Historical soil redox regimes mediate soil greenhouse gas emissions

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Global climate models predict that precipitation events in the Midwestern United States will increase in variability and intensity in the coming decades, likey resulting in a higher frequency of ponding of upland mesic soils. Ponding can affect redox sensitive biogeochemical processes that produce and consume greenhouse gases (GHGs) in soil, including carbon dioxide (CO_2) and nitrous oxide (N_2O). Poorly-drained soils that frequently experience dynamic soil redox may respond differently to ponding compared to more well-drained soils that rarely experience large redox fluctuations. We conducted field and lab experiments in an active agricultural field in Urbana, Illinois, USA to elucidate how soil drainage history affects GHG emissions in response to ponding.

We found that ponding of well-drained soils led to pulses of net N_2O efflux caused by stimulation of gross N_2O production via denitrification. In contrast, poorly-drained soils had high net N_2O effluxes only during interludes between large rain events. Similar patterns were observed for CO_2 flux. In a survey of 8 sites across Champaign County, IL, USA, we found higher total C and HCl-extractable iron concentrations as well as pH in poorly-drained compared to well-drained soils ($p < 0.05$). Partial correspondence analyses of OTUs determined using Illumina sequencing of 16S rRNA and a suite of N-cycling functional genes showed distinct microbial communities in poorly- versus well-drained soils at each site. Together, these results suggest that historical soil redox regimes caused by drainage patterns can alter soil properties and the soil microbial community to regulate soil GHG dynamics in response to intense precipitation.

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