Four wheel driving, Wangrah Farm, Tenterfield, Southern Downs

Courtesy of Tourism Queensland

Impacts and adaptation strategies for a variable and changing climate in the **EASTERN DOWNS REGION**

This summary describes the likely impacts of a variable and changing climate on the major primary industries of the Eastern Downs (ED) region including grazing, dairy, cropping and horticulture, and the potential adaptation strategies, which can be implemented to minimise climate risks.

Courtesy of Tourism Queensland

Regional Profile

The Eastern Downs (ED) region is located at the headwaters of the Murray-Darling Basin in southern Queensland, covers an area of 24,453 km^2 and includes the towns of Toowoomba, Dalby and Stanthorpe. Most of the region sits in the sub-tropical and temperate climatic zone, with hot summers and cool winters. The climate is generally cooler than the rest of the state. Temperatures are from an annual average minimum of 11.5°C to an annual average maximum of 22.5°C in Toowoomba and 8.7°C to 21.4°C in Stanthorpe. Rainfall in the ED is highly seasonal (summer dominant) and irregular with an average historical annual rainfall of 949 mm in Toowoomba (1887-2015) and 764 mm in Stanthorpe (1873-2015). The region is one of the most productive agricultural areas in Australia.

Major Primary Industries

The major agricultural industries in the region are cropping (wheat, sorghum, barley and cotton), horticulture, and grazing, as well as related activities such as feed lots, abattoirs and processing plants. The pastoral area is known as a major sheep, cattle and dairying area. The gross value production (GVP) in 2014-15 of agricultural commodities in the Condamine region was $1.3 B or 11% of the state total GVP for agricultural commodities ($11.9 B, ABS 2016a).

Courtesy of Tourism Queensland

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	+0.15 to +0.40	+0.10 to +0.15	+0.15 to +0.40
Minimum Temperature (°C)	1950	+0.10 to +0.30 (south)	+0.05 to +0.30	+0.10 to +0.30
Mean Temperature (°C)	1950	+0.15 to +0.30	+0.15 to +0.20	+0.15 to +0.30
Pan Evaporation (mm)	1970	-5 to +2.5	-2.5 to +2.5	-2.5 to 0
Rainfall (mm)	1950	-30 to 5	-10 to NSC	-10 to 0
Number of Hot Days	1970	+2.5 days		
Cold Spell Duration	1970	+1.5 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

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	**19.4**	**25.4**	**19.8**	**12.4**	**20.0**
	Projections for 2030	**+1** **+0.5 to +1.6**	**+1** **+0.4 to +1.8**	**+1** **+0.1 to +1.6**	**+1** **+0.6 to +1.7**	**+1** **+0.5 to +1.8**
Rainfall (mm)	Historical means	**614**	**246**	**132**	**86**	**151**
	Projections for 2030	**-5%** **-20% to +7%**	**0%** **-16% to +21%**	**-3%** **-25% to +14%**	**-7%** **-40% to +15%**	**-5%** **-33% to +14%**
Potential Evaporation (mm)	Historical mean	**1539**				
	Projections for 2030	**+4%** **+1% to +7%**				
Relative Humidity	Projections for 2030	**-2%** **-4% to +4%**				
Wind Speed	Projections for 2030	**+1%** **-1% to +37%**				

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 Ekström et al. 2015.

Mural – Old Butter Factory, Millmerran, Queensland

Courtesy of Tourism Queensland

Impacts of a variable and changing climate in the Eastern Downs 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 (Marshall 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 2011a)	
• 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.

