**Assessing the capacity of Australian broadacre mixed farmers to
adapt to climate change: identifying constraints and opportunities**

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Abstract: Farmers are continually striving to adapt to Australia's highly variable climate. As a function of global warming, future climatic conditions will present further challenges, but may also present many new opportunities for farmers. We involved a range of rural communities via 14 workshops across a range of Australia's large-scale broadacre cropping regions employing a rural livelihoods framework to elicit and interpret community responses. Farmers identified indicators and rated them on the extent to which they might constrain or enable adaption to increased climate variability or climate change. Financial issues, such as low equity or limited capital were considered to be most constraining, and natural capital assets, such as high soil productivity and low rainfall variability were considered to be most enabling. Most indicators were of broad-scale significance, affecting broadacre mixed farmers across a range of locations, and were not necessarily specific to climate change only. Broad-scale constraints identified were isolation/rural decline, limited access to services, poor regional infrastructure, equity/debt, and the high cost of production. Conversely, enabling factors identified were farmer education/experience, sense of community, and off-farm income. Actions to address these perceived constraints related to farm management practices, training, community, technology/research, communication, funding and institutional arrangements. In the Australian context, adapting to climate variability and change is more than just implementing a new technology, but is also about enhancing the broader resilience of the community in ways that will ensure its long term viability. To achieve this it will be necessary for different components of government and other institutional actors to work together to improve the adaptation capacity of farmers in the future.

Keywords: adaptation, adaptive capacity, agriculture, indicators, rural livelihoods, participatory research

Abbreviations:

CMA	Catchment Management Authority
DAFWA	Department of Agriculture and Food Western Australia
DPI	Department of Primary Industries,
GRDC	Grains Research and Development Corporation
I&I	New South Wales department of Industry and Investment
LHPA	Livestock Health and Pest Authority
NRM	Natural Resource Management (agency)
QMDC	Queensland Murray-Darling Committee
SEQ	South East Queensland
WUE	Water use efficiency

1. Introduction

Australia will be subjected to a range of climate change impacts including higher temperatures and shifting regional rainfall patterns (Hennessy et al. 2010). Water availability is likely to be more important than temperature given crops can be grown under thermal stress if sufficient water is provided to the crop (Lizumi and Ramankutty 2015; Thornton et al.

2014). Resultant impacts on agricultural production as simulated by a range of biophysical models suggest that adaptation will be required for farmers to maintain or increase production (Dai 2012; Easterling et al. 2007; Howden et al. 2007; Howden and Crimp 2011; Laing et al. 2009; Lobell et al. 2011). Despite these negative production implications, surveys reveal that less than half of the farmers in Western Australia (Evans et al. 2011) and in Victoria (Schwarz et al. 2012) stated that they agreed that climate change was occurring or that it was a threat to their farm business, however, Steffan et al. (2011) argues that producers and industry themselves can best define significant climate risks. Australian farmers are experienced in dealing with highly variable climatic conditions, and are relatively well supported by industry and research to maximise production/profit under such conditions (Kingwell et al. 2013). Despite this preparedness ongoing changes in extremes will severely test existing coping strategies, raising the question: do producers think that current management strategies be sufficient in the future? Marshall et al. (2013) noted that primary producers that have a greater awareness of the potential impacts of climate change also have a greater capacity to adapt.

At a global scale food security and food production are issues of increasing concern in response to both a rapidly growing population driving demand and a series of climatic extremes that have served to interrupt supply (Nelson et al. 2009; Schmidhuber and Tubiello, 2007). Australian farmers produce almost 93% of Australia's daily domestic food supply and export 60% (in volume) of total agricultural production (PMSEIC 2010). Australian food production represents 1% of all food consumed in the world feeding some 40 million people each day outside Australia (PMSEIC 2010). While Australia is well placed to continue to be a major producer, consumer and exporter of agricultural products into the future, the next 40 years will see new challenges which will need to be considered and addressed, including: (1) maintaining the quality of land, water and biological resources whilst enhancing productivity; (2) adapting to climate change and its related impacts and legislative responses; and (3)

94 dealing with declining terms of trade. If Australian farmers wish to continue farming, and to
95 run profitable enterprises in the future, then they will need to be able to respond to a range of
96 these challenges. Identifying existing and future challenges and opportunities and exploring
97 appropriate responses should enable farmers to increase their capacity to adapt, particularly if
98 they are involved in identifying the solutions (Adger et al. 2009; Engle 2011).

99 In an agricultural context, adaptation can be interpreted as ‘the decision-making
100 process and the set of actions undertaken to maintain the capacity to deal with current or
101 future predicted change’ (Nelson et al. 2007, p. 396). Adaptation can also be viewed as
102 adjustments in ecological, social and economic systems in response to observed or expected
103 changes in climate stimuli under which change in farm management will occur in response to
104 perceived future constraints or benefits (Adger et al. 2005; Stokes and Howden 2010). These
105 adaptation responses can occur on a range of spatial and temporal scales and various models
106 have been developed to describe potential responses including incremental to transformational
107 adaptation (Howden et al. 2010; Nelson et al. 2007) and transitional to transformational
108 change (Brown et al. 2015, Pelling 2011). These adaptive or anticipatory responses may be
109 supported by policy initiatives across a range of scales from local to national governance
110 levels (Adger et al. 2005). For example, the Tasmanian Government, with funding from the
111 Commonwealth, has instigated the development of irrigation infrastructure across the State in
112 an effort to reduce the impact of drought on agricultural production. Farmers needed to
113 commit to a regional irrigation scheme before infrastructure was provided. Support during the
114 process of adapting from dryland to irrigated agriculture was provided by a State Government
115 organisation, Tasmanian Irrigation (<http://www.tasmanianirrigation.com.au/>).

