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Social vulnerability to climate change in primary producers: A typology approach

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ABSTRACT

Adaptation of agricultural industries to climate change will make a major difference to the extent of the impacts experienced as a result of climate change. Vulnerability assessments provide the basis for developing strategies to reduce social vulnerability and plan for climate adaptation. Primary industries have been identified as the most vulnerable industry sector globally. We review how primary producers might be socially vulnerable to climate change and develop a 'vulnerability typology' of cattle producers based on survey responses from 240 producers across northern Australia. We measured social vulnerability according to ten indicators of climate sensitivity (resource dependency) and four indicators of adaptive capacity. Using a *K*-means clustering analysis we identified four main 'types' of cattle producers. Type 1 producers (43%) were vulnerable because they had low strategic skills and low interest in changing behaviour. Mean age was 59 years old, they were weakly networked within the industry and businesses were small. Type II producers (41%) had low strategic skills, poorly managed risk and uncertainty, had medium sized businesses and were 51 years old on average. Only 16% of producers (Type III and IV) appeared to have resilience to change. Type III producers (13.4%) had a stronger psychological and financial buffer, were 52 years old on average, were well networked and managed or owned larger businesses. Type IV producers (2.6%) managed risk well, liked to experiment with options and were interested in change. They were 41 years old on average, managed extremely large properties, were well networked, perceived themselves as responsible for the future productivity of their land and were early adopters of new technology. By providing knowledge of the different ways in which people can be vulnerable to climate change, vulnerability assessments can enable decision-makers to prioritise their efforts, provide a basis for early engagement, and tailor a range of adaptation approaches to most effectively accommodate and support the divergent requirements of different "types" of resource-users.

1. Introduction

Primary producers and industries, which include the sectors of agriculture, forestry and fisheries, are especially vulnerable to climate change because they are dependent on highly climate-sensitive natural resources (IPCC, 2007; Stokes and Howden, 2010). In addition to the existing backdrop of conventional drivers including economic, biophysical, institutional, cultural and political pressures, primary resource users are expected to contend with more frequent climate crises (such as drought and flood), increased climate variability (Cooper et al., 2008), environmental degradation (such as eroding soils, increased pests and diseases; Volney and Fleming, 2000), cultural change (such as new practices and climate technology; Darnhofer et al., 2010) and in some instances: climate-related regulatory change (Cabrera et al., 2006).

Humans can influence the impacts of climate change in two ways. The first is mitigation: by reducing global emissions of greenhouse gasses we can deal with the root cause of the issue and limit the magnitude of human-induced global climate change (Howden et al., 2007). The second, and the focus of this paper, is adaptation: by building the capacity of people to adjust climate-sensitive activities to plausible future climate scenarios, we can limit our vulnerability to the climate change that does occur (Wreford and Adger, 2010). The two are linked in that the more effort that is put into mitigation efforts, the less effort will be required for adapting to climate changes (Verchot and Cooper, 2008). While strong arguments exist to stabilise greenhouse gas concentrations before the climate system passes irreversible thresholds, we can also accelerate efforts to prepare for those changes that are inevitable.

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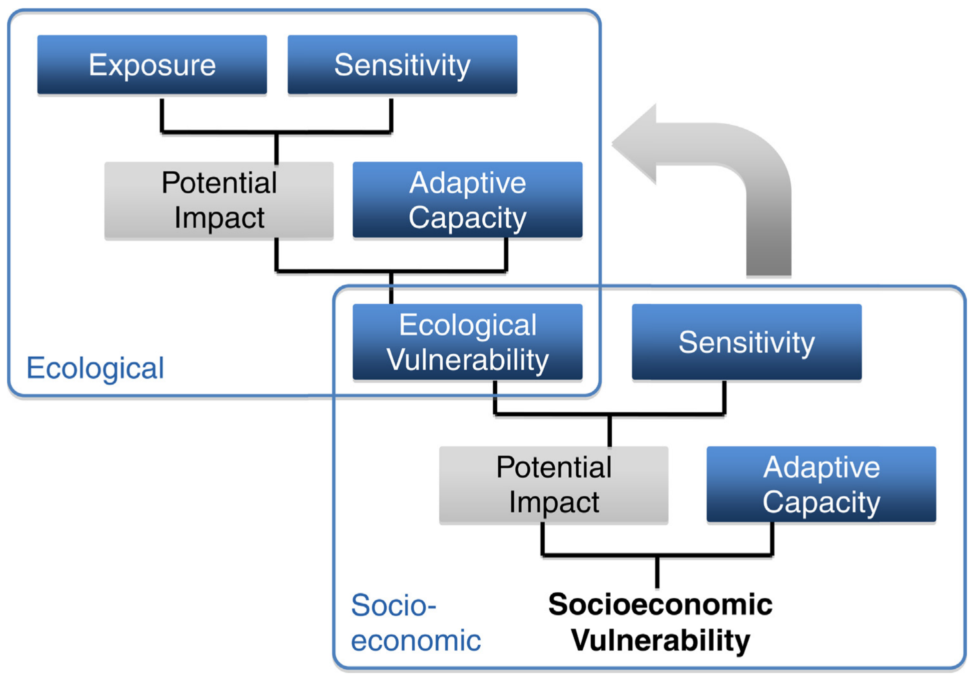

