

Rapid regional-scale assessments of socio-economic vulnerability to climate change

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2016 Environ. Res. Lett. 11 034016

(<http://iopscience.iop.org/1748-9326/11/3/034016>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 210.77.64.109

This content was downloaded on 07/04/2017 at 04:35

Please note that [terms and conditions apply](#).

You may also be interested in:

[Australia's first national level quantitative environmental justice assessment of industrial air pollution](#)

Jayajit Chakraborty and Donna Green

[A systematic review of dynamics in climate risk and vulnerability assessments](#)

Alexandra Jurgilevich, Aleksi Räsänen, Fanny Groundstroem et al.

[Community-level climate change vulnerability research: trends, progress, and future directions](#)

Graham McDowell, James Ford and Julie Jones

[The state of climate change adaptation in the Arctic](#)

James D Ford, Graham McDowell and Julie Jones

[How is adaptation, resilience, and vulnerability research engaging with gender?](#)

A Bunce and J Ford

[Vulnerabilities—bibliometric analysis and literature review of evolving concepts](#)

Carlo Giupponi and Claudio Biscaro

[What we know, do not know, and need to know about climate change vulnerability in the western Canadian Arctic: a systematic literature review](#)

James D Ford and Tristan Pearce

[A comprehensive framework for tourism and recreation drought vulnerability reduction](#)

Deborah S K Thomas, Olga V Wilhelmi, Taryn N Finnessey et al.

[Investigating potential transferability of place-based research in land system science](#)

Tomáš Václavík, Fanny Langerwisch, Marc Cotter et al.

Environmental Research Letters



LETTER

Rapid regional-scale assessments of socio-economic vulnerability to climate change

OPEN ACCESS

RECEIVED

29 October 2015

REVISED

21 February 2016

ACCEPTED FOR PUBLICATION

23 February 2016

PUBLISHED

7 March 2016

Original content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](#).

Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Erin F Smith¹, Scott N Lieske, Noni Keys and Timothy F Smith

University of the Sunshine Coast, Australia

¹ Author to whom any correspondence should be addressedE-mail: esmith2@usc.edu.au, s.lieske@unsw.edu.au, nkeys@usc.edu.au and tsmith5@usc.edu.au**Keywords:** adaptation, resource dependency, sensitivity, secondary data, census data, regional decision-making, AustraliaSupplementary material for this article is available [online](#)

Abstract

Assessing socio-economic vulnerability to climate change impacts to support regional decision-making is conceptually and practically challenging. We report on research that tested a rapid assessment approach of socio-economic vulnerability in Australia's natural resource management regions. The approach focuses on regionally important economic sectors, identified using existing datasets, which are likely to be sensitive to climate change impacts. Disaggregated spatial representations of factors known to be associated with vulnerability function as multiple lines of evidence for highlighting intra-regional hotspots of high potential vulnerability. Our results show that a small number of factors based upon contextually relevant empirical evidence offers a low-cost, rapid assessment process, which is readily transferable across regions and provides end-users with guidance for interpreting the results within the context of regional conditions.

1. Introduction

Successful climate change adaptation is dependent upon the provision of high quality information at scales commensurate with the jurisdictions of organisations responsible for adaptation policy (Cash *et al* 2006, Measham *et al* 2011, Lemieux *et al* 2014). Consistent with moves towards regionalisation across a range of policy sectors (Morrison 2007), the 'region' has emerged as the preferred scale for many forms of decision-making such as natural resource management (NRM) in several developed countries (Gardiner *et al* 1994, Bryce *et al* 1999, Jennings and Moore 2000, Brunckhorst 2002, Clark *et al* 2005, Holmes *et al* 2005). Despite recent attempts to integrate vulnerability assessment approaches developed by the hazard and climate change communities (Costa and Kropp 2013, IPCC 2014), there is no accepted approach for assessing socio-economic vulnerability to climate change impacts and environmental hazards that may be used to inform regional priorities and decision-making.

To address this gap, we developed an approach to assess intra-regional socio-economic vulnerability using multiple lines of evidence derived from

disaggregated spatial representations of regionally-relevant factors known to be associated with vulnerability. We applied the approach to priority sectors in three Australian NRM regions, which were selected by applying the concept of resource dependency (Marshall *et al* 2007, Marshall 2011).

Here, we demonstrate the utility of this approach by presenting a spatially explicit snapshot of the socio-economic vulnerability of the South East Queensland (SEQ) horticultural sector. Multiple lines of evidence allows nuanced assessments of the differences in potential vulnerability between subregions. Crucially, the approach facilitates rapid assessment and renders it readily transferrable across NRM organisations with differing resources, capacities and funding cycles (Robins and Dovers 2007).

The field of climate change vulnerability assessment is characterised by a diversity of valid approaches that vary in their complexity and are operationalised at different scales to address climate change policy questions (Füssel and Klein 2006). Despite this diversity, rapid and cost-effective approaches to assess socio-economic vulnerability suited to regional-scale decision-making are rare. Responding to this pressing research need is

conceptually and practically challenging. These challenges may be overcome by framing assessments using the concept of resource dependency and selecting regionally-relevant factors known to influence socio-economic vulnerability to climate change impacts. In line with Australia's commitment to regional-scale NRM decision-making (Hajkowicz 2009), we tested how these techniques may be used to explore and assess socio-economic vulnerability in three NRM regions on the east coast of Australia. While we focus upon SEQ here, we demonstrate the transferability of our approach by presenting the vulnerability assessments for the Burnett Mary (Queensland) and Hawkesbury–Nepean (New South Wales) regions in this article's supplementary information.

2. Operationalising resource dependency at the regional scale

Marshall *et al* argue that resource dependency is a useful means to measure climate sensitivity because social systems that are more dependent upon natural resources may be more sensitive to the changes in the biophysical systems anticipated under climate change (Marshall *et al* 2013, Marshall *et al* 2014). While the concept has been developed to measure climate sensitivity at the scale of individual actors (Marshall *et al* 2013), it has important utility for assessing vulnerability at larger scales because it provides an intuitive means by which regional-scale vulnerability assessments may be framed. To do this, we used employment data from the Australian Census of Population and Housing (2011) to determine upon which agricultural sector each NRM region was most socially reliant. We combined these data with value of agricultural commodities produced (VACP) data from the Australian Agricultural Census (2010–11) to determine upon which agricultural sector a region was most economically reliant. Spatial representations of these data provide an indication of the intra-regional distribution of the dominant agricultural sector against which spatial representations of factors known to influence socio-economic vulnerability may be compared.

