Evaluating and Modeling the Alternative Hypotheses that Connect Organic Inputs to Soil Carbon

Matthew E. Craig[1]*, Benjamin N. Sulman[1], Melanie A. Mayes[1], Rose Z. Abramoff[1], Anthony P. Walker[1]

[1]Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN

Contact: (craigme@ornl.gov)
Project Lead Principal Investigator (PI): Paul J. Hanson
BER Program: ESS
Project: ORNL Terrestrial Ecosystem Science SFA
Project Website: https://tes-sfa.ornl.gov/

The rate and quality of carbon inputs to soil are a primary control on belowground carbon storage, and carbon inputs are being altered by environmental changes—e.g., those that alter productivity or shift plant communities. Yet, the ability of soil carbon models to simulate the effects of altered inputs has been repeatedly challenged in recent years. Conventional models predict that soil carbon should increase linearly with input rates, and most dramatically with low-quality inputs. But modern biogeochemical theory emphasizes that microbial and mineral interactions can lead to counterintuitive relationships between inputs and soil carbon. For example, priming effects could offset increased inputs, or fast-decomposing plant products could promote greater mineral stabilization of soil carbon. The newest generation of soil carbon models attempt to capture these phenomena by including more sophisticated representations of mineral and microbial dynamics, yet these models make vastly different predictions because immense uncertainty still exists about the processes connecting inputs to soil carbon.

Here, we discuss our progress on a key question: How do alterations to the rate and quality of organic inputs drive changes in soil carbon storage? We have implemented several microbially explicit models in the multi-assumption architecture and testbed (MAAT)—a modular modeling code that can easily vary model process representations—with the goal of identifying the sources of process-level uncertainty among contemporary soil carbon models. We find that models simulate markedly different responses of soil carbon to alterations in inputs, ranging from highly sensitive to complete insensitivity. Alternative hypotheses about the turnover of mineral-associated and microbial biomass pools account for a large portion of this uncertainty. Whereas both processes are often modeled as a linear first-order process, results from a literature synthesis and from microcosm experiments support the hypothesis that both processes depend on the size of the microbial biomass pool. Standardizing models to include this assumption leads to a convergence of model predictions. We will discuss how using MAAT, or similar tools, to probe process-level uncertainty can inform empirical studies to efficiently progress our predictive understanding of ecosystem carbon cycling.