Geophysical Research Abstracts
Vol. 20, EGU2018-12093, 2018
EGU General Assembly 2018

Upscaling microbial stoichiometric adaptability in SOM turnover: the SESAM model

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In order to understand the coupling of carbon (C), nitrogen (N), and phosphorous (P) cycles, it is necessary to understand C, N and P-use efficiencies of microbial soil organic matter (SOM) decomposition. While important controls of those efficiencies by microbial community adaptations have been shown at the scale of a soil pore, an abstract simplified representation of community adaptations is needed at ecosystem scale. The soil enzyme allocation model (SEAM) explicitly models community adaptation strategies of resource allocation to extracellular enzymes and enzyme limitations on SOM decomposition. It thus provides a scaling from representing several microbial functional groups to a single holistic microbial community. However, this model is still too detailed and complex for the incorporation into global models capable of simulating large-scale and long-term dynamics of soil organic matter.

Therefore, we further scaled the SEAM model by applying a quasi-steady state assumption for extracellular enzyme pools involved in SOM depolymerization and present here the soil enzyme steady allocation model (SESAM). The resulting exact model formulation involves complex, numerically demanding equations of optimal microbial investments into decomposition of alternative substrate pools. We present and compare results of several means to further abstract from the exact formulation, such as computing a heuristic direction of change instead of the exact optimum of investments, and incorporating delayed dynamics to attenuate short-term effects of the assumption of immediate quasi-steady-state of enzyme pools. We discuss challenges near the points of co-limitation of the microbial biomass by C, N, and P. We further discuss under which conditions and time scales the predictions of the upscaled model differ from the mechanistic model. We will outline what these results imply for the development of the soil component of the global MPI Earth system model.

Our developments show how simplified representations of SOM turnover can be derived and validated based on mechanistic formulations.