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Abstract: Resource-dependent industries are particularly vulnerable to climate change, and their ability to adapt will be as critical to society as to the natural systems upon which they rely. More than ever, resource-users will need to anticipate, and prepare for, climate-related changes, and institutions will need to be particularly supportive, if primary resource industries and the extended social systems dependent on them are to be sustained. I examine the capacity of cattle-graziers in Australia to cope and adapt to climate variability as a precursor for understanding their vulnerability to climate change by assessing: (i) their perception of risk, (ii) their capacity to plan, learn and reorganise (iii) their proximity to the thresholds of coping, and (iv) their level of interest in adapting to change. Graziers perceived themselves to be resilient to climate variability in their perceptions of climate risk, reorganising capacity, coping, and interest in adapting. Their dependency on the grazing resource and use of seasonal climate forecasts were significant influences, suggesting that resilience could be enhanced. Facilitated collaborative learning amongst graziers and other stakeholders may assist to develop strategic skills, increasing climate awareness, developing financial security and adopt climate tools such as seasonal climate forecasts. Enhanced strategies for coping with climate variability will provide a way for encouraging gradual, incremental adjustments for climate adaptation.

18 September 2009

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Dear Professors Adger, Brown and Hulme,

I am most grateful for the comments from the reviewers and for the opportunity to address their concerns. Please find attached a revised manuscript and a report that addresses reviewer concerns

With best regards,

Nadine Marshall

***Title page (with author details, acknowledgements or affiliations)**

Understanding social resilience to climate variability primary enterprises and industries

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Nadine Marshall
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18 September 2009

Dear Professors Adger, Brown and Hulme,

I most sincerely appreciate the detailed comments made by the reviewers and the opportunity to respond to their concerns. Following, I address each concern in turn;

Reviewer 1.

Something missing: "A description of each dimension can be found elsewhere (xxx)" (and elswhere)

The sentence has been replaced with: A description of each dimension can be found in Marshall and Marshall (2007).

This seems rather simplistic; "Likely uptake was measured as the response to the single statement, "I am definitely interested in using seasonal climate forecasts in my everyday working life"." This is uptake of a single technology. Why was their a focus on only one tool? This seems simplistic and reduces the value of the paper, but there is nothing that can be done at this point. ALSO: spell out clearly somewhere what the overall response to "uptake of seasonal climate forecasts" was - only in the discussion do I find that most did not want to uptake this technology (i.e. present this result in the "results")

Results now commence with a section entitled, "Likely uptake of seasonal climate forecasts". The text beneath it reads: Forty percent of graziers were highly interested in using seasonal climate forecasts in their everyday working life.

Table 1: Clarify which dimension of the table is related to dependency and which is related to social resilience.
Done

Table 2: Spell out SCF.
Done

Results - well described apart from the lack of mention of the degree to which respondents were positive about uptake of the forecasting tool (see above).
Done

Discussion

This is mostly good.

However, I find it too much of a push for the forecasting tool. Without significant evidence of its usefulness. For example "Results from this study suggest that seasonal climate forecasts can significantly enhance social resilience through enhancing the perception of risk, assisting with planning, learning and reorganising, and developing an interest in adapting to seasonal variability and ultimately climate change". This suggests causality where there may be none. The question about "interest in using seasonal climate forecasts" not about whether they actually used the climate forecasts and this led to, e.g. better perceptions of risks. I could argue that those people who are highly risk averse and who have advanced perceptions about risk are more likely to uptake the technology, i.e. the causality is the other way around.
I agree with this sentiment. I have deleted the mentioned sentence and edited the paragraph so that it puts less emphasis on the importance of SCFs, and rather on SCFs as a tool to assist graziers

The last paragraph gives a lot of attention to "collaborative learning" - this paper is not about collaborative learning so that paragraph should be substantially reduced.
The last paragraph has been reduced substantially to that less emphasis is placed on the concept of collaborative learning

Reviewer #2: Global Environmental Change

Manuscript: GEC-D-09-00022

Title: Understanding social resilience to climate variability in a resource-dependent industry: foundations for climate adaptation

Summary
This is a research article which sets out to examine the adaptive capacity of cattle-graziers in the Upper Burdekin 'dry tropics' region in north eastern Queensland to cope and adapt to climate variability, as a way to understand how they cope with vulnerability to climate change. The paper uses a framework developed by Marshall and Marshall (2007) previously tested in the context of commercial fishers in the Great Barrier Reef, Australia. While the paper is rich in empirical understanding there are several places throughout that could be strengthened to make this a more robust contribution. The paper is recommend for publication subsequent to revisions.

Specific strengths and weaknesses

Overall this is an interesting piece of empirical work in an arena that often fails to provide adequate examples from practice. The paper's strengths and weaknesses are outlined below. Followed by some detailed comments and suggestions.

To start with, I felt that the title of the paper could be amended to the 'Understanding social resilience to climate variability in primary enterprises and industries.' as it stands the attention to resource-dependence detracts the reader from the focus on industries and enterprises and misses the explicit attention to how primary industries will experience challenges of global climate change.
Done.

I felt that the abstract could be strengthened by pointing out how the capacity of cattle-graziers to cope and adapt is measured in the paper.
The abstract now contains a description of how adaptive capacity was measured. Some other minor edits are also made.

