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Participatory approaches to address climate change: perceived issues affecting the ability of South East Queensland graziers to adapt to future climates

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Abstract We used a participatory approach and a rural livelihoods framework to explore the knowledge and capacity of southeast Queensland graziers to adapt to climate change. After being presented with information on climate change projections, participants identified biophysical and socio-economic opportunities and challenges to adaptation. Graziers identified key opportunities as components of resilience (incremental change), and in many cases were options that they had some knowledge of either from their own region or elsewhere in the grazing industry. The major constraint to adaptation was the lack of financial capital: with low profitability of the industry and high land costs restricting their capacity to diversify and exploit economies of scale. These constraints were exacerbated by the pressure many graziers experienced from the demand for land as a result of urban expansion. While the focus of the workshop was on the impact of climate change and capacity to adapt, many of the issues raised by graziers were pressures not solely related to climate change. Adaptation needs to be considered in light of the appropriate level (resilience–transition–transformation) and spatial scale (field to region) required to tackle the issues identified. Policy needs to support good natural resource management, rural amenity, and food and fibre production close to urban population and markets in the face of urban encroachment.

Keywords Adaptive capacity · Extreme events · Grazing · Soil erosion · Policy · Rural livelihoods framework · Urban encroachment · Vulnerability

Abbreviations

CBNRM	Community based natural resource management
CMA	Catchments management authority
IPCC	Intergovernmental Panel on Climate Change
MLA	Meat and livestock Australia
SEQ	South East Queensland
THI	Thermal heat index

Introduction

Farmers face a range of future challenges, including land degradation and global climate change (Meinke and Stone 2005; McKeon et al. 2009; Crane et al. 2011), particularly with projected increases in demand for food and fibre (FAO 2006; Keating et al. 2010). The impact of increased CO_2 in the atmosphere will lead to changes in rainfall patterns, temperatures, frost risk, heat stress, and extreme weather events (Hennessy et al. 2010), which will lead to effects on plant growth and natural resources. To cope with

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these challenges farmers will need to be able to adapt by adjusting practices, processes and capital in response to real or perceived threats (Ellis 2000; Berkes and Jolly 2001; Adger and Vincent 2005; Adger et al. 2009) and take advantage of new opportunities (McKeon et al. 2009). Adapting to climate change is also likely to require responses in the decision environment, such as changes in social and institutional structures, or altered technical options that influence the potential or actual capacity for these actions to become a reality (Howden et al. 2007). Farmers adapt continually, especially farmers working in highly variable environments such as those experienced in Australia (Steffen et al. 2011). In particular, social capital and social networks can supports farmers, particularly in times of change (Nelson et al. 2014). However, climate change will add to the existing pressures and will interact strongly with food security challenges as the global population is expected to stabilise at 9 billion. Securing food production needs to be carried out simultaneously with reducing greenhouse emissions, reducing the impact on biodiversity and the natural resource base while facing competition for land from urban encroachment and biofuel production (Howden and Stokes 2010; Hochman et al. 2013).

Livestock grazing is an important industry throughout the world contributing fibre and a large proportion of meat for the world's population. Meat is a primary source of protein and the global demand for it is increasing, especially as Asian countries become more developed (Delgado 2003). It is important to maintain a viable industry in the future to meet these growing demands. The top five cattle meat producing countries in the world (USA, Brazil, China, Argentina and Australia) will be affected by climate change to some extent in the future (Easterling et al. 2007), so a better understanding of constraints to adaptation will be necessary. In Australia, extensive grazing is the most widespread agricultural land use. It covers just over 4 million km^2, which is approximately 58 % of land area (ACLUMP 2010). Much of this is low-intensity production of beef and sheep (meat and wool) in arid or semi-arid regions. The main challenges identified for the grazing industry in Australia under climate change are declines in pasture productivity, reduced forage quality, livestock heat stress, greater problems with some pests and weeds, more frequent droughts, more intense rainfall events, and a greater risk of soil degradation (Crimp et al. 2010; Stokes et al. 2010, Steffen et al. 2011). However, Stokes et al. (2010) suggest that some areas, particularly the productive eastern grazing lands, may provide opportunities for increases in production, however, this might need to be balanced against urban expansion.

Many studies on broadacre grazing focus largely on technical considerations of adaptation with strong involvement by researchers, extension officers and natural resource management groups (e.g. Cobon et al. 2009; McKeon et al. 2009; Stokes et al. 2010). These studies focus on ranking and prioritising adaptation options based on impacts, risks, exposures, and sensitivities. While these approaches generate important priorities for informing management and policy decisions, there is often minimal reflection or input by broadacre grazers themselves. Such an approach runs the risk of ignoring farmers' deep knowledge of their operating environment, their capacity to implement change and their willingness to take on recommendations that do not reflect their perspective. This paper describes a participatory approach using a livelihoods framework to ask how we can incorporate producer knowledge to assess the vulnerability of the grazing industry to climate change, to identify some practical adaptation options, to determine the limits of adaptation for coping with climate change, and to consider some policy implications. If science is to play a role in building farmers' capacity to adapt to global change, it is necessary for scientists to engage farmers in an on-going discussion about the likely impacts of climate change and to co-identify potential adaptation options (following Hoffmann et al. 2007). In recognition of the complex nature of on-farm decision making, beyond technical considerations, we use the rural livelihoods framework to examine household capacity, external influences, management practices and aspirations of South East Queensland (SEQ) and ask graziers about how they can manage and overcome for the perceived constraints and changes in climate.

There is a strong interest in the SEQ region because of the biophysical exposure to climate change and the increasing economic and social exposure and sensitivity over the coming decades, particularly because SEQ contains Australia's fastest growing urban population, together with agriculture and natural systems which are important both economically and culturally. This has led to a focus on a range of sectors including biodiversity, urban water security and flooding, electricity systems and coastal settlements (McAllister et al. 2014). While Keys et al. (2014) focussed on building adaptive capacity in the SEQ region, the focus was largely on urban planning, health, emergency management, coastal management, infrastructure, environmental conservation and energy, and only a small was mention given to agriculture. Given the highly complex biophysical, infrastructure, urbanisation and social change underway in the SEQ region, our study was designed to specifically fill the gap for the important grazing industry in SEQ and to consider the determinants of adaptive capacity and identifying what can be done to overcome these constraints. Here, we define adaptive capacity as "the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements” (Nelson et al. 2007). This is important in terms of helping farming communities to think about their resources and assets to enable adaptation.