Fig. 1. A framework for conceptualising vulnerability across both ecological and socio-economic (social) domains. In this paper we refer only to social vulnerability, which consists of sensitivity to change (described in the text as "resource dependency") and adaptive capacity. Adapted from Marshall et al. (2013).

Adaptation to climate change will make a major difference to the degree of impact of climate change (Stokes and Howden, 2010; Webb et al., 2013). The specific challenge faced by primary producers will be to build the productivity and profitability of their resource (agricultural) enterprises in the face of climate uncertainty without degrading the ecosystem services on which they depend (McKeon et al., 2004). Climate change will also bring opportunity. Increases in temperature and precipitation in some regions, for example, could open up new and profitable agriculture opportunities (Stokes and Howden, 2010). Flexibility and responsiveness, however, will be needed to realise potential benefits (Howden et al., 2007). Thus, preparing for climate-related changes will not only mean preparing for the worst; in some cases it may also mean preparing to take advantage of new conditions (Fankhauser et al., 1999). Primary producers and industries that are resilient to climate change will be able to both minimise the social and economic impacts and maximise the opportunities. Most importantly, resilient resource industries will be better prepared to manage 'climate surprises' where change is no longer seen as a disturbance, but as a trigger for the reorganisation of resources, and for the renewal of resource-based practices and activities (Darnhofer et al., 2010). However, climate adaptation processes are proving to be less straightforward, as some resource-users appear better able to cope and adapt, whilst some are more vulnerable than others (Marshall, 2010; Marshall and Smajgl, 2013).

Vulnerability assessments are the logical place to start for most industry leaders or policy-makers wishing to direct or support efforts to reduce vulnerability and develop plans for climate adaptation (Moser and Ekstrom, 2010). The intergovernmental panel on climate change (IPCC), amongst others, define system vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (Smit and Wandel, 2006). Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007; Marshall et al., 2013). These elements are important for assessing vulnerability within both socio-economic and biophysical subsystems and we refer to a modification of the IPCC framework where social vulnerability is explicitly based on the vulnerability of the biophysical components of the system (see Marshall et al., 2013). In social systems, we view 'social vulnerability' as a function of both climate sensitivity (which we characterise here in terms of resource dependency; see 'Components of Vulnerability' below) and adaptive capacity (Fig. 1) (Marshall, 2011). Establishing that resource dependency and adaptive capacity are key components of vulnerability within social and ecological systems can help evaluate the nature and magnitude of a climate change threat, detect key sources of vulnerability and identify actions to help reduce or manage a climate threat (at any point within the system).

The aim of this study was to assess the social vulnerability of livestock producers (herein cattle producers) to climate change across northern Australia and about the extent to which the cattle industry might be vulnerable to climate change. We focus at the scale of the individual, which is often over-looked in the development of regional policies, but which is necessary to complement research and adaptation planning at broader scales.

We represent the vulnerability of primary producers through the concept of 'types'. Typing people provides an opportunity to understand social heterogeneity within a population (Emtage et al., 2006; Valbuena et al., 2008). Climate adaptation plans and other regional natural resource management (NRM) plans and policies often assume that there is an 'average' or 'typical' resource-user on which strategies for long-term sustainability are based (Andersen et al., 2007). However, this assumption does not reflect the full range of diversity among resource-users within a region, thereby risking plans that will be irrelevant and ineffective for some. Understanding social heterogeneity within populations of resource-users is important for effective natural resource management and climate adaptation planning (Andersen et al., 2007). Understanding 'types' based on criteria relevant to natural resource management is a useful way to represent diversity within a region. It provides an opportunity to directly 'match' various potential adaptation options to the full range of individuals on the rangelands and savannas (Marshall and Smajgl, 2013).

1.1. Components of vulnerability

We measured social vulnerability in terms of ten components of climate sensitivity and four components that describe adaptive capacity. Each of these components is briefly explained below.