Farmstay, Gordon Country, Southern Downs Courtesy of Tourism Queensland

Biodiversity

The Brigalow Belt (BB) and New England Tablelands (NET) bioregions are present within the Eastern Downs region. The BB is the largest bioregion in Queensland and is very rich in species, including large numbers of plants and animals with small ranges. This bioregion has endemic and near-endemic eucalypt, wattle and invertebrate species. The outstanding feature of the NET is the Granite Belt, which is an elevated rocky plateau that has long served as a refuge for plants and animals. The NET is Queensland's coldest bioregion and is the northern limit for large numbers of animals and plants with temperature distributions, including the Superb Lyrebird (*Menura novaehollandiae*), Common Wombat (*Vombatus ursinus*), Snow Gum (*Eucalyptus panciflora*) and the Juniper Grevillea (*Grevillea juniperina*). Several species are confined in within Queensland in the Girraween National Park, including the Common Wombat, Bell's Turtle, Alpine Water Skink, New England Tree Frog, New England Crayfish and various plants. The degree of ecological change caused by climate change is more likely to be greater in the plant biological group than that of mammals, amphibians or reptiles (Williams 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 Brigalow Belt • Severe drought in the BB may result in deaths of many trees including Brigalow and Cypress pines. • Buffel grass invasion is of particular concern within the BB. Invasion of this species may displace groundcover plants and significantly increase fire risk. **Impacts in the New England Tableland** • Very large hot fires may threaten shrubs and smaller plants within the NET. For example, a geebung species, endangered in New South Wales, recently disappeared from its one known site in Girraween, Queensland, after a hot fire. • Populations of mammals confined to the region, including the common wombat, Northern hairy nosed wombat and bridled nailtail wallaby, may be threatened by rising temperatures and severe drought followed by intense fires.	• Fire management. • Manage weeds and invasive pasture grasses, such as buffel grass and guinea grass. • Control pests and feral animals, including goats, pigs and horses, to reduce losses and protect rare plants. • Protect refugia habitats.

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 the Condamine region were 0.5 M in 2014-15 which was 5% of the total cattle numbers for Queensland (ABS 2016b). In 2014-15 the GVP for cattle, sheep and wool for Condamine was $231 M (ABS 2016a) or 2% of state and 18% of the value of Condamine 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 ED are Aristida-Bothriochloa (50% of region), Queensland Blue Grass (22%), Black Spear Grass (12%) and Brigalow (11%) (Tothill and Gillies 1992). The soil fertility is excellent (Brigalow) to average (Aristida-Bothriochloa) and growth of pastures is usually limited by inadequate rainfall. Cattle numbers in the Condamine were 542,300 in June 2010 (MLA 2010).

Case Study - Impacts in the Eastern Downs 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 Eastern Downs region were undertaken for the Chinchilla, Dalby and Stanthorpe 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 (10.89 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 Chinchilla, Dalby and Stanthorpe 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	+H	+H	+H
2xCO_2	+M	-M	+H	+H	LC
+3°C, 2xCO_2	+H	-M	+H	+H	+H
+3°C, 2xCO_2, +10% rainfall	+H	-H	+H	+H	+H
+3°C, 2xCO_2, -10% rainfall	+M	-M	+H	+H	+M

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:

- pasture growth, liveweight gain of cattle, frequency of burning and green pasture growing days are expected to increase with the future climate scenarios studied here; and
- doubled carbon dioxide and combined future climate scenarios studied here are likely to reduce pasture quality.

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 - 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 Dalby has fluctuated between -8 and +9% 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.

