Department of Environment and Heritage Protection

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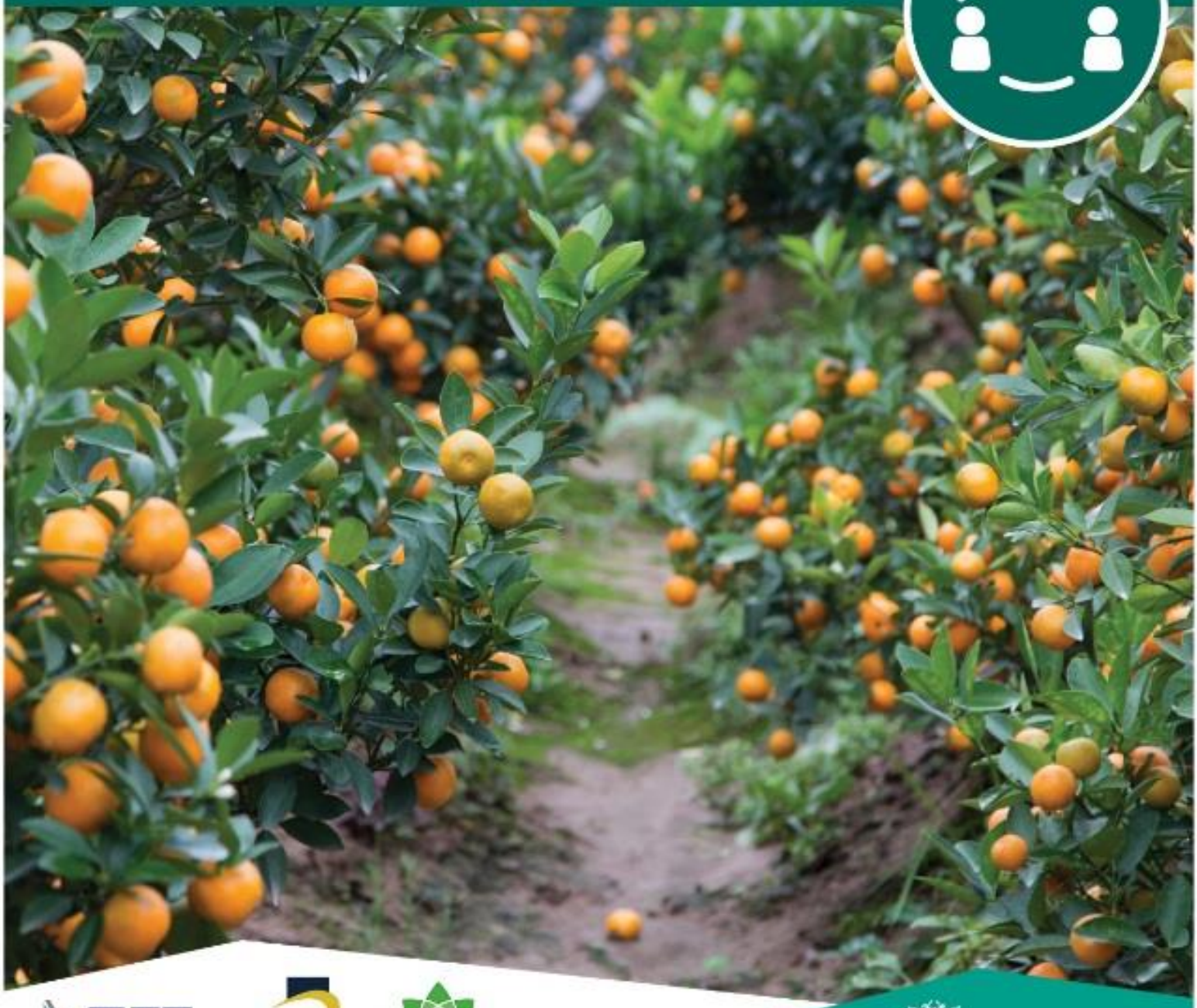
Queensland Climate Adaptation Strategy

Agriculture Sector Adaptation Plan



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Queensland Government

This Sector Adaption Plan was developed by the Agriculture industry with the support of the Queensland Government. Sector Adaptation Plans are important components of the Queensland Climate Adaptation Strategy, outlining industry-led responses to the challenges presented by climate change.

More information on the Queensland Climate Adaptation Strategy is available from https://www.qld.gov.au/environment/climate/adapting/

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Foreword

The Queensland Farmers' Federation (QFF) is the united voice of intensive agriculture in Queensland. It is a federation that represents the interests of peak state and national industry organisations, which in turn collectively represent more than 13,000 primary producers across Queensland. QFF engages in a broad range of economic, social, environmental and regional issues of strategic importance to the productivity, sustainability and growth of the agricultural sector. QFF's mission is to secure a strong and sustainable future for Queensland's primary producers.

The effects of climate change on the long-term viability of farm businesses across the state are a risk that must be managed. Developed under the Queensland Climate Adaptation Strategy, this Agriculture Sector Adaptation Plan (Ag SAP) provided an opportunity to take stock of current adaptation activities and resources in Queensland's agricultural sector. To ensure the plan addresses issues across the entire Queensland agriculture sector, QFF partnered with AgForce, the representative body for the extensive agriculture industries including grazing and grains. The Ag SAP identifies critical barriers, gaps and industry needs, and makes recommendations for future actions that provide a way forward for building a stronger and more sustainable sector.

Climate adaptation for agriculture centres on continuous improvement in the capacity of farmers to deal with a changing climate, and ensuring the necessary tools are available. Increasing the knowledge and understanding of climate change leads to more resilient farmers and their businesses. Increasing the resilience of the sector through better climate modelling and management tools is imperative for its long-term sustainability. Risk management, in all its forms, is central to modern farming and business planning, and climate change must be considered a normal business risk that is incorporated into all decision making.

Developing the Ag SAP was only possible due to the contributions and support from several peak agricultural organisations. QFF thanks those organisations for their involvement and the Queensland Government for funding the work and having the wisdom to allow industry to develop this document.

Travis Tobin

Chief Executive Officer

Queensland Farmers' Federation

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The Queensland Climate Adaptation Strategy (Q-CAS) provides Queensland with a strong framework for empowering climate risk management and adaptation action, across the government, economic, social, environmental and personal spheres. The Q-CAS is built around four pathways of action: Sectors and Systems, Local Governments and Regions, State Government, and People and Knowledge, that will build upon the Queensland Government's investment in climate science with new tools and engagement activities across Queensland's community.

Sector Adaptation Plans (SAPs) are important components of the Q-CAS Sectors and Systems Pathway, and each SAP should be considered within the framework provided by Q-CAS.

This Agriculture Sector Adaptation Plan (Ag SAP) provided an opportunity to take stock of current adaptation activities and resources in Queensland's agricultural sector. The Ag SAP has identified critical barriers, gaps and industry needs, and has made recommendations for future actions and a way forward to build a stronger and more sustainable agricultural sector.

Executive summary

The Ag SAP is a component of the Queensland Climate Adaptation Strategy. The Ag SAP highlights current climate adaptation activities within the agriculture sector and considers gaps and barriers to sound climate adaptation in the farming community. The Ag SAP is the first step to address the adaptation needs of this highly diverse industry. Ongoing development and refinement will be required for each agriculture sector to develop more targeted individual strategies.

An extensive literature review and widespread stakeholder consultation has formed the base for the Ag SAP. The following six key findings and recommendations for the agriculture sector will build a platform for sustainable adaptation action:

1. Optimise access to climate hazard information and projections at scales that can inform industry and farm-level risk assessments

2. Continue to develop and refine tools and resources that support farm, regional, supply chain and industry-level management decision-making

3. Support the delivery of facilitation and engagement programs

4. Improve access to necessary finance and agriculture insurance

5. Explore mechanisms to enable climate risk management and climate adaptation to be addressed across agricultural supply chains

6. Enhance investment in programs and initiatives that support and catalyse innovation and resilience, with a particular focus on the "next generation" in the agriculture sector.

Scope of the plan

The Ag SAP considers all of Queensland's major terrestrial farming industries: extensive livestock, intensive livestock, dairy, grains, sugarcane, viticulture, horticulture (including fruit, vegetables, nuts, garden and nursery industry, turf and cut flowers), forestry, cotton and also aquaculture. Wild catch fishing (recreational, commercial and Indigenous) is not included in this plan as it differs widely from the other agricultural sectors with regards to impacts and possible adaptation actions. Wild fisheries are expected to be considered within the future Biodiversity and Ecosystems Sector Adaptation Plan.

The Ag SAP focuses on climate adaptation at farm business, regional and industry scales. While agricultural supply chains and processing industries are an important part of the wider agri-food sector and will also be impacted by climate change, adaptation strategies for these industries are not covered within the plan. The plan does, however, incorporate supply chain-level adaptation strategies necessary to support farm-level adaptation.

While the Ag SAPs focus is adaptation, it is important to consider mitigation and ensure that adaptation actions do not result in increasing emissions or use of natural resources such as water.

It is also noted that this is a first step to develop a plan that considers and addresses the adaptation needs of a highly diverse agricultural sector. It is, therefore, important to recognise that the adaptation plan will require on-going development and refinement, including opportunities for individual agricultural industries to develop and progress their own, more targeted adaptation strategies.

How the plan was developed

This Ag SAP was developed under a project managed by the Queensland Farmers' Federation (QFF) and funded by the Queensland Department of Environment and Heritage Protection (EHP). The Ag SAP has been developed through consultation with industry organisations, government agencies, research agencies, regional natural resource management groups and other stakeholders. A comprehensive literature review has also been conducted to gather information from key publications addressing climate adaptation in agriculture. A full list of references is provided at the end of the Ag SAP. The key information sources that have informed the Ag SAP are:

- CSIRO 2008. *An overview of climate change adaptation in the Australian agricultural sector – impacts, options and priorities*. CSIRO, Canberra.
- Stokes C & Howden M 2010. *Adapting agriculture to climate change: Preparing Australian agriculture, forestry and fisheries for the future*. CSIRO, Canberra.
- Agriculture Sector Stakeholder Workshop, July 2016
- Agriculture Sector Stakeholder Workshop, March 2017. A participation list for this workshop can be found in Appendix 1.

Definitions

A few definitions for key terms used within this plan:

Climate change - long term changes in average climate.

Climate variability - natural short-term variations in weather.

Climate hazards - climatic conditions that may cause impacts to agriculture production.

Climate risks - risks associated with climate hazards, often exacerbating existing risks.

Climate adaptation - changes in practices or systems that will lead to reduced negative impacts from climate change or take advantage of emerging opportunities.

Climate mitigation - lowering or avoiding carbon emissions, or permanently storing carbon to minimise the effect of climate change

Incremental adaptation – small adjustments to farming operations keeping the essence of the current management system in place.

Transformational adaptation - major and non-marginal changes to farming management systems to address climate change risks.

Context and background

Introduction

The long term sustainability of Queensland's agricultural sector is vital to everyone for a safe and reliable food and fibre production, and the social and economic prosperity of our regions. The Garnaut Review (2011) noted the impacts of climate change can put pressure on the international food market as seen in 2008 where global food prices increased significantly and some countries banned food exports. As Australia is recognised as a developed nation with the greatest risk associated with climate change, sound climate adaptation is a necessity to ensure future food security across the country (Garnaut 2011). Food security is an additional driver, from a community perspective, for sound climate adaptation in the agriculture sector. Climate adaptation is not only about profitable agriculture businesses and thriving rural communities; it is an important step to ensuring food security for the future of Australia.

The gross value of production for the state's primary industry commodities is forecast to be $14.55 billion for 2016-17, well above the average for the last five years and six per cent greater than 2015-16 (DAF 2016); although the impacts to gross value from Tropical Cyclone Debbie are still unknown.

While the outlook is generally positive for the industry, several factors are threatening the industry's prosperity for the future. Climate change is already influencing many of Queensland's agricultural industries and the pressure for climate change adaptation is increasing. Climate change causes direct physical impacts but also secondary impacts such as changed growing conditions in other parts of the world that might impact supply and demand. While many changes are anticipated to have a negative impact on current agricultural production systems, climate change may also provide some opportunities for Queensland agriculture if appropriate adaptation actions are taken.

Climate change is not the only risk facing Queensland farmers. The industry faces a number of challenges such as an aging workforce, competition for land use, access to finances for investment, lack of available/suitable crop insurance, water restriction/scarcity, technological transition, changes in consumer preferences. These risks are considered barriers to climate adaptation and are important to consider when developing adaptation actions.

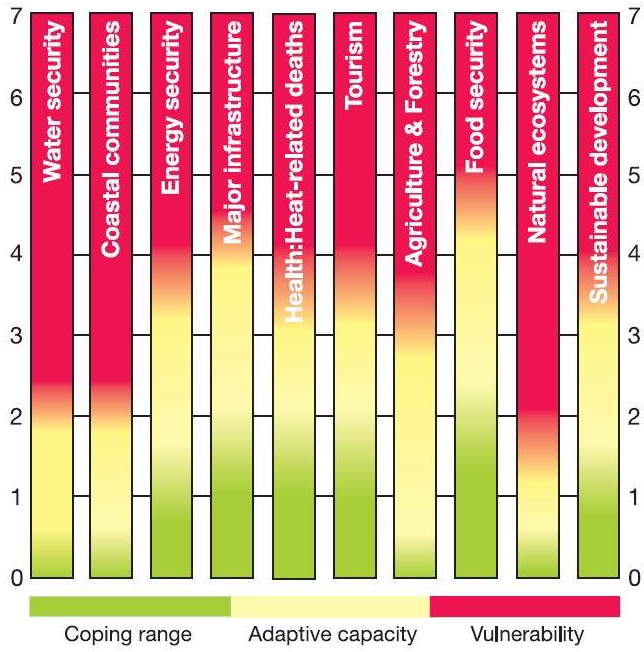

Figure 1 Coping range and adaptive capacity for key sectors in Australia and New Zealand. Y-axis shows temperatures in Celsius (from Hennessy et al. 2007).

Figure 1 demonstrates that the agriculture and forestry sectors are highly vulnerable to climate change (red area), have a low coping threshold to such impacts (green area) but also have a high adaptive capacity (yellow area). This highlights the importance of taking pre-emptive action to address emerging climate hazards as the coping range without adaptation is limited.

