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The roles of manganese in stabilizing and destabilizing soil organic matter

ELIZABETH HERNDON[1], KRISTEN BIDAS[1,2], HUI LI[3], FERNANDA SANTOS[1] AND BENJAMIN SULMAN[1]

[1]Oak Ridge National Laboratory
[2]University of Tennessee Knoxville
[3]North Carolina State University

Presenting Author: herndonem@ornl.gov

Geochemical reactions in soils influence nutrient availability and carbon storage but are poorly constrained and typically excluded from predictive models of terrestrial carbon budgets. Manganese (Mn) is a critical micronutrient and redox-active soil component that may exert a poorly recognized control on carbon cycling. Manganese enrichment is proposed to affect ecosystem carbon fluxes by inhibiting plant growth, increasing rates of litter decomposition, and both stabilizing and degrading soil organic matter. Despite recognition of these processes, it remains unclear whether interactions between Mn and organic matter influence long-term carbon storage in terrestrial ecosystems. This work combines laboratory and field experiments with data synthesis and modeling efforts to explore how plant-soil interactions enrich Mn in surface soils and potentially contribute to enhanced degradation of soil organic matter. We determine that forest vegetation accumulates high concentrations of foliar Mn(II) that are subsequently immobilized in surface soils as Mn(IV)-oxides during litter decomposition. Manganese that accumulates in surface soils can bind and stabilize and/or oxidize and degrade organic compounds through multiple pathways. For example, experimental addition of soluble Mn(II) increases the release of carbon dioxide during leaf litter decomposition, presumably by stimulating enzymatic oxidation of lignin and other recalcitrant compounds. Manganese(IV)-oxides can bind and stabilize organic matter in quantities that are similar to Fe(III)-oxides but also oxidize and transform organic compounds through multiple interaction mechanisms. The net effect of these processes may be to decrease soil C storage where Mn bioavailability is high, as suggested by model simulations of coupled Mn-C interactions and supported by observations of negative correlations between Mn and C storage in organic horizons across diverse ecosystems. Our findings indicate that Mn may serve as an important regulator of C cycling in terrestrial ecosystems.