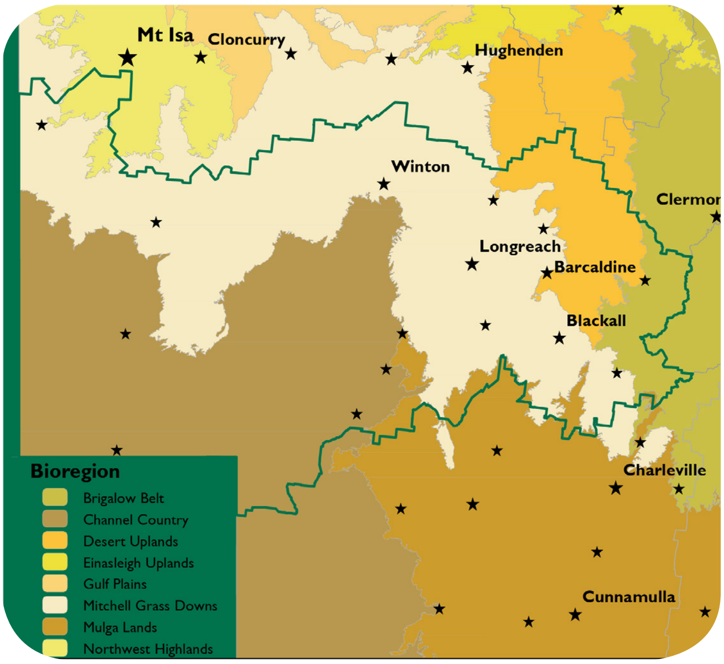
Climate Impact and Adaptation Series

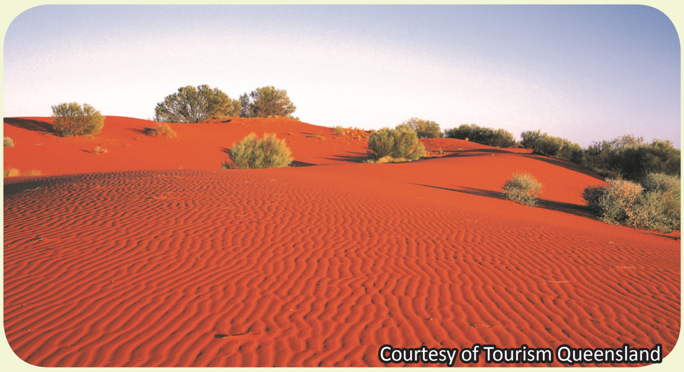
Australian Stockman Hall of Fame, Longreach, Queensland

Courtesy of Tourism Queensland

Impacts and adaptation strategies for a variable and changing climate in the CENTRAL WEST QUEENSLAND REGION



This summary describes the likely impacts of a variable and changing climate on the major primary industries of the Central West Queensland (CWQ) region, most notably for grazing, and the potential adaptation strategies which can be implemented to minimise climate risks.



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Regional Profile

The Central West Queensland (CWQ) region covers a large land-based area of 509,933 km^2. The major centres in CWQ include Longreach, Barcaldine, Blackall and Winton. The climate in this region is classified as semi-arid or arid, with long hot summers and mild to cold winters. At Longreach, the average annual minimum and maximum temperatures are 15.5°C and 31.2°C, and at Birdsville they are 15.7°C and 30.4°C respectively. The rainfall is low and highly variable from year-to-year with an average historical annual rainfall of 430 mm in Longreach (1893-2015) and 166 mm in Birdsville (1892-2015).

The region forms part of the Lake Eyre catchment and includes the Mitchell Grass Downs, Channel Country and Desert Uplands biogeographic regions. Extensive Mitchell Grass Downs dominate the north and central parts. The vast floodplains of the Channel Country are a major feature of the region.

Vegetation clearing and planting of improved pastures is mainly a feature of the more eastern areas of the region. The region incorporates the nationally significant rangelands and biodiversity hotspot, the Desert Uplands.

Major Primary Industries

Grazing on native pastures is the major primary industry in the region. However, the CWQ region has significant growth potential in existing and new industries such as clean energy (e.g. geothermal energy, solar voltaic and solar thermal production), carbon farming, organic agriculture, agribusiness, ecotourism and cultural tourism and mining industries. The gross value production (GVP) in 2014-15 of agricultural commodities in the Desert Channels region was $672 M or 5.6% of the state total GVP for agricultural commodities ($11.9 B, ABS 2016a).

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Climate Trends and Projections

Historical changes in the key climate variables relevant to agricultural production including temperature, evaporation, rainfall, hot days, duration of warm periods and length of growing season are summarised in Table 1. Table 2 provides information on the historical means for the key variables and the projected changes for 2030.

Table 1: Historical Climate Trends (Interpreted and summarised from BoM 2016).

