Cropping and Climate Change in the East Coast Cluster: Impacts & Opportunities

Briefing Note #3: A resource document for exploring adaptation options with the cropping industry

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Key messages

- Farming industry bodies recognise that managing climate variability in cropping businesses must become part of **normal business risk management and decision-making**, and that it will increasingly take place under conditions of uncertainty.
- Over the next two to three decades**, changes to rainfall patterns** are likely to be masked by natural variability in the Cluster regions. However, rainfall may occur in less frequent, **higher intensity storm events** that can erode soils of farms but also increase the contribution to downstream water quality impacts on the environment.
- On cropping land under dryland grain and oil seed production, a hotter (summer maximum temperature) and drier (winter rainfall) climate will lead to **a significant contraction of the area suitable for grain growing**, which generally will shift to grazing in coming decades. Roughly two-thirds of grain producing businesses in the Fitzroy region, for example, are mixed enterprises also running cattle, which may assist this transition. With irrigated cropping, competition and availability of water resources will become increasingly pressing.
- Economic analysis suggests that there are areas within each of the East Coast Cluster regions that may support **viable carbon farming projects** using native forest regrowth, environmental plantings and avoided deforestation. These are mainly in sub-coastal areas. Larger projects, with commensurate economies of scale, could be viable in most regions and would benefit from multi-property coordination supported through NRM networks.
- At enterprise level, improving water use efficiencies whilst enhancing yields will be critical for adaptation. In addition, producers who develop **broad advice networks and professional and personal support networks** are better able to steer their businesses through prolonged unfavourable conditions. NRM/LLS groups working with industry bodies can contribute to providing valuable advice and support networks, particularly in areas of **property level risk management, preparedness and maintaining natural resource condition**.

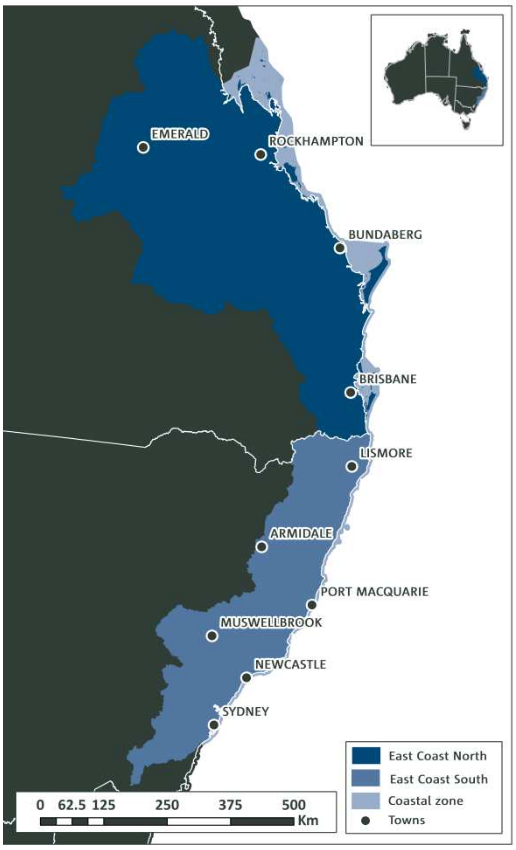

Figure 1. Map of the East Coast Cluster (Dowdy et al., 2015)

Background

The focus of this briefing note is to assist regional Natural Resource Management (NRM) and Local Land Services (LLS) groups within the East Coast Cluster to plan future engagement with the cropping industry on issues related to climate change. The cropping resource-base is highly sensitive to a changing climate, making the cropping industry vulnerable to projected climate changes such as rising temperature, reduced water availability and extreme weather events. However, the industry need not be negatively impacted if well prepared. Preparing for climate change adaptation sooner than later is important, and may mean that any opportunities associated with the future prosperity of the industry will be better secured.

This briefing note reports on climate change vulnerability and adaptation opportunities for the cropping industry within the six NRM/LLS regions of the East Coast Cluster (Figure 1).

These regions include from north to south, the Queensland NRM regions of Fitzroy Basin, Burnett-Mary and South East Queensland (SEQ) (also referred to as East Coast North), and the New South Wales LLS regions of North Coast, Hunter and Greater Sydney (East Coast South). The briefing note is structured using a series of headings and sub-headings that reflect the main parts of an *integrated vulnerability assessment framework*, e.g. exposure, ecological/biophysical impacts, socio-economic impacts, and adaptive capacity. This framework has been developed specifically to help think about sector-based adaptation to climate change in resource dependant industries, and has been adapted to suit the writing of this briefing note (Marshall et al., 2013). The briefing note also summarises cropping industry policy perspectives and outlines a suite of adaptation responses where opportunities for cooperation between industry and NRM/LLS groups on shared priorities exist for reducing vulnerability to climate change.

While this document takes a whole-of-industry perspective to cropping in the East Coast Cluster, the description of likely ecological impacts later in the document uses dryland cereal cropping as a case study to illustrate anticipated changes. Detailed scientific data used in this analysis were commissioned by the Australian Government's Department of Environment and can be accessed through the references listed in the final section.