In the introduction the review of the literature is fine and sets out the basic issues. However, the introduction does not raise any research questions and does not set out what the paper aims to cover or how it aims to do that. The paper would be strengthened by clear sign posting.
The last paragraph of the introduction now reads:
In sum, the aims of this study were to examine the capacity of cattle-graziers to cope and adapt to climate variability as a precursor for understanding their vulnerability to climate change and to test whether their capacity is influenced by the use of seasonal climate forecasts and/or their level of dependency on the grazing resource.

The methods section requires some work to detail how the design fits with the research and how the response to the single statement fits into the framework and assessment. Why this statement?

I have included 2 additional paragraphs in the methods section which read: Whether the uptake of climate tools such as seasonal climate forecasts is likely to occur was assessed by measuring the response to the single statement, "I am definitely interested in using seasonal climate forecasts in my everyday working life". Graziers were also asked whether they use other climate tools such as the southern oscillation index, the Kelvin Wave, the Walker Cycle, synoptic charts or satellite cloud images.
In order to assess the influence of resource dependency and uptake of seasonal climate forecasts (as an example of a climate tool) on adaptive capacity, Pearson correlations were made between dimensions of adaptive capacity and dimensions of resource dependency and between dimensions of adaptive capacity and likely uptake.

The paper also has the potential to make more of explaining the relationship between 'social resilience to climate variability'. In this regard there are two key issues that require consideration. One is the relevance of extrapolating the findings from this one region in north eastern Queensland to graziers to the general. It is suggested that throughout the paper the authors be specific to the fact that they are talking about graziers in the context of Burdekin catchment Queensland Australia. Another point of caution relates to the discussion, and generalizing lessons about learning and adaptive capacity. I felt that the authors could reflect more critically on the fact that the literature cited grapples with assumptions about how to go about building adaptive capacity. For example, the paper refers to "Building capacity through collaborative learning can be facilitated by government organisations charged with managing natural resources or industry based associations or
natural resource management organisations and local community groups (Schusler et al. 2003, Folke et al. 2005)." Yet such statements/assumptions have still to be proven by evidence-based research.
Throughout the discussion, I have made sure that I have referred to graziers in the Dalrymple Shire rather than to graziers generally. Secondly, and as recommended by reviewer #1, I have placed less emphasis on collaborative learning.

Schusler et al. 2003 is also missing from the bibliography.
The text for this reference has been removed.

Finally, the paper should also provide some reflections on the contributions of the method, both strengths and weaknesses, used in this paper to assess social resilience to climate variability.

The concluding paragraph of the paper now reads:
The capacity of primary enterprises and industries to cope and adapt to climate change can be influenced. This research has provided one method to assess the significance of factors that potentially are important. More effort needs to be invested into identifying and testing other influences if the capacity of primary enterprises and industries is to be enhanced. As the concentration of greenhouse gases increases in our atmosphere, so does the urgency with which adaptation must occur. Given that it is not possible to directly control the climate, developing strategies to support resilience and adaptation in the face of uncertainty are perhaps the only current options that primary enterprises and industries have.

Detailed comments and suggestions

Introduction, para 2: Whilst other approaches are available (Hodge, 1997, Brunckhorst, 2002)
Unclear what there other approaches are
Unclear why 'socio-ecological' is in quotations
The quotations have been removed. The sentence has been expanded to: Whilst other approaches are available such as those used in the sustainability sciences (Hodge, 1997, Brunckhorst, 2002), the resilience-based approach offers a systematic thinking for understanding the adaptation process.

Disciplines such as Social Impact Assessment research
Is SIA a discipline?
No. The discipline reference has been removed.

Why are Armitage et al., 2008, Olsson et al., 2004a cited in the context of adaptation to climate change? Their work focuses more on ecosystems and management and governance of ecosystems. How does this extend to the context of climate change?
The references are not meant to reflect climate change but rather the characterisitics needed for adaptation. I have expanded this sentence to be:
Like developing resilience in systems, resource users must be politically, culturally and financially supported and given the opportunity to be flexible, plan, experiment and learn if they are to effectively adapt to climate change and climate-driven policy initiatives (Armitage et al., 2008, Olsson et al., 2004a).

Adaptive capacity can be influenced (Acosta-Michlik et al., 2008, Enfors and Gordon, 2008, Ostrom, 2008) - sentence ends abruptly.
This sentence now reads: Adaptive capacity is a quality or process that can be influenced

Methods

Possible biases in asking the DPI and the NRMs to discuss the research with local people?
This sentence was deleted.

What do you base the estimated 120-130 families on?
The sentence now reads: There are around 120-130 grazing families that live and work on the 230 properties within the region (many properties are owned by the same

grazing family) so that results from this study represent at least 77% of the region (Reimer et al. 2003).

Why 100 graziers? What statistical relevance?
A sentence has been added: One-hundred graziers were interviewed in order to capture the range of social variability within the region; which was completely unknown prior to the research.

Analysis

How can you qualify they respondents felt positive? E.g. suggesting that they felt positive about the future - could it be that they are simply pragmatic about the future instead of positive? On what basis make this assumption?
Actually – the word positive is simply a description of whether graziers responded to a statement as a 1 or a 2, rather than a 3 or a 4. Bit clunky, I know. I am not meaning to make a judgement on whether graziers are positive or pragmatic – but rather whether they agree or disagree with each statement.

Style

Overall some sloppy writing style listed as follows:

Some discrepancy in the use of commas throughout, e.g. between McKeon et al., 2000, Johnston et al., 2000 and Stokes et al. 2004, Stokes et al. 2007).
Apologies. I have endless problems with saving formatting changes with my 'Endnote' bibliography! Hopefully all is well now.

