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Impacts of extreme hydro-meteorological conditions on ecosystem functioning and productivity patterns across Australia

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As Earth's climate continues to change, the frequency and intensity of warm droughts, extreme precipitation patterns, and heat waves will alter in potentially different ways, ecosystem structure and functioning with major impacts on carbon and water balance, and food security. The extreme hydro-meteorological conditions that are presently impacting Australia approach those anticipated with future climate change and thus provide unique opportunities to study ecological sensitivity and functional responses and cross-biome productivity changes using contemporary, in-situ and satellite observational datasets. Here, we combined satellite vegetation index products from MODIS and AVHRR, total water storage (TWS) from the GRACE twin satellites, precipitation data and in-situ tower flux measurements to characterise ecosystem sensitivity, and analyse climate change impacts on ecosystem productivity and resilience. Recent advances in eddy covariance tower flux measurements and spatially contiguous remote sensing data provide innovative and promising capabilities to extend ecosystem functioning and productivity studies from local to regional and continental scales.

In general, Australia exhibited ecosystem-level shifts in water demands with water availability across wet and dry years, and over all biomes analysed (arid grasslands to humid forests). In the drier years, higher ecosystem water use efficiencies (WUEe) enabled plants to maintain higher levels of productivity than would otherwise be expected for the lower amounts of rainfall and available water. Further, there were unique, functional class-specific coping strategies to drought and water availability. With prolonged warm drought conditions, biomes became increasingly water-limited and WUEe continued to increase until reaching a 'dry edge' threshold, a cross biome maximum WUEe, that cannot be sustained with further reductions in water availability and could potentially break down ecosystem resilience and induce significant drought-induced mortality. Semi-arid rangelands were most sensitive to drought and wet pulses, generating large land carbon sinks with subsequent rapid carbon dissipation rates. We also found an intensification of drought and wet cycles from the 1980's, inducing similar impacts on the carbon cycle. More efforts are needed to understand and generalize vegetation responses to extreme hydro-meteorological conditions in order to better inform land managers and other stakeholders of potential environmental and economic impacts.