1.1.1. Climate sensitivity (resource dependency)

The sensitivity of resource-users to climate change is determined to a large extent by how dependent they are on a climate-sensitive natural resource. The more dependent people are on a natural resource, the more sensitive they are to changes in condition or access to the resource. Resource dependency is thus a good measure of climate sensitivity (Marshall, 2011; Marshall et al., 2011). Resource-users such as cattle producers can be dependent on a natural resource in economic and non-economic (social) ways. In brief, those that are more dependent on the resource have less psychological, financial and cultural flexibility with which to experiment with their options for the future (Marshall et al., 2012).

i. Attachment to occupation: Resource-users such as producers, farmers, fishers, and loggers can be sensitive to change because of their attachment to their occupation. When a person who has a strong attachment to their occupation is suddenly faced with the prospect that they are no longer able to continue in that occupation, they may not only lose a means of earning an income, they lose an important part of their identity (Lankester, 2012). Hence, individuals with a strong identity created around their resource-based operation are likely to be sensitive to changes in quality, quantity or access to the resource.

ii. Employability: People living and working in resource dependent communities often have limited experience in other occupations (Krannich and Zollinger, 1997). As a result, they often lack transferable skills and, consequently, become 'locked' into their occupation. People who are older, have little education or are uninterested in working elsewhere are likely to be especially sensitive to changes such as climate change since they are usually least equipped to take advantage of other employment opportunities (Allison and Hobbs, 2004). Useful proxies for employability include age, education, level of transferrable skills sets and attitude to working elsewhere.

iii. Family: When resource-users experience adversity associated with loss of income and livelihood, members of their social and economic networks and family will also be sensitive to this adversity (Price and Evans, 2009). The number of dependent children that a resource-user possesses can be a useful indicator of the extent that they can experiment with their options for the future.

iv. Attachment to place: This concept describes the level of connection that individuals have with their physical community. It describes the identity created around the locality, the sense of pride associated with belonging to the town and the strong friendships and networks that exist within it or connections to ancestors (Gustafson, 2001). Attachment to a place can often lead to people preferring the stability associated with remaining in the one community, rather than moving locations, and this can increase their dependency on the natural resource (Stedman, 1999) and decrease their capacity to effectively respond to climate change (Marshall, 2011).

v. Business size and skills/approach: The business skills that people possess can be good indicators of their competitive advantage within a resource-based industry and their level of transferable skills outside of the industry (Marshall, 2011). Typically, the extent of business skills that an individual resource-user has is correlated with the size of business that they operate (Allison and Hobbs, 2004). Generally, larger businesses are more likely to buffer themselves from unpredictable problems such as mechanical breakdowns, difficulties with employees and fluctuations in the weather since they can take bigger risks and experiment with their options for the future. Business owners with large operations are more likely to be strategic, have the capacity to motivate, plan, organise and act and are more likely to be driven by economic incentives to harvest the resource. Capital investments, however, can limit flexibility and stifle innovation (Bohnet, 2008) especially in the face of extreme events such as cyclones and flooding (Marshall et al., 2013).

vi. Financial status and access to credit: The income and debt levels of a resource-user, and their ability to access credit, can also significantly influence the extent to which a resource-user can effectively respond to change. For example, resource-users with a lower financial status often lack the flexibility with which to successfully absorb the costs of change and are often reluctant to take on further risks (Darnhofer et al., 2010). Resource-users with higher financial status or access to credit are also more likely to be able to diversify (Steneck et al., 2011).

vii. Income diversity: Individuals with a household income derived from multiple resource types or sectors are likely to be less sensitive to resource impacts from climate change (Bailey and Pomeroy, 1996). In many regions that are regarded as "less stable", individuals tend to diversify their income sources to spread risk, manage seasonality, increase flexibility, achieve stability, and better cope with shocks (Li et al., 2008). For example, resource-users who target a single species or market and who operate a small farm, shop or chandlery in addition to their resource-based business can be expected to have more options for responding to climate-induced changes. They are potentially less sensitive to climate changes than those who derive most of their income from a single-sourced enterprise (Howden et al., 2007).

viii. Local environmental knowledge: Local environmental knowledge is the investment that people have made in getting to 'know' their local environment from which they derive an income. They typically recognise and respond to environmental feedbacks where they can detect subtle changes in resource condition over time. They understand that their actions may be having negative environmental impacts. While individuals with high levels of local knowledge can be well adapted to current conditions, they are also less likely to forfeit their resource-based activities because they have invested so much in developing that knowledge (Marshall, 2010).