A brief overview of the industry in the face of climate change

In Australia, broadacre cropping of various winter and summer cereals, oilseeds and pulses, as well as cotton and sugarcane (irrigated and non-irrigated) is an important industry. It has a gross value of about $17,050M annually and occurs over an area of around 24Mha (ABS, 2014a; 2014b). In the East Coast Cluster, the total area of land used for broadacre cropping is 536,937ha (486,535ha in the QLD NRM regions and 50,402ha in the NSW LLS regions) (ABS, 2014a). In 2012-13, the total gross value of production of the cropping industry in the East Coast Cluster was just under $550M (Table 1) (ABS, 2014b). In the same years, the region also had approximately 2612 farm businesses focused on broadacre cropping (ABS, 2014a).

Overall, the cropping industry is economically significant in the Fitzroy Basin and Burnett Mary NRM regions, but plays a less important role in the southern regions of the East Coast Cluster. In the Fitzroy Basin, the cropping industry is characterised by a diverse range of broadacre crops, including wheat, sorghum, oats, maize and cotton. Whilst cotton is mostly irrigated, the vast majority of land is used for dryland cropping. The total area of land used for broadacre crops within the Fitzroy Basin is 384,115 ha, and there are nearly 600 agricultural businesses engaged in broadacre cropping in the region (Table 1) (ABS 2014a). Cropping also contributes nearly $300 million to the regional economy annually, which is nearly a quarter of the total gross value of agricultural commodities.

In the Burnett Mary, the majority of the cropping activity centres on sugar cane growing. Other broadacre crops include wheat, sorghum, peanuts and maize. The total area of land used for broadacre cropping within the Burnett Mary is 83,721 ha, and there are more than 870 agricultural businesses that undertake cropping in the region (ABS, 2014a). In 2012-13, the total gross value of production of the cropping industry in the Burnett Mary was almost $170 million (ABS, 2014b).

Table 1: Number of agricultural businesses and total gross value of agricultural commodities produced (VACP) in the cropping industry

	No. of agricultural businesses (a)	Gross VACP ($m)(b)	% of total gross VACP (b)
Fitzroy	593	295.5	24%
Burnett-Mary	872	169.6	15%
SEQ	363	19.2	2%
Northern Rivers	669	55.8	7%
Hunter-Central Rivers	61	6.9	1%
Hawkesbury-Nepean	54	2.3	0.3%
Total	2,612	549.3	

Source: Table adapted from Smith et al 2014; (a) Agricultural Commodities, Australia, 2012-13 (ABS, 2014a); (b) Value of Agricultural Commodities Produced, Australia, 2012-13 (ABS, 2014b)

Australia is recognised as having the world's most variable climate as a result of the very many influences on its climate (Howden and Stokes, 2010). Climate change is expected to have complex effects on the growth and quality of broadacre crops. For instance, changes in temperature and precipitation will affect agricultural productivity.

Most crops are highly sensitive to climate, where both dry years and wet years can significantly impact on productivity and crop quality (Howden et al., 2010). Rainfall is a key determinant of yields, and crop productivity can increase or decrease with rainfall. Dryland cropping yields are highly dependent on the quantity and timing of rain prior to and during the growing season (Productivity Commission, 2009). Climate change is expected to affect cereal crops differentially within the region. Warmer temperatures in the cooler parts of the region may benefit perennial plants, but annuals and plants growing in the hotter climates may be negatively affected (Howden and Stokes, 2010). Climate change is also expected to have some interesting positive effects on crops. Carbon dioxide fertilisation is a complex process in which elevated atmospheric carbon dioxide can increase the efficiency of use of light, water and nitrogen and partly offset increases in evaporation or decreases in rainfall (Steffen and Canadell, 2005). Indeed, Australian grain yields may increase by about 21% at CO_2 concentration of 550 ppm and by 30% at 700 ppm when compared with a year 2000 baseline of 370ppm. However, there is likely to be an associated decrease in grain protein content (Howden et al., 2010).

Sugarcane growers in the East Coast Cluster have a long history of managing the impacts of climate on crop production. Key sugarcane production districts within the East Coast Cluster stretch from Bundaberg in the north via Childers, Maryborough and Rocky Point to Condong and Harwood in the south (Canegrowers, 2012). The production of sugarcane strongly depends on three climatic constraints: (i) water availability; (ii) amount of solar radiation received; and (iii) minimum temperature at which growth starts and maximum temperature at which growth ceases (Park et al., 2010). Nationwide, around 60% of sugarcane production depends on some form of irrigation (Inman-Bamber et al., 2012). The sugarcane industry around Bundaberg in the Burnett Mary NRM region is also increasingly relying on supplementary irrigation due to increased rainfall variability. Additional adaptation measures will be required to reduce the adverse impacts of projected climate variability and to improve the management of limited water supplies in this region (Park et al., 2010).

Against this backdrop, climate change presents a very real threat to the viability of broadacre cropping within the East Coast Cluster as well as some very real opportunities. NRM organisations have an important part to play in the future of the cropping industry within the region. Adaptation within the cropping industry will need to take a flexible, risk-based approach that incorporates future uncertainty and provides strategies that will be able to cope with a range of possible future local climate change scenarios (Howden and Stokes, 2010). Farmers need the capacity to evaluate and implement these as needed, rather than focussing too strongly on exactly where and when these impacts and adaptations will occur. A common adaptation option will be to enhance and promote existing management strategies for dealing with climate variability. This will assist farmers to manage climate change until longer term trends become clearer.

