Planning for Change

The Climate Report 2024

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Foreword

Banks are by their very nature, risk managers - and when nature presents risks, we do our best to understand them. We can choose to accept, avoid, transfer or mitigate risks.

Farming, export trade and agribusiness have of course been subject to risk and the vagaries of changing weather for millennia. Changing climate is an altogether more long-term, difficult and at times controversial topic to address, but ultimately, we can all make choices based on best available information.

The Rural Bank Insights team have had many deep conversations about the ifs, buts and maybes as they relate to climate change and how it is changing not just the physical landscape, but the business and regulatory landscape as well. We have drawn upon the wisdom of our forebears and been inspired along the way by the quest for knowledge from those who face the coming decades as the remainder of this century unfurls.

This report is essentially food for thought for our primary producers and we have endeavoured to present what we believe is an easy-to-read compilation of likely and predicted scenarios that those who produce our food and fibre can consider and factor into their management planning.

Rural Bank sees agribusiness as having a very important and increasing role to play in reducing emissions, and understanding how carbon mitigation programmes work is something we are keen to help our customers understand.

In conclusion, we aim to help farmers improve the productivity and resilience of their farm while reducing greenhouse gas emissions. The end goal is that farms embarking on such a journey should be a better business overall as a result.

Andrew Smith
Head of Development - Business and Agribusiness

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Executive summary

In this report, Rural Bank characterises the physical causes of climate change, and its current and future impacts.

Global warming has been accelerating since the 1980s, with consequences in global climate drivers and ecosystems. Species movement to new habitats has been measured in a very large number of species globally. Marine species in particular are monitored due to their capacity to move freely to new regions as they are not limited by as many physical impediments as their land-dwelling counterparts.

The potential impacts across agricultural industries and across the states are described. We discovered that all commodities are affected by upper heat thresholds with significant impacts on productivity. Some commodities have a gradient starting at around 25°C. Most share the threshold of 35°C where damage impacts bottom lines. For this reason, we provide maps comparing predictions of days over 35°C now and in ten years.

We walk readers through the carbon market's evolution and its drivers in the medium term. We explore carbon farming's role in slowing the addition of greenhouse gases to the atmosphere, providing a critical window in which to understand and address climate change drivers.

The urgency expressed in the majority of scientific assessments has been rising over the past five years. Recently, professional risk assessors have raised deep concern because climate tipping points are not included in the current modelling of future scenarios. There is increasing evidence to support inclusion of this risk while we gather more data and assess its import. Economic impacts were initially underestimated. It is highly desirable that national level assessments of the potential impacts of climate change be conducted and regularly updated and it is critical to put significant focus on chronic impacts. Their importance is likely to prove greater over time than acute events.

Commodity analysis is currently uneven, with some commodities providing detailed analysis but not an integrated view of the interactive effect of all likely impacts. Such integrated analyses would be beneficial for the strategic planning of farming businesses.

Where climate scenarios are generated from change drivers and statistical analysis, there is too little consistency in baseline eras and especially in unhelpful selection of future climate eras. The people who will be in senior roles in 2090 for example, are just being born now or are yet to be born. We recommend using future eras that are ten and twenty years ahead, for the benefit of strategic planning by readers. They should be revised at five-year intervals, given the rate of change in understanding of the risks.

The business environment is increasingly uncomfortable. The horizon has more risks and less certainty. Nontheless, collectively we can avoid, reduce, or mitigate the risks by concerted efforts – but only if we start now, with the understanding that the atmosphere does not care who emitted excess greenhouse gas emissions, nor their reasons for doing so.

Ultimately, what matters is a willingness to make changes to restore safe levels of greenhouse gases in the atmosphere. Such an approach should result in more efficient and more resilient businesses, and more generous natural systems.

Climate Change: Understanding causes and impacts

Summary

1. Changes to our climate have been formally observed for at least three decades. It is not a possibility that could emerge in the future; it is happening now.
2. There is increasing and deep concern that the speed of change and the extent of its impacts are being underestimated. The trajectory is worse than earlier calculated.
3. Limiting climate change to 1.5°C rise in average global temperatures above pre-industrial levels is now nearly impossible. Average increases of 3°C are now more likely. This amount of change could have potentially very large economic and geopolitical impacts. It warrants greater understanding.
4. Climate change will not be evenly distributed around the globe or even within Australia. Air temperature change in some regions may be more than the global average.
5. A rapid transition to net zero greenhouse gas emissions is required if the international community is to limit warming to "well below 2°C". Early and urgent action reduces the scale of the impacts.
6. Tipping points are temperatures that drive additional changes in earth systems such as ice coverage or large ocean currents. Feedback loops may increase the change or drive additional tipping point changes. There is increasing concern that there are signs of tipping points being triggered.
7. For our comfort and economic well-being, we are relying on two fundamental assumptions:
   a. the level of warming has a roughly linear relationship with the cumulative emission of greenhouse gases by human activities, and
   b. the climate system will eventually stabilise at a level that is determined by the total cumulative emissions, once human emissions have achieved net zero.
8. "*Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks*".[1]
9. Given the variations in policies that affect greenhouse gas emissions, and the varying amount of local adoption, the IPCC provides four Representative Concentration Pathways (RPCs) with RCP8.5 representing business as usual.

1 International Panel on Climate Change, *Synthesis Report: Future Climate Changes, Risks and Impacts* , at https://ar5-syr.ipcc.ch/topic_futurechanges.php

What is climate change and what causes it?

Climate change is **the significant variation of average weather conditions over several decades or longer**. The climate can, and has, become colder, wetter, drier or warmer both globally and regionally when one looks back across events in recorded history and in what we learn from landforms near the poles.

A range of factors can alter the climate significantly. Many natural phenomena can affect air temperature:

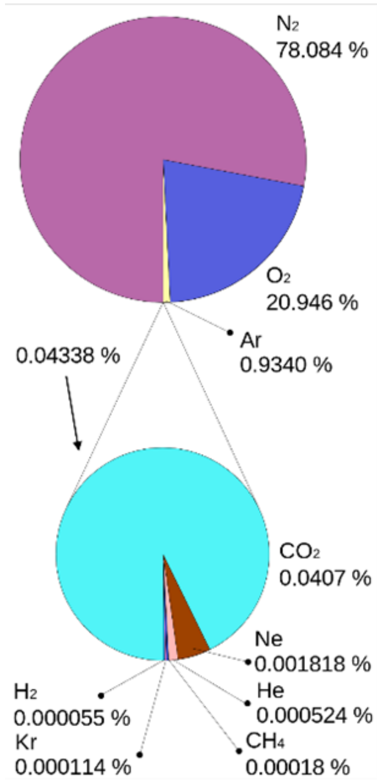
1. **Changes in the earth's rotation:** Changes in the earth's orbit and rotation changes the amount of summer sunshine falling on the Northern Hemisphere. It appears to be the primary cause of past cycles of ice ages.
2. **Changes in the sun's energy output:** The sun's energy output varies slightly over a natural 11-year cycle. Satellite measurements since 1978 show no net increase in the sun's output.
3. **Changes in the Earth's Reflectivity (albedo):** Albedo is the proportion of sunlight that is diffusely reflected by an object or surface. The amount of sunlight absorbed or reflected by the planet depends on features on the earth's surface and in the atmosphere. Dark objects and surfaces, like the ocean, forests, and soil, will absorb more sunlight storing it as heat. Light-coloured objects and surfaces, like snow and clouds, reflect sunlight. Light can pass through the atmosphere. Thermal wavelengths are partially reflected back into the atmosphere by the physical nature of the greenhouse gases.
4. **Volcanic Activity:** Volcanic eruptions released large quantities of carbon dioxide in the distant past. Large volcanic eruptions can throw particles including sulphur dioxide into the upper atmosphere. These particles can reflect enough sunlight back to space to cool the surface of the planet for several years. They are not factors in climate change due to their short duration, but large events have affected prices on stock exchanges and for agricultural commodities.

The most important contributor to higher temperatures is the concentration levels of greenhouse gases in the atmosphere. We cannot manage natural events such as those above, but we can manage the human-caused factors in climate change. It is also the most important because some greenhouse gases can last in the atmosphere for hundreds of years. This is much longer than natural drivers last.

The constituents of the atmosphere are primarily nitrogen at 78.08%, oxygen at 20.95%, and argon at 0.9%. Carbon dioxide (CO_2) and methane (CH_4) plus some other minor gases make up only 0.4% of the atmosphere. It is not their concentration but their atomic structure which causes heat energy in the infrared wavelengths to be reflected back into earth's atmosphere.

When light from the sun reaches the atmosphere, some of it passes through to the earth's surface. Along the way, some is reflected in the atmosphere, and some is absorbed by the surface it reaches on earth. This light energy heats the objects on the earth's surface. The heat is released back into the atmosphere in infrared wavelengths.

Light photons pass through the gases fairly easily on their way to the earth's surface. They do however cause vibration of the CO_2 energy bonds within that molecule. The vibration increases reflection of the infrared wavelengths released by the earth. As a result, more heat stays in the atmosphere for a longer time and the air temperature rises.



Constituents of the Earth's atmosphere

What do the records show for 2023?

Berkeley Earth[2], a science-based impartial provider of environmental data concludes in its recent report that: "2023 was the warmest year on Earth since 1850, exceeding the previous record set in 2016 by a clear and definitive margin."[3] This is echoed in other similar reports.

"As can be expected from the global warming caused by greenhouse gases, the temperature increase over the globe is broadly distributed, affecting nearly all land and ocean areas. In 2023, 95.5% of the Earth's surface was significantly warmer than the average temperature during 1951-1980, 3.5% was of a similar temperature, and only 1% was significantly colder."[4]

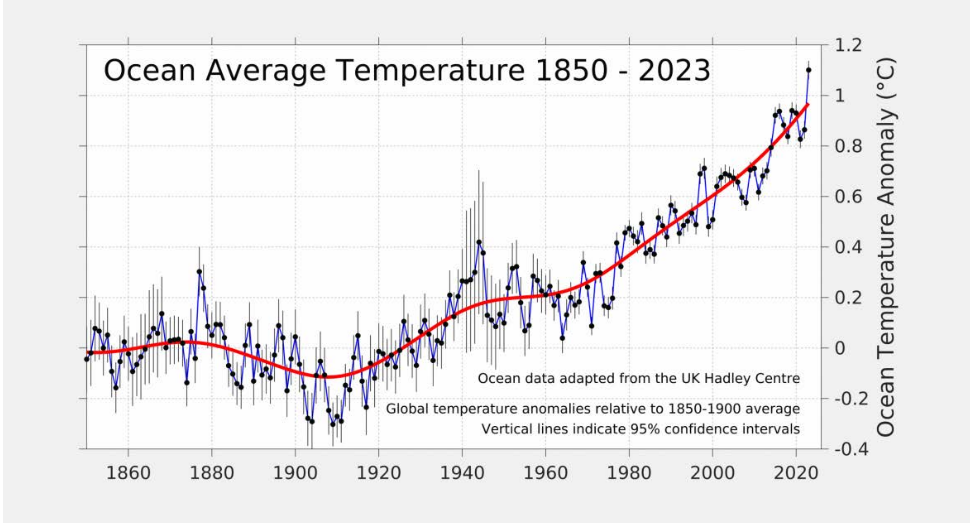
Berkeley's scientists estimate the global annual average temperature change for 2023 as 1.54 ± 0.06°C (2.77 ± 0.11°F) above the average during the period 1850 to 1900, often used a reference for the pre-industrial period. This is the first time that any year has exceeded the key 1.5°C (2.7°F) threshold. The last nine years have included all nine of the warmest years observed in the instrumental record.

For sea surface temperatures, 2023 was also the warmest year directly observed, reaching a record 1.10°C above the pre-industrial average. It is the first year with an ocean-average change greater than 1.0°C, exceeding the previous record 0.16°C rise set in 2020 by a very large margin.

They also note that none of the Earth's surface had a record cold annual average in 2023, and that there are slightly better than even chances that 2024 will be warmer than 2023.

The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases, such as those that occurred at the end of the last ice age 11,000-17,000 years ago. In May 2023, carbon dioxide hit 424 ppm—a new record[5].

Over the past two hundred years of the fossil fuel use in the Industrial Revolution, the ocean has absorbed enough carbon dioxide to lower its pH by 0.1 units. This 30% increase in acidity affects organisms that build structures with calcium including reef organisms and clams[6].



Berkeley Earth's data for the oceans is adapted from the UK Hadley Centre's HadSST4 data product after interpolation.

The European Union Copernicus Climate Service formed similar conclusions from its 2023 data:

1. *2023 is confirmed as the warmest calendar year in global temperature data records going back to 1850;*
2. *2023 had a global-average temperature of 14.98°C, 0.17°C higher than the previous highest annual value in 2016;*
3. *2023 was 0.60°C warmer than the 1991-2020 average and 1.48°C warmer than the 1850-1900 pre-industrial level;*
4. *It is likely that a 12-month period ending in January or February 2024 will exceed 1.5°C above the pre-industrial level; and*
5. *Each month from June to December in 2023 was warmer than the corresponding month in any previous year.*[7]

2 About Berkeley Earth: https://berkeleyearth.org/about/ . Berkeley Earth supplies comprehensive open-source global air pollution data and highly accessible global temperature data that is timely, impartial, and verified. See also https://en.wikipedia.org/wiki/Berkeley_Earth

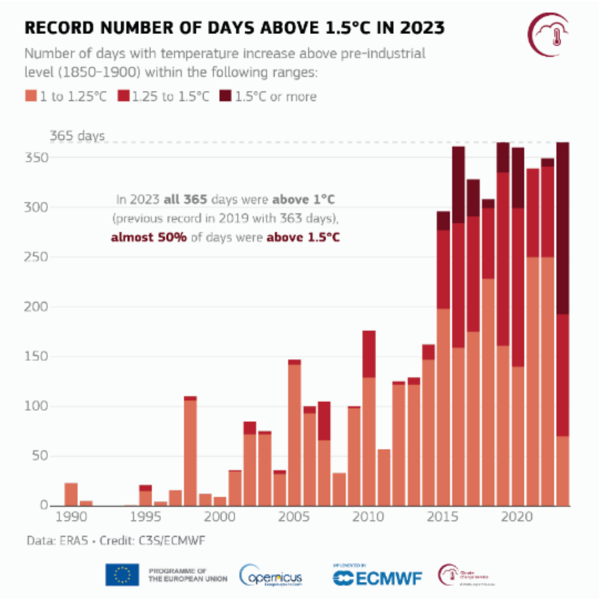
3 Berkeley Earth, Global Temperature Report for 2023, at https://berkeleyearth.org/global-temperature-report-for-2023/

4 https://berkeleyearth.org/global-temperature-report-for-2023/

5 https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

6 https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

7 European Commission, Global Climate Highlights 2023 https://climate.copernicus.eu/global-climate-highlights-2023



See also NASA's news article *NASA Analysis Confirms 2023 as Warmest Year on Record*[8].

The highlights in the Bureau of Meteorology's Annual Statement 2023 note:

- (2023 was) Australia's equal eighth-warmest year on record with the national mean temperature 0.98°C warmer than the 1961–1990 average;
- Both the mean annual maximum and minimum temperatures were above average for all States and the Northern Territory; and
- Winter was Australia's warmest on record, with the national mean temperature 1.53°C above the 1961–1990 average.[9]

The World Meteorological Organization (WMO) very recently released its assessment of the global climate, the State of the Global Climate 2023. It describes the WMO view of changing ocean temperatures as a red alert because it could take millennia for the absorbed heat energy to make its way back into deep space. In the words of the Report: *"Around 90% of the energy that has accumulated in the Earth system since 1971 is stored in the ocean. As energy has accumulated in the ocean, it has warmed and the heat content of the ocean) has increased."*

The report goes on to confirm the view that climate change seems to be gathering pace.

"The WMO report confirmed that 2023 was the warmest year on record, with the global average near-surface temperature at 1.45°Celsius (with a margin of uncertainty of ± 0.12°C) above the pre-industrial baseline. It was the warmest ten-year period on record."[10]

One year of temperatures around 1.5°C above the baseline does not give us evidence of passing that temperature tipping point. The temperature levels from 2023 may not be repeated in 2024, however, the longer-term trend is apparent. It gives no comfort that the threshold value will not be passed this year. It could be passed again in 2025. It does however signal a need to factor in this risk in climate change assessments.

8 https://www.nasa.gov/news-release/nasa-analysis-confirms-2023-as-warmest-year-on-record/
9 http://www.bom.gov.au/climate/current/annual/aus/
10 2024 State of the Global Climate 2023 https://wmo.int/publication-series/state-of-global-climate-2023

Are we making progress in reducing emissions?

Regrettably we are not.

The global carbon budget is a concept which adds up carbon emissions from human activity to the atmosphere ('emissions' in the graphic) and compares that to the carbon extracted by natural systems ('sinks' in the graphic). They are measured in billions of tonnes of CO_2. The difference between the budget (sinks) and the expenditure (emissions) could be described as the debt owed to the future. In 2023, emissions were about 1.7 times the capacity of natural systems to absorb the extra carbon.

