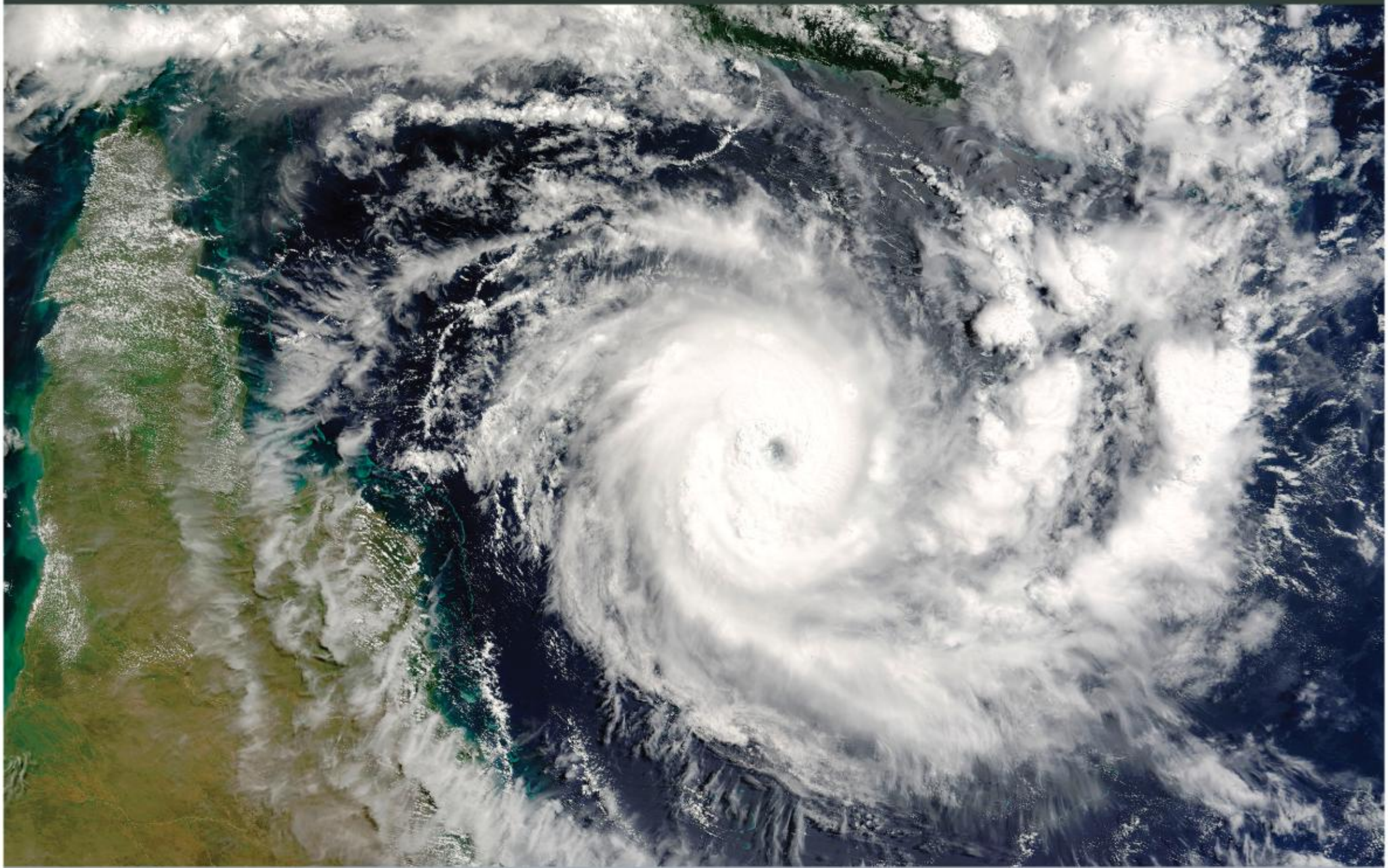
WET TROPICS
NRM CLUSTER

CLIMATE CHANGE IN AUSTRALIA
IMPACTS & ADAPTATION INFORMATION FOR AUSTRALIA'S NRM REGIONS



# Adaptation Pathways and Opportunities for the Wet Tropics NRM Cluster region

## Volume 2. Infrastructure, Industry, Indigenous peoples, Social adaptation, Emerging planning frameworks, Evolving methodologies and Climate adaptation planning in practice.

Edited by Catherine Moran, Stephen M. Turton and Rosemary Hill

# 5. Industry - adaptation pathways and opportunities in the Wet Tropics Cluster

James Langston and Stephen M. Turton

| IN A NUTSHELL |
|---|
| • The main industries in the region have a high degree of dependence on the natural environment and hence are highly susceptible to climate change impacts.<br>• Adaptation options for farmers are largely consistent with current 'best practice' management, although diversification is likely to be an important part of adaptation for primary producers. Ecosystem-based management of fisheries has potential as an adaptation pathway for this industry. There are limited adaptation options for the tourism industry.<br>• Adaptation for the mining sector is complex and difficult and will require more site-specific challenges than other industries. |

