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How extreme weather events affect the CO_2 fluxes from grassland and bare soils: a manipulation experiment under the temperate continental climate

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Carbon cycle and its main components interact closely with climate changes via feedbacks. Current climate changes in Central Russia include an increase of the frequency of extreme weather events such as severe droughts, heavy rains, and deep soil freezing. The study was aimed to evaluate the effect of extreme and mild climates on summer and winter CO_2 fluxes from grassland and bare soils under temperate continental climate.

To simulate extreme, mild, and ambient conditions, the manipulation precipitation experiment was established in grassland cenosis and bare soil (Luvisols Haplic, Moscow region, 54°50'N, 37°36'E; continental-temperate climate). During the warm period (May–October), the following precipitation patterns were foreseen: Sum1 — optimal moisture regime (regular irrigation), Sum2 — repeating short droughts (5–7 weeks without rainfall), and Sum3 — severe drought (ca. 3 months without rainfall). To evaluate the effect of freezing events of different intensity on CO_2 fluxes from soils, the following winter scenarios were applied: Win1 — exclusion of freeze (simulation of deep snow cover by artificial heat insulation material); Win2 — natural depth of snow cover, and Win3 — deep freezing (without snow cover). In the frame of the whole experiment, variant S1 together with Win1 simulated mild climate (Mild), while variants Sum2 and Win2 corresponded to 'ambient' temperate climate (Ambient). Variants Sum3 and Win3 together simulated extreme climate conditions (Extreme) with severe summer drought and deep freezing during winter time. CO_2 emission fluxes (total soil respiration, TSR) were measured by closed chamber method 2–3 times per week from the end of October 2015 to November 2016 using syringe technics (Li-COR820) during the cold season and by Li-COR 6400 system over the warm period.

For the cold season, the cumulative TSR flux from grassland plots during 6 months of field observations varied between 82–87 g C/m2 (Win2, Win3) and 164 g C/m2 in Win1 variant. For the bare plots, the cold TSR fluxes were 1.3–1.7 times lower than those in grassland soils. Over the warm period, the TSR in Sum1 variant comprised 1383 and 203 g C/m2 in grassland and bare plots, respectively. Severe drought stress reduced the TSR by 40% in grassland and only by 5% in bare soil. The increase in summer CO_2 fluxes due to their notable burst after wetting of soils in Sum2 variant (Birch' effect) comprised 5–12%.

We conclude that under continental temperate climate, summer TSR is regulated mainly by severe summer drought while the impact of repeated droughts was weaker due to the Birch' effect. During the cold season, freezing events played an important role and significantly reduced winter CO_2 emission from soils. In general, under extreme climate, TSR decreased by 32% in bare plots and 42% under grass vegetation during the 12 months of experiment. The effect of climate mitigation was much weaker compared to extreme climate: total TSR in grass and bare variant increased by 10–11% compared to ambient climate.
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