The impacts of, and strategies to ameliorate, the intensity of climate change on enterprises in remote Australia

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Climate as a driver of change

People and businesses in remote Australia are experiencing change from multiple sources, bringing both opportunities and challenges. The historically variable climate of, and projected climate change for, central and northern Australia remains a powerful driver of liveability and business viability. While people and businesses in remote Australia have always exhibited an innate capacity to cope with variable and extreme weather, the full impacts of climate are not always well understood. Northern Australia is under increasing focus for its potential for economic development, yet such development faces some critical challenges. Furthermore, if the liveability and business viability of central and northern Australia are to be enhanced, greater consideration of how to thrive – rather than just coping or surviving – in the future climate projected for this region is needed. While there is growing evidence that people and businesses are adapting to extreme weather, there is a lack of reliable locally specific information about how to invest in transformative change that's positive, strategic and long term.

The *Green Paper on Developing Northern Australia* (PMC 2014) outlines the development potential in central and northern Australia (loosely defined as the area north of the Tropic of Capricorn), particularly that development flowing from the mineral and energy sectors, agriculture and tourism. Much of the demand and expected growth in these industries is due to northern Australia's proximity to rapidly growing economies in Asia (China, India, Korea and Indonesia). While the mineral and energy sectors are major contributors to the economic development of northern Australia, these sectors are also a source of strain within the wider economy – making it difficult for people employed in sectors with lower wages. The gross value of agricultural production in northern Australia was $5.2 billion in 2010–11, with about 60% of this value generated by the beef cattle industry (around 11.7 million cattle). Prominent crops include sugar cane, mango and banana. Fisheries production was valued at about $400 million in 2011–12. Exporting products via ports in northern Australia was valued at about $120 billion in 2012–13 (55% of the national total), with most being mineral and energy resources.

Outside these large scale industries, many small and medium-sized enterprises (SMEs) operate across Australia's desert region: more than 41,000, which is more per capita than the national average, and of which about 500 are Aboriginal-owned (Rola-Rubzen et al. 2009). Art centres have become an important enterprise in remote communities over recent decades, with an estimate of more than 100 community-controlled art centres across the region (Acker et al. 2013).

The rapid growth of mining and energy projects has led to commensurately rapid increases in housing costs (both the purchase and rental) in surrounding townships. Also, the current and projected climate in

central and northern Australia adds to development costs and maintaining liveability, with higher construction and living costs (Maru et al. 2012). For example, in Alice Springs the annual energy requirement for a 5-star rated house may rise by more than 60% by 2050 and by over 200% by 2100 just to maintain the current level of comfort in a warming climate (Wang et al. 2010). Climate change is considered by many to be a major challenge and is a driver of change throughout Australia's economy; it is bringing direct impacts of more extreme weather as well as the anticipation of future impacts, which is increasing insurance premiums against flood, fire and storms. There is also a wide range of direct impacts of climate change on people, such as heat stress and spread of tropical diseases, as well as increasing disruption to energy and transport systems due to flooding or storm damage. There are also the direct and indirect impacts on natural systems (e.g. drying water bodies, altered fire regimes, spread of feral animals and weeds and altered health and regeneration of native biodiversity).

The Cooperative Research Centre for Remote Economic Participation (CRC-REP) is conducting research to explore the impacts of climate change on the enterprises that are integral to the economy of central and northern Australia. This report outlines strategies to lessen these multiple impacts. The CRC-REP acknowledges that climate change is one of a range of drivers of change shaping the lives and businesses in remote Australia, but one that can be increasingly understood and prepared for to reduce the negative impacts.

Overview of climate change: implications for people, businesses and industries

The Intergovernmental Panel on Climate Change (IPCC) has confirmed in its Fifth Assessment Report that 'warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia' (IPCC 2014, p. 37). Scientists from the Bureau of Meteorology and CSIRO contribute to the IPCC's global assessment and have also produced a series of updates on Australia's climate, the *State of the Climate 2014* report (BoM and CSIRO 2014) and *Climate Change in Australia* (BoM and CSIRO 2015), which includes specific projections on the rangelands that cover much of remote Australia. Australian data are consistent with the IPCC's global assessment, in that there has been 'further warming of the atmosphere and oceans in the Australian region' (BoM and CSIRO 2014, p. 3). In particular for central and northern Australia, during recent decades there has been more warm weather and extreme heat (Figure 1) and large increases in annual rainfall in the north-west.