## Precis

This chapter discusses some of the climate adaptation options and opportunities for key industries in the Wet Tropics Cluster (WTC) region. Specifically, this chapter considers potential options for adaptation to climate change impacts for tourism, grazing, agriculture (with cropping, horticulture and forestry), fishing and mining. This chapter is written for the NRM community and its key industries and is intended to provide a framework for considering options when developing potential climate adaptation pathways for the WTC region. The key messages associated with each of the topics addressed in this chapter are:

| TOPIC | KEY MESSAGES |
|---|---|
| Tourism | 114. Tourist destinations in the WTC region have limited options for climate adaptation due to predicted significant declines in the quality of key natural assets and limited diversification opportunities for the nature-based tourism sector.<br>115. Strategic adaptation decisions are constrained by uncertainties in regional climate changes, limited concern, lack of leadership and limited forward planning by the tourism sector. |
| Grazing | 116. Improved land management practices resulting in enhanced stock and land condition are vital to increased system buffering capacity in the face of elevated climatic variability.<br>117. Land management regimes and agribusiness flexibility will need to be adjusted as the climate changes.<br>118. More widespread wet season 'spelling' rates will promote better quality pasture, and increase pasture regrowth rates.<br>119. Appropriate fire management, in conjunction with better grazing management regimes will |

| TOPIC | KEY MESSAGES |
| --- | --- |
| | reduce woody thickening.<br>120. Intensified agroforestry species will provide a wide range of benefits if utilised in grazing landscapes. |
| Agriculture, cropping, horticulture and forestry | 121. There are opportunities for increased agricultural production and planting of climate-ready crops.<br>122. Many climate adaptation options for agriculture are similar to existing ‘best practice’ and good natural resource management, and therefore do not require farmers to make radical changes to their operations in the near term.<br>123. For the agricultural sector the imperative for NRM planning for climate adaptation should be proactive rather than reactive.<br>124. Information delivery on climate change, crop varieties and plant nutrition should be enhanced and regulatory agencies should introduce legal incentive for private agronomic services to provide the newest and best available data.<br>125. Adaptation to more extreme climatic events will be a significant challenge for long-lived crops and most forms of horticulture and forestry.<br>126. Diversification may be an effective adaptation pathway.<br>127. There may be some production benefits associated with higher levels of $CO_2$, but data is unclear and should be scrutinised as $CO_2$ is only one factor of the environmental conditions that needs integrated consideration. |
| Fishing | 128. Ecosystem-based fisheries management provides a useful platform for the fishing industry to adapt to climate change.<br>129. Indigenous fishers and integrated management bodies should seek greater involvement with one another.<br>130. Certification for better-managed fisheries may provide niche markets to industry players.<br>131. Intensified aquaculture endeavours may be explored as an alternative to wild seafood production. |
| Mining | 132. Local governments express more concern about climate adaptation for the mining sector than the mining industry itself.<br>133. Climate adaptation must be considered for the linked feeder systems (e.g. fly in fly out mines).<br>134. Climate adaptation in the mining sector requires addressing the site-specific challenges more so than other industries. |

# Introduction

The private sector in the Wet Tropics Cluster (WTC) region is largely dependent on a small handful of industries: agriculture, grazing, fishing, mining and tourism and many of these are small- to medium-sized enterprises. These industries are heavily reliant upon the natural environment, and so are vulnerable to the potential impacts of climate change (see review by Stoeckl *et al*. 2014). They each face different drivers of, barriers to– and the subsequent pathways towards–

effective planned adaptation.[1] Their adaptive capacity ranges from moderate to high, but many positively perceive their own capacities, which may in fact make them vulnerable to more extreme and frequent climate events. In addition they face major constraints at local and regional levels, especially when 'transformational' climate adaptation responses may be the only option (Chapter 1, this report). A recent report suggests that adaptation is a matter of changing management practices, technologies, institutions and expectations to fit the prevailing or projected future climate (Stokes *et al*. 2012). Adapting primary industries effectively may offset some of the negative impacts of climate change, and will possibly allow producers to take advantage of opportunities afforded by our changing climate (Stokes & Howden 2010). Incremental adaptation[2] measures exist in all the WTC industry sectors, but transformational measures will likely have to be considered in the longer term. Uncertainty about the degree of change will remain a barrier for transformational responses.

The private sector is recognised to have a strong role in delivering adaptation but it is also at risk of adaptive failures and maladaption.[3] In order to strengthen adaptive capacity, planned adaptations are necessary, as autonomous adaptation[4] on its own will likely be inadequate to sustain employment, income, and livelihoods. In order of perceived importance, the risks to businesses in addressing climate impacts are regulatory, physical, reputational and litigation risks. It is commonly understood that comparative advantages will accrue to businesses that take early action.

It is noted that there is a range of adaptation actions potentially available to Australian agriculture, with some strategies common across sectors – increased research and development (R&D), better training, the establishment of a framework to manage this transition and the development of appropriate policies – and others specific to individual types of agriculture. At present there is no cohesive framework in place to guide such a transition, but there are some examples of specific agricultural strategies, for example, some actions identified by Beer *et al*. (2013) for cropping/horticulture include:

- species change, including a switch to summer growing grains and herbage pulses
- variation in planting time
- better crop management, including the universal adoption of zero tillage, extended fallow periods and lowering plant populations
- nutrient management
- erosion management.

There are some inherent features of climate adaptation that make engagement on these topics particularly problematic. These features include – but are not limited to – the presence of climate change related misinformation and scepticism, behaviours of people and groups regarding how they handle uncertainty, and variation in different stakeholders' capacities for long-term planning. On the basis of these features and the related relevant literature, a number of psychological mechanisms have been identified that relate to adaptation engagement. The adaptation pathway (see Figure 1.5, Chapter 1 this report) may serve as a protocol for engagement with NRM stakeholders. The drivers will help promote progress along the pathway, and barriers indicate where opportunities for interventions lie (Gardner *et al*. 2009).

Engaging industry in discussion on climate change adaptation faces these barriers, however there are drivers that will enable progress towards enhanced adaptive capacity. CSIRO's (former) Climate Adaptation Flagship provides a valuable resource for industries and

---

[1] Planned adaptations are proactive and can either adjust the system incrementally or transform it (IPCC 2014)

[2] Incremental adaptation: adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale (IPCC 2014).

