

ON THE FRONTLINE: CLIMATE CHANGE & RURAL COMMUNITIES



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Preface

Australia's rural and regional communities experience many disadvantages compared to their urban counterparts. Unemployment rates are higher, and they experience greater rates of poverty and reduced access to health, education and transport services.

The risks posed by climate change to health, security, environmental assets and economy threaten to exacerbate many of the social, economic and health inequalities already experienced by those in rural and regional areas. Rural and regional communities are particularly vulnerable to increasing droughts, bushfires and heatwaves being driven by climate change. Furthermore, decreases in rainfall significantly reduce runoff and increased temperatures result in high evaporation rates, with serious implications for water availability in rural and regional areas.

In addition to affecting agricultural production, climate change also threatens to increase the cost of essential goods and services and rural and regional communities are often poorly equipped to deal with the health impacts of higher temperatures. While all Australians will be affected by these challenges, those living in rural communities will be the worst affected.

This report focuses on how climate change is affecting, and will continue to affect rural communities that are largely reliant on primary agricultural production. We recognise that climate change will also have important impacts on rural and regional communities via effects on sectors such as fisheries, forestry, mining and tourism – these impacts will be explored in future reports. We have also provided more detail on how climate change will continue to affect Australian agriculture in our report "Feeding a Hungry Nation: Climate Change, Food and Farming in Australia".

While climate change poses many challenges and risks to rural landholders and their communities, transitioning to new ways of producing energy also provides many opportunities. Rural landholders manage the majority of Australia's land area, and so their collective actions have important implications for our water supplies, food production, and environment, and can play an important role in moving to a more sustainable, healthier, and prosperous Australia.

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Key Findings

1

Rural and regional communities are disproportionately affected by the impacts of climate change.

- › Climate change is worsening extreme weather events such as bushfires and drought and rural and regional communities will continue to be disproportionately affected.
- › Many agricultural businesses surveyed have used financial reserves and/or have taken on increased debt in response to extreme weather events.
- › Australia's agricultural sector is showing signs of decreasing capacity and faltering productivity gains and the resilience of some rural industries is under threat.

2

The systemic disadvantages experienced by rural and regional communities over those in urban areas are likely to worsen if climate change continues unabated.

- › Rural and regional communities have already seen a significant reduction in population that has prompted further losses in services and unemployment. Climate change will further exacerbate these stresses.
- › Strong climate action is required to protect rural and regional communities from the worsening impacts.

3

Rural and regional communities are already adapting to the impacts of climate change but there are limits and costs.

- › Adaptation to cope with a changing climate may be relatively incremental, such as changing sowing and harvesting dates, or switching to new breeds of livestock and new varieties of crops.
- › More substantial adaptation options may involve changing production systems (eg. from cropping to grazing), or relocating to more suitable areas.
- › The more transformational adaptive changes may be risky and expensive, especially for individual farmers.
- › As the climate continues to change, adaptation will become increasingly challenging.

4

While rural and regional communities are on the frontline of climate change impacts, tackling climate change also provides these communities with many opportunities.

- › In Australia, rural areas receive around 30 - 40% of the total investment in renewables, valued at \$1-2 billion per year.
- › Renewable energy projects bring jobs and investment into rural and regional communities. Delivering half of our electricity from renewable sources by 2050 would create more than 28,000 jobs.
- › The transition to clean energy will also reduce the health burden of burning coal, which is almost entirely borne by rural and regional areas, eg the Hunter and Latrobe valleys.
- › Farmers can build the climate-resilience of their farms by adding additional revenue streams, such as by hosting wind turbines and other renewable energy projects. Across Australia, approximately \$20.6 million is paid annually in lease payments to farmers and landholders hosting wind turbines.
- › Community funds and additional rate revenue for rural and regional areas from renewable energy can be used to improve public services such as schools and local infrastructure.
- › Renewable energy can reduce electricity costs for rural and remote communities, who traditionally pay much higher prices than their urban counterparts. It also offers independence from the grid with several towns now racing to be the first to operate on 100% renewable energy.

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1. Introduction

Australian rural and regional communities have had to adapt to many challenges, and many have become very adept at doing so. But these challenges are escalating in ways that call for more skillful, imaginative and coordinated adaptation than ever. Central to many of these challenges is climate change, which presents not only additional problems but often exacerbates existing vulnerabilities and risks, including increased climatic variability and extreme events such as droughts, floods, heatwaves and bushfires.

While many studies on climate change and agriculture focus on the impact on crop yield or livestock productivity, the drastic impacts on rural and regional communities more broadly should not be overlooked. The myriad of climate change challenges means that the sustainability, health, livability, productivity and prosperity of Australia's rural and regional industries, landscapes and communities require a strong commitment to policies and practices to assist in coping with climate change (adaptation). Far more than just a task for individuals, climate change adaptation requires families, communities, businesses, industry sectors and all levels of government to work together. Adaptation to climate change, and the challenge of reducing greenhouse gas emissions, presents exciting opportunities as well as hard decisions. Strengthening cooperative relationships, tackling long-standing demographic and environmental problems, enhancing resilience, generating new visions, and moving to a new, low carbon economy are all part of what climate change adaptation can entail.

In this report, we firstly describe the nature of Australia's rural communities and the general challenges they face. We also describe some of the main features of primary production in Australia, followed by how the Australian climate has already changed, and how it is projected to change in coming decades. We then explore the impacts observed and expected on landscapes, agriculture, food security, health and the social fabric of rural communities. Next, we look at adapting to the impacts of a changing climate, the options, limits and barriers. Finally, we describe the diverse opportunities for rural communities that building resilience and transitioning to a new, low carbon and sustainable economy present. Such progress is not only positive in its own right - it is a key part of scaling up Australia's and the world's efforts to combat future climate change in this critical decade for urgent and decisive action.

2. | THE SETTING



2.1 Rural Communities in Australia

To understand the challenge climate change poses for Australian rural communities, it is vital to consider the context of existing challenges and changes faced in rural Australia. Climate change is just one of a complex set of environmental, social, health, political and economic issues affecting rural populations (Brooks and Loevinsohn 2011; Puig *et al.* 2011; Kiem and Austin 2013a).

Australia's rural and regional communities are diverse in their characteristics and level of prosperity. Some 'resource towns' are dominated by relatively short-term extractive industries such as coal or gas, and some have local economies sustained by tourism or service industries, particularly if they are located in high amenity areas. But agriculture remains the key economic foundation of many rural communities (Rickards 2012).

In 2015, it was estimated that Australia had a rural population of approximately 2,500,000 (Geohive 2016). Although population trends across rural and regional Australia are uneven, in general the rural population is diminishing in both absolute and relative terms as urban Australia grows. Factors such as technological advances, amalgamation of properties (from family to corporate owned), and retirements have combined to reduce the ratio of farmers to farmland.

Agriculture remains the key economic foundation of many rural and regional communities.

In 2011 there were nearly 20,000 fewer farmers in Australia than in 2006.

In 2011 there were nearly 20,000 fewer farmers in Australia than in 2006, a fall of 11% over five years (Figure 1). Over the 30 years to 2011, the number of farmers declined by 106,200 (40%), equating to an average of 294 fewer farmers every month over that period (ABS 2012a). Exit rates from farming were particularly high in the 1980s and 1990s, largely due to falling wool prices and drought (Millar and Roots 2012). Indeed,

extreme events such as droughts have had a major impact on the rural workforce - a decline of 15% was recorded over just a single year in the midst of the 2002-03 drought (ABS 2012a). The number of young farmers entering the sector is also falling, adding to the ageing of the farmer population (Barr 2014), which is already considerably older, on average, than the rest of Australia's employed population (ABS 2012b).

The number of farmers nationwide is declining.

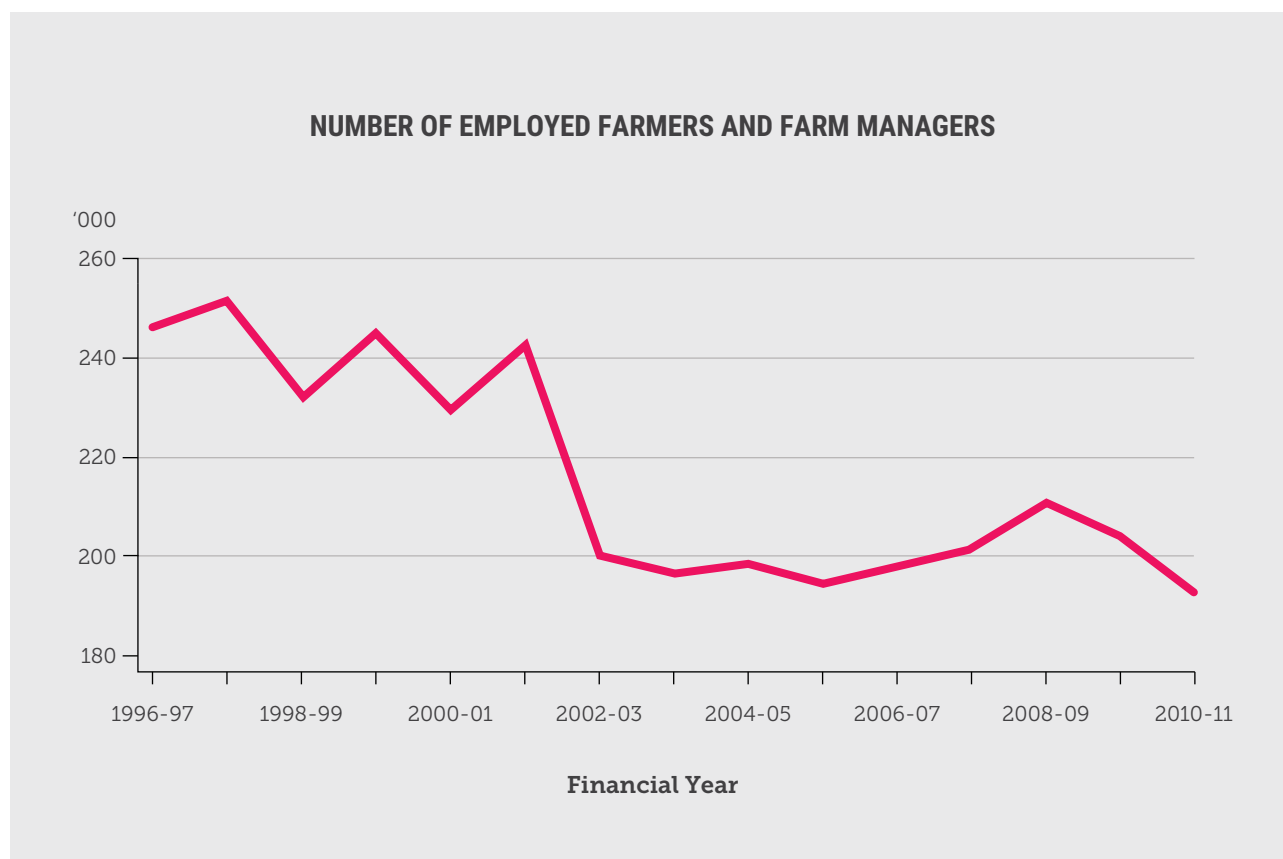


Figure 1: Changes in the Australian farming workforce over past two decades. Source: ABS 2012b.

Declines in farming populations can diminish the support base for rural services, contributing to the closure of such services, particularly in a market-driven environment with little or no government support (Alston and Kent 2004; Askew and Sherval 2012; Hogan and Young 2013). Research suggests that the decline of these

services, including schools, government agencies, banks, health clinics and hospitals, threatens the survival of some small communities in rural and regional Australia (eg Markey et al. 2010; Keating et al. 2011). Rural communities in Canada and the United States are facing similar challenges (Sullivan et al. 2014).

Access to services and off-farm work are crucial for the viability of family farms.

One way the loss of services affects rural communities is by undermining the viability of remaining businesses (Sullivan et al. 2014), including farms and the agribusinesses that support them. Such businesses are often critical to the capacity of farm families to remain in the area. This includes the employment options that they and other organisations provide, with more than half of the farms run by families reliant on off-farm income, mainly provided by women working in “nearby” towns (Alston 2012, 2013). Juggling off-farm work and the need to travel greater distances to access schools and other services can mean that the logistics of some farm families’ lives are increasingly complex and dependent on the provision of adequate transport networks (Rickards 2012). The time commitments involved can also place considerable pressure on health and relationships (Strazdins et al. 2011; Alston 2012). As some families relocate to larger towns for family reasons, it is farmers who are becoming the commuters, bringing new management challenges (Rickards 2012).

Irrespective of the above issues, some farms and rural regions are thriving, with diverse populations, vibrant social networks, and numerous innovative initiatives under way (Sullivan et al. 2014). Some towns

are, for example, making the most of relatively cheap house prices (helped in some cases by government incentives) and are attracting new entrants, including young families and people from different socio-economic and cultural backgrounds. Indeed, regional Australia is full of examples of how community cooperation, social networks, and good leadership can generate positive outcomes. This provides a strong base on which to face the challenges and opportunities of climate change.

At the same time, effective climate change adaptation in rural Australia (see Section 5) is going to demand that many of the existing challenges and systemic disadvantages at work in rural Australia are addressed. Furthermore, Australia inherited a European fiscal system based on regular and predictable cash flow models supported by good soils, regular rainfall, reliable and predictable seasons, and easy access to large markets. Many of the serious socioeconomic and environmental impacts associated with recent droughts are due to economic imperatives bought about by a fiscal system that is not adaptive enough for the Australian environment and a changing climate (Kiem and Austin 2016).

While there are challenges, many rural regions are thriving.

2.2 Australian Agriculture and Rural Industries

Agriculture has been an important contributor to the Australian economy since 1788. Although some rural and regional centres have diversified over time - establishing a range of industries as well as cultural, transport, education, and tourist hubs - agriculture remains the economic backbone of many rural communities. The risks posed to agriculture from the rapidly changing climate therefore have direct impacts on the communities supported by these industries.

According to the 2010-11 Agricultural Census, there were 135,000 farm businesses across Australia, the majority involved in beef cattle farming (28%), mixed grain-sheep or grain-beef cattle farming (9%), other grain growing (9%) or specialised sheep farming (8%) (see Figure 2). Other common types of farming businesses included dairy cattle (6%), mixed sheep-beef cattle (5%) and grape growing (4%) (ABS 2012a). While production has become increasingly concentrated on large farms, the majority of Australia's farms are comparatively small, with around a third covering less than 50 hectares, and another third covering 50-500 hectares. In 2010-11, just over half (55%) had an estimated value of agricultural operations of less than \$100,000 (ABS 2012a). Dryland livestock grazing, which largely takes place in arid and semi-arid regions, is the dominant land use, accounting for 3.8 million km² or 51% of the continent (Barlow et al. 2011). Trade in Australian agribusiness overall (that is, all those involved from the farm to the consumer) equates to approximately 3% of global food trade, which is 3 times greater than domestic demand (Mohson 2015).

Agriculture remains the economic backbone of many rural communities.



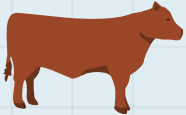
AUSTRALIAN AGRICULTURE

PROVIDES
ABOUT

93%

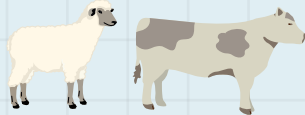
OF THE COUNTRY'S
DOMESTIC FOOD NEEDS

THE MAJORITY OF THE 135,000 FARMS IN AUSTRALIA ARE:



28%

BEEF CATTLE



9%

MIXED GRAIN-SHEEP
OR GRAIN-BEEF CATTLE



9%

OTHER GRAIN
GROWING



8%

SPECIALISED
SHEEP FARMING

FARM SIZES IN AUSTRALIA

1/3

ARE SMALL FARMS
less than 50 hectares



1/3

ARE MEDIUM FARMS
50-500 hectares



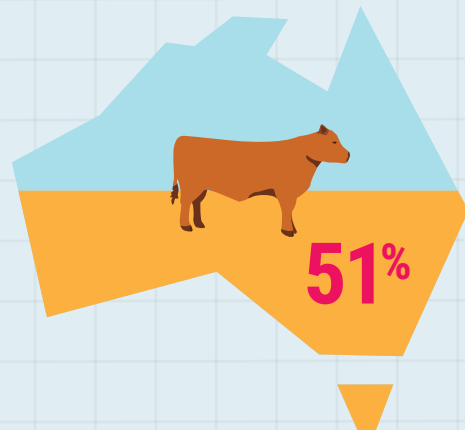
1/3

ARE LARGE FARMS
larger than 500
hectares



DRYLAND LIVESTOCK GRAZING

TAKES UP 51% OF AUSTRALIA



THAT'S 3.8 MILLION KM²
OF AUSTRALIA

EMPLOYMENT IN AGRICULTURE

300K

in Australia
are employed directly



1.6M

employed in entire Australian
agriculture supply



Climate change is a threat multiplier.

In some regions, forestry and fishing play an important economic role, together employing 56,000 people (2010-11) and producing commodities worth nearly \$4.9 billion (2010-11) (ABS 2012b). Primary industries also support industries such as tourism and transport and a wide range of local cultural, economic and social activities (Barlow et al. 2011).

Australian agriculture provides about 93% of the country's domestic food needs, and in 2010-11, employed over 300,000 people directly and ~1.6 million if the entire agriculture supply chain is taken into account (NFF 2015; Figure 2). The Australian food industry comprises more than 700,000 businesses, food retailers and wholesalers (Michael and Crossley 2012). Overall agricultural production has been increasing at approximately 2.8% per year, despite the decline in the number of farmers (NFF 2015).

Some researchers have warned that many of the farming enterprises on which we rely for our food and fibre production are operating on limited profits and unstable or unsound finances (eg Kiem et al. 2010; Kiem and Austin 2013a, 2013b). Many Australian farm businesses have high levels of debt, reflecting the rising costs of inputs and other operating costs, periods of poor profitability over the last decade, and the limited number of options other than debt to finance farming activities (McGovern 2014; Moshin 2015).

The challenges that climate change poses for rural communities in an already difficult operating environment should not be underestimated. Climate change can be thought of as a threat multiplier – exacerbating existing stresses on rural industries and communities as well as adding new ones. But adapting to these challenges can also bring benefits and opportunities, including strengthening the resilience of rural businesses and communities to climatic extremes, which as discussed below, are increasing in severity and/or frequency under climate change (Whittaker et al. 2012; Reisinger et al. 2014) (see Sections 4 and 5.2).

The challenges that climate change poses for rural communities in an already difficult operating environment should not be underestimated.

2.3 Rural Landscapes

Australia's rural landscapes, the agricultural enterprises they support, and their relative economic and environmental health, are highly varied. Some farmers are now having to manage legacies such as salinity that have arisen from poor management in the past, while others are facing the emerging health, environmental and economic costs of degrading activities such as coal mining (see, for example, Figure 3).

Deterioration of the natural environment reduces the valuable services that healthy ecosystems provide. In the Murray Darling Basin, for example, rural communities that rely on healthy river systems are facing the urgent need to restore ecosystem health (eg Gell and Reid 2014).

Soil quality is of particular importance to agriculture. Ongoing degradation of agricultural soils in many regions is contributing to the risks faced by the farming sector and without significant action to reduce this trend, it has been estimated that reduction in yields of as much as 30% could occur by 2060 (see Turner et al. 2016).

Figure 3: Image of a Bowen Basin mine in Queensland. There have been recent reported cases of 'Black Lung' (Coal Workers' Pneumoconiosis) in the Bowen Basin area and other parts of Queensland. In Australia, there is no mandatory reporting system and no national data on the prevalence of CWP. There were 25,000 deaths from black lung disease globally in 2013.



The Murray Darling Basin in particular, faces ongoing water availability challenges, which are likely to be exacerbated by climate change (see Section 3; Figure 4). The Basin is Australia's largest and most diverse river system, covering more than 14% of Australia's land area, including large areas of Queensland, New South Wales, the ACT and South Australia (MDBA 2014a). It supports about two million people directly within its boundaries, accounts for over 40% of Australia's agricultural produce and generates about \$15 billion per year for the national economy (MDBA 2014a, 2014b). Another 1.3 million people rely on the Basin for household water supply.

Water availability has presented challenges for the Murray Darling Basin in the past few decades, particularly during the Millennium drought (1996 to 2010). Several policy initiatives aim to reduce vulnerability to climate variability and change, including the establishment of the Murray Darling Basin Authority to address over-allocation of water resources (Connell and Grafton 2011; MDBA 2011). The Murray Darling Basin Plan (MDBA 2011, 2012a, 2012b) commits to return 2750 gigalitres per year of consumptive water (about one-fifth of current entitlements) to river ecosystems in the Basin and outlines water sharing mechanisms designed to cope with current and future climates (Reisinger et al. 2014).

Figure 4: Murray Darling River near Mildura, Victoria. Climate change is projected to decrease water availability in parts of the Murray Darling Basin, challenging the livelihoods of communities in and around this region.



3. | OBSERVED AND PROJECTED CHANGES IN AUSTRALIA'S CLIMATE



3. Observed and Projected Changes in Australia's Climate

Australia is the driest inhabited continent on Earth. Much of Australia is also subject to extreme heat which, coupled with the highly variable water cycle and generally poor soils, presents a challenging environment for farmers and communities reliant on primary production.

Our climate has already changed substantially over the past century. Overall temperatures have been rising, consistent with global trends, with growing evidence of increases in extreme heat, rising bushfire risk, and heavy rainfall events (details in Table 1). These changes are expected to accelerate in the next few decades, with significant impacts for rural communities and agricultural production. The magnitude of the impacts in the second half of this century, however, will be highly dependent on the success of actions to reduce greenhouse gas emissions. Please see Appendix A for details about the 'Basis of Climate Projections for Australia'.

Table 1: Observed and projected changes in Australian climate.

Climate characteristic	Observed changes	Projected changes
Temperature and extreme heat	› Average surface temperature increased 0.9°C since 1910; largest increases across inland QLD and NT (Figure 5); warming stronger over inland than coastal regions. › Day time extreme heat records since 2001 have outnumbered extreme cold records by 3 to 1 and night time records by 5 to 1. › Frequency and extent of extremely hot days also increased markedly since 1950, with half of these events occurring in the past 20 years. › 2013 was Australia's hottest year. Summer of 2012/2013 was the hottest and included the hottest day, hottest week, hottest month, and longest and most spatially extensive national heatwave. › Recent hot summers and record temperatures have been influenced by climate change. The record heat in Australia during 2013, for example, was virtually impossible without climate change. › Australia recorded its hottest ever October in 2015, 2.89°C above the long-term average and recent research has found that global warming increased the chance of these record-breaking temperatures by a factor of at least six. › From 1950-2013, the number of heatwave days increased over much of Australia, particularly in the eastern half and in central Western Australia (Figure 6). › First heatwave of season occurring earlier virtually everywhere; heatwaves occurring more frequently in many regions; hottest day of a heatwave becoming even hotter across south.	› Annual average temperature by 2030 projected to be 0.6-1.3°C above the 1986-2005 baseline (~1.2-1.9°C above pre-industrial level); temperatures by 2090 very dependent on success of reducing greenhouse gas emissions; projected temperature rise ranges from 0.6-1.7°C for a low emissions scenario to 2.8-5.1°C for a high emissions scenario (measured against 1986-2005 baseline). › Warming projected to be greater across inland regions than along the coast especially in the southern coastal areas in winter; marked southward movement of hot/warm climates, corresponding to a shift of about 900 km in climate zones; present-day cooler climates expected to contract to the high altitude areas of the southeast and to Tasmania (Figure 7). › Increase in extreme heat expected in all capital cities and in some regional centres by 2030 and 2090. › Incidence of frost across inland Australia reduced, and exceptionally unlikely from coastal regions by 2090 under a high emissions scenario.

Climate characteristic	Observed changes	Projected changes
Bushfire weather	› Extreme fire weather days have become more frequent over the past several decades. › Increase in Forest Fire Danger Index (FFDI), measured cumulatively over an annual (July-June) period from 1973 to 2010 at all 38 sites measured with 16 sites (mostly in southeast) showing statistically significant increases. › Extension of fire season into spring and autumn. › The impact of climate change on extreme weather, increasing the number of hot days and heatwaves, is driving up the likelihood of very high fire danger weather. › After a record breaking dry spring and a dry, hot summer, in January 2016 bushfires burnt large areas of Tasmania's ancient forests and World Heritage wilderness.	› More severe bushfire weather expected in eastern and southern Australia, consistent with rising temperatures and, in the south, the decrease in rainfall; combination of warming and drying will likely (66-100% chance) dry out fuel and increase its flammability. › Increases in the average forest fire danger index (FFDI) and in the number of days with severe fire danger weather. › Projections for changes in fire frequency and extent for tropical and monsoonal northern Australia less certain.
Rainfall	› Total averaged rainfall across Australia has increased slightly when comparing 1970-2013 period to 1900-1960. › Significant changes in regional and seasonal distribution of rainfall across continent. › Warm season (October-April) rainfall increased across northern and central Australia since 1970s, with rainfall very much above average over the 1997-2013 period (Figure 8a). › 2010-2012 recorded the highest 24-month rainfall totals for Australia as a whole due to two strong La Niña events. › Cool season (May-September) rainfall trends showed marked decreases in rainfall in southwest and southeast (Figure 8b). › Rainfall decline up to 40% in some regions of southwest over past 50 years, leading to large decreases in runoff.	› Cool season (winter and spring) rainfall projected to continue to decrease across southern Australia (including southwest WA wheat belt and the Murray Darling Basin). › Decrease in rainfall in southwest by 2090 could be as much as 50% in winter under the highest emissions scenario. › Potential shift of summer-dominated rainfall zone to the south, and southward expansion of boundary between the summer and winter rainfall zones. › Relative humidity projected to decline in inland regions, with decreases relatively small by 2030 but larger by 2090, especially in winter and spring as well as annually. › Likely increase in evapotranspiration rates and reduced soil moisture and runoff in southwestern WA and southern SA.

