (DCCEE, 2012). To be

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approved, mitigation activities had to meet three key criteria: additionality (the activity was not required by law or already a common practice activity), leakage (the activity did not increase emissions elsewhere in the economy), and in the case of sequestration, permanence (the activity could store carbon in the long-term) (permanance requirement; DCCEE, 2012). Once approved, eligible activities were called 'methodologies'. After a change in government in 2013, the CFI was incorporated into a new policy: the Emissions Reduction Fund (ERF; Parliament of the Commonwealth of Australia, 2014). The ERF operates across the whole Australian economy, not just within the land sector. The ERF uses a reverse auction scheme whereby the government purchases mitigation from project participants, who offer varying quantities of mitigation and prices per tonne of CO_2e. The government purchases mitigation from the lowest-cost providers.

As of the 6th of May 2016, 348 ERF projects had been contracted by the government (Clean Energy Regulator, 2016). Project participants funded by the ERF include commercial carbon abatement providers, energy companies, businesses, indigenous land corporations, local councils and a few individual farmers (Clean Energy Regulator, 2016). The majority of the contracted projects (185) are vegetation projects, such as regenerating native forests, reforesting cleared lands, or establishing permanent native-species plantations on cleared land. A further 146 projects are emissions avoidance projects such as capturing and combusting methane gas from landfill (86 projects) or early dry season savanna burning (47 projects). Only 17 agriculture projects were contracted: 7 soil carbon sequestration and 10 emission avoidance projects.

A mandatory statutory review of the original CFI found that during its lifetime (during which farmers received a carbon price of about $23/$tCO_2$e) Australia's greenhouse gas emissions fell by 10 million tonnes of CO_2e (an average rate of approximately 2.5 million tonnes per year; Climate Change Authority, 2014). Only 5% of this emissions reduction came from vegetation-based projects, and just 1% from agriculture. The quantity of abatement achieved was well short of what some had proposed the agricultural sector could deliver. For example, Lal (2004) states that soil carbon sequestration can be a win-win mitigation strategy that could offset 5–15% of global fossil fuel emissions. The amount of abatement provided by the CFI has partly been restricted by the relatively slow approval of methodologies, thereby limiting the range of activities for which credits could be claimed, especially in the first years of the CFI (Climate Change Authority, 2014). Other constraints were policy uncertainty and doubt about the future price of credits (Climate Change Authority, 2014). Although some authors have analysed how the CFI policy's characteristics could present barriers to its success (e.g. Macintosh, 2013; Thamo and Pannell, 2015), little work has been done on the importance of farmer engagement with the scheme. Carbon farming policies have received political support, but their ultimate success will depend on improved adoption of carbon farming and participation in the policies by land managers. Understanding farmers' drivers and barriers to adopt and participate in carbon farming is therefore vital for future policy success.

In this paper, we provide an evaluation of the drivers and barriers that affect the uptake of carbon farming by broad-acre farmers in Western Australia (WA). Our approach explicitly recognises the importance of stakeholders in shaping policy implementation. We draw on quantitative and qualitative information from farmer surveys to identify the key factors that drive engagement with carbon farming. Finally, important implications for the design and implementation of carbon farming policies are identified.

2. Literature review – farmers' adoption of new practices

A landholder's involvement in carbon farming can involve adopting a carbon farming practice and/or participating in a carbon farming policy program. We define *adoption* of carbon farming as a landholder changing their behaviour to land use or management practices that can capture carbon in soils or vegetation for long periods of time. Adopting carbon farming does not necessarily entail participation in a formal carbon farming policy scheme. We define *participation* in carbon farming as a landholder carrying out land management changes for climate change mitigation within the framework of a formal carbon farming policy program, administered by a government or other agency.

In this section, we briefly review the main themes from the literature on adoption and participation in a land management context. The main factors that drive the adoption of land management practices include characteristics of: (1) the land management practice itself; (2) the farm or landholding; (3) the farmer or landholder; and (4) the context, most particularly the social context. A category that becomes relevant in the case of participation in land management programs is (5) characteristics of the program.