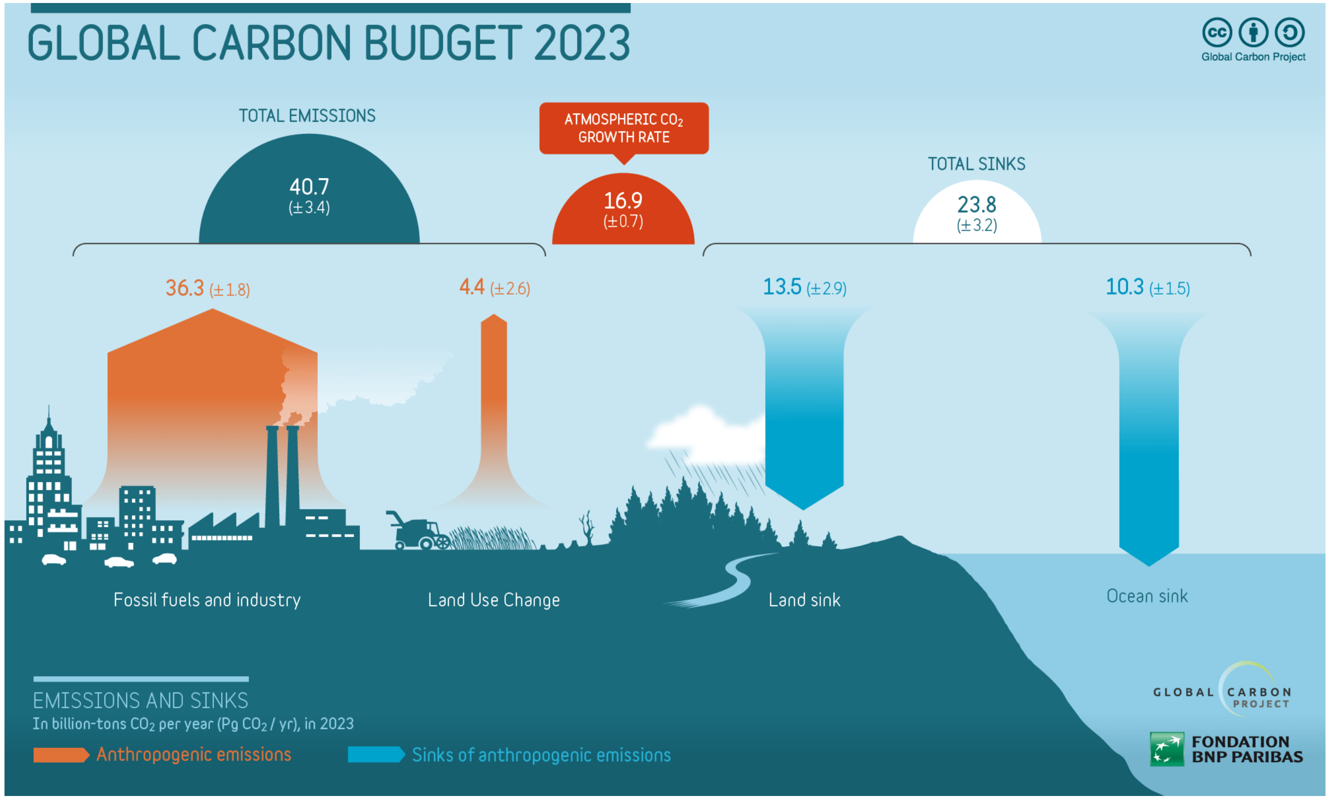
In total, emissions are increasing. The Global Carbon Budget 2023 report estimated fossil CO_2 emissions (including cement carbonation) will have further increased in 2023, to 1.4% above their pre-COVID-19 pandemic 2019 level. Emissions from coal, oil, and gas in 2023 are all expected have been slightly above their 2022 levels (by 1.1%, 1.5%, and 0.5%, respectively).

Some countries are reducing their emissions, but others are increasing their emissions. Fossil fuel emissions in 2023 are expected to have decreased by:

- 7.4% in the European Union;
- 3.0% in the United States; and
- 0.4% for the rest of the world.

In the BRIC (Brazil, Russia, India and China) countries emissions are expected to have increased by:

- 4.0% in China;
- 8.2% in India; and



- Land use change is a large contributor to emissions from clearing and peat burning. Brazil, Indonesia, and the Democratic Republic of the Congo collectively release more than half of global land-use CO_2 emissions.

The continuing increases in carbon emissions are the result of the sovereign right of nations to manage their affairs. One of the measures used in debates about national targets is the per capita emissions. In a recent Working Paper from the International Monetary Fund[11], the authors raise this idea: "*India is the world's third largest greenhouse gas (GHG) emitter, however in terms of emissions per capita it has the lowest level in the G20. Figure 3 shows India has slightly more emissions than the European Union (EU) but only one third of the emissions per capita, while the United States has 7 times higher emissions per capita. Given India's modern economic development began considerably later than that of advanced economies, it has a small contribution to global historical cumulative GHG emissions of approximately 3 percent (UNEP, 2022).*"

11 2023 Chateau J et al A Framework for Climate Change Mitigation in India. A Working Paper of the International Monetary Fund. Available at: https://www.imf.org/en/Publications/WP/Issues/2023/10/20/A-Framework-for-Climate-Change-Mitigation-in-India-535854

The global warming challenge is one where the impacts of individual choices affect the world. This kind of circumstance has been called *the tragedy of the commons*. The atmosphere does not care about the source of emissions nor about the geopolitical perspectives that cause it.

The challenge is to solve the energy conundrum at a global scale, not nationally. Reducing greenhouse gas emissions requires using other energy sources than fossil fuels where the usage is biggest. It is a problem that humanity has in common, globally.

The risks must be assessed not in terms of their overall environmental impact but in comparison to the likely impacts that failure to change could cause. The focus on narrow and national interests distracts us from the heart of the matter.

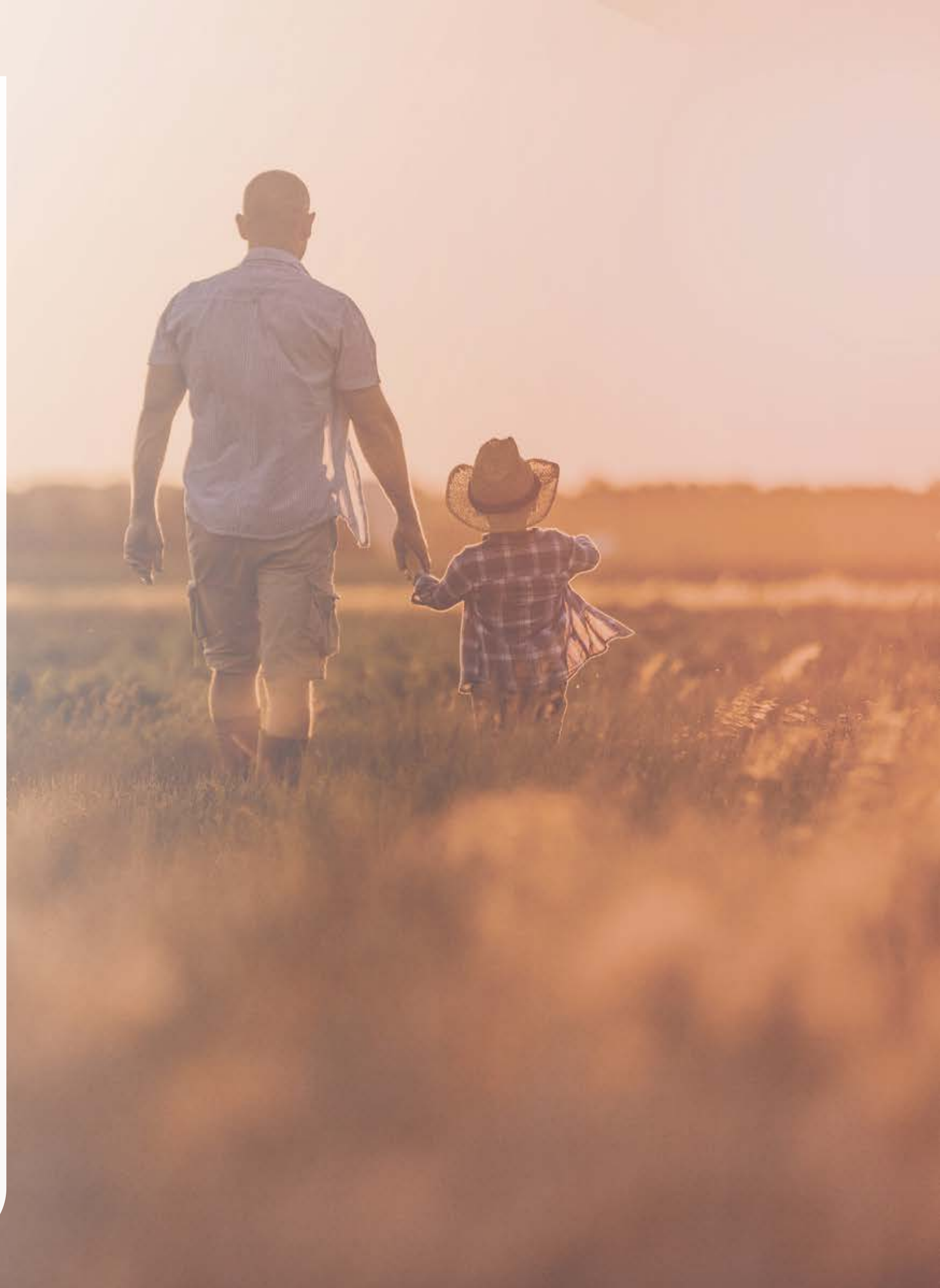
The two most important and implicit assumptions in analyses of climate change risks are:

1. the level of warming has a roughly linear relationship with the cumulative emission of greenhouse gases by human activities, and
2. the climate system will eventually stabilise at a level that is determined by the total cumulative emissions, once human emissions have achieved net zero.

Rapid intrinsic and sudden changes in the earth's systems may play an increasingly important role in the trajectory of the system as human influence increases, with the potential of a 'cascade' to become the dominant driver of the trajectory[12].

These two assumptions are built on a preference for slow adaptation. They may be mistaken as the sentence above implies. The cascade effect is also referred to in discussions of tipping points. The latter are threshold levels. Once the threshold is passed, physical changes may be self-reinforcing and/or prompt other changes or interact with other tipping points.

12 https://www.science.org.au/supporting-science/science-policy-and-analysis/reports-and-publications/risks-australia-three-degrees-c-warmer-world



What are the likely consequences?

Climate change is a significant challenge for society because of the real potential to disrupt all the natural and human-made systems on which we rely, whether the climate changes from a favourable balance to unfavourably hot or unfavourably cold.

The changes that arise from global warming are, like warming itself, underway in many global systems. They include record-breaking heatwaves, warming and rising seas, increasingly longer and more severe fire seasons, challenges to agriculture, human health impacts, and ecosystem transformation. Increased levels of atmospheric CO_2 have been absorbed in the upper layers of the ocean, driving ocean acidification and associated impacts on marine organisms and ecosystems.

Some of these changes are visible and affect our lives and livelihoods now. Others are increasingly being observed by scientists. In 2020 researchers compiled a global geodatabase of climate-induced species redistribution over land and sea. Some 30,000 species are listed. Not all records have high levels of certainty, but most are the results of prudent scientific observation[13].

This does not happen evenly since temperature ranges are not the only factor supporting or limiting the species in a locale. It may include an unravelling of the ecosystem in which the species participate with no certainty it will be rebuilt robustly in new locations. This affects human societies because of resulting changes in ecosystem services such as fisheries on which communities and consumers rely. The impacts are not solely on particular species. There can be significant economic impacts.

Australians may be familiar with the case of the long-spined sea urchin which has expanded its range about 650 km south due to temperature change in ocean waters. These waters have now warmed above a winter average of 12°C. This is the temperature at which urchin larvae can develop during spawning. The ocean is warming faster than land, heating at a rate of 4°C per century[14].

Researchers report that there is insufficient research done on these very large changes of range. Australian waters encompass the world's third largest marine jurisdiction, extending from tropical to sub-Antarctic climate zones, and have waters warming at rates twice the global average in the north and two to four times in the south. Since range shifts were first reported in the region in 2003, 198 species from nine Phyla (families) have been documented shifting their distribution, 87.3% of which are shifting poleward. The reason for the interest in changes of distribution in ocean life is that there are few physical boundaries to movement in the ocean. They become a signal or indicator.

Climate change is widely discussed in reference to changes in nature and loss of biodiversity. It is a highly influential factor in changes in biodiversity.

It is also predicted to have profound impacts on the global economy. The UK based Institute and Faculty of Actuaries (IFoA)[15] concluded that: "*Some models implausibly show the hot-house world to be economically positive, whereas others estimate a 65% GDP loss or a 50–60% downside to existing financial assets if climate change is not mitigated, stating these are likely to be conservative estimates.*"

In summary, the near to mid-term future is turbulent and contains more uncertainty than recent decades.

As a financial institution, assessing risk is core business for Rural Bank. Assessing risk is an important part of the business of farming. Our objective in this report is to provide farm businesses with information for assessing risk and strategic planning, to introduce the key themes referred to in discussions about climate change, summaries of likely climate changes per state, and for important commodities.

13 2020 Lenoir et al. Species better track climate warming in the oceans than on land. https://www.nature.com/articles/s41559-020-1198-2

14 https://www.imas.utas.edu.au/news/news-items/can-we-eat-our-way-through-and-exploding-urchin-problem

15 https://actuaries.org.uk/

What kind of changes can we expect and the Representative Concentration Pathways (RCP) Predictions

The International Panel on Climate Change (IPCC) currently summarises the changes in stark language:

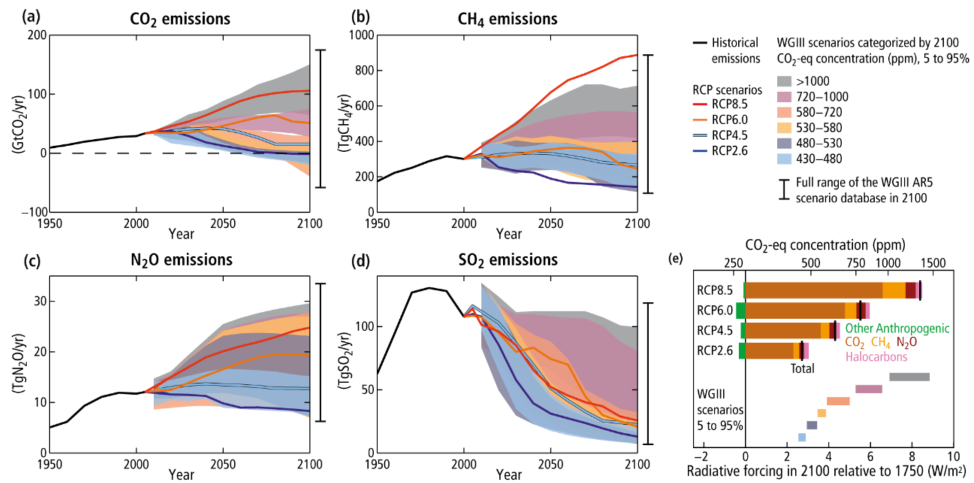
"Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks".[16]

To assess potential physical consequences of climate change, the IPCC has developed models integrating the critical factors that need to be considered, including both socio-economic development and climate policy. The modelling of physical factors and their interaction continues to improve. Changes to understanding of climate drivers will certainly occur in future. It is likely that the science in this domain will advance more quickly than it has previously.

The capacity of countries to enforce changes in policy across their populations varies. In some countries, local decision making, and commercial decision making has more impact than policy. Still others focus on economic progress. Given the variations in policies that affect greenhouse gas emissions, and the varying amount of local adoption, the IPCC provides four Representative Concentration Pathways (RPCs) intended to collectively cover the range of likely scenarios. In that term, *concentration* refers to the greenhouse gas concentration in the atmosphere[17].

The RCPS are:

- RCP2.6 which assumes significant efforts and deep implementation of greenhouse gas reduction strategies;
- RCP4.5 and RCP6.0, which assume varying levels of greenhouse gas emissions reductions; and
- RCP8.5 which assumes business-as-usual with little reduction in greenhouse gas emissions. This option most closely characterises the likely climate pathway we are on now, and outcomes, given current global commitments and reductions.



(a) CO_2 or carbon dioxide, (b) CH_4 or methane, (c) N_2O or nitrous oxide, (d) SO_2 or sulphur dioxide.

In the four charts on the left and in centre and above (a – d), the likely change in emissions is shown for one greenhouse gas over the four RCP scenarios. In the zones behind the lines, are the predictions of the IPCC Working Group III (WGIII) for emissions concentrations.

Radiative forcing factor

The chart (e) shows the impact of the predictions. Radiative forcing is a term for the additional heat energy remaining in the atmosphere as compared to the beginning of the industrial era in 1750. It is measured in watts per square meter on the earth's surface. RCP8.5 envisages more than 3 times more heat energy ambient in the atmosphere than RCP2.6 and more than eight times heat energy than what was present in 1750.

16 International Panel on Climate Change, *Synthesis Report: Future Climate Changes, Risks and Impacts* , at https://ar5-syr.ipcc.ch/topic_futurechanges.php
17 https://ar5-syr.ipcc.ch/topic_pathways.php#:~:text=Mitigation%2C%20adaptation%20and,and%20land.%20%7B

The IPCC summarises the changes in this way:

> *" Mitigation, adaptation and climate impacts can all result in transformations to and changes in systems. Depending on the rate and magnitude of change and the vulnerability and exposure of human and natural systems, climate change will alter ecosystems, food systems, infrastructure, coastal, urban and rural areas, human health and livelihoods. Adaptive responses to a changing climate require actions that range from incremental changes to more fundamental, transformational changes. Mitigation can involve fundamental changes in the way that human societies produce and use energy services and land."*

The Australian Academy of Science in its 2021 report noted that:

> *" Constraining the global mean surface temperature to an increase of "well below 2°C" becomes extremely difficult and temperatures of 3°C more likely. This amount of change could have potentially catastrophic impacts. To put these changes into historical context, the difference in global mean surface temperature between the last glacial period (the ice age that ended 20,000 years ago) and today is only 5°C, yet a quarter of earth's land area was covered by ice, sea levels were more than 100 m lower, and ecosystems were markedly different in their distribution and composition."*[18]

It may also be useful to assess climate predictions more closely, using high integrity sources. Some characterisations of climate events get simplified and afforded a sense of urgency that does not match the facts. In other cases, risk to the economy is significantly understated. We share the view with many other organisations that this matter is too important to be the subject of partisan political debate.

The same position led to the founding of Berkeley Earth by well-regarded scientists to test the validity of some public criticism for the betterment of the science, and to provide high integrity data.

It is certain that the science around climate change will improve. Comments and projections made several years ago may be shown to be in error in light of new knowledge. So far new science and better models have not only confirmed the trend of climate change. They have suggested that the world community is underestimating the likely impact of the change.

18 2021 Australian Academy of Science The Risks To Australia of a 3°C warmer world.https://www.science.org.au/supporting-science/science-policy-and-analysis/reportsand-publications/risks-australia-three-degrees-c-warmer-world

What are the likely impacts in Australia?

While climate change is discussed in reference to average global temperature change, changes to Australia's climate will vary regionally.