Industry perspectives on the challenge ahead

Understanding how the industry sees and describes the challenges it faces with managing climate variability and extreme weather events is crucial to designing appropriate and effective responses from an NRM perspective. A review of recent industry policies, reports and submissions (2009-2014) highlight several important themes:

(i) An exposed sector facing rapid change

By and large, industry organizations and representative bodies recognise the growing exposure of farmers and agricultural industries as a whole to an increasingly variable climate. Whilst emphasising that farmers are 'good managers of variability' and change is 'normal' they also acknowledge that the rate of change and the associated impacts of these changes may soon outstrip existing management capabilities, signalling the need for urgent action:

> *Australia's climate is continuously changing. Evidence now suggests that climate is changing at a faster rate and has become more variable. As a sector highly exposed to changes in climate the Association believes that the agricultural sector must take action to address changing climatic conditions and increased climate variability in order to maintain and increase its productive capacity (NSW Farmers' Association, 2012, p 23).*

> *Whilst Australian agriculture is considered to have a strong and proven history of adapting practices to the Australian climate, it is also accepted that impacts of a speed never before seen in the history of this sector may indeed be on the door of current practice (AgForce Queensland, 2009, p.2).*

The Queensland Farmers Federation – a peak body representing a range of rural industry organisations including sugar cane and cotton groups – submission to the Productivity Commission Inquiry into Barriers to Effective Adaptation, describes however that at farm enterprise level adaptation is generally served through an incremental approach to "decision-making under uncertainty" where:

> *…there is no clear distinction between what is a human action in response to climate change and one in response to climate variability. In farming, enterprise decisions made in an uncertain environment tend to be risk management decisions in a continuous adjustment to circumstances, rather than an absolute adjustment (QFF, 2011, p.3).*

Canegrowers, the peak body for Australian sugarcane growers, has developed a booklet outlining climate variability tools for primary producers in the Queensland sugar industry. It includes decision support tools to aid in the timing of production, harvesting, storage and logistics planning. According to this toolkit, the success of the sugar industry depends heavily on:

> *...capitalising on good weather, being prepared for future climate and weather patterns, and minimising the risks associated with climate variability (Canegrowers, 2012, p.3).*

(ii) Managing and recovering from risk

The national industry group for grain producers, Grain Growers, identifies 'two broad adaptation options for agriculture' – both of which emphasise risk management:

> *Operationally manage risk through improved adaptation tactics, however this often requires additional capital. Allow the risks to be borne by those best able to manage them; and, Management of risk by adapting enterprises to manage risk better requires changes at the enterprise level such as new crop varieties, and greater flexibility of enterprise to adjust to seasonal conditions as they arise (Grain Growers, 2011, p.63).*

A consistent theme is an emphasis on normalising risk management and bolstering the capacity of enterprises to recover from major climatic events:

> *[F]armers must focus on embedding climate variability as a normal business "risk" decision, whilst maintaining a focus on productivity and profitability in the short to medium term. The NFF supports a resilience approach to climate change. Resilience is the ability to recover from shocks, such as drought, to a similar initial state, while continuing to deliver valuable services. For agriculture, this means actions and attitudes that enhance its capacity to deal with the conditions associated with and to reduce its vulnerability to climate change. Adaptation is the broader response to climate change where resilience is not enough (NFF, 2014).*

This also shows a preference for risk and resilience based approaches over more transformative types of adaptation. The exception, however, is that when transformation is market driven (e.g. structural adjustment or diversification) it is generally considered as acceptable and necessary[1].

(iii) Intersection of climate risk with other issues

Climate risk and related drought policies are also seen by industry bodies to closely intersect with a range of other policy and programmatic issues, which are often framed as more pressing for the sector. These include land use planning and competition for agricultural land, emissions reduction / mitigation activities and natural resource related policies such as water availability and pricing:

> *…those areas likely to experience significant increases in risk will have to adapt to greater climate variability and, most likely, trading risk due to government mitigation policies. Added to this will be increases in the value of water as it becomes scarcer due to reduced rainfall and stream flows (Grain Growers, 2011 p.63).*

> *…when addressing policy frameworks such as drought policy and exceptional circumstances, to ensure that landscape resilience is provided for…policy frameworks are required so that perverse outcomes such as ongoing landscape competition removing agriculturally productive land from the market, do not come to fruition…(AgForce Queensland, 2009, p.2).*

[1] Example here is the Grain Growers State of the Industry Report, 2011

(iv) Impacts of major events and adaptive capacity

Many of the climate-related impacts described relate to the physical impacts of major natural disaster events such as floods and prolonged drought conditions. For example several types of impacts associated with major flood events on land and natural resource condition are described, including "weed seed introduction by floodwaters…; scouring; silt deposition; sheet erosion; land slippage; drainage channel damage; reduced access for machinery" (AgForce Queensland, 2014b). Industry bodies describe the impacts of drought on productivity, the relationship this has with government extension, and the shrinking time gap between these events and its effect on the adaptive capacity of producers:

> *The…declining potential for crop yields in farming areas means there has been little opportunity for producers to recover, let alone put preparedness measures in place (AgForce Queensland, 2014a).*
>
> *Grain producers are reporting that the prolonged drought has weakened their ability and confidence to invest in new technologies. It appears that risk management could be a factor depressing productivity as producers change their input use and management practices to address the riskiness caused by drought (Grain Growers, 2011, p.34).*
>
> *Drought conditions over the past decade have exacerbated the downturn in agricultural productivity… In addition to this increased climate variability [drought conditions], another reason for the negative productivity growth over the past decade points toward declining public investment in agricultural research and development (Grain Growers, 2011, p.33).*

Exposure

This section provides a summary of future climate projections for the East Coast Cluster region based on the CMIP5 model, which also underpins the Fifth Assessment Report of the IPCC. A set of four scenarios, also referred to as Representative Concentration Pathways (RCPs), has been produced which represent the full range of plausible future emission scenarios. This briefing note focuses on the **high** scenario (in terms of future carbon emissions – RCP8.5) and the **moderate** scenario (intermediate scenario resulting from moderate emissions reduction - RCP4.5).

Due to the large climate diversity of the East Coast cluster region, projections are presented individually for the Queensland and the New South Wales parts of the region, namely: **East Coast North** (comprising Fitzroy, Burnett Mary and SEQ), and **East Coast South** (comprising North Coast, Hunter and Greater Sydney) (Dowdy et al., 2015).

Current climate for the East Coast Cluster

The East Coast Cluster region spans a large range of latitude and altitude, resulting in a diverse range of climatic conditions. Its climate is predominantly subtropical, with regional variations such as tropical influences in the north and temperate influences in the south. Since the close proximity to the ocean has a moderating influence on temperatures, the East Coast Cluster generally experiences fewer hot days than locations elsewhere in Australia at similar latitudes. Overall, the **East Coast North** region exhibits a clear seasonal variation in temperature with daily mean temperatures ranging from about 26°C degrees in summer to about 15°C in winter (Figure 2).

In the **East Coast South** region temperatures are somewhat lower, with daily mean temperatures ranging from about 22°C in summer to about 10°C in winter. The annual average temperature is 21.3°C for **East Coast North** and 16.4°C for **East Coast South** (Dowdy et al., 2015).

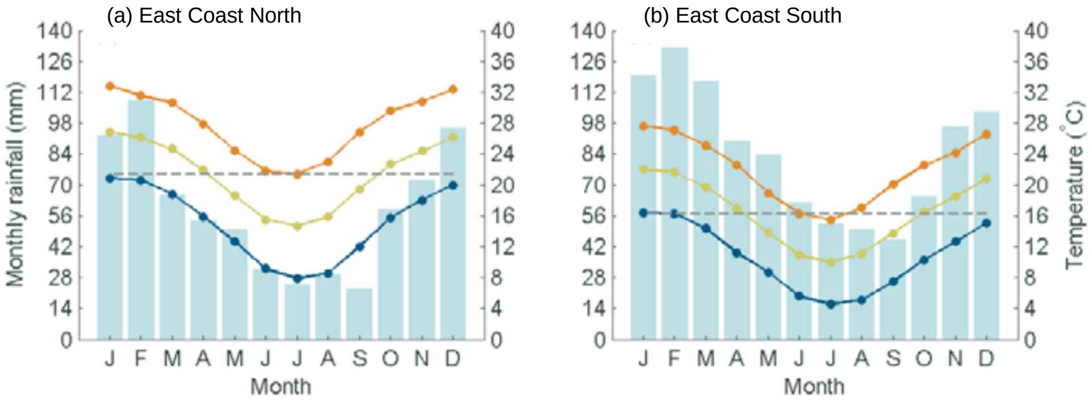

Figure 2. Seasonal rainfall (blue bars) and temperature characteristics for the East Coast Cluster North (a) and South (b) (1986-2005). Monthly mean temperature (green line), monthly mean maximum temperature (orange line), monthly mean minimum temperature (blue line), and annual average of mean temperature (grey line). Temperature and rainfall data are from the Australian Water Availability Project (AWAP) (Dowdy et al., 2015).

The seasonal rainfall characteristics in the East Coast Cluster are determined by a complex series of rain-bearing weather systems that occur in this region (i.e. trade winds, easterly trough, tropical cyclones, fronts and low-pressure systems, changes in sea surface temperatures). There is a clear variation in rainfall throughout the year in both the **East Coast North** and the **East Coast South** regions. In both regions, February is the wettest month, followed by a dry period during the cooler months (June to September) (see Figure 2 above). However, in contrast to the **East Coast South** region, the **East Coast North** region has a more pronounced difference between the wet and the dry months of the year, relating to stronger tropical influences. Across the region, there is a spatial gradient in rainfall, where locations near the coast generally experience more rainfall than locations further inland (Dowdy et al., 2015).

Climate futures for the East Coast Cluster

Overall, the East Coast Cluster region is projected to continue to warm throughout the 21st century. Mean surface air temperature between 1910 and 2013 has already increased by about 1°C in the **East Coast North** and by about 0.8°C in the **East Coast South**. For the near future (2030) the mean warming is around 0.4 to 1.3°C above the climate of 1986-2005, with only minor differences between the model scenarios (RCPs) (Table 2). For the far future (2090) the mean warming is 1.3 to 2.5°C for the moderate scenario (RCP4.5) and 2.7 to 4.7°C for the high scenario (RCP8.5). There will also be changes to temperature extremes, including a substantial increase in temperature of the hottest days, a greater frequency of hot days, and a substantial decrease in frost frequency (Dowdy et al., 2015).