116 Ongoing adaptation to changing physical and socio-economic conditions will require
117 continued building of adaptive capacity. To do this within the context of Australian large-
118 scale broadacre agriculture will require ongoing dialogue with farmers and rural communities

in order to identify perceived current barriers and potential synergies to improve adaptive capacity and to develop well-targeted adaptation policies (Adger and Vincent 2005; Below et al. 2012, Smit and Wandel 2006). Uptake of adaptation policies, particularly top-down initiatives, will result in change on the ground only where they are perceived to be of benefit, thus an understanding of local context is important (Morse et al. 2009). Marshall et al. (2010, p. 251) concluded that ‘the impact of climate change on agriculture will only be moderated if adaptation options are effectively implemented on the ground by individual managers’. Understanding farmers’ perceptions is necessary to develop appropriate policy options, building on strengths and reducing the influence of weaknesses. Given the variation in potential climate impacts and the variable nature of farming across Australia, it is necessary to understand the extent of similarity or differences in issues being faced to better understand and ultimately facilitate adaptation.

The aim of our work was to better understand and assess rural community perspectives on adaptive capacity to climate change and to identify commonalities among perceived barriers to adaptation for a range of communities across Australia. We achieved this through a series of structured workshops with rural landholders involved in mixed cropping/grazing agricultural enterprises across six states of Australia. In order to provide a common framing for the responses from disparate rural communities, a five capitals approach was employed (Chambers and Conway 1992; Ellis 2000; Scoones 1998). An important advantage of this actor-oriented perspective (De Haan 2012) or ‘bottom-up’ approach was the commonality with other top-down studies using national-level data to develop and map adaptive capacity of broadacre farming communities (Crimp et al. 2010; Nelson et al. 2010a,b). This bottom-up participatory approach lends itself to the development of a better understanding of farmers’ perceptions of the relative strengths of their asset base i.e. the five capitals; human, social, natural, physical and financial, and combined with the targeted

involvement of local community leaders, i.e. those who facilitate change at the local level (Morse et al. 2009), the approach allows for more informed policy development, and potential for on-ground change around climate adaptation strategies. Such an approach has not been undertaken before across multiple locations across Australia. We asked: (1) What are the perceived national and regional constraints and opportunities that face broadacre farmers in Australia under climate change? (2) What do farmers suggest needs to be done to build adaptive capacity in the rural communities? (3) What institutional arrangements are likely to facilitate adaptation to climate change?

2. Methods

2.1 Adaptive capacity workshops

Fourteen workshops were conducted across rural communities reliant on large-scale mixed cropping/grazing enterprises in the six Australian states of Western Australia, South Australia, Victoria, Tasmania, New South Wales and Queensland (Figure 1). In this context, mixed broadacre farming refers to large-scale production of grains, oilseeds and other crops and grazing of livestock for meat or wool on large parcels of land (>1,000 ha). These enterprises are important to Australia's export economy and the rural communities examined in this study formed part of a broader study where farmers and researchers worked together to identify and examine a range of adaptation options to manage for increased climate variability and climate change (Crimp et al. 2013; Rodriguez et al. 2014). Local co-ordinators involved in the broader study were utilised to ensure the inclusion of community members who had wider land management or natural resource management interests in order to capture perspectives of participants broader than just as farmers. These community leaders were

potentially important due to their influence in implementing on-ground change with respect to developing and implementing adaptation options (Morse et al. 2009). The workshops were conducted from April 2010 to July 2011, and involved 115 participants (Table 1), excluding researchers and state-based local coordinators. As is common in rural communities, many participants had multiple roles, for example, most government staff were also farmers.

Insert Figure 1 here

Insert Table 1 here

At the beginning of each workshop, a local co-ordinator provided background information regarding the likely regional implications of projected climate change for the near-term period 2030. The projection information was derived from four General Circulation Models (GCMs) used in the Inter-governmental Panel on Climate Change Fourth Assessment Report (AR4). The GCMs were selected based on formal evaluation of performance over Australia and represented four of the top eight performing models in terms of simulating Australian climatologies (Moise et al., 2015). This selection of models resulted in a range of climate future states all clustered around warmer and drier future conditions. The participants were then asked to describe their farming system (mix of cropping/grazing, farm size etc) and to draw an area on a map that they felt best represented the area they had knowledge of and therefore felt comfortable representing in response to the workshop questions (shown in Figure 1). There are weaknesses to this approach (farmer's perceptions of spatial expertise, who was present on the day, less local specificity etc), however the areas reflected the diversity of landuse and community resilience. Some participants (e.g. rural finance councillor or government agents) had a good understanding of issues over a broader region.

This was followed by a facilitated discussion around the implications these changes may have on the local communities and discussion about issues affecting the communities' capacity to adapt. To reduce facilitator bias, all workshops were facilitated by PRB (n=6) KB (n=2) or both (n=6). We followed the four-step process outlined in Brown et al. (2010) and modified the approach used by Leith et al. (2012) and Brown et al. (2012), being:

1. Presentation of the adaptive capacity self-assessment methodology.
2. Workshop session to identify 3-5 locally relevant indicators under each of the five capitals (human, social, natural, physical and financial).
3. Facilitated discussion to enable the participants to self-assess the current levels of adaptive capacity of the group and zone they represent for each indicator within each capital. Each indicator was scored from 0 (constraining adaptation for climate change in the future) to 5 (enabling adaptation for climate change in the future). The following questions were addressed:
 - a. What was the rationale for using these indicators?
 - b. Why were the scores high or low?
 - c. What were the priorities for building adaptive capacity? *Who* needs to do *what*?
4. Moderation session to:
 - a. Moderate the ranking of adaptive capacity for the location by the participants after considering all indicators (eg were scores appropriate, was there anything missing?); and
 - b. Identify common priorities for building adaptive capacity, and practical strategies for collective action between the wider community, industry and governments to achieve this.