The table below shows the estimated change in days where the air temperature is higher than 30°C. The reference average shows the average count of days per year in the era 1981 to 2010. The range is minimum and maximum count of days exceeding 30°C as estimated by eight climate models. The data is extracted from the Thresholds Calculator tool at http://climatechangeinaustralia.gov.au/en/projections-tools/threshold-calculator

Days above 30°C

City	Reference Avg 1981-2010	Estimated Range in 2030	Estimated Days by averaging all Models
Perth	61.1	69.6 – 80.4	75.2
Adelaide	48.6	54.6 – 62.9	57.8
Melbourne	29.1	33.6 – 39.7	36.1
Sydney	27.3	35.6 – 43.8	38.9
Brisbane	53.6	77.4 – 100.4	85.4
Far North Queensland	157.9	178.4 – 213.8	193.9

In a 2020 study using high resolution climate projections, researchers explored how heatwave characteristics are likely to change under 1.5°C, 2.0°C, and 3°C of global warming across all of Queensland's local government areas. The study found that:

- Under 1.5°C of global warming, heatwaves would occur three times a year with each event lasting on average 7.5 days;
- With global warming of 2°C, heatwaves would occur at least four times a year, on average lasting 10 days; and
- At 3°C of global warming, heatwaves would happen as often as seven times a year, with events lasting 16 days on average.

Additional Impacts

- Likelihood of more exotic/overseas pest incursions;
- Risks from bushfires will increase substantially with moderate confidence that the number of extreme fire days will double for global warming of 3°C and large decreases in seasonal rainfall will occur in southern Australia. Fire risk will increase by 30% or more in south-eastern Australia;
- Risk of more days over 35°C threshold for working outdoors;
- Increasing risk that temperatures rise too early/too high for the crop, damaging its growth sequence especially at flowering;
- Changes in the network of services that businesses and families rely on as regional residents respond to climate change;
- Reduced capacity of electricity transmission lines under climate change;
- Greater impact on infrastructure by natural disasters and reduced capacity to maintain essential infrastructure;
- Impacts from declining rainfall and more frequent droughts for areas such as south-eastern and south-western Australia would intensify under 2°C or more of global warming;
- Declining river flows would reduce water availability for irrigated agriculture and increase water prices. Future water resource availability would be affected by the combined changes in rainfall and global surface temperature increases;
- Heat stress will be a significant issue for livestock systems due to impacts on animal welfare, reproduction and production. Projected temperature and humidity changes suggest an increased number of heat stress days per year; and
- More frequent storms and heavy rainfall would likely lead to worsening erosion of grazing land or loss of livestock from flooding.

Impacts for primary producers and rural communities include lost profitability for Australian farms, reduced water availability and elevated heat stress affecting land use for crops. For example, broadacre crops such as wheat and barley in some regions will see declines in productivity, not just due to more variable rainfall, but due to increasing daily maximum temperatures. Temperature above 35°C during flowering will affect yield. In one 2018 study by Taylor et al. on the trend in wheat yields in Western Australia under several climate scenarios, the authors found: "*Median wheat yields modelled for South West Australia projected declines between 26% and 38%, under a 'most-likely' case for RCP 4.5 by 2090, and between 41% and 49%, under a 'most-likely' case for RCP 8.5. Median wheat yields declined under RCP 8.5 for the 'most-likely' case across the majority of wheat producing regions, with a range of 1% to 49%.*"[19] Since the projections have particularly long timeframes, it is difficult to precisely predict the extent of impact in a given decade. The impacts will vary over time. Some years will have more impact; some will have less impact, but the trend will be for increasing declines given current knowledge and technology. The risk of reduced yields is increasing but the risk is not evenly distributed in time nor in geography.

Summary

1. Climate-related risks fall into two major categories:
    a. risks related to the physical impacts of climate change; and
    b. risks related to the transition to a lower-carbon business and economy.
2. Physical risks can be further subdivided into:
    a. Acute risks that are short term event-driven; and
    b. Chronic risks that are slow-moving and persist for a long time. Chronic risks may be the most significant.
3. Australia is the country with the most variable rainfall. Its rainfall is four times more variable than that of Russia and twice that of India and New Zealand.
4. *While it is widely recognized that continued emission of greenhouse gases will cause further warming of the planet and this warming could lead to damaging economic and social consequences, the exact timing and severity of physical effects are difficult to estimate. The large-scale and long-term nature of the problem makes it uniquely challenging, especially in the context of economic decision making.* ***Accordingly, many organisations incorrectly perceive the implications of climate change to be long term and, therefore, not necessarily relevant to decisions made today.***"[20]

19 2018 Taylor et al. Trends in wheat yields under representative climate futures: Implications for climate adaptation. See https://findanexpert.unimelb.edu.au/scholarlywork/1321211-trends-in-wheat-yields-under-representative-climate-futures--implications-for-climate-adaptation?cache=1707597913533

20 Available at https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

Distinguishing types of risk to consider in strategic planning

The specific choices an individual farming business might make are beyond the scope of this report. We focus instead on the types of risks and responses that comprise the options for farmers to consider. Financial institutions consider two forms of risk and response:

(1) Risks related to the physical impacts of climate change; and

(2) Risks related to the transition to a lower-carbon business and economy.

Physical Risk

Physical risks resulting from climate change can be event driven (acute) or longer-term shifts (chronic) in climate patterns. Physical risks are widely predicted to have increasing financial impacts on all businesses, including farming. Examples of physical risk, such as direct damage to assets and indirect impacts from supply chain disruption. The financial performance of businesses is likely to be increasingly affected by changes in water availability, excess heat and insufficient chilling hours, supply chain consistency, transport availability, and employee safety.

Physical risks are further subdivided into two types:

Acute Risk

Acute physical risks refer to those that are short term event-driven, including increased severity of extreme weather events, such as cyclones, fires, or floods. These are well recognised risks and attract considerable media attention. The consequences can be far reaching for businesses as supply chain partners and infrastructure may be damaged beyond economic recovery.

Acute risk may seem easily addressed by insurance and counting on a measure of good fortune to avoid damage in some risk events. Insurers, however, are becoming wary of insuring assets in high-risk zones. This is due to the additional costs to build or rebuild to new standards or higher standards in new areas. For example, cyclone building codes might be imposed below the Tropic of Capricorn in Queensland or Bushfire Attack Level (BAL) standards might be imposed more widely in NSW, adding substantially to the cost of building or rebuilding as analysis of risk becomes easier with technology advances and increasing volumes of relevant data.

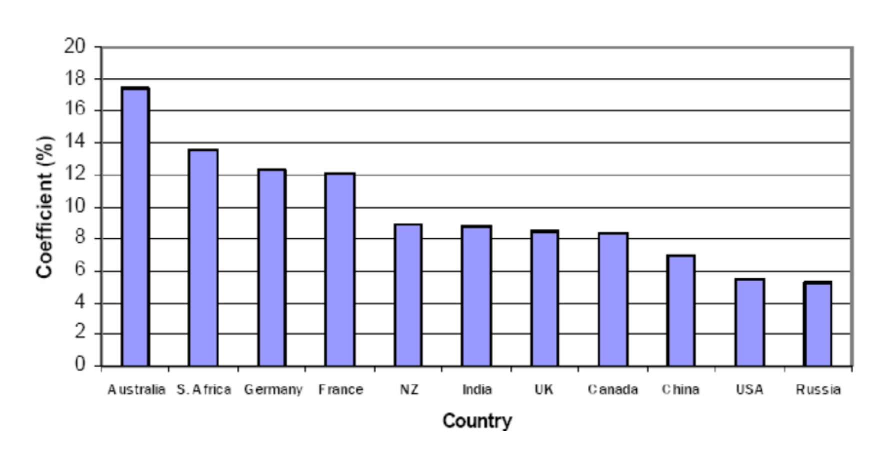
Chronic Risk

Chronic physical risks refer to longer-term shifts in climate patterns (e.g., sustained higher temperatures) that may cause chronic heat waves, changes in rainfall amount and distribution, or sea level rise. These slow-moving risks are harder to assess intuitively or based on experience than acute risks. They are also less the subject of widespread concern and attention. It is therefore more likely that chronic risk is underestimated in business planning and adaptation.

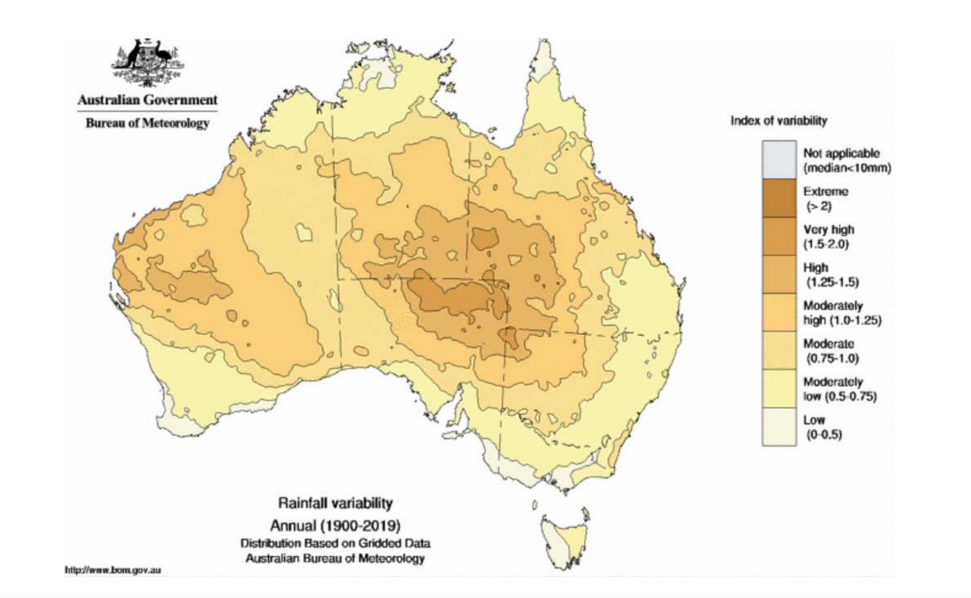
ABARES modelling found that: *"In the 20 years since 2000, the risk of very low farm returns (due to climate variability) essentially doubled (relative to the period 1950 to 2000), increasing from a 1 in 10 frequency to more than 1 in 5"*[21]

21 https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation#recent-changes-in-seasonal-conditions-have-affected-the-profitability-of-australian-farms

Australia is the country with the most variable rainfall. Its rainfall is four times more variable than that of Russia and twice that of India and New Zealand.



2010 Hanna, Liz et al. *Australia, Lucky Country or Climate Change Canary: what future for her rural children? from: https://www.researchgate.net/figure/Country-comparisons-100-year-rainfall-variability_fig1_276848792 [accessed 15 Feb, 2024]*



Transition Risk

The second type of risk is transition risk.

Transitioning to a lower-carbon business entails navigating among extensive policy changes at national and international level, changing legal liabilities, new technology, and market changes as the entire economy alters direction to address mitigation and adaptation requirements related to climate change. The nature, speed, and focus of these transition risks may pose varying levels of financial and reputational (e.g. social licence to operate) risk to farming businesses.

Assessing the way forward in the new business environment

There is continuous change in almost all the risk types mentioned.

Acute: The acute physical risks may occur more frequently and, importantly, have longer term impacts on infrastructure. Some of the major floods and fires have had impacts that went community-wide and continued to ripple for years. Insurers are increasingly wary of regular acute events such as floods. They are pricing in the risk in particular areas with increasing levels of detail. Insurance may not serve as a solution against acute physical risks to the same extent it previously did. Some insurers are asking farming businesses to take steps to reduce risk at the source.

Chronic: Chronic physical risks deserve more attention than acute risks. The slow creep of hotter weather southwards across the continent will impact most agricultural businesses in one way or another. Threshold temperature levels may be breached. Days above 35°C harm grains at various stages in plant growth. Heat stress in livestock causes loss of condition and vigour. Lack of sufficient chilling hours may damage productivity in horticulture. We explore this subject for several commodities in a later section.

Transition: Transitional risks involve assessments of markets which may have considerable positive and negative uncertainty attached to them. It's clear that there are - and will continue to be - new opportunities arising from changes in policy around climate. In a policy-driven environment, changes of direction can be sudden and significant, impacting on business models.

Responses to climate change include adaptation and migration action. An example of this, to a limited extent, is using gene technology to breed crop varieties and livestock with higher tolerances for drought or water-logging and more suited to a new climate regime. In other words, producers will need to control the unfavourable conditions, change the focus of the business, or move to a climate zone that will likely become more and more favourable to the existing business and new varieties.

Migration is already occurring in agricultural businesses. We have seen this occuring in horticulture, due to its specific requirements for best quality soil and reliable water supplies. In an article on changes to the global wine industry prompted by climate change, the New York Times reported the movement of vineyards towards the poles from more southernly latitudes has accelerated. Sparkling wine producers from previously favoured areas in central France are investing in vineyards in southern England. Some colder varieties are being established in Norway and Sweden. There is exploration of new potential regions in Tasmania, and in southern Chile.

It's not just horticulture. There are suggestions by reputable researchers that by 2050 the area around Hamilton, Victoria may be more suited to grains than to its current commodities.

There are additional challenges for industries with very specialised requirements. Locales with quality soils, sufficient water and desirable range of temperatures are more likely to be more tightly held with the passage of time. Land prices may further reflect the increased competition.

Adaptation may be a more suitable option for many farm businesses. It doesn't entail as much disruption to the business as moving location would. There may be management, technological and nature-based solutions to the challenge of an increasingly unsuitable temperature regime. It is prudent to consider whether the chosen adaptations will serve the business well in the medium term. There will come a time for some businesses where a step change is required as climate change pushes productivity down each year, and the damage done by acute events such as days above temperature thresholds combine to seriously damage resilience and profitability.

To summarise the commercial landscape around farming businesses, it is a currently a complex matrix of moving pieces that interact with each other. Decisions that meet the evolving conditions will be hard to make. On the other hand, not making a decision is also intrinsically unsafe. The more successful approaches seem to include taking steps where a business can capture benefits.

The gathering momentum in changes to the climate will not be easily stopped. Climate change is affecting people and businesses globally in different ways. The changes impacting businesses and especially agricultural businesses, present complex choices. For farming businesses, the choices will be considered in some cases against a background of generations-long attachment to properties and communities.

Each potential response to climate change has its own risks. It is not possible to avoid the impacts by avoiding decisions about the optimum path for any given business. We can expect turbulent geo-political times ahead, so better strategies and plans are likely to arise from deeper understanding of what is forecast.

As the Taskforce on Climate-Related Financial Disclosure[22] warned: "*One of the most significant, and perhaps most misunderstood, risks that organizations face today relates to climate change. While it is widely recognized that continued emission of greenhouse gases will cause further warming of the planet and this warming could lead to damaging economic and social consequences, the exact timing and severity of physical effects are difficult to estimate. The large-scale and long-term nature of the problem makes it uniquely challenging, especially in the context of economic decision making.* ***Accordingly, many organisations incorrectly perceive the implications of climate change to be long term and, therefore, not necessarily relevant to decisions made today.***" (our emphasis)[23]

It is therefore prudent to investigate the likely impacts on your particular commodity, and your region.

22 The Financial Stability Board's Taskforce on Climate-related Financial Disclosure. https://www.fsb-tcfd.org/
23 From https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

Projected impacts on agricultural commodities

CATTLE

Rising maximum temperatures will increase the risk of heat stress in cattle and the frequency of heatwaves.

It arises from the interaction of several factors:

- The count of hours where air temperature levels are above 35°C;
- The extent to which air temperatures drop below 25°C overnight enabling the cattle to release heat and drop body temperature; and
- The humidity in the atmosphere which makes it more difficult to shed heat.

If cattle are subject to hot environmental conditions, accompanied by high humidity, and hot nights, they may be unable to shed heat generated by their metabolism. Heat is also added from direct sun rays and reflected solar energy while grazing. In these circumstances cattle will experience heat stress with potentially serious health consequences including mortality.

Compared to *Bos taurus*/British breeds of cattle, *Bos indicus*/Indian breeds have an improved ability to regulate body temperature in response to hot, humid environments. The better response of *Bos indicus* breeds appears to be the result of their better capacity to shed heat, and a slower metabolism than *Bos taurus* breeds. The coats of *Bos indicus* cattle are often light in colour, reflecting the sun's energy more effectively than dark colours.

Higher temperatures enable air masses to hold more moisture, producing humid air in some regions. This will increase the intensity of storm rain, potentially leading to erosion. For land managers, maintaining ground cover will become more critical.

The risk of acute heat stress in cattle, and erosion are not the only impact of rising temperatures. The chronic impacts affect productivity every year, despite their unspectacular presence.

If average temperatures rise 2°C in southern Australia, there will be changes in the composition of grazing swards. The productivity of temperate zone C3 plants has been shown to decline. Plants like rye grass and nitrogen-fixing legumes such as clover fall into that category. The tropical C4 species similarly increase in density and productivity, leading to an increase in gross dry matter production, and more carbon cycling from plant trash. Previously minor weed species may become more widespread and difficult to manage, leading to higher input costs.

In periods of low ground cover due to low soil moisture and high evaporation, the risk increases of cattle eating poisonous plants or other dangerous materials, requiring more management.

Importantly, a reduction in fertility due to less mating activity is also observed, with a corresponding drop in birth weights.

These impacts on productivity fall into the chronic class. They are easily underestimated compared with the acute impacts of heat stress. They will also lead to issues of oxidative stress, immune suppression and an increase in infections. In addition to this, a reduction of appetite is a frequent symptom of chronic high temperatures. Eating less leads to lower body temperatures that cannot be achieved in other ways under the adverse weather conditions.

DAIRY

Dairy production is strongly affected by climate change for reasons intrinsic to the lines of cattle involved and the high levels of nutrition provided to enhance productivity.

As observed above, the internal temperature of cattle is highly influenced by physiological activity. The more quantity and higher protein quality of food consumed, the higher the body temperature for any given animal. As a result, the most researched topics related to the dairy industry are the impacts of heat stress and ways of managing this factor to keep it lower.