2.1. Characteristics of the practice

Two key characteristics of practices that impact their uptake are (i) the relative advantage they offer compared to the practices they supersede, and (ii) how easy they are for landholders to trial within their existing farming system (Pannell et al., 2006). Additionally, adoption is more likely where relative advantage encompasses multiple benefits (e.g. financial advantages, productivity gains, and environmental benefits; Moon and Cocklin, 2011; Rogers et al., 2012). Reimer and Prokopy (2014) find that participation in incentivised conservation programs is strongly driven by environmental benefits, even more so than to financial incentives.

2.2. Characteristics of the landholding

Certain characteristics of the landholder's property can also impact their adoption of new practices or participation in programs. For example, numerous studies indicate that farm size and profitability are positively associated with adoption (e.g. Prokopy et al., 2008; Rodriguez-Entrena et al., 2014) and participation (e.g. Atari et al., 2009; Bremer et al., 2014; Ma et al., 2012). Microclimatic conditions and natural resource endowments can play a role in the participation decision, as does farm type because some farm types (e.g. cropping farm versus livestock farm) may be more suited to different conservation activities (Atari et al., 2009).

2.3. Characteristics of the landholder

Socio-demographic or attitudinal characteristics of the landholders exposed to the particular practice or program can play a role in the adoption and participation decisions. Socio-demographic characteristics include education, income, agricultural training, years of farming experience, and having children who will ultimately inherit the property (Atari et al., 2009; Prokopy et al., 2008; Rodriguez-Entrena et al., 2014). Important attitudinal characteristics include a farmer's attitude towards their own knowledge and skill, towards the environment, conservation, and climate change, as well as perceptions of future risks and financial conditions (Bremer et al., 2014; Greiner and Gregg, 2011; Greiner et al., 2009; Markowski-Lindsay et al., 2011; Morgan et al., 2015; Prokopy et al., 2008). For example, Markowski-Lindsay et al. (2011) observe that family forest owners in Massachusetts are more likely to participate in carbon markets if they believe that forests can help reduce the impact of climate change. Also, it has been shown that positive environmental attitudes and environmental awareness can be positively associated with adoption of agricultural best management practices (Prokopy et al., 2008).

2.4. Characteristics of the context

The context in which a particular practice or program is situated could be defined in different ways; social, geographical, political,

temporal, etc. The literature commonly points to the importance of the social context and the critical role of social networks in adoption (Baumgart-Getz et al., 2012; Greiner and Gregg, 2011; Prokopy et al., 2008; Rochecouste et al., 2015; Rodriguez-Entrena et al., 2014) and participation processes (Atari et al., 2009; Bremer et al., 2014; Meadows et al., 2014; Morrison et al., 2011; Silva and Mosimane, 2014). For example, the adoption of conservation agriculture is greatly enhanced where trusted colleagues endorse the novel practice (Rochecouste et al., 2015; Rodriguez-Entrena et al., 2014). Similarly, landholders are more likely to participate in environmental policy programs when they feel connected to other participating landholders (Morrison et al., 2011).

2.5. Characteristics of the program

Finally, various aspects of the design and delivery of land management programs will affect their participation rates. These aspects include whether financial incentives form part of the program or not (Bremer et al., 2014; Moon and Cocklin, 2011). Note, however, that some authors have found that monetary motivations are less relevant than non-monetary drivers of the participation decision (Atari et al., 2009; Blackmore and Doole, 2013; Reimer and Prokopy, 2014; Silva and Mosimane, 2014). Other program characteristics found to play a role in participation decisions include program complexity (Reimer and Prokopy, 2014), information provision (Page and Bellotti, 2015) and program rules (Markowski-Lindsay et al., 2011; Meadows et al., 2014). Highly complex programs can deter participation, as can stringent or inflexible program rules (e.g. excessively long contracts, additionality requirements, and early withdrawal penalties). Similarly, if landholders cannot easily access sufficiently detailed information about the program, they are unlikely to participate and may not even be aware it exists. The agency that delivers the program can also play a role, with landholders averse to some providers (Meadows et al., 2014), particularly where the agency is perceived as being associated with political uncertainty (Page and Bellotti, 2015).

The studies we reviewed were drawn from a wide range of geographical contexts, and encompass a broad range of environmental issues. This literature casts some light on the key drivers and barriers in landholders' decisions to adopt novel land management practices, or participate in environmental programs. What is not clear is how these factors apply to the adoption of carbon farming practices by Australian farmers, particularly following the introduction of an innovative climate change mitigation policy. Our work aims to fill this gap, drawing on survey data gathered from broad-acre farmers in Western Australia.