An Excel spreadsheet, visible to the workshop participants, was used to capture the discussion so that the key points could be seen by all and facilitators could check for

clarification and meaning as the workshop progressed. With permission from participants, all discussions were captured on a digital audio recorder to double check our interpretation when summarising workshop discussions. We encouraged discussion on the underlying reasons for why indicators were enabling or constraining adaptation to increased climate variability or change rather than focussing too much on the actual score that was given. Generally there was broad agreement by workshop participants about the scores for individual indicators. Where there was disagreement, further discussion was encouraged to resolve the definition or scoring of the indicator. In a small number of cases, the indicator was split to represent two separate issues, and each was then scored separately. The moderation session in step 4 allowed some modification of scores or definitions after examining other issues, and to ensure the researchers adequately captured the issues. Collective actions were then captured by considering only the highly constraining indicators through a discussion about what could be done to relieve the constraint and who should be responsible for action.

All the information discussed during the workshops was entered into an Excel spreadsheet, with codes for State and location of workshop. This information formed the data for analysis. A summary of each workshop was prepared and sent back to the local coordinators who verified the results via circulation to all participants for feedback or additional comments.

2.2 Analysis

The indicators were summarised using common themes identified by the authors through a word content analysis (following Leith et al. 2012). A total of 56 summary indicators were identified, allowing for similar issues to be compared across locations and subsequent quantitative analysis. The 56 summary indicators were further explored to develop

common descriptions regarding the rationale for choosing the indicators, and to identify collective actions associated with that indicator. The collective actions were summarised by grouping them into seven categories emerging from discussions.

Quantitative data analyses were indicative only, with information being summarised in pentagon diagrams (Carney 1998, following the approaches of Crimp et al. 2010; Nelson et al. 2010a,b). Each point on the pentagon is a mean score for the indicators associated with each of the five capitals. This method, while masking variability in responses, allowed a quick assessment of the relative balance and level of each capital with reference to other locations. The results were used to discern broad regional similarities and differences, particularly for regions within states.

Box plots (using SigmaPlot Version 12) were constructed for each summary indicator and grouped by capital and sorted by mean values. This approach allowed an examination of general trends in terms of how each indicator might constrain or enable adaptation to climate change as well as allow the examination of the full distribution of responses. If the interquartile range of data (central grey box) was positioned to the left side of the graph and the median value was less than 2.5 (the central value of scores), then they were considered as constraining adaptation for climate change. Similarly, if the median value was greater than 2.5 and the interquartile data range is positioned to the right of the graph, then they were considered as enabling adaptation for climate change.

3. Results

3.1 Regional comparisons

The pentagon diagrams revealed different patterns across each of the regions (Figure 2). These need to be viewed in relation to key regional issues affecting farmers in each location (Box 1). For example, in New South Wales, the mean scores for all capitals (except financial capital) were lower at Grenfell compared to Holbrook. Participants in Grenfell considered they were more constrained in their ability to manage for climate change than participants in Holbrook. Also, in Western Australia, participants from Geraldton felt better able to cope with climate change than participants from Merredin, although participants from both locations identified that they had moderate levels of human capital. Irrespective of the regional variation in indicator scores, financial capital in most cases seemed to rank lowest; the exceptions being Upper North in South Australia and Roma in Queensland. The pentagon diagrams should be viewed in this way to discern broad similarities and differences rather than looking for detailed absolute values. It is necessary to look at the scripts from each workshop to better understand why indicators were chosen and why a particular score was assigned to them.

Insert Figure 2 here

Insert Box 1 here

3.2 Indicators identified at the workshops

The box plots reveal the extent of variation in scores for the indicators across all workshops and to what extent they are enabling or constraining adaptation (Figure 3). For example, *farmer networks* under social capital were perceived to highly enable adaptation ($n=6$ workshops), while *isolation/rural decline* was perceived to be highly constraining ($n=6$);

conversely *climate* under natural capital, was perceived to be highly variable ($n=7$) which might be a reflection of the range of locations and climate types. Of the 56 indicators (shown in Figure 3), 23 represented broad-scale drivers of national relevance for mixed farming systems which were raised at seven or more of the 14 workshops (Table 2).

Insert Figure 3 here

Insert Table 2 here

3.3 Priorities for building adaptive capacity

Participants were asked to provide potential means of addressing issues that were identified as constraining their abilities to adapt to climate change. The responses were grouped into seven categories or themes (Table 3). The first five categories (farming practice, training, community, technology and research, and communication) were easily identifiable within capitals, while the last two categories (funding and institutional arrangements) were broad and consisted of actions aimed at delivering outcomes to all five capitals. The authors ascribed levels of institutional arrangements appropriate to undertake actions listed in each category.

Insert Table 3 here

Both farming practice and training focused on developing the human and financial capitals of farming families, in the context of developing, maintaining or increasing the viability of the farm business. Extension services (public and/or private) from local to national

scales were identified as the main delivery method to increase the capacity of farmers to manage their enterprise into the future (Table 3).

The category ‘community’ focused on collective action related to improving social capital, particularly the attractiveness of regional centres as a place to live for farmers, their families and local businesses (both farm and non-farm related businesses). The need to provide appropriate services for families, including sporting facilities, schools and medical services and off-farm employment opportunities for spouses and children was identified as a significant activity to create vibrant rural communities, which in turn support farm businesses. Mental health was also identified as an important issue in rural communities, and the ability to spend time off-farm either at sporting events or other social gatherings is highly desirable. Improving social capital was seen to be the role of regional and national policy makers (Table 3).

The broad category ‘funding’ was relevant to capacity development across all five capitals, to be achieved through national government policies. The focus on regional infrastructure, relating to the efficient movement of product to market was high due to recent extreme events. For example, flooding destroyed many road and rail networks in SE Queensland in 2011, making it difficult for farmers to transport livestock to market. Centralisation of processing centres out of regional areas has increased farmers’ reliance on transport networks to sell food and fibre.