Breeding for maximum milk production increases the metabolic heat load of milk production. This increases the susceptibility to heat stress. It also has impacts on productivity. Heat stress reduces milk yield, changes milk components, reduces fertility and feed efficiency, while increasing culling and mortality rates. It has been reported that for each 10 kg/day increase in milk yield, the heat stress threshold will decrease by 5°C. [24]

The temperature threshold at which such impacts begin is widely reported in the international literature as 25°C. Under conditions of acute heat stress, milk productivity has been shown to be negatively affected within 24 hours in proportion to heat load (Silanikove et al., 2009). Garner et al. (2017) found that exposing dairy cows to moderate heat stress over 4 days in a climate chamber-controlled study reduced milk yield by 53% and reduced dry matter intake by 48%.

As Silanikove et al observed[25], a number of factors in the business environment around dairying may affect the business model, having significant impacts on profitability. These include:

- Competition for high quality feedstocks due in part to climate-induced reduction in grain productivity. Price competition may divert some grains from dairy feedstocks to human food products;
- The rising temperature and increasing frequency of heat stress days combined with increasing costs of energy will be challenging; and
- The long history of reliance on high productivity systems may be less suitable under climate change.

Some producers may find it more effective to switch from maximising every factor in productivity to optimising them. This could even prompt some producers to consider switching species to dairy goats. As the authors note: "Among domestic ruminants, goats are the most adapted species to imposed heat stress in terms of production, reproduction and resistance to diseases."

Incorporating breed types such as the Australian Milking Zebu (AMZ) developed by the CSIRO, into herds is another alternative to address heat stress. While this would come at the cost of lower milk production per lactation, per animal, high production and higher heat loads are incompatible. New business models may need to be explored.

Of course, migrating the business to other more favourable regions for temperature may be an option for some, for other dairy businesses, a mix of adaptation to the new conditions at the site may be more suitable. Still others may conclude that medium term climate and business changes may best be addressed by altering their production course to another industry.

24 2023 Cartwright S et al. Impact of heat stress on dairy cattle and selection strategies for thermotolerance: a review. https://www.frontiersin.org/articles/10.3389/fvets.2023.1198697/full

25 2015 Silanikove N and N Koluman. Impact of climate change on the dairy industry in temperate zones. from https://www.sciencedirect.com/science/article/abs/pii/S0921448814003150

CROPPING

In Australia, rainfall is the most significant factor in year-on-year variation in crop productivity. Rainfall is not the only cause of yield variation. Other factors including average daytime temperature, timing of rainfall, temperature extremes, soils and timing of operations, all contribute to variation.

As noted above, daily or even weekly rainfall is hard to predict fifteen or twenty years into the future. We can however predict likely changes in rainfall in future decades, because unlike tomorrow's local rainfall which is affected by local terrain and current air masses, the trends on rainfall in future decades are influenced by likely changes in global scale climate drivers. Nonetheless, Australia as described previously, is the country most subject to rainfall variability. The long-term trend may be aptly described but even annual total rainfall estimates may be much less precise.

In some Australian production regions, the long-term trend of weather risk is rising, so we have chosen to focus initially on the impacts of temperature change on cropping productivity.

The widely held view is that climate change will raise minimum temperatures, reducing the incidence of frost damage to a much more infrequent event.

In Australia, the risk from heat stress days is becoming an issue in certain regions.

The flowering and reproductive stages of growth are the most affected by temperatures above the threshold, since flower opening usually occurs in cool seasons.

Each life cycle stage has different responses to heat stress:

- At fertilisation – specialised cell division that occurs as part of flowering, heat stress causes ovule and pollen sterility along with the splitting open of the anthers;
- During pollen development, temperatures >30°C causes pollen abortion;
- At anthesis, heat stress limits resource translocation to developing grain, resulting in small grain and low yields; and
- During grain development, heat stress shortens the grain-filling duration and decreases starch and protein accumulation.

Scientific reviews of research point to long-term reductions in productivity from the chronic effects of climate change. One review noted the impacts as below[26]:

- Globally, a 6% yield loss in wheat has been projected for each extra degree in global mean temperature, if no CO_2 fertilization, effective adaptation in management practices nor crop genetics were considered (Asseng et al., 2015, Zhao et al., 2017);
- From 1990 to 2015, simulated water-limited potential yields of wheat in Australia have declined by 27% likely due to reduced rainfall and increased temperature that were only partly compensated by a positive impact of increased atmospheric CO_2 concentration (Hochman et al., 2017); and
- Global warming has complex effects on crops, due to changes in occurrence and intensity of abiotic stress factors, CO_2 fertilisation, and acceleration of crop development at higher temperatures (e.g. Lobell et al., 2015). For current farming practices, wheat yield in Australia has been projected to decrease by 2050 under RCP4.5 and RCP8.5 (Wang et al., 2018, Ababaei and Najeeb, 2020), even when ignoring direct impact of heat and frost on grain set and size.

When Hochman Z and H Horan (2018)[27] studied heat stress impacts on wheat they found the impact was correlated to growth stage and the maximum temperature in one day. The table below is adapted from their paper.

Growth Stage	Maximum Temperature in One Day	Yield Potential Reduction
growth stage is > = Z60 (first flower) and < Z79 (end of grainfilling)	> 32 °C and = < 34 °C	10%
growth stage is > = Z60 and < Z79	> 34 °C and = < 36 °C	20%
growth stage is > = Z60 and < Z79	> 36 °C	30%

26 2021 Collins, B and Chenu K Improving productivity of Australian wheat by adapting sowing date and genotype phenology to future climate. From https://www.sciencedirect.com/science/article/pii/S2212096321000292#s0130

27 2018 Hochman Z and H Horan Causes of wheat yield gaps and opportunities to advance the water-limited yield frontier in Australia. From https://www.sciencedirect.com/science/article/abs/pii/S0378429018304040

HORTICULTURE

The range of fruits and vegetables grown and the range of varieties within each fruit or vegetable species make it complex to characterise the likely impacts of climate change in horticulture. We have restricted our comments to themes that touch on many horticultural crops with occasional specific examples.

Both the chronic impacts of temperature and the acute effects of rainfall will have effects on productivity.

Rainfall being more intense and less distributed in time will increase the risk of physical damage to many crops, and of water splash costing more in terms of management effort around fungal diseases and product packing. Irrigation may be required more frequently, calling on water storage facilities. The risk of erosion from the volume and intensity of rainfall will increase, putting emphasis on erosion mitigation strategies for all producers. Ground cover will be an increasingly important first line of defence.

Intense rainfall events also result in more rainfall running off. It is well-known that frequent smaller rainfall events replenish soil moisture more effectively, reducing energy costs to the farm. There is a strong possibility that there will be more periods where soil moisture falls below desirable levels.

The more difficult challenge comes from temperature range change. There are two parts to this problem:

1. Minimum night temperatures will not be as low as prior to 1980. There will be fewer chilling hours in many regions. Instances of damaging frosts will probably retreat southwards.
   In some regions, the total chilling hours requirement for a crop may not be met consistently. This is already affecting commodities such as cherries and oranges in some locations.
2. Temperatures above critical thresholds is a parallel issue. Soil temperatures control growth, but with thresholds at both ends. Higher soil temperatures affect planting windows.
   Air temperatures higher than the upper threshold for the commodity typically damage flowering and pollination, and the optimum rate of maturing of the crop. Many commodities are susceptible to this risk.

The solution to this problem may be a step change, not a smaller adaptation.

SHEEP

Sheep production is affected at both ends of the temperature scale. The acute impacts of a greater number of days exceeding the heat stress level are more significant and more likely going forward than the impacts of low temperatures. Nonetheless, the greater frequency of extreme weather events is likely to change the risks of lamb mortality.

Heat stress thresholds vary by breed. Thresholds are noted in the literature at 25°C - 31°C, 32°C and 35°C. The impacts are of the same nature:

- A decrease in mating activity;
- Lower birth weights;
- Reduced appetite, leading to a decrease in milk production; and
- An increase in lamb mortality.

Body temperature balancing is lower in wool sheep, especially breeds from Britain. The insulating effects of wool can be helpful with both ambient heat energy and direct radiant energy reduced by some wool types. The counterbalancing effect is that wool reduces heat loss through the animal sweating.

It may be increasingly important to manage the flock's Temperature Humidity Index (THI). THI is commonly used as an indicator of the degree of climatic stress on animals where a THI of 72 and below is considered as no heat stress (cool), 73–77 as mild heat stress (HS), 78–89 as moderate and above 90 as severe.

Heat stress occurs when the combination of environmental conditions, i.e. air temperature, relative humidity, air movement or solar radiation cause the effective temperature of the environment to be higher than the animal's comfort zone. For an adult sheep with full fleece this comfort zone is between −12°C and 32°C.

This suggests wool cover restricts productivity in sheep in a hot environment by restricting evaporative and other ways to shed potentially damaging body heat.

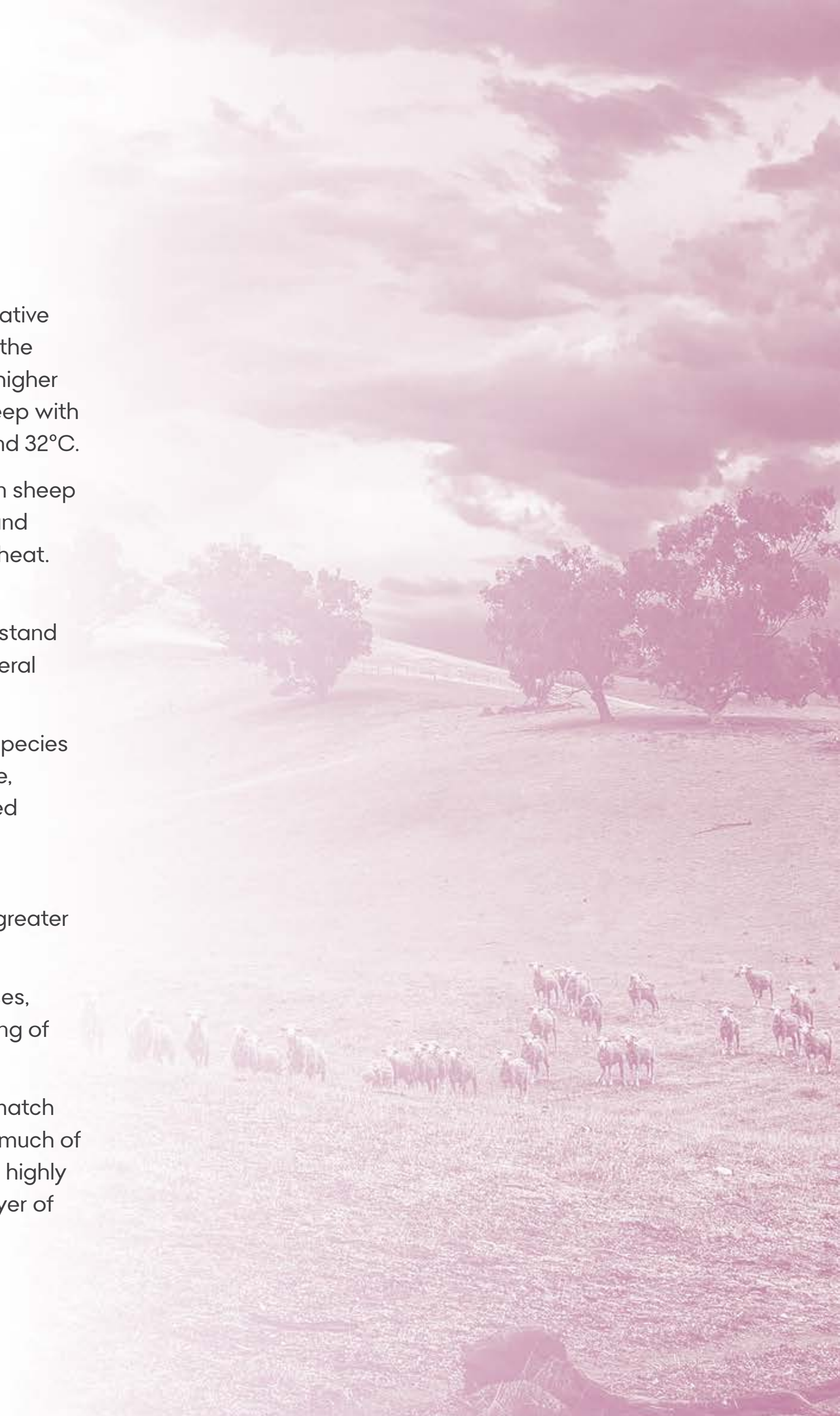
Merino lines have a well-recognised capacity to withstand more heat stress. The breed can withstand an external temperature as high as 43°C for several hours, provided humidity is less than 65%.

Among the chronic effects, temperate pasture species are less productive as average temperatures rise, adding feed changes to the challenge of reduced appetite.

Higher minimum temperatures may reduce the frequency and severity of weather that causes greater lamb mortality and post-shearing losses.

An increase in the incidence of pests and diseases, including changes in types of pests and the timing of the season for individual pests is very likely.

Chronic impacts also include an increasing mismatch between water resources and stock demand in much of Australia. As noted previously, rainfall is naturally highly variable, but climate change will add another layer of uncertainty into the mix.



WOOL

The likely impacts of climate change on wool production are in concert with other agricultural industries. The industry is not immune to the forces of change that will prompt transitional adjustments to the composition of agriculture pursuits in some regions.

The chronic physical impacts of climate change on resources, feed and water, and animal health will prompt reassessments of long-term fit of grazing and cropping in locations that have historically served them well.

Likely climate change scenarios will prompt a reassessment of pastoral sheep zones as:

- Increased variability and uncertainty of rainfall will reduce pasture production and watering points and produce feed gaps as temperate fodder species growing season is reduced;
- Chronic thermal stress reduces productivity / growth rates with heat induced appetite suppression;
- Warmer temperatures and accompanying humidity contributing to temperature-humidity index being exceeded more frequently may reduce reproductive performance of rams and may increase lambing losses depending on the timing of lambing. Conversely lambing percentages could be assisted by a reduction in acute cold-stress events; and
- More generally there are likely to be changes in the incidence of pests and diseases due to the changes in average weather. Higher humidity in summer and more rainfall will encourage greater numbers of blowflies. Other parasites that become management problems in cooler wet weather may reduce in significance. Overall, a change in the timing and focus of management effort is likely to be required. It may become more costly.

Wool researchers have considered the overall effects of these factors because they can interact with each other. The interactions vary between region however, consistent between these is the need for management to adapt fodder quality, water management and animal health. The net effect can be variations in wool quantity and quality i.e. increased in vegetable fault, contamination, micron, staple length and strength.

These integrated factors deserve consideration when making or reviewing strategic plans for the business. There is a possibility that the interaction with other industries dealing with similar considerations may result in competition for land, resulting in reduction of wool production or a change in the profile of wool produced which is unrelated to demand.

Regional Impacts

Summary

We cover anticipated climate changes by state. The keen reader can cross-reference their agricultural industry with their state for a generalised guide as to what the research and modelling suggest - and what impact it could have on their business in the near to medium future.

We provide readers with a summary of anticipated impacts of climate change by state with two maps showing projected days above the 35°C threshold for heat stress. We also decided to compare two eras that are within the strategic planning horizon for many farm businesses and therefore provide two a decade apart.

The values shown for each map are as noted the ***additional*** heat stress days for that location. The months of December, January and February were selected as summer months, covering risk periods for many agricultural commodities from dairying through cropping and extensive grazing.

Climate change has impacts that vary by district, microclimate and regional geography. Larger geographies lead to larger generalisations about impacts - and more uncertainty, so it is difficult to make business decisions with this level of generalisation. It is however an important step in setting a state-wide context, despite that state boundaries are not the natural boundaries of broader ecosystems.

From the viewpoint of farming businesses, the climate change that matters is very local to their operations. Chronic changes of average temperature per month and acute events such as days with temperatures above the threshold relevant to their business (commonly 35°C) intense rainfall, floods, and fires are the events that will be front of mind. The acute events may lend themselves to adaptation more so than the chronic conditions.

The chronic condition that impacts most on productivity is temperatures above the thresholds for each specific commodity. The cumulative impact of the chronic changes may the more significant ones, and as significant as drought for some commodities.[28]

Projections

In this section, we elected to provide readers with a summary of anticipated impacts of climate change by state with two maps showing projected days above the 35°C threshold for heat stress.

The CSIRO projections that we used in developing the maps are based on an era from 1986 to 2005. For each month in the year, CSIRO modelled the average number of days above the heat stress threshold. The data source has measured or extrapolated values for each square five km by five km area in the country.

By comparing the maps, users will be able to identify zones of change in heat stress days across a time horizon that has a human scale. The maps share a legend showing a range from 0 days to 90 days to enable that comparison of like with like.

Rainfall impacts uncertain

Predicting future rainfall is far more complex than future temperature, due to the uncertain effects of local terrain on rainfall and the many overlapping effects of climate drivers, such as the Indian Ocean Dipole, and the El Nino Southern Oscillation. Some state governments report general rainfall changes over long timeframes, but future monthly rainfall projections are subject to far more uncertainty than longer term general trends. For this reason, changes in monthly rainfall over shorter intervals were not provided.

Further analysis over time may reveal ways to identify meaningful trends in rainfall as data sets improve, especially given potential changes in climate drivers.

28 2023 Univ Qld submission to Parliamentary inquiry into the impacts of climate change on Queensland's agricultural production. from https://documents.parliament.qld.gov.au/com/SDRIC-F506/IQ-81CF/submissions/00000003.pdf

Climate Change impacts in Queensland

Queensland's climate is projected to continue to change over the coming decades. By mid-century, the following changes are projected[39]:

- Queensland will continue to get hotter into the future;
- Under the business-as-usual/high emissions scenario (RCP8.5), Queensland can expect an average annual temperature increase of around 1.3-2.5°C (central estimate of 1.9°C);
- The number of heat stress days (>35°C) will increase from approximately 2 to 8 days per year in Brisbane and from approximately 4 to 14 days per year in Toowoomba;
- Extreme rain events in Queensland are projected to become more intense, increasing the risk of crop flooding in some regions;
- As a whole, Queensland is likely to become drier in the May-October period. In the monsoon region, the change in average annual rainfall change is unclear. Significant change is possible. Both wetter and drier futures should therefore be considered equally likely; and
- In the future, east coast lows are projected to decrease by up to 20% under the business-as-usual scenario, primarily during winter.