In order to engage effectively with a diverse group of graziers located within traditional grazing districts which are now subject to urban expansion, we considered that a modified rural livelihoods framework would be an appropriate framework for engagement. The rural livelihoods framework has been used to look at issues about adaptation for climate change and for improved natural resource management (Scoones 1998, 2009; Ellis 2000; Adger and Vincent 2005; Brown et al. 2010; Nelson et al. 2010a, b). It is important also to understand whether the potential adaptation options will actually lead to improvements for their industry and to identify factors that might constrain or enable adaptation. This participatory approach sets in place mechanisms for on-going discussions between farmer groups, community based natural resource management (CBNRM) groups (e.g., Catchment Management Authorities), researchers and policy makers, and complements the approach used by Keys et al. (2014), but is targeted at the grazing industry. It was necessary to engage graziers in this process, to make impacts relevant to them and to help them make informed decisions about what they can do themselves and what support they need.

To effectively engage farmers in discussions about the future, it is necessary to appreciate that many farmers have a good sense of the ‘climate’ on their farms and how this impacts on their natural resources and agricultural production. It is also reasonable to expect that they have a good sense of how other parts of their region differ climatically from their farm (Duru et al. 2012). Our aim, therefore, was to explore the future with the farmers by presenting climate change scenarios alongside current geographically distributed climatic differences to enable them to relate future scenarios at their location to current conditions in other, familiar places in the region.

Methods

We used the rural livelihoods framework (Scoones 1998; Ellis 2000) to consider various aspects of how graziers could adapt to climate change. A workshop format was used (Brown et al. 2010) to engage with SEQ graziers using principles of focus group discussions. We applied four main elements of the framework. First, we examined the external influences (contexts, conditions and trends), particularly the climate drivers that graziers themselves have experienced over the previous 10–15 years, with consideration of any other external pressures that were thought to be relevant. Secondly, we explored how graziers have been managing climate variability over the previous 10–15 years and how these practices might help them manage for further increased variability of climate through to climate change in the future. Thirdly, we determined relevant indicators of the capacity of households (livelihood resources) within the five capitals (human, social, natural, physical and financial), which were then self-assessed as to the extent to which they constrained or enabled adaptation to climate change, leading to policy implications (institutional processes and organisational structures). Finally, we considered the aspirations of the graziers in terms of what farming system they would like to see in the future and what they would like to do to get there were ascertained through case study interviews (livelihood strategies and outcomes).

We ran a full day workshop in April 2010 with the cooperation of SEQ Catchments (a gazetted natural resource management region in Queensland) and AgForce (a farmer association). There were 20 participants including 12 cattle graziers drawn from the area indicated in Fig. 1, four staff from the SEQ Catchments management authority (CMA), two AgForce representatives, two interested (non farmer) members of the SEQ community. Four staff from CSIRO made technical presentations and facilitated the workshop. Regionally relevant input on the grazing industry was sought from the landholders and regional support staff (SEQ CMA and AgForce). We asked the workshop participants to introduce themselves, describe where their properties were located and the type of grazing and other businesses they were engaged in. Property size ranged 65–830 ha and many graziers had a small proportion of cropping land. The participants strongly felt they were adequately able to represent the views of graziers from the SEQ region. With the permission of the stakeholders we recorded all information through note-taking and the discussions pertaining to the adaptive capacity component were audio recorded.

Study region

The SEQ region covers about 61,000 km^2 characterised by diverse land uses with urban and industrial areas, forestry in native and plantation forests, national parks, and dryland and irrigated agriculture. About 56 % of the woody vegetation cover of South-East Queensland has been cleared for urbanisation, agriculture and grazing. Grazing accounts for most of the agricultural land use in the region and the annual value of commodities from the cattle industry is about AU$150 million (Robinson and Mangan 2007). Compared with other parts of the Australian livestock industry, grazing in SEQ is conducted on relatively smaller land holdings and in a wetter (sub-tropical) environment. The region is also subject to a range of pressures and changes including land use change, urbanisation, change in

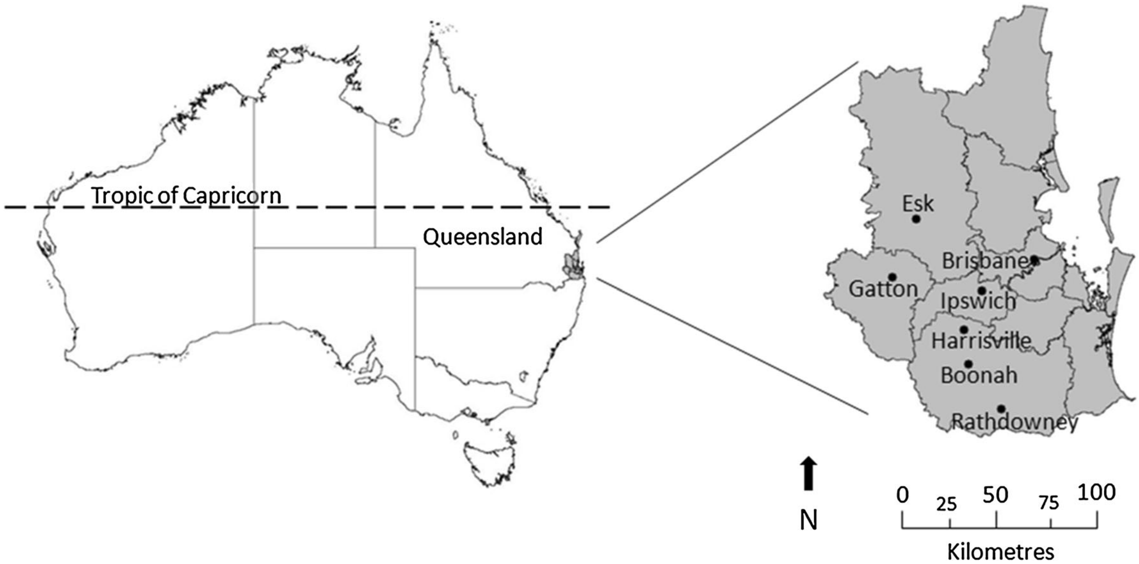

Fig. 1 Location of SEQ showing the area from which the workshop participants were drawn and case study farms identified by their respective numbers

