Changes in northern farming system climate conditions - Goondiwindi

Steven Crimp and Mark Howden, Australian National University

Key words

climate projections, production impacts, adaptation options

Take home messages

- Greenhouse gas (GHG) emissions continue to accumulate in the earth's atmosphere and drive warmer global temperatures. Warming of globally averaged air temperatures of just over 1°C since records began in 1850 has produced national, regional and local changes in environmental conditions. These changes have shifted debate from "Is climate change real?" to "What should we do about it?"
- Adapting agricultural practises will be required to respond to changing environmental conditions and will require all components of the agricultural value chain to work together in order to maintain resilient and profitable food systems

Historical changes in climate?

Preliminary results suggest that 2019 is likely to be either the second or third warmest year on record, with globally annual averaged air temperatures now 1°C warmer than the long-term average calculated for the period 1961 to 1990. This warming is driven by increasing concentrations of all the major long-lived greenhouse gases in the atmosphere, with carbon dioxide (CO_2) concentrations rising from 208ppm prior to the industrial revolution, to 413.65 ppm as of 4 January 2020 (NOAA, 2020).

In Australia, warming in average temperature (average temperature) has resulted in 2019 being the warmest year on record (1.52°C above the 1961 to 1990 average of 21.8°C) (BoM, 2020). Average daytime maximum temperatures in 2019 of 30.69°C were 2.09°C above the 1961 to 1990 average. In December 2019 more than 40% of the entire country recorded maximum temperatures greater than the 97th percentile i.e. top 3% of temperatures. Examining the shift in the distributions of monthly day and night-time temperature shows that very high monthly maximum temperatures that occurred around 3% of the time in the past (1951–1980) now occur around 12% of the time (2003–2017) (BoM & CSIRO, 2018). Very warm monthly minimum, or night-time, temperatures have shown a similar change from 2% of the time in the past (1951–1980) to 12% more recently. This shift in the distributions towards hotter temperatures and more extreme high temperature conditions has occurred across all seasons, with the largest change being in spring (BoM & CSIRO, 2018).

In the Goondiwindi region over the period 1960 to 2019 (length of the temperature record), warming has occurred in both minimum and maximum temperatures with mean temperatures now approximately 1.4°C warmer than in 1960. For the period 1960 to 1991 an annual average maximum temperature of 28°C occurred, on average, 10% of the time. More recently (1992 to 2019) this temperature now occurs on average 19% of the time. Similarly mean annual minimum temperatures have warmed with the frequency of a minimum temperature of 13°C increasing from 25% to 35% of the time (Figure 1). Despite warming in both minimum and maximum temperatures the number of frost events (i.e. defined here as the temperatures below 0°C) has more than tripled during June to August, with an average of 9 events occurring most recently. Daily minimum temperatures of -2°C now occur 38% of the year as opposed to only 20% of the time over the period 1960 to 1991. When examining the extreme daily maximum temperature values, considerable warming has occurred in Goondiwindi. Extreme maximum temperatures of 43°C occurred on average 18% of the year for the period 1960 to 1991 (Figure 2). During the more recent period (1992 to 2019), this temperature occurred, on average 38% of the year.

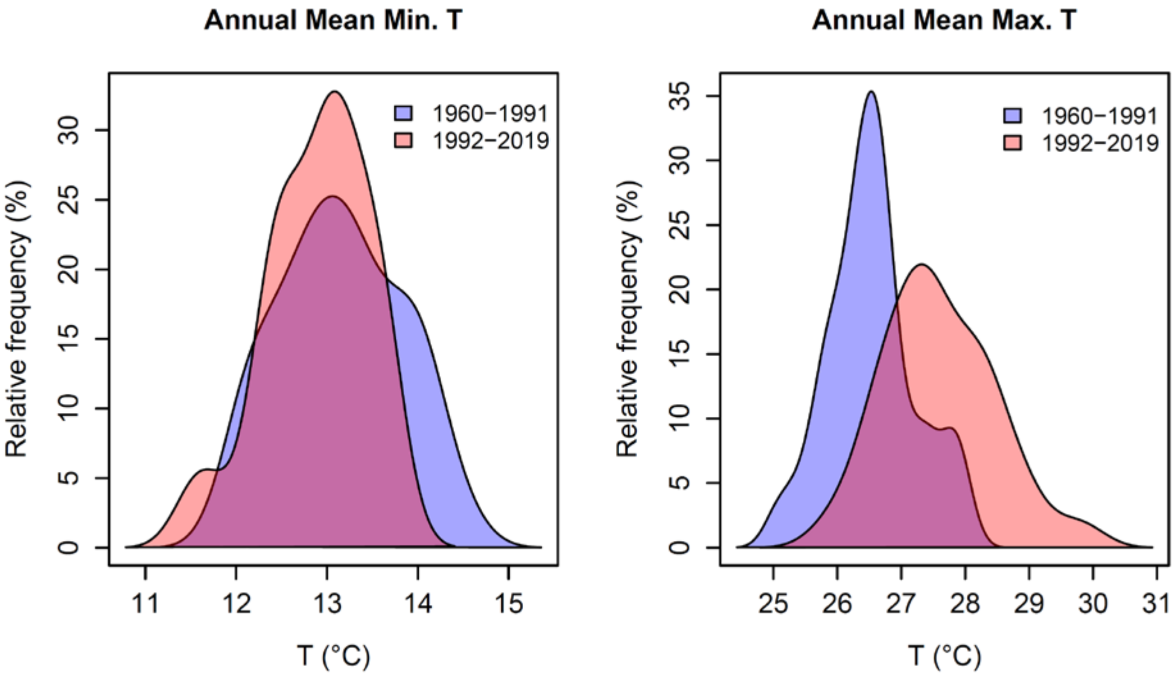

Figure 1. Probability distributions of annual mean maximum temperature (right) and annual mean minimum temperatures (left) for Goondiwindi for two periods, namely 1960 to 1991 and 1992 to 2019.

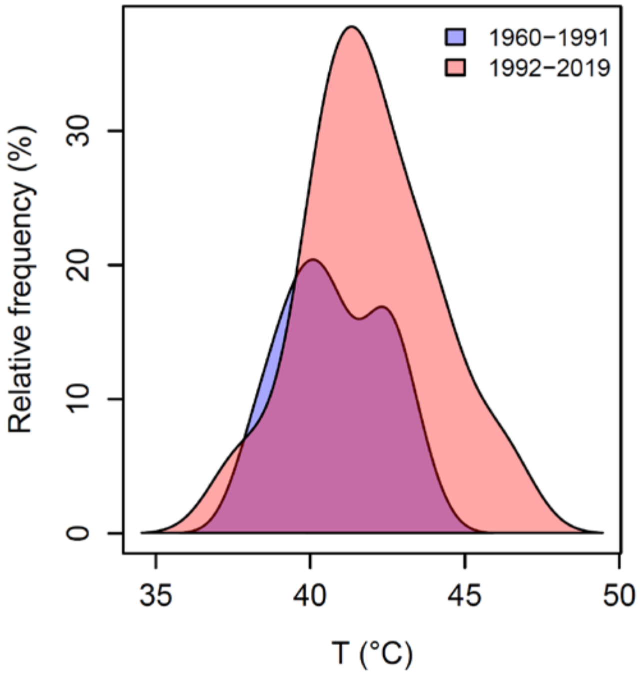

Figure 2. Probability distributions of daily maximum temperature extremes for Goondiwindi for two periods, namely 1960 to 1991 and 1992 to 2019.

The Goondiwindi rainfall record exhibits a declining trend, with declines during the June to August and September to November periods most pronounced. Mean dry spell lengths have also increased, with the average time between rainfall events now three days longer during June to August (i.e. an average dry spell length of 12 days for the period 1986 to 2018) (Figure 3). Similarly the number of heavy rainfall events (i.e. greater than the 90th percentile) across the whole year has declined, again most notably during the June to August and September to November periods. The maximum number of consecutive dry days has increased across the whole year with March to May, June to August and September to November periods increasing by 3, 4 and 5 days respectively (i.e. now 33, 28 and 22, days respectively).