Why quotations in places e.g. "the yellow pages"
Quotations have been removed here and from "dry tropics".

Missing references in several places, e.g. (xxx) (xxxx forthcoming).
Corrected.

Some references cited twice in bibliography, with different authors
Marshall, N. A. & Gordon, I. J. submitted. Why are graziers reluctant to use innovations to enhance their resilience to climate change in rangelands? . submitted to Global Environmental Change.
Marshall, N. A., Gordon, I. J. & Ash, A. J. in review. Why are Graziers Reluctant to Use Innovations to Enhance their Resilience to Climate Change in Rangelands? . submitted to Global Environmental Change.
These should be corrected now.

I hope that my responses are satisfactory. Please let me know if I can improve on them in any way.

Highest regards,
Nadine

Understanding social resilience to climate variability in primary enterprises and industries

Abstract

Resource-dependent industries are particularly vulnerable to climate change, and their ability to adapt will be as critical to society as to the natural systems upon which they rely. More than ever, resource-users will need to anticipate, and prepare for, climate-related changes, and institutions will need to be particularly supportive, if resource industries and the extended social systems dependent on them are to be sustained. I examine the capacity of cattle-graziers in Australia to cope and adapt to climate variability as a precursor for understanding their vulnerability to climate change by assessing: (i) their perception of risk, (ii) their capacity to plan, learn and reorganise (iii) their proximity to the thresholds of coping, and (iv) their level of interest in adapting to change. Graziers perceived themselves to be resilient to climate variability in their perceptions of climate risk, reorganising capacity, coping, and interest in adapting. Their dependency on the grazing resource and use of seasonal climate forecasts were significant influences, suggesting that resilience could be enhanced. Facilitated collaborative learning amongst graziers and other stakeholders may assist to develop strategic skills, increasing climate awareness, developing financial security and adopt climate tools such as seasonal climate forecasts. Enhanced strategies for coping with climate variability will provide a way for encouraging gradual, incremental adjustments for climate adaptation.

Key words: climate change, adaptive capacity, adoption, decision-making, seasonal climate forecasts, vulnerability

1. Introduction

The resilience and adaptive capacity of resource-dependent industries has never been more important to assess, influence and monitor. Climate predictions suggest that the scale and rate of change driven by increases in concentration of greenhouse gases in the atmosphere is unprecedented in human history, and will significantly – and in many cases dramatically – alter the accessibility and quality of natural resources (Dessai et al., 2007, Liverman, 2008, IPCC, 2007). Primary enterprises and industries, which include the sectors of agriculture, forestry, fisheries and mining, are highly vulnerable to climate change because of their dependency on climate-sensitive natural resources for their prosperity and sustainability (Zamani et al., 2006). Specifically, primary enterprises are expected to contend with more frequent climate crises (such as drought and flood), environmental degradation (such as eroding soils and limited production during drought periods), cultural change (such as implementing new practices or using climate technology) and inevitable climate-related regulatory change. These stressors occur against an existing backdrop of conventional drivers including economic, biophysical, institutional, cultural and political pressures. Thus, the capacity of resource-dependent enterprises to cope and adapt with the compounding influence of climate change is largely uncertain (Stokes and Howden, 2009, Dessai et al., 2007). More than ever, resource-users will need to anticipate, and prepare for, each climate-related challenge, and institutions will need to be particularly supportive, if resource industries and the extended social systems dependent on them are to be sustained.

A strategy for industries, communities and policy-makers to adequately support the capacity of resource-users to cope and adapt to climate change, is through maintaining the properties that confer resilience (Gunderson et al., 2002, Gunderson, 1999, Kates et al., 2000, Walker et al., 2002). This ‘resilience-based’ approach is useful for guiding and supporting more inclusive and effective approaches to the management of ecosystems and the dependent societies (Ludwig et al., 1997, Berkes and Folke, 1998, Levin et al., 1998). Whilst other approaches are available such as those used in the sustainability sciences (Hodge, 1997, Brunckhorst, 2002), the resilience-based approach offers a systematic thinking for understanding the adaptation process. In sum, the basis of resilience theory is that social and ecological (socio-ecological) systems are intrinsically coupled and constantly face change; the outcomes of which are inherently unpredictable.

This thinking is different to other approaches such as Social Impact Assessment research; recognising and describing vulnerability is a core goal (Becker and Vanclay, 2003, Fenton et

al., 2003). Resilience theory has challenged how we view and manage our natural systems and places great emphasis on avoiding stability and on recognising the complexity and dynamic nature of socio-ecological adaptive systems (Gallopín, 2006, Colding et al., 2004, Walker et al., 2004, Acosta-Michlik and Espaldon, 2008). Where 'sustainable yields' or quotas have been set, natural resources and dependent social systems have collapsed or are close to it (Milich, 1999, Jackson et al., 2001, Ayensu et al., 1999, MacKenzie, 2003). In the same way that resources cannot be harvested according to set limits and must be managed fluidly through monitoring, feedbacks, learning and adaptation (Berkes and Folke, 1998, Ludwig et al., 1997), resource-users cannot be made to change their behaviour and become 'climate-adaptable'. Like developing resilience in systems, resource users must be politically, culturally and financially supported and given the opportunity to be flexible, plan, experiment and learn if they are to effectively adapt to climate change and climate-driven policy initiatives (Armitage et al., 2008, Olsson et al., 2004a).