Current adaptive practices are mainly incremental and have been developed in response to the existing highly

variable climate experienced in Queensland. These practices are increasingly seen as being inadequate as a response to long term climate change (Rickards and Howden 2012). Climatic extremes and natural disasters are unavoidable and responses to these can be seen as a stepping stone towards long term adaptation. However, it is suggested that incremental adaptation can also lead to overconfidence in the farming community and a false sense of security causing delay of essential transformational adaptation (Rickards and Howden 2012). Australian farmers are often praised for their capacity to adapt to climate variability; this can increase the sense of short term security both within the farming community but also within industry groups, the research community and politicians. In the long term, adaptation to climate variability rather than adapting to climate change could be insufficient and even prove to lead to maladaptation (NCCARF 2013).

Summary of climate hazards and risks for agriculture

Changes in the trends of temperatures and rainfall along with increased risks of extreme weather events are creating significant hazards for Queensland's agriculture sector. These hazards will escalate and exacerbate the risks farm businesses already face. Effective adaptation action is needed to minimise the risks and also to take advantage of any opportunities climate change creates.

Climate change impacts for the agricultural sector vary significantly between industries and geographical regions; however, the principal predicted hazards are summarised below (EHP 2016).

Increased temperatures

A rise in temperatures, both minimum and maximum, will increase the risk of heat stress in workers, animals and plants, and advance phenology for many horticulture crops.

Changes in rainfall

Rainfall projections have a high uncertainty but indicate a trend towards a drier climate with more intense rainfall events. For intensive cropping, this can lead to higher reliance on irrigation and less water availability. While extensive farming would experience fewer rainfall events and high risk of runoff. Heavier rainfall also leads to higher risk of erosion and loss of topsoil.

Changes to natural ecosystems

Even a small rise in temperature can impact biodiversity and ecosystems, increasing stress on the system and competition between species. This can cause changes in the distribution of pests and diseases which may increase pressure on agricultural industries. It can also impact some of the valuable services ecosystems provide such as clean air and water, habitat for pollinators etc. (Cork 2012).

Sea-level rise

Sea-level rise will cause inundation of low lying areas along the coast and estuaries, along with intrusion of saltwater. Higher sea-levels also increase the risk associated with storm tides.

Extreme weather events

Climate change will bring an increase in the incidences of heavy rainfall events, and with that the risk of flooding. An increase in the proportion of tropical cyclones in the more severe categories is also expected. Increased level of bushfire conditions such as fuel dryness and hot, dry and windy conditions are also likely to bring around more bushfires.

Drought

It is likely that southern Queensland will experience longer periods of drought at the end of the century if current emissions levels persist. For other regions projections around droughts are not clear, but increasing temperatures and higher risk of heatwaves are magnifying the effects of droughts, as it increases evapotranspiration and thereby the need of water (CSIRO and Bureau of Meteorology 2015).

Droughts place significant pressure on many agricultural industries. The grazing industry and broadacre farming is especially vulnerable while irrigated industries have a buffer, though face increased costs of water and demand for storage.

Ocean acidification

Increasing levels of atmospheric CO_2 dissolves into the ocean and decreases ocean pH. A more acidic ocean is likely to cause negative effects on aquaculture industries.

Risks to agricultural industries

CSIRO has completed the most comprehensive reviews of the climate changes expected to affect agriculture, likely impacts, and options and priorities for adaptation (CSIRO 2008; Stokes and Howden 2010). These studies consider in detail the issues relevant to each industry. While newer technologies, crop varieties and management options have emerged since these analyses were published, the physical impacts and adaptation options they identify remain highly relevant for the current time.

Ecosystem services are essential to a sustainable agricultural industry; these systems are very vulnerable to climate change and fewer options for adaptation are available in these natural systems than for the heavily managed farm systems (CSIRO 2010). Changes to natural systems will impact underlying resources such as water availability, suitability of the land for agriculture production and pollination services.

An overview of climate change hazards and the impacts they may cause in the agriculture sector was developed with information drawn from the 2010 CSIRO report. This table was then further developed with input from the stakeholder workshop held in March 2017. The table is presented in Appendix 3 and provides a useful overview of the key risks arising from climate hazards for each industry.

Further insight into the major climate hazards to which agricultural industry members are currently responding was generated during the March workshop. These include:

- A drying climate, increased drought and reduced water security
- A warming climate with increased heat stress
- Increasing climatic variability
- Increased intensity of rainfall
- Increased storm risk
- Increased pest pressure and biosecurity risks
- Increased electricity costs
- Reduced reliability of imported products – in particular fish meals and fertilisers.

The cumulative effects of extreme weather will also need to be considered when talking about climate change and increased risk of natural disasters in the form of floods, heat waves, bush fires and increased intensity of cyclones. A decade of cyclones and floods in Queensland seem to continue, putting additional pressure on farming businesses both financially and physically in form of degrading soil health and stress on orchards etc.

Key stakeholders in agriculture adaptation

The agriculture sector has an extensive list of stakeholders covering, government departments, industry organisations, regional Landcare groups, irrigation groups, conservation groups, research and development organisations, agronomists, vets and consultancies. A summary of key stakeholders in agriculture adaptation is provided in Appendix 2.

Overview of Queensland agricultural industries

Aquaculture

The aquaculture industry in Queensland had a Gross Value of Production (GVP) of $115 million in 2015-16 (DAF 2016). The increasing list of species cultured includes a variety of prawns, oysters, crayfish, freshwater species, eels and barramundi. Several sectors are also under development in Queensland including crabs, oysters, sea cucumbers, tropical marine fish, sponges and Hervey Bay sea scallops.

Climate change presents both threats and opportunities for the aquaculture industry in Queensland. Anomalous warm or cold temperatures can impact production and thus farm income (Spillman et al. 2015). Increased temperatures are likely to lead to higher growth rates for tiger and banana prawns resulting in better production efficiency (Stokes and Howden 2010). Some disease outbreaks may be more prevalent with changes in the water temperatures.

Projected increases in the intensity of storms and cyclones, and associated floods is likely to be the biggest threat to the industry leading to overflow, damage to pond and dam walls which can cause mass mortalities. These events can also cause infrastructure damage which is very costly to the industry (Stokes and Howden 2010, Spillman et al. 2015). Ocean acidification will also cause significant problems for the aquaculture industry. The effects on calcifying animals are well researched but the full impacts of a decreasing pH are not properly understood (NOAA).

Weather forecasting for up to one week is only suitable for short-term decision making while many strategic decisions need weeks or months of projections to successfully guide management decisions on timing of seeding and harvesting. Reliable seasonal forecasts are needed for improved and proactive management (Spillman et al. 2015).

Cotton

Queensland produces about a third of Australia's cotton, with a forecasted GVP for 2016-17 of $870 million (DAF 2016). Cotton fields in Queensland cover a total of 153 000 hectares between the New South Wales border and Emerald (Cotton Australia).

Climate change presents both positive and negative impacts to the cotton growing industry. Increased temperatures may prolong the growing season while higher CO_2 levels can increase yield in well-watered crops. However, higher temperatures can also cause fruit loss, lower yield and reduced water use efficiency (Stokes and Howden 2010). Declining availability of water under a warmer climate will put cotton production under pressure to improve water use efficiency. Expansion of growing regions to northern Australia, where water supply is more assured, will need further research to ensure other parameters are favourable (Stokes and Howden 2010).

As Australian cotton is mainly grown for export, growers need to keep updated on trends in the international cotton markets and consider these in adaptation plans (Cotton Australia 2017b).

Extensive livestock

Broadacre grazing is the most widespread agriculture industry in Queensland with about 86 per cent of the land under low-intensity beef or sheep (meat and wool) production (DAF 2013). The cattle and calves industry has a forecast GVP for 2016-17 of $4.06 billion and the sheep and lamb industry forecasted to a GVP of $62 million (DAF 2016).

Rising CO_2 levels, increasing temperatures and changing rainfall patterns will all influence pasture productivity. Changes in rainfall regimes are seen to be the biggest threat to a sustainable grazing industry with pasture productivity and forage quality declining in dry conditions. If annual averages remain the same, the effectiveness of the rain for pasture and forage will be reduced in more intense rainfall events as is projected for the future (CSIRO 2008). Drought conditions are a major threat to a sustainable grazing industry. Increased temperatures will cause more heat stress days which leads to reduced productivity, decreased reproductive rates and increased concerns for animal welfare. Heat stress is a function of temperature, relative humidity, solar radiation and wind or air movement causing decreased productivity often because of reduced feed intake (Williams 2016). Increased temperatures will also lead to higher water demand for the animals and lower the range from which the animals can travel from their water source thus limiting the use of the grazing resources, and increasing pressure and risk of soil degradation, unless additional water infrastructure is installed.

Pests and diseases already have a significant impact upon the grazing industry. Increased temperatures could

alter the geographical range of some pests and diseases, increasing the risks and thereby costs of control measures and loss in productivity (CSIRO 2008). Other indirect effects of climate change include changed fire patterns, changes in local and international markets, land use and economic return. These will all impact and shape the future of the grazing industry (Stokes and Howden 2010).

The least productive arid desert regions are likely to be the most severely impacted while the more productive eastern and northern regions could find some opportunity for increased production under a changing climate (Stokes and Howden 2010).

Forestry

Queensland's forestry industry has a forecast GVP of $260 million for 2016-17, an increase of seven per cent compared to the year before and 38 per cent higher than the average for the previous five years (DAF 2016).

While increased CO_2 levels may increase production levels in plantations, drier conditions and bushfires are major threats to the forestry industry and changes in rainfall patterns are likely to increase these risk. Coupled with an increase in temperatures leading to a growing need for water this could lead to tree mortality. Species grown over a wide range of climatic conditions across Australia are likely to cope with climate change in the short to medium term unless serious pest or disease problems emerge (Stokes and Howden 2010). Increase in the intensity of cyclones and the likelihood of cyclones tracking further south will present risks of more severe damage to forests infrastructure and processing facilities (Williams 2016).

The nature of forestry which encompasses a long time frame from planting to harvesting, means the industry is particular vulnerable to climate change and long term planning is essential. Climate change projections and on-site monitoring of bioclimatic conditions will be crucial for successful adaptation in the forestry industry (Stokes and Howden 2010).

Grains

Queensland grain growers produce about 10 per cent of Australia's grain; about half of which is exported. Grain production is a capital intensive industry requiring high investment in on-farm machinery and technology. In Queensland, there is an opportunity to grow two annual crops, whereas the climate in other growing regions of Australia can only support summer cropping. Queensland's grain industry has a collective forecasted GVP in 2016-17 of $1.67 billion (DAF 2016).

Drought and high temperatures are the main climate change risks facing the grains industry. Grains are reliant on water availability at planting along with rainfall during growing season; prolonged periods without rainfall have negative impacts on yield. Grains are temperature sensitive, both increased temperatures and frost can cause stress and lower yield. Along with water and temperatures, weather extremes and natural disasters can also cause substantial damage on crops.

The *State of the Australian Grains Industry 2016* (Gordon 2016) identifies limited water availability and climate variability as two major physical constraints for the future of the grains industry. The paper states that research and development will be the key to mitigating the impacts. While Australian grain growers compete with a heavily subsidised international market, the national growers' competitiveness is highly influenced by the supply chain that delivers the produce to domestic and international markets.

GrainGrowers (the peak body representing grain producers) has identified drought preparedness as one of six key policy priorities to ensure farmers are well prepared to deal with climate variability. Activities such as taxation measures and increased investment in climate information are priorities. The possibility of introducing multi-peril crop insurance products is also welcomed and supported (GrainGrowers 2015, 2016).

A CSIRO research project on climate change impacts on grain yields is one of the first to cover a period as long as 26 years. The results show stagnation in yield despite improvements in technology that should have led to yield gains. Impacts such as research and development investment, changed land use patterns and soil fertility were ruled out. Climate change was identified as the key reason for this stagnation in yield, also ruling out climate variability as only blurring the obvious trend in a changing climate (Hochman et al. 2017).

Horticulture and viticulture

Horticulture production in Queensland has a total GVP of $4.28 billion. The main Queensland horticulture industries - fruit and nuts and vegetables, collectively have a forecast GVP of $3.04 billion for 2016-17, nurseries are estimated at $898 million, turf at $185 million and cut flowers at $156 million (DAF 2016). Horticulture

production is intensive and has a high input and GVP per unit area of production.

Climate change is expected to have severe impact on the horticulture industry which has many temperature sensitive crops. Horticulture growers have managed past climate changes very well and are therefore generally optimistic for the future. The primary climate concerns for horticulture growers are increases in both maximum and minimum temperatures. As the majority of horticulture crops in Queensland are irrigated, most climate change research for horticulture has focused on temperature and excluded water availability. However, the importance of rainfall and runoff to irrigation storage should not be underestimated. Intensification in rainfall events may also have considerable negative impacts in the form of erosion and waterlogging (Putland 2010).

With vineyards having a lifespan of 30-100 years, wine estates have to plan ahead and plant varieties suitable for the future, as with many horticulture crops, grapevines are sensitive to temperatures impacting quality, style and wine characteristics. Increased temperatures will advance ripening and potentially compress the harvesting window. This could result in additional pressure on expensive winery infrastructure and affect financial viability. Intensification of rain events is likely to bring increased risk of fungal diseases. Increasing risks of bushfires is a major concern for the viticulture industry as wine grapes are very sensitive to smoke (Williams 2016).

For some short term crops, the periods with temperatures exceeding their threshold can largely be avoided by altering planting times. Some regions will become unsuitable for certain crops, such as seen with tomatoes in the Lockyer Valley, where new extended periods of higher temperatures make the region less suitable for sustainable production. Orchards and longer growing crops will need to be carefully considered before planting. Solutions such as sprinklers to cool crops or netting for shade are expensive options and can even be maladaptive over the longer term (Deuter 2011).

Intensive livestock industries

Intensive livestock includes the dairy industry, pigs, eggs and chicken meat and is worth more than $1.22 billion to the state economy.

The individual industries estimated GVPs for 2016-17 are:

- Dairy - $233 million
- Poultry - $619 million
- Pigs - $333 million
- Eggs - $217 million.

Warmer and drier conditions are raising the likelihood of heat stress in animals (Stokes and Howden 2010). Increased likelihood of extreme weather events will cause risk of infrastructure damage and animal losses (DAF 2016).

Many intensive livestock industries are sheltering their animals and therefore have a buffer for rising temperatures and heatwaves, although the increased electricity and water demand to cool housing systems and keep livestock hydrated can cause a significant increase in input costs (Stokes and Howden 2010).

The dairy industry is experiencing similar risks to the extensive livestock industry with reduced pasture growth and quality. Dairy cows will also experience the same increased risks of heat stress with rising temperatures, negatively impacting milk yield along with increased risks of pests and diseases such as a prolonged tick season. Temperatures above 27° Celsius compromises dairy production in form of reduced milk yield, reduced conception rates and higher mortality rates (Williams 2016).