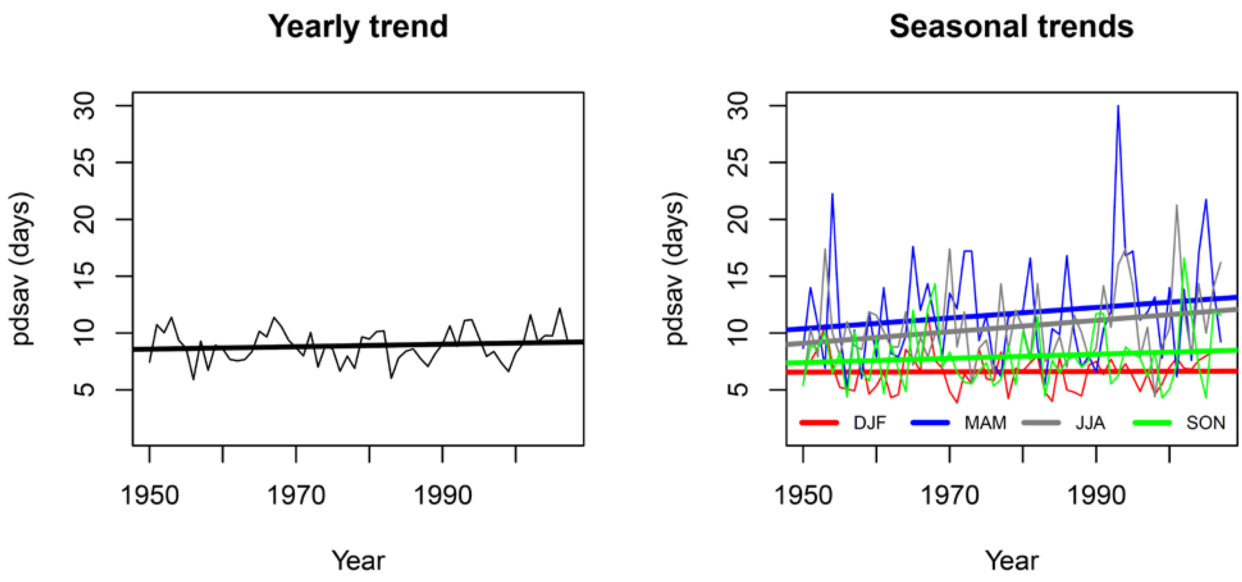

Figure 3. Mean annual dry spell length (left) and seasonal dry spell length for December to January (DJF), March to May (MAM), June to August (JJA) and September to November (SON). Dry spell lengths are expressed in days.

The current acceleration of global warming is expected to continue based on future greenhouse gas (GHG) emissions trajectories. Previous studies have examined how the rates of record-breaking have changed in the US (Anderson et al., 2011), the UK (Kendon, 2014), and Australia (Lewis & King, 2015). These studies have found increased rates of hot temperature records and decreased record setting for cold temperatures in recent decades (King et al., 2015; King, 2017). Lewis and King (2015) found that from 2000 to 2014 there were 12 times as many hot record-breaking temperatures as cold records in Australia and attributed this to anthropogenic climate change. Recent BoM analyses has shown that from 1960-2018 the ratio of hot records to cold records set across Australia was 6:1 whereas from 1910-2018 the ratio was 9:1 (Blair Trewin pers Comm. 2020). In 2019 the ratio of hot to cold records broken at the state area average level was 34:0 (Blair Trewin pers Comm. 2020). Across the world, there were about five times more record-breaking monthly temperatures than would be expected without a long-term warming trend (Coumou et al., 2013) over the early 21st century.

During the 2018/19 Australian summer more than 206 individual location extreme temperature records were broken in just 90 days (Climate Council, 2019). Climate change has been found to not only increase the likelihood of breaking high temperature records (e.g. Lewis and Karoly, 2013), but record-breaking hot summers and years over previous decades are also attributable to anthropogenic climate change (King et al., 2016). More recent research by Mann et al. (2018) has shown that the synoptic features (large scale weather systems) responsible for prolonged heatwaves are on average 50% more prevalent under a business-as-usual GHG emissions trajectory.