Variable	*Trend Since (year)*	*Change per decade*		
		Annual	Summer	Winter
Maximum Temperature (°C)	1950	+0.5 (north) to +0.30 (south)	-0.5 (north-east) to +0.4 (south)	+0.2 to +0.30
Minimum Temperature (°C)	1950	+0.15 to +0.30	+0.15 to +0.40 (west)	-0.05 (west) to +0.40 (east)
Mean Temperature (°C)	1950	+0.10 (east) to +0.30 (west)	+0.05 (east) to +0.40 (west)	+0.10 (west) to +0.30 (east)
Pan Evaporation (mm)	1970	-5 (south) to +10	-2.5 to +5	-2.5 to +2.5 (east)
Rainfall (mm)	1950	-30 (east) to +5 (west)	-15 (east) to +10 (west)	-5 to 0
Number of Hot Days	1970	0 (east) to +7.5 (west) days		
Cold Spell Duration	1970	0 to -3.0 days		
Growing Season Length	1970	0 (west) to +4 (east)days		

NSC - No significant change | Unknown Growing Season Length | Pan Evaporation = the amount of water evaporated from an open pan per day **| Hot Days** = annual count of days with maximum temperature >35°C **| Cold Spell Duration** = Annual count of nights with at least 4 consecutive nights when daily minimum temperature < 10th percentile **| Growing Season Length** = Annual (01 July to 30 June) count between first span of 6 or more days with daily mean temperature >15°C and first span of 6 or more days with daily mean temperature <15°C.

Additional climate projections for Queensland

- Global atmospheric **carbon dioxide concentration** (CO_2) is rapidly increasing. In March 2015, the monthly global average carbon dioxide concentration exceeded 400 ppm, well above the natural historical range from the last 800,000 years of 172 ppm to 300 ppm (CSIRO and BoM 2012a). Global CO_2 levels are projected to reach 540 ppm by 2050 and 936 ppm by 2100 (RCP8.5 high emissions) (IPCC 2013).
- Queensland can expect **longer dry periods** interrupted by **more intense rainfall** events. The frequency of both extreme El Niño and extreme La Niña events are likely to nearly double in response to greenhouse warming (Cai et al. 2014, 2015).
- The amount of time spent in **extreme drought** will increase in the highest emission scenarios (CSIRO and BoM 2015).

Table 2: Historical means for the period 1986-2005 and climate projections for 2030 (2020-2039) under the RCP8.5 emissions scenario relative to the model base period of 1986-2005.

Variable		Annual	Summer	Autumn	Winter	Spring
Temperature (°C)	Historical mean	**23.9**	**30.4**	**24.0**	**16.2**	**25.2**
	Projections for 2030	**+1** **+0.4 to +1.7**	**+1** **+0.4 to +2.0**	**+1** **0.0 to +1.7**	**+1** **+0.5 to +2.0**	**+1** **+0.5 to +1.8**
Rainfall (mm)	Historical mean	**326**	**161**	**72**	**36**	**57**
	Projections for 2030	**-5%** **-20% to +10%**	**0%** **-17% to +15%**	**-6%** **-35% to +35%**	**-11%** **-50% to +19%**	**-7%** **-32% to +24%**
Potential Evaporation (mm)	Historical mean	**1789**	**Historical means from 1986-2005** **Projections for 2030 (20-year period centred on 2030)** **Best Estimate** **Range of Change (5th - 95th)** *For more information, including projections for 2050 and 2070, please refer to* *http://www.climatechangeinaustralia.gov.au/en/* *or Watterson et al. 2015.*			
	Projections for 2030	**+3%** **0% to +5%**				
Relative Humidity	Projections for 2030	**-2%** **-6% to +7%**				
Wind Speed	Projections for 2030	**+2%** **-1% to +12%**				

Lake Bindegolly Sunset, Thargomindah, Outback

Courtesy of Tourism Queensland

Impacts of a variable and changing climate in the Central West Queensland Region

Whilst a more variable and changing climate will impact the key primary industries in the region, the population and natural environment will also feel the effects.

Human Well-Being

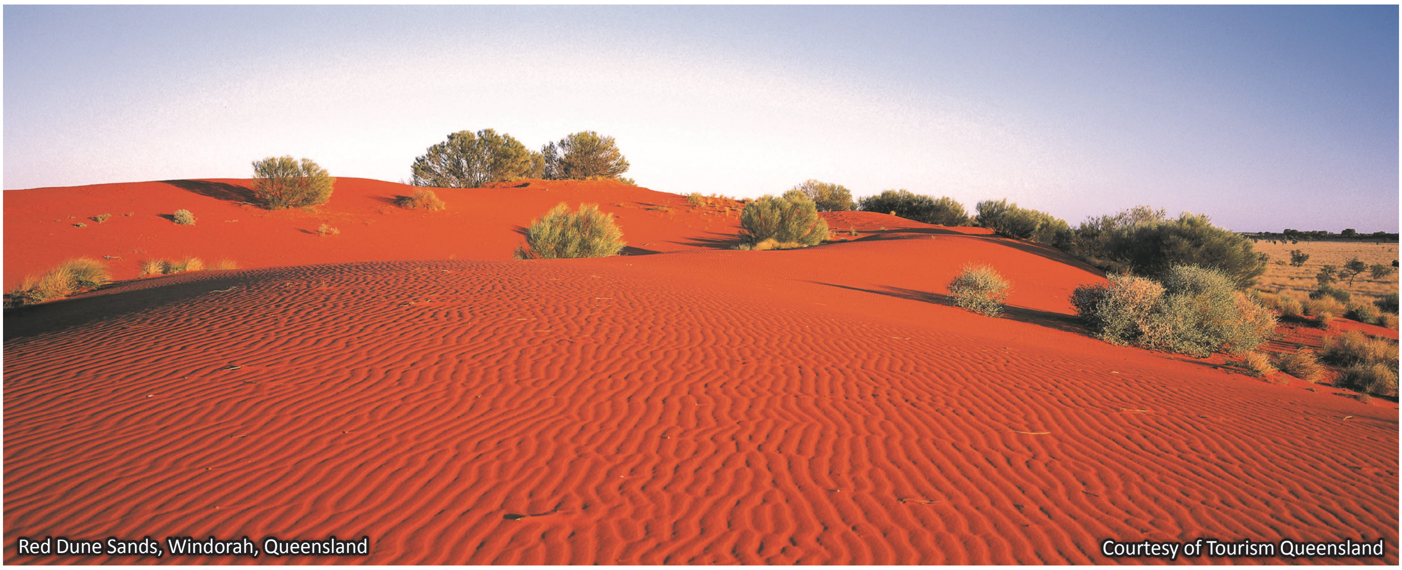
The variable and changing climate of the region will have both direct and indirect impacts on health, location and living arrangements. There are a range of adaptations and NRM planning processes that will increase both community and individual resilience (Addison et al. 2013, Maru et al. 2014).