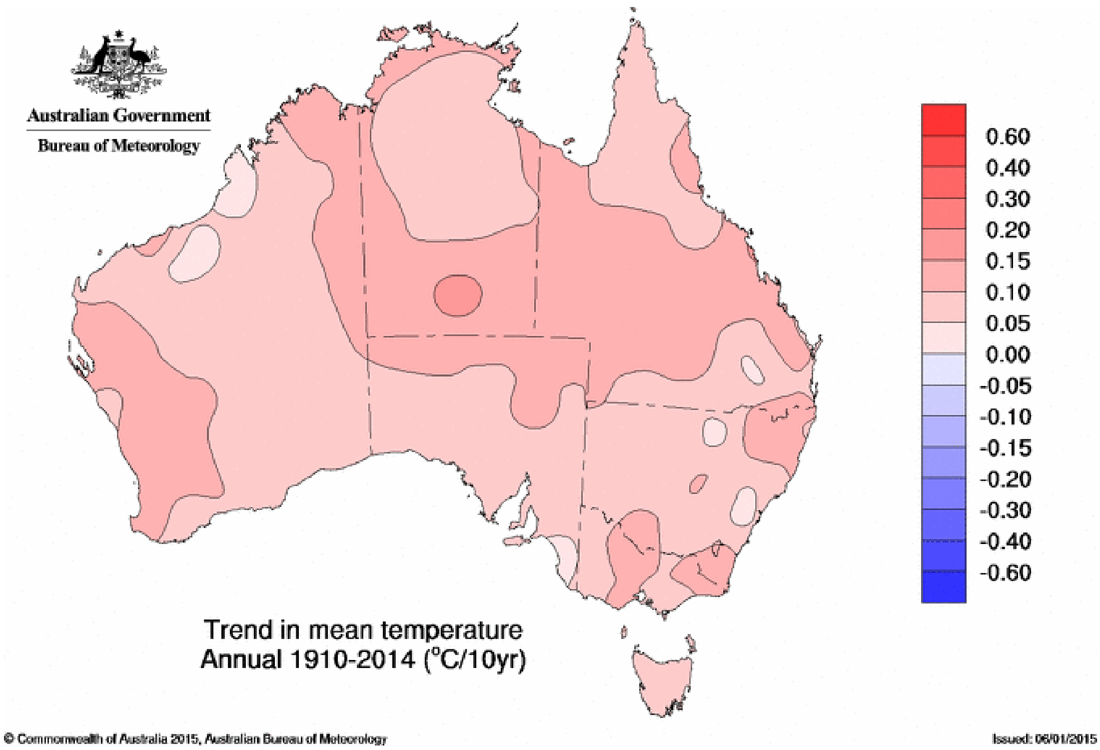

Figure 1: Trend in mean annual temperature 1910–2014

Source: BoM 2014

Predicting short-term weather patterns and long-term trends in the climate is complex – beyond merely combining data for rainfall and temperature (although these two variables are key components) – so it is inherently challenging to generate accurate long-term projections. However, the best available data indicate that Australia's climate will continue to warm over coming decades, particularly for central and northern Australia (Figure 2).