In SEQ, horticulture was the most socially and economically important agricultural sector (table 1 and supplementary information). We do not suggest that the horticultural sector is the most climate sensitive sector in SEQ, rather operationalising resource dependency in this way functions as a prioritisation tool to target regionally important sectors. Simply put, we cannot focus on everything all of the time.

3. Identifying regionally-relevant factors for assessing vulnerability

Regionally-relevant factors for exploring and assessing socio-economic vulnerability were identified from a systematic review of the empirical, peer-reviewed

Table 1. Assessing the dominant agricultural sector in South East Queensland natural resource management region.

	Agricultural sector	Percentage
Persons employed in agriculture	Grazing	29.0%
	Horticulture	46.3%
	Other agriculture	24.7%
Total gross VACP from the region	Grazing	17.0%
	Horticulture	53.9%
	Other agriculture	29.2%

NOTES: The grazing and horticultural sectors are defined by Australian Bureau of Statistics' classifications (see supplementary information) (Australian Bureau of Statistics 2011, 2012).

climate change impacts and climate related hazards literature in our jurisdictions of interest (i.e., Queensland and New South Wales) (Smith *et al* 2015). Selecting factors on this basis is consistent with contemporary perspectives conceptualising vulnerability as a place-specific phenomenon (Adger 2003, Calgaro *et al* 2013). Only those factors that repeatedly were shown to influence socio-economic vulnerability were used in our assessment.

Creating spatial representations of these factors was facilitated by freely available, national datasets that are appropriate for use at regional scales. The five factors and indicators used to represent them were: (1) reliance upon agriculture using the percentage of the labour force employed in agriculture; (2) geographic remoteness using the Australian Bureau of Statistics' (ABS) Remoteness Structure; (3) socio-economic disadvantage using the ABS' Index of Relative Socio-economic Advantage and Disadvantage (IRSAD); (4) economic diversity using the Hachman Index; and (5) age using workforce age profiles (table 2).

While composite indicators are often created to assess vulnerability at broader and finer scales using large numbers of indicators and statistical techniques to combine them (Rygel *et al* 2006, Solangarachi *et al* 2012, Arthurson and Baum 2015), they often obscure the key influences underlying the resultant vulnerability scores. Thus, our approach represents a deliberate departure from composite index approaches. Instead, to enhance rapid assessment and transferability to other regions the factor maps remain disaggregated, each representing one line of evidence in the overall assessment. Intra-regional vulnerability may be explored by interpreting the spatial heterogeneity of each map in line with the ways in which each factor influences vulnerability based upon the peer-reviewed empirical literature (table 2). The rationale of the approach is that areas in which multiple vulnerabilities coincide highlight subregions of higher potential vulnerability compared to the wider regional context. Although the factors used here are directly relevant to the socio-ecological systems in our region of interest, the small number of factors for which there is empirical evidence included in this assessment

Table 2. Factors and indicators used to assess potential socio-economic vulnerability.

Factors influencing vulnerability	Indicator	Interpretation
		When compared to other areas of a given region...
Reliance upon agriculture (Marshall <i>et al</i> 2013, Marshall and Stokes 2014)	Percentage of the labour force employed in agriculture	...areas characterised by high percentages of the labour force employed in agriculture may have high potential vulnerability because populations reliant upon resource dependent economic sectors may be highly sensitive to climatic variability.
Geographic remoteness (Dean and Stain 2010, Clemens <i>et al</i> 2013, O'Brien <i>et al</i> 2014)	ABS' Remoteness Structure	...areas that are more remote may have high potential vulnerability because they are located further from urban centres where services and facilities are readily accessible.
Socio-economic advantage/dis-advantage (Clemens <i>et al</i> 2013)	ABS' Index of Relative Socio-economic Advantage/Disadvantage	...areas characterised by high levels of socio-economic disadvantage may have high potential vulnerability because populations in these areas may have increased sensitivity to the impacts of – and reduced capacity to respond to – climatic and environmental changes.
Economic diversity (Alston 2011)	Hachman Index	...areas with low economic diversity may have high potential vulnerability because the range of alternative employment opportunities may be limited if individual sectors experience a downturn due to economic or environmental factors.
Age (Guo <i>et al</i> 2011, Clemens <i>et al</i> 2013, Turner <i>et al</i> 2013, Coates <i>et al</i> 2014)	Age profiles of horticultural workforce: owner/managers and employees	<p>...horticultural workforces with high percentages of workers aged 65 years or older may have high potential vulnerability arising from the increased physical sensitivity of older people.</p> <p>...horticultural workforces with high percentages of workers aged 25–54 years may have high potential vulnerability because working aged adults may have reduced adaptive capacity arising from adverse impacts on their business property combined with adverse social impacts with their having dependent children.</p>

invites some caution. In addition, there may also be instances where significant vulnerability in one area may distort the utility of a focus on intersecting lines of evidence. Thus, we qualify our terminology with the word 'potential', suggesting that this rapid assessment approach should be viewed as a precursor to more detailed, contextual vulnerability studies. Before presenting the socio-economic vulnerability assessment for the SEQ horticultural sector, we outline the methods and data compilation procedures.