Likely Impacts	*Potential Strategies for Adaptation*
Extremes of weather and climate (drought, flood, cyclones, heatwaves etc.) on human well-being (TCI 2011, Hughes and McMichael 2011, NCCARF 2011).	
• Direct effects of extremes of weather include injury and death during floods and cyclones, heat stress during heatwaves, and a reduction of cold-related deaths. • Indirect effects of extremes of weather could include an increase in the: o number of bushfires due to extreme heat and aridity; o risk of mosquito-borne, water-borne and food-borne diseases; o number of infectious and contagious diseases with an increase in the number of injuries; and o incidence of disease from microbial food poisoning with an increase in temperature. • Increases in extreme events can lead to increased pressure on health systems, including an increased demand for health professionals, ambulance and hospital workers. • Rural, regional and remote communities are particularly exposed in a changing climate compounding the chronic difficulties and inequities that already face many communities. Many parts of the country already find it hard to recruit dedicated health care and social service professionals. A changing climate will also increase the demand for social support and mental health services, and, at the same time, make it harder to recruit and retain staff in affected areas. • Severe weather events can destroy places and disrupt livelihoods and communities leading to long-term mental health effects. According to Bonanno et al. (2010), a significant part of the community, as many as one in five, will suffer the de-bilitating effects of extreme stress, emotional injury and de-spair. • The emotional and psychological toll of disasters can linger for months, even years, affecting whole families, the capacity for people to work and the wellbeing of the community. • Evidence is beginning to emerge that drought and heatwaves lead to higher rates (by about 8%) of self-harm and suicide (Doherty and Clayton 2011). • Those most vulnerable to extremes of weather and climate include children, the elderly, Indigenous communities and people with pre-existing diseases and disabilities.	• Adapt existing buildings and plan any new infrastructure to take into account climate impacts and extreme events such as flooding. • Implement control measures to reduce the impact of bushfires, heatwaves, mosquitoes, water-borne and food-borne diseases, infectious and contagious diseases and injuries. • Continue to obtain information on the expected effects of a changing climate. • Develop agreements with your workers on how to manage extreme hot days, or identify periods of time where weather and climate affect working conditions. • Develop social support networks. • Contact your local council or relevant government department to find information on social and health support programs.

Biodiversity

The Mitchell Grass Downs (MGD), Channel Country (CC) and Desert Uplands (DU) bioregions are present within the Central West Queensland region. The MGD has large, treeless areas in which plant and animal diversity is low. Most of the species in this bioregion are well adapted to high summer temperatures, low rainfall and frequent droughts, however, a hotter drier climate may shift many species beyond their limits causing biodiversity decline. There has been a recent decline in Mitchell grass (*Astrebla*) due to extended drought. The CC is the hottest and driest bioregion in Queensland. Most of the species in these regions are well adapted to high summer temperatures, low rainfall and frequent drought however, a hotter and drier climate may push many species beyond their limits causing declines of many species. Most of the plants and animals found in the CC are widespread in central Australia. Very dry, episodic flooding of the wide alluvial plains attracts many thousands and sometimes millions of waterbirds from elsewhere in Australia to breed. The DU is dominated by a large sand sheet, has fewer endemic species than the adjoining bioregions and lacks large numbers of species with vulnerability to a changing climate. In general, the degree of ecological change caused by climate change is more likely to be greater in the plant and reptile biological groups than that of mammals or amphibians (Williams et al. 2014). Other impacts and adaptations regarding climate change and biodiversity can be found in Parvey et al. (2014).