intensity of agriculture, water quality decline and hydrological regimes, and social-economic changes (Low Choy et al. 2007) which makes our study a relevant addition to recent studies on climate adaptation, because these studies did not consider SEQ (e.g. Cobon et al. 2009; McKeon et al. 2009; Stokes et al. 2010).

Climate projections

We presented the participants with Australian Bureau of Meteorology maps highlighting observed annual trends in maximum and minimum temperature from 1970 to 2008. Over this period, SEQ experienced a warming trend of 0.4–0.6 °C/10 years for maximum temperatures and a small negative trend of −0.05 to −0.1 °C/10 years for minimum temperatures. We also presented modelled climate change scenarios or storylines for 2030 based on dynamical downscaling for SEQ using 18 GCM[1]s with the Intergovernmental Panel on Climate Change (IPCC) SRES[2] marker emissions scenario A1B[3] (Nakicenovic and Swart 2000) (shown in Table 1). Most projections indicated an annual temperature rise in the range of 0.5–1.5 °C and little change in annual precipitation (−5 to +5 %). This period covered graziers' likely experiences and likely future planning horizons. We also presented OZClim maps of modelled seasonal change.[4] We presented the GFDL-CM2.1 model outputs using the SRES marker Scenario A1FI[5] with high climate sensitivity to illustrate a scenario with reduced precipitation during the critical summer rainfall period of November to April because subtropical systems that are depended on warm season rainfall for most pasture production.

We explored a range of future climate change indicators (cattle heat stress, pan evaporation, number of frost days) with the farmers by presenting climate change scenarios (futures that are 1 or 2 °C warmer) alongside current geographically distributed climate differences. Farmers were thus invited to relate a future scenario at 'my place' either to current conditions at a familiar place or to appreciate that it is outside of the range of conditions that currently exist in the SEQ region. Consequences of a future that is either 1 or 2 °C warmer were presented as in Table 2 in terms of an increase in the number of days in which cattle would experience heat stress (when the Thermal Heat Index [THI] exceeds 85; at THI = 85 cattle require more drinking water, suffer loss of appetite and gain less weight; at THI = 100 cattle die from heat stress; Thom 1959). This contextualised presentation style enabled local participants to imagine future change in geographical terms that may be

[1] General circulation models (GCMs) represent physical processes in the atmosphere, ocean, cryosphere and land surface to simulate the response of the global climate.

[2] Special Report on Emissions Scenarios (SRES) are sets of scenarios used by the IPCC to explore future developments in the global environment. See http://www.ipcc.ch/ for more details.

[3] A1B is a specific emissions scenario characterising alternative developments of energy technologies considering a balance across energy sources (described as "business as usual"). See http://www.ipcc.ch/ for more details.

[4] See http://www.csiro.au/ozclim/home.do.

[5] A1FI considers alternative developments of energy technologies considering fossil intensive sources (described as "worst case scenario"), using one of 23 specific models (GFDL-CM2.1 model). See http://www.ipcc.ch/ for more details.

Table 1 Summary of annual change in temperatures and rainfall as predicted for 2030 in SEQ based on the A1B scenario using 18 global circulation models

Annual precipitation (% change)		Temperature (°C)			
		Slightly warmer (<0.5)	Warmer (0.5–1.5)	Hotter (1.5–3.0)	Much hotter (>3.0)
Much drier	(<−15 %)	No evidence	No evidence	No evidence	No evidence
Drier	(−15 to −5 %)	No evidence	Unlikely (5 models)	No evidence	No evidence
Little change	(−5 to 5 %)	No evidence	Likely (17 models)	No evidence	No evidence
Wetter	(5 to 10 %)	No evidence	Very unlikely (2 models)	No evidence	No evidence
Much wetter	(>15 %)	No evidence	No evidence	No evidence	No evidence

Table 2 Average number of days of cattle heat stress (THI > 85) increase with global warming at 5 locations in South East Queensland

Location	No change	1 °C↑	2 °C↑
Esk	3	5	9
Gatton	9	**15**	**20**
Harrisville	7	**12**	**19**
Boonah	4	8	**12**
Rathdowney	2	4	6
Mean (SEQ)	4	8	**12**

Bold numbers represent numbers of days beyond that experienced from other locations

more familiar to them than the presentation of generalised climatic data. For example, a participant from Boonah could see that currently her cattle experience on average four heat stress days/year and that a 1 °C increase in average temperatures is projected to increase heat stress in Boonah to 8 days/year. In addition, she can readily envisage that the new average frequency of heat stress will be similar to the frequency currently experienced at Harrisville and Gatton. However, a 2 °C rise may lead to 12 heat stress days/year, a frequency not currently experienced in the SEQ region. Similarly, a participant at Gatton would need to identify locations outside SEQ to find a place where cattle currently experience an average of 12 heat stress days/year which is projected for a 1 °C increase in annual temperatures. Similar presentations were made for the impacts of 1 and 2 °C warming on mean daily pan evaporation and for the decrease in the number of frost days (not shown).

Adaptation options

We held a discussion to identify farmers' past responses to dealing with climate variability. We reminded participants that many of the elements of projected threats associated with climate change are already being observed, and that climate variability is such that they already experience extreme events and are probably managing for them. We asked each farmer to describe changes (climatic and other) that they had experienced over the last 10 or more years and how they have adapted their management of pastures and livestock to these changes. Quotes in this paper are identified using bracketed codes.

