Impacts of large-scale extreme hydroclimatic variations on ecosystem function in Southeastern Australia

Xuanlong Ma, Alfredo Huete, Susan Moran, Guillermo Ponce-Campos, Derek Eamus

Abstract
Amplification of the hydrologic cycle as a consequence of global warming is predicted to increase climate variability and the frequency and severity of droughts. Recent large-scale drought and flooding over numerous continents provide unique opportunities to understand ecosystem responses to climatic extremes. In this study, we investigated the impacts of the early 21st-century extreme hydroclimatic variations in southeastern Australia on vegetation productivity using Moderate Resolution Imaging Spectroradiometer Enhanced Vegetation Index and Standardized Precipitation-Evapotranspiration Indexes. Results revealed dramatic impacts of drought and wet extremes on vegetation dynamics, with abrupt between-year changes in productivity. Drought resulted in widespread reductions or collapses in the normal patterns of seasonality such that in many cases there was no detectable phenological cycle during drought years. Across the full-range of biomes examined, we found semi-arid ecosystems to exhibit the largest sensitivity to hydroclimatic variations, exceeding that of arid and humid ecosystems. This result demonstrated the vulnerability of semi-arid ecosystems to climatic extremes and potential loss of ecosystem resilience with future mega-drought events. A skewed distribution of hydroclimatic sensitivity with aridity is of global biogeochemical significance because it suggests current drying trends in semi-arid regions will reduce hydroclimatic sensitivity and suppress the large carbon sink that has been reported during recent wet periods (e.g., 2011 La Niña).

Figure 1. Land cover type and mean climatology of Southeastern Australia. (a) Land cover map, (b) mean annual precipitation, and (c) mean annual temperature. Solid blue triangles are six local sites that represent different land covers.

Figure 5. Comparison of hydroclimatic variation-induced shifts in seasonality for hummock grassland and shrubland, which are the most widespread vegetation types across extreme drought and wet years; (2) determine the consequences of contemporary, the early 21st-century climate extremes on ecosystem functioning in southeastern Australia; (3) assess the concomitant and relative importance of climate and vegetation types in determining ecosystem sensitivity and resilience to the impacts of drought. We focused on Australia because it has one of the most variable climates around the globe, and thus it is of interest and importance to know how ecosystems behave under such extreme climate variability.

Data and Method
MODIS EVI
Approximately 14 years (February 2000 - December 2013) of 16-day 0.05° resolution MODIS Enhanced Vegetation Index (EVI) data (MCD12Q1. Collection 5) were obtained from the NASA Land Processing Distributed Active Archive Center (https://ladsweb.modaps.eosdis.nasa.gov/). Quality control was applied to retain high-quality observations while minimizing aerosol and cloud contamination. EVI is a proxy for canopy greenness, which is an integrative composite property of green foliage, leaf chlorophyll content, and canopy architecture. Annual-integrated EVI (named EVI) has been widely used as a remoteensing surrogate of annual vegetation productivity from and gradual to forests. In Australia, MODIS EVI has been found to be strongly correlated with annual gross primary productivity (GPP).

Standardised Precipitation-Evapotranspiration Index (SPEI)
Drought severity was determined as when “0.5 < SPEI < 0.5”. The grey horizontal dashed line in Figure 3a indicates the position of precipitation and temperature anomaly equal to zero, while the grey, blue, and red horizontal dashed lines in Figures 3a and 3b indicate the position of SPEI equal to zero, maximum and minimum SPEI during the 1950-2013 time period.

Figure 7. Sensitivity of vegetation productivity to hydroclimatic variations across arid to humid climate regimes. Extremely dry or wet conditions have been found to strongly influence the vegetation productivity patterns across Australia (ARC-DP140102698, Huete lead) and the NASA SPaWNP Science Definition Team under agreements 08-SPIP/2708-0002, and the NASA SPaWNP Science Definition Team under agreements NNX09AB77G.

Figure 6. Seasonal and interannual variations in EVI and SPEI at six local sites within southeastern Australia. The solid green line is standardized anomaly of monthly MODIS EVI (iEVI). Vertical bars are monthly SPEI, and comparison of hydroclimatic variation-induced shifts in seasonality for hummock grassland and shrubland, which are the most widespread vegetation types across extreme drought and wet years; (2) determine the consequences of contemporary, the early 21st-century climate extremes on ecosystem functioning in southeastern Australia; (3) assess the concomitant and relative importance of climate and vegetation types in determining ecosystem sensitivity and resilience to the impacts of drought. We focused on Australia because it has one of the most variable climates around the globe, and thus it is of interest and importance to know how ecosystems behave under such extreme climate variability.

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