[3] Maladaption: actions or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future (IPCC 2014).

[4] Autonomous adaptation: adaptation that does not constitute a conscious response to climate stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (IPCC 2014).

the range of associated stakeholders. It presents best practice for engaging industries in finding ways to reduce vulnerabilities by enhancing their adaptive capacity, notably their Working Paper 3 (http://www.csiro.au/resources/CAF-working-papers#a1).

Climate adaptation is not something to be left to farmers, businesses, NRM groups, or governments alone. Everyone involved in primary industry, including policy makers, supply chains, Research and Development (R&D) providers, and enterprise managers – should all contribute to solutions by working in collaboration. For example, governments can ensure that water and drought policies accord with successful farm adaptation and do not impede it. R&D providers – working with farmers – can help facilitate effective climate adaptation options and technologies for the sector. These may include suitable crop varieties, improved water use efficiency standards, greater use of seasonal forecasting tools for improved decision making, or new farming or fishing methods. Not only do R&D providers help provide and guide choices, they should ensure that they are available and can be delivered when needed. There is a limitation here as R&D investment by government into innovation is decreasing, while privatisation is increasing. At stake here is potential diverted focus from system resilience into product penetration. Businesses need the skills, the financial assets, access to the best information and advice, and good incentives to make necessary changes. Climate adaptation will be most successful by considering the system-wide consequences of proposed adaptation measures at all social levels, at all points in the industry value and production chains, and in relation to other simultaneous challenges.

Consequently, there will be increasing demand for strong science–policy linkages, analysis of alternative governance models, and stronger focus on the institutional arrangements to support adaptation in all the NRM industrial sub-sectors (see Chapter 8, this report).

# Industry-specific adaptation and opportunities

## Tourism

**Tourist destinations in the WTC region have limited options for climate adaptation due to predicted significant declines in the quality of key natural assets and limited diversification opportunities for the nature-based tourism sector.**

**Strategic adaptation decisions are constrained by uncertainties in regional climate changes, limited concern, lack of leadership, inadequate government policies, and limited forward planning by the tourism sector.**

Future impacts of climate change on tourism have been evaluated for parts of the WTC region (Turton *et al*. 2010; Wilson and Turton 2011; Turton 2014a). The Great Barrier Reef (GBR) is expected to degrade under all climate change emission scenarios reducing its attractiveness as a global tourism icon (Marshall and Johnson 2007; Wilson and Turton 2011; Chapter 2, this report). Higher temperatures will place increasing stress on upland rainforest tourist destinations in the Cairns region, with extinctions likely for some key cool-adapted endemic vertebrate species (Turton 2014a; Chapter 2, this report). Sea level rise will result in pressures on coastal and island areas and any associated tourism infrastructure will be threatened (see Chapter 4, this report).

Australia has formalised climate adaptation strategies for tourism (Turton *et al*. 2010; Zeppel and Beaumont 2011). Institutions at various levels promote preparation for more extreme events and strengthening ecosystem resilience to maintain quality of tourist destinations, e.g. GBR (GBRMPA 2009). According to Reisinger *et al*. (2014), short investment, high substitutability and a high proportion of human capital compared with built assets give high confidence that the adaptive capacity of Australian tourism is high overall, except for destinations where climate change is projected to degrade core natural assets and diversification opportunities are limited, e.g. tourism relying on the quality of the GBR and upland rainforests in the WTC region (Wilson and Turton 2011; Turton 2014a).

Given that climate change adversely affects key tourism assets in the WTC region, and will continue to do so in the future, it is critical that forward planning be undertaken by the sector to ensure that adaptation strategies be adopted over medium-to-long times scales (Turton *et al*. 2010; Turton 2014a). Likewise, government agencies responsible for ongoing management of the WTC's globally significant world heritage properties (GBR, Wet Tropics and potentially Cape York) will also have to be considering adaptation strategies and options to strengthen their ecological resilience to climate change through management of anticipated environmental stress factors (see Chapter 2, this report). Adaptation to climate change in the tourism sector will need to consider actions at the operator, industry and local community levels (Turton *et al*. 2010). Adaptation options for tourism-related infrastructure are discussed in Chapter 4 of this report. Chapter 2 discusses adaptation options for terrestrial and marine biodiversity that provides the basis for the WTC's nature-based tourism industry.

There are a number of barriers to climate adaptation in the tourism industry (Turton *et al*. 2010). Firstly, there is a high degree of uncertainty and scepticism across the sector concerning climate change projections; this appears to be the main reason for the lack of action in the short term compared with other industries, e.g. agriculture. Secondly, communication and community involvement in climate adaptation is somewhat lacking in many tourist destinations, including those in the WTC region. Local tourism communities and the tourism industry need to be more heavily involved in planning and implementation of adaptation strategies at the grassroots level. Thirdly, one of the perceived limitations to adaptation within the tourism sector is the high proportion of small and medium enterprises (SMEs) that characterise regional tourism. Much concern revolves around the issue that these SMEs are operating on small overheads with little or no capital or capacity to implement major climate adaptation strategies.

The adoption of adaptation strategies and subsequent actions by the tourism sector in the WTC region will require the following (Turton *et al*. 2010):

- confidence that the climate really is changing and that increased variability in climate is part of the process
- motivation to avoid risk or take up potential opportunities
- demonstration of new technologies
- transitional and legislative support from government
- resources from government and private stakeholders
- effective monitoring and evaluation, given that climate change is a moving target.