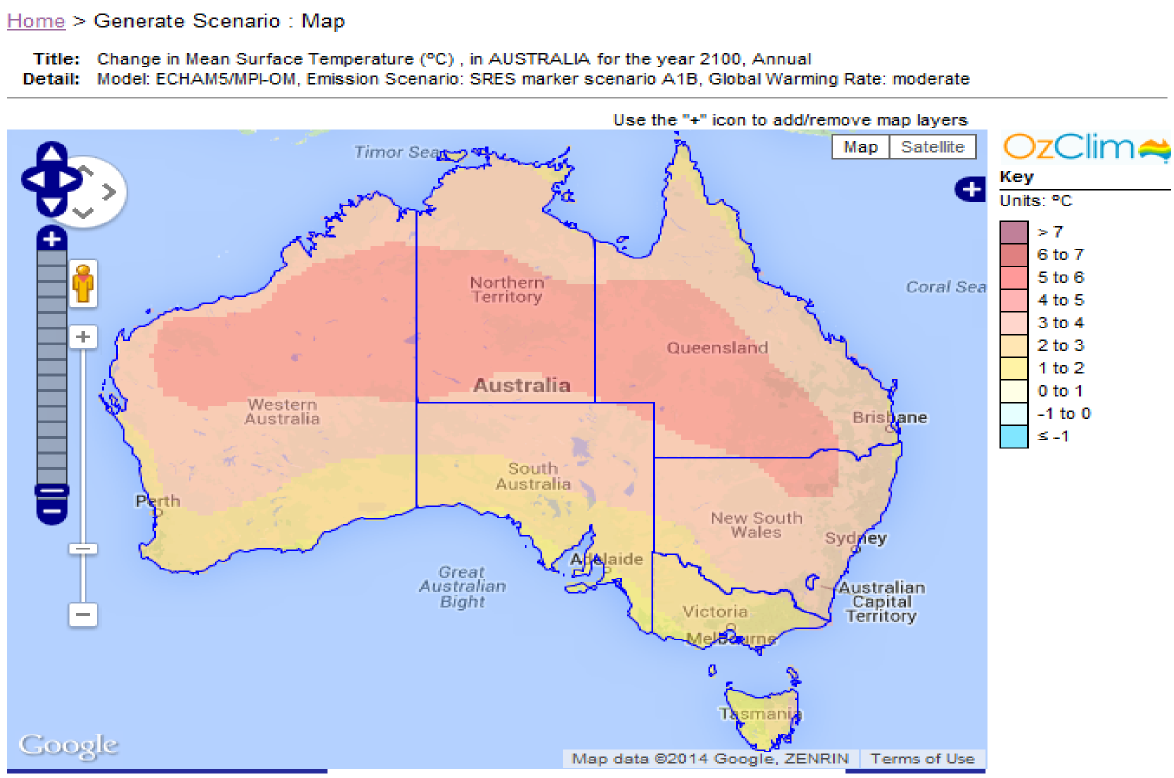

Figure 2: Projected temperature change for Australia

Source: CSIRO 2014

The projections for future rainfall patterns are more uncertain, with some analyses indicating a slight decline and others indicating an increase across northern Australia. There is equal uncertainty about the future frequency and intensity of cyclonic storms (BoM and CSIRO 2014). Some of the key points from the State of the Climate 2014 report are provided in Box 1.

Box 1: Some key points from State of the Climate 2014 report

- Australia's climate has warmed by 0.9°C since 1910, and the frequency of extreme weather has changed, with more extreme heat and fewer cool extremes.
- Rainfall averaged across Australia has slightly increased since 1900, with the largest increases in the northwest since 1970.
- Rainfall has declined since 1970 in the southwest, dominated by reduced winter rainfall. Autumn and early winter rainfall has mostly been below average in the southeast since 1990.
- Extreme fire weather has increased, and the fire season has lengthened, across large parts of Australia since the 1970s.
- Australian temperatures are projected to continue to increase, with more extremely hot days and fewer extremely cool days.
- Average rainfall in southern Australia is projected to decrease, and heavy rainfall is projected to increase over most parts of Australia.
- Sea-level rise and ocean acidification are projected to continue.

Source: BoM and CSIRO 2014, p. 3.

Climate impacts on human health and wellbeing

The direct impacts of climate change for people in central and northern Australia are expected to be largely from heat stress and tropical storms (Addison 2013, McMichael et al. 2006). An increase in hot weather (i.e. higher temperatures and extended summer periods) will mean less comfortable conditions for living and working in central and northern Australia – a reduced liveability.[1] It is anticipated that heat stress will be felt most acutely by people working outdoors and living in housing with poor thermal control. Less comfortable living conditions for extended periods leads to greater prevalence of fatigue, illness and emotional stress; thereby eroding people's coping capacities at the individual, family and community levels. The flow-on impacts of prolonged discomfort are declining engagement with education and employment opportunities, diminishing contributions to family and community and withdrawal from social activities; these conditions are likely to exacerbate feelings of isolation and poor mental health.

Some projections of the hotter weather to be experienced in central and northern Australia are listed in Table 1.

Table 1: Average number of days per year above 35°C at selected sites for the current climate (average for 1971–2000), and for 2030 and 2070

Current		2030 A1B low	2030 A1B median	2030 A1B high	2070 B1 low	2070 B1 median	2070 B1 high	2070 A1F1 low	2070 A1F1 median	2070 A1F1 high
Alice Springs	90	102	109	118	112	122	138	132	155	182
Brisbane	1.0	1.5	2.0	2.5	2.1	3.0	4.6	4.0	7.6	20.6
Broome	54	71	86	107	89	119	173	147	220	281
Cairns	3.8	5	7	9	8	12	22	19	44	96
Darwin	11	28	44	69	49	89	153	141	227	308

Source: Hugo 2012, p. 35 (citing CSIRO and BoM 2007, p. 61)

Extended periods of hot weather are correlated with drought conditions, so there may be an increasing loss of grassy vegetation (groundcover) in the semi-arid/arid zone of central Australia. This may lead to more airborne dust, causing a range of impacts from minor respiratory and skin discomfort through to more severe breathing difficulties. Conversely, wetter conditions in northern Australia due to tropical storms may lead to increased flooding and the subsequent spread of diseases (e.g. malaria and dengue fever) and contamination of water supplies (siltation and organic load in water supplies).