Sugarcane

Queensland accounts for about 95 per cent of Australia’s sugar production. Growing regions are located on coastal plains and river valleys along the eastern coast from Mossman to the New South Wales border. The sugarcane industry has an annual GVP of $1.42 billion, providing economic stability for many coastal communities (CANEGROWERS 2010).

The sugarcane industry is likely to experience its largest direct impact of climate change from changes in rainfall patterns. Many regions will experience a decrease in effective rainfall and increased evapotranspiration, leaving less water available for the crop with risk of decrease in yield. Crop water stress is causing reduced leafy area and canopy development, decreased photosynthesis and decreased tillering and stalk length. In the Wet Tropics, where water logging and flooding events are common, any reduction in summer rain would be likely to increase yield as a result of reduced anaerobic conditions and nutrient loss through leaching (Stokes and Howden 2010).

Policy framework

An extensive legislative and policy framework influences responses to climate change in the Queensland agriculture sector. A brief overview of the key international, national and state-level treaties, laws and policies is provided below.

Commonwealth level

The Australian Government is a signatory to international frameworks for cooperative responses to climate change, in particular the Paris Agreement, and the Doha Amendment to the Kyoto Protocol. The focus of national policy is reducing carbon emissions accordingly:

- Under the Paris Agreement, the Australian Government has committed to achieving a 26-28 per cent reduction in national greenhouse gas emissions by 2030 (using 2005 emissions as a baseline)
- Achieving this target would result in a 65 per cent reduction in the emissions intensity of the Australian economy.

To support achievement of its emissions reductions target, the Australian Government has established an Emissions Reduction Fund which provides a framework for the creation of carbon credits for a variety of emissions reduction projects, including improving energy efficiency, fuel switching, capturing methane from landfills and storing carbon in forests and soils.

Another key policy platform is the Renewable Energy Target, which aims to shift almost a quarter of Australia's electricity to renewable sources by 2020. The scheme assists households and businesses to install solar and other renewable energy technologies. Shifting to renewable energy sources in agricultural enterprises may have a dual benefit of supporting climate adaptation in the agricultural sector.

The *Agricultural Competitiveness White Paper* (Commonwealth of Australia 2015) also includes strategies that may support climate adaptation in the Queensland agriculture sector, including:

- $3.3 million to give farmers more accurate, more local and more frequent seasonal forecasts
- Immediate tax deduction of the cost of new water facilities and fencing for farmers, and depreciation of capital expenditure on fodder storage assets over three years
- $29.9 million over four years for farm insurance advice and risk assessment grants to help farmers evaluate options
- Increased financial counselling services and improved access to community mental health
- $100 million extension of the Rural R&D for Profit Programme to 2021–22 to get research onto the farm
- Up to $250 million in Drought Concessional Loans each year for 11 years
- Farmers will be able to double their Farm Management Deposits (FMDs) to $800,000
- $500 million National Water Infrastructure Fund for farmers' future water security.

Queensland level

At a policy level the Queensland Government is concerned about the implications of anthropogenic climate change for the state's economy, communities and environment. To address climate change mitigation and emission reductions, the Queensland Government has a strong focus on supporting a large scale shift to renewable energy sources, in particular solar power. The Queensland Government has introduced a number of policies which contribute to shifting Queensland to a low-carbon economy, including the *Queensland Climate Transition Strategy* and the *Advance Queensland Biofutures 10-Year Roadmap and Action Plan*.

The Queensland Government's key mechanism for facilitating climate adaptation is the *Queensland Climate Change Adaptation Strategy* (Q-CAS).

A brief overview of Queensland Government legislation that may have an influence on adaptation options in the agricultural sector is provided in Appendix 4. Legislation that has the strongest potential to influence the capacity of agricultural industries and businesses to adapt to climate change includes the *Water Act 2000* and the *Vegetation Management Act 1999*. National disaster relief and recovery arrangements are also highly relevant along with land tenure restrictions and the *Regional Planning Interests Act 2016.*

The *Water Act 2000* provides a framework for the management of Queensland's water resources from watercourse, overland flow and underground sources. While this framework is essential to ensure the sustainable management of water, protect entitlement integrity and the protection of river systems and marine environments, the tight regulation of water entitlements and options to establish on-farm water storages may significantly

constrain the opportunities for agricultural industry members to adapt to a drying climate and shifting rainfall patterns.

Australia's Natural Disaster Relief and Recovery Arrangements (NDRRA) are a joint Australian Government-State arrangement that reduces the financial burden of disaster recovery for state and territory governments, and supports the provision of urgent financial assistance to disaster affected communities. Under these arrangements, the state or territory government determines which areas receive NDRRA assistance and what assistance is available to individuals and communities.

Where the NDRRA is activated, the Australian Government will fund up to 75 per cent of the assistance available to individuals and communities. This contribution is delivered through a number of NDRRA measures and may include:

- personal hardship and distress assistance
- counter disaster operations
- concessional loans or interest subsidies for small businesses and primary producers
- transport freight subsidies for primary producers
- restoration or replacement of essential public assets.

In addition, clean-up and recovery grants may be made available to assist businesses, including farm businesses, to resume trading as soon as possible. The grants may be used for clean-up activities, replacement of damaged equipment and stock, and other general repairs.

The NDRRA is an important mechanism that may influence the capacity for climate adaptation in the Queensland agriculture sector, particularly to increasingly frequent and intense extreme weather events.

In practice, in Queensland much of the available NDRRA assistance is implemented through QRIDA (previously, QRAA). Following a number of recent natural disaster events, significant constraints have been identified regarding the guidelines for recovery grants or loans. These have curtailed opportunities for agricultural businesses to progress climate adaptation actions during the disaster recovery and rebuilding phase.

Current state of climate adaptation in Queensland agriculture

To underpin the development of the Ag SAP, it is important to recognise and understand a number of factors such as industry members' beliefs and attitudes, adaptive capacity, and current knowledge and awareness, and also, to take into account the adaptive actions that are already occurring within the sector.

The stakeholders' workshop provided an opportunity to capture important anecdotal evidence of producers' beliefs and attitudes from those who work directly with them, in particular, personnel from industry organisations, and regional and government extension staff. Workshop participants noted that there are quite mixed views within the agricultural community, though many are sceptical about anthropogenic climate change and have limited trust in the opinions of climate scientists. The workshop also identified that some members of the agriculture community find the threat of climate change frightening and/or overwhelming.

Published research also confirms that there are likely to be highly mixed views amongst members of Queensland's agricultural industries regarding climate risks and the influence of climate change on those risks. National-scale studies indicate that while the majority of urban and rural people do perceive changes are occurring in the climate, around half attribute this change to natural variations in climatic patterns (Arbuckle et al. 2015, Buys et al. 2012, Leviston and Walker 2012, Prokopy et al. 2015). Research from rural Australia showed that climate variability is considered to be a "normalcy of rural life" and that this may reduce perceptions of larger scale trends in climate and the need for adaptive action (Buys et al. 2012). Farmers' perceptions of climate risks tend to be varied, complex, and heavily influenced by their worldviews and conservative media, and short term economic goals are often prioritised over recognition of climate risks (Stuart et al. 2012). Studies of agricultural and fisheries industries in Australia and the US have found that the experience of extreme weather events and more frequent natural disasters can lead industry members to perceive an increase in climate risks and move towards a 'problematisation' of climate change (Arbuckle et al. 2015, Fleming et al. 2014, Park et al. 2012).

Understanding adaptive capacity

The adaptive capacity of farmers is determined by a number of factors from the individual characteristics and circumstances of primary producers and industries within Australia, to government policies from a local to global scale.

Five forms of capitals have been identified that can support successful adaptation to climate change and improve rural livelihoods: human, social, financial, physical and natural (Rickards 2013). Research suggests that pressures arising from climate change are eroding these five capitals and leave farming businesses less prepared for transformational change, and also with a higher risk of maladaptation. Good adaptation is increasingly assessed under the following criteria; equity, social legitimacy and sustainability. Adaptation activities with excessive costs or that increase emissions are seen as maladaptive.

Rickards notes that the adaptive capacity of the primary industry sector is a key research topic that has received limited attention in the climate change research field.

Type of capital	Adaptive capacity constraints in some populations or areas of primary industries identified in literature review
Human capital	• Poor physical and mental health • Unhelpful coping strategies • Low levels of understanding and acceptance of climate change • Distorted perceptions of climate change and risks of different response options • Time scarcity
Social capital	• Poor social networks and support • Lack of government support or poorly targeted support • Labour constraints and lack of alternative employment • Eroding or constraining intergenerational bonds • Unhelpful cultural norms • Threats to consumer support • Constraining industry characteristics • Inadequate research and professional capacity

Financial capital	• Limited on-farm investments • Lack of off-farm investment to diversify income • Excessive or limited access to credit
Physical capital	• Limits to current productive biodiversity, including genetic diversity • Limits to and limitations of irrigation
Natural capital	• Natural limits to carrying capacity • Loss of landscape quality • Path dependence - limited opportunity for diversification
Cross-capital issues	• Conflicting goals • Development trajectories • Barriers to participation • Barriers to climate change communication • Barriers to coordination

Table 1: Highlights the constraints to adaptive capacity that have been identified in the agriculture sector (adapted from Rickards 2013).

Research arrangements underpinning knowledge of climate adaptation

Fifteen rural Research and Development Corporations (RDCs) support the agriculture sectors across Australia with strategic and targeted investment in research, development and adoption. The Australian Government matches levy funds for investment through the RDCs. The RDCs, together with state and federal Governments, CSIRO, Bureau of Meteorology and universities, implement 14 commodity-specific and eight cross-sector strategies.

Each RDC has a different structure and decision process for investment. Levy payers can become members or shareholders of their relevant RDC and actively be involved in decision making at annual general meetings and through the election of directors.

National RDCs are important for research investment in the agriculture sector; however the structures of the RDCs have historically been a barrier for industry stakeholders to gain influence on direction of investments. Discussions with stakeholders within the grains and extensive livestock industries indicated a desire for more regional specific research. For climate change adaptation, local conditions influence whether specific management strategies will be successful and sustainable.

With grain growers in Queensland being small players nationally, the growers struggle to influence research decisions to suit specific regional needs.

One of the cross-sector strategies is the Climate Change Research Strategy for Primary Industries (CCRSPI). CCRSPI was formed as a partnership of federal, state and territory governments, RDCs and CSIRO in 2008 to address the needs for research, development and extension in the agricultural sector. The strategy is focused around three key outcomes: production systems based on best-available climate information; lowering of greenhouse gas emissions intensity of products; and proactive participation in carbon constrained economy. Under the first outcome, the CCRSPI initiative aims to support primary industries to better manage climate variability, improve and apply climate change projections, and assist producers, industries and regions adapt to the biophysical impacts of climate change (CCRSPI 2011).

Under the CCRSPI partnership, in 2011-12 a total of 589 projects, worth $549 million, were carried out on national climate change research, development and extension (RDE) across the primary industries sector.
Forty nine per cent of the invested dollars went towards adaptation investment and 18 per cent were used for RDE in climate projections. The 2012-2017 strategy is currently under review. The last review in 2012 found that the majority of funding within the extensive livestock sector was directed towards mitigation while the grains and cropping sectors main investments were towards adaptation.

Current responses and progress towards climate adaptation

The Queensland agriculture sector is well accustomed to managing for climate variability. The knowledge and management skills industry members have already developed to deal with the variability of the Queensland

weather can take the industry a long way in adapting to climate change. Rickards and Howden (2012) have discussed different modes of climate adaptation and most of the adaptation practices currently taking place on farms in Queensland would fall into what they identify as incremental adaptation. However, it is argued that transformational change will be needed to address the projected changes in the climate hazards for agriculture. Transformational adaptation is defined as having a higher proportion of alteration with little continuation of current practice. With this comes a higher level of risk and challenges but also potential benefits.

At the agriculture stakeholder workshop in July 2016, participants identified that agriculture industries are already experiencing impacts of climate change and best management practices are being used to adapt to climate change and climate variability. They also noted that climate awareness and literacy has increased in the recent years; in particular, the younger generation of farmers were noted to be more able and willing to adapt. High intensity farming is more heavily impacted by climate change than the low intensity industries. Workshop participants acknowledged that while climate and weather forecasting was improving, the farming community needed more accurate and localised forecasting to better support farm management decision-making.

At the March 2017 workshop, participants identified a significant number and diversity of adaptive actions that are already occurring within the Queensland agricultural industries. The most significant and extensive adaptations were to on-farm management practices and business planning and management. Other areas of adaptation included adjustments to water resource management, financial management strategies, and regional, industry or supply chain-level adaptations. The full list of adaptations identified at the workshop is presented in Appendix 5.

Further insights can be drawn from the published research. Responses to climate change have been studied in Australia in the sheep/beef, grains, horticulture, peanut, wine and seafood industries (Fleming et al. 2014, Galbreath 2011, Galbreath 2014, Hogan et al. 2011, Lim-Camacho et al. 2015, Marshall et al. 2014, Milne et al. 2008, Park et al. 2012, WIDCORP 2009). The available research suggests that a mix of responses to climate risks is occurring in the agriculture sector, though predominantly at the farm or production level. There is an emerging recognition, however, that climate adaptation efforts in agriculture should adopt a whole of supply chain approach, incorporating strategies in the processing, transport and marketing stages and addressing governance arrangements to enable supply chain coordination and climate risk management (Lim-Camacho et al. 2015, Muller 2017). There is also growing recognition that governments need to more strongly engage with agriculture and food industries to support responses to emerging climate risks.

Responses to climatic changes in agricultural industries identified through recent studies include agronomic adjustments such as changes to canopy management, improved water use efficiency or conservation, and adjustment to harvest times. More significant adaptations involve diversification into other crops, diversifying or restructuring farm businesses, increasing off-farm income, or diversifying, relocating or expanding production or harvest sites etc. (Galbreath 2011,2014, Lim-Camacho et al. 2015, Marshall 2014, Park et al. 2012, WIDCORP 2009). Beyond the production stages in the seafood industry, further potential responses identified were relocation of cold storage facilities, improving transport and logistics services, and pursuing enhanced information sharing, communication and even vertical integration through the supply chain. Peanut industry members were found to recognise that industry-scale adaptation planning would be necessary to avoid impacts on the shelling and processing facilities in the downstream supply chain (Marshall 2014).

