

## Early indicators of the extent of climate change on Australian farms

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**Abstract.** More research is needed before we know the implications of climate change for Australian farms. Nevertheless given the information at hand, an assessment can be made of some early indicators. First, the severity of the recent drought was compared with earlier droughts. Second, the trend in rainfall was examined. Third, projections of climate change were reviewed to assess the likely course of climate variability, and hence provide a picture of the severity of future droughts. Although further research is warranted, the indications are that even if rainfall is no lower in future droughts, they may seem more severe because rising temperatures will tend to increase evaporation and reduce runoff.

**Keywords:** Drought, climate change, climate variability, farming.

### Introduction

Recent dry conditions over eastern Australia have not only highlighted the challenges posed by climate variability but have also led to conjecture about whether these conditions are within the realms of natural climate variability or are a reflection of longer-term climate change. The high level of natural rainfall variability and the regular occurrence of droughts as a natural feature of the Australian climate make it difficult to discern natural variability from longer-term climate change.

Rainfall is not as directly influenced by increases in greenhouse gases as temperature is. Changing temperature patterns across the planet influence atmospheric circulation patterns, which in turn can change rainfall patterns (IPCC 2007). The way in which these atmospheric and oceanic circulations change under higher concentration of greenhouse gases and temperatures is not fully understood. Despite the degree of uncertainty, the impact of climate change on the quantity and variability of Australian rainfall is an important question for both farmers and researchers. A link between climate change and rainfall raises questions about the robustness of strategies that farmers have historically adopted to manage climate variability and the suitability of agricultural technologies developed by research bodies.

There are three separate, but related questions about recent and projected rainfall under climate change. First, how exceptional is the current drought in the context of previous droughts? Second, has climate change led to a trend towards lower annual rainfall? And third, will climate change lead to more dry years and a more variable climate generally? Each of these questions is briefly addressed in this paper.

### How exceptional is the current drought compared with previous droughts?

For the most recent drought period in Australia to be declared exceptional, and thereby be at least partly attributed to climate change, evidence is required that the recent drought's duration and/or its severity has exceeded that of previous droughts. Similar questions have recently been posed in the Productivity Commission's 'Inquiry into Government Drought Support' (Productivity Commission 2008), in the context of determining the adequacy of policy measures. Some of the reported findings are of direct relevance here. As part of the inquiry, the CSIRO and Bureau of Meteorology were commissioned to assess the impact of climate change on the nature and frequency of exceptional climatic events in Australia (Hennessy et al. 2008).

Recent conditions were compared with conditions in other periods within the climatic record in terms of the extent of areas experiencing exceptionally low rainfall and low soil moisture. Exceptional events were defined as events that occurred on average once in 20 years (i.e. the bottom 5 per cent of years); this is consistent with current National Drought Policy. The analysis was supplemented with data on average rainfall for each of the major regions as well as a more disaggregated regional assessment of rainfall in different periods. The results are summarised in Table 1 and the regional definitions are in Figure 1.

Table 1 shows that there have been previous six-year periods in the climate record that have had lower than average annual rainfall and a greater area influenced by exceptionally low rainfall than the most recent dry period of 2002 to 2007. The exception is south-west WA where average rainfall, and the area affected by drought

were at record levels during this recent period. Fewer data were available for soil moisture comparisons, but they also confirmed (with the exception of south-west Western Australia) that there were years in the climate record that had a lower level of soil moisture than the recent drought period. Overall, rainfall during the most recent drought period of 2002 to 2007 was found to rank with the Federation Drought and the Forties Drought as the three most severe, widespread and prolonged dry periods since 1900 across most of Australia.

So while the recent drought has been unusually severe (putting it in the bottom 5% of years), the occurrence of other more severe droughts makes attribution solely to climate change tenuous. In addition, while rainfall during the period of 2002 to 2007 was close to the lowest on record, runoff and inflows were easily the lowest on record. The greater impact on runoff might be a result of higher evaporation, changes in the seasonality of rainfall, greater interception by farm dams and land use change.

