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Rainfall variability and ecosystem response 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 discrete 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 in terms of frequency and event size is a major determinant of temporal variability in soil water content. The importance of the discrete nature of rainfall inputs has been widely recognized in arid ecosystems, where pulses of different sizes and durations are effective at activating processes at different levels of organization. We contend that this concept also applies to the relatively mesic, but still water-limited grasslands of the eastern Central Plains grasslands of North America.

We have implemented two ongoing watering quantity/interval experiments in tallgrass prairie at the Konza Prairie Biological Station, Kansas, USA (39.1^{o}N, 96.9^{o}W) . The Rainfall Manipulation Plot experiment (RaMPs), initiated in 1998, consists of twelve native grassland study plots covered by rainfall exclusion shelters, that receive either the ambient rainfall pattern in size and timing of inputs, or an altered, more variable rainfall regime with longer dry intervals and larger rainfall events but the same total rainfall quantity as ambient. The Prairie Microcosm facility, initiated in 2004, consists of 64 3.6 m^3 outdoor containers 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, experimental rainfall regimes with increased temporal variability (larger events separated by longer dry intervals) caused predictable increases in the temporal variaiblity in soil moisture, and impacted several key ecosytem properties related to carbon cycling. In the RaMPs, temporal variation in soil moisture due to increased rainfall variaiblity was strongly correlated with photosynthetic carbon gain (R^2 = 0.68, $p < 0.0001$) in two dominant C_4 grass species that account for $> 50\%$ of aboveground net primary productivity (ANPP) in this ecosystem. Growing seasons with the greatest temporal variability soil moisture had the lowest ANPP (R^2 = 0.56, p = 0.01), and increased variability significantly increased plant species diversity (p = 0.04). In the microcosm experiment, leaf photosynthesis, soil CO_2 efflux, ANPP, and leaf area index all showed strong responses to increasing rain event size when applied at the most frequent watering interval, and progressive declines with increasing event size at longer watering intervals (interval x pulse size $p < 0.0001$ in all cases). Thus, these experiments suggest that mesic grasslands are highly sensitive to changes in in rainfall patterns, with complex interactions among rainfall event size, the duration between events, and total rainfall quantity. These precipitation parameters influence critical components of carbon cycling and diversity, and these results are likely to be generally applicable to grassland ecosystems, and useful in predicting future ecosytem characteristics under a range of future rainfall scenarios.