## Grazing

**Improved land management practices resulting in enhanced stock and land condition are vital to increased system buffering capacity in the face of elevated climatic variability.**

**Land management regimes and agribusiness flexibility will need to be adjusted as the climate changes.**

**More widespread wet season 'spelling' rates will promote better quality pasture, and increase pasture regrowth rates.**

**Appropriate fire management, in conjunction with better grazing management regimes will reduce woody thickening.**

**Intensified agroforestry species will provide a wide range of benefits if utilised in grazing landscapes.**

Heat stress is an impact that will reduce productivity, reproductive performance and enhance mortality under future climate scenarios. Increased thermal stress on livestock is very likely in the WTC region (Howden *et al*. 1999a) due to predicted increases in heat waves (Turton 2014b). However, there are opportunities here, as tick risks will decline due to excessively high temperatures. The control of ticks on beef cattle in northern Australia is based largely on host resistance that is acquired in response to tick feeding. Host resistance is most strongly expressed by the large majority of *Bos indicus* (zebu) cattle (Sutherst and Utech 1991). Zebu cattle are also more tolerant of extreme environmental conditions, so there may be adaptation opportunities in Zebu selective breeding for host resistance and increased heat tolerance (White 2003).

Graziers in the WTC region will have a comparative advantage in dealing with pests, weeds and diseases compared with more southern, sub-tropical and temperate regions of Australia. Most concerns in the grazing sector in Australia are of a southern spread of tropical pests and diseases into sub-tropical and temperate zones.

Key strategies for adaptation to climate change in the region include managing stocking rates and promotion of wet season spelling to maintain a high percentage of 3P grasses, i.e. palatable, perennial and productive. Overstocking and continuous grazing has led to a significant decline in 3P grasses on the better land types in the region (Shaw *et al*. 2007). Resilient enterprises in the future will rely more on business/herd recording and management systems that constantly improve breeder mortality rates, reproduction rates and annual live weight gains (Phelps *et al*. 2014).

Selective breeding for increased feed efficiency and/or reduced methane emissions appears to be one option eminently suited to northern Australia and hence parts of the WTC region where the grazing industry is important (Alford *et al*. 2006). Bortolussi *et al*. (2005) surveyed segments of the northern industry in the 1990s and found weaning rates varied between 50 and 80%. When this is coupled with low weaning weights of <0.3 of the maternal weight, it is clear that there is major scope for improvement in both weaning rate and weight (Henry 2012). Moreover, phosphorus supplementation may mean significant increases in productivity, leading to fewer cows required for the same number of progeny and a faster rate of turnoff.

Fire-vegetation models suggest that with appropriate stocking-rate management, fire can be used to manage woody plant cover whilst maintaining or improving live weight gain per hectare (LWG/ha) and hence profits in northern Australia. Active stock management such as reducing stocking rates, matching stocking rates to available forage and spelling, can be used to facilitate fire-use under lower rainfall. Under high rainfall there will be more opportunities to burn (including more risk of wildfire), but there may also be a greater need to burn more often as woody plant cover may increase in response to higher wet season rainfall and increasing levels of $CO_2$.

According to Meat and Livestock Australia (MLA), modelled results suggest that the implementation of fire has both economic and ecological benefits. There are opportunities in holding workshops with industry representatives for 'best practices' in implementing fire regimes matched with appropriate stocking rates. For example, it has been shown that there is an important role for fire management in parts of the WTC region for both ecosystem (Reside *et al*. 2014) and pastoral production (Stoeckl *et al*. 2014), but fire can only be implemented with appropriate stocking rates. Consequently, the management of grazing and fire are integrally related to the maintenance of productive and resilient grazing systems under climate change (Phelps *et al*. 2014).

Agroforestry systems with appropriate shade tree species have been shown to enhance microclimate effects on grazing productivity, and to mitigate surface water reductions (Neely *et al*. 2009). There is an opportunity to determine which tree species would be most appropriate for the WTC region for this practice, and what densities will benefit grazing lands the most.

Increasing the amount of carbon (C) sequestered as soil organic matter (SOM) can enhance rainfall effectiveness through increased infiltration and water-holding capacity and water source replenishment to withstand times of drought. This may be achieved through better fire management and appropriate stocking rates and through use of shade trees in the landscape. Bunching stock into large herds and moving them frequently will contribute to better pasture growth and nutrient content. Controlled grazing allows for more even distribution of dung and urine that can enhance SOM and nutrients for plant productivity. This has the knock on benefits of more quickly regenerating pastureland and improved livestock production. Other options include 'improved' grass and legume mixtures. They have a relatively large percentage of C sequestered in the fine root biomass, which is an important source of C cycling in the soil system (Mannetje *et al*. 2008). Thus, one of the most effective strategies for sequestering soil C is fostering deep-rooted plant species. Agroforestry species, specifically shade trees with deep root systems will have knock on benefits of reduced heat stress on the stock and improved water maintenance (Neely *et al*. 2009).

To avoid land degradation, management and adaptive strategies include:

- matching stocking rates to carrying capacity, e.g. through objective on-ground assessments, or future tools such as *PaddockGRASP* (http://www.longpaddock.qld.gov.au/grasp/)
- adopting moderate flexibility in annual stocking rate adjustments (increasing stocking rates by up to 10-20% and decreasing by up to 30-40% annually, with some regional variation), e.g. using forage budgeting tools such as the *StockTake* application (http://futurebeef.com.au/resources/workshops/sustainable-grazing-workshops/stocktake-balancing-supply-and-demand/)
- more widely implementing wet season 'spelling', e.g. based on regional best-practice guidelines
- reducing woodland thickening impacts through appropriate fire management.

These strategies are shown to lead to profitable enterprises in the long term under low and medium GHG emission scenarios.