4. Methods

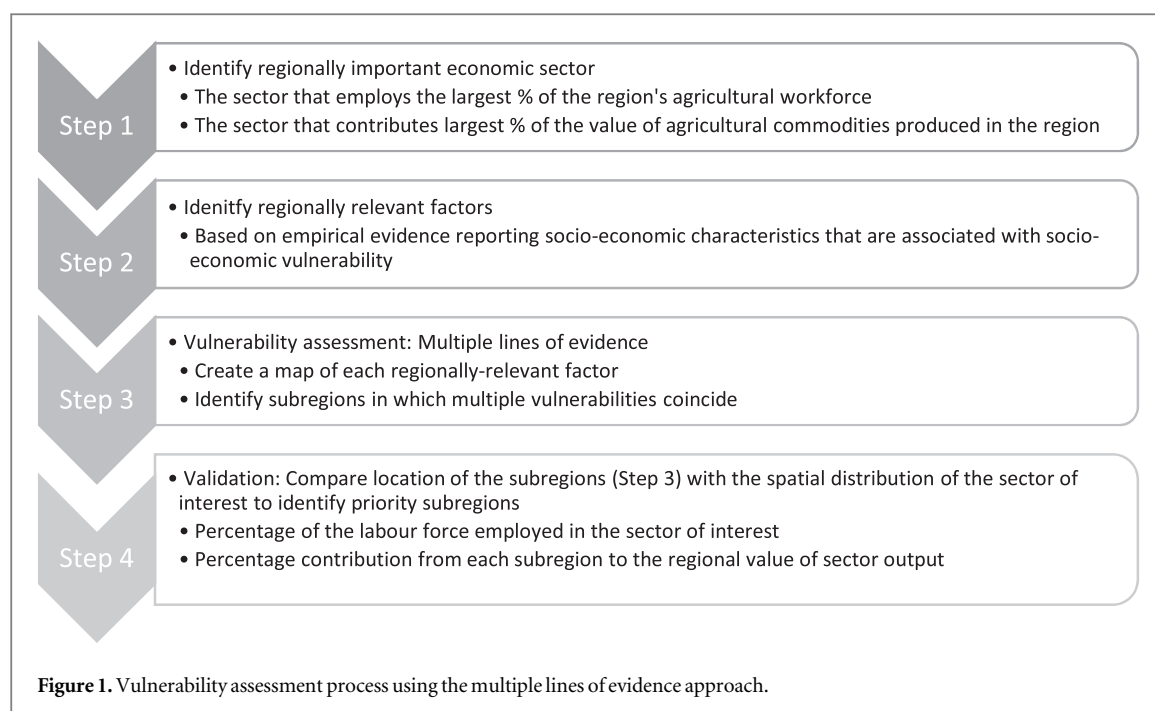
Figure 1 summarises the multiple lines of evidence approach to socio-economic vulnerability assessments in four steps.

4.1. The indicators

A region's reliance upon the agricultural sector was indicated using the percentage of the labour force employed in agriculture. Data were accessed from the ABS' 2011 Census of Population and Housing (Australian Bureau of Statistics 2011). Geographic remoteness was assessed using the ABS' Remoteness

Structure which comprises five categories of relative remoteness: (1) major cities, (2) inner regional Australia, (3) outer regional Australia, (4) remote Australia, and (5) very remote Australia (Pink 2013a). The ABS' IRSAD was used to assess advantage/disadvantage. The IRSAD is a composite index comprising 25 variables that rank areas in terms of relative socio-economic advantage and disadvantage, which the ABS defines as 'people's access to material and social resources, and their ability to participate in society' (Pink 2013b, p 3). High scores indicate areas with relatively high levels of advantage and relatively low levels of disadvantage. None of the variables included in the IRSAD overlap any of the other indicators used in this vulnerability assessment.

Economic diversity was assessed using Hachman Index scores. The Hachman Index is a measure of how closely the employment distribution of the region of interest resembles the distribution of employment in a benchmark region. Hachman scores range from 0 to 1, where the economic diversity of the Australian economy was assumed to be equal to 1. Regional and sub-regional scores closer to 1 indicate a more diverse economy (Thomsen *et al* 2012). Employment data were accessed from the ABS 2011 Census of



Population and Housing. 'Place of work' data were used, instead of 'usual residence' data, to provide a better reflection of the employment opportunities available in a given area (Australian Bureau of Statistics 2011).

Finally, age was assessed using age profiles of the horticultural workforces. Age profiles were preferred to other options such as indicating the percentage of the workforce 65 years or older because it allows for a more nuanced analysis of the ways in which age influences different dimensions of vulnerability. Data were accessed from the ABS 2011 Census of Population and Housing (Australian Bureau of Statistics 2011). The total workforce was organised into two broad categories to differentiate between people who are likely to have decision-making responsibility and the wider workforce: owner/managers and employees. Six age groups were created: 15–24 years, 25–34 years, 35–44 years, 45–54 years, 65 years and older), and then combined into age cohorts broadly consistent with the findings of Clemens *et al* (2013). Percentages for four age cohorts were calculated: (1) owner/managers 65 years and older; (2) owner/managers aged 25–54 years; (3) employees 65 years and older; and (4) employees aged 25–54 years. Clemens *et al* (2013) conclude that adults of working age were disproportionately affected by the 2010/11 Queensland natural disasters when compared to older people. They hypothesise that this finding may reflect the 'greater likelihood that this age group participates in the labour force, owns an income-producing property, and is financially responsible for dependents' (Clemens *et al* 2013, p 554). Here, we use the age cohort 25–54 years to reflect those who are likely to represent this combination of commitments.

4.2. Maps

Regional maps for factors 1–4 were created in ArcGIS using geographic and tabular data freely available from the ABS' website. The reliance upon the agricultural sector, and socio-economic disadvantage were represented at the ABS' geographic unit statistical area 1 (SA1). Geographic remoteness was represented using the ABS' remoteness structure. In the case of economic diversity, the ABS' statistical area 2 (SA2) was used because this is the smallest scale at which 'place of work' data are available. The age profiles were presented using subregional aggregations of SA2s. An SA1 is a geographic unit in the ABS' Australian Statistical Geography Standard (effective from July 2011). They represent regions with populations in the range of 200–800 persons. SA2s are the next largest geographic unit, which represents regions with populations in the range of 3000–25 000 persons (Pink 2011).

4.3. Data analyses: multiple lines of evidence

Each factor and its corresponding map are considered to be one line of evidence for potential socio-economic vulnerability. Areas in which multiple lines of evidence intersect suggest higher potential vulnerability than areas in which fewer lines intersect. Areas of potential high vulnerability are then compared to the areas that are characterised by high reliance upon the horticultural sector. Reliance upon the horticultural sector is indicated by: (1) percentage of the gross value of horticultural commodities produced; and (2) percentage of the labour force employed in horticulture.