Climate characteristic	Observed changes	Projected changes
Drought	› Three major droughts experienced over past century or so: 1. "Federation Drought" (1895-1903) 2. "World War II Drought" (1939-1945) 3. "Millennium Drought" (1996-2010) ...but little evidence for trends to date.	› Drought projected to worsen in southern Australia through this century, consistent with the expected decline in winter and spring rainfall, normally the wettest time of the year in this region. › Time in drought expected to increase, with the projections showing more certainty for southern Australia. › Frequency of extreme droughts projected to increase in all regions.
Heavy rainfall	› Increase in the proportion of rain falling as extreme rainfall events, especially evident since 1970s but with considerable seasonal and regional variation (Figure 8a). › Widespread and very heavy rainfall 2010-2013 attributed mainly to two successive pair of La Niña events, but long-term warming of the climate could also have been a factor.	› Frequency of heavy rainfall events very likely to increase across all regions even where annual rainfall average is projected to decrease, increasing risk of flooding and erosion. › The exception to this is southwest WA, where the projected strong drying trend may not lead to an increase in heavy rainfall events.
Cyclones	› No clear trends in cyclone frequency or intensity (wind speeds) in the Australia. › No clear evidence of climate change influence yet.	› Increase in intense cyclone activity more likely than not in Australian region later this century; possibly southward extension of storm tracks.

Main sources: Cai and Cowan 2008; Hennessy et al. 2008; Lucas 2010; Trewin and Vermont 2010; CSIRO 2012; BoM 2013; Clarke et al. 2013; Gallant et al. 2013; Perkins and Alexander 2013; Trewin and Smalley 2013; Lewis and Karoly 2014; BoM 2015; CSIRO and BoM 2015; Karoly and Black 2015; Climate Council 2016a; King and Black 2016.

Probability descriptors used in this table are based on IPCC (2013): Virtually certain 99-100%, Very likely 90-100%, Likely 66-100%, About as likely as not 33-66%, Unlikely 0-33%, Very unlikely 0-10%, Exceptionally unlikely 0-1%.

LINEAR TREND IN MEAN TEMPERATURE FROM ACORN-SAT FOR 1910-2013

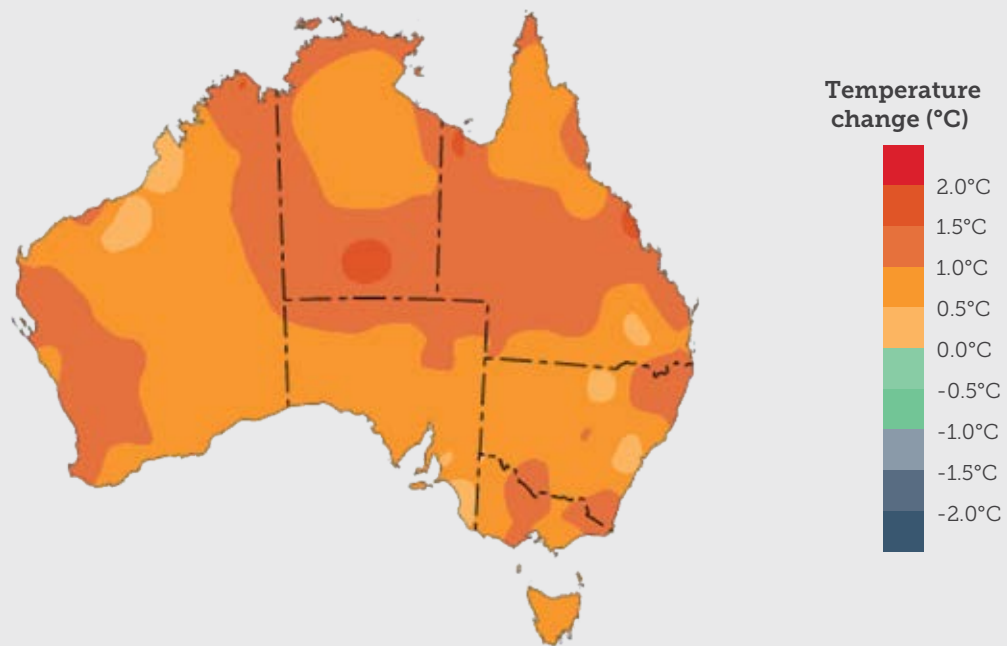


Figure 5: Linear trend in mean temperature from the Australian Climate Observations Reference Network (ACORN-SAT) calculated for the entire period 1910-2013. **Source:** Adapted from BoM 2014.

HEATWAVE DAYS EXPRESSED AS A PERCENTAGE OF ALL SUMMER DAYS PER SUMMER

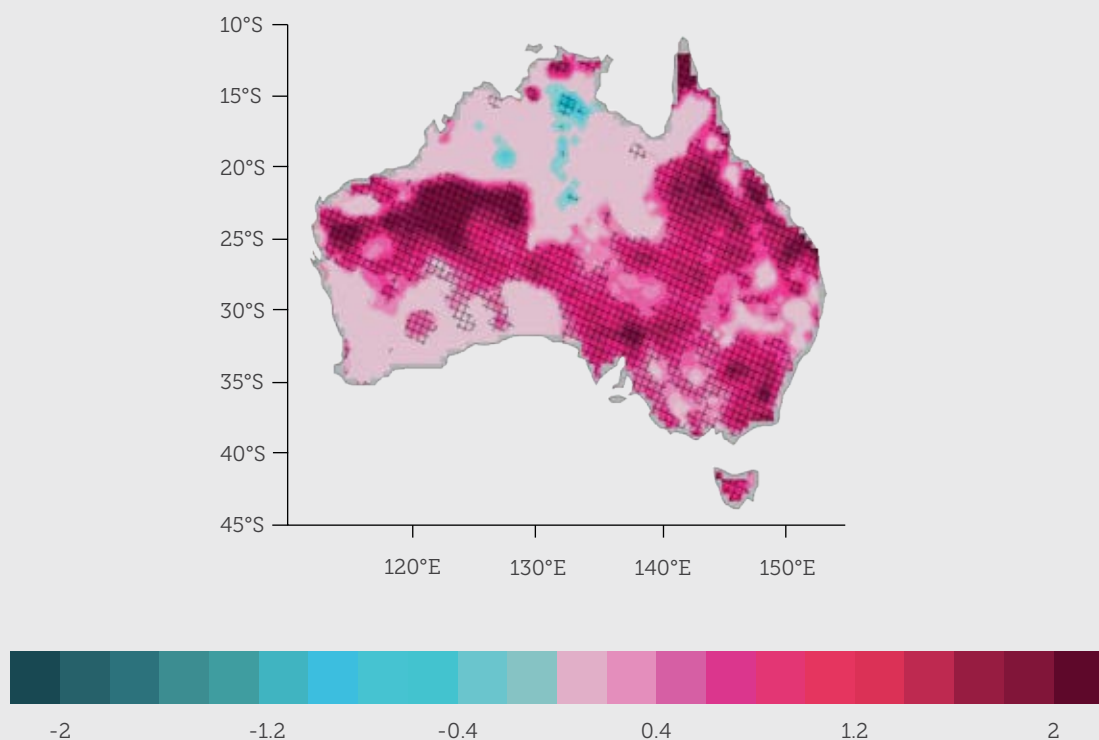


Figure 6: Change in the number of heatwave days from 1950-2013, expressed as a percentage of all summer days per summer. **Source:** Adapted from Perkins and Alexander 2013. Heatwaves are defined as a period of at least three days where the combined effect of high temperatures and excess heat is unusual within the local climate (Nairn and Fawcett 2013).

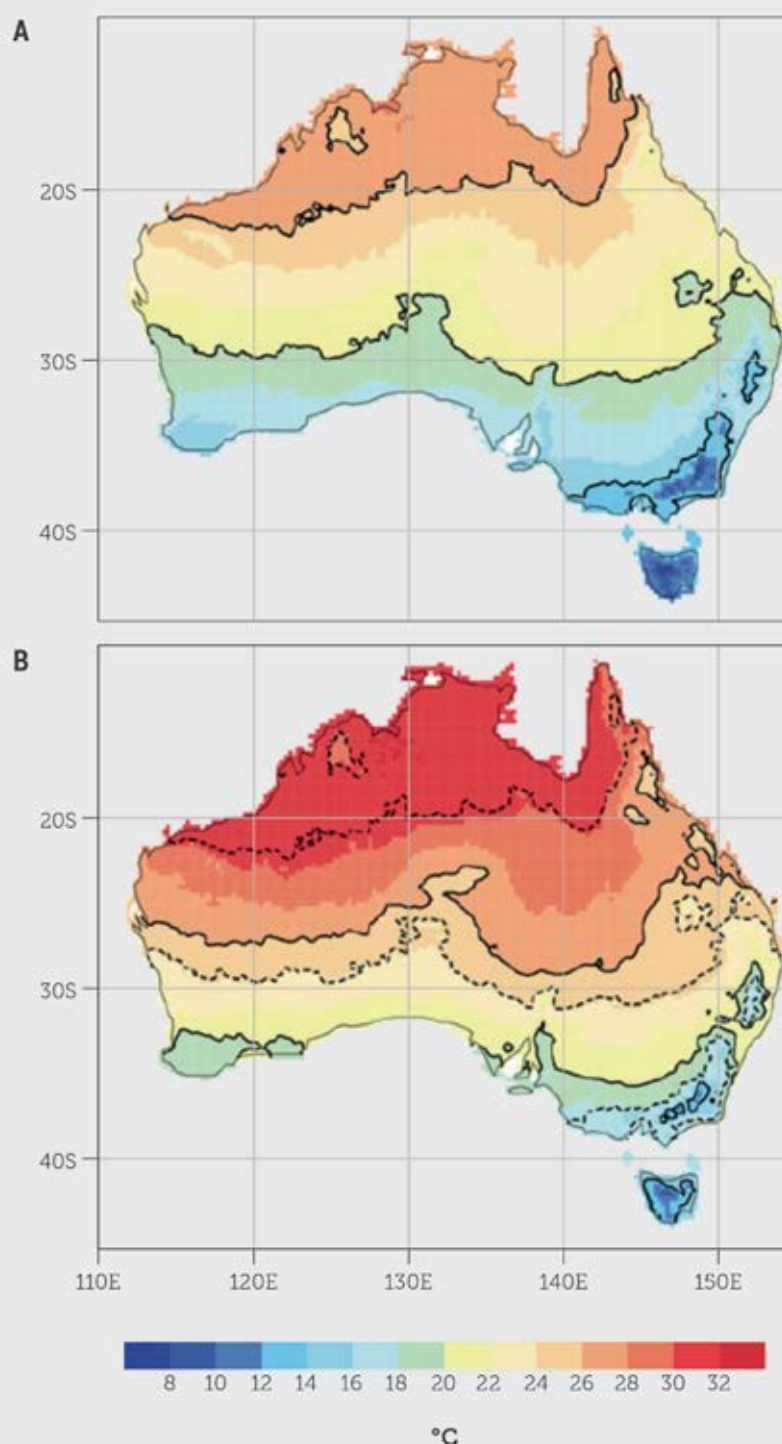


Figure 7: Annual mean temperature (in °C) for the present climate (a) and for the late 21st century (b). The future case is calculated by adding the median warming from 1986-2005 to 2080-2099 under the high emissions scenario to the mean temperature of the present climate. In each panel the 14, 20 and 26°C contours are shown with solid black lines. In (b) the same contours from the original climate are plotted as dotted lines. To provide the clearest depiction of the shifts in contours, the longer period 1950-2008 BoM dataset is used for the present climate, on a 25° grid. Source: Adapted from CSIRO and BoM 2015.

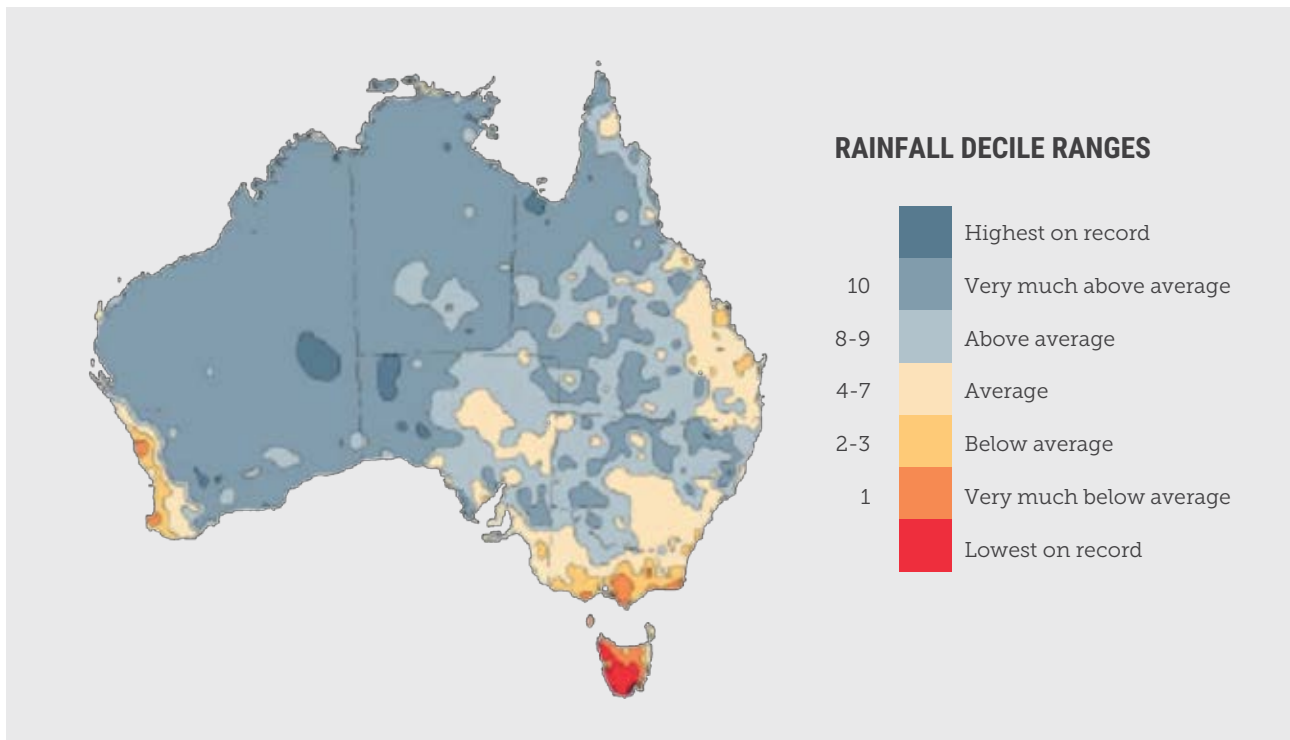


Figure 8a: Rainfall deciles for October to April (the northern wet season) from 1997 to 2013, relative to the reference period 1900-2013, based on AWAP data. **Source:** Adapted from BoM 2014.

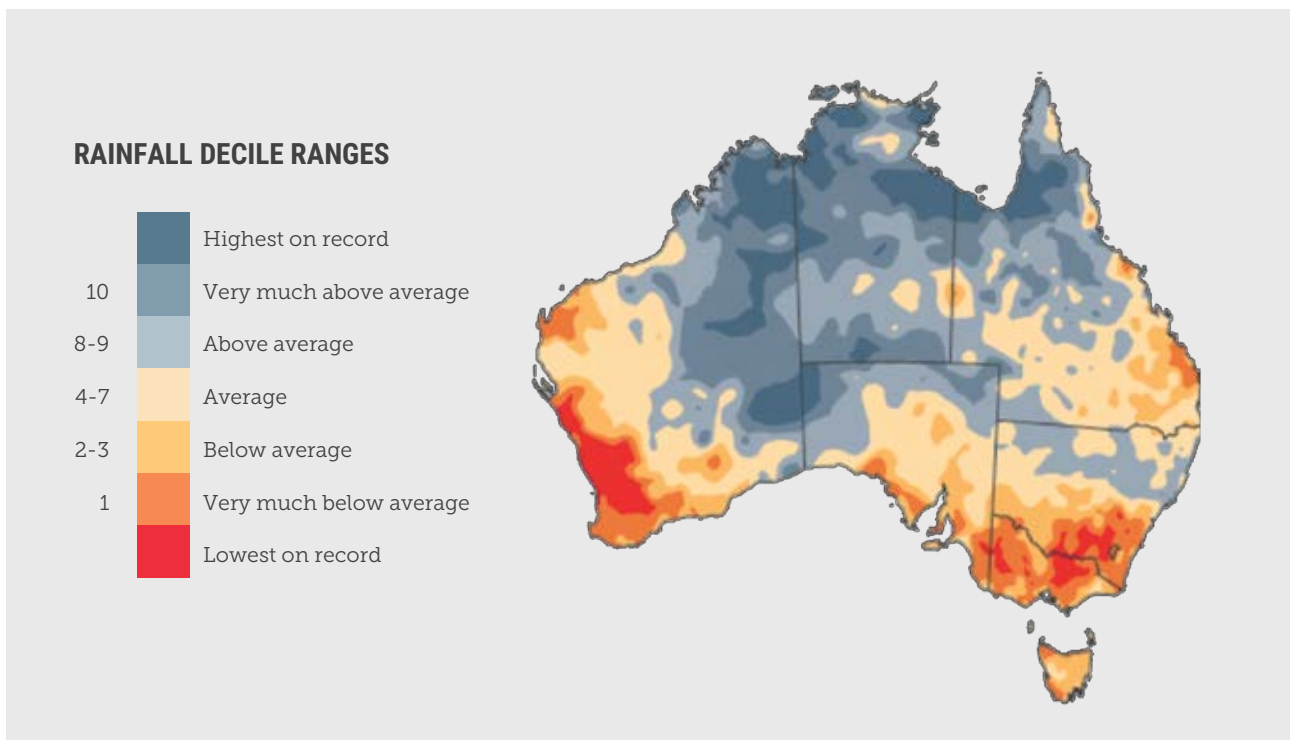


Figure 8b: Rainfall deciles for April to September 1997-2013, relative to the reference period 1900-2013, based on AWAP data. **Source:** Adapted from BoM 2014.

4. | RISKS FROM CLIMATE CHANGE



4. Risks from Climate Change

Australia's rural and regional communities are vulnerable to a wide range of impacts from our changing climate. Coping with these risks will require a concerted adaptation effort from all parties (see section 5).

Direct impacts of the changing climate on factors such as crop productivity are relatively straightforward to quantify (Table 2). Other more indirect impacts, such as changes to the distribution and incidence of pests and diseases, interruptions to supply chains and transportation networks, altered seasonality and work schedules, and pressures on the agricultural workforce are more complex. Even more difficult to measure are losses due to factors such as reduced confidence in investments and adoption of new technologies, and changes to the social fabric of communities (Garnaut 2008; Hayman et al. 2012).

Rural and regional communities are vulnerable to a wide range of impacts from our changing climate.

OBSERVED AND PROJECTED IMPACTS OF CLIMATE CHANGE ON AUSTRALIA'S MAJOR CROPS

Crop	Characteristics	Observed and projected climate change impacts
Grains 	The grain industry includes wheat, barley, canola, sorghum, oats, rice and pulses; from 2013-14 Australia exported over \$2.5 billion of grain. Production is divided into winter and summer crops. Most regions are only able to produce one crop per year. Wheat production is particularly variable from year to year (up to 60%) depending on rainfall. More than 1 million tonnes of rice per year grown, worth ~\$800 million p.a. and accounting for ~2% of world trade; grown in paddy cultivation and highly dependent on irrigation, requiring (on average) 1000 mm water p.a.	Cereal crops are sensitive to the timing of frosts, and crops such as wheat in southern Australia rely on winter-spring rainfall patterns that are already declining. CO₂ fertilisation effects may mitigate some reductions in yield but also reduce protein and micronutrient concentrations, leading to poorer nutritional quality; reduced rainfall in core cereal regions such as SW WA and Victoria are having substantial negative impacts on yields of existing cultivars and Australia could become a net importer of wheat in future decades. Reduced rainfall in core rice growing areas and/or the headwaters of rice irrigation water sources such as the Murrumbidgee River would reduce rice production; higher CO₂ levels typically increase biomass production but not necessarily yield; higher temperatures can also reduce yield by causing flowers to become sterile; possible adaptations to water declines in southern regions include shifts of cultivation to more northern regions (although this could increase the risk of high temperature impacts), irrigating more efficiently and using dryland varieties.
Wine grapes 	Australian wine exports have increased dramatically to ~5% global supply in the 2000s (1.4 billion L) and wine-grape growing is Australia's largest fruit industry. From 2013-2014 Australia exported \$1.8 billion worth of wine. Most production comes from areas with a favourable temperate or Mediterranean climate; grapes are highly sensitive to temperature and water availability during critical growth stages.	Up to 70% of Australia's wine-growing regions with a Mediterranean climate will be less suitable for grape growing by 2050; iconic grape-growing regions such as Margaret River (WA), the Barossa and Riverland (SA), Sunraysia (VIC) and the Riverina (NSW) will be the most affected by higher temperatures and lower rainfall, especially for red varieties such as Shiraz, Cabernet Sauvignon and Merlot; higher temperatures likely to continue to cause earlier ripening and consequent reductions in grape quality; expansion to new regions such as Tasmania is already occurring.
Fruit 	From 2013-2014 Australia exported \$724 million worth of fruit. Most deciduous fruit and nut crops need sufficient accumulated chilling (vernalisation) to break winter dormancy.	Higher night temperatures are a risk for some late harvested varieties; extreme day time temperatures cause sunburn and reduce yield; shorter frost seasons may be a benefit but inadequate chilling due to warmer winter temperatures result in prolonged dormancy in pome and stone fruit, leading to reduced fruit yield and quality; increased intensity of rainfall causes increased losses; increased intensity of tropical cyclones pose ongoing risks for northern crops such as bananas.
Sugar 	Grown from northern NSW through to far-north QLD, requires strong sunlight and at least 1.1 m of annual rainfall, or irrigation. Australia is the 3rd largest supplier of raw sugar globally; 80% crop exported with a \$1.7-2 billion value p.a.	Increased sunshine associated with reduced rainfall enhances sugar content and yields in sugar crops in northern and north-eastern cropping regions, but reduced rainfall in winter/spring and early summer affects overall irrigation and water supply; plantations on coastal flats are vulnerable to sea-level rise and salt-water flooding from cyclone-induced storm surges.
Vegetables 	Vegetable growing uses less than 1% of Australia's agricultural land but was valued at \$3.7 billion (gross) in 2013-14, with 93% produced for domestic consumption; the sector employs 25% of all agricultural workers. All vegetable crops are sensitive to temperature which influences yield and quality; many vegetable crops are highly water-intensive.	Maximum temperature limits exist for many vegetable crops; reduced rainfall threatens irrigation supply; extreme heat causes sunburn, reduced flower number, reduced pollination, and affects quality and flavour; higher temperatures and humidity increase risk of diseases such as powdery mildew.



Impacts of climate change, both direct and indirect, will also interact with changing international and national markets for inputs and commodities, as well as technological, social, institutional, demographic and environmental changes, including pressures on resources such as water. A recent example of these interconnected dynamics is the effect of the Russian ban on wheat exports after extreme heat and fire caused crop losses in 2010 (see, for example, New York Times 2010; Welton 2011). Combined with secondary impacts such as the further concentration of agricultural services into larger centres, and a growing consumer focus on the greenhouse gas intensity of agricultural products, climate change is expected to have transformational impacts on Australia's primary industries sector, and the people it supports.

The impacts of climate change, both direct and indirect, vary both within and among communities, and over time. As seen in Tasmania in early 2016, one community can be fighting fires while others are dealing with floods. Impacts also vary due to the different contexts of each community, including their environmental characteristics and condition, their social and institutional connectedness to others, and their sources of income. For those communities whose economic foundations are deeply embedded in agricultural production, especially dryland, broadscale farming, the substantial risks posed to farming by climate change equate to risks to the whole community. An assessment of the vulnerability of rural communities to climate change concluded that, at both the national and state levels, climate change poses especially significant risks for communities already tackling problems of demographic change, economic restructuring and spatial remoteness (see Beer et al. 2013, 2014).

Climate change poses especially significant risks for communities already tackling other challenges.

4.1 Impacts on Agricultural Production

Climate is the key determinant of what grows where, and the profitability of virtually any agricultural enterprise.

Any changes to the climate that reduce water availability and/or lead to stressful high temperatures can, in turn, have serious negative impacts on farm production (Table 3) (Niles et al. 2015; and see the Climate Council report "Feeding a Hungry Nation: Climate Change, Food and Farming in Australia").

Table 3: Climate impacts on agricultural production.

Impact	Explanation of effect	Regions affected	Industries affected
Water scarcity	Climate change is altering rainfall patterns nation-wide. Areas that are already dry are generally getting drier. Furthermore, reduced rainfall can cause significant (two to three-fold) decreases in runoff.	Cool season (May-September) rainfall trends showed marked decreases in rainfall in southwest and southeast, including the southwest WA wheat belt and the Murray Darling Basin.	› Crops › Livestock
Extreme heat	Climate change is making heatwaves hotter, longer and occur more often. Increased temperatures can enhance evaporation rates, with serious implications for water availability for agriculture.	Australia-wide, particularly in the eastern half and in central Western Australia. In the longer term, a 3°C increase in average temperature is projected to result in a 4% reduction in gross value of the beef, sheep and wool sector. A decline of dairy production in all regions except Tasmania is also projected under midrange climate scenarios by the middle of the century.	Crops: The yields of many important crop species such as wheat, rice and maize are reduced at temperatures more than 30°C, especially if soil moisture is limiting. The sugar content and flavour of horticulture crops, including wine grapes, may also be negatively affected by high temperatures. Higher temperatures likely to continue to cause earlier ripening and consequent reductions in grape quality. A 1°C rise in nighttime temperature may reduce rice yields by about 10%. Livestock: Heat stress reduces animal growth, feeding rates, reproduction, and milk quality and raises issues of animal welfare, especially during transport and in saleyards and feedlots. Increased average and extreme temperatures exacerbate heat stress for intensive livestock industries, especially dairy. Heat stress reduces milk yield by 10-25%, and by up to 40% in extreme heatwave conditions; these impacts can last a considerable period after the stress event. Aquaculture: The marine heatwave in Tasmania (summer 2015-2016) caused the loss of oyster beds, at least 80 jobs and \$12 million in industry losses, while salmon farmers reported slower fish growth.
Bushfires	The impact of climate change on extreme weather, increasing the number of hot days and heatwaves, is driving up the likelihood of very high fire danger weather.	Southeast Australia	Bushfires cause loss of crops, livestock and rural infrastructure. Bushfire smoke adversely affects wine grape quality. Bushfires have destroyed large olive plantations, with younger trees more susceptible.