The projections in this summary are given for 20-year periods centred on 2030 and 2070. The 2030 high and low emissions scenarios are so similar that only the high emissions scenario has been used in this publication. Projections are represented as a change relative to the average for the period 1986–2005.

For example, in 2070 under a high emissions scenario, average temperature in Queensland is projected to rise by 2.9°C (1.9 to 3.9°C). In this case, the middle temperature rise determined by all the models is 2.9°C. The range is between 1.9°C and 3.9°C, meaning 95% of model results indicated a rise of at least 1.9°C and 95% of the model results indicated a rise of 3.9°C or less.

Maximum, minimum and average temperatures are projected to continue to rise. For the near future (2030), the annual average warming is projected to be between 0.5°C and 1.5°C above the climate experienced between 1986 and 2005. By the year 2070, the projected range of warming is between 1.2°C (low emissions) and 3.9°C (high emissions from business as usual).

There is likely to be a substantial increase in the temperature reached on the hottest days, and an increase in the frequency of hot days and for the duration of warm spells. A substantial decrease in the frequency of frost risk days is projected by 2070.

In January 2023, Queensland initiated a parliamentary inquiry into the impacts of climate change on Queensland's agricultural production. Public submissions are accessible at https://www.parliament.qld.gov.au/Work-of-Committees/Committees/Committee-Details?cid=0&id=4232. The report from the Inquiry is not yet finalised.

This analysis is essential not only for agriculture, but across the economy. There is a good deal of worthy information in the public domain about impacts on human beings and biodiversity. There is less information in the public domain about the economic impacts, so wider public discussion should enable a better range of proposed solutions to come forward for consideration and assessment.

The University of Queensland's submission noted[40]:

There can be a significant loss of yield if crops are exposed to high temperatures at the wrong time. Our research shows that drought will continue to play an important role in the two main grain crops of the region (wheat and sorghum). Heat directly impacts the yield of these crops when it coincides with flowering and grain set, causing abortion of grains. We estimate that aggregate yield impacts of direct heat stress by mid-century may equal drought impacts for wheat and be as much as half as important as drought for sorghum.

39 From https://www.climatechangeinaustralia.gov.au/en/changing-climate/state-climate-statements/queensland/

40 2023 University of Queensland submission to the Parliamentary Inquiry into the Impacts of Climate Change on Queensland's Agricultural Production. from https://documents.parliament.qld.gov.au/com/SDRIC-F506/IQ-81CF/submissions/00000003.pdf

These results indicate that efforts to adjust sorghum and wheat systems (including development of new varieties) to cope with (or escape) extreme heat will be an important part of agricultural adaptation to climate change in this region; a continued focus on drought will not be enough.

Warmer temperatures already reduce the life cycle of wheat and will cause flowering to be 2-3 weeks earlier by 2030.

The warming climate and more frequent extreme heat events will be one of many contributors to changes in the cropping systems present in a geographical region. Recent examples of regional cropping system changes include the expansion of the cotton growing region into Victoria and the transition from sugar to horticultural crops such as macadamia and avocado taking place around Bundaberg."

For some high-value crops, migration to vertical farming may be a viable solution in terms of 'transitioning'. Such measures may also solve a number of other issues including proximity to wholesalers to enable rapid delivery of product and managing for temperature, however, intensive controlled cultivation presents multiple challenges as well. The reduction in pest issues may be overstated in research as compared to enclosed commercial facilities.

As we described above there can be cascading and interacting effects of climate change across many domains. The University's submission noted this interaction with regard to the areas of animal nutrition, animal behaviour, physiological changes, animal wellbeing, as well as on the sustainability of environment, economic, and human health and welfare. Climate change will impact further on water availability, pasture and forage availability and quality, along with animal diseases and pest distribution. There is also the likelihood of increased transmission of animal diseases through both domesticated and native animals. The pressure from some pests may also reduce due to unfavourable climate conditions.

On the next page are two maps each showing days of *additional* heat stress (days above 35°C) above the era 1986-2005. The values shown for each map are as noted, the *additional* heat stress days for that location. The left-hand map shows the heat stress days for summer 2023-24. The right-hand map shows the heat stress days for summer 2034-2035. The months of December, January and February were selected as summer months.

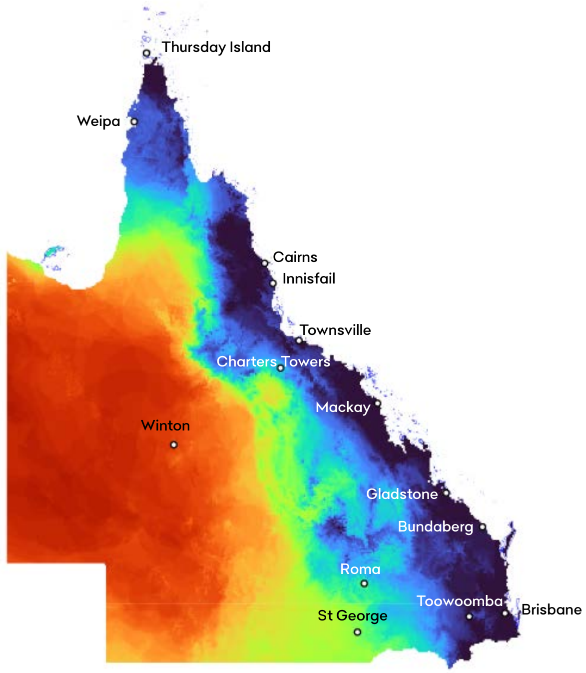
Additional Days above 35°C

The baseline era is 1986-2005.

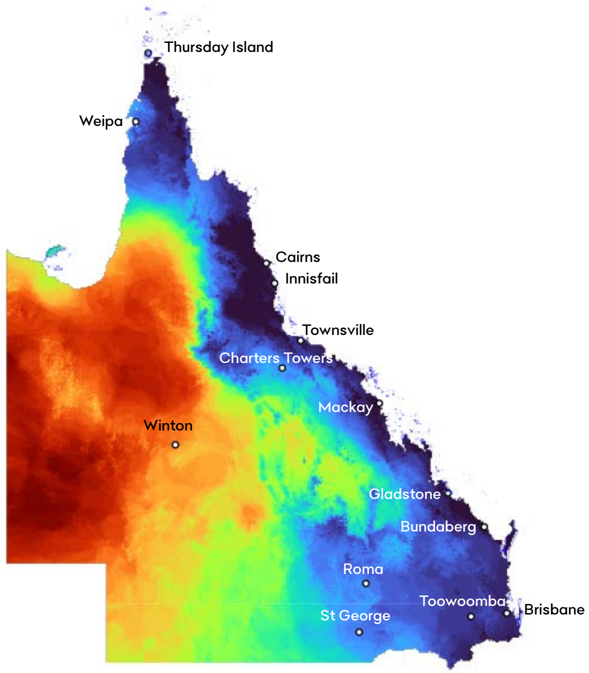
Readers will detect the change in extra heat stress days between the two eras shown in the maps.

In the western Fitzroy and parts of the Central West, the warming area grows east towards the coast and is stronger in the 2034-35 era.

Also visible in the same era is an area of less heat stress west of Toowoomba.



Predicted additional days above 35°C in Summer 2023-24



Predicted additional days above 35°C in Summer 2034-35

Additional days above 35°C compared to 1986-2005

Climate Change impacts in New South Wales (NSW)

In 2021, the NSW Office of Environment and Heritage (OEH) carried out an analysis of climate change for the state as a whole, breaking it down into regions. The documents characterise two eras chosen by OEH: the near future (2020–2039) which OEH labels 2030 and far future (2060–2079) labelled 2070. It should be noted that these projections were released in 2021. Current consensus suggest conditions now make it likely that we cannot avoid a rise in average global temperature of about 1.5°C.

Below we extract some of the key points that may be of interest to farming businesses and their networks. Following their guidance and projections, we comment on some potential challenges and opportunities that could arise. The projections are extracted and adapted from the NSW climate change snapshot[38]:

- NSW is expected to experience an increase in all temperature variables (average, maximum and minimum) for the near future and an even greater increase in the far future;
- Maximum temperatures are projected to increase by 0.7°C in the near future and up to 2.1°C in the far future. Summer and spring will experience the greatest change with maximum temperatures increasing by up to 2.4°C in the far future. Increased maximum temperatures are known to impact human health through heat stress and increasing the number of heatwave events;
- Minimum temperatures are projected to increase by 0.7°C in the near future and up to 2.1°C in the far future. Increased overnight temperatures (minimum temperatures) can have a significant effect on human and animal health especially during heatwaves. The greatest increases in average temperatures are projected for the northwest of the state during summer. Increases in temperatures are projected to occur across all of the state but vary by region (see regional notes below);
- The number of hot days in NSW increases with distance inland, ranging from no days in the more mountainous parts of the state, fewer than 10 days per year near the coast and more than 80 hot days per year in the far north-west. Seasonal changes in hot days could have significant impacts on agricultural production because temperature thresholds will be exceeded more often with implications for many industries. Bushfire danger, infrastructure development and native species diversity are also expected to be affected;
- NSW is expected to experience more hot days in both the near future and the far future;
- The greatest change is projected for the northwestern NSW region with an additional 10–20 hot days in the near future increasing to over 40 additional hot days per year by 2070. Currently this part of the state experiences between 50 and 80 hot days each year. These projections suggest that by 2030, up to 100 days per year may exceed heat stress thresholds. By 2070 parts of north-western NSW may experience temperatures above the 35°C heat stress threshold across four months annually;
- Areas east of the Great Dividing Range and along the coast experience fewer hot days than inland regions. Along parts of the coast and Ranges, the number of hot days is projected to increase by up to an additional 20 days per year by 2070. These increases in hot days are projected to occur mainly in spring and summer although in the far future, hot days are also projected to extend into autumn;
- NSW is expected to experience fewer cold nights in the future. The changes will occur across all seasons, with the largest decreases during winter and spring;
- The greatest changes are projected to occur along the Great Dividing Range including the Snowy Mountains, with 10–20 fewer cold nights in the near future, and over 40 fewer cold nights by 2070. There could be positive impacts for industries damaged by frost, and negative impacts where chilling hours are essential, such as temperate-climate fruits; and
- Minor changes are projected for coastal NSW and the far west. Approximately 5–10 fewer cold nights are projected for the western slopes and plains.

38 https://www.climatechange.environment.nsw.gov.au/sites/default/files/2021-06/NSW%20climate%20change%20snapshot.pdf

Regional Summaries

North-east NSW

The north-east of the state is projected to have decreases in rainfall in summer and winter by 2030. By 2070 most models project a decrease in winter rainfall along the coast and an increase in winter rainfall inland.

The north-east is projected to have increases in rainfall during autumn and spring by 2030. By 2070 the north-east is projected to have increased rainfall in autumn and summer, and spring (along the coast).

North-west NSW

The north-west of the state is projected to have increases in summer and autumn rainfall in the near and far future and decreases in spring rainfall in the near and far future.

The north-west is projected to see decreases in winter and spring rainfall in the near future. Decreases in spring rainfall persist, but by 2070 changes in winter rainfall patterns are less certain.

South-east NSW

The south-east of NSW is projected to have increases in summer and autumn rainfall with greater increases by 2070.

The south-east is projected to see decreases in winter and spring rainfall, with greater declines by 2070, particularly along the south coast in winter.

South-west NSW

The south-west of the state is projected to have increases in rainfall during summer and autumn in the near and far future, while spring rainfall decreases. Winter rainfall decreases in the near future but changes in winter rainfall patterns in the far future are more variable.

More details of regional impacts of climate change are available at https://www.climatechange.environment.nsw.gov.au/resources-and-research/regional-climate-change-snapshots

On the next page are two maps each showing days of *additional* heat stress (days above 35°C) above the era 1986-2005. The values shown for each map are as noted, the *additional* heat stress days for that location. The left-hand map shows the heat stress days for summer 2023-24. The right-hand map shows the heat stress days for summer 2034-2035. The months of December, January and February were selected as summer months.

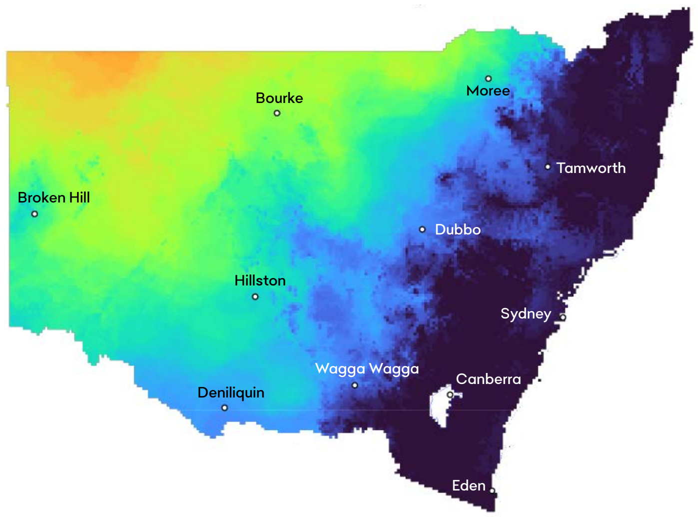
Additional Days above 35°C

The baseline era is 1986-2005.

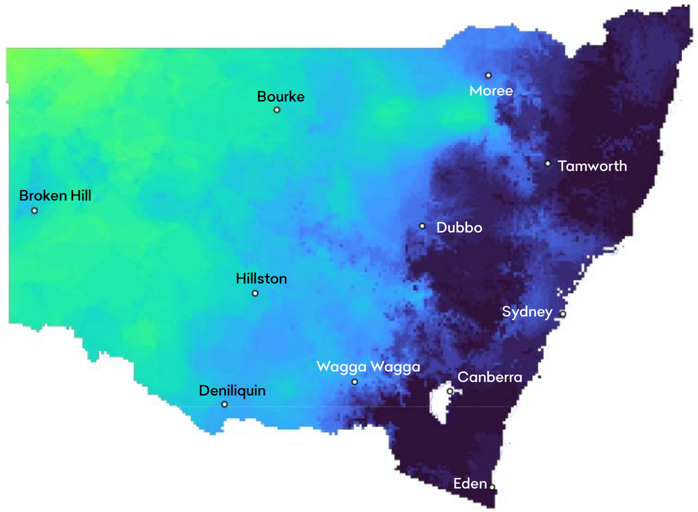
Readers will detect the change in extra heat stress days between the two eras.

In the western half, the increase becomes more evenly spread and with slightly fewer days.

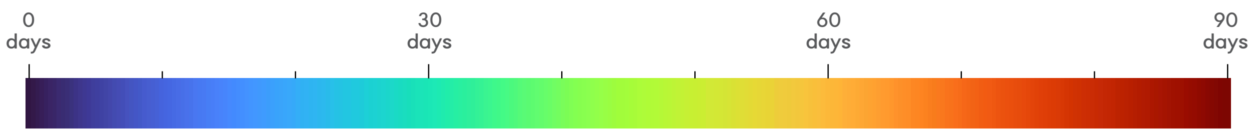
In the central west, the 2034-35 era shows more days of heat stress in summer.



Predicted additional days above 35°C in Summer 2023-24



Predicted additional days above 35°C in Summer 2034-35



Additional days above 35°C compared to 1986-2005

Climate Change impacts in Victoria

As a result of climate change, Victoria is likely to become hotter and drier from the north towards the south. In addition, the availability of fresh water is likely to become more critical.

Comparison of observations and projections in Victoria suggest that temperature has been tracking towards the upper limit of projections while winter rainfall has been tracking towards the drier end of projections. Annual rainfall is projected to decrease across the state, due to declines across autumn, winter and spring.[34] The decrease follows the trend of weather systems. The usual storm tracks are shifting southwards due to changes in climate drivers. As a result, drier conditions may progressively push into southern regions. Local-scale projections show greater reductions in rainfall on the windward (western) slopes of the Victorian Alps in autumn, winter and spring.
It may be prudent to expect weather patterns to be different across much of the state well into the future.

Heat stress days are those where the temperature exceeds 35°C. For almost all agricultural industries, that threshold signals likely reductions in productivity, as well as risks to workers.

The Victorian Climate Projections 2019 (VCP19)[35], developed by CSIRO's Climate Science Centre is a government program providing local-scale climate projections for Victoria. The following is snapshot from VCP19 of climate projections for the key cropping regions of Victoria, the Wimmera and Mallee.

Results are shown for two plausible scenarios of future greenhouse gas emissions: medium emissions (RCP4.5) and high emissions (RCP8.5 or business-as-usual).

Temperature

Victoria's temperature increased by just over 1°C between 1910 and 2018. This warming is expected to continue and as a result, temperatures in the Wimmera and Mallee will also increase.

Under the high global emissions scenario described earlier on page 35 as RCP8.5, maximum temperatures in the Wimmera Southern Mallee are expected to increase by 1.3°C by the mid-2030s, compared to the average in the 1986–2005 reference era. By 2050, the increase is likely to be greater, with a median of 2.2°C.

Observed temperature in Victoria is tracking towards the upper limit of projections

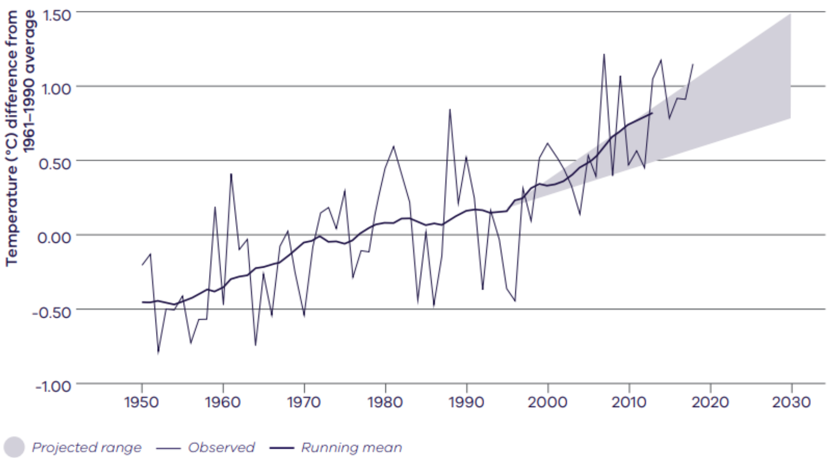


Figure 12: Comparison of the observed average annual temperatures for Victoria with the projected range of change. Shown are observed temperature difference from 1961-1990 average (thin black line) plus the 10-year running average (thicker line), and the projected temperature change to 2030 across climate models and emissions scenarios (relative to a 1986–2005 baseline period). For more details on the method, see Grose et al. (2017b) (CSIRO, 2019).

