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Past, present, and future droughts in the Murray-Darling Basin

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Abstract: Managing future water security and ecosystem functions pose substantial challenges for the Murray–Darling Basin (MBD). At the core of this issue is the need for a robust assessment of how long, how frequent, and how severe future droughts could be. To achieve this, a thorough understanding of natural climate variability is required to better quantify future drought risk.

Insights from palaeoclimate records show that the instrumental period does not account for the full range of natural climate variability in Australia. Thus, observed climate alone is insufficient to characterise baseline climate risks, particularly for extreme events, which are by nature infrequent and poorly sampled in relatively short historic records. Tree rings can be used to provide a much longer time series of streamflow with which to evaluate recent droughts overcoming some limitations of the instrumental data.

In this work we present a new palaeo-streamflow reconstruction of September–February Murray River discharge based on climate-sensitive tree rings. Our reconstruction captures over 750 years of variability in MDB streamflow. We use this extended record to benchmark the severity of the Millennium and Tinderbox droughts.

To do this, we assessed drought events in the palaeo-streamflow reconstruction based on different characteristics relevant to water management. Events were ranked separately by their duration, magnitude, and peak value, with increasing ranks for increasing parameter values. The rank scores were then summed to obtain the final score, where a higher score represents a more severe drought episode.

We estimated the return periods of known drought events using bivariate models which account for the different distributions of the various drought elements (duration, magnitude, and peak) and the correlation between them. The return period of a drought could then be approximated as the inverse of its modelled exceedance probability.

To contextualise how future drought risk compares to the past seven centuries, we repeated the joint probability analysis considering future streamflow projections. We calculated projections of Murray River streamflow using an ensemble of four downscaled and bias-corrected CMIP5 climate models from the Australian Water Outlook.

Our analysis shows that the Millennium Drought was exceptional compared to the palaeo-record, supporting previous studies that found that increasing temperatures are amplifying the impact of precipitation deficits in eastern Australia. Compared to the instrumental period droughts, climate models project an increase in future drought severity, with droughts of much longer duration and substantially higher magnitude than the Millennium Drought occurring in two projections. While the median likelihood of a drought exceeding the Millennium Drought in both length and magnitude remains small, such events should be considered in long-term water management planning, given the potential socio-economic and environmental consequences.

Keywords: *Drought, tree rings, reconstruction, probability, climate models*