Impact	Explanation of effect	Regions affected	Industries affected
Pests and disease	The impacts of climate change on production via its impact on pests and diseases are difficult to predict.	Some key risks that have been identified include the southerly spread of the Queensland fruit fly and the insect vector of blue-tongue disease. Increased risks from pests such as cattle ticks are likely in areas of southern Queensland and northern New South Wales unless more resistant breeds are introduced.	› Crops › Livestock
Storms and cyclones	No clear trends to date in cyclone frequency or intensity (wind speeds) in Australia.	Increase in intense cyclone activity more likely than not in the Australian region later this century; possible southward extension of storm tracks.	Crops: Storm surges and flooding can affect sugar cane crops in NSW and Queensland. Tropical fruit crops in Northern Australia are vulnerable to increased intensity of tropical cyclones. Cyclone Larry in 2006, for example, destroyed 90% of the North Queensland banana crop, affecting supply for nine months; Cyclone Yasi in 2011 had similar impacts.
Soil degradation	Soil degradation from acidity, salinisation, erosion and loss of carbon and nutrients.	The severe phase of the Millennium Drought in 2007-2010 resulted in the lowest water levels in the Murray Darling Basin ever recorded in South Australia. The drying led to increased soil acidification that persisted in floodplain sediments and water for two years following the drought.	Crops: For example, increased temperatures, elevated levels of CO ₂ and changing hydrological regimes will affect soil carbon. Increasing temperatures will accelerate soil decomposition, in turn accelerating the rate of CO ₂ release from soils. Declining soil carbon stocks have a range of negative impacts, including increasing erosion and reduced productivity.
Weeds	Climate change will enhance the distribution and competitiveness of crop weeds. Climate change is also likely to increase the probability of new species becoming weeds.	There is extensive modelling of species distributions for southern Australia, mostly indicating a southern shift. However, there is a need for increased species modelling for central and northern Australia.	› Crops

Impact	Explanation of effect	Regions affected	Industries affected
Loss of winter chill	Plants growing faster in a warmer climate can expose flowering to higher risk from frosts. Fruit crops that require chilling periods to set flowers and fruit may be disadvantaged.	Over the next decade or two, frost may increase in the southern states due to an increase in clear, dry nights in winter.	Cereals are sensitive to the timing of frosts. Fruit: Inadequate chilling due to warmer winter temperatures results in prolonged dormancy in pome and stone fruit, leading to reduced fruit yield and quality. Lemon trees are frost-sensitive, with spring frosts a particular risk if trees have flowered due to warmer winters. Climate change effects on peach growing will differ greatly among regions. Minimal impacts are anticipated for Tasmania, for example, while the southwest of Western Australia is expected to experience notable declines in cold weather. Climate change could lead to insufficient chilling in many regions, resulting in uneven bud break and erratic flowering. This would make raspberry crops more susceptible to damage from extreme temperatures in summer, when it is ripening, reducing berry production and quality. Nuts: Almonds - Restricted winter chilling due to a warming climate is likely to delay flowering until later in spring, when high temperatures will restrict pollination and fruit set. Frost damage costs Australian agriculture millions of dollars each year due to reduced yield.

Sources: ABC Rural 2015; CSIRO and BoM 2015; Finlay et al. 2009; Lal 2004; Hanslow et al. 2013; Heimann and Reichstein 2008; Howden et al. 2014; McKeon et al. 2009; Millar and Roots 2012; Mosley et al. 2014; National Irrigators Council 2009; Porter et al. 2014; Reisinger et al. 2014; Scott et al. 2014; Sutherst 1990; Sutherst et al. 2010; White et al. 2003; Whittaker et al. 2012; WWF Australia 2015; ABC 2016a; Hobday et al. 2016.

Climate change is already reducing crop productivity in some regions.

Climate change is projected to decrease water availability in areas of the Murray Darling Basin, posing a major risk to the livelihoods of communities in and around this region (Reisinger et al. 2014; CSIRO and BoM 2015). Agricultural production in the Basin could be significantly reduced if the climate scenarios predicting substantial drying are realised, even with comprehensive adaptation (Garnaut 2008; Quiggin et al. 2010; Qureshi et al. 2013a, 2013b).

Climate change is also reducing crop productivity in some regions via the increased frequency and intensity of extreme weather events, and by favouring certain pests and diseases (Figure 9). Temperature changes are already altering the timing of crop life cycles (phenology), such as by advancing flowering dates (Anwar et al. 2015). Selection of appropriate cultivars and changes in sowing times may help counteract some of these effects, at least in some regions. Reisinger et al. (2014) suggest that such adaptations may increase wheat yields in wetter areas such as southern Victoria, or maintain current production in some drier areas, such as northwest Victoria. But if the dry end of the future rainfall scenarios is realised, such adaptation measures may not be sufficient to maintain current yields by later this century (Luo et al. 2009). Indeed, under the more extreme climate scenarios, Australia could become a net importer of wheat (Howden et al. 2010).

Climate change is projected to decrease water availability in areas of the Murray Darling Basin, posing a major risk to the livelihoods of communities in and around this region.

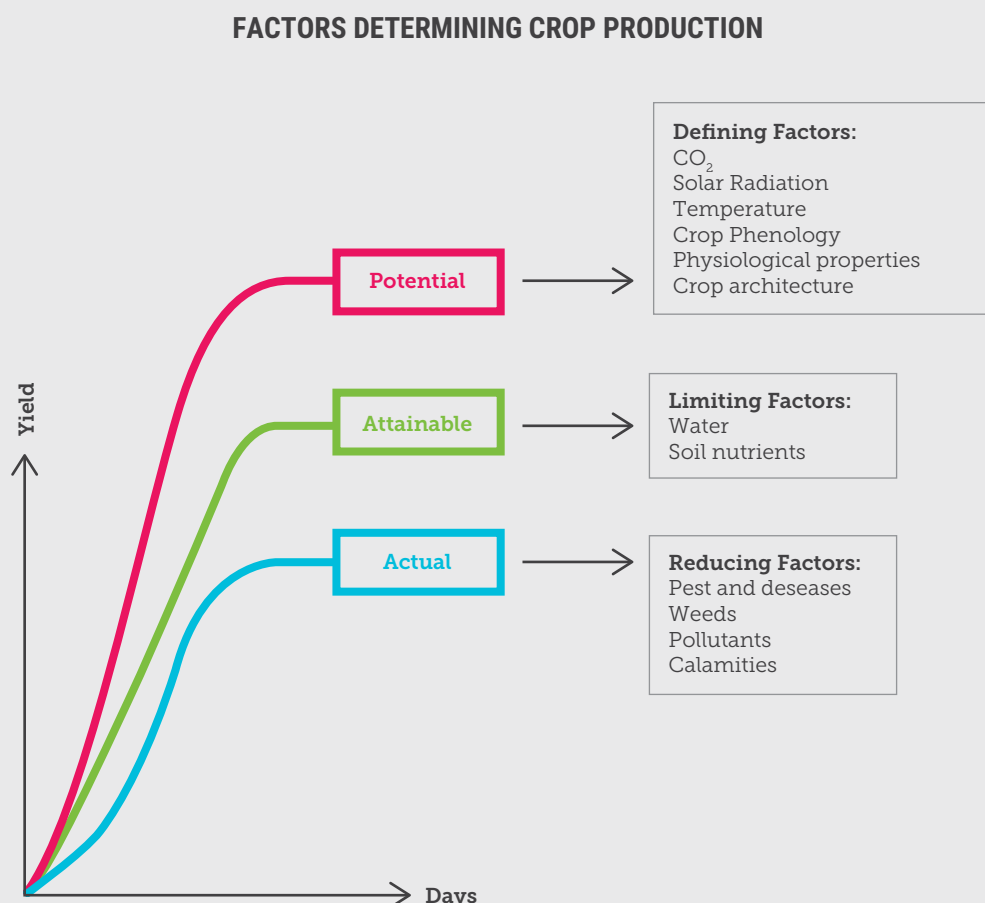


Figure 9: Factors determining crop production. Source: Adapted from Anwar et al. 2013.

Climate change also presents major challenges for grazing in Australian rangelands because it can result in lower and more variable pasture productivity, reduced forage quality, and increased heat stress for livestock (Harle et al. 2007; Stokes and Howden 2008; Moore and Ghahramani 2013). Water scarcity and reduced water quality (due to salinity or bacteria, for example) also pose serious health issues for livestock. Heat stress reduces animal growth, reproduction, and milk quality and raises issues of animal

welfare, especially during transport and in saleyards and feedlots. In the longer term, a 3°C increase in average temperature is projected to result in a 4% reduction in gross value of the beef, sheep and wool sector (McKeon et al. 2009). A decline of dairy production in all regions except Tasmania is also projected by the middle of the century (Hanslow et al. 2013). However, the recent drought in Tasmania suggests that the state may indeed also be vulnerable.

Climate change impacts on ground water and surface water catchments are of particular concern. Reduced rainfall or increased rainfall variability will especially affect key intensive irrigated enterprises such as horticulture, cotton, sugar, dairy, livestock, and viticulture by limiting irrigation water availability and allocations, given the concurrent need to support ecological services of aquatic systems (see the Climate Council report "Feeding a Hungry Nation: Climate Change, Food and Farming in Australia" for more details). Any reduction in irrigation will have extremely important economic impacts because approximately 50% of all profits from Australian agriculture derive from irrigated production (National Irrigators Council 2009). Declines in rainfall, especially during winter, of up to 40% in the southeast and 20-70% in the southwest are projected for a 2°C increase in temperature (Reisinger et al. 2014). Runoff declines may be exacerbated by rising temperatures with associated evaporation, reduced connection between surface and groundwater, interceptions by farm dams and water impoundments, and tree regrowth after more frequent fires. Such potential declines in freshwater resources were identified as a key risk for Australian food production in the Fifth Assessment Report of the IPCC, especially in the Murray Darling Basin (Reisinger et al. 2014), while the Australian Productivity Commission (2009) referred to "irrigation droughts" as 'unchartered territory'. Jiang and Grafton (2012) concluded that under a 'modified 2030 dry extreme scenario' there would be 'substantial reductions in water use, irrigated agriculture and profits' (p. 10).

For farm families, concerns about water scarcity and other challenges can add doubt to the question of who, if anyone, will take over the farm, when and how. This in turn can affect farm management. Research with irrigated farmers in the Murray Darling Basin found that farms 'with no successor in place are more likely to go into a period of stagnation (such as selling land, not adopting efficient irrigation infrastructure and not increasing irrigated area)' (Wheeler et al. 2012, p.266).

The most arid and least productive rangelands are likely to be affected substantially by reductions in rainfall or increases in temperature because of their existing marginality. Rainfall changes will alter the relative competitiveness of grazing vs cropping. Cropping may increase at the expense of grazing in regions that become wetter, and vice versa in drier areas (Harle et al. 2007). Increased atmospheric CO₂ may partially offset the negative impacts of reduced rainfall in some areas (Stokes et al. 2010) and in southern regions, reduced winter mortality of lambs and other stock could occur (Harle et al. 2007). Increased risks from pests such as cattle ticks are likely in areas of southern Queensland and northern New South Wales unless more resistant breeds are introduced (White et al. 2003). While some weed species are expected to contract in range under climate change (Gallagher et al. 2013), higher temperatures, especially during winter, may make some pests, such as Queensland Fruit Fly, more threatening by directly or indirectly enabling them to increase in population and to shift and/or expand their distribution (Webber et al. 2014). Pest outbreaks, including weeds, fungus, locusts and mice, may also occur following very wet periods (eg Rickards 2012). A greater risk and prevalence of pests may encourage increased pesticide use, which carries its own risks, including pesticide resistance.

Decline in fresh water resources is a key risk for Australia.



Figure 10: Australia's wine industry contributes significantly to the Australia economy, but viticulture is highly sensitive to changes in the climate.

Intensive animal industries include dairies, beef and sheep feedlots, poultry production, and piggeries. Direct climate impacts on these systems will include the increased incidence of extreme hot days, in turn leading to increased energy demand for cooling (in indoor production facilities), as well as increased water demand for drinking. As for other livestock operations, reduced water quantity and quality in some regions represents a serious risk to livestock health. These industries rely heavily on feed produced off-farm, and the quality and costs of supplementary feed produced elsewhere will depend on climate changes in supply areas. While caring for stock during a drought is difficult, many livestock farmers have invested significant amounts in their breeding programs and so selling off all of their livestock at these periods carries its own considerable costs.

Intensive plant industries based on plants that are long-lived (and so are more irreplaceable) are often particularly sensitive to heat stress, loss of winter chilling requirements, or extreme events such as heatwaves, frost, drought, high winds and hail (see Table 3). For viticulture (Figure 10) and horticulture, higher rates of evaporation and reduced runoff to dams and rivers will likely have a greater impact than rainfall reduction itself, because these industries tend to be highly reliant on irrigation (Potter et al. 2010). The geographically extensive Millennium Drought (1996 to 2010) demonstrated the problems that result when on-farm water shortages coincide with irrigation water shortages, requiring water to be carted extremely long distances and at great expense. Even where rainfall is sufficient, higher evapotranspiration could increase salinity on productive land (Stokes and Howden 2010).

Climate change and the increase in atmospheric carbon dioxide could temporarily increase levels of production in some enterprises if increasing temperatures or changes to water availability enable higher productivity or allow a primary industry to expand. Some of the more productive eastern and northern rangelands may become more productive, at least in the short term, provided rainfall does not decrease (McKeon et al. 2009). But these advantages are likely to peak by the middle of the century, with progressively more negative impacts evident in the later decades if strong mitigation efforts do not take place (Stokes and Howden 2008). Furthermore, increases in production may or may not translate to increases in profitability if they are outweighed by other factors, such as declining terms of trade, greater economic volatility or difficulty accessing or servicing farm credit (some of which are likely to be worsened by climate change).

Of concern to all agricultural enterprises and land managers is how climate change will affect soil (Figure 11). Besides affecting soil organic matter, climate change threatens to directly and indirectly cause structural degradation of soils, especially for hard-setting soils in temperate and subtropical regions where reduced rainfall infiltration and water use efficiency and increased soil erosion is likely (Chan 2011, Lal 2011). Modelling of the Lower Murray agricultural region suggests that there is a high risk of increased wind erosion under future conditions (Bryan et al., 2009). Soil erosion and biodiversity loss are also interacting with climate change in complex ways (Figure 11). Severe fires have the potential to adversely affect soil texture (Mataix-Solera et al. 2011) and even to burn away ancient peat soil, as seen in the recent Tasmanian fires. The ways in which climate change is and will affect the communities of invertebrates and micro-organisms in soil are poorly understood, but significant impacts on nutrient availability and decomposition and mineralization rates are likely (eg Rivers et al. 2011, Stevnbak et al. 2012, Eisenhauer et al. 2012).

Climate change threatens to exacerbate soil degradation.

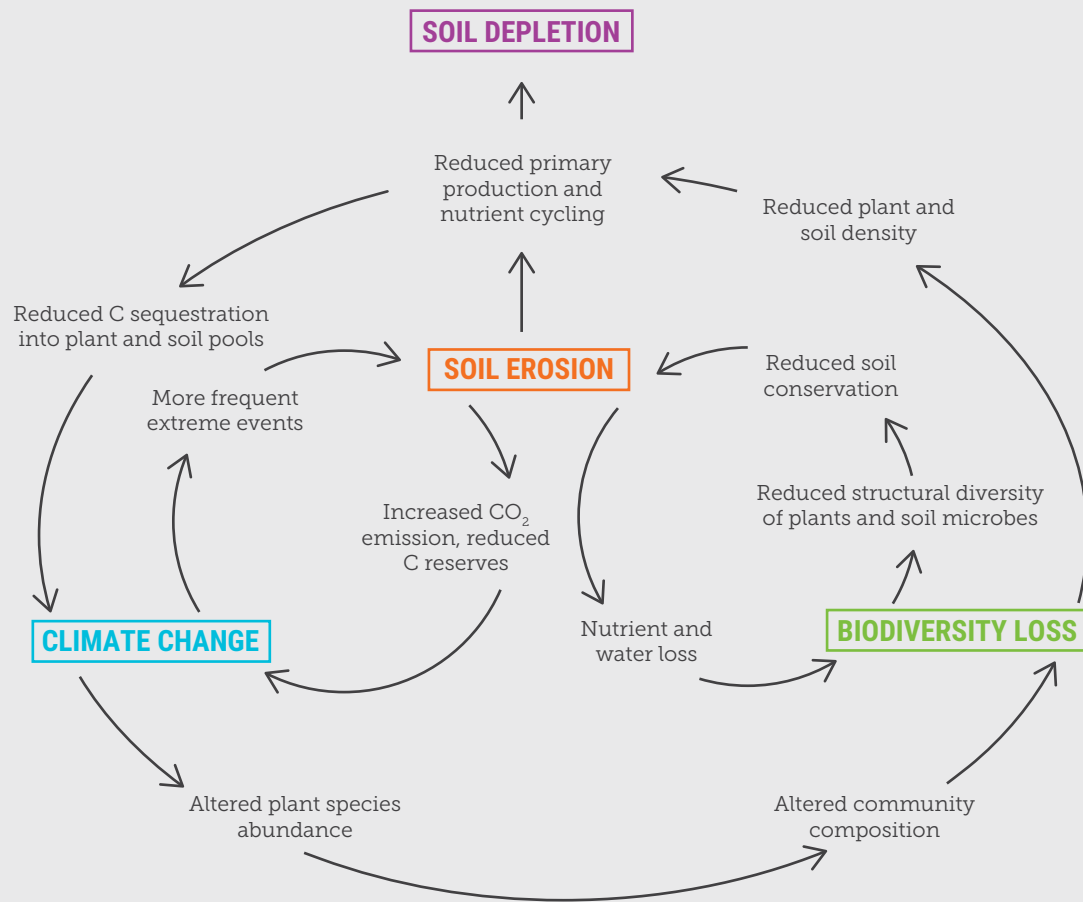


Figure 11: Inter-relationships and feedbacks between climate change, biodiversity loss and soil health.
Source: Adapted from Eldridge et al. 2011.

4.2 Impacts of Extreme Events

Many of the most significant impacts of climate change on both natural and human systems are a result of the increasing frequency and intensity of extreme weather events such as fire, droughts, heatwaves, cyclones and floods.

While extreme weather events are part and parcel of doing business in much of rural and regional Australia, some communities are finding they have to deal with multiple extremes at once or in rapid succession, with the effects of one (eg drought) still being felt as another hits (eg fire, floods), vastly reducing people's capacity to cope with the latter. This is especially evident when different parts of a region are managing extreme events at the same time, as in the case of the floods across south-eastern Australia in 2011, or in Tasmania in 2016 with fires and floods that coincided.

Many of the most significant impacts of climate change are a result of the increasing frequency and intensity of extreme weather events.

Many agricultural businesses have taken on increased debt due to the impacts of extreme weather.

A survey of more than 24,000 Australian agribusinesses in 2009 found that 84% of respondents had experienced droughts, severe frosts, hail, severe storms, floods or an increase in seasonal variation during the period 2007-2008 (ABS 2009). These estimates ranged from almost 90% of agricultural businesses in New South Wales and Victoria, to just over half in Western Australia. Nearly a third of those surveyed reported using financial reserves and or taking on increased debt in response.

Simultaneous events in a region reduce people's capacity to call upon others and supplies from elsewhere in the region (eg stock feed, emergency services or to move stock to another farm). Resultant delays in dealing effectively with the immediate effects of these extremes contribute to the conversion of climatic extremes into disaster situations, increasing their impact and the vulnerability to further challenges.

Severe climatic extremes, or ones superimposed onto an already vulnerable situation, can act as tipping points for individual businesses or regions. Farmers' actions taken to cope with drought, for example, can accumulate to the point that once the drought is broken they find it very difficult to get the business "back to normal". In particular, responses to drought such as destocking and de-prioritising the upkeep of infrastructure on the farm, can make it difficult to restart livestock enterprises after the drought has passed (Robertson and Murray-Prior 2016).

Table 4: provides some examples of the health and economic impacts of extreme events in Australia. Many of these impacts have been felt by people in rural and regional communities.

Major event	Losses (deaths and injury)	Losses (including residential property, stock, damage to industry)	Significant insured losses ¹
Bushfires			
Alpine fires January-March 2003, Victoria	1 (Stephenson et al. 2013)	>17,000 stock (Stephenson et al. 2013) 2,500 hectares of plantations (State Government Victoria 2013)	\$24 million (ICA 2015)
Black Saturday February 2009, Victoria	173 (Teague et al. 2010, Stephenson et al. 2013) Major injuries: 130 Minor injuries: 670 (Stephenson et al. 2013)	>2000 homes (CFA 2012, Stephenson et al. 2013) 8000-11,800 stock (Teague et al. 2010, Stephenson et al. 2013) 430,000 ha of farmland and eucalypt forest destroyed (Morgan and Leonard 2015)	\$1.266 billion (ICA 2015) Net cost to agriculture >\$700 million (2009\$) (Stephenson and Handmer 2012) Net losses to the viticulture industry >\$300 million (2009\$) (Stephenson and Handmer 2012)
Bicheno, TAS fires January 2013	0	203 homes (Tasmanian Government 2013) >600 km of fencing (Tasmanian Government 2013) 10,000 stock (Tasmanian Government 2013)	\$89 million (2013\$) (ICA 2015)
Blue Mountains, Port Stephens, Lake Munmorah, Hunter, Hawkesbury, Central Coast & Southern Highlands fires October 2013	2 (NSW PRS 2014)	222 homes (NSW PRS 2014)	>\$183 million (ICA 2015)
Sampson Flat bushfire, Adelaide Hills January 2015	0	12,500 hectares of land 27 homes 900 livestock (Slattery et al. 2015)	\$36.6 million (Insurance Council of Australia 2015)
Record heat and ensuing bushfires of 2015 October	No data	\$1-2 billion losses in Victoria alone (Climate Council 2016b)	No data

¹ Costs normalised to 2011\$ unless otherwise indicated.

Major event	Losses (deaths and injury)	Losses (including residential property, stock, damage to industry)	Significant insured losses ²
Droughts			
The Federation Drought 1895-1903	Around 160 people died of heat and heat-related diseases in 1896 in Bourke, NSW (Garden, 2010). In the period 1897-1898 the death rate increased by over 20% in NSW (Garden, 2010)	Sheep numbers halved to around 54 million, and cattle numbers declined by 40% by the end of the drought (Garden, 2010). These losses are estimated to be the greatest in Australia's agricultural history (Australian Bureau of Statistics 1988)	Near impossible to quantify, however extensive amounts of pastoral land were decimated as a result of overstocking, drought induced bushfires, and the rabbit plague (Garden, 2010)
The World War II Drought 1939-1945	Drought responsible for the Black Friday fires in which 71 lives were taken (DEPI 2015)	Resulted in plummeting wheat yields and disastrous bushfires 10 million sheep were lost in NSW (Australian Emergency Management Institute 2016) Four million sheep were lost in SA between 1944-1945	No data
1982-1983 Drought	Responsible for the Ash Wednesday Fires of 1983, where 75 people died across Victoria and South Australia (Victoria State Government 2015)	Total loss of \$3 million in agricultural production (Australian Bureau of Statistics 1988) National production found to be only 63% of the past five years (Gibbs 1984) Associated Ash Wednesday fires destroyed over 125000 ha of agricultural land (Gibbs 1984) Estimated loss of \$7 billion to the total economy (Australian Government 2015)	No data
The Millennium Drought 1996-2010	Between 2001-2007 the average rate of rural suicide was one farmer every 3 weeks in Victoria (Congues 2014)	Agricultural production fell from 2.9% to 2.4% of GDP between 2002-2009 (van Dijk et al. 2013) Southeast Australia experienced lowest 13-year rainfall record since 1865 (CSIRO 2012) From 2007-2008 GDP in the Murray Darling Basin fell 5.7% and 6000 jobs were lost (IPCC 2014) Australian government had paid \$4.4 billion of direct drought assistance by mid-2010 (ABARES 2012)	No data

² Costs normalised to 2011\$ unless otherwise indicated.

Major event	Losses (deaths and injury)	Losses (including residential property, stock, damage to industry)	Significant insured losses ³
Heatwaves			
Heat wave in southeast Australia 2009	374 excessive deaths during the heatwave in Melbourne in late January 2009 (DHS 2009).	2008-2009 wine grape production season was 1.7 million tonnes - around 7% - lower than the harvest of 2007-2008 (Gunning-Trant 2010) 18,000 homes lost power in Victoria as a result of the high demand for electricity (Australian Government 2015) Estimated losses of around \$800 million to total economy (Climate Council 2014)	"There have been relatively few economic estimates of agricultural losses due to heat waves" (Climate Council 2014, pp. 35).
Cyclones			
Cyclone Larry 2006	0	Banana crops in Innisfail received 100% damage and no banana crop for 7-8 months in the Innisfail region (Glick DJ 2006) 200,000 tonnes of bananas destroyed (80% of Australia's banana crop), worth \$300 million (AEM 2011a) \$15 million worth of avocados destroyed (AEM 2011a)	\$609 million
Cyclone Yasi 2011	0	\$300 million in losses in agricultural production for Queensland (AEM 2011b) \$650,000 in concessional loans provided to affected farmers (AEM 2011b) Canegrowers estimate cost to sugar cane industry \$500 million (Canegrowers Australia 2011) 75% of banana crop affected; 20% of avocado crop lost (Queensland Government 2011)	\$1.412 billion (ICA 2015)

³ Costs normalised to 2011\$ unless otherwise indicated.