Table 2. Projected temperature change (°C). Compared to 1986-2005. For 20-Year Periods (centred on 2030 and 2090) and three RCPs. The median projection across the models is shown. With the 10th to 90th percentile range of model results in brackets.

	RCP2.6 Low emissions	RCP4.5 Intermediate emissions	RCP8.5 High emissions
2030	0.8 (0.4 to 1.1)	0.9 (0.6 to 1.2)	1.0 (0.6 to 1.3)
2090	0.9 (0.5 to 1.5)	1.9 (1.3 to 2.5)	3.7 (2.7 to 4.7)

Source: Adapted from Dowdy et al., 2015

Projections of rainfall changes are less clear than temperature changes for the East Coast Cluster. Overall, annual rainfall has not shown any long-term trend during the 20th century, but has demonstrated intermittent periods of wetter and drier conditions. In the **East Coast North** region, models show a range of results under both moderate (RCP4.5) and high (RCP8.5) emission scenarios in the far future (2090). Generally, models show either little change or slight decreases of rainfall, particularly in winter and spring. In the **East Coast South** region, models project a decrease in winter rainfall in the far future under both scenarios. A range of changes is projected in the other seasons, with a tendency for increase in summer rainfall. However, uncertainty over driving processes and some inconsistent results from downscaling mean that the direction of change cannot be reliably projected (Dowdy et al., 2015). With such contrasting model simulations, it is therefore important for farmers to consider the risk of both a drier and wetter climate in any planning activities.

Importantly, many of the earliest and most significant impacts of a changing climate are likely to be experienced as changes in extreme weather events rather than changes to the mean climate. For instance, whilst the projection for mean rainfall is tending towards a decrease in the East Coast Cluster region, the intensity of heavy rainfall events is projected to increase, causing flooding impacts. Projected changes to drought share much of the uncertainty of mean rainfall change, and there is no clear indication on changes to drought condition. Under the high emission scenario (RCP8.5) there is evidence which indicates an increase in the proportion of time spent in drought towards the end of this century. However, the picture is less clear for the moderate emission scenario (RCP4.5) (Dowdy et al., 2015).

Ecological and biophysical impacts

As discussed above, climate change will impact broadacre farmers in the East Coast Cluster due to the effects of increasing temperatures, changing rainfall regimes and more extreme weather events. This section predominantly focuses on the ecological/biophysical impacts of climate change on dryland summer and winter cereal cropping, but its broader messages may also be applicable to other types of broadacre crops. Distribution models using software called *MaxEnt* were used to predict the probability of an area being suitable for dryland cereal cropping in the future, based on changes in climate variables. Two potential future climate scenarios (or Global Climate Models (GCMs)) were developed, representing (i) a ‘worst case’ warmer and drier future, and (ii) a ‘best case’ wetter and cooler future.

The modelling was undertaken for cropping in only five of the six NRM/LLS regions within the East Coast Cluster (i.e. Fitzroy Basin, Burnett-Mary, South East Queensland, North Coast and Hunter). In the Greater Sydney LLS region cropping was not modelled since production is not significant in this area.

The analysis showed that 'rainfall (May-October)' was the most important predictor for the future suitability of dryland cereal cropping in the five assessed NRM/LLS regions of the East Coast Cluster. This variable acts as an indicator for the growing period. 'Maximum temperature in summer' was the second most important variable, acting as an indicator for the harvesting period (Hosking et al., 2014a, b, c, d, e).

Climate change will impact the suitability of land for dryland cereal cropping in the East Coast Cluster to varying degrees. In the two most northern NRM regions of the East Coast Cluster (Fitzroy and Burnett Mary) cropping suitability is predicted to contract and shift from west to east. However, in the more central and southern NRM/LLS regions of the East Coast Cluster (SEQ, North Coast and Hunter) cropping suitability is predicted to remain generally unchanged from current conditions. Overall, changing climatic conditions will impact the suitability of cropping to a lesser degree than grazing. There are also likely to be land use changes over time. On cropping land under dryland grain and oil seed production, a hotter and drier climate will lead to a contraction of the area devoted to grain growing, which generally will shift to grazing. In summary, modelling undertaken within five of the six NRM/LLS regions of the East Coast Cluster shows the following results:

- In the Fitzroy Basin, cropping suitability is predicted to shift and contract from the west to the east. Cropping will be less affected under the wetter-cooler GCM. However, under the warmer-drier GCM, cropping suitability will be significantly reduced in the western parts of the Fitzroy Basin (Hosking et al., 2014a).
- In the Burnett Mary NRM region, areas suitable for cropping are predicted to contract and shift from the west to the east, but with a less pronounced eastwards shift under the cooler-wetter GCM (Hosking et al., 2014b).
- In the SEQ region, cropping suitability is predicted to remain generally unchanged from the current climate, with the highest suitability remaining in central SEQ (Hosking et al., 2014c).
- In the North Coast LLS region, areas currently suitable for cropping are predicted to remain suitable in the northern half of the region under both GCMs. (Hosking et al., 2014d).
- In the Hunter LLS region, cropping is predicted to remain suitable mostly in the north-western area of the region (Hosking et al., 2014e).