34 https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf
35 https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0035/429884/Wimmera-Southern-Mallee-Climate-Projections-2019_20200219.pdf

Rainfall

Rainfall in Victoria has declined in most seasons over recent decades, with the greatest decreases in the cooler seasons. The Wimmera Southern Mallee's rainfall is naturally highly variable, and this natural variability will dominate the rainfall received over the next decade or so.

Over time, annual rainfall totals are likely to decline, particularly under high global emissions, with the greatest decline being in spring. By late century, the climate change trend becomes obvious compared to natural variability (not shown) with a median 26% decrease in annual totals, with a 32% decrease in spring.

Observed winter rainfall in Victoria is tracking towards the drier end of projections

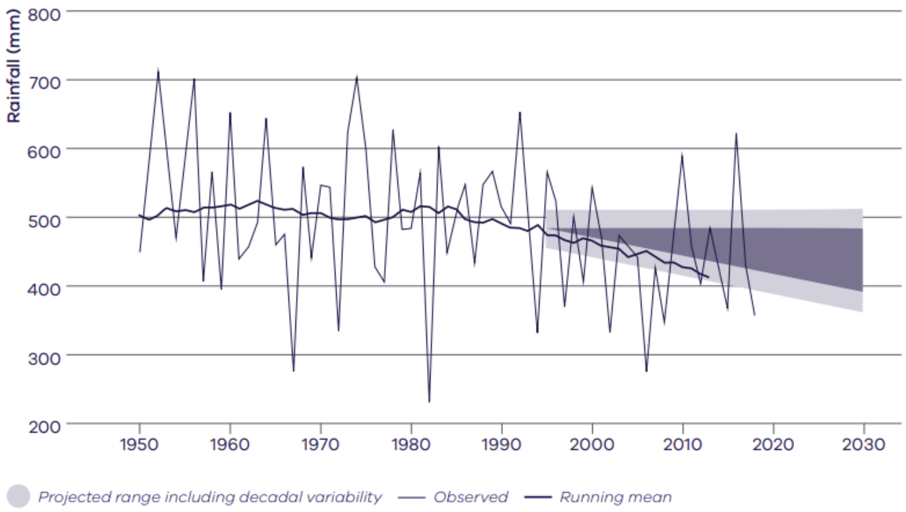


Figure 13: Observed rainfall averaged over Victoria (Australian Water Availability Project; thin black line) plus the 10-year running mean (thicker line), and the projected rainfall change to 2030 across climate models and emissions scenarios (relative to a 1986–2005 baseline period) (dark grey shading) plus an indication of decadal variability (light grey shading; one standard deviation of 10-year running average from the observations). For more details on the method, see Grose et al. (2017b) (CSIRO, 2019).

Evaporation projections by CSIRO suggest increased evaporation of surface moisture towards 2040. Some regions are favoured by reliable rainfall due to local factors. Regions such as the southern Otways and southeast Gippsland show the long-term positive effects of these microclimatic local conditions.

Infiltration of rainfall into soils will assist in optimising available rainfall. In general, well-structured soils provide good infiltration. Managing to optimise soil structure and soil organic matter will support this. Areas with high clay at or near the surface are likely to experience less infiltration and higher evaporation. As noted earlier, rainfall is not always linearly related to groundwater recharge and surface water storage. Small reductions in rainfall may result in much less recharge of storages.

For agriculture, the integrated effect of higher temperatures causing more plant water demand, and damage to physiological stages such as crop flowering, sunburn of some crops, and stress on animals, combined with reductions in rainfall and soil moisture stand to present significant challenges to farm businesses. When considering strategic plans, there may be limits to incremental adaptation. As the adaptation plans document suggests[36], within 15 years, farm businesses should have given due consideration long term climate projections and developed a strategic plan. That plan may include in some regions, a transition rather than adaptation.

On the next page are two maps each showing days of *additional* heat stress (days above 35°C) above the era 1986-2005. The values shown for each map are as noted, the *additional* heat stress days for that location. The left-hand map shows the heat stress days for summer 2023-24. The right-hand map shows the heat stress days for summer 2034-2035. The months of December, January and February were selected as summer months.

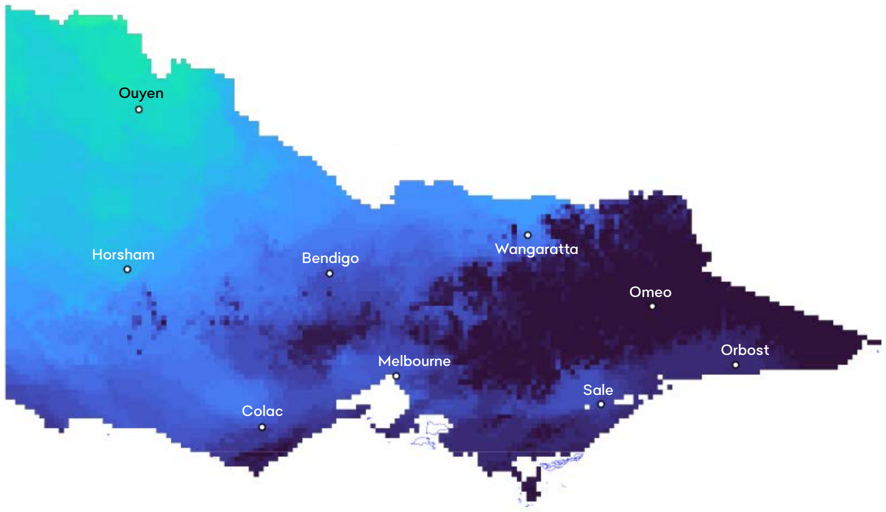
36 https://www.climatechange.vic.gov.au/building-victorias-climate-resilience/our-commitment-to-adapt-to-climate-change/primary-production-adaptation-action-plan

Additional Days above 35°C

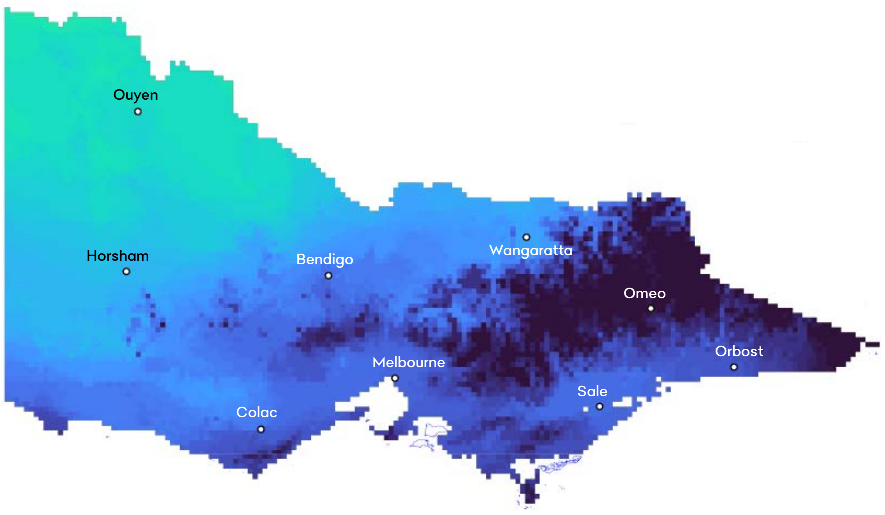
The baseline era is 1986-2005.

Victoria shows the increased heat stress days particularly in the western part of the state where the 2034-35 era shows a widening of the area experiencing more heat stress days and a push southward.

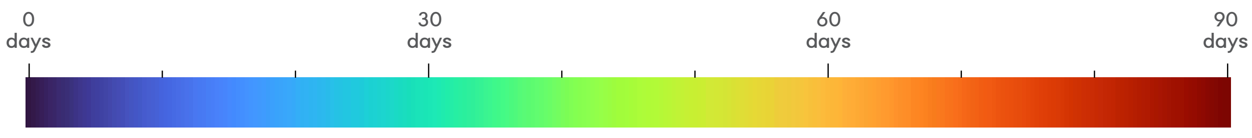
Gippsland also shows changes in the same era.



Predicted additional days above 35°C in Summer 2023-24



Predicted additional days above 35°C in Summer 2034-35



Additional days above 35°C compared to 1986-2005

Climate Change impacts in Tasmania

Climate change predictions in Tasmania have suggested that the temperature rise will be less than for most of the rest of Australia. The moderating influence of ocean temperatures and currents reaches to most regions of the island state. Mean annual rainfall is projected to change regionally.

Though the amount of change in rainfall seems not to be dramatic, the combination of changed rainfall and higher temperatures will have strong influences on agriculture.

Tasmanian agriculture has been limited by temperature more than by rainfall. Mean annual rainfall is not projected to change greatly throughout the 21st century under the business-as-usual/high emissions scenario. There will continue to be variability across the decades. The projections indicate some regional changes of significance:

- An increase of 20% to 30% in summer and autumn rainfall along the east coast;
- A decrease on the west coast by 15% in winter and 18% in summer; and
- A decrease in all seasons on the central plateau.[37]

Due to a combination of the latitude, proximity to the ocean and rainfall patterns, temperature has historically been a major driver for the choice and management of crops. Under rising temperatures, it will continue to be the major driver and may prompt adaptations, transitions and migration of agricultural businesses.

Even subtle changes in the projected amount or seasonal distribution of rainfall, or projected changes in temperature and evaporation rates, may influence outcomes such as seasonal crop and pasture growth patterns, nutrient and irrigation requirements, and water availability.

Small changes in average temperature can have large impacts on agricultural production. For example, the increasing temperature is predicted to drive an increase in evaporation of up to 19%. Chill hours are projected to decrease in the lower-elevation warmer regions and increase at higher elevations.

The researchers noted that the incidence of frost is likely to reduce substantially by the end of the century with many sites likely to experience less than half the current number of frosts. The period of frost risk is projected to shorten from March-December to just May-October for many areas in Tasmania but there may still be damaging late winter and spring frosts, especially since bud burst is likely to occur earlier.

Since climate change is not a simple slope of rising temperatures, growers may still experience damaging late winter and spring frosts during bud burst which itself may occur earlier in the calendar year. Yields and quality of high-chill fruit varieties, such as for some cherries, may be adversely affected in lower-elevation, warmer coastal areas.

Dryland pasture production from ryegrass and other C3/temperate species is projected to increase by 10% to 100% depending on region by 2085. Areas that are currently temperature-limited will experience the greatest increases, mainly through an earlier start to spring and higher growth during spring and early summer. Substantial increases in annual yield of phalaris-sub clover pastures are projected for the Midlands to the middle of the century but thereafter to decline in response to hot summer days.

The contribution from sub clover is projected to increase by about 50% throughout the century as this winter-growing species benefits from increased winter temperatures. Yields of irrigated pasture are projected to increase until around 2040 and thereafter decrease due to high temperatures during the summer months.

Temperature and moisture changes will influence the survival, behaviour and interactions among pests in Tasmania. These changing conditions will increase suitability for a wide range of exotic pests of crop plants as well. The range of significant vertebrate and invertebrate pests, weeds and diseases is likely to change, as is the timing and duration of their presence. Pest monitoring and responses will need to cover a wider scope going forward.

Land use is likely to change in Tasmania and Australia generally in response to a changing climate. Increasing temperatures on currently temperature-limited land (in particular, high-elevation areas) will allow for more choices that are likely to lead to changes to land uses.

On the next page are two maps each showing days of *additional* heat stress (days above 35°C) above the era 1986-2005. The values shown for each map are as noted, the *additional* heat stress days for that location. The left-hand map shows the heat stress days for summer 2023-24. The right-hand map shows the heat stress days for summer 2034-2035. The months of December, January and February were selected as summer months.

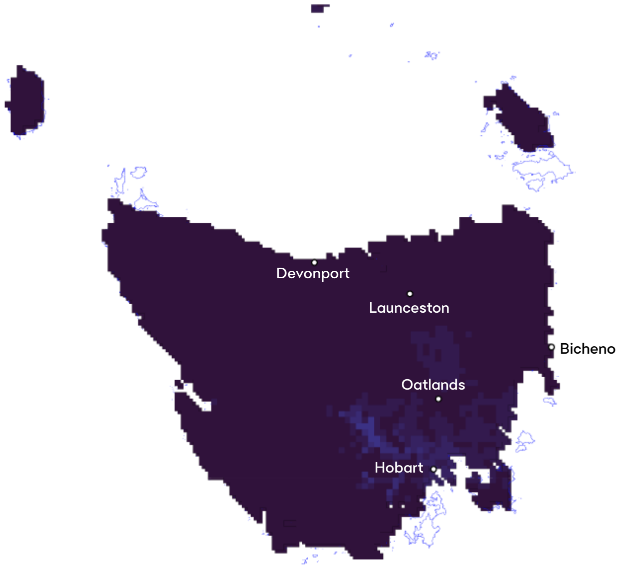
37 2010 Impacts on Agriculture – Technical Report (Full Report) found at https://climatefutures.org.au/wp-content/uploads/2023/05/Impacts-on-Agriculture-Technical-Report-Full-Report.pdf

Additional Days above 35°C

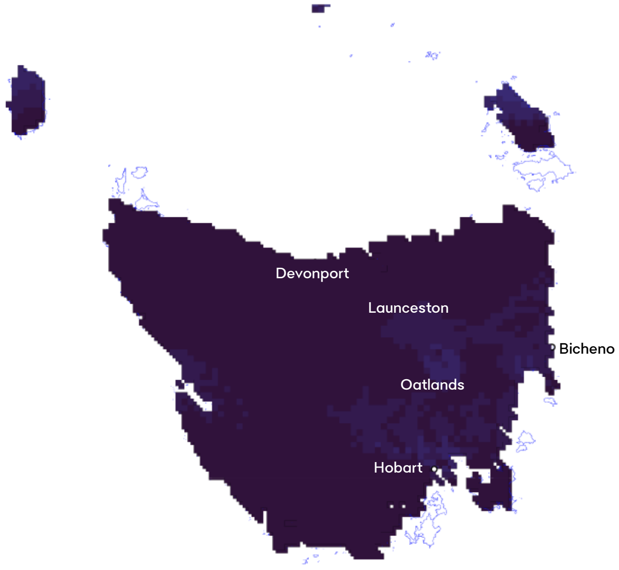
The baseline era is 1986-2005.

Readers will note that Tasmania generally is projected to experience little additional heat stress.

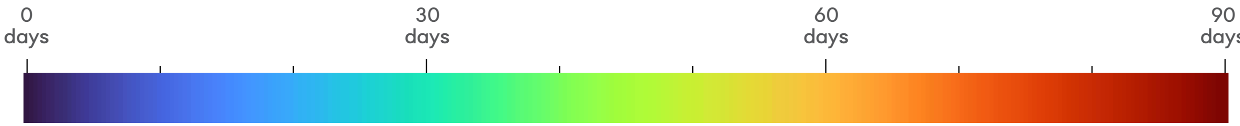
Northern Midlands and Central and Southern Midlands are likely to experience a few more heat stress days. If these are accompanied by warmer days either side, there may be pasture benefits.



Predicted additional days above 35°C in Summer 2023-24



Predicted additional days above 35°C in Summer 2034-35



Additional days above 35°C compared to 1986-2005

Climate Change impacts in South Australia (SA)

The South Australian Department for Environment and Water prepared detailed analysis of the potential changes to the future climate across the state and in some landscape regions.

Below we have extracted some of the key points that may be of interest to farming businesses and their networks. Following the Department's guidance and projections, we comment on some potential challenges and opportunities that could arise.

The average temperature in SA is rising at a higher rate than the average land temperatures worldwide. The state has experienced a strong warming trend since the 1970s, with average temperatures currently 1.1°C warmer than in the 1970s. Climate projections forecast further temperature increases and more days above 40°C by 2050.

Rainfall trends vary across the state. In SA's southern agricultural areas, rainfall is declining in the window of April to October.[30]

Projections for Temperature Change

By 2030 mean annual *maximum* temperatures are projected to increase by up to 1.3°C across the state, with a greater increase projected in the north. In the fire-prone Adelaide Hills and in the Fleurieu regions, mean daily *maximum* temperatures are projected to increase by 1.0°C.

In the same time frame, mean *annual minimum* temperatures are projected to increase by up to 1.1°C. In the Limestone Coast region, annual mean *minimum* temperatures are projected to increase by 0.8°C. By 2050 mean *annual minimum* temperatures are predicted to increase by up to 1.7°C.

Across all SA regions, warming in spring is likely to be greater than in any other season. By 2030, mean daily maximum spring temperatures are projected to increase by up to 1.6°C across the state. In the Northern and Yorke and Eyre Peninsula regions, mean daily spring maximum temperatures are projected to increase by 1.3°C.

Mean daily maximum winter temperature increases of up to 1.1°C can be expected. The Northern and Yorke and Eyre Peninsula regions may see a daily maximum winter temperature rise of 1.0°C.

By 2050, mean maximum spring temperatures are projected to increase across the state by up to 2.7°C; mean maximum winter temperatures are projected to increase by about 2.0°C. In the Northern and Yorke regions, mean daily spring maximum temperatures are projected to increase by 2.2°C compared to 1.7°C for mean daily winter maximums.

Despite continued warming, the number of frost days and length of the frost season has increased in recent decades, as a result of changing atmospheric conditions that brought more very cold air from further south. Research suggests that frost frequencies over the August to November period will remain comparable to current levels until the early part of the 2030 decade. After this point it is forecast that frost frequency will decline.

Predictions for Rainfall Changes across the State

Annual rainfall will decline across all SA regions.

By 2030, annual rainfall across the state is projected to decline by 1.7%–6.8% from the baseline period of 1968-2005.

The Murraylands and Riverland regions are projected to have the greatest decline at 6.8%. The Northern and Yorke and Eyre Peninsula regions are projected to have declines of 6.6%, and 4.6% respectively. A decline of 1.7% is projected for the Limestone Coast region.