3. Data sources

3.1. Survey design and administration

The data for this study comes from a survey of broad-acre farmers in Western Australia (WA). Focussing on the WA wheatbelt allows us to gain insight from one of the largest (approximately 10 million hectares; Australian Bureau of Statistics, 2016) and most economically-valuable broad-acre farming regions in Australia. The survey design process was informed by the literature review, and further refined by interviewing experts on carbon farming practices, farm management, and the economics of broad-acre systems across Australia. The final survey was programmed in Qualtrics (Qualtrics, 2013), and distributed to farmers in the WA wheatbelt (Fig. 1) with the help of local natural resource management organisations and grower groups. Informed consent was obtained from all participants included in the study.[2,3]

Respondents were first asked general questions about their farm business, before focussing on carbon farming practices. For the purpose of the survey, carbon farming was defined as techniques that can capture (sequester) carbon in soils or vegetation for long periods of time. Respondents were asked for their opinions on the existence and causes of climate change in a multiple choice question (following Leviston et al., 2011). They were also asked whether they knew any colleagues who had adopted carbon farming practices, and whether they thought that encouraging carbon farming was an appropriate policy measure for climate change mitigation. The survey also included questions about whether respondents believed that their farm business was experiencing any impacts of climate change and, if yes, to describe the type of impacts experienced.

We used two approaches to investigate what factors encourage or prevent farmers from adopting carbon farming practices. In an initial survey wave (administered between December 2012 and January 2013), respondents were asked to indicate their level of agreement with potential reasons for, or barriers to, adoption of carbon farming practices and participation in carbon farming policies on a 5-point Likert scale. Landholders were presented with a list of potential drivers and barriers. In addition, they could select an "other" category, which enabled an analysis of qualitative responses. This initial survey wave yielded 107 completed surveys. Because Likert scale questions provide limited ability to investigate respondents' *ranking* of drivers/barriers, we ran a second survey wave in August–September 2013, which was sent to a different sample of farmers in the northern wheatbelt of WA. This period overlapped with a federal election campaign, during which changes to Australia's climate change policies were a major discussion point. In the second wave, respondents were asked to identify the three most important factors that would encourage (or prevent) their adoption of carbon farming practices and participation in carbon farming policies. Again, respondents could select "other" and expand on their answer. In this second wave, 43 responses were collected. Collectively, the two survey waves constitute a rich data-set from which we can draw valuable inferences regarding the drivers and barriers to adoption of/participation in carbon farming.

3.2. Sample socio-demographic characteristics

Of the 150 surveys returned, 125 were considered relevant to the analysis. We excluded respondents with: (i) total farm size less than 50 ha, (ii) a postcode outside the WA wheatbelt, or (iii) no crops or livestock in the 2011–2012 financial year. We also removed respondents who identified as agribusiness consultants to restrict the sample to farm owners and managers with decision-making responsibilities in the study region. Characteristics of the survey sample are shown in Table 1.

The majority of respondents were male and over 45 years of age (Table 1). Overall, the average farm size was 4984 ha (median 3200 ha). This is in line with the average WA mixed-crop livestock and cropping-only farm size, as recorded in the AGSURF database (ABARES, 2015). The majority of respondents were mixed crop-livestock farmers. Wheat and sheep were important components of respondents' farm businesses; 78% of respondents produced wheat and 74% had sheep on their farm. Farm census data from 2011 indicates similar demographics for the wider farmer population (Australian Bureau of Statistics, 2012).

Nearly all respondents had heard of the term carbon farming, and about half of the respondents (44.8%) knew someone undertaking carbon farming practices (Table 1). Approximately a third of respon-

[2] Note that membership of grower groups and NRM organisations is common in WA (www.gga.org.au). The groups distributing the surveys cannot specify how many broad-acre farmers received the survey, especially as there is overlap in memberships across collaborating organisations. Therefore, we cannot estimate a survey response rate.

[3] A copy of the survey questions is available upon request from the authors.