There are likely to be more deaths and increased ambulance call-outs associated with hotter temperatures. For example, one analysis indicates that climate change could cause as many as 768 temperature-related deaths per year in the NT by 2100 (compared to the current level of about 60 temperature-related deaths per year) (Bambrick et al. 2008, p. 13).

The NT also has conditions highly receptive to mosquito-borne diseases such as dengue fever, which can lead to serious and sometimes life-threatening illnesses. Under moderately warmer and wetter climate conditions, there may be an increase in the prevalence of some mosquito-borne diseases in some parts of the NT (Addison 2013).

[1] Liveability is a term used in this report that combines the interaction between people's physical and social environments (see Addison 2013).

Outdoor employment

Where more heat and droughts are expected, workers may have reduced productivity and greater absenteeism. There may be increased financial pressures and a loss of local farm labour. Social cohesion may be affected as sea-level rise displaces populations or there is reduced recreation, community and family time during droughts for primary producers (Addison 2013). A similar situation could arise for anyone with outdoor-dominated employment, such as those involved in the building and construction industry (e.g. builders, outdoor maintenance staff and road workers). The social impacts of extreme weather are likely to increase employment costs, with lower productivity, higher absenteeism and disruption to work.

Variations in pre-existing health, socio-economic status, geographical location, social capacity, infrastructure and demographic attributes mean that particular groups of people are likely to be more affected than others. Employers may have an increasing duty of care for employees, which may translate into a narrowing of health and wellbeing criteria when selecting new employees for positions where they are likely to be exposed to sustained heat stress and extreme weather events (e.g. testing of physical fitness and mental health for positions may become more rigorous). Those with poor health – particularly those with pre-existing illnesses such as respiratory or cardiovascular disease, or those with mental illness, a high body mass index or poor fitness – are likely to be most impacted. People whose economic prosperity directly depends on weather patterns, those with thermally stressful occupations who return to work prior to acclimatisation (e.g. fly-in, fly-out mine workers) or those undertaking heavy labour will also be sensitive to the projected climate change in central and northern Australia.

Mobility in Central Australia, and in some industries, may have been an effective strategy for managing climatic variability in the past (e.g. moving away when intense storms are anticipated), but it is difficult to provide high levels of health and social support services for a mobile population, particularly when seeking to address chronic health issues. Also, more intense storms are anticipated to cause flooding, increased illness and injury among residents, damage to infrastructure and housing, restricted road access and degraded telecommunication, all of which increase pressure on community-based health clinics and staff. Intense storms are expected to restrict the travel of health professionals or make relocating patients more difficult – at a time when the need for professional healthcare is most acute.

Adaptation options for employment and recreation

1. Employers may be required to adopt higher levels of duty of care in relation to minimising the exposure of employees to extreme weather. This may require a change in work practices (e.g. working during cooler periods of the day during summer, greater use of mechanisation/technology) and increased protection for employees from extreme weather (e.g. clothing and vehicles).
2. Social norms can be influenced so that people can start making voluntary adjustments to their behaviour at home and in the workplace. For example, such changes could include ensuring fresh water is readily available, wearing protective clothing and planning to avoid excessive physical work outdoors during the hottest period of the day during summer. Examples from the pastoral industry may include handling livestock in cooler periods of the day and providing adequate shade and water in yards, which can provide benefits to both people and livestock.

3. Summer sporting activities are likely to require greater investment in infrastructure (e.g. lights for playing at night, synthetic grass surfaces so that watering is minimised, robust shade structures) to maintain the enjoyment and safety for participants and spectators. For example, cricket and tennis may increasingly become an evening or night-time activity, to avoid players being exposed to long periods of hot weather.