The research demonstrates that businesses and industries most actively pursuing climate adaptations are those that have directly experienced an increase in climate impacts, such as drought or extreme weather events (Fleming et al. 2014, Galbreath 2011,; Lim-Camacho et al. 2015, Marshall et al. 2014, Park et al. 2012). Research in the wine industry noted two contrasting approaches to climate adaptation amongst industry members (Park et al. 2012). Some industry members made little distinction between climate and other drivers of industry change, tended not to believe in anthropogenic causes of climate change and took a shorter-term, reactive and incremental approach to managing climate pressures. Other industry members, however, perceived climate change as posing a management challenge distinct from other issues, were more likely to accept anthropogenic causes of climate change, sought to proactively manage climate pressures to achieve present and future benefits, and were more likely to interact with other members of their supply chain to develop responses to climate challenges. These industry members demonstrated greater flexibility and potential to access to business growth opportunities and were more likely to implement transformational climate adaptation.

Two studies draw attention to the potential roles of corporate or supply chain governance in climate adaptation. Galbreath (2011) found that the establishment of an overarching governance mechanism (the environmental leadership team) within a large-scale wine company achieved important benefits: a clear signal of top level support for management responses to climate change, and facilitation of collective efforts towards adaptation in all levels of the business. Lim-Camacho and colleagues (2015) suggest that enhanced linkages and governance structures in fisheries supply chains could support a clearer understanding of impacts and opportunities for adaptation throughout the chain and note that eco-certification schemes could facilitate greater communication

and connections between supply chain partners.

Important roles for government and government-based institutions in food industry adaptation to climate change have been identified in the literature, such as maintaining robust public infrastructures that support reliable transport and logistics services, investing in appropriate research and development efforts (Lim-Camacho et al. 2015), providing tax incentives for investment in adaptive actions and making location-specific climate projections available to producers (Galbreath 2014). Lim-Camacho and colleagues (2015) also noted that policy and regulatory frameworks can impede adaptation opportunities in fisheries supply chains, indicating that governments should engage in industry adaptation planning.

The extensive livestock industry has taken action on the trend of increased drought periods and developed a drought strategy, or Agricultural Business Cycle, that emphasises producers and government taking a more proactive, collaborative approach to managing drought risk. The Cycle encourages farmers to develop plans across financial, environmental and social elements and set clear deadlines, influenced by rainfall effectiveness, for decision making in regards to practical management actions, including stocking and destocking. The Cycle also has a mental health component and encourages farmers to continue social activities during drought. The Cycle seeks to empower producers when selecting individually-relevant private and publicly funded drought preparation, management and recovery measures, tempered with mutual-obligation expectations, including on government to provide certainty around available assistance (AgForce QLD and DoC 2017).

Existing programs and tools

Over the last decade a suite of government and industry programs and tools have been developed to support risk management and climate adaptation in the agriculture sector.

Many agricultural industries have developed and rolled out Best Management Practice (BMP) programs, incorporating various tools that can support producers to plan and implement best management practice within their own enterprise. The delivery method of the programs varies from industry to industry and the aspects of farm business management that are included in the programs are also diverse. While many industry BMP programs do not incorporate a specific climate adaptation module, program elements such as water use efficiency or biodiversity management often contribute indirectly to climate adaptation. Further, the overall goal for BMP programs is to build a sustainable and efficient farm business which is an essential foundation for undertaking climate change adaptation activities. The advantage of using BMP programs to support climate adaptation amongst agriculture enterprises is that the simplified module process can help engage a broad audience, and therefore, potentially extend the reach of climate adaptation extension efforts. A risk, however, is that the details and complexity of climate change risks and adaptation may be lost (or not sufficiently addressed) when incorporated into an established industry BMP program. If industry BMP programs are extended to include climate risk management and adaptation, it will be important to ensure the process enables consideration of region and business-specific information and recommendations. One way to ensure individual and local risks and opportunities are considered, is to provide comprehensive extension services and one-on-one support for businesses to develop their climate adaptation strategy. A review plan for BMP programs is important to ensure ongoing updates so latest science and knowledge is incorporated in the tools.

Appendix 6 provides an overview of available industry BMP programs.

The Long Paddock

The Long Paddock is a diverse collection of products, data and information that can be used independently or in conjunction – to value-add as information source, for education, modelling, and workshop material. The Long Paddock supports a number of key priority areas for both DAF and EHP, such as drought mitigation, land management, reef catchment modelling, climate adaptation, State of the Environment reporting and species modelling. A full summary and links to the products can be found in Appendix 7.

The Climate Change Risk Management Matrix can also be found on The Long Paddock, and is a tool that can help address uncertainty by identifying the impacts, risk and vulnerability and adaptive responses associated with climate change. Identifying and analysing risks and opportunities, using this risk management approach, can help to plan responses to climate variability and climate change – and can enable organisations to be proactive and more effective in adapting to future uncertainty.

National Climate Change Adaptation Research Facility

NCCARF has developed CoastAdapt, a management tool giving decision support for climate adaptation in Australia’s coastal regions. CoastAdapt delivers comprehensive background information on climate change and

can take users through a risk assessment process. It is a multi-industry tool that would be beneficial for the aquaculture sector and all terrestrial agriculture businesses in close proximity to the ocean and estuaries.

CoastAdapt can be found online on https://coastadapt.com.au/.

Queensland Government Drought and Climate Adaptation Program (DCAP)

In 2016, the Queensland Government allocated funds to support drought and climate adaptation in the agriculture sector. Funding to extend this program for five years was included in the 2017-18 State Budget.

DCAP has three major elements:

- Helping producers be better prepared for risks such as drought (e.g. grazing BMP as a vehicle to encourage improved financial literacy and climate risk management)
- Establishing the Queensland Drought Mitigation Centre, as a partnership between DAF, University of Southern Queensland and the Department of Science, Information Technology and Innovation. The Centre works with national and international climate modellers to improve seasonal forecasts for northern Australia, and provides RD&E into improving predictions of multi-year droughts, workshops and decision support tools. These products could be used as inputs to a variety of systems and extension products that support decision making by primary producers
- Delivering programs to help Queensland agriculture adapt to future climate scenarios and access improved regional climate change forecasts.

In its first year DCAP supported research, development and extension projects, with a focus on climate modelling and seasonal forecasting, farm-level decision support and risk management tools, drought resilience initiatives, and investigation of insurance options. The second phase of the DCAP program has three broad objectives:

- Improving the drought resilience and preparedness of primary producers
- Improving the capacity of primary producers to manage climate variability
- Improving the capacity of primary producers to adapt to climate change.

Regional Natural Resource Management Plans

Natural Resource Management (NRM) groups are undertaking extension work with landholders and agriculture businesses across the state. There are 14 natural resource management regions in Queensland, each with a representative organisation and natural resource management plan. Most NRM plans have included climate adaptation through the lens of landscape function. The roles of the NRM groups and plans are to facilitate the process of land managers identifying their assets, the risks to those assets and mitigation of those risks

Climate Q

A large review of Queensland's climate change strategies was undertaken in 2008 resulting in the report *ClimateQ: toward a greener Queensland*. Community consultation revealed concern about lack of research and information on possible action on climate change were barriers to addressing climate change impacts. Water, drought, biosecurity and pest management were mentioned as key concerns. The Queensland Government's response to the report included support for industry groups to educate the farming community and extension of the Rural Water Use Efficiency Initiative (RWUEI). RWUEI is still playing an important role in delivering water use efficiency across the farming industry; an important part of adapting farm businesses to a potential drier climate. Community feedback also raised the possibility of assisting farmers to implement risk-based farm management systems.

Bureau of Meteorology

The Bureau of Meteorology (BOM) has actively engaged with industry through several different forums. In Queensland, this has been through monthly Climate and Weather Briefings, an annual Queensland Agricultural Consultative Committee meetings and the continued engagement through regional staff.

Industry groups can also engage BOM to participate in workshops, field days, and training activities. An example of this is the recent climate and weather workshop held by QFF as part of the Cyclone Marcia Agricultural Recovery Project. The workshop aimed to increase landholders understanding of primary climate drivers, short term weather forecasting and the impacts both these have on farm management decisions.

Ongoing cooperation with BOM is important in educating the agriculture community to use the wide range of products delivered by BOM and to drive a larger understanding and correct interpretation of weather patterns and short term weather forecasting.

Managing Climate Variability

Managing Climate Variability (MCV) is a long running national climate risk research and development program supporting farmers and NRM groups to deal with the risks and exploit the opportunities of a variable climate. The goals of MCV are to improve accuracy of forecasting to increase value for farmers, provide services, tools and products to manage climate risks and increase climate literacy. The MCV has been a critical partner in the development of BOM's Predictive Ocean Atmosphere Model for Australia (POAMA).

The current MCV Research and development operational plan runs from 2016-17 to 2021-22 and is aiming to deliver timely, accurate and easy-to-understand information about climate events that will have an impact, either good or bad, on farming business (McIntosh 2017).

Gaps

While it is clear that progress is being made towards climate adaptation in the agriculture sector and valuable resources have been established to support adaptation, a number of critical gaps can be identified that impede further progress. An understanding of these gaps will shape the development of priority Ag SAP implementation strategies. This section outlines both gaps in available programs and tools and critical knowledge gaps, for the sector as a whole and for individual agricultural industries.

Gaps in available programs and tools

Drawing from the reviewed literature and stakeholder consultation, the most significant gaps in available programs and tools are considered to be:

- Inadequate incorporation of climate risk management and adaptation planning in industry BMP programs
- Low levels of awareness within the agricultural community of the climate information sources and decision support tools that are currently available
- Limitations within currently available climate information sources and decision support tools regarding their capacity to inform decision making at farm business and regional scales
- Availability and affordability of insurance
- Insufficient focus in industry R&D programs on climate risk and adaptation.

Industry BMP programs

Industry BMP programs offer some of the best options to engage with primary producers on their management practices and help them identify areas where improvements can be made. The majority of industry BMP programs and tools, however, do not incorporate an explicit focus on the increased risks associated with climate change and potential adaptation needs. The Grains BMP is an exception as it does include a climate risk module. The horticulture industry is also currently developing a climate risk module within its Hort360 program. It is important to note, however, that building consideration of climate risks into a BMP program does not guarantee improved business-level climate adaptation in practice. Because of the complexity of climate change and adaptation responses, it will be essential that business managers have the opportunity to access one-on-one facilitation and support to work through the BMP process. The generally low levels of awareness of climate change issues and understanding of adaptation needs within the agricultural community is partly due to there being an inadequate communication of the tools available to support agriculture business management. This gap is partly caused by insufficient focus in industry R&D programs on climate risk and adaptation. It should also be noted that industry stakeholders have warned against over-loading BMP programs with too many agendas as this may risk undermining the trust industry organisations have built amongst primary producers in industry-owned and directed programs.

Insurance

Insurance is an important risk transfer mechanism. It enables people or businesses to receive financial compensation for losses or damages caused by events beyond their management control. In the agricultural sector, there are nominated/named peril insurance products for specific crops (e.g. hail insurance for cotton) and multi-peril crop insurance (MPCI) for winter cereals. MPCI covers losses due to multiple risks or perils (e.g. flooding, hail, storm damage). Currently MPCI is available only in a small number of crops, and nominated perils insurance products, although available in a growing number of agricultural commodities, are still limited.

Due to the narrow range of agricultural commodities covered by insurance products, there is an increasing push from agricultural industries to develop suitable insurance products for a wider range of crops to provide additional risk management options for farm businesses. It is argued that if primary producers had increased access to

tailored insurance products, this could free up capital/finance - enabling farmers to invest in climate adaptation and mitigation measures rather than using their limited financial resources to rebuild and recover from damaging weather events.

Projects that lay out a pathway for the facilitated development of insurance products are required. This project would enable the agricultural sector to be involved in the development of suitable insurance products for a broader range of crops/industries. It should also be noted that of the research reviewed by Rickards et al. (2013), there was no inclusion of how insurance can help build adaptive capacity. This suggests that targeted research regarding insurance issues and their intersection with climate adaptation in agricultural industries may be useful. Both DCAP and the Australian Government funded Managing Farm Risk Programme are investigating and supporting opportunities for the introduction of new insurance products.

Knowledge gaps and research priorities

The literature review process undertaken for the Ag SAP has identified key knowledge gaps and research needs. NCCARF's work on the National Adaptation Research Plan for Agriculture and the *Climate Change Adaptation in the Australian Primary Industries: An Interpretive Review of Recent Literature* (Rickards 2013) provides useful analysis of specific research needs. Rickards (2013) provides important insight into the major research topics covered on a national level. The report divides adaptation action into three levels, incremental, system level and transformational adaptation. The authors conclude that much research pertinent to the topic of climate change adaptation in the primary industries has been conducted but it is highly fragmented and often difficult to identify. From stakeholder engagement it was also noted that there is a general concern in the research community on the lack of investment in Australian specific climate change risks and adaptation over the last years.

The NCCARF developed a National Adaptation Research Plan (NARP) for agriculture in 2011 followed by an Update Report in 2013. The agriculture NARP identified the research questions in Table 2 as high priority.

While the NARP research questions were developed back in 2012, and some have been incorporated in research commenced since then, the questions remain relevant. Research on adaptive capacity, levels of adaptation and adjusting production will always be needed as they are evolving topics. Topics such as changes to production systems, transformational change and integrating, implementing and reviewing adaptation have not been covered in detail and will need ongoing research as the industry undertake adaptation action.

A common issue around research is lack of extension work and effort to get research findings incorporated in farm management. Including extension efforts in research budgets will help to deliver research results to the farming community and facilitate practice change.

The NARP Update Report (2013) was informed by a line of new research, new policy initiatives, a comprehensive review of the previous two years scientific research and inputs from Primary Industries Adaptation Research Network (PIARN) and the Climate Change Research Strategy for Primary Industries (CCRSPI). It points out the rising need in the agriculture community for extensive information on policy initiatives, reflected in the implementation at the time of the Clean Energy Future Carbon Price and Carbon Farming Initiative. While these policies have been abolished, policies such as Direct Action and the Emissions Reduction Fund are in place and have raised similar requirements.

Direct physical impacts and the responses to these are the major research topics. Crop management is the most researched area within climate change adaptation in agriculture, covering climate change impacts especially in regards to grains. Topics include crop breeding and choice, sowing dates, crop rotations, pre-crop field management, harvest practices and the role of best management practices. For livestock management, reduction of heat stress has been the dominant topic on climate change related research. An emerging research topic is pasture management, an important aspect in livestock farming as diet stress is identified as a key vulnerability (Rickards 2013).

Research in adaptive capacity is increasing with a shift in focus from climate change exposure to other aspects of vulnerability and enhancement of adaptations and activities (Smith et al. 2011). However, empirical studies of how to study, measure and increase adaptive capacity are missing and remains unclear (Rickards 2011).