The data for percentage of the gross value of horticultural commodities produced were accessed from the ABS' Agricultural Census 2010–11 and mapped at SA2, the smallest geography at which the data is

available. Horticultural commodities were defined by three categories: (1) nurseries, cut flower and cultivated turf; (2) fruit (including tree nuts); and (3) vegetables for human consumption (Australian Bureau of Statistics 2012). The percentage of the labour force employed in horticulture was assessed using employment data from the Census of Population and Housing 2011 and mapped at SA1 (Australian Bureau of Statistics 2011).

5. The study area: SEQ NRM region

The SEQ NRM region is on the Queensland/New South Wales border and encompasses the city of Brisbane, Queensland's capital and Australia's third largest urban centre. The region is home to approximately 70% of the state's population, but includes only 1.3% (23 200 km²) of its land area (Department of State Development, Infrastructure and Planning 2014). The region's NRM body is SEQ catchments, a not-for-profit organisation.

The vulnerability of this region to climate-related hazards and climate change impacts was highlighted by the intergovernmental panel on climate change that considered SEQ as a 'hot spot' of high vulnerability by 2050 under a medium emissions scenario (Reisinger *et al* 2014). Current vulnerability was demonstrated by the December 2010/January 2011 floods, which caused flash flooding in many regional communities and Brisbane city, inundating thousands of homes and businesses, and causing 33 fatalities (Queensland Reconstruction Authority 2011).

The SEQ horticultural sector's sensitivity to climate impacts arises from the specific temperature requirements of most crops for the development of optimum yield and quality (Deuter 2008, Deuter *et al* 2011). The higher temperatures projected for SEQ under several Representative Concentration Pathways (Dowdy *et al* 2015) will likely impact the timing of crop developmental stages, increase the incidence of sunburn, and alter the prevalence and distribution of pests, weeds and diseases (Deuter 2008, Webb and Whetton 2010). Changed rainfall patterns and increased evaporation are expected to adversely impact soil moisture and runoff which may place pressure on water supplies (Webb and Whetton 2010). In turn, horticultural businesses may need to accommodate increased input costs for fuel, fertilisers and pesticides (Deuter 2008). If these impacts exceed horticulturalists' adaptive capacity at specific locations, horticultural production zones are expected to shift southwards (Deuter 2008, Webb and Whetton 2010).

6. The SEQ horticultural sector: hotspots of potential vulnerability

In 2011, the SEQ horticultural sector employed 46% of the region's agricultural workforce (4758 people),

and generated 54% (\$656 million) of the gross VACP in the region in 2010–11 (table 1). The region's horticultural sector employs 37% Queensland's horticultural workforce (10% of the total Australian horticultural workforce) and 29% of the value of horticultural commodities produced in the state (8% of the total Australian value of horticultural commodities). Thus, when compared to the wider Queensland horticultural sector, there is much at stake if the SEQ horticultural sector is adversely impacted by climate change (see supplementary information).

The multiple lines of evidence approach revealed three subregions that were characterised by high potential vulnerability: (1) Southwest, (2) Northeast, and (3) Northwest (figures 2 and 3). When compared to other areas within SEQ, these subregions were generally characterised by higher percentages of the labour forces employed in agriculture (often more than 20%, figure 3, Map a), higher levels of socio-economic disadvantage (often deciles 1 to 2 and 3 to 4, figure 3, Map c), and more specialised economies (often Hachman scores less than 0.40, figure 3, Map d). In addition, the northwest subregion was the most remote area in SEQ (outer regional, figure 3, Map b).

The age profiles of the horticultural workforces also contributed to the potential vulnerability of these three subregions. With the exception of horticultural employees in the Northeast, the three subregions were characterised by horticultural workforces comprising higher percentages of workers aged 65 years or older when compared to the total Australian workforce (table 3). These results are broadly consistent with the wider Australian agricultural sector which tends to have a considerably older age profile than other sectors (Palmer 2012).

Figure 4 shows the spatial distribution of SEQ's horticultural sector by the value of horticultural commodities produced in 2010–11 (figure 4, Map e) and the percentage of the labour force employed in horticulture (figure 4, Map f). These maps allow validation of the multiple lines of evidence approach in the context of the wider SEQ horticultural sector and identifies the relative significance of vulnerability among sub-regions. In the Northeast and Southwest subregions, over 1100 people were employed in the horticultural sector (Northeast = 1185; Southwest = 1120), and up to 33% of the labour forces were employed in the horticultural sector (figure 4, Map f). In the Northwest, while up to 20% of the labour forces were employed in horticulture (figure 4, Map f), only 187 people were employed in horticulture.

The SEQ horticulture sector was similarly skewed towards the Northeast and Southwest when subregions' contributions to the regional value of horticultural commodities produced is examined (figure 4, Map e). The Southwest contributed the largest percentage towards the regional value of horticultural commodities (approximately 33%), followed by the Northeast's contribution of approximately 20%. In

