Collaborative Research: Elucidating Unifying Principles of Soil C-N Coupling using a Contintental-Scale Grassland Experimental Network

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Despite decades of research on decomposition responses to human-caused atmospheric N deposition, the coupling between concurrently changing C and N cycles remains a key uncertainty in understanding feedbacks between the terrestrial C cycle and climate change. For example, coupling of C and N in earth system models fundamentally alters critical feedbacks between the land biosphere and the global climate system. Yet, existing coupled models do not consider the full suite of linked C-N processes, particularly belowground, that could drive future C cycle-climate feedbacks. Thus, a more mechanistic coupled C-N model is needed that is evaluated using continental-scale empirical studies of belowground C and N cycling.

The research team will use a continental-scale network of replicated, long-term grassland nutrient addition experiments, the Nutrient Network, to enhance the Microbial ENzyme Decomposition (MEND) model towards determining how N inputs affect: (1) biochemical stabilization of soil organic matter (SOM) by altering the quantity and quality of plant inputs to soils, and soil microbial community structure, stoichiometry, and functional potential; and (2) physicochemical stabilization of SOM by altering soil aggregate formation and SOM-mineral interactions. Grasslands are spatially extensive with substantial soil C stocks, yet are understudied with respect to N effects on SOM dynamics. In forests, N sometimes increases decomposition of labile soil C and litter, but impedes decomposition of more recalcitrant C. Whether grasslands exhibit such effects of N on decomposition is unknown. Yet, given their distinct microbial and plant communities, grasslands likely exhibit unique effects of N on decomposition.

At ten Central Great Plains Nutrient Network experiments that span soil texture and water balance gradients, the project will elucidate N enrichment effects on SOM dynamics, and the mechanisms underpinning such effects, by measuring the stoichiometry and quantities of plant inputs; the stoichiometry, composition, and activity of soil microbes; and the formation of micro- and macroaggregates. Empirical work on C-N interactions will be integrated into a modeling framework, via parameterization, model development, and model evaluation of the MEND model. MEND will be used to explore the combined effects of N enrichment on SOM dynamics via altered litter inputs and stoichiometry, microbial communities, microbial biomass, and hydrolytic vs. oxidative enzyme activity, to determine whether the proposed model structure captures the variation in soil C responses to N additions observed across the Central Great Plains.

Intellectual Merit The proposed research has intellectual merit because it will integrate results from extensive cross-site coordinated experiments with new process modeling to advance mechanistic understanding of the coupling of belowground C and N in grassland ecosystems. This is a key knowledge gap for Earth system models used to predict the biogeochemical consequences of human-caused global environmental changes and to refine predictions of C cycle feedbacks to climate change. The proposed research is unique and powerful in its multi-faceted, comprehensive approach to understanding coupled C-N cycles in soils, combining molecular genetic, biogeochemical, ecological, soil chemical and physical methods, and modeling to improve predictions of the effects of N on soil C cycling. Furthermore, the proposed research will link new knowledge of grassland microbiomes, which remain largely uncharacterized, to process-level understanding.

Broader Impacts The enhanced MEND model will be incorporated into the Community Land Model (CLM), and made available to the scientific community at large through the Department of Energy's Accelerated Climate Model for Energy program. All data generated from the proposed work will be publically available through the Nutrient Network. The proposed research will engage with and provide content and data for the education and outreach programs of the Cedar Creek Long Term Ecological Research project. These programs are aimed at training K-12 students and teachers in the STEM disciplines and at increasing participation and retention of women and members of other underrepresented groups in science, particularly through mentoring of undergraduate Native Americans in research. Project investigators additionally will mentor graduate students and post-doctoral scholars.