# Research Report

June 2019

Australian Farm Institute

FCA
FARMERS FOR CLIMATE ACTION

# Change in the air:

*defining the need for an Australian agricultural climate change strategy*


ISBN 978-1-921808-46-3

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The Australian Farm Institute acknowledges the financial assistance of Farmers for Climate Action in order to undertake this research.



**Publication Data**

McRobert, K, Admassu, S, Fox, T & Heath, R (2019), *Change in the air: defining the need for an Australian agricultural climate change strategy,* Research Report, Australian Farm Institute.

ISBN 978-1-921808-46-3

# Change in the air: defining the need for an Australian agricultural climate change strategy

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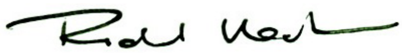
## Richard Heath

Executive Director
Australian Farm Institute

Australian agriculture has always been a risky business. However, any sort of complacency about how well risk has been dealt with over time should be challenged by the threat that climate change poses to the sector. *Change in the air: defining the need for an Australian agricultural climate change strategy* clearly lays out the case for co-ordinated action on climate change so that Australian farmers can both respond and adapt to the climate threat as well as address the sectors role in mitigating the causes.

The climate threat that is faced by Australian agriculture is not contained within State boundaries or sectoral research silos. Developing collaborative and co-ordinated R&D, industry and government responses at a national level is imperative but will be challenging. Embracing the challenge will reap rewards on many levels. Action taken now will decrease future impact and, importantly, will provide opportunity for Australian agriculture to continue to set the agenda on efficient, profitable and sustainable climate resilient farming systems.

Co-ordinated action requires a clear plan and this report puts the case forward for the development of a comprehensive climate action strategy. One of the first steps that will need to be taken in the development of a strategy is a more thorough understanding of the consequences of inaction. A clearer ability to assess the risk that climate change poses to agriculture and the communities it depends on will drive the discussion around whether continued incremental change needs to be replaced by transformational changes to the sector.



**Richard Heath**

***Executive Director,***
***Australian Farm Institute***

## Lucinda Corrigan

Chair
Farmers for Climate Action

Climate change is a wicked challenge representing a serious threat to the viability of Australian agriculture, and forcing us to critically evaluate how our farming systems can both effectively mitigate and adapt to the challenges presented.

As farmers, we are on the frontline of climate change and we need to be part of its solution. We need tools to help us manage extreme weather events, which are set to occur with increasing frequency, and we need long term government policy to limit future warming. The following report – ***Change in the air: defining the need for an Australian agricultural climate change strategy*** – highlights the essential elements of a proactive national approach to rising to the greatest challenge we face.

As producers, we know that the extent of tomorrow's climate change impacts on Australian agriculture will be influenced by the strategies determined and actions taken today, both on and off the farm.

There have been times in the past when climate change and agricultural mitigation and adaptation have struggled to achieve a dominant place in mainstream agricultural discourse. Through the efforts of leading agricultural and climate researchers, trusted organisations like the Australian Farm Institute and leading innovative farmers, this is now changing. Climate change is increasingly recognised as one of the most significant risks facing our industry.

My hope for this research report is that we can harness the energy for change in our physical and political environments to effect great policy for the future of food, families and farming. The future of our industry and our communities depends upon it.

It is my privilege to commend this report as an outstanding resource for policy-makers, researchers, rural communities and farmers Australia-wide.

**Lucinda Corrigan**
***Chair, Farmers for Climate Action***

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# Executive summary

Climate change represents a serious and present threat to the Australian agricultural sector's continued viability, which impacts our long-term food security and the sustainability of regional communities. Agriculture is more vulnerable to climate impacts than other economic sectors, and projected productivity declines are likely to impact all subsectors.

While the agriculture sector is both vulnerable to and partially responsible for the heightened challenges of climate change, cohesive strategy to mitigate the negative impacts and facilitate improved resilience in agriculture is either absent or immature in Australian policy.

*The extent of tomorrow's climate change impacts on Australian agriculture will be influenced by the strategies determined and actions taken today.*

An extensive body of literature on climate change and Australian agriculture outlines negative effects on productivity, health, food and water security and geo-political stability. To address these issues, a long-term, bipartisan commitment to tackling climate change must be supported and advanced by agri-political leaders from industry and government (including AGMIN[1]) to circumvent policy stagnation.

A successful **national strategy for climate change and Australian agriculture** must be underpinned by research, development and extension to enable systemic adaptation and identify the priority gaps where action and strategic policy are needed.

More work is required on identification and categorisation of climate risks to enable appropriate deployment of resources within a strategic national framework. A focus on realisation of potential opportunities underpins the value proposition of a national strategy and should be included in commentary and extension.

*A systemic view of climate impacts across society should inform a national strategy on climate change and agriculture.*

The new operating environment for Australian agriculture contains many unknowns, thus continuous and responsive evaluation facilitated by a strong RD&E environment is necessary to enable timely sectoral adaptation.

A national transition to clean energy is intrinsically linked to climate change mitigation and has the additional benefit of providing a buffer for agricultural producers and supply chain operators in an increasingly energy insecure environment. The capture and storage of carbon offers opportunities to not only reduce emissions but also improve natural resource management, social cohesion and economic stability for the agricultural sector. As such, these should also be key pillars of a national strategy on climate change and agriculture.

As the climate continues to change, so must the relevant policies and strategies evolve. However, evolution should not be mistaken for reinvention, rebadging or reneging. Cohesive climate policy which actively seeks to address gaps is required to drive substantial investment in adaptable farming systems and low-emissions energy generation in Australia.

**The extent of tomorrow's climate change impacts on Australian agriculture will be influenced by the strategies determined and actions taken today.**

1 The Agriculture Ministers' Forum (AGMIN) membership comprises Australian/state/territory and New Zealand government ministers with responsibility for primary industries and is chaired by the Australian Government Minister for Agriculture. AGMIN's role is to enable cross-jurisdictional cooperative and co-ordinated approaches to matters of national or regional interest.

# Key recommendations

The authors are aware that public policy is often framed through an economic lens. However, the projected economic impacts of climate change on agriculture – which range from moderate to catastrophic depending on many diverse factors discussed throughout the report – are difficult to quantify in dollar terms.

Moreover, the financial impact is part of a cascade of impacts and represents both a symptom of natural capital loss and a driver of further social and economy-wide effects which must be considered when discussing climate change and agriculture.

The authors strongly recommend that **a systemic view of climate impacts across society** informs a policy on climate change and agriculture. We recommend that subsequent studies should investigate the sector-specific triple bottom line impacts (social, environmental and financial) of climate change on Australian agricultural subsectors, to enable selection of the most appropriate adaptation and mitigation strategies and effective resource allocation.

Additionally, we recommend that **a national strategy on climate change and Australian agriculture be urgently adopted** by the Federal Government via AGMIN to better co-ordinate currently disparate industry, government and NGO efforts and ensure the impacts of and on agriculture are considered in context of other Australian industries. This strategy should sit on a foundation of risk minimisation, supported by the pillars of strong research, development and extension, adoption of clean energy and a focus on the capture and storage of carbon, within an environment of continuous improvement (Figure 1).

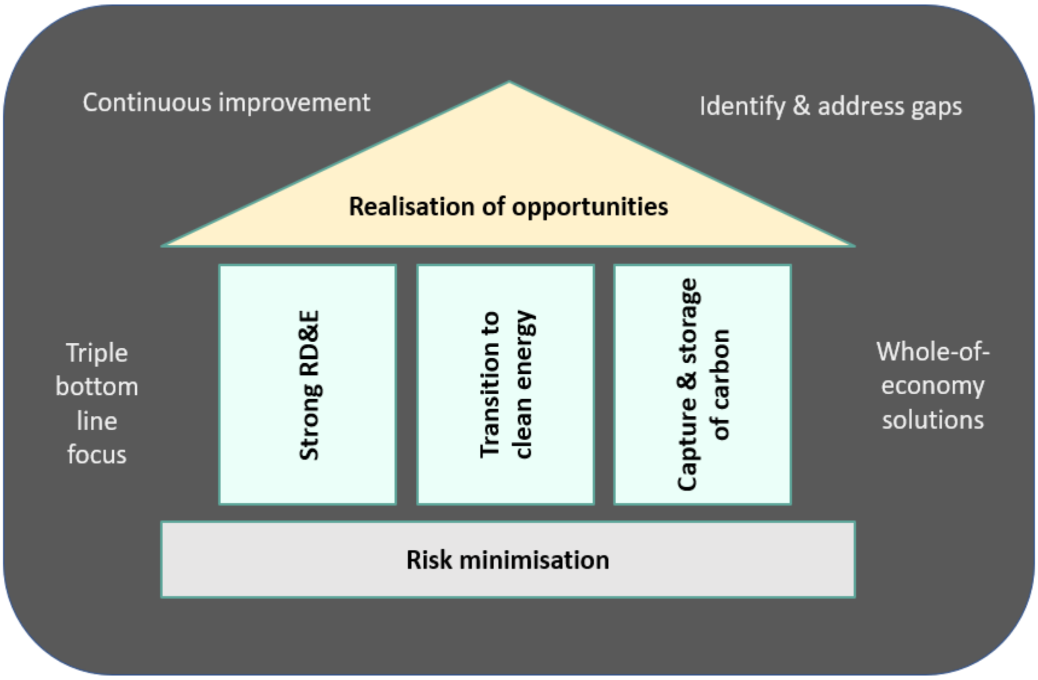


**Figure 1:** Proposed pillars of a national strategy for climate change and agriculture.

- **Risk minimisation** should be a guiding principle of a national strategy for climate change and agriculture. The interconnection of biophysical, transition and indirect climate risks on farm income, food security and health require a collaborated cross-sectoral policy approach.
- A **focus on potential opportunities** underpins the value proposition of strategic goals and should be included in commentary and extension of a national strategy.
- **Strong RD&E** underpins a national strategy for climate change and agriculture. The new operating environment for Australian agriculture contains many unknowns, thus continuous and responsive evaluation, discovery and extension is necessary to enable timely sectoral adaptation.
- A **transition to clean energy generation in agriculture** is intrinsically linked to climate change mitigation and has the additional benefit of providing a buffer for agricultural producers and supply chain actors in an increasingly energy insecure environment. As such, it should be a key pillar of a national strategy on climate change and agriculture.
- The **capture and storage of carbon** offers opportunities to not only reduce emissions but also improve NRM, social cohesion and economic stability for the agricultural sector. This pillar minimises risks and realises opportunities and should also be central to a national strategy on climate change and agriculture.
- Cohesive climate policy which actively seeks to **address gaps** is required to drive substantial investment in adaptable farming systems and low-emissions generation in Australia. Identification of policy gaps should be part of the process of continuous improvement for a national strategy on climate change and agriculture, rather than a strategic pillar.

If the pillars, principles and processes discussed herein are not included in a cohesive and overarching national strategy on climate change and agriculture, the Australian agricultural sector will continue to face significant threats to viability and obstacles to transition:

- **agricultural production will fall**
- **farm profits will decline**
- **food insecurity will rise**
- **rural health will be adversely impacted**
- **sectoral trust will decrease**
- **barriers to adaptation will remain**
- **energy transition will be impeded**
- **investment will lag behind need**

# 1. Introduction

"Farming communities are highly exposed to climate change. On the other hand, agriculture can deliver and stands to benefit from smart climate actions."
– Verity Morgan-Schmidt, FCA CEO, December 2018

"We're adapting, but our ability to adapt has limits. We have no more time to waste."
– Lucinda Corrigan, FCA Chair, June 2019

"Climate change is a reality that should be fundamentally changing the way policy is developed."
– Richard Heath, AFI Executive Director, November 2018

Climate change is a 'wicked problem' representing not only a threat to the Australian agricultural sector's profitability and international competitiveness but also to our long-term food security and the viability of some regional communities.

## 1.1 Sectoral exposure

The agriculture sector is both vulnerable to and partially responsible for the heightened challenges brought about by climate change. Globally, agriculture contributes a significant share of the greenhouse gas (GHG) emissions causing climate change – 17% directly through agricultural activities and an additional 7% to 14% through land use changes – which in turn negatively affects crop and livestock systems in most regions (OECD, 2014). To minimise the severity of projected impacts of the warming trend caused by increased GHG levels, the sector has an imperative to continue efforts in emissions mitigation and to accelerate cross-industry progress, backed by a supportive policy and investment framework.

Both in Australia and internationally, agriculture is one of the sectors most exposed to adverse climate change impacts. Climate change-induced deviations in water availability and quality, average temperatures, and increased incidence of pests, diseases and weeds are all very likely to negatively impact agricultural productivity directly and indirectly (Adams, Hurd & Reilly, 1999; Cline, 2007; Gunasekera et al., 2008; Steffen et al., 2019; Stokes & Howden, 2010). While the effects of climate change will impact all sources of the agriculture sector's stores of value,[2] this report focuses primarily on the biophysical impact on natural capital and the need for policy to address this concern.

The complexities of climate impact on the interrelationship between human health and productivity, supply chain efficiencies, market shifts and changed food demands and societal priorities cannot be ignored in policy setting. While these issues are outside the immediate scope of this report,[3] the authors strongly recommend that **a systemic view of climate impacts across society informs a national strategy on climate change and agriculture.**

## 1.2 Food insecurity

Climate change could potentially increase regional food insecurity (Linehan et al., 2012; Michael & Crossley, 2012) with food price spikes focusing attention on rising food demand and how this will be met. Institutions such as the Food and Agriculture Organization of the United Nations (FAO, which presents both threat and opportunity to Australia.

2 The impact of climate change on natural capital consequently impacts the financial and manufactured capital derived from natural capital. Climate change also affects human, social and relationship capital (and thus intellectual capital) directly and indirectly via health impacts and socioeconomic disruption.

3 AGMIN has tasked Agriculture Senior Officials' Committee (AGSOC) to prepare a paper on supporting agriculture in adapting to climate change which will include a comprehensive scan of potential climate change scenarios and impacts and a stocktake of approaches to adaptation across jurisdictions. This project is being co-ordinated by Agriculture Victoria.

As our near neighbours face increased volatility in productive capacity, Australia has an opportunity to lead by example in climate-smart farming adaptation (developing a 'knowledge economy') and also to provide goods to new export markets in regions which do not adapt to the challenges as quickly. Just as Australian farmers have looked to Israel on how to grow crops in a desert, Australia's struggle with extreme heat and drought could serve as a case study for other nations facing similar situations under climate change (Patterson, 2015).

Conversely, a threat exists that without significant, systemic change to adapt practices and to mitigate the negative impacts of climate change, Australia may not be able to maintain agricultural productivity to a standard which upholds food security in the region. For example, Hughes, Lawson and Valle (2017) found that a significant deterioration in climate conditions for cropping over the past 15 to 20 years contributed to productivity shocks in the mid-1990s and 2000s (ABARES, 2019).

*The agriculture sector's continued ability to meaningfully contribute to the Australian economy and regional food security is jeopardised by climate disruptions.*

Due to population increase, depletion of natural capital resources such as soil and the effects of climate change, considered management of the intensification of agricultural production is now an imperative for global security (Jeffery, 2017). The allocation of funding for climate mitigation and adaptation measures represents an investment in the stability of Australia's geopolitical region by avoiding food and water insecurity (Foreign Affairs, Defence and Trade Committee, 2018).

Australian food consumption is projected to be almost 90% higher in 2050 than it was in 2000 (Michael & Crossley, 2012) and the real value of world agrifood demand in 2050 (in 2007 US dollars) has been projected to be 77% higher than in 2007 (Linehan et al., 2012). With typically less than 30 days' supply of non-perishable food and less than five days' supply of perishable food in the supply chain at any given time, a low level of on-hand food reserves makes Australia extremely vulnerable to supply chain disruptions via extreme weather events (Hughes et al., 2015).

Climate-induced reductions in Australian agricultural production will also erode export competitiveness, especially if warmer and wetter conditions elsewhere boost production of key products such as red meat (Hughes et al., 2015). As an export-dependent industry, the projected increase in food demand combined with the likelihood of reduced production rates and increased supply chain disruptions exponentially raise the sector's risk exposure.

**If our current climate trajectory and supply chain processes remain unchanged, the agriculture sector's continued ability to meaningfully contribute to the Australian economy and regional food security is jeopardised by climate disruptions.**

## 1.3 Ecosystem management

Farmers are also responsible for managing much of Australia's ecosystem with 48% of Australia's land privately owned or leased for agricultural production (NFF, 2018), which is thought to hold about two-thirds of Australia's remnant native vegetation (Barson, Mewett & Paplinska, 2012). Australian farmers have both a societal obligation and an economic imperative to care for this natural capital, but upholding this stewardship grows more difficult and more costly as climate change impacts both the health of the natural environment and farmers' financial capital stores. As discussed in Section 2.3, the current model of on-farm environmental stewardship is reliant on significant contributions of time and money by farmers and land managers. Variability in farm income directly related to weather impact will increase with climate change, compromising the capacity for farmers to utilise equity (Heath, 2018) for environmental projects.

**Adaptation to a changing climate can provide alternative financial opportunities for farmers while promoting natural capital protection and regeneration.**

## 1.4 Policy stagnation

Much like water management (particularly in the Murray-Darling Basin), the impacts of a changing climate are seen to be everyone's problem but nobody's responsibility. Programs exist and new initiatives are underway to support farmers to use more energy efficient equipment, incorporate land-use changes such as revegetation, and adopt new farming practices.

*Cohesive strategy to mitigate the negative impacts of climate change and facilitate improved resilience in agriculture is either absent or immature in Australia.*

However, while an increasing proportion of Australian farmers are adopting practices which integrate soil, water and vegetation management – thus increasing the natural capital that underpins their farm's productivity and sustainability (Jeffery, 2017) – these incremental changes alone will not provide the sector-wide resilience needed to function sustainably within a changed natural system (Rickards & Howden, 2012).

**To date, cohesive strategy to mitigate the negative impacts of climate change and facilitate improved resilience in agriculture is either absent or notably immature in Australian policy.**

A successful climate adaptation and mitigation policy for Australian agriculture must be underpinned by research into the practices that are already proving effective, identifying the priority gaps where action and strategic policy are needed, and ensuring appropriate resources to extend successful practices rapidly and extensively.

## 1.5 Report structure

This report does not seek to set out a complete adaptation plan for the sector, nor is it a comprehensive review of existing plans and strategies. Rather it attempts to interrogate the need for a national strategy on climate change and agriculture and offer direction for the industry's next steps on this issue within relevant local and global frameworks.

Section 2 is a broad literature review of work relating to the degradation of Australian agriculture's natural capital from the impacts of climate change. Section 3 discusses the state of play in global and local efforts to address this threat, and Section 4 analyses proposed pillars of a national strategy on climate change and agriculture.

# 2. Natural capital at risk

Climate change represents a serious threat to the continued sustainability of the natural capital on which Australian agriculture is inexorably dependent (Figure 2), yet the sector faces this threat without a cohesive, overarching national strategy.

Natural capital describes the stocks of natural assets (which include soil, air, water and all living things) from which a wide range of services are derived to support life on earth. **Agriculture is reliant on access to natural capital to a greater degree than almost any other sector of the economy.**

Disruptions to the useability or decline in health of natural capital assets significantly impact on profits and productivity of the agricultural industry. The degradation of natural resources from impacts of climate change impairs the sustainable development of farmers, businesses and nations and imposes external costs on society and future generations (FAO, 2015).

While not yet commonly used in policy consideration, natural capital accounting[4] and monetisation is increasingly being used by the business community (FAO, 2015). As discussed in Section 2.5, climate change risk exposure has become a serious governance concern in agriculture. Growing pressure to implement environmental, social and governance (ESG) ranking tools to assess agricultural businesses throughout the supply chain for exposure to such risks has become a mainstream issue for directors and investors. The ongoing decline of natural capital assets is already increasing business risk (KPMG, 2014) and endangering economic and social quality of life.

*Agriculture is reliant on access to natural capital to a greater degree than almost any other sector of the economy.*

Australian farmers have always managed natural assets within a highly variable climate, but climate change adds significant additional complexity to their management decisions and risk exposure (Laurie et al., 2019; University of Melbourne, 2015). Farmers are responsible for managing much of Australia's ecosystem with 48% of Australia's land privately owned or leased for agricultural production (Climate Change Authority, 2018; NFF, 2018), which is thought to hold about two-thirds of Australia's remnant native vegetation (Barson et al., 2012). Upholding the public good obligation to care for natural assets is growing more

4 Organisations have historically focused on financial and manufactured capitals in reporting. Integrated reporting also considers intellectual, social and human capitals within the frame of natural capital, which provides the environment in which the other capitals sit (Figure 2) (IIRC, 2013).