Agricultural sector

In a comprehensive assessment of climate change impacts on the Australian economy (Garnaut 2008), the agricultural sector was identified as having a high risk of negative impacts. Increased temperatures and variable or reduced water availability reducing crop and pasture growth were viewed as the dominant risks, followed by heat stress on livestock health and production. These impacts will increase production risks for agriculture, such as:

- heat stress of livestock and pastures
- crop and livestock losses from flood and drought
- shifts in the extent and severity of pest and disease outbreaks
- reduced predictability of seasons
- changes in regional suitability of different production systems.

Yet many agribusiness analysts argue that Australian agriculture has historically adapted to a highly variable climate, and will be to adapt to the new challenges (AAG 2011). Agriculture in northern Australia has a dual narrative in terms of climate change impacts and adaptive capacity. For instance, while the climate change projections indicate intensifying summer temperatures and perhaps an increase in tropical storms (BoM and CSIRO 2014), the study by Nelson et al. (2010) indicates that much of northern Australia includes rural communities among the least vulnerable to climate change.

In contrast to the assessment by Nelson et al. (2010), a subsequent study by Stokes et al. (2012, p. 3) found that 'the northern beef industry across the main production regions is highly vulnerable to relatively small adverse changes in its market and production context', including any adverse effects of projected climate change. However, Stokes et al. (2012) suggest that the risk of declining productivity due to climate change could largely be offset by improving productivity with better pastures (e.g. drought/heat tolerant). Importantly, Stokes et al. (2012, citing McCosker et al. 2010) extend their analysis beyond agronomic factors, to also review the financial status of pastoral operations in northern Australia. Many pastoral businesses appear to be unprofitable, with limited capacity to adapt or invest in improved operations. However, the characteristics of the top performing 20% of operations included larger properties (land area and number of livestock), conservative stocking rates, higher gross margins and lower overhead costs. They also tended to have strong social networks, a strategic view of their business and high levels of environmental awareness and knowledge compared with managers of less viable business operations. Other research showed that improved land condition combined with improved livestock management led to increased productivity and profitability (Bray et al. 2013).

In terms of land area, dryland beef cattle production is the dominant agricultural enterprise in northern Australia. There are areas of more intensive irrigated farming, such as around the Ord River (Lake Argyle) in WA, where a range of crops (e.g. sugar) are grown. In general terms, the further inland (e.g. central Australia), the greater the direct impacts of climate change, largely in terms of hotter summer temperatures and increased evapo-transpiration leading to reduced pasture growth and increased heat stress for livestock (AAG 2011). Climate change is likely to put at risk agricultural production, particularly beef production in the NT. The NT had an estimated beef cattle population of around 1.7 million in 2009, yet the impacts of climate change could reduce beef production by about one-fifth in 2030 and by one-third by 2050. Climate change may also exacerbate the impacts of heat stress and cattle ticks on beef production.

If water storage is reliable, and perhaps with supplementary groundwater, irrigation can be used to moderate the prevailing climate, overcoming short-term or seasonal impacts of drought. Indeed, decreased rainfall may actually lead to increased crop yields if irrigation is possible (AAG 2011), by lengthening the growing season. Even if there is no change in rainfall, increased temperatures will lead to increased evapo-transpiration, so water conservation and management will become increasingly critical.

While throughout the northern tropical wet zone, agriculture is thought to be among the least vulnerable industry to climate change, there may be increased risks from tropical storms and spread of pests and diseases. In the semi-arid/arid rangelands region, rainfall is highly variable and, as a consequence, so is pasture growth. Aggregate rainfall can be a misleading indicator of grazing potential, as for much of the region a rainfall event needs to be about 50+ mm to promote good pasture growth (but it depends on other factors as well, such as initial plant condition) (Bastin 2014a).

Pastoralists should be increasingly prepared for drought (i.e. have a drought management strategy with clear trigger points for decision-making) and adopt a conservative stocking rate so that land quality is not compromised. For example, regular monitoring of groundcover (or bare soil) and plant condition, even remotely at a landscape scale, is likely to be important for informing appropriate grazing strategies (Bastin 2014b). Hotter maximum temperatures and increased frequency and duration of heatwaves will require pasture species (or pasture mixes) to evolve to be more heat tolerate and robust to grazing pressure. For example, Meat & Livestock Australia (MLA) is supporting development of grazing systems for farmers in low to medium rainfall areas that incorporate perennial native shrubs. Work towards developing a variety of old man saltbush with higher digestibility and palatability to sheep has reached the final stages of commercialisation with a pre-commercial ‘research release’ (Emms 2014).