#### **Has climate change led to a trend towards lower annual rainfall?**

This question is closely related to the first but focuses on trends in rainfall rather than a single exceptionally low rainfall period. Measuring changes in rainfall resulting from changes to atmospheric composition is more difficult than measuring changes in temperature. The difficulty arises from greater complexity in the way precipitation is driven by the atmospheric and oceanic circulations and processes. This complexity results in the naturally variable patterns of rainfall experienced in Australia.

Trends in Australian annual rainfall can be readily obtained from the Bureau of Meteorology. The Bureau provides an online service for interrogating and analysing climate data from before 1900 to the present (Bureau of Meteorology 2009). These data can be aggregated by state or region for monthly, seasonal and annual time steps in a spatial or time series format. The time series of annual rainfall shows considerable decadal variation since 1900 as shown in Figure 2. This makes the selection of the starting point of the analysis the crucial determinant of observed rainfall trends. This was made evident when alternative starting points of 1900 (during the Federation drought - Figure 3) and 1950 (a historically wet period - Figure 4) were selected. When the full climatic record was used, the overall trend from 1900 to 2008 was found to be slightly towards wetter conditions. In contrast, when the climatic record 1950 to 2008 was used,

the overall trend was found to be towards much drier conditions. As a consequence, it is not clear whether recent rainfall trends are simply a return to drier periods experienced in the early 1900s or whether a fundamental shift has occurred as suggested by the trend towards lower rainfall from the 1950s.

Nicholls (2006) undertook a review of detection and attribution studies of climate change in Australia. Only in the case of the large reduction in rainfall in south-west Western Australia did the studies Nicholls reviewed confirm a link with climate change. He suggested this decline in rainfall could be related to increased greenhouse gas concentrations, natural climate variability and land-use change.

However, Nicholls found that to date, 'nearly all the attribution studies in Australia have been informal, rather than the formal statistical studies based on model-based 'fingerprints' of climate change' (Nicholls 2006, p.209). He proposed that a comprehensive and formal Australia-wide detection and attribution study for rainfall be completed. Until such a study is done, the significance of recent rainfall conditions and their possible linkage to climate change will remain uncertain.

Similarly, Power and Smith (2007) noted similar problems in assessing the frequency of El Niño events. They found that while the frequency of El Niño events had peaked during the last 30 years (11 events), they also pointed out that this could represent natural fluctuations in the climate system and that natural variability alone can drive substantial inter-decadal variability in ENSO.

The uncertainty that exists around the 'significance' of recent rainfall trends contrasts with temperature trends. The Australian average annual mean temperature has increased by 0.9°C since 1910 (Hennessy et al. 2008). Like increases in global temperatures, changes in Australian temperatures are attributed to rising greenhouse gas emissions. 'Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations' (IPCC 2007, p. 5). A clear temperature trend exists for many regions including the Murray-Darling Basin as shown in Figure 5.

A trend of rising temperatures will act to make drought periods more severe for any given level of rainfall because of higher evaporation levels. Nicholls (2004) proposed that this was the factor that made drought conditions in 2002 worse than those in 1982 and 1994.

### **Will climate change lead to more dry years and a more variable climate generally?**

Hennessy et al. (2008) undertook an assessment of the likely future changes in exceptional climatic events through to 2040 given climate change. They used 13 climate models that performed well in the Australian region, to assess changes in the occurrence of exceptionally high temperatures, rainfall and soil moisture. Their analysis of temperature showed both an increase in the geographic extent and frequency of exceptionally hot years, consistent with a robust trend towards increased temperatures generally. Shifts in rainfall and soil moisture were less significant relative to temperature overall, although there were some regions where large changes were found to be likely. A summary of the mean model results for exceptionally low rainfall and soil moisture is provided in Table 2.

Some regions including Queensland, NSW, Northwest and the Murray-Darling Basin are predicted to have similar areas affected by extremely low rainfall and a similar frequency of years (ie. the return period) affected by these conditions as is currently the case. In other regions (most notably Victoria, Tasmania and south-west Western Australia) large changes are predicted in both indicators towards more arid conditions.

Compared with the rainfall results, the results for exceptionally low soil moisture show a marginal increase in both the extent of area affected and the frequency of these conditions. This is to be expected given that soil moisture captures changes in rainfall, higher temperatures and evaporation. Even in the absence of rainfall changes, a trend toward hotter temperatures (and higher evaporation) implies that farmers will face periods of lower soil moisture and 'effectively drier' climatic conditions.