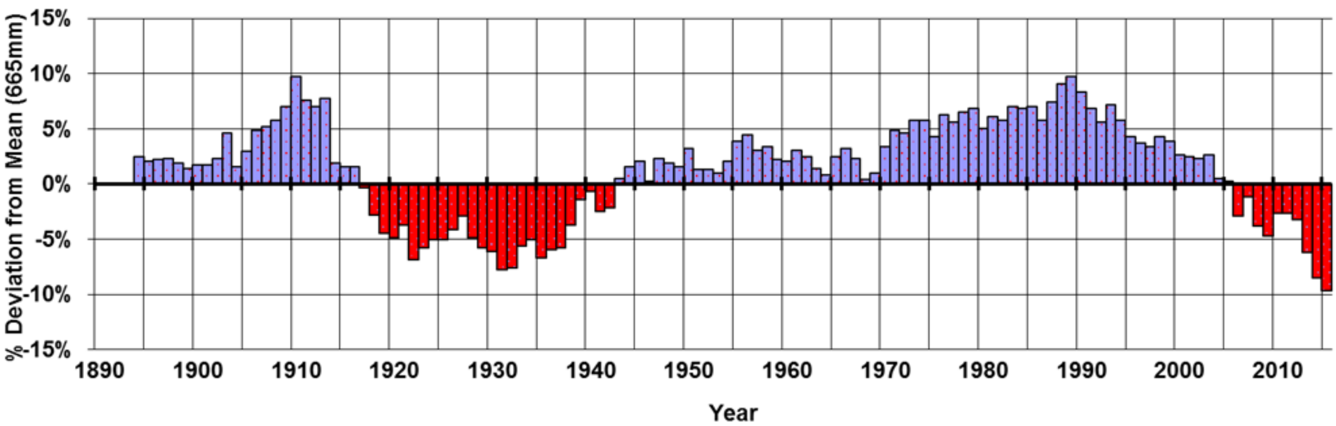

Figure 1: 25-year moving average rainfall (12 months, April in year 1 to March in year 2) at Dalby, Queensland (Source: Clewett et al. 2003).

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, 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:
	  o LongPaddock (http://www.longpaddock.qld.gov.au);
	  o AussieGRASS (http://www.longpaddock.qld.gov.au/about/researchprojects/aussiegrass/index.html);
	  o ClimateArm http://www.armonline.com.au/ClimateArm
	  o 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, Dalby under warming of 3°C is likely to receive temperatures currently experienced south of Charters Towers (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. • Increased heat stress reduces fertility, conception, peri-partum survival and follicle development in sheep. • 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.