Fig. 1. Case study area in the Wheatbelt and South-West of Western Australia.

dents believed that climate change is a result of natural fluctuations in the Earth's temperature, while many (61%) believed that humans are at least partially contributing to climate change. Less than half of respondents agreed that it is appropriate to encourage changes in farm practices to help reduce Australia's greenhouse gas emissions.

More than 70% (n = 89) of respondents said that they were experiencing the impacts of climate change. The types of impacts that were mentioned most were:

- Decrease in annual rainfall (n = 78; 62%).
- More variability in rainfall (n = 73; 58%).
- Prolonged and more pronounced drought events (n = 55; 44%).
- More extreme rainfall events (n = 43; 34%).
- Greater variability in temperatures (n = 42; 34%).
- Higher average temperatures (n = 36; 29%).

Approximately half of the respondents (n = 58) said that they were currently undertaking carbon farming actions on their land, although no respondents were participating in the CFI at the time the survey was administered. The type of abatement activities that were named by respondents included:

Table 1
Demographic and attitudinal characteristics of sample respondents (n = 125).

	Number of respondents	%
Gender		
Male	96	76.8
Female	29	23.2
Age group (years)[a]		
18–34	18	14.4
35–44	18	14.4
45–54	29	23.2
55–64	38	30.4
65 +	21	16.8
Farm size (hectares)		
Average (range)	4,984 (50–45,220)	
Farming enterprise type		
Mixed crop-livestock	82	65.6
Cropping only	26	20.8
Livestock only	17	13.6
Heard of carbon farming and/or the Carbon Farming Initiative before?		
Yes	119	95.2
No	6	4.8
Know anyone who undertakes carbon farming practices?		
Yes	56	44.8
No	69	55.2
Opinions about climate change		
I don't think that climate change is happening	3	2.4
I have no idea whether climate change is happening or not	5	4
I think that climate change is happening, but it is a natural fluctuation in Earth temperatures	41	32.8
I think that climate change is happening, and that human actions are contributing to the change	58	46.4
I think that climate change is happening, and that human actions are causing it	18	14.4
Carbon farming appropriate to reduce greenhouse gas emissions?		
Yes	56	44.8
No	33	26.4
Unsure	36	28.8

[a] One missing answer for age.

- Revegetation activities (e.g. planting tree belts along fence lines, reforestation or forestry plantations, protecting remnant vegetation) (n = 41; 33%).
- Emission reduction activities (e.g. reduced burning, improved fuel efficiency, targeted fertiliser application) (n = 37; 30%).
- Minimum- or no-tillage cropping (n = 39; 31%).
- Stubble retention (n = 32; 26%).

4. Results

4.1. Drivers of carbon farming adoption

Respondents who self-identified as already undertaking carbon farming practices (henceforth called 'adopters') were asked what drove them to do so. Improved soil quality was selected as a major driver of adoption (86%; Table 2). Productivity benefits were also important, with 72% of adopters selecting 'increased yield and/or productivity of the land' as a motivation for undertaking carbon farming practices (Table 2). In their qualitative responses, farmers frequently referred to production co-benefits like *"reduced erosion"*, and "*moisture capture and fertiliser efficiencies*", which are closely linked to improved soil condition and improved productivity.

Environmental outcomes such as improved on-farm biodiversity were also commonly identified as a driver of adoption (60%), as was the ability to increase and/or diversify farm income sources (33%). Other drivers included: improving resilience against climate change impacts, global climate change mitigation, and incentives provided by local natural resource management bodies or grower groups.

Five farmers explicitly referred to moral responsibility as a motivating factor for adoption. In a qualitative question, adopters wrote that carbon farming is the "*best thing to do*", and will "*contribute to global reductions in climate change risk*". The opportunity to earn Australian carbon credits was one of the least important reasons to undertake carbon farming. Less than 20% of adopters named financial incentives through government programs as a driver of carbon farming uptake.

Table 2
Drivers for adopting carbon farming practices, as identified by farmers who had already adopted some carbon farming activities on their land (n = 58).