The rotational spelling regime of a 6-month summer-season spell – every four years – is capable of improving pasture condition, carrying capacity and animal productivity in the spelled paddocks and overall property profitability under both current climate and future climates, providing stocking rates are appropriate to each climate. Land condition can be improved through combining wet season spelling with moderate stocking rates and not solely through low stocking rates that are often recommended. This may be a more acceptable approach to grazing industry in parts of the WTC region (Phelps *et al*. 2014).

## Agriculture, cropping, horticulture and forestry

**There are opportunities for increased agricultural production and planting of climate-ready crops.**

**Many climate adaptation options for agriculture are similar to existing 'best practice' and good natural resource management, and therefore do not require farmers to make radical changes to their operations in the near term.**

**For the agricultural sector the imperative for NRM planning for climate adaptation should be proactive rather than reactive.**

**Information delivery on climate change, crop varieties and plant nutrition should be enhanced and regulatory agencies should introduce legal incentive for private agronomic services to provide the newest and best available data.**

Despite many challenges, potential benefits and fresh opportunities also arise from climate change for the agricultural sector. For example, it is likely that production of horticulture and pasture will increase due to projected higher temperature (Stokes and Howden 2011). Under elevated $CO_2$ in the atmosphere it is likely that plant growth and plant water use efficiency will increase (Lawler 2009; Stokes and Howden 2011). As different plants will respond in a different ways the competitive nature among plant communities may also be changed under elevated $CO_2$ levels; therefore some plants will be more resilient to climate change, including many weed species that may thrive. Planting crops that are drought tolerant, tolerant of higher temperatures and elevated atmospheric $CO_2$ levels (climate-ready crops) are likely to protect farmers from unexpected losses due to climate change (Stafford Smith and Ash 2011).

In the agriculture sector adaptations are adjustment made by farmers to their changing circumstances. It is expected that farmers will take decisions based on their own experience, observations, and available updated knowledge, such as planting of drought-resistant crops or trees (Stafford Smith and Ash 2011).

Climate change projections on a very fine spatial scale and in the short term – as well as focusing on seasonality and long term changes – will help farmers to plan well ahead of time. Information about suitable crop varities, plant nutrition and techniques such as precision fertiliser use and legume rotations will also be useful (Stokes and Howden 2011).

**Adaptation to more extreme climatic events will be a significant challenge for long-lived crops and most forms of horticulture and forestry.**

**Diversification may be an effective adaptation pathway.**

**There may be some production benefits associated with higher levels of $CO_2$, but data is unclear and should be scrutinised as $CO_2$ is only one factor of the environmental conditions that needs integrated consideration.**

There may be few incremental adaptation measures available to farmers that are at risk to extreme events – such as tropical cyclones – in long-lived crops and horticulture. Transformational adaptation measures include changing crops to types that can be harvested annually. This hastens the speed by which they can recover in the event of complete crop destruction. The forestry sector has begun withdrawing from the WTC region for this reason in response to recent tropical cyclone events (Turton 2012).

However, some crop systems (e.g. bananas) may benefit from protective agroforestry species. Crop damage by winds from extreme events may be minimised or prevented by the use of windbreaks. These can be natural or artificial. Properly oriented and designed wind-breaks are very effective in stabilising agriculture in regions where strong winds can potentially cause mechanical damage and impose moisture stress on growing crops. Windbreaks save the loose soil from erosion and increase the supply of moisture to the soil in the dry season.

Early harvests in anticipation of extreme events – such as cyclones – have proven effective in the past. This is more likely to be successful if crops are selected that mature frequently, and if safe storage areas are constructed. Irrigation canals and embankment of rivers in risk zones should be maintained and repaired to avoid breaching. Crop diversification may be necessary as a long-term measure to reduce the crop damage during the cyclone and storm season (Das 2005). This may include growing a variety of climate-ready crops in an area or geographically separating production of a single crop across the WTC region, e.g. bananas.

In the planning of relocation of crop lands, which may be necessary from coastal inundation from extreme events or sea-level rise, Geographical Information Systems (GIS) can be extremely useful tools in the analysis of flood-prone areas. Slope and aspect of regions - in addition to other data types – may provide opportunities to the best practice design of agricultural systems while also accounting for risk.

Table 5.1 shows climate adaptation options and priority ranking (1 as highest priority) for cropping and horticulture (Das 2005). It should be noted that the priority ranking is context-specific so may not necessarily represent priority ranking for the WTC region, but is nonetheless indicative of where future NRM investments in climate adaptation may be directed. Such investments may also be different at the regional compared with cluster levels.

Mulching the soil surface with organic matter for example will reduce the loss of water through evaporation. Kaolin clay applied to plants, usually for pest and disease control, has been demonstrated to reduce the effects of water and heat stress though results have been variable so further studies are needed (Das 2005).

*Table 5.1 Climate adaptation options and priority ranking for cropping and agriculture.*

| ADAPTATION OPTIONS | Priority ranking |
|---|---|
| Temperature increase. Determine climatic thresholds to plant growth and product quality. | 1 |
| Re-assess location in regional terms to optimise reduction of climatic risk. | 1 |
| Invest in conventional breeding and biotechnology to address future adaptation capacity. | 1 |
| Tailor seasonal climate forecasts to horticultural requirements | 2 |
| Develop and modify markets for new crops and crop schedules | 3 |
| Change crop production schedules to align with new climate projections | 3 |
| **$CO_2$** | |
| Ascertain the crop-specific interactive effect of increased $CO_2$, temperature and water use. | 1 |
| Determine the effect of $CO_2$ on pests, diseases and weed species. | 1 |
| **Rainfall** | |
| Integrate catchment management and climate change projections to assess future water availability. | 1 |
| Constantly benchmark irrigation management to increase efficiency. | 1 |
| **Pests and diseases** | |
| Geographically sensitive pest and disease risk assessments using projected climate data. | 2 |

Source: after Das (2005)

Autonomous adaptation is a particularly important category because farmers have traditionally adapted their methods in response to changes in climate and other drivers. Historically, new techniques have diffused through the industry, with innovative farmers being the first to introduce new techniques, and others adopting these approaches once they are seen to be successful. Farmers tend to be responsive in the short term by altering cropping patterns and management practices but may find it more difficult to focus on medium- to long-term changes in climate (Kingwell *et al*. 2013).