We explored the implications of climate change for the beef industry at a much broader scale through a presentation based on recent studies (Cobon et al. 2009; McKeon et al. 2009; Stokes et al. 2010). The presentation covered potential impacts of elements of climate change on the production system including pasture growth and quality, changes in botanical composition of pastures, implications for animal production, animal welfare, invasive species, pests and diseases. Summarised results were also presented of experiments on impact of elevated CO_2 concentration on plants; impact of higher evaporation; impact of higher minimum temperatures; and the impact of higher maximum temperature scenarios out to 2030.

Expected impacts of global warming on eastern Australia (based on Cobon et al. 2009) are elevated CO_2 (to 420–460 ppm), increased evaporation, higher minimum temperatures (fewer frosts), higher maximum temperatures (more days >35 °C), more droughts, increased storm intensity, decreased summer and winter rainfall and more wildfires.

Participants then identified their top threats and top opportunities arising from climate change and a list of actions that could take advantage of the opportunities and counter the threats. We recorded and summarised the responses on a whiteboard for viewing by all participants.

Adaptive capacity

The final session of the workshop allowed participants to self-assess their levels of adaptive capacity as representatives of the grazing industry in SEQ. The process undertaken was modified from the four step process described by Brown et al. (2010). In the first step, we gave the workshop participants a short presentation on rural livelihoods analysis and how an adaptive capacity index could be constructed using data from the Australian Bureau of Agricultural and Resource Economics for broadacre land managers (Nelson et al. 2010a, b). The key features were to demonstrate how indicators were used to show different elements of the five capitals, how these indicators and capitals could be nested, and to demonstrate how land managers in different areas have different levels of adaptive capacity. The data specific to the SEQ region were presented in comparison with data for Queensland and Australia as a whole.[6]

In the second step we went through each of the five capitals (human, social, natural, physical and financial capitals, see Brown et al. 2010) and asked the workshop participants to collectively identify indicators relevant for the grazing industry in their region. This involved a discussion about the potential indicators that could be used, and the alignment of these indicators with each of the five capitals. Participants were asked to justify why each indicator was important for managing climate change in the future for the grazing industry in SEQ.

In the third step we asked the participants to score each indicator on the extent to which they considered it to be supportive of adaptation to climate change. The scoring was based on Brown et al. (2010), where a scale from '0' to '5' was used, such that a score of '0' indicated that a particular indicator was not judged to be effectively supporting adaptation to climate change, through to '5' which indicated that a particular indicator was effectively supporting adaptation to climate change. The reasoning behind the selection of scores for each indicator was also captured. Responses were typed into a spreadsheet which was projected on to a screen for all to see. The facilitators continually checked with workshop participants to ensure the main points of the discussion were recorded.

We then ran a short moderation session (step 4) to review all of the indicators and scores to provide a reality check to ensure that the indicators which scored low or scored high seemed appropriate to the workshop participants. An overall picture of the balance between the capitals was presented by using a pentagram plot.

Results

Discussion on projections

In open discussion, graziers made a number of observations on their experience of changes in temperature, rainfall, or frost so far. Their perception of variability in rainfall emerged as the biggest issue. "I've been on this property for 13 years—and we've had three good years and seven pretty crook ones … You can have two floods and three droughts in the same year… You can have 6 months of drought and 1,000 mm of rain in a [single] year" [#8]. "I didn't realise how dry it was until I saw this season [a good rainfall distribution]—how tall the grass was supposed to grow" [#7]. "It's the way the rain fell this year and the weather [moderate evaporative conditions] we had with it" [#6].

Another focus of discussion was the incidence of frost which was highly variable between regions. One non-grazier participant had noticed a reduced incidence of frost over the last 20 years. This prompted a grazier [#1] to comment that the problem with cattle ticks is worse with reduced frost. Another grazier [#7] countered that it snowed last year at his place and another noted [#1] that there was "a doozy of a frost" in 2009.

Current adaptation practices

In response to the question, "Have you adapted your management of pastures/livestock to suit changed conditions?" graziers described a range of adaptations:

- Some were storing more water in dams to buffer runoff from extreme events and for use in dry periods—"I have put in a 20 mega litre 'Turkey Nest' dam so we can irrigate" [#5].
- Destocking in response to a dry season [#12].
- Looking for alternative feed sources such as different pasture plants better suited to the conditions. This was exemplified by the statement of one grazier [#7] that "The scrub was cleared 80 years ago. The Rhodes grass [*Chloris gayana*] died. Kikuyu [*Pennisetum clandestinum*] died, and was replaced with weeds on steep scrub country… Now I have more drought tolerant grasses, I have a new respect for native grasses."
- Changing livestock breeds. One grazier [#7] changed cattle breeds from Hereford to Brahmans but has responded to market signals by bringing in Angus cattle "which attract every insect there is" so he is now crossbreeding Angus into the Brahman herd—hoping to "end up with a composite for the climate and the market."
- Looking for alternative management strategies including a shift from set stocking to controlled grazing [#9 & #10], and a shift from hay making to preserving standing hay [#11 & #3].

Graziers also expressed concern about increased difficulty in controlling weeds in pastures and the appearance of new weeds (e.g. African love grass, *Eragrostis curvula*, and fireweed, *Senecio madagascariensis*): "They move in when other species are under stress. Then they never leave and nothing is being done [by government] about them" [#6]. Another grazier remarked "lantana [*Lantana camara*]

[6] Data were extracted from http://www.apsim.info/VulnerabilityAssessmentAustralia/VA15.htm.

is moving down [southward]. Is it adapting to climate?" [#2]. Similarly, graziers [#1 & #6] expressed concern regarding the management of livestock pests, especially a perceived increased difficulty of controlling cattle ticks.

Diversification was another strategy: "Four years ago we bought another property for growing lucerne [*Medicago sativa*] etc. to feed the cattle. We are overstocked on one property but can supply feed from other properties" [#5]. Furthermore, diversification in business enterprises has proven value: "My family also have an earthmoving business so it is easier/cheaper for them to do these developments than it might be for others… It makes the [grazing] business viable… We have diversified with enterprises and geographically" [#5].