Drivers of carbon farming adoption	Number of respondents	Percent of respondents
Improved soil condition	50	86.2
Increased yield and/or productivity of the land	42	72.4
Improved on-farm environmental outcomes	35	60.3
Potential for increased and/or diversified farm income by selling carbon credits	19	32.8
Other	36	62.1

We estimated a logit model (Cox, 1958) to identify the key variables that influence the uptake of carbon farming practices. The probability that a farmer in the sample was an adopter (dependent variable = 1) was estimated as a function of socio-demographic and attitudinal characteristics in Stata 13 (StataCorp, 2013). The only two variables collected in the questionnaire that had a positive and significant influence on the probability of adoption were 'Knowing another farmer who has adopted carbon farming practices' and 'Believing that changing land management practices is an appropriate way to reduce Australia's greenhouse gas emissions' (Table 3). Other socio-demographic variables such as age, gender, attitudes toward climate change and the cause of climate change were not significant in explaining the adoption of carbon farming practices.

4.2. Barriers to carbon farming adoption

In our analysis of the barriers to carbon farming uptake, we differentiate between barriers to adoption of practices, and barriers to participation in the CFI. Only respondents who had indicated that they had not adopted any carbon farming practices were asked about the barriers they experienced to adopting carbon farming practices (n = 67). For barriers to participate in the CFI policy, we were interested in responses from the whole sample (n = 125). Respondents selected their most important barriers from a list of options provided.

The most common barrier to adoption was 'Not enough information' or 'uncertainty about the possible carbon farming practices and their impacts on the farm business' (74.6%). For example, farmers stated that "*carbon farming information is confusing*" and that they need *"specific information about carbon yields from revegetation in my rainfall zone/soil type"*. This information barrier was followed by high costs (59.7%), and concerns about the impact of carbon farming practices on yield and productivity (25.4%; Fig. 2).

Barriers mentioned in respondents' written responses (referred to as 'other' in Fig. 2) included a lack of required technologies, and incompatibility of carbon farming practices with current farm management strategies. Some barriers were related directly to the landholder's characteristics, such as not having the skills or management ability to adopt carbon farming practices. Farmers also mentioned consequences for the re-sale of properties that have tree plantations as a barrier, as evidenced by one farmer's statement that "*carbon tree farms in this area are un-saleable*". This indicates that farmers are not willing to adopt carbon farming practices when they consider carbon farming practices to be incompatible with their other objectives.

The primary barriers to participation in the CFI were the policy

Table 3
Logit model estimates for having adopted carbon farming practices (yes = 1, no = 0) (n = 125).

Variable	Coefficient	St.Error	P-value
Constant	−1.760	1.487	0.236
Knowing other carbon farmers (*yes = 1; no = 0*)	1.134*	0.399	0.005
Believing that changes to farm management are appropriate to reduce Australia's greenhouse gas emissions (*yes = 1; no/unsure = 0*)	0.842*	0.429	0.049
Believing that climate change is happening (*no/unsure/believe it is a natural phenomenon = -1; yes and humans are partly causing it = 0; yes and humans are causing it = 1*)	0.366	0.314	0.243
Having heard of carbon farming or the Carbon Farming Initiative (*yes = 1; no = 0*)	1.363	1.184	0.250
Farming is core business (*yes = 1; no = 0*)	−0.382	0.312	0.221
Older farmers (*age ≥ 60 yrs old = 1; age < 60 yrs old = 0*)	0.008	0.014	0.564
Male (*male = 1; female = 0*)	−0.325	0.485	0.503
Total farm size (*'000 s of hectares, continuous*)	−0.015	0.034	0.670
Model statistics			
Log likelihood	−74.91		
Pseudo R^2	0.126		

* Significant at $p < 0.05$.

context or design of the policy itself. The most commonly-cited barrier was 'too much policy uncertainty' (85%), followed by 'too much carbon price uncertainty' (74%), high costs (69%), and not enough information (68%; Fig. 2). Other barriers included too much paperwork involved, uncertainty about number of buyers in the voluntary carbon market, insufficient approved methodologies, and long commitment periods.