Likely Impacts	***Potential Strategies for Adaptation***
Extremes of weather and climate (drought, flood, cyclones, heatwaves etc.) on Biodiversity (Low 2011).	
Impacts in the Mitchell Grass Downs • Mitchell grasses are very well adapted to a hot climate and severe drought, however, widespread die-offs can occur during severe droughts with serious implications for wildlife. **Impacts in the Channel Country** • Heatwaves that follow drought induced die-offs of trees could have catastrophic consequences for wildlife, including the loss of some species in the bioregion. • An increase in camel numbers with drought driving populations eastwards will have a marked impact on vegetation. • Higher numbers of feral animals, such as goats and camels, could seriously threaten rare and endemic shrubs in the region. • Fish, turtles, crustaceans and aquatic insects survive the dry years in deep waterholes, which will face several threats with a changing climate. • Reduced rainfall will reduce breeding success of waterbirds. **Impacts in the Desert Uplands** • Buffel grass invasion is of particular concern within the DU. Invasion of this species may displace groundcover plants and increase the risk of intensive fires. • As higher temperatures increase heat stress for cattle and sheep, more producers may farm goats or encourage feral goats. Higher goat numbers could seriously threaten rare and endemic shrubs in the region.	• Develop management guidelines to maximise Mitchell grass survival during drought. • Conserve all permanent waterholes and deep waterholes as a drought refugia and a source of productivity for bird breeding events and to prevent desiccation during droughts. • Actively control prickly acacia, mesquite and parkinsonia. • Manage weeds and invasive pasture grasses, such as buffel grass, to prevent spread into conservation areas and the habitats of rare species. • Control camel numbers in western Queensland before their numbers increase to highly damaging numbers. • Control goats to protect rare plants. • Keep old sheds and shade-producing structures in conservation areas to reduce the impacts of heatwaves. • Reduce grazing around lakes to protect habitat for ground animals and nesting birds.



Red Dune Sands, Windorah, Queensland

Courtesy of Tourism Queensland

Grazing Industry

Cattle, sheep and wool are important primary industries in Queensland. In 2014-15 their combined GVP was $5.2 B (44% of the total Queensland GVP of agricultural commodities, ABS 2016a) which is made up of the production and marketing of beef cattle ($5.1 B), sheep and lambs ($66.4 M) and wool ($66.2 M).

Cattle numbers in Desert Channels region were 1.4 M in 2014-15 which was 12% of the total cattle numbers for Queensland (ABS 2016b). In 2014-15 the GVP for cattle, sheep and wool for Desert Channels was $669 M (ABS 2016a) or 6% of state and 99% of the value of Desert Channels agricultural commodities.

The majority of beef, sheep and wool production come from native pastures which cover about 85% of Queensland. The main pasture communities in CWQ are Mitchell grass (47% of region), Spinifex (24%), Mulga pastures (11%) and Channel pastures (10%) (Tothill and Gillies 1992). The soil fertility is average to very good and growth of pastures is usually limited by inadequate rainfall.

Pastoralism in the region will be affected by climate change at both the enterprise scale and regionally. The following paragraphs present adaptation responses that may result in a more resilient regional grazing system (Bastin et al. 2014).

Case Study - Impacts in the Central West Queensland Region

The impacts of a changing climate are complex because of interacting and opposing forces operating within the biophysical system (McKeon et al. 2009). The process of assessing the impacts of a changing climate often involves deriving the 'best estimate' projections of future climate, simulating the grass growth and grazing strategies under changing climate conditions using well-calibrated grass/grazing system models, and combing the simulation output with successful producer and researcher experience in regional Queensland. A good example of a proven process of assessing the impacts, adaptive responses, risks and vulnerability associated with a changing climate is the 'risk matrix' approach (http://www.longpaddock.qld.gov.au/products/matrix/index.html, Cobon et al. 2009, 2016) which is customised for primary industries and is based on the Australian and New Zealand Risk Management Standards (Standards Australia 2004).

There are many gaps in knowledge, for example, the future climate projections are uncertain (particularly for rainfall) and in some cases the projected changes in rainfall and temperature appear smaller than to year-to-year variability. Nonetheless, a risk-averse approach to grazing management based on the 'best estimate' projections in combination with short-term management of climate variability is likely to take advantage of any opportunities and reduce the risk of adverse impacts. There are major known uncertainties in identifying the impacts of a changing climate in the grazing industry in relation to:

1) carbon dioxide and temperature effects on pasture growth, pasture quality, nutrient cycling and competition between grass, trees and scrubs;

2) the future role of woody plants including the effects of fire, climatic extremes and management of stored carbon (see McKeon et al. 2009 for more detail); and

3) carbon dioxide effects on diet quality and liveweight gain of cattle (Stokes 2011).

Modelling analyses of native pasture grasses (C4 tropical and sub-tropical grasses) for the Central West Queensland region were undertaken for the Winton, Jundah and Blackall areas (Cobon et al. 2012 *unpublished data*, Table 3). The average impacts of future climate scenarios from the three locations were examined for pasture growth, pasture quality (% nitrogen of growth), liveweight gain of cattle (LWG kg/ha), frequency of burning and frequency of green pasture growing days (GPGD). The baseline climate period was 1960-1990 and carbon dioxide concentration was 350 ppm. Improvements in water and nitrogen use efficiency resulting from doubling of carbon dioxide levels were accounted for in the modelling as per Stokes 2011. The impacts were either positive or negative, and as a guide were also classified as being of either High (>20% change from baseline, H), Medium (5%-20%, M) or of little or no impact (5 to -5%, LC). The soils were of average fertility (20 kgN/ha) and the density of trees (3.92 m^2/ha tree basal area) resembled that of open parkland.