Major event	Losses (deaths and injury)	Losses (including residential property, stock, damage to industry)	Significant insured losses ⁴
Cyclones cont'			
Cyclone Oswald 2013	6 (AEM 2013)	Agricultural losses likely to exceed \$100 million (QLD Reconstruction Authority 2013)	\$1.1 billion (ICA 2015)
Cyclone Ita 2014	0	90% of the sugarcane crop was damaged in some degree; 27.5 million tonnes of crop affected to varying degrees (Canegrowers Australia 2014) Tomato, banana and eggplant crops substantially damaged (ABC News 2014a) Agricultural losses totalled \$1.1billion (AON Benfield 2014)	>\$8 million (ICA 2015)
Flooding			
Newcastle/Hunter Valley Severe Storm June 2007	9 (NCCARF 2010b)	Damage and loss of work related property totalled \$458 million (Carpenter 2007) \$69,680,000 of insurance claims for rural, industrial and marine bodies (Carpenter 2007)	\$1,742,000,000 (ICA 2015)
East Coast Low May 2009	2 (NCCARF 2010a)	Significant coastal erosion stretching from south east Queensland to northern NSW. Considerable losses to coastal tourism operations (NCCARF 2010a)	\$55 million (ICA 2015)
Victorian Floods 2011	1 (AEM 2011c)	>\$1.5 billion damage to Victorian agriculture 2000 km of fencing >40000 ha of crops destroyed >6000 livestock killed (The Age 2011)	\$126 million (ICA 2015)

⁴ Costs normalised to 2011\$ unless otherwise indicated.

The losses listed in the table above are only a fraction of the true costs of extreme events because many costs are very difficult/impossible to quantify, including those that arise from stress and interruption to normal life and business operations; the destruction of treasured environments; the loss of loved animals and possessions; the complications and struggles of the recovery period; lingering infrastructure malfunction; the derailing of business development,

retirement or succession plans; and long-term changes to families and communities. Thus the impacts of extreme events are not restricted to the emergency period itself or to the formal accounting of losses. Even disasters far afield can have flow on effects that disrupt and shift people's normal professional and personal lives in difficult ways. All of these challenges can lead to serious health impacts, as we now discuss.

Figure 12: Royal Australian Navy helicopter surveys flooding near Spring Hill in 2011. The floods in Victoria caused \$1.5 billion in damages to Victorian agriculture.



4.3 Impacts on Human Health

Compared to life in urban environments, rural living can have many health-enhancing qualities, including fresh air, opportunities for abundant physical activity, peaceful environments, and community connectedness. These potential benefits, however, are being undermined.

Across Australia as a whole, the health status of many rural and regional communities lags behind their urban counterparts, despite decades of strategies aimed at redressing the imbalance (Hanna et al. 2011). Statistically, people in rural and remote communities have lower life expectancies and higher rates of suicide, chronic disease, substance abuse and mental illness (Page et al. 2007; Phillips 2009; AIHW 2010). Reasons for this disparity include high levels of exposure to agricultural chemicals (Hanna 2005), often harsher physical environments (eg extreme heat); lower average socio-economic status (including lower levels of education, income and employment rate); occupational risks, notably in farming; an ageing workforce; fewer health and social services, particularly specialists; and less reliable or affordable access to nutritious fresh food (Pollard et al., 2014), especially in remote regions (Lé et al., 2014). The need to drive long distances poses its own health risks, including the risk of crashes and fatalities (Koetse and Rietveld 2009).

Australia's rural health disparity is intensified in remote Indigenous communities (Beard et al. 2009; Phillips 2009; AIHW 2010). Remote Indigenous communities are particularly vulnerable to increasing severity and frequency of extreme events such as heatwaves, combined with water shortages, and decreases in traditional plant and animal resources (Beer et al. 2013; Leonard et al. 2013; Green et al. 2015). The deep connection to country of Aboriginal people contributes to the far-reaching impacts on wellbeing

that adverse environmental effects can have (Green et al. 2009). 'Strange changes' in the weather are already causing concern in some Indigenous communities (Petheram et al. 2010). Rising sea levels and associated coastal inundation are already evident in Indigenous communities in the Torres Strait (Figure 13), and future displacement of these peoples to other islands will have significant cultural and economic consequences (McNamara et al. 2012). Drought-induced

downturns in the workforce of the north western Queensland pastoral industry in 2013 were found to displace some Aboriginal pastoralists by cutting their work opportunities and forcing them to migrate to regional centres, exacerbating mental health and social problems (Pearce et al. 2015). The impacts of drought on the workforce, and the subsequent mental health and social problems, are felt by the entire community.

Figure 13: Rising sea levels because of climate change pose a significant threat to Torres Strait Island communities.



As described above, extreme events such as heatwaves, fires, droughts and floods can cause injury, longer-term health issues and even death (Table 4). Such events disproportionately affect rural communities and their health and emergency services, many of which are already under pressure (Bi and Parton 2008; Horton et al. 2010; Loughnan et al. 2010). Increasing severity and/or frequency of extreme events will impose greater demands on many rural health support and emergency services that are already over-stretched and hampered by poor infrastructure such as unreliable access to the internet (Blashki et al 2010). Heatwaves pose particular risks for the elderly in rural communities (e.g. Loughnan et al. 2010), due to social isolation and a lack of cool public spaces that provide refuge (Williams et al. 2013). The health services in some rural communities have also been found to have a relatively low level of preparedness for extreme events (Purcell and McGirr 2014).

Climatic extremes and more volatile weather in general (eg storms, winds) can demand intense bursts of physical activity from farmers and other rural residents as they work to respond to unfolding events in a timely manner. Less predictable weather conditions mean that some farmers are finding that certain farm tasks such as harvesting or sowing have to be completed in short and sudden windows of time, reducing

their capacity to bring in outside help such as contractors (Rickards 2012). Overlapping demands such as regular stock watering, the accumulation of postponed tasks such as equipment maintenance, and the generation of new ones such as repairs and clean up, can result in extended periods of supreme work, sometimes under harsh physical conditions.

Rural work in general tends to expose individuals to a range of occupational health and safety (OHS) risks (Hanna 2005). As the climate changes, these risks increase for direct and indirect reasons. The need to focus on immediate issues can decrease the probability that farmers have time, motivation and capacity to look after themselves and stay safe, fit and well (Brumby et al. 2011a; Rickards (2012). Depression - which may be initiated or worsened by climate change stresses - doubles the risk of unintentional injury, particularly for males (Fragar et al. (2013). Financial pressure combined with difficulties finding farm workers adds to the chances that farmers spend considerable time working alone, which is also known to increase the risk of injury. Financial pressure increases the chances that farm businesses do not have Work Cover or insurance. Injuries to sole-operated or small farm businesses can thus have severe financial impacts (Guthrie et al. 2009).

Extreme events disproportionately affect rural communities and their health services.

Periods of extreme heat have already increased in Australia over the past few decades (see Table 1). Such conditions can be disruptive and even deadly, dramatically increasing work absenteeism, reducing the quantity and quality of work performance, increasing accidents and leading to substantial economic losses (Kjellstrom et al. 2009; Climate Council 2016b). A recent study estimated that the cost of hot conditions in 2013-2014 in Australia was US\$6.2 / A\$8.3 billion (95% CI: 5.2–7.3 billion) or 0.33 to 0.47% of Australia's GDP (Zander et al. 2015). Heat is a particular risk for outdoor workers, especially when it intersects with OHS requirements such as wearing protective clothing to manage other health risks such as exposure to agrichemicals, many of which become more volatile and dangerous in hot conditions (Applebaum et al. 2016). A survey of workers' compensation claims in South Australia (2001-2010) found that claims increased 6.2% during heatwaves, with those older than 55, and those employed in agriculture, fishing and forestry over-represented (Xiang et al. 2014).

The changing climate also means that rural individuals can be increasingly exposed to infectious diseases such as salmonellosis and other bacterial causes of diarrhoea, to which certain groups such as pregnant women and the elderly are especially sensitive (Harley et al. 2011; Climate Council 2016b). Food and water-borne infections increase when food storage and access to potable water is adversely affected, exacerbating the fact that rural people already tend to have less access to good quality fresh food than their urban counterparts (Friel et al. 2014). Exposure to vector-borne disease such as Dengue fever will likely increase in some regions as shifts in climatic conditions expand the range of disease-carrying organisms such as mosquitoes (Figure 14), ticks, tsetse flies, and sandflies (Mills et al. 2010).

A recent study estimated that the cost of hot conditions in 2013-2014 in Australia was \$8.3 billion.

Risks from particulate and particle-associated contaminants and pathogens associated with agriculture could also rise (Boxall et al. 2009), especially with increased levels of soil dust and wildfire smoke that are known to exacerbate asthma and other respiratory conditions (Applebaum et al. 2016; Reid et al 2016).

The devastating impacts of extreme events on farm production, profitability and future viability can impose considerable mental stress on those involved (Hunter and Biddle 2011) (see Box 1: Drought and

Rural Mental Health). There is growing evidence that exposure to extreme events, especially drought, is associated with increased prevalence of mental distress and illness among rural populations, including depression and anxiety (Horton et al. 2010; O'Brien et al. 2014; Figure 15), and suicide (Hannigan 2012). This relationship is affected by many variables (Powers et al 2015, Friel et al. 2014), and reflects the magnitude and interaction of the multiple pressures upon farming which need to be tackled in tandem to collectively increase the adaptive capacity of rural families and communities.

Figure 14: Mosquito-borne diseases (such as dengue fever) pose a risk to rural communities, particularly in northern Australia. Dengue fever will likely increase in some regions as shifts in climatic conditions expand the range of disease-carrying mosquitoes.





Figure 15: Exposure to extreme events, especially drought, can cause increased incidences of mental distress and illness among rural populations.

BOX 1: DROUGHT AND RURAL MENTAL HEALTH

Although often less visible in Australian society than other climatic extremes, droughts can be easily as disruptive and distressing as any other, particularly given their often long and insidious character. The hot, dry conditions of droughts provide a window into potential future baseline conditions for many regions in southern Australia, where droughts are projected to worsen through this century (CSIRO and BoM 2015).

During times of drought and financial hardship, households can find it difficult to afford fresh nutritious food, especially if drought further exacerbates the availability of affordable, high quality food products in rural centres. There are indications that drought also increases the stressfulness of such food insecurity (Friel et al. 2014). Whereas poverty associated with drought can reduce alcohol consumption for some, for others the stress of drought appears to be associated with increased alcohol consumption (Edwards et al. 2009), adding to the already relatively high alcohol consumption within rural populations (Brumby et al. 2011b).

Besides financial pressure, droughts cause stress by directly affecting things that many farming families hold dear, such as their livestock, natural environment and local community. Having to destroy or sell stock, plough in long-nurtured crops (such as fruit trees), and watch domestic and public places decline can be extremely stressful. Droughts can induce 'solastalgia': distress triggered by the

degradation of one's local environment, especially if associated with a sense of lack of control (Albrecht et al. 2007, Sartore et al 2008). This is exacerbated by the loss of friends and support structures as some families move away or valued businesses close (Rickards 2012).

Droughts are also associated with increased incidence of suicide in rural populations. In NSW during the period 1970-2007, suicide amongst rural males in the 30-49 year age group increased during drought by 15% (Hanigan et al. 2012). Another study found that drought years were associated with an increase in suicide rate of 7% in men and 15% in women across the whole NSW population (1901-1998) (Page et al. 2002). Mental health impacts of drought are not confined to adults. Among adolescents, experience of drought is also associated with behavioural problems, stress, hyperactivity and difficulty in maintaining relationships (Dean and Stain 2010).

The 2008 "Kenny" report on the perceptions and impacts of living with dryness in Australia called for greater investment in primary and allied health services in rural communities to build coping capacity for ongoing drought impacts. Programs such as the Targeted Community Care (Mental Health) Program were established to boost local service networks in order to increase community health advice and pathways to recognise and respond to distress (Horton et al. 2010).



Figure 16: Drought brings numerous challenges to rural communities in Australia, including health-related issues.

4.4 Impacts on Communities

Beyond the impact on farming *per se*, climate change poses serious challenges for rural communities more broadly. For one thing, the impacts of climate change on agriculture and farming families flow through to local communities, with many of them still economically reliant on farm family spending (Race et al. 2011). Local economic depression can place the long term viability of local businesses and services at risk of closure and/or reduce employment options within them (Cocklin and Dibden 2005; Beer 2012).

In particular, the loss of key services, such as banks, health clinics, retirement homes, schools, or supermarkets, can be a “tipping point” for a town (eg Tonts and Artheley 2005), reducing the viability of remaining organisations, including those that rely on volunteers. The result can be population decline and the consolidation of rural settlements into fewer, larger towns, and a further reduction in local services (Luck et al. 2011).

Young people, especially young women, regularly leave rural communities to seek education, employment and lifestyle options in larger centres (Argent and Walmsley 2008). While some return after a number of years, it can be difficult for rural areas to attract them back, especially if possible returnees have partners and children. For similar reasons, attracting city-trained professionals such as doctors, is an ongoing challenge for rural areas (Scott et al. 2013; Lincoln et al. 2014, Cosgrave et al. 2015). A study into the ‘maldistribution’ of Australian rural GPs, for example, found it was those in the smallest communities that were most likely to leave, just as it was hardest for those communities to attract new recruits (McGrail and Humphreys 2015). While there are valuable new initiatives emerging that offer incentives

The direct impacts of climate change can have flow on effects through a community.

to people from urban Australia and overseas to relocate to rural Australia, the basic question of how to make rural living more feasible and attractive remains an important one, particularly given the challenges that climate change poses to rural towns. The number of forced and voluntary international migrants is also likely to increase under climate change. A growing number of refugees are resettling in rural and regional Australia voluntarily, where their retention is shaped by the same challenges around employment and social opportunities faced by others (Schech 2013).

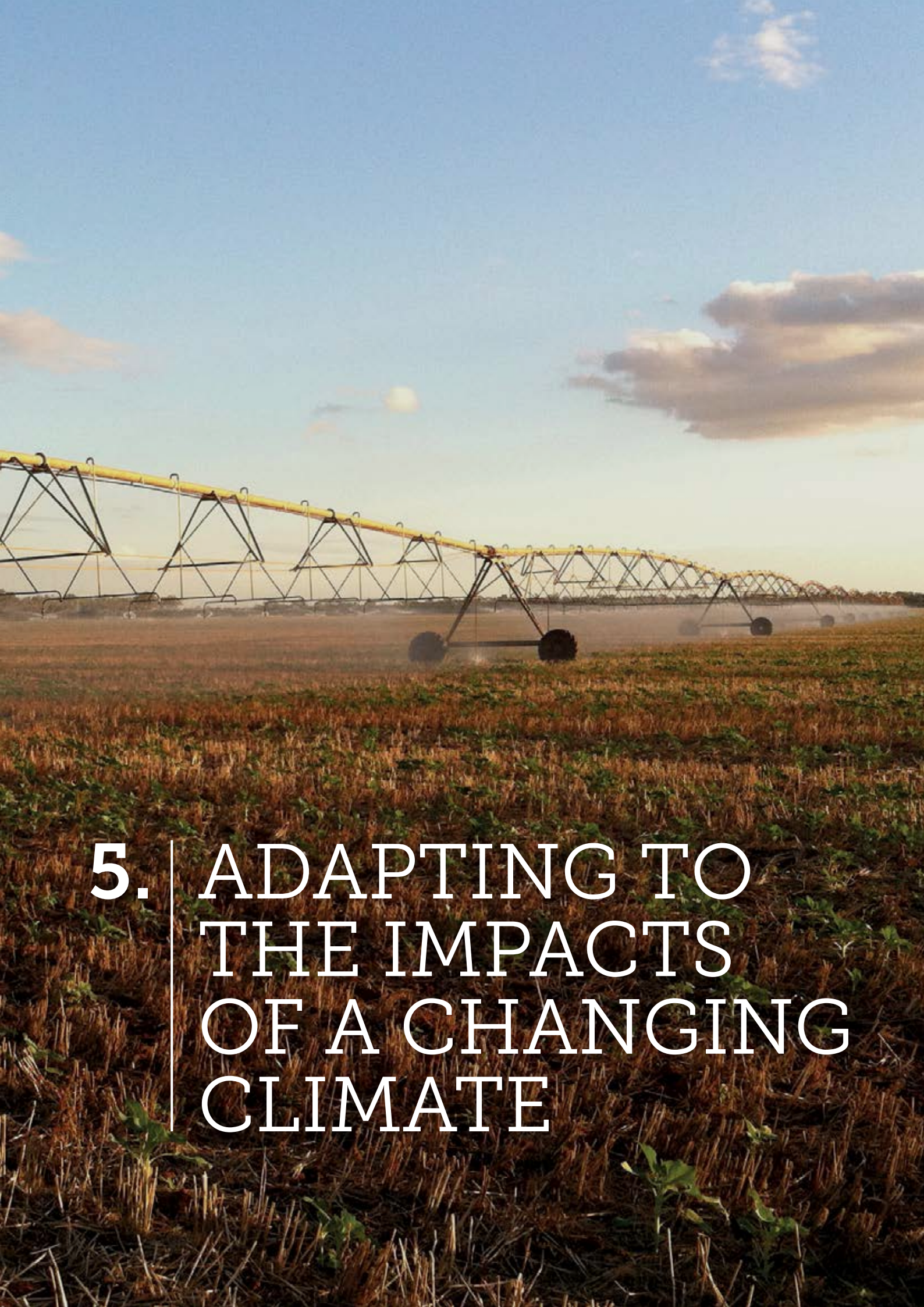
Those living in rural communities are also directly exposed to climatic impacts such as extreme heat and water shortages, leading to physical discomfort and diminishing the livability of exposed rural areas. Race et al. (2011) suggest that difficult physical living conditions may already be contributing to people moving out of inland rural communities.

Some groups in rural communities are more exposed and sensitive to climatic impacts than others. This is especially the case for the elderly. For example, a study of mortality-temperature thresholds in rural Victoria found that 'hot weather results in an increase in mortality in persons aged 65 years and older' (Loughnan et al. 2010, p.1287). Access to affordable potable water is important in enabling older people, and others, to remain in an area, thus affecting the extent to which communities can support healthy ageing (Rogers et al 2013). Being able to maintain domestic gardens for food and aesthetic

purposes can also be especially important for the wellbeing of older people and migrants. Loss of private and public gardens and parks due to water shortages or other climatic factors is known to diminish people's sense of place and wellbeing (Rickards 2012).

Rural organisations and services depend on volunteers. Smaller active populations mean that either those still involved carry a greater proportion of the work burden or that some organisations, such as sporting clubs or church congregations, fall into abeyance. Reduced engagement with volunteer associations can diminish individuals' and families' social capital, increasing their own vulnerability and sense of belonging to the community (Rickards 2012). The level of volunteerism in Australia has been declining while at the same time, the need and/or demand for some services, including volunteer fire fighters and other emergency services personnel, is increasing due to climate change.

With climate change affecting agriculture and rural communities in so many ways simultaneously, the need for adaptation is increasing rapidly. We turn now to consider the many things that can be done to reduce the impacts of climate change and increase the wellbeing and security of rural Australia, above and beyond critical need to reduce greenhouse gas emissions.



5. ADAPTING TO THE IMPACTS OF A CHANGING CLIMATE

5.1 Climate Change

Adaptation:

The Concept

Climate change is altering virtually every element of the environment and simultaneously having diverse impacts on social, health, political and economic arenas. The challenge is to respond in a way that is collectively as well as individually beneficial so that in the process rural Australia is regenerated and negative climate change impacts are minimized.

Relative to many others, rural communities are well practiced at adapting to changing conditions. Agriculture tends to require an ongoing degree of flexibility to accommodate Australia's highly variable climate and environment, as well as volatile economic conditions. Adaptation to current and future climate change builds on these valuable experiences and skills. See Appendix B for a glossary of adaptation-related terms.

Good climate change adaptation in rural communities will draw upon not only existing local knowledge about a region, but experiences and insights into what helps generate positive change. It will involve local communities engaging in new approaches and learning from lessons elsewhere. The processes of innovation and improvement that already characterize everyday life for many rural people are an asset to climate change adaptation. It is not difficult to imagine a future in which expertise in climate change adaptation becomes a new rural characteristic, and even a new knowledge export.

5.2 Adaptation Options

Adaptation options to reduce climate change risks range from the generic to the specific.

Generic adaptation actions aim to enhance the general capacity of a group or individual to respond to any impact, building their 'generic resilience' by strengthening existing systems, and improving the management of uncertainty (Walker and Salt 2006). Specific adaptations are aimed at reducing the risk of particular climate change impacts. These approaches can range from incremental, such as progressively altering sowing or harvesting dates, to transformational change, such as wholesale relocation of a rural enterprise.

5.2.1 Generic Adaptation Approaches

When a community is already under stress or particularly vulnerable, adapting to change is often much harder. Strengthening existing systems and services, such as improving water supply, putting in place appropriate policies for drought management, improving soil health, and adequately resourcing emergency services will reduce risks from current and future climate change.

Building flexibility and redundancy into systems (eg by designing additional water storages) and sharing services by using regional community networks also builds resilience across a region and helps manage future uncertainty.

The ability to cope with existing climate variability is considered a good indicator of capacity to deal with new climate challenges. While many farmers and farming communities have proved highly adaptable in the face of coping with Australia's highly variable climate, this resilience is not universal. A survey of 240 peanut producers in northern Australia, for example, indicated that only 16% had a strong capacity to manage existing climate variability (Marshall et al. 2014).

A farmer's current capacity to cope with climate variability is a good indicator of capacity to cope with ongoing climate change.

One of the challenges of farming is that many, if not most management decisions, are made in anticipation of certain conditions, whether they be climatic, market, or other variables (Hayman 2011). Assisting farmers and other inhabitants of rural communities to incorporate realistic projections of future climate conditions into current decision-making is critical. Like economic forecasts, projections of climate change impacts in the future come with some degree of uncertainty. But uncertainty about precise future conditions does not mean we know nothing about the future or that any outcome has an equal chance of manifesting. Rather, projections of future climate provide odds that any particular conditions will emerge.

Tools such as seasonal climate forecasts are increasingly used by farmers to help make decisions in the face of increasing climate variability and change (Meinke and Stone 2005). Many farming organisations are actively helping farmers engage with the new forecasting tools and integrate them into decision-making (e.g. Hochman et al. 2009, Rotz et al 2015).

An important method for better adapting to climate change in the face of uncertainty is scenario planning: the analysis of different situations that may emerge and how to plan for them (see Box 7: Resources for a Changing Rural World: A Toolbox). For example, in the Avon wheatbelt, scenario planning was used to develop detailed scenarios for the region in the future, based on possible environmental and market conditions which resulted in the identification of some new opportunities and challenges (O'Connor et al. 2005). Scenario planning in Hamilton, Victoria, revealed that climate change could have far more complex impacts on the region than first imagined (Smith et al. 2011).

5.2.2 Specific Adaptation Approaches

Specific adaptations can be thought of as ranging from incremental (small, tactical changes) to transformational (larger, strategic changes).

Incremental adaptation changes are those that perpetuate or remain close to existing practice and objectives. Many incremental adaptations to climate change are already underway or under consideration in Australian agriculture. Examples include changing crop varieties and livestock breeds, and alteration of sowing and harvesting dates. As climatic conditions become harsher, there may be increasing use of more heat-tolerant sheep breeds such as the

Dorper (Figure 17), or tick resistant cattle, such as zebu (*Bos indicus*). Although some heat-tolerant breeds have lower meat quality and lower reproductive rates (Stokes and Howden 2008).

Somewhat more substantial changes, involving higher transaction costs but also greater adaptation gains, are sometimes referred to as "system level changes". Examples include changing production systems (eg from dryland to irrigation) or enterprise mix (Hayman et al. 2012). Illustrating the latter, grain cropping in western Victoria is expanding as reduced rainfall and reduced waterlogging make these crops more profitable (Barlow et al. 2011).



Figure 17: Climate change may increase the use of more heat-tolerant breeds, such as the Dorper sheep.

Farmers and rural communities are already adapting to a changing climate.

 BOX 2: THE WESTERN AUSTRALIAN GRAIN BELT



Figure 18: WA grainbelt under threat from climate change.

In the WA grain belt, average temperatures have increased by 0.8°C over 50 years, with a disproportionate increase in the frequency of hot days (Asseng and Pannell 2012; Kingswell et al. 2013), and cool season (May – September) rainfall has declined up to 40% in some regions over several decades (CSIRO and BoM 2015).

Adaptation measures to adjust to increasing water scarcity in the region include increased water use efficiency at farm level, changes to cropping systems with lower water requirements, adoption of water saving technologies, and increased use of groundwater (Alston and Whittenbury 2011).

Transformational adaptation involves the more substantial, system-wide, changes from existing practices. It often requires the development of new skills, understanding of new markets, and building of new infrastructure (Rickards and Howden 2012; Hertzler et al. 2013). Although transformational climate change adaptation promises many positive outcomes, it is generally not rapid, easily reversible, or risk-free for those involved (Stafford-Smith et al. 2011; Rickards and Howden 2012).

In agriculture, the clearest example of transformational adaptation to climate change is the relocation of farm businesses. Some wine grape growers have already relocated from mainland Australia to Tasmania (Park et al. 2012) to avoid some of the risks of warming on the mainland (Fleming et al. 2015a, 2015b). Similarly, in the WA grainbelt, some farmers have diversified by buying land in other areas to spread their risk (Alston and Whittenbury 2011).

5.3 Maladaptation

Maladaptation is adaptation action that does not achieve its intended goal or that generates perverse outcomes (Adger and Vincent 2005; Hayman et al. 2012). For example, adaptation measures that increase (or fail to decrease) the production of greenhouse gas emissions and thus global climate change may be considered maladaptive because they contribute to the problem itself (Barnett and O'Neill 2010). Likewise, adaptations that are highly energy or water intensive are at risk of being or becoming perverse both for those undertaking them and other users of those resources.