In the qualitative questions, many respondents commented on the impracticability of the 100 year permanence period, e.g. "*100 year*

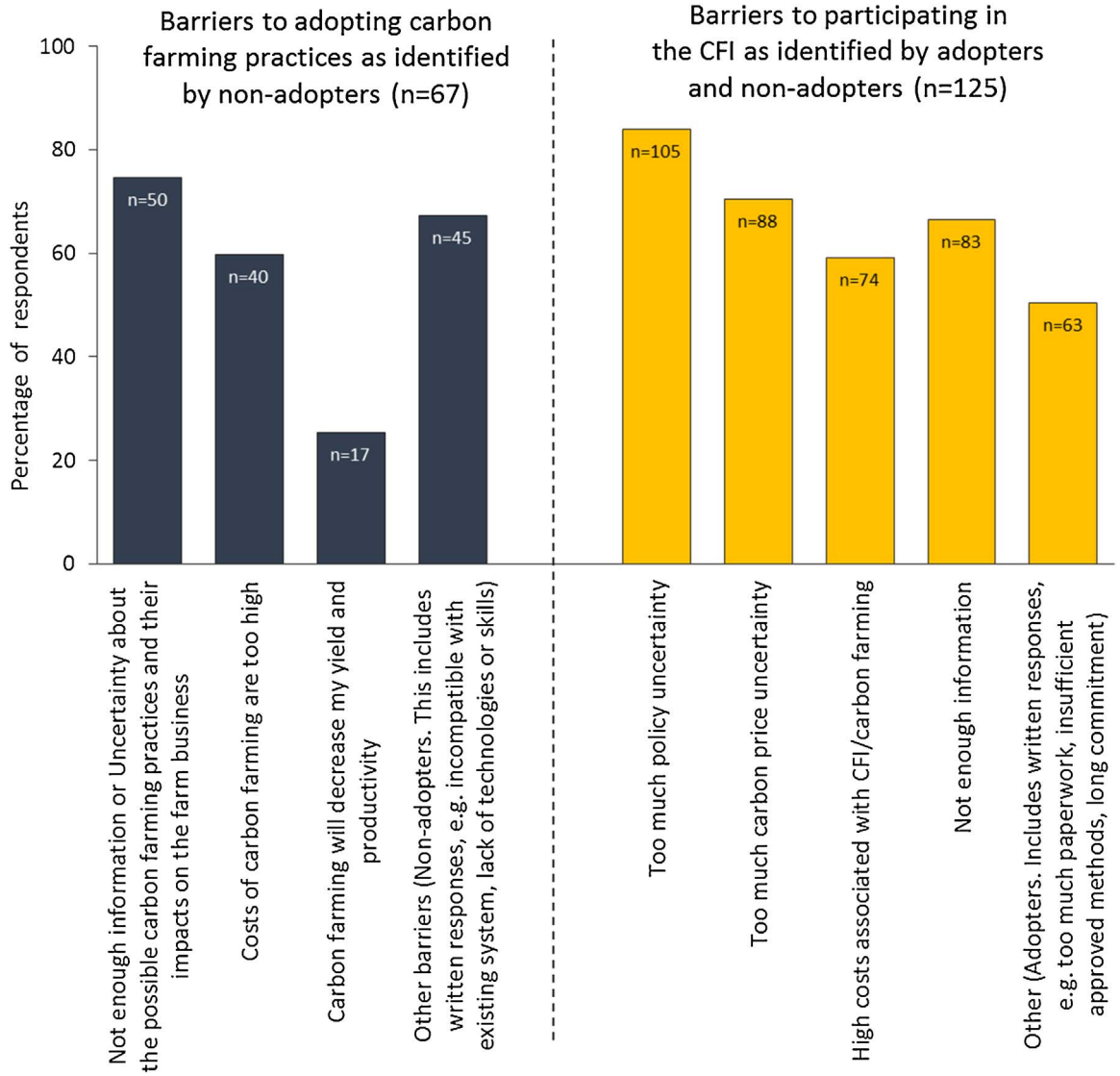

Fig. 2. Barriers to adopting carbon farming practices and to participating in the CFI, as identified by farmers who had not adopted any carbon farming practices ('non-adopters') and those who had ('adopters'). The y-axis shows the percentage of respondents, total number of respondents as data-label in bar-graph.

permanence a deal breaker", the financial implications of participation, e.g. "*Show me the money", "CFI is not economically worth it to participate at present*", and "*Will not do it unless it is worth our while (economically)*".