ix. Environmental awareness: Environmentally educated and aware resource-users tend to be more flexible and supportive of resource-protection strategies. They typically develop identities such as 'land steward' or 'best practice operator' (Joseph et al., 2008), which makes them less dependent on traditional resource-management practices and more willing to adopt new practices that enhance not only their own resilience to change, but that of the environment.

x. Formal and informal networks: Networks can be formal; through legal structures and government agencies, or informal; through friends, families and associates. Individuals with stronger, more informed and more effective networks often have reciprocal connections of interactions, increased levels of trust and access to information that are exchanged for mutual benefit (McAllister et al., 2008). People that are well networked tend to have more options available to them (Marshall, 2011; McAllister et al., 2006).

1.1.2. Adaptive capacity

Adaptive capacity is a description of the potential or preconditions necessary to cope with novel situations and enable adaptation without overly losing options for the future (Nelson et al., 2007). It describes the capacity to convert current resources (financial, physical, human, social or natural capitals) into successful adaptation strategies (Adger et al., 2003). Characteristics that contribute to adaptive capacity reflect learning, the flexibility to experiment and adopt novel solutions, and the ability to respond generally to a broad range of challenges (Darnhofer et al., 2010; Gunderson, 2000). At the individual (resource-user) scale, adaptive capacity has been comprehensively operationalised according to four measurable attributes reflecting the individual's skills, circumstances, perceptions and willingness to change. These four dimensions are described here.

i. Perceptions of risk and uncertainty (RISK)*:* Not all individuals are equally capable of dealing with uncertainty. Yet, positively managing the risks associated with change and uncertainty are fundamental aspects for coping and adapting to change. How risk is perceived and managed reflects individual and cultural differences in experiences, knowledge, beliefs, values, attitudes and judgements as well as differences in abilities to plan and execute plans (Taylor, 2003). Some people recognise and accept that potential rewards may be highest when uncertainty is highest. A risk-averse individual, in contrast, will select strategies with more certain outcomes, even if the benefits are lower. They will tend to use imitation rather than innovation in solving environmental challenges (Taylor, 2003).
ii. Skills for planning, experimenting, learning and reorganizing (PLAN)*:* This component reflects the capacity to anticipate and prepare for the future. The capacity to plan, experiment, learn and reorganise in the face of change is dependent on novelty, creativity, sharing experiences and possessing the skills to make the most of opportunities (Colding et al., 2004; Olsson et al., 2008). Without it, any response to climate changes will be reactive.
iii. The ability to cope with change (COPE)*:* Climate change will affect the security of individuals and populations as well as the security of states (Adger, 2010). In social systems, the ability to cope is a measure of the proximity to emotional and financial thresholds (Marshall, 2010). Individuals with emotional and/or financial buffers are better able to absorb the costs of change and adapt (Lawes and Kingwell, 2012; Marshall et al., 2012). Health issues will typically influence the capacity of older resource users to cope and adapt, and mental health issues will influence the capacity of resource users already experiencing financial hardship (Berry et al., 2011)
iv. The level of interest in change *(*INTEREST*):* This dimension of adaptive capacity corresponds with the degree to which the system is capable of 'self-organisation'. Individuals that have a higher level of interest in adapting to the requirements of the future usually have a higher financial, social and/or emotional flexibility. The level of interest in climate change adaptation can be influenced by climate education and access to climate technology, expertise and information (Marshall et al., 2011). People interested in adaptation to change can identify the consequences, impacts and possible responses ("adaptation options") to climate change (Howden et al., 2007).

1.2. The north Australian cattle industry as a case study

Grazing lands, or rangelands, are variably productive and tend to be socially remote landscapes representing some 33% of the world's terrestrial landscapes (Sivakumar et al., 2005; Stafford Smith et al., 2007) and 70% of the Australian landmass (Stafford Smith, 2007). Within the Australian context, the pastoral industry has tended towards enterprise consolidation and intensification, which has caused fragmentation in land use and changed the scale at which humans and livestock access patchily-distributed resources in their landscapes (Stokes et al., 2006). Cattle producers, like other resource users, must contend with variability in the climate each season within the context of an already harsh environment (Hobbs et al., 2008). For example, drought is a 'normal' characteristic for cattle producers in northern Australia. In Queensland drought was declared 15 times between 1965 and 1989 and in some areas (e.g. Charters Towers) prior to 2000 drought declaration could occur for up to 34% of time (McKeon et al., 2004). Since 2000, the eastern Australia was drought affected for most of the next decade (until 2009) (Risbey et al., 2013). Most environmental degradation also occurs during drought periods (McKeon et al., 2004; Watson, 2004). Hence, making the most of good years and avoiding losses and reductions in resource condition in drought years is imperative. 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). Recognising critical periods and years can be crucial in determining the extent and magnitude of associated socio-economic impacts (Walker, 2005). Knowing when and by how much to adjust stocking rates in response to changes in forage availability, for example, can differentiate between those producers who are likely to be successful in the long term and those that are not (Hansen, 2002). Producers must also allocate resources each season on the basis of their expectations about yields, prices and seasons. If these expectations are unfounded then their decisions will not be optimal (Andersson et al., 2005). Producers that can anticipate or effectively react to climate extremes are more likely to adapt to new climate conditions, however, previous research has suggested that this capacity is not distributed equally throughout cattle producers (Marshall and Smajgl, 2013).

