Toward a predictive understanding of the response of belowground microbial carbon turnover to climate change drivers in a boreal peatland

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High latitude peatlands cover only 3% of the Earth's land surface but store approximately 1/3 of all soil carbon (C), and act as sinks for atmospheric C. Despite their significance, wetland-specific processes are not included in global climate models, including the land component (CLM4) of the Community Earth System Model. Soil organic matter (SOM) pools and decomposition rates used in these models are derived from mineral soils, which are likely to respond very differently to climate change drivers compared to the saturated organic soils of peatland systems. The flux of C from terrestrial soils to the atmosphere is projected to increase with climate change, but acceleration of the terrestrial C cycle does not necessarily mean that soils will lose a greater proportion of their large C stores to the atmosphere.

The proposed research will address the question of whether changes in soil carbon in peatlands are 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 on a critical positive feedback loop. This proposal is inspired by research conducted under a previous DOE award. We will leverage the infrastructure and site characterization conducted at the Marcell Experimental Forest (MEF), northern Minnesota, where the Oak Ridge National Lab (ORNL) has established an experimental site known as Spruce and Peatland Response Under Climatic and Environmental Change (SPRUCE). Using advanced analytical chemistry and next generation gene sequencing, the proposed project will quantify the response of SOM storage and reactivity, decomposition, and the functional diversity of microorganisms to climate change manipulation at the ecosystem scale. Through a close collaboration with SPRUCE investigators at ORNL, these new insights will be embodied into the CLM4 model to improve climate projections. For example, we propose to develop carbohydrate content (O-alkyl-C content) as a better and more efficient predictor of soil decomposition rate than the operationally-defined SOM fractions currently in use. Carbohydrates predominate over the plant-derived SOM pools in peatlands and microbes use these carbon compounds to produce greenhouse gases.

We will test the following hypotheses:

1.) warming and elevated CO_2 (eCO_2) will increase growth and transpiration of vascular plants and decrease the productivity of Sphagnum and other bryophytes. These changes will alter the reactivity of SOM and microbial dynamics;

2.) warming and eCO_2 will result in the instability of buried peat C, thereby accelerating microbial respiration rates and greenhouse gas production;

3.) accelerated microbial metabolism will result in changes in the functional diversity of microbial communities leading to changes in the pathways of SOM mineralization and the ratio CH_4/CO_2;

4.) CO_2 enrichment will lead to increased delivery of labile C substrates from enhanced primary production and root exudation, resulting in increased decomposition, mobilization and export of ancient peat C as dissolved organic carbon (DOC) from extensive belowground reservoirs;

5.) mobilization of ancient peat C in response to climate change drivers will be dependent upon interactions between microbial populations and the C-use efficiency of the microbial groups that degrade labile and/or recalcitrant SOM pools.

In response to the climate change manipulation, we will determine:

1.) changes in the reactivity of solid peat, DOC, and microbial respiration products (CO_2, CH_4);

2.) changes in the abundance, community structure, and function of soil microbial communities;

3.) compositional and ^{14}C isotopic changes in the exported DOC of peatland and enclosure outflow;

4.) the response of SOM lability as indicated by infrared spectroscopy determined humification indices, the function of specific microbial groups, and the efficiency of organic matter decay to climate change manipulation under controlled conditions in the laboratory using microcosm experiments.