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# How stable are Australian farmers' climate change risk perceptions? New evidence of the feedback loop between risk perceptions and behaviour

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1     **How stable are Australian farmers' climate change risk perceptions? New evidence of**  
2                     **the feedback loop between attitudes and behaviour**

3  
4                     **Sarah Ann Wheeler, Céline Nauges, Alec Zuo**

5  
6     **Abstract**

7     The exact relationship between people's climate change attitudes and behaviour is a topic that  
8     engages policy-makers and researchers worldwide. Do climate change attitudes influence  
9     behaviour or is it possible that behaviour can change attitudes? This study uses a unique  
10    repeated survey dataset of 275 farmers (irrigators) in the southern Murray-Darling Basin from  
11    2010-11 to 2015-16, to explore the dynamic relationship between climate change attitudes and  
12    farm adaptation behaviour. Farmers who had an increased risk exposure (expressed through  
13    higher debt, larger irrigated areas, greater share of permanent crops, and located in areas with  
14    higher temperatures and less rainfall) were more likely to agree climate change posed a risk.  
15    Whilst farmers became more accepting towards climate change over the time-period, a  
16    significant percentage of these attitudes were unstable. We suggest one reason for this  
17    instability is due to the presence of reverse causality (a feedback loop) between attitudes and  
18    behaviour. Namely, new evidence was found that farmers who agreed climate change was a  
19    risk in 2010-11, were more likely to undertake farm decisions to reduce that risk (e.g.  
20    changing crop mix, reducing irrigated area and consequently selling water entitlements) –  
21    which had the impact of negatively feeding back and reducing their stated climate change  
22    concerns in 2015-16. Conversely, farmers who were originally deniers were more likely to  
23    undertake somewhat riskier farm-production decisions (e.g. increasing water utilisation rates  
24    and irrigation areas) – which consequently had the impact of positively increasing their  
25    climate change risk perceptions in 2015-16.

26    **Keywords:** Irrigators; Murray-Darling Basin; climate change attitudes; climate change risk  
27    perception; endogeneity.

28  
29    **Introduction**

30    Farming is both vulnerable to changes in climate and a significant source of greenhouse gas  
31    emissions, prompting increasing calls for coordinated adaptation and mitigation initiatives to

32 help protect global resource supply chains (Coumou and Rahmstorf 2012; Garnaut 2011;  
33 Lim-Camacho et al. 2017). Given the success of such initiatives will depend on the  
34 participation of agricultural communities and individual farmers, it is crucial to understand  
35 how climate change attitudes influence farmer adaptation and mitigation behaviours (Haden et  
36 al. 2012; Arbuckle et al. 2013).

37 Australia has often been described as the ‘front line of the battle for climate change  
38 adaptation’ (Palutikof 2010, p. 219) and, indeed, Australian farmers face considerable and  
39 mounting pressures from earlier seasons, longer droughts, more erratic rainfall and higher  
40 temperatures (Garnaut 2011; Kiem and Austin 2013; Austin et al. 2020a; Wheeler et al.  
41 2020b). However, Australian climate change policy has been roundly criticised, and many  
42 believe it has stymied action for the past decade (Burke 2016; Cheung and Davies 2017;  
43 Garnaut 2011). Some have suggested that the National Party of Australia (which traditionally  
44 has represented graziers, farmers and rural voters) has had a disproportionate impact on  
45 Australian climate policy (Cheung and Davies 2017; Crowley 2017).

46 Studies have consistently found that, compared to Australian farmers, the general public are  
47 much more accepting of climate change science and that climate change is occurring (Hogan  
48 et al. 2011; Wheeler et al. 2013). For example, in 2019, 77% of the Australian public accepted  
49 climate change was occurring, 12% did not and 11% were unsure (Australia Institute 2019).  
50 This contrasts with Australian farmers’ attitudes; with many studies in the past decade finding  
51 only around a third of farmers accepted that climate change was happening (Hogan et al.  
52 2011; Raymond and Spoehr 2013; Wheeler et al. 2013).

53 The psychological and environmental literature has long studied how environmental attitudes  
54 can influence behaviour (Fishbein and Ajzen 1975; Ajzen 1991); while more recent literature  
55 has studied how behaviour can influence attitudes (Albarracin and Wyer 2000; Nauges and  
56 Wheeler 2017) and the link between risk perceptions, a sense of control and attitudes (Lo and  
57 Chow 2015; Slovic 1987, 2000; Wilson et al. 1993). Van Raaij (1981) was one of the first to  
58 outline complex feedback loops between economic conditions, perceptions, and behaviour.  
59 Other research has pointed out that attitudes are often not the major driver of environmental  
60 behavioural change, and sometimes not even linked to behavioural change at all (Kollmuss  
61 and Agyeman 2002).

62 There has also been a huge increase in research that has tried to identify the characteristics  
63 that predict people’s climate change attitudes (Hornsey et al. 2016; van der Linden 2014),

64 with some of this research focussing on farmers' climate change attitudes (e.g. Hogan et al  
65 2011; Raymond and Spoehr 2013). The fungibility of climate change attitudes, and how they  
66 change (or flux) over time has been noted in many synopses of public attitudes (e.g. Australia  
67 Institute 2019). However, tracking attitudes towards climate change over a long period of  
68 time, and attempting to explain why views have changed, is rare in the literature (indeed, we  
69 have not found any examples of this).

70 Within Australia, the Murray-Darling Basin (MDB) (an area of significant agricultural,  
71 environmental, recreational and indigenous importance) provides a much-cited example of an  
72 area that will need to adapt to changing rainfall and temperature patterns, as well as  
73 significant reductions in the water that has been allocated for irrigation use (Kiem and Austin  
74 2013; Zuo et al. 2016; Wheeler et al. 2020b). The basin, which spans four states and one  
75 territory, is an area where the MDB Plan was fully legislated in 2012. This plan represents  
76 one of the largest returns to environmental water from a reduction in consumptive use. This  
77 water is sourced from willing sellers through buyback of licences and upgrading on- and off-  
78 farm infrastructure (see Grafton 2019 and Wheeler et al. 2017, 2020a for more detail). As  
79 well as being subject to considerable water and regulation policy change, the water allocated  
80 to irrigation has fluctuated widely over the past fifteen years – particularly during the  
81 Millennium drought of the 2000s. There is ongoing controversy over the impact that climate  
82 change will have on irrigators' water allocations, the environment, agricultural production and  
83 future viability of the irrigation industry (Wheeler et al. 2017, 2020a). Irrigators most exposed  
84 include those relying on permanent crops and larger shares of irrigation, and those utilising  
85 higher percentages of the water allocated to them, and many of them have had to adapt to both  
86 lower rainfall and lower water allocations in the past couple of decades (Grafton 2019).  
87 Increased uncertainty and stressful conditions have increased the level of distress among the  
88 general and rural population, as evidenced from a set of studies conducted recently in non-  
89 metropolitan New South Wales (Austin et al. 2018, 2020a, 2020b).

90 We created a panel dataset (i.e. repeated observations from the same respondents) from two  
91 surveys of the same MDB irrigators in 2010-11 and 2015-16, to try to understand how and  
92 why farmers' climate change risk perceptions have changed over time, and if there is a  
93 feedback loop between attitudes and behaviour. More precisely, the evidence for this  
94 feedback loop is established by investigating the following three questions:

95 *Question 1: Can we characterise farmers who, in 2010-11, agreed that climate change posed*  
96 *a risk to their region, versus those who did not perceive a climate change risk or were not*  
97 *sure?*

98 *Question 2: Have farmers' climate change risk perceptions evolved over time? Did farmers,*  
99 *who did not perceive a climate change risk in 2010-11, agree that climate change was a risk*  
100 *in 2015-16, and/or vice versa?*

101 *Question 3: Are farmers' climate change risk perceptions associated with major farm*  
102 *production decisions made on the farm between the two surveys? Can we detect a feedback*  
103 *relationship between risk perceptions and behaviour?*

104 We hypothesise that there may be a feedback loop between climate change risk perceptions  
105 and farmer behaviour, in the sense that actions undertaken by farmers between the two  
106 surveys may have altered their exposure to risk and hence their perception of the risk posed  
107 by climate change. We focus specifically on major production decisions which included  
108 buying and selling of land and water entitlements, increasing or decreasing irrigated area,  
109 changing crop mix, improving irrigation infrastructure, and utilising solar and battery  
110 technology for irrigation water pumping.

111

## 112 **Literature Review of Farmers' Climate Change Attitudes**

113 Farmers' stated attitudes towards climate change were often influenced by how the questions  
114 were asked. For example, farmers were more likely to agree with the statements that the  
115 climate is changing (or occurring) than they were in regards to statements that climate change  
116 is caused by human activity (Raymond and Spoehr 2013). In an early study among farmers in  
117 the US, Diggs (1991) revealed that 30-41% of farmers (n=432) agreed with the question 'is  
118 the climate changing'. This proportion has steadily increased over time; with later US studies  
119 generally finding between half and two-thirds of American farmers agreeing that climate  
120 change is now occurring (Safi et al. 2012; Arbuckle et al. 2013, 2015; Niles et al. 2013;  
121 Campbell et al. 2019). Elsewhere, it has also been found that: 55% of Danish farmers  
122 (n=1053) in 2014 agreed that global change was occurring (Woods et al. 2017); 70% of  
123 Chinese farmers (n=1133) agreed climate change posed a risk to their livelihoods (Zhai et al.  
124 2018); two-thirds of Iranian farmers (n=350) stated global warming is taking place (Azadi et  
125 al. 2019); 48% of Scottish farmers (n=550) agreed that average annual temperatures will  
126 increase in the future (Barnes et al. 2013); and just over half of New Zealand farmers (n=490)

127 agreed that the global climate was changing (Niles and Mueller 2016). In particular, Niles and  
128 Mueller (2016) investigated how the presence of irrigation infrastructure was associated with  
129 climate change perceptions, and found evidence to suggest that the presence of infrastructure  
130 potentially positively influenced perceptions that annual rainfall had increased over time.  
131 Within Australia, Hogan et al. (2011; Table 11) reported that belief in climate change varied  
132 from 27-42% across different types of farmers (comfortable non-adaptors, cash poor longer-  
133 term adaptors and transitioners, as identified by cluster analysis using twenty climate change-  
134 related latent variables) in 2008 (n=3993). A small survey of Victorian farmers (n=90) found  
135 that 70% believed that the climate is indeed changing (Rogers et al. 2012); while Wheeler et  
136 al. (2013) provide the only specific survey of irrigators (that we know of) – they found that  
137 32% of MDB irrigators in 2010-11 (n=946) believed climate change posed a risk for their  
138 region.

139 Farmer views regarding the main causes of climate change (e.g. human versus non-human  
140 induced) were more divergent than the presence of climate change itself. Farmers were less  
141 likely to believe that climate change is human induced (e.g. see US studies by Arbuckle et al.  
142 2013; Campbell et al. 2019; Rejesus et al. 2013; Safi et al. 2012). Within the Australasia  
143 region, a survey of 292 farmers in South Australia by Raymond and Spoehr (2013) found that  
144 39% agreed that human-induced climate change existed. Rogers et al. (2012) found 68% of  
145 Victorian farmers agreed that human activity was influencing climate change, and Niles and  
146 Mueller (2016) also found the majority of New Zealand farmers agreed. In a study of 823  
147 rural residents in New South Wales, Austin et al. (2020a) highlighted that major concerns  
148 about climate change related to: i) suffering under climate change; ii) causes of climate  
149 change; iii) extremes of climate change; and iv) leadership and action to address climate  
150 change.

151 In terms of understanding the socio-demographic characteristics associated with farmers’  
152 climate change attitudes, a range of studies have found that female farmers are more likely to  
153 acknowledge the existence of climate change and hold more scientifically accurate knowledge  
154 (Smith et al. 2014; Hamilton et al. 2015; Zamasiya et al. 2017). Similarly, higher education  
155 levels among farmers were found to be associated with believing in climate change,  
156 recognising the role of human activity within climate change, and the perception of climate  
157 change risks (Barnes et al. 2013; Raymond and Spoehr 2013; Wheeler et al. 2013; Hamilton  
158 et al. 2015). Wheeler et al. (2013) and Hamilton et al. (2015) found that lower farmer age was  
159 significantly associated with believing in climate change, while Rejesus et al. (2013) found

160 the opposite result. As discussed above, localised effects of climate change were found to be a  
161 major influence on farmer attitudes, with Mase et al. (2017) highlighting a significant positive  
162 correlation between a farmer noticing more variable weather and belief in anthropogenic  
163 climate change. Further results from California (Niles et al. 2013), China (Shi et al. 2019) and  
164 Nigeria (Ayanlade et al. 2017) also indicate the large majority of farmers recognised  
165 fundamental changes in climatic conditions.

166 Other notable positive influences on climate change attitudes included a farmer having: a  
167 successor (Barnes et al. 2013; Wheeler et al. 2013); higher on-farm income (Raymond and  
168 Spoehr 2013); off-farm employment (Rejesus et al. 2013); higher concern about future  
169 impacts (Arbuckle et al. 2013; Niles and Mueller 2016); and democratic political affiliation  
170 (Smith et al. 2014). In terms of water availability, Haden et al. (2012) found that perceived  
171 changes in water availability had significant effects on Californian farmer intentions to adopt  
172 climate change mitigation and adaptation strategies. Furthermore, Wheeler et al. (2013) found  
173 that Australian farmers' acceptance of climate change risk was statistically significantly  
174 associated with having received fewer water allocations – during both the current season and  
175 over the previous five years. Finally, and returning to the prominence of agriculture within the  
176 landscape of climate change, Hogan et al. (2011) concluded that an ability to cope with  
177 change, social connectedness and readiness to use information constructively, all positively  
178 influenced farmer interest in (and capacity to adapt to) climate change.

### 179 *Risk perceptions and climate change*

180 There has been an increasing focus in the climate change attitudinal literature on the  
181 relationship between a sense of control and climate change concerns. Slovic (1987, 2000) first  
182 proposed that individuals' risk perceptions are affected by their ability to control such risks,  
183 and this ability was highly associated with their financial resources. Indeed, a sense of control  
184 has been found associated with both country and individual household wealth (Lo and Chow  
185 2015), and that wealth and income determine the level of risk people are willing to take (Lo  
186 2016). Higher income and resources could lead to an increased sense of control about the  
187 world and future outcomes, a reduced sense of personal vulnerability and, therefore, reduced  
188 concern about climate change issues. In a study of households across eleven OECD countries  
189 on the relationship between climate change concerns and water and energy mitigation  
190 behaviour, Nauges and Wheeler (2017) found that while it was true that climate change  
191 attitudes positively influenced specific household mitigation actions, the relationship was

192 more complex in the sense that adoption of mitigation behaviour negatively fed back on  
193 households' climate change concerns. This effect was more likely to occur in  
194 'environmentally-motivated' households, and for mitigation behaviour that was high cost and  
195 lower diagnostic in nature (e.g. putting solar panels on the house, rather than actions such as  
196 turning off lights more often). In addition, Wheeler et al. (2013) found that farmers in the  
197 MDB who agreed climate change posed a risk to their region were not planning to expand  
198 their farm, but they were planning to change their crop mix; adopt new efficient irrigation  
199 infrastructure; decrease their irrigated area; and buy more water entitlements (albeit these last  
200 two actions were insignificant). Reverse causality (a feedback loop) between attitude and  
201 behaviour was found for farm actions that involved implementing strategies to deal with  
202 current or future water shortages (changing crop mixes, adopting more efficient infrastructure,  
203 selling land and decreasing irrigated area). Reverse causality was not found for the impact of  
204 climate change perceptions on other types of farm behaviour (e.g. such as selling water  
205 entitlements, buying farm-land or increasing irrigation area). Such results suggest the flexible  
206 nature between risk perceptions and adaptation behaviour. This study only looked at future  
207 farm adaptation at one point in time, it did not study the relationship between actual  
208 implemented farm actions and climate change beliefs, nor how beliefs or farm behaviour  
209 changed over time. Nauges and Wheeler (2017) recommended that additional experiments, or  
210 panel datasets that follow people's concerns and behaviour over time, would be needed to  
211 explore this relationship further and to investigate in particular the presence of a lag between  
212 experiencing concern and implementing mitigation behaviour, and vice versa.

213 Hence, of key interest to this study is the relationship between farm action and climate change  
214 beliefs, and how attitudes can change over time, depending upon both a) personal and local  
215 environment conditions; and b) farm actions undertaken within the time-period. To date, the  
216 literature has focussed on cross-sectional (e.g. one year) snapshots of farmers' (and public)  
217 attitudes at particular points in time, and the associations of those beliefs with a set of  
218 locational, farm and socio-demographics. Wilson et al. (1993) discussed a possible feedback  
219 phenomenon between behaviour (actions) and perceptions in a study of US dairy farmers' risk  
220 perception and management tools. Along the lines of van Raaij (1981)'s framework showing  
221 complex feedback loops between economic conditions, perceptions, and behaviour, Wilson et  
222 al. (1993) argued that farmers' actions undertaken to manage risk in the past, by altering the  
223 sources of variability, may have changed their current perception of risk. However, this  
224 assertion could not be formally tested since the dairy farmers were surveyed only once. Austin

225 et al. (2020b) explained the variability of New South Wales rural residents' attitudes to  
226 drought by the possibility 'that people have started to adapt (e.g. changes to household  
227 budget, farming practices or lifestyle) to drought or that government funding has become  
228 available' (Austin et al. 2020b: 14). Niles and Mueller (2016) have provided one indication of  
229 how a sense of control in agriculture (namely the presence of irrigation infrastructure) was  
230 associated with farmers' views that annual rainfall had increased over time; while Wheeler et  
231 al. (2013) and Nauges and Wheeler (2017) provided evidence of some reverse causality  
232 between climate change risk perceptions and behaviour. This study seeks to extend the  
233 literature by investigating the same farmers' climate change attitudes and behaviour over a  
234 period of five years, using a unique survey dataset, during which 275 Australian farmers were  
235 surveyed twice (2010-11 and 2015-16).

236

### 237 **Data and Case Study Area**

238 The empirical analysis that follows combines data from two telephone surveys of irrigators  
239 living in three states of the southern Murray Darling Basin (MDB): New South Wales (NSW),  
240 South Australia (SA) and Victoria (VIC). The three regions cover various industries: annual  
241 crops such as rice and cereal in NSW (Murray and Murrumbidgee River regions); livestock  
242 production and dairy in VIC (Goulburn–Murray Irrigation District and Murray River regions);  
243 and perennial crops such as citrus, wine grapes, fruit and nuts in SA (Riverland). The first  
244 telephone survey was conducted in 2010-11 (n=946); and the second was conducted in 2015-  
245 16 (n=1000).<sup>1</sup> The surveys were randomly sampled from a given irrigator population and are  
246 regarded as representative. For example, average age, industry and farm size are similar to  
247 ABS (Australian Bureau of Statistics) and ABARES (Australian Bureau of Agricultural and  
248 Resource Economics and Sciences) irrigation farm surveys (Zuo et al. 2016). Information was  
249 collected on farmland; irrigation infrastructure; intentions and plans for the past five years and  
250 next five years; socio-demographic characteristics; climate change risk perceptions; and a  
251 range of values and attitudes. Our focus is on farmers' perception of climate-related risk,  
252 which we measure through their answer to the following question: "Do you believe that  
253 climate change poses a risk to your region?" Possible answers were: i) no, ii) yes, iii) unsure,  
254 or iv) don't know. From now on we combine the "unsure" and "do not know" together under

---

<sup>1</sup> Irrigators were randomly sampled from irrigator organisations and commercial farming lists. The first survey had a total response rate of 30% (or 37% which included those who agreed to be surveyed at a later date, but were not called back given sample sizes were reached); while the second survey had a response rate of 51% (or 73% including call-backs).

255 an “unsure” label. The term “climate change” was not specifically defined to the survey  
256 participants so we are not able to distinguish whether farmers’ risk perceptions were formed  
257 from their current knowledge about climate change in general or from their observation of  
258 changes in (local) weather patterns. The understanding of how their climate-related  
259 perceptions were built is outside the scope of this research.