2. Methods

2.1. Survey development

In order to assess the vulnerability of cattle producers to climate variability we developed a survey to examine the ten components of resource dependency (listed in the above framework) and the four dimensions of adaptive capacity. Most questions had been developed in other studies (Marshall, 2010; Marshall et al., 2011). Some questions within the survey required simple straightforward answers. 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". A list of the survey questions pertaining to resource dependency and adaptive capacity are presented in Table 1. 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 and is especially useful in quantifying and comparing attitudes, since results can be standardized and contrasted (Spector, 1992). A five-point scale was not used because mid-way responses are often difficult to interpret and respondents were asked to leave a question blank if they preferred. Responses for negative statements were reversed prior to analysis. An initial version of the survey was pilot-tested with ten producers in their homes to ensure that the questions were readable and unambiguous. A copy of the survey can be obtained through the primary author.

2.2. Survey administration

An intensive media campaign commenced the survey administration phase to introduce the research to producers across

Table 1
Types of cattle producers based on their vulnerability to change[a].

Vulnerability components	TYPE I	TYPE II	TYPE III	TYPE IV
Numbers of producers (as % of sample)	100 (43.1%)	95 (40.95%)	31 (13.4%)	6 (2.6%)
Risk	−.05768	−.20124 (Less likely to manage risk)	.67630	1.46228 (More likely to manage risk well
Plan	−.10054 (Unlikely to experiment and plan)	.09851	−.08211	.72139 (Likely to experiment and plan)
Cope	.09739	−.18931 (Less likely to cope)	.42102 (More likely to cope)	−.87522
Interest	−.13929 (Unlikely to be interested in change)	.10262	.0437	.94812 (Likely to be interested in change)
Identity	−.14170 (Weaker identity)	−.07211	.83484 (Stronger identity)	1.11073 (Stronger identity)
Employability	−.02157 Mean age = 59	.14578 Mean age = 51	−.74297 Mean age = 52	1.19598 Mean age = 41
Networks	−.18120 (Weaker networks)	−.08357	.78091 (Stronger networks)	.95230 (Stronger networks)
Children at home	.07 (Unlikely to have children)	4.20 (Likely to have children)	4.03 (Likely to have children)	1.00
Approach	−.06656	−.14282 (Unlikely to be strategic)	.57002	.91606 (Likely to be strategic)
Business size	−.16686 Small 72,728 ha Employ 1.9, Cattle 4600 Income = $1–5 M	.03057 Medium 111,634 ha Employ 3.4 Cattle 7,000 Income = $1–5 M	10.11315 Very large 364,639 ha Employ 8.9 Cattle 12,000 Income = $1–5 M	.03144 Large 218,428 ha Employ 6.3 Cattle 2,000 Income = >$5 M
Environmental Awareness (1–5)	4.58	4.46	4.71	5.00 (Highly aware)
Are you the owner	1.76 Owner	1.76 Owner	1.58 Manager/Owner	1.17 Manager
Percentage family income from cattle	80–99%	80–99%	100%	100%

[a] Results show the *F*-scores for the components of adaptive capacity and resource dependency that directly contributed to differentiating between types. (i.e., not all dimensions are presented)

northern Australia. Grazing families also received a personal letter informing them of the research and inviting them to participate. Names, addresses and telephone numbers of producers were obtained from the yellow pages, an online business directory. Within two to three weeks of receiving the letter, producers received a telephone call and were again invited to participate in the research. Some producers were happy to complete the survey immediately, and others made an appointment at a more convenient time. Of the 303 producers that were contacted, 63 refused to participate in the research. Our sample of 240 producers thus represented 79% of those contacted.