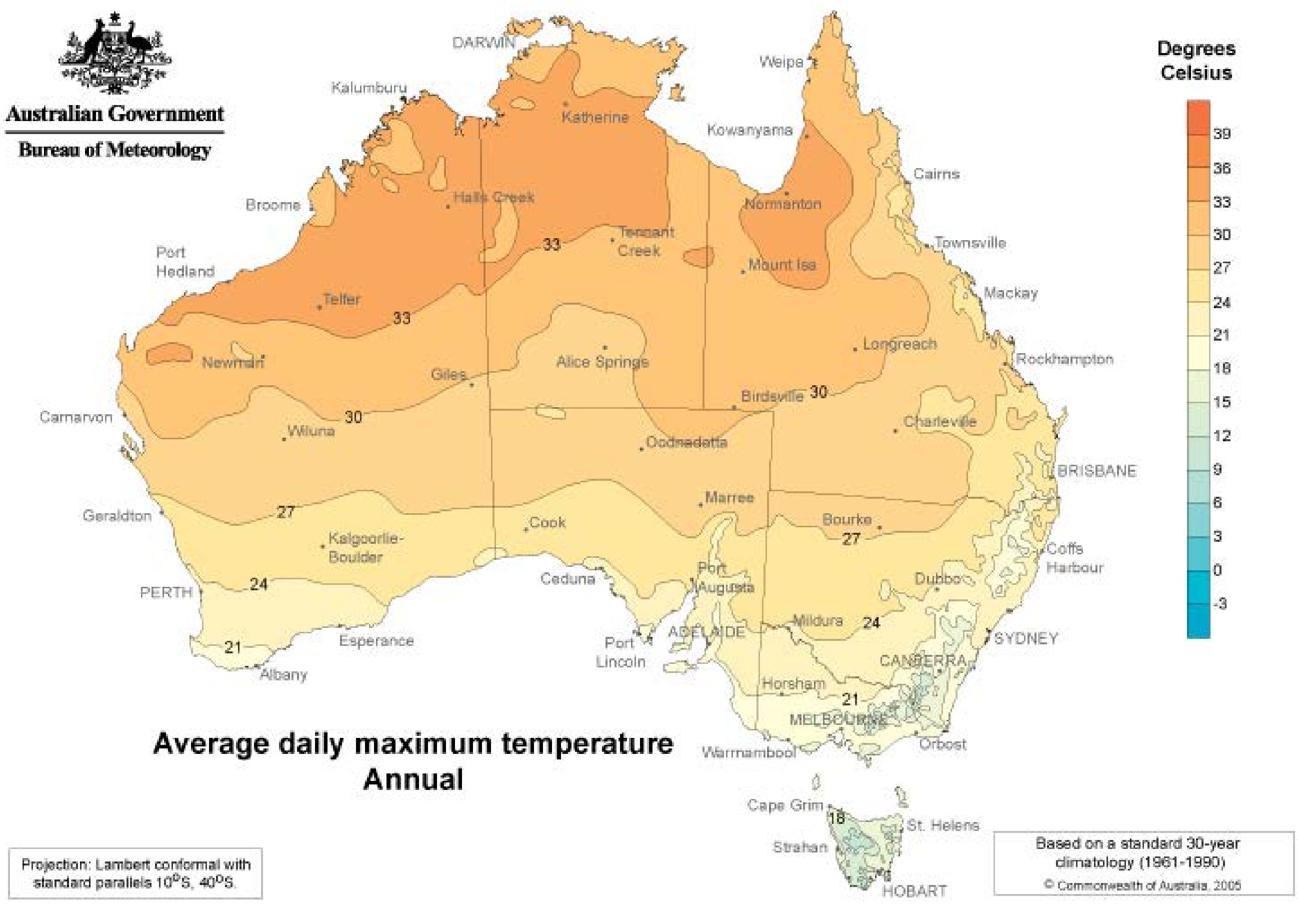

Figure 2: Annual average temperature in Australia (Source: Bureau of Meteorology). One degree of warming is roughly equivalent to moving 145 km toward the equator.

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). • 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. • Support assessments of the benefits and costs of diversifying property enterprises. • 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 (e.g. increase *Bos indicus* content), efficient feed conversion and lighter coat colour (Finch et al. 1984, King 1983).

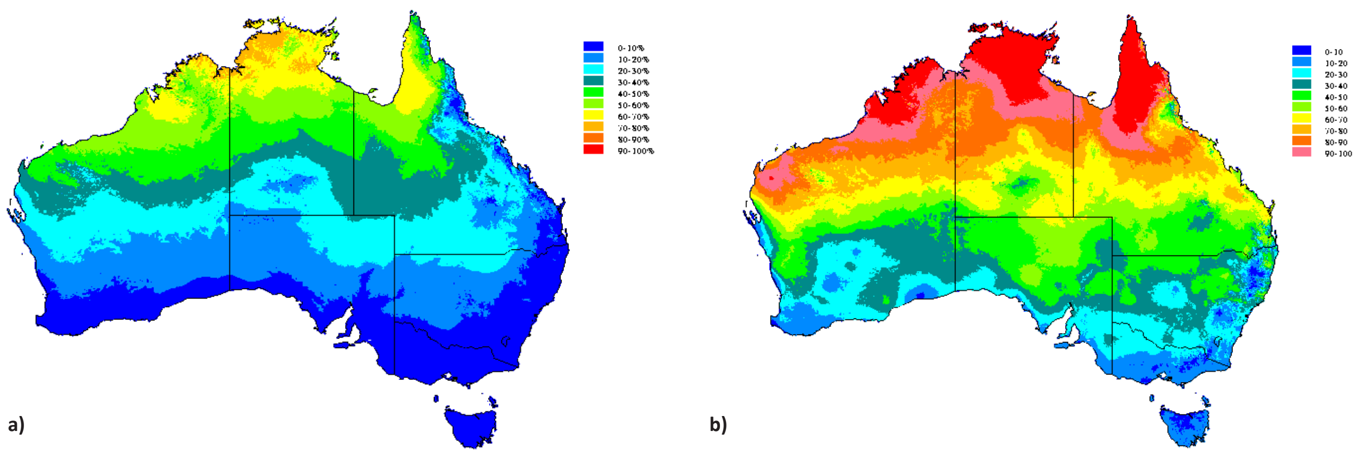

Figure 3: Frequency of days per year that the THI>80 for a) 1957-97 and b) a future climate scenario of +2.7°C. Thermal stress is significant in beef cattle when the THI exceeds 80 (Source: Howden et al. 1999).