## Fishing

**Ecosystem-based fisheries management provides a useful platform for the fishing industry to adapt to climate change.**

**Indigenous fishers and integrated management bodies should seek greater involvement with one another.**

**Certification for better-managed fisheries may provide niche markets to industry players.**

**Intensified aquaculture endeavours may be explored as an option for wild seafood production.**

Ecosystem-based fisheries management (EBFM) is a useful holistic tool that may provide benefits to many stakeholders in the fisheries sector as they adapt to climate change and other drivers. EBFM takes into account interrelationships among exploited fish stocks, non-target species, the environment and human action. Adaptation options in the EBFM suite include developments in by-catch reduction. Improved targeting practices will have the dual benefit of minimising impacts on non-target species, and they will provide potential alternatives to spatial closures to protect species of interest. Multi-species fisheries should continue to develop species-specific fishing equipment and targeting practices to improve future adaptability. Species-specific equipment will allow individual species to be targeted, without impacting other species that may be in decline due to climate change, and therefore their protection from fishing (Stokes *et al*. 2010).

Adaptation strategies to cope with a permanent change in distribution of key species include improvements in locating stocks of fish, changes in home port to minimise economic costs associated with transport of harvested catch, and zoning of fishing habitats to minimise unwanted species interactions (e.g. Hobday and Hartmann 2006; Hobday *et al*. 2009: in Stokes *et al*. 2010).

Indigenous fishers will be supported by greater involvement with integrated management bodies. They would benefit by supporting a reduction of fishing pressure on species impacted and of concern. Fishers – Indigenous and recreational – will be affected by changes in the biophysical environment due to climate change. Adaptive strategies are about advocating that regulations for vessel and shore-based safety measures are adhered to. Adaptive strategies would also include the support of increased use of ocean forecasts. Both Indigenous and recreational groups should become active in fisher education to increase awareness and monitor environmental changes. There may be opportunities for business in new regions, and for longer seasons in the same regions. For example, game fishing targets 'warm-water species', so southward movements due to ocean warming may be an advantage with regard to longer fishing seasons, and increased availability to the southern areas of the WTC region (Hobday *et al*. 2007b; Hobday 2010).

Certification initiatives such as the Marine Stewardship Council have been successful for industrial players, putting them at a comparative advantage in the market. This has been evident in several developed countries including New Zealand, the USA and Australia (Gulbrandsen 2009).

## Mining

**Local governments express more concern about climate adaptation for the mining sector than the mining industry itself.**

**Climate adaptation must be considered for the linked feeder systems (e.g. fly in fly out mines).**

**Climate adaptation in the mining sector requires addressing the site-specific challenges more so than other industries.**

Hodgkinson *et al*. (2010) indicate that though every stage of mining is potentially influenced by climate change, the direct production stage is most at risk. Other research has suggested that all parts of the supply chain are at some degree of risk, with ports, rail lines, bridges and roads subject to extreme weather conditions (Stoeckl *et al*. 2014). Some risks may be dealt with by simply strengthening existing infrastructure or building new infrastructure to higher standards (see Chapter 4, this report).

Fly-in fly-out (FIFO) mining practices impose human capital risks with respect to climate change. Extreme weather events may prevent workers attending the mine and/or impede workers leaving the mine in the case of flood, fire or cyclone. Moreover, the impacts of disruption in mine schedules may be felt throughout the feeder settlement systems, including metropolitan and non-metropolitan places distant from the areas of the mining production sites. Fundamentally, a long term disruption to mining production may challenge the incomes of these and many other rural households, placing their economic sustainability at risk.

A survey of mining companies' adaptive capacities indicated that in general, local governments expressed greater concern than do the companies. While 45 percent of local government authorities in mining areas were undertaking climate adaptation activities, only around 15 per cent of mining companies were doing so. Regarding barriers to climate adaptation, the reasons given for not undertaking preparatory action differed greatly between governments and mining companies. Mining company respondents typically claimed uncertainty around climate change impacts and political/regulatory settings, were inhibiting their investment into enhancing adaptive capacity. Government respondents most often nominated financial assets and human capital to be the main inhibitors towards investing in enhanced adaptive capacity.

Regarding factors that could assist climate change adaptation, both government and companies identified the need for better climate change projections and specific advice about adaptation options and solutions. It is also evident that the information most valued for assisting adaptation is that which is organisationally specific, locally relevant, and technical in nature (Loechel *et al*. 2013).