‘Institutional arrangements and policy makers’ is also relevant to all capitals, with all levels of government highlighted as having a role to play in assisting rural communities to be resilient in the future. Potential solutions range from the individual/community level to regional, state and national institutional arrangements. The discussion around these collective actions provided insights into the interconnectedness of farm businesses with local communities, regional management issues (e.g. natural resource management) and national

and international markets. A holistic approach, particularly integration across value chains, and support for rural communities are strong messages that emerged from our engagement. A range of institutions (formal and informal) would need to assist with development of policy to overcome the constraints identified here. There are roles to play for banks, Rural Finance Councillors, CMAs, Local Government, State Government and Federal Government (Tables 2 and 3). Many policies are within constraints of one portfolio/jurisdiction but potential solutions for rural industries are inter-connected.

4. Discussion

4.1 Issues that constrain or enable adaptation to climate change

Farmers identified a range of factors that constrained their ability to adapt that were not directly related to managing for increased climate variability or change. For example, there were many aspects of social capital (isolation/rural decline, access to services), physical capital (regional infrastructure, communication technology, farm business size) and financial capital (equity/debt, cost of production, access to credit, business management, land price) that were perceived to be constraining farmers' ability to continue farming into the future. Financial constraints are well known as barriers to adaptation (e.g. Berry et al. 2011; Deressa et al 2009; Fleming and Vanclay 2010). These constraints need to be addressed before farmers can start to think about managing for future climate change. There was common agreement across workshops that there is no single 'silver bullet' that could provide an easy path towards adaptation.

Farmers were generally confident in their ability to manage for climate variability; particularly for capitals that they felt they could effectively manage in response to seasonal

climate conditions, namely the physical and natural capitals. Furthermore, farmers felt confident they could continue to enhance their agricultural production; for example, they felt that they had sufficient experience in managing the particular requirements for their soil types. Even if farmers considered that they had poor soil types, they often did not identify that soil quality was a constraint, rather, they believed that they knew and understood the limitations of their soil and believed that they managed it appropriately. Constraining factors were generally those that farmers felt they had less control over, e.g. those factors requiring action from governments or industry.

A comparison of the shape of the pentagons indicates where perceived strengths and weaknesses exist between and across regions, the results suggest that regions like SA, parts of WA and QLD assessed the scores across the five capitals as low due to a combination of poor natural, social and financial capital. This provides insights into regionally relevant constraints. Examples of responses relating to recent flooding (loss of regional infrastructure) and prolonged drought (focus on irrigation development) are likely to change over time. While the score for indicators may vary over time, the importance of the indicator itself may be retained (Leith et al. 2012), suggesting that the method is robust (Jacobs and Brown 2014).

4.2 Opportunities for adapting to climate change

Participants largely focused on incremental changes to their farm business to maintain ‘the essence and integrity of an incumbent system of process at a given scale’ (Park et al. 2012: p5). These could be termed as coping mechanisms, and may be regarded as reactionary or anticipatory, depending on the context of the change being made, and the perception of the person making the change (Adger et al. 2005). Strong cultural links to traditional enterprises form a significant barrier to change for existing farmers (Adger et al. 2009; Crane et al. 2011)

and adoption will only occur if a landholder perceives an adaptation will provide them a 'relative advantage' (Pannell et al, 2006). Potential incremental or system adaptation changes can be identified from assessing results across all workshops, but implementation will require a good understanding of drivers of change from an individual's perspective. These included exploring alternative farming activities/techniques, exploring options for storing water, new irrigation schemes, stewardship payments, and diversifying income sources (Table 2). Robertson and Murray-Prior (2016) found that there should be a focus on short-term adjustments as a path to longer-term adaptation. Transformational changes i.e. changes in goal and or location (Rickards and Howden 2012) were not widely discussed at the workshops. However, the option of leaving farming, one form of transformational change (Howden et al. 2010), was raised in response to continued low prices for products and high land prices.

Responses supplied at the workshops could be considered to be 'experiential' in the sense that participants see climate change as just another issue within the context of other more pressing issues. It was not the main focus of discussion, and therefore was not regarded as 'scalar', that is an envelope around other issues (Rickards et al. 2011). While an experiential perspective provides insights into the decision-making process at the farm level, most of the responses focused on incremental rather than transformational change. However, insights into transformational changes may be required in response to longer-term pressures from climate change (Rickards et al. 2011). We argue that this experiential, contextual approach is useful to gain an understanding of perceived local needs to assist farmers to plan for and adapt to climate change.

While many adaptation options were considered as biophysical (natural and physical), understanding the socio-ecological context is highly important for the development of adaptation options. Social capital (Woolcock 1998) is very important for rural communities,

and it is often ignored or under-examined. Furthermore, it needs to be studied in the context of off-farm, non-science or non-agricultural knowledge or processes (Rickards and Howden 2012). The value of involvement in sporting teams, local clubs and Landcare groups is critical for all rural communities (bonding social capital), because they play an important role bringing people together to talk or share their experiences with farming, and could include adapting to climate change. Informally, this helps people to share their experiences and problems, but also more formal groups can assist with access to information about how to manage for climate change. Bridging social capital activities such as building trust (e.g. participation in government programs) that connect people with new ideas and linking social capital (e.g. use of information portals such as the internet) to facilitate access to resources and implement collective actions are also critically important (Meinke et al. 2009). In terms of human capital, health is strongly linked to social and financial capitals, with poor health being linked to a farmer's inability to adapt particularly if under financial and social stress (Berry et al. 2011).

Farmers also identified limited financial capital, mainly due to the rising production costs and increasing debt levels, as severe constraints on their ability to adapt to climate change. Farmers rarely rely on traditional income from farming alone; they rely on shares, off-farm, non-farm income or spouse income (e.g. Schwarz et al. 2012). However, while business decisions are central to the longevity of any farming business, it is very often the social structure of the farm unit and the local community that provides long-term resilience during economic hardship (Pannell et al. 2006). Decision-making on farm may be heavily impacted during periods of extreme stress such as drought (Pelling 2011; Stehlik 2003). The strong supportive role of off-farm income, common across many regions, is critical for farmers to cope in these situations as farmers under financial stress, are more likely to focus on the immediate future rather than decades into the future (Carmody 2010). Pressing issues

that were highlighted were finances, the availability of skilled labour, including the ability for young people to farm, and the social context of farming both at the family and rural community level.