Dairy Industry

In 2014-15 the Queensland dairy industry had a herd of about 168,000 dairy cattle of which 91,000 are cows in milk (ABS 2016b). The Queensland dairy industry produced 411 million litres of milk from 448 farms, which was 4.2% of Australia's milk production (Dairy Australia 2015). In 2014-15 SEQ produced nearly 21% of the value of Queensland's whole milk ($236 M, ABS 2016a).

Much of the information below on the impacts of a changing climate for the dairy industry is drawn from Dairy Australia (2011).

Opportunities for the Dairy Industry

- Increased plant photosynthesis and associated increased production with increases in carbon dioxide.
- Increased pasture growth during cooler months due to increased minimum temperatures and less frosts.
- Lower water availability will favour short rotation pasture systems.

Case Study - The effects of increased temperature on dairy cows.

Cows have the ability to off-load heat; however prolonged periods of heat, particularly above 25°C, may lead to heat stress. Heat stress reduces the cows' ability to produce milk and get in calf. There may also be health and welfare problems.

Management and adaptation tools to minimise the risk of heat stress include increased provisions of shade, active cooling sprays and breed selection.

Likely Impacts	***Potential Strategies for Adaptation***
Increased temperatures	
• Rising temperatures may cause an increase in the incidence of heat stress to dairy cows. Impacts include reduced milk yield, reduced conception rates, and increased mortality rates. • Lower pasture growth and quality. • Higher temperatures may make C4 pasture species more competitive at the expense of nutritious C3 species, however higher carbon dioxide is expected to favour C3 species more than C4. • Water and irrigation requirements may be increased with higher temperatures.	• Provide more cooling mechanisms for dairy cows e.g. shade and active cooling sprays. • Selectively breed stock, pasture and feedstock for their ability to withstand higher temperatures. • Switch to pasture species that will adapt to changing conditions. • Sow pastures earlier to match warmer conditions. • Use nitrogen fertiliser during winter months. • Use short rotation pasture systems and winter fodder crops.
Decreased rainfall	
• There may be associated lower runoff and reduced soil moisture. • Less water will be available causing more competition for water. • Lower growth of rain-fed pastures and crops.	• Decrease evaporation rates in water storage and in the soil. • Install more efficient irrigation systems and improve water use efficiency. • Change feed system. • Apply more emphasis to crops. • Switch to pasture species that will adapt to changing conditions.
More intense and frequent storms with increased seasonal variability	
• Livestock could be injured by more intense storms and hail, particularly in intensive production systems where animals are concentrated. • Extreme wet seasons can negatively impact milk production, herd health and property infrastructure.	• Use summer housing for dairy cows. • Develop and implement a risk management plan when long range weather forecasts indicate a higher than average probability for either a wet or dry season ahead.

Farm crops at sunrise, Darling Downs, Queensland — Courtesy of Tourism Queensland

Cropping Industry

Broadacre cropping in Queensland produces a range of cereal, oilseed and legume crops, including wheat, maize, barley, sorghum, chickpea, mungbean, soybean, sunflowers and peanuts (QFF 2012). In Queensland the most commonly grown winter crop is wheat (1 M tonnes in 2014-15, ABS 2016b) and summer crop is sorghum (1.6 M tonnes in 2009-10, ABS 2016b). In 2014-15 the value of broadacre crops, excluding crops harvested for hay, cotton and sugar was $1.1 B (ABS 2016a) in Queensland and $450 M in the Condamine region (ABS 2016a). In 2014-15 the value of cotton was $138 M (36% of state cotton GVP) and pasture and cereal crops cut for hay was $30 M in the Condamine region (ABS 2016a).

Broadacre cropping across the region will be affected by climate change at both the enterprise scale and regionally. The information below details the impacts of a changing climate on the cropping industry and adaptation responses that may result in a more resilient system (Cobon et al. 2016, Stokes and Howden 2010 and references therein).

