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Contrasting responses of shrubland carbon gain and soil carbon efflux to drought and warming across a European climate gradient

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Understanding the relationship between above- and belowground processes is crucial if we are to forecast feedbacks between terrestrial carbon (C) dynamics and future climate. To test if climate-induced changes in annual aboveground net primary productivity (aNPP) will drive changes in C loss by soil respiration (Rs), we integrated data across a European temperature and precipitation gradient.

For over a decade, six European shrublands were exposed to repeated drought (-30 % annual rain) during the plants' growth season or year-round night-time warming (+1.5 oC), using an identical experimental approach. As a result, drought reduced ecosystem C gain via aNPP by 0-25 % (compared to an untreated control) with the lowest C gain in warm-dry sites and highest in wet-cold sites (R2=0.078, p-value = 0.544, slope = 14.35 %). In contrast, drought induced C loss via Rs was of a lower magnitude (10-20 %) and was most pronounced in warm-dry sites compared to wet-cold sites (R2=0.687, p-value = 0.131, slope = 7.86 %). This suggests that belowground activity (microbes and roots) is stabilizing ecosystem processes and functions in terms of C storage. However, when the drought treatment permanently altered the soil structure at our hydric site, indicating we had exceeded the resilience of the system, the ecosystem C gain was no longer predictable from current (linear) relationships. Results from the warming treatment were generally of lower magnitude and of opposing direction compared to the drought treatment, indicating different mechanisms were driving ecosystem responses.

Overall, our results suggest that aNPP is less sensitive than Rs to climate stresses and soil respiration C fluxes are not predictable from changes in plant productivity. Drought and warming effects on aNPP and Rs did not weaken over decadal timescales at larger, continental scales if no catastrophic threshold is passed. However, indirect effects of climate change on soil properties and/or microbial communities need to be further explored