By 2030, rainfall declines are projected for all regions for spring and autumn. Declines are greater in spring than any other season. At the higher end of rainfall decline is a predicted 8.8% decline in the Limestone Coast region.

By 2050 rainfall declines are projected for all regions in all seasons, with minor exceptions.

Potential evapotranspiration[31] is projected to increase across all seasons and regions in SA. Potential evapotranspiration provides an indication of the potential water stress of crops and other vegetation.

30 2022 Department for Environment and Water. Guide to Climate Projections for Risk Assessment and Planning in South Australia 2022, Government of South Australia, through the Department for Environment and Water, Adelaide. Available at https://data.environment.sa.gov.au/Content/Publications/Guide%20to%20climate%20projections%20for%20risk%20assessment%20and%20planning%20in%20South%20Australia%202022.pdf

31 Potential evapotranspiration is a standardised estimation of the evaporation and transpiration that would occur given a limitless supply of water. It is the combination of two separate processes: evaporation from water bodies, or the ground surface and transpiration through the leaves of vegetation.

By 2030, increases in annual potential evapotranspiration in SA will range from 3.4% for the Northern and Yorke Landscape Regions to lesser amounts in other regions. The Green Adelaide, the Hills, the Fleurieu, Murraylands, and Riverland regions are projected to have an increase of 3.1% in evapotranspiration losses. Increased evapotranspiration losses of 2.9%, and 2.7% are projected for the Southeast and Eyre Peninsula regions respectively.

By 2050, increases in annual potential evapotranspiration in South Australia will range from 5.5 % for the Northern and Yorke region. The Green Adelaide, Hills, Fleurieu, Murraylands, Riverland, Southeast and Eyre Peninsula regions are projected to experience increased losses due to evapotranspiration of between 4.6 and 5.2%.[32]

Further Considerations

Australia is subject to the most variable rainfall in the world. Since SA is the driest state in the driest continent, planning for climate change in South Australia has world-record levels of uncertainty associated with it. That uncertainty should play a big part in strategic approaches to climate change. It may be appropriate to accept and work with the uncertainty, by building as much physical resilience and financial resilience into the farm business as possible. Soil physical condition, soil organic matter, and maintaining ground cover to the maximum extent possible are recognised land management methods to support physical resilience to avoid causing damage to yield in the better seasons.

The projections above are for individual attributes of potential future climatic conditions. These conditions and other well-known but unquantified factors interact with each other.

The evolution of climate change impacts will vary by region and its existing industries. Higher minimum temperatures can for example prompt early bud break in pome and stone fruits, a feature we characterize as chronic, or ongoing annually. This early flowering may be damaged by a day of above threshold temperatures which damage pollen, reducing yield for that year. In addition, changed temperatures may prompt different timing for the emergences of both familiar pests and pests new to your region.

Conversely, grain production may be affected by high temperatures which push physiological stages of growth faster than normal, yet still be subject to late frosts. Grain producers may wish to consult *Investigating Climate Change Impacts In South Australia's Cropping Zone*[33] for further information.

Wine production may be affected by higher night temperatures. Some locations may also be increasingly subject to heat stress. Below we provide maps drawn from CSIRO projections on the increasing count of days above 35°C. Globally wine producers are seeking the optimum combination of variety and terroir.

More generally, less rainfall will mean less infiltration into the soil. Well-structured soils favour infiltration. By contrast, clay near the surface slows infiltration exposing the lesser amounts of rainfall to more evapotranspiration. Maintaining ground cover will assist the reduction of soil moisture.

The increased evapotranspiration levels in regions will put additional pressure on lesser volumes of water. It is not yet clear how climate change will affect water supplies from surface and underground supplies however researchers have noted that a small reduction in rainfall can have much larger impacts on surface water and underground storage over time.

Given that we are now experiencing high temperatures, temperatures that exceed the expectations of a few years ago, and changes to rainfall, it is worth noting that adaptation will enable business resilience to the evolving conditions - but that it may not be sufficient in the medium term. The mix of solutions for each farm business and region will be specific to their conditions and aspirations. Previously, strategic planning may have considered climate as an unpredictable variable. Rainfall remains very difficult to predict but rising average temperatures are more predictable and have potential impacts across the range of commodities.

On the next page are two maps each showing days of *additional* heat stress (days above 35°C) above the era 1986-2005. The values shown for each map are as noted, the *additional* heat stress days for that location. The left-hand map shows the heat stress days for summer 2023-24. The right-hand map shows the heat stress days for summer 2034-2035. The months of December, January and February were selected as summer months.

32 Tracking changes in South Australia's environment: Trend and condition report cards overview 2023. Government of South Australia, Department for Environment and Water. from https://data.environment.sa.gov.au/Content/Publications/SA_2023_ReportCards_OverviewReport.pdf

33 Sweeney et al 2013 Investigating Climate Change Impacts In South Australia's Cropping Zone. Available at https://cdn.environment.sa.gov.au/environment/docs/kb-fact-climate-change-erosion.pdf

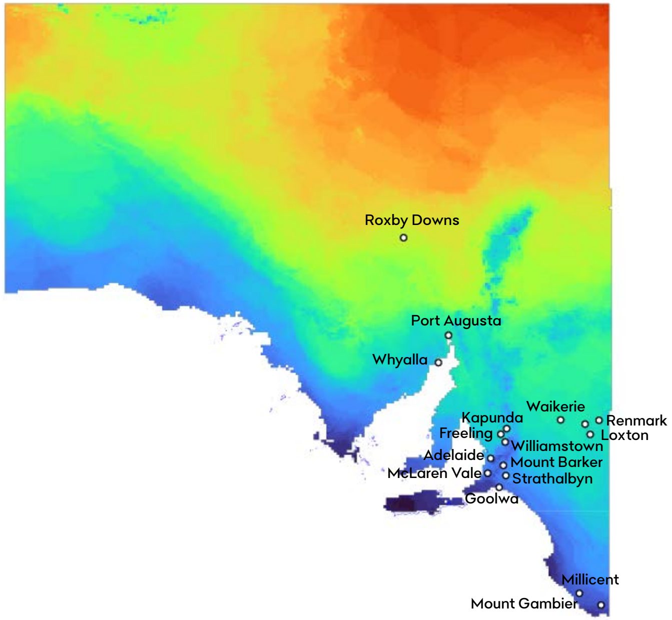
Additional Days above 35°C

The baseline era is 1986-2005.

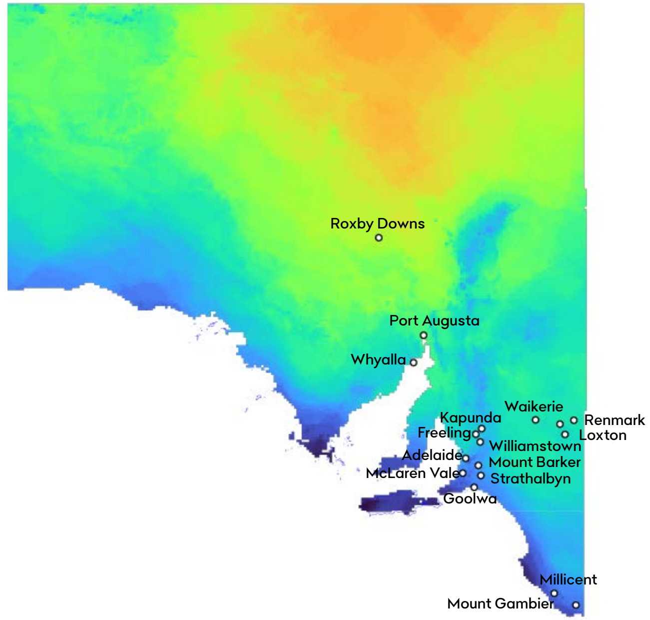
Readers will detect the change in extra heat stress days between the two eras.

In the cropping areas of the Eyre Yorke Peninsulas, more heat stress days are moving south.

In the Adelaide Hills, the 2034-35 era shows more days of heat stress in summer.



Predicted additional days above 35°C in Summer 2023-24



Predicted additional days above 35°C in Summer 2034-35

Additional days above 35°C compared to 1986-2005

Climate Change impacts in Western Australia (WA)

Changes in climate drivers are resulting in long term changes of temperature and rainfall. Rainfall reductions in WA are predicted to occur in winter and spring. Climate change comes as an influence over the top of the naturally very high variability in rainfall in much of Australia.

Significant changes in temperature are predicted for spring in Western Australia during the time wheat is flowering and filling grain.

Modelling of long-term trends in climate under the greenhouse gas scenario that seems most likely at present (business as usual, or RCP 8.5) suggests that median wheat yields in south-west Western Australia may decline between 41% and 49% across the sixty-five years to 2090.[29]

The authors of a research paper on wheat and climate change concluded that:

- Yields are projected to decline in drier eastern and northern areas and remain largely unchanged or increase in wetter western and southern areas;
- Higher temperatures, and to a lesser extent declining rainfall, will hasten development times and reduce the flowering period; and
- Plant available water capacity of soils becomes increasingly important to yield potential, because yield declines are greater on clay soils than on sands in eastern areas.

Decreased water availability is concerning to all producers, but particularly for those irrigating their horticultural crops. Declining rainfall will have a profound effect on surface water and groundwater supplies. If rainfall declines by 14% in the south-west, it has been projected that streamflow will decline by 42% and groundwater recharge will decline by 53%.

Forage production may be reduced by up to 10% over the agricultural areas and southern rangelands and by 10%–20% over the rest of the state. Additionally, if heat tolerant C4 tropical plant species become more dominant in forage mixes, it will reduce pasture digestibility and protein content, however, the decline in forage quality may be offset by increased growth rates of leguminous species.

The need to retain soil cover will impact on livestock productivity and profitability. Rainfall decline and increased variability in pasture production is likely to place severe stress on rangeland ecosystems and grazing enterprises in southern WA over time. This chronic stress may prompt some producers to consider a step change transition in their business.

During wet periods in the higher rainfall areas of the south-west, higher average temperatures in winter and early spring could increase forage production, reduce livestock feed requirements and increase the survival rate of young animals or shorn sheep.

In warmer areas of WA, and during the summer months, increased temperatures and heat stress could reduce forage growth, reduce reproductive success and milk production, and increase livestock water requirements.

Increased day/maximum and night/minimum temperatures could reduce chill accumulation by up to 100 hours. Chill accumulation is critical to meeting the dormancy requirements of horticultural crops and particularly deciduous perennial plants, such as vines. Increased average and maximum temperatures may also reduce fruit quality and cause burning of some leafy horticultural crops. The impact will vary by crop type, cultivar and location. By 2030, the research suggests that the south-west will remain suited to grape production, but banana production may be negatively affected in the north of WA at Kununurra.

On the next page are two maps each showing days of *additional* heat stress (days above 35°C) above the era 1986-2005. The values represented in each map are as noted, the *additional* heat stress days for that location. The left-hand map shows the heat stress days for summer 2023-24. The right-hand map shows the heat stress days for summer 2034-2035. The months of December, January and February were selected as summer months.

29 Taylor et al. 2018 Trends in wheat yields under representative climate futures: Implications for climate adaptation. https://www.sciencedirect.com/science/article/abs/pii/S0308521X17304134

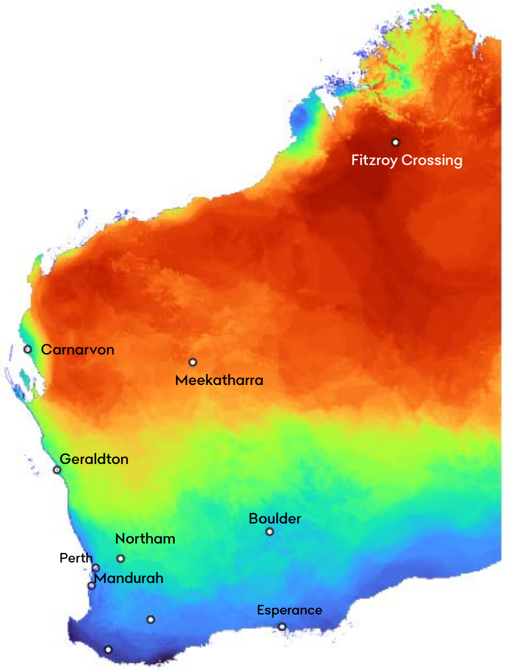
Additional Days above 35°C

The baseline era is 1986-2005.

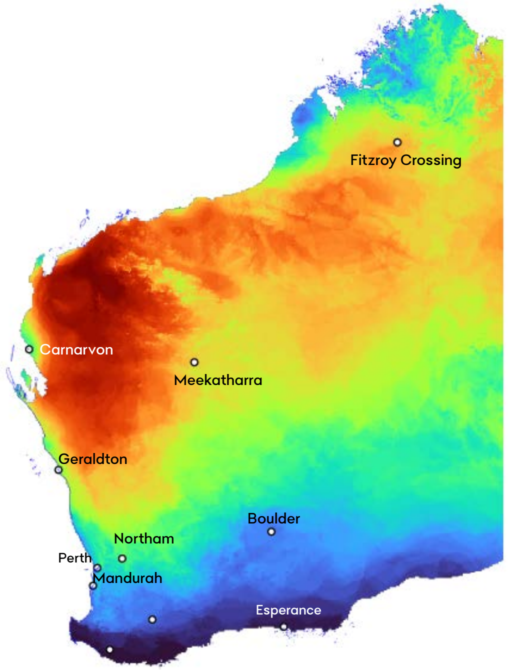
Readers will detect the change in extra heat stress days between the two eras shown as maps.

In the Avon – Midlands region, the increase in heat stress days moves west, closer to the coast all the way down to Perth.

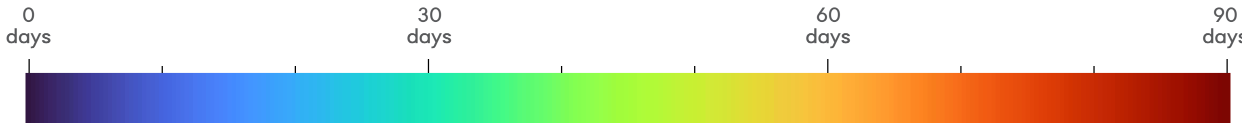
This increase in heat stress days is also evident in the Central/Kwinana region.



Predicted additional days above 35°C in Summer 2023-24



Predicted additional days above 35°C in Summer 2034-35



Additional days above 35°C compared to 1986-2005

Carbon Markets and Carbon Credits

Summary

- Legislation and related commercial changes around climate and carbon footprint reporting are starting to reach the farm gate;
- The factors driving the growth of the carbon credit market are very likely to sustain the demand for credits well into the future;
- Nature-based solutions such as regenerating forest (the Human Induced Revegetation method) for carbon sequestration reach a new natural equilibrium. Trees have filled the space available. After that point, additional carbon sequestration is low;
- Emerging technologies present significant potential for very long-term sequestration but scaling those up cost-effectively will take both financial resources and time;
- Pressures to improve the integrity and simplicity of access to carbon farming opportunities are leading to improvements;
- **We face an urgent but seemingly manageable climate challenge if we keep climate change below 2°C. To achieve that we need to scale up technologies and techniques that are market ready now - and urgently;**
- Technologies with permanence will help secure the longer-term future and enable us to potentially reduce greenhouse gas emissions to pre-industrial levels, providing the Earth and its inhabitants with a buffer against discomfort and substantial risk;
- There are no penalties for delaying a business decision to take up carbon farming opportunities. There may, however, be commercial disadvantages for businesses *not* reporting on their greenhouse gas emissions when asked - and taking steps to minimise them; and
- Consumers, and subsequently buyers and suppliers, are increasingly seeking information on the sources and sustainability of the food and other goods that they are purchasing. This has already led to significant change in the egg and poultry industries and can be expected to increasingly be a factor in purchasing decisions at the checkout and in export markets for other produce.

The Carbon Credit Market: how we got here and where we are going

Farmers are essentially land managers and are used to change. It seems to be the one consistent factor in the business environment. We are entering an era where the change that matters will not only happen in weather, and in markets, but in long term climate and an ever-wider range of government policies.

As noted earlier in this report, the world may be close to, or has passed, the point where we can constrain climate change to a 1.5°C increase above pre-industrial temperatures. The Paris Agreement (2015) bound the 195 countries that subscribed to it, to substantially reduce global greenhouse gas emissions. The aim is 'to hold global temperature increase to well below 2°C above pre-industrial levels and pursue efforts to limit it to 1.5°C above pre-industrial levels' The signatories recognised that this would significantly reduce the risks and impacts of climate change on the global economy. Failure to do so could trigger feedback events where the impact of existing climate change causes additional climate change, raising the risk and the cost of amelioration.

Listen to Episode 11 of our Unpacking Ag podcast "Understanding Carbon Projects" where we unpack what a carbon project is, why a farmer might want to start one, and how to do it. Available on Spotify, Apple and Google Podcasts.

Planning for change

Since it is increasingly apparent that constraining warming to 1.5C may be missed, there is a strong likelihood of more legislation across all industries to reduce emissions. This will also entail more reporting but could also drive demand for carbon credits as well.

Planning for change will be challenging, but Rural Bank is committed to increasing efforts to assist farmers to be aware of the current climate indicators and to the relevant policy changes that will impact operations, along with updates to clarify confusion in community discussions that might obscure clear business judgement.

Climate science continues to evolve. In the past two years for example, new satellite sensors have enabled the detection of methane plumes from oil and gas operations, among other sources. This has changed perceptions of which methane sources are important.[41] The focus has shifted toward those energy sectors.

Systems for rewarding the removal of carbon in the atmosphere or preventing its release to the atmosphere, such as the Carbon Farming Initiative have been under development for more than a decade. They are maturing and will continue to be refined into the foreseeable future.

Financial incentives

Carbon markets arose as a financial incentive to reduce carbon levels in the atmosphere at the lowest cost, while adding a new industry to rural areas globally. Carbon markets have several advantages, in particular, that they are a rapid response to an urgent problem. It was clear from the earliest days that these measures were not a sufficient solution. In fact, it is structured into the design of carbon markets that there are limits to the capacity of natural systems to sequester more carbon. The system achieves a new balance where additional sequestration is small. The practical biological limit is set at twenty-five years. This is the timeframe for the crediting period of carbon farming projects.