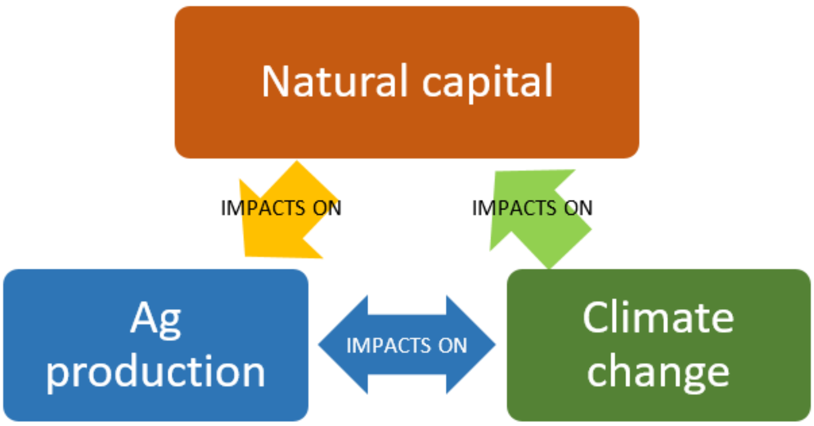


**Figure 2:** Interdependence of agriculture and climate change.

difficult and more costly, as the weather extremes brought about by climate change impact not only the health and integrity of the natural environment but also farm incomes.

Climate change-induced weather extremes which impede agricultural production (Hughes et al., 2015) are a direct physical threat to the soil and water which comprise the agro-ecosystem. Australia's water security has already been significantly influenced by climate change: rainfall patterns are shifting, and the severity of floods and droughts has increased (Jeffery, 2017). Additionally, periods between droughts will increasingly experience other extreme weather events (such as floods, severe frosts and heat waves) which already seriously impact Australian agriculture and impede recovery (Crimp et al., 2016; Heath, 2018).

Concurrently, the global population is growing in both size and wealth, and demand for food is expected to increase exponentially. **While natural capital is declining, the food and agriculture value chain will have to produce more with less to ensure long-term sustainability and economic viability.**

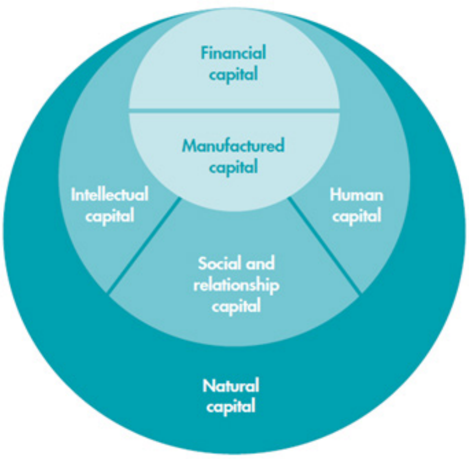


**Figure 3:** The six capitals of Integrated Reporting.

***Source:*** IIRC (2013).

Degradation of natural capital impacts productivity, business profitability, cash flow, supply risk and reputation, and inevitably undermines the value of other capitals[5] due to their interdependence (Figure 3). The historical response to natural resource degradation has been to shift production to unused resources, for example new agricultural regions, fisheries and forests.

*The extent of the future impacts of this constant change will be influenced by the strategies determined and actions taken today.*

However, the impacts of climate change on Australian productive land, combined with land use competition from the energy industry and an expanding population, make this option increasingly unviable (Barlow, 2014).

Data indicates that the impacts of climate change will not result in a 'fixed state' scenario and will likely amplify other stresses such as fragmentation, deforestation, invasive species, introduced pathogens and pressure on water resources (Australian Academy of Science, 2019). **The extent of the future impacts of this constant change will be influenced by the strategies determined and actions taken today.**

Maintenance of natural capital is essential to long-term sustainable development or regenerative production, with food and fibre being one of the dividends of this capital. Sustainable development does not prioritise environmental goals over economic and social goals but rather emphasises the intrinsic links between these needs (Figure 4, over page). An economy underpinned by healthier natural capital will outperform (over the medium to longer term) an economy where natural capital is degraded (Nous Group, 2014). However, a study by the

*Cohesive cross-sectoral policy should address stewardship to ensure the natural capital needed for agriculture remains a useable and healthy asset.*

5 Financial and manufactured capitals are commonly considered as business core capitals, however integrated reporting takes a holistic view by also considering intellectual, social and human capitals with natural capital, which provides the environment in which the other capitals sit, and emphasising the interrelationship between all six capitals. (IIRC, 2013)


**Figure 4:** Sustainable development interlinkages.

***Source:*** LLC (n.d.).

Australian Academy of Technological Sciences and Engineering noted that implementing this long-term strategic view will lead to conflicts with short-term financial survival and profit imperatives, as well as the direct and opportunity costs of maintaining natural capital (Barlow, 2014).

The pressure of feeding growing populations in conditions of increasingly extreme heat and water scarcity, the ongoing deterioration of the natural resource base and uncertainties in patterns of global trade leave no room for policy complacency (Hughes et al., 2015).

**Cohesive cross-sectoral policy should address the responsibility of stewardship to ensure the natural capital needed for agriculture remains a useable and healthy asset.**

## 2.1 The economic impact

With one of the highest contributing gross domestic product (GDP) percentages in the developed world and supplying more than 90% of the nation's food supply, the Australian agricultural sector is the "prism through which we have historically thought about the effect of climate on the economy" (Debelle, 2019)[6].

*The studies reviewed for this report are consistent in concluding that the overall outcomes will be negative for agricultural productivity and GVP.*

Climate change will detrimentally affect agriculture more than other sectors of the economy, leading to a significant reduction in agricultural productivity (Iqbal & Siddique, 2015) and disruption in supply chains (Hughes et al., 2015), yet specific information on the direct economic impacts of climate change on Australian agricultural gross value of farm production (GVP) is difficult to obtain. This is due in part to inconsistent data, but primarily because the complexity of climate change impacts – on agricultural productivity, yield, growth rates, market demand, trade, supply chains and business governance – confound quantification.

The economic importance of agriculture to Australia is clear. While Australia's agricultural output as a proportion of the economy has declined from 25% of GDP in the first half of the 20th century to just 2% in 2015, this percentage remains among the highest in the Organisation for Economic Co-operation and Development (OECD) (Hughes et al., 2015). Providing 93% of Australia's domestic food supply (Brown, Bridle & Crimp, 2016), the agricultural industry is comprised of more than 85,000 farm businesses, 99% of which are wholly Australian-owned (NFF, 2018). Australia exports more than $30 billion worth of food annually, daily providing food for up to 40 million people outside the country (Jeffery,

6 For example, the model of the Australian economy used at the Reserve Bank in the 1990s (developed by Gruen and Shuetrim) had the Southern Oscillation Index as a significant determinant of GDP (Debelle, 2019).

2017). Any economic loss in agriculture from climate change will be detrimental to the national economy.

The direct effects of climate change on Australian agricultural production include fluctuations in growing conditions, water availability and frequency of adverse weather events resulting in price volatility and market uncertainty. These factors combined make modelling the economic or productive impact of climate change very challenging. Given the complexity of the problem and the uncertainties, assumptions and often lengthy timeframes inherent in predictions, any modelling results need to be thoroughly interrogated.

Several studies on climate change effects have modelled the direct impacts of temperature change and water stress on agricultural yields at an aggregated level and a handful of studies have assessed the comparative effect of climate change on the various crop, livestock, fishery and forestry sectors. However, the specific impacts of climate change on food insecurity, farm performance, or social wellbeing are not well documented. While useful and indicative, these results need to be augmented with up to date and more detailed analysis that explicitly indicates the opportunity cost of not responding to the climate change effect.

Using the GTEM and Ausregion modelling methods, Gunasekera et al., (2007) estimated that climate change impacts would cause Australian gross domestic product (GDP) to decline by 5–11% in 2050, compared to a business-as-usual (BAU) GDP scenario without climate change.[7] Their analysis also indicated that future climate changes could cause Australian production of wheat, beef, dairy and sugar to decline by an estimated 13–19% by 2050, relative to the 'reference case' (or BAU production without climate impacts).

A recent study by Kompas et al. found that the long-run impacts of increased temperature averages of 1°C, 2°C, 3°C and 4°C climate change scenarios would cause a reduction of total Australian GDP by −0.287%, −0.642%, −1.083% and −1.585% respectively per year (Kompas, Pham & Che, 2018).

Leveraging the work by Kompas et al., the Climate Council (Steffen et al., 2019) has also attempted to model the projected economic impact of climate change on the sector and related industries. In modelling the compound costs (based on current trends), the report found that the accumulated loss of national wealth due to reduced agricultural productivity and labour productivity as a result of climate change is projected to exceed $19 billion by 2030, $211 billion by 2050 and $4 trillion by 2100 (Figure 5). However, the authors note that the damage functions used in this study are very limited, i.e. losses from floods, bushfires, storms and tropical cyclones (which are increasing in frequency and/or severity due to climate change) and the impacts of climate change on properties and infrastructure are not included. Notably, the model does not place any value on biodiversity and ecosystems, thus these losses are not reflected in the costed damages.[8]

7 That is, the research by Gunasekera et al. determined that Australian agricultural GDP without climate change would be X in 2050, and GDP with climate change impacts would be X minus 5–11% in 2050. This study also assumed no adaptation measures in agricultural production and an overall slowdown of global economic growth from climate change, based on Stern (2007). The reference case (BAU scenario) used in comparison with the modelling assumed no future impact on economic growth from climate change.

8 The work by Steffen et al. focuses on a time path for local temperatures that is consistent with a business-as-usual emissions trajectory (RCP 8.5) and draws baseline population and GDP projections from a socioeconomic pathway that assumes a doubling of global food demand, high level use of fossil fuels and a tripling of energy demand over the course of the century (SSP5). This is consistent with the highest GHG emissions pathway. Damages are expressed in 'real terms' using a 5% discount rate to convert future losses into current dollars. Values are expressed as the present values of cumulative damages up until each year (i.e. up until 2030, 2050 and 2100).

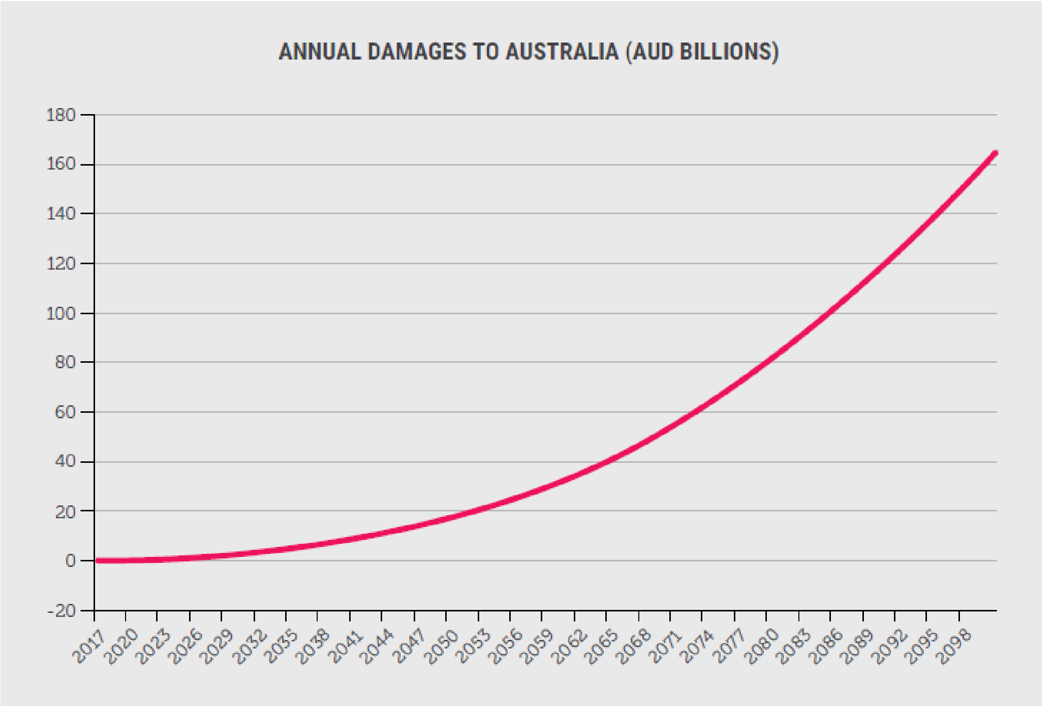


**Figure 5:** Annual damages to the Australian economy from reduced labour productivity and agricultural productivity due to climate change.

***Source:*** Steffen et al. (2019).

Although differing in the estimated magnitude of climate change impacts on the sector, the various studies reviewed for this report are consistent in concluding that **the overall outcomes will be negative for agricultural productivity and GVP.**

Reserve Bank Deputy Governor Guy Debelle has noted that both the physical impact of climate change and the transition to a less carbon-intensive world are likely to have first-order effects on the economy, particularly agriculture. A negative supply shock to agriculture (such as a drought or cyclone) reduces output but increases prices, complicating policy response because the two parts of the Reserve Banks's dual mandate (output and inflation) are moving in opposite directions. Given that climate change is a trend rather than cyclical (IPCC, 2018), monetary policy assessment becomes exponentially more complicated as supply shock is no longer considered temporary but close to permanent (Debelle, 2019).

While the negative directional change suggested by these studies is clear, the differences apparent in the literature underscore the need for policy-makers to assess the percentage or dollar impacts derived from different models with appropriate caution.

The authors recommend that subsequent studies should investigate the sector-specific triple bottom line impacts (social, environmental and financial) of climate change on Australian agricultural subsectors, to enable selection of the most appropriate adaptation and mitigation strategies and effective resource allocation.

Porfirio et al., (2018) note that a strong economic structure with agile and robust policies could mitigate negative climate impacts on agricultural production during a transition to a low carbon economy.

**For consistency of comparison and to enable evaluation, a national strategy on climate change and agriculture should clarify needs and priorities for economic reporting to help define preferred frameworks and methods for future impact/outcome modelling.**

## 2.2 Climate and agricultural productivity

While the impacts of climate change on each subsector of the agricultural industry are highly variable, the data demonstrates net negative outcomes for all sectors.

Although implications from a changing climate may benefit some areas and sectors in the short term through increased yield from elevated CO2 levels, these benefits are likely to be outweighed by compromised quality. More importantly, the combination of reduced rainfall, increased heat (Figure 6 and Figure 7) and evaporation will further exacerbate already marginal growing conditions.

The 2018 State of the Climate report states that Australia's climate has warmed by just over 1°C since 1910, leading to an increase in the frequency of extreme heat events (BOM & CSIRO, 2018). Sea levels are rising and oceans around Australia have warmed by around 1°C since 1910 and are becoming more acidic. Rising sea levels are likely to increase rising water table and salinity issues and exacerbate poor drainage and tidal intrusion in floodplain production areas (Williams, 2016). These issues are cause for concern for fisheries and coastal producers such as low-lying sugar cane growers or dairies, as well as some horticulture, viticulture and forestry.

Australia is projected to experience further increases in these trends, leading to decreases in rainfall across southern Australia with more time in drought, but an increase in intense heavy rainfall[9] throughout the country.

The drying in recent decades across southern Australia is the most sustained large-scale change in rainfall since national records began in 1900. The drying trend has been most evident in the south-western and south-eastern corners of the country. This decrease, at an agriculturally and hydrologically important time of the year, is linked with a trend towards higher mean sea level pressure in the region and a shift in large-scale weather patterns, i.e. more highs and fewer lows (BOM & CSIRO, 2018).

Increased climate volatility is already affecting agricultural production and farmers' ability to recover from shocks. One of the most significant climate change-related impacts on Australian agriculture is not just that there will be more droughts, but that the ability to recover from droughts is going to be much more difficult due to more frequent extreme weather events. Historically Australia has experienced relatively long and benign inter-drought periods during which financial equity and natural capital lost during drought could be rebuilt. What climate change science tells us is not just that these inter-drought periods will be shorter, but also that those periods will be subject to more extreme weather events such as floods, frost and heat waves (Heath, 2018).

9 As the climate warms, heavy rainfall is expected to become more intense, based on the physical relationship between temperature and the water-holding capacity of the atmosphere.

| | Present average (1971–2000) | 2030 average (mid emissions) | 2070 average (low emissions) | 2070 average (high emissions) |
|---|---|---|---|---|
| Brisbane (Qld) | 1.0 | 2.0 (1.5–2.5) | 3.0 (2.1–4.6) | 7.6 (4–21) |
| Hobart (Tas) | 1.4 | 1.7 (1.6–1.8) | 1.8 (1.7–2.0) | 2.4 (2.0–3.4) |
| Sydney (NSW) | 3.5 | 4.4 (4.1–5.1) | 5.3 (4.5–6.6) | 8.2 (6–12) |
| Canberra ACT) | 5.3 | 7.8 (7.6–10.5) | 10.4 (8.2–13) | 16.8 (11.7–25.1) |
| Melbourne (Vic) | 9.1 | 11.4 (11–13) | 14.0 (12–17) | 20.0 (15–26) |

**Figure 6:** Projected average number of days per year above 35 deg C.

***Source:*** Stokes and Howden (2010).

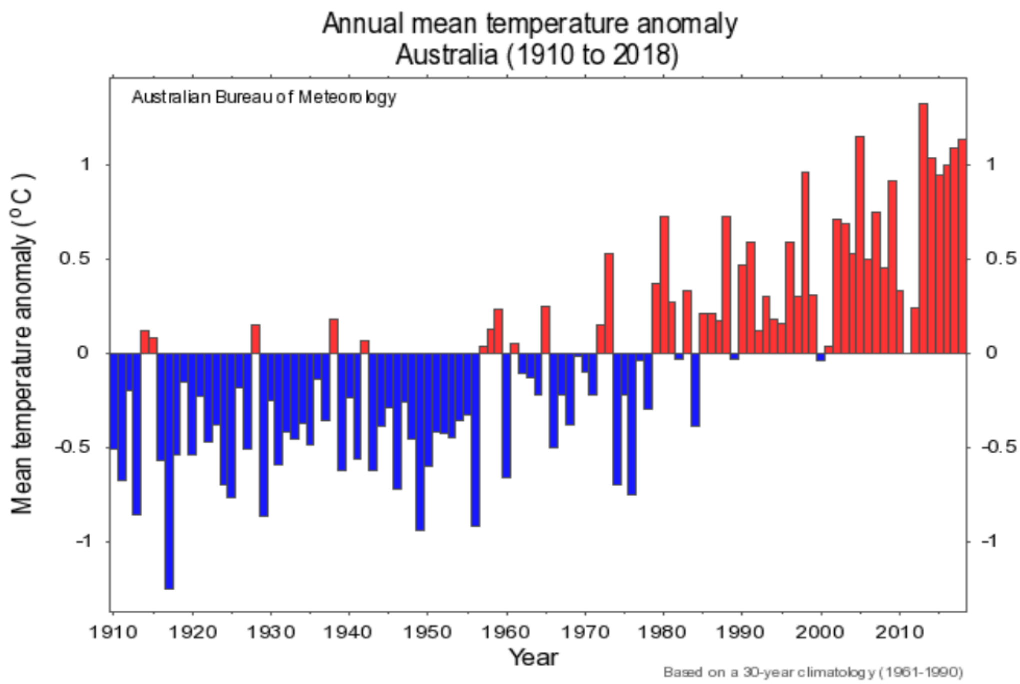


**Figure 7:** Annual mean temperature anomaly Australia 1910–2018.

***Source:*** Bureau of Meteorology.

## Subsectoral impacts

Brief overviews of climate change impacts on each subsector from the literature review are outlined in this section of the report. Tables outlining likely outcomes of climate change for each subsector along with an overview of climate change adaptation and mitigation strategies collected from a review of available literature can be found in Appendix 1.

Climate change is causing higher atmospheric levels of CO2 concentration, which may increase plant production in terms of biomass production but not necessarily increase yield (Hochman et al., 2017; Climate Council, 2015). Increased CO2 will likely result in reductions in the quality of **grain crops** (Ludwig & Asseng, 2006), and increased drought conditions (reduced rainfall and higher temperatures) will impact grains production.

Climate impacts on Australian agricultural production include:

- Water-limited yield potential of wheat declined by 27% between 1990-2015
- 45 species of fish have shifted south due to rising ocean temperatures since the 1800s
- Beef production in Qld and the NT could decline 19% by 2030 and 33% by 2050
- Up to 70% of wine-growing regions could be unsuitable for grapes by 2050
- Cotton yields could decrease 17% by 2050

A CSIRO simulation results of 50 grain zone representative sites showed that water-limited yield potential of **wheat** declined by 27% over a 26-year period from 1990 to 2015, with a further 4% loss prevented due to the positive effect of elevated atmospheric CO2 (Hochman, Gobbett & Horan, 2017). Additionally, frost-related production risk has increased by as much as 30% across much of the Australian **wheatbelt** over the past two decades in response to an increase in later frost events (Crimp et al., 2016).

Analysis presented in the *Journal of Agricultural Science* showed that due to changes in climatic factors on production localities, the areas where **wheat** and **cotton** can be grown in Australia will diminish from 2030–2050 and 2070–2100[10] (Shabani & Kotey, 2016).

Historically, **cotton** production in Australia has decreased during drought conditions due to the crop's reliance on water (Stokes & Howden, 2010) and water insecurity is expected to have a significant impact on future cotton crops. Although increased carbon in the atmosphere and decrease in the number of cold days may positively influence **cotton** production, increases in temperatures above 35°C and reductions in water availability are likely to be detrimental leading to a net negative impact on the sector (NSW DPI, 2019).

The effect of future climate change on **cotton** yield in Southern Queensland and Northern NSW as modelled by Williams et al. showed that changes in the influential meteorological parameters caused by climate change would result in cotton yields in 2050 decreasing by 17% (without the effect of CO2 fertilisation) from current yields. Including the effects of CO2 fertilisation ameliorated the effect of decreased water availability and yields could increase by 5.9% by 2030, but then decrease by 3.6% in 2050.