260 In this article, we study 275 irrigators who answered both telephone surveys. Since we are  
261 primarily interested in the (possible) change in the same respondent’s climate change risk  
262 perception between 2010-11 and 2015-16, it is important to check that it was the same person  
263 (and not different household members on the same farm) interviewed in both years.<sup>2</sup> Given  
264 that the name of the respondent was not recorded for ethical reasons, the criteria we used to  
265 establish it was the same respondent during both surveys were if the respondent’s: a) gender  
266 was the same; and b) age between the two survey rounds varied between 4 and 6 years. Table  
267 A1 in the Appendix includes statistics on the key characteristics such as geographical  
268 location, farm size, farm income, respondent’s age, education, gender, industry, and water  
269 ownership for the panel sample of 275 irrigators – as well as the full sample of 946 irrigators  
270 in 2010-11. The comparisons suggested that the panel sample and the full sample were not  
271 statistically significantly different in terms of these key characteristics and therefore attrition  
272 bias was unlikely.

273

## 274 **Methods**

275 For the descriptive statistics, the independent two sample t-test was used to compare the mean  
276 of continuous variables and proportion test for binary variables between two groups, i.e.  
277 agreed that climate change posed a risk to their region (“Yes” answer) vs. others (“No” or  
278 “Unsure” answer) and climate change risk denier (“No” answer that climate change posed a  
279 risk) vs. others (“Yes” or “Unsure” answer).

280 The independent t-test, assuming the variances of the two groups are equal, has a null  
281 hypothesis that the difference between the two groups is zero. Suppose Group A (e.g.,  
282 believer) and Group B (others) are the two groups to compare; the t-test statistic value can be  
283 calculated as follows:

---

<sup>2</sup> For example, if we were interested in modelling a farm characteristic such as water extracted rather than a personal characteristic, a larger panel dataset would have been available (e.g. 338 farms used in Wheeler et al. 2020a).

$$t = \frac{m_A - m_B}{\sqrt{\frac{s^2}{n_A} + \frac{s^2}{n_B}}}$$

284 where  $m_A$  and  $m_B$  represent the means of groups A and B respectively,  $n_A$  and  $n_B$  represent  
 285 the sizes of groups A and B respectively, and  $s^2$  is an estimator of the common variance of  
 286 the two samples which can be calculated as:

$$s^2 = \frac{\sum(x - m_A)^2 + \sum(x - m_B)^2}{n_A + n_B - 2}$$

287 For binary variables, a proportion test with a null hypothesis that the proportions of the two  
 288 groups are equal is employed. Let  $\widehat{P}_A$  be the observed proportion in Group A and  $\widehat{P}_B$  be the  
 289 observed proportion in Group B. A test of the difference between the two proportions used an  
 290 asymptotically normally distributed test statistic expressed as:

$$z = \frac{\widehat{P}_A - \widehat{P}_B}{\sigma}$$

291 where  $\sigma$  is the standard error of  $\widehat{P}_A - \widehat{P}_B$ .

292 In order to investigate our third research question, Probit regression models were used to  
 293 model changes in irrigators' climate change risk perceptions between 2010-11 and 2015-16.  
 294 Two types of changes were investigated including: 1) from 'believer' in 2010-11 to 'denier'  
 295 or 'unsure' in 2015-16; and 2) from 'denier' in 2010-11 to 'believer' or 'unsure' in 2015-16.

296 The following equation was estimated for each of the changes:

$$297 \quad \text{Change}_k^* = X\beta + \varepsilon \quad (1)$$

298 where:  $k=1,2$  respectively for change 1) and change 2),  $\text{Change}_k^*$  is a latent variable ranging  
 299 from  $-\infty$  to  $\infty$ ,  $X$  is a vector of independent variables including major farm production  
 300 decisions between 2010-11 and 2015-16,  $\beta$  is a vector of parameters to be estimated and  $\varepsilon$  is a  
 301 classical error term. The observed binary variable for change is 1 if  $\text{Change}_k^* > 0$  and 0 if  
 302  $\text{Change}_k^* \leq 0$ . Two distributions of  $\varepsilon$  are commonly assumed:  $\varepsilon$  is assumed to be distributed  
 303 normally with  $\text{Var}(\varepsilon) = 1$  – the binary probit model; and second,  $\varepsilon$  is assumed to be  
 304 distributed logistically with  $\text{Var}(\varepsilon) = \pi^2/3$  – the binary logit model.<sup>3</sup> Models were checked  
 305 for any serious multicollinearity (i.e. no variance inflation factors above five, and absolute

---

<sup>3</sup>The two approaches are similar in terms of comparing the marginal effects of regressors (Amemiya 1981).

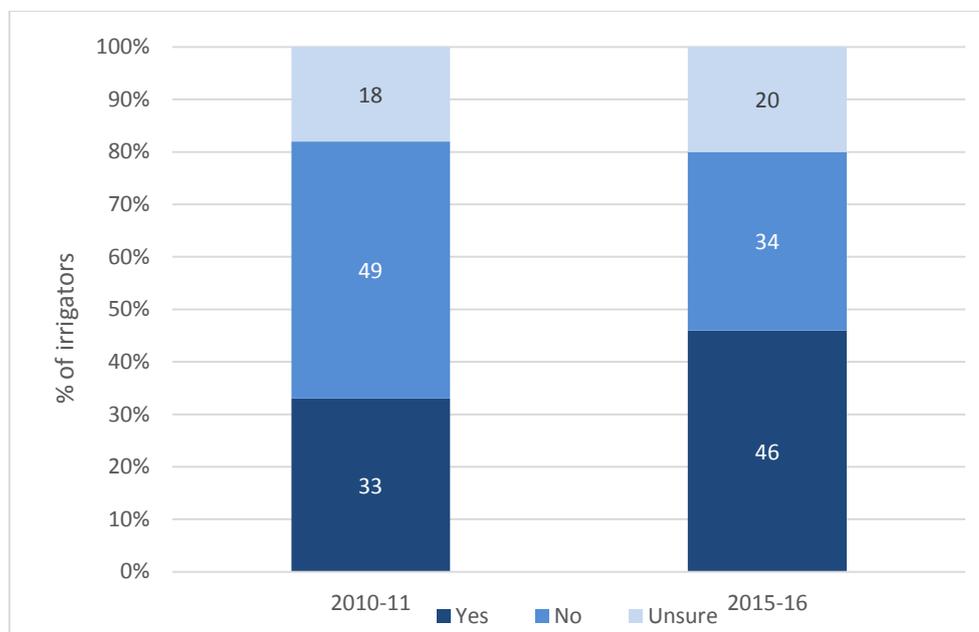
306 correlation coefficients above 0.7), and robust standard errors were used. Independent  
307 variables in Equation (1) are defined in Table A3 in the Appendix.

308

### 309 **Results: climate change risk perceptions**

310 We first study the responses to the climate change risk question: “Do you believe that climate  
311 change poses a risk to your region?” Figure 1 shows the distribution of the three possible  
312 answers among the sample of farmers (n=275) across the five years. Note, Table A2 in the  
313 Appendix presented the results for the full sample of farmers and similar distributions are  
314 observed.

315 **Figure 1. Distribution of farmers’ climate change risk perceptions for their region**  
316 **(n=275)**



317

318

319 The perceived risk induced by climate change has strengthened among the 275 farmers  
320 between 2010-11 and 2015-16. Over the five-year interval, the number of farmers who  
321 believed that climate change *did not* pose a risk to their region decreased from 49% (135  
322 farmers) to 34% (94 farmers). In contrast, there was a 13% increase (from 33% to 46%) of  
323 farmers who *do* believe climate change poses a risk to their region, and a 2% increase of  
324 farmers who stated they were unsure. Such an increase in farmers’ climate change risk  
325 perceptions was similar to the trend in views of the general Australian public, with 64%

326 agreeing that climate change was occurring in 2012, and 77% in 2019 (Australia Institute  
327 2019).

328

### 329 **Results: insights on the three main questions**

330 *Question 1: Can we characterise farmers who, in 2010-11, accepted climate change posed a*  
331 *risk to their region, versus those who did not perceive climate change as a risk or were not*  
332 *sure?*

333 Table 1 illustrates the mean characteristics of farmers in 2010-11 across the entire sample, and  
334 for sub-groups of farmers classified based on their climate change risk perception. We  
335 distinguish between those who believed climate change posed a risk in 2010-11 (i.e. the 91  
336 farmers who answered “Yes” to the climate change question) and those who disagreed (i.e.  
337 the 135 “No” farmers). The “Yes” group characteristics are compared to the sample  
338 remainder (namely 184 farmers) including: a) those who disagreed that climate change posed  
339 a risk (the deniers); and b) those who were unsure. The “No” group characteristics are  
340 compared to the sample remainder of 140 farmers who answered “Yes” or were unsure.  
341 Variables for which mean tests were found statistically significant at the 1, 5 or 10% level are  
342 in bold.<sup>4</sup>

343 We observed some significant differences across MDB states: in the group of deniers (last  
344 column, “No” answer in Table 1), there is a (significantly) higher representation of farmers  
345 operating in VIC and a (significantly) lower representation of farmers living in SA, compared  
346 to the rest of the sampled population. These discrepancies, in terms of climate change risk  
347 perceptions across the three states, are most likely related to the type of industry farmers are  
348 engaged in. Deniers had the lowest percentage of land planted with permanent crops (grapes  
349 or fruit trees). Indeed, in SA permanent crops dominate our panel dataset, since 79% of land  
350 was planted with either grapes or fruit trees in 2010-11 (on average over the 275 farmers);  
351 while permanent crops covered an average of 13% of the land owned by Victorian farmers  
352 and 14% in NSW.

353

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<sup>4</sup> We ran a simple Probit regression on the group of 275 farmers to try and identify significant explanatory variables to explain the probability of believing climate change poses a risk in 2010-11 (the “Yes” farmers). Results confirm the outcome of our mean tests in general. We also find that those farmers who are not indebted are less likely to agree with climate change risk.

