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Impact of varying storm intensity and extended dry periods on grassland soil moisture

John D. Hottenstein (1), Guillermo E. Ponce-Campos (2), and M. Susan Moran (2)

(1) University of Arizona, Agricultural and Biosystems Engineering, Tucson, AZ USA, (2) USDA ARS Southwest Watershed Research Center, Tucson, AZ, USA

Intra-annual precipitation patterns are expected to shift toward more intense storms and longer dry periods due to changes in climate within the next decades. Using MODIS satellite-derived plant growth data from 2000-2012, this study quantified the relationship between extreme precipitation patterns, annual soil moisture, and plant growth at nine grassland sites across the southern United States. Across all sites, total precipitation was strongly linked to surface soil moisture (at 5-cm depth), and in turn, soil moisture was strongly related to MODIS-based estimates of above-ground net primary production (ANPP). In fact, soil moisture was a better predictor of ANPP than was total precipitation.

Results showed a fundamental difference in the response to altered precipitation patterns between mesic and semiarid grasslands. Soil moisture in mesic grasslands decreased with an increase of high-intensity storms, and semi-arid grassland soil moisture decreased with longer dry periods. This was explained in relation to general climate patterns in these two precipitation regimes. The soil moisture at mesic sites tends to reside closer to field capacity than soil moisture at semiarid sites. So, for semiarid sites, storm events of any size will impact soil moisture; whereas for mesic sites, high intensity storms result in greater runoff than low intensity storms, and less impact on soil moisture. In this field study, the length of consecutive dry days (CDD) had a significant impact on soil moisture only at semiarid sites. This was attributed to the fact that the variation in length of CDD was naturally low at mesic sites and not variable year-to-year, in contrast to the high variability of CDD at semiarid sites. For semiarid sites, long periods of CDD decreased the mean annual soil moisture regardless of the total precipitation throughout the year.

Our decision to use soil moisture measured at 5-cm depth was largely based on the fact that the currently orbiting Soil Moisture Ocean Salinity (SMOS) and planned Soil Moisture Active Passive (SMAP) sensors will provide global measurements of soil moisture at this depth. For our study sites, we found a reasonable relation between in situ point measurements and the 40-km^2 soil moisture data obtained from the SMOS satellite. Considering the difference in scale, this gives some confidence in interpreting the results obtained herein for application with satellite-based measurements such as SMOS and SMAP.

This research explains the varying results of previous studies and offers a consistent hydrometeorological explanation for how mesic and semiarid grasslands will respond to changing precipitation patterns and a changing climate. Incorporation of intra-annual patterns of storm intensity in mesic grasslands and CDD in semiarid grasslands will help improve estimates of annual soil moisture and better predict grassland production. This improved ability to predict soil moisture and plant growth with changing hydro-climatic conditions will result in more efficient resource management and better informed policy decisions.