2.3. Data analyses

The ten components of resource dependency and the four components of adaptive capacity were assessed for each cattle producer by calculating an *F*-score or 'weighted mean' for the set of responses to relevant statements. *F*-scores were calculated by conducting a factor analysis or principal components analysis in SPSS® and forcing the data into one factor only. This means that we assumed that the responses to the set of statements representing each dimension of resource dependency and adaptive capacity were correlated (as has been tested in Marshall 2008). The *F*-scores were then used to allocate each producer into a 'type' of producer based on their vulnerability. Types were identified using *K*-means clustering of the *F*-scores, and results were considered for up to ten clusters. We found that most information about vulnerability was explained through four clusters. An analysis of variance *F* statistics was used to provide information about each variable's contribution to the separation of the types.

3. Results

We identified four types of cattle producers according to their vulnerability to climate change, which was based on measures of resource-dependency and adaptive capacity (Table 1). The two most vulnerable types were the most prevalent within the sample. The main type of cattle producer represented 43% of the sample (Type I). This type was vulnerable because they had low skills for planning, experimenting, reorganising and learning and little interest in adapting to the future. They were 59 years old on average and were only weakly networked within the industry. Their businesses were generally small (mean size was 72,728 ha, 1.9 employees, 4600 head of cattle and a business turnover between A$1–$5 million).

The second type of cattle producer represented 41% of the sample (Type II), managed risk and uncertainty poorly and lacked strategic direction in their businesses, thus leaving them vulnerable. These producers were 51 years on average. Their businesses were medium-sized (mean size was 111,634 ha, 3.4 employees, 7000 head of cattle and a business turnover between A$1–$5 million).

Type I and II producers combined represented about 84% of the sample. Only 16% of producers appeared to have higher levels of resilience to change. The next category of cattle producer, represented 13.4% of producers (Type III), and had a stronger psychological and financial buffer than Type I and II producers. They were well networked and tended to operate large businesses (mean size was 364,639 ha, 8.9 employees and a business turnover between A$1–$5 million). The last type of producer, representing only 2.6% of the sample (Type IV), managed risk well, liked to experiment with options and was interested in change. Their mean age was 41 years old. They were well networked and used technology such as seasonal climate forecasts (Marshall et al., 2011). They also operated large businesses (>A$5 million) and perceived themselves as responsible for the future productivity of their land.

4. Discussion

Preparing for climate change will be difficult. The nature and severity of impacts are likely to vary geographically and across industry sectors and, as our study has suggested, the nature and severity of vulnerability to climate change is also likely to vary amongst individuals. We found that cattle producers across northern Australia could be allocated to one of four different 'types' based on their vulnerability to change. Several key factors in particular differentiated between individuals. These included identity, number of dependents, networking, employability (or age), business size, diversity in income, whether producers were business owners or managers, business and environmental approaches, and adaptive capacity (four dimensions).

Our results support the need to clearly distinguish between adaptive capacity and climate sensitivity when considering social aspects of vulnerability. Whilst other studies have shown that factors such as a strong occupational identity act to make resource-users highly dependent on the resource and thus sensitive to change (Marshall et al., 2012), our results suggest that these factors do not necessarily make producers more vulnerable. That is, resource-users that are highly sensitive to change can have compensatory levels of adaptive capacity. In our study, the two types of producers that were least vulnerable also had noticeably higher levels of occupational identity. A strong occupational identity has previously been understood to render producers resistant to change, the supposition being that producers with their identity threatened were more likely to erect barriers to change (Gonzalez and Benito, 2001; Marshall and Marshall, 2007). However, our research suggests that producers with high occupational identity can be less vulnerable to change as long as they have a correspondingly high level of adaptive capacity. Producers with a strong occupational identity might have an added incentive or motivation to remain working within their occupation and could thus be more receptive and flexible to change and, therefore, better able to recognise the inevitability of change. This insight is particularly important for understanding where and how to target investments to minimise vulnerability of individuals. For example, facilitating a reduced attachment to the occupation may not be particularly strategic: rather investing in increasing producers' adaptive capacity, such as strategic management skills, may be a more tactical approach for successful adaptation.