The graziers were concerned about some social changes over the last decade, particularly the ageing population in the beef industry, and the subsequent need to find ways to make do with decreased labour inputs. Graziers also expressed their concern that the proliferation of 'lifestyle subdivisions' in previously rural areas has led to increases in land values beyond the intrinsic agricultural production value of the land, making land too expensive to buy for profitable expansion of agricultural activity. There is a feeling that newcomers and people from urban centres will dictate the future. Grazier #7: "I've been around here 30 years—population growth will be an issue and we won't be allowed to have things bellowing in the night. Population increase will increase demand for water—that's why we need dams". Grazier #1: "The focus is on city based policies not rural ones".

Future adaptation options

Workshop participants collectively considered the main opportunities and threats for their grazing industry and suggested responses to counteract them. The opportunities were directly relevant to climate change, focusing on changes within the grazing enterprise such as using different plant and livestock genetics better suited to changes in growing seasons, but also opportunities for alternative income streams. Perceived threats included difficulties in managing pasture quality including addressing dry-season feed gaps and weed management through increasing climate variability. Management of pests, particularly cattle ticks and parasites, was another area of concern (Table 3).

When asked to think about exploiting opportunities, participants' responses were aligned with the opportunities suggested in the adaptation literature, but offered a broader range of options including plant and animal genetics; increasing water storages on farm, changing pasture composition and grazing management and expanding markets e.g. niche markets and carbon trading. Many of the options for countering threats addressed increasing vigilance in monitoring pests and weeds, water use efficiency and the retention and further development of shelter belts and ground cover to retain soil moisture (Table 3).

Self-assessed adaptive capacity

Self-assessment of adaptive capacity provided greater context for whether graziers were able to act on the threats and opportunities highlighted above. Financial capital was rated as low (mean score = 1.8, on a 0–5 scale) and was thought to constrain graziers' ability to manage their industry for future climate change. The other capitals were rated as moderate: Human (3.0), Social (2.6), Natural (3.3) and Physical (2.7); and in general were thought to enable their ability to manage the grazing industry for future climate change.

Indicators of Financial capital that were particularly limiting graziers' ability to manage for climate change were *on-farm income/profitability* (score = 0), the *cost of land for diversification* (score = 1), and the *ability to raise capital* (score = 1; see "Appendix"). For Human capital the indicator limiting graziers' ability to manage for climate change was *attitude to change* (score = 2); indicators for Social capital were *over-regulation of community groups*, *speed and reliability of access to electronic information*, *changing social demographics* and *changing communication across social groups* (all scores = 2); the indicator for Natural capital was *access to water resources* (score = 2), and for Physical capital indicators were *water resources*, *size of enterprise* and *shade for stock* (all scores = 2; see Appendix).

The SEQ region has undergone major land use change in recent years with urban expansion, a trend which is expected to continue to 2031 (Queensland Treasury and Trade 2012). Some farmers involved in the workshop were managing farms that had been in the family for generations (130 years in one case). Therefore an overarching theme for participating graziers was that despite relatively good climatic conditions, soils, topography and access to market and good opportunities for off-farm income, there were significant pressures from urban encroachment and hobby (lifestyle) farmers. This affected the profile of the community such that there were perceived differences emerging in social outlook, existing knowledge of land management (the farmers' perception was that they have the knowledge and that the hobby farmers do not) and access and use of information, but also access to credit that may be required to act on potential changes to the enterprise. It also affected land values impacting on the ability of graziers to expand their enterprises or to diversify, which is a key adaptation strategy for this industry in other regions.

Discussion

Participants were in general agreement that the climate is changing and graziers have noticed and are responding to an increase in variability. Future projections indicate that annual rainfall may not change dramatically from current values. Historically, there was a small but significant ($p < 0.05$) positive trend (0.26 mm/year) in annual rainfall from 1910 to 1988 observed in the Lawes–Gatton region, and was associated with more rainy days and less intense rain events (Nicholls and Kariko 1993). However, graziers have noticed changes to seasonal rainfall variability, which is projected to change along with the intensity of extreme events which have been experienced by graziers in the region (e.g. frost, frequency and intensity of floods).

The graziers involved in this workshop appeared to be striving to develop farming systems that could cope with inter- and intra-annual rainfall variability, particularly to maintain pastures and to manage livestock effectively. Weeds were also an important issue, and were linked to grazing management and regeneration of pastures. Responses to variable water supply were mostly focused on building more or larger dams, even though one grazier [#7] observed that "We have 25 dams but 20 have been dry for the past 10 years", while responses to pasture issues included changing pasture and livestock species to hardier breeds and changing the grazing system from set-stocking to rotational grazing.

Graziers were able to provide numerous examples of how they have been modifying their management in response to increased climate variability. The shift to hardier cattle breeds, rotational grazing and a focus on maintaining and increasing perennial ground cover are initiatives that preserve natural resources and significantly increase resilience. The condition of the land was discussed as an important influencing factor; particularly degradation due to past management practices. Graziers recognised that improving land condition could be a best bet strategy to reduce vulnerability to climate change.

These initiatives are also consistent with options suggested in the scientific literature (see options based on Cobon et al. 2009). The actions undertaken by one farmer, to spread the water flow from high intensity rainfall events over the landscape, may well prove to be an effective adaptation. However, some of the other initiatives mentioned by graziers, in particular relying on more dams to manage for increased intensity of rainfall events and to store water for longer periods of time to cover the intervening dry periods, when considered at a catchment scale, are not likely to contribute to climate change adaptation in the longer term (Marshall et al. 2010).

Comments made in the breakout sessions focussed on what farmers could do as individuals to adapt to climate change. Responses were generally positive (natural and physical capitals), though when it came to invasive species graziers' opinion was that it was up to governments to act. The adaptive capacity component of the workshop teased out the financial and human capital issues and identified more barriers to adaptation while also identifying actions that the farming community could undertake.