Opportunities for the Cropping Industry

- Increased carbon dioxide may result in higher crop yields and biomass due to increased carbon dioxide fertilisation and photosynthesis.
- C3 plants (cereal grain crops like wheat) respond better to increased carbon dioxide than C4 plants (tropical-origin crops such as sugar cane and maize).
- The effect of increased temperature may, however, have the opposite effect due to increased water stress. Therefore the net results remain uncertain (NCCARF 2011b).
- In cooler months, increased temperatures may reduce frost risk.

Case Study – Effects of higher temperatures and increased carbon dioxide on the growth of cotton

Simulation modelling of cotton growth indicates that an increase in temperature and a 20% decrease in rainfall would cause a decrease in cotton yield of 20%. However, an increase of atmospheric CO_2 (to 555 ppm) will moderate such effects to

only a 4% decrease in yield (Williams et al. 2015).

Likely Impacts	*Potential Strategies for Adaptation*
Increased temperatures and carbon dioxide concentration	
• Higher carbon dioxide may increase biomass production and grain yields which will in turn reduce both the average nitrogen level of grain and the frequency of achieving key nitrogen thresholds. • Warmer temperatures and increased rainfall are likely to favour the slower-maturing cultivars (greater thermal time requirements) that could benefit from an earlier date of flowering and a longer period of photosynthesis (with adequate moisture). • Heat stress during the summer months is likely to cause poor seed set in summer grain crops, such as mung bean, sunflower and maize because higher temperatures lead to earlier flowering crops and poor pollination. • Heat stress during spring may decrease yield of winter crops (e.g. wheat). • Warmer temperatures in spring may allow earlier planting of summer crops with lower frost risk. • Decreased frost incidence may benefit winter crops because of less chance of frost at flowering, however this will be complicated by the fact that they will flower earlier.	• Adjust planting times of summer crops (e.g. mung beans, sunflower and maize) so that they are not flowering during the hottest months. • To maintain grain nitrogen content at historical levels, there will be a need to increase fertiliser application rates by up to 50% depending on the yield expectations. Therefore, increase nitrogenous fertiliser application or increase use of pasture legume rotations may be needed to maintain grain yields and protein content. • Increase application rates of other crop nutrients (e.g. P, K).
Changed rainfall patterns and increased storm frequency	
• Increased risk of storm damage and erosion. • Increased occurrence of some pests and diseases. • Heavy rainfall can increase leaching of nutrients and movement of salts, although total rainfall is likely to decline. • Decreased yields as a result of increased crop water stress.	• Optimise availability of all resources (e.g. through precision agriculture). • Adopt efficient irrigation technology to control water table, monitor water table position and improve catchment vegetation distribution and ground cover to increase infiltration rate. • Apply fungicides to wheat crops to decrease leaf disease (Meinke and Hochman 2000 in Stokes and Howden 2010). • Reduce soil moisture loss by: o increasing residue cover by minimal or no-tillage; o establishing crop cover in high loss periods; o weed control; and o maximising capture and storage of excess rainfall on-farm.