Rural decline (Race et al. 2011) was a recurring theme throughout many of the workshops, and the participants described it in terms of the withdrawal of services from small towns and fewer people, but also isolation. Pannell et al. (2006) argues that the decline in the number of farming enterprises over time is a response to technological developments, economies of scale and has resulted in some regions in the demise of rural communities. This demise is exacerbated by the trend towards fewer workers operating and the withdrawal of government services from rural areas. There are significant implications of loss of services; particularly for communities (e.g. loss of sports teams, fewer people volunteering, increased travel to health services). The loss of some services can be overcome by technological developments, for example through electronic communication (broadband internet access and web cams), but technology cannot replace all services. Farmers provided ideas about improving conditions for local communities, including encouraging younger people into farming and improving succession planning. Rural decline also affects access to skilled labour, due to better opportunities elsewhere inside and outside of the industry (e.g. mining). Alternatively, skilled labour becomes too expensive so that farmers cannot afford to hire the labour. Sense of place, community and relative isolation are important components of farm and rural resilience, affecting agricultural ‘performance’ (Crane et al. 2011; Pannell et al. 2006).

4.3 Institutional arrangements to promote adaptation

There is a clear role for government in supporting adaptation of farmers (Table 3) (Rickards and Howden 2012), but formal institutional arrangements are just one approach. Informal institutions (e.g. rural community organisations) can also be effective in supporting adaptation by Australian farmers. Adaptation options and support for farmers needs to be co-developed with farmers, researchers, agribusiness, rural community and policy making agencies (Rickards and Howden 2012).

We have identified some opportunities for farmers to build on their current adaptive capacity such as willingness to adapt to new technologies, education and experience, ability to access and process information, positive attitude for change, the existence of good existing farmer networks, a strong sense of community, access to technology (e.g. GPS), support from off-farm income and opportunities to diversify. These were borne out of the indicators that farmers considered were enabling their ability to adapt. This needs to be further enhanced and supported through engagement with stakeholders to build a foundation for incorporating climate change adaptation considerations into management and policy. Robertson and Murray-Prior (2016) also found it important to have an understanding of the link between adaptation and enabling factors and relevant technologies. Webb et al. (2013) used an approach to evaluate adaption options in the context of a range of multiple drivers to assess 12 adaptation options for the livestock industry in north-eastern Australia. The assessment combined a multiple-criteria evaluation by graziers with a model-driven analysis of options to feed into the development of policy.

4.4 Reflection on approach

We used a rapid approach to discuss and capture some key elements of the issues surrounding adaptation for farmers across a range of farming systems across Australia. Our

approach draws strongly on elements of effectiveness, efficiency, equity and legitimacy to develop successful adaptation options for climate change (Adger et al. 2005). Scientific input into adaptation must be salient, credible and legitimate (Cash et al. 2003; Meinke et al. 2009). Criticism of the five capitals approach includes: the mechanical and quantitative use of data; the method of measuring and analysing capitals; the level of ‘trust’ present amongst participants; the vulnerability of the results to temporal shocks e.g. drought; the awareness of participants on their impact on and ability to manage capitals, e.g. natural capital; and, how to translate findings into policy interventions that result in on-ground change (Morse et al. 2009). Our analysis of the data provides insights into local, regional and national contexts in which broadacre farmers perceive their ability to adapt to climate change. The use of existing producer groups in most regions was seen as a positive in increasing the level of trust within group participants. Participants in many regions had recently experienced floods or drought or both and therefore discussed and incorporated ‘shocks’ into their responses. We recognise this was a snap-shot in time, but as has been demonstrated elsewhere, we are confident that the indicators chosen and the scores are relatively robust (Jacobs and Brown 2014). Also, while the numbers of participants was sometimes low (e.g. 5-6 participants), we were impressed with their confidence to represent the broader farming community from those areas. This could only be validated by running a series of workshops over a number of years for the same region with different participants, but we were unable to do this because of limited time horizon of the project. While participants might have perceived natural capital to be relatively high, we did not question this perception as this might have undermined the workshop process and affected the level of trust. However, based on the process we followed, there is the ability to identify such issues and to incorporate them into policy initiatives. The development and implementation of policy initiatives relies on the provision of regional knowledge and local support, particularly from community leaders. The process we adopted, participatory

workshops with the farming community, has provided such knowledge and has engaged with local farmers and community leaders to inform policy development.

4.5 Conclusions

Comparisons across regions have shown many shared indicators across the five capital framing used in this project. This commonality in indicators does suggest a robustness of this approach, in that farmers undertaking common landuse activities raised common issues regarding adaptation. A focus on aggregation of indicators allows for national, state and regional insights that may underpin policies that are inclusive of actions relevant to local conditions. Development of actions to maximise opportunities and minimise constraints can be made for all levels of institutions and policy makers including at the community and individual level. While the drivers for including the indicators that were collated from the 14 workshops were not solely focused on adaptation to climate change, the information collected has provided valuable insights from farmers into actual and potential issues of adapting to climate change. These insights facilitate the identification of core issues at national and regional levels. The opportunity for rural communities to discuss potential solutions is likely to result in some level of uptake were such suggestions to be acted upon. Relative comparisons between regions can lead to the development of appropriate approaches/policies to build adaptive capacity at range of levels, which should increase the ability of farmers, regional and national institutions to absorb shocks (Engle 2011).

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Table 1. Summary of 14 workshops conducted across 6 states in Australia providing a summary of workshop participant representation and number of participants. Most government staff also considered themselves as farmers.