The results of Global Circulation Models suggest a trend towards drier conditions in many areas of Australia, particularly south-eastern Australia and south-west Western Australia (CSIRO 2001; CSIRO and Bureau of Meteorology 2007; Pittock 2003). For example, the CSIRO and the Bureau of Meteorology (2007) best estimates of median annual rainfall to 2030 varied from little change in the far north to decreases of 2 percent to 5 percent elsewhere. By 2050, under the B1 scenario (a mid-range emissions scenario) of the Intergovernmental Panel on Climate Change (IPCC 2007), the impact on rainfall is uncertain. The median annual rainfall is expected to be between 15 percent lower and 7.5 percent higher in central, eastern and northern areas, with a

best estimate of little change in the far north grading southwards to a decrease of 5 percent (CSIRO and Bureau of Meteorology 2007, p. 69).

This drying trend found in Global Circulation Models is a product of faster rates of modelled warming in the central and eastern tropical Pacific compared with the western tropical Pacific. This pattern of sea surface temperatures is consistent with more 'El Niño-like' conditions with associated negative implications for Australian rainfall.

There are some doubts about whether a shift to more 'El Niño-like' conditions will actually occur. A review of ENSO simulation within 20 Global Circulation Models found that 'those models that have the largest ENSO-like climate change also have the poorest simulation of ENSO variability' (Collins 2005). Collins concluded that the most likely scenario was 'for no trend towards either mean El Niño-like or La Niña-like conditions'. Similarly, the Australian Academy of Science (2006) found that there was no consistent evidence from dynamic climate models to suggest how ENSO will be influenced by an enhanced greenhouse effect. The lack of evidence was attributed to current models having limited capability in simulating the characteristics of ENSO.

### **Conclusions**

In summary, for most regions of Australia the research needed to establish a clear link between climate change and rainfall has yet to be done. The highly variable nature of Australian rainfall makes this a difficult relationship to analyse. The current limited capability of climate models to represent ENSO also makes it difficult to establish this link between climate change and rainfall.

There is, however, some degree of consistency between climate models in terms of a projected drying trend in south-eastern Australia. Even in the absence of any drying trend, it is apparent that projected higher temperatures under climate change will exacerbate the severity of years of below average rainfall. For this reason alone, climate variability will remain an important issue for farmers to manage.

Further research is warranted. As noted by Nicholls (2006), a formal Australia-wide detection and attribution study for rainfall should be completed. Also, the way in which climate change and ENSO interact could be a significant influence on future climate events in Australia. This interaction is also worthy of a more sustained research effort. Indeed, the accuracy of currently available statistically-based climate forecast systems may also be adversely affected by climate change,

providing further support towards the current trend of the development of dynamic forecasting systems.

## References

- Australian Academy of Science 2006, Report of workshop on the science of seasonal climate prediction, 2-3 August 2006, Australian Academy of Science, Canberra.
- Bureau of Meteorology 2007, 'SILO: meteorology for the land', viewed October 2007, <<http://www.bom.gov.au/silo/>>.
- Bureau of Meteorology 2008, "Time series - Australian climate variability and climate change. Murray Darling Basin annual rainfall", viewed July 2009, <[http://www.bom.gov.au/cgi-bin/silo/reg/cli\\_chg/timeseries.cgi?variable=rain&region=mdb&season=0112](http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi?variable=rain&region=mdb&season=0112)>
- Bureau of Meteorology 2009, 'Trend maps - Australian climate variability and change', viewed January 2009, <[http://www.bom.gov.au/silo/products/cli\\_chg/index.shtml](http://www.bom.gov.au/silo/products/cli_chg/index.shtml)>.
- Collins, M 2005, 'El Niño or La Niña-like climate change?' *Climate Dynamics*, vol. 24, no.1, pp. 89-104.
- CSIRO 2001, Climate change projections for Australia, CSIRO Atmospheric Research, Aspendale.
- CSIRO and Bureau of Meteorology 2007, Climate change in Australia: technical report 2007, CSIRO Atmospheric Research, Aspendale.
- Hennessy K, Fawcett R, Kirono D, Mpelasoka F, Jones D, Bathois J, Stafford Smith M, Mitchell C and Plummer N 2008, 'An assessment of the impact of climate change on the nature and frequency of exceptional climatic events', Bureau of Meteorology and CSIRO, Melbourne.
- IPCC 2007, 'Intergovernmental Panel on Climate Change (IPCC) 4th assessment synthesis report: summary for policymakers', viewed June 2008, <[http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr\\_spm.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf)>.
- Nicholls N 2004, 'The changing nature of Australian droughts', *Climatic Change*, vol. 63, no. 3, pp. 323-336.
- Nicholls N 2006, 'Detecting and attributing Australian climate change: a review', *Australian Meteorological Magazine*, vol. 55, no. 3, pp. 199-211.
- Pittock AB 2003, 'Climate change - an Australian guide to the science and potential impacts', Australian Greenhouse Office, Canberra.
- Power SB and Smith IN 2007, 'Weakening of the Walker Circulation and apparent dominance of El Niño both reach record levels, but has ENSO really changed?' *Geophysical Research Letters*, vol. 34, L18702, doi:10.1029/2007GL030854.
- Productivity Commission 2008, Government drought support, Draft Inquiry Report, Melbourne.

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Table 1. Comparison between the 2002–2007 drought and other drought periods

	Average annual rainfall			Exceptionally low rainfall			Exceptionally low moisture		
	2002-07 mm	Lowest since 1900 mm	period	2002-07 % area	Highest since 1900 % area	period	2002-06 % area	Highest since 1957 % area	period
Queensland	552	483	1900-05	7.5	24.8	1900-05	9.0	18.7	1966-70
NSW	451	417	1940-45	10.7	19.2	1940-45	11.4	15.7	1966-70
Vic & Tas	671	643	1940-45	14.1	15.7	1967-72	6.2	12.0	1966-70
Southwest	252	213	1935-40	5.4	15.1	1940-45	6.6	13.8	1977-81
Northwest	536	372	1933-38	5.6	13.5	1961-66	1.6	10.4	1991-95
MD Basin	405	387	1940-45	11.4	16.5	1940-45	10.9	16.1	1966-70
S.West WA	591	577	2001-06	10.6	25.8	1967-72	11.7	11.7	2002-06
Australia	457	396	1935-40	5.1	13.0	1924-29	na	na	na

na not available

(Source: Productivity Commission 2008)

Table 2. Projected changes in exceptionally low rainfall and exceptionally low soil moisture using mean model results

	Exceptionally low rainfall				Exceptionally low soil moisture			
	Area affected (%) <sup>a</sup>		Return periods (yrs) <sup>b</sup>		Area affected (%) <sup>a</sup>		Return periods (yrs) <sup>b</sup>	
	1900-2007	2010-2040	1900-2007	2010-2040	1957-2006	2030 mean	1957-2006	2030 mean
Queensland	5.5	5.8	18.1	16.0	6.5	7.4	16.5	12.6
NSW	5.6	5.6	18.0	18.0	6.3	7.1	16.4	14.0
Vic & Tas	5.4	9.7	18.3	12.4	6.6	11.0	16.8	9.4
Southwest	5.6	8.4	18.0	13.7	6.2	8.5	16.3	11.5
Northwest	5.6	5.3	18.0	16.2	6.3	7.0	16.3	13.5
MD Basin	5.6	6.0	18.0	17.3	6.2	7.3	16.2	13.4
S.West WA	5.5	18.4	18.1	6.5	6.1	15.9	17.0	6.0

a: percentage of the region that experiences exceptionally low rainfall or exceptionally low soil moisture

b: the return period (years) for either exceptionally low rainfall or low soil moisture events. Lower values suggest more regular occurrence of these events.

(Source: Hennessy et al. 2008)

Figure 1. Reporting regions

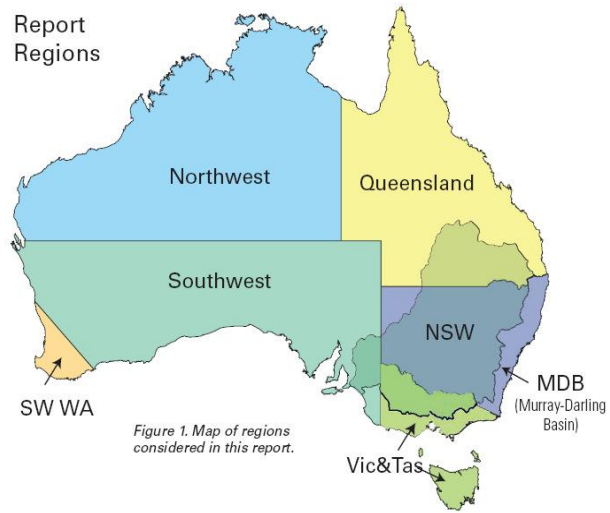
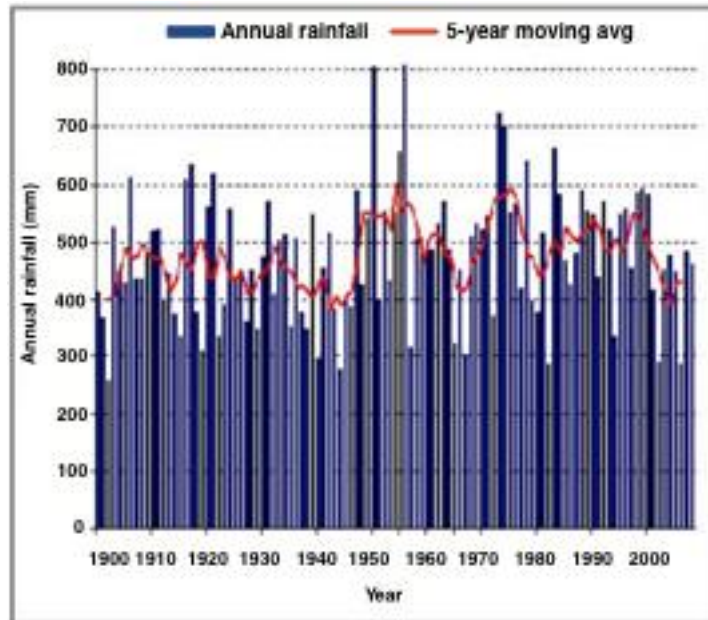
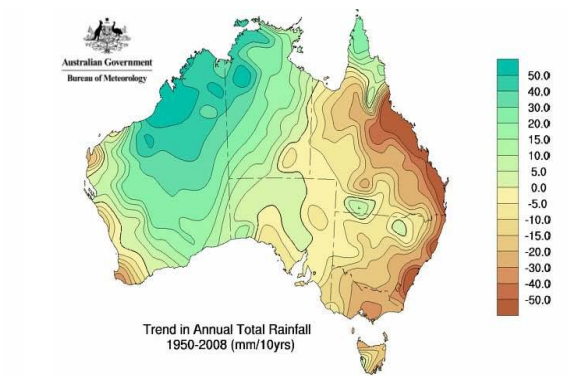


Figure 2. Indicators of Australian rainfall variability (Murray Darling Basin)



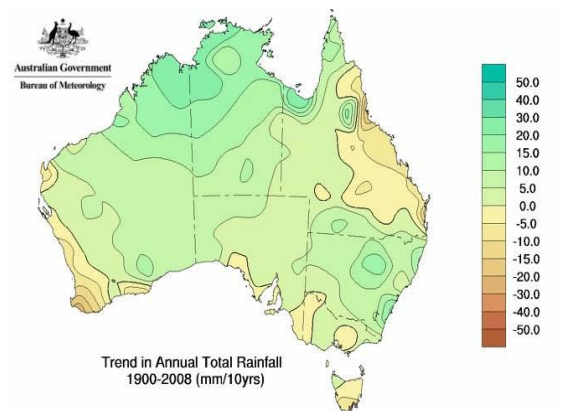
(Source: Bureau of Meteorology 2008)

Figure 3. Rainfall trends in Australia with a starting point of 1900



(Source: Bureau of Meteorology 2009)

Figure 4. Rainfall trends in Australia with a starting point of 1950



(Source: Bureau of Meteorology 2009)

Figure 5. Murray-Darling Basin temperature variability (base = 1961-90)

