

Changes in northern NSW farming system climate conditions - Bellata

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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 (CO₂) 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 Bellata region over the period 1960 to 2019 (length of the temperature record), warming has occurred in both minimum (1.6°C) and maximum temperatures (2.1°C). For the period 1960 to 1991 an annual average maximum temperature of 27°C occurred, on average, 10% of the time. More recently (1992 to 2019), this temperature now occurs on average 22% of the time. Similarly mean annual minimum temperatures have warmed, with the frequency of a minimum temperature of 12°C increasing from 21% to 25% of the time (Figure 1). As a result of the warming, the frequency of extreme minimum temperatures of -4°C have declined from 12% during 1960 to 1991 to 6% in the most recent period. The frequency of extreme maximum temperature extremes has increased, with temperatures greater than 45°C now occurring about 4% of the time (Figure 2).

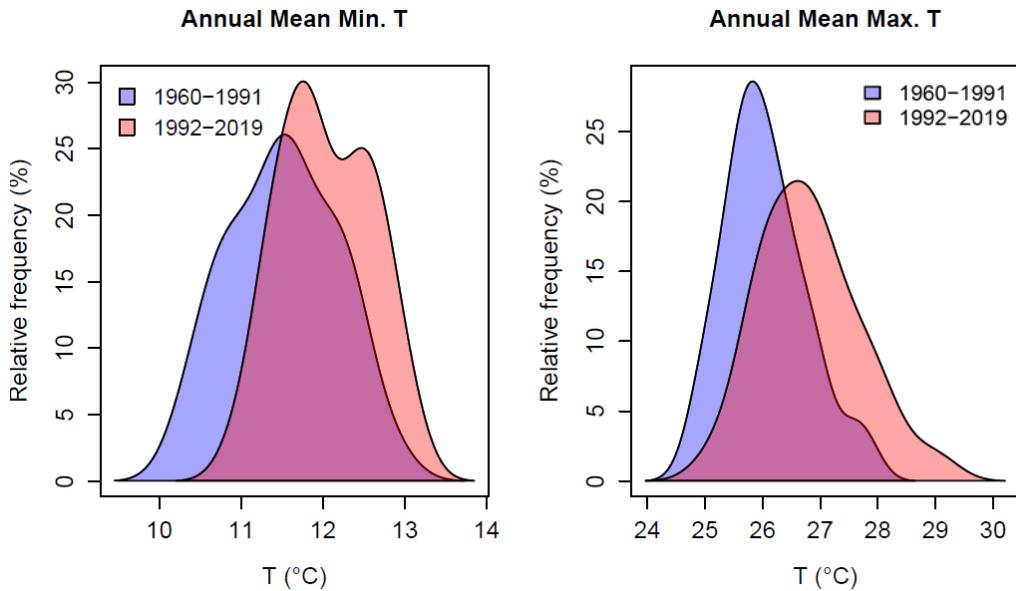


Figure 1. Probability distributions of annual mean maximum temperature (right) and annual mean minimum temperatures (left) for Bellata for two periods, namely 1960 to 1991 and 1992 to 2019.

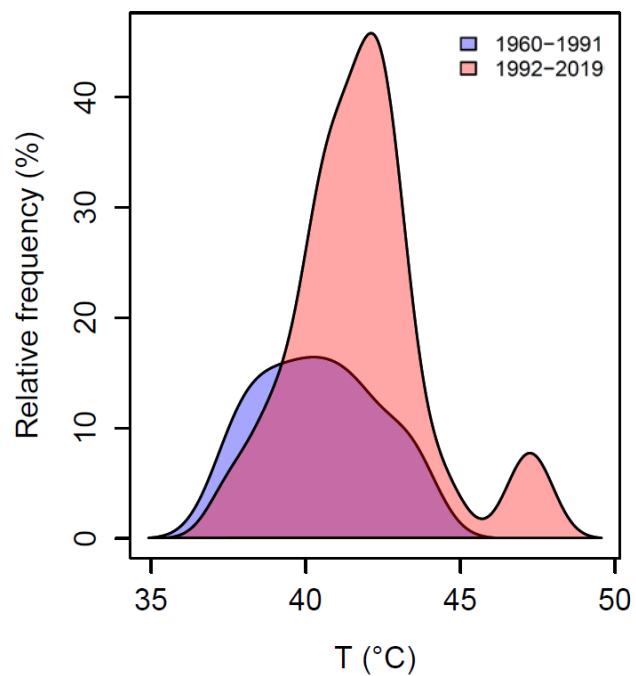


Figure 2. Probability distributions of daily maximum temperature extremes for Bellata for two periods, namely 1960 to 1991 (blue) and 1992 to 2019 (pink).