Conversely, periods of average/above average rainfall can lead to an increase in grassy biomass, creating a greater fire risk during the fire season. For example, the spread of buffel grass (Cenchrus ciliaris) can greatly increase the fuel load and therefore the fire risk at a local level. Compounding the spread of buffel grass is that it appears tolerant of increased temperatures and fire compared with similar native species – so the species may become more invasive under climate change.

Climate change adaptation is being undertaken by a range of producers across the spectrum of Australia’s agricultural industries as a response to the impacts already being experienced. The impacts of climate change on individual agricultural industry sectors, and across industry sectors, are dynamic and variable (Stokes & Howden 2010). For example, wine grape production in southern Australia is particularly vulnerable to late-season frosts when vines are flowering and buds forming (Hayman et al. 2009, Webb et al. 2012). Beef production in northern Australia, on the other hand, is most vulnerable to extended periods of hot weather that reduces pasture growth and causes symptoms of heat stress in livestock (Henry et al. 2012). Even within individual primary industry sectors, there is often a wide range of adaptation strategies employed by operators. Some operators choose to employ short-term operational or tactical strategies (e.g. temporary reduction of inputs), while others choose to invest in long-term strategic strategies (e.g. infrastructure to improve water use efficiency) (Howden et al. 2013, Howden et al. 2008, Mazur et al. 2008, Thwaites et al. 2008). Some operators have even made substantive and sustained changes to the core of their farming system (e.g. by moving out of one enterprise into another); this is called transformational change (Park et al. 2012).

Importantly, not all adaptation options are physical or technical in nature, with some of the most effective strategies to strengthen the adaptive capacity of producers in the primary industries being 'soft' or socially geared in nature. For example, recent research with beef producers in northern Australia indicated that those with the greatest adaptive capacity had strong social networks (social capital) and high levels of personal education/training, and they regularly utilised computer-based technology (Marshall et al. 2013). That is, effective climate adaptation is more than just physical changes to the operations of primary production; a mix of socio-economic and environmental factors contribute to decisions made by individual primary producers to maintain or enhance their business viability.

Most primary industries appear to have a wide menu of climate adaptation options, but it can be very difficult to identify the most valuable strategy to invest in for individual producers. The uncertainty about the efficacy of adaptation options affects the advice and support offered by agribusiness advisors, government agencies and industry representatives, in terms of what is the most cost-effective and strategic adaptation option that an individual producer and the wider primary industry should pursue. Strategic adaptation options for one producer could be an ineffective option, or even a maladaptive response, for another – even if they are producers in the same industry sector.

Adaptation options for the agricultural sector

1. Integrated data management: spatially referenced climate variables (rainfall, temperature), pasture production, livestock condition, crop yield, input costs, market prices – to inform short-term (e.g. livestock-handling activities) and medium-term (e.g. livestock-carrying capacity) management decisions. Over time, integrated data analysis can inform long-term decisions, such as design of infrastructure (e.g. livestock-handling facilities, location and supply of water points) and grazing systems (e.g. pastures species, breed of livestock). Information analysis can enable informed business agility and operational flexibility.
2. Conservative stocking of livestock: apply a cautious livestock-carrying capacity in response to lower pasture production due to increased temperatures and similar rainfall (increased evapo-transpiration) in most of the central Australia rangelands (note: there may be increased rainfall in the north-west region of the rangelands). This will also enhance land condition.
3. Evolve pasture species: so that the mix of pastures species includes a greater proportion of heat- and drought-tolerant plant species (e.g. the mix may include a proportion of woody perennial shrubs, such as native saltbush).
4. Refine livestock management: select for heat tolerance in livestock breeds, and choose handling facilities that can be used at night. Develop clear trigger points for decisions about de-stocking or re-stocking, and make greater use of telemetry for real-time monitoring of system (e.g. livestock movement, water points).
5. Minimise heat stress in livestock and workers: move livestock-handling activities to cooler periods of the day and increase shade over yards; conduct some outdoor activities at night (this may require installing lights over yards).
6. Storm preparedness: intense tropical storms can cause infrastructure failure (loss of electrical power) or closures (e.g. flooding of roads, reducing deliveries and supplies), so feasible contingencies should be planned in advance (e.g. use mobile generators, choose alternate transport routes and move livestock to 'safe' areas prior to storms).