Adaptation measures can also compound vulnerability by inadvertently exacerbating exposure or sensitivity to other specific climate changes such as pest outbreaks or infrastructure failure, or by deepening background stressors such as soil degradation, family stress, population decline and economic volatility. One example is the increase in domestic rainwater tanks as an adaptive response to water scarcity because these tanks can provide breeding habitat for mosquitoes that are vectors of diseases such as Dengue fever (Beebe et al. 2009).

Careful forward thinking, coordinated action and continual adaptive management, including monitoring and evaluation processes and keeping a range of options open, can help to minimize this risk (Krause et al 2015; Claessens et al 2012).

5.4 Limits to Adaptation

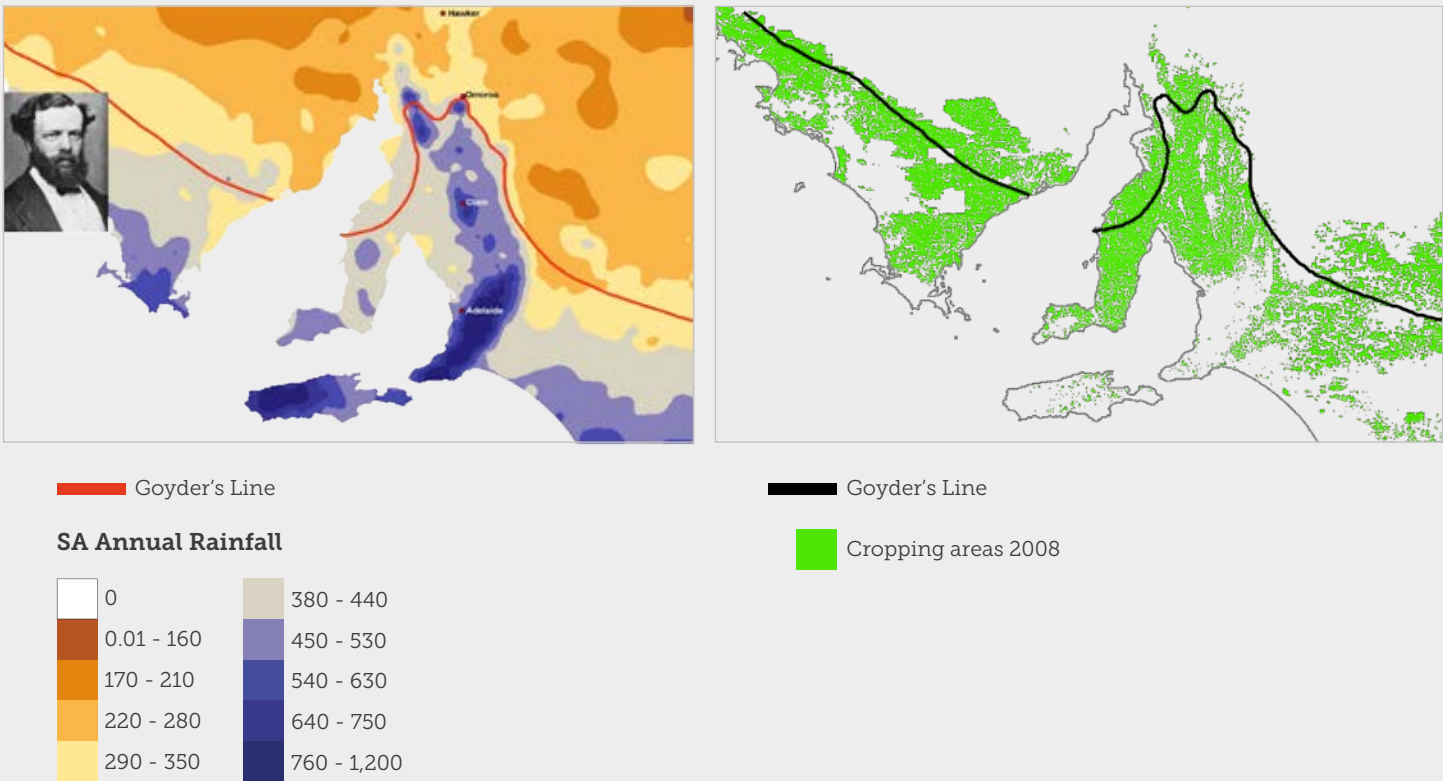
All adaptation approaches have limits. Some limits are biological, such as extreme temperatures that exceed the threshold that plants or animals can tolerate and survive.

While technological developments can stretch these biological limits (for example, through breeding to decrease a crop's water requirements), a limit will still exist. A well-

established limit to cropping within Australia is the rainfall boundary in South Australia known as Goyder's Line (Figure 19). Although Goyder's Line is subject to short-term movement due to cyclical climate variability (Tozer et al. 2014), when averaged over longer periods, climate changes also affects the position of the line, further constricting the area to the south suitable to dryland cropping (Nidumolu et al. 2012).

Figure 19: Goyder's Line: A rainfall boundary that defines the limit to cropping within Australia. Left panel depicts Goyder's line and annual rainfall in South Australia. By comparing both panels, the right side shows a strong relationship between rainfall and the current extent of grain farms. **Sources:** Uday Nidumolu CSIRO (left panel, rainfall map) and South Australian Department of Environment Water and Natural Resources (right panel, grain map).

GOYDER'S LINE SHOWING ANNUAL RAINFALL AND CROPPING AREAS IN SOUTH AUSTRALIA



Limits to adaptation also depend on social, economic, institutional and psychological factors (Inderberg and Eikeland 2009; Dow et al. 2014). For example, while growing a certain crop in an area may be physically possible under future climates, it might not be financially viable due to increased input requirements such as irrigation.

The rate at which the climate changes is critical to the feasibility of many adaptation approaches. If individual farmers or rural communities adapt more slowly than the climate is changing, new practices may become unsuitable (Barnett et al. 2015).

5.5 Barriers to Adaptation

Like all change, many climate change adaptation approaches will encounter challenges and obstacles that need to be worked around, avoided, or overcome.

For some types of adaptation, the strongest barriers arise from their complexity, irreversibility, and/or difficulties in assessing their impacts (Pannell et al. 2006; McCann et al. 2015). In rural communities, other common barriers include financial constraints (Mazue et al. 2013), rural decline (Whittaker et al. 2015), and institutional barriers (Waters et al. 2014). A survey of rural landholders in Victoria, for example, found that few were taking longer-term action because of constrained financial resources (Mazur et al. 2013). Furthermore, farmers and members of rural communities can at times have difficulty accessing and/or understanding climate information provided (see Kiem et al. 2013c).

If climate change demands more dramatic transformational adaptation, having an inflexible commitment to any aspect of the existing situation, including location, business type, or existing practices, can become a barrier to adaptation. Likewise, the decisions and actions taken by an individual can be hampered by their position in society. Rural women, older people, young people or new arrivals can face barriers to adaptation due to not having access to decision-making power in their setting. Other key barriers include the existing level of stress in a community, and the community's perception about current and future risk (Grothman and Patt 2005; Mazue et al. 2012; Fleming et al. 2015). Paradoxically, while rural communities can be considered far more at risk from climate change than their urban counterparts, some surveys suggest that rural populations have been more resistant to messages about long-term anthropogenic climate change although this is changing rapidly (Box 3 Perceptions of Climate Change in Rural Communities).

Views on climate change are not always a barrier to adopting climate change adaptation, but can constrain or distort the actions people take. For example, several studies have found that farmers who understand the human impact on climate change are more likely to invest in adaptation strategies now (Milne et al. 2008, Marshall et al. 2013, Raymond and Spoehr 2013, although see Rogers et al. 2012 for contrasting results). Some farmers, however, are adopting a "wait and see" approach that may ultimately reduce options and opportunities (Buys et al. 2012; Hayman et al. 2012; Beer et al. 2013). A common reason for the wait and see approach is the uncertainty about specific rainfall projections.

Lack of financial resources is preventing many landholders from preparing for climate change.

 BOX 3: PERCEPTIONS OF CLIMATE CHANGE IN RURAL COMMUNITIES

70% of rural population want stronger government climate action.

General awareness of the basics of climate science and the risks that ongoing climate change poses are now widespread in the general Australian community (Leith and Vanclay 2015).

A survey of 17,493 Australians by CSIRO in 2014 found that the vast majority of people in Australia understand that climate change is happening, with only 8% of respondents expressing the belief that the climate is not changing - a far smaller proportion than most people assume, given the politicization of the topic (Leviston et al. 2013, 2015). The CSIRO survey suggests that the main points of contention among the public about climate change are what is causing it (i.e role of human activity vs natural variability) and the level of risks posed. Regardless of such opinions, there is widespread support for adaptation initiatives, reflecting the fact that such initiatives often have broader benefits.

Research into the specific views of rural communities indicates that members of these communities are more likely than those in urban areas to state that climate change is not happening or that observed climate change is a natural cycle (Buys et al. 2012; Connor and Higginbotham 2014). However, an international study found that, of the countries reviewed, Australia had the highest proportion of farmers understanding that climate change is human-induced, with a majority of farmers subscribing to such a view (Prokopy et al. 2015). Recent results from the ABC's Vote Compass project (July 2016) indicated that 70% of people in rural communities wanted to see the government take more action on climate change (ABC 2016b).

6. | OPPORTUNITIES FOR RURAL COMMUNITIES



6.1 Reducing Greenhouse Gas Emissions

Increasing concentrations of greenhouse gases in the Earth's atmosphere (such as carbon dioxide, methane and nitrous oxide) due to human activities are the main cause of climate change (IPCC 2013).

Agriculture is the fourth largest source of emissions after the electricity, stationary energy and transport sectors (Department of Environment 2016), responsible for about 13% of Australia's greenhouse gas emissions (in the year to December 2015).

Ruminant animals like cows and sheep are the largest single source of agricultural greenhouse gas emissions, producing large amounts of methane as they digest their food. Emissions from manure, fertilizer application, savanna and field burning, and cropping (mainly rice cultivation) also contribute (Department of Environment 2016). Some industries are extremely emissions intensive. The beef industry, for example, is more emissions intensive than aluminium or steel production (BZE 2014), especially if the powerful greenhouse effect of short-lived emissions is taken into account (Wedderburn-Bisshop et al. 2015).

The land use, land use change, and forestry sector is responsible for an additional 2% of Australia's greenhouse gas emissions each year. A large component of this comes from land clearing. Land clearing is increasing in some states such as Queensland, where 296,000 hectares of bushland was cleared in 2013-14 – three times as much as in 2008-09 – mainly for conversion to pastures (Maron et al. 2016).

It follows that the land use sector can play a very important role in reducing Australia's net emissions, especially from changes in agricultural practices and revegetation (Garnaut 2011 a, 2011b; BZE 2014). Consumers and the public at large increasingly expect the agricultural sector to demonstrate that it is tackling climate change. Providing lower carbon products is becoming an increasingly important aspect of the sector's 'social licence to farm', alongside adaptation actions that avoid land degradation and animal welfare issues. Experience suggests that 'embracing the social licence challenge in a positive manner may be the most effective way to ensure continued support from the community' (Martin and Williams 2011, p.202).

Agriculture can play a very important role in reducing Australia's emissions.

Many opportunities exist for agriculture to reduce emissions and sequester atmospheric carbon. A report by Beyond Zero Emissions (BZE 2014) has calculated that revegetation of 13% of cleared land could draw down enough carbon to offset emissions from all other land use activities. Other opportunities exist for biochar production and alternative biofuels (see Box 4: Bioenergy – food vs fuel).

Significant research effort in Australia is focused on reducing methane emissions from livestock and nitrous oxide emissions from fertilisers (Eckard et al. 2010; Henry et al. 2012; Finn et al. 2015). In some cases, there are synergies between adaptation actions and those taken to reduce emissions (mitigation) - eg planting trees can provide shade for stock, but also increase carbon dioxide uptake from the atmosphere. Using current best practice for applying fertilizer can reduce emissions of nitrous oxide as well as increasing productivity and reducing costs.

Opportunities for rural communities more generally to mitigate climate change include the normal suite of options for reducing energy use, reducing consumption of embodied energy, using energy more efficiently, and using less greenhouse intensive energy sources. Some energy-intensive aspects of rural life, such as travelling long distances by road, are hard to avoid (Kamruzzaman et al. 2015) and point to the need for efficient vehicles, good roads, cleaner fuel sources (discussed below), alternative modes of transport and alternative ways of accessing distant services.

BOX 4: BIOENERGY: FOOD VERSUS FUEL



Figure 20: Sugarcane field in Queensland. Bioethanol is produced in Australia from sugarcane molasses.

Bioenergy is a form of renewable energy derived from biomass used to generate electricity and heat or to produce liquid fuels for transport (ARENA 2015; Bioenergy Australia 2015; Geoscience Australia 2015). Biomass is the term used for all organic material originating from plants or animals which are grown, collected or harvested for energy (Clean Energy Council 2015a, 2015b; Geoscience Australia 2015). Current bioenergy resources consist of residues from forestry and agriculture, municipal wastes and biomass production from pasture land, wood plantations and sugar cane (IEA Bioenergy 2014; Geoscience Australia 2015).

The main growth markets for bioenergy are the European Union, North America, Central and Eastern Europe and Southeast Asia. In Australia, some bioenergy technologies are well established and are currently in commercial use (Geoscience Australia 2015). Bioenergy currently contributes almost 1% of Australia's electricity production and 7% of renewable electricity production (ARENA 2015; Clean Energy Council 2015a). CSIRO research (Farine et al. 2012) suggests that bioenergy could mitigate 26 Mt CO₂-e, which is the equivalent of 38% of road transport emissions and 5% of Australia's emissions but other estimates of the proportion of Australia's petrol

usage that could be replaced by biofuels range from 10 to 140% (Herr and Dunlop 2011).

Expansion of bioenergy from the current small industry base in Australia will require the widespread deployment of new energy technologies, and will depend on a range of economic and policy settings (Farine et al. 2012). There are also significant social and environmental issues (e.g., health, poverty, biodiversity) associated with bioenergy, which may be positive or negative depending on local conditions and the design and implementation of specific projects (Chum et al. 2011; Farine et al. 2012). On the one hand, bioenergy offers the potential for considerable economic benefits, including increasing Australia's energy security, stimulating regional development, and reducing greenhouse gas emissions (IEA 2010; Chum et al. 2011; Kraxner et al. 2013; ARENA 2015). Conversely, pristine forests, biodiversity, agricultural land, soil and water resources will all be under additional pressure from increases in the use of biomass from agriculture, forestry, and waste for producing energy (Kraxner et al. 2013). In Australia, most cleared land is already used for some form of agriculture (cropping or grazing), and therefore any substitution with bioenergy crops will involve some trade-off with food production (Herr and Dunlop 2011; Farine et al. 2012).

6.2 Rural Renewable Energy Opportunities

In addition to producing zero emissions electricity, renewable energy presents many opportunities for rural development and economic growth.

Projects such as wind and solar farms and biomass plants benefit rural areas by investing in the local economy, providing an alternative source of income for landowners, contributing to the local shire rate base, and creating a variety of flow-on business, employment and training opportunities. Biomass plants can turn agricultural waste (such as crop residues) into energy as well as producing valuable by-products such as fertilizers. Landowners and communities are also adopting renewable energy as a way to reduce costs and become self-sufficient. Off-grid (or fringe-off-grid) renewable energy systems are cost-effective, especially in remote locations where they can reduce or replace reliance on diesel (McHenry 2012; REN21 2015). Further, rural communities are also developing the knowledge, skills and capacity to be able to develop their own community-led and community-owned renewable energy projects (OECD 2012).

Renewable energy presents many opportunities for rural development and economic growth.

6.2.1 Economic Benefits of Renewable Energy: Local Investment and Job Creation

Australia is rich in renewable energy resources including solar, wind, wave, geothermal and bioenergy resources (Geoscience Australia and BREE 2014). In particular, Australia's wind and solar resources are among the best in the world.

Investment in renewable energy is growing worldwide. In 2015, a record \$286 billion was invested in renewable energy – \$329 billion if large-scale hydropower is included in the total (REN21 2016). Since 2010, annual investment in renewable energy has exceeded investment in new fossil fuel power every year. In 2015, investment in renewable electricity more than doubled the investment in new coal and gas plants (REN21 2016).

Much of the investment in clean energy flows to rural areas, which are *"sparsely populated [and] amply endowed with renewable sources of energy"* (OECD 2012). In the United States, rural areas receive over half of the total investment in renewables. Here in Australia, rural areas share of investment is around 30 - 40% (OECD 2012; SKM 2012), valued at \$1-2 billion per year (Clean Energy Council 2014).

Like investment, global employment in renewable energy is growing. In 2015, more than eight million people were employed in the renewable energy sector. In Australia in 2015, fourteen thousand people (down by 5,000 from 2012) were directly employed in the renewable energy industry, many in regional areas (Clean Energy Council 2016). Renewable energy generates more jobs per unit of energy than fossil fuels, with solar photovoltaic (PV) energy creating the most jobs per unit of energy (Wei et al 2010; IRENA 2011).

Increasing Australia's share of renewable electricity results in net jobs growth both nationwide and in every state (Climate Council 2016c). Employment modeling for renewable energy growth under a business as usual scenario (leading to 34% renewable electricity in 2030) and a 50% renewable electricity scenario shows that more renewable energy creates more jobs. Reaching 50% renewable electricity by 2030 will lead to over 28,000 new jobs (more than 50% more employment than business as usual).

Renewable energy generates more jobs per unit of energy than fossil fuels.

Unlike other industrial transitions (such as car manufacturing where jobs have been lost offshore), increasing Australia's renewable electricity supply creates jobs locally in Australia. Constructing, operating and maintaining utility scale power such as wind farms and solar power plants offers opportunities to increase employment in regional, rural and remote areas (Climate Council 2016c).

Renewable energy also supports the creation of many more indirect jobs along the supply chain – in construction, manufacturing and services. For example, even in a country without a solar PV manufacturing and export industry, solar creates numerous jobs for wholesalers, project developers, system designers and installers, construction workers, meteorologists, technicians and maintenance staff (IRENA 2011). Many renewable energy projects provide apprenticeship and training opportunities (SKM 2012).

For a wind farm, the investment in rural and regional areas includes turbine tower manufacturing; site construction and maintenance involving civil and electrical works, equipment hire and local materials; and services such as transport, accommodation and food (SKM 2012).

The land required for a wind farm is minimal (wind turbine tower foundations are typically around 10m by 10m) and agricultural activities such as grazing and cropping can generally continue within and around the wind farm. Livestock tend to graze in the shade created by wind turbine towers and solar panels, much like shade created by trees and vegetation (NSW Farmers 2016; Figure 21).



Figure 21: Livestock grazing beneath wind turbine towers and solar panels.

Farmers and rural landowners who lease their land for wind turbines benefit by receiving annual lease payments of around \$10,000 per turbine per year (Epuron 2014b). Across Australia, approximately \$20.6 million is paid annually in lease payments to farmers and landholders hosting wind turbines (calculated from Chapman 2013; Clean Energy Council 2016; Epuron 2014b). Such lease payments provide a consistent, additional source of income to farmers unaffected by weather (ABC 2015).

In addition to local investment from installation, construction and operation, large-scale renewable energy projects pay annual rates to rural shire councils and establish community benefit funds. Amounts vary between different states and for different renewable technologies. For example, the Snowtown Wind Farm in South Australia contributes approximately \$50,000 per year in council rates and \$50,000 per year to a community fund (Epuron 2014a). The Waubra Wind Farm in Victoria contributes \$166,000 per year in rates and \$64,000 per year to a community fund (ABC 2007;

ACCIONA Australia 2015). The Nyngan Solar Plant in NSW is still negotiating a rate agreement with Bogan Shire but in the meantime is contributing \$28,000 per year during construction to a local Community Fund (ABC 2014; AGL 2014). Community funds and additional rate revenue for rural and regional areas from renewable energy can be used to improve public services such as schools and local infrastructure (OECD 2012). For example, the Nyngan Solar Plant's community fund recently provided the local pre-school with a 6kW solar PV system, reducing ongoing energy bills by more than \$3,000 per year (Nyngan Observer 2015).

Renewable energy also encourages innovation in rural areas and can spur local entrepreneurship. Berrybank Piggery, near Windemere in southwest Victoria, is an example of a farm demonstrating innovation by turning a significant waste stream into a useful resource – an onsite supply of renewable electricity and heat as well as useful by-products such as fertilizer (Box 5: Energy from pigs).

BOX 5: ENERGY FROM PIGS

Berrybank Farm (Windemere, southwest Victoria) has installed a state-of-the-art biogas generator (a form of renewable energy) that turns waste from its piggery into electricity and heat able to be used on the farm and sold back into the grid.

The piggery produces a huge amount of sewage every day - 275,000 litres – an amount similar to the waste produced by a town of 50,000 people. The waste from the 20,000 pigs is continuously collected in a series of drains around and under

the piggery, grit is removed, and the resulting "slurry" is thickened. The waste product is then broken down in two large tanks, producing biogas. Sulphur is removed with scrubbers and the biogas can then be used to produce heat and electricity.

The 192 kW biogas plant produces electricity to run the farm, heat the pig sheds, and surplus electricity that is sold into the grid, saving the farm around \$180,000 per year. The farm also uses organic by-products from the generator to produce potting mix and fertilizer.

Sources: Sustainability Victoria 2001; Maraseni and Maroulis 2008; MTU Detroit Diesel Australia 2014; Energy and Earth Resources 2015.

6.2.2 Affordable Energy, Community Empowerment and Self-sufficiency

Energy costs in regional areas are often higher than in the major cities, both globally and in Australia (OECD 2012; AECOM 2015a), and can cause “energy stress” where households spend a significant proportion of their income to stay warm (or cool in a heatwave).

In Australia, regional areas connected to the grid face greater energy costs due to higher service charges and usage rates (National Rural Health Alliance and ACOSS 2013). In more remote, off-grid areas, 74% of electricity is generated from imported natural gas or diesel, making it Australia’s most expensive electricity (AECOM 2015a). Current diesel generation in off-grid mines and communities cost \$240 - 450/MWh, compared with average prices of \$30 - 54/MWh in the National Electricity Market (AECOM 2015a).

Renewable electricity (such as wind and solar photovoltaics) is already a cheaper option for providing electricity to remote, off-grid and island communities compared with the cost

of extending the electricity grid (OECD 2012; AECOM 2015a). Some energy companies, such as Horizon Energy in Western Australia, have begun tendering for large battery storage and solar systems to supply electricity to some regional towns instead of extending the electricity grid (Renew Economy 2014).

King Island off the coast of Tasmania (Figure 22) is an example of an off-grid, island community using battery storage to boost its reliance on renewable energy (Hydro Tasmania 2015). Previously relying entirely on diesel for its electricity, King Island is now powered mainly by wind, solar and biodiesel together with one of the largest battery storage systems in Australia. The island’s 3 MW / 1.6 MWh advanced lead acid battery system is designed to enable wind power to provide up to 70% of the Island’s electricity demand (at times providing 100% renewable energy) while maintaining a stable grid. Since installing the renewable energy and storage system, King Island has halved its diesel consumption from 4.5 to 2.6 million litres per year (AECOM 2015b).

Renewable energy is a cost-effective option for providing electricity to remote, off-grid and island communities.



KING ISLAND

AN **OFF GRID**
COMMUNITY

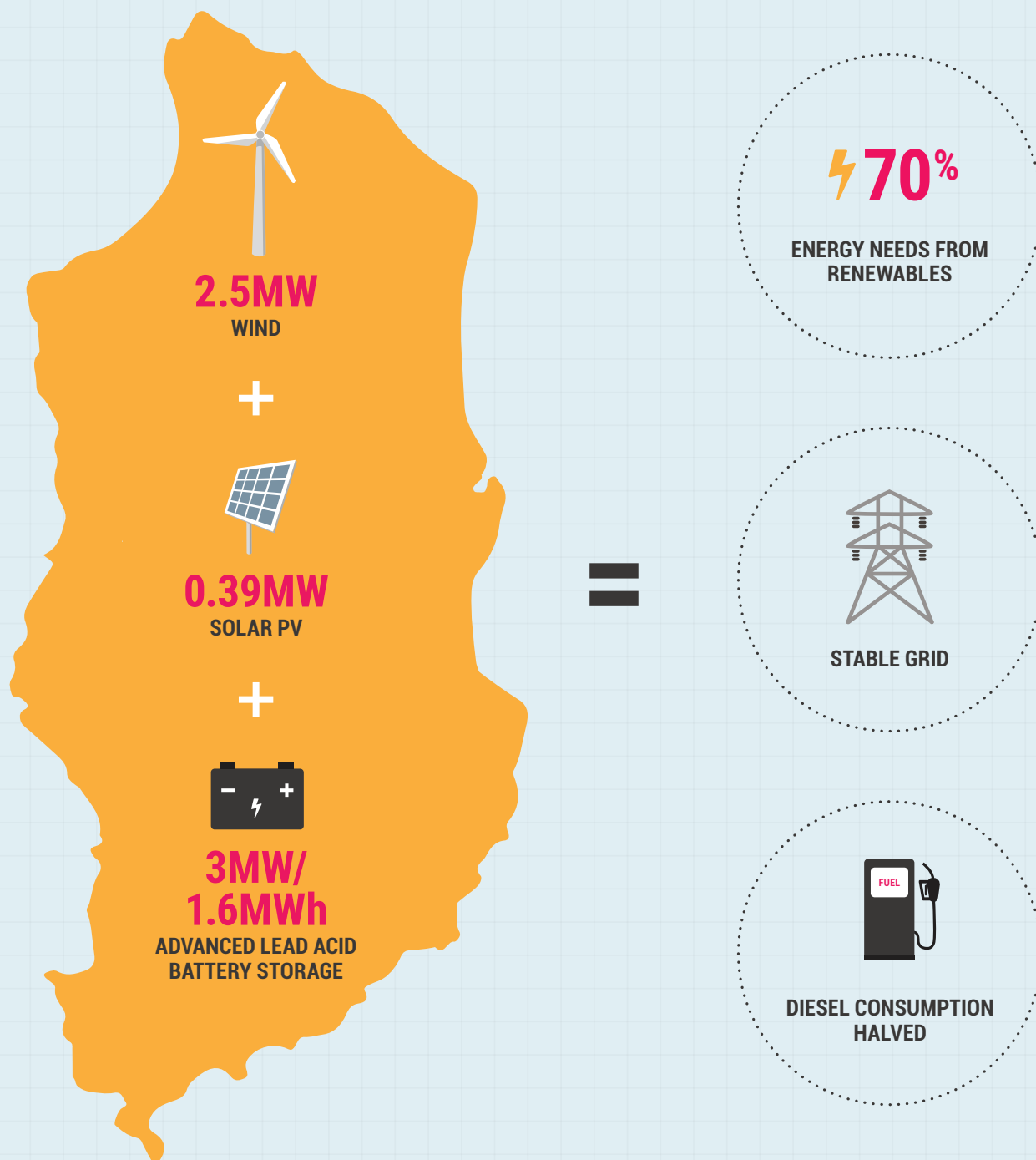


Figure 22: King Island, an off-grid community in the middle of the Bass Strait between Victoria and Tasmania's northwest coast. The island's use of renewables (wind and solar) and battery storage has enabled it to reduce its diesel consumption by as much as 50%.