Date	Location	Attendees	Industry Representation
Apr 2010	Qld – South East Qld (SEQ) (Fernvale)	15	Graziers and SEQ Catchments staff
Jul 2010	Tas – NRM South (Hobart)	6	Small-medium mixed farmers: beef (including organic), horses, sheep and fine wool production, native pastures, lucerne and cereal production
Aug 2010	Tas – NRM North (Launceston)	6	Small-medium mixed farmers (grazing and conservation, irrigated pasture, cropping (poppies), beef, wool and meat sheep), extension officers, NRM staff
Feb 2011	SA – Upper North (Orroroo)	7	Mixed farmers (wheat and sheep), who were also a rural finance councillor, an agronomist for Rural Solutions SA, an NRM officer, members on local councils regional development board, NRM board, and a health worker
Feb 2011	SA – Eyre Peninsula (Wudinna)	16	Mixed farmers (wheat and sheep), who were also a NRM drought coordinator, a farm manager of an agricultural research station, a rural finance councillor and a staff member of Rural Solutions SA
Mar 2011	NSW – Holbrook	13	Landholders, involved in beef, fat lamb, horticulture, cropping enterprises, representatives from the Holbrook Landcare, the Murray CMA, a beef cattle consultant, a pasture agronomist, and a town councillor
Mar 2011	NSW – Cootamundra	6	Mixed farmers (cropping and sheep enterprises), private consultants and projects officer with the Murrumbidgee CMA
Mar 2011	NSW – Grenfell	6	Landholders (cattle, wool, lamb and winter cropping) who were also the livestock specialist for I&I NSW, Lachlan Livestock Health and Pest Authority (LHPA), a private agronomist and a retired DPI NRM consultant, and 2 district agronomists
Mar 2011	Vic – Mallee (Birchip)	5	Broadacre cropping and sheep grazing (opportunistic or continuous), private consultant
May 2011	Qld – Goondiwindi	5	Mixed farming (cropping, livestock) and irrigated cotton, Landcare, QMDC and DPI staff
May 2011	Qld – Roma	9	Graziers, mixed farmers (sheep, cattle, cropping), with interests in local government, farming and community initiatives, and Landcare; two staff from QMDC; and a rural finance councillor
July 2011	WA – Merredin	6	Mixed farmers (sheep, cropping, one with piggery; property sizes 4,500-7,500 ha), a weed management officer for DAFWA, and a DAFWA staff member who is the climate officer but also has a small lifestyle property
July 2011	WA – Geraldton	6	Mixed farmers (sheep, cropping; property sizes 2,500-8,000 ha), GRDC panel member, a rural finance councillor who also ran a B&B home-stay, and two DAFWA staff that lived on farms
July 2011	Tas – Northwest (Devonport)	9	Mixed farmers who grew vegetables for the fresh market and processing, poppies, pyrethrum and a mixture of trade cattle and prime lambs, cattle trader; member of a grower group and chairman of the irrigators board; field officers and NRM land co-ordinator
Total number of participants		115	

B&B = Bed and breakfast accommodation; CMA = Catchment Management Authority; DAFWA = Department of Agriculture and Food, Western Australia; DPI = Department of Primary Industries; GRDC = Grains Research and Development Corporation; I&I = NSW Department of Industry and Investment; LHPA = Livestock Health and Pest Authority; NRM = Natural Resource Management; NSW = New South Wales; Qld = Queensland; QMDC = Queensland Murray-Darling Committee; SA = South Australia; SEQ = South East Queensland; Tas = Tasmania; Vic = Victoria; WA = Western Australia

Box 1: Key regional issues affecting broadacre farmers.

New South Wales *Cootamundra*

- Participants thought they were enabled by topography/landform and were well connected, with access to off-farm income opportunities and access to services.
- They felt constrained by a lack of skilled labour, and they suggested that it was important to have good farm business skills and to support clubs and social networks.

New South Wales *Grenfell*

- Participants felt they were constrained by a range of issues across all capitals. Services such as rail networks, health and education services were declining, and they felt constrained by the lack of availability of skilled labour. There was a decline in motivation for farming, compounded by declining financial assets, leading to a lack of confidence.

New South Wales *Holbrook:*

- Participants considered they were well connected (main road from Sydney to Melbourne), had good soil, rainfall conditions, and a strong community (e.g. Landcare).
- They felt constrained by access to skilled labour, volunteers and a range of Financial indicators (cost of inputs, level of debt, ability to pay for labour, attitude and willingness to invest, and land value/return to equity).

Tasmania *Northwest Region*

- Participants thought they were constrained by a range of Social and Financial indicators. Despite feeling socially isolated, they thought that they were able to adapt.

Tasmania *NRM North Region*

- Participants felt that the topography and soils along with access to irrigation enabled adaptation in their region.
- They felt constrained by the high cost of land, an ageing farmer population and declining terms of trade.

Tasmania *NRM South Region*

- These farmers experienced a three year drought (2006-2008) unprecedented in their lifetime. They felt constrained by perceived low levels of Human, Social and Financial capitals.
- They felt that there was a lack of funds to enable them to adapt to climate change, and many had small property sizes. They felt the local community was in demise and was unsupported, leading to a loss of confidence.

Queensland *Goondiwindi*

- Participants had access to irrigation and felt they had an agricultural system that enabled adaptation. They felt there was no 'rural decline' in their region and that mining had improved access to services so were well connected.
- They felt constrained by high land prices, a change in the nature of farming (from traditional family farms to corporate farms), which has led to money being spent out of the local community. There were perceived low levels of Financial capital and a lack of skilled labour.

Queensland *Roma*

- Mining was a big feature in the region. Participants were unsure of the pace of expansion, what it meant for sustainability and what effect this might have on groundwater resources. They felt they had good levels of off-farm income. They considered it important to maintain sporting clubs.
- They felt constrained by skilled labour, access to services and access to information. They were severely affected by floods in January 2011.

Queensland *Southeast Queensland*

- Participants felt that their climate, soils, topography, access to market and off-farm income enabled adaptation.
- They felt constrained by urbanisation and hobby farmers, meaning land management and traditional values were changing. They thought it would be difficult to expand their operations under these circumstances.

Victoria *Mallee*

- Farmers in this region have experienced long-term drought over the last 10 years. They expected that it would take a few years to recover, but they thought they had learnt from this time which will prepare them well for the future.
- They felt constrained by a lack of time, high costs and lack of rural services.