When the certainty of future projections and the skills and knowledge for appropriate action are high it lowers the risk of doing transformational adaptation. This is underpinning the importance of research and development for climate change adaptation. One particularly important aspect of climate adaptation planning is high resolution mapping and reliable projections. These are needed to successfully plan and undertake adaptation action. However, the tools available have to be interpreted correctly to be used to their full potential. Time and skills to use these tools could be a constraint for farming businesses, this problem can either be met by rolling out facilitated programs or training for interested farmers.

High priority research questions (2012)
1. Understanding and expanding adaptive capacity
1.1 What is adaptive capacity in the primary industries sector, what are the key factors that affect it and how can it be measured and increased at individual, industry, regional and national levels?
1.2 How does industry structure and leadership affect adaptive capacity in the primary industries sector?
2. Levels of adaptation
2.1 What factors define the effectiveness of different levels of adaptation response: adjusting practices, changing production systems and transforming enterprises, industries and regions?
2.2 What information, knowledge, tools, management skills, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities?
3. Adjusting primary production practices and technologies
3.1 What adjustments to production practices and technologies need to be developed to increase the adaptive capacity of Australia's primary industries, how can their effectiveness (benefits and costs) be monitored and measured, and what practical issues need to be addressed for implementation?
3.2 How might climate change benefit primary industries in Australia, such as through increased atmospheric CO_2 and changes in temperature and water availability?
4. Changing primary production systems
4.1 What characteristics of production system change in primary industries are likely to provide advantage under changed climate conditions?
4.2 What information, knowledge, tools, programs and policies are needed to support effective changes to primary production systems?
5. Transforming primary production enterprises and industries
5.1 What characteristics of transformational change in primary industries are likely to provide advantage under changed climate conditions?
5.2 What information, knowledge, tools, programs and policies are needed to support effective transformative adaptation in primary production systems?
5.3 How can the well-being of individuals and communities unable to undertake transformational changes be maintained?
6. Integrating, implementing and reviewing adaptation
6.1 How can integrated climate change adaptation response plans be developed at the local, landscape and regional scales?
6.2 How can information about climate change adaptation options, strategies, benefits and costs be integrated with other information critical to primary producers and industries?
6.3 How can information about climate change adaptation options, strategies, benefits and costs be communicated to support effective adaptation being identified and implemented.
6.4 How can the effectiveness of adaptation by primary industries be monitored and measured across all business activities, including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives?
6.5 How can potential synergies between climate change adaptation and mitigation be identified and achieved and potential perverse outcomes avoided in Australia's primary industries sector?
6.6 What strategies and management approaches can support effective climate change adaptation for primary industries in the face of changed incidence and intensity of extreme weather events?
6.7 What are the roles and responsibilities of key stakeholders and decision-makers involved in climate change adaptation for primary industries?

Table 2: Identified key research priorities in the agriculture NARP (NCCARF 2013).

Gaps for each specific industry

Industry	Specific gaps
Aquaculture	• Specific regional studies on climate impacts on individual species will improve understanding of hazards and guide adaptation action. • Decision support tools for climate adaptation.
Cotton	• More research is needed into the integrated effects of climate change risks, including development of cultivars tolerant to stresses such as more extreme hot temperatures and drought situations (Howden 2010).
Extensive livestock	• Research and development is taking place, but industry groups and farmers identify extension as a missing link, with limited application on farms. • The Grazing BMP is identified as the only mechanism to drive change and it is not focused on climate change adaptation but only has aspects of it built into it. However, the BMP is also shorter term focused and might not be able to take grazing farmers into a substantial warmer and drier climate as some drastic management practice solutions could be needed for long term adaptation. • The increased risk of disease loads in cattle farming also remains relatively unexplored.
Forestry	• Urgent need for improved knowledge of the effects of increased atmospheric CO_2, changes in temperatures and rainfall patterns on tree growth. This information is required for both specific species and sites.
Grains	• With industry specific BMPs identified as a tool for encouraging and promoting climate change adaptation action, it is unfortunate that the grain industry have a BMP that is not actively being promoted and facilitated. However, work is being done to find funding for both updating the tool but also to run a facilitated program to guide growers through the modules and the following process of optimizing farm procedures.
Horticulture & viticulture	• A number of high feasibility adaptation options are listed in 'An overview of climate change adaptation in the Australian agricultural sector – impacts, options and priorities' (CSIRO 2008). Water and irrigation efficiency along with use of seasonal forecasting are the few initiatives that are already implemented. The remainder of the activities should be a high priority in research, assessment and implementation of adaptation strategies (CSIRO 2008). • Early focus of adaptation options for horticulture is mainly focusing on temperatures' impact on productivity. The majority of horticulture crops in Queensland are under irrigation and changes in precipitation will therefore have secondary impacts on most businesses. However, a significant drop in overall rainfall and/or more intense rainfall events can also have financial impacts on a business as more water storage capacity will be required or higher water costs. • Horticulture and viticulture include a wide variety of crops, growing regions and climatic regions. More specific research and extension work will be required to successfully develop adaptation strategies and support the growers in implementing them.
Intensive livestock	• Heat stress in animals is a common risk from increased temperatures, the traditional adaptation strategies include high energy and water usages are maladaptive and research are needed to identify new adaptation strategies. Knowledge of conditions beyond the farm gate and national borders is essential for intensive livestock industries to be able to incorporate rapid changes in response to changes in environmental, economic and social conditions (Howden 2010).

Sugarcane	• Enhancement of current RD&E activities to continually improving efficiency and management practices. Research is desired into climatically-optimal locations for growing sugarcane.

Table 3: Knowledge gaps by industry (Howden and Stokes 2010; CSIRO 2008).

Barriers to adaptation in agriculture

Queensland's agricultural stakeholders identified extensive barriers to climate adaptation in the sector (Workshop March 2017). Some of these barriers relate to psychological factors, beliefs, attitudes and behaviours. Social factors, such as a perceived lack of community acceptance of climate change, and political factors including the lack of a consistent political narrative and stable policy framework, were also raised. There are limitations in primary producers' knowledge of climate change issues and "literacy" around climate science. Importantly, significant practical considerations were also identified, such as farm and business management factors, financial constraints, and supply chain factors. Stakeholders also noted that available decision-support tools and industry programs do not adequately address climate risk management or cannot deliver information at a fine-enough scale. The complexity of climate risk makes the development of effective tools and programs difficult. A full list of barriers identified at the workshop is provided in Appendix 8.

Continuing uncertainties in projections and local forecasting create a significant barrier to adaptation and can lead to reactive adaptation rather than proactive management decisions. Modelling and projections for future climate change are constantly improving, however, it has been noted that delaying adaptation in agriculture is likely to increase costs and losses, and that it is not desirable to postpone action until uncertainties in projections have diminished (CSIRO 2008).

Many management practices and emerging technologies are not necessarily identified as supporting climate adaptation but may nevertheless help agriculture enterprises adapt to emerging climate risks. As advanced practices and innovations are often only implemented by more innovative producers, the impact and reach of their benefits may be limited. This highlights the essential role of extension in supporting knowledge and skill development amongst producers and providing education regarding new technologies and management practices.

Transformational adaptation is required in the agriculture sector to maintain or increase production. However, there is a lack of empirical work related to what drives, or constrains transformational adaptation (Rickards 2013). Initial research suggests that capacity to analyse, plan and assess the costs and benefits of transformational adaptation activities is essential to drive change.

The agricultural sector and rural communities are highly dependent on each other. Rural communities have seen a significant reduction in population, which has prompted losses in services and increasing unemployment. Inadequate climate adaptation will increase pressure on rural communities when farm businesses struggle to run sustainably or provide local employment. The downward spiral in rural livelihood is also negatively impacting farming businesses that depend on local services, knowledge and labour. A slowdown in the centralisation of communities would benefit agricultural businesses in keeping services and people in the local community.

Changes or discontinuation of climate policies and conflicting policies (e.g. between state and federal government) creates challenges and mistrust in farming businesses (NCCARF 2013). Bipartisan agreement on policies can help increase confidence and engagement with schemes such as the Emissions Reduction Fund.

Potential solutions to the identified gaps and barriers

Potential solutions to gaps and barriers to climate adaptation in the agriculture sector have been identified through both a literature review and at the March 2017 stakeholders' workshop. A summary of actions identified that help address key barriers and gaps is presented in Table 4.

Table 4: Summary of key barriers to climate adaptation and potential strategies to address them.

Themes	Barriers	Potential solutions
Beliefs, attitudes & behaviours	• Many agricultural producers distrust climate scientists and/or remain unconvinced about anthropogenic climate change. Many do not see a need for an urgent response. • There is a strong culture within most agricultural industries of taking a reactive or responsive approach to management challenges. The experience of incremental climatic shifts, in the context of a highly variable climate, favours an incremental approach to adjustment/adaptation. • Agricultural producers draw on memories and farm records to interpret current weather events and make assessments of future risks.	• Deliver climate projections and adaptation recommendations through established trusted networks and knowledge brokers. • Present the case for a need for a cultural shift across the agriculture sector towards pre-emptive management of climate risks. • Deliver information to agricultural producers that clarifies the distinction between climate variability and climate change. • Encourage agricultural producers to assess historical farm weather records and BoM historical data to build a stronger understanding of trends and climatic shifts.
Psychological factors	• The concept of climate change can be too frightening to believe and can unsettle a person's sense of security or confidence. • Climate change can seem like a cancer diagnosis with no treatment plan – unsettling and frightening, with no pathway to action/solutions. • Messages around climate change and the need to adapt are perceived as yet more negative messages targeting rural people and rural industries.	• Assist agricultural producers to see climate adaptation as a manageable challenge. Facilitate risk assessment processes within agricultural industries/communities to re-consider climate hazards, risks to agricultural enterprises, and risk management options. • Ensure communication strategies around agriculture sector climate adaptation incorporate the actions being undertaken across all economic sectors.
Social factors	• Acceptance of climate change as a reality has not yet been socially normalized, and is therefore an awkward topic of conversation amongst agricultural producers that tends to be avoided. • There is a widespread belief that there is still scientific debate regarding climate change. • Agricultural producers already feel they face public disapproval for environmental issues and are under-appreciated for the good practices they have implemented.	• Implement communication strategies targeting all Queenslanders that there is strong scientific consensus regarding climate change to re-engage people with the urgency for action. • Shift towards a more positive dialogue regarding climate adaptation opportunities and progress.
Political factors	• Political leadership regarding the need for climate change mitigation and adaptation has been poor and inconsistent. • The instability of the policy framework for climate action and adaptation within federal and state governments has caused uncertainty and confusion.	• Communicate the urgent need for political commitment and a comprehensive and stable policy framework to support agricultural (and wider) climate adaptation. • Emerging paleo-historical analysis that demonstrates the shift in climatic patterns may assist with defusing the political debate.

Knowledge & awareness	• In general, 'climate literacy' amongst agriculture producers is fairly low and access to relevant climate information is inadequate. The available information can be confusing and is often not at an appropriate scale to support farm-level decision making, or reliability and accuracy is not sufficient for the period of interest. There has not been enough use of existing networks of trusted sources to deliver climate information. • It is difficult at the farm-scale to distinguish between climate variability and climate change. Further, the experience of extreme weather events tends to be absorbed into producers' expectations of climate variability, which can lead to a failure to recognize escalating climate hazards. • Many producers do not know what actions to take to address climate adaptation and there is insufficient information to develop a clear business case for investment in adaptation strategies. • There is insufficient baseline/core data at fine enough scale to support modelling and analysis that can underpin agriculture-relevant climate hazard/risk assessment.	• Improve opportunities for climate education for agricultural producers (making greater use of established advisory networks) and maintain a regular cycle of training to keep the next generation of farm business managers informed. Develop capabilities within government agencies, industry organisations and registered training organisations (RTOs) to deliver climate adaptation-focussed training/professional development. • Invest in down-scaling climate models and projections to underpin business level climate risk assessment and support targeted industry delivery of this information. • Improve ease of access to seasonal forecasting. • Provide necessary granularity of data through increased investment in highly localised weather stations.
Practical farm & business management factors	• The majority of agriculture enterprises are either in survival mode or consumed in meeting day-to-day challenges and schedules. There is little capacity to consider strategic level needs such as climate adaptation. • A high proportion of agriculture enterprises are suffering the cumulative impacts of multiple natural disasters. • There are many structural and systemic barriers to change, and people tend to avoid major change unless there is a crisis that forces a response. Climate adaptation is risky because the outcomes or chances of success are uncertain. • Evolution/adaptation in agricultural businesses and industry tends to be episodic. There is a natural investment horizon: large-scale, new investment occurs when assets or systems are due to be renewed. Many known adaptations are more feasible for larger-scale operations and are difficult for smaller-scale enterprises to implement. • Business stage has a significant influence on the likelihood of producers implementing major change. Many agriculture businesses are operated by an older generation focused on retirement or succession. • Those who are already adapting may believe they are doing enough and not appreciate the extent of projected climate hazards.	• The immediate pressures on agricultural businesses need to be addressed. Programs that support improved financial and business management capabilities and resilience are required to help producers manage cash flow and achieve profitability. • Progress climate adaptation planning/extension within a multi-faceted framework that deals with a range of drivers of business management. Where possible, focus on addressing other (more obvious or immediate) business drivers in a way that also delivers climate adaptation outcomes. Holistic industry BMP programs offer a mechanism to support such a process if they are further developed to incorporate climate risk assessment and management modules. • The recovery period following a natural disaster can trigger new investment and present an opportunity for adaptation. • Efforts are needed to analyse and demonstrate the financial and business benefits of adaptation measures.