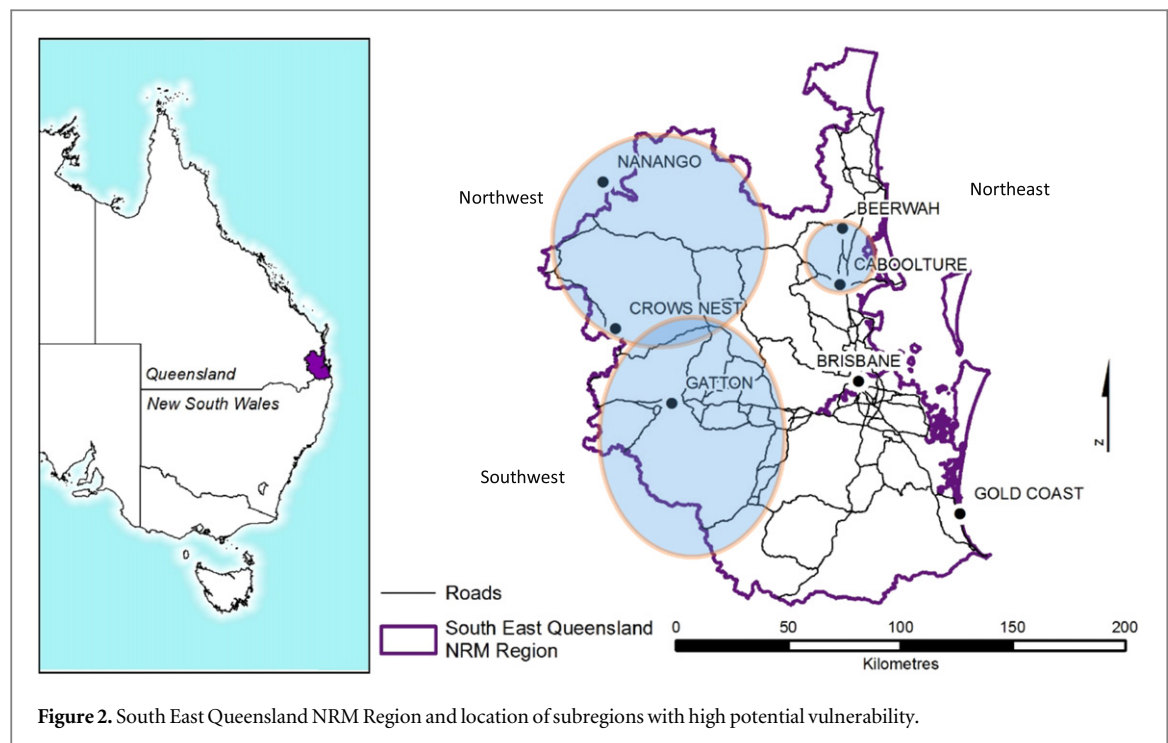


Figure 2. South East Queensland NRM Region and location of subregions with high potential vulnerability.

contrast, the Northwest subregion contributed around 4% to SEQ's total value of horticultural production. Thus, from a regional perspective, the horticultural sectors in the Northeast and Southwest are of greater significance than the Northwest.

Focusing upon the two subregions in which high potential vulnerability coincided with high reliance upon the horticultural sector—the Northeast and Southwest—differences in the ways potential vulnerability is constituted in each subregion are observable. First, the larger contribution to SEQ's value of horticultural commodities from the Southwest suggests that from an economic perspective there was more at stake in the Southwest than Northeast if the horticultural sector was adversely affected by climate change. Second, the differing age profiles of the horticultural workforces in these subregions reveals that there were higher percentages of owner/managers aged 65 years or older, employees aged 65 years or older, and owner/managers aged 25–54 years in the Southwest when compared to the Northeast, which also suggests relative higher potential vulnerability in the Southwest (table 3).

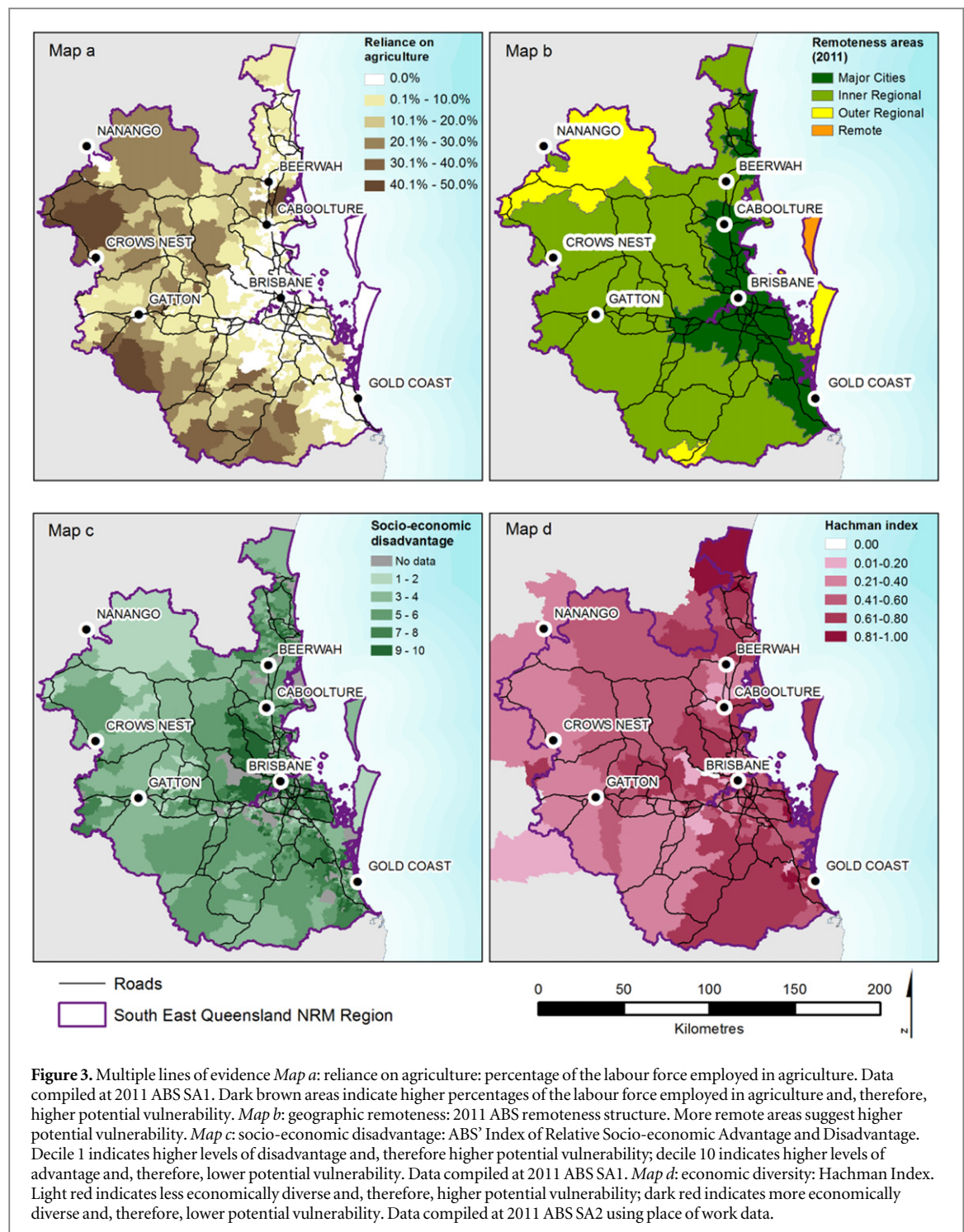
7. Towards rapid, regionally-relevant vulnerability assessments

There are three key ways in which our approach advances knowledge about climate change socio-economic vulnerability assessments. First, increased commitment to regional modes of policy and planning in developed countries means that tools and techniques designed to deliver information at this scale are

pertinent to the effectiveness of climate change adaptation decision-making (Measham *et al* 2011). Thus, our approach specifically focuses upon regional-scale assessments to provide regionally-relevant information to organisations operating at the same scale. However, our approach goes beyond simply matching the scale of analysis to the jurisdictions of administrative organisations responsible for climate change adaptation policies and practices. The regional relevance of our approach is enhanced through the inclusion of techniques that target regionally important sectors and identify place-based factors associated with vulnerability.