The resilience-based approach is particularly apt for managing the impacts of climate change since climate predictions are inherently uncertain (Dessai et al., 2007, Mander et al., 2007). Managing for climate resilience is a means by which communities and resource managers can design strategies that allow both social and ecological systems to cope with climate uncertainty and adapt (Adger, 2006, Dessai and Hulme, 2007, Smith, 1997). Through the maintenance of properties that can confer resilience, the sustainability of natural resources and the social systems dependent upon them is not only possible but essential for the prosperous development of society (Lane and Rickson, 1997, Gunderson, 2004, Kates et al., 2000, Levin et al., 1998). Through 'managing for climate resilience', resource-dependent industries will move towards possessing the necessary 'pre-conditions' for successfully incorporating, and adapting to, climate change events and processes.

Adaptive capacity, a term from anthropology, is a crucial component of resilient systems that describes the necessary 'pre-conditions' for adapting to change (Gallopín, 2006, Grothmann and Patt, 2005, Janssen and Ostrom, 2006, Adger et al., 2005, Pielke Jr, 1998). It refers to the ability of individuals or communities to adapt to adversity and stressful life events by 'reorganising' through networks or institutions that learn, store knowledge and experience and are creative, flexible and novel in their approach to problem solving (Vayda and McCay, 1975, McCay, 1981, Sonn and Fisher, 1998). It is enhanced by learning, the flexibility to experiment and adopt novel solutions, and the ability to respond generally to a broad range of challenges (Levin et al., 1998, Gunderson, 2000). In sum, it refers to the capacity of individuals, communities, industries or nations to proactively or reactively cope and adapt to adverse life-events such as climate change (Nelson et al., 2007a). Social scientists have

accordingly developed tools to assess adaptive capacity and the implications for social resilience across a range of spatial and temporal scales (Adger et al., 2005, Marshall, 2008, Berkes and Jolly, 2001, Abel and Langston, 2001). However, while there have been important advances in operationalising the concepts of resilience and adaptive capacity for resource-dependent industries, there remain few examples where these properties have been evaluated as a basis for adaptation planning (Liu et al., 2008, Smit and Wandel, 2006, Vogel, 2006).

I use the cattle grazing industry in Australia to illustrate how a resilience-approach can provide vital information about the adaptive capacity of resource-users. Grazing lands, or rangelands, are a variably productive and mostly socially remote landscape representing some 33% of the world's terrestrial landscapes (Stafford Smith et al., 2007). Graziers, like other resource-users, must contend with variability in the climate each season and an already harsh environment (Hobbs et al., 2008). Climate variability is a challenging phenomenon that requires graziers to make appropriate management decisions in the face of uncertainty (McKeon et al., 1990, Clewett et al., 1991, Smithers and Smit, 1997). Success not only depends on maximising productivity during any one season, but also on minimising impact on the future ability of the land to produce (McKeon et al., 2004). If stocking rates are too high at the onset of drought, for example, soil sustainability will be diminished and the productivity of future years will be impacted (Watson, 2004, Watson, 2003). Graziers that can anticipate or effectively react to climate extremes are more likely to adapt to new climate conditions. An aim of this study is to evaluate the adaptive capacity of cattle graziers in the Australian rangelands.

Adaptive capacity is a quality or process that can be influenced (Acosta-Michlik et al., 2008, Enfors and Gordon, 2008, Ostrom, 2008). Seasonal climate forecasts are an example of a supportive technology that can, with variable accuracy, provide probabilistic information about future climate for a period of three to twelve months (Ash et al., 2007a, Jones et al., 2000, Tompkins and Adger, 2005). Climate technology may be able to assist graziers to minimise losses in drought years and take advantage of favourable seasons (Hayman et al., 2007, Salinger et al., 2005, Hansen, 2002, Eto, 2003, Moss, 2007). Knowing when to alter stocking rates, when to supplement feeding, when to agist, when to burn, when to manage weeds and when to alter water supplies, for example, should differentiate between those graziers likely to be successful and those that are not. In this study I look at how the use of seasonal climate forecasts can influence (or is correlated with) social resilience to climate variability (Patt and Gwata, 2002). Graziers that are likely to adopt seasonal climate forecasts are hypothesised to be resilient to climate variability and/or conversely, graziers that are more

resilient are more likely to use potentially beneficial technology such as seasonal climate forecasts.

Adaptive capacity can also be influenced by the nature and strength of the relationship that people have with the environment that they depend upon for income and everyday living (Force et al., 1993, Bailey and Pomeroy, 1996, Krannich and Zollinger, 1997). Resource-dependent communities such as cattle-grazing communities are more likely to be vulnerable to climate change since climate change is likely to significantly affect the grazing resource and the people dependent on it. However, resource dependency is a complex relationship since it has social, economic and environmental components (Jones, 2002). Graziers with higher dependency on the resource, on all dimensions, are hypothesised to be less resilient to climate variability (Eakin and Bojórquez-Tapia, 2008).

In sum, the aims of this study were to examine the capacity of cattle-graziers to cope and adapt to climate variability as a precursor for understanding their vulnerability to climate change and to test whether their capacity is influenced by the use of seasonal climate forecasts and/or their level of dependency on the grazing resource.