354 **Table 1. Farmers' average characteristics and climate change risk perceptions in 2010-**  
355 **11**

	<i>2010-11 Full sample (n=275) Freq. (%) or mean</i>	<i>2010-11 "Yes"<sup>a</sup> (n=91) Freq. (%) or mean</i>	<i>2010-11 "No"<sup>b</sup> (n=135) Freq. (%) or mean</i>
State: NSW	98 (36%)	34 (37%)	43 (32%)
VIC	108 (39%)	33 (36%)	<b>65 (48%)*</b>
SA	69 (25%)	24 (27%)	<b>27 (20%)*</b>
Education level:			
Below year 10	46 (17%)	<b>9 (10%)*</b>	<b>31 (23%)*</b>
Year 10-12	140 (51%)	43 (47%)	72 (53%)
Tafe and equiv.	38 (14%)	<b>18 (20%)*</b>	15 (11%)
Uni. and equiv.	51 (19%)	21 (23%)	<b>17 (13%)*</b>
Male	0.90	0.87	0.91
Age (years)	55.4	54.4	56.0
Environ. group member (0/1)	0.27	0.32	0.26
Farm size (ha)	506	465	<b>594<sup>c</sup></b>
Irrigated size (ha)	153	<b>195*</b>	126
Irrigated land in permanent crops - grape & fruit trees (%)	30.0	35.1	<b>22.8***</b>
Irrigated broadacre land (%)	24.7	23.9	26.1
Irrigated pasture/grazing land (%)	35.1	<b>28.3*</b>	<b>41.1**</b>
Total volume of high entitlement water held (ML)	297	322	300
Mean end allocation previous 5 years <sup>d</sup>	52.2 (264 obs.)	53.8 (87 obs.)	50.5 (130 obs.)
Water utilisation rate (%) <sup>e</sup>	55.7	58.4	55.4
Net farm income (\$1,000)	33.8 (247 obs.)	31.5 (84 obs.)	35.8 (119 obs.)
Off-farm income (% of total income)	38.9%	37.8%	40.2%
Debt to equity ratio	0.40	0.49***	0.35**
Likelihood of successor (yes=1)	0.38 (261 obs.)	<b>0.28**</b> (87 obs.)	<b>0.43*</b> (130 obs.)
Mean annual temperature (°C, 1982-2011)	23.2	23.3	<b>23.1**</b>
Annual total rainfall (mm, previous year)	402	395	411*
Mean annual total rainfall (mm, 1982-2011)	365	366	368
Standard dev. annual temp. (°C, 1982-2011)	0.69	0.70	0.69
Standard dev. of annual rainfall (mm, 1982-2011)	110	111	111
Mean annual rainfall percentile (2006-2011)	36.3	36.1	36.1

356 **Notes:** <sup>a</sup> \*, \*\*, \*\*\* indicate statistical significance from the two-sample t-test for equal means (at the 10, 5 and  
357 1% level, respectively) of the difference between the mean of the variable for 2010-11 believers ("Yes" column)  
358 and the mean for the rest of the farmers. No indication indicates "non-statistically significant".  
359 <sup>b</sup> \*, \*\*, \*\*\* indicate significance (at the 10, 5 and 1% level, respectively) of the difference between the mean for  
360 2010-11 deniers ("No" column) and the mean for the rest of the farmers. No indication indicates "non-  
361 statistically significant".  
362 <sup>c</sup> significant at the 11% level.  
363 <sup>d</sup> weighted by security ownership.  
364 <sup>e</sup> Defined as the water extracted by irrigators as a percentage of the water allocated/received for a given year,  
365 taking into account entitlement reliability. It can be significantly influenced by using much larger volumes  
366 through purchased water, than water received from entitlements owned. Hence, water utilisation rates were  
367 capped to 100%, indicating these irrigators used 100% of their own water entitlements.

368

369 Conversely, deniers had a higher percentage of land in pasture and grazing compared to the  
370 believer group. Farmers who have engaged primarily in permanent cropping are significantly  
371 less represented in the denier group, therefore are more likely to agree climate change poses a  
372 risk. It is known that farmers having permanent crops are more exposed to the risk of drought,  
373 since these crops have to be irrigated for the trees (and the investment) to be preserved over  
374 future years (Wheeler et al. 2020a). The risk faced by farmers planting annual crops is not as  
375 pressing in the sense that a major drought would only affect production in the current year/s –  
376 and farmers also usually have the choice between growing an annual crop each year or not  
377 (Nauges et al. 2016).

378 In line with attitudes found among the general population and other farming surveys, we  
379 observe that farmers with lower education are more likely to be in the denier group (Barnes et  
380 al. 2013; Wheeler et al. 2013; Hamilton et al. 2015, Nauges and Wheeler 2017). The average  
381 mean temperature over the last 30 years was found to be significantly ( $p$ -value $<0.05$ ) lower  
382 among deniers locations (albeit the difference between means very small), and total rainfall in  
383 the previous year – which is found significantly ( $p$ -value $<0.10$ ) higher among deniers farm  
384 locations. This supports literature (e.g. Mase et al. 2017) that suggests local environmental  
385 conditions play a part in influencing climate change risk perceptions.

386 There is an almost statistically significant difference in average farm size (at the 11% level)  
387 for those farmers who did not believe climate change posed a risk in 2010-11. Farm size was  
388 larger on average for deniers than in the rest of the sampled population, which may again be  
389 linked to the type of industry farmers are engaged in. However, believers had a significantly  
390 statistically larger irrigated area than all other farmers. While there was no statistically  
391 significant difference in net farm income, water utilisation rate or off-farm income for either  
392 believers or deniers, believers had statistically significantly higher debt to equity ratios –  
393 while deniers had statistically significantly lower debt to equity ratios. Finally, we observed  
394 that there are a significantly higher proportion of farms with an identified successor among  
395 the denier group. This is not really surprising since deniers, due to their perception that  
396 climate change is not posing a risk, most likely have more positive expectations about the  
397 future than farmers who are believers.

398 Other than education, irrigators' climate change risk perceptions seem to be driven by their  
399 capital exposure to the risk of drought, as well as their capacity to mitigate any consequences  
400 in terms of debt to equity levels. Those having a larger share of their land planted with grapes

401 or fruit trees – hence being more exposed to the risk of crop failure (and more exposed to the  
 402 risk of losing a long-lived asset) – are more likely to believe climate change is posing a risk.

403 *Question 2: Have farmers’ climate change risk perceptions evolved over time? Did farmers,*  
 404 *who did not perceive climate change risk for their region in 2010-11, perceive it as a risk in*  
 405 *2015-16, and vice versa?*

406 Table 2 describes the evolution in risk perceptions between 2010-11 and 2015-16.

407 **Table 2. Matrix of farmers’ climate change risk perceptions across time (n=275)**

		<i>2015-16</i>			<i>Total</i>
		<i>No</i>	<i>Yes</i>	<i>Unsure</i>	
<i>2010-11</i>	<i>No</i>	71 53%	36 27%	28 20%	135 100%
	<i>Yes</i>	13 14%	71 78%	7 8%	91 100%
	<i>Unsure</i>	10 20%	20 41%	19 39%	49 100%
	<i>Total</i>	94 34%	127 46%	54 20%	275 100%

408

409 Among the 275 farmers, 161 (59% of the sample) perceived risk in a similar manner in 2010-  
 410 11 and in 2015-16. A total of 71 farmers in Table 2 (26% of the sample) believed climate  
 411 change would not pose a risk to their region in 2010-11 and kept the same opinion in 2015-16  
 412 (“No”- 2010-11 and “No”- 2015-16). The same number of farmers (71, or 26% of the sample)  
 413 believed in 2010-11, and still believed in 2015-16, that climate change posed a risk to the  
 414 region (“Yes”- 2010-11 and “Yes”- 2015-16). Only 19 farmers (7%) declared being unsure in  
 415 both years.

416 We are primarily interested in the 118 farmers (43% of the sample) whose perceptions about  
 417 climate change risk changed over the five-year interval: these include 36 respondents who,  
 418 initially, did not believe climate change posed a risk for their region but, five years later,  
 419 changed their mind and stated the opposite. Among the deniers in 2010-11, another 28  
 420 became unsure in 2015-16. Interestingly we also observe that 20 farmers, who believed  
 421 climate change posed a risk in 2010-11, changed their minds in 2015-16 by answering “No”  
 422 or “unsure” in 2015-16.

423 Table 3 classified farmers who had changed their minds about climate change risk into two  
 424 groups: 1) 20 farmers who originally perceived climate change posed a risk in 2010-11 and  
 425 then changed their mind in 2015-16 (either to denial or unsure); and 2) 64 farmers who

426 believed climate change did not pose any risk in 2010-11 and then changed their mind in  
427 2015-16 (hence answering “Yes” or “Unsure”). In each column we report the variable mean  
428 of either group 1 or 2 and the variable mean for the rest of the farmers inside parentheses.

429 Group 1, which includes the 20 farmers (versus the rest) who believed climate change posed a  
430 risk in 2010-11 and no longer believed this in 2015-16, has a significantly lower proportion of  
431 males and a significantly lower net farm income than the rest of the population. Group 2,  
432 which includes the 64 farmers (versus the rest) who perceived climate change a greater risk  
433 after the 5-year interval (from denier to believer or unsure), has more of the low-educated  
434 farmers than the rest of the population. Farmers in Group 2 also recorded a higher net farm  
435 income and a lower share of land in permanent crops (both measured in 2010-11) than the rest  
436 of the population. Finally, farmers in Group 2 experienced a much larger decline in rainfall in  
437 the previous year than the rest, which may contribute to the switch from denier in 2010-11 to  
438 believer in 2015-16. While acknowledging the relatively small sample size, this suggests that  
439 – although climate change is a long-term concept – farmers may link it to short-term climatic  
440 fluctuations over the period of just a few years.

441 In the following section, we seek to better understand the characteristics identified in Table 3,  
442 by considering why risk perceptions may have changed after farmers modified their exposure  
443 to risk by undertaking long-term/investment decisions – implying significant structural  
444 changes on the farm.