Second, in our approach the factors used to assess socio-economic vulnerability are selected based upon empirical, place-based research examining the dynamics of vulnerability. From a conceptual perspective, this process more explicitly aligns with understandings that vulnerability to drivers operating at a range of scales is influenced by the set of social, economic and environmental conditions in particular places (Turner *et al* 2003). Two benefits arise from selecting factors in this way: (1) each factor has direct relevance to the region of interest; and (2) end-users obtain guidance about how the factors should be interpreted within the context of regional conditions (table 2).

One potential limitation is the small number of socio-economic factors that were included in this assessment, and consequently we may have omitted important determinants of vulnerability. This feature of the approach reflects the dearth of place-based research relevant to our area of interest (Smith *et al* 2015), rather than the unavailability of suitable



secondary data upon which vulnerability assessments could be made. These features of the research bases in other regions/countries may differ, leading to the inclusion of a larger number of factors, which will strengthen applications of the approach in other contexts. In the case of Queensland, as the place-based vulnerability literature expands, additional factors may be incorporated to enhance examinations of socio-economic vulnerability.

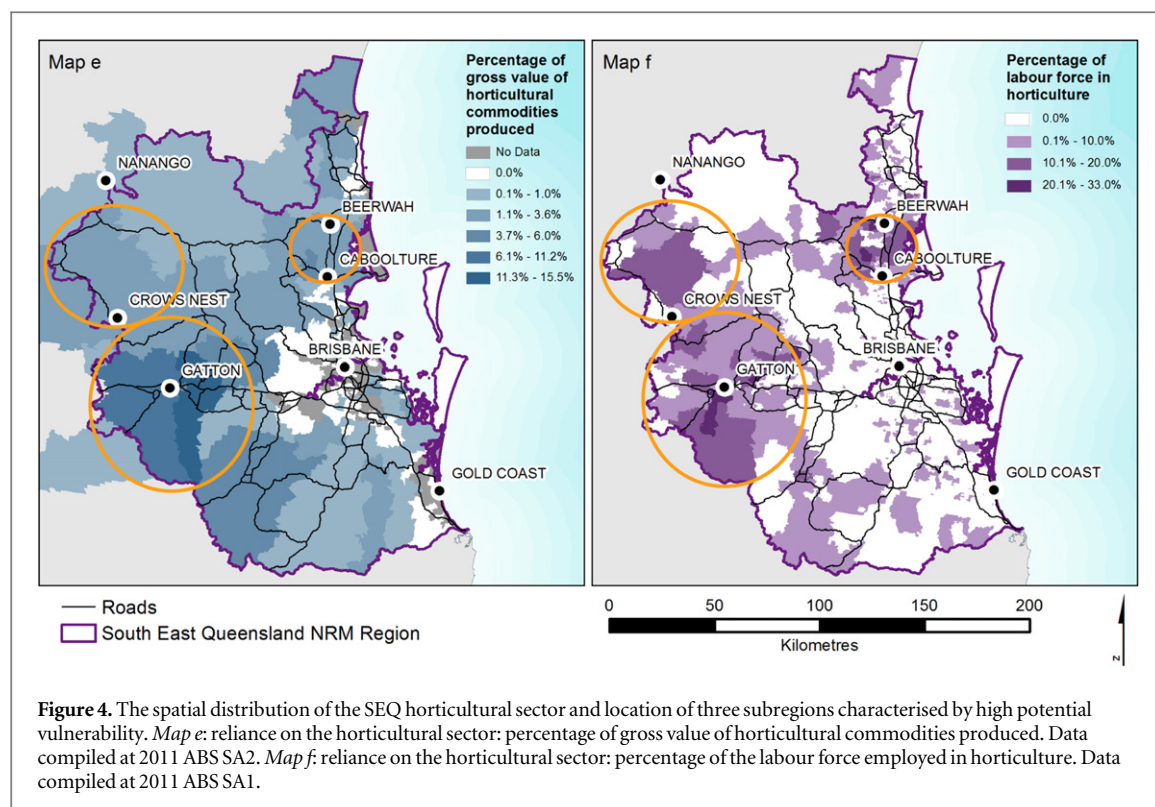
While secondary data for a wider range of factors exists, comparing multiple time periods is currently more problematic. A fundamental change to the ABS'

geographical framework introduced in 2011 hinders straight-forward comparisons with earlier time periods and, therefore, also hinders projections of how indicators may change in the future. Assessment of how individual factors have and may change over time coupled with climate change scenarios represent useful avenues to extend this multiple lines of evidence approach in future applications.

Third, the SEQ findings demonstrate that a small number of factors represented spatially (and based upon contextually relevant empirical evidence) offers a nuanced assessment process capable of identifying

Table 3. Summary of South East Queensland subregions with high potential vulnerability for each factor.