The self-assessed factors that are enabling SEQ graziers to adapt are their high education levels and intellectual ability; their involvement in active industry and farmer groups; the topography and aspect of SEQ; the current (favourable) climate; and good access to markets (including roads and railways). The factors that are constraining their ability to adapt are mainly their low financial capital: the low on-farm income/profitability; the high cost of land required to achieve either diversification or economies of scale; and graziers' ability to raise capital for investment on farm. The high cost of land is a consequence of urban encroachment and of 'hobby-farmers' and 'life stylers' paying more for living in this attractive environment than the value of the land based on its agricultural production potential (Low Choy et al. 2007; Race et al. 2011). Keys et al. (2014) also identified that financial capital, but also social networks needed to be enhanced to improve adaptive capacity. Some of these factors were also identified by broadacre land managers in the Murray Darling Basin (Crimp et al. 2010). There are issues associated with resistance to change, most of which are described as social issues (Vanclay et al. 2009). Leith et al. (2012) identified that constraints to capacity were often perceived as externally imposed, whereas enablers were often local characteristics or regional organisations, communities and individuals.

Graziers' self-assessment of threats, opportunities and ability to address them allowed the research team to develop a classification framework for attributing elements of adaptive capacity to adaptation action at the various scales leading to implications for policy (Table 4). We grouped the indicators for adaptive capacity identified at the workshop against the scale of action required from paddock to industry or regional scale. We utilise the framework of Pelling (2011) to ascribe an adaptation type from resilience to transition to transformation and show a range of specific adaptations, which allowed us to consider some of the likely policy implications (discussed further below) and to show where both the enablers and barriers to adoption might lie. There are potential limits to adaptation; reflection on Table 4 suggests that low scoring indicators of adaptive capacity and various challenges exist for adaptation at all scales. For example, the on-farm income, profitability, ability to raise capital and the cost of land (all scored 0 or 1 on a 0–5 scale) might prevent further 'movement' along Pelling's (2011) resilience–transition–

Table 3 Grazier identified opportunities and threats for managing climate change in Southeast Queensland and options for exploiting and countering the opportunities and threats

Opportunities	Threats
Increased potential for plant growth and extended seasons	Increased dry conditions (length and dryness) from winter to spring—July–Oct
Decreased frost	Increased risks from weed and pest species—woody weeds, ticks and parasites
Consider plant species and stock bloodlines	Increased variability/extremes (e.g. storm intensity)
Diversify current practice—income stream and on-farm production	Increased maximum temperatures, increased evaporation from soils and from dams
Favour tropical legumes	Decrease in productive value of traditional feed sources e.g. temperate legumes
Better understanding of soils—sequestration—ground cover and soil organic carbon	
Exploiting opportunities	**Countering threats**
Choice of appropriate (fit for purpose) plant species and stock bloodlines. Experiment with different species including native pasture species	Monitor plants/stock
Increase water storage	Increase awareness and use of shade and shelter for livestock
Decreased frost—longer growing season	Choose more pest/disease-resistant strains/breeds of plants and animals
Advantageous marketing of seasonal produce (e.g. watermelons available before Christmas)	Change grazing management and fodder storage options e.g. potential for early storage/harvest resulting in two cuts per season
Manage cycle of growth: crops and pastures including fodder storage e.g. baling hay vs standing dry matter	Increase proactive weed/pest management, including quarantining of livestock, wash-down of machinery and increased chemical control
Explore other farming practice information: viability of the property; maximising production/capacity	Manage woody weeds
Explore carbon trading options	Change water management: efficiency; storage; reuse
	Reduce evaporation by improving soil cover and adding windbreaks

transformation path. This implies that additional policy support is probably required to enable adaptation at an enterprise scale or any degree of transitional or transformational change. Conversely, some indicators would facilitate movement along the transition-transformation path but still require policy support across various scales (see below). These indicators included education level, topography and aspect, current favourable climate, active farmer/industry groups, underground resources, access to markets and roads and railways (all scored 4 on the 0–5 scale).

The scenarios presented for 2030 at the workshop indicate participants' focus on gradual adaptation rather than transformational change. This result is unsurprising and has been recorded elsewhere (see Duru et al. 2012). Exposing farmers to the information presented in this workshop may facilitate a longer term view (Duru et al. 2012). Follow up workshops or interviews would help to determine this. In the absence of this knowledge a longer term view might call for transformational change but given the barriers to adaptation identified at the workshop, and the lack of an urgent imperative for transformational change in the near to medium future it would be unrealistic to expect imminent transformational change without strong policy intervention. If transformational enterprise change will be required to overcome some of the barriers identified it is important to consider the degree of adaptation that would be required to achieve such change. Another avenue to explore is to what extent generalised and institutionalised trust are important in how farmers might diversify livelihood strategies or further enhance production activities (e.g. Groenewald and Bulte 2013).

Policy implications

This study draws attention to a number of policy issues that require closer attention. Grazing is a major land use in SEQ and good land stewardship is critical to maintain the regional natural resource base for private and public benefit. The devastating flood of January 2011 dramatically illustrated the on-farm and off-farm consequences of insufficient vegetation cover to protect steeper country from erosion. Grazing also generates a gross annual income of about AU$150 million but it is not a profitable industry. Graziers struggle to generate sufficient income from beef production to provide a living wage to support a family. Off farm income and business ventures are necessary to keep graziers on the land. Diversification, changing enterprise mix to better suit the land area available, and niche marketing may improve farm finances. However, the keys to survival for broadacre farmers in other parts of Australia such as specialization and economies of scale, are limited

Table 4 A classification framework for attributing elements of adaptive capacity to adaptation action at the various scales and level of change they enable