South Australia *Eyre Peninsula*

- The perception was that they were constrained by Social capital. They felt they were in rural decline, with declining social networks and government services. Farmers were experiencing poor terms of trade, and there were problems with affordability and availability of labour. Despite this, they felt vibrant.

South Australia *Upper North*

- Farmers identified the declining social aspects of the community (reduction in some services, declining population) as a big driver in the region which influenced their mental health, making it difficult to obtain people with the right skills, and affecting succession and generational change. They felt that inadequate regional storage and transport infrastructure restricted their ability to take full advantage of the (relatively rare) years with very high grain production.
- Overall they were reasonably optimistic. Farmers were coming out of an extended drought, so while things were looking better than they were a few years ago, they commented that it would take some time to get out of debt.

Western Australia *Geraldton*

- Farmers had higher economic returns in 2008 and 2010 due to higher than average in-crop rainfall, so farmers were confident and happy, after very poor years in 2006 and 2007. Because of high variability and because farmers survived the poor years, they felt confident about being able to manage their farms under climate variability and change in the future.
- Farmers stated that they would not sow if conditions were very dry, but would capitalise in good years. All participating farmers were well connected to Geraldton which had good services.

Western Australia *Merredin*

- Farmers in this area had very low yields, but very large areas of land. They spent a long time sowing their crops and have moved to sowing dry. It was considered difficult to take advantage of highly variable climatic conditions because of the amount of time needed to sow large areas.
- Profitability of farming was seen as the greatest constraint which was related to access to finance, high interest rates and poor business skills. They said that access to services in rural areas was declining because families had to drive to Perth to access specialist services. This affected their quality of life and reduced the time available to spend on their farm and in the community.

Table 2. Broad-scale drivers identified from at least 7 of the 14 workshops conducted in six states. The priorities for action were developed for indicators that received scores between 0 and 1.

Big drivers	Issue in relation to adapting to climate change	Priorities for action
Human		
Age/health (n=15)	Farming is a physical career. Stage of life has an impact on future decisions and investments, including the adoption of new technologies. If health is poor, farming is difficult.	Encourage share farming, encourage opportunities for value-adding, and improve vibrancy of rural communities
Farmer education/ experience (n=11)	Farmers draw on their own experiences and education levels to make decisions about their farm. The more education and experience they have, the better able they feel they could adapt to climate change.	
Skilled labour (n=11)	The number of people employed on farms has decreased over time as farming methods have become more efficient. The lack of attractiveness of agricultural careers compared to other remote activities (e.g. mining) has reduced the availability of skilled labour on farms.	Support training, education and short courses for farmers, encourage consultants to talk to farmer groups about succession, and involve external people in succession planning
Business skills (n=8)	Having good business skills enables farmers to make good sound decisions in a timely manner. Many skills are developed through experience, but farmers need a broader skill set than ever before, including enhanced business skills.	Encourage social groups, support training, education and short courses for farmers, and encourage on the job training
Attitude for change (n=7)	This indicator was largely positive, i.e. farmers seem to be willing to think about adaptation (to climate change) as farmers already feel confident in their ability to manage for climate variability.	
Social		
Rural communities (sense of community) (n=16)	Sense of community (belonging) provides an off-farm experience for farmers into the broader community, which is important for mental health. Support networks such as Landcare groups and sporting clubs reduce the sense of isolation and help to maintain community spirit.	
Access to services (n=12)	Access to services varies between regions with some having good access to important facilities such as regional health, education and extension services. Other regions are experiencing 'rural decline' where services are removed from the community, which impacts on the ability of the region to attract residents, limits capacity to earn off-farm income and reduces the support of social networks such as sporting clubs within the region.	Improve local services, improve social networks, discourage decentralisation, encourage population growth, attract specialists into rural areas, and promote the use of video conferencing where possible
Access to information (n=9)	Related to internet use, phone coverage, access to consultants information on the internet etc. Farmers need access to a wide range of information via such sources as telephone, internet and face-to-face with consultants, to help them make timely decisions. The internet can be used to follow commodity prices which assists in decision making to sell, and provides access to seasonal weather forecasts which will become more important as the accuracy of the forecasts and climate variability increases.	
Family unit (n=8)	The internal support networks provided by families is critical to the success of family farms as decision making is undertaken by and/or on behalf of the family unit. Succession planning for handing over to younger family members is perceived to be important, but is not always done very well. Families provide important support in remote communities but can break down if regional services are poor. Farms that have been held in the same family for generations are common, and passing down of aspirations, value systems, motivation, and ethos help to shape the sense of place of farmers. Farmers find it hard to change/adapt if the family is not functioning well.	
Natural		
Water resources (n=14)	Farmers link the importance of water availability, quantity and quality to their capacity to capture, store and use it as a response to a decrease in the reliability of rainfall.	Explore options for water storage, improve WUE and research on WUE, and develop more frost/drought tolerant varieties
Soil health (n=13)	If soils are in good condition, they will enable adaptation. Farmers felt that they have a good understanding of the soil constraints and have been trying to manage their soils appropriately through a long history of improving soil health, particularly after drought.	
Climate (n=7)	The shift in seasonality, decreased reliability of rainfall and changes to frost risk and heat events will require changes to mixed farming systems. Opportunities and constraints were identified. Farmers in southern Australia will benefit through infrastructure developments, e.g. irrigation. Genetic improvements will also provide opportunities for producers to match plant and animal genetics with climatic conditions.	Improve WUE, explore alternative farming activities/techniques, and explore timing of sowing and use quicker varieties
Physical		