	Northeast	Southwest	Northwest	Potential vulnerability assessment (rank)	
<i>Factors</i>					
Reliance on agriculture (% of labour force employed in agriculture)	0.1%–50.0% (mostly +10.1%)	0.1%–50.0% (mostly +10.1%)	0.1%–50.0% (mostly +20.1%)	1. Northwest 2. Northeast & Southwest	
Geographic remoteness	Major cities/Inner regional	Inner regional	Inner/Outer regional	1. Northwest 2. Southwest 3. Northeast	
Socio-economic disadvantage (Index of Relative Socio-economic Advantage & Disadvantage)	Mostly deciles 3–4; some deciles 5–6; a small area deciles 7–8	Mostly deciles 3–4 & 5–6	Deciles, 1–2, 3–4 & 5–6	1. Northwest 2. Southwest 3. Northeast	
Economic diversity (Hachman Index)	0.01–0.40 (Caboolture = 0.61–0.80)	0.21–0.60 (Gatton = 0.61–0.80)	0.21–0.60	1. Northeast 2. Northwest 3. Southwest	
<i>Age</i>	Owner/managers 65 years & older	12% (4% higher than Australian workforce)	16% (8% higher than Australian workforce)	13% (5% higher than Australian workforce)	1. Southwest 2. Northwest 3. Northeast
	Employees 65 years & older	1% (1% lower than Australian workforce)	4% (2% higher than Australian workforce)	4% (2% higher than Australian workforce)	1. Southwest & Northwest 2. Northeast
	Owner/managers 25–54 years	60% (8% lower than Australian workforce)	65% (3% lower than Australian workforce)	54% (14% lower than Australian workforce)	1. Southwest 2. Northeast 3. Northwest
	Employees 25–54 years	63% (4% lower than Australian workforce)	65% (2% lower than Australian workforce)	62% (5% lower than Australian workforce)	1. Southwest 2. Northeast 3. Northwest



intra-regional hotspots of potential vulnerability. Once subregions are identified, retaining disaggregated maps allows for closer inspection of the differences (and similarities) in potential vulnerability between them. In turn, adaptation actions may be prioritised. Alternatively, the rapid identification of vulnerability hotspots provides a sound rationale for more detailed, contextual analyses of the place-based dynamics of vulnerability at smaller scales.

8. Conclusions

Our research demonstrates that rapid, regionally-relevant socio-economic vulnerability assessments are feasible using existing datasets to target important economic sectors that are likely to be sensitive to climate change impacts. The approach appeals for the following reasons. First, it is comparatively simple when compared to a wide range of other approaches for assessing socio-economic vulnerability, which are often time and resource intensive. Thus, it enables rapid assessments of spatial heterogeneity and the underlying factors that contribute to potential vulnerability—information that may be used for regional-level decision-making and priority setting. Second, it appeals because of its reliance upon freely available, national datasets that can be easily customised to regional scales, rendering the approach highly transferable across multiple regions and time periods. Thus, the approach is more accessible across organisations with differing resources and capacities.

Finally, utilising the concept of resource dependency as an assessment-framing device offers scope to extend the approach beyond the agricultural sector to other resource dependent sectors (e.g., tourism, mining, outdoor recreation). Investigation of the ways in which resource dependency might be used to integrate vulnerability assessments conducted at broader and finer scales also deserves researchers' attention.

Acknowledgments

This article received funding from the Department of Climate Change and Energy Efficiency as part of the Natural Resource Management Climate Change Impacts and Adaptation Research Grants Program, under the Natural Resource Management Planning for Climate Change Fund—A Clean Energy Future Initiative (Australia). The views expressed herein are not necessarily the views of the Commonwealth of Australia, and the Commonwealth does not accept responsibility for any information or advice contained herein.

References

- Adger W N 2003 Social capital, collective action, and adaptation to climate change *Econ. Geogr.* **79** 387–404
- Alston M 2011 Gender and climate change in Australia *J. Sociol.* **47** 53–70
- Arthurson K and Baum S 2015 Making space for social inclusion in conceptualising climate change vulnerability *Local Environ.: Int. J. Justice Sustainability* **20** 1–17
- Australian Bureau of Statistics 2011 *Census of Population and Housing* Australian Bureau of Statistics