10 While the study showed cotton could be grown over extensive areas of the country until 2070, the area grown to wheat will decrease significantly over the period.

The study noted that producers would need to increase irrigation amounts by almost 50% to maintain adequate soil moisture levels in this scenario (Williams et al., 2015).

The **red meat** sector is likely to experience negative impacts on production and profitability from the direct impacts of climate change. Pasture quality and quantity will be compromised from increased drought-like conditions (MLA, 2019; NSW DPI, 2019) and the risk of impaired meat quality will rise as temperatures increase and heat stress becomes a more prominent issue in livestock (Gregory, 2010). S*ee the red meat case study in Section 3.2.*

As heat stress reduces milk yield in the Australian **dairy** industry by 10–30% – up to 40% in extreme heatwave conditions (Hull, 2016) – predicted temperature increases are a serious concern for the industry and could prompt relocation or industry exits. S*ee the dairy case study in Section 3.2.*

Impacts of climate change on the **wool** sector include reductions in the growth, quality and nutritional value of pasture and fodder crops, with severity of these impacts dependant on location and climatic zone. This will likely lead to reductions in quantity and quality of wool production as well as productivity on farms.

Estimates indicate that by 2050, up to 70% of Australia's wine-growing regions with a Mediterranean climate will be less suitable or unsuitable for **grape production** (Climate Council, 2015). Higher temperatures and lower rainfall will particularly affect production of the red varieties, with the rise in temperatures causing earlier ripening and consequent reductions in grape quality. Expansion of the **viticulture** sector to colder growing regions, such as Tasmania, is already occurring. While a general warming trend could offer opportunities for planting different fruit varieties, pests and pathogens are also expected to increase, while water availability will decrease. S*ee the viticulture case study in Section 3.2.*

Climate trend analyses also predict changes in the 'frost window' which are likely to have a negative impact on **broadacre cropping, viticulture** and **horticulture**. Despite overall temperature increases since 1960, the 'frost season' has increased. Modelling has shown that over the past two decades frost-related production risk has increased up to 30% across the Australian wheatbelt region. With frost damage estimated to currently cost agricultural sectors between $120 million and $700 million each year and frost damage predicted to increase as climate change effects are felts, the economic impact on agricultural sectors are likely to rise (Crimp et al., 2016).

**Horticulture** is sensitive to variation in temperature and rainfall for the development of optimum yield and quality. The absence of winter chilling, increased frequency and severity of extreme weather events such as heatwaves, frost, drought, high winds, cyclones and hail will all negatively impact the sector. While an expansion of the industry in some regions may occur with a decreased frost risk, along with a potential southward shift in the optimum growing regions, the overall impacts of climate change on the reliability and viability of horticultural production are negative.

Increased temperatures and CO2 are also likely to lead to accelerated crop development, increased yield and an extended growing season for **sugarcane**. Despite the crop's resilience to occasional dry spells and floods, the rise in temperature and reduced rainfall will likely result in a net negative impact for the sugarcane industry due to reduction in overall availability of irrigation water and decrease in quality and quantity of sugar content in the plant. Rising sea levels are likely to increase the difficulty of managing water tables and acid sulphate soils and may potentially reduce the areas suitable for crop growth (Williams, 2016). In addition, plantations on coastal flats are vulnerable to sea-level rise and salt-water flooding from cyclone-induced storm surges (Climate Council, 2015).

While the Australian **rice** sector has improved water use efficiency by 50% over the past decade (Department of Agriculture and Water Resources, 2015), production is entirely dependent on water availability (Ashton & van Dijk, 2017). The predicted climate change effects of reduced rainfall and increased evaporation via higher temperatures make the rice crop particularly vulnerable.

The most substantial impact the **pork** industry is likely to experience from climate change is an increase in cost and decrease in availability of inputs. Climate change-related increases in pork sector input prices such as grains, electricity and fuel will diminish producer profitability and force growers to further compete with cheaper imported products (Flor, Plowman, Cameron, Luethi & Lovett, 2009).

There is little research and literature on the implications of climate change effects on the **poultry** industry. However, increased temperatures and more frequent heatwaves will increase the risk of heat stress for layer hens, which causes reduced feed intake, poor weight gain, poor laying rate, reduced egg weight and shell quality, reduced fertility and increased bird mortality (AEL, 2018).

The Australian **fishery** industry is seen as having a greater ability to adapt to climate change compared to other commodities such as cropping and red meat (Brown et al., 2016). This is due to the ability of some species to be able to adapt to rising temperatures over time or move further south. Last et al., (2011) note that since the 1800s, 45 species of fish have shifted south due to rising ocean temperatures. However, these southward migrations will alter fisheries' catch rates and target species.

Reproduction and development rates of fish will also be implicated by rising temperatures. Destruction of assets (vessels and nets) may rise due to the increased likelihood of extreme weather events such as cyclones and storms.

A 2011 study on the potential impacts of climate change on six **forestry** regions around

Australia calculated that most species were projected to experience net reductions in growth by 2030, dependent on the species and region of the forestry (ABARES, 2011). Increased temperatures and reduced rainfall will result in decreases in the growth rate of trees, while the rise in the frequency and intensity of bushfires will impact tree survival.

**Although the practical effects and magnitude of impacts of climate change on each agricultural subsector differ, there are commonalities which will impact the entire industry. A nationally co-ordinated policy approach can help address the common issues and build sector-wide resilience.**

## 2.3 Ecosystem conservation

Australian agricultural production is inexorably dependent on access to both human capital and to the ecological services derived from a healthy agro-ecosystem sustainably connected to its landscape (Grafton, Mullen & Williams, 2015).

Agricultural landholders manage almost half of Australia's landmass, thus playing a significant role in the stewardship of rural landscapes (ABARES, 2018). Climate change will have significant adverse effects on these landscapes which will consequently impact native flora and fauna as well as the production of agricultural commodities.

For millennia, the agroecological practices of Indigenous Australians shaped the productive environment to ensure balance and predictable availability of food for the population (Gammage, 2012). This systemic, localised approach to production has been almost completely superseded by the economically-driven modern European model of land ownership and farming over the past two centuries, which has at times resulted in a mismatch between farmscapes and healthy functioning landscapes (Grafton et al., 2015) and subsequent degradation of the natural capital on which future food and fibre production depend.

While the industry has taken notable steps towards a more sustainable or regenerative approach, the acknowledgement of errors of commission and omission as recommended in systems thinking approaches (Ackoff, 2006) is key to enabling the systemic transformation required in the face of climate change, rather than incremental improvements which can be counterproductive[11].

*Systemic transformation is required in the face of climate change, rather than incremental improvements alone which can be counterproductive.*

Numerous challenges exist in the current business model for natural resource conservation in agriculture which should be considered when developing policy to secure the future of Australia's ecosystem health.

Although farmers have a social responsibility and expectation to undertake on-farm environmental stewardship, the current model is based largely on significant voluntary contributions by farmers and land managers. Martin (2018), suggests policy should provide more options for compensation to primary producers for the direct financial cost of environmental works and for income foregone from conducting the work.

The impacts of climate change on biophysical production and on market forces will exacerbate volatility in farm incomes, which in turn impacts the viability of environmental projects; i.e. low productivity or commodity prices, natural disasters and supply chain disruptions impact farm incomes and thus producers' ability to financially support environmental projects. These disruptions can cause longer-term projects to be put on hold which can often waste or undermine prior effort, for example in weed or feral animal control.

Other challenges in developing policy to manage rural biodiversity include:

- Capacity issues, e.g. lack of workforce, physical capacity of some farmers (age) and limits in capacity of Aboriginal land stewardship

11 Incremental adaptation alone may cause a 'lock in trap', obstructing necessary change by increasing investment in the existing system and narrowing down alternatives for change (Rickards & Howden, 2012).

- The vast size of Australia, relatively limited population and national income
- Participation from all individuals so as not to damage social licence

The introduction by the Federal Government of a pilot Agriculture Biodiversity Stewardship Program in March 2019 could partially address some of these issues. The initiative has set aside $30 million to financially reward farmers for their role in managing the environment by improving biodiversity and sequestering carbon (Littleproud, 2019). This fund, in addition to a $2 billion increased investment in the Climate Solutions Fund (formerly the Emissions Reduction Fund) over 10 years from 2020 (adding to residual funding of $226 million) could be utilised to enable ecosystem regeneration and transitions to more sustainable and climate-responsive production methods.

**A strong national climate change policy should consider and address the challenges of managing ecosystem health and compensate producers for the conservation and protection of Australia's natural environment.**

## 2.4 Agriculture's mitigation role

As an historically significant GHG emitter, the agriculture sector shares responsibility for mitigating the degree and rate of climate change.

OECD data indicate that agriculture contributes a significant share of the GHG emissions causing climate change – 17% directly through agricultural activities and an additional 7% to 14% through land use changes – which in turn negatively affects crop and livestock systems in most regions (OECD, 2014).

Confusion can often occur from the differing methodologies used in calculations of emission figures. Consistency in data methodologies when conducting comparisons is vital in ensuring accuracy. An example where this has occurred is in the US where studies implemented different methodologies to calculate emissions from the livestock and transportation industries. Figures for livestock emissions included the entire lifecycle of production – land clearing, fertiliser use, and direct animal emissions – while the manufacturing of vehicles was not included in the calculations, resulting in a large overstating of emissions from livestock (Mitloehner, 2018a).

The Australian agricultural sector was responsible for approximately 13% of Australia's total GHG emissions in 2017 (Climate Council, 2018). Emissions have trajected down since 2005, likely as a result of the reduction in agriculture from the Millennium Drought. However, prospects of future reductions have been labelled by the Climate Council as difficult and likely to project upwards (Bourne et al., 2018).

While the industry has taken positive steps to implement practices which lift productivity while reducing emissions (Meyer, Graham & Eckard, 2018), further progress must still be made if agriculture is to meet its share of emission reduction targets or carbon neutrality, indicating the need for a nationally co-ordinated approach.

As shown in Table 1, the Department of the Environment and Energy (2017) has projected direct emissions from agriculture to increase by 2020 and 2030, primarily attributed to projected increases in global food demand. This study does not take into consideration the abatement of emissions from initiatives and policies which are still undergoing development but does account for the projections of policies such as the ERF and National Energy Productivity Plan which were current and developed at the time of producing these calculations.

Without continued progress in emissions reduction by the sector, agricultural emissions are likely to increase over time as increased food demand is required for a growing global population.

**Table 1:** Direct Australian agricultural $CO_2$-e emissions in million metric tonnes.[12]

| Sector | 2017 | 2020 | 2030 |
|---|---|---|---|
| Lime and urea | 3 | 3 | 4 |
| Other fertilisers | 4 | 4 | 5 |
| Other animals | 1 | 1 | 1 |
| Crop | 6 | 4 | 5 |
| Pigs | 1 | 2 | 2 |
| Sheep | 13 | 14 | 15 |
| Dairy | 9 | 9 | 10 |
| Grain fed beef | 3 | 3 | 4 |
| Grazing beef | 33 | 36 | 38 |
| **Total** | **72** | **75** | **82** |

$CO_2$-e = Carbon dioxide equivalent

***Source:*** Department of the Environment and Energy (2017).

**A national strategy to address climate change in Australian agriculture could provide the required framework to enable consistency and comparability in emissions calculations and reporting.**

A solid methodology and reporting system coherent with global standards will aid the industry in determining progress and areas of improvement, particularly given that reduction of GHG emissions by Australia alone cannot be assumed to reduce climate impacts – i.e. the effect of climate change on any country is caused not only on that country's emissions but by global emissions.

Recent research from CSIRO concluded that there is a net economic benefit for agriculture in transitioning to a low carbon economy, as under a modelled mitigation scenario agricultural systems are more productive and able to meet the demand for food imposed by a growing population (Porfirio, Newth & Finnigan, 2018). The authors also noted that mitigating $CO_2$ emissions has the co-benefit of creating a more stable agricultural trade system that may be better able to reduce food insecurity.

## 2.5 Complexity of response

The compound difficulties of responding to climate change are exacerbated by the complexity of the decision-making environment (Maani, 2013) – a particular difficulty for agriculture, given the heterogeneity of the commodities produced, methods of production, regional climatic and agroecological variations, a lack of strategic industry cohesion and policy uncertainty.

A recent EY report noted that the effectiveness and efficiency of Australian agricultural innovation is undermined by poor cross-industry and cross-sectoral collaboration (Ernst & Young, 2019), and that national frameworks and priorities do not drive investment decisions. The siloed nature of the existing organisational structure means strategic priorities and direction are set independently by system participants, making systemic change difficult.

Additionally, poorly designed or incohesive sustainability projects can lead to perverse outcomes (Climate Change Authority, 2014), for example by placing excessive pressure on water resources.

Systemic thinking (recognising that the whole is more than the sum of its parts) is a core tenet for sustainable development. Australian agriculture can be described as a system in that it loses its essential properties when taken apart (Johannes, 2016). Within this system there are many distinct heterogeneous units (including social, environmental and financial elements), some functioning with only a tenuous link to the overarching 'organisation' of Australian agriculture.

These units are generally represented as sectors (e.g. horticulture), subsectors (e.g. citrus) and categories (e.g. organic), as well as interdependent supply chain actors (e.g. processing facilities). However, each of these units – whether or not they belong to a representative body, a research group such or a socio-political association – is an intrinsic

12 Includes emissions from enteric fermentation, manure management, rice cultivation, agricultural soils and field burning of agricultural resides. It does not include emissions from electricity use or fuel combustion from operating equipment.

part of the organisation. Each represents a social and economic unit within a system which is managed to pursue collective goals, with clearly defined structures determining relationships between activities and participants.

In striving for a transformational response to the challenge of climate change, the diversity of these elements represents both strength (via the application of creative cross-sectoral solutions and the spreading of risk) and weakness (in the fragmented approach to implementation).

While individuals farm and disparate businesses trade primary commodities, the organisation of agriculture is a highly interdependent network requiring strong rapport and cohesive actions from land managers, livestock producers, input suppliers, transporters, processors, wholesalers, retailers and consumers to function.

To effect the disruptive change needed to address climate change it is necessary to focus on the interactions of the parts rather than their behaviour taken separately. A visual representation of the drivers, outputs and outcomes of this systemic approach is presented in Figure 8.

## Differences across zones

The projected effects of climate change naturally vary between agro-climatic conditions as well as crop and animal variety, from region to region, dryland to irrigated, C3 to C4 plants[13], soil to soil. The diversity of agricultural, ecological and climatic conditions in Australia is globally unique (Figure 9).

Table 2 (over page) summaries the results of a study which developed a Potential Vulnerability Value (PVV) for several agricultural ecological zones (AEZs). These results indicate not only

13 C3 plants include grain cereals, rice, wheat, soybeans, rye, barley; vegetables such as cassava, potatoes, spinach, tomatoes, and yams; trees such as apple, peach, and eucalyptus. C4 plants include forage grasses of lower latitudes, maize, sorghum, sugarcane, fonio, tef, and papyrus.

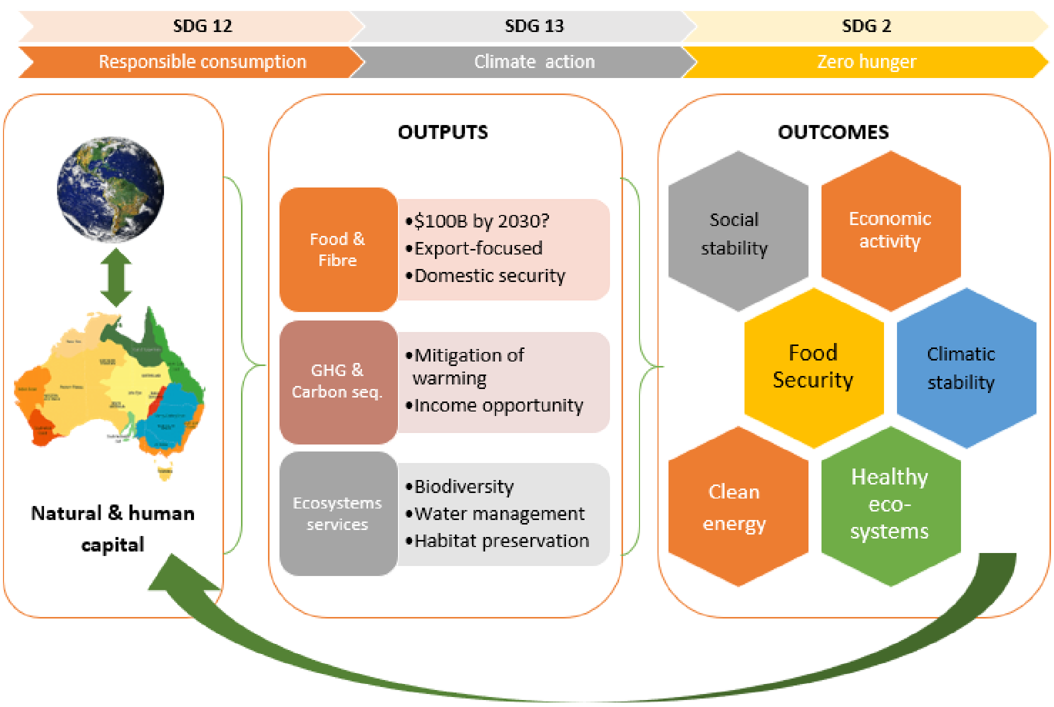


**Figure 8:** A systemic view of agricultural climate response.

*Source:* Authors, and Keating (2008).

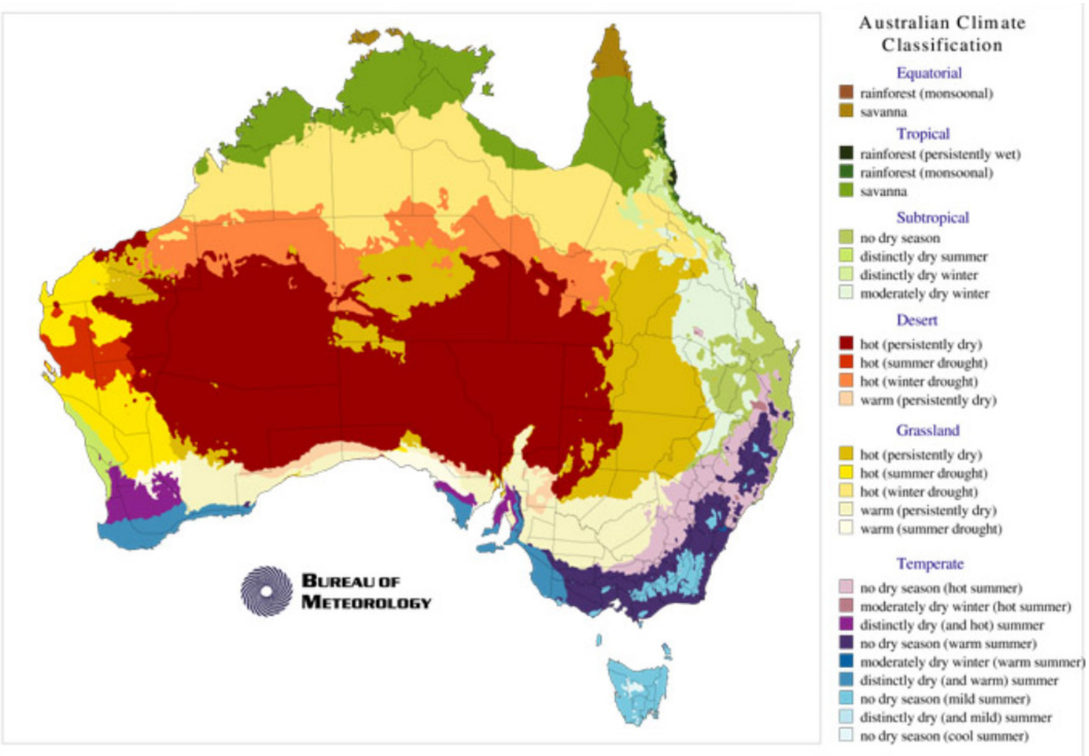


**Figure 9:** Agro-climatic categories of Australia.

***Source:*** Bureau of Meteorology.

the differences across Australia depending on AEZ and sector, but also within larger sectors spread across multiple AEZs. Due to this diversity policy-makers must ensure they are informed by robust empirical evidence on the effects of climate change on specific commodities and regional zones (AAG, 2011; Stokes, Howden & CSIRO, 2008).

## Costs of adaptation and mitigation

To manage the many impacts of climate change across Australian agriculture, comprehensive adaptation and mitigation strategies are both needed – however, these measures have cost implications.

A study assessing the capacity of Australian broadacre mixed farmers to adapt to climate change identified financial issues (such as low equity or limited capital) as the most constraining factors limiting adaptation, and natural capital assets (such as high soil productivity and low rainfall variability) the most enabling (P. R. Brown, Bridle & Crimp, 2016).

The cost of climate change adaptation for developed economies has been estimated at 2% of GDP, for example, Gunasekera et al. (2007) indicates that the introduction of a broad-based carbon penalty of $40/tonne of CO2-equivalent emissions would raise Australian agricultural production costs by 3% for the livestock sector and 4.5% for cropping (if agriculture was excluded from the scheme). If agriculture was included, production costs would rise by 18% for livestock and 6% for cropping (Gunasekera et al., 2007, 2008). In selected agricultural regions in Australia, it is estimated that adaptation measures can reduce the projected economic impacts of climate change by half.