Tourism sector

Tourism is a major industry and employment sector for central and northern Australia, with much of the sector focused on attracting visitors to enjoy the natural environment (e.g. the Great Barrier Reef, Kakadu National Park, Uluru). In the NT, tourism contributes about 10% of economic activity; in 2010, there were about 1.3 million visitors to the NT who spent over $1.4 billion. However, the number of international visitors to Kakadu, Arnhem Land and the Katherine and Douglas Daly regions has fallen by more than 50% over the past decade, indicating the global competitiveness of the tourism sector. Interestingly, first-time visitors to Australia tend to include a remote destination (e.g. a national park) on their itinerary and stay almost twice as long as other international tourists (Jacobsen 2014).

Climate change is expected to have complex and multiple impacts on Australia's tourism sector (Turton et al. 2009), as illustrated with Kakadu National Park (Box 2). In central and northern Australia, anticipated hotter temperatures and possible intensifying tropical storms are likely to make outdoor activities more uncomfortable – affecting visitor experiences and numbers (duration and frequency of visitation) and the ability to attract and retain staff (high turnover of staff can drain an enterprise of necessary expertise and experience). To offset increasing discomfort, tourism operators may be faced with increased capital and operating costs (e.g. to upgrade the comfort of accommodation, higher energy and water inputs). Intensifying tropical storms may also increase the risk of damage to tourism infrastructure and disruption to visitor holiday arrangements (e.g. flight cancellations), leading to an increase in insurance premiums and the expense of repairs.

Box 2: Climate change impacts on Kakadu National Park, Northern Territory

In a study of five key tourist destinations (Kakadu National Park, the Cairns region, the Blue Mountains, the Barossa Valley and the Victorian Alps) Kakadu was the most affected region from climate change alone (that is, not yet taking into account the effects on the region of changes in tourism due to climate change). It is world-renowned for its native biodiversity, landscapes and Aboriginal cultural heritage. During 2004–05, Kakadu attracted 165,300 visitors, who contributed $58.1 million to the Northern Territory economy. For the traditional owners, Kakadu remains an important place for hunting and gathering bushfood, ceremonies and other cultural activities. Tourism provides the largest number of jobs in the region. Many of the popular tourist sites are accessed via sealed roads year-round, while other sites are seasonally accessible due to flooding of access roads. Kakadu is also a biodiversity hotspot, because it has a large diversity of birds, mammals, reptiles, insects and plants. The northern part of Kakadu comprises, and is surrounded by, a low-lying coastal zone, making it vulnerable to saltwater intrusions from sea level rise and coastal storm surges (72% of the freshwater habitat is vulnerable). Although most people visit Kakadu during the dry season, so are unlikely to experience discomfort or tropical storms, the impact of saltwater flooding into the wetlands during the wet season could negatively affect the quality and appeal of the wetlands the following dry season. Also, some species are likely to be more sensitive to temperature increases, such as the saltwater crocodile, which has temperature-dependent breeding. The spread of feral animals (buffalo, pigs) and weeds (Mimosa sp.) could change as the climate shifts, and mosquito-borne diseases.

Climate change may shorten the tourism season and perhaps narrow the age and health range of visitors. Cyclonic storms, while likely to have little direct impact on tourists as they occur during the wet season (which is the low season for tourism), may damage infrastructure (e.g. tourist accommodation, roads, signage). Flow-on affects may include less biodiversity and therefore lower visitor satisfaction, reducing frequency and duration of visits.

Source: Turton et al. 2009

Much of Australia's tourism sector is comprised of SMEs that typically have lower financial reserves and shorter investment time horizons (1–3 years) than large corporate enterprises. Also, SMEs tend to be less interested or willing to invest in strategies to adapt to threats that may eventuate over the longer term (>10 years). Larger operators are more likely to plan and respond (adapt) to negative climate impacts, as they have greater likelihood of having the resources to act and may also be pushed to demonstrate corporate responsibility (e.g. from shareholders).

As the natural environment is a prominent feature of tourism in central and northern Australia, any impacts on it are likely to be larger for the tourism sector in this part of Australia than in some other places (e.g. urban-based attractions such as theme parks, galleries and museums). Impacts on the natural environment that might directly affect the tourism sector include decline of habitat for iconic native species (e.g. brolgas, saltwater crocodiles), spread of feral animals and weeds, decline in extent and health of wetlands and inland waterholes.

