Geophysical Research Abstracts
Vol. 16, EGU2014-15579, 2014
EGU General Assembly 2014
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Integrating plant-microbe interactions to understand soil C stabilization with the MIcrobial-MIneral Carbon Stabilization model (MIMICS)

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If soil organic matter is predominantly microbial biomass, plant inputs that build biomass should also increase SOM. This seems obvious, but the implications fundamentally change how we think about the relationships between plants, microbes and SOM. Plant residues that build microbial biomass are typically characterized by low C/N ratios and high lignin contents. However, plants with high lignin contents and high C/N ratios are believed to increase SOM, an entrenched idea that still strongly motivates agricultural soil management practices. Here we use a combination of meta-analysis with a new microbial-explicit soil biogeochemistry model to explore the relationships between plant litter chemistry, microbial communities, and SOM stabilization in different soil types. We use the MIcrobial-MIneral Carbon Stabilization (MIMICS) model, newly built upon the Community Land Model (CLM) platform, to enhance our understanding of biology in earth system processes. The turnover of litter and SOM in MIMICS are governed by the activity of r- and k-selected microbial groups and temperature sensitive Michaelis-Menten kinetics. Plant and microbial residues are stabilized short-term by chemical recalcitrance or long-term by physical protection. Fast-turnover litter inputs increase SOM by $>10\%$ depending on temperature in clay soils, and it's only in sandy soils devoid of physical protection mechanisms that recalcitrant inputs build SOM. These results challenge centuries of lay knowledge as well as conventional ideas of SOM formation, but are they realistic? To test this, we conducted a meta-analysis of the relationships between the chemistry of plant liter inputs and SOM concentrations. We find globally that the highest SOM concentrations are associated with plant inputs containing low C/N ratios. These results are confirmed by individual tracer studies pointing to greater stabilization of low C/N ratio inputs, particularly in clay soils. Our model and meta-analysis results suggest that current ideas about plant-microbe-SOM relationships are unraveling. If so, our reconsideration of the mechanisms stabilizing SOM will also challenge long-held views about how to optimize plant community management to increase SOM.