Table 3: Matrix showing potential opportunities and risks associated with the average impacts of future climate scenarios from Winton, Jundah and Blackall for modelled pasture growth (kg/ha), pasture quality (% nitrogen in growth), liveweight gain of cattle (LWG kg/ha), frequency of burning and green pasture growing days (GPGD) (Source: Cobon et al. 2012 *unpublished data*).

Future climate	**Growth**	**Quality**	**LWG**	**Burning**	**GPGD**
+3°C	-M	LC	-M	-M	LC
2xCO$_2$	+H	-M	+H	+H	LC
+3°C, 2xCO$_2$	+H	-M	+M	+H	LC
+3°C, 2xCO$_2$, +10% rainfall	+H	-M	+H	+H	+M
+3°C, 2xCO$_2$, -10% rainfall	LC	LC	-M	LC	LC

H= high, M= medium, LC = little change
Shading indicates positive and negative impacts
Positive impacts showing either High or Medium opportunities
Negative impacts showing either High or Medium risks

This study found that:

- positive impacts from doubled carbon dioxide associated with increased pasture growth, liveweight gain and higher frequency of burning (providing more opportunity for prescribed burning to control weeds, regrowth and dry vegetation). These impacts are likely to outweigh the disadvantages caused by a 3°C rise in temperature; and
- a reduction in the quality of native pasture grasses from doubled carbon dioxide.
- The combined effects of a 3°C rise in temperature, doubled carbon dioxide and 10% more rainfall is likely to increase pasture growth, liveweight gain, burning frequency and green pasture growing days.
- The combined effects of a 3°C rise in temperature, doubled carbon dioxide and 10% less rainfall are likely to reduce liveweight gain

Cattle, Birdsville, Queensland

Courtesy of Tourism Queensland

Opportunities for the Grazing Industry

- Increased production of biomass will result from rising carbon dioxide levels as plants use water, nutrients and light resources more efficiently (Nowak et al. 2004).
- Improved plant water use efficiency will allow pastures to produce more biomass using the same amount of water (Stokes et al. 2011).
- Elevated carbon dioxide will increase the efficiency of water and nitrogen use by the pastures (Stokes et al. 2008), but this increase in growth of pastures is likely to be offset by a reduction in overall pasture quality (lower protein and lower digestibility) (Stokes et al. 2011).

Case Study – Impacts on Mitchell Grass Pastures

Similar to the study above, modelling studies in Mitchell grass pastures showed a 3°C rise in temperature is likely to result in a reduction in forage production of 7%. This study also found that the combined effects of a 3°C rise in temperature and doubling carbon dioxide are likely to result in higher forage production (11%), more green pasture days (10%), higher carrying capacity (11%) and wool production (15%) (Cobon and McKeon 2003). These benefits are likely to be boosted by higher rainfall but more than offset by a 10% reduction in rainfall (McKeon et al. 2009).

Case Study - Using past records to help understand future impacts

Projected changes in rainfall of the order of ± 10% appear low compared to year-to-year variability, or even in the difference between the average of El Niño and La Niña years (-20% and 20% rainfall respectively in eastern Australia) (McKeon et al. 2004). However, when the historical range of variation is analysed for a 25-year (climate change time-scale) moving average then a change in rainfall of ±10% is relatively high. For example, the 25-year moving average of rainfall at Longreach has fluctuated between -14 and +19% compared with the long-term average since 1881 (Figure 1). The extended periods of lower rainfall (mid 1910s to mid-1920s, 1930s to 1950s, 1980s to 2000s) have been associated with extensive droughts, degradation events, reduced profits and greater debt and human hardship. It is likely that under drier climatic conditions these circumstances will become more familiar with shorter and less frequent recovery periods.