The financial incentive associated with participation in the CFI does not appear to be sufficient to overcome the barriers that farmers face or perceive they face. This is well summarised by the following quote: "*The co-benefits of management changes (to increase soil carbon) will probably be of more financial benefit (to the farmer) without participating in the credits and trading market*". Furthermore, some farmers perceive that the policy rewards farmers with a history of poor land management, which deters participation. This indicates that farmers' personal sentiments may provide a participation barrier, along-side the economic, and policy-design barriers outlined above. One farmer elaborates on this point quite extensively: "*Many of us have already adopted what would otherwise be useful actions including very low soil disruption with minimum till and very targeted fertiliser use which means this whole program is aimed at poor operators and ineffective managers which results in the efficient operators finding it hard to take it seriously. I would ask why would you aim to benefit those that are causing the problem while not rewarding those who have adjusted early*?"

5. Discussion

In an attempt to meet emissions reduction targets, the Australian Government has introduced policies to incentivise the adoption of carbon farming by landholders. Achieving greenhouse gas mitigation this way relies heavily on farmers actually engaging with the policies and changing their management on-ground. By surveying broad-acre farmers in Western Australia about their adoption of carbon farming practices, we identify which factors most strongly influence the adoption of carbon farming practices. Our analysis also provides insights into the drivers and barriers to participation in a carbon farming program (i.e. the Carbon Farming Initiative). At the time of data collection, the CFI was newly-introduced, and topic of political debate during the 2013 federal election campaign. Responses will need to be considered in this context. Nevertheless, it is likely that many of the insights we derive in this paper regarding the drivers of and barriers to adoption of carbon farming practices will be similarly relevant to (future) carbon farming programs in other States and countries.[4]

Our study confirms that characteristics of the practice, farmers' individual characteristics and social context, as well as characteristics of the policy program can all strongly impact decisions regarding adoption and participation in a carbon farming context.

As suggested by earlier literature on adoption (e.g. Mendham et al., 2007; Moon and Cocklin, 2011; Torabi et al., 2016), the relative advantages offered by the practice being targeted can strongly impact adoption and participation decisions. In particular, we find that adoption is enhanced if farmers perceive multiple benefits (co-benefits) of carbon farming. The relative advantage that carbon farming could provide—in terms of yield and productivity—was one of the significant drivers of adoption. Environmental co-benefits such as improving soil health, enhancing the condition of the environment, and conserving vegetation, were also identified as drivers of participation in the carbon farming policy in our study.

While earlier work has indicated that farm size and profitability can be associated with adoption and participation, we did not find evidence for this in our sample. There were also no significant differences between different types of farm businesses (mixed livestock-cropping or crop-only farms). It should be noted, however, that our survey was conducted amongst broad-acre farmers in WA. Whilst our results indicate that farm characteristics do not strongly affect engagement with carbon farming in the WA wheatbelt, we acknowledge that results may vary in regions with different farming systems and climates.

Similar to previous work (e.g. Markowski-Lindsay et al., 2011; Prokopy et al., 2008) personal attitudes were identified as key reasons to adopt carbon farming practices. Some farmers mentioned a moral responsibility to contribute to climate change mitigation, while a logit analysis showed that farmers who believed that changes to farm management are appropriate to reducing national GHG emissions were more likely to adopt carbon farming. Contrary to expectations, farmers' beliefs about climate change being a human-induced phenomenon was not a significant driver of adoption rates. Directly observable socio-demographic variables such as age or gender also did not significantly influence adoption.

The social context in which landholders are embedded strongly influences the likelihood that they will decide to adopt carbon farming practices or participate in policy programs. Trusted colleagues who are early adopters of new practices are a valuable source of information for farmers interested in carbon farming. This means that organisations interested in increasing adoption of carbon farming will need to encourage early adopters to share success stories. The Australian Government's Extension and Outreach program introduced in 2014 aims to do this through the "My Carbon Farming" website (www.mycarbonfarming.com.au, Department of Agriculture and Water Resources, 2016). "My Carbon Farming" features descriptions of successful carbon farming projects as well as contact details for experts that can assist farmers to gather more information, and details of upcoming events designed to share information and farmer experiences. However, given the low rates of adoption, these nation-wide examples may be insufficient to reach individual farmers. Potential participants may put more trust in local peer ('neighbourhood') examples which could therefore be more relevant to increase adoption.

