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Diverse responses of semi-arid grasslands to severe droughts in Inner Mongolia, China

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Covering almost one-third of the land, grasslands play an important role in providing ecosystem functions and services such as carbon cycling. Further, grasslands are considered to be one of the ecosystems most sensitive to drought. As the frequency and intensity of droughts increase globally with climate change, it is urgent to quantify the characteristics and mechanisms of grassland responses to drought events.
In this study, we studied the response of grassland growth to drought events in the semi-arid grasslands of Inner Mongolia, China. This semi-arid grassland is characteristic of many grasslands globally, such as in the entire Eurasian steppe belt. By utilizing remote sensing data (MOD13A1), gridded climate data interpolated from weather station observations (CRU TS4.03), and drought index calculated from the CRU datasets (SPEI03 from SPEI database) at 500m*500m spatial resolution, we found that the semi-arid grasslands in our study area experienced severe droughts in the summers (June, July, and August) of 2007 ($SPEI03_{min}$ = -1.94) and 2017 ($SPEI03_{min}$ = -2.37). Surprisingly, in 2017, the grasslands appeared to be almost unaffected by the extreme drought (EVI_{ano} = 0.004), while in 2007, productivity was reduced during drought (EVI_{ano} = -0.026).
To explore why the semi-arid grasslands responded differently to these two summer drought events, partial correlation analysis was done by considering the influence of temperature, precipitation, and SPEI03 on EVI in summer during 2001-2018. The results showed that grasslands are generally significantly correlated to SPEI03 (39.73% pixels with $p<0.1$) rather than to temperature (13.27% pixels with $p<0.1$) or to precipitation (11.39% pixels with $p<0.1$). However, when we compare the spatial distributions of EVI, temperature, precipitation, and SPEI in summer in 2007 and 2017, a different pattern emerges. Temperature patterns were similar between summer in 2007 and 2017, but precipitation patterns were different, resulting in different SPEI patterns. In regions which showed a significant, positive correlation with precipitation, there was heavier rainfall (100mm/month<precipitation<140mm/month) in 2017 than in 2007 (precipitation<100mm/month). The heavy rains offset the negative effect of heatwave, and enhanced grass productivity in areas with moderate temperature in summer in 2017. These results demonstrate the importance of monthly to seasonal precipitation patterns and provide a reference for management in response to extreme drought events in semi-arid grassland ecosystems.