Financial constraints	• Producers may not have access to necessary financial capital to invest in adaptation measures. • Available insurance products are insufficient and/or expensive	• Engage financial sector stakeholders in discussions supporting climate adaptation in the agricultural sector. • Improve access to insurance products. • Encourage analysis by economists and/or financial institutions to model the costs/benefits of adaptive action versus of inaction, and to model the profitability outcomes of alternate management. Develop regionally-contextualised analysis. Communicate the financial opportunities/competitive advantage in climate adaptation. • Roll out more programs like PIPES and CEFC, but build in greater flexibility for variations in business scale and type. • Further develop market-based instruments and programs such as carbon trading markets, which support soil health, soil carbon and retention of native vegetation.
Lack of tools to support adaptation decision making	• The scale and complexity of anticipated climate change can be overwhelming and creates a planning and investment challenge. Adaptation to climate change demands multi-faceted, multi-level solutions, which are difficult to design. The available tools do not meet the complex risk assessment and management needs of most agriculture enterprises. • Some of the available tools are too 'top down'	• Integrate climate risk assessment/management/financial modelling into broader risk management frameworks and industry BMP programs. Ensure decision-support tools and information is contextualised to the industry and region. • Deliver decision-support tools in partnership with trusted advisors/brokers. Support peer-to-peer exchange of information and management options. • Develop risk assessment and decision-support tools that help unpack the complexities and adaptation options. Tools should identify and promote low risk, low cost adaptation strategies and also help to tease out options from incremental responses through to transformational change, and how to implement over time. • Establish effective feedback loops between on-ground adaptive actions and industry R&D to guide on-going research with a focus on priority needs.
Supply chain factors	• Most agricultural enterprises are driven by the demands of their customers and/or supply chain. Most supply chains (especially supermarket supply chains) are focused on achieving lowest cost supply, leanness and efficiency. Risk is pushed back along the chain and largely rests with producers. There is little or no focus on addressing climate risk or adaptation. • For some potential climate adaptation options (such as GMO crops), there is a low level of consumer acceptance/support. • There is a strong disconnect between what consumers say is important and what they actually buy or are prepared for pay.	• Engage with wider agricultural supply chain members about climate issues and consider pursuing initiatives that support supply chain partners to collectively re-assess climate hazards and the risks posed to the chain / food security. • Encourage a shift in business culture from leanness and efficiency towards resilience and reliability of supply. • Implement communication strategies with consumers regarding climate adaptation needs in agriculture and food supply chains.

Funding for adaptation initiatives

Many adaptation and mitigation activities have been initiated and funded by government departments. While government investment maintains a significant role in the adaptation space, the importance of successful adaptation is calling for expansion of potential investors. RDCs have contributed to both adaptation and mitigation research and the industry needs to lobby for funding going towards climate adaptation. CCRSPI's strategy is currently under review. One of the current, 2012-2017 strategy's three focus outcomes 'Production systems based on best-available climate information', is focusing on climate variability and change. However, the strategy has a strong focus on mitigation with a vision of 'Primary producers, communities, regions and governments adapting, viable and vibrant in a carbon constrained economy' (Montagu, Kelly, Hull & Barlow 2012). While mitigation is highly important, it is desired that adaptation has a stronger role in the new strategy than seen in the current vision.

The Clean Energy Finance Corporation, co-funded through the banks (Commonwealth Bank, Westpac, NAB, Firstmac and Eclipx), provides loans for energy efficiency and renewable energy projects in multiple industries, including the agriculture sector. The Clean Energy Innovation Fund is a $200 million program supporting innovative clean energy technologies. The fund could potentially support food waste to energy projects in the agriculture sector.

With options for multi-peril crop insurance currently being investigated there is a potential opportunity for insurance companies to have vested interests in sustainable and well climate adapted agriculture businesses.

Philanthropic organisations with interest and visions in the environmental, animal welfare or social area could potentially have interests in supporting climate adaptation in the agriculture sector.

Agriculture Sector Adaptation Plan: Intent

Vision

Members of Queensland's agriculture sector are well informed of emerging climate hazards, have access to effective climate risk assessment and management tools, and are well positioned to proactively adapt to climate change and capitalise on any opportunities that emerge.

Objectives

The Ag SAP aims to identify risks associated with climate change within the agriculture sector in Queensland. The overarching objectives are for government and industry stakeholders to identify climate adaptation needs, opportunities, existing adaptation activities and solutions, along with knowledge and practice gaps. The Ag SAP will be an essential tool in the process of taking climate change adaptation to the next level.

The desired outcome of this plan is for Queensland agriculture to be a successfully adaptive industry that can sustain production levels into the future by being less vulnerable to production losses caused by climate change hazards.

Principles underpinning the adaption plan

A number of principles emerged from the discussions, perspectives and ideas shared by participants in the stakeholder workshop. These have been adopted as guiding principles for the Ag SAP:

- Acknowledge and build on the strong capacity that exists amongst primary producers to be responsive to climate variability.
- Acknowledge that climate change is anticipated to escalate, exacerbate or amplify existing climate hazards – for the most part, it is not generating entirely new risks. Because primary producers are already highly skilled and experienced in managing climate hazards, initial adaptation actions are likely to involve taking existing climate risk management strategies to a more advanced level. The more extreme impacts of climate change, however, are likely to require transformational change. Engaging primary producers in climate adaptation must avoid creating an atmosphere of doom which would likely lead to feelings of helplessness and hopelessness. Instead, the Ag SAP must engender a sense of confidence, optimism, rising to the challenge, pursuit of opportunities and fresh thinking. Entrepreneurialism, innovation and resilience are likely to be central to the agriculture sector adapting successfully to climate change.
- The Ag SAP must also recognise, however, that many agricultural enterprises (and in some cases, whole industries) are currently experiencing severe hardship and struggling to survive under current conditions. In other cases, enterprises that are achieving profitability are finding that meeting the existing set of industry and market challenges demands all of their attention, energy and effort. In this context, many primary producers have a limited capacity to consider and address escalating climate hazards.
- Pursuing 'stand-alone' climate adaptation strategies at industry or enterprise levels is unlikely to be effective or practical (or resonate with primary producers). It will be more sensible to frame and communicate climate adaptation as climate risk management, approached in a holistic way with other key drivers of business management.

Agriculture Sector Adaptation Plan: Initiatives

Adaptation strategies for Queensland's agricultural industries

Six key focus points have been identified as essential to build sustainable climate adaptation in the Queensland agriculture sector.

1. Optimise access to climate hazard information and projections at scales that can inform industry and farm-level risk assessments

Up to date science and accurate and detailed climate projections are some of the key fundamentals to build successful adaptation outcomes in the agriculture sector. Ongoing research and development specifically aimed towards refining information and projections to inform climate adaptation in agriculture industries, regions and businesses is an important priority.

Targeted efforts and investment are also needed to optimise the generation of raw data to feed climate models. A review should be conducted to assess the adequacy of critical data gathering facilities such as rural weather stations and stream/river gauging stations. Efforts and investments could also be directed towards investigating the value that could be gained from accessing "big data" relevant to climate analysis and modelling.

2. Continue to develop and refine tools and resources that support farm, regional, supply chain and industry-level management decision-making

Where aligned with the actual decision-making process of producers, resources and decision-support tools at business level and at a regional industry scale will bring information and projections into the decision making process at an individual business or industry scale. Further research into producer decision-making and the best management practices used successfully by producers to manage climate risk is needed. In particular, there is a need to enhance the current suite of industry BMP programs with climate modules or to build in adaptation questions. To address the difference between incremental and transformational change, identification of these different steps and when they are appropriate should be incorporated in the tools available for decision making. Business cases and examples of the cost of inaction will provide valuable support in the process of moving into transformational change. Many industry BMPs are lacking climate risk and climate management aspects. Inclusion of these will bring focus on the topic and also deliver valuable data on the extent and success of climate adaptation, which are important aspects of the ongoing process of monitoring, evaluating and improving strategies.

3. Support the delivery of facilitation and engagement programs

Along with decision making tools a supportive engagement and education program is vital for farmers to understand the limitations of and get the most value out of the tools and information available but also to best possible develop specific solutions for individual businesses, industries or regions. Facilitated BMP processes will support farmers to not only go through the assessment process but also to review and implement the recommendations. The facilitator can also ensure that individual differences and requirements are taken into consideration for the management plan.

Education and training of the farming community is important to keep farmers and extension workers informed on the latest science. A broad range of offers should be made available to offer education and training to the farming community. Budgets for climate adaptation research should include funding for extension work on research findings. Climate adaptation only represents a small part of a farming business and it cannot be expected that all businesses have a staff educated and trained on the topic and it is therefore important to also have extension people on the forefront of this.

A focus on profitability and holistic business risk management rather than climate adaptation will encourage a greater uptake. Incentives in form of access to premium markets etc. can also stimulate use of BMPs and the recommended practices.

4. Improve access to necessary finance and agriculture insurance

Limited access to sufficient and appropriate finance and investment in climate adaptation poses a constraint to adaptation efforts in the agriculture sector. Efforts should be made to develop and communicate modelling and quantification of the costs of inaction to encourage financial investments. It is also important for financiers to highlight to their clients the need to assess and manage climate risks.

Disaster recovery assistance and guidelines for QRIDA loans limits primary producers to rebuild at same standards. Change in these restrictions could encourage inclusion of a more resilience building approach post disaster. While the disaster recovery phase is difficult for farmers it also provides an opportunity for re-assessing business models and farm infrastructure. Grants and loans available for rebuilding should, therefore, encourage and support upgrade of farm designs to build more resilient farm businesses.

The development of solutions to the affordability and accessibility of effective insurance options is an urgent priority. Increasing insurance premiums are prompting some businesses to under-insure their assets. The investigations and analysis conducted by Queensland Farmers' Federation and others to date suggest that multi-peril crop insurance is unlikely to become a viable option - either for farm businesses or for insurers. On-going efforts are therefore needed to investigate alternate insurance products or other innovative financial risk management strategies. It is important that there is development of sound policies, new insurance products, and investment in data collection and improved granularity of data to help facilitate viable and sustainable insurance.

5. Explore mechanisms to enable climate risk management and climate adaption to be addressed across agricultural supply chains

Most agricultural enterprises are highly driven by the demands of their supply chain and customers. Currently, there is little or no pressure coming through the supply chain to adapt to climate change. Instead, the primary focus of most supply chains (but especially of supermarket supply chains) is to achieve lowest cost supply, leanness and efficiency. In most supply chains, risk is pushed back along the chain and largely rests with producers. Few agricultural enterprises would be able to obtain support from their supply chain partners to collectively consider climate risks to the chain and how these may be better managed.

There is a significant opportunity to invest in initiatives or research that engage all key members of a supply chain to properly consider emerging climate risks and negotiate how the risks can be collaboratively addressed through the chain. Research projects should be designed to analyse the costs and benefits of shared climate risk management and climate adaptation with respect to supply chain stability, the distribution of profits and losses amongst chain partners, and wider considerations such as food security. Progress under this theme could help generate further solutions to the matters of finance and insurance outlined above and support an improved capacity to pursue more transformational climate adaptations such as innovative protected cropping systems.

6. Enhance investment in programs and initiatives that support and catalyse innovation and resilience, with a particular focus on the "next generation" in the agriculture sector.

The demands arising from climate change will test the capacity of each and every member of the agriculture sector. The frequency of recurrence of major climate impacts, particularly drought and extreme weather events, is already creating a significant drain on primary producers.

While programs that help industry members to re-assess climate risks (in the broader context of other business risks) and identify adaptive actions are essential, it will also be vital to support primary producers to build their capacity to respond to unanticipated situations and bring entirely new thinking to the challenges they face.

Next steps

This Ag SAP is an important first step towards developing a comprehensive framework to inform and support climate adaptation in Queensland's agricultural sector.

Further industry and stakeholder consultation is required to confirm the issues and needs identified, and to further develop and refine the proposed vision, objectives, guiding principles and adaptation strategies.

Following this, investment needs can be assessed and clear implementation strategies and partnership arrangements can be developed.

While this plan focuses largely on adaptation inside the farm gate, it is acknowledged that a wide range of cross sector issues will impact on the agriculture sector both outside and inside the farm boundaries. Through the development of Q-CAS, EHP have work developed a broad network of industry stakeholders from relevant sectors across the state. This network will play an important role in addressing these issues. A review of all sector plans, when developed, will identify potential gaps and appropriate cooperation. At a preliminary level, a few key cross sectoral linkages for agriculture can be identified:

- A robust transport infrastructure is essential for agriculture, particularly a road and bridge network that is resilient in the face of extreme weather events
- A reliable and affordable energy supply is also essential to agriculture
- Agricultural industries have strong reliance on a robust tourism industry to access both casual and skilled farm labour.

Establishing a sound monitoring and evaluation (M&E) framework will also be an important next step. An effective M&E program is essential to ensure current information is used to review and inform decision making at all stages of the adaptation process. A monitoring and evaluation plan for climate adaptation will differ from most other plans on some areas. Time frames for climate change and adaptation outcomes are likely to be longer than for more traditional M&E plans. Uncertainty related to the projections of climate change, risks and accumulative effects can influence M&E results. Continuing changes to the climate can also result in a need to change initial baselines (NCCARF 2016).

An M&E plan for climate adaptation in agriculture will have to include a range of feedback loops to guarantee all parameters of the plan are properly included. Research and development in the field is continuously moving the goalposts so R&D organisations such as industry R&Ds, NCCARF, CSIRO and CCRSPI are essential partners in this process.

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Appendices

Appendix 1 Agriculture stakeholder workshop March 2017

Participation list at Stakeholder workshop March 2017

Name	Organisation	Name	Organisation
Kiri Yapp	Ernst and Young	Peter Deuter	PLD Horticulture
Rebecca Paine	DAF	Jane Muller	Growcom
Ramona Dalla Pozza	DSITI	Ross Bigwood	Healthy Land & Water
Grant Stone	DSITI	Brian Paterson	DAF
John Carter	DSITI	Louise Orr	Healthy Land & Water
Melanie Cox	DNRM	Kate Sargeant	DAF
Susie Chapman	Healthy Land & Water	Ruth Chalk	QDO
Alice Lethborg	EHP	Neil Cliffe	DAF
David West	HQ Plantations	Matt Kealley	CANEGROWERS
Dave Putland	EHP	Lauren Hewitt	AgForce
Georgine Roodenrys	EHP	Ross Henry	QFF
Lynne Turner	DAF	Andrew Drysdale	Qld NRM Groups Collective
Bob Speirs	QLD NRM Groups Collective		

Appendix 2: An overview of key stakeholders in agriculture adaptation

Industry	Government Provide a policy platform for adaptation across the sector. Set regulation and planning boundaries to drive adaptation. Facilitate innovative funding support.	Industry organisations Advocacy of industry adaptation issues. Provide industry pathways for adaptation. Delivery of projects related to climate adaptation. One-on-one engagement and extension support. Economic and strategic support of R&D.	Regional groups Delivery of projects related to climate adaptation. Provide one-on-one engagement and extension support.	R&D Provide research on climate adaptation and the impacts on agriculture sectors. Research step changes and transitional changes –with government, industry organisations and landholders.	Consultants etc. One-on-one technical advice, innovation and extension support to landholders.
All industries	**National** • Dept. of Agriculture & Water Resources • Dept. of the Environment & Energy • Dept. of Industry, Innovation and Science • Bureau of Meteorology **Queensland** • Dept. of Agriculture & Fisheries • Dept. of Environment & Heritage Protection • Dept. of Science, Information Technology & Innovation • Dept. of Energy & Water Supply • Dept. of Natural Resources & Mines • Dept. of Tourism, Small Business, Major Events & the Commonwealth Games • QRIDA • Local government	• Queensland Farmers' Federation • National Farmers' Federation • AgForce	• Regional Groups Collective • Natural Resource Management Groups (NRMs) • Local Catchment organisations	• Climate Change Research Strategy for Primary Industries (CCRSPI) • Commonwealth Scientific & Industrial Research Organisation (CSIRO) • Australian Farm Institute (AFI) • University & research sector • Pesticide & chemical companies	

