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Effect of summer drought on the coupling of photosynthesis and soil respiration under current and future climate

Kathiravan Meeran (1), Johannes Ingrisch (1), David Reinthaler (1), Lena Müller (1), Alberto Canarini (2), Andreas Richter (2), Wolfgang Wanek (2), Erich M. Pötsch (3), and Michael Bahn (1)

(1) University of Innsbruck, Institute of Ecology, Innsbruck, Austria (kathiravan.mohamed-meeran@uibk.ac.at), (2) Department of Microbiology and Ecosystem Science Division of Terrestrial Ecosystem Research,University of Vienna, Austria, (3) Institute of Plant Production and Cultural Landscape, Agricultural Research and Education Centre, Raumberg-Gumpenstein,Austria

Belowground carbon allocation acts as a key determinant of the fate of carbon in terrestrial ecosystems. It immediately connects the two largest fluxes of CO_2, i.e. photosynthesis and soil respiration. Climate extremes such as drought can exert a major impact on the ecosystem carbon balance by altering carbon uptake and release processes. Drought has also been shown to slow down the allocation of recently assimilated carbon belowground, thereby reducing the coupling of photosynthesis and soil respiration. However, it is still unclear whether and how such drought effects are altered by a future warmer climate under elevated atmospheric CO_2. Positive effects of elevated CO_2 on photosynthesis and soil moisture could be counterbalanced by warming effects on evaporative demand, with uncertain consequences on drought effects in a future climate.

As part of the ClimGrass experiment, we studied the impact of drought on the coupling of photosynthesis and soil respiration in a managed C3 grassland under current versus future climate conditions. We simulated the future climate by experimentally increasing the air temperature by 3˚C and atmospheric CO_2 concentration by 300ppm above ambient, treatments starting 3 years prior to the drought study. We performed two $^{13}CO_2$ pulse-labeling experiments to trace the fate of carbon from photosynthesis to soil respiration during peak drought and 10 days after the end of drought, i.e. the recovery period. We measured plant carbon assimilation, soil respiration and the amount of ^{13}C respired in soil relative to initial label assimilation (rel.^{13}C).

Our results show that during drought, plant carbon assimilation, soil respiration and rel.^{13}C respired were reduced. The impact of drought was stronger under future climate conditions, which was evident from a stronger reduction of soil respiration and a more pronounced post-drought stimulation of CO_2 efflux (‘Birch’-effect). Interestingly, drought effects on the coupling of assimilation and respiration – expressed in dampened diurnal dynamics of rel.^{13}C respired from soil – were less pronounced under future climate than under current climate conditions. During the recovery period, soil respiration recovered quickly. Post-drought effects on the assimilation and rel.^{13}C respired prevailed longer under current compared to future climate conditions. Moreover, the lower residence time of rel.^{13}C respired also indicates faster recovery under future climate conditions.

Hence our results suggest that under future climate conditions, the resistance of soil respiration to drought decreases, however, effects on assimilation and coupling of assimilation and respiration are mitigated. We conclude that plant and soil carbon dynamics have different sensitivities to interactive effects of elevated CO_2, warming and drought. This emphasizes the complexity of future climate change on ecosystem carbon dynamics.