ABSTRACT: Organic matter decomposition involves the close coupling between abiotic soil processes and biotic microbial processes. We contend that, to inform land-atmosphere greenhouse gas fluxes in an earth system model, a biogeochemical module should consistently represent the interactions between microbial community structure, microbial activity, and soil biogeochemistry. Here, we propose a model structure that integrates the dynamic energy budget (DEB) theory and a trait-based modeling (TBM) approach to characterize soil microbial processes relevