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Pulsed responses of soil-atmosphere CO_2, CH_4 and N_2O fluxes to extreme rewetting events

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Frequency and intensity of extreme weather events like severe drought and heavy rainstorms will increase in Central Europe due to shifts in global precipitation patterns with climate change. Changes in precipitation affect soil moisture, which is one of the main determinants of soil greenhouse gas (GHG) emissions. While drought generally inhibits the activity of soil microorganisms and plant roots, reducing the production of GHGs in soil, rewetting often leads to abrupt and disproportionately high GHG emission rates. The present study investigated the impact of repeated severe drying-rewetting cycles on soil GHG emissions in the field.

The experiment was conducted at the ILTER-site "Rosalia" in Austria, where a precipitation manipulation experiment started in 2013 to examine the impact of repeated severe droughts and rainfalls on soil processes, including GHG emissions. Two different rainfall redistribution schemes were applied from 2013 to 2015 during the vegetation period (May-October): a "moderate stress" treatment where soils underwent six drying-rewetting cycles (one-month rainfall exclusion followed by 75 mm rain), and a "severe stress" treatment that experienced three drying-rewetting cycles (two-months rainfall exclusion followed by 150 mm rain). Rainfall was excluded from soils with roofs (1 m above soil), and rainfall events were simulated using sprinklers. Soil-atmosphere GHG fluxes were continuously measured using an automated chamber system coupled to an NDIR gas analyser for CO_2 detection (LI-COR 840A), and a GC equipped with a FID for CH_4 detection and an ECD for N_2O detection. This system was used to measure soil-atmosphere GHG fluxes with 3-hourly resolution over the entire duration of our experiment. During one irrigation, we replaced the GC-FID/ECD with a novel CH_4/N_2O laser analyser (Los Gatos Research), which allowed us to increase the temporal resolution to 30 min and enabled us to follow GHG dynamics during rewetting more closely.

Irrigation increased soil water-filled pore space from 22 % pre-wetting to 45 % post-wetting. This change in soil moisture strongly affected soil-atmosphere GHG fluxes in both treatments within minutes: compared to pre-wetting flux rates, rewetting increased CO_2 emissions up to 200 %. CH_4 uptake rates were reduced by 16 % compared to pre-wetting fluxes. The strongest response was shown by N_2O, where emissions increased up to 800 % compared to pre-wetting fluxes. CO_2 and N_2O emission rates remained higher than pre-wetting levels for $\sim$15 h, while the decrease in CH_4 was more persistent in time and continued over one week. While our long-term observations showed an overall decrease in soil respiration and an increase in CH_4 uptake in response to the rainfall redistribution, results from the laser measurements showed that rewetting events can trigger rapid and disproportionate responses that are short in duration but can contribute substantially to ecosystem C and N cycling. This suggests an underestimation of GHG budgets during drying-rewetting cycles if temporal resolution is low. In addition, we stress that models that predict ecosystem C and N balance would significantly improve if they accounted for the duration and frequency of drought periods and heavy rainfall events.