As a consequence, decarbonisation of production systems was always part of the solution. While agriculture has an important role to play, decarbonisation is the part of the overall puzzle that needs to play the biggest role. Currently the expansion of industrial production to meet the needs of the growing global population implies more greenhouse gas releases. Quite a few larger companies are investing in ways to reduce their carbon footprint. This technological solution appeals to financial markets because it implies new technologies, new patents and protected markets. The transport sector has benefited from risk capital, for example, although agriculture is benefitting far less from capital investment in carbon reduction or sequestration technologies. This should change.

New technologies have a difficult transition from the laboratory to scaling up in implementation. Some will fail to reach commercialisation for intrinsic reasons that the developers could not solve or imagine at the laboratory phase. In almost all cases it takes much longer to get new initiatives to market than originally expected.

CSIRO concluded in their 2022 report *Australia's carbon sequestration potential: A stocktake and analysis of sequestration technologies*[42] that geological storage, and many nature-based sequestration options such as tree plantings and the soil methods offered the most promise in Australia.

There is however a difference between the enormous technical potential of some technologies and their current economic potential. The report noted:

> *"Geological storage has greatest technical potential for sequestration with 227 Gt total. It was estimated that if all geological storage projects in development are totalled, an estimate for 2035 economic sequestration would be ~24Mt per year, with an estimate of 50Mt per year for 2050."*

With regard to nature-based solutions the report noted:

> *"Many nature-based solutions have good technical potential for sequestration, particularly permanent plantings, plantation and farm forestry, and soil carbon, with technical potential sequestration of 480Mt per year, 631Mt per year and 115 Mt per year, respectively, by 2050. The nature-based technologies of plantation and farm forestry and permanent plantings have significant differences between technical and economic sequestration. This difference is related to a combination of factors, some regulatory, but some based on the economics of plantings in remote areas with low sequestration rates. Some fraction of this gap might be closed by removing constraints to planting, incentivising plantings or through innovations that reduce costs of establishment and project delivery considerably. Uptake has been high in nature-based technologies due to their high technology readiness levels and policy support through the carbon farming initiative and the Emissions Reduction Fund."*

41 https://www.nasa.gov/centers-and-facilities/jpl/methane-super-emitters-mapped-by-nasas-new-earth-space-mission/

42 2022 CSIRO *Australia's carbon sequestration potential: A stocktake and analysis of sequestration technologies.* Available at: https://research.csiro.au/tnz/australias-carbon-sequestration-potential/#:~:text=Findings,Australia's%20vast%20geological%20storage%20capacity

Considering the current high risk arising from climate change, and the longer road to market, many are advocating that all technologies and techniques should be used to reduce the climate risk without risking other adverse outcomes.

Multinational company Microsoft explained their planning in June 2023: "*Time is non-renewable and the next several years are crucial for global carbon removal capacity. …Microsoft continues to plan for a portfolio of greater than 5 million metric tonnes of carbon removal per year in 2030. We're committed to a portfolio that balances relatively proven low-durability, nature-based solutions with medium- and high-durability solutions, where low-durability options face perhaps the greatest qualitative challenges and the high-durability opportunities need the greatest scaling. Limiting warming this century to anything close to 2°C will likely require scaling CDR (carbon dioxide removal) to not less than 6 billion metric tonnes per year by 2050. Carbon removal will not reach the magnitude needed at mid-century without an all-of-the-above approach.*"

At present we can see this carbon dioxide removal as ideal, but it is not economically feasible to implement at scale. What is needed is focussed research to improve its economic feasibility and the broader role that agriculture and land management can play in reaching agreed targets.

Regulators around the globe are playing a part by bringing in changes to consumer legislation to require high standards of evidence for environmental claims about products including about carbon neutrality. It will not be sufficient to claim that flights or cruises or other products are carbon neutral without doing due diligence to ensure that any carbon offsets used to achieve neutrality have high credibility. The consequence is higher costs for carbon projects to demonstrate their carbon sequestration, but these costs add value to carbon credit products.

Evolution of the carbon market and potential associated products will continue well into the middle of the century and beyond. The sophistication of current technologies such as soil methods, tree planting technologies, technologies for quantifying carbon sequestered and more will continue to improve.

All these developments should make carbon farming more attractive to farm business operators. After a decade of slow development, there is now rapid growth in the registration of carbon projects.

The impact of climate adaptation and reporting on farms

All that glitters is not gold, and the glitter of the market for carbon credits should not blind farm managers to other important factors in the business environment. The potential new line of business and new income needs to be developed strategically and synchronised with decarbonisation of the business.

Legislation is in development and commercial pressure is already reaching farm gates, the intent of which is to encourage the reduction of greenhouse gas emissions of Australian businesses. The very largest emitters are currently obliged to stay below a threshold under the Safeguard Mechanism. If the threshold is exceeded, the company is required to purchase carbon credits from the market to offset the excess.

Among the changes that will increasingly affect businesses (including farm businesses) in Australia is increasing expectations of emissions calculation and climate-related disclosure.

One hundred and twenty regulators and governmental entities worldwide now support standardised climate and emissions disclosure. Brazil, Hong Kong, Japan, New Zealand, Singapore, Switzerland, the United States, the United Kingdom and the European Union have already made climate and emissions reporting mandatory for certain entities.

Best practice guidance outlines that organisations disclose how climate risks and opportunities are included in governance, strategy, risk management and targets. Rural Bank voluntarily reports our emissions, as well as all major Australian banks.

On 27 March 2024, the government introduced to parliament the Treasury Laws Amendment Bill which, if legislated, would require mandatory climate disclosures for Australia's largest organisations. The proposed legislation will come into effect in three stages.

First annual reporting periods starting on or after	Entities that meet at least two of the below thresholds:			NGER Reporters	Asset Owners (e.g. management investment schemes and superannuation funds)
	Consolidated revenue	EOFY consolidated gross assets	EOFY employees		
1 January 2025 Group 1	$500 million or more	$1 billion or more	500 or more	Above NGER publication threshold	N/A
1 July 2026 Group 2	$200 million or more	$500 million or more	250 or more	All other NGER reporters	$5 billion assets under management or more
1 July 2027 Group 3	$50 million or more	$25 million or more	100 or more	N/A	N/A

Source: Clayton Utz, New mandatory climate reporting laws one step closer | Clayton Utz.

The reporting does not stop at the entities in Group 3. Each entity must report on their Scope 3 emissions. These are the emissions embedded in products or services used by the main entity, and the impacts of use of the entity's product. In other words, businesses in the entity's supply chain, both upstream and downstream.

This reaches out as far as farm level. Farms are being asked now to report on their carbon footprint, and their plans to reduce their greenhouse gas emissions. All entities from the very largest financial institutions down the line to individual businesses are being asked to reduce their greenhouse gas emissions.

We encourage farm businesses to see this reporting as a business decision, not a political decision. What is being sought is partly to better understand the impact of climate change on your business, as well as what sources of emissions might be arising from your business activities. As the old saying goes, if you can't measure it, you can't manage it. There are several emissions calculator tools online and most industry bodies now host one.

It is early days in this journey. The overall perspective through the value chain is that collaborative exploration of potential reductions across the chain should now be the priority.

Keeping in mind that the main greenhouse gases of concern in agriculture are methane from ruminants primarily, and nitrous oxide from soil and nutrient management practices, here are the Department of Agriculture, Fisheries and Forestry (DAFF)'s suggestions for actions leading to reductions:

For cattle, sheep and goats:

- Using best breeding practices;
- Using feed supplements known to reduce methane release; and
- Improve the quality of livestock feed.

For cropping and horticulture:

- Improving soil management to increase biomass in the soil by reducing soil disturbance; and
- Retaining soil cover either as live plants or as plant trash. Better matching fertiliser application timing to the uptake of nutrients, perhaps by split applications and utilising larger drones to target places of developing nutrient deficiency in the leaves. And for all farms increasing revegetation in unproductive areas and introducing dedicated forestry plantation blocks.

Each one of these is very likely to be an economic benefit to the farm. Especially once it becomes a mainstream part of farm planning.

Disruption to established practices is rarely welcomed, however, over time record keeping will get easier and is certain to be increasingly automated. There are software developments already out there that will be integrated with your record keeping, or perhaps replace manual systems.

The outcome, no matter how you adapt, should in most cases be that the farm remains a farm, and a better managed farm as a result.

Closing Observations

Along this journey lack of uniformity in the reference era against which projections are made and the use of distant projection time frames has emerged as a challenge. It is very desirable for agricultural commodities to have common reference eras and near term projection time frames for use in strategic planning.

There are few reference eras for predictions about future climate that are used in common across all Australian states. Many reports provide their own unique reference era. Fortunately, the CSIRO/Bureau of Meteorology predictions do use a meaningful and shared reference or baseline era. As this report uses data from those sources, we used the 1986-2005 era as a baseline when possible. It would be desirable to use a common reference era for all projections.

A source of further confusion is the use by different organisations of future states with eras as far away as 2090 and the twenty-first century. While the result may seem to show dramatic, perhaps even frightening change at that era, it is not particularly useful for strategic planning purposes. Indeed, it is possible that this very distant future state discourages engagement with an issue that is affecting the global and national economy now. Even 2050, another era appearing in some reports, is too far away to fall within formal and informal planning horizons.

As each year advances, the level of scientific understanding and reflection is deepening. In many cases the level of concern expressed by various organisations has been rising for more than a decade. The University of Exeter-based Institute and Faculty of Actuaries[43] commented that most current climate change models do not include the likely impacts of exceeding tipping points. This is despite rising awareness that exceeding the threshold may cause self-reinforcing changes to climate across large regions and affect other tipping points, causing the 'cascade effect' mentioned earlier. The result is a general underestimation of climate-based risk.

This underscores the urgency for authorities to update climate analysis regularly.

It would also be useful for farming businesses to have available some analysis of the integrated impacts of climate change in their industry as well as the likely impacts at an individual level. The integrated impact assessment provides a measure of significance to readers. The individual impacts provide the list of impacts for consideration in strategic planning.

The future business terrain is increasingly uncomfortable. The horizon suggests turbulence, more risks and less certainty.

Nonetheless, collectively the global community can reduce, avoid or mitigate the risks and the rising costs of them by concerted effort. That can only happen if we start now with the deep conviction that the atmosphere does not care who emitted excess greenhouse gases, nor their reasons for doing so. What matters is the combination of an open mind and the willingness to make changes to restore safe levels of greenhouse gases in the atmosphere. That should result in more efficient and more resilient businesses, and more generous natural systems.

43 2023 Trust S et al. The Emperor's New Climate Scenarios: Limitations and assumptions of commonly used climate-change scenarios in financial services. https://actuaries.org.uk/media/qeydewmk/the-emperor-s-new-climate-scenarios.pdf

Planning for Change: The Climate Report

In 1865, George Goyder was tasked with surveying a line defining arable regions in South Australia where rainfall varied from reliable to unreliable. On a horseback journey of some 3200km, he documented indicators such as transitions in native vegetation which today can be easily observed and monitored from space. This huge effort greatly assisted the preparation of his final recommendations.

Goyder's work anticipated today's awareness that natural systems set limits on economic activity and that utilising the best available data can assist in planning and aid in avoiding economic loss.

Abandoned farmhouse near Burra, to the east of the Goyder Line in South Australia

For banking enquiries on our range of specialist farm finance products and services, search Rural Bank, call 1300 660 115, or visit your local Bendigo Bank branch.

For Climate report enquiries and more detail about our other in-depth insights and customised reports, email insights@ruralbank.com.au

Or search Rural Bank and **subscribe for free** to receive future research and analysis that support you in making informed business decisions on your farm.

References

2010 Impacts on Agriculture – Technical Report (Full Report) found at https://climatefutures.org.au/wp-content/uploads/2023/05/Impacts-on-Agriculture-Technical-Report-Full-Report.pdf

2013 Sweeney et al Investigating Climate Change Impacts In South Australia's Cropping Zone. Available at https://cdn.environment.sa.gov.au/environment/docs/kb-fact-climate-change-erosion.pdf

2015 Silanikove N and N Koluman. Impact of climate change on the dairy industry in temperate zones. from https://www.sciencedirect.com/science/article/abs/pii/S0921448814003150

2017 Final TCFD Report. available at https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

2018 Hochman Z and H Horan Causes of wheat yield gaps and opportunities to advance the water-limited yield frontier in Australia. From https://www.sciencedirect.com/science/article/abs/pii/S0378429018304040

2018 Taylor et al. Trends in wheat yields under representative climate futures: Implications for climate adaptation https://www.sciencedirect.com/science/article/abs/pii/S0308521X17304134

2019 Asimov E How Climate Change Impacts Wine Eric https://www.nytimes.com/interactive/2019/10/14/dining/drinks/climate-change-wine.html

2019 Victoria's Climate Science Report 2019. https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf

2019 Wimmera-Southern-Mallee Climate Projections 2019 Available at: https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0035/429884/Wimmera-Southern-Mallee-Climate-Projections-2019_20200219.pdf

2020 Lenoir et al. Species better track climate warming in the oceans than on land. https://www.nature.com/articles/s41559-020-1198-2

2021 Australian Academy of Science The Risks To Australia of a 3°C warmer world. https://www.science.org.au/supporting-science/science-policy-and-analysis/reports-and-publications/risks-australia-three-degrees-c-warmer-world

2021 Collins, B and Chenu K Improving productivity of Australian wheat by adapting sowing date and genotype phenology to future climate. From https://www.sciencedirect.com/science/article/pii/S2212096321000292#s0130

2021 NSW climate change snapshot. Available at: https://www.climatechange.environment.nsw.gov.au/sites/default/files/2021-06/NSW%20climate%20change%20snapshot.pdf

2022 CSIRO Australia's carbon sequestration potential: A stocktake and analysis of sequestration technologies. Available at: https://research.csiro.au/tnz/australias-carbon-sequestration-potential/#:~:text=Findings,Australia's%20vast%20geological%20storage%20capacity

2022 Department for Environment and Water. Guide to Climate Projections for Risk Assessment and Planning in South Australia 2022, Government of South Australia, through the Department for Environment and Water, Adelaide. Available at https://data.environment.sa.gov.au/Content/Publications/Guide%20to%20climate%20projections%20for%20risk%20assessment%20and%20planning%20in%20South%20Australia%202022.pdf

2022 Ullah A et al. Heat stress effects on the reproductive physiology and yield of wheat. Available at https://onlinelibrary.wiley.com/doi/epdf/10.1111/jac.12572

2023 Cartwight S et al. Impact of heat stress on dairy cattle and selection strategies for thermotolerance: a review. https://www.frontiersin.org/articles/10.3389/fvets.2023.1198697/full

2023 Chateau J et al A Framework for Climate Change Mitigation in India. A Working Paper of the International Monetary Fund. Available at: https://www.imf.org/en/Publications/WP/Issues/2023/10/20/A-Framework-for-Climate-Change-Mitigation-in-India-535854

2023 European Commission, Global Climate Highlights 2023 https://climate.copernicus.eu/global-climate-highlights-2023

2023 Tracking changes in South Australia's environment: Trend and condition report cards overview 2023. Government of South Australia, Department for Environment and Water. from https://data.environment.sa.gov.au/Content/Publications/SA_2023_ReportCards_OverviewReport.pdf

2023 Trust S et al. The Emperor's New Climate Scenarios: Limitations and assumptions of commonly used climate-change scenarios in financial services. https://actuaries.org.uk/media/qeydewmk/the-emperor-s-new-climate-scenarios.pdf

2023 Univ Qld submission to Parliamentary inquiry into the impacts of climate change on Queensland's agricultural production. from https://documents.parliament.qld.gov.au/com/SDRIC-F506/IQ-81CF/submissions/00000003.pdf

2024 State of the Global Climate 2023 available at https://wmo.int/publication-series/state-of-global-climate-2023

About Berkeley Earth: https://berkeleyearth.org/about/

Berkeley Earth Global Temperature Report for 2023, at https://berkeleyearth.org/global-temperature-report-for-2023/

http://www.bom.gov.au/climate/current/annual/aus/

https://actuaries.org.uk/

https://data.environment.sa.gov.au/Content/Publications/SA_2023_ReportCards_OverviewReport.pdf

https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation#recent-changes-in-seasonal-conditions-have-affected-the-profitability-of-australian-farms

https://www.beefcentral.com/news/oppressive-long-weekend-weather-leads-to-feedlot-mortalities/

https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

https://www.climatechange.environment.nsw.gov.au/resources-and-research/regional-climate-change-snapshots

https://www.climatechange.vic.gov.au/building-victorias-climate-resilience/our-commitment-to-adapt-to-climate-change/primary-production-adaptation-action-plan

https://www.climatechangeinaustralia.gov.au/en/changing-climate/state-climate-statements/queensland/

https://www.dairyaustralia.com.au/climate-and-environment/climate-risk-and-adaptation/dairy-farm-climate-impacts

https://www.imas.utas.edu.au/news/news-items/can-we-eat-our-way-through-and-exploding-urchin-problem

https://www.mla.com.au/research-and-development/Environment-sustainability/climate-variability/climate/

https://www.nasa.gov/centers-and-facilities/jpl/methane-super-emitters-mapped-by-nasas-new-earth-space-mission/

https://www.nasa.gov/news-release/nasa-analysis-confirms-2023-as-warmest-year-on-record/

https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

https://www.pericoli.com/en/temperature-humidity-index-what-you-need-to-know-about-it/

https://www.qld.gov.au/__data/assets/pdf_file/0023/68126/queensland-climate-change-impact-summary.pdf

https://www.science.org.au/supporting-science/science-policy-and-analysis/reports-and-publications/risks-australia-three-degrees-c-warmer-world

https://www.vfca.org.au/livestock#:~:text=Animals%20are%20subjected%20to%20multiple,ensuring%20the%20welfare%20of%20livestock.

International Panel on Climate Change, Synthesis Report: Future Climate Changes, Risks and Impacts , at https://ar5-syr.ipcc.ch/topic_futurechanges.php

The Financial Stability Board's Taskforce on Climate-related Financial Disclosure. https://www.fsb-tcfd.org/

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