Likely Impacts	*Potential Strategies for Adaptation*
	• Establish a higher percentage of summer crops relative to winter crops as rainfall changes point towards the largest decreases being in winter and spring. • In mixed farming systems, where cropping is marginal and may become more so, consider incorporating a greater proportion of livestock into the farm business for profitability.
Increased temperatures and decreased rainfall	
• Warmer temperatures and a significant decrease in rainfall are likely to favour winter crop varieties (e.g. wheat and barley) with earlier-flowering characteristics which allow grain-fill to occur in the cooler, wetter parts of the year in dry areas. Varieties with characteristics such as higher response to elevated carbon dioxide conditions, rapid germination, early vigour and increased grain set in hot/windy conditions may also be favoured. • Increased temperatures and evaporation may reduce the yield of dryland crops like wheat and sorghum (Potgieter et al. 2004); however, this may be offset by increased carbon dioxide. • Irrigated crops may be adversely affected due to a reduction in supply of irrigation water. • There will be more pressure and challenges for managing groundcover, crop choice (winter or summer), soil nutrient requirements, pest and weed control, soil carbon etc., especially from higher temperature, increased soil moisture stress and higher rainfall variability. • Lower rainfall may reduce deep drainage in dryland cropping systems. For example, at Dalby a 30% reduction in deep drainage will occur if the rainfall is reduced by 15%, which may reduce the risk of soil salinity and sub-soil acidification, but also reduce soil moisture storage especially in dry seasons.	• Incorporate 'best practice' farm management by constantly varying crops and inputs based on the availability of limited and variable resources and signals from the operating environment (Rodriguez et al. 2011a, Rodriguez et al. 2011b). • Use varieties that incorporate the traits of appropriate thermal time (degree days) and vernalisation (exposure to cold temperatures required for flowering) requirements and with increased resistance to heat shock and drought. • Diversify the farm enterprise (e.g. using opportunistic planting). • Increase the use of legume-based pastures and leguminous crops or further increase nitrogen fertiliser application to maintain grain quality, especially protein content. • Adjust planting times to cater for changes in crop maturity and the duration and timing of heatwaves. • Adopt efficient irrigation technology. • Increase use of supplementary water. • Optimise irrigation scheduling. • Use more effective irrigation water delivery technologies (i.e. trickle tape). • Construct on-farm water storage facilities. • Use drought-tolerant or more water efficient varieties. • Modify row spacing. • Minimise tillage. • Use cover crops. • Manage water resources and improve efficiency of irrigation systems. • Integrate cropping into regions of higher rainfall. • Make crop planting decisions based on seasonal climate forecasting, soil tests and other climate related information obtained from tools such as Rainman, Whopper Cropper and APSIM. • Use adaptive crop management techniques such as: o zero-tillage practices, minimum disturbance planting techniques (e.g. seed pushing); o controlled traffic; o responding to planting opportunities when they occur; o widening row spacing or skip-row planting; o lowering plant populations; o using efficient on-farm irrigation management with effective scheduling, application and transfer systems; and o assessing fertiliser inputs. • Reduce surface soil erosion by: o increasing residue retention; o maintaining erosion control infrastructure (e.g. contour banking); and o using controlled traffic systems. • Control pests and diseases.

Horticulture Industry

Horticulture is Queensland's second largest primary industry (QFF 2012). Queensland grows approximately one third of Australia's horticulture produce, with more than 120 different types of fruit and vegetables being grown in 16 defined regions covering a total area of 100,000 hectares and 2800 farms (QFF 2012, HAL 2012). In 2014-15 the value of production for Queensland was about $2.5 B which was made up of $1 B for vegetables, $1.2 B for fruit and nuts and $290 M for nurseries, cut flowers and turf (ABS 2016a).

In 2014-15 the Condamine region produced about 3% of the total value of the state's horticulture, including 7% of the value of vegetables and 1% of the value of nurseries, cut flowers and turf (ABS 2012a). The major fruit and vegetables grown in the Condamine region includes melons, a small amount of potatoes, avocados, broccoli and onion (HAL 2012).

Much of the information below on the impacts of a changing climate for the horticulture industry is drawn from reports commissioned for the Garnaut Review (Deuter 2008).

Opportunities for the Horticulture Industry

- Increased minimum temperature, reduced frost frequency and shortened frost period during the growing season may increase the area climatically suitable for optimum growth of frost sensitive sub-tropical crops such as avocado, and decrease the areas climatically suitable for current cultivars of apples and stone fruit.
- Vegetable growers producing summer crops in temperate regions will have the additional option of planting earlier, and later, therefore extending the production season.
- Increased runoff (from higher intensity rainfall events) may provide opportunities for growers to capture more water for irrigation.

Case Study – Chilling hours on the Granite Belt

For the Granite Belt pome and stone fruit growing region, there are some years when climate variability is such that 1200 chilling hours are not reached. A 1°C warming will significantly decrease the number of years when sufficient chilling will be achieved. A 2°C warming may make apple production at this site, using traditional high chill cultivars such as Red Delicious, uneconomical. Plantings will need to concentrate on varieties with chilling requirements below 1000 hours (Deuter 2008).