However, given the uncertainty of projected future rainfall and temperature patterns, the magnitude of impacts derived from such models should be read with appropriate caution.

Overall, the spread of effort across adaptation and mitigation combined can reduce the cost of response to climate change, benefiting both the agricultural economy and stores of natural capital. Appendix 2 – *Adaptation and mitigation strategies* provides further detail of adaptation and mitigation strategies in place for each sector, which highlights the varying levels of implementation and specific priorities of each sector.

**A national strategy is needed to provide cohesion amongst the differing methods of remediation being undertaken across the industry and to improve cost/benefit analysis of the associated costs.**

Additionally, the costs of *not* adapting or attempting to mitigate impacts must be considered. Climate and risk are now mainstream governance issues in agriculture and natural resource management. Investment analysts are increasing pressure to implement environmental, social and governance ranking tools to assess agricultural companies for their exposure to (and mitigation plans for) risks such as water stress, climate change and energy security (Dairy Australia, 2018). At the Governance Institute of Australia's risk forum in mid-2018, speakers noted that regulators are increasing their focus on non-financial risks; for example, water management practice in primary production will be an increasing focus for investors (Guerin, 2019).

**Table 2:** Potential Vulnerability Values in agro-ecological zones.

| AEZ | Sector | Warming impact by 2030 | Rainfall impact by 2030 | Key issues | PVV Range[14] (0=low risk, 5=high risk) |
|---|---|---|---|---|---|
| **Dry** | Beef/Veal, Limited Forestry | Up to 2°C | 5% – 10% drop in centre, 2% – 5% drop on margins | Increased heat stress, increased tick-related losses, reduction of natural pasture carrying capacity | **2–4** |
| **Mediterranean** | Horticulture, Wheat, Rice, Viticulture, Dairy, Forestry | 1°C – 2°C | 5% – 10% drop | Unclear effects on wheat yields, shift in dryland boundaries of wheat profitability, increased heat stress, reduced frost damage, unclear effect on forestry | **0–3** |
| **Subhumid, Temperate and Tropical** | Cotton, Wheat, Viticulture, Beef/Veal, Minor Forestry | 1°C – 1.5°C | 2% – 5% drop | Similar to Mediterranean region, except increased variability in irrigation allowances, possible increase in irrigated crop production if water availability continues | **0–3** |
| **Moist, Subtropical and Tropical** | Horticulture, Dairy, Sugar, Beef/Veal, Minor Forestry | Up to 1°C | 0% – 5% drop | Increased costs of cooling in cattle industries, increased volatility of irrigation allowances and its associated effects on irrigated crop production | **1–3** |
| **Wet, Tropical Warm Season and Tropical** | Sugar, Horticulture, Beef/Veal and Limited Forestry | Up to 1.5°C | 0% – 2% drop | Possible increase in natural hazards, increased heat stress for feed lotting | **0–2** |
| **Wet, Cold and Temperate Cool Season** | Horticulture, Wheat, Viticulture, Dairy and Forestry | Up to 1°C | 0% – 2% drop | Reduced cold-stress, reduced heating costs, changes in the regional optimal horticultural and viticultural settings | **0–2** |

***Source:*** AAG (2011).

14 **Potential Vulnerability Values (PVV):** 0 = No danger from climate change, possible increase in agricultural viability; 1 = Very few negative effects, little expected economic loss as a result of climate change, slight need for mitigation and adaption, but not immediately; 2 = Some negative effects, but not on a scale likely to result in significant economic losses, adaption and mitigation somewhat necessary but not immediately; 3 = Moderate probability of negative effects, some economic loss expected if no adaption or mitigation implemented; 4 = High probability of negative effects, very likely that economic losses could be incurred if action is not taken for mitigation and adaption in the shorter term; 5 = Likelihood of severe damage to agriculture due to climate change is very high, severe economic losses expected, little scope for mitigation or adaption.

## Socio-cultural factors

While investigations of agricultural adaptation to climate change have primarily focused on biophysical responses, the socio-ecological context must also be considered for the development of effective adaptation strategies (Brown, Bridle & Crimp, 2016). The nexus between climate change and human health, productivity, supply chain efficiencies, market shifts, changed food demands and societal priorities is one of the more complex aspects in understanding the impacts of climate change on agriculture.

As noted in Section 4.1.1, climate change impacts not only the direct biophysical risks to agricultural production but also has secondary effects on human health and social wellbeing, as well as infrastructure and supply chains. The institutional risks associated with climate change such as changing consumer and investor expectations regulatory impacts and legal liability also influence social and economic security.

The biophysical impacts of climate change on landscape, livestock and production are intertwined with social and structural factors. For many farmers, work and home are intimately linked and the impacts of climate change – such as the increased frequency of drought and natural disasters such as flood or fire – cannot be separated into occupational, financial, community and personal stressors (Austin et al., 2018).

*The impact of climate change in communities which are reliant on agriculture can severely damage social capital.*

The interrelated risks posed by climate change will also exacerbate the social, economic and health inequalities already experienced by rural and regional communities (Hughes, Rickards, Steffen, Stock & Rice, 2016). For example, the flow-on effects of poor employment in a drought-affected local economy and a widespread loss of services adversely affect the entire community, not just individuals (Edwards et al., 2018).

**The impact of climate change via these combined stressors in communities which are reliant on agriculture can severely damage social capital.** This capital is 'the glue that holds society together' in the form of trust, reciprocity and exchanges, social networks and groups and underpins rural resilience.[15] Resilient communities are characterised by high levels of 'community capital', which includes environmental (ecological resilience), human and cultural (social resilience) and structural / commercial capitals (economical resilience) (Beekman et al., 2009).

When this social capital is damaged by climate impacts on physical and mental health, rural resilience and adaptability are impaired. Social capital should be studied and assessed in the context of off-farm, non-science or non-agricultural knowledge or processes (Rickards & Howden, 2012) in order to understand the interconnected consequences of climate change. Maintaining social capital in rural areas should be a key climate adaptation strategy to strengthen community networks and reduce the increased risks to mental distress and suicide (Steffen et al., 2018).

Recent literature has highlighted the correlation between drought and rural mental health, as well as extreme weather events and physical health. Drought is associated with poor mental health in rural areas (Austin et al., 2018; Hughes et al., 2016; Steffen et al., 2018) and has not only a substantial negative economic impacts but also multiple direct and indirect health impacts on farmers and others employed in the agricultural sector (Edwards, Gray & Hunter, 2018; Pearce, Rodríguez, Fawcett & Ford, 2018). Steffen et al. (2018) also describe a series of varied human health impacts from extreme weather events associated with climate change in addition to the direct physical risks, including a reduction in water quality and availability, disruption to medical services and an increase in vector-borne diseases.

**While these socio-cultural factors are perplexingly complex, policy-makers must account for these compound impacts when considering a national response to climate change and agriculture.**

15 Social capital also refers to the stocks of social trust, norms and networks that people can draw upon in order to solve common problems.

# 3. State of play

A national strategy on climate change and agriculture cannot be developed in a vacuum. Context and consistency are important factors for successful policy, and this section provides an overview of relevant global and domestic policy frameworks, initiatives and trends.

## 3.1 Global context: the SDGs

Three interlinked objectives of sustainable development – economic growth, environmental protection and social inclusion (Figure 4) – underpin the 17 United Nations Sustainable Development Goals (UN SDGs) depicted in Figure 10. These SDGs in turn provide a cohesive and globally consistent reference for organisational sustainability by defining sustainable development priorities to 2030.

The SDGs call on action from governments at all levels, as well as other actors such as business, civil society and academia. As one of the 193 member states that ratified the SDGs, Australia is expected to report on its progress towards achieving the SDGs, including the action taken to implement them (ACFID, ACOSS, GCNA, SDSN Australia, NZ & Pacific & UNAA, 2018).

Four SDGs in particular (expanded in Table 3) have the greatest relevance for an Australian national strategy on climate change and agriculture and also correspond with triple bottom line (social, environmental and financial) impacts:

- **SDG 2 – Zero Hunger** *(social impact)*

  To meet the core purpose of providing natural food and renewable fibre, the sector must provide adequate nutrition to feed the growing global population.

- **SDG 7 – Affordable and clean energy** *(financial and environmental impact)*

  To reduce emissions and improve resilience to energy price increases, the sector should support extension of renewable energy adaptation.

- **SDG 12 – Responsible consumption and production** *(financial impact)*

  To reduce the environmental, economic and social costs of production, the industry must reduce emissions by revising supply chain processes from farm to fork while regenerating healthy ecosystems.

- **SDG 13 – Climate change action** *(environmental impact)*

  To lessen its contribution to global warming and mitigate negative impacts, the organisation must reduce its carbon footprint and invest in clean energy and climate-smart agriculture.

Aspiring to achieve the second SDG of zero hunger will require mitigating the impacts of climate change on agricultural yields and liberalising world agricultural markets (Porfirio, Newth, Finnigan, et al., 2018) as well as addressing food waste (NFF, 2018).


**Figure 10:** The UN Sustainable Development Goals.

***Source:*** United Nations (n.d.).

To meet any of the 2030 SDG targets, transformation not only in Australian agriculture but also in our industries and cities is necessary in order to decouple economic growth from environmental degradation (ACFID et al., 2018).

**Table 3:** The relationship of SDGs to Australian agricultural climate response.

| SDG | GOAL | OUTCOME | KPIs |
|---|---|---|---|
| Zero hunger *(social)* | **1. Produce enough food for needs (domestic & export)** | Reduced food waste | • Prevalence of undernourishment / malnutrition (trading partners)<br>• Prevalence of obesity (domestic)<br>• Prevalence of food insecurity based on UN Food Insecurity Experience Scale (FIES) |
| | | Improved productivity | |
| | **2. Fair and just distribution of food** | Increased food security | |
| | **3. Improved nutritional value of produce** | Healthier global population | |
| Affordable clean energy (*financial & environmental*) | **4. Support extension of renewable energy adaptation** | Better farmer/business resilience to energy price shocks | • Percentage of renewable energy use across sector<br>• Energy emissions measurements<br>• Percentage of farmer/ag supply chain income spent on energy use |
| | | Lower emissions from energy use | |
| Responsible consumption *(financial)* | **5. Sustainably productive environments** | Increased efficiency | • Proportion of productive agricultural area under sustainable farming methods<br>• Volume of production per labour unit by enterprise size<br>• Biodiversity of agricultural production<br>• Improvement in water use efficiency and soil health |
| | | Improved environmental health | |
| | **6. Increased natural capital** | Greater stores of values for future production needs | |
| | | Improved land management | |
| Climate action *(environmental)* | **7. Carbon neutral production** | Reduced global warming | • Reduction in agricultural contribution GHG emissions (to zero)<br>• Percentage of producers with a drought plan<br>• Percentage of producers using renewable energy |
| | | Closed loop production systems | |
| | **8. Resilience and adaptive response to climate hazards** | Mitigation of climate change impacts on food/ fibre production | |

## 3.2 Local context: a unique position

While still part of the world-wide agricultural system, the Australian system is discrete in that it is geographically separate from global agricultural enterprise, agroecologically unique and almost entirely domestically owned. Strategy for Australia should therefore relate to a global framework but retain an appropriately distinct identity.

Development of climate change policy has been problematic in the current Australian political landscape, with inconsistent messaging from governments and within parties a hallmark of the past decade. Despite sometimes conflicting statements from politicians, Australia has committed to a target of reducing emissions to 26–28% on 2005 levels by 2030, representing a 50–52% reduction in emissions per capita and a 64–65% reduction in the emissions intensity of the economy between 2005 and 2030 (Department of the Environment and Energy, 2015).

Federal Government strategies have supported agricultural adaptation to and mitigation of climate change impacts, for example the Emissions Reduction Fund, which in 2017 the Australian Farm Institute estimated distributed more than $225 million between farmers, land managers and carbon service providers. In February 2019 the Australian Government established a Climate Solutions Fund (CSF) to provide an additional $2 billion for purchasing low-cost abatement. The CSF aims to continue the work of the Emissions Reduction Fund by providing funds for farmers, businesses and Indigenous communities to undertake emissions reduction projects. The Clean Energy Finance Corporation (CEFC) also offers opportunities for agricultural businesses to reduce their operating costs by enabling investment in energy-efficient equipment and renewable energy upgrades (CEFC, 2015).

In addition, there is a significant body of work underway in the sector dealing with climate risks and primary industries, for example a 2011–12 stocktake by the Climate Research Strategy for Primary Industries identified 589 projects with a life-of-project value of $549 million (CCRSPI, 2012). In subsequent years, some of these projects have evolved into practical strategies, such as the Australian Dairy Industry Sustainability Framework (Dairy Australia, 2018), the Australian Beef Sustainability Framework (RMAC, 2017) and Climate Proofing Australia, a conservation and industry alliance focused on natural resource management comprised of Farmers for Climate Action (FCA), the Red Meat Advisory Council (RMAC), Greening Australia and the Australian Forest Products Association (AFPA).

In April 2018, AGMIN requested that the Agriculture Senior Officials Committee (AGSOC) prepare a paper on supporting the sector in adapting to climate change. The paper will include a comprehensive scan of potential climate change scenarios and impacts; current emissions management work in agriculture; a stocktake of approaches to adaptation across jurisdictions; and an analysis of risks and opportunities for the agricultural industries. This project is being co-ordinated by Agriculture Victoria. Ministers are expected to discuss the outcomes of this work at the next Agriculture Ministers Forum, which has yet to be scheduled.

Implementation of a cross-sectoral Agriculture Sustainability Framework by 2025 is also a key pillar of the National Farmers' 2030 Roadmap (NFF, 2018). Pillar 2 of the Roadmap outlines the need for *Growing Sustainably*, with metrics identified as:

- The net benefit for ecosystem services is equal to 5% of farm revenue.
- Australian agriculture is trending towards carbon neutrality by 2030.
- A 20% increase in water use efficiency for irrigated agriculture by 2030.
- Maintain Australia's total farmed area at 2018 levels.
- Halve food waste by 2030.

This pillar describes targets which, if embraced, would require genuinely transformational change for the agriculture sector. The actions required to deliver them would lead to entirely new income streams and ways of thinking about delivering the desired environmental and social outcomes without penalising farm businesses and the agricultural economy (Heath, 2019). Delivering on these metrics would position Australia as a global leader in sustainable, viable and climate-resilient agriculture.

To provide focus and cohesion to these initiatives, the FCA alliance (a member of the Climate Action Network Australia) has called on all Australian governments to commit to a **long-term, bipartisan national strategy on climate change and agriculture** to 2050, supported by AGMIN (Farmers For Climate Action, 2019). The 2050 Strategy proposed by FCA would support the long-term viability of Australian agriculture in a changing climate via focus on these goals:

1. Physical risks: Identify direct and indirect risks to Australian agri-food systems, including risks to primary production, biosecurity, food processing, food safety, farmer health, key infrastructure, equity, animal welfare, export markets, farm inputs, etc.
2. Identify risks associated with likely changes in policy, technology, and market conditions in the transition to a low-carbon economy.
3. Identify opportunities to:
    a. Enhance the capacity of key agri-food stakeholders to manage risk and build resilience;
    b. Reduce emissions from the agri-food system while lifting productivity; and
    c. Promote the innovation, efficiency, and overall performance and productivity of the agri-food sector in a low-carbon economy and a changing climate
4. Identify priorities for research, development, and extension, and facilitate an augmented RD&E capacity.
5. Build on existing state and federal climate-related policies and plans, identify gaps in the policy architecture, and strengthen governance arrangements.
6. Include a long-term strategy for clean energy development and energy security in rural and regional Australia.
7. Realise the long-term carbon sequestration and resilience potential of production landscapes.
8. Build the climate and carbon literacy along with innovation and adaptive capacity of farmers and other key stakeholders, including by engaging them in the development of the 2050 Strategy.
9. Set ambitious yet achievable short-, medium-, and long-term targets for emissions reduction and climate change adaptation in the agri-food sector in accordance with Australia's international commitments (Farmers For Climate Action, 2019b)

These goals can be summarised thus:

1. **Minimise the risks** to agriculture, food security, and rural communities from climate change by adapting, reducing emissions, and lifting productivity.
2. Help agriculture to **realise opportunities** to build value, make efficiency gains, and diversify as the world economy shifts into low-carbon gear.
3. Strengthen agricultural research, development, and extension (**RD&E**) so farmers can manage the risks and be part of the solution.
4. Build a strong **clean energy** sector with benefits shared fairly by rural and regional communities.
5. Realise the long-term potential of **healthy working landscapes** to capture and store carbon.
6. Identify **gaps in current policies** and programs – federal and state – and fill them.

While still in preliminary stages, work in Australian agriculture to both minimise and adapt to climate change impacts has progressed. National emissions reduction targets have been set in line with global standards and several initiatives have focused specifically on Australia's unique agricultural sector.

**However, climate change policies for agriculture lack the overarching cross-industry and cross-sectoral focus required to drive the substantial investment which would enable transformational systemic change.**

## Case study: Relocating viticulture

The Climate Council (2015) has estimated that by 2050 **up to 70% of Australia's wine-growing region with a Mediterranean climate will be less suitable or unsuitable for grape production.** In order for the Australian wine sector to survive in the face of this forecast, adaptation strategies are crucial.

Adaptation strategies already being undertaken by some producers include:

- Providing optimal leaf shading for bunches through canopy management
- Increasing moisture retention through mulching
- Changing trellising systems to better manage canopies
- Changing vine plantings to cooler areas to minimise excessive sun exposure
- Manipulating harvest dates by delaying pruning

(Hooke & Powell, 2019; Wine Australia, 2015)

Relocation is an adaptation strategy being undertaken by some viticulture businesses. For example, Brown Brothers (previously located in Victoria) purchased a Tasmanian wine estate for $32.35 million with the motivation for the shift attributed to rising temperatures and increased bushfire risks from climate change (Climate Council, 2015).

However, relocation is not a suitable adaptation option for many wine businesses due to the large amount of capital expenditure required and the potential loss of income resulting from the time taken to establish a new crop.

Although new tourism opportunities could arise from the shifting of viticulture production, economic impacts will be felt on the regions which wineries are likely to leave.

It is unreasonable to expect an entire agricultural sector to relocate to cooler climates to adapt to climate change. Shifting to more temperature tolerant and water efficient varieties of grapes is another adaptation strategy that wine growers are likely to implement. Along with establishment costs with planting new vines, other costs will include rebranding and marketing of the new types of wine to consumers (Hooke & Powell, 2019).

## Case study: Carbon neutral red meat industry by 2030

The red meat sector contributes significantly to the Australian economy. It accounts for approximately 1.6% of Australian GDP, directly employs 200,000 people and was the second largest exporter of beef behind Brazil in 2018 (Australian Beef Sustainability Framework, 2019).

However, like other agricultural sectors, red meat producers are facing the challenge of maintaining and increasing production with constrained natural resources and pressure to reduce environmental impacts. Decreased water availability and increased water requirements of animals due to heat stress is one of the direct challenges red meat producers will face from a changing climate.

Several studies indicate that production and profit will be impacted by climate change. A 19% decline by 2030 has been projected for **beef** production in Queensland and the Northern Territory due to climate change, based on ABARES 2007 modelling – and a 33% decline by 2050 (AMPC, 2016).

Ghahramani and Moore (2015) indicated that in the absence of adaptation to climate change, livestock operating profit at 25 locations across southern Australia will fall by an average of 27% in 2030, 32% in 2050 and 48% in 2070 (relative to a reference period between 1970 and 1999). The fall in operating profit will occur through reductions in stocking rates due to a negative effect on the sustained holding capacity of land and pasture.

The red meat sector has a complicated relationship with the environment through high emissions contribution. Approximately 10% of total Australian greenhouse gas emissions are from the red meat sector (Australian Beef Sustainability Framework, 2019). CSIRO (2017) found that 70% of Australia's greenhouse emissions from agriculture were produced by cattle and sheep. The high percentage of emissions ascribed to animal agriculture has resulted in increased scrutiny from the community (Mitloehner, 2018b).

A strategy has been put in place for the Australian red meat sector to become **carbon neutral by 2030**, primarily by reducing emissions through farm management process changes and increasing carbon sequestration.

Although it is no easy task, progress is being made. The *2019 Annual Australian Beef Sustainability Annual Update* reported that from 2005 to 2016, the beef sector has reduced carbon emissions by 55.7%. It also reported a decrease in greenhouse gas emission intensity (kg of carbon emitted per kg of liveweight from raising beef) of 8.3% over the past five years. (Australian Beef Sustainability Framework, 2019).

Mark Wootton, a farmer in Hamilton in Western Victoria, achieved carbon neutrality in 2010 on his property of 3,000 hectares which runs 550 cows and 25,000 ewes. 600 hectares of trees were planted to offset the emissions from the livestock with half being saw log timber to generate a profit after 10–15 years. Mark noted that biodiversity on the property had significantly increased through transitioning to carbon neutrality (Verley et al., 2019).