The characteristics of the carbon farming policy programs (the Carbon Farming Initiative and the Emissions Reduction Fund) appear to be key considerations in the participation decision. Previous studies provide mixed evidence as to whether or not incentive payments are a key driver of the uptake of environmental practices. While Kusmanoff et al. (2016) suggested that appealing to private benefits may help to engage a greater number of landholders (Kusmanoff et al., 2016), Torabi et al. (2016) find that the characteristics of a program and biodiversity co-benefits are important factors driving participation. Our study suggests that the provision of financial incentives in government programs is not a main driver of adoption. Instead, farmers cited program characteristics such as complexity of the scheme (e.g. the amount of paperwork involved with becoming a registered offset provider) and stringent program rules (e.g. permanence requirements) as barriers to participation. Information constraints emerged as a key barrier to adopting carbon farming practices and to participating in policy programs. The "Extension and Outreach" program that was implemented after data collection for this study could help to address this barrier. Since 2014, the Australian Government has funded a range of extension projects being delivered by regional natural resource management bodies and grower groups to raise awareness about carbon farming policies and opportunities for farmers to participate (Department of Agriculture and Water Resources, 2016). However, farmer participation in Australia's carbon farming policies remains low (Clean Energy Regulator, 2016) so, it could be argued that the Extension and Outreach program is not achieving its full potential. It is possible that the information provided through the Extension and Outreach program is not sufficiently relevant to farmers, failing to convincingly demonstrate scientifically-proven benefits and co-benefits of carbon farming, or to fully explain how much it is likely to impact the farm enterprise (e.g. cost, productivity, yield). The way in which benefits are framed in communications to landholders will influence their engagement in land management schemes Kusmanoff et al. (2016). Our work suggests that, to increase the adoption of carbon

[4] Programs that encourage climate change mitigation by farmers are provided by some local natural resource management or catchment management groups in Australia. Overseas examples include the Alberta Carbon Offset System and the New Zealand Emissions Trading Scheme.

farming practices in Australia, Extension and Outreach projects will need to promote the potential relative advantages and environmental co-benefits of alternative practices, and work with key members of farmers' social networks to facilitate the diffusion of information.

The most frequently-cited barrier to participating in carbon farming programs in our study was the policy uncertainty associated with climate change mitigation policies and carbon markets. This is perhaps unsurprising, given the political debate around Australia's long-term commitment to climate change mitigation at the time of the survey (particularly during the second survey wave; n = 43). The high political uncertainty is illustrated by various policy changes. For example, the carbon pricing mechanism that was introduced in July 2012 (offering carbon credits at approximately $23 per tonne of CO_2e) was repealed by the next government. Following the 2013 change in government, the original Carbon Farming Initiative was merged into an Emissions Reduction Fund in July 2014 (Parliament of the Commonwealth of Australia, 2014). These changes in climate change mitigation policies, and the political dialogue that has dominated the climate change debate since the 2013 federal election, will have damaged farmers' confidence in government programs and carbon farming policies. The history of policy changes will remain a barrier to farmer participation in carbon farming programs especially if participation involves long-term commitment and financial incentives that are too low to make carbon farming economically viable.

6. Conclusion

Uptake of carbon farming practices (and environmental land management practices in general) can be influenced by many factors. Understanding these factors is an important research goal in itself, but the full value of such work is realised by its application to identifying opportunities to increase farmer adoption of carbon farming practices and ultimately contribute to climate change mitigation. By assessing the drivers of adoption of carbon farming practices, we identify a need to promote carbon farming practices using information that farmers consider important e.g. relative advantage and economic implications of the new practice. A potential challenge to increasing landholder engagement with carbon farming is that the barriers to *adopt* carbon farming practices appear to be different to the barriers that limit *participation* in Australia's carbon farming policy. Increasing adoption of carbon farming, therefore, may not necessarily increase participation in programs, given that participation is limited by policy uncertainty and various program characteristics.

Research to identify carbon farming practices that meet multiple farmer objectives will be important to increase farmer adoption of carbon farming practices and influence the design of policies that incentivise carbon farming for climate change mitigation. Furthermore, increasing adoption of carbon farming will not only require financial incentives, but also (a) ongoing extension and engagement programs that leverage landholders' social networks and inform farmers (and other stakeholders) of the practices that can achieve greenhouse gas abatement, and (b) more information—and indeed demonstrations—about how carbon farming practices could benefit farm profitability and/or environmental sustainability.

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