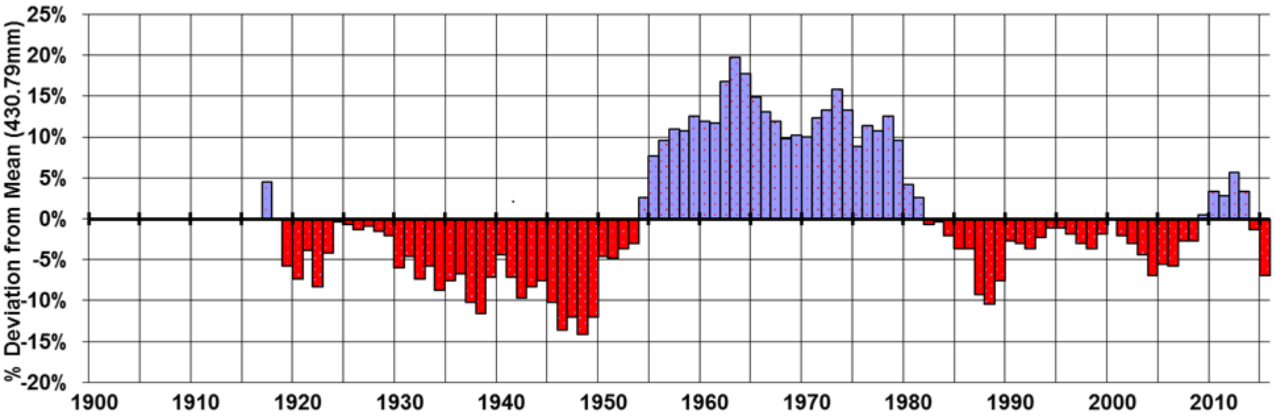


Figure 1: 25-year moving average rainfall (12 months, April in year 1 to March in year 2) at Longreach, Queensland (Source: Clewett et al. 2003).

Likely Impacts	*Potential Strategies for Adaptation*
Changed rainfall patterns	
• Longer and more frequent droughts associated with more extremes of climate, fewer recovery events, changes in decadal rainfall variability and ENSO will decrease forage production, surface cover, livestock carrying capacity, animal production and cause major changes in plant and animal species composition (Cobon et al. 2009, McKeon et al. 2009). • Erosion risks are likely to increase due to greater year-to-year variability in rainfall. • Rising tree densities and declining pasture condition raise the sensitivity of pastures to climate induced water stress.	• Manage perennial grass cover using 'best management practice' for the pasture community. For example, in Mitchell Grasslands set the annual stocking rate at the end of each growing season to utilise a safe proportion (10-20%) of available pasture and make adjustments accordingly for beneficial or spoiling rainfall in winter or spring, early breaks to the dry season, locust plagues and forecasts of rainfall for the coming summer. • Monitor trends in rainfall. • Use climate indicators to make early adjustments in animal numbers. • Manage non-domestic grazing pressure. • Use wet season spelling of pastures. • Manage invasive plant species. • Maintain refugia especially around wetlands (Cobon et al. 2009). • Manage climate variability and change by using forecasts of rainfall (and temperature) in decision making. • Manage intra-seasonal (MJO, 30-60 day cycle), inter-annual (ENSO, 2-7 year cycle) and decadal rainfall variability (PDO/IPO, 20-30 year cycle) using indicators of MJO, ENSO (SOI, SST) and PDO, and climate analysis tools to adjust animal numbers commensurate with past and projected climate trends, such as: ○ LongPaddock (http://www.longpaddock.qld.gov.au); ○ AussieGRASS (http://www.longpaddock.qld.gov.au/about/researchprojects/aussiegrass/index.html); ○ ClimateArm http://www.armonline.com.au/ClimateArm ○ Bureau of Meteorology Website http://www.bom.gov.au, http://reg.bom.gov.au/climate/mjo; • Use supplementary feeding, early weaning and culling animals at risk to reduce mortalities in dry conditions (Fordyce et al. 1990). • Increase or maintain *Bos indicus* content in herd to increase cattle tick and buffalo fly resistance/resilience. • Monitor spread of pests, weeds and disease. • Introduce more species of dung fauna (control of buffalo fly larvae). • Promote greater use of traps and baits (buffalo and sheep blowflies) and vaccines (cattle ticks and worms). • Use fire to control woody thickening.

Likely Impacts	*Potential Strategies for Adaptation*
Increased temperatures	
• Warming will be greatest toward the interior of the continent away from the moderating influence of the ocean. Each 1°C increase in temperature will cause a warming that would be roughly equivalent to moving about 145 km (or about 2° in latitude) closer to the equator (Stokes et al. 2011). For example, Longreach under warming of 3°C is likely to receive temperatures currently experienced north of Georgetown (Figure 2). • Livestock will be exposed to a greater risk of heat stress. They are unlikely to travel as far to water which concentrates grazing pressure and increases the risk of adverse pasture composition changes and soil degradation (Howden et al. 2008). • Increased day time temperatures increases water turn-over and evaporative heat loss resulting in reduced rate of passage and forage intake in livestock (Daly 1984). • Increased night time temperatures can reduce recovery time of livestock and increase the effects of heat stress during the day. • Warmer conditions favour vectors and the spread of animal disease (White et al. 2003). • Pastures could cure earlier under warmer climates shifting the timing of fires to earlier in the season. • Warmer drier conditions with higher frequency of storms could increase the risk of wildfires.	• Arrange water points to reduce distance to water and even out grazing pressure. • Select the time of mating to optimise nutritional requirements and reduce the risk of mortality in new-borns. • Select cattle lines with effective thermoregulatory controls, efficient feed conversion and lighter coat colour (Finch et al. 1984, King 1983). • Proactively control disease by targeting known sources of disease and vectors (Sutherst 1990). • Maintain high standards of animal welfare to build domestic and export meat and fibre markets (Mott and Edwards 1992). • Incorporate greater use of prescribed burning to reduce the risk of wildfires and control woody thickening. • Rotate paddocks of heavier grazing for use as fire breaks. • Maintain or improve quarantine capabilities, monitoring programs and commitment to identification and management of pests, disease and weed threats. • Develop species resistant to pests and disease. • Use area-wide improved management practices.