Flinders + Co have achieved carbon neutrality throughout their supply chain through a combination of emissions reduction activities such as renewable energy sources and utilising carbon offset programs. The company is hopeful consumers will look for carbon neutrality certification and be willing to pay a premium price for the product in the future and that other red meat supply chains see their actions and realise the transition is achievable (Australian Beef Sustainability Framework, 2019).

The creation of the carbon neutrality by 2030 target, the actions being undertaken by stakeholders to achieve it and the fact that progress is being made, illustrates the sector's positive response to the challenge of climate change.

## Case study: Dairy's climate-challenged future

Climate change is increasing the frequency and duration of extreme weather conditions (Hennessy et al., 2016) which affect the fertility, health and welfare of dairy livestock as well as reducing the volume and quality of milk production and thus farm income. The impacts of extreme hot days on dairy also include increased energy demand for cooling and demand for livestock drinking water.

Heat stress is measured using Temperature Humidity Index (THI) and describes the inability of livestock to dissipate body heat. This excessive heat load (heat stress) leads to reduced feed intake, production losses and potentially lead to tissue organ damage and death.

Dairy cows are highly susceptible to heat stress, which can reduce milk yield by 10–25% (up to 40% in extreme heatwave conditions), thus the predicted temperature increases of climate change are a serious concern for the industry and could prompt relocation or exits.

Research led by Brendan Cullen and Margaret Ayre of University of Melbourne applied climate, biophysical and economic models to develop projections to 2040 for three farm systems, in Victoria's Gippsland region, South Australia's Fleurieu Peninsula and north-west Tasmania.

These studies found that climate change would result a loss of operating profit of 10–30% if farmers did not adapt to the warmer and drier climates (Hull, 2016). In the United States, the estimated cost of heat stress to the dairy industry is approximately $897 to $1,500 million/year in revenue (Gunn et al., 2019).

Input costs for the dairy sector could also increase, as the quality and price of supplementary feed is dependent on climate conditions.

The dairy industry is also working to mitigate climate change. Direct livestock emissions account for around 10% of Australia's overall greenhouse gas (GHG) emissions, with dairy and meat cattle responsible for about 65% of the livestock sector's emissions.

The challenge for dairy is to produce more milk without exacerbating climate change impacts further. To this end, the Australian dairy industry is targeting a 30% reduction in GHG emissions per litre milk produced by 2020 (Dairy Australia, 2015). Some of the activities consider for reducing on-farm greenhouse gas emissions include:

- Selecting cow genetics for feed conversion efficiency
- Feeding high quality feed to increase milk production and reduce GHG emissions
- Applying nitrogen fertiliser at the right time and rate
- Improving reproductive efficiency to reduce the number of replacement heifers
- Improving irrigation water use and energy use efficiency

Energy efficiency is the dairy industry's primary opportunity for reducing both operating costs and emissions. The areas of highest energy use are milk cooling, milk harvesting and hot water production. A study by Dairy Australia show that solar units installed in dairies at an average cost of around $16,000 can save more than 15 tonnes of CO2-e emission and more than $3,000 in electricity costs per annum (Dairy Australia, 2015).

A comprehensive national framework for climate change and agriculture would enable the dairy industry to identify priority areas for mitigation and evaluate actions in relation to sectoral, regional and national standards. It could also enable cross-sectoral learning so that best practice adaptation and mitigation efforts can be shared both from and to the sector.

# 4. Need for a national strategy

Climate change policy is undoubtedly a wickedly complex issue. The adverse effects of climatic change (i.e. significant negative economic impact and limitations on productive capacity) will disrupt all sectors of agriculture, resulting not only in financial costs but also social impacts.

Current climate change policies in Australia lack an adequate national approach such as a synchronised sector-specific comprehensive agreement on understandings and responsibilities of climate change strategies (Head, 2014; Talberg, Hui & Loynes, 2016).

**A robust yet flexible national strategy for climate change and agriculture, built on evidence-based policy and backed by significant resources to deliver both adaptation and mitigation from the farm gate up through the value chain, could better co-ordinate efforts and resources to minimise direct and indirect risks.**

A strong national climate change strategy that aids the industry in combating challenges – supported by governments, industry stakeholders and primary producers – will also provide opportunities for agricultural growth and aid the transition a low-carbon economy. Collaboration between agricultural sectors and other industries to share knowledge and experience in managing climate change impacts will be vital for the success of such a strategy.

*Australia lacks an adequate national approach such as a synchronised sector-specific comprehensive agreement on climate change strategies.*

Additionally, it is important to understand the financial, infrastructural, social and institutional constraints on farmers' adaptive capacity in the context of a national strategy. For adaptation and mitigation strategies to be effective, the impacts of climate change on the agricultural economy, agricultural communities, agrobiodiversity and agroecosystems must also be considered together.

This section evaluates the potential efficacy of the proposed FCA strategy pillars by discussing the benefits of the pillars and the consequences of excluding a pillar from a national strategy. The strategy pillars are interdependent in forming a national policy, and Figure 11 (over page) depicts their interrelationship, with dotted lines representing no clear boundaries between actions and goals – i.e. success in one area is necessary for success in all. Continuous monitoring and improvement of policies, strategies and action plans will be necessary to ensure agriculture is not left vulnerable to adverse impacts.

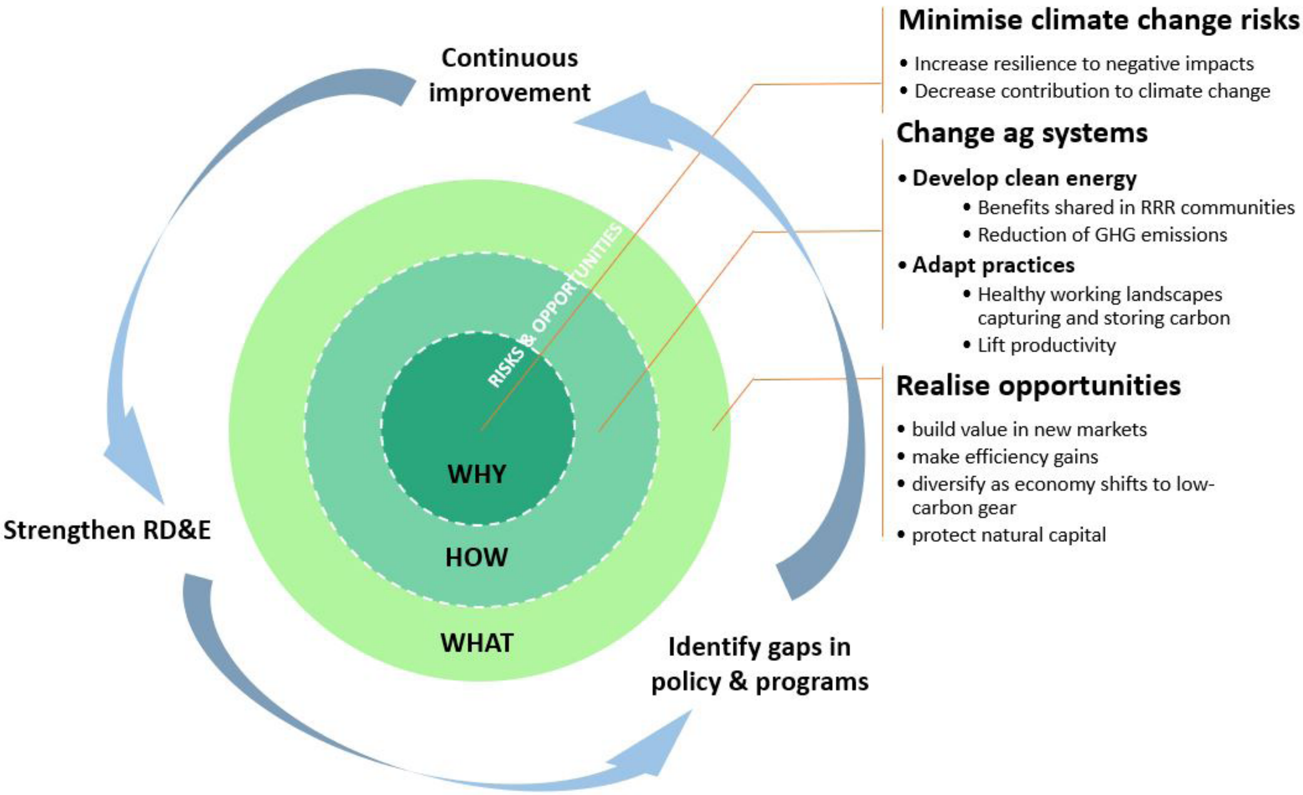


**Figure 11:** Interrelationship of policy pillars.

# 4.1 Strategy pillars

## 4.1.1 Minimise risks

*Minimise the risks to agriculture, food security, and rural communities from climate change by adapting, reducing emissions and lifting productivity.*

The 2018 Global Risks Report has identified failure of climate change adaptation and mitigation as a risk with a high likelihood of occurrence and high impact (World Economic Forum, 2018). A national climate change strategy must consider mitigation of the risks to the agricultural industry, to food security, to land management and to rural communities. While climate risk should also be central to investor decision-making (IGCC, 2017), this is discussed in Section 2.

Climate change poses significant risks to Australian agriculture that range from adverse growing conditions and water scarcity to reduced farm profit margins and significant industry contraction, impacting the country's triple bottom line of social, environmental and economic security.

Climate risks have been summarised by Ernst & Young as:

- **Physical:** damage to land, buildings, stock or infrastructure owing to physical effects of climate-related factors, such as heat waves, drought, sea levels, ocean acidification, storms or flooding
- **Secondary:** knock-on effects of physical risks, such as falling crop yields, resource shortages, supply chain disruption, as well as migration, political instability or conflict
- **Policy**: financial impairment arising from local, national or international policy responses to climate change, such as carbon pricing or levies, emission caps or subsidy withdrawal

- **Liability:** financial liabilities, including insurance claims and legal damages, arising under the law of contract, tort or negligence because of other climate-related risks
- **Transition:** financial losses arising from disorderly or volatile adjustments to the value of listed and unlisted securities, assets and liabilities in response to other climate-related risks
- **Reputational:** risks affecting businesses engaging in, or connected with, activities that some stakeholders consider to be inconsistent with addressing climate change (EY Australia, 2016)

The physical risks of climate change exacerbate the difficulties in managing on-farm risk by shifting the frequency and intensity of weather-related risks and increasing uncertainty (Choudhary et al., 2016). However, climate risk as it relates to agriculture is not only restricted to the *direct biophysical risks* to production but also includes secondary or *indirect risks* (e.g. to human health, social wellbeing, infrastructure, supply chains, export markets, and knock-on effects from impacts in other sectors), institutional or *transition risks* (e.g. poorly designed policy, regulatory impacts, changes in insurance, changing consumer and investor expectations, technological changes), and *legal liability risks*.

The interconnection of climate-related physical, transition and financial impacts (Figure 12) on farm income, food security and health underscore the need for collaborated risk management and mitigation tools and policy.

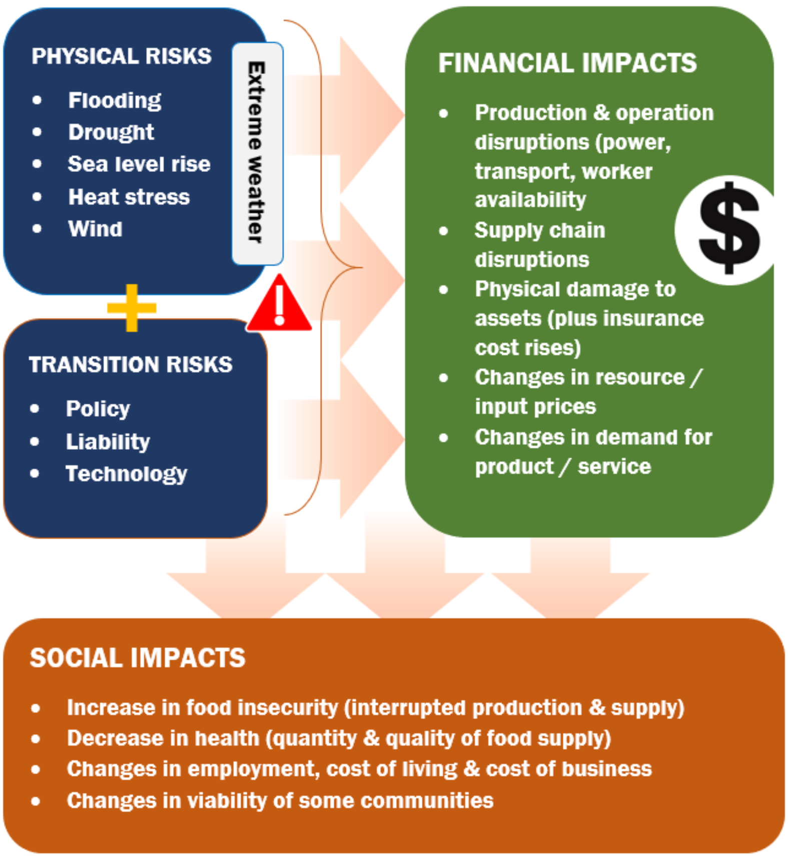


**Figure 12:** Climate risk and financial impacts.

***Adapted from:*** Clapp, Lund, Aamaas & Lannoo (2017).

In order to ensure success in ameliorating impacts, a suite of risk mitigation tools should be utilised rather than favouring one over another. A detailed examination of risk management options for Australian producers can be found in the AFI report *Australian agriculture: an increasingly risky business* (Laurie et al., 2019). A national initiative to address climate change should encourage increased participation of risk reduction and mitigation actions instead of solely relying on risk coping strategies alone.

The goals identified under this policy pillar to minimise risk are:

- adaptation
- reducing carbon emissions
- increasing productivity

If climate risks are not managed and mitigated, agricultural production in Australia is likely to fall, farm profits will decrease, health and economic wellbeing of rural communities will suffer, and regional food security will be jeopardised.

## Summary:

Risk minimisation should be a **guiding principle** of a national strategy for climate change and agriculture, but more work is required on identification and categorisation of risks to enable appropriate deployment of resources within a strategic framework. The interconnection of biophysical, transition and indirect climate risks on farm income, food security and health require a collaborated cross-sectoral policy approach.

### 4.1.2 Realise opportunities

*Help agriculture to realise the opportunities to build value, make efficiency gains, and diversify as the world economy shifts into low-carbon gear.*

A transition by agricultural producers to low-carbon gear is likely to significantly reduce contributions to GHG emissions and could also provide economic benefit to offset transition costs. For example, Pearson and Foxon (2012) indicated that policy-makers and academic researchers have discussed a technological shift that takes the form of a 'low carbon industrial revolution' which economically and environmentally rewards early transition into a low carbon economy.[16]

While systemic transition necessarily entails costs, the costs of a low carbon transition are less than the costs and risks of unmitigated climate change impacts (Stern, 2007). For example, Kompas et al. recently investigated the effects of climate change on GDP by country and the global economic gains from complying with the Paris Climate Accord (i.e. acting to keep the temperature change below 2°C). Compared to a scenario of a 2°C change in global temperatures, a 3°C climate change could cause a global GDP loss of $US 3,934 trillion a year in the long term, and a 4°C deviation could cause a loss of approximately $US 17,489 trillion a year. The economic impact of deviation from the Paris Accord target is much worse than the global loss of GDP during the 1930 Great Depression for several countries (Kompas, Pham & Che, 2018).

For countries such as Australia with a relatively conducive environment for climate-friendly investment and innovation, promoting these opportunities in a national strategy could improve adoption rates of movements to

16 Pearson & Foxon (2012) argue for the emergence of a 'low carbon industrial revolution' on the following grounds: (1) past industrial revolutions comparable scale of changes in technologies, institutions and practices needed to mitigate greenhouse gas emissions and climate change; (2) past industrial revolutions comparable economic welfare gains from the improvement in the productivity from a low carbon transition.

a low-carbon economy.[17] Implementing emission reduction techniques into business management processes offers positive opportunities for agriculture, for example:

- decreases in costs of labour, fuel and machinery maintenance from reduced tillage
- improvements to livestock growth rates through implementing feeding programs which promote increased weight gain and reduce emissions in the short and long term
- reductions in salinity, acidification and soil loss from erosion by restoring farmland which is less productive (ClimateWorks Australia, 2011; Meyer et al., 2018)

*Implementing emission reduction techniques into business management processes offers positive opportunities for agriculture.*

The process of changing agricultural practice to sequester carbon in soil and vegetation – carbon farming – can provide financial rewards for emissions mitigation and management practices (as discussed in Section 4.1.5). The Carbon Farming Initiative (CFI), developed through the 2011 Carbon Credits Bill, is a good example. By reducing emissions or storing carbon, farmers and other land managers were able to earn carbon credits which could be sold or traded. Such mechanisms of transforming land resource management to increase carbon sinks can generate efficiency and significant mitigation benefits (Djojodihardjo & Ahmad, 2015) and provide additional income streams while improving NRM outcomes.

The Climate Change Authority has noted that many policy options exist for creating new markets or incentives on the land so that carbon offset projects can deliver multiple benefits across a range of opportunities (Figure 13, over page), for example via a targeted Land and Environment Investment Fund. Like the CEFC, this Fund could be staffed by market experts well placed to assess the risk of such investments and offer targeted loan products that meet the needs of landholders while still delivering a commercial rate of return on investment (Climate Change Authority, 2018).

Recently a new Federal Government agricultural stewardship initiative (Littleproud, 2019) has set aside $30 million to financially compensate farmers for their role in managing the environment by improving biodiversity and sequestering carbon, with an extra $4 million to establish an internationally recognised certification scheme aimed at attracting a price premium for producers involved.

Participation in the former ERF provided a significant source of revenue for the rural sector as a whole, but transaction costs have been noted as a barrier for uptake of individual projects (Climate Change Authority, 2018). Other related schemes, such as the Ecological Outcomes Verification program (Land to Market Australia, 2018), are also in development.

Opportunities also exist for Australian agriculture associated with increasing global demand for agricultural commodities and the opening up of new markets (Climate Change Authority, 2018; Climate Council, 2015), and via increased demand for low-carbon food production.

As Australian society has become more urbanised, educated and wealthier, expectations of agriculture have changed and social pressures on farming have increased. These expectations extend to responsible land management and preservation or regeneration of biodiversity and ecosystems. Actions to respond to climate change in agriculture can also increase community trust in the sector, reducing the likelihood of institutional shocks such as sudden regulatory change.

Emission-minimising methods of production can enable Australian agriculture to diversify, garner efficiency gains and build social and financial value. However, several barriers restrict Australian agriculture from making this systemic shift. If a national policy does not promote the advantages of moving to a low-carbon gear, these barriers will remain in

17 However, under current policy settings Australia is unlikely to achieve a 26% reduction target below 2005 levels in emissions in the agriculture sector by 2030 (Bourne et al., 2018).

### Positive impacts of emission reduction policies on natural resource management outcomes

- Planting indigenous vegetation for carbon storage improves biodiversity and soil health
- Managing grazing practices to increase soil carbon improves soil health
- Early dry season burning of savannas to reduce emissions improves biodiversity, social and cultural outcomes
- Reducing fertiliser application to reduce nitrous oxide emissions reduces water pollution
- Managing livestock manure to reduce emissions improves soil health, and reduces water, air and odour pollution
- Revenue from carbon projects increases landholders capacity to undertake natural resource management activities

### Positive impacts of emission reduction policies on agriculture outcomes

- Changes in land-use and management practices to reduce emissions and increase storage increase farm revenue and profitability, and diversify farm income through sale of Australian Carbon Credit Units
- Modifying livestock manure management to reduce emissions increases farm revenue, reduces energy costs, and enables the sale of electricity and renewable energy certificates
- Changes in livestock management practices to reduce methane emissions increases farm productivity and profitability
- Modifying fertiliser use to reduce nitrous oxide emissions reduces farm input costs

### Positive impacts of natural resource management policies on emissions

- Ecological restoration programs increases carbon storage in biomass and soils
- Planting of windbreaks increases carbon storage in biomass and soils
- Conservation reserves protect carbon stocks
- Pest and weeds management protects carbon stocks and helps to restore degraded ecosystems thereby increasing carbon storage
- Measures to reduce fertiliser and nutrient runoff reduce nitrous oxide emissions and increase soil carbon

### Positive impacts of agriculture policies on emissions

- Agricultural programs promote more efficient livestock herd management, resulting in increased production efficiencies and reduced methane and nitrous oxide emissions
- Agricultural programs promote composting and use of livestock manure, resulting in increases in productivity and reduced emissions
- Management to increase soil fertility increases soil carbon
- Research and development discovers new technologies to increase farm productivity and reduce emissions

**Figure 13:** Positive interactions between policies.

***Source:*** Climate Change Authority (2018).

place, market opportunities could be missed and the sector's social licence to operate could be eroded.

> **Summary:**
>
> Realisation of opportunities is an outcome rather than an action or goal and does not sit as a pillar for specific inclusion in a national strategy for climate change and agriculture, rather (like risk minimisation) it is a **guiding principle.** A focus on potential opportunities underpins the value proposition of strategic goals and should be included in commentary and extension.

### 4.1.3 Strengthen RD&E

*Strengthen agricultural research, development, and extension (RD&E) so farmers can manage the risks and be part of the solution.*

A robust and continuously improving RD&E environment provides the knowledge base and tools needed for agriculture to adapt to climate change impacts and to realise the potential in mitigating climate risks.