Plant & machinery (n=13)	Investment in new more efficient machinery and irrigation means that farmers are best placed to deal with climate variability. This investment is expensive and farmers need to have adequate support, education and knowledge to run technologically advanced systems e.g. GPS installed on tractors. On farm storage was seen as important because the regional infrastructure was not good and related to transportation issues.	
Road and rail networks (n=13)	Good road and rail networks allows farmers to minimise inefficiencies by getting their product to market in a timely and efficiently manner, to obtain inputs, to physically connect with others and to facilitate family life (eg access to school transport). Transport networks affect the ability to rapidly respond to changing markets and circumstances.	
Regional infrastructure (n=10)	Access to market through rail and road networks is critical for farmers. Processing and storage facilities are also important. Farmers need to get their products to market in a timely fashion to maximise returns. There is a general decline in the condition and availability of storage silos, resulting in farmers storing grain on farm or transporting it further which increases infrastructure and travel costs and travel time.	Improve on-farm storage facilities, encourage opportunities for recycling wastes, improve regional storage facilities, improve vertical integration of industries within regions, and seek government assistance for improving regional infrastructure, roads and rail
Technology (n=9)	Many new machines are fitted with tools such as GPS, allowing for VRT, one-pass technology etc. While these technologies are increasing productivity there are still issues with implantation including access to technologically competent mechanics and skilled labour to operate the machines.	
Genetics (plants & animals) (n=8)	Genetics is seen to be important to develop appropriate species and varieties under a changing climate, e.g. increased water efficiency of plants and cattle that are tolerant of extreme heat.	
Water infrastructure (n=7)	Access to water is necessary to finish crops and grow pastures in some regions. Anticipate need for more water in the future – reliable sources and a diverse supply.	New irrigation schemes are available in some areas. Cost of water will determine whether they choose to use it or not, and is also dependant on the return they are getting for the crops.
Financial		
Equity/debt (n=14)	Farmers are asset rich but cash poor. They are not necessarily in a position to loan more which restricts their adaptation options.	Encourage good business management training, encourage share farming and leasing, encourage saving during good years, explore use of stewardship payments, support development of first farm buyers grant, and encourage and support diversified income sources
Land prices (n=12)	The price of land is increasing, which impacts on the ability of farmers to diversify through increasing farm size, but at the same time raising equity and better access to loans. Alternatives to buying land include share farming/leasing/contracting. Mining and housing pressures have forced up land prices in many regions, as land price increases, returns from production need to increase to cover higher costs.	Encourage good business management training, and encourage share farming and leasing
Cost of production (n=11)	Input costs such as fertiliser and diesel are increasing while other costs e.g. herbicides have decreased. Increasing efficiency is seen as a way to minimise input costs but if costs continue to increase then they will constrain adaptation.	Encourage use of contractors, encourage sharing of equipment, improve management of inputs to improve efficiency, and encourage good business management training
Off farm income (n=10)	Mixed farmers across the country perceive off-farm income to be an important component of their adaptive capacity. Off-farm income can be used to generate cash flow through contracting or partner's ability to earn an income. An important question is whether farmers need off-farm income to allow them to continue farming (i.e. farming alone is not profitable), or is it a lifestyle choice, providing an outlet form community engagement unrelated to the farm business?	
Business management (n=7)	Farmers are generally unaware of the return on investment for their enterprise. Alerting them to this may increase their decision making capacity with respect to adaptation actions. Market deregulation means that farmers need to spend more time watching prices. Managing finances and managing risks are critical, especially when adopting or changing.	

Table 3. Collective actions identified by participants in workshops to improve adaptation for climate change. The collective actions are grouped into seven broad categories, and possible scale and responsibility for achieving the actions are provided.

Category	Collective actions	Scale of action
Farming practice (Financial capital)	Encourage and support diversified income sources, opportunities for value-adding, saving during good years, share farming and leasing, sharing of equipment, use of contractors, alternative farming activities/techniques, explore opportunities for clever marketing, timing of sowing and use quicker varieties, improve management of inputs to improve efficiency, management of soil types, on-farm storage facilities, WUE, and involve external people in succession planning.	<u>Local/regional scale</u> : Provision of extensions services (including agricultural productivity, financial planning, marketing, facilitation to develop new operating models (e.g. share farming)
Training (Human capital)	Encourage business management training, consultants to talk to farmer groups about succession, on the job training, explore development opportunities for regional extension staff, explore role of women or third party running books, support skills in managing labour, and training, education and short courses for farmers.	<u>Local/regional scale</u> : Provision of extensions services (including agricultural productivity, financial planning, marketing etc) <u>National scale</u> : policy support e.g. farm ready grants for training.
Community (Social capital)	Encourage social groups and volunteers and volunteer groups, improve local services, social networks, vibrancy of industries in regions, and vibrancy of rural communities.	<u>Regional/National scale</u> : Policy initiatives for industry support and development in rural communities, attracting others to the region.
Technology/research (Physical and Natural capital)	Conduct research and development of attitude for investment, develop more frost/drought tolerant varieties, encourage opportunities for recycling wastes and technologies suited to soil type, explore options for water storage, improve research on stock infrastructure, and research on WUE.	<u>National</u> : Research, Development and Extension (RDE) industry/government
Communication (Human and Social capital)	Improve and streamline supply chains and logistics, communication and collaboration at regional level to improve pest and weed management, and communication of GM developments, promote the use of video conferencing where possible, and raise awareness of differences between production versus profit.	<u>National/regional</u> : Communications infrastructure (national), regional extension services
Funding (All capitals)	Develop infrastructure funds, encourage Australian owned regional investment options, explore use of stewardship payments, Government assistance and financial assistance to promote change, improve funding and incentives for stock infrastructure, seek government assistance for improving regional infrastructure, roads and rail and government assistance for investment in water infrastructure, and support development of first farm buyers grant.	<u>National</u> : Federal Government policies
Institutional arrangements and policy makers (All capitals)	Assist with accessing seasonal/overseas labour (visa issues), attract specialists into rural areas, encourage females into farming, government restructure programs, government to change water infrastructure legislation/policies, population growth, population growth and discourage decentralisation, improve level of income for farmers, regional storage facilities, and vertical integration of industries within regions.	<u>Regional and National</u> : Catchments, local government, State Government and Federal Government – potential for some overlap here with community

Figure 1

Figure 2

Figure 3