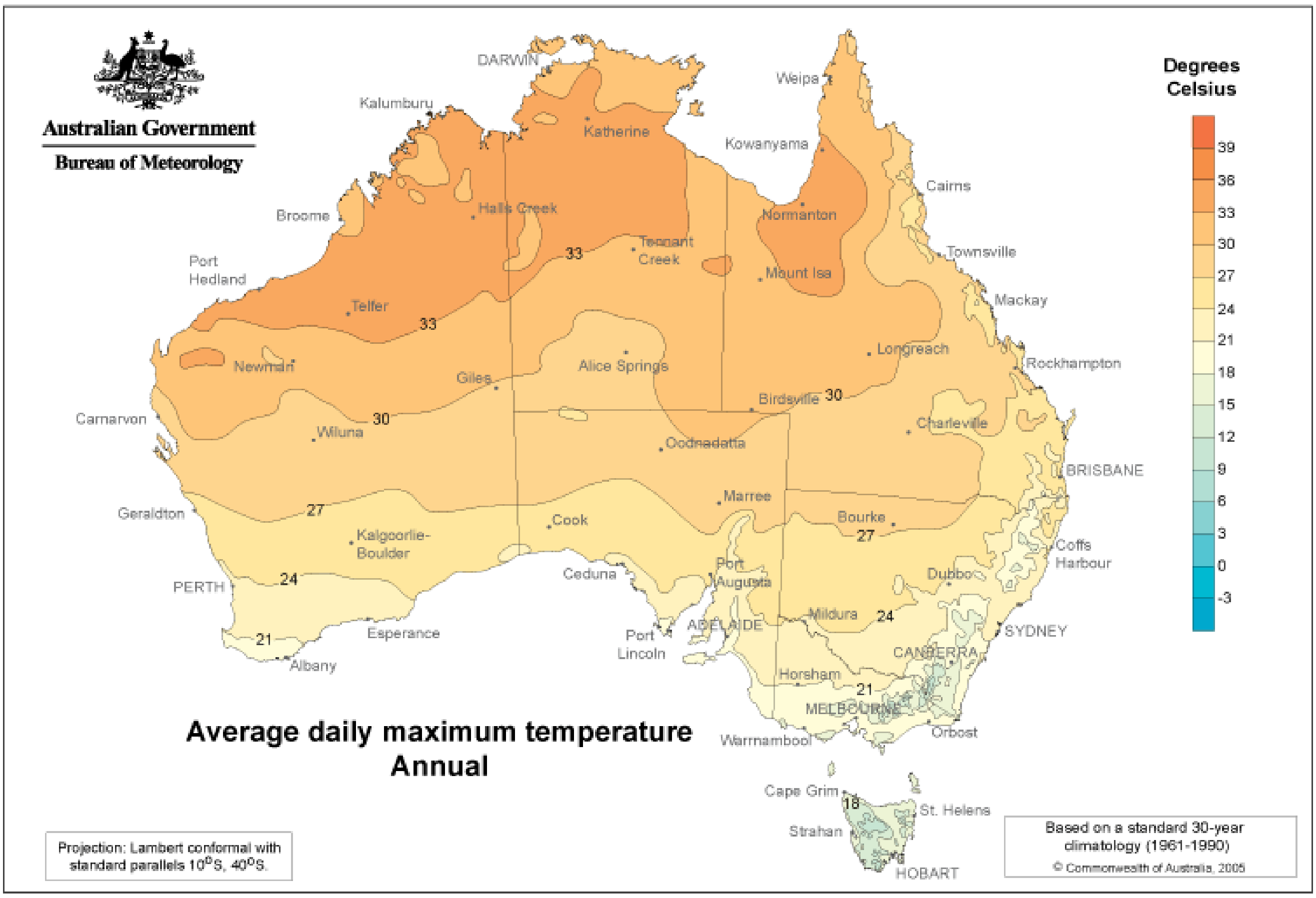


Figure 2: Annual average temperature in Australia (Source: Bureau of Meteorology). One degree of warming is roughly equivalent to moving 145 km toward the equator.