Research into reducing carbon emissions is already a priority in several agricultural sectors. For example, the Australian red meat industry has set a goal to become carbon-neutral by 2030, and the dairy and grains sectors have developed sustainability strategies which account for a changing climate. Implementation of these goals requires evidence-based strategic action.

The sectoral analysis section of this report outlined several methods of climate risk mitigation and adaptation strategies developed and implemented through RD&E, such as breeding and cropping methods to increase heat tolerance, genetic selection of livestock, vegetation management and improved water efficiency strategies.

Without strong RD&E to aid in the development of solutions to climate change, new technologies to assist in adaptation will remain expensive, private investment risks being directed away from the sector and Australia's agricultural productivity will inevitably decline.

> **Summary:**
>
> While broad in focus, a pillar of strong RD&E underpins a national strategy for climate change and agriculture. The new operating environment for Australian agriculture contains many unknowns, thus continuous and responsive evaluation, discovery and extension is necessary to enable timely sectoral adaptation.

### 4.1.4 Clean energy

*Build a strong clean energy sector with benefits shared fairly by rural and regional communities.*

Supporting extension of renewable energy adaptation is the focus of SDG 7, which is to ensure universal access to affordable, reliable and modern energy services by 2030. Establishment of a strong clean energy sector creates several opportunities to Australian agriculture in mitigating the risks and impacts of climate change. Benefits include a reduction in GHG emissions, a buffer against inevitable energy price rises and increased energy supply security. Flores et al. (2015) noted some the potential benefits of investing in renewable energy on-farm as:

- Security of energy supply – decreases the risk of blackouts or voltage spikes
- Protection from increased energy prices and increased efficiency through automated control systems
- Increased demand from product differentiation and ability to utilise marketing; platforms such as 'carbon neutral' or 'sustainably grown'
- Improving sustainability of enterprise and environment

Electricity prices have more than tripled since 2000, while wages have only increased by about 75%, which represents a near doubling of electricity prices relative to wages (SDG Transforming Australia, 2017). As farm businesses face becoming uncompetitive due to the cost of traditional energy sources, many have considered renewable energy and off grid solutions.

Agriculture is the fourth most energy-intensive industry in Australia, behind manufacturing, transport and mining (Clean Energy Finance Corporation, 2015). Most sectors of Australian industry have experienced significant gains in energy productivity over the past decade, except for agriculture, where energy productivity has declined by more than 21% since 2008 (Agriculture Industries Energy Taskforce, 2017).

The total energy cost of agricultural subsectors (excluding processing) currently represents 9% of the sector's total GVP, and in response to the threat to profitability posed by rising energy prices Australian farm businesses are increasingly implementing off-grid or alternative energy solutions in an attempt to better control energy price exposure (Heath, Darragh & Laurie, 2018), particularly solar power. Projections indicate that solar photovoltaic (PV) capital costs continue to fall at a faster rate than most other technologies and solar PV is projected to represent one of the largest contributors to electricity generation by 2050 (Graham, Hayward, Foster, Story & Havas, 2018).

Figure 14 indicates some aspects of a net-zero energy system which include demand reduction, system balancing and decentralised generation (Fairchild & Weinrub, 2017), and Table 4 outlines examples where Australian agricultural stakeholders have achieved energy efficiency gains by moving to clean energy systems.

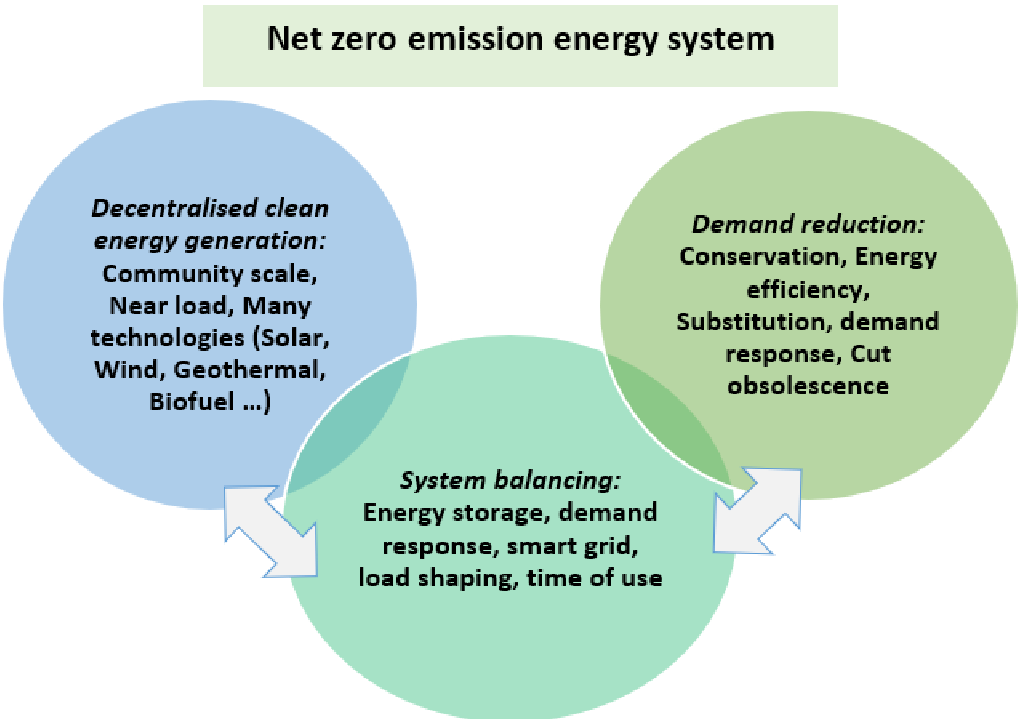


**Figure 14:** A decentralised energy system.

***Source:*** Fairchild and Weinrub (2017).

**Table 4:** Examples of clean energy initiatives in Australian agriculture.

| Initiative | Organisation/location | Overview |
|---|---|---|
| **Renewable energy** | AACo, QLD (beef) | Reduction in consumption of grid energy by 30% through installation of solar PV units across multiple sites |
| | Darling Downs Fresh Eggs, Pittsworth QLD | Investment in anaerobic digestor and generators to generate energy from chicken manure and organic waste which reduced electricity usage by 60%. |
| | Blantyre Farms, Young NSW | Establishing infrastructure to capture methane from pig effluent and turn into fuel to power biogas generators. Excess energy not used on the farm is sold back to the grid. |
| | Crookwell Wind Farm, Crookwell NSW | 28 wind turbines built on Charlie Prell's sheep property on areas unsuitable for farming, which are expected to generate enough energy to power 41,600 homes per year. |
| | Dairy farmers, King Island TAS | A group of nine dairy farmers have co-ordinated the installation of solar hot water systems for dairy sheds which is predicted to cut hot water costs by up to 50%. |
| **Energy efficiency** | Rivalea Australia, Corowa NSW | Cut abattoir energy costs by 10% through upgrading refrigeration. |
| | Nightingale Bros., Wandiligong, VIC (apple and chestnut grower) | Invested in updated refrigeration which cut energy costs by approximately 40%. |

***Sources:*** Clean Energy Council (2018), Clean Energy Finance Corporation (2015), Flores et al. (2015), and Noon (2018).

Adoption of renewable energy is highest in the intensive and facility-based sectors such as dairy, where an estimated 40% of farms have already installed some form of renewable energy (Clean Energy Finance Corporation, 2015). The Clean Energy Finance Corporation (CEFC) also offers opportunities for agricultural businesses to reduce their operating costs by enabling investment in energy-efficient equipment and renewable energy upgrades (CEFC, 2015).

'Energy democracy'[18] is also emerging as a viable option for farmers and regional communities, in the context of aspirations for a low-carbon transition that include wider socio-economic and political transformation (van Veelen & van der Horst, 2018). A transition to clean energy needs to consider the fair sharing of benefits among all actors to avoid the possible creation of a 'clean energy monopoly' that might adversely affect some participants (Fairchild & Weinrub, 2017).

A sectoral transition to renewable energy sources could not only reduce emissions but also improve resilience to energy price increases.

18 Energy democracy is a term representing a social shift from the corporate, centralised fossil fuel economy to a decentralised clean energy system governed by communities for shared benefit.

## Summary:

A transition to clean energy in agriculture is intrinsically linked to climate change mitigation and has the additional benefit of providing a buffer for agricultural producers and supply chain operators in an increasingly energy insecure environment. As such, it should be a key pillar of a national strategy on climate change and agriculture.

### 4.1.5 Capture and store carbon

*Realise the long-term potential of healthy working landscapes to capture and store carbon.*

The potential for land sector carbon abatement provides a unique market advantage to Australia and could play a central role in Australia's transition to a clean energy economy (Butler & Frydenberg, 2017).

The process of changing agricultural practice to sequester carbon in soil and vegetation – carbon farming – can provide environmental, economic and socio-cultural benefits (Carbon Market Institute, 2017). A study by Kragt et al. (2017) into adoption of carbon farming in Western Australia found that engagement could be increased through demonstrating triple bottom line benefits. For example, carbon farming projects can deliver social and cultural benefits through community cohesion as well as improving NRM and providing income.

Extensive environmental benefits can be derived from carbon farming through transforming carbon emitting activities to carbon sinks. A long-term trial in Wagga Wagga by the NSW Department of Primary Industries found that soil organic carbon increased at the rate of 185 kg C/ha/year when wheat was produced under no-till and stubble retention methods (Young Carbon Farmers, n.d.).

Federal Government strategies have supported agricultural adaptation to and mitigation of climate change impacts including carbon sequestration activities, such as the Emissions Reduction Fund (ERF) which is estimated to have distributed more than $239 million annually between farmers, land managers and carbon service providers (Keogh, 2017).

In February 2019 the Australian Government established a Climate Solutions Fund (CSF) to provide an additional $2 billion for purchasing low-cost abatement. The CSF aims to continue the work of the ERF by providing funds for farmers, businesses and Indigenous communities to undertake emissions reduction projects.

Although government policies have supported increased uptake of carbon farming in Australian agriculture, there are several risks which need to be considered by producers when making decisions about these investments. Some of the risks include: the trajectory of offset prices, the costs of sequestration, a lack of knowledge and experience in carbon farming and permanence. A major risk likely to increase as adoption rises is additionality. This refers to the risk that carbon farming activities will become common practise and be no longer eligible to generate offsets (Department of Primary Industries and Regional Development, 2018). This risk is difficult to include in return on investment calculation and cost benefit analysis. A national strategy needs to include strategies to decrease these risks to ensure widespread adoption is undertaken.

The Carbon Market institute has set out four pillars for industry development in their *Carbon Farming Industry Roadmap:*

- Optimising policy and regulatory frameworks
- Unlocking finance and investment
- Quantifying co-benefits and creating new markets
- Communicating benefits and building capacity

(Carbon Market Institute, 2017)

These pillars, the triple bottom line benefits of carbon farming, knowledge gained from previous government policies and risks should be considered when developing a national strategy for climate change in agriculture.

**Summary:**

The capture and storage of carbon offers opportunities to not only reduce emissions but also improve NRM, social cohesion and economic stability for the agricultural sector. This pillar minimises risks and realises opportunities and should be central to a national strategy on climate change and agriculture.

### 4.1.6 Identify gaps

*Identify gaps in current policies and programs – federal and state – and fill them.*

Australia's political commitment to climate change action has been referred to as directionless, erratic and inconsistent (Talberg et al., 2016). Climate change policies have to date lacked a genuinely national approach, such as agreement on the responsibilities of each sector. The differences between the two major Australian political parties in framing climate policies have also provided challenges in developing a comprehensive national strategy (Climate Council, 2019a; Talberg et al., 2016). Policy-makers thus often struggle to respond to these complex issues, particularly when short-term interests (e.g. elections) conflict with long-term benefits (Head, 2014).

While there are several strategies currently in place across Australia to aid transition to a clean energy economy, alleviate the impacts of climate change on the agriculture sector and mitigate the contribution of agriculture to climate change, the apparent lack of collaboration between the States and Territories hampers progress (Climate Council, 2019b). Table 5 depicts the lack of national consistency and collaboration through the differing renewable energy and net zero emissions strategies across the country.

Howden et al. (2009) noted that 'mainstreaming' climate change into effective policies will aid in dealing with barriers to adaptation, and that these policies should cover a range of responsibilities and scales.

The Climate Change Authority has published a review of Australia's climate goals and policies which recommended a scalable toolkit of policies to meet emissions reduction obligations in the Paris Agreement, with five-yearly reviews (Climate Change Authority, 2016). The Authority noted that Australia's recent history of significant climate policy uncertainty prescribed the need for overarching policy architecture to provide investment certainty while the suggested toolkit measures evolved and strengthened over time.

Effective climate change solutions require a shared responsibility, understanding and accepted long-term goals by all stakeholders – i.e. policy-makers and politicians, sector and industry leaders, directors of representative bodies and individuals. Despite the complexity of the task, it is imperative that a national strategy on climate change and agriculture also be continually reviewed and adapted as the climate continues to change.

**Table 5:** Renewable energy and net zero emissions targets in Australia.

| State/Territory | Percentage of renewable energy in 2017 | Renewable energy strategy | Net zero emissions strategy |
|---|---|---|---|
| **Australia** | 23.5% | n/a | n/a |
| **TAS** | 87.4% | 100% by 2022 | **achieved**[19] |
| **ACT** | 46.2% | 100% by 2020 | by 2045 |
| **SA** | 43.4% | n/a | by 2050 |
| **VIC** | 13.6% | 25% by 2020<br>40% by 2025 | by 2050 |
| **NSW** | 12.6% | n/a | by 2050 |
| **WA** | 7.5% | n/a | n/a |
| **QLD** | 7.1% | 50% by 2030 | by 2050 |
| **NT** | 3.0% | 50% by 2030 | n/a |

***Source:*** Climate Council (2019b).

19 Tasmania achieved zero net emissions in 2018 (Archer, 2018).

**Summary:**

Relevant policies and strategies must evolve; however, evolution should not be mistaken for reinvention, rebadging or reneging. Cohesive climate policy which actively seeks to address gaps is required to drive substantial investment in adaptable farming systems and low-emissions generation in Australia. Identification of gaps should be part of the **process** of continual improvement for a national strategy on climate change and agriculture, rather than a strategic pillar.

## 4.2 If not, then what?

If the pillars, principles and processes discussed above are not included in a national strategy on climate change and agriculture, the sector will continue to face significant threats to viability and obstacles to transition, for example:

- **agricultural production will fall**
- **farm profits will decline**
- **food insecurity will rise**
- **rural health will be adversely impacted**
- **sectoral trust will decrease**
- **barriers to adaptation will remain**
- **energy transition will be impeded**
- **investment will lag behind need**

### 4.2.1 Agricultural production will fall

If the risks of rising average temperatures, decreased rainfall and increased severity of drought conditions are not minimised, agricultural productivity and production will decline. For example, the gross value of agricultural production (GVP) for 2018–19 is forecast to be $58 billion, which is a 6% reduction from 2016–17 estimates due to drought conditions impacting east coast crop production (ABARES, 2018).

The sectoral analysis of climate change impacts reveals that without a combination of adaptation and mitigation efforts, production levels in both cropping and livestock sectors are likely to decrease. Climatic change is already limiting areas where crops can be suitably grown, altering regional distribution and the size of arable land for agricultural commodities, and is thus likely to compound the negative impact on total agricultural production.

Growth in productivity of Australian agriculture has slowed to a rate of less than 1% since 2000, with some sources suggesting this slump began as far back as 1994 (Sheng, Mullen & Zhao, 2010). Cline (2007) estimated that agricultural productivity would decline by 17% by 2050 due to climate change.

Grafton, Mullen and Williams (2015) state that a significant proportion of this productivity slump in agriculture can be interpreted as resulting from stagnated public investment in agricultural R&D since the late 1970s.

As noted in Section 2.2, the effects of a changing climate can impact on sectors in various ways including decreased production quantities, yield, profitability and productivity. To maintain or improve productivity in the face of climate change, **strong RD&E** will be needed to combat the effects of adverse climatic conditions which threaten to reduce current levels of productivity; and to seek solutions to redress the weakened growth rate.

### 4.2.2 Farm profits will decline

The predicted paths of income for farmers with and without adaptation and mitigation strategies is strikingly different. As an example, the conceptual illustration of Stern (2007) depicted in Figure 15 indicates that the gap in incomes in the short term from up-front costs of implementing mitigation is compensated by sustainable higher long-term gains. The path with mitigation is likely to increase sustainable long-term productivity and farm income.

Predicted climate change impacts include reductions in average rainfall and increased

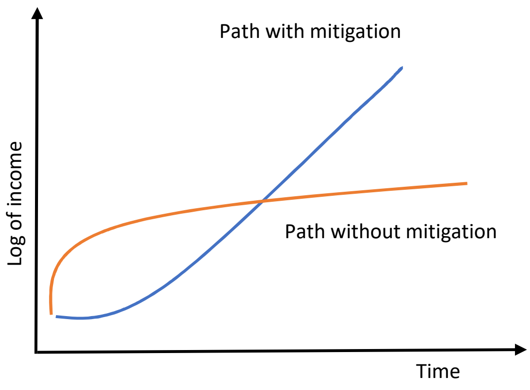


**Figure 15:** Conceptual approach to comparing divergent growth paths over the long term.

***Source:*** Stern (2007).

time between rainfall events. ABARES have used historic data to construct a model of changes in farm cash income between good (90th percentile) and bad (10th percentile) years of rainfall (Figure 16). This model indicates that in a bad year, cropping farms can expect a reduction in farm income exceeding 60% when compared to a good year. Farm cash incomes of Australian primary producers will be severely impacted as climate change increases the frequency of bad years.

In addition, while geographic relocation may be an option for some producers as a long-term solution, this in turn requires expenditure and investment which will have further effects on productivity and profitability.

Policies that reduce agricultural emissions and enhance natural resource management (NRM) outcomes can also help farmers improve their profitability (Climate Change Authority, 2018). A failure to capitalise on these opportunities represents lost potential alternative income and a missed option for diversification and income stabilisation.

Farmers and other supply chain partners also stand to benefit from increased demand of products differentiated via marketing as 'carbon neutral' or 'sustainably grown' (Flores et al., 2015).

Food products marketed as sustainable and eco-friendly are likely to increase in value as consumers become more aware of the carbon footprint of agricultural commodities they are buying. Sustainable growth and responsible production in Australian agriculture could differentiate products from other food and fibre suppliers, enhancing a competitive market advantage (Barlow, 2014). The industry should capitalise on these emerging trends but understand product differentiation

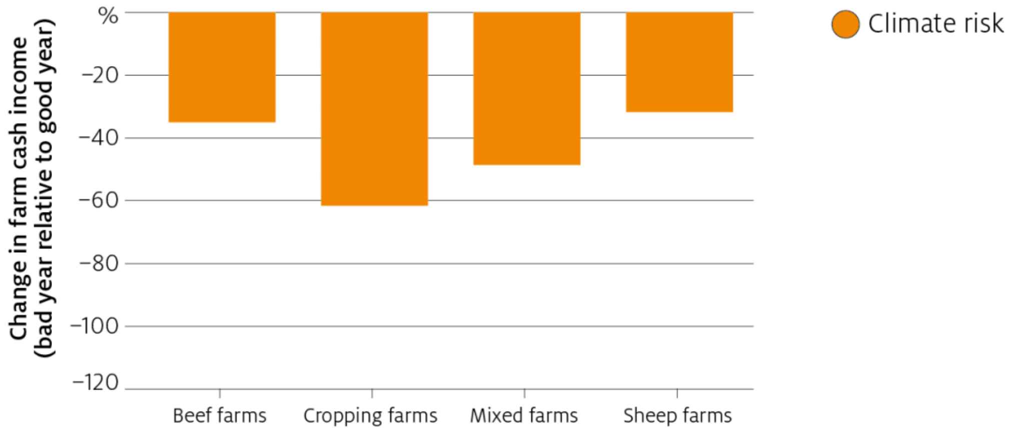


**Figure 16:** Broadacre farm cash income risk by sector (bad year relative to good year).

***Source:*** ABARES model estimate (Hatfield-Dodds, 2019).

is still needed as sustainability is not of equal importance to all consumers (Henchion et al., 2014).

Failure to secure a position in these markets in a timely fashion could mean opportunities lost to local or regional competitors.

### 4.2.3 Food insecurity will rise

Food demand in Australia in 2061 is likely to be 90% above the 2000 level of demand (Michael & Crossley, 2012) and a rise in the global population is likely to increase the export demand of agricultural commodities, threatening the food security of some nations (Hughes et al., 2015; Newth et al., 2018).

While global demand for food and fibre is predicted to significantly rise in the next three decades, a traditional productivist[20] approach is considered by some to be an insufficient strategy to reach the long-term agricultural production volumes required to guarantee national food security (Lawrence, Richards & Lyons, 2013). With production potentially decreasing as demand increases, climate change is likely to impact not only quantity but also food accessibility, affordability, safety and quality (Hughes et al., 2015). A purely economic cost/benefit measuring of food policy is no longer sufficient due to new broader health, social and environmental drivers resulting from climate change impacts on six food security areas in Australia, namely: agricultural production; biodiversity and ecosystems; land use; resilience to natural disasters; water scarcity; and biosecurity (Garnaut, 2011; Slade & Wardell-Johnson, 2013).

