Minerals control soil decomposition and organic carbon accumulation over decadal timescales: A modeling analysis

Authors: RZ Abramoff, J Tang, K Georgiou, MS Torn, WJ Riley

Soil carbon (C) is the largest actively cycling terrestrial pool of C with a mean residence time that can exceed 10,000 years. The formation and release of soil C is controlled by biogenic processes (e.g., plant allocation to litter and root exudates, microbial growth and metabolism) and chemical processes (e.g., sorption to minerals, temperature, water availability), and thus the rate of decomposition can change non-linearly over time as a result of multiple constraints. Heterotrophic decomposition releases organic C back into the atmosphere as carbon dioxide and is therefore an important feedback to global change. Terrestrial biosphere models of soil decomposition generally use a linear turnover rate for 1–9 soil C pools that vary in lability, assuming that the persistence of soil organic carbon (SOC) is due to intrinsic chemical recalcitrance. However, recent work has suggested sorption to minerals as an alternative mechanism for SOC protection. This paradigm is supported by experiments that show that old SOC can have low thermodynamic stability and turn over quickly with warming or other disturbance.

We performed a modeling experiment using a model that explicitly represents microbial activity, mineral sorption, nutrient availability, and water stress as potential constraints on the rate of decomposition and the long-term SOC stock. We spun-up eight model runs for 1000 years using a range of mineral surface area derived from literature. We then ran each model for 1–50 years over a range of plant inputs and climatic conditions to test for the relative effect of mineral, plant, and climate drivers on seasonal- and decadal-scale SOC storage. We found that sorption to mineral surfaces was an important control over decadal SOC stock dynamics while changes in temperature and water content had a smaller relative effect. The magnitude and stoichiometry of plant inputs affected decomposition rates and SOC stocks on seasonal and decadal scales. On seasonal timescales, decomposition rate was sensitive to microbial physiology parameters such as maximum growth rate, but on decadal timescales microbial growth was limited more by substrate supply than intrinsic rate. The model output coincided with published observed relationships between SOC stocks, geochemical variables, and climate from multiple ecosystems, suggesting that mineral sorption is an important long-term control on soil C stock.