Socio-economic impacts

Climate change is likely to have significant socio-economic impacts on the cropping industry given that climate change is likely to cause large changes in resource condition and impact the viability of cropping businesses within the region. Of particular note is the likely reduction in area of land suitable for cropping (particularly dryland cereals) and the likely change in land use towards grazing. Secondary impacts within the region may be associated with economic volatility, increasing costs and increased problems associated with pests and weeds, disease and fire risk.

Social and economic impacts within cropping families are likely to manifest as psychological impacts, stress-related family impacts, cultural impacts and economic impacts. The most significant changes are likely to be those that are associated with extreme events as well as those associated with changes in land-use. Psychological impacts are likely to occur where the viability of cropping enterprises is threatened through sudden and extreme changes or gradual changes in resource condition. Farming businesses that are unable to adapt to the impacts of these changes in the medium to longer term will face pressures to exit the industry. Occupational identity that is created around primary production can be so significant that many farmers will have difficulty considering another occupation, and mental health issues will likely become apparent. In extreme cases mental health issues may result in elevated suicide rates and occurrences of domestic violence (Berry et al., 2011; Marshall et al., 2014). Stress-related family impacts are likely to be associated with changes in resource condition that decrease the economic viability of cropping enterprises, making the enterprise a less enticing option for younger family members and women, and elevating rates of divorce and domestic violence.

With the anticipated changes in land suitability and increasingly variable and extreme weather events, some farmers, under current production systems and technologies, will be unable to remain viable. There are several characteristics of farming businesses in the northern East Coast Cluster, however, that suggest strong potential for coping with these changes. For example, in the Central Queensland area, in particular, many grain growing businesses are in fact mixed beef grazing-grain operations and so are better positioned to manage a conversion to grazing land uses. However, a loss of diversification in the business model may increase susceptibility to market and other risks and reduced potential to grow feed locally for cattle may increase transport costs. It is perhaps the specialist grain production businesses that are likely to face the most pressure. However, this may be compensated by highly specialised farming skill sets that may be transferable to other locations or production systems.

The types of farmers that are likely to succeed or adapt to climate change are likely, in turn, to influence the culture of the region. Cultural impacts are thus also likely to develop in the region as a result of climate change through a shift in the nature and size of cropping enterprises. The tendency will be to move from smaller enterprises towards larger and more integrated, corporate-style production enterprises (Marshall et al., 2014).

Adaptive capacity

Adaptive capacity is the ability to convert existing resources (natural, financial, human, social or physical resources) into a successful adaptation strategy (Marshall et al., 2014). Importantly, adaptive capacity is not about having or providing financial resources. Characteristics of adaptive capacity include: possessing creativity and innovation (for identifying solutions or adaptation options); testing and experimenting with options; recognizing and responding to effective feedback mechanisms; employing adaptive management approaches; possessing flexibility; being able to reorganize given novel information; managing risk; and, having necessary resources at hand (Marshall, 2010).

Adaptation processes are dynamic, continual and can be influenced at any time. Cropping people that can anticipate or effectively react to the effects of climate change are more likely to adapt to new climate conditions. Studies in the grazing and fishing sectors show that farmers with a higher adaptive capacity tend to display consistent characteristics. Whilst adaptive capacity has not been measured within the cropping industry of the East Coast cluster, studies in other sectors highlight that recognising and enhancing adaptive capacity becomes increasingly important for resource-based industries facing significant climate change.

Adaptive capacity can be measured according to four key attributes reflecting skills, circumstances, perceptions and willingness to change (Marshall et al., 2012). These are described as: 1) how risks and uncertainty are managed, 2) the extent of skills in planning, learning and reorganising, 3) the level of financial and psychological flexibility; and 4) the anticipation of the need and willingness to contemplate and undertake change (Marshall, 2010; Park et al., 2011).

These dimensions are mostly skills based and can be learned. Managing climate change and adapting is about planning for the future even though the future is uncertain. A constructive approach for climate adaptation planning is to plan for a range of plausible climate scenarios, and take the path of "least regrets", which accounts for a range of uncertainties about the future. Uncertainty can exist around the level of variability in ecological conditions, failure to observe change, inadequate communication, lack of clear goal setting, and outcome uncertainty.

The cropping industry within the East Coast region may autonomously adapt to climate change impacts through adjusting gradually to changes. However, there will be instances when incremental changes will be insufficient as a strategy and more active planning will be needed. In some instances, transformational changes, where the industry considers changes in its structure or function, may be necessary. The industry will benefit from a flexible, risk-based approach that incorporates future uncertainty and provides strategies that can enable them to cope with a range of possible future local climate change scenarios (Howden and Stokes, 2010). A key challenge for the industry will be to identify and incorporate opportunities where they may exist.

