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Mineralization of cellulose in frozen boreal soils

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Soils of high-latitude ecosystems store a large fraction of the global soil carbon. In boreal forests, the microbial mineralization of soil organic matter (SOM) during winter can affect the ecosystems net carbon balance. Recent research has shown that microorganisms in the organic surface layer of boreal forest soil can mineralize and grow on simple, soluble monomeric substrates under frozen conditions. However, any substantial impacts of microbial activity in frozen soils on long-term soil carbon balances ultimately depends on whether soil microorganisms can utilize and grow the more complex, polymeric constituents of SOM.

In order to evaluate the potential for soil microorganisms to metabolize carbon polymers at low temperatures, we incubated boreal forest soil samples amended with [13C]-cellulose and studied the microbial catabolic and anabolic utilization of the substrate under frozen and unfrozen conditions (-4 and +4°C).

Freezing of the soil markedly reduced microbial utilization of the cellulose. The [13C]-CO_2 production rate in the samples at +4°C were 0.52 mg CO_2 SOM -1 day-1 while rates in the frozen samples (-4°C) were 0.01 mg CO_2 SOM -1 day-1. However, newly synthetized [13C]-enriched cell membrane lipids, PLFAs, were detected in soil samples incubated both above and below freezing, confirming that cellulose can sustain also anabolic activity of the microbial populations under frozen conditions.

The reduced metabolic rates induced by freezing indicate constraints on exoenzymatic activity, as well as substrate diffusion rates that we can attribute to reduced liquid water content of the frozen soil. We conclude that the microbial population in boreal forest soil has the capacity to metabolize, and grow, on polymeric substrates at temperatures below zero, which involves maintaining exoenzymatic activity in frozen soils. This capacity manifests the importance of SOM mineralization during the winter season and its importance for the net carbon balance of soils of high-latitude ecosystems.