Hybrid renewable energy and diesel systems are cheaper than diesel alone (AECOM 2015a). Rural groups such as the Northern Territory Cattlemen's Association have recognised the cost-saving potential of hybrid renewable-diesel systems. With the support of the Northern Territory and federal governments, the Cattlemen's Association researched specific options for large cattle stations to convert to renewable electricity. The research resulted in a handbook to assist cattle stations seeking to reduce their diesel fuel consumption through renewable electricity and energy efficiency measures (Northern Territory Cattlemen's Association 2015).

As well as regional, remote and island communities, renewable energy and battery storage also provides an economically attractive option for powering remote mines and infrastructure facilities. For example, construction is currently underway on a 10.6MW solar PV and a 6MW battery storage system for the DeGrussa copper mine in Western Australia, located 900 kilometres northeast of Perth. The solar and battery storage system supported by the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency is expected to reduce the mine's reliance on diesel, saving about 5 million litres each year (CEFC 2015; Engineers Australia 2015).

Many rural and regional communities are now working towards greater energy independence through 100% renewable energy or zero carbon goals, or community driven projects. The town of Uralla in New South Wales is one of several Australian towns now racing to be the first entirely powered by renewable energy (RenewEconomy 2015). Uralla aims to be independent of the electricity grid within ten years (Williams 2014). A feasibility study is currently underway to determine the mix of renewable energy, storage technologies

and energy efficiency measures needed to satisfy the town's energy needs. Uralla aims to provide an example of a "zero net energy town" with affordable and reliable renewable energy supply for other regional towns to follow (see Box 6 for more example of renewables in New England).

Recent polling conducted by the NSW Government (2016) found that support for renewable energy in New England had increased to 93% in 2015. Locals were more likely than the general NSW population to "strongly support" renewable energy projects like wind and solar, and had the highest awareness and self-assessed knowledge of renewables (NSW Government 2016).

The towns of Daylesford and Hepburn Springs in Victoria have developed a different kind of blueprint for renewable energy in regional Australia. The Hepburn Community Wind Park (Figure 23) is Australia's first community developed, owned and operated wind farm. The farm produces enough electricity to provide for the 2,300 households in the local community. The project began by locals educating and engaging with their community about renewable energy – 135 street stalls and seven bus tours to other sites – and eventually raised enough funds through local community subscriptions to get the project started. The Hepburn Community Wind Park's two turbines have been operating now for over three years. Embark; a non-profit organisation seeking to foster and support similar community-owned renewable energy projects was borne out of the community's experience developing their own project (ABC 2011; ACF 2012). Other successful community energy projects such as the Denmark Community Wind Farm, Western Australia and Repower Shoalhaven, New South Wales have followed in Hepburn's footsteps (Coalition for Community Energy 2015a).



Figure 23: Opening of the Hepburn Community Wind Farm.

While community developed and owned renewable energy is a relatively new phenomenon in Australia (compared to in Europe and the United States), there are currently 20 operating community energy projects, totaling over 9 MW in capacity and over 70 community energy groups in Australia (Coalition for Community Energy 2015b). Benefits of community led energy projects include:

- › A local response to increasing power prices
- › New source of funding to improve local energy infrastructure
- › Reduced greenhouse gas emissions for the local area
- › Creation of local and regional employment and education opportunities
- › Strengthened community resilience, empowerment and pride (Coalition for Community Energy 2015a).

BOX 6: NEW ENGLAND RENEWABLE ENERGY HUB

The New England region of New South Wales, located west of the Great Dividing Range, has become a focus in recent years for community initiatives and large-scale projects in renewable energy.

The area has long been identified as having significant wind, solar and bioenergy resources, which if fully developed, could create 1,700 jobs and power more than a million homes (The Climate Institute 2011; Australian Government 2014).

In 2009, the NSW Government selected New England as one of six "Renewable Energy Precincts" based on the region's wind resource and the community's strong (82%) support for wind farms (NSW Government 2009; NSW Government 2010). A key project currently under development is designed to improve grid capacity to enable more wind and solar plants to connect to the grid (NSW Government 2015). Grid constraints in the area currently limit potential new renewable generating capacity in New England to 120MW, whereas grid improvements will allow for more than 700MW of renewable capacity (TransGrid 2015).

As a result of its renewable potential, community and government support, New England has attracted a number of large-scale renewable energy projects that are at varying stages of development, construction or completion (Climate Institute 2011; Glen Innes Examiner 2016). The Moree Solar Plant has recently been completed and has begun feeding electricity into the grid, and a number of wind farm projects are expected to begin construction in 2016. This includes the 32-turbine Sapphire Wind Farm and the 119-turbine, \$400 million White Rock Wind Farm (ABC 2013). These projects will be an important source of local employment and investment; for example the White Rock Wind Farm is expected to create 200 direct jobs during construction, and 10 ongoing positions (Northern Daily Leader 2016a).

There are numerous other New England renewable energy projects in development. A smaller, lower impact form of hydro-electricity generation called "run-of-river" has been proposed for Dorrigo. The proposal is to tap into the energy-generating potential from existing water supply systems (The Coffs Coast Advocate 2015). A 20-25MW solar farm adjacent to the White Rock Wind Farm (and sharing access tracks, grid connection and some internal cabling with the wind farm) has been short-listed as a "high merit" project for potential funding from the Australian Renewable Energy Agency. If the solar farm goes ahead, the project will be the first hybrid wind and solar facility in New England (ABC 2016c; Ecogeneration 2016).

New England is also notable for its numerous local and community-led renewable energy projects.

The town of Lismore is home to an award-winning community solar project, "Farming the Sun" which has installed more than \$6.7 million dollars worth of solar panels, solar hot water, solar thermal heating and cooling to date. The organisation is now focused on developing the first ever council-operated and community-funded solar farm in Australia, the Lismore Community Solar Farm (Farming the Sun 2016).

Another local community group "New England Wind" aims to develop the first community-owned wind farm in NSW. The group has undertaken a range of activities to determine and establish local support for the project and is currently monitoring wind speeds at four potential sites in New England (New England Wind 2016).

In addition, the town of Uralla is working towards being the first town in Australia to supply all of its energy needs from renewable sources. In 2014, Uralla successfully bid (competing with four other New England towns - Walcha, Manilla, Tenterfield, and Bingara) for a \$105,000 NSW Government grant to develop a business case to become a "zero net energy" town (RenewEconomy 2014; Moreland Energy Foundation 2015). Uralla has developed a two-stage approach to achieving its ultimate goal of being supplied by 100% renewable energy:

1. Stage one involves taking immediate actions to reduce energy use, for example through upgrading lighting, appliances and domestic hot water and encouraging local renewable energy generation, such as rooftop solar panels.
2. Stage two involves exploring regional opportunities for large-scale renewable energy generation.

Uralla's businesses, such as the local Foodworks and the New England Brewing company, are jumping on board with the plan, taking up energy efficiency opportunities and investigating rooftop solar (RenewEconomy 2014; Moreland Energy Foundation 2015).

In December 2015, the Gwydir Shire Council signed a Memorandum of Understanding with the German-based Institute for Applied Material Flow Management to develop and implement a "Circular Economy Master Plan" for the shire. The "Circular Economy" concept proposes an alternative economic model to the mainstream approach of digging up resources to make products, which are later discarded to landfill. The concept involves energy self-sufficiency through renewables, designing products with longer lifespans that can be repaired, and reused, and focusing on providing services to meet needs rather than selling products (such as car share schemes) (The Conversation 2014; The Bingara Advocate 2015).

In April, 2016, the University of New England announced a proposal to build a \$6.6 million solar farm on the university's grounds in Armidale, NSW. The solar farm is expected to be completed by 2018 and will supply half of the university's energy needs (Northern Daily Leader 2016b).

6.2.3 Linking Renewable Energy with Regional Development

The best outcomes for rural development occur where renewable energy is an integrated part of the local economic development strategy; ensuring that benefits such as job creation and investment in the surrounding region are maximized (OECD 2012).

The ability of rural communities to have access to clear and reliable information and to influence key decisions about renewable energy in their towns and regions is also a critical component of successful renewable energy projects (OECD 2012). Renewable energy developments can successfully drive economic development where they are tailored to the specific needs of the local community. The OECD (2012) observed similar characteristics among renewable energy projects with strong links to rural development.

Sundrop Farms outside Port Augusta, South Australia, is an example of a renewable energy project driving local investment and job creation. Sundrop Farms is using solar thermal power (Figure 24) to heat and cool 20 hectares of greenhouses, and to produce fresh water (from desalinated sea water) for growing 15,000 tonnes of truss-tomatoes annually. Through its self-reliance on solar energy for power and desalination, Sundrop Farms saves 16,000 tonnes of carbon dioxide and over 400 million litres of freshwater annually (The Advertiser 2016).

The self-sustaining tomato farm has a 10-year contract to provide tomatoes for Coles supermarkets and already employs nearly 200 people. The company is considering expanding into capsicums and cucumbers. This innovative approach is providing critical jobs and a future industry for Port Augusta, a town in transition after the closure of two coal-fired power plants and hundreds of job losses in 2015 (The Advertiser 2015; Sundrop Farms 2016).

Figure 24: Sundrop Farms Solar Thermal.



BOX 7: RESOURCES FOR A CHANGING RURAL WORLD: A TOOLBOX

The Food Climate Research Network

The Food Climate Research Network at the Oxford Martin Programme on the Future of Food at Oxford University has a wide range of resources, tools and publications on the relationship between climate and the food system.

www.futureoffood.ox.ac.uk/project/food-climate-research-network

Climate Kelpie: rounding up tools for Australian farmers

Climate Kelpie connects Australian farmers and their advisors to tools and information about climate to assist decision-making about farm businesses.

www.climatekelpie.com.au

Climate projections for Australia (CSIRO and Bureau of Meteorology)

www.climatechangeinaustralia.gov.au

This website provides access to a wide range of tools, datasets and guidance material. These tools include:

- › **Climate analogues tool** – Helps users find analogue towns with a current climate that matches the future climate of a selected site, e.g. the user can select Dubbo, and ask what it would look like under (a) a warming of X°C and rainfall change of Y% or (b) a plausible climate change scenario for a given year and emission scenario. There are over 100 sites to choose from.
- › **Thresholds calculator** – Users can explore projected changes in the annual-average number of days above or below selected thresholds for maximum and minimum temperatures at over 100 sites.
- › **Australian Climate Futures** – A tool that tabulates projected changes in two climate variables, selected from a list of up to 16

variables. It shows the clustering and spread of projections from up to 40 climate models, for selected years and emission scenarios. This information can guide the selection of a small subset of climate models for use in impact assessment. Users can select a 'worst case' scenario, a 'best case', or a 'maximum consensus' case that is relevant to their context.

- › **Map explorer** – This tool allow users to produce a map of climate projections for individual climate models across a range of variables, time periods and emissions scenarios. Users can zoom into regions of interest and download data in different formats.

Other tools on the site include an Extremes Explorer (to view projections for cold nights, hot days and extreme rainfall) and the Marine Explorer (for sea level rise and other oceanic variables).

Further information about climate science, climate models, projections and data can be found in the Climate Campus, designed to build knowledge in key climate science areas.

Southern Livestock Adaptation:

Tools produced by Meat and Livestock Australia (MLA)

www.SLA2030.org.au

Greenhouse Gas Accounting Tools:

Listed at www.greenhouse.unimelb.edu.au/Tools

Bureau of Meteorology Climate Resilient Water Sources

Online portal allows you to view, download and contribute to data on Australia's alternative water sources including recycled water and desalinated water. It includes a national overview, a site explorer, data download facility and the ability to upload datasets.

www.bom.gov.au/water/crews/introduction.shtml

BOX 7: CONTINUED

Embark

Embark is a non-profit organization supporting community renewable energy projects through capacity-building tools and seed and investment funding.

www.embark.com.au/display/WebsiteContent/Home

State-based climate change tools:

NSW and ACT

NARcliM has produced an ensemble of robust regional climate projections for southeastern Australia that can be used by the NSW and ACT community to plan for the range of likely future changes in climate.

www.climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARcliM

Starfish Initiatives

Provides professional services to address challenges for rural and regional sustainability (e.g. community energy and regenerative farming).

<http://starfish-initiatives.org/>

Tasmania

Climate Futures for Tasmania project: This project is managed by the Antarctic Climate and Ecosystems Cooperative Research Centre provides the first fine-scale climate information for Tasmania by downscaling six global climate models with two emission scenarios (high emissions scenario – A2; and lower emissions scenario – B1) to generate climate information from 1961 to 2100.

http://www.dpac.tas.gov.au/divisions/climatechange/adapting/climate_futures

Government of Tasmania (2015): Embracing the Climate Challenge: Tasmania's draft climate change action plan 2016-2021, 41 pages, December 2015. www.dpac.tas.gov.au/divisions/climatechange/what_the_government_is_doing/tasmanias_climate_change_action_plan

Western Australia

The Western Australian Local Government Association has developed a toolkit to help local governments adapt to climate change.

www.walgaclimatechange.com.au

Victoria

The climate change adaptation navigator is a web-based tool to assist the local Victorian government with climate change adaptation and planning.

<http://adaptation-navigator.org.au>

Queensland

Climate projections are available at <https://www.longpaddock.qld.gov.au/climateprojections/index.html>. Users must register on-line to receive the data.

Climatedogs:

Explanations using animations of the drivers that influence Victoria's climate

www.depi.vic.gov.au/agriculture-and-food/farm-management/weather-and-climate/understanding-weather-and-climate/the-climatedogs-the-four-drivers-that-influence-victoriaas-climate

7. | THIS IS THE CRITICAL DECADE



7. This is the Critical Decade

The climate is warming, and many other changes to the global climate system – patterns of precipitation, sea-level rise, melting ice, acidification of the ocean – are also occurring. It is beyond reasonable doubt that the emission of greenhouse gases by human activities, mainly carbon dioxide from the combustion of fossil fuels, is the primary cause for the changes in climate over the past half-century.

The impacts of climate change can already be observed. Sea levels are rising, heatwaves have become longer and hotter. High bushfire danger weather has increased in southeast Australia. Heavy rainfall events are increasing, while the southeast and southwest corners of the continent have become drier.

In December 2015 in Paris, the 195 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed to hold the increase in global average temperatures to *“well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C”*. Further, the Parties agreed to *“aim to reach global peaking of greenhouse gas emissions as soon as possible....and to undertake rapid reductions thereafter in accordance with the best available science....”*.

Despite these fine aspirations, the collective emissions reduction pledges by the nations who met in Paris (known as Intended National Determined Contributions, INDCs), even if fully implemented, are nonetheless likely to lead to a world that is 2.7-3°C warmer than in pre-industrial times (UNFCCC 2015; Climate Council 2015). This means that despite the Paris Agreement being hailed as a landmark, significant climate risks must be anticipated and there is no room for complacency.

There are some promising signs that the first steps are being taken towards decarbonising the global economy. Renewable energy technologies are being installed at increasing rates in many nations and some of the world’s biggest emitters are beginning to take meaningful actions to limit and reduce emissions (for further information please see the Climate Council’s report *The Global Renewable Energy Boom: How Australia is missing out*). However, the rapid consumption of the carbon budget, not to mention the discovery of many new fossil fuel reserves, highlights the enormity of the task. Much more needs to be done to reduce emissions... and quickly.

The trend of increasing global emissions must be slowed and halted in the next few years and emissions must be trending downwards by 2020 at the latest. Investments in and installations of renewable energy must therefore increase rapidly. And, critically, most of the known fossil fuel reserves must remain in the ground.

Australian rural communities are on the frontline of climate change impacts. Many of these communities already face significant social and economic disadvantage, with poorer infrastructure, and poorer access to health, education and other social services. Climate change has the potential to greatly exacerbate these challenges, especially in those regions facing high exposure to extreme heat, and water scarcity, both directly, and indirectly via negative impacts on agricultural production.

Australian farmers and rural communities have demonstrated great resilience in the face of harsh physical and social challenges. Many individuals, business and communities are already demonstrating adaptation to the climatic change experienced so far, and many are planning for further change. But progressive, small-scale adaptive steps may become increasingly inadequate, warranting expensive and disruptive transformational change in coming decades. Further, if the present rate of climate change is maintained, there will be some challenges to which adaptation is simply not possible.

Transitioning urgently to a new, low carbon economy is critical. The new economy presents enormous opportunities, with new income streams and real prospects for energy self-sufficiency. Some rural communities in Australia are already leading the way. Consumers and the public will increasingly expect farmers to provide low carbon products.

This is the critical decade to get on with the job of responding proactively to climate change.

Appendix A

BOX 8: BASIS OF CLIMATE PROJECTIONS FOR AUSTRALIA

Projected changes to Australia's climate (Table 1) are based on a synthesis of (i) understanding of the climate system and how it operates, (ii) observed trends in important climate indicators such as temperature and rainfall, and (iii) quantitative projections from simulations of the climate system by a suite of global climate models that have contributed to the IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report (IPCC 2013). These projections have been explored in detail for Australia in a recent CSIRO and BoM (2015) study, and unless otherwise stated are used as the main source in this report.

The model simulations are driven by several assumptions about the trajectory of human greenhouse gas emissions through the rest of this century, ranging from a scenario of rapid and deep emission reductions (called "RCP2.6" by the IPCC; in essence, a strong mitigation pathway) to a business-as-usual scenario of increasingly high annual emissions through the century (RCP8.5), with an intermediate scenario (RCP4.5) (referred to in the rest of the report as "low", "high" and "medium" emission scenarios respectively). The difference in projected climate changes among these emissions scenarios is relatively small for the next couple of decades, but becomes quite large by the end of the 21st century.

The baseline for the projections is usually taken as the average climate of 1986-2005, so the projections must be added on to the average climate of that period. Significant changes to the climate had already occurred by the 1986-2005 period, so these observed changes must be added to the projections if the projections are to be evaluated against a pre-industrial baseline.

Appendix B: Glossary of Adaptation-related Terms

Adaptation

Adjustment in natural or human systems, in response to existing or expected climate change and its effects, which limits harm or exploits beneficial opportunities (IPCC 2007).

- › Generic adaptation
Adaptation actions which aim to enhance the general capacity of a group or individual to respond to any impact, building their 'generic resilience' (Walker and Salt 2006).
- › Specific Adaptation
Adaptation actions which target specific climate change impacts.
- › Incremental (small-scale) adaptation
Adaptation as small adjustments to an existing system, such as adjusting practices or technologies, which allow the same system to continue (Rickards and Howden 2012).
- › Transformational adaptation
Adaptation as substantial, system-wide, changes from existing practices. It often requires the development of new skills, understanding of new markets, and generation of new infrastructure (Rickards and Howden 2012; Hertzler et al. 2013).

For example: Range of adaptation responses to climate change by crop-livestock farmer in Australia, encompassing incremental small changes to large and transformational changes (Robertson and Murray-Prior 2016)

Adaptive capacity

The ability of a system to adjust to climate change in order to limit potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2007).

Capacity-building

Increasing the ability of individuals, groups, or organisations to adapt to climate change – for example, by increasing their skills, knowledge or access to resources (Adger et al. 2005).

Maladaptation

Maldaptation is adaptation action that doesn't achieve its intended goal, that increases vulnerability, or that generates significant problems.

Scenario planning

Scenario planning is the anticipation and analysis of different situations that may emerge and how to plan for them (Rickards et al. 2014).

Social capital

Social networks and relationships which facilitate co-operation between or within groups (OECD 2001).

Sustainable Development

Development that meets the cultural, social, political and economic needs of the present generation without compromising the ability of future generations to meet their own needs (IPCC 2007).

References

- ABC (2007) Wind farm funds may not return to community. Accessed at <http://www.abc.net.au/news/2007-06-20/wind-farm-funds-may-not-return-to-community/75134>.
- ABC (2011) Community-owned wind powers up. Accessed at <http://www.abc.net.au/environment/articles/2011/08/02/3263656.htm>.
- ABC (2013) Sapphire Wind Farm manager says inaugural CCC to sit within weeks. Accessed at <http://www.abc.net.au/news/2013-07-19/4832416?site=newengland>.
- ABC (2014) Calls for rating for solar and wind developments. Accessed at <http://www.abc.net.au/news/2014-07-18/calls-for-rating-for-solar-and-wind-developments/5606218>.
- ABC (2015) Farmers use wind farm rent to pay on-farm costs. Accessed at <http://www.abc.net.au/news/2015-04-23/farmers-use-wind-farm-rent-to-pay-on-farm-costs/6415126>.
- ABC (2016a) CSIRO scientist says Tasmania's warm summer gives glimpse to climate future. *The World Today*, 20 April 2016. Accessed at <http://www.abc.net.au/worldtoday/content/2016/s4446749.htm>.
- ABC (2016b) Vote Compass: Australians back carbon pricing, want more action on climate change. Accessed at <http://www.abc.net.au/news/2016-06-03/vote-compass-climate-change-carbon-price/7467242>.
- ABC (2016c) Funding possible for potential Glen Innes solar farm. Accessed at <http://www.abc.net.au/news/2016-01-14/funding-possible-for-potential-glen-innes-solar-farm/7087976>.
- ABC Rural (2015) Climate change blamed for Australia's increased frost risk for cereal crops. Jodie Gunders, 21 August 2015. Accessed at <http://www.abc.net.au/news/2015-08-21/qch-frost-field-trial/6715106>.
- ABS (2009) (Australian Bureau of Statistics) 7111.0 - Principal Agricultural Commodities, Australia, Preliminary, 2007-08.
- ABS (2012a) (Australian Bureau of Statistics) Australian farming and farmers. Accessed at <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features10Dec+2012>.
- ABS (2012b) (Australian Bureau of Statistics) 1301.0 - Year Book Australia, 2012. Accessed at <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Home%20page~1>.
- ABS (2014) (Australian Bureau of Statistics) Land management and farming in Australia, 2012-2013. Accessed at <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4627.0>.
- ACCIONA Australia (2015) Community benefits. Accessed at <http://www.acciona.com.au/community/community-benefits>.
- ACF (Australian Conservation Foundation) (2012) Hepburn Wind's renewable ambition. Accessed at <http://www.acfonline.org.au/news-media/news-features/hepburn-winds-renewable-ambition>.
- Adger WN and K Vincent (2005). "Uncertainty in adaptive capacity." *Comptes Rendus Geoscience* 337(4): 399-410.
- Adger W, Arnell N and Tompkin E (2005) Successful adaptation to climate change across scales. *Global Environmental Change*. 15: 77-86.
- AECOM (2015a) Australia's off-grid clean energy market research paper. Accessed at http://arena.gov.au/files/2014/12/ARENA_RAR-report-20141201.pdf.
- AECOM (2015b) Energy Storage Study. Funding and knowledge sharing priorities. Prepared for ARENA. Accessed at <http://arena.gov.au/files/2015/07/AECOMEnergy-Storage-Study.pdf>.
- AEM (Australian Emergency Management Knowledge Hub) (2011a) Cyclone Larry, North Queensland 2006. Australian Government. Accessed at <https://www.emknowledge.gov.au/resource/?id=448>.
- AEM (Australian Emergency Management Knowledge Hub) (2011b). Cyclone Yasi Queensland 2011. Australian Government. Accessed at <https://www.emknowledge.gov.au/resource/?id=503>.
- AEM (Australian Emergency Management Knowledge Hub) (2011c) Flood Victoria 2011. Australian Government. Accessed at <https://www.emknowledge.gov.au/resource/?id=507>.
- AEM (2013) Cyclone Oswald Qld and NSW. Australian Government. Accessed at <https://www.emknowledge.gov.au/resource/?id=3487>.
- AGL (2014) AGL gives \$28,000 to Nyngan community. Accessed at <http://www.agl.com.au/about-agl/media-centre/article-list/2014/august/agl-gives-28000-dollars-to-nyngan-community>.
- AIHW (Australian Institute of Health and Welfare) (2010) Australia's Health 2010. Canberra: 2010. AIHW cat. no. AUS 12. Accessed at <http://www.aihw.gov.au/publications/index.cfm/title/11374>.
- Albrecht G, Sartore G.-M, Connor L, et al. (2007). Solastalgia: the distress caused by environmental change. *Australasian Psychiatry* 15(sup1): S95-S98.
- Alston M (2012) Rural male suicide in Australia. *Social Science & Medicine* 74: 515e522.
- Alston M (2013) Women and adaptation. *WIREs Climate Change* 4, pp. 351-358.
- Alston M and Kent J (2004) Social Impacts of Drought: Report to NSW Agriculture. Wagga Wagga: Centre for Rural Social Research, Charles Sturt University.