## Summary of adaptation options for industry

***Table 5.2 Major climate change impacts and potential adaptation options for industry.*** Adaptation options that also potentially mitigate greenhouse gas emissions are marked **(M)**.

| | | EXAMPLE ADAPTATION OPTIONS | | |
|---|---|---|---|---|
| **Climate change** | **Major impacts** | **Protect** | **Accommodate** | **Retreat** |
| Increased temperatures, sea level rise, more variable rainfall, more extreme events (intense cyclones, heatwaves, heavy rainfall) | 1. Less reliable growth of grasses for livestock | | · Managed, flexible stocking rates;<br>· Widespread wet season spelling of pastures;<br>· Selective livestock breeding for increased feed efficiency and reduced methane emissions **(M);**<br>· Phosphorus supplementation;<br>· 'best practice' fire management regimes;<br>· agro-forestry to mitigate surface water reductions;<br>· enhanced carbon sequestration of soil **(M)**;<br>· improved grass-legume mixes. | Relocated livestock production from unsuitable areas. |
| | 2. Increased thermal stress on livestock during heatwaves | | · Selective breeding of species with higher heat tolerance (e.g., Zebu cattle). | |
| | 3. Changed growing seasons, reduced suitability for some crops. | | · Variation in planting times;<br>· New, 'climate ready' crops (e.g., tolerant of drought, high temp., high $CO_2$, salt);<br>· zero tillage;<br>· mulching or application of Kaolin clay to plants to | Relocate cropping from unsuitable areas e.g., coastal lowlands impacted by salt water inundation. |

| EXAMPLE ADAPTATION OPTIONS | | | | |
|---|---|---|---|---|
| | | | reduce water and heat stress;<br>· extended fallow periods;<br>· lower planting densities. | |
| | 4. Long-lived horticulture crops especially impacted by extreme events. | Construct windbreaks (natural or artificial) around crops. | · Harvest early in anticipation of extreme event; construct safe storage.<br>· Maintain irrigation canals and embankments to minimise inundation;<br>· Shift to annually-harvested crops. | Relocate production to less impacted regions or separate geographically. |
| | 5. Changes in numbers, distribution and interrelationships among fish stocks. | | · Ecosystem-based fisheries management;<br>· Shift location of home port for fishing vessels;<br>· Zone fishing habitats to minimise unwanted species interactions;<br>· Take advantage of longer seasons e.g., for 'warm-water species'. | |
| | 6. Degradation of core natural tourism assets such as the Great Barrier Reef and mainland coastal areas. | | | Develop tourism industries in less-impacted areas. |
| | 7. Risk of disruption and damage in every stage of mining production, including all parts of the supply chain. | | Strengthening or building stronger infrastructure. | |
| | 8. Risk caused by long-term disruption to economic sustainability of workers' households and | | | |

| | EXAMPLE ADAPTATION OPTIONS | | | |
|---|---|---|---|---|
| | feeder settlement systems. | | | |
| Increased temperatures & $Co_2$ | 1. Increased plant growth | | · Take advantage of increased productivity of horticulture and pasture;<br>· Manage changed competitive interactions (e.g., advantaged weeds) | |

# Summary and conclusions

The agriculture, tourism and mining industries – all of which are crucially dependent upon the region's natural resources – sustain the private sector in the WTC region. Climate change is likely to have a profound effect upon the region's natural resources and may thus – by extension– have a profound effect upon these industries and the region's economy. They each face different drivers of, barriers to - and the subsequent pathways towards - effective planned adaptation. Their adaptive capacity is moderate to high but faces major constraints at local levels, especially when transformational adaptation responses may be the only option.

Adapting primary industries effectively will not only offset negative impacts of climate change, but will allow producers to take advantage of opportunities afforded by our changing climate. Incremental adaptation measures exist in all the WTC industry sectors, but transformational measures will likely have to be considered in the longer term. Uncertainty about the degree of change will remain a barrier for transformational responses. The private sector is recognised to have a strong role in delivering adaptation but it is also at risk of adaptive failures and maladaption.

Adaptation is not something to be left to farmers, businesses, NRM groups, or governments alone. Everyone involved in primary industry, including policy makers, R&D providers, and enterprise managers – should all contribute to solutions by working in collaboration. Climate adaptation will be most successful by considering the system-wide consequences of proposed adaptation measures at all social levels, at all points in the industry value and production chains, and in relation to other simultaneous challenges. Consequently, there is will be increasing demand for strong science–policy linkages, analysis of alternative governance models, and stronger focus on the institutional arrangements to support adaptation in all the industrial sub-sectors.

# Literature cited


Alford A.R., Hegarty R.S., Parnell P.F. *et al*. (2006) The impact of breeding to reduce residual feed intake on enteric methane emissions from the Australian beef industry. *Aust. J. Exp. Ag.* 46, 813–20. doi:10.1071/EA05300

Beer, A, Tually, S., Kroehn, M. *et al*. (2013) Australia's country towns 2050: What will a climate adapted settlement pattern look like? *National Climate Change Adaptation Research Facility*, Gold Coast, 139 pp.

Bortolussi G, McIvor, J., Hodgkinson, J. *et al*. (2005) The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. *Aust. J. Exp. Ag.* 45, 1075–91. doi:10.1071/EA03097

Bray S., Walsh D., Rolfe J. *et al*. (2014) Climate Clever Beef: On Farm Demonstration of Adaptation and Mitigation Options for Climate Change in Northern Australia. Department of Agriculture, Fisheries and Forestry, Queensland; Department of Primary Industry and Fisheries, Northern Territory; *Commonwealth Scientific and Industrial Research Organisation. Meat & Livestock Australia Limited.*

Cleugh H., Smith M., Battaglia M. & Graham P. (2011) *Climate change: science and solutions for Australia,* CSIRO.

Das H. P. (2005) Agrometeorological impact assessment of natural disasters and extreme events and agricultural strategies adopted in areas with high weather risks. In *Natural Disasters and Extreme Events in Agriculture* (eds M.V.K. Sivakumar, R.P. Motha, & H.P. Das), pp. 93-118, Springer.

Gardner J., Dowd A-M., Mason C. and Ashworth P. (2009) *A framework for stakeholder engagement on climate adaptation.* CSIRO Climate Adaptation Flagship Working paper No.3. http://www.csiro.au/resources/CAF-working-papers.html.