Food security extends beyond physical supply and demand of food to include access to nutrition, the way in which food is used and personal health. Australia historically has enjoyed a high level of food security due to a combination of factors including relatively high per capita incomes; social security; robust human, biosecurity and animal health systems; a competitive food retailing sector; low trade barriers; and a globally competitive agricultural sector (Michael & Crossley, 2012).

To maintain regional food security at current levels, Australian agricultural production will need to adapt to climate change impacts and account for new business risks. Improved risk management can take the adaptive capacity of operating firms, and their supporting infrastructure and service providers, to a new level, with associated benefits for food security (Michael & Crossley, 2012).

### 4.2.4 Rural health will be impacted

Climate change is intertwined with the health of rural communities both directly and indirectly. In some regions, agriculture is the dominant economic activity which underpins local infrastructure. Without a strong agricultural industry to inject capital back into the community, population growth in these areas is likely to decline and essential services (such as health and education) will be consequently reduced or removed.

Climate change-induced physical and mental health hazards will also be prevalent. A sustained increase in temperatures and drought conditions can impact the health of vulnerable people in regional communities such as children and the elderly (Horton, Hanna & Kelly, 2010). Moreover, a greater incidence of significant rainfall events and flooding could increase the occurrence of mosquito-borne diseases such as Dengue and Ross River virus which have severe health implications (Steffen et al., 2018).

In addition, rural and remote Australians have higher rates of mental health disorders and risk of suicide (but much less access to mental health services) and drought compounds this disadvantage, placing farmers and their communities at greater risk of mental illness and disability (Shorthouse & Stone, 2018). Associations between suicide in rural areas and drought, socio-economic hardship, and financial strain among farmers have been reported (Austin et al., 2018).

Economic hardship, water insecurity, physical and psychological stress and depression

20 Productivism embodies the belief that more production is necessarily good (i.e. that measurable productivity and growth are the purpose of human organisation), usually favoured by government and industry.

combined with the impact of drought on social networks are likely to increase as the climate changes. Mitigation of these risks is paramount to maintaining social capital and well-being in Australian farming communities.

### 4.2.5 Sectoral trust will decrease

Farm practices and economic viability are already under challenge from social licence-driven regulatory change, as demonstrated by changes to native vegetation and threatened species legislation and the focus on discontinuing the use of glyphosate (Heath, 2018).

The threat of new and emerging institutional risk factors such as social licence (i.e. community trust in farming practices) has been identified as a major concern for the Australian agricultural industry (Laurie et al., 2019). As these risks are the product of an increasingly active and engaged consumer base, they are unlikely to diminish as the climate changes.

Implementation and promotion of the positive steps Australian agriculture is taking towards a low-carbon economy can increase community trust in the sector. Conversely, ignoring the clear and present danger posed by climate change (and in part caused by agricultural production methods) will further undermine the right to farm.

Additionally, climate and risk have become key governance issues in agriculture. For investors, there are material financial risks from investments linked to unsustainable land use (IGCC, 2017). Investment analysts are increasing pressure on agribusinesses to implement environmental, social and governance ranking tools to assess exposure to (and mitigation plans for) risks such as climate change (Dairy Australia, 2018). Regulators are also increasing their focus on related non-financial risks such as water management practice in primary production (Guerin, 2019).

Failure to take up the available opportunities could undermine investor confidence in the sector.

### 4.2.6 Barriers to adaptation will remain

Several barriers restrict farmers' adoption of adaptation strategies (Kragt, Mugera & Kolikow, 2013; Stern, 2007). Figure 17 outlines the connection of some of these barriers, which could be addressed by better co-ordination under a national strategy for climate change and agriculture.

Barriers to better co-ordinating climate change action on the land include a lack of information,[21] transaction costs associated with participating in government programs and challenges inherent in co-ordinating the many different government and non-government players involved in delivering policy (Climate

21 Both in terms of getting information to landholders on agricultural R&D and the availability of baseline data for developing and evaluating policy.

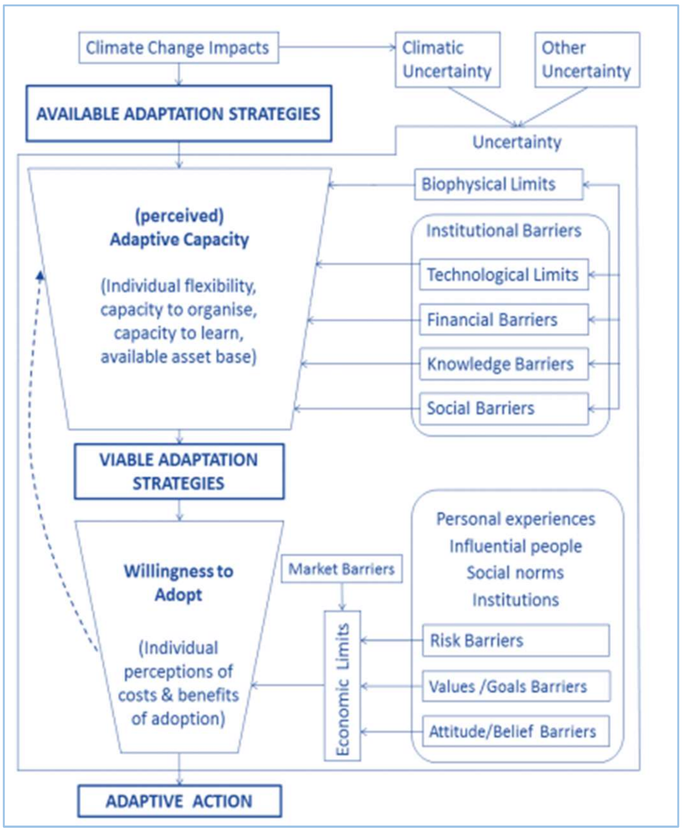


**Figure 17:** An interdisciplinary framework of limits and barriers to agricultural climate change adaptation.

***Source:*** Kragt, Mugera and Kolikow (2013).

Change Authority, 2018). Contentious policy initiatives are hard to implement when knowledge bases are divergent and incomplete, when short-term interests conflict with long-term benefits, and when problems are construed or framed in very different ways (Head, 2014).

Policy gaps may be small and local, or large and global, such as an unjust application of targets or a failure of integration between programs. Without a cohesive, collaborative policy in place, the agriculture sector is likely to continue to address climate change risks in a fragmented and inefficient manner.

Additionally, despite the high current cost of carbon efficient agricultural technologies, experience shows that RD&E enables these technologies to become more affordable over time in comparison to traditional carbon intensive options.

Figure 18 shows a new electricity-generation technology as an example to illustrate that as adoption and purchases of low-carbon technologies increase in scale, the marginal costs decline; i.e. increased knowledge through strong RD&E takes a length of time to achieve the benefits of economies of scale indicated at point A on the graph, beyond which the new technology becomes cheaper than the established technology. However, although a common experience, not all technologies produce decreasing marginal costs over time as some may be constrained by availability and costs of inputs. As such, if RD&E is not strengthened, new technologies remain expensive and unaffordable, limiting the rapid diffusion of the desired impacts of the technology.

## 4.2.7 Energy transition will be impeded

Without the incorporation of a transition to clean energy in a national agricultural strategy, efforts to move to these systems are likely to remain fragmented and piecemeal, exposing farmers to energy insecurity.

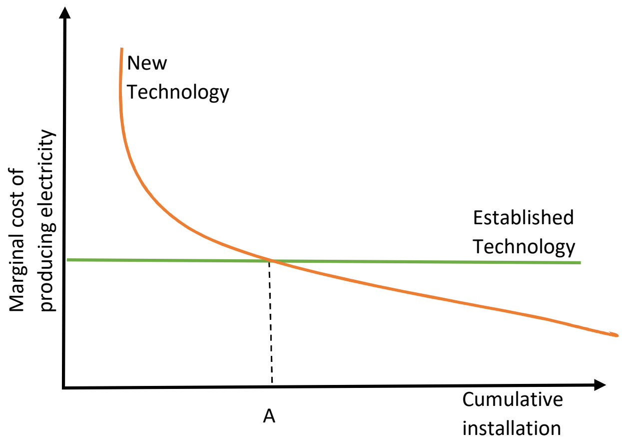


**Figure 18:** Costs of technologies fall over time.

***Source:*** Stern (2007).

Heath et al. (2018) noted that a major shift to a more renewably powered agricultural industry has not yet eventuated despite the apparent benefits and lower capital costs. The Climate Institute (2014) believed that this is explained by the lack of a comprehensive Commonwealth framework for the uptake of new generation technologies and low government support in the form of subsidies.

In the absence of federal incentives for renewables, future investment will rely on state-based policies and commercial returns, putting future levels of investment and emission reduction targets at risk (SDG Transforming Australia, 2017)

Energy production is by far the dominant source of Australia's GHG emissions (Climate Council, 2018; Figure 19). The cross-industry transition of energy systems to clean, renewable sources[22] can mitigate the negative impacts of climate change on agriculture by dramatically reducing GHG emissions.

If the adoption of clean energy is not promoted cohesively and across all Australian economic sectors, agriculture will remain compromised. In addition, if clean energy systems are not underpinned by an overarching industry strategy or policy, agriculture will struggle to harness the full benefits of the growing carbon market.

22 For example, solar, wind, hydroelectricity, wave, tidal, biomass and geothermal energy sources.

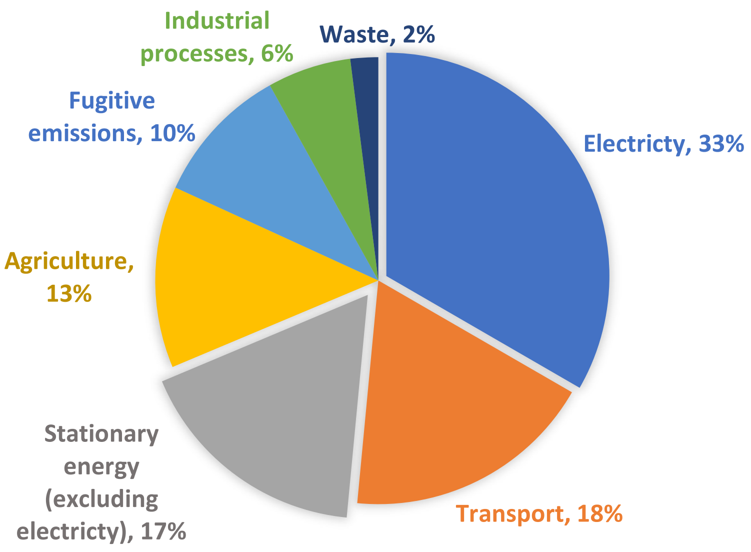


**Figure 19:** Sources of Australia's GHG emissions in 2017.

***Source:*** Climate Council (2018).

### 4.2.8 Investment will lag behind need

Gaps in climate policy can undermine well-meant actions by fragmenting efforts, diverting resources and fostering uncertainty for potential participants and investors. For example, while renewable costs vary between projects and are likely to continue to fall over time, in general they are likely to remain substantially higher than the incumbent systems for the foreseeable future (Climate Change Authority, 2016), meaning low-emissions investment in Australia requires policy support.

Investment in direct action, business systems transition, carbon abatement and related climate responses requires a degree of certainty of return. With both the physical impact of climate change and the transition likely to have first-order economic effects (Debelle, 2019), a robust and reliable policy environment is necessary to secure support for agriculture's climate response.

Policy initiatives such as the CFI,[23] the new Biodiversity Stewardship program and Climate Solutions Fund reward positive behaviour and facilitate transition towards climate-smart agricultural systems. The CFI achieved approximately 10 million tonnes of emissions reductions, however many policy bottlenecks hindered the uptake rate of the initiative, such as perceived uncertainty over long-term returns, small price expectation for credits, coverage gaps and high transaction costs (Climate Change Authority, 2014).

Climate change can also erode economic productivity by diverting funds away from investments in new technology, machinery or research and towards recovery, hampering long-term growth (Steffen et al., 2019). To encourage investment in proactive strategies as well as the necessary reactive responses, cohesive climate policy which actively seeks to address gaps and thus improve certainty is necessary.

23 The CFI ran from 2011 until 2014 at which point it was integrated into the Emissions Reduction Fund (ERF), which made some improvements in streamlining the process to reduce transaction costs and increase participation.

The Australian agricultural innovations review report by Ernst & Young (2019) noted that participation has not been conducted in a collaborative manner and cross-sectoral and cross-industry knowledge is under-utilised. Agricultural RD&E needs to draw on other industry and sector knowledge to address the shared challenge of climate change.

The lack of cross-sector co-investment and collaboration is not a new problem for Australian agriculture. Although there have been notable collaboration examples, such as the Climate Variability in Agriculture Program established in 1992, improvement is needed to effectively combat complex issues which significantly impact all sectors (Finney, 2018), of which climate change is a clear priority.

Further growing the total funding pool and increasing private sector investment into agricultural RD&E will also aid in achieving improved and more diverse outcomes. Although Australia's private investment in agriculture is growing, it lags behind international benchmarks (Ernst & Young, 2019).

While collaboration in agriculture between public and private enterprises has not always been a positive experience (Keogh et al., 2017), some partnerships between Research and Development Corporations (RDCs) and private enterprises – such as the $45 million partnership between GRDC and Bayer in tackling the issue of herbicide-resistant weeds (Goucher & McKeon, 2018) – stand as examples for private/public collaboration on climate solutions.

R&D is key to improving farmers' productivity while reducing emissions and improving NRM outcomes (Climate Change Authority, 2018). Cohesive focus on agricultural RD&E under a national climate change strategy could encourage cross-sector and cross-industry collaboration and provide the certainty which attracts private research investment. To fast-track the necessary RD&E solutions for agriculture's climate crisis, this collaboration and resourcing is key.

# 5. Conclusion

Australia's natural capital is already experiencing climate change impacts. The viability of agriculture depends on this capital, yet the sector faces this threat without an overarching national policy.

To sustainably address the needs of a burgeoning population with increasingly climate-limited resources, the sector must urgently reduce GHG emissions and environmental degradation to mitigate climate change impacts, while adapting to those same impacts to maintain productivity and regenerate natural capital. These changes must be made cohesively across all elements of an integrated system to avoid fragmentation of human, financial, manufactured and environmental resources.

Recognition of the sector-specific triple bottom line impacts of population growth and climate change on Australian agricultural subsectors is imperative to enable effective response. A national strategy for climate change and agriculture could improve not only the sector's response but also the country's response, by enabling cross-industry collaboration and resource-sharing.

The central theme of the FCA climate response strategy pillars is to **minimise climate risks to agriculture, food security and rural communities and thus maximise the opportunities in a sustainably productive, clean-energy economy.** To achieve this, the interconnected supporting pillars of strong RD&E, support for clean energy adoption and comprehensive, cohesive policy are essential.

Strong RD&E provides the innovation and knowledge base to develop risk mitigation programs and identify opportunities in a new economy. A successful climate adaptation and mitigation policy for Australian agriculture must be underpinned by research into the practices that are working, and the appropriate resourcing to extend those practices rapidly and extensively.

A robust clean energy sector ameliorates the sector's contribution to climate change, offers financial benefits and could improve energy security for primary producers and supply chain actors.

*Recognition of the sector-specific triple bottom line impacts of population growth and climate change on Australian agricultural subsectors is imperative to enable effective response.*

While research gaps exist on the overall dollar value of the economic impact, there is an extensive body of literature on climate change and Australian agriculture which outlines negative effects on productivity, health, food and water security and geo-political stability. What is needed next is not more 'admiring of the problem' but a uniting policy supported by all stakeholders.

A long-term, bipartisan commitment to tackling climate change via clearly delegated actions within a short-term timeframe must be supported and advanced by the Agriculture Ministers' Forum[24] to circumvent the current policy stagnation. Following the review of climate change strategies being undertaken by AGSOC, an inquiry into a more complete understanding of the costs of climate change to Australian agriculture would be key to prioritising actions and resources.

Australian agriculture is getting on with implementing practices suitable for a changing and variable climate, regardless of the prevailing policy environment (Heath, 2018). However, climate change adaptation and mitigation strategies are extraordinarily complex and without cohesion, there is a risk that efforts could be duplicated, counter-productive or lapse into obscurity (see Appendix 3). Industry level, sectoral, local, regional, national and international

24 The Agriculture Ministers' Forum (AGMIN) membership comprises Australian/state/territory and New Zealand government ministers with responsibility for primary industries and is chaired by the Australian Government Minister for Agriculture. AGMIN's role is to enable cross-jurisdictional cooperative and co-ordinated approaches to matters of national or regional interest.

*Implementation of this strategy requires leadership in policy development, social change and systemic reform.*

efforts should cascade to have a meaningful impact in reducing the effects of climate change.

A focus on the priority goals of the proposed national framework will help Australian agriculture close the loop and become a truly sustainable organisation: producing and distributing enough nutritious food for domestic and global needs; increasing natural capital of productive environments; and mitigating climate change impacts.

**To overcome organisational fragmentation and political apathy, implementation of this strategy requires leadership in policy development, social change and systemic reform to ensure the needs of the present are met without compromising the capacity of future generations to meet their own needs** (United Nations, 1987).

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# Appendix 1 – Detailed subsector impacts

Table 6 outlines individual likely outcomes of climate change for each sector and Table 7 notes some climate change adaptation and mitigation strategies for Australian agricultural subsectors collected from a review of available literature.

The majority of these outcomes are negative (shown in red text) however, some may be counteracted by positive consequences (shown in green text). Due to the diverse range of literature reviewed when collating the tables, inconsistencies in language are apparent and some impacts or strategies listed are quite broad in nature, while others are more specific.

Due to the absence of information on some sectors and the complexities associated in predicting climate change outcomes across differing climatic zones, conclusions have not been made as to the overall combined level of severity climate change will have on each agricultural sector.

The tables provide a broad comparison which demonstrates where many impacts and redress measures align or overlap, highlighting the need for a unifying national strategy for climate change and agriculture.

*Table 6: Predicted climate change impacts on Australian agricultural subsectors*

| | | | | | |
|---|---|---|---|---|---|
| **GRAINS** | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Increased crop growth and expanded growing season in the cold/wet regions (currently limited cereal cropping)<br><br>Potential reductions in frost may increase crop variety options and geographic spread of planting<br><br>Increase in unpredictability of frost timing<br><br>Increased summer heat stress likely to cause poor seed set in summer crops; heat stress during spring may decrease yield of winter crops | Potentially significant reductions in yield of winter crops such as wheat<br><br>Increased water stress may decrease yield overall<br><br>Lower rainfall may reduce deep drainage in dryland cropping systems<br><br>Reduction in soil moisture content | Potential higher crop yields<br><br>Potential reduction in crop quality | Increased incidence of crop damage<br><br>Some increase in risks of soil erosion and pests and diseases in tropical warm-season moist zones | Increased occurrence of some pests and diseases<br><br>Warmer temperatures / significant decrease in rainfall likely to favour winter crop varieties with earlier-flowering characteristics |
| **COTTON** | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Potential improved growing conditions (longer seasons), if irrigation water is available in temperate subhumid zones<br><br>Increased temperatures could cause fruit loss, decreased yields, water use inefficiency | Reduction in area planted due to reduction in available water<br><br>Reduction in soil-water balance leading to decreased production and yields | Increased atmospheric CO2 could lead to increased yields due to carbon fertilisation impact | Increase in drought, storms, flooding could cause significant crop loss and decreased production and yields | Less irrigation water, higher temperatures and greater evaporative demand by crops will impact yield and fibre quality in the subtropical sub-humid zones |
| **SUGARCANE** | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Projected warming will extend growing seasons and improve crop growth in frost-prone western districts<br><br>Sucrose content may decrease due to higher | Exacerbate limited supply of irrigation water and reduce quality of supplementary water<br><br>Reduced spring rain would negatively impact crop establishment | Increased growth of stalk and total biomass<br><br>Increased competitiveness from temperate grass weeds | Increased waterlogging in the northern region may limit paddock access, particularly in growing season | Pests and diseases may increase<br><br>Projected sea level rise likely to exacerbate poor drainage, tidal intrusion in the lower floodplains, rising water table and salinity issues |