Scale	Adaptation type	Adaptation options	Indicators of adaptive capacity	Policy implications
Paddock (individual)	Resilience	Alternative pasture and livestock management practices (e.g. monitor plants/stock, take advantage of longer seasons, cut or store hay, manage standing vegetation)	❷ Accessing information ❷ Water access ❷ Water resources ❸ Vegetation ❸ Storage capacity for fodder ❹ Education level/intellectual ability	Increase access to knowledge (MLA/Ag-Force) and funding to implement change (CBNRM support) Short term planning horizon
Farming system (individual)	Resilience–Transition	On-farm production (e.g. change plant and livestock species, provide more shade/shelter/windbreaks, improve groundcover)	⓿ On-farm income/profitability ❷ Attitude to change ❷ Shade for stock ❸ Soil health and type ❸ Off-farm income ❹ Topography & aspect	Provide training and support to increase awareness, support farm business planning and reduce perceived risk associated with change (MLA/Ag-Force/CBNRM)
Enterprise (individual)	Transition	Enterprise mix (e.g. diversification across multiple farm locations, new agricultural enterprises) Livelihood mix Better ways to utilise production capacity Question viability of production on your land	❶ Cost of land (diversification) ❶ Ability to raise capital ❷ Size of enterprise ❸ Physical ability/health ❸ Age ❹ Current favourable climate	Promote farm business planning, retirement/succession planning, whole farm plans, long-term planning Catchment level infrastructure planning (State Government initiatives) Long term planning horizon
Farming Community Action	Transition	Industry mix Manage woody weeds and other invasive species Marketing of products	❷ Community groups ❸ Geographic diversity ❹ Active industry/farmer groups	Peer support information sharing focusing on supporting adaptation (use existing farmer groups) Strengthen extension services to better link with formal/informal farmer networks (MLA/Ag-Force/CBNRMs)
Industry and regional	Transformation	Regional policy National policy	❷ Changing social demographic/communication across group ❸ New polluting industries ❹ Underground resources ❹ Access to markets (roads & railways) ❹ Roads and railways	Inclusive of other landholders (e.g. hobby farmers)—(CBNRMs, local clubs and societies) Complementary regional planning initiatives (Local/State Government planning)

Adaptation type is based on Pelling (2011). The indicators of adaptive capacity have been sorted by the score obtained at the workshop (scores ranged from '0' which indicated that a particular indicator was not judged to be effectively supporting adaptation to climate change, through to '5' which indicated that a particular indicator was effectively supporting adaptation to climate change). MLA is the Meat and Livestock Australia, a research and development agency, Ag-Force is a farmer/industry association and CBNRM are community based natural resource management agencies (such as the Catchment Management Agencies) responsible for on-ground natural resource management

for SEQ graziers because of high land values due to urban encroachment. This urbanisation trend is set to continue into the foreseeable future (Low Choy et al. 2007; Queensland Treasury and Trade 2012) and it is therefore necessary that any land stewardship policy be actively inclusive of all SEQ landholders.

Proximity to a major urban centre has meant that SEQ farmers are competing with rural 'life stylers' for the appropriation and management of expensive land. This is a phenomena that is occurring throughout the world (e.g., Abrams and Bliss 2013), with new non-farming landholders having different motivations and values (Mendham et al. 2012). This limits expansion of the existing enterprise and exacerbates issues such as weed and pest management. Recognising that urban encroachment of SEQ is inevitable; policy intervention is required if good natural resource management, rural amenity, and food and fibre production close to urban population and markets are deemed to be desirable. The information compiled from the workshop informs what constraints are there and what opportunities are available to realise potential outcomes for sustainable food production and for healthy natural resources under climate change.

Securing water resources and their management on farm was identified as a constraint to adaptation that would take advantage of a longer but warmer and possibly drier growing period. There were also indications that graziers are finding ways of getting around (mal-adapting to) policy settings that are designed to manage water resources at a regional scale. This issue is likely to continue to challenge policy makers into the future, particularly with potential increased demand from urban encroachment and changing enterprises (e.g., hobby farms, vineyards, turf farms; Low Choy et al. 2007), so it is essential that such policy take into account climate change and be resilient in the face of extreme events. Lessons will need to be learned from the floods that devastated SEQ in January 2011.

A refinement of actions to improve performance (e.g., resilience; see Pelling 2011) can be addressed by increasing the knowledge base of individuals through training and support for short-term planning. Research and extension agencies can help identify effective adaptation options especially through applying existing knowledge in more effective and innovative ways (Marshall et al. 2010). Transformational large scale adaptations require long-term farm business planning including succession and retirement plans supported by CBNRM agencies and regional and State Governments.

Policies to enable adaptation traverse three scales (Table 4). (1) At an *individual level* this would include input from peer support groups (e.g. existing farmer groups), and provision of extension materials (Industry/CBNRM/State Government). This is in alignment with the view of Adger et al. (2009) who contend that social and individual factors limit adaptation action. (2) At the *industry level* (adaptation collectively driven by industry) this would include the expansion of research, development and extension service networks to support change on farm [grazing industry research and development organisation (MLA[7])/private consultants/farmer and industry associations (Ag-Force)/CBNRMs]. (3) At the *government level* (where there is a case for public intervention) this would include regional planning initiatives that support agricultural enterprises, natural resource management and ecosystem service provision and rural community development (Local and State governments/CBNRMs). The potential role of government increases as options move from resilience through transition towards transformational (Table 4). Improvement in relations across tiers of government and farming communities should improve social capital (Brown et al. 2012).