Gulbrandsen L. (2009) The emergence and effectiveness of the Marine Stewardship Council. *Mar. Pol.* 33, 654-660.

Henry B., Charmley E., Eckard R., *et al*. (2012) Livestock production in a changing climate: adaptation and mitigation research in Australia. *Crop & Pasture Sc.,* 63, 191-202.

Hobday A.J. & Hartmann K. (2006) Near real-time spatial management based on habitat predictions for a longline bycatch species. *Fish. Manag. and Ecol.* 13, 365–380.

Hobday A., Poloczanska E. & Matear R. (2007) Implications of climate change for Australian fisheries and aquaculture: a preliminary assessment, CSIRO Marine and Atmospheric Research. Report to the Department of Climate Change, Canberra. December 2007. Available at http://www.climatechange.gov.au/impacts/publications/fisheries.html

Hobday A.J., Flint N., Stone T. & Gunn J.S. (2009) Electronic tagging data supporting flexible spatial management in an Australian longline fishery. In *Electronic Tagging and Tracking in Marine Fisheries II. Reviews: Methods and Technologies in Fish Biology and Fisheries.* (eds. Silbert J.R. & Nielsen J.S.), pp. 381–403, Springer, The Netherlands.

Hobday A. (2010) Ensemble analysis of the future distribution of large pelagic fishes in Australia. *Prog. in Oceanography* 86, 291-301.

Hodgkinson J.H., Littleboy A., Howden M. *et al*. (2010) *Climate adaptation in the Australian mining and exploration industries.* CSIRO Climate Adaptation Flagship Working paper No. 5. http://www.csiro.au/resources/CAF-working-papers.html

I.P.C.C. (2014) *Climate Change 2014: Impacts, Adaptation and Vulnerability*.

Kingwell R., Anderton L., Islam N. *et al*. (2013) Broadacre farmers adapting to a changing climate, *National Climate Change Adaptation Research Facility*, Gold Coast, 171 pp.

Loechel B., Hodgkinson J. & Moffat K. (2013) Climate change adaptation in Australian mining communities: comparing mining company and local government views and activities. *Climatic Change,* 119, 465-477.

Metzger M., Leemans R., Schröter D., & Cramer W. (2004) The ATEAM vulnerability mapping tool. *The ATEAM consortium. Quantitative approaches in systems analysis* 27.

Meyer W., Bryan B., Lyle G. *et al*. (2013) *Adapted future landscapes – from aspiration to implementation,* National Climate Change Adaptation Research Facility, Gold Coast, 94 pp.

Mustafa S. (2010) Seafood Security in a Changing Climate, Koln, Germany: Lambert Academic Publishing

Neely C., Bunning S. & Wilkes A. (2009) *Review of evidence on drylands pastoral systems and climate change: implications and opportunities for mitigation and adaptation*. Land and Water Discussion Paper 8, FAO UN, Rome.

Phelps D., Broad K., Cowley R., Emery *et al*. (2014) *Climate savvy grazing: Developing improved grazing and related practices to assist beef production enterprises across northern Australia to adapt to a changing and more variable climate.* Department of Agriculture, Fisheries and Forestry (Queensland) & Meat & Livestock Australia Limited.

Shaw K.A., Rolfe J.W., English B.H. & Kernot J.C. (2007) A contemporary assessment of land condition in the Northern Gulf region of Queensland. *Tropical Grasslands* 41, 245-52.

Smith B., Burton I., Klein R.J. & Wandel J. (2000) An anatomy of adaptation to climate change and variability. *Climatic change,* 45, 223-51.

Stoeckl N., Farr M., Reside A., *et al*. (2014) Potential impacts of climate change on industries. In *Climate Change Issues and Impacts in the Wet Tropics NRM Cluster region* (eds. D. Hilbert, R. Hill, Rosemary, C. Moran & S. Turton) Chapter 6, James Cook University, Cairns.

Stokes C. & Howden M. (2010) *Adapting agriculture to climate change: preparing Australian agriculture, forestry and fisheries for the future*, CSIRO publishing.

Stokes C., Marshall N., & Macleod N. (2012) *Developing improved industry strategies and policies to assist beef enterprises across northern Australia.* CSIRO. Meat & Livestock Australia Limited.

Sutherst R. & Utech K. (1991) Controlling Livestock Parasites with Host Resistance', in *CRC Handbook of Pest Management in Agriculture, 2nd edn. II*, (ed. D. Pimentel), pp. 379-410. CRC Press, Boca Raton.

Turton S. (2014a) Climate change and rainforest tourism in Australia. In *Rainforest Tourism, Conservation and Management: Challenges for*

*Sustainable Development.* (ed B. Prideaux). Earthscan.

Turton S. (2014b) Climate change projections for the Wet Tropics cluster*.* In *Climate Change Issues and Impacts in the Wet Tropics NRM Cluster region* (eds. D. Hilbert, R. Hill, Rosemary, C. Moran & S. Turton) Chapter 2, James Cook University, Cairns.

Turton S., Dickson T., Hadwen W., *et al*. (2010) Developing an approach for tourism climate change assessment: evidence from four contrasting Australian case studies. *J Sustain Tour* 18, 429-47.

Turton S. M. (2012) Securing landscape resilience to tropical cyclones in Australia's Wet Tropics under a changing climate: lessons from Cyclones Larry (and Yasi). *Geographical Research* 50, 15-30.

White N., Sutherst R., Hall N. & Whish-Wilson P. (2003) The vulnerability of the Australian beef industry to impacts of the cattle tick (*Boophilus microplus*) under climate change. *Climatic Change,* 61, 157-90.