The Bellata rainfall record exhibits a declining trend, with an average 89mm less annual rainfall now than in the 1960s. A comparison of the annual rainfall between the period 1960 to 1991 and 1992 to 2019 (Figure 3) does show a slight change in the annual distribution of rainfall in the Bellata region. The analysis highlights an increase in the occurrence of low annual rainfall amounts less than 300mm in the most recent record as well as an increase in the occurrence of annual rainfall amounts greater than 950mm (Figure 3).

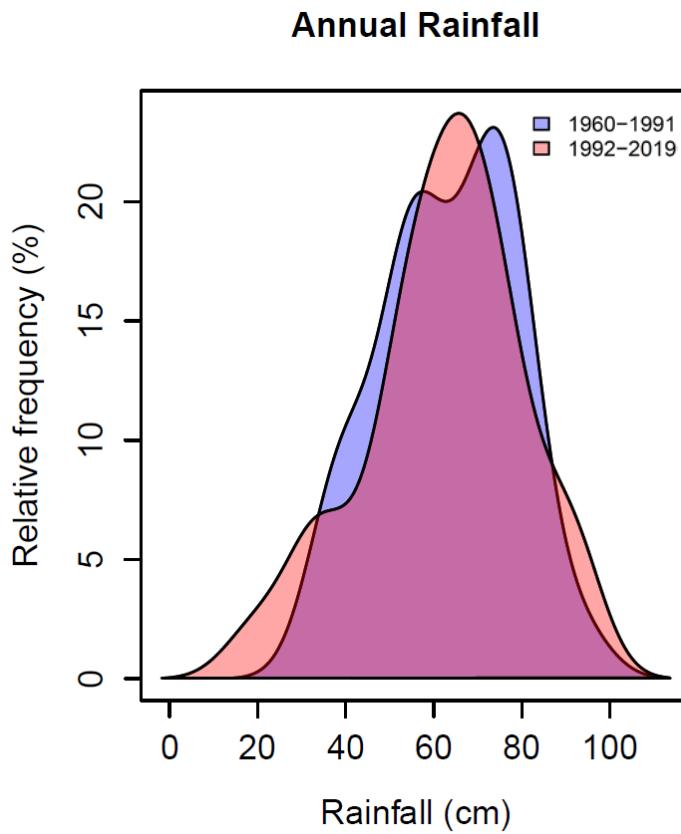


Figure 3. Probability distributions of annual rainfall amounts for Bellata for two periods, namely 1960 to 1991 (blue) and 1992 to 2019 (pink).

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 forcing's (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 New England and north west region (Bellata represents a town in the northwest of this study region) are summarised in Table 1. In addition to warmer temperatures. By 2030 the median value of annual potential evaporation is projected to increase by 5% under a high emissions scenario.

Table 1. Projected changes in temperature and rainfall for New England and north west region (Bellata represents a town in the northwest of this study 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 NSW Department of Planning and Environment.

Variable	Season	Historical mean (1986 to 2005)	2030	2070
Mean temperature change (°C change)	Annual	19.2°C	0.7 (0.4 to 1.0)	2.2 (1.8 to 2.6)
	Summer	26.0°C	0.9 (0.4 to 1.4)	2.4 (1.7 to 2.9)
	Autumn	19.6°C	0.7 (0.5 to 0.9)	2.2 (1.5 to 2.7)
	Winter	11.7°C	0.5 (0.3 to 0.7)	1.9 (1.4 to 2.4)
	Spring	19.4°C	0.8 (0.5 to 1.3)	2.3 (2.1 to 2.8)
Mean rainfall change (% change)	Annual	658mm	+1.6 (-12 to +15)	+7.7 (-10 to +25)
	Summer	245mm	-3.3 (-14 to +15)	+9.8 (-12 to +40)
	Autumn	123mm	+14.9 (-12 to +46)	+16.8 (+1.0 to +47)
	Winter	128mm	-7.6 (-29 to +16)	-0.7 (-29 to +30)
	Spring	164mm	+2.6 (-22 to +20)	-0.7 (-20 to +30)

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.

References

- Anderson, A., Kostinski, A., Anderson, A., and Kostinski, A. (2011). Evolution and distribution of record-breaking high and low monthly mean temperatures. *Journal of Applied Meteorology and Climatology*, 50(9), 1859–1871. <https://doi.org/10.1175/JAMC-D-10-05025.1>
- BoM (2020) Retrieved from <http://media.bom.gov.au/releases/739/annual-climate-statement-2019-periods-of-extreme-heat-in-2019-bookend-australias-warmest-and-driest-year-on-record/>
- BoM and CSIRO (2019) Retrieved from <http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2018.pdf>
- Climate Council (2019). The Angriest Summer. 978-1-925573-91-6

- Coumou, D., Robinson, A., and Rahmstorf, S. (2013). Global increase in record-breaking monthly-mean temperatures. *Climatic Change*, 118(3–4), 771–782. <https://doi.org/10.1007/s10584-012-0668-1>
- CSIRO and Bureau of Meteorology (2015). Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia.
- Ghahramani, A., Kokic, P.N., Moore, A.D., Zheng, B., Chapman, S.C., Hoden, S.M., and Crimp, S.J. (2015). The value of adapting to climate change in Australian wheat farm systems: farm to cross-regional scale. *Agriculture, Ecosystems & Environment*, 211, 112–125.
- Hayman, P. (2005). Linking Climate change to Farming Systems. Research Update for Advisers – Southern Region (http://www.grdc.com.au/growers/res_upd/south/_content.htm)
- Hochman, Z, Gobbett, D.L. and Horan, H (2017). 'Climate trends account for stalled wheat yields in Australia since 1990', *Global Change Biology*, vol. 23, pp. 2071–81. <https://doi:10.1111/gcb.13604>.
- Howden, S.M. and Crimp S.J., (2011). Regional Impacts: Australia. Yadav, S.S., Redden, R.J., Hatfield, J.L., Lotze-Campen, H. and Hall, A.E. (ed.) Crop adaptation to climate change. Wiley-Blackwell, Oxford.
- IPCC, (2018). Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.
- IPCC, (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.<https://doi.org/10.1017/CBO9781107415324>.
- Kendon, M. (2014). Has there been a recent increase in UK weather records? *Weather*, 69(12), 327–332. <https://doi.org/10.1002/wea.2439>.
- King, A.D. (2017). Attributing Changing Rates of Temperature Record Breaking to Anthropogenic Influences. *Earth's Future*. <https://doi.org/10.1002/2017EF000611>.
- King, A.D., Black, M.T., Min, S.K., Fischer, E.M., Mitchell, D.M., Harrington, L.J., and Perkins-Kirkpatrick, S.E. (2016). Emergence of heat extremes attributable to anthropogenic influences. *Geophysical Research Letters*, 43(7), 3438–3443. <https://doi.org/10.1002/2015GL067448>.
- King, A.D., Donat, M.G., Fischer, E.M., Hawkins, E., Alexander, L.V., Karoly, D.J., Perkins, S.E. (2015). The timing of anthropogenic emergence in simulated climate extremes. *Environmental Research Letters*, 10(9), 94015. <https://doi.org/10.1088/1748-9326/10/9/094015>.
- Kokic, P. Crimp S.J., Howden, S.M. (2014). A probabilistic analysis of human influence on recent record global mean temperature changes. *Climate Risk Management*, 3, 1–12. <https://doi.org/10.1016/j.crm.2014.03.002>
- Lewis, S.C., and Karoly, D.J. (2013). Anthropogenic contributions to Australia's record summer temperatures of 2013. *Geophysical Research Letters*, 40(14), 3705–3709. <https://doi.org/10.1002/grl.50673>.

Lewis, S.C., and King, A.D. (2015). Dramatically increased rate of observed hot record breaking in recent Australian temperatures. *Geophysical Research Letters*, 42(18), 7776–7784. <https://doi.org/10.1002/2015GL065793>.

Mann, M.E., Rhamstorf, S., Kornhuber, K., Steinman, B. A., Miller, S. K., Petri, & Coumou, D. (2018) Projected changes in persistent extreme summer weather events: The role of quasi-resonant amplification. *Science Advances*, 4(10), eaat3272. <https://doi.org/10.1126/sciadv.aat3272>.

McKeon, G.M. (2006). ‘Living in a variable climate’, article prepared for the 2006 Australia State of the Environment Committee, Department of Environment and Heritage, Canberra.

NOAA (2020) Retrieved from <https://www.esrl.noaa.gov/gmd/ccgg/trends/>

Porter, J.R., Xie,L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B. and Travasso, M.I. (2014). Food security and food production systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533

Watkins, A.B. (2005). ‘The Australian Drought of 2005’, *Bulletin of the World Meteorological Organisation* 54:156-162.

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