We identified four main types of producers across northern Australia based on their vulnerability to change (Table 1). The first type (representing 43%) was vulnerable because they were unlikely to be able to reorganise (dimension two) and were particularly uninterested in change (dimension four). They tended to be older, business-oriented, independent, self-employed on a (relatively) smaller property, and were more likely to have a diverse household income. Potential strategies to enhance their adaptive capacity would need to stimulate interest in change and an interest in developing strategic skill sets (Howden et al., 2007; Stafford Smith et al., 2007). The second type of cattle producer Type II (41%) was vulnerable for very different reasons. They were less likely to manage risk (dimension one) or cope with the adverse impacts from change (dimension three). They tended to be lifestyle-oriented owner-operators on medium sized properties with dependents, lower environmental awareness and with a diverse household income. Potential strategies that would be necessary to enhance their adaptive capacity would need to be different to those targeting Type I. For example, increasing off-farm income may increase their sense of security and allow the risks associated with change to be managed less stressfully. The third and fourth types of producers showed evidence of being most resilient to climate change. Both showed signs of managing the risks associated with change well. Type III (13%) were less vulnerable because they were more able to cope with change and Type IV (3%) were able to reorganise; they liked to plan, experiment and learn. It should be noted that managers will have reporting obligations, so they have to plan, whilst owners only report to themselves. Both types (III and IV) had a strong identity, strong networks, were interested in change (e.g. adopting new technology), had high environmental awareness, earned 100% of their income from the cattle industry, and managed large to very large properties. Type III producers tended to be older (mean 52 years) and Type IV producers tended to be younger, suggesting that age alone is not a particularly strong indicator of vulnerability. Type III and Type IV producers do not appear to need assistance to adapt to change, yet they are the types most likely to receive attention from government and researchers because of their willingness to partake in 'new' thinking.

A significant finding from our research is that the majority of industry members (84%) are likely to be highly vulnerable to change. That is, 84% of industry members are within Types I and II and are unlikely to adapt to climate change without significant interventions. The future of the industry may rest with 16% of its members. We suspect that this observation is not unique to the northern Australian cattle industry. Yet, the implications of our findings for the cattle industry, regional communities, the nation and environment are potentially quite profound. Industry-wide adaptation plans, which typically require a critical mass of members to support them (Marshall et al., 2012), are unlikely to be successful since potentially 84% of constituents are unlikely to have the capacity to adopt new practices. With the possible onset of longer and more intensive periods of drought on rangelands (Sivakumar et al., 2005), a large proportion of producers with a low capacity for adapting to change may be unable to remain viable or self-sufficient without welfare assistance (Cobon et al., 2009). The previous drought in Australia (2000–2004) cost tax-payers over A$4 billion in subsidies (White, 2000;), suggesting that the future costs of welfare assistance for drought - in Australia, at least, may be unsustainable. Environmental sustainability and food security remain a serious concern as demands for food production rises (Ingram et al., 2008; Polsky and Easterling, 2001). Current producers may struggle to remain profitable during climate challenges and may sacrifice long-term environmental and social goals for shorter economic gains (Clark, 2005). Historic episodes of irreversible environmental degradation in Australian rangelands have been well documented, and linked to delays in reducing stock numbers during periods of drought (particularly when droughts coincide with low livestock prices) (McKeon et al., 2004).

If adaptation to climate change is to occur on the Australian rangelands, and elsewhere, then considerable effort will be needed to minimise social vulnerability (Darnhofer et al., 2010). Enhancing the adaptive capacity of producers is paramount (Marshall, 2010; Marshall and Smajgl, 2013). We also recognise that, while adaptation is clearly in the interests of those producers most vulnerable, it is often policy makers and resource managers who are best positioned to facilitate increased adaptive capacity and implement vulnerability-reducing strategies. An important question for adaptation planning then is: should industry and community leaders invest resources equitably in all industry members, or should attention be focused toward managers who are most receptive to change (Types III and IV)? On the one hand, people with the greatest vulnerability are likely to warrant priority in allocation of adaptation resources (Tschakert, 2007). In some cases, highly vulnerable types may face great hardship or be required to undergo transformation (e.g. to another industry or other function) if they do not receive adaptation assistance (Marshall et al., 2012). On the other hand, types that are most vulnerable are likely to be the least receptive to interventions and, thus, adaptation strategies will vary in the benefit they deliver (Marshall et al., 2011). Other types of producers (e.g. Type III and Type IV) are likely to respond more actively to adaptation efforts and deliver larger or more sustainable adaptation benefits for a particular investment. Types of producers are also likely to vary in their ability to provide economic benefits to the wider society or economy, potentially providing another metric for deciding on allocation of resources. A challenge will be to evaluate 'need' in ways that enable leaders and adaptation practitioners to rank types of candidates for adaptation in a way that provides a transparent, socially equitable and defensible basis for decisions about the allocation of adaptation resources (Füssel, 2007). We see that reducing vulnerability across all types of resource-users can also advance other agendas. Resource-users such as producers are more likely to support a broader range of industry and community initiatives and measures—including those addressing goals for environmental sustainability—if they are assisted with developing the capacity to cope and adapt.