2. Methods

Frameworks for assessing social resilience, resource dependency and likely uptake of climate technology, and research design

The framework for assessing the capacity to cope and adapt in this study is based on Marshall and Marshall (2007) and comprises four key characteristics: (i) the perception of risk associated with change, (ii) the ability to plan, learn and reorganise (iii) the proximity to the thresholds of coping and (iv) the level of interest in change. These characteristics were developed on the basis of the resilience and social science literatures, and were tested on 100 commercial fishers in the Great Barrier Reef, Australia (Marshall, 2008, Marshall and Marshall, 2007). The framework focused on the individual as the main unit of analysis. In this study (as in many others), the individual represents an important source of resilience across other scales (Adger, 2000, Vincent, 2007). Measuring these dimensions relies on resource-users describing their perception of the future and their capacity to control it. A description of each dimension can be found in Marshall and Marshall (2007).

The framework for assessing resource dependency is based on Marshall et al. (2007). The social, economic and environmental components of the relationship between resource-users

and a resource is based on quantifying the level of attachment to the occupation, employability, attachment to place, family dependency, financial circumstances, business size, business approach, local knowledge and skills A description of each dimension can be found in Marshall et al. (2007).

Whether the uptake of climate tools such as seasonal climate forecasts is likely to occur was assessed by measuring the response to the single statement, "I am definitely interested in using seasonal climate forecasts in my everyday working life". Graziers were also asked whether they use other climate tools such as the southern oscillation index, the Kelvin Wave, the Walker Cycle, synoptic charts or satellite cloud images.

In order to assess the influence of resource dependency and uptake of seasonal climate forecasts (as an example of a climate tool) on adaptive capacity, Pearson correlations were made between dimensions of adaptive capacity and dimensions of resource dependency and between dimensions of adaptive capacity and likely uptake.

Study site selection

In the Australian rangelands drought is a 'normal' characteristic for cattle producers (or graziers). In Queensland, for example, drought was declared 15 times between 1965 and 1989 and in some parts (e.g. the Burdekin region) drought can be a continual state for up to 34% of time (McKeon et al., 2000, Johnston et al., 2000). The survey, in this study, was conducted in the Upper Burdekin dry tropics region which is located in north eastern Queensland and covers an area of about 36,000km2 (see figure 1). It is a sub-catchment of the Burdekin River, one of the largest rivers in the state. The high rainfall variability of the region is strongly correlated ahead of time with relatively well understood aspects of ENSO, making forecasting relatively beneficial for those who choose to use it (Ash et al. 2007). The climate is characterised by pronounced wet and dry seasons, with most rain falling between November and April. Average rainfall ranges between 650-1,500mm annually (Stokes et al., 2004). Other than some basalt soils, most soils in the region have low levels of nitrogen, organic matter and fertility (Stokes et al., 2004, Stokes et al., 2007).

Survey development

Survey questions were developed so as to quantify a grazier's capacity to adapt to climate variability, their level of dependency on the resource and their likely uptake of seasonal climate forecasts (Marshall 2008). Some questions within the survey, such as 'in what year were you born?', required simple answers. Some questions such as, 'are you employed as a

land manager on someone else's land?' required a 'yes' or 'no' answer. Answers to most questions, however, were expressed as a statement and reflected an attitude, opinion or stance. For example, one statement was, "I do not talk about strategies to survive drought much with others". Respondents were asked to rate how strongly they agreed with each statement using a 4-point rating scale (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree). This scale builds upon the Likert scale (Mueller, 1986, Likert, 1932) and is especially useful in quantifying and comparing attitudes, since results can be standardized and contrasted (Spector, 1992). Responses for negative statements were reversed prior to analysis. An initial version of the survey was pilot-tested with 10 graziers in their homes to ensure that the questions were readable and unambiguous.

Survey administration

An intensive media campaign commenced the survey administration phase to introduce the research to the region. Next, names, addresses and telephone numbers of graziers were obtained from the yellow pages; an online business directory. All grazing families with the Dalrymple Shire received a personal letter informing them of the research and inviting them to participate.

The final version of the survey was administered to 100 graziers in their homes by two interviewers working as a team between March 2007 and June 2007. One-hundred graziers were interviewed in order to capture the range of social variability within the region; which was completely unknown prior to the research. Appointments were made by telephone. At the start of each interview, the researcher introduced and explained the survey in the same way each time. All participants gave verbal consent for the interview to take place. Of the 103 families that were contacted, 100 agreed to participate in the research. Hence a response rate of 97% was achieved for the study. There are around 120-130 grazing families that live and work on the 230 properties within the region (many properties are owned by the same grazing family) so that results from this study represent at least 77% of the region (Reimer et al. 2003).

Data analyses

Quantitative data were analysed using standard statistical techniques (using SPSS®). Responses to each survey question are described in the text and the overall resilience to climate variability on all 4 dimensions is presented as a mean of the mean responses for each dimension. The influence of resource dependency, and likely uptake on each component of adaptive capacity was quantified using Pearson correlations. A 'weighted mean' or F-score

was calculated for the set of relevant statements for each component of resource dependency and social resilience. Pearson correlations were made between uptake and the F-scores for each conceptual variable. Bonferroni adjustments were made to offset the chance of a false rejection of the null hypothesis in a large number of separate t-tests.

3. Results

Likely uptake of seasonal climate forecasts

Forty percent of graziers were highly interested in using seasonal climate forecasts in their everyday working life.