- Australian Bureau of Statistics 2012 *Agricultural Census 2010–11* Australian Bureau of Statistics (<http://abs.gov.au/ausstats/abs@.nsf/Lookup/7101.0main+features2Dec%202012>)
- Brunckhorst D J 2002 Institutions to sustain ecological and social systems *Ecological Manag. Restor.* **3** 108–16
- Bryce S A, Omernik J M and Larsen D P 1999 Ecoregions: a geographic framework to guide risk characterization and ecosystem management *Environ. Pract.* **1** 141–55
- Calgaro E, Dominey-Howes D and Lloyd K 2013 Application of the destination sustainability framework to explore the drivers of vulnerability and resilience in Thailand following the 2004 Indian Ocean Tsunami *J. Sustainable Tourism* **22** 361–83
- Cash D W, Adger W N, Berkes F, Garden P, Lebel L, Olsson P, Pritchard L and Young O 2006 Scale and cross-scale dynamics: governance and information in a multilevel world *Ecology Soc.* **11** 8 (www.ecologyandsociety.org/vol11/iss2/art8/)
- Clark B, Burkardt N and King D 2005 Watershed management and organizational dynamics: nationwide findings and regional variation *Environ. Manag.* **36** 297–310
- Clemens S L, Berry H L, McDermott B M and Harper C M 2013 Summer of sorrow: measuring exposure to and impacts of trauma after Queensland's natural disasters of 2010–2011 *Med. J. Aust.* **199** 552–5
- Coates L, Haynes K, O'Brien J, McAneney J and de Oliveira F D 2014 Exploring 167 years of vulnerability: an examination of extreme heat events in Australia 1844–2010 *Environ. Sci. Policy* **42** 33–44
- Costa L and Kropp J P 2013 Linking components of vulnerability in theoretic frameworks and case studies *Sustainability Sci.* **8** 1–9
- Dean J G and Stain H J 2010 Mental health impact for adolescents living with prolonged drought *Aust. J. Rural Health* **18** 32–7
- Department of State Development, Infrastructure and Planning 2014 *South East Queensland Regional Plan Review: a snapshot of the South East Queensland region* Department of State Development, Infrastructure and Planning (www.statedevelopment.qld.gov.au/resources/factsheet/regional/seq-regional-plan-fs4.pdf)
- Deuter P 2008 Defining the impacts of climate change on horticulture in Australia *Garnaut Climate Change Review* Department of Primary Industries and Fisheries Queensland
- Deuter P, White N, Putland D, Mackenzie R and Muller J 2011 *Critical (Temperature) Thresholds and Climate Change Impacts/Adaptation in Horticulture* Department of Employment, Economic Development and Innovation Queensland
- Dowdy A *et al* 2015 *East Coast Cluster report. Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports* ed M Ekström *et al* CSIRO and Bureau of Meteorology (http://www.climatechangeinaustralia.gov.au/media/ccia/2.1.5/cms_page_media/172/EAST_COAST_CLUSTER_REPORT_1.pdf)
- Füssel H-M and Klein R T 2006 Climate change vulnerability assessments: an evolution of conceptual thinking *Clim. Change* **75** 301–29
- Gardiner J, Thomson K and Newson M 1994 Integrated watershed/river catchment planning and management: a comparison of selected Canadian and United Kingdom experiences *J. Environ. Plan. Manag.* **37** 53–67
- Guo Y, Barnett A G, Yu W, Pan X, Ye X, Huang C and Tong S 2011 A large change in temperature between neighbouring days increases the risk of mortality *PLoS One* **6** e16511
- Hajkowicz S 2009 The evolution of Australia's natural resource management programs: towards improved targeting and evaluation of investments *Land Use Policy* **26** 471–8
- Holmes M G R, Young A R, Goodwin T H and Grew R 2005 A catchment-based water resource decision-support tool for the United Kingdom *Environ. Modelling Softw.* **20** 197–202
- IPCC 2014 *Climate change 2014: Impacts, adaptation and vulnerability Working Group II contribution to the Intergovernmental Panel on Climate Change Fifth Assessment Report* (Cambridge: Cambridge University Press)
- Jennings S and Moore S 2000 The rhetoric behind regionalization in Australian natural resource management: myth, reality and moving forward *J. Environ. Policy Plan.* **2** 177–91
- Lemieux C J, Thompson J, Slocombe D S and Schuster R 2014 Climate change collaboration among natural resource management agencies: lessons learned from two US regions *J. Environ. Plan. Manag.* **58** 654–77
- Marshall N A 2011 Assessing resource dependency on the rangelands as a measure of climate sensitivity *Soc. Nat. Resour.* **24** 1105–15
- Marshall N A, Fenton D M, Marshall P A and Sutton S G 2007 How resource dependency can influence social resilience within a primary resource industry *Rural Sociol.* **72** 359–90
- Marshall N A and Stokes C J 2014 Identifying thresholds and barrier to adaptation through measuring climate sensitivity and capacity to change in an Australian primary industry *Clim. Change* **126** 399–411
- Marshall N A, Stokes C J, Webb N P, Marshall P A and Lankester A J 2014 Social vulnerability to climate change in primary producers: a typology approach *Agric. Ecosyst. Environ.* **186** 86–93
- Marshall N A, Tobin R C, Marshall P A, Gooch M and Hobday A J 2013 Social vulnerability of marine resource users to extreme weather events *Ecosystems* **16** 797–809
- Measham T, Preston B, Smith T, Brooke C, Gorrard R, Withycombe G and Morrison C 2011 Adapting to climate change through local municipal planning: barriers and challenges *Mitigation Adaptation Strateg. Glob. Change* **16** 889–909
- Morrison T H 2007 Multiscalar governance and regional environmental management in Australia *Space Policy* **11** 227–41
- O'Brien L V, Berry H L, Coleman C and Hanigan I C 2014 Drought as a mental health exposure *Environ. Res.* **131** 181–7
- Palmer J 2012 *Australian Social Trends: Using Statistics to Paint a Picture of Australian Society* (cat. no. 4102.0) Australian Bureau of Statistics Canberra, Australia (<http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/EED42391CD269634CA257B4800143EAC?opendocument>)
- Pink B 2011 *Australian Statistical Geography Standard (ASGS): Main Structure and Greater Capital City Statistical Areas* vol 1 (Canberra, Australia: Australian Bureau of Statistics)
- Pink B 2013a *Australian Statistical Geography Standard (ASGS) Remoteness Structure* vol 5 (Canberra: Australian Bureau of Statistics)
- Pink B 2013b *Socio-Economic Indexes for Areas (SEIFA) 2011: Technical Report* Australian Bureau of Statistics Canberra
- Queensland Reconstruction Authority 2011 *Operation Queensland: The State Community, Economic and Environmental Recovery and Reconstruction Plan 2011–2013* Queensland Reconstruction Authority Brisbane
- Reisinger A, Kitching R L, Chiew F, Hughes L, Newton P C D, Schuster S S, Tait A and Whetton P 2014 *Australasia ed V R Barros et al Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* pp 1371–438 Cambridge University Press, Cambridge
- Robins L and Dovers S 2007 NRM Regions in Australia: the 'haves' and the 'have nots' *Geogr. Res.* **45** 273–90
- Rygel L, O'Sullivan D and Yarnal B 2006 A method for constructing a social vulnerability index: an application to hurricane storm surges in a developed country *Mitigation Adaptation Strateg. Glob. Change* **11** 741–64
- Smith E F, Keys N, Lieske S N and Smith T F 2015 Assessing socio-economic vulnerability to climate change impacts and environmental hazards in New South Wales and Queensland, Australia *Geogr. Res.* **53** 451–65
- Solangaarachchi D, Griffin A L and Doherty M D 2012 Social vulnerability in the context of bushfire risk at the urban-bush

- interface in Sydney: a case study of the Blue Mountains and Ku-ring-gai local council areas *Nat. Hazards* **64** 1873–98
- Thomsen D C, Smith T and Stephenson C 2012 *Sustainability indicators: Annual sustainability trends for the Sunshine Coast. Report prepared for the Sunshine Coast Council, Queensland, Australia. Sippy Downs* Sustainability Research Centre, University of the Sunshine Coast, Australia
- Turner B L *et al* 2003 A framework for vulnerability analysis in sustainability science *Proc. Natl Acad. Sci. USA* **100** 8074–9
- Turner L R, Connell D and Tong S 2013 The effect of heat waves on ambulance attendances in Brisbane, Australia *Prehospital Disaster Med.* **28** 482–7
- Webb L and Whetton P H 2010 Horticulture ed M Howden and C Stokes *Adapting Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for the Future* (Melbourne: CSIRO) pp 119–36