1 **Some primary producers are more likely to transform**
2 **their agricultural practices in response to climate change**
3 **than others**

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9
10 **Abstract**

11 Climate change is altering the productivity of natural resources with far-reaching
12 implications for agriculture. In some instances, the scale and nature of the likely impacts
13 means that transformations of function or structure of agriculture and/or agricultural
14 enterprises will be required if communities dependent on agriculture are to be sustained.
15 However, industry-wide transformations are unlikely to be supported unless individual
16 primary producers have sufficient capacity to undergo transformational change. We look
17 at: (i) the extent to which primary producers in Australia would be willing to transform,
18 (ii) the extent that transformational capacity is likely to exist within producers, and (iii)
19 the common attributes of producers with high levels of transformational capacity. We
20 conducted a telephone survey of 195 primary producers (response rate 59%) across
21 livestock, cropping and mixed enterprises across five national transects on the Australian
22 continent with a high to low rainfall gradient. About half of the sample (55%) suggested
23 that their land would be suitable for diversification and 45% would consider land-use

change. These producers were more likely to come from a dry region rather than a wet region, came from an already mixed production enterprise, were more likely to irrigate and have completed university or a trade. These producers were also more likely to have a higher transformational capacity, particularly in their level of interest in adapting to the future. Across our sample, 23% had high levels of transformational capacity, whilst nearly half (45%) had either low or extremely low capacity to implement such change. Producers with a higher capacity were more likely to have a mixed enterprise, an internal locus of control, and higher levels of trust in networks, government, researchers, and agronomists and in self. Our results provide some important insights into what makes some producers more successful or able to transform than others. Investment in the capacity of producers to transform is likely to be an effective strategy to support Australian agriculture in the face of climate change.

Key words: social resilience, vulnerability, adaptive capacity, trust, resource dependency, diversification, transformation

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1. Introduction

Climate change predictions suggest that the scale and rate of change driven by increases in concentration of greenhouse gases in the atmosphere is unprecedented in human history, and will significantly – and in many cases dramatically – alter the accessibility and quality of natural resources (IPCC, 2014). Changes in key climatic variables such as temperature and rainfall will act to push natural resource systems towards their

46 thresholds of change, in some cases threatening the future of industries and communities
47 dependent on them (Lenton, 2011). Primary enterprises and industries, which include
48 the sectors of agriculture, forestry, fisheries and mining, are especially vulnerable to
49 climate change because of their dependency on climate-sensitive natural resources for
50 their prosperity and sustainability (Zamani *et al.*, 2006; Bennett *et al.*, 2014). These
51 enterprises are expected to contend with more frequent climate crises (such as drought
52 and flood), environmental degradation (such as eroding soils and limited production
53 during drought periods), cultural change (such as implementing new practices or using
54 climate technology) and even climate-related regulatory change (IPCC, 2014). These
55 stressors occur against an existing backdrop of conventional drivers including economic,
56 biophysical, institutional, cultural and political pressures (Howden *et al.*, 2007; Marshall
57 *et al.*, 2012; Kiem and Austin, 2013).

58 The specific challenge for producers is to build productivity and profitability without
59 depleting the resources on which they depend. However, current observations of climate
60 shifts suggest that meeting this challenge through undertaking incremental developments
61 may be insufficient; primary industries and enterprises may need to undergo
62 transformations that include changes in function or structure if they are to remain viable
63 (Park *et al.*, 2012). Producers, including farmers, fishers, foresters, graziers and their
64 respective industry organisations, may need to consider innovative strategies such as
65 diversification, using different energy sources, accessing different markets, developing
66 new networks, experimenting with new labour options, using new technologies or
67 translocating to where conditions are more amenable to making a living (Folke *et al.*,
68 2002; Marshall *et al.*, 2012). If the process involves crossing ecological or social
69 thresholds, where some of the biophysical or socio-economic components of a system
70 are fundamentally changed from one form, function, nature or location to another, and

71 not necessarily irreversibly, then it is defined here as a transformation(Walker *et al.*,
72 2004).

73 As in any adaptation, in order for transformation to occur, there must be the capacity to
74 do so. Moser and Ekstrom (2010), suggested that the distinction between adaptive and
75 transformational capacity is mostly one across temporal, spatial and social scales, where
76 transformational change occurs at the long-term end of the adaptation spectrum whilst
77 coping measures occur in the short-term. In their analysis, they found that
78 transformations typically require greater time and effort than shorter-term coping or
79 adaptation measures. Correspondingly, being able to identify and distinguish a
80 transformational change is dependent on being explicit about scale. For example, in
81 larger socio-economic or ecological systems, transformation is signified by change in
82 core functions and can involve institutional change and collective action, both co-
83 ordinated and un-coordinated, by constituent members (Olsson *et al.*, 2006). At an
84 industry scale, radical changes in function and structure may come about due to a
85 myriad of small changes made by individuals, resulting in an overall transformation.
86 Land use change is an example of transformation at larger scales. At individual scales,
87 however, transformation may be indistinguishable by outsiders and signified by major
88 changes in social variables such as occupational identity, place attachment, values,
89 vulnerabilities, capacities and networks (Adger *et al.*, 2012; Marshall *et al.*, 2012). For
90 example, an individual may transform their identify from being a “cattle producer” to a
91 “land steward”. Autonomy and choice, as well as government leadership, action and
92 support, will be central to how individuals perceive and undergo transformation (Webb
93 *et al.*, 2013; Claassen *et al.* 2013; Wu 2000). Recognising the importance of scale in
94 decision-making and climate adaptation, we focus on the primary producers involved in
95 decision-making at the property or enterprise level. These actors are critical to the

96 process of climate adaptation where success is only likely to occur when decision-making
97 processes are streamlined and complementary with government initiatives. A key
98 challenge for governments then in responding to changing agro-climatic conditions, will
99 be to ensure that sufficient capacity exists among individual primary producers and that
100 transformations result in outcomes that benefit both society and ecosystems (Adger *et al.*,
101 2002).

102 At the individual scale, transformational capacity has been assessed according to four
103 measurable attributes reflecting an individual's skills, circumstances, perceptions and
104 willingness to change (Marshall *et al.*, 2013a; Marshall *et al.*, 2014a). These attributes, or
105 'preconditions' for successful transformation explicitly are: 1) how risks and uncertainty
106 around transformations are perceived and managed (where some individuals are better
107 able to plan for an uncertain future), 2) the extent of skills in planning, learning and
108 reorganising for transformation, 3) the level of financial and /or psychological flexibility
109 to undertake transformational change; and 4) an interest and willingness to contemplate
110 and undertake transformational change (Marshall *et al.*, 2012). These attributes are not
111 unlike those associated with adaptive capacity, but focus on addressing changes that are
112 larger in scale. We use this conceptual model for transformational capacity in this study.

113 Primary producers are known to be diverse in their capacity to adapt and whilst there are
114 many factors that are known to influence capacity, the influence of resource dependency
115 has been well observed (Marshall *et al.*, 2007; Moon *et al.*, 2012; Marshall *et al.*, 2013a).

116 Resource dependency describes the relationship that primary producers have with a
117 natural resource and the extent to which they are sensitive to changes in that relationship
118 (Marshall, 2011; Marshall *et al.*, 2014c). For example, primary producers might be
119 dependent on a natural resource because of their level of occupational attachment to

120 their resource-based industry (Gonzalez and Benito, 2001), or their level of attachment
121 to their place (Marshall *et al.*, 2014b). For example, regardless of the untenability of a
122 situation, primary producers are likely to resist adaptation options that require a change
123 in occupation, making them especially sensitive to changes that threaten their ability to
124 remain within their occupation (Marshall *et al.*, 2012). . In this study, we test the
125 influence on transformational capacity of; (i) climate change awareness and attitudes, (ii)
126 sense of place and identity, (iii) level of engagement and trust with networks, (iv)
127 business approach, and (v) local knowledge and environmental attitudes.

128 We also test for the influence of the locus of control on transformational capacity. The
129 locus of control has not previously been tested for its influence on the capacity to adapt
130 or transform within any context. A sense of being able to control one's destiny is known
131 to be an important precursor for engaging in sustainable land management (Leviston *et*
132 *al.*, 2014; Price and Leviston, 2014) and a likely influence on the ability of a producer to
133 cope and adapt to transformational change. The concept 'Locus of Control' was first
134 introduced by Rotter (1966), who divided individuals into two groups based on their
135 general expectancies about where control over events and outcomes is located. Those
136 with an internal locus believe that outcomes are contingent on their own actions; those
137 with an external locus believe that chance, fate or powerful others control outcomes. An
138 internal locus of control has been found to predict environmentally responsible
139 behaviour and environmental concern (Leviston *et al.*, 2011). An internal locus is also
140 associated with entrepreneurial innovation strategies, higher levels of farm planning and
141 operation and farmers' managerial style and ability (Darner, 2009; Leviston *et al.*, 2011;
142 Price and Leviston, 2014). Locus of control has been identified as an important
143 personality trait that may influence farmers' interpretation of events and, subsequently,
144 levels of stress (Pannell *et al.*, 2006).

The aims of this study were thus to; (i) assess the extent that primary producers in Australia were likely to transform their activities in order to be resilient to climate change, (ii) assess the extent that transformational capacity is likely to exist within agricultural Australia, and (iii) identify factors that are associated with producers with high levels of transformational capacity. Australian agriculture crosses a broad spectrum of land and climatic conditions, supports a range of primary products from irrigated, broad acre cropping to grazing and provides diverse social and economic benefits to local communities and the nation. This study represents a preliminary study of farmers' adaptation behaviours along particular national transects with rainfall patterns ranging across high to low rainfall,

2. Research Methods

2.1 Research approach

This study was based on telephone interview surveys of a representative sample of producers. Producers were located across five national transects with a high to low rainfall gradient in NSW, Victoria, South Australia, Western Australia and across the tropical north (QLD, NT and WA; see Figure 1). The diverse production types and climatic conditions across these transects enabled us to develop a big-picture pattern of Australian agriculture, and the diversity existing within it at a social level. Diversity, and the accommodation of diversity in planning processes, can be particularly important, especially in the development of novel or untested strategies such as transformational adaptation options (Webb *et al.*, 2013).

<figure 1 around here>

2.2 Survey design

The survey included questions about demography, level of transformational capacity, locus of control, networks, occupational identity, family characteristics, business approach, farming motivations, local knowledge, environmental attitudes, climate change attitudes, sources of climate change information and climate change normative beliefs. Most questions were presented as a statement designed to elicit an attitude, opinion, or stance. The wording of many of the statements was based on previous studies (e.g. (Marshall and Marshall, 2007; Kuehne *et al.*, 2008; Marshall, 2010; Leviston *et al.*, 2011; Leviston *et al.*, 2014; Marshall *et al.*, 2014c). Respondents were asked to rate how strongly they agreed with each statement using a ten-point rating scale. An initial version of each survey was pilot-tested with three producers to ensure that the questions were comprehensible and unambiguous. A final copy of the survey may be obtained through the primary author.

2.3 Survey administration

Contact details of primary producers were obtained from a list broker (Baron Strategic Services) and was compiled from the White Pages, the electoral roll and market surveys. A total of 567 primary producers were contacted by post or email with attached flyer explaining the research and inviting them to participate. Producers were telephoned within 2-3 weeks of receiving the letter and interview appointments were made. Of the 567 names on the list, 133 producers were not interested in participating, 46 were no longer farming. The survey was completed by 195 producers giving a response rate of 59% (195/328 eligible and contactable potential respondents). The sample was stratified across 4 transects; (i) NSW (n=50), (ii) VIC and SA (n=50 combined), (iii) southern WA (n=45) and (iv) a northern Australian sector encompassing respondents from QLD, NT

and WA (n=50 combined). The survey was conducted between January and April 2014 and telephone interviews took between 25 and 70 minutes to complete.

2.4 Data analysis

Responses to structured survey questions were analysed descriptively using means, standard errors and medians where appropriate.

Transformational capacity was assessed as the mean of the mean responses for each dimension. The dimensions for transformational capacity were: 1) how risks and uncertainty around transformations are perceived and managed (RISK), 2) the extent of skills in planning, learning and reorganising for transformation (SKILLS), 3) the level of financial and psychological flexibility to undertake transformational change (BUFFERS); and 4) the anticipation of the need and willingness to contemplate and undertake transformational change (INTEREST).

Producers in this study were assessed as having high capacity if they scored 9 or 10 (on the ten point scale). They were assessed as having moderate capacity if they scored 7 or 8. Producers who scored 5 or 6 or less were assessed as having low capacity, and those less than 5 were considered extremely low. Rating scores were inverted if the statement was presented in a negative manner (e.g. "I am less likely to survive drought compared to other landholders I know").

The influence of resource dependency factors on the dimensions of transformational capacity was quantified using Pearson correlations. Pearson correlations were computed by correlating the 'weighted mean' or F-scores for each dimension of transformational capacity and each set of survey statements representing resource dependency. F-scores were calculated using a factor analysis (SPSS version 21) where responses to statements

representing a single dimension (such as ‘perceptions of risk’) were forced into a single factor using factor analysis and f-scores saved. Significant correlations are highlighted.

3. Results

3.1 Description of Australian producers in sample

The total sample of primary producers (n=195) was derived across the whole country, except Tasmania, and was spread over five transects. Transects were described as either ‘wet’, ‘dry’ or ‘northern’. The majority of respondents (n=162; 83.5%) did not use irrigation for their enterprise. Nearly 60% (n=114) of producers predominately produced livestock (59%), 14% of producers were croppers (n=28) and 27% undertook a mix of cropping and livestock (n=52). The main focus of business activities or stage (diversifying, downsizing etc.) are presented in table 1. Some 50% of producers were maintaining their business as usual. Around 38% of producers had completed year 12 of high school and 5% had completed a university degree. The mean age of the producers was 56.2 years ($\pm$ SE=0.82). Producers had lived on their property for a mean of 32.3 years ($\pm$ SE=1.28) and within the region for 41.5 years ($\pm$ SE=1.30). Respondents had been primary producers for an average of 49.0 years (SE 1.02).

3.2 Description of the resource dependency of primary producers

The dependency of Australian primary producers on the natural resource is summarised in Table 2. Of particular note are the relatively high responses to statements about the strength of friendships in the community, the love for the occupation, the independent nature of decision-making, and trust in their own knowledge of land management and that of their management team.

3.3 Description of the perceptions of climate change of primary producers

Producers were asked if they had seen any significant or long term shifts in the weather and climate of their region during their time on the land, and 41% (81/195) indicated that they had. Four producers were unsure. Reported climatic changes included: drier conditions (n=33), more variability in the weather (n=18), hotter conditions (n=10) and less winter rainfall (n=6). Producers were asked: “Do you expect any significant changes in the weather and climate of your region over the next 20 years?” Fewer than a third of respondents, 29% (n=56/193), indicated that they did expect significant changes, while 48% (n=92) indicated that they did not. Those who were uncertain/undecided represented 23% (n=45) of the sample. Among those that expected significant climatic change, the sorts of changes they expected included hotter weather (n=18), more variability and extreme weather (n=17), and drier conditions (n=14).

Among the producers who expected that there would be no change in the future, 31 (16%) mentioned that they thought that the changes to the climate were natural cycles. One producer noted “weather to me is very cyclic! Run of wet years and then run of dry years, I wouldn't say I don't believe in climate change at all. I think weather is inclined to change every 30-40 years.”

3.4 Willingness to transform and the main influences

Producers were asked whether their land would be suitable for diversification as an example of a transformation, and whether they would be prepared to change land use and produce a different product as an option for responding to climate variability. Over half of the sample population of producers (55%) suggested that their land would be suitable for diversification, and 44% of producers suggested that they would change land

use if necessary. Some 20% of famers were unsure if they would change land use if necessary.

Whilst we recognise that there are some producers who have no viable or realistic diversification options, producers that were more likely to diversify and/or change land use were more likely to come from a 'dry' region rather than a wet region (Pearson correlations, $p < 0.001$), come from an already mixed production enterprise, were more likely to irrigate and have completed university or a trade certificate (Table 3). These producers were more likely to have a higher adaptive capacity to change, particularly on the dimension: level of interest to adapt to the future. They were also more likely to have an interest in climate change. Those less likely to undertake transformational changes were more likely to have livestock, and in particular beef, and were more likely to have a high place attachment.

3.5 Transformational Capacity

The mean and standard errors for each statement reflecting the transformational capacity of producers for each dimension of capacity, and the proportion of producers that were assessed as having extremely low, low, moderate or high capacity are shown in Table 4.

Results indicate that there was substantial variability in transformational capacity. Some 23% of producers within this study had high levels of transformational capacity, 42% had moderate levels, 24% had low capacity and 21% had extremely low capacity (Table 4). Producers scored lowly or extremely lowly in their: (i) perceptions of risk (60.9%), (ii) strategic skills, (47.8%), (iii) buffers (34.8%), and (iv) interest in change (44.5%).

A particular strength of the participants was that 52.3% of producers perceived themselves to be highly resilient and "[not] less likely to survive drought compared to

other landholders [they] know”. Similarly, 30.3% of producers rated highly for their interest in new technology, as indicated by their responses to the statement, “knowing about new technology that becomes available is important to me”.

By contrast, nearly a third (30.3%) fell within the extremely poor category of possessing a financial buffer where they were currently suffering “a severe short-term financial constraint”. Similarly, 29.4% of the sample were extremely poor in the ability of “completely changing the way [they] do things around here”.

3.6 Influences on transformational capacity

The perception of risk as a dimension of transformational capacity was significantly correlated with only two factors in this study: the level of trust in research institutions such as CSIRO and Universities, and the level of trust in their own knowledge of land management (Table 5).

The level of strategic skills, the second dimension of transformational capacity, was significantly correlated with three factors in this study: the level of trust in the network of producer contacts, the level of trust in government departments and advisors, and the level of trust in paid agronomists and their networks (consultants).

The extent to which emotional and financial buffers existed was significantly correlated with five factors: living either in the wet or dry region (producers living in a wet region were more likely to have strong buffers to change); whether or not producers used irrigation (producers that irrigated were more likely to score lowly on this dimension – and possess strong buffers to change); what producers produced (producers that were mixed in what they produced were more likely to have strong buffers, whereas producers of livestock only were more likely to have weaker buffers); the locus of control

(producers that perceived themselves to have more control over their fate tended to have stronger buffers to change); and, the level of trust in their own knowledge of land management (producers that did not trust their own knowledge of land management were more likely to have weak buffers to change) (Table 5).

4. Discussion

This study suggests that if and when Australian primary producers across a range of rainfall conditions need to undertake transformations such as diversification in order to successfully adapt to climate change, then only about half of the population (55%) would see their land as suitable, and about half (45%) would consider changing their land-use if necessary. These results imply that an industry-led or regionally-led initiative to change the structure and/or function of agriculture (and diversify land-use for example) is unlikely to be immediately supported by about half of the agricultural population. Some producers have no viable or realistic diversification options and cannot make changes even if they would like to. Producers that see their land as suitable are more likely to come from a harsh region ('dry'), already be diverse and irrigating. These primary producers may be more willing to support transformational initiatives since they may be more aware of environmental feedbacks and the limitations of their land to produce, having already diversified to some extent.

Diversification is a realistic transformation option for Australian agriculture. Whilst calls for diversification have been made across various agricultural contexts as a mechanism for managing risk and uncertainty, both within and beyond Australia (Howden *et al.*, 2007;), very few studies have investigated the likelihood that diversification strategies will be adopted by producers (Fleming and Vanclay, 2010). Land diversification will necessitate integration of climate change-related issues with other risk factors, such as

climate variability and market risk, and with other policy domains, such as sustainable development (Howden *et al.*, 2007). Dealing with the many barriers to effective adaptation will require a comprehensive and dynamic policy approach covering a range of scales and issues. At the individual scale the understanding by farmers of change in risk profiles to the establishment of efficient markets that facilitate response strategies will be an important factor to consider in developing diversification options (Howden *et al.*, 2007).

Producers in this study that were more likely to diversify were more likely to have a higher adaptive capacity to transform (“transformational capacity”), particularly in their level of interest to adapt to the future. However, there was a concerning lack of transformational capacity within our sample population of producers. Only 23% of producers had high levels of transformational capacity, whilst nearly half (45%) had either low capacity or extremely low capacity to cope and adapt to climate change impacts. These results are not necessarily representative of Australian producers as our sample was constrained by certain climate conditions (e.g. low rainfall versus high rainfall) and along national particular transects. However, the insights that we have gained from this preliminary study of farmers’ adaptation behaviours may have significant implications for the future of Australian agriculture. Industry-wide adaptation plans, such as diversifying land-use, which may require a critical mass of members to support them, may be unlikely to be successful since potentially 77% of constituents will be unlikely to have the capacity to support them. Future studies will need to be conducted to test the applicability of these results across the entire national agricultural sector, however with the possible onset of longer and more intensive droughts in many parts of Australia (Sivakumar *et al.*, 2005), a large proportion of producers with a low capacity for adapting to change may be unable to remain viable or self-sufficient without

welfare assistance (Cobon *et al.*, 2009). Given the previous drought in Australia (2000-2004) cost tax-payers over A\$4 billion in subsidies (White and 2000), the future costs of welfare assistance for drought in Australia may be unsustainable, and a more thorough investigation into the capacity held by producers to adapt would be useful.

Environmental sustainability and food security remain a serious concern as demands for food production rises (Polsky and Easterling, 2001; Ingram *et al.*, 2008). Current producers may struggle to remain profitable during climate events such as drought and may sacrifice long-term environmental and social goals for shorter term gains (Clark, 2006). Historic episodes of environmental degradation in Australian rangelands have been well documented, and linked to delays in reducing stock numbers during periods of drought (particularly when droughts coincide with low livestock prices) (McKeon *et al.*, 2004). Adapting to future conditions will be critical for Australian agriculture. Other research has highlighted a relatively low level of capacity to adapt in similar contexts (northern beef and horticulture) (Marshall, 2010; Marshall *et al.*, 2011; Marshall *et al.*, 2012; Webb *et al.*, 2013; Marshall *et al.*, 2014a; Marshall and Stokes, 2014; Marshall *et al.*, 2014c) and within other Australian primary industries such as commercial fishing (Gooch *et al.*, 2012; Marshall *et al.*, 2013b). Marshall *et al.* (2014) for example, found that only 16% of northern beef producers had the capacity to deal with current and future challenges such as climate variability (Marshall *et al.*, 2014c). Cumulative insights across all of these studies strongly suggests that there is likely to be insufficient capacity among a large proportion of Australian primary producers to transform to cope with and adapt to the impacts of climate change.

The aspects of transformational capacity that were particularly low in this study were those that could be relatively easily remedied and managed. Enhancing transformational

379 capacity could be achieved through directing attention (investment) towards improving
380 producers' ability to perceive and manage for risk and uncertainty (for example through
381 developing strategies be developed that collectively consider the risks associated with a
382 range of likely future scenarios), capacity to strategically approach change (through
383 developing planning, experimenting and learning skills) and to have an interest in change
384 (Hochman, 2011). Enhancing these aspects of producers may significantly and positively
385 enable producers to effectively prepare for and adapt to likely climate change scenarios
386 (Jones *et al.*, 2000; Adger *et al.*, 2003; Akcaoz and Ozkan, 2005; Boomiraj *et al.*, 2010;
387 Kiem and Austin, 2013). Such an approach to securing the future of Australian
388 agriculture may require a cultural change at the industry and government levels.

389 We looked at a range of factors that could potentially influence producer capacity to
390 transform. We were looking to understand the factors that were more typically
391 associated with the 23% of producers that had high capacity to change. Marshall *et al.*
392 (2012) reported that transformational capacity could be negatively influenced by place
393 attachment and occupational identity, even though these factors may be important
394 positive influences on the capacity to adapt to incremental change. They suggested that
395 the nature of the change event was important, and that place attachment and
396 occupational identity could act as barriers to transformational change, especially when
397 those transformations included either a change in location or change in occupation.
398 These findings make clear the importance of identifying transformation options that
399 deliver to the needs of the nation, whilst complementing or meeting the needs of primary
400 producers. We found that only a few factors could predictably describe the difference
401 between high capacity producers and those with less capacity. The factors associated
402 with higher capacity included what was being produced (producers that were mixed in
403 their outputs were more likely to have higher capacity), an internal locus of control (the

404 belief that outcomes are contingent on own actions), and the levels of trust in producer
405 networks, government, researchers, agronomists and in self. These results provide some
406 insight into what makes some producers more successful than others. Knowledge of the
407 influence of each of these factors however can significantly assist in the development of
408 national strategies aiming to enhance the capacity of producers to transform for climate
409 change adaptation.

410 Insights into the role of trust in climate change adaptation processes are also important
411 for understanding climate change adaptation processes and for planning purposes. We
412 have known that networks are significant assets and are associated with successful
413 producers (McAllister *et al.*, 2006; Stokes *et al.*, 2007; McAllister *et al.*, 2008), but to date,
414 we have not recognised the importance of trust within both formal and informal
415 networks in developing transformational capacity. Whilst lack of trust may be
416 reasonably based within the industry, our results suggest that producers with higher
417 levels of trust in their networks tended to score more highly in their transformational
418 capacity. These results suggest that trust in formal and informal networks may be
419 important because many people lack resources such as time and knowledge to make
420 decisions in relation to management practices and trusting relevant organisations and
421 government agencies may be an effective way to develop informed and effective
422 solutions and decisions (Siegrist *et al.*, 2000; Price and Leviston, 2014). In agriculture,
423 trust has been shown to be a key determinant of effective extension practices (Carolan,
424 2006b, a), where trusting advocates of agricultural innovation has been critical to the
425 adoption of such innovations (Leviston *et al.*, 2014). However, levels of trust and
426 willingness to be guided by the actions and attitudes of others differ among individuals
427 (Leviston *et al.*, 2011). Similarly, an internal locus of control was identified as being a
428 significant influence on transformational capacity suggesting that farmers that are

429 already innovative, entrepreneurial and more in control of their own destiny are more
430 likely to transform, regardless of other factors such as enterprise size.

431 **5. Conclusions**

432 Our survey found that only 23% of Australian producers had high levels of
433 transformational capacity, whilst nearly half (45%) had either low or extremely low
434 capacity to cope and adapt to climate change impacts. Whilst we were able to identify
435 factors that could be used to enhance capacity (such as trust and the locus of control),
436 these results indicate that regardless of the investment into developing adaptation options
437 and technologies, or the efforts of government and industry to initiate transformation,
438 only a minority of the producer population may have the capacity to support them. If
439 Australian agriculture is to successfully adapt to the challenges of climate change and
440 transform, our results emphasise the likelihood that enhancing the transformational
441 capacity of primary producers will be important.

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449 **6. References**

Adger, W.N., Brown, K., Barnett, J., Marshall, N.A., O'Brien, K., 2012. Cultural dimensions of climate change impacts and adaptation. *Nature - Climate Change*, doi:10.1038/nclimate1666

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D., Naess, L., Wolf, J., Wreford, A., 2009. Are there social limits to adaptation to climate change? *Climatic Change* 93, 335-354.

Adger, W.N., Kelly, P.M., Winkels, A., Huy, L.Q., Locke, C., 2002. Migration, Remittances, Livelihood Trajectories, and Social Resilience. *Ambio* 31, 358-366.

Adger, W.N., Saleemul, H., Brown, K., Conway, D., Hulme, M., 2003. Adaptation to climate change in the developing world. *Progress in Development Studies* 3, 179-195.

Akcaoz, H., Ozkan, B., 2005. Determining risk sources and strategies among farmers of contrasting risk awareness: A case study for Cukurova region of Turkey. *Journal of Arid Environments* 62, 661-675.

Bennett, N.J., Dearden, P., Murray, G., Kadfak, A., 2014. The capacity to adapt?: communities in a changing climate, environment, and economy on the northern Andaman coast of Thailand. *Ecology and Society* 19.

Boomiraj, K., Wani, S.P., Garg, K.K., Aggarwal, P.K., Palanisami, K., 2010. Climate change adaptation strategies for agro-ecosystem - a review. *J Agrometeorol* 12, 145-160.

Carolan, M.S., 2006a. Do you see what I see? Examining the epistemic barriers to sustainable agriculture. *Rural Sociology* 71, 232-260.

Carolan, M.S., 2006b. Risk, trust and 'the beyond' of the environment: A brief look at the recent case of mad cow disease in the United States. *Environ Value* 15, 233-252.

Clark, B.M., 2006. Climate change: A looming challenge for fisheries management in southern Africa. *Marine Policy* 30, 84-95.

Claassen, R., Duquette, E., and Horowitz, J. 2013. Additionality in agricultural conservation payment programs. *Journal of Soil and Water Conservation* 68(3), 74a-78a.

Cobon, D.H., Stone, G.S., Carter, J.O., Scanlan, J., Toombs, N.R., Zhang, X.D., Willcocks, J., McKeon, G., 2009. The climate change risk management matrix for the grazing industry of northern Australia *The Rangeland Journal* 31, 31-49.

Darner, R., 2009. Self-Determination Theory as a Guide to Fostering Environmental Motivation. *J Environ Educ* 40, 39-49.

Fleming, A., Vanclay, F., 2010. Farmer responses to climate change and sustainable agriculture. A review. *Agron Sustain Dev* 30, 11-19.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B., 2002. Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *Ambio* 31, 437-440.

Gonzalez, J.J., Benito, C.G., 2001. Profession and Identity. The Case of Family Farming in Spain. *Sociol Ruralis* 41, 343-356.

Gooch, M., Vella, K., Marshall, N.A., Tobin, R.C., Pears, R., 2012. A rapid assessment of the effects of extreme weather on two Great Barrier Reef Industries. *Australian Planner* 50, 198-215.

Hochman, Z., and Carberry, P.S. (2011) Emerging consensus on desirable characteristics of tools to support farmers' management of climate risk in Australia. *Agricultural Systems* 104(6), 441-450.

Howden, S.M., Soussana, J., Tubiello, F.N., Chhetri, N., Dunlop, M., Meinke, H., 2007. Adapting Agriculture to Climate Change. *Proceedings of the National Academy of Sciences* 104, 19691-19696.

Ingram, J.S.I., Gregory, P.J., Izac, A.M., 2008. The role of agronomic research in climate change and food security policy. *Agriculture, Ecosystems & Environment* 126, 4-12.

IPCC, 2007a. Climate Change 2007 - Impacts, Adaptation and Vulnerability -
 Contributions of Working Group II to the Fourth Assessment Report of the
 International Panel on Climate Change. Cambridge University Press, Cambridge.
 IPCC, 2007b. Climate change 2007 - The Physical Science Basis - Contribution of
 Working Group I to the Fourth Assessment Report of the International Panel on
 Climate Change. Cambridge University Press, Cambridge.
 Jones, J.W., Hansen, J.W., Royce, F.S., Messina, C.D.-. 2000. Potential benefits of
 climate forecasting to agriculture. *Agriculture, Ecosystems and Environment* 82, 169-
 184.
 Kiem, A.S., Austin, E.K., 2013. Drought and the future of rural communities:
 Opportunities and challenges for climate change adaptation in regional Victoria,
 Australia. *Global Environ Chang* 23, 1307-1316.
 Kuehne, G., Bjornlund, H., Cheers, B., 2008. Identifying common traits among
 Australian irrigators using cluster analysis.
 Lankester, A., Marshall, N.A., Gordon, I.J., Sutton, S.J., Cottrell, A., in review. "It's a
 part of who we are": Sense-of-place for beef producers in north-eastern Australia *Geogr
 Res-Aust*.
 Lenton, T.M., 2011. Early warning of climate tipping points. *Nat Clim Change* 1, 201-
 209.
 Leviston, Z., Price, J., Bates, L., 2011. Key influences on the adoption of improved land
 management practice in rural Australia: the role of attitudes, values and situation. *Rural
 Society* 20, 142-159.
 Leviston, Z., Price, J., Bishop, B., 2014. Imagining climate change: The role of implicit
 associations and affective psychological distancing in climate change responses. *Eur J
 Soc Psychol* 44, 441-454.
 Marshall, N.A., 2010. Understanding social resilience to climate variability in primary
 enterprises and industries. *Global Environ Chang* 20, 36-43.
 Marshall, N.A., 2011. Assessing Resource Dependency on the Rangelands as a Measure
 of Climate Sensitivity. *Soc Natur Resour* 24, 1105-1115.
 Marshall, N.A., Dowd, A., Fleming, A., Gambley, C., Howden, M., Jakku, E., Larsen,
 C., Marshall, P.A., Moon, K., Park, S., Thorburn, P., 2014a. Transformational Capacity
 in Australian Peanut Farmers for Better Climate Adaptation. *Agron Sustain Dev*.
 Marshall, N.A., Dowd, A.M., Fleming, A., Gambley, C., Howden, M., Jakku, E.,
 Larsen, C., Marshall, P.A., Moon, K., Park, S., Thorburn, P.J., 2014b.
 Transformational capacity in Australian peanut farmers for better climate adaptation.
Agron Sustain Dev 34, 583-591.
 Marshall, N.A., Fenton, D.M., Marshall, P.A., Sutton, S.G., 2007. How resource
 dependency can influence social resilience within a primary resource industry. *Rural
 Sociology* 72, 359-390.
 Marshall, N.A., Marshall, P.A., 2007. Conceptualizing and operationalizing social
 resilience within commercial fisheries in northern Australia. *Ecology and Society* 12.
 Marshall, N.A., Park, S., Howden, S.M., Dowd, A.B., Jakku, E.S., 2013a. Climate
 change awareness is associated with enhanced adaptive capacity. *Agricultural Systems*
 117, 30-34.
 Marshall, N.A., Park, S.E., Adger, W.N., Brown, K., Howden, S.M., 2012.
 Transformational capacity and the influence of place and identity. *Environmental
 Research Letters* 7.
 Marshall, N.A., Stokes, C.J., 2014. Influencing adaptation processes on the Australian
 rangelands for social and ecological resilience. *Ecology and Society* 19.

549 Marshall, N.A., Stokes, C.J., Webb, N.P., Marshall, P.A., Lankester, A.J., 2014c. Social
 550 vulnerability to climate change in primary producers: A typology approach. *Agriculture,
 551 Ecosystems & Environment* 186, 86-93.
 552 Marshall, N.A., Tobin, R.C., Gooch, M., Hobday, A., Marshall, P.A., 2013b. Social
 553 vulnerability of marine resource users to extreme weather events. *Ecosystems* 16, 797-
 554 809.
 555 McAllister, R.J.J., Abel, N., Stokes, C., Gordon, I., 2006. Australian Pastoralists in
 556 Time and Space: The Evolution of a Complex Adaptive System. *Ecology and Society*
 557 12, www.ecologyandsociety.org/vol11/iss12/art41/
 558 McAllister, R.R.J., Cheers, B., Darbas, T., Davies, J., Richards, C., Robinson, C.J.,
 559 Ashley, M., Fernando, D., Maru, Y.T., 2008. Social networks in arid Australia: a review
 560 of concepts and evidence. *Rangeland J* 30, 167-176.
 561 McKeon, G.M., Hall, W.B., Henry, B.K., Stone, G.S., Watson, I.W., 2004. Pasture
 562 Degradation and Recovery in Australia's Rangelands: Learning from History.
 563 Queensland Department of Natural Resources, Mines and Energy, Brisbane, Australia,
 564 pp. 1-255.
 565 Moon, K., Marshall, N.A., Cocklin, C., 2012. Personal circumstances and social
 566 characteristics as determinants of landholder participation in biodiversity conservation
 567 programs. *Journal of Environmental Management* 113, 292-300.
 568 Moser, S.C., Ekstrom, J.A., 2010. A framework to diagnose barriers to climate change
 569 adaptation. *Proceedings of the National Academy of Sciences* 107, 22026-22031.
 570 Nielsen, J.Ø., Reenberg, A., 2009. Temporality and the problem with singling out
 571 climate as a current driver of change in a small West African village. *Journal of Arid
 572 Environments* 74, 464-474.
 573 Olsson, P., Gunderson, L.H., Carpenter, S.R., Ryan, P., Lebel, L., Folke, C., Holling,
 574 C.S., 2006. Shooting the rapids: Navigating transitions to adaptive governance of social-
 575 ecological systems. *Ecology and Society* 11.
 576 Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R., 2006.
 577 Understanding and promoting adoption of conservation practices by rural landholders.
 578 *Australian Journal of Experimental Agriculture* 46, 1407-1424.
 579 Park, S.E., Marshall, N.A., Jakku, E., Dowd, A.M., Howden, S.M., Mendham, E.,
 580 Fleming, A., 2012. Informing adaptation responses to climate change through theories of
 581 transformation. *Global Environ Chang* 22, 115-126.
 582 Polsky, C., Easterling, W.E., 2001. Adaptation to climate variability and change in the
 583 US Great Plains: A multi-scale analysis of Ricardian climate sensitivities. *Agriculture,
 584 Ecosystems & Environment* 85, 133-144.
 585 Price, J.C., Leviston, Z., 2014. Predicting pro-environmental agricultural practices: The
 586 social, psychological and contextual influences on land management. *Journal of Rural
 587 Studies* 34, 65-78.
 588 Rickards, L., Howden, S.M., 2012. Transformational adaptation: agriculture and climate
 589 change. *Crop Pasture Sci* 63, 240-250.
 590 Seo, S., Niggol, N., 2009. Is an integrated farm more resilient against climate change? A
 591 micro-econometric analysis of portfolio diversification in African agriculture. *Food
 592 Policy* 35, 32-40.
 593 Siegrist, M., Cvetkovich, G., Roth, C., 2000. Salient value similarity, social trust, and
 594 risk/benefit perception. *Risk Analysis* 20, 353-362.
 595 Sivakumar, M.V.K., Das, H.P., Brunini, O.-. 2005. Impacts of Present and Future
 596 Climate Variability and Change on Agriculture and Forestry in the Arid and Semi-Arid
 597 Tropics. *Climatic Change* 70, 31-72.

598 Stokes, C.J., McAllister, R.R.J., Ash, A.J., Gross, J.E., 2007. Changing Patterns of
 599 Land Use and Tenure in the Dalrymple Shire, Australia. In: Galvin, K.A., Reid, R.,
 600 Behnke, R.H., Hobbs, N.T. (Eds.), Fragmentation in semi-arid and arid landscapes:
 601 consequences for human and natural landscapes, pp. 93-112.
 602 Walker, B., Holling, C.S., Carpenter, S., Kinzig, A., 2004. Resilience, Adaptability and
 603 Transformability in Socio-ecological Systems. *Ecology and Society* 9, online at:
 604 www.ecologyandsociety.org/vol9/iss2/art5.
 605 Webb, N.P., Stokes, C.J., Marshall, N.A., 2013. Integrating biophysical and socio-
 606 economic evaluations to improve the efficacy of adaptation assessments for agriculture.
 607 *Global Environ Chang* 23, 1164-1177.
 608 White, B., , 2000. The Importance of Climate Variability and Seasonal Forecasting to
 609 the Australian Economy. In: Hammer, G.L., Nicholls, N., Mitchell, C. (Eds.), *Atmos*
 610 *Ocean Sci Lib*. Kluwer Academic Publishers, London, pp. 1-22.
 611 Wu, J.J. 2000. Slippage effects of the conservation reserve program. *American Journal of*
 612 *Agricultural Economics* 82(4), 979-992.
 613 Zamani, G.H., Gorgievski-Duijvesteijn, M.J., Zarafshani, K., 2006. Coping with
 614 Drought: Towards a Multilevel Understanding Based on Conservation of Resources
 615 Theory. *Human Ecology* 34, 677-692.

Figure 1. A map of the transects highlighting rainfall (mm)

Table 1: Respondents' main focus of farming activities at time of survey (n=195).

Business focus	n	Percent of respondents
Maintaining business as usual	98	50%
Increasing the size of their enterprise	35	18%
Downsizing	16	8%
Waiting for a good time to sell	14	7%
Specialising	11	6%
Diversifying	8	4%
Other	13	7%

Table 2. Means and standard errors of survey questions representing resource dependency Ranked within each category from strongest agreement to strongest disagreement. Rating scale 1-10; 1 = Disagree very strongly; 10 = Agree very strongly; n=195.

Potential influences on transformational capacity	Mean (1-10)	±SE
A. Sense of Place		
I have some strong friendships in this community	8.8	.11
This region is very special to me	7.6	.18
My property is a part of me	7.4	.20
I would rather sell off-farm investments at a loss than sell any part of my farm	5.4	.25
I could never imagine living anywhere other than this area - even if my land becomes unproductive	4.9	.23
B. Identity		
I love what I do; it is who I am	8.9	.10
Farming is the only occupation I can imagine doing.	6.3	.21
C. Engagement		
I make decisions about my land independently of others	7.8	.17
I discuss approaches for managing my land with other local landholders	7.0	.17
I participate in local landholder-based groups that discuss various aspects of the industry	5.9	.24
I discuss approaches for managing my land with government agencies and researchers	4.6	.23
Other producers are increasingly becoming my competitors	4.0	.21
Generally, producers are less willing to share information than they were ten years ago.	3.6	.19
Compared to ten years ago I am less inclined to share information with other producers.	3.5	.19
D. Business approach		
Financial gain is the only reason for my involvement in farming.	3.9	.16
I am more of a 'lifestyle' producer and focus less on making money	3.1	.22
E. Local knowledge		
I keep a record of the weather so that I can recognise important changes	6.5	.22
F. Environmental attitudes		
I am prepared to lower my on-farm profitability in the short-term when there are long-term benefits to the environment	6.5	.18
G. Locus of control		
Operating a successful farm is a matter of managing it well and luck has little to do with it	7.0	.15
The success of my farm business is mostly determined by factors outside my control	6.5	.20
There's not much that individual producers can do to influence the fate of farming.	5.1	.19
There are people around me who have a big influence on what I can and can't do on the farm.	4.7	.19
H. Groups, networks and institutions and rating of trust		
My management team	8.3	.11

My own knowledge of land management	8.2	.09
My network of producer contacts	7.4	.12
Paid agronomists and their network	6.5	.16
Research institutions (e.g. CSIRO, universities)	6.2	.15
Natural Resource Management Organisations (NRMs)	5.4	.14
Government departments and advisers	5.2	.15
Media (e.g. radio, newspapers, TV)	4.3	.14
Social media (e.g. Facebook, Twitter)	2.9	.16
I. Climate change attitudes questions		
I need more evidence to be convinced that climate change is a problem in my region	7.4	.17
My views on climate change are similar to those in the rest of my community	6.7	.16
I have a good understanding of how projected changes in climate could influence my business.	6.2	.16
If the climate changes, there is much that I can do to respond.	6.0	.17
I do not believe that future climate will be any different from my past experience	5.7	.19
I am worried that the seasons in my region are changing	5.0	.21

Table 3. Influences on the willingness to diversify land use and change land use (n=195). Results of Pearson correlations between the willingness to diversity and change land use with the F-scores representing resource dependency and transformational capacity. P-values are displayed and significant p-values are highlighted by an asterix (*p<0.05, **p<0.01)

F-scores	Is your land suitable for diversification?	Are you prepared to change land use?
Resource Dependency		
Livestock/cropping/mixed	.000**	.000**
Transect: Wet/Dry	.000**	.006**
Main product	.000*	.015*
Education	.031*	.037
Place attachment	.031*	.427
Climate change awareness	.123	.049*
Years in region	.507	.027*
Irrigate	.216	.043*
Locus of control	.465	.825
Gender	.123	.346
Identity	.168	.427
Seen climate shifts	.216	.406
Manager/owner	.569	.952
Business approach	.607	.425
Expect shifts	.659	.194
Age	.614	.785
Networks	.962	.184
Transformational capacity		
1. Perception of risk and uncertainty	.454	.989
2. Strategic skills	.680	.486
3. Buffers	.643	.609
4. Interest	.553	.037*

Table 4. The level of transformational capacity amongst Australian primary producers (rating scale 1-10;
1 = Disagree very strongly; 10 = Agree very strongly)

Transformational capacity questions	Mean rating (±SE)	High (%)	Mod (%)	Low (%)	V. Low (%)	Combined % of questions
Perceptions of risk						
I am happy to make decisions when faced with much uncertainty (n=194)	7.23 (±SE=0.15)	27	44	20	9
I am willing to take higher than average risks in order to get higher financial returns (n=194)	5.76 (±SE=0.16)	9	33	30	28	
I prefer to wait and see how things work on other properties before I try something new* (n=195)	4.88 (±SE=0.17)	20	25	29	26	
Strategic skills						
I like to discuss new ways of managing my land with others (n=193)	7.07 (±SE=0.16)	24	46	18	13
I would be good at completely changing the way I do things around here (n=143)	5.55 (±SE=0.19)	8	27	36	29	
Buffers						
I would say that I have a severe short-term financial constraint* (n=143)	5.08 (±SE=0.23)	30	19	20	30
I am less likely to survive drought compared to other landholders I know* (n=195)	3.10 (±SE=0.16)	52	29	13	5	
Regardless of what happens, I have made sure that we are financially secure (n=195)	6.84 (±SE=0.17)	26	38	18	18	
Interest						
I regularly think of, and implement, new ways of managing my land (n=145)	6.76 (±SE=0.17)	15	49	26	11

Knowing about new technology that becomes available is important to me (n=145)

7.66
($\pm$ SE=0.15)

30

50

14

6

Overall Capacity

24

36

22

18

Producers were assessed as having high capacity if they scored 9 or 10 (on the ten point scale). They were assessed as having moderate capacity if they scored 7 or 8. Producers who scored 5 or 6 were assessed as having low capacity, and those who gave ratings of 4 or below were considered very low.

*Rating scores were inverted for questions with negative phrasing.

Table 5. Influences on transformational capacity. Results of Pearson correlations (r-values) between each dimension of transformational capacity (Risk, Skills, Buffers, Interest), and factors describing resource dependency. *suggests a significant correlation ($p < 0.05$) and ** suggests a strongly significant correlation ($p < 0.01$)

Resource dependency	Transformational capacity dimensions:			
	Risk (r)	Skills (r)	Buffers (r)	Interest (r)
LOCATION & FARM TYPE				
Irrigate or not	-.103	.098	-.258**	-.186*
Livestock/cropping/mixed	.069	.147	.254**	.183*
Main product	.112	.117	.130	.230**
Transect: Wet/Dry	-.069	.072	-.166*	.075
ROLE & EXPERIENCE				
Manager/owner	-.037	.123	.073	-.010
Years on property	.060	.039	-.150	.064
Years in region	.074	-.048	-.005	.080
Years as producer	.060	-.136	-.032	.037
DEMOGRAPHICS				
Age	-.029	-.025	.111	-.014
Gender	-.011	.026	.004	-.014
Education	.050	.027	.005	.193*
CULTURAL CONTEXT				
Locus of control (external)	-.002	-.063	.167*	-.289**
Identity	.144	.076	-.005	.046
Place attachment	.129	.046	.013	-.022
Business approach	.047	-.046	.107	-.114
CLIMATE CHANGE VIEWS				
Climate change awareness	.029	-.024	-.010	-.130
Seen climate shifts	.082	-.118	.008	-.084
Expect climate shifts	.065	.000	.025	-.006
TRUST				
Trust in producer networks	.151	.359**	.067	.486**
Trust in govt	.099	.169*	-.112	.214**
Trust in agronomists	.052	.181*	-.102	.174*
Trust in researchers	.186*	.136	-.164	.159
Trust in self	.171*	.013	-.177*	.021
Trust in NRM groups	.025	.027	-.077	.051
Trust in media	-.004	-.010	.106	.024