A recent environmental stocktake of the northern grains production region (Darbas et al., 2013) makes some interesting observations that may help understand the adaptive capacity of grain growers in the East Coast cluster. Darbas et al. (2013) describe how the development of the grains sector in eastern Australia followed a south-to-north spatial pattern of historical development. Because of this trend, the northernmost areas of grain production such as the Burnett and Fitzroy, developed much more recently compared to southern areas. This period of northern development coincided with the development of conservation agriculture systems of production, and as such these methods are more normalised and widespread in northern districts, as is generally, farmer awareness of environmental impacts and responsibilities of agricultural production. A state of the industry report prepared by Grain Growers also describes the northern industry, in broad terms, as having in recent years outperformed the southern industry in improving water use efficiencies whilst at the same time improving yields (Grain Growers, 2011).

A recent report by Kingwell et al. (2013), who studied different types of grain growing enterprises in the south-western Australian production region, argued that many of these producers have successfully steered their enterprises through a decade of warming and drying conditions while boosting productivity and profitability. The segment of enterprises who were most successful were those who regularly sought external advice on business and farming improvement, and who developed professional and personal support networks.

Social vulnerability

The vulnerability of the cropping industry to climate change within the region depends on how well the industry is able to manage the likely associated biophysical and socio-economic impacts. Given the high dependence of the industry on the region's natural resources, the industry is likely to be highly sensitive to climate change (that affects the quality of the natural resource). However, socio-economic impacts do not necessarily need to manifest if the industry has sufficient capacity to moderate climate change impacts (Marshall et al. 2013).

NRM planners in conjunction with the cropping industry can be a major influence on the vulnerability of the industry in the region. Minimising vulnerability of the cropping industry to climate change will require careful consideration of the likely biophysical and socio-economic impacts and a committed investment to enhancing the adaptive capacity of cropping people. Vulnerability assessments will be the logical place to start for NRM planners and industry leaders wishing to direct or support efforts to minimise vulnerability to climate change. By understanding how the industry is sensitive to climate change and identifying how best to invest in the adaptive capacity of the industry, vulnerability assessments can enable planners to prioritise their efforts and provide a basis for engagement with farmers. Meaningfully and effectively involving broadacre farmers and their industry in NRM planning, program and project implementation processes can help to provide a politically and culturally supportive environment.

Adaptation opportunities and responses

Considering the range of material discussed above, this section proposes a number of adaptation responses that may be suitable for broadacre cropping in the East Coast Cluster. These responses fall into four broad, and often inter-related categories:

- Investing in the adaptive capacity of growers and enterprise management
- Property level risk management and preparedness
- Farming practices, technologies and systems
- Anticipating landscape and regional level changes

Some of these responses may be actionable by individual growers or the sector as a whole. In other cases these may require partnerships between industry and other stakeholders, such as governments, research organisations, regional NRM or LLS groups and other NGOs.

Investing in the adaptive capacity of growers and enterprise management

Investing in the adaptive capacity of producers may be the next important step to assist the industry to effectively adapt to climate change. Growers will need to further expand the number of management factors they consider to remain viable and make the most of opportunities in the future. Adaptive capacity can be enhanced through better networks, increasing environmental awareness, recognising and responding to environmental and other feedbacks, developing strategic/business skills, developing an interest in new knowledge and technology and fostering a culture of shared learning. NRM organisations, working with industry bodies, have skills in many of the areas that can facilitate improvements in adaptive capacity such as workshop facilitation, establishing partnerships with or coordinating extension services to landholders, communications and monitoring. More importantly, the multi-stakeholder platforms that NRM/LLS groups provide can contribute to social learning outcomes on adaptation strategies or practices that bring together technical, scientific, local and industry knowledge.

Property level risk management and preparedness

Broadacre industry groups have proposed several responses to drought, disaster risk reduction and recovery policies that are highly relevant to cropping sector adaptation in the East Coast Cluster. In addition to new financial measures (e.g. taxation or insurance that are outside the scope of NRM bodies), regional NRM/LLS groups could partner industry groups to improve:

- the use of improved weather forecasting technologies and tools (such as more reliable six and twelve month seasonal forecasts), including user-friendly reporting, to help producers improve productivity and proactive decision-making;
- flexible training and skills development programs in agricultural production and finance that allow producers to voluntarily select modules that best cater for their stage of the business cycle and to support effective strategic farm planning (AgForce Queensland, 2014a); and
- the incorporation of disaster recovery and preparedness planning within property management planning processes that includes assessments of land and natural resource condition (pre-disaster and post-disaster) and identification of actions to return to condition (but also encourages opportunity for re-design of property infrastructure, boundaries and resource utilisation practices to improve resilience for future events) (AgForce Queensland, 2014b).

There is also an opportunity to connect these disaster recovery plans and property planning/mapping processes to sub-catchment and regional level strategies that identify native vegetation re-growth priorities as part of possible future carbon-farming initiatives.

Farming practices, technologies and systems

Industry groups point to the importance of investing in and communicating the product of research and development activities to support adaptation:

In the medium term, sufficient industry led research, development and extension is required to determine what other adaptations are possible. This may include new genetics, dealing with new pest, weed and disease threats and changes to the management of farm systems (NFF, 2014).

