EGU2020-12521
https://doi.org/10.5194/egusphere-egu2020-12521
EGU General Assembly 2020

Nutrients unlocked from permafrost thaw affect microbial methane metabolism

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The biological conversion of frozen carbon-rich soil (permafrost) into greenhouse gases such as carbon dioxide could cause a positive feedback to climate change. Another significant consequence of permafrost thaw is the collapse of soil structure and subsequent higher water table that can shift vegetation toward water-adapted plant communities that emit high concentrations of methane (CH_4). Plants and microbes respond rapidly to labile carbon (C) and nitrogen (N) released from permafrost thaw, however, the microbial response to phosphorus (P) is unknown. Here we investigated how the nutrient status of permafrost and peat affect microbial activities in four minerotrophic communities in a peatland undergoing permafrost thaw. We experimentally fertilized soils in vitro with a permafrost soil slurry, inorganic P, organic N, or organic N and P. This method isolated the effect of permafrost thaw on microbial processes by removing the confounding effect of plant-soil interactions. The four peatland communities include 1. palsas (intact permafrost mounds rising above the surrounding peatlands), 2. pockets of collapsed palsas dominated by *Sphagnum fuscum*, 3. adjacent eutrophic *Sphagnum*-dominated lawns with thawing permafrost and 4. inundated, sedge-dominated minerotrophic fens with no permafrost remaining. Permafrost had high extractable inorganic N concentrations, averaging 30 µg N g-1 soil dry weight (dw), whereas extractable P concentrations were low, averaging 1.4 µg P g-1 soil dw. While N concentrations in the permafrost were over four times the concentration in adjacent peatland communities, extractable P concentrations were relatively lower. *Sphagnum* lawns positioned at the base of palsas, had nine times the extractable P concentrations averaging 12.6 µg P g-1 soil dw compared to the permafrost, suggesting that P availability increases as permafrost thaws. However, in the fen where no permafrost remains, extractable P concentrations were again low, 2.4 µg P g-1 soil dw, despite high total P. These fen communities are also marked by higher iron concentrations, likely resulting in P immobilization by higher concentrations of metals. The addition of inorganic P and the combination of organic N and P in these fen sites strongly enhanced CH_4 oxidation rates while organic N did not, indicating the importance of P for these energy intensive transformations. Nutrient amendments did not have a significant effect on CH_4 production rates, however, permafrost slurries significantly decreased CH_4 production in *Sphagnum* lawn communities, suggesting an unknown inhibitory effect of permafrost chemistry on CH_4 production. The results of our study highlight the effects of permafrost degradation on nutrient release and provide new insight into how nutrients unlocked

from permafrost affects greenhouse gases.