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Ecosystem response to rainfall variability and warming in a mesic grassland

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Grassland ecosystems are strongly responsive to climatic variability, and many fundamental aspects of their structure and function are tied to spatial and temporal variation in precipitation. The pulsed nature of precipitation inputs- short periods of rainfall separated by longer periods during which soil moisture is depleted- means that the temporal pattern of rainfall inputs (event frequency and size) is a major determinant of temporal variability in soil water content. Relationships among precipitation variation and ecosystem function are critically important because of the documented increases in the frequency of extreme rainfall events worldwide, and the likely interactions of precipitation variability with rising atmospheric [CO_2] and warming.

To better understand these interactions we are conducting two rainfall variability experiments in tallgrass prairie in eastern Kansas, USA (39.1ºN, 96.9ºW). The Rainfall Manipulation Plot experiment (RaMPs), initiated in 1998, consists of twelve native grassland study plots covered by rainfall exclusion shelters, that receive 1) an altered rainfall regime with longer dry intervals and larger rainfall events and 2) increased temperatures via infrared lamps, combined in a fully factorial design with rainfall and temperature controls. The Rainfall Mesocosm facility, initiated in 2004, consists of 64 3.6 m^3 outdoor cells located under a rainout shelter and filled with native soil and planted with a mixture of native tallgrass C_4 grasses, legumes, and non-legume forbs.

There are 16 watering treatments (n = 4 microcosms trt^{-1}): four annual quantities (400, 600, 800, and 1000 mm yr^{-1}) factorially combined with four watering intervals (3, 6, 10, and 15 d), with individual watering event sizes from 4 to 53 mm.

In both studies, increased temporal variability (larger events separated by longer dry intervals) in rainfall caused predictable increases in the temporal variability in soil moisture, and impacted several key ecosystem properties related to carbon cycling and biotic diversity. In the RaMPs, temporal variation in soil moisture due to increased rainfall variability was negatively correlated with aboveground net primary productivity (ANPP; R^2 = 0.41). Warming caused only slight reductions in soil moisture and ANPP compared to unwarmed controls. Analyses of leaf photosynthesis and water status responses in the dominant grass *Andropogon gerardii* to rainfall quantity and interval combinations in the Mesocosm experiment revealed strongly non-linear photosynthetic responses to increasing rain event size. These non-linear responses reflect varying effectiveness of different rain event sizes on soil moisture availability, and indicate that temporal variability in rainfall contributes to the weak correlation between leaf level carbon gain and ANPP. Impacts of rainfall and temperature treatments on plant species diversity were weaker than those for ANPP. Variability was positively correlated with plant species diversity (H’; R^2 = 0.25), although warming had no significant effect on H’. Early growth stages in most species were strongly responsive to varying rainfall intervals, suggesting that patterns of rainfall variability can strongly affect recruitment into these communities. In summary, rainfall variability can influence critical components of ecosystem carbon cycling and plant species diversity in grasslands, and should be considered in predictions of ecosystem responses to a range of future rainfall scenarios.