UMEÅ UNIVERSITET

A song of ice and mud

Interactions of microbes with roots, fauna and carbon in warming permafrost-affected soils

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Abstract

Permafrost-affected soils store a large quantity of soil organic matter (SOM) – ca. half of worldwide soil carbon – and currently undergo rapid and severe warming due to climate change. Increased SOM decomposition by microorganisms and soil fauna due to climate change, poses the risk of a positive climate feedback through the release of greenhouse gases. Direct effects of climate change on SOM decomposition, through such mechanisms as deepening of the seasonally-thawing active layer and increasing soil temperatures, have gathered considerable scientific attention in the last two decades. Yet, indirect effects mediated by changes in plant, microbial, and fauna communities, remain poorly understood. Microbial communities, which may be affected by climate change-induced changes in vegetation composition or rooting patterns, and may in turn affect SOM decomposition, are the primary focus of the work described in this thesis.

We used (**I**) a field-scale permafrost thaw experiment in a palsa peatland, (**II**) a laboratory incubation of Yedoma permafrost with inoculation by exotic microorganisms, (**III**) a microcosm experiment with five plant species grown either in *Sphagnum* peat or in newly-thawed permafrost peat, and (**IV**) a field-scale cold season warming experiment in cryoturbated tundra to address the indirect effects of climate change on microbial drivers of SOM decomposition. Community composition data for bacteria and fungi were obtained by amplicon sequencing and phospholipid fatty acid extraction, and for collembola by Tullgren extraction, alongside measurements of soil chemistry, CO_2 emissions and root density.

We showed that *in situ* thawing of a palsa peatland caused colonization of permafrost soil by overlying soil microbes. Further, we observed that functional limitations of permafrost microbial communities can hamper microbial metabolism *in vitro*. Relieving these functional limitations *in vitro* increased cumulative CO_2 emissions by 32% over 161 days and introduced nitrification. In addition, we found that different plant species did not harbour different rhizosphere bacterial communities in *Sphagnum* peat topsoil, but did when grown in newly-thawed permafrost peat. Plant species may thus differ in how they affect functional limitations in thawing permafrost soil. Therefore, climate change-induced changes in vegetation composition might alter functioning in the newly-thawed, subsoil permafrost layer of northern peatlands, but less likely so in the topsoil. Finally, we observed that vegetation encroachment in barren cryoturbated soil, due to reduced cryogenic activity with higher temperatures, change both bacterial and collembola community composition, which may in turn affect soil functioning.

This thesis shows that microbial community dynamics and plant-decomposer interactions play an important role in the functioning of warming permafrost-affected soils. More specifically, it demonstrates that the effects of climate change on plants can trickle down on microbial communities, in turn affecting SOM decomposition in thawing permafrost.

Keywords
microbial communities, permafrost, functional limitations, rhizosphere, SOM decomposition, soil fauna, climate change, carbon dioxide

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