Impact of compound weather extremes on winter wheat in Germany

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In the last decades, Europe has experienced an increase in the occurrence of extreme spring-to-summer heat and rainfall deficit. The compound impact of both hazardous weather events causes extreme drought conditions, which are likely to increase in frequency in the coming decades, with large impacts on agriculture and crop productivity. In this study, we analyze and attribute the effects of compound weather extremes on yield anomalies in Germany from 1989 to 2019.

To characterize the impact of compound events on irrigated and rainfed crops, statistical index-based approaches have widely been used, linking historic weather aggregates to yield records. To analyze and predict the impact of compound extreme events on crop yield, productivity and cultivation area at subnational level for Germany, we merged available yield data from multiple sources to create a consistent yield record of the last 30 years at county level. We then calculated indices on gridded meteorological data and records of phenological crop phases and agricultural practices, covering three decades, to analyze the effect of compound weather extremes on winter wheat yield.

We evaluated the SPEI (Standardized Precipitation Evaporation Index) for the 6-month period before winter wheat is harvested, to account for extremes in excess and lack of water availability. We further calculated the HMD (Heat Magnitude Day) index for the 3-month period before harvest, to assess the impact of heat stress conditions. Finally, a composite indicator the CSI (Combined Stress Index), based on a linear superposition of the standardized HMD and SPEI, is applied. The CSI is calibrated to local conditions by determination of coefficients that maximize the explanatory power of the index, using a bilinear ridge regression and county level yield observations.

The results of this study help to better understand the impacts of compound extremes on winter wheat in Germany and reveal regions that are especially threatened by yield losses from compound weather extremes.