Effects of Coupled Biogeochemical Processes on Soil Organic Carbon Storge and Fluxes

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Project Abstract: Improved understanding of the biogeochemical processes that regulate decomposition of organic matter and their incorporation into process-based models are needed to predict how watersheds will store and process carbon (C) in response to changing climate. Current ecosystem representations focus largely on biological components and disregard geochemical processes; however, soil carbon storage and fluxes are regulated by complex biotic and abiotic interactions amongst organic matter, nutrients, and metals. The objective of this research is to use laboratory, field, and modeling experiments to investigate interactive effects of manganese (Mn), nitrogen (N), and warming on leaf litter decomposition and organo-mineral interactions. Dissolved Mn stimulates enzymatic oxidation of recalcitrant lignin by soil microorganisms and may serve as a limiting nutrient to decomposition. Furthermore, Mn enrichment has been proposed to counteract inhibitory effects of N deposition on decomposition rates.

In a field decomposition experiment, surface organic soils were enclosed in nylon mesh bags and incubated for up to one year in upland soils of the temperate forested Walker Branch watershed in east Tennessee. Soils were either warmed +2-3°C or not and received between zero to 10 mg g^{-1} monthly aqueous Mn(II) addition. Measurements of litter mass loss and soil respiration were coupled with spectroscopic measurements and microbial analyses to evaluate C transformation and efflux during decomposition. Complimentary laboratory incubations were performed to measure the effects of Mn enrichment on C transformation and greenhouse gas (CO_2, N_2O) production in N-fertilized and unfertilized agricultural soils. We further developed a novel biogeochemical model based on existing observations that simulates how Mn bioavailability interacts with N and warming to influence soil organic C stocks in temperate forests. We determined that Mn addition accelerated decomposition of leaf litter into CO_2 and into decomposition products that associated with minerals, and these effects were primarily observed under experimental N enrichment. Mn addition also suppressed N_2O emissions, indicating the potential for complex effects of Mn biogeochemistry on greenhouse gas emissions. Based on simulations and experiments, we predict that warming and N enrichment generate Mn limitation

to litter decomposition where Mn is poorly soluble, enabling C accumulation over decadal timescales. Through this work, we aim to establish a quantitative coupled modeling-experimental framework for evaluating geochemical controls on how C is stored, processed, and released from watersheds.