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Reduced summer aboveground productivity in temperate C3 grasslands under future climate regimes

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Temperate C3 grasslands provide important ecosystem services, such as livestock forage production, substrate for biogas and carbon storage. These ecosystem services are primarily controlled by biomass production, which is assumed to decrease with lower amounts and higher variability of precipitation, while increasing air temperature might either foster or suppress biomass production. In addition, higher atmospheric CO_2 concentrations ($[CO_2]$s) should increase biomass through direct stimulation of photosynthesis and an increased water use efficiency (CO_2 fertilization effect). Thus, biomass productivity is controlled by the partly opposite effects of changing climatic conditions and $[CO_2]$, which results in high uncertainties of future biomass production and carbon storage estimates.

Consequently, this study investigates the contrasting influences of global change on the basis of an Free Air Carbon Dioxide Enrichment (FACE) experiment ($\sim$20% over ambient $[CO_2]$; 18 years) in order to statistically predict the aboveground summer biomass (AGB) in the middle of the 21st century. An information-theoretical screening provided the most important predictors based on air temperature and precipitation measurements. The AGB production was predicted within different climate regimes, the latter were derived from the observations of the experimental period. We found that future AGB production depends mainly on precipitation, followed by air temperature and precipitation variability. More variable precipitation reduced the AGB and vice versa. AGB production under dry conditions further decreased with increasing air temperatures. In contrast to the widely expected yield increases due to increased $[CO_2]$, such conditions lead to AGB predictions below those of current AGBs, under ambient $[CO_2]$. Since climate models for summer in Central Europe project rising air temperatures and decreasing precipitation with increasing variability, our results indicate a reduced future summer grassland AGB contradicting the widely expected positive yield anomalies from increasing $[CO_2]$.