445

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**Table 3. Profile of farmers depending on the change in their climate change risk perception**

	<i>Group One – Believer that climate change posed a risk in 2010-11 to Otherwise in 2015-16<sup>a</sup></i>	<i>Group Two – Denier that climate change posed a risk in 2010-11 to Otherwise in 2015-16<sup>b</sup></i>
Male	<b>0.75 (0.91)**</b>	0.89 (0.90)
Age (years) in 2010-11	54.6 (55.5)	54.5 (55.7)
Low education in 2010-11 <sup>c</sup>	0.65 (0.68)	<b>0.75 (0.65)<sup>e</sup></b>
Env group membership in 2010-11	0.30 (0.26)	0.30 (0.26)
Farm size (ha) in 2010-11	287 (523)	608 (475)
Net farm income (AU\$ 1,000) in 2010-11	<b>21.0 (35.0)**</b>	<b>40.2 (32.0)*</b>
Land in permanent crops in 2010-11 (1 if permanent cropping is present on the farm; 0 otherwise)	40.0% (29.2%)	<b>20.3% (33.0%)**</b>
Likelihood of successor in 2010-11	0.32 (0.38)	0.42 (0.36)
Total volume of high entitlement water held in 2010-11 (ML)	381 (290)	286 (300)
Mean end allocation previous 5 years in 2010-11 <sup>d</sup> (%)	54.8 (52.0)	50.0 (52.9)
Water utilisation rate in 2010-11 (%)	55.9 (55.7)	55.5 (55.8)
Difference between rainfall (mm) in 2014-15 and rainfall in 2009-10	-147 (-142)	<b>-163 (-136.0)***</b>
Long term rainfall percentile of previous five years in 2015-16	56.3 (55.2)	<b>54.3 (55.6)**</b>
# of farmers	20 (compared to the other 255 farmers in brackets)	64 (compared to the other 211 farmers in brackets)

448 Notes: <sup>a</sup> \*, \*\*, \*\*\* indicate statistical significance (at the 10, 5 and 1% level, respectively) from the two-sample  
 449 t-test for equal means of the variable for farmers in Group 1 and the mean for the rest of the farmers. No  
 450 indication indicates “non-statistically significant”. <sup>b</sup> \*, \*\*, \*\*\* indicate statistical significance (at the 10, 5 and  
 451 1% level, respectively) from the two-sample t-test for equal means of the variable for farmers in Group 2 and the  
 452 mean for the rest of the farmers. No indication indicates “non-statistically significant”. <sup>c</sup> Dummy variable that  
 453 takes the value 1 if farmer’s education level is year 12 maximum, and 0 otherwise. <sup>d</sup> Weighted by security  
 454 ownership. <sup>e</sup> Mean difference is significant at the 15% level of significance.  
 455

456 *Question 3: Are farmers' climate change risk perceptions associated with major farm*  
457 *production decisions made on the farm between the two surveys? Can we detect a feedback*  
458 *relationship between perceptions and behaviour?*

459 As has been found previously in the literature (e.g. Nauges and Wheeler 2017), we  
460 hypothesise climate change risk perception could be endogenous and subject to a feedback  
461 loop, in the sense that actions undertaken by farmers between the two survey periods may  
462 have altered their exposure to risk and hence their perception of the risk posed by climate  
463 change. Taking farmers' original climate change belief as a base, we compared farmers'  
464 significant production decisions made between 2010-11 and 2015-16. We focussed on farm  
465 major production choices (all binary variables), and also the change in total irrigated area  
466 (continuous decision expressed in percentage terms).

467 Farmers who agreed climate change posed a risk to their region in 2010-11 were more likely  
468 to sell land between 2010-11 and 2015-16 (18% of believers versus 8% of deniers/unsure).  
469 Believers, as at 2010-11, were also more likely to sell water entitlements between 2010-11  
470 and 2015-16 (40% of believers versus 29% for deniers/unsure). The difference was  
471 statistically significant at the 10% level. On the contrary, those who did not perceive climate  
472 change as a risk in 2010-11 were more likely to buy water entitlements over the next five  
473 years (probability of 20% for deniers versus 12% for believers/unsure, with the difference  
474 statistically significant at the 10% level). In line with the purchase of water entitlements, we  
475 observed that deniers in 2010-11 increased their irrigated area significantly more than  
476 believers/unsure (this is reflected in the variable that measures the change in irrigated area).

477 Figures in Table 4 suggest two categories of farmers may coexist: the first category being  
478 believers in 2010-11 who decided to disinvest by selling land and water entitlements. These  
479 farmers presumably saw (irrigation) farming as a risky activity, and we know they considered  
480 climate change a risk factor. They reduced their risk exposure by lowering the scale of their  
481 farming activities and hence their irrigation farming dependence. We do not see any  
482 statistically significant evidence that these farmers planned to exit and sell the farm (although  
483 believers were relatively more likely to have said they were thinking of leaving the farm in  
484 2010-11). It must be noted that our panel dataset includes everyone who continued farming,  
485 so this is not the best test for farm exit.

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**Table 4. Relationship between climate change risk perceptions in 2010-11 and major production decisions over the next five years**

<i>Between 2010-11 and 2015-16, irrigators' major production actions:</i>	<i>2010-11 Strong believer ("Yes only")</i>	<i>2010-11 "No" or "Unsure"</i>	<i>Mean test p-value</i>	<i>2010-11 Strong denier ("No only")</i>	<i>2010-11 "Yes" or "Unsure"</i>	<i>Mean test p-value</i>
Sold farm-land (0/1)	0.18	0.08	**	0.08	0.14	<i>n.s.</i>
Bought farm-land (0/1)	0.20	0.22	<i>n.s.</i>	0.22	0.21	<i>n.s.</i>
Sold water entitlements (0/1)	0.40	0.29	*	0.30	0.34	<i>n.s.</i>
Bought water entitlements (0/1)	0.14	0.17	<i>n.s.</i>	0.20	0.12	*
Increased irrigated area (0/1)	0.23	0.19	<i>n.s.</i>	0.24	0.19	<i>n.s.</i>
Decreased irrigated area (0/1)	0.34	0.22	**	0.25	0.26	<i>n.s.</i>
Change in irrigated area (%) <sup>a</sup>	31	280	<i>n.s.</i>	348	57	**
Improved irrigation efficiency (0/1)	0.79	0.81	<i>n.s.</i>	0.81	0.79	<i>n.s.</i>
Changed crop mix (0/1)	0.53	0.53	<i>n.s.</i>	0.53	0.52	<i>n.s.</i>
Utilised solar and battery technology (0/1)	0.36	0.28	<i>n.s.</i>	0.31	0.30	<i>n.s.</i>
Change in water utilisation rate	16.50	22.71	<i>n.s.</i>	25.85	15.65	**
Climate Change Actions (e.g. tree planting; soil management; timing changes; canopy/shed for plant/shelter) (0/1)	0.07	0.07	<i>n.s.</i>	0.06	0.07	<i>n.s.</i>
# of farmers (275 in total)	91	184		135	140	

490 Notes: <sup>a</sup> Computed as (irrigated area in 2015-16 take irrigated area in 2010-11)/irrigated area in 2010-11. The  
 491 change can be either negative or positive. There were 21 farms that had zero irrigated area in 2010-11 but  
 492 positive irrigated area in 2015-16. Hence their percentage change in irrigated area was not defined and they are  
 493 not included in the calculation of the variable named "change in irrigated area".

494

495 The second group includes deniers in 2010-11. In the following five years, deniers increased  
 496 their farm-irrigated area and purchased more water entitlements. It seems these farmers hoped  
 497 to continue farming in the future, but wanted to be better protected against drought risk  
 498 through increased water entitlements. This may illustrate water entitlement trade is partly  
 499 driven by differences in risk perception and risk management strategies (as suggested in  
 500 Nauges et al. 2016). Group 1 farmers (the believers) disinvest in farming and send water  
 501 entitlements to the second group of farmers (the deniers) who aim to continue farming  
 502 activities, albeit with reinforced protection against drought.

503 Finally, we test our feedback hypothesis: namely that changes in climate change perceptions  
504 from 2010-11 to 2015-16 could have been driven, among other factors, by major farm  
505 decisions undertaken during this time-period, in particular production decisions including:  
506 buying and selling of land and water entitlements; increasing or decreasing irrigated area;  
507 changing crop mix; improving irrigation infrastructure; tree planting; soil management;  
508 changing timing of practices, and utilising solar and battery technology for irrigation water  
509 pumping.<sup>5</sup> We used the two groups of farmers to test the research questions. The main  
510 hypothesis tested was that farmers who were (or were not) originally concerned about climate  
511 change risk may have changed their mind after undertaking various production decisions that  
512 decreased (or increased) their exposure to climate change risk. We hypothesise that selling  
513 land, decreasing irrigated area and consequently selling water entitlements, decreasing water  
514 use percentage, changing crop mix, and utilising solar and battery technology leads to a  
515 reduced risk exposure. Reducing risk increases farmers' sense of 'control' and hence  
516 decreases the likelihood that they perceive climate change as a risk. Conversely, farm actions  
517 such as purchasing land, increasing irrigated area and consequently increasing water  
518 entitlements, increases risk exposure and hence the likelihood that climate change is perceived  
519 as a risk. If there is evidence for the above two hypotheses, it would suggest that climate  
520 change perception and behaviour influence and feed back on each other, and that farmers' risk  
521 perceptions are influenced by their risk exposure.

522 We ran two Probit models to analyse the change in climate change risk perceptions between  
523 2010-11 and 2015-16. Independent variables included combinations of nine actual farm  
524 production actions between 2010-11 and 2015-16 and also controlled for a range of  
525 demographic, socio-economic and farm level characteristics. The nine farm production  
526 actions were defined as dummy variables: 1) selling land; 2) purchasing land; 3) selling water  
527 entitlements; 4) purchasing water entitlements; 5) increasing irrigated area; 6) decreasing  
528 irrigated area; 7) changing crop mix; 8) improving irrigation infrastructure; 9) utilising solar  
529 and battery technology for pumping irrigation water; and 10) climate change plan action (e.g.

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<sup>5</sup> Unfortunately we had limited information on tree planting, soil management and other types of 'softer' farm adaptation behaviour because only farmers who answered they had a climate change risk plan were asked to provide more information on what they were doing as part of this plan. Given this, although a wide range of variables was included in the full regression modelling shown in Table A4 in the Appendix, it was not statistically significant and it limits any ability to fully infer insights. One such hypothesis is that more 'softer' farm adaptation behaviour (unlike other major production decisions) will not feed back negatively on climate change attitudes, due to the fact such behaviour is more diagnostic, knowledge-based and lower financial cost in nature (similar to findings in Nauges and Wheeler, 2017, regarding different types of household behaviour). Indeed, the coefficients in Table A4 provide some support that this type of farm adaptation behaviour has a positive feedback impact on climate change attitudes (but the results were not statistically significant and larger sample sizes will be needed).