- Alston M and Whittenbury K (2011) Climate change and water policy in Australia's irrigation areas: a lost opportunity for a partnership model of governance. *Environmental Politics* 20: 899-917.
- Anwar, M.R., Liu, D.L., Macadam, I. et al. Theor Appl Climatol (2013) 113: 225. doi:10.1007/s00704-012-0780-1.
- Anwar M R, Liu D L, Farquharson R, Macadam I, Abadi A, Finlayson J, Wang B, Ramilan T (2015) Climate change impacts on phenology and yields of five broadacre crops at flour climatologically distinct locations in Australia, *Agricultural Systems* 132, pp. 133-144.
- AON Benfield (2014) 204 Catastrophe Recap. Impact Forecasting. Accessed at http://thoughtleadership.aonbenfield.com/Documents/20140507_if_april_global_recap.pdf.
- Applebaum K M, Graham J, Gray G M, LaPuma P, McCormick S A, Northcross A, Perry M J (2016) An Overview of Occupational Risks from Climate Change, *Current Environmental Health Reports* 3, pp. 13-22.
- ARENA (2015) (Australian Renewable Energy Agency) Bioenergy. Accessed at <http://arena.gov.au/about-renewable-energy/bioenergy/>.
- Argent N and Walmsley J (2008) Rural youth migration trends in Australia: an overview of recent trends and two inland case studies. *Geographical Research* 46: 14.
- Askew LE and Sherval M (2012) Short-term emergency or recurring climatic extreme: a rural town perspective on drought policy and programs. *Australian Journal of Public Administration* 71: 290-302.
- Asseng, S. and Pannell, D. (2012) Adapting dryland agriculture to climate change: Farming implications and research and development needs in Western Australia. Climatic Change DOI 10.1007/s10584-012-0623-1.
- Australian Government (2014) Australian Energy Resource Assessment. Second Edition. Accessed at https://d28rz98at9flks.cloudfront.net/79675/79675_AERA.pdf.
- Australian Government (2015) Natural disasters in Australia. Accessed at <http://www.australia.gov.au/about-australia/australian-story/natural-disasters>.
- Australian Productivity Commission (2009) Government Drought Support Inquiry Report. Accessed at <http://www.pc.gov.au/inquiries/completed/drought/report/drought-support.pdf>.
- Barlow S, Grace P, Stone R, et al. (2011) National Climate Change Adaptation Research Plan for Primary Industries, National Climate Change Adaptation Research Facility, Gold Coast, 64pp.
- Barr N (2014) New entrants to Australian agricultural industries: Where are the young farmers? *Rural Industries Research and Development Corporation Report* Accessed at <https://rirdc.infoservices.com.au/items/14-003>.
- Barnett J and O'Neill S. (2010) Maladaptation. *Global Environmental Change-Human and Policy Dimensions* 20(2): 211-213.
- Barnett, J., et al. (2015). "From barriers to limits to climate change adaptation: path dependency and the speed of change." *Ecology and Society* 20(3): 5.
- Beard JR, Tomaska N, Earnest A et al. (2009) Influence of socioeconomic and cultural factors on rural health. *Australian Journal of Rural Health* 17: 10-15.
- Beebe NW, Cooper RD, Mottram P, Sweeney AW (2009) Australia's dengue risk driven by human adaptation to climate change PLoS Neglected Tropical Diseases. 3(5): e429.)
- Beer A (2012) The economic geography of Australia and its analysis: from industrial to post-industrial regions. *Geographical Research* 50: 269-281.
- Beer A, Tually S, Kroehn M et al. (2013) Australia's country towns 2050: What will a climate adapted settlement pattern look like? National Climate Change Adaptation Research Facility, Gold Coast, 139 pp.
- Beer A, Tually S, Kroehn M et al. (2014) Climate change and the future of Australia's country towns. Pp 332-341 in *Applied Studies in Climate Adaptation* (Palutikoff JP, Boulter SL, Barnett J and Rissik D eds.) John Wiley & Sons.
- Bi P and Parton KA (2008) Effect of climate change on Australian rural and remote regions: What do we know and what do we need to know? *Australian Journal of Rural Health* 16: 2-4.
- Bioenergy Australia (2015) Bioenergy – How it Works? Accessed at <http://www.bioenergyaustralia.org/pages/bioenergy-how-it-works.html>.
- Blashki G, Armstrong G, Berry H, Weaver HJ, Hanna EG, Bi P, et al. (2010) Implications of Climate Change for Health Services in Australia. State of the Science and Policy. Discussion Paper no. 3. Canberra.
- BOM (2013) Special Climate Statement 43 – Extreme heat in January 2013. www.bom.gov.au/climate/current/statements/scs43e.pdf.
- BOM (2014) (Bureau of Meteorology) State of the climate. Accessed at <http://www.bom.gov.au/state-of-the-climate/>.
- BoM (2015) Climate Summaries Archive, Accessed at http://www.bom.gov.au/climate/current/statement_archives.shtml?region=aus&period=month.
- Boxall A, Hardy A, Beulke S et al. (2009) Impacts of climate change on indirect human exposure to pathogens and chemicals from agriculture. *Environmental Health Perspectives* 117: 508-514.
- Brunby S, Chandrasekara A, McCoombe S et al. (2011a) Reducing psychological distress and obesity in Australian farmers by promoting physical activity. *BMC Public Health* 11: 362.
- Brunby S A, Kennedy A J, Mellor D, McCabe M P, Ricciardelli L A, Head A, Mercer-Grant C (2011b) The Alcohol Intervention Training Program (AITP): A response to alcohol misuse in the farming community, *BMC Public Health* 11: 1-6.
- Bryan B A, Hajkowicz S, Marvanek S, Young M D (2009) Mapping Environmental Economic Returns to Agriculture for Informing Environmental Policy in the Murray-Darling Basin, Australia, *Environmental Modeling & Assessment* 14, pp. 375-390.

- Buys L, Miller E, and van Megen K (2012) Conceptualising climate change in rural Australia: community perceptions, attitudes and (in)actions. *Regional Environmental Change* 12: 237–248.
- BZE (2014) (Beyond Zero Emissions) Zero Carbon Australia Land Use: Agriculture and Forestry Discussion Paper. Beyond Zero Emissions Melbourne Sustainable Society Institute, The University of Melbourne pp 184.
- Cai W and Cowen T (2008) Dynamics of late autumn rainfall reduction over southeastern Australia. *Geophysical Research Letters* 35: L09708.
- Canegrowers Australia (2011) Snapped, flattened, flooded Cyclone Yasi unleashes wrath on sugar. Australian Canegrower. Accessed at http://www.canegrowers.com.au/icms_docs/98672_australian_canegrower_2011-02-21.pdf.
- Canegrowers Australia (2014) Steamrolled: Sugarcane down but not out. Australian Canegrower. Accessed at http://www.canegrowers.com.au/page/Industry_Centre/Media_Centre/Media_Releases/Steamrolled_by_Ita_Sugarcane_down_but_not_out/.
- Carpenter G (2007) Australian East Coast Storm 2007: Impact of East Coast Lows.
- CEFC (Clean Energy Finance Corporation) (2015) CEFC finances major solar storage project at remote mine. Accessed at <http://www.cleanenergyfinancecorp.com.au/media/releases-and-announcements/files/cefc-finance-major-solar-storage-project-at-remote-mine.aspx>.
- CFA (Country Fire Authority) (2012). Major fires. Accessed at <http://www.cfa.vic.gov.au/about/major-fires>.
- Chan K Y (2011) Climate Change on Soil Structure and Soil Health: Impacts and Adaptation in Singh B P, Cowie A L and Chan K Y's (eds.), *Soil Health and Climate Change*, Springer Berlin Heidelberg, pp. 49–67.
- Chapman S (2013) The Conversation. 18th September, 2013 Accessed at <http://theconversation.com/wind-turbinesyndromefarm-hosts-tell-verydifferent-story-18241>.
- Chum H, Faaij A, Moreira J et al. (2011) Bioenergy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [Edenhofer O, Pichs-Madruga R, Sokona Y et al. (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Claessens L, Antle JM, Stoorvogel JJ, et al. (2012) A method for evaluating climate change adaptation strategies for small-scale farmers using survey, experimental and modeled data. *Agricultural Systems* 111(0): 85–95.
- Clarke H, Lucas C, Smith P (2013) Changes in Australian fire weather between 1973 and 2010. *International Journal of Climatology* 33: 931–944.
- Clean Energy Council (2014) Clean Energy Australia 2013. Accessed at <http://www.cleanenergycouncil.org.au/policy-advocacy/reports/clean-energy-australia-report.html>.
- Clean Energy Council (2015a) Clean Energy Australia Report 2014. Accessed at <https://www.cleanenergycouncil.org.au/policy-advocacy/reports/clean-energy-australia-report.html>.
- Clean Energy Council (2015b) Bioenergy. Accessed at <http://www.cleanenergycouncil.org.au/technologies/bioenergy.html>.
- Clean Energy Council (2016) Wind Energy. Accessed at <https://www.cleanenergycouncil.org.au/technologies/wind-energy.html>.
- Climate Council (2014) Heatwaves: Hotter, Longer and More Often. Hughes L and Steffen W. Accessed at <http://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf>.
- Climate Council (2015) A Whole New World: Tracking the renewables boom from Copenhagen to Paris. Andrew Stock, Petra Stock and Martin Rice. Accessed at <http://www.climatecouncil.org.au/wholenewworldreport2015>.
- Climate Council (2016a) The Heat Marches On. Will Steffen and Jacqui Fenwick. Accessed at <http://www.climatecouncil.org.au/marchheatreport>.
- Climate Council (2016b) The Silent Killer: Climate Change and the Health Impacts of Extreme Heat. Lesley Hughes, Elizabeth Hanna and Jacqui Fenwick. Accessed at <http://www.climatecouncil.org.au/silentkillerreport>.
- Climate Council (2016) The Silent Killer: Climate Change and the Health Impacts of Extreme Heat. Lesley Hughes, Elizabeth Hanna and Jacqui Fenwick. Accessed at <http://www.climatecouncil.org.au/silentkillerreport>.
- Coalition for Community Energy (2015a) National Community Energy Strategy. Accessed at <http://c4ce.net.au/nces/home-v9-videos-and-parallax/downloads/>.
- Coalition for Community Energy (2015b) National Community Energy Strategy. Accessed at <http://c4ce.net.au/category/news/general/>.
- Connor LH and Higginbotham N (2014) “Natural cycles” in lay understandings of climate change. *Global Environmental Change* 23: 1852–1861.
- Cosgrave C, Hussain R and Maple M (2015). Retention challenge facing Australia's rural community mental health services: Service managers' perspectives. *Australian Journal of Rural Health* 23(5):272–6.
- CSIRO (2012) Climate and water availability in south-eastern Australia – A synthesis of findings from Phase 2 of the South Eastern Australian Climate Initiative (SEACI), CSIRO, September.
- CSIRO and BoM (2015) Climate change in Australia: projections for Australia's NRM regions. Australia Government. Accessed at http://climatechangeinaustralia.gov.au/media/ccia/2.1.4/cms_page_media/168/CCIA_PROJECTIONS_TECHNICAL_REPORT.pdf.
- Dean JG and Stain HJ (2012) Mental health impact for adolescents living with prolonged drought. *Australian Journal of Rural Health* 18: 32–37.
- Department of Environment (2016) Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2015. Accessed at <https://www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/quarterly-update-australias-national-greenhouse-gas-inventory-dec-2015>.

- Dow K, Berkhout F, Preston BL, et al. (2014) Limits to adaptation. *Nature Clim. Change* 3(4): 305-307.
- Eckard RJ, Grainger C, de Klein CAM (2010) Options for the abatement of methane and nitrous oxide from ruminant production: A review. *Livestock Science* 130: 47-56.
- Ecogeneration (2016) Shortlisted 20 MW White Rock Solar Farm a ground-breaking hybrid project. Accessed at http://ecogeneration.com.au/news/shortlisted_20_mw_white_rock_solar_farm_a_ground-breaking_hybrid_project/100970.
- Edwards B, Gray M, Hunter B (2009) The impact of drought on mental health and alcohol use, *Australian Social Policy Conference: An inclusive society? Practicalities and Possibilities*, Sydney, Australia.
- Eldridge D J, Greene R S B, Dean C (2011) Climate Change Impacts on Soil Processes in Rangelands in B P Singh, A L Cowie and Y K Chan's *Soil Health and Climate Change*, Springer Berlin Heidelberg, pp. 237-255.
- Energy and Earth Resources (2015) Turning piggery waste into electricity. Accessed at <http://www.energyandresources.vic.gov.au/energy/sustainable-energy/bioenergy/turning-piggery-waste-into-electricity>.
- Engineers Australia (2015) Miner turns to off-grid solar. Accessed at <https://www.engineersaustralia.org.au/portal/news/miner-turns-grid-solar>.
- Epuron (2014a) Minutes of meeting Rye Park Wind Farm community consultation committee http://www.epuron.com.au/wp-content/uploads/2014/05/dt_intfc4ef928e173cce_5369b1408cd7a.pdf?RYP_CCC%20Meeting%20No%207%20Minutes_30%20April%202014.pdf.
- Epuron (2014b) Landowners. Accessed at <http://www.epuron.com.au/community/landowners/>.
- Farine DR, O'Connell DA, Raison RJ et al. (2012) An assessment of biomass for bioelectricity and biofuel, and for greenhouse gas emission reduction in Australia. *Global Change Biology: Bioenergy* 4: 148-175.
- Farming the Sun (2016) Farming the Sun. Accessed at <http://farmingthesun.net/>.
- Finlay KJ, Yen AL, Aurambout JP et al. (2009) Consequences for Australian biodiversity with establishment of the asiatic citrus psyllid, *Diaphorina citri*, under present and future climates. *Biodiversity* 10: 25-32.
- Finn D, Dalal R, Klieve A (2015) Methane in Australian agriculture: current emissions, sources and sinks, and potential mitigation strategies. *Crop and Pasture Science* 66: 1-22.
- Fleming A, Dowd A-M, Gaillard E, et al. (2015) "Climate change is the least of my worries": stress limitations on adaptive capacity. *Rural Society* 24(1): 24-41.
- Fleming A, Park SE and Marshall NA. (2015a) Enhancing adaptation outcomes for transformation: climate change in the Australian wine industry. *Journal of Wine Research* 26(2): 99-114.
- Fleming A, Rickards L and Dowd AM. (2015b) Understanding convergence and divergence in the framing of climate change responses: An analysis of two wine companies. *Environmental Science & Policy* 51: 202-214.
- Fragar L, Inder KJ, Kelly BJ et al. (2013) Unintentional Injury, psychological distress and depressive symptoms: is there an association for rural Australians? *The Journal of Rural Health* 29: 12-19.
- Friel S, Berry H, Dinh H, O'Brien L, Walls H L (2014) The impact of drought on the association between food security and mental health in a nationally representative Australian sample, *BMC Public Health* 14, pp. 1102-1113.
- Gallagher R V, Duursma D E, O'Donnell J, Wilson P D, Downey P O, Hughes L, Leishman M R (2013) The grass may not always be greener: projected reductions in climatic suitability for exotic grasses under future climates in Australia, *Biological Invasions* 14:5, pp. 961-975.
- Gallant AJE, Reeder MJ, Risbey JS and. Hennessy KJ (2013) The characteristics of seasonal-scale droughts in Australia, 1911-2009. *International Journal of Climatology* 33: 1658-1672.
- Garnaut R (2008) The Garnaut climate change review. Cambridge University Press: Melbourne. Accessed at: www.garnautreview.org.au.
- Garnaut R (2011a) Transforming rural land use. Update Paper 4. Garnaut Climate Change Review Update 2011, Canberra, ACT.
- Garnaut R (2011b) Transforming rural land use. Update 5 of the 2008 Garnaut Report, Canberra, ACT.
- Gell P and Reid M (2014) Assessing change in floodplain wetland condition in the Murray Darling Basin, Australia, *Anthropocene* 8, pp. 39-45.
- Geohive 2016, *Urban/rural division of countries for the years 2015 and 2025*. Accessed at http://www.geohive.com/earth/pop_urban.aspx.
- Geoscience Australia (2015) Bioenergy. Accessed at <http://www.ga.gov.au/scientific-topics/energy/resources/other-renewable-energy-resources/bioenergy#heading-2>.
- Geoscience Australia and BREE (2014) Australian Energy Resource Assessment. 2nd Ed. Geoscience Australia, Canberra. Accessed at <http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/GA21797.pdf>.
- Glen Innes Examiner (2016) Comment sought on solar farm plan. Accessed at <http://www.gleninnesexaminer.com.au/story/3830771/comment-sought-on-solar-farm-plan/>.
- Glick DJ (2006) Banana Farms in the Innisfail Region: eight months after Cyclone Larry, dynamics of farm-level recovery. Centre for Disaster Studies: James Cook University. Accessed at http://www.jcu.edu.au/cds/public/groups/everyone/documents/technical_report/jcutst_056205.pdf.
- Guthrie R, Westaway J, Goldacre L (2009) Workers compensation and occupational health and safety in the Australian agricultural industry. *Australian Journal of Rural Health* 17: 77-85.
- Green D, King U, Morrison J (2009) Disproportionate burdens: the multidimensional impacts of climate change on the health of Indigenous Australians. *Medical Journal of Australia* 190: 4-5.

- Green D, Bambrick H, Tait P, Goldie J, Schultz R, Webb L, et al. (2015) Differential Effects of Temperature Extremes on Hospital Admission Rates for Respiratory Disease between Indigenous and Non-Indigenous Australians in the Northern Territory. *International Journal of Environmental Research and Public Health* 12:14988.
- Hanna EG. (2005) Environmental health and primary health care: Towards a new workforce model. [PhD by Research Thesis]. Melbourne: La Trobe University.
- Hanna EG, Bell E, King D and Woodruff R (2011) Climate change and Australian agriculture: a review of the threats facing rural communities and the healthy policy landscape. *Asia Pacific Journal of Public Health* 105S-18.
- Hanigan IC, Butler CD, Kokic PN and Hutchinson MF (2012) Suicide and drought in New South Wales, Australia, 1970–2007. *Proceedings of the Royal Academy of Sciences* 35: 13950–13955.
- Hanslow KD, Gunasekera BR, Cullen B, and Newth D (2013) Economic impacts of climate change on the Australian dairy sector. *Australian Journal of Agricultural and Resource Economics* 58: 60–77.
- Harle KJ, Howden SM, Hunt and Dunlop M (2007) The potential impact of climate change on the Australian wool industry by 2030. *Agricultural Systems* 93: 61–89.
- Harley D, Bi P, Hall G et al. (2011) Climate change and infectious diseases in Australia: future prospects, adaptation options, and research priorities. *Asia-Pacific Journal of Public Health* 23: 54S–66S.
- Harman B, Cunningham R, Jacobs B, et al. (2015) Engaging local communities in climate adaptation: a social network perspective from Bega Valley. Canberra, Australia: CSIRO.
- Hayman, P. (2011). "Seasonal Climate Forecasts: Can Decision Analysis Help Agriculture?" *Issues* (December): 19–24.
- Hayman P, Rickards L, Eckard R, and Lemerle D (2012) Climate change through the farming systems lens: challenges and opportunities for farming in Australia. *Crop and Pasture Science* 63: 203–214.
- Heimann M and Reichstein M (2008) Terrestrial ecosystem carbon dynamics and climate feedbacks. *Nature* 451: 289–292.
- Hennessy K, Fawcett R, Kirono D, et al. (2008) An assessment of the impact of climate change on the nature and frequency of exceptional climatic events. CSIRO and BoM. Accessed at <http://www.oisaweb.es/documents/10148/30643/Impact+of+climate+change+on+the+nature+of+exceptional+climatic+events.pdf>.
- Henry B, Charmley E, Eckard R et al. (2012) Livestock production in a changing climate: adaptation and mitigation research in Australia. *Crop and Pasture Science* 63: 191–202.
- Herr A and Dunlop M (2011) Bioenergy in Australia: an improved approach for estimating spatial availability of biomass resources in the agricultural production zones. *Biomass and Bioenergy* 35: 2298–2305.
- Hertzler G, Sanderson T, Capon T et al. (2013) Will primary producers continue to adjust practices and technologies, change production systems or transform their industry? An application of real options, National Climate Change Adaptation Research Facility, Gold Coast, 93 pp.
- Hobday A, Oliver E, McDonald J and Grose M (2016) Was Tasmania's summer of fires and floods a glimpse of its climate future? The Conversation, 19 April 2016. Accessed at <http://theconversation.com/was-tasmanias-summer-of-fires-and-floods-a-glimpse-of-its-climate-future-58055>.
- Hochman Z, van Rees H, Carberry PS, et al. (2009) Re-inventing model-based decision support with Australian dryland farmers 4. Yield Prophet helps farmers monitor and manage crops in a variable climate. *Crop & Pasture Science* 60: 1057–1070.
- Hogan A and Young M (2013) Visioning a future for rural and regional Australia. *Cambridge Journal of Regions, Economy and Society* 6: 319–330.
- Horton G, Hanna L and Kelly B (2010) Drought, drying and climate change: Emerging health issues for ageing Australians in rural areas. *Australasian Journal on Ageing* 29: 2–7.
- Howden SM, Crimp S and Nelson R (2010) Australian agriculture in a climate of change. In *Managing Climate Change. Papers from the Greenhouse 2009 Conference*. (Eds I Jubb, P Holper and W Cai) pp. 101–112. CSIRO, Melbourne.
- Howden SM, Schroeter S and Crimp S (2014) Agriculture in an even more sunburnt country. In *Four Degrees of Global Warming: Australia in a hot world*. (Ed P Christoff). Earthscan, Routledge, Oxford and New York. Pages 101–120.
- Hunt W, Birch C, Vanclay F, Coutts J (2014) Recommendations arising from an analysis of change to the Australian agricultural research, development and extension system, *Food Policy* 44, pp. 129–141.
- Hunter B and Biddle N (2011) Migration, labour demand, housing markets and the drought in regional Australia. Australian Institute of Family Studies. *Australian Policy Online* 28 September 2011. Accessed at <http://apo.org.au/research/migration-labour-demand-housing-markets-and-drought-regional-australia>.
- Hydro Tasmania (2015) King Island Renewable Energy Integration Project. Accessed at <http://www.kingislandrenewableenergy.com.au/>.
- ICA (Insurance Council of Australia) (2015) Historical Disaster Statistics. Accessed at <http://www.insurancecouncil.com.au/industry-statistics-data/disasterstatistics/historical-disaster-statistics>.
- IEA (International Energy Agency) (2010) Energy technology perspectives. Scenarios & strategies to 2050. Executive summary. Paris: OECD/IEA; p. 16.
- IEA Bioenergy (2014) Strategic Plan 2015–2020. Accessed at http://www.bioenergyaustralia.org/data/IEA_Bioenergy_Strategic_Plan_2015-2020_-_Brochure.pdf.

- Inderberg TH and Eikeland PO. (2009) Limits to adaptation: analysing institutional constraints. In: Adger W, Lorenzoni I and O'Brien K (eds) *Adapting to Climate: Thresholds, Values and Governance*. Cambridge: Cambridge University Press, 433–447.
- IPCC (Intergovernmental Panel on Climate Change) (2007). *Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability*. Fourth Assessment Report.
- IPCC (2013) *Climate Change 2013: The Physical Science Basis*. Working Group I Contribution to the IPCC 5th Assessment Report—Changes to the underlying Scientific/ Technical Assessment. <http://www.ipcc.ch/report/ar5/wg1/>.
- IPCC (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field C, Barros V, Mach K, Mastrandrea M (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 485–533.
- IPSOS (2015) *Climate change report 2015*. Accessed at http://ipsos.com.au/Ipsos_docs/CC2015/Ipsos_Climate_Change_Report_2015.pdf.
- IRENA (2011) *IRENA Working Paper: Renewable Energy Jobs: Status, Prospects & Policies*. Accessed at <http://www.irena.org/documentdownloads/publications/renewableenergyjobs.pdf>.
- Jiang Q, Grafton R Q (2012) Economic effects of climate change in the Murray-Darling Basin, Australia, *Agricultural Systems* 110, pp. 10–16.
- Kamruzzaman M, Hine J and Yigitcanlar T (2015) Investigating the link between carbon dioxide emissions and transport-related social exclusion in rural Northern Ireland. *International Journal of Environmental Science and Technology*: 12(11):3463–78.
- Karoly D and Black M (2015) It's been Australia's hottest ever October, and that's no coincidence, *The Conversation*, 29 October, Accessed at <https://theconversation.com/its-been-australias-hottest-ever-october-and-thats-nocoincidence-49941>.
- Kiem AS, Askew LE, Sherval M, et al. (2010) Drought and the future of rural communities: Drought impacts and adaptation in regional Victoria, Australia, National Climate Change Adaptation Research Facility, Gold Coast, 150 pp.
- Kiem AS and Austin EK (2013a) Drought and the future of rural communities: opportunities and challenges for climate change adaptation in regional Victoria, Australia. *Global Environmental Change*, 23(5), 1307–1316, doi:10.1016/j.gloenvcha.2013.06.003.
- Kiem AS and Austin EK (2013b) Disconnect between science and end-users as a barrier to climate change adaptation. *Climate Research* 58: 29–41.
- Kiem AS and Austin EK (2013c) Disconnect between science and end-users as a barrier to climate change adaptation. *Climate Research*, 58, 29–41, doi:10.3354/cr01181.
- King A and Black M. 2016. We traced the human fingerprint on record-breaking temperatures back to the 1930s. *The Conversation*. 8 March. Accessed at: <https://theconversation.com/we-traced-the-humanfingerprint-on-record-breaking-temperatures-back-to-the-1930s-55438>.
- Kjellstrom T, Kovats R S, Lloyd S J, Holt T, Tol R S J (2009) The Direct Impact of Climate Change on Regional Labor Productivity. *Archives of Environmental & Occupational Health*. 64: 217–227.
- Koetse M, Rietveld P (2009) The impact of climate change and weather on transport: an overview of empirical findings. *Transportation Research Part D*, 14, 205–221.
- Kraxner F, Nordström EM, Havlík P et al. (2013). Global bioenergy scenarios—future forest development, land-use implications, and trade-offs. *Biomass and Bioenergy* 57: 86–96.
- Krause D, Schwab M and Birkmann J. (2015) An Actor-Oriented and Context-Specific Framework for Evaluating Climate Change Adaptation. *New Directions for Evaluation* 2015(147): 37–48.
- Lal R (2004) Soil carbon sequestration to mitigate climate change. *Geoderma* 123: 1–22.
- Lal R (2011) Soil Health and Climate Change: An Overview in B P Singh, A L Cowie and K Y Chan's (eds.), *Soil Health and Climate Change*, Springer Berlin Heidelberg, pp. 3–24.
- Lê Q, Auckland, S, Nguyen HB, et al. (2014) Food security in a regional area of Australia: a socio-economic perspective. *Universal Journal of Food and Nutrition Science* 2: 50–59.
- Leith P and Vanclay F. (2015) Translating Science to Benefit Diverse Publics Engagement Pathways for Linking Climate Risk, Uncertainty, and Agricultural Identities. *Science, Technology & Human Values*: 0162243915577636.
- Lempert RJ, Groves DG, Popper SW, et al. (2006) A general, analytic method for generating robust strategies and narrative scenarios. *Management Science* 52(4): 514–528.
- Leonard M, Westra S, Phatak A, Lambert M, van den Hurk B, McInnes K, Risbey J, Schuster S, Jakob D, Stafford-Smith M (2014) A compound event framework for understanding extreme impacts, *WIREs Climate Change* 5, pp. 113–128.
- Leonard S, Mackenzie J, Kofod F, et al. (2013) Indigenous climate change adaptation in the Kimberley region of North-western Australia. Learning from the past, adapting in the future: Identifying pathways to successful adaptation in Indigenous communities, National Climate Change Adaptation Research Facility, Gold Coast, 131 pp.
- Leviston Z, Walker I and Morwinski S. (2013) Your opinion on climate change might not be as common as you think. *Nature Climate Change* 3(4): 334–337.
- Lincoln M, Gallego G, Drew A et al. (2014) Recruitment and retention of allied health professionals in the disability sector in rural and remote New South Wales, Australia. *Journal of Intellectual and Developmental Disability* 39: 86–97.
- Loughnan M, Nicholls N and Tapper N (2010) Mortality–temperature thresholds for ten major population centres in rural Victoria, Australia. *Health and Place* 16: 1287–1290.