Perception of risk associated with climate variability

On a scale of 1-4, where any value greater than 2 is considered to be a positive response, the mean response of graziers to survey questions about risk was 2.9 (standard error=0.03). Graziers in the Burdekin region positively perceived the risks associated with drought, but not overly. For example, 90.1% of graziers believed that they were more "likely to survive drought compared to other cattle producers". Most graziers were more positive towards approaching drought periods than they had been in their past since 82.5% were, ".. learning to survive drought periods more easily as [they] got older". Some 90.6% felt that they were prepared to, " …take advantage of a particularly good season", suggesting that they felt positive about the future. More than half (56.9%) of the grazier population also disagreed with the sentiment that, "I am too young to retire and too old to find work elsewhere", suggesting that they felt positive as to their long-term business outcomes on the rangelands. Most graziers (81.4%) were not worried about the financial impacts of drought, since they had, "planned for [their] financial security in the event of a drought".

Graziers were not positive about markets and their livelihood options. For example, 61.1% of graziers disagreed that they "sell cattle only when the prices are high and buy when the prices are low," and that only 64.3% of graziers believed that they had, "..many options available to [them] other than being a cattle producer".

Planning, learning and reorganising for climate variability

On a scale of 1-4, the mean response of graziers to questions about planning was 2.93 (s.e.=0.03). Graziers were confident that they had the skills to plan and prepare for drought. Only a few graziers (21.2%), said that they "just hope for the best…if there is a drought" and only 28.8% believed that the, "future will look after itself." Most graziers (83.5%) said that,

“at the onset of drought [they] plan a way to survive it”. All the same, some 52% said that they, “..ignore rumours of drought and deal with the consequences once they occur”. Over 90% (90.4%) of graziers believed that they were, “..good at doing what [they] do and ..trust [their] own decision.” However, only 33.6% said that they, “rely on talking with other graziers to decide what drought strategy to employ”.

Ability to cope with climate variability

Overall, the mean response to questions about coping was 2.98 (s.e.=0.03) on a scale of 1-4. Over 55% of graziers thought that, “the uncertainty surrounding drought is worse than the drought event itself”, where 75.5% said that their family was, “used to bad times and [they know they] will survive future drought.” Some 82.9% believed that their, “good years help [them] to survive the bad years”. Whilst 82.9% suggested that their, “stress levels greatly increase in [their] family during drought periods”, only 23.4% of graziers believed that, “my partner and I have different opinions about how to manage drought”, and only 29.5% suggested that their, “current level of debt means that drought will be especially difficult to recover from.” Many graziers (58.8%) disagreed that their, “financial situation is a constant source of worry.” Instead, most graziers (90.9%) saw, “climate uncertainty as a normal part of [their] everyday life”, where 79.1% say that, “regardless of what happens…have made sure that [they] are financially secure.” Only 11.2% of graziers suggested that they, “rely on drought assistance to get [them] through drought years.” All the same, 50.8% of graziers said that, “it was important for [them] to know how other graziers are coping in their business.” Interestingly, if drought did force people off the land, only 54.2% of people said that they were, “interested in learning new skills outside of the industry”.

Interest in adapting to climate variability

The mean response to questions about the level of interest in change was 2.89 (s.e.=.06) on a scale of 1-4. This result reflects that 83.5% were, “interested in learning how [they] could better prepare for drought.” Some graziers (60.4%), “attend workshops to get new ideas to better manage drought” and 71.5%, “talk about strategies to survive drought with others”.

The influence of resource dependency on social resilience

Results indicate that the capacity to cope and adapt is significantly correlated with aspects of resource dependency (table 1). Specifically, the perception of risk associated with seasonal climate forecasts (dimension 1) was positively correlated with employability, business approach and attachment to occupation and place. Planning, learning and reorganising (dimension 2) was significantly and positively correlated with business approach and

attachment to place and negatively with attachment to occupation. Coping (dimension 3) was significantly and positively correlated with attachment to place, and negatively with family dependents and financial aspects. The level of interest in adapting (dimension 4) was significantly and positively correlated with employability, business approach, financial aspects and environmental aspects (table 1).

The influence of seasonal climate forecasts on resilience

Results suggest that uptake of seasonal climate forecasts can influence adaptive capacity (or that people with a higher capacity are more likely to use seasonal climate forecasts) (table 2). Three dimensions of adaptive capacity (risk, planning and interest) were highly significantly correlated with uptake. The coping dimension was not correlated with uptake, suggesting that whether people cope with climate variability, or not, does not influence whether they are likely to uptake forecasts (table 2).

4. Discussion

Despite theoretical advances in resilience thinking (Walker et al. 2002), this is one of the few studies providing practical knowledge of individual adaptive capacity that could inform climate adaptation planning. An evaluation of graziers from the Dalrymple Shire in northern Australia has revealed that these resource-users perceive themselves to be resilient to climate variability. Highest resilience was associated with graziers who were more interested in using seasonal climate forecasts, highly attached to 'place', employable, strategic and financially secure. These findings have several implications including; (i) graziers do not perceive the need to use forecasts to enhance their resilience to climate variability (given current forecast reliability), (ii) resilience to climate variability might not adequately reflect resilience to climate change, (iii) perceived resilience to climate variability may, in fact, make graziers vulnerable to climate change, and (iv) adaptive capacity can be enhanced through decreasing resource dependency and improving the likely uptake of seasonal climate forecasts. These four points are discussed in turn.