- **The Granite Belt is a major producer of the states pome fruit, stone fruit, grapes and a variety of vegetables, and is a part of the Eastern Downs region for the purposes of this study; however, the horticulture production from the Granite Belt is included in the Border Rivers and Maranoa Balonne region (ABS 2012a data).**

Granite Belt, Queensland

Courtesy of Tourism Queensland

Likely Impacts	*Potential Strategies for Adaptation*
Increased temperatures	
• Changes to the suitability and adaptability of some crops. • Potential shift in the optimum growing regions from the current hotter producing areas towards areas currently regarded as too cool. • Change the timing and reliability of plant growth, flowering, fruit growth, fruit setting, ripening and product quality; fruit size, quality and pollination. • Change harvesting times for different areas. • Reduce the time to reach maturity (earlier in the season). • Reduce the occurrence and distribution patterns of fruit fly, *Helicoverpa* and diamond back moth. • Potentially downgrading product quality. • Result in pollination failures. • Increase active soil-borne diseases and insect infestation for longer periods during the year. • May cause fruit yellowing of tomatoes, and affect the post-harvest quality for some crops such as beans, melons and strawberries that are required to be cooled quickly. • Potential influence fruit quality and pollination of some sub-tropical crops, e.g. avocado. • Reduced diurnal temperature range will potentially reduce the overlap between open stages of male and female flower parts thus decreasing the chances for pollination and resulting in more pollination failures, fruit drop and sunburn to fruit. • Increased minimum temperatures and reduced occurrence of frost may benefit some production systems if managed correctly. The winter production season will be shortened. • A decrease in the number of chilling hours experienced in future years will drive a shift towards lower chill pome and stone fruit varieties within this region. • Changes in disease and pest distribution ranges.	• Select for, or change to, cultivars which are more adaptable to a changing and variable climate. • Select and review growing site/location to avoid unsuitable climate factors through identifying threshold temperatures or other climate conditions for crops. • Choose optimal timing of planting. • Use chemical treatments such as hydrogen cyanamide to induce bud break to manage the variable and non-uniform budburst and to protract full bloom of pip, stone fruit and nut trees if dormancy is affected. • Start breeding programs for heat tolerant, low chill, and more adaptable varieties of various horticultural crops. Varieties with higher quality under enhanced carbon dioxide and elevated temperatures will need to be evaluated then considered in breeding programs. • Apply the latest research results and best management techniques to maintain product quality. • Use crop protection treatments including solar radiation shading and evaporative cooling through overhead irrigation to maintain fruit quality. • Use tools/models associated with managing climate variability to improve both quality and quantity of horticulture products. • Plant varieties with chilling requirements below 1000 hours.
Changed rainfall patterns	
• Increased risk to crops reliant on irrigation where irrigation water availability is reduced especially during dry periods. • Changes to the reliability of irrigation supplies, through impacts on recharge to surface and groundwater storages.	• Adopt more efficient irrigation monitoring and scheduling technologies which provide further water-use efficiencies. • Apply the latest research results and best management techniques to maintain product quality, including fertiliser timing and amounts according to crop requirements. • Use tools/models associated with managing climate variability to improve both quality and quantity of horticulture products.
More intense storms	
• Increased runoff may providing opportunities for growers to capture more water for irrigation. • Lead to conditions favouring foliar diseases and some root invading fungi, for example, the fungus *Phytophthora cinnamomi*. • Increase the likelihood of crop damage, decreasing quality and production. • Affect the timing of cultural practices and ability to harvest, as well as negative effects on yield and product quality. • Increase the risk of the spread and proliferation of soil borne diseases; soil erosion and off-farm effects of nutrients and pesticides.	• Improve Integrated Pest and Disease Management (IPDM) practices to adapt to a changing climate and encourage disease suppressive soil techniques. • Improve on-farm water storage linked to drainage and water harvesting systems. • Improve sediment runoff protection via grassed waterways and erosion control structures. • Improve plant nutrition management. • Improve all-weather access to cropping areas.

More Information

For more information, including projections for 2050 and 2070, please refer to http://www.climatechangeinaustralia.gov.au/en/ or Ekstrom 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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