In addition to record breaking temperatures, changes in rainfall patterns, sea levels, rates of glacial retreat and biological responses have also been detected consistent with expected climate change projections. This mounting evidence has led to scientific consensus that:

- Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that affect the climate system and these changes and resultant trends will continue for the foreseeable future; and
- There is at least 95% confidence that humans are the main cause of global warming since 1950, and most likely responsible for 100% of that temperature rise (IPCC, 2018) with a less than 1 in 100 000 chance that human activities are not responsible for the observed increase in global temperatures (Kokic et al., 2014).

These changes are already likely to have negatively impacted on Australian agriculture, acting as a major drag on yield growth with similar impacts on yield growth globally for the major crops (Porter et al., 2014).

A major issue in understanding historical and future climate change is how much are the various human-induced climate forcings (greenhouse gas emissions, stratospheric ozone depletion, Asian aerosols, and landcover change) interact with components of natural variability (Watkins, 2005, McKeon, 2006). Thus, it is important for successful climate adaptation that agricultural decision-makers keep informed of the evolving climate science and updated climate change scenarios. As scientific understanding improves and there is more confidence in emission scenarios, current and future uncertainties can be rapidly assessed in terms of decision making.

What is expected to happen in the future?

In response to the continued growth in atmospheric GHG concentrations, scientists estimate that global average temperatures could increase by up to 4.8°C by the end of the present century, dependent on global population growth, technological advancement and economic growth (IPCC, 2013). To put this in context, the difference between our historical temperatures and those of the last ice age was only about 5°C. So even though 4.8°C does not sound like much, it signals a huge change in how the climate-ocean-land systems of the earth function and hence how agriculture will operate.

In Australia, national projections suggest additional warming of up to 1.3°C of additional warming could be experienced by 2030 and up to 5.1°C of warming could be experienced by 2090, with the greatest warming being in inland Australia and the lesser warming along the southern coast and Tasmania (CSIRO, 2015). Global studies indicate that a rule of thumb is that global potential crop production drops by 6% per degree warming (Porter et al., 2014).

Whilst changes in rainfall are more uncertain, projections suggest drier conditions in the southern half of Australia, particularly in the south-west and during the cool season months of May to October, with as much as 20% less by 2030 and up to 50% less rainfall by 2090 in the south-western parts of Australia by 2090, respectively (CSIRO, 2015).

At a regional scale projected change in climate for the Eastern Downs region (Goondiwindi represents a southern town in this study region) are summarised in Table 1. In addition to warmer temperatures and declines in mean annual rainfall, evaporation rates are likely to increase. The annual potential evaporation (1986-2005) for the region is 1539 mm. By 2050 the median value of annual potential evaporation is projected to increase by 6 % under a high emissions scenario.

Table 1. Projected changes in temperature and rainfall for Eastern Downs region (Goondiwindi is on found on the Southern part of this region). Present average temperatures and rainfall are calculated for the period 1986 to 2005. The data contained in this table represents information compiled from the Queensland Department of Environment and Science, SILO database.

Variable	Season	Historical mean (1986 to 2005)	2030	2050	2070
Mean temperature change (^{o}C change)	Annual	20.0^{o}C	1.1 (0.5 to 1.6)	1.9 (1.1 to 2.6)	2.9 (2.0 to 3.8)
	Summer	26.4^{o}C	1.1 (0.4 to 1.8)	2.0 (1.0 to 2.9)	3.0 (2.0 to 4.3)
	Autumn	20.4^{o}C	1.0 (0.1 to 1.6)	1.8 (0.9 to 2.6)	2.9 (1.8 to 3.6)
	Winter	12.7^{o}C	1.0 (0.1 to 1.7)	1.9 (1.2 to 2.5)	3.0 (2.1 to 3.8)
	Spring	20.6^{o}C	1.1 (0.5 to 1.8)	1.9 (1.0 to 3.2)	3.0 (2.0 to 4.2)
Mean rainfall change (% change)	Annual	636mm	-5 (-20 to +7)	-6 (-23 to +14)	-9 (-23 to +13)
	Summer	248mm	0 (-15 to +21)	0 (-23 to +27)	-2 (-21 to +29)
	Autumn	144mm	-3 (-28 to +27)	-4 (-33 to +36)	-8 (-42 to +41)
	Winter	106mm	-1 (-25 to +13)	-14 (-39 to +13)	0 (-49 to +14)
	Spring	139mm	-6 (-22 to +20)	-8 (-34 to +12)	0 (-42 to +21)