- Lucas C (2010) On developing a historical fire weather data-set for Australia. *Australian Meteorological and Oceanographic Journal* 60: 1-13.
- Luck GW, Black R and Race D (2011). Demographic change in rural Australia: opportunities and challenges. Pp. 375-384 in: *Demographic Change in Australia's Rural Landscapes: Implications for society and the environment*. (Luck GW, Race D, Black R eds.) Melbourne, CSIRO Publishing.
- Luo Q, Bellotti W, Williams M and Wang E (2009) Adaptation to climate change of wheat growing in South Australia: analysis of management and breeding strategies. *Agriculture, Ecosystems & Environment* 129: 261-267.
- Maraseni TN and Maroulis J (2008) Piggery: From environmental pollution to a climate change solution, *Journal of Environmental Science and Health, Part B: Pesticides, Food Contaminants, and Agricultural Wastes* 43:358-363.
- Maron M, Laurance B, Pressey B, Catterall C, McAlpine C, Possingham H, Watson J, Rhodes J, Wilson K and Hockings M (2016) Queensland land clearing is undermining Australia's environmental progress. The Conversation, 22 February 2016. Accessed at <https://theconversation.com/queensland-land-clearing-is-undermining-australias-environmental-progress-54882>.
- Marshall NA, Park S, Howden SM, Dowd AB and Jakku ES (2013) "Climate change awareness is associated with enhanced adaptive capacity." *Agricultural Systems* 117: 30-34.
- Marshall NA, Dowd AM, Fleming A, Gambley C, Howden M, Jakku E, Larsen C, Marshall PA, Moon K, Park S and Thorburn PJ (2014) Transformational capacity in Australian peanut farmers for better climate adaptation. *Agronomy and Sustainable Development* 34(3):583-591.
- Martin P and Williams J (2011) Renegotiating farmers' social licence. pp. 195-202 *Defending the Social Licence of Farming: Issues, challenges and new directions for agriculture*. (Williams J, Martin P eds.) Melbourne, CSIRO Publishing.
- Mataix-Solera J, Cerdà A, Arcenegui V, Jordán A, Zavala L M (2011) Fire effects on soil aggregation: A review, *Earth-Science Reviews* 109, pp. 44-60.
- Mazur N, Curtis A and Rogers M (2013) Do you see what I see? Rural landholders' belief in climate change. *Society and Natural Resources: An International Journal* 26: 75-85.
- McCann L, Gedikoglu H, Broz B, et al. (2015) Effects of observability and complexity on farmers' adoption of environmental practices. *Journal of Environmental Planning and Management*: 1-17.
- McGovern M (2014) Subprime agriculture, and Australia?, *Economic Analysis and Policy* 44:3, pp. 243-258.
- McGrail M, Humphreys J (2015) Geographical mobility of general practitioners in rural Australia. *The Medical journal of Australia* 203: 92-96.
- McKeon GM, Stone GS, Syktus JI et al. (2009) Climate change impacts on northern Australian rangeland livestock carrying capacity: a review of issues. *The Rangeland Journal* 31: 1-29.
- McNamara KE, Smithers SG, Westoby R and Parnell K (2012) Limits to climate change adaptation for low-lying communities in the Torres Strait, National Climate Change Adaptation Research Facility, Gold Coast, p.87.
- Meinke H. and R Stone (2005). "Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations." *Climatic Change* 70: 221-253.
- Michael DT and Crossley RL (2012) Food security, risk management and climate change, National Climate Change Adaptation Research Facility, Gold Coast, 152 pp.
- Millar J and Roots J (2012) Changes in Australian agriculture and land use: implications for future food security. *International Journal of Agricultural Sustainability* 10: 25-39.
- Mills J, Gage K, Khan A (2010) Potential influence of climate change on vector-borne and zoonotic diseases: a review and proposed research plan. *Environmental Health Perspectives* 118: 1507-1514.
- Milne M, Stenekes N, Russell J (2008) Climate risk and industry adaptation. Australian Government, Bureau of Rural Sciences, Canberra. Accessed at <http://web.mclink.it/MI2795/climatici/climateriskandindustryadapt--augov--bureauofruralscience--mag08.pdf>.
- Mohson M (2015) Agribusiness Financing in Australia: Issues and Research Agenda, *International Journal of Economics and Finance* 7, pp. 1-18.
- Moore AD and Ghahramani A (2013) Climate change and broadacre livestock production across southern Australia. 1. Impacts of climate change on pasture and livestock productivity, and on sustainable levels of profitability. *Global Change Biology* 19: 1440-1455.
- Moreland Energy Foundation (2015) ZeroNet Energy Town Uralla Case Study. Accessed at http://z-net.org.au/wp-content/uploads/2015/10/ZNET-CaseStudy_Uralla_v18.pdf.
- Mosley LM, Palmer D, Leyden E et al. (2014) Acidification of floodplains due to river level decline during drought. *Journal of Contaminant Hydrology* 161: 10-23.
- MTU Detroit Diesel Australia (2014) Berrybank Farm, Windemere – Victoria. Accessed at <http://www.mtudda.com.au/wp-content/uploads/2014/10/141023-Berrybank-Farm-Case-Study.pdf>.
- Nairn J and Fawcett R (2013) Defining Heatwaves: Heatwave defined as a heat-impact even servicing all community and business sectors in Australia. CAWCR Technical Report, No. 060. CSIRO and Australian Bureau of Meteorology, p 96.
- National Irrigators Council (2009) Irrigation Facts. Accessed at <http://www.irrigators.org.au/?page=facts>.
- National Rural Health Alliance & ACOSS (2013) A snapshot of poverty in rural and regional Australia. Accessed at http://ruralhealth.org.au/documents/publicseminars/2013_Sep/Joint-report.pdf.

- NCCARF (National Climate Change Adaptation Research Facility) (2010a) Storm Tides, Coastal Erosion and Inundation. Accessed at http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Helman_2010_Storm_tides_coastal_erosion_inundation.pdf.
- NCCARF (National Climate Change Adaptation Research Facility) (2010b) East Coast Lows and the Newcastle/Central Coast Pasha Bulker Storm. Accessed at http://www.nccarf.edu.au/sites/default/files/attached_files_publications/Verdon-Kidd_2010_East_Coast_Lows_Pasha_Blaker_Storm.pdf.
- New York Times (2010) Russia, Crippled by Drought, Bans Grain Exports. Andrew E. Kramer, August 5 2010. Accessed at <http://www.nytimes.com/2010/08/06/world/europe/06russia.html>.
- NFF (National Farmers Federation) (2015) Farm Facts. Accessed at <http://www.nff.org.au/farm-facts.html>.
- Nidumolu U, Hayman P, Howden S, et al. (2012) Re-evaluating the margin of the South Australian grain belt in a changing climate. *Climate Research* 51(3): 249.
- Niles M T, Lubell M, Brown M (2015) How limiting factors drive agricultural adaptation to climate change, *Agriculture, Ecosystems and Environment* 200, pp. 178-185.
- Northern Daily Leader (2016a) Wind farm go-ahead: \$400m project near Glen Innes to create 200 jobs. Accessed at <http://www.northerndailyleader.com.au/story/3837332/wind-farm-go-ahead-400m-project-near-glen-innes-to-create-200-jobs/>.
- Northern Daily Leader (2016b) UNE solar farm. Accessed at <http://www.northerndailyleader.com.au/story/3845599/une-set-to-install-solar/>.
- NSW Government (2009) Submission from the NSW Minister for Energy Ian MacDonald to the Australian Energy Market Commission. Accessed at <http://www.aemc.gov.au/getattachment/df53e4bd-01bc-4cdc-817a-72fcc3d38648/NSW-Government-Received-18-August-2009.aspx>.
- NSW Government (2010) Community attitudes to wind farms and renewable energy in NSW. Department of Environment, Climate Change and Water NSW http://communityrenewables.org.au/wp-content/uploads/2013/02/NSW-Gov_comm-attitudes-wind_2010.pdf.
- NSW Government (2015) NSW Renewable Energy Action Plan. Annual Report 2015. Accessed at http://www.resourcesandenergy.nsw.gov.au/_data/assets/pdf_file/0008/586601/reap-annual-report.pdf.
- NSW Government (2016) Community Attitudes to Renewable Energy in NSW. Accessed at <http://www.environment.nsw.gov.au/resources/actionmatters/community-attitudes-renewable-energy-150419.pdf>.
- NSW PRS (NSW Parliamentary Research Service) (2014) Bushfires in NSW: timelines and key sources. Accessed at [https://www.parliament.nsw.gov.au/prod/parliament/publications.nsf/key/Bushfiresin%20NSW:timelinesandkeysources/\\$File/Bushfires%20in%20NSW%20-%20timelines%20and%20key%20sources.pdf](https://www.parliament.nsw.gov.au/prod/parliament/publications.nsf/key/Bushfiresin%20NSW:timelinesandkeysources/$File/Bushfires%20in%20NSW%20-%20timelines%20and%20key%20sources.pdf).
- Northern Territory Cattlemen's Association (2015) Renewable Remote Power Generation. Accessed at http://www.ntca.org.au/our_land/RRPGP.html.
- Nyngan Observer (2015) Solar system boost for local preschool. Accessed at <http://www.nynganobserver.com.au/story/2952637/solar-system-boost-for-local-preschool/>.
- O'Brien LV, Berry HL, Coleman C and Hanigan IC (2014) Drought as a mental health exposure. *Environmental Research* 131: 181-187.
- O'Connor, M. H., et al. (2005). "The Avon River Basin in 2050: scenario planning in the Western Australian Wheatbelt." *Australian Journal of Agricultural Research* 56(6): 563-580.
- OECD (Organisation for Economic Co-operation and Development) (2001), *The Well-Being of Nations: The Role of Human and Social Capital*, OECD, Paris.
- OECD (2012) *Linking Renewable Energy to Rural Development Executive Summary Brief for Policy Makers*. Accessed at http://www.oecd.org/berlin/Linking%20Renewable%20Energy%20to%20Rural%20Development_es.pdf.
- Page A, Morrell S and Taylor R (2002) Suicide and political regime in New South Wales and Australia during the 20th century. *Journal of Epidemiology and Community Health* 56:766-772.
- Page A, Morrell S, Taylor R et al. (2007) Further increases in rural suicide in young Australian adults: secular trends, 1979-2003. *Social Science and Medicine* 65: 442-453.
- Pannell D, Marshall G, Barr N, et al. (2006) Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture* 46(1407-1424).
- Park SE, Marshall NA, Jakku E, et al. (2012) Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change* 22(1): 115-126.
- Pearce, M., et al. (2015). Cut from 'country': the impact of climate change on the mental health of aboriginal pastoralists. *Australasian Journal of Regional Studies* 21: 50-79.
- Perkins S and Alexander L (2013) On the measurement of heat waves. *Journal of Climate* 26:4500-4517.
- Petheram L, Zander KK, Campbell BM et al. (2010). 'Strange changes': Indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia). *Global Environmental Change* 20: 681-692.
- Phillips A (2009) Health status differentials across rural and remote Australia. *Australian Journal of Rural Health* 17: 2-9.
- Pollard CM, Landrigan TJ, Ellies PL, et al. (2014) Geographic factors as determinants of food security: a Western Australian food pricing and quality study. *Asia Pacific Journal of Clinical Nutrition* 23: 703-713.

- Porter JR, Xie L, Challinor A, et al. (2014) Food Security and Food Production Systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field C, Barros V, Mach K, Mastrandrea M (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 485-533.
- Potter N, Chiew FHS and Frost AJ (2010) An assessment of the severity of recent reductions in rainfall and runoff in the Murray-Darling Basin. *Journal of Hydrology* 1: 52-64.
- Powers JR, Dobson AJ, Berry HL, Graves AM, Hanigan IC, and Loxton D (2015) Lack of association between drought and mental health in a cohort of 45-61 year old rural Australian women. *Australian and New Zealand Journal of Public Health*: 2015 Dec 1;39(6):518-23.
- Prokopy LS, Arbuckle J, Barnes AP, et al. (2015) Farmers and climate change: a cross-national comparison of beliefs and risk perceptions in high-income countries. *Environmental Management* 56(2): 492-504.
- Purcell R and McGirr J (2014) Preparing rural general practitioners and health services for climate change and extreme weather. *Australian Journal of Rural Health* 22: 8-14.
- Queensland Government (2011) State Budget 2011-12: Budget Strategy and Outlook. Accessed at: www.budget.qld.gov.au/budget-papers/2011-12/bp2-2011-12.pdf.
- Raymond CM and Spoehr J (2013) The acceptability of climate change in agricultural communities: Comparing responses across variability and change. *Journal of Environmental Management* 115: 69-77.
- Reid C, et al. (2015) Spatiotemporal prediction of fine particulate matter during the 2008 northern California wildfires using machine learning. *Environmental science & technology* 49.6 (2015): 3887-3896.
- Reisinger, A., R.L. Kitching, F. Chiew, et al. (2014) Australasia. In: 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 [Barros, V.R., C.B. Field, D.J. Dokken, M.D. et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1371-1438.
- REN21 (2015) Renewables 2015 Global Status Report. Accessed at http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015-Onlinebook_low1.pdf.
- Reid C, et al. (2015) Spatiotemporal prediction of fine particulate matter during the 2008 northern California wildfires using machine learning. *Environmental science & technology* 49.6 (2015): 3887-3896.
- RenewEconomy (2014) Five NSW towns bid to be Australia's first zero net energy town. Accessed at <http://reneweconomy.com.au/2014/five-nsw-towns-bid-to-be-australias-first-zero-net-energy-town-16968>.
- RenewEconomy (2015) NSW town provides blueprint for 100% renewable energy communities. Accessed at <http://reneweconomy.com.au/2015/nsw-town-provides-blueprint-for-100-renewable-energy-communities-72709>.
- Rickards L (2012) Critical Breaking Point? The effects of climate variability, climate change and other stressors on farm households. Final Report. Birchip, Victoria, Birchip Cropping Group.
- Rickards L and Howden SM (2012) Transformational adaptation: agriculture and climate change. *Crop and Pasture Science* 63: 240-250.
- Rickards L, Ison R, Fünfgeld H, et al. (2014) Opening and closing the future: climate change, adaptation, and scenario planning. *Environment and Planning C: Government and Policy* 32(4): 587-602.
- Rivers M R, Weaver D M, Smettem K R J, Davies P M (2011) Estimating future scenarios for farm-watershed nutrient fluxes using dynamic simulation modeling, *Physics and Chemistry of the Earth* 36, pp. 420-423.
- Rogers M, Curtis A and Mazur N (2012) The influence of cognitive processes on rural landholder responses to climate change. *Journal of Environmental Management* 111: 258-266.
- Rotz CA, Skinner RH, Stoner AM, et al. (2015) Farm Simulation Can Help Dairy Production Systems Adapt to Climate Change. *Improving Modeling Tools to Assess Climate Change Effects on Crop Response* (advagricsysmodel7).
- Sartore G.-M, Kelly B, Stain H et al. (2008). Control, uncertainty, and expectations for the future: a qualitative study of the impact of drought on a rural Australian community. *Rural and Remote Health* 8: 950.
- Scott A, Witt J, Humphreys J et al. (2013). Getting doctors into the bush: General Practitioners' preferences for rural location. *Social Science & Medicine* 96: 33-44.
- Scott, JK, Webber BL, Murphy H, Ota N, Kriticos DJ and Loebel B (2014) AdaptNRM Weeds and climate change: supporting weed management adaptation. Accessed at: http://adaptnrm.csiro.au/wp-content/uploads/2014/08/Adapt-NRM_M2_WeedsTechGuide_5.1_LR.pdf.
- Schech, S. (2013). "Silent Bargain or Rural Cosmopolitanism? Refugee Settlement in Regional Australia." *Journal of Ethnic and Migration Studies* 40(4): 601-618.
- SKM (2012) Wind farm investment, employment and carbon abatement in Australia Report. Accessed at <http://www.cleanenergycouncil.org.au/technologies/wind-energy/benefits-of-wind-energy.html>.
- Smith, JA et al. (2011). Scenarios for Engaging a Rural Australian Community in Climate Change Adaptation Work. *Climate Change Adaptation in Developed Nations*. J. D. Ford and L. Berrang-Ford, Springer Netherlands. 42: 413-422.
- Stafford-Smith M, Horrocks L, Harvey A, et al. (2011) Rethinking adaptation for a 4 C world. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 369(1934): 196-216.

- Stephenson C and Handmer J (2012) Estimating the net cost of the 2009 Black Saturday Fires to the affected regions. Bushfire CRC. Accessed at http://www.bushfirecrc.com/sites/default/files/news/estimating_the_net_cost_of_the_2009_black_saturday_fires_to_the_affected_regions.pdf.
- Stephenson C, Handmer J, Betts R (2013) Estimating the economic, social and environmental impacts of wildfires in Australia. *Environmental Hazards* 12: 93-111.
- Stevnbak K, Scherber C, Gladbach D J, Beier C, Mikkelsen T S, Christensen S (2012) Interactions between above- and belowground organisms modified in climate change experiments, *Nature Climate Change* 2, pp. 805-808.
- Stokes CJ and Howden SM (eds) (2008) An Overview of Climate Change Adaptation in Australian Primary Industries: Impacts, Options, and Priorities. Report prepared for the National Climate Change Research Strategy for Primary Industries. CSIRO Publishing, Canberra.
- Stokes CJ, Crimp S, Gifford R et al. (2010) Broadacre grazing. pp153-170 In: *Adapting Australian Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for the Future* Stokes CJ and Howden SM eds). CSIRO Publishing, VIC.
- Strazdins L, Griffin A L, Broom D H, Banwell C, Korda R, Dixon J, Paolucci F, Glover J (2011) Time scarcity: another health inequality? *Environment and Planning A* 43, pp. 545-559.
- Sundrop Farms (2016) Sundrop System. Accessed at <http://www.sundropfarms.com/sundrop-system/>.
- Sustainability Victoria (2001) Total waste management system at Berrybank Farm Piggery, Charles I.F.E Pty Ltd. Accessed at <http://www.sustainability.vic.gov.au/~media/resources/documents/publications%20and%20research/knowledge%20archive/bioenergy%20resource%20in%20victoria/archive%20bio%20berrybank%20piggery%20case.pdf>.
- Sutherst RW (1990) Impact of climate change on pests and diseases in Australasia. *Search* 21: 230-232.
- Sutherst RW, Collyer BS and Yonow T (2000) The vulnerability of Australian horticulture to the Queensland fruit fly, *Bactrocera* (Dacus) tryoni, under climate change. *Australian Journal of Agricultural Research* 51: 467-480.
- Tasmanian Government (2013) Tasmanian Bushfires Inquiry Report: volume one. Department of Premier and Cabinet. Accessed at: <http://www.justice.tas.gov.au/bushfiresinquiry>.
- Teague B, McLeod R, Pascoe S (2010) Victoria Bushfires Royal Commission. 2009 Victorian Bushfires Royal Commission: Final Report: Government Printer, South Africa, 2010.
- The Age (2011) \$2b damage bill for Victorian flood recovery. Accessed at <http://www.smh.com.au/business/2b-damage-bill-for-victorian-flood-recovery-20110125-1a4pq.html>.
- The Bingara Advocate (2015) Gwydir Shire looks towards a Circular Economy. Accessed at <http://www.bingaraadvocate.com.au/page21623/News.aspx?newsid=11445>.
- The Climate Institute (2011) Clean Energy Jobs in Regional New South Wales, Snapshot New England Tablelands. Accessed at http://www.climateinstitute.org.au/verve/_resources/cleanenergyjobssnapshot_newenglandtablelands.pdf.
- The Coffs Coast Advocate (2015) Dorrigo hydro plan powers up. Accessed at <http://www.coffscostadvocate.com.au/news/hydro-plan-powers-up/2643356/>.
- Tonts M, Atherley K (2005) Rural restructuring and the changing geography of competitive sport. *Australian Geographer* 36: 125-144.
- Transgrid (2015) Next steps for the Renewable Energy Hub. Accessed at <https://www.transgrid.com.au/news-views/blog/Lists/Posts/Post.aspx?ID=47>.
- Trewin, B. and H. Vermont. 2010. Changes in the frequency of record temperatures in Australia, 1957-2009. *Australian Meteorological and Oceanographic Journal* 60: 113-119.
- Trewin B and Smalley R (2013) Changes in extreme temperatures in Australia, 1910 to 2011. In: 19th AMOS National Conference, Melbourne, pp 11-13.
- Turner G M, Dunlop M, Candy S (2016) The impacts of expansion and degradation on Australian cropping yields – An integrated historical perspective, *Agricultural Systems* 143, pp. 22-37.
- UNFCCC (United Nations Framework Convention on Climate Change) (2015) Intended Nationally Determined Contributions (INDCs). Accessed at http://unfccc.int/focus/indc_portal/items/8766.php.
- Victoria State Government (2015) Ash Wednesday 1983. Accessed at <http://www.depi.vic.gov.au/fire-and-emergencies/managing-risk-and-learning-about-managing-fire/bushfire-history/ash-wednesday-1983>.
- Walker B and Salt D. (2006) *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*, New York: Island Press.
- Waters, E., et al. (2014). "Contrasting perspectives on barriers to adaptation in Australian climate change policy." *Climatic Change* 124(4): 691-702.
- Webber B, Van Linken R, John S (2014) Invasive plants in a rapidly changing climate: an Australian perspective in Z Lewis and J Dukes' (eds.), *Invasive Species and Climate Change*, CABI, UK
- Wedderburn-Bisshop G, Longmire A and Rickards L (2015) "Neglected Transformational Responses: Implications of Excluding Short Lived Emissions and Near Term Projections in Greenhouse Gas Accounting." *International Journal of Climate Change: Impacts & Responses* 7(3).
- Wei M, Patadia S and Kammen D. (2010) Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US? Energy Policy, Accessed at http://rael.berkeley.edu/sites/default/files/WeiPatadiaKammen_CleanEnergyJobs_EPolicy2010.pdf.
- Welton G (2011) The Impact of Russia's 2010 Grain Export Ban, Oxfam Research Report, June 2011. Accessed at <https://www.oxfam.org/sites/www.oxfam.org/files/rr-impact-russias-grain-export-ban-280611-en.pdf>.

Wheeler S, Bjornlund H, Zuo A, Edwards J (2012) Handing down the farm? The increasing uncertainty of irrigated farm succession in Australia, *Journal of Rural Studies* 28:3, pp. 266-275.

White N, Sutherst RW, Hall N and Whish-Wilson P (2003) The vulnerability of the Australian beef industry to impacts of the cattle tick (*Boophilus microplus*) under climate change. *Climatic Change* 61: 157-190.

Whittaker J, Handmer J and Mercer D (2012) Vulnerability to bushfires in rural Australia: A case study from East Gippsland, Victoria. *Journal of Rural Studies* 28: 161-173.

Whittaker J, McLennan B and Handmer J. (2015) A review of informal volunteerism in emergencies and disasters: Definition, opportunities and challenges. *International Journal of Disaster Risk Reduction*.

Williams L (2014) Cutting the grid energy apron strings at Uralla. Lesley Williams, Member for Port Macquarie, Accessed at <http://www.lesliewilliams.com.au/cutting-the-grid-energy-apron-strings-at-uralla>.

Williams S, Bi P, Newbury J et al. (2013) Extreme heat and health: perspectives from health service providers in rural and remote communities in South Australia. *International Journal of Environmental Research on Public Health* 10: 5565-5583.

WWF Australia (2015) Appetite for Change: Global warming impacts on food and farming regions in Australia. Prepared by the University of Melbourne for Earth Hour 2015. Accessed at: http://sustainable.unimelb.edu.au/sites/default/files/MSSI_AppetiteForChange_Report_2015.pdf.

Xiang J, Bi P, Pisaniello D and Hansen A (2014) The impact of heatwaves on workers' health and safety in Adelaide, South Australia. *Environmental Research* 133: 90-95.

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