Aquaculture		• National Aquaculture Council • Aquaculture Assoc. of Qld. • Commodity groups		• Fisheries Research & Development Corp.	• Technical consultants
Cotton		• Cotton Australia	• Irrigation groups	• Cotton Research & Development Corp. • Monsanto, Bayer etc.	• Precision agriculture consultants • Agronomists
Dairy		• Qld. Dairy Organisation • Dairyfarmers Australia • Subtropical Dairy		• Australian Dairy Farmers	• Precision agriculture consultants • Agronomists
Extensive livestock		• AgForce		• Meat & Livestock Australia	• Precision agriculture consultants • Agronomists
Forestry		• Timber Qld. • HQ Plantations		• Forestry & Wood Products Australia	• Precision agriculture consultants • Agronomists
Grains		• AgForce • GrainGrowers • Cropping groups		• Grains Research & Development Corp.	• Precision agriculture consultants • Agronomists
Horticulture		• Growcom • Commodity groups • Regional growers' groups	• Irrigation groups	• Horticulture Innovation Australia	• Precision agriculture consultants • Agronomists
Intensive livestock (chickens, pigs, feedlotters)		• QCGA • Aust. Egg Farmers • Feedlotters Assoc. • ACMF • QCMC		• RIRDC • AECL • Poultry CRC • Pork CRC • MLA	• Vets • Nutritionists
Nursery and garden		• NGIA • NGIQ		• Horticulture Innovation Australia	• Precision agriculture consultants • Agronomists

Sugarcane		• CANEGROWERS • Australian Sugar Cane Farmers' Association	• Irrigation groups	• Sugar Research Australia	• Precision agriculture consultants • Agronomists • Productivity services
Viticulture		• Winemakers' Federation of Australia • Wine Grape Growers Australia		• The Australian Wine Research Institute • Wine Australia	

Appendix 3: Risks and opportunities for the agriculture sector arising from climate change

An overview of the main risks and opportunities posed in agriculture industries from climate hazards, developed from a review of available peer reviewed literature, industry reports and consultation with key industry informants at the Agriculture Sector Adaptation Plan Workshop.

The table is developed with inspiration from the climate change risk assessment matrix: a process for assessing impacts, adaptation, risk and vulnerability previously developed by Queensland Climate Change Centre of Excellence.

Trends in climate variables that create hazards for agriculture	**Risks and opportunities for agricultural industries**								
	Aquaculture	**Cotton**	**Extensive livestock**	**Dairy**	**Horticulture & viticulture**	**Forestry**	**Grains**	**Intensive/ housed livestock**	**Sugarcane**
Elevated CO2	↑acidification ↓shell formation ↓bivalve production	↑yield ↑weed competition	↑pasture growth - change in species composition	↑pasture growth		↑plantation productivity ↑woody competition	↑grain yield ↓grain protein ↑risk of pathogens	↑pasture growth	↑growth
Increased evaporation	↓pond water quality ↑salinity ↑pumping costs ↓productivity ↑stress-related disease risk	↓yield ↑irrigation demand ↓water use efficiency		↑irrigation demand ↓water use efficiency in irrigated pasture/crops	↑irrigation demand ↓water use efficiency	↑mortality of seedlings	↓grain numbers ↓harvest index ↓grain yield		↑irrigation demand ↓water use efficiency

Higher average temp.	↑increased ocean temperature - change location for suitable environments for aquaculture species ↑productivity in southern areas ↑cost of feed input as growth rate increases ↑stress-related disease risk	↑growing season -shift in variety selection drives pressure for rapid development of new varieties ↑sunburn ↑planting window but often with increased irrigation demand		↑heat stress / accumulated heat load index ↓milk yield	↑growing season for some crops ↓quality for some crops ↓suitability for growing stone fruits ↑risk of pests, diseases and weeds ↓quality of wine grape ↓suitable growing regions for wine grapes ↑costs of post-harvest mgt. esp. higher cooling costs	↓plantation productivity ↑mortality of mature trees	↓quality of grain ↑pathogen development ↑need for post-harvest fumigants in silos with health and safety implications for workers and the transport industry	↑heat stress in animals ↑energy use for cooling ↑pest/disease hazards e.g. buffalo fly, ticks etc.	↑growing season ↓yields ↑commercial-grade sugar content ↑reliance on electricity
Higher minimum temp.	↑productivity in southern areas			↓fertility ↓milk yield	↑growing regions for some crops ↓chill hours may reduce productivity/yield		↓quality of grain		
Less frost				↑tick incidence / longer tick season / need more intensive pest management	↑growing regions for some crops				↑in production areas - change in seasonal timing

Higher maximum temp.	↑disease ↓fish health ↓yield/body size ↑growth rate ↑productivity ↑algal blooms	↓yield ↓quality	↑heat stress	↓crop/pasture volume and quality ↑heat stress	↑risk of sunburn	↑fire hazard			
More days over 35° C	↑disease ↓fish health	↓yield ↓quality	↓soil moisture	↓crop/pasture volume and quality ↑heat stress	↑risk of sunburn	↑fire hazard	↓quality of grain		
Decreased overall rainfall/water availability/ shifting rainfall patterns	↓freshwater production	↓yield ↓quality ↓irrigation water supply reliability ↑driver for development / increase of on-farm water storage - shift towards dryland production	↓pasture growth	↓irrigation water supply reliability ↓yield/quality of pasture and crops	↓irrigation water supply reliability	↓plantation productivity ↑mortality of seedlings and mature trees	↓grain yield ↓fungal diseases - shift to dryland production		↑need for irrigation ↑access for harvest equipment ↓irrigation water supply reliability ↑energy use for irrigation

Increased incident of extreme rainfall events	↑ runoff carrying sediment /nutrient /pollutants causing decreased productivity ↑mortality ↑infrastructure damage/losses ↓access to markets/inputs when roads cut	↓productivity	↑soil erosion	↑soil erosion ↑infrastructure damage/losses ↓animal health ↑crop losses	↑soil erosion/loss of alluvial soils ↑risk of rain events occurring at times of no soil cover ↑crop losses	↑ infrastructure losses ↓access to markets	↑soil erosion/runoff	↑pressure on effluent management systems ↑hazard of contaminated runoff	↓paddock access ↑soil erosion
Increased storm frequency and/or increased cyclone/storm intensity	↑infrastructure damage/losses ↓yield ↑product spoilage	↑crop damage		↑crop damage	↑crop damage	↑crop damage	↑crop damage		↑crop damage
Higher peak wind speeds				↑crop damage	↑crop damage	↑crop damage			↑crop damage
Increased intensity /duration of drought		↓yield	↓productivity	↓productivity	↓yield	↓productivity	↓yield		↓yield
Sea level rise	↓productivity ↓biosecurity related to higher tides causing reduced opportunity to dry out ponds								

	fallow periods ↓mangroves which protect farms from damage								
Ocean acidification	↑productivity esp. for shell fish								
Increased fire weather conditions	↑infrastructure damage/losses	↑infrastructure damage/losses	↑animal mortality ↓pasture production ↑infra-structure damage/losses	↑infrastructure damage/losses	↑crop loss ↑infra-structure damage/losses	↑crop loss ↑protection costs	↑crop loss ↑infrastructure damage/losses	↑infrastructure damage/losses	↑infrastructure damage/losses

Additional issues raised during March 2017 agriculture stakeholder workshop

Sector-wide

- The implications of climate change on bee populations and pollination services, which may affect a diverse range of cropping industries, and biodiversity and ecosystems.
- The risk that climate change and extreme weather events may lead to reduced electricity/power reliability, linked to application of load-shedding strategies.
- Likely changes to rainfall are more difficult to model/predict than changes in temperature, although there is strong observational evidence of shifts in temporal distribution of total rainfall across the year. Observed shifts pose both hazards and opportunities for agricultural industries but the uncertainty associated with future rainfall patterns is highly problematic for farm businesses/industry adaptation planning.
- Many horticultural crops/industries in regions are designed around the expectations of/historical observation of rainfall patterns – significant shifts in the distribution of rain across the seasons/year could be a 'game changer' in horticulture.
- Greater variability within and across seasons makes overall farm business management much more challenging (e.g. in intensive livestock and aquaculture industries, planning for required volumes of feed is very difficult) and increases unreliability of profitability.
- An increase in frequency of extreme weather events is linked to significant impacts on rural road/bridge network. When damaging events recur frequently, regional councils run out of funds to repair/re-grade roads.
- Access to finance and insurance is becoming increasingly difficult and expensive for agricultural businesses. Banks are becoming increasingly risk averse.
- Identified hazards can lead to second-order issues/hazards
- Impacts of range of/accumulated impacts of changing climate variables on soil health are not known.
- Increased heat and extreme weather events impact the health of farm workers and working animals (esp. dogs and horses).
- Mental health impacts especially from feelings of loss of control; shifts in crops/industries traditional associated with a farming district has impacts in the social/cultural dimensions of the district/community.
- Escalating climate hazards generate risks to soils, water availability, workers, infrastructure (electricity, water, and transport), and ability to access finance/insurance.

Forestry/Timber industry

- The timber industry faces significant challenges accessing necessary finance and insurance. Insurance is not an option for most companies because there are limited available policies and the premiums are cost-prohibitive.
- Companies currently rely on asset diversification as their key financial management strategy.
- Timber has experienced a distinct hardening of the financial/insurance market.

Sugar, cotton and grains industries

- Climate change is likely to reverse the trend towards forward contracting because emerging climate risks/increasing variability or unpredictability of climate/weather conditions will increasing outweigh the benefits. May drive a shift back towards a greater emphasis on spot selling.

Cotton

- Collected climate change hazards are contributing to a shift in variety selection; the development of new varieties.
- Changes in product quality e.g. overcast conditions during maturation period may result in quality and colour downgrades.

Grains

- Opportunity to shift/diversify mix of crops in crop rotations.

Horticulture

- Changes across multiple climate variables can decrease consistency of crop development – reducing harvest efficiency/increasing harvest costs; increasing failure to meet market requirements/specifications.

Aquaculture

- Fish highly sensitive to temperature variability/fluctuation. Increased temperature variability leads to decreased fish health/productivity, especially rapid falls in temperature.
- Increased temperatures may increase growth rates/productivity driving increased demand for feed. Sourcing fish feed supplies may be problematic. Price of fishmeal impacts feed/production costs

Appendix 4: Current Queensland legislation that may influence land use change for climate adaptation in agriculture

The *Land Act 1994* administers the use of non-freehold land, including land held under a deed of grant in trust, and agricultural leasehold land, and includes provisions for transition to freehold status.

The *Water Act 2000* regulates the taking of water from watercourses, overland flow, and underground/artesian sources. In areas where a Water Resource Plan is in place, works for taking or interfering with water may be prohibited, assessable or self-assessable under the *Sustainable Planning Act 2009.*

The *Vegetation Management Act 1999* regulates the clearing of native vegetation on freehold and leasehold land.

Proposals for land use change in designated State Development Areas (e.g. Bromelton in the Scenic Rim Regional Council area) require approval. The relevant legislation is the *State Development and Public Works Organisation Act 1971*.

Requirements under the *Sustainable Planning Act 2009* or the *Coastal Management and Protection Act 1995* may be triggered by earthworks, including for stock and domestic water storage, draining works or pondage banks in some circumstances.

The *Nature Conservation Act 1992* provides protection of native plants and animals and regulates the commercial harvesting of protected species (such as kangaroos)

The *Sustainable Planning Act 2009* which governs material changes of use on land. Establishing or intensifying a farming enterprise generally does not require approval under this legislation, however, developments such as establishing feedlots, piggeries or other intensive animal facilities do require a development approval. As of 3 July 2017, the *Sustainable Planning Act 2009* is being replaced by a new *Planning Act 2016*.

The *Regional Planning Interests Act 2014* identifies and protects areas of regional interest, seeking to manage impacts and support coexistence of resource activities. The Act protects living areas in regional communities, high-quality agricultural areas from dislocation, strategic cropping land and regionally important environmental areas. The Act can regulate or limit irrigation in strategic environmental areas.
The *Forestry Act 1959* manages the use of State owned forestry areas, and forest products on other tenures that are owned by the State.

The *Fisheries Act 1994* provides for the protection and use of fisheries resources and habitats, and the management of aquaculture.

Some agricultural activities require an environmental approval under the Environmental Protection Regulation 2008.

Appendix 5: Adaptation actions in the agriculture sector

March 2017 workshop participants noted a significant range of climate adaptation actions that are already occurring in the broader agricultural sector. It is important to note that it was acknowledged that adaptations are rarely driven only by climate hazards, and that producers are usually responding to multiple drivers.

The adaptations identified can be grouped into the following themes.

On-farm management practices

- Sharper focus on precision/advanced management/uptake of best practice
- Stronger focus on information driven management – greater use of digital technologies and remote sensing
- Application of micro-level, real time data collection and monitoring
- Greater use of benchmarking
- Increased interest in applying new advances
  - Polymers that protect soils
  - Protective cropping structures
- Water resource management (storage, water-use efficiency, capture & re-use of farm run-off) – at farm and wider scales
- Adjustments to drainage management and design
- Greater use of irrigation for cooling/managing heat stress
- Protected cropping systems
- Increased interest in analysing soil carbon stocks and flows, and use of carbon grazing principles
- Shifts in production schedules and stocking rates/timing
- Shifts in work schedules (e.g. harvesting in cooler hours of day/night)
- Emissions management (capture of effluent gas)
- Shifts to alternate/renewable energy and farming inputs (including to reduce reliance on imports)
- Shifts in soil management/cultivation practices
- Increased emphasis on animal health and resilience to improve capacity to cope with heat stress.

Water resource management

- Increased emphasis on on-farm storage and water use efficiency including on-farm recycling
- Increased need for regional water management/storage.

Business planning and management

- Enterprise diversification
- Relocation and/or diversification/expansion of production areas
- Market diversification, including shift in balance between domestic and international markets
- Greater use of BMP processes, and commitment to operating at BMP level
- Greater use of/interest in climate risk assessment processes and accessing climate information
  - Weather/seasonal forecasting
  - Early warning systems
  - Climate projections
- Greater interest in accessing industry support services
- Growth in cooperatives and other business structures that enable risk sharing
- Increased interest in/involvement in carbon markets and solar farms
- Increased reliance on alternative/off-farm/diversified income sources
- Silver lining: using disasters to make significant improvements or adaptations
- Greater emphasis and support for addressing mental illness and enhancing mental wellbeing.