Adapting to projected climate changes

Climate change is likely to pose a significant challenge for Australian agriculture. Of greatest concern are likely to be changes in water availability, and the change in frequency of climatic extremes (e.g. heatwaves, drought and floods).

Many of the actions required for adapting to climate change are extensions of those currently used for managing climate variability. For this reason, efforts to improve current levels of adaptation to climate variability will have positive benefits in addressing likely climate change impacts.

Examples of likely farm level adaptation options include:

- Enhancing the current implementation of zero tillage and other minimum disturbance techniques, retaining crop residues, extending fallows, changing row spacing, changing planting density, staggering planting times, traffic and erosion controls
- Alter planting decisions to be more opportunistic – more effectively taking into account environmental condition (e.g. soil moisture), climate (e.g. seasonal climate forecasting) and market conditions
- Expand routine record keeping of weather, production, degradation, pest and diseases, weed invasion
- Incorporating seasonal climate forecasts and climate change into farm enterprise plans
- Improve efficiency of water distribution systems (to reduce leakage and evaporation), irrigation practices and moisture monitoring

- Learning from farmers in currently more marginal areas
- Selection of varieties with appropriate thermal time and vernalisation requirements, heat shock resistance, drought tolerance, high protein levels, resistance to new pests and diseases and perhaps that set flowers in hot/windy conditions
- Enhance current consideration of decision support tools/training to access/interpret climate data and analyse alternative management options (e.g. APSIM, EverCrop).

There are also longer-term decisions at a family farm level - to sell up, to buy more land, where to invest. These are especially pertinent for farmers in low rainfall regions and it will increasingly be more difficult to find no-regret decisions if climate change progresses as anticipated (Hayman, 2005). These decisions, along with industry infrastructure (silos etc.) and industry support (drought policy) are hard decisions requiring full understanding of the likely future risks (Hayman, 2005).

The value of adaptation

In Australia a number of studies have examined the economic benefits of adaptation in the wheat industry at both national and regional scales under a range of likely future climate conditions. Hochman et al. (2017) highlighted that the adoption of new technology and management systems held actual yields fairly steady: without these advances, water-limited yield would have dropped by 27%. It was estimated that rainfall declines should have accounted for about three-quarters of the fall in simulated yield potential, whilst observed warming should have accounted for about a quarter of fall in yield potential.

Continued adaptation to climate change has been estimated to add an additional AU$500M per annum (Howden and Crimp, 2011) via the introduction of improved water-use efficiency options and may mitigate potential yield losses by up to 18% through broader scale adaptation (Ghahramani et al. 2015).

The results suggest a number of adaptation options exist to manage increased future downside risk however the effectiveness of adaptation is driven by the extent of future change. Under conditions of large climate change, tactical adaptation will only have limited effectiveness and more extensive adaptation options, often defined as transformation adaptation, may be required.

Advisers have a key role to play in changing the nature of the climate change dialogue. In the space of about five years many grain growers and their advisers have moved from asking "What is climate change?" or "Is it real?" to "How do we manage for climate change?" and "What will the impact be on the grains industry?"

Advisers have a vital role to play in this dialogue, not only in assisting grain growers in reducing greenhouse gas emissions from on-farm activities, but also in developing information systems that growers can tap into in order to build farming systems that can cope with current climate variability and can adjust to ongoing climate changes.

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Contact details

Dr. Steve Crimp
Climate Change Institute
Australian National University
Fenner School of Environment and Society
Building 141, Linnaeus Way, Action, ACT 2601
Ph: 02 6125 7265
Email: Steven.Crimp@anu.edu.au