Firstly, that graziers in the Dalrymple Shire perceive themselves to be resilient to climate variability on 4 resilience dimensions may explain, in part, why only around 40% of graziers are likely to uptake technology such as seasonal climate forecasts (Ash et al., 2007b, Rayner et al., 2005, Marshall and Gordon, submitted, Marshall et al., in review). Graziers are used to managing climate variability. Graziers with a strong and long connection to their land have already demonstrated their success in managing climate variability; hence they perceive

climate variability as ‘normal’ (Dow et al., 2007, Zamani et al., 2006) (or at least, they do not recognise that their methods for managing climate variability could be having deleterious long-term impacts since any impacts are possibly masked by temporal and spatial factors (Antle et al., 2006, Stafford Smith et al., 2000, Stafford Smith et al., 1999, Stafford Smith et al., 2007)). Indeed, graziers that positively perceive their capacity to cope and adapt to climate variability have operated within the industry for sufficient time to know that climate variability is not a significant threat to their livelihood and unlikely to affect their long-term resilience. However, the true capacity of graziers to cope and adapt to climate variability in countries such as Australia and the USA is possibly masked by the provision of government subsidies that allow graziers to be sustained through extreme climatic events when they would have been otherwise rendered unviable (Stafford Smith et al., 1999, Hacker et al., 2000, Howden et al., 2007, Nelson et al., 2007b). Nonetheless, results from this study suggest that graziers whom perceive themselves to be resilient are more likely to be strategic (and thereby less resource dependent), and adopt innovative technology. Graziers who are less likely to be resilient either do not perceive that seasonal climate forecasts can enhance their adaptive capacity (Maines, 1996, Meinke et al., 2001), or that they do not perceive themselves to be vulnerable to climate variability and therefore not in need of supportive climate technology. Encouraging graziers to be more strategic in the way they run their business is likely to enhance their capacity to adapt to climate variability.

Secondly, resilience to climate variability may be inappropriate as a proxy to assess vulnerability to climate change (Baker, 2002). Whilst the nature of climate variability and climate change are broadly similar, graziers must now increasingly contend with a heightening frequency and intensity of droughts and floods as global climate change occurs (Sonn and Fisher, 1998, IPCC, 2007). The scale and rate of change driven by increases in concentration of greenhouse gases in the atmosphere is unprecedented in human history and beyond the experience of graziers. However, there may yet be substantial validity in extrapolating results of this study to obtaining important insights into the nature of human vulnerability. Many of the strategies that are likely to enhance resilience to climate variability are also likely to enhance resilience to climate change. For example, enhancing the strategic skill-set of graziers in the Dalrymple Shire will have great advantage in approaching climatic events regardless of their magnitude or frequency. Enhanced strategies for coping with climate variability will provide a way for encouraging gradual, incremental adjustments for climate adaptation.

Thirdly, this study brings attention to the fact that graziers’ positive perceptions of their capacity to cope and adapt to climate variability in this study may, in fact, make them

vulnerable to more extreme and frequent climate events predicted for the future. Climate change is likely to seriously challenge the skills, experience and judgement of graziers on the rangelands and savannas, and unless graziers use novelty, creativity, experimentation, learning and planning in approaching this change, they are unlikely to cope and adapt (Hiedanpaa, 2005, Folke et al., 2005, Olsson et al., 2004b, Dow et al., 2007). Using climate forecasts can help graziers more positively assess the risks associated with climate variability; can help graziers plan, learn and reorganise; and can encourage graziers to be interested in adapting to climate variability. One-hundred year models show that graziers that use them over the longer term are more likely to be profitable and maintain land in better condition (Stafford Smith et al., 2000, Ash et al., 2000, Ash and Stafford Smith, 2003, Campbell and Stafford Smith, 2000). Assuming that forecasts are sufficiently skilful and temporally and spatially appropriate over the short-term, enhancing uptake of seasonal climate forecasts may be an important step in assisting graziers to cope and adapt to more extreme climatic events (Stern and Easterling, 1999).

Fourthly, the adaptive capacity of graziers in the Dalrymple Shire can be influenced. Assisting graziers to develop transferable skills (including strategic skills), increase their environmental knowledge (especially within a climate context), develop financial security and adopt seasonal climate forecasts, in combination, may enhance the capacity of graziers to effectively cope and adapt to climate variability and possibly climate change. A possible technique to address each of these strategies and enhance awareness of vulnerability to climate change is through 'collaborative learning' (Pelling and High, 2005, van Aalst et al., 2008). Collaboration amongst resource-users provides opportunities for dialogue, sense-making and identifying creative solutions to difficult problems (Kallstrom and Ljung 2005). However, an important finding of this research was that graziers plan, learn and reorganise independently of others. Graziers expressed confidence in their own abilities to manage climate variability and, in particular, drought. Graziers, in general, are unlikely to engage with colleagues to collaboratively address the challenges associated with climate change (Marshall *in review)*. Like commercial fishers, but unlike miners and loggers that work in close proximity to each other, graziers in Queensland work alone and a considerable distance apart from each other (Marshall et al., 2007). If the resilience of graziers to climate variability in the Burdekin catchment is to be enhanced, their ability to learn collaboratively needs to be improved (Feldman et al., 1996, Tschakert, 2007, Rayner et al., 2005). These ideas and information injected into current extension programmes, industry-based workshops and targeted media may not only significantly enhance the resilience of individual graziers, but also the resilience of the combined rangelands socio-ecological system as it approaches the

full impacts of climate change (Gross et al., 2006, Carpenter and Gunderson, 2001, Levin et al., 1998).