Financial management strategies

- Sourcing/securing finance
- Sourcing/securing insurance and/or other financial risk management products.

Industry or regional level adaptation planning and support

- Industry groups increasingly developing decision support tools, BMP programs etc
- Increased importance of biosecurity management
- Land use change occurring as some agricultural land shifts out of production.

Supply chain strategies including agricultural inputs

- Exploring cooperatives and other risk management mechanisms within supply chains
- Increased demand for new (climate adapted) breeds and varieties
- Retailers increasingly engage with customers regarding climate/weather impacts on quality/availability/price.

From the adaptations identified at the workshop, the key climate drivers/hazards that producers/growers are adapting to can be inferred to include:

- A drying climate, increased drought and reduced water security
- A warming climate with increased heat stress
- Increasing climatic variability
- Increased intensity of rainfall
- Increased storm risk
- Increased pest pressure and biosecurity risks
- Increased electricity costs
- Reduced reliability of imported products
- Amongst the adaptations noted in the workshop, there is a strong focus on
- An increased emphasis on precision management, supported by fine scale data/monitoring/analysis
- Efforts to optimize efficiency
- Efforts to reduce input/production costs (e.g. energy costs).

Appendix 6: Overview of available Best Management Practice programs (BMPs)

Industry	Focus points/modules	Link	Notes
Cotton	• Biosecurity • Energy and input efficiency • Fibre Quality • Human Resources and Work Health and Safety • Integrated Pest Management – insects, weeds and diseases • Pesticide management • Petrochemical storage and handling • Soil health • Sustainable natural landscape (natural assets) • Water management	https://www.mybmp.com.au/	Volunteer program but has 65 per cent uptake mainly thanks to its link to the Better Cotton Initiative giving access to premium markets with best practice marks are achieved in specific modules.
Meat Chicken EMS	• Natural resource and amenity • Design and operation • Environmental improvement/monitoring	https://rirdc.infoservices.com.au/items/14-100	Chicken meat businesses are required to have an EMS system in place. Regular workshops are run to support the process.
Dairy	• Soils • Fertilisers • Effluent Management • Irrigation • Greenhouse Gas Emissions • Biodiversity • Energy and Water in the Dairy, • Pests and Weeds • Chemicals • Farm Waste	http://www.dairysat.com.au/	
Horticulture	• Energy • Irrigation • Sediment • Water quality	http://www.hort360.com.au/	Employs a facilitated process. About 850 growers across Queensland have completed one or more modules in the program

	• Waste management biodiversity • Noise and air • Industrial relations • Workplace health and safety • Finance		
Grazing BMP	• Soil health • Grazing land management • Animal production • Animal health and welfare • People and business	https://futurebeef.com.au/resources/projects/grazing-bmp/	The grazing industry's BMP has a wide uptake across the state, 1600 producers are making use of the program. In the three priority reef catchments, 38 per cent of the producers have used the BMP. The grazing BMP does not have a specific climate adaptation component. However, some questions are related to climate change issues, especially management activities related to droughts are represented in the tool.
Grains	• Soil Fertility Management • Property Design and Layout • Pesticide Application • Making Best Use of Rainfall • Integrated Pest Management • Managing Climate Risk	https://www.grainsbmp.com.au/	The Grains Best Management Practice (BMP) program is currently unfunded and as such sitting as an online tool available to growers but with no facilitation process is in place. The program is developed in 2009 and is therefore in need of a review and update. The Grains BMP is developed in Queensland with its main uptake in the reef catchment areas.
Pork – environmental risk assessment	• Water • Nutrient monitoring • Paddock rehabilitation • Mortalities management • Odour, dust and noise	http://australianpork.com.au/industry-focus/environment/national-environmental-guidelines-for-piggeries/	Environmental Risk Assessment – Self Assessment Conventional and rotational outdoor
Sugarcane	• Soil health and plant nutrition management • Pest, disease and weed management • Drainage and Irrigation management • Crop production and harvest management • Natural systems management • Farm business management • Workplace health and safety management	https://www.smartcane.com.au/home.aspx	

Appendix 7: Summary of Queensland Government products

While many products are focused on climate variability, those businesses that successfully adapt to current seasonal and longer term variability will be well placed to manage impacts of climate change.

The Long Paddock website

The Long Paddock website is a communication tool to enable primary producers to incorporate climate information into their decision-making, with a long-standing brand name with public and industry recognition. The Long Paddock website is a diverse collection of publications, products, data and information that can be used independently or in conjunction – to value-add as information source, for education, modelling, and workshop material. The Long Paddock supports action in a number of key priority areas for both DAF and EHP, such as drought mitigation, land management, reef catchment modelling, climate adaptation, State of the Environment reporting and species modelling. The Long Paddock website is the entry point for many of the products described below and is currently being redeveloped to a modern, innovative platform to deliver climate and drought information to stakeholders.

The Climate Change Risk Management Matrix

The Climate Change Risk Management Matrix is a tool that can help address uncertainty by identifying the impacts, risk and vulnerability and adaptive responses associated with climate change. This risk management approach can help businesses plan responses to climate variability and climate change, making them more proactive and effective in adapting to future uncertainty.

Operational products include:

- Matrix workbook (PDF or electronic)
- Matrix workshop process (DAF, USQ, DSITI collaboration).

The Consistent Climate Scenarios Project

DSITI provides climate change projections data for 2030 and 2050 in ‘ready-to-use’ formats suitable for input to biophysical model pasture and crop models for example, GRASP and APSIM. It is primarily designed to support crop and pasture scientists, although summary data can be used by a larger audience. Researchers studying climate change impacts on primary industries require access to climate change projections in a format suitable for biophysical modelling, and climate change impacts and adaptation studies. By developing projections data in a consistent manner across Australia and making these data readily accessible to researchers, the Consistent Climate Scenarios Project makes it easier to undertake climate change adaptation studies and to compare results.

Biophysical models typically require daily climate input data for individual locations. This project provided daily projections of rainfall, evaporation, minimum and maximum temperature, solar radiation and vapour pressure deficit for individual locations. Projections data were also developed on a 0.05 degree (approximately 5 kilometre) grid across Australia.

Operational products include:

- Daily climate change projections point location data files for 2030 and 2050 via three methods and 2070 by one methodology.

The Queensland Agricultural Land Audit

The Queensland Agricultural Land Audit (the Audit) identifies land important to current and future production and the constraints to development, highlighting the diversity and importance of Queensland's agricultural industries across the state. It is a key reference tool helps guide investment in the agricultural sector and informs decision making to ensure the best use of agricultural land.

The Audit covered the Queensland’s 12 regions, based on regional planning boundaries, and assessed the opportunities and constraints including current land use, infrastructure or logistical issues and planning processes.

Operational products:

- WALI mapping tool with preloaded land use, historical climate and pasture analyses.

Agricultural Values Assessment and Climate reports

To assist land managers and investors better understand agricultural values and climate patterns across Queensland, the Department has developed the Agricultural Values Assessment (AVA) and Agricultural Climate Assessment (ACA) reports.

These auto-generated reports bring together information from hundreds of sources in concise and easy to understand reports with maps. The reports can be tailored to anywhere in the state, and provide detailed information to support investment and planning. The reports are free and there is no limit on the number of requests you can submit.

The Assessment Area is land within a 25 kilometre radius from a central coordinate.

Agricultural Values Assessment report (PDF email) includes:

- Baseline information regarding agricultural land classes within the Assessment Area
- Calculated areas (expressed as hectares and percentages) for current and potential agricultural land uses, and other land use interests such as water resource planning
- Proximity of the Assessment Area to processing facilities (such as sugar mills and cotton gins) and major infrastructure (such as airports and seaports).

Agricultural Climate Assessment report (PDF email) includes:

- Temperature and rainfall ranges for the Assessment Area
- Temperature, rainfall, evaporation, pasture growth, crop yield, natural disaster and extreme weather event information
- Weather station locations within the Assessment Area
- Information on the major drivers of climate variability in the region of interest.

FORAGE Land Management Information System

FORAGE is an online system which generates and distributes information relating to climate and pasture condition at user-specified locations. The system receives requests from users, processes requests and generates the requested information which is then emailed back to the user.

The primary aim of FORAGE is to incorporate a number of products such as SILO climate data, satellite imagery and the outputs from DSITI's grazing system models GRASP and AussieGRASS, into a grazing land and environmental management decision support tool. Reports can be requested through The Long Paddock website and a report will be sent within in 10 minutes to a few hours, depending on the complexity of the report. Reports for sustainable carrying capacity and improved pasture growth forecasts are under development.

Operational products:

- Rainfall and Pasture report
- Rainfall and Pasture by Land Type report
- Ground Cover report
- Regional Comparison Ground Cover report
- Indicative Land Type report
- Foliage Projective Cover report
- Rainfall and Pasture Growth Outlook report
- Regional Climate Projections report
- Drought Assessment report
- Erodible Soils report (Burdekin and Fitzroy regions)
- Crop Frequency report (selected southern central and north Queensland cropped areas).

AussieGRASS

The AussieGRASS Environmental Calculator is a national simulation framework for Australian grasslands and rangelands, operating at a 5 x 5 km resolution across Australia. The AussieGRASS modelling framework (Carter et al. 2000) comprises GRASP as the base model (Rickert et al. 2000), input parameter layers of soils, pasture types, tree cover and stock numbers, and data layers of climate information (Jeffrey et al. 2001) including rainfall, temperature, radiation, humidity, evaporation and vapour pressure deficit. The modelling framework also includes data sources such as NDVI from NOAA and extensive ground-truthing across the continent (Hassett 2000).

AussieGRASS has evolved since its inception in 1996. However, it continues to deliver high quality, near real-time

products on a national basis to provide rangeland climate and land condition information to scientists, government policy, catchment management groups and land managers. AussieGRASS has contributed to both Exceptional Circumstance submissions and regional drought assessments. The operational components of the AussieGRASS modelling framework are available for use in other applications such as the National Production Monitoring System and fire warning systems. It has been used to calculate methane emissions from fire, cattle and sheep and growth indices have been used by ABARE to assess regional farm performance (Kokic et al. 2004).

Operational products include:

- Rainfall, pasture growth, pasture biomass, groundcover, curing index, fire risk and runoff in absolute terms (monthly) and percentiles (relative to history) on a 1, 3, 6, 12, 24, 36, 48 month basis – maps and GIS gridded data (5x5km) by state and nationally
- SubIBRA time series and text-file data (monthly and annually) for rainfall, pasture growth, pasture biomass, temperature, utilisation and evaporation - by state and nationally.

Seasonal climate outlook

DSITI produces a monthly climate statement which interprets seasonal climate outlook information for Queensland. The monthly climate statement is based on DSITI's own information and also draws on information from national and international climate agencies. DSITI assessment of rainfall probabilities is based on the current state of the ocean and atmosphere and its similarity with previous years. DSITI monitors the current and projected state of the El Niño-Southern Oscillation (ENSO) referring to information such as sea-surface temperature (SST) anomaly maps and the Southern Oscillation Index (SOI). Based on this information, DSITI uses two systems to calculate rainfall probabilities for Queensland:

DSITI's SOI-Phase system produces seasonal rainfall probabilities based on 'phases' of the Southern Oscillation Index. DSITI's experimental SPOTA-1 (Seasonal Pacific Ocean Temperature Analysis - version 1) monitors Pacific Ocean SSTs from March to October each year to provide long-lead 'outlooks' for Queensland summer rainfall. Outlooks based on both the SOI-Phase system and SPOTA-1 are freely available, although a password is required to access the experimental SPOTA-1 information (email: rouseabout@dsiti.qld.gov.au).

Operational products:

- Monthly climate statement
- Southern Oscillation Index values, data files and Graphs of monthly SOI values and SOI Phases, 1899 to current
- Rainfall probabilities based on 'phases' of the Southern Oscillation Index
- Commentary on rainfall probabilities based on phases of the SOI
- sea surface temperature anomaly map
- SPOTA-1 (Seasonal Pacific Ocean Temperature Analysis version 1).

SILO

SILO is an enhanced climate database hosted by DSITI. SILO contains Australian climate data from 1889 to the present, in a number of ready-to-use formats, suitable for research and climate applications. In addition, SILO provides users with access to climate change projections data for 2030 and 2050 in a daily format. SILO's patched point datasets for Queensland are available free of charge through the Queensland Government Open Data Portal.

Operational products include:

- Daily climate files for weather stations across Queensland in ready to use format, for modelling or analyses.

Rainfall and pasture growth posters

A variety of annual and periodic posters showing rainfall, pasture growth with and without cyclone tracks have been produced, these are available as digital pdfs or hardcopy posters.

Operational products include:

- Australia's Variable Rainfall Poster depicts twelve monthly rainfall (April-March) in maps for the years 1890 through 2016 alongside a graph of Southern Oscillation Index and Inter-decadal Pacific Oscillation values.

Soon to be released on The Long Paddock:

- Australia's Variable Pasture growth Poster depicts twelve monthly rainfall (April-March) in maps for the years

1890 through 2016 alongside a graph of Southern Oscillation Index and Inter-decadal Pacific Oscillation values.
- Australia's Variable Rainfall Poster with cyclone tracks depicts twelve monthly rainfall (April-March) in maps for the years 1910 through 2016 alongside a graph of Southern Oscillation Index and Inter-decadal Pacific Oscillation values. Cyclone tracks have been added and named where systems have crossed the eastern coast – and data have been available.
- Queensland's extended wet and dry periods (with Australian rainfall percentiles) from 1889 to 2016.

Regional climate change impact summaries

The Regional climate change impact summaries aim to help Queenslanders understand and adapt to our changing climate by providing a snapshot of the climate risks, impacts and responses in each region. Projections for 2030, 2050 and 2070 are summarised on a state-wide and regional planning scale.

Climate Change in Queensland map application

The Climate Change in Queensland map application illustrates the projected impacts of climate change for the years 2030, 2050, 2070. Using the map application, you can view the average changes in temperature, rainfall and evaporation projected for your region. The application features pop-up charts, graphs and data tables showing climate change projections for both lower and high greenhouse gas emissions.

Climate change impact and adaptation regional factsheets

Operational products: Available soon on University of Southern Queensland website.

Thirteen regional fact sheets that give detailed climate related impact and adaptation information on bioregions, major agricultural industries. Historical and projected values are given for rainfall, temperature, evaporation and other important variables. Results from case studies and modelling analyses are tabled and discussed.

Climate Change

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