Earlier work on adaptation in the cropping and particularly grains sector has identified a suite of adaptation options that can improve productivity and profitability of agricultural enterprises but that also have strong natural resource management benefits. Many of these suggested actions relate to improved soil and water management practices or technologies, on-ground monitoring and knowledge sharing, and align strongly with the core business of natural resource management bodies. These are summarised and modified from Howden et al. (2010):

- Develop further practices that help ameliorate risk (e.g. zero till and other minimum disturbance techniques, retaining residue, staggering planting times, controlled traffic, erosion control infrastructure);
- Opportunistic planting linked to environmental conditions;
- Maximise utility of seasonal climate forecasts linked with on-ground measurements (e.g. nitrogen and soil moisture) and market information;
- Revise soil fertility management (fertiliser applications, type and timing, increase legume phase in rotations) on an ongoing basis and consider implications for off farm impacts (GHG emissions, water quality etc.);
- Continue training to enhance self-reliance through improved climate-risk management;
- Explore transformation options in the cropping zones that consider multiple benefits from future possible changes to cropping locations or types;
- Design and implement adaptation monitoring programs (e.g. at farm, district or regional levels) to improve understanding of what works, what does not and why; and
- Further develop area-wide management operations, integrated pest management and other innovative pest, disease and weed adaptations.

For other crops, such as cotton and sugarcane, adaptation options that have been suggested in earlier studies include (Bange et al., 2010; Park et al., 2010):

- Improved management of limited water supplies (e.g. use of improved irrigation technologies such as trickle tape, improved capture and storage of water, improved irrigation scheduling, etc.);
- Altered cropping system design and agronomic management;
- Selection of cultivars with appropriate heat-stress resistance, drought tolerance, higher agronomic water use efficiency, resistance to new pest and diseases; and
- Building capacity through targeted extension, improving skills and providing a more industry-wide knowledge base.

Moreover, the type of integration and adaptive learning required to understand the links between farm level adaptation and broader regional level and policy level changes will need better interaction between farming communities, researchers and decision-makers (Howden et al, 2010). It is these types of relationships that regional NRM/LLS groups have been effective in brokering and coordinating in partnership with industry, government and scientific organisations.

Anticipating landscape and regional level change

(a) Carbon Farming

Carbon farming is an emerging opportunity that may convey economic benefits to broad acre cropping areas. Some carbon farming activities may also increase landscape resilience to climate changes. Restoration of native forests using native forest regrowth or environmental planting has potential to soften the impacts of past clearing on landscapes, by helping to conserve native species and address other negative impacts of past-clearing such as salinity. Increasing the extent of habitat for native species will also generally increase a landscape's adaptive capacity and resilience to climate changes.

Economic analysis suggests that there are areas within each of the East Coast Cluster regions that may support viable carbon farming projects using native forest regrowth, environmental plantings and avoided deforestation (Butler and Halford, 2014). These are mainly in sub-coastal areas, but high sensitivity to assumptions about costs suggests that large projects, with commensurate economies of scale, could be viable in most regions. There are myriad possible approaches that regional NRM/LLS groups and other stakeholders may use to identify where carbon farming activities could be placed to strategically optimise co-benefits to biodiversity and other ecosystem services. Butler and Halford (2014) and Drielsma et al. (2014) present two possibilities focused on biodiversity co-benefits for the East Coast Cluster region. Either technique could be used to prioritise efforts by NRM organisations to facilitate uptake of carbon farming opportunities or underpin engagement of NRM/LLS groups in strategic land use and allocation planning processes.

Despite the clear potential for carbon farming to bring benefits to landscapes, uptake to date has been limited. Without significantly higher prices for carbon credits, and a more stable policy context, it is likely to be years or even decades before carbon farming occurs on sufficient scale to have noticeable regional effects. However, identification of strategic locations in the landscape is crucial for not limiting potential future opportunities, and is useful to regional bodies in pursuing other investment opportunities in revegetation. This opportunity is also recognised by industry bodies that represent broadacre agriculture interests:

> *While the carbon trading system has its downsides [fuel, electricity and processing sector costs], it may also present opportunities for landholders to play a role as part of the solution to climate change mitigation through land management techniques (e.g. tree planting or regrowth retention) (AgForce Queensland, 2014c).*

(b) Taking a long-term, integrated, regional view of farming land and communities

Regional NRM/LLS groups have historically worked through, and indeed helped create, local and regional communities of interest that seek to address issues of change (such as sustainability) through place-based approaches. They have also, historically, sought to align regional strategy for natural resource management to other regional economic development and local government planning, but with perhaps more limited success. National farmer bodies recognise the importance of taking a long-term, integrated approach to adaptation from the regional perspective, which presents the opportunity for cooperation on this front:

> *For agriculture, adaptation is likely to focus on adaptation in the existing location or region (e.g. purchasing a property nearby but with slightly different soils and climate). There are many reasons for this, but it is highly linked to the way farmers see themselves as part of the local community of interest. Therefore, adaptation measures must necessarily focus on appropriate policies for skills/labour, taxation, the provision of infrastructure and the supply chain (tipping points for regionally established processing facilities) (NFF, 2011 p.5).*

Moreover at a national level, industry bodies recognise that in the longer-term adaptation may require changes to what is farmed and where farming land uses take place, suggesting regional or multi-regional level challenges for land use planning, as well as considering succession planning for landscapes that are abandoned or shift to less intensive forms of production:

> *In the longer term…[e]xamples of adaptation might include changes in the location of agricultural industries and changes in the types of agriculture. These types of adaptation have social and economic consequences for current and future regional communities of Australia (NFF, 2014).*

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