Adaptation options for tourism enterprises

1. Reduce operating costs: do this particularly for energy and water (e.g. take energy-efficiency measures), for example, by deliberately appealing to customer segments that are environmentally conscious, such as by obtaining environmental accreditation (e.g. certified eco-tourism).
2. Prepare contingency plans: have strategies to visit alternate locations, accommodation venues and travel arrangements, so as to minimise disruptions (risks) to the business.
3. Improve liveability: increase the comfort of visitors and workers by providing protective clothing (e.g. hats) and shade; consider changing the timing of activities, such as moving them towards morning and evening tours (travel during the day). The tourism sector is relatively labour-intensive (compared with agriculture and mining), so conditions that affect comfort and wellbeing may have a disproportionate impact on business viability.
4. Link with local efforts for adaptation: co-invest at the local and regional levels, such as for feasible contingency plans (e.g. with other tour operators, other sectors).

Transport systems

A functional transport system is vital to the economy and liveability of central and northern Australia. Remote communities tend to have a narrow range of transport options than the larger population centres (e.g. Alice Springs, Cairns, Darwin). Transport infrastructure and networks are likely to be more frequently and more severely impacted by climate change, with remote communities likely to be most acutely affected (Addison 2013, Beer 2012, Beer et al. 2012, Maru et al. 2012, McGuirk 2011, Memmott et al. 2013, Peterson et al. 2008, Race 2012, Rowan et al. 2014, Sheehan and Symons 2008, Wall et al. 2014).

Impacts on transport systems are likely to increase operating costs for businesses, due to damage, disruption and increased insurance premiums. Impacts are also expected for communities, such as when there are delays and disruptions to daily travel or food supplies (e.g. road closures leading to depleted food supplies, less fresh food and greater food miles, which increases food costs). A summary of the expected impacts of climate change on transport systems is presented in Tables 2 and 3, below.

Table 2: Climate change effect, direct impact and consequences for road infrastructure

Climate change effect	Direct impact on road infrastructure	Consequences for road infrastructure
• Increased temperatures and solar radiation • Increased rainfall • Rising sea levels • Flooding • Bushfires • Salinity effects	• Degradation of bitumen • Loss of water seal causing potholing • Low-lying roads may be submerged • Damage to road foundations as a result of prolonged drought and low rainfall	• Temporary or permanent blocked road access • Interruption to commercial activities that depend on road transport • Increased maintenance costs to increase resilience • Re-routing to avoid climate change–affected roads • Increased risk of liability resulting from road damage • Higher insurance costs

Source: Maddocks et al. (2010, p. 5)

Table 3: Climate change effect, direct impact and consequences for air infrastructure

Climate change effect	Direct impact on air infrastructure	Consequences for air infrastructure
• Increased rainfall and storm events • Increased severity and speed of winds • Increased intensity and frequency of storms • Increased temperature and solar radiation • Bushfires	• Damage to terminals • Expansion of joints, protective cladding, coatings and sealants on aerobridges and other airport infrastructure • Flooding of runways and access roads • Reduced life of asphalt on airport tarmacs • Reduced airlift • Reduced visibility	• Disruption to airline operations • Increased maintenance and replacements costs • Need to construct longer runways to compensate for reduced airlift • Need for ground-cooling mechanisms • Increased risk of liability resulting from air infrastructure damage • Higher insurance costs

Source: Maddocks et al. (2010, p. 18)

Adaptation options for transport sector

Adaptation research for the transport sector is still in its infancy, and there is a large gap between generic suggestions for adaptation and more technological solutions. Some adaptation options are:

1. Infrastructure owners and operators should conduct comprehensive assessment of climate change risks
2. Transport infrastructure development and maintenance should be reviewed to ensure that the infrastructure can withstand the effects of climate change – now and in the future
3. Transport operators should ensure equipment and vehicles provide adequate passenger and staff comfort and safety in future climates
4. Use multiple communications methods (e.g. traditional and social media) to advise of infrastructure damage, service interruptions and delays potentially caused by more extreme weather.

Conclusion

Key messages:

- Pathways for effective adaptation are not necessarily clear or straightforward and are likely to include some risk and uncertainty.
- Enterprises' planning should incorporate this risk and uncertainty.
- Adaptation needs to be seen as an ongoing process, so enterprises should create strategies for regularly reviewing their performance and strategic direction and develop strategies for change as necessary (adaptive management).
- Individual enterprises should support sector-specific initiatives that scan and evaluate the drivers of change for people and enterprises in remote Australia (including fluctuating economic circumstances, operating costs, demographic movements, climate change) with analyses synthesised for stakeholders.
- Communities should establish and support processes that help enterprise managers exchange information, review their current performance, benchmark with peers and take active steps to build the assets (capitals) that underpin their livelihoods and enhance resilience.

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The Smith Family — everyone's family

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