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Toward a predictive understanding of the microbe-plant-environment interaction networks that regulate soil carbon sequestration in northern peatlands

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Climatically-sensitive northern peatlands store approximately one-third of all terrestrial soil carbon (C); however, their future role in C sequestration remains uncertain and depends on the impact of global change-related perturbations on their C balance. Our research on belowground soil C processes leverages the resources of a largescale climate manipulation experiment (SPRUCE) to determine if the response of decomposition to climate change is driven by higher C-inputs to the soil from plants or rather by the mobilization of stored older C through increased microbial activity, or both, thereby shedding light onto a potentially critical positive feedback loop. Our team has compiled a 7-year time series of the concentrations and isotopic composition($\delta^{13}C$ and $\delta^{14}C$) of major carbon species (solid peat, porewater CO_2 and CH_4, dissolved organic carbon), metabolites, enzyme activities, and microbiomes in the experimentally warmed SPRUCE peatland which includes experimental manipulation of CO_2 (eCO_2). Significant correlations are observed between metabolites and temperature consistent with increased availability of labile substrates which stimulates microbial metabolism. Production of the potent greenhouse gas CH_4 is shown to increase at a faster rate in comparison to CO_2 in response to warming. We are just beginning to see statistically significant changes in microbial community dynamics and a stimulation in the respiration of ancient peat C, deposited under prior climate (cooler) conditions. Shifts in microbial communities point to a loss of stability with warming, with potentially dramatic implications for ecosystem functioning. Multi-omics data show that the physiology/activity of methanogens is stimulated in response to temperature, whereas a change in abundance or biomass is likely more muted and difficult to detect beyond natural heterogeneity. Methanogens thus appear to increase their efficiency, resulting in an increase in the CH_4 to CO_2 ratio. While soil carbon has accumulated over millennia in peatlands, our results demonstrate that the vast deep carbon stores are vulnerable to microbial decomposition in response to warming. Elevated rates of methanogenesis are fueled by plant metabolites. Thus, as peatland vegetation trends towards increasing vascular plant cover with warming, we can expect a concomitant shift towards increasingly methanogenic conditions, which are likely to persist resulting in amplified climate-peatland feedbacks.