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| | temperatures during harvest season<br><br>Could cause yield decrease due to stomatal closure and leaf damage (NB: increased $CO_2$ may override these effects) | May increase trafficability, improving harvesting efficiency<br><br>Reduced anaerobic conditions in soil<br><br>Poor crop establishment, decreased yields due to increased crop water stress<br><br>Reduced rate of early leaf area and canopy development<br><br>Increased commercial cane sugar through more effective drying-off period<br><br>Reduced soil nutrient loss through less leaching / erosion | Increased growth of vegetative plant parts (i.e. increased volume of trash)<br><br>Higher carbon to nitrogen ratio of leaves | Physical damage to crops and infrastructure<br><br>increased soil erosion and nutrient / sediment runoff into the Great Barrier Reef lagoon<br><br>Decreased yield through reduced infiltration of rainfall into soil (increased runoff)<br><br>Increased intrusion of saltwater into coastal aquifers<br><br>Increased flooding will cause land degradation, soil erosion | Reduced photosynthesis, tillering and stalk length<br><br>Increase carbon decomposition / soil nitrogen mineralisation and result in crop energy diverted into producing trash and fibre |
| **RICE** | **> Temperatures** | **< Rainfall** | **> $CO_2$** | **> Extreme Weather** | **General Impacts** |
| | Individual crop demand for water is likely to increase<br><br>Risk of crop heat-damage may increase<br><br>Decrease in water availability from evaporation<br><br>Possibility of yield increases as the average canopy temperature rises, before the industry sees reductions (when canopy temperature is >35°C)<br><br>Likelihood of cold damage during flowering may decline | Limited water supply causes decrease in production and yield | | Physical damage to crops and infrastructure | Increase in pests and diseases – e.g. sheath blight disease |

| | > Temperatures | < Rainfall | > CO2 | > Extreme Weather | General Impacts |
|---|---|---|---|---|---|
| VITICULTURE | Potential increased geographic distribution of planting | | | | |
| | Some areas previously too cool for viticulture may become suitable for grape production<br><br>Some varieties that would not ripen in the present climate may be successfully planted in the future warmer climate<br><br>Higher temperatures could increase pathogens and pests | Disease incidence may reduce with lower rainfall in spring<br><br>Negative impacts on yield and quality in existing production areas | Combined with higher temperatures, could cause phenological shifts (e.g. budburst, flowering and veraison) thus ripening in a warmer part of the season, affecting grape quality | Drought, storms, flooding could cause significant crop loss and decreased production / yields<br><br>Physical damage to crops and infrastructure | Expansion to colder growing regions, such as Tasmania<br><br>Contraction of existing temperate growing regions due to changes in average temperature, rainfall |
| HORTICULTURE | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Reduction in chilling over winter may affect some perennial fruit crops in Mediterranean regions<br><br>Undesirable physiological responses in some horticultural crops<br><br>Expansion of industry in some regions may occur with decreased frost risk (potential southward shift in the optimum growing regions)<br><br>Change in timing and reliability of plant growth, flowering, fruit growth, fruit setting, ripening and product quality; fruit size, quality and pollination | Reduced reliability of irrigation supplies via impacts on recharge to surface and groundwater storages | Crop cycle timing for annual horticulture crops may be hastened<br><br>Could create conditions favouring foliar diseases and some root-invading fungi<br><br>Increased likelihood of crop damage and waterlogging | Physical damage to crops and infrastructure<br><br>Increased soil erosion and off-farm effects of nutrients and pesticide<br><br>Increased likelihood of waterlogging | Change in the occurrence and distribution patterns of fruit fly and other pests<br><br>Increase in active soil-borne diseases and insect infestation for longer periods during the year |

| | > Temperatures | < Rainfall | > CO2 | > Extreme Weather | General Impacts |
|---|---|---|---|---|---|
| **RED MEAT** | Increased risk of heat stress in animals, causing adverse impacts their food intake and productivity as well as long-run impact on fertility, organs and muscles health<br><br>Adverse implications on animal reproduction and fertility due to increased heat stress | Reduction of pasture availability for grazing<br><br>Reduction in supply of surface water, irrigation water and restrictions to irrigation area<br><br>Increased water requirement from animals | Rising CO2 may favour trees at the expense of pasture production - pasture quality may decline<br><br>Negative effects on northern savannas may initially be offset from by the benefits of higher CO2 and a prolonged growing season from warming | Increase in severe weather events likely to cause rise in stock mortality rates<br><br>Soil erosion, pasture damage | Reduced growth, quality of pasture/grain likely to impact livestock weight gain and productivity<br><br>Shift from C3 to C4 grasses which are harder for animals to digest; decline in pasture quality will adversely impact on nutrition gain from grazing<br><br>Changes in movements and wider distribution of pests and diseases (e.g. tick lines moving south) |
| | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| **DAIRY** | In cold wet regions, intensive dairies likely to benefit from increased warming and drying trends<br><br>Dry (grazing) regions likely to experience the greatest warming / drying, further stressing marginal enterprises<br><br>Heat stress issues for livestock significantly decreases dairy production and also requires increased energy demand for cooling of production sheds | Irrigated dairy likely to be impacted by reduced water allocation<br><br>Reduction of pasture availability for grazing | Rising CO2 may favour trees at the expense of pasture - feed quality may decline<br><br>Potential prolonged growing season in northern savannas | Increased incidence of damage to assets and infrastructure<br><br>Increased extremity of wet seasons can negatively impact milk production and general herd health<br><br>Soil erosion, pasture damage | Changes in movements and wider distribution of pests and diseases (e.g. tick lines moving south) |

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| | Temperate cool-season wet regions likely to benefit from warming, particularly in Tasmania | | | | |
| **PORK** | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Increased heat stress in animals (risk of damage to organs and muscles) causing decrease in meat eating quality<br>Increased energy demand for cooling of production sheds (in Mediterranean, subtropical zones) | Less water available for livestock needs and for piggery management (i.e. cooling, cleaning)<br>Water and irrigation requirements likely to increase; water availability to decrease | | Increased incidence of damage to assets and infrastructure | Decrease in availability and increase in cost of grain for feed (competition with human consumption and biofuel production) |
| **POULTRY** | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Heat stress decreases productivity of laying hens, increases bird mortality | Water and irrigation requirements likely to increase; water availability to decrease | | Increased incidence of damage to assets and infrastructure | Decrease in availability and increase in cost of grain for feed (competition with human consumption and biofuel production) |
| **WOOL** | **> Temperatures** | **< Rainfall** | **> CO2** | **> Extreme Weather** | **General Impacts** |
| | Heat stress is a major factor in lowering sheep reproductive performance and can impact animal health and growth | As temperatures increase, livestock demand for water will increase, limiting use of resources in extensive operations and increasing grazing pressure near watering points | Changes in the nutrient value of both native pastures in the pastoral and wheat-sheep zones and in sown pastures in the wheat-sheep and high rainfall zones | Soil erosion, pasture damage<br>Increased stock mortality rates | Shift from C3 to C4 grasses which are harder for animals to digest; decline in pasture quality will adversely impact on nutrition gain from grazing<br>Increased incidence of pests and diseases |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | Changes in movements and wider distribution of pests and diseases (e.g. tick lines moving south) |
| **FISH** | **> Temperatures** | **< Rainfall** | **> $CO_2$** | **> Extreme Weather** | **General Impacts** |
| | Adverse implications to reproduction, developmental rates, physical size at hatching<br>Higher natural mortality from earlier age of maturity<br>Movement of geographical location of pests and diseases<br>Southerly shift in species due to searching for cooler waters results in a decreased catch rate for some fisheries | Decrease in catch rates and species availability<br>Change in species locations | | Destruction of assets (e.g. vessels and nets)<br>Reduced time to fish due to dangerous conditions; inability to access certain locations<br>Reduced catch rate up to 12 months after a tropical cyclone | Damage to natural habitats (coral reefs, tidal flats, wetlands, mangroves) impacts species which rely on these habitats to reproduce<br>Potential increased seafood demand if red meat prices rise due to climate change impacts |
| **FORESTRY** | **> Temperatures** | **< Rainfall** | **> $CO_2$** | **> Extreme Weather** | **General Impacts** |
| | Increased evaporation leads to a decrease in water availability<br>Plantation loss from bushfires<br>Increased summer heat stress on seedlings | Decreased growth rate<br>Increased tree mortality | Increased growth rate | Destruction of assets<br>Fewer harvesting days per year<br>Greater incidences of crop damage | Change in geographic location of and increased susceptibility to pests and diseases<br>Decreased ability of trees to rehabilitate from pest / disease impact |

***Sources:*** *(ABARES, 2011; Allen et al., 2010; Australian Eggs Limited, 2018; Australian Pork Limited, 2016; Bange, 2007; Battaglia & Bruce, 2017a; Biswas, Graham, Kelly, & John, 2010; Brown et al., 2016; Christie, Gourley, Rawnsley, Eckard, & Awty, 2012; Climate Council, 2015; Cobon, Terwijn, & Williams, 2017; CSIRO, 2010; Dairy Australia, 2007; Department of Agriculture, 2013; Dunkley, 2014; Fleming, Park, & Marshall, 2015; Flor, Plowman, Cameron, Luethi, & Lovett, 2009; Gregory, 2010; Hanslow, Gunasekera, Cullen, & Newth, 2014; Harle, Howden, Hunt, & Dunlop, 2007; Holbrook & Johnson, 2014; Howden, Crimp, & Stokes, 2008; International Trade Centre, 2011; Koehn, Hobday, Pratchett, & Gillanders, 2011; Luck et al., 2011; T. N. Maraseni, Cockfield, & Maroulis, 2010; Tek N. Maraseni & Maroulis, 2008; Mayberry et al., 2018, 2018; Meat & Livestock Australia, 2019; Meynecke, Lee, Duke, & Warnken, 2006; Morton, n.d.; NCCARF, 2012, 2012; Nelson et al., 2010; Nidumolu et al., 2010; Nolan et al., 2018; NSW Department of Primary Industries, 2019a, 2019b; Pankhurst & Munday, 2011; Pecl et al., 2014; Perkins, Watts, Mushtaq, Marcussen, & Stone, 2015; Pitman, Narisma, & McAneney, 2007; Rojas-Downing et al., 2017; SRDC, 2008; Stokes & Howden, 2008; Sumaila, Cheung, Lam, Pauly, & Herrick, 2011; The Poultry Site, 2009)*

# Appendix 2 – Adaptation and mitigation strategies

*Table 7: Sector-specific examples of climate change redress strategies*

| **ADAPTATION / MITIGATION STRATEGIES for Australian agriculture** |
|---|
| **Grains** |
| • Adjust planting times of summer crops so they are not flowering during the hottest months<br>• Increase nitrogenous fertiliser application or increase use of pasture legume rotations to maintain grain yields and protein content<br>• Optimise resource use through precision agriculture<br>• Apply fungicides to wheat crops to decrease leaf disease<br>• Reduce soil moisture loss, e.g. increasing residue cover by minimal or no-tillage; establishing crop cover in high loss periods; weed control; and maximising capture and storage of excess rainfall on-farm<br>• Farm management, e.g. constantly varying crops and inputs, opportunistic planting<br>• Focus on improved water use efficiency (e.g. more efficient irrigation technology)<br>• Utilise drought-tolerant varieties<br>• Utilise insurance / reinsurance options to offset risk |
| **Cotton** |
| • Improved water use efficiency via irrigation practice and variety choice<br>• Modification of crop management (planting date, row configurations, irrigation scheduling)<br>• Develop breeding varieties of cotton tolerant to climatic change (i.e. heat resistant, require less water)<br>• Change sowing time<br>• Select variety choice for tolerance to heat stress<br>• Utilise insurance / reinsurance options to offset risk |
| **Sugarcane** |
| • Improve catchment vegetation distribution and ground cover to increase infiltration rate<br>• Plant trees around paddocks as windbreaks; adopt integrated pest management systems; focus on water use efficiency<br>• Increase use of precision agriculture, adopt conservation tillage to reduce soil compaction, modify row spacing<br>• Schedule irrigation to favour sucrose accumulation and use ripeners to better manage sugar accumulation<br>• Optimise irrigation efficiency, increase use of supplementary water and on-farm water storage<br>• Bring growing season forward to track increases in minimum temperatures<br>• Monitor water table position and water quality in aquifers<br>• Reduce excessive biomass accumulation by planting later and emphasising erect growth habit in breeding and variety selection<br>• Lengthen the period of harvest time to increase yield or grow additional fallow or cash crops<br>• Use machinery suitable for harvesting a lodged crop; choose varieties with reduced propensity to lodging<br>• Alter harvest season duration to coincide with cooler temperatures<br>• Adopt farming practices to reduce lodging (e.g. hilling up)<br>• Utilise insurance / reinsurance options to offset risk<br>• Use trash blanketing to intercept rainfall, increase soil carbon stores etc.<br>• Construct man-made seawater defences and investigate new regions to plant sugarcane.<br>• Develop crop varieties with tolerance to higher temperatures<br>• Utilise legume crops to break soil pest and disease cycles<br>• Restrict groundwater pumping, abandon bores already impacted by saltwater intrusion.<br>• Investigate new regions to plant sugarcane |
| **Rice** |
| • Utilise breeding varieties resilient to pests and diseases<br>• Further improve water use efficiency<br>• Utilise water-saving sowing methods<br>• Some scope to adapt rice production in current ponded culture, however aerobic and alternate-wet-and- |

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| dry rice represent future adaptation options<br>• Utilise insurance / reinsurance options to offset risk |
| **Viticulture** |
| • Planting of 'longer season' varieties to fit the warmer climate<br>• Choose more drought and heat tolerant varieties<br>• Utilise insurance / reinsurance options to offset risk<br>• Source grapes from cooler locations (e.g. Tasmania); shift growing areas further south<br>• Allow yield to go up to compensate for reduced quality |
| **Horticulture** |
| • Improve all-weather access to cropping areas<br>• Adjust intake scheduling and marketing responses as cropping cycles change<br>• Use crop protection treatments including solar radiation shading and evaporative cooling through overhead irrigation to maintain fruit quality<br>• Utilise insurance / reinsurance options to offset risk<br>• Adopt protected cropping (greenhouse, polytunnel)<br>• Review growing site/location and consider relocation<br>• Develop more heat tolerant, low chill varieties of various horticultural crops<br>• Review optimal timing of planting<br>• Consider growing frost-sensitive fruit in regions previously considered unsuitable<br>• Adopt more efficient irrigation monitoring and scheduling technologies<br>• Improve on-farm water storage linked to drainage and water harvesting systems<br>• Improve sediment runoff protection via grassed waterways and erosion control structures |
| **Red Meat** |
| • Landscape rehydration through wetland creation; sow pastures earlier; change livestock feed system<br>• Reduce carrying capacity of land to climatic conditions<br>• Provide more cooling mechanisms for livestock, e.g. shade and active cooling areas<br>• Using pasture-spelling regimes to encourage increased recovery and carrying capacity; use short rotation pasture systems and winter fodder crops<br>• Switch to appropriate pasture species for increased temperatures, reduced rainfall<br>• Increase vaccines and feed supplements to counteract pests and diseases<br>• Select breeds better suited to hotter conditions; improve conception rates<br>• Install more efficient irrigation systems, improve water use efficiency, decrease evaporation rates in water storage and soil<br>• Utilise prescribed burning to control weed growth in pasture<br>• Utilise insurance / reinsurance options to offset risk |
| **Dairy** |
| • Select breeds better suited to hotter conditions; improve conception rates<br>• Provide more cooling mechanisms for livestock, e.g. shade and active cooling areas.<br>• Change feed system; use summer housing for livestock<br>• Switch to appropriate pasture species; sow pastures earlier to match warmer conditions<br>• Utilise insurance / reinsurance options to offset risk<br>• Reduce carrying capacity of land to climatic conditions<br>• Increase vaccines and feed supplements to counteract pests and diseases<br>• Using pasture-spelling regimes to encourage increased recovery and carrying capacity<br>• Install more efficient irrigation systems, improve water use efficiency, decrease evaporation rates in water storage and soil<br>• Use nitrogen fertiliser during winter months; use short rotation pasture systems and winter fodder crops<br>• Landscape rehydration through wetland creation |
| **Pork** |
| • Design sheds to reduce water use / increase use of recycled water; improve water use efficiency<br>• Utilise insurance / reinsurance options to offset risk |

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| • Provide more cooling mechanisms for livestock, e.g. shade and active cooling areas<br>• Build effluent ponds to capture methane gas for energy (electricity generation through biogas)<br>• Preconditioning animals to higher temperatures before transit to increase survival rate<br>• Increase feed-use efficiency, utilise low-protein diets and waste food products |
| **Poultry** |
| • Decrease stocking density to cope with increased temperatures<br>• Design sheds to reduce energy use and enhance water recycling<br>• Genetic selection for heat-tolerant phenotypes; improve feed conversion ratio / feed efficiency<br>• Install more efficient irrigation systems, improve water use efficiency,<br>• Decrease evaporation rates in water storage<br>• Increase energy use to cool/ventilate sheds; provide more shade and active cooling areas<br>• Utilise insurance / reinsurance options to offset risk |
| **Wool** |
| • Shift mating to ensure lambing coincides with peak forage availability<br>• Reduce carrying capacity of land to climatic conditions; use pasture-spelling regimes to encourage increased recovery and carrying capacity<br>• Increase vaccines and feed supplements to counteract pests and diseases<br>• Install more efficient irrigation systems, improve water use efficiency, decrease evaporation rates in water storage and soil<br>• Utilise insurance / reinsurance options to offset risk<br>• Provide more cooling mechanisms for livestock, e.g. shade / active cooling areas<br>• Switch to appropriate pasture species for increased temperatures, reduced rainfall; sow pastures earlier to match warmer conditions<br>• Use short rotation pasture systems and winter fodder crops<br>• Select breeds better suited to hotter conditions; improve conception rates |
| **Fish** |
| • Change of catch locations (southwards shift)<br>• Change target species; change fishing times / seasons<br>• Some species may adapt to climatic changes (e.g. increased sea temperature)<br>• Utilise insurance / reinsurance options to offset risk |
| **Forestry** |
| • Greater consideration into site selection for new plantations<br>• Planting fewer trees depending on climatic conditions and forecasting models<br>• Irrigation (rarely feasible but some potential for effluent irrigation)<br>• Increased fire management (planned burns and habitat/vegetation control)<br>• Greater consideration of species selection<br>• Changes to fertiliser application<br>• Utilise insurance / reinsurance options to offset risk |

*Sources: (ABARES, 2011; Allen et al., 2010; Australian Eggs Limited, 2018; Australian Pork Limited, 2016; Bange, 2007; Battaglia & Bruce, 2017; Biswas et al., 2010; Brown et al., 2016; Christie et al., 2012; Cobon, Terwijn, & Williams, 2017; CSIRO, 2010; Dairy Australia, 2007; Department of Agriculture, 2013; Dunkley, 2014; Fleming, Park, & Marshall, 2015; Flor et al., 2009; Gregory, 2010; Hanslow et al., 2014; Harle et al., 2007; Holbrook & Johnson, 2014; Howden, Crimp, & Stokes, 2008; International Trade Centre, 2011; Koehn et al., 2011; Luck et al., 2011; Maraseni, Cockfield, & Maroulis, 2010; Maraseni & Maroulis, 2008; Mayberry et al., 2018; Meat & Livestock Australia, 2019; Meynecke et al., 2006; Morton, n.d.; NCCARF, 2012; Nelson et al., 2010; Nidumolu et al., 2010; Nolan et al., 2018; NSW Department of Primary Industries, 2019a, 2019b; Pankhurst & Munday, 2011; Pecl et al., 2014; Perkins et al., 2015; Pitman, Narisma, & McAneney, 2007; SRDC, 2008; Stokes & Howden, 2008; Sumaila et al., 2011; The Poultry Site, 2009)*

# Appendix 3 – Prior programs

*The following information was prepared by Professor Richard Eckard, Primary Industries Climate Challenges Centre, and Dr Tom Davison, National Livestock Productivity Program at the request of Farmers for Climate Action as a briefing paper for policy-makers. While it is difficult to quantify the exact scope of investment required for these efforts within the scope of this report, we draw attention to prior programs and existing unmet funding needs to advance effective climate risk mitigation within the agricultural sector.*

***Background***

During the period 2007-2013, there was significant investment in the Land Sector via a suite of packages designed to advance knowledge of climate change and agricultural productivity.

- **Biodiversity Fund - $946 million**
- **Climate Change Research Program (CCRP) 2009 to 2012**
    - Soil Carbon Research Program (SCaRP) $9.6M
    - Reducing Emissions from Livestock Research Program (RELRP) $11.3M
    - Nitrous Oxide Research Program (NORP) $4.7M
    - National Biochar Initiative $1.4M
    - **Carbon Farming Futures 2012 – 2015 ($429M)**
    - *Filling the research gap ($201M)*
        - National Soil Carbon Program (NSCP) $13.2M
        - National Livestock Methane Program (NLMP) $13.8M
        - National Agricultural Nitrous Oxide Research Program (NAORP) $14.1M
        - National Agricultural Manure Management Program (NAMMP) $3M
        - National Agricultural Greenhouse Gas Modelling Program (NAGMP) $1.8M
    - *Action on the ground ($99M)*
    - *Extension and outreach ($64M)*
    - **National Climate Change Adaptation Research Facility**, funded by the Australian government, hosted by Griffith University, to build resilience to climate change in government, NGOs and the private sector. Although, of note that this facility did not invest much in agriculture.

***Where are we today?***

- Regrettably, many of the projects outlined above have since lapsed and new projects have not been initiated.
- Previous investments made under the Carbon Farming Initiative (now Emissions Reduction Fund) currently underpin a number of Carbon Farming Offset methods in Australia.
- However, mainstream agriculture is still not engaged in Carbon Farming, mainly due to
    - High administration costs and low returns from individual Carbon Farming offset methods;
    - Uncertainty in policy and the longevity of the ERF
- While previous investments were excellent and well leveraged to position Australia to establish a successful carbon industry
    - Much of the capability developed under the previous climate change investments has now eroded and moved onto other areas of research
    - The nature of the investments meant that the productivity, adaptation, sequestration and abatement benefits were not well integrated into a whole-of-farm value-proposition. This lack of integration is also apparent in the reductionist approach taken in individual carbon offset methods, when most land managers think at systems scale.