Likely Impacts	*Potential Strategies for Adaptation*
Increased temperature, higher carbon dioxide concentration and changed rainfall	
• Pastures growing under a climate characterised by consistent water stress appear to benefit most from increased plant water use efficiency under elevated carbon dioxide. • The fertilisation effects of doubled carbon dioxide (700 ppm) were found to offset declines in forage production under 2°C warming and a 7% decline in rainfall (Webb et al. 2011). • At Boulia, forage production increased by 30% under a warmer (2°C) drier (-7% rainfall) climate with doubled carbon dioxide (700 ppm) (Webb et al. 2011). The benefits of elevated carbon dioxide are likely to be highest in moderately dry climates. • The combined effects of elevated carbon dioxide (650 ppm), higher temperature (3°C) and lower rainfall (10%) resulted in 10-20% lower forage production (McKeon et al. 2009). In this study increased temperature and declining rainfall outweigh the conservatively represented benefits of increasing carbon dioxide. • Rising carbon dioxide will result in a reduction in overall pasture quality (lower protein and lower digestibility) (Stokes et al 2011).	• Maintain land in good condition to reduce potential declines in forage production under a warmer drier climate. • To compensate for declining forage quality, increase the use of supplements (N, P and energy) and rumen modifiers. • Destock earlier in the season to make greater use of feedlots to finish livestock. • Explore alternative land use in marginal areas. • Apply safe carrying capacity of ~10-15% utilisation of average long-term annual pasture growth. • Undertake risk assessments to evaluate needs and opportunities for changing species, management of land and land use. • Introduce pasture legumes to improve nitrogen status.
More intense storms	
• Rainfall intensity is expected to increase as temperature and moisture content of the atmosphere increase. • A 1°C increase in temperature may result in an increase in rainfall intensity of 3-10% (SAG 2010). • More intense storms are likely to increase runoff, reduce infiltration, reduce soil moisture levels and pasture growth, and increase the risk of soil erosion.	• Maintain pasture cover for optimal infiltration of rainfall. • Adjust livestock numbers to maintain good coverage of perennial pastures during the storm season.
Higher temperature humidity index (combination of maximum temperature and dewpoint temperature)	
• Temperature humidity index (THI) is an indicator of heat stress. Heat stress in beef cattle is significant at a THI of over 80. Frequency of days per year above this level is shown in Figure 3 for historical and projected climate. • Rising temperature by 2.7°C increases the occurrence of heat stress by about 30% points (Howden et al. 1999). • Heat stress reduces liveweight gain and reproductive performance in beef cattle, and increases mortality rates (see Howden et al. 1999). • Heat stress reduces the development of secondary wool follicles in sheep, reducing lifetime wool production in sheep (Hopkins et al. 1978).	• Select cattle lines with effective thermoregulatory controls, efficient feed conversion and lighter coat colour (Finch et al. 1984, King 1983).

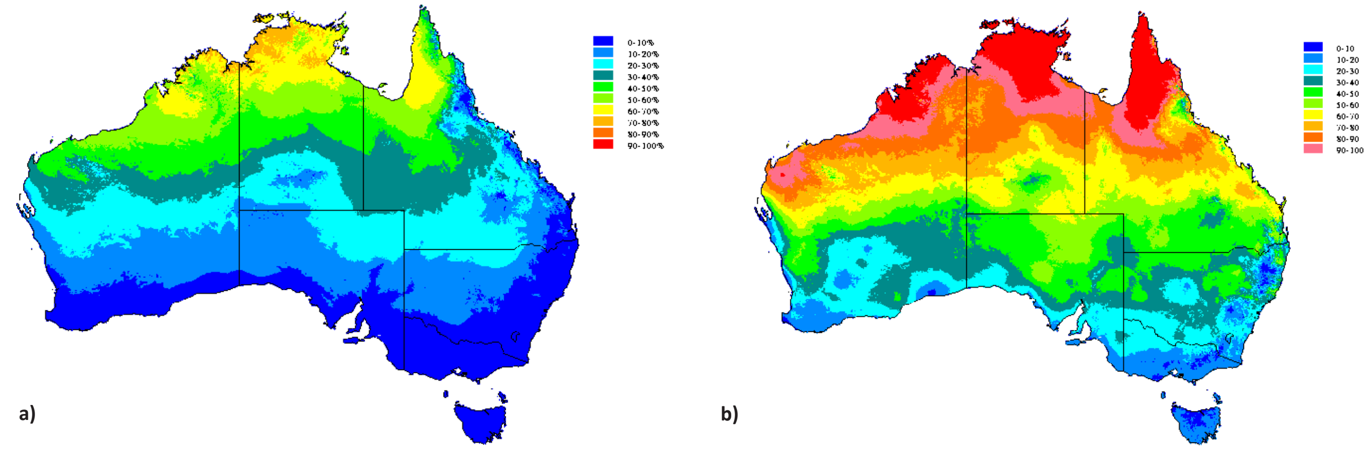


Figure 3: Frequency of days per year that the THI>80 for a) 1957-97 and b) a future climate scenario of +2.7°C. Thermal stress is significant in beef cattle when the THI exceeds 80 (Source: Howden et al. 1999).

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More Information

For more information, including projections for 2050 and 2070, please refer to *http://www.climatechangeinaustralia.gov.au/en/* *or Watterson et al. 2015.*

For more information on the varying and changing climate please see the Queensland Government and The Long Paddock websites at *http://www.qld.gov.au/environment/climate/climate-change/* *and* *http://www.longpaddock.qld.gov.au*, *in particular:*

- **The Climate Change Risk Management Matrix -** *http://www.longpaddock.qld.gov.au/products/matrix/index.html*
- **Queensland Coastal Hazard Area Maps -** *http://ehp.qld.gov.au/coastal/management/coastal_plan_maps.php#map_layers*

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Acronyms
APSIM, Agriculture Production Simulation Model
ENSO, El Niño Southern Oscillation
IPO, Interdecadal Pacific Oscillation
GVP, Gross Value of Production
MJO, Madden Julian Oscillation or 40 day wave
PDO, Pacific Decadal Oscillation
SOI, Southern Oscillation Index
SST, Sea Surface Temperature

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