The capacity of primary enterprises and industries to cope and adapt to climate change can be influenced. This research has provided one method to assess the significance of factors that potentially are important. More effort needs to be invested into identifying and testing other influences if the capacity of primary enterprises and industries is to be enhanced. As the concentration of greenhouse gases increases in our atmosphere, so does the urgency with which adaptation must occur. Given that it is not possible to directly control the climate, developing strategies to support resilience and adaptation in the face of uncertainty are perhaps the only current options that primary enterprises and industries have.

5. Figures and tables

Figure 1. Map of region

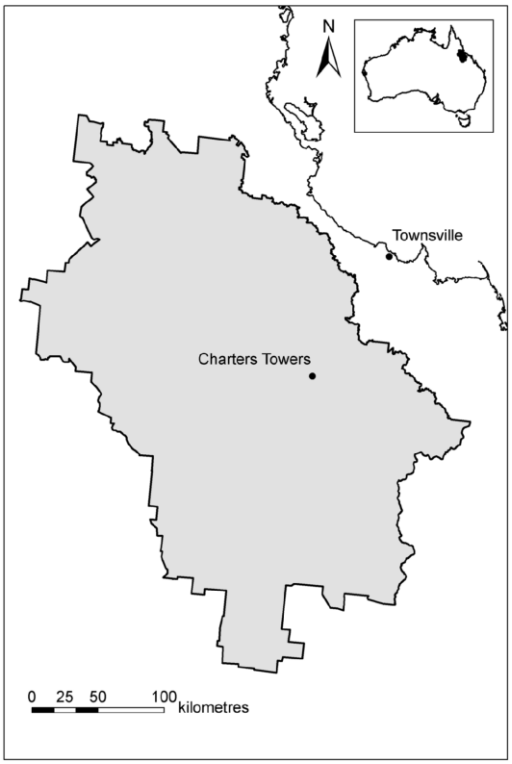

Table 1. Results of the Pearson Correlation Matrix examining the relationship between (i) aspects of resource dependency and (ii) social resilience.

	RESILIENCE COMPONENTS			
DEPENDENCY	**Risk**	**Planning**	**Coping**	**Interest**
Attachment to occupation	.241(*)	-.242(*)	.123	-.187
Attachment to place	.234(*)	.276(**)	.212(*)	-0.037
Employability	.434(**)	.106	.118	.372(**)
Family dependents	-.087	-.159	-.256(*)	-.055
Business size	.068	-.088	-.007	-.033
Business approach	.282(*)	.519(**)	.059	.461(**)
Financial aspects	-.269	-.196	-.315(*)	.321(*)
Environmental aspects	.074	.205	-.031	.337(**)

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 2. Results of the Pearson Correlation Matrix examining the relationship between (i) aspects of social resilience and (ii) the likelihood that seasonal climate forecasts (SCFs) will be used.

	"Definitely interested in using SCF in my everyday life"
Perception of risk	.252*
Capacity to plan, learn and reorganise	.443**
Ability to cope with drought	.037
Interest in adapting to drought	.286**
Overall positive resilience	**.333****

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

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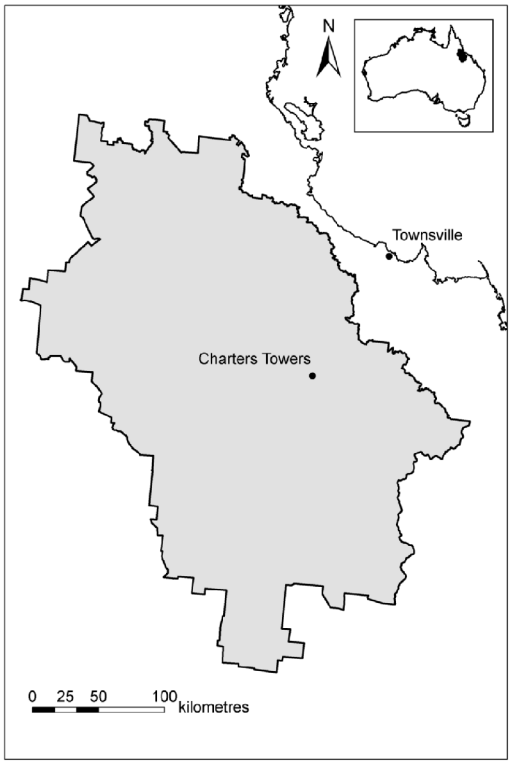
Figure(s)

Figure 1. Map of the Burdekin region, Queensland, Australia



Table(s)

Table 1. Results of the Pearson Correlation Matrix examining the relationship between (i) aspects of resource dependency and (ii) social resilience.

	RESILIENCE COMPONENTS			
DEPENDENCY	**Risk**	**Planning**	**Coping**	**Interest**
Attachment to occupation	.241(*)	-.242(*)	.123	-.187
Attachment to place	.234(*)	.276(**)	.212(*)	-0.037
Employability	.434(**)	.106	.118	.372(**)
Family dependents	-.087	-.159	-.256(*)	-.055
Business size	.068	-.088	-.007	-.033
Business approach	.282(*)	.519(**)	.059	.461(**)
Financial aspects	-.269	-.196	-.315(*)	.321(*)
Environmental aspects	.074	.205	-.031	.337(**)

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 2. Results of the Pearson Correlation Matrix examining the relationship between (i) aspects of social resilience and (ii) the likelihood that seasonal climate forecasts (SCFs) will be used.

	"Definitely interested in using SCF in my everyday life"
Perception of risk	*.252**
Capacity to plan, learn and reorganise	*.443***
Ability to cope with drought	*.037*
Interest in adapting to drought	*.286***
Overall positive resilience	***.333****

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level