If industry-wide adaptation is to occur, then strategies need to be developed that effectively target each type of cattle producer and draw upon a wide range of resources both within and outside the industry. Since Type I producers are limited in their strategic skills and interest in change, they may be uninterested in attending formal workshops. More creative solutions such as facilitating networking opportunities that encourage shared or collaborative learning may best enhance adaptive capacity in Type I producers (Kallstrom and Ljung, 2005; Olsson et al., 2008). Providing such opportunities may assist Type I producers to learn from others and acquire the skills, resources and attitudes to adapt to changes in the environment (Marshall, 2010). Through participating in shared learning experiences, resource-users may identify innovative options, subsequently experiment, and then refine options to maximise profits during productive periods and minimise losses during unproductive periods—concurrently developing an interest in adapting to change. Resource-users may need assistance to recognise that some strategies lend themselves to co-operation that may be vital for survival, and that collaborating with other producers does not necessarily mean that the competitive edge will be compromised. Developing an interest in adaptation for Type I producers may also occur with increasing climate awareness and access to climate information and technology (Jones et al., 2000). Developing such interest may be assisted more by collaboration through producer networks than by formal avenues and simple provision of information (Marshall, 2011).

Type II producers were closer to the thresholds of coping, and found it difficult to manage risk and uncertainty. Enhancing adaptive capacity for Type II producers may therefore require a range of both formal learning opportunities (through workshops and access to professional advice, including extension services) and informal networking opportunities (e.g. community events) (Armitage et al., 2008; Lebel et al., 2006). Learning about risk–based approaches and preparing financial and psychological buffers for a range of foreseeable future scenarios (planning) are skills that might be enhanced through both formal and informal approaches. Community and industry leaders may need to invest in the regional economy and create or manage a range of livelihood options to assist resource users in managing risk and uncertainty (Goklany, 1995). Resource users may need to seek alternative or supplementary opportunities to generate income and increase their level of transferrable skills (O'Farrell et al., 2009).

Other strategies likely to be important in developing adaptive capacity include: convincing resource users such as cattle producers that projected climate changes pose a substantial threat that require proactive responses (Howden et al., 2007); convincing industry members that the projected changes will significantly impact on their enterprise with a range of consequences; developing, demonstrating and making available the technical and other options necessary to respond to the projected changes (Thomas, 2008); supporting transitions such as industry adjustment and enterprise relocation where climate impacts may require major transformations (this may require direct financial and material support), creating alternative livelihood options, supporting community partnerships such as Landcare (community/industry-based natural resource management), enhancing social capital and the sharing of information, and re-training), and; developing infrastructure, policies and institutions to support changes in management and land and water use arrangements such as irrigation infrastructure and efficient water use technologies, transport and/or storage infrastructure.

Developing suitable strategies for minimising vulnerability across agricultural industries such as farming, forestry, fishing and cattle producing is best done in participation with those likely to benefit, since they can help identify strategies that are most feasible, attractive and acceptable (Webb et al., 2013). Many research studies have shown that meaningful involvement in the planning process is essential to foster feelings of satisfaction, understanding, trust and confidence in the future (Howden et al., 2007). These feelings are necessary for a successful transition to adapting to change–and in particular policy change. Our research suggests that the resource-users in this study perceive the risks associated with change poorly and feel that they do not have the capacity to cope with the impacts of change. If people feel confident about their future and the future of the resource, then they are more likely to positively assess the risks associated with change and their ability to cope: both of which are vital components of adaptive capacity and for maintaining social resilience. To navigate through global change, natural resource industries will require strong collaborative networks and good leadership in order to develop sound strategies that directly address the factors that contribute to vulnerability of individuals (Olsson et al., 2008).

5. Conclusion

Vulnerability assessments provide information about the nature and magnitude of impacts expected from climate change and informs decisions about the form and urgency of adaptation activities and strategies. Vulnerability assessments should help decision-makers better understand the nature and complexity of vulnerability across scales and provide insights that can assist in the development of strategies that could minimise vulnerability and maximise opportunities for adaptation (Endfield, 2012; Marshall et al., 2010). By providing knowledge of the different types of vulnerability of resource-users, vulnerability assessments can enable decision-makers to prioritise their efforts, provide a basis for early engagement, and tailor a range of adaptation approaches to most effectively accommodate and support the divergent requirements of the different "types" of resource-users.

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