Conclusion

This article asked how we can incorporate producer knowledge to assess the vulnerability of the grazing industry to climate change and to identify some practical adaptation options and what can be done to overcome constraints to adaptation. Our study moved beyond technical considerations of adaptation for the graziers and demonstrated how the rural livelihood framework could be used to determine at a regional scale the vulnerability of an agricultural industry to climate change, to help make farmers tacit knowledge explicit, and how to link grazier perspectives with researchers and the need for policy interventions in a highly complex and rapidly changing region. Even though there were only 12 cattle graziers involved in the workshop (out of 20 participants in total), all participants were well informed and engaged, and they felt they adequately represented graziers from the SEQ region. The use of the framework contributed new insights into the adaptive capacity of the SEQ grazing industry and reinforced insights gained from discussions to provide a consistent and nuanced understanding of the industry's vulnerability to climate change and of the challenges that this presents to individuals and to good governance. Participants identified that the climate is already changing and graziers are already responding to increased climate variability, however, it was necessary to have locally-relevant climate projections to facilitate a practical discussion about future issues. The factors enabling adaptation were high education and intellectual ability, involvement in active industry and farmer groups, the topography and aspect of SEQ, current favourable climate and good access to markets, but these were offset by the constraints of low on-farm income/profitability, high cost of land for diversification, and ability to raise capital for investment on farm (all related to financial capital). Policy needs to support good natural resource management, rural amenity, and food and fibre production close to urban population and markets in the face of urban encroachment. At this stage, minor adjustments to allow adaptation appears to be sufficient, but further research is required to examine how further movement along the resilience–transition–transformation scale could occur, such as described by Sinclair et al. (2014). Further research could focus on repeating the process over time and to look at changes in response to different drivers (e.g., Jacobs and Brown 2014). This process could be easily adapted for use in other regions and for other industries.

[7] Meat and Livestock Australia (MLA), an industry research and development corporation which delivers marketing and research and development services for Australia's cattle, sheep and goat producers.

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Appendix

See Table 5.

Table 5 Summary of indicators selected, scores given by participants, importance of indicators and justification of the scores

Capital/indicator	Score	Pressures/importance of indicator	Justification of score
Human capital (skills, health and education)			
Attitude to change	2	Attitude to change is important in the context of graziers & managing for climate change	For industry in general is relatively low. There are lag times & depends on what change is being proposed
Physical ability/health	3	Access to labour is low, so if work needs doing, the grazier needs to do it, but this is affected by physical ability & overall health	There are few labour resources graziers can call on, so they have to do themselves. Mental health fluctuates with seasons
Age	3	Mean age increasing, fewer younger people returning to farming. Not sure what impact this has for adapting to climate change. Depends on long-term profitability of farming (not necessarily related to climate change)	There are some younger farmers around & the average age at livestock sales is 45–50. Doesn't prevent people of any age to adapt to climate change
Education level/ intellectual ability	4	Knowledge & education can help graziers to manage for climate change (not necessarily academic qualifications). Farmer's ability to adapt depends on knowledge, (confidence in decision making) & resourcefulness	Reasonably good experience for these farmers. Information is available, but it is how it is applied
Social capital (family, community and other social networks and services)			
Community groups	2	Community groups are important as support network to cope with a range of drivers	There are problems with over regulation of community groups—not for fun anymore
Accessing information—electronic (inc. TV)	2	Effective communication is important, particularly through a range of electronic media types	Despite closeness to Brisbane, there is poor TV reception & poor to non-existent mobile coverage in some areas. Poor access to expertise in some areas
Changing social demographic/ communication across groups	2	Issue of different requirement for locals versus weekenders & how they perceive problems & act on information	There is a widening gap between locals & weekenders which is changing the dynamics of the community which affects information & ability to adapt
New/polluting industries	3	New industries coming into region impacting some groups but not others	Will impact on some but not others
Active industry groups/farmer groups	4	There is a good network of farmers linked with extension services sharing advice	Information sharing fairly good, but not sure where to go for some information & there are some problems with extension services
Natural capital (productivity of land, water and biological resources)			
Water access (dam, bore, river) & quality	2	Access to water (quantity & quality) is needed to take advantage of longer growing period	Changes to legislation may constrain how graziers can do this with longer dry spells
Soil health & type	3	Good soils are needed to manage for climate change. Need to manage grazing pressure & erosion, & improve soils anyway. Some farms at an advantage by having better soil	Some areas overgrazed. Soil management for changing land uses is an issue
Vegetation	3	Management of vegetation seen as important to maintain ground cover & trees for shelter	Could do more to manage pastures & trees & shelter & soil carbon content

Table 5 continued

Capital/indicator	Score	Pressures/importance of indicator	Justification of score
Topography & aspect	4	Opportunities exist for some farmers because they have a range of topography & aspect to store water	Relatively good opportunities for some farmers, but not for all
Underground resources	4	Mining activities might mean that graziers lose their ability to manage their land, but it does not stop them from adapting	There is nothing stopping graziers from adapting
Current climate	4	Climate largely drives financial returns, but will affect enterprise mix in the future	Reasonably good flexibility to manage for climate
Physical capital (*infrastructure*, *equipment and breeding resources*)			
Water resources/ Reservoirs covered	2	Need to explore options to better manage water resources	More needs to be done to improve this
Size of enterprise	2	Larger land is required to remain viable, but is expensive	Cost of land is expensive & may prevent acquisition of larger land areas
Shade for stock	2	Sheds & other infrastructure required to protect stock	More sheds & other infrastructure are required
Storage capacity (fodder)	3	Need to explore storage options for fodder	More could be done to better manage/conserve fodder
Geographic diversity (land)	3	Spread the risk of climate change across multiple locations	Cost of land is expensive & may prevent acquisition of larger land areas
Roads & railways	4	Access to market & resources/supplies is important. SEQ relatively well off for access	Access good, close to Brisbane
Financial capital (*access to income*, *savings and credit*)			
On-farm income/ profitability	0	Little income from farm. High costs	Very poor profitability. Can't sell because lose money
Cost of land (diversification)	1	Land values going up because of population pressures & location to Brisbane	Cost of land is high, so unable to diversify into other areas
Ability to raise capital	1	Low ability to raise capital means graziers are unable to purchase new equipment or good quality stock	Poor ability to raise capital, so constrain ability to invest in new equipment
Off-farm income	3	Farmers diversifying & changing the way properties are being managed. Location allows good opportunities for off-farm income	Reasonably good opportunities for off-farm income, but down side is cannot afford labour or off-farm income insufficient to be able to make a change
Access to markets	4	There is good access to markets, but physical infrastructure could still be improved	Access is good, but prices need to remain high to continue to produce

Scores were rated from 0 to 5, with 0 considered as constraining and 5 considered as enabling

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