530 tree planting, soil management etc). Pre-testing of the independent variables suggested that  
531 the farm actions of water entitlement trade and irrigation area had interaction effects.  
532 Therefore, in the reported models, two interaction terms were created between selling water  
533 entitlements and decreasing irrigated area, and purchasing water entitlements and increasing  
534 irrigated area.

535 Since the sample size of 275 irrigators is relatively small, the statistical power of our analysis  
536 may be low, which suggests a higher probability of failing to detect a statistically significant  
537 difference when such a difference actually exists (also called a type II error). Power  
538 calculations were undertaken for the variables of most interest to the study—climate change  
539 risk perception between 2010-11 and 2015-16, and irrigators' production decisions regarding  
540 water entitlements and irrigated area. Although our sample size is relatively small, for the  
541 purpose of our analysis, the statistical power is sufficient or close to sufficient (i.e. above or  
542 close to 0.80).<sup>6</sup> In line with best practices in the literature (Gabaix and Laibson 2008), a  
543 parsimonious model was estimated using the nine actual farm production actions between  
544 2010-11 and 2015-16 if they are statistically significant (0.10 level) and only the statistically  
545 significant (0.10 level) control variables, such as education, state location, succession status,  
546 etc. However, for robustness check, another model using the full list of independent variables  
547 was estimated as well and reported in Table A4 in the Appendix.

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<sup>6</sup> In our sample, there are 140 irrigators who did not sell water entitlements and did not reduce irrigated area, and 25 irrigators who did both. The proportion of group 1 (from Yes to otherwise) for the 140 irrigators is 0.04 while the proportion of group 1 for the 25 irrigators is 0.24. The power of a two-sided test to detect a statistically significant difference between the two proportions, assuming a 0.05 significance level is 0.85, which is above the usual 0.80 default level, suggesting the probability of committing a type II error is 0.15. Similarly, there are also 190 irrigators who did not buy water entitlements and did not increase irrigated area, and 19 irrigators who did both. The proportion of group 2 (from No to otherwise) for the 190 irrigators is 0.20 while the proportion of group 2 for the 19 irrigators is 0.48. The power of a two-sided test to detect a statistically significant difference between the two proportions, assuming a 0.05 significance level is 0.76, which is close to the usual 0.80 default level, suggesting a type II error probability is 0.24.

550 **Table 5. Estimated coefficients of parsimonious probit models for change in climate**  
551 **change risk perception between 2010-11 and 2015-16**

	<i>Group One:</i>		<i>Group Two:</i>	
	<i>From 'Yes' to otherwise</i>	<i>From 'No' to otherwise</i>	<i>From 'Yes' to otherwise</i>	<i>From 'No' to otherwise</i>
	<i>Marginal effect</i>	<i>Delta-method Std. Err.</i>	<i>Marginal effect</i>	<i>Delta-method Std. Err.</i>
Sold farm-land in last 5 years	-	-	-0.192**	0.090
Bought farm-land in last 5 years	0.169***	0.045	-	-
Neither sold water entitlement nor reduced irrigated area (reference group) in the last five years	-	-	-	-
Only reduced irrigated area	0.016	0.043	-	-
Only sold water entitlements	0.080**	0.035	-	-
Sold water entitlements and reduced irrigated area	0.146***	0.039	-	-
Neither bought water entitlement nor increased irrigated area (reference group) in the last five years	-	-	-	-
Only increased irrigated area	-0.001	0.034	0.002	0.067
Only bought water entitlements	-0.185***	0.071	0.079	0.088
Bought water entitlements and increased irrigated area	-0.123**	0.062	0.187**	0.084
Changed crop mix in last five years	0.104***	0.032	-	-
Improved irrigation infrastructure in last 5 years	0.136**	0.064	-	-
NSW state (SA and VIC reference group)	-	-	-0.192***	0.059
Low education dummy in 2015-16 <sup>1</sup>	0.114***	0.035	-	-
Successor dummy in 2015-16 <sup>1</sup>	-0.128***	0.030	-	-
Permanent crop dummy in 2015-16 <sup>1</sup>	0.062**	0.029	-	-
Net farm income (\$1,000) in 2015-16 <sup>1</sup>	-0.001***	0.0002	0.0006*	0.0003
Debt to equity ratio in 2015-16 <sup>1</sup>	-0.092**	0.044	-	-
Total high security water entitlement (ML) in 2015-16 <sup>1</sup>	0.0001***	0.00004	-0.0002**	0.0001
Change in water utilisation rate in last 5 years	-	-	0.001**	0.0005
Mean rainfall percentile in the last 5 years (20km around farm)	0.009***	0.003	-	-
Observations		275		275
Wald Chi-2 statistics		39.08***		24.41***
Pseudo R <sup>2</sup>		0.38		0.08
% of correct predictions		94		79

552 <sup>1</sup>Variables in 2010-11 were also tried and results were similar for most. Since succession plan had 14 missing  
553 values in 2010-11, all these variables in 2015-16 were used instead. For model results with the full list of  
554 independent variables, refer to Table A4 in the Appendix. The models reported here were kept as parsimonious  
555 as possible.

556 \*\*\*, \*\*, \* indicates statistical significance at the 1%, 5% and 10% level respectively.

557

558 Findings from the first (Group 1) Probit model (shown in Table 5) suggest that irrigators were  
559 more likely to change their original climate change risk perception from “Yes” to otherwise  
560 (including no and unsure) five years later if they bought farmland (with an increasing  
561 probability of 0.17), decreased irrigated area and meanwhile sold water entitlements (with a  
562 probability of 0.15), changed crop mix (with an increasing probability of 0.10), and improved  
563 irrigation infrastructure (with an increasing probability of 0.14). Irrigators were also less  
564 likely to change their original climate change risk perception from “Yes” to otherwise five  
565 years later if they bought water entitlements but did not increase irrigated area (with a  
566 decreasing probability of 0.19), or bought water entitlements and meanwhile increased  
567 irrigated area (with a decreasing probability of 0.12). This suggests support for decreased risk  
568 exposure from farm action - resulting in a weaker belief in climate change, or for increased  
569 risk exposure resulting in a stronger climate change risk perceptions. Other statistically  
570 significant results include farmers with low education were more likely to have switched from  
571 a believer to a denier/not sure, and those who had a succession plan in place were less likely  
572 to have switched from being a believer to denier/not sure. Higher net farm income and higher  
573 debt to equity levels - which suggest higher risk exposure from increased debt levels - are  
574 associated with a lower likelihood in switching from a believer to otherwise. A higher rainfall  
575 in the farm’s location (decreased risk exposure) in the last five years was found to increase the  
576 likelihood in switching from a believer to otherwise.

577 Results of the second (Group 2) Probit model in Table 5 suggest that irrigators were more  
578 likely to change their original climate change risk perception from “No” to otherwise if they  
579 increased irrigated area and also consequently bought more water entitlements (with an  
580 increasing probability of 0.19), had an increased water utilisation rate and did not sell  
581 farmland – during the five years between 2010-11 and 2015-16. These results indicate that  
582 overall increased irrigation risk exposure from farm action means farmers were more likely to  
583 change from being a denier towards believing climate change poses a risk or being unsure.  
584 Although caution is recommended due to the small sample size, our results suggest that  
585 farmers’ climate change perceptions may be influenced by farm production decisions that  
586 impact their risk exposure. But it is also important to note that it is possible that other  
587 variables beyond those able to be included in our regression models could also impact  
588 farmers’ perceptions of climate-related risk.

589

590

## 591 **Discussion**

592 Although there has been much research in the literature on understanding the drivers of both  
593 consumers' and farmers' climate change beliefs (Austin et al. 2020a; Hornsey et al. 2016;  
594 Raymond and Spoehr 2013; van der Linden 2014), nearly all of this work has used snapshots  
595 of observed behaviour and beliefs at one point in time, making it difficult to study their  
596 dynamics within a specific population. There has also been increasing literature that has  
597 highlighted the complex relationship between attitudes and behaviour, and that undertaking  
598 climate change adaptation and mitigation action can sometimes feed back negatively on  
599 climate change attitudes (Nauges and Wheeler 2017; Wheeler et al. 2013). This study has  
600 extended the literature by using a panel dataset of the same 275 Australian farmers over a  
601 five-year period to explore and understand: a) the extent, stability and influences associated  
602 with farmers' climate change perceptions; and b) how farmers' climate change risk  
603 perceptions are associated with major farm changes – and to further test the potential  
604 feedback (endogenous) relationship between attitudes and long-term farm behaviour.

605 Overall, it was found that MDB farmers' perceptions towards climate change became more  
606 accepting over the five-year period (from 33% agreeing that climate change posed a risk to  
607 their region in 2010-11 to 46% in 2015-16). This is a positive sign for policy-makers trying to  
608 encourage increased farm adaptation, in the face of a hotter and more variable climate future.<sup>7</sup>  
609 Our analysis in this paper supports the role that farmer characteristics (e.g. education, has a  
610 farm successor) and farm characteristics (e.g. location, farm size, irrigated area, industry  
611 (permanent versus annual crops), debt, and climate conditions (temperature and rainfall)) play  
612 in driving climate change perceptions. The interplay between risk exposure and perceptions is  
613 revealing: MDB farmers in higher debt, with greater permanent crops, in areas that have had  
614 higher temperatures and less rainfall, were all more likely to accept climate change poses a  
615 risk to their region (similar to results found by Mase et al. 2017).

616 This study found some evidence that farmers who went from believers in 2010-11 to  
617 deniers/unsure in 2015-16, were more likely during the five years to change crop mix,  
618 upgrade irrigation infrastructure, reduce irrigated area and consequently sell water  
619 entitlements. We suggest this decreased their overall risk exposure and hence *negatively* fed

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<sup>7</sup>Indeed, there is evidence in the past couple of years of increased action by farmers towards climate change, given that Australia has seen the creation of the following groups such as Young Carbon Farmers and Farmers for Climate Action. The country has also had the first ever rally on climate change by farmers in Canberra in 2018, national adverts in 2018 on the need for climate change action by farmers and since 2016 the National Farmers Federation have taken increasingly stronger positions on the need to reduce carbon emissions.

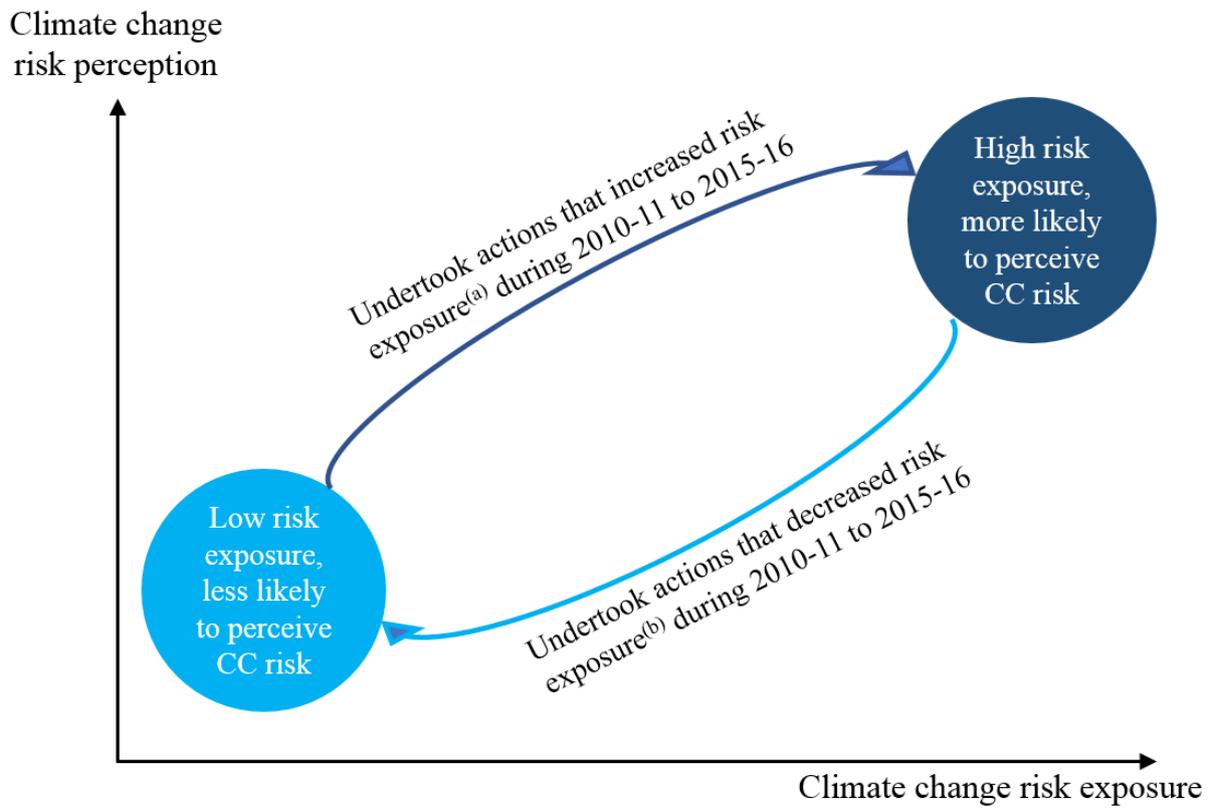
620 back on their stated climate change concern in 2015-16. Indeed, there may be some link  
621 between the presence of upgraded irrigation infrastructure (increasing the ‘sense of control’)  
622 and lessening climate change beliefs, as suggested by the findings of Niles and Mueller  
623 (2016). This study found evidence to suggest that the presence of infrastructure potentially  
624 positively influenced farmer perceptions that annual rainfall had increased over time. Niles  
625 and Mueller (2016) proposed these perceptions were important, with regards to how the  
626 presence of infrastructure influenced how people perceived and responded to climate change.  
627 The identification of a significant increase in water extraction of up to 28% by Wheeler et al.  
628 (2020a), from subsidising irrigation infrastructure in the southern MDB, indicates one such  
629 negative consequence of government policy.

630 Similarly, climate change deniers in 2010-11 were more likely in the following five years to  
631 increase irrigated area and consequently purchase water entitlements – plus increase their  
632 water utilisation rate, which in turn increased their overall risk exposure. This then  
633 correspondingly *positively* fed back on their stated climate change attitudes in 2015-16, and  
634 they became more concerned about the risk of climate change. Our findings echo Wilson et al.  
635 (1993)’s analysis of risk perception and management decisions of US dairy farmers as an  
636 outcome of complex feedback loops between perceptions and behaviour (van Raaij, 1981). It  
637 also complements recent findings by Austin et al. (2020b) on the dynamics of drought-related  
638 attitudes and adaptive capacity in the NSW non-metropolitan population. However, to the best  
639 of our knowledge, this is the first time a link between farm action and farmer attitude has been  
640 shown from any behavioural data over a period of years.

641 In regards to the relationship between attitudes and major farm production decisions, our main  
642 findings regarding the dynamics and relationships of exposure, perceptions and actions are  
643 summarised in Figure 2, which shows a feedback loop happening between attitudes and  
644 behaviour. We argue that this feedback from actions to perceptions is one reason to explain  
645 the instability in climate change perceptions. In our panel data sample, 43% of surveyed  
646 farmers did not have the same climate change perceptions five years later, and – although  
647 more farmers were likely to switch to agreeing that climate change posed a risk – it was also  
648 true that some reversed their former statement that climate change was occurring. Our  
649 findings also demonstrated that change in local weather conditions partly explained the  
650 change in climate-related risk perception.

651

652 **Figure 2. Key summary of relationship between climate change (CC) risk perceptions,**  
 653 **risk exposure and changed farm behaviour**



654  
 655  
 656  
 657

Notes: <sup>a</sup>In particular, bought water entitlements and also increased irrigated area  
<sup>b</sup>In particular, sold water entitlements and also decreased irrigated area

658 Whether farmers do or do not accept climate change, they all have to deal with the uncertainty  
 659 of weather and, indeed, farmers have been managing uncertainty for a very long time. The  
 660 question is how we can help farmers adapt the most to a changing climate in the future,  
 661 understanding that there is a complex link between perceptions and behaviour. Given that the  
 662 term ‘climate change’ can be so polarising, education campaigns to change farmers’  
 663 perceptions will probably not provide the desired results – although it is clear from our results  
 664 that higher farmer education in general is associated with more stability in climate change  
 665 perception. George et al. (2019) recommended a focus on education, extension on risk  
 666 management and developing best management practices for dealing with extreme climatic  
 667 events. We also recommend an implementation of policies that improve farmers’ risk-  
 668 management and decision-making, by focusing on how adaptation to weather variability can  
 669 increase profitability and strengthen the farm’s viability. Similar to household behaviour  
 670 (Nauges and Wheeler 2017), a portfolio of policies, regulation, targeted incentives and  
 671 information is needed. Indeed, different populations of farmer cohorts may need a different

672 mix of policies. Farming policy should be more strategic and forward thinking, with subsidies  
673 removed for inputs and outputs that can distort farmers' decision-making (e.g. Wheeler et al.  
674 2020a for comments on irrigation infrastructure subsidies) – and reward farmers for good land  
675 practice (e.g. greater use and implementation of soil carbon markets and land stewardship).  
676 Many farmers are already making significant investment in planning for climate change on  
677 their farm, and the challenge for policy-makers is how to maximise such behaviour going  
678 forward.

679 The limitations of our study include the relatively small sample size (n=275), and the fact it  
680 only covers five years of farm data and attitudes. The small sample size also did not allow us  
681 to break up the data into typologies of farmers (e.g. traditional farmers versus environmentally  
682 friendly farmers versus corporate/profit minded farmers), nor industries for further analysis.  
683 We also had limited information on more diagnostic and knowledge forms of farmer  
684 adaptation behaviour (tree planting, changes of practices etc) – where with further data it  
685 would be very interesting to test for the existence of a negative (or indeed even a positive)  
686 feedback loop with climate change perceptions. The surveys were done in two very different  
687 climatic years, which, although this was controlled for in our modelling, may have had an  
688 impact on climate change risk perceptions. Further research in this space on the feedback loop  
689 between attitudes and behaviour for both consumers and farmers across developed and  
690 developing countries may be warranted, through a variety of different methods such as  
691 experimentation, repeated survey analysis and in-depth qualitative analysis.

692

## 693 **Conclusion**

694 The exact relationship between people's climate change attitudes and behaviour is a topic that  
695 is very important for climate change policy worldwide. Do climate change attitudes influence  
696 behaviour or is it possible that behaviour can change attitudes? If the influence is just one  
697 way, then education to try and change climate change attitudes may be one of the most  
698 effective ways of encourage adaptation to climate change. However, if there is a feedback  
699 loop between behaviour and attitudes, then more sophisticated policy instruments may be  
700 needed. There is emerging literature highlighting this complex relationship between attitudes  
701 and behaviour, and that undertaking climate change adaptation and mitigation action can  
702 sometimes feed back on climate change attitudes. However, the majority of the current  
703 literature that has studied these relationships have focussed on cross-sectional analysis (one-

704 off surveys at a point in time). This study has extended the literature by using a panel  
705 (repeated survey of the same irrigators) dataset of 275 MDB farmers, over the time-period of  
706 2010-11 to 2015-16, to examine the evidence for the existence of a feedback loop. It does so  
707 by exploring three main questions: 1) understanding farmers' climate change risk perceptions  
708 and the characteristics associated with their perceptions; 2) identifying how farmers' risk  
709 perceptions have evolved over time and how stable those risk perceptions are; and 3)  
710 identifying if climate change risk perceptions are associated with major farm action long-term  
711 changes.

712 It was found that farmers became more accepting of climate change risk in their region over  
713 the time-period (those agreeing increased from 33% to 46%). However, climate change  
714 perceptions were not stable: 41% of surveyed farmers in our panel dataset did not have the  
715 same climate change perception five years later, and although more farmers were likely to  
716 change to agreeing that climate change posed a risk, it was also true that some farmers  
717 reversed their former statement that climate change was occurring. This variability in attitudes  
718 is one reason why it has been found that attitudes are often not the major driver of behavioural  
719 change.

720 This study found new evidence of the feedback loop between perceptions and behaviour in  
721 Australia. Namely, farmers who believed at the start of the time-period that climate change  
722 was a risk, were more likely to undertake decisions that reduced their risk exposure overall  
723 (e.g. changed crop mix; upgraded irrigation infrastructure; and reduced irrigated area and  
724 consequently sold water entitlements). This correspondingly negatively fed back on their  
725 climate change concern (i.e. they became less concerned about the risk of climate change).  
726 Conversely, non-believers who increased their risk exposure over the time-period (e.g.  
727 increased water utilisation; increased irrigated land and consequently bought water  
728 entitlements) were more likely to change their mind afterwards and believe that climate  
729 change posed a risk.

730 Given these findings, and the similarities noted between our study and farmers' climate  
731 change perceptions in other developed countries, it is important that policy-makers worldwide  
732 understand the complex relationship between attitudes and behaviour, and how various  
733 policies to change behaviour can impact negatively (or positively) on attitudes. Going  
734 forward, policies that improve farmers' risk-management and decision-making by focusing on  
735 how adaptation to weather variability can increase profitability and strengthen the farm's

736 viability will be highly important; and a portfolio of policies, regulation, targeted incentives  
737 for good land management and information is needed.

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884

**Table A1. Key characteristics of the full sample and panel sample in 2010-11**

	Full sample (n=946)	Panel sample (n=275)
State: NSW	33% [30%, 36%]	36% [30%, 42%]
VIC	38% [35%, 41%]	39% [34%, 45%]
SA	29% [26%, 32%]	25% [20%, 31%]
Education level:		
Below year 10	16% [14%, 19%]	17% [13%, 22%]
Year 10 to year 12	52% [49%, 55%]	51% [45%, 57%]
Tafe and equiv.	12% [10%, 15%]	14% [10%, 18%]
Univ. and equiv.	19% [17%, 22%]	19% [14%, 24%]
Gender (male = 1)	88% [86%, 90%]	90% [86%, 93%]
Age (years)	55.0 [54.3, 55.7]	55.4 [54.2, 56.7]
Likelihood of successor (yes=1)	36% [32%, 39%]	38% [32%, 43%]
Environ. group member (yes=1)	26% [23%, 28%]	27% [21%, 32%]
Farm size (ha)	471 [410, 533]	506 [400, 613]
Irrigated size (ha)	144 [125, 163]	153 [120, 186]
Irrigation Land in permanent crops - grape and fruit trees (%)	31.6 [28.7, 34.5]	30.0 [24.7, 35.3]
Irrigation land in broadacre crops	23.3 [21.1, 25.6]	24.7 [20.3, 29.0]
Irrigation land in grazing and pasture	35.0 [32.2, 37.7]	35.1 [30.1, 40.0]
Total volume of high entitlement water held (ML)	294 [259, 329]	297 [250, 344]
Net farm income(AU\$1,000)	30.4 [28.5, 32.3]	33.8 [30.2, 37.5]
Off-farm income (% of total income)	40.1 [37.6, 42.7]	38.9 [34.3, 43.6]
Debt to equity ratio	0.42 [0.39, 0.44]	0.40 [0.35, 0.44]

887 Note: The 95% confidence intervals are in square parentheses, which overlap each other between the  
888 full sample and panel sample, suggesting they do not differ statistically significantly with regard to  
889 any of the characteristics above.

891 **Table A2. Distribution of farmers' perception on risk posed by climate change**  
 892 **in 2010-11 and 2015-16 (full sample)**

	2010-11		2015-16	
	Freq.	Percent	Freq.	Percent
No	455	48	352	35
Yes	304	32	435	44
Unsure	187	20	213	21
<b>Total</b>	<b>946</b>	<b>100</b>	<b>1,000</b>	<b>100</b>

893

894

895 **Table A3. Summary statistics for all variables in the probit models of Table A4 (n=275)**

	<i>Obs</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min</i>	<i>Max</i>
<b><i>Dependent variable</i></b>					
Group One: From 'Yes' to otherwise	275	0.073	0.260	0	1
Group Two: From 'No' to otherwise	275	0.233	0.423	0	1
<b><i>Independent variable</i></b>					
Sold farm-land in last 5 years	275	0.113	0.317	0	1
Bought farm-land in last 5 years	275	0.215	0.411	0	1
Neither sold water entitlement nor reduced irrigated area (reference group) in the last five years					
Only reduced irrigated area	275	0.167	0.374	0	1
Only sold water entitlements	275	0.233	0.423	0	1
Sold water entitlements and reduce irrigated area	275	0.091	0.288	0	1
Neither bought water entitlement nor increased irrigated area (reference group) in the last five years					
Only increased irrigated area	275	0.149	0.357	0	1
Only bought water entitlements	275	0.091	0.288	0	1
Bought water entitlements and increased irrigated area	275	0.069	0.254	0	1
Changed crop mix in last five years	275	0.527	0.500	0	1
Improved irrigation infrastructure in last 5 years	275	0.804	0.398	0	1
Utilised solar and battery technology in last 5 years	275	0.098	0.298	0	1
VIC state (NSW reference group)	275	0.393	0.489	0	1
SA state (NSW reference group)	275	0.251	0.434	0	1
Age in 2015-16	275	60.553	10.662	25	84
Male gender dummy in 2015-16	275	0.898	0.303	0	1
Low education dummy in 2015-16	275	0.167	0.374	0	1
Environmental group membership dummy in 2015-16	275	0.196	0.398	0	1
Successor dummy in 2015-16	275	0.378	0.486	0	1
Farm size (ha) in 2015-16	275	701.043	1962.424	0	20193.83
Permanent crop dummy in 2015-16	275	0.342	0.475	0	1
Irrigated area (ha) in 2015-16	275	267.464	625.786	0	8000
Total high security water entitlement (ML) in 2015-16	275	251.891	370.592	0	2000
Net farm income (\$1,000) in 2015-16	275	81.226	79.781	0	250
Debt to equity ratio in 2015-16	275	0.313	0.402	0	3
Mean end allocation % in last 5 years	275	0.856	0.278	0	1
Change in water utilisation rate in last 5 years	275	20.658	43.449	-100	100
Mean rainfall percentile in the last 5 years (20km around farm)	275	55.276	4.359	44	66
Climate Change Actions–Have undertaken actions in response to climate change risk in 2015-16: planting trees; installing canopy/shed for plant/livestock shelter; soil management; or changing timing of agricultural practices (1=yes, 0=no)	275	0.07	0.25	0	1

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**Table A4. Estimated marginal effects of Probit models for change in climate change risk perception between 2010-11 and 2015-16, with full list of independent variables**

	<i>Group One:</i>		<i>Group Two:</i>	
	<i>From 'Yes' to otherwise</i>		<i>From 'No' to otherwise</i>	
	<i>Marginal effect</i>	<i>Delta-method Std. Err.</i>	<i>Marginal effect</i>	<i>Delta-method Std. Err.</i>
Sold farm-land in last 5 years	-0.026	0.037	-0.247***	0.085
Bought farm-land in last 5 years	0.176***	0.049	-0.015	0.066
Neither sold water entitlement nor reduced irrigated area (reference group) in the last five years				
Only reduced irrigated area	0.028	0.042	-0.035	0.069
Only sold water entitlements	0.090***	0.033	-0.104	0.065
Sold water entitlements and reduced irrigated area	0.154***	0.037	0.048	0.090
Neither bought water entitlement nor increased irrigated area (reference group) in the last five years				
Only increased irrigated area	0.013	0.035	0.004	0.069
Only bought water entitlements	-0.153**	0.068	0.062	0.089
Bought water entitlements and increased irrigated area	-0.122**	0.060	0.190**	0.095
Changed crop mix in last five years	0.111***	0.031	-0.0003	0.049
Improved irrigation infrastructure in last 5 years	0.133**	0.067	0.020	0.068
Utilised solar and battery technology in last 5 years	0.033	0.036	-0.041	0.083
VIC state (NSW reference group)	0.049	0.048	0.253***	0.071
SA state (NSW reference group)	0.005	0.047	0.214**	0.088
Age in 2015-16 <sup>1</sup>	0.0001	0.002	0.0002	0.002
Male gender dummy in 2015-16 <sup>1</sup>	0.009	0.042	-0.021	0.079
Low education dummy in 2015-16 <sup>1</sup>	0.116***	0.035	0.085	0.066
Environmental group membership dummy in 2015-16 <sup>1</sup>	-0.058	0.045	0.036	0.056
Successor dummy in 2015-16 <sup>1</sup>	-0.132***	0.036	-0.105**	0.055
Farm size (ha) in 2015-16 <sup>1</sup>	-0.000001	0.00001	0.00001	0.00002
Permanent crop dummy in 2015-16 <sup>1</sup>	0.085**	0.039	-0.120*	0.068
Irrigated area (ha) in 2015-16 <sup>1</sup>	-0.00003	0.00005	-0.000003	0.00005
Total high security water entitlement (ML) in 2015-16 <sup>1</sup>	0.0001***	0.00004	-0.0002***	0.0001
Net farm income (\$1,000) in 2015-16 <sup>1</sup>	-0.001**	0.0002	0.001*	0.0003
Debt to equity ratio in 2015-16 <sup>1</sup>	-0.094**	0.041	0.096	0.066
Mean end allocation % in last 5 years	-0.060	0.051	-0.018	0.104
Change in water utilisation rate in last 5 years	0.0003	0.0004	0.001*	0.001
Mean rainfall percentile in last 5 years (20km around farm)	0.010**	0.004	-0.001	0.007
Climate Change Actions (e.g. tree planting; soil management; timing changes; canopy/shed for plant/shelter)	-0.073	0.057	0.056	0.092
Observations		275		275
Wald Chi-2 statistics		68.71***		42.82**
Pseudo R <sup>2</sup>		0.42		0.14
% of correct predictions		94		79

898 <sup>1</sup> Variables in 2010-11 were also tried and results were similar for most. Since succession plan had 14 missing  
899 values in 2010-11, all these variables in 2015-16 were used instead.

900 \*\*\*, \*\*, \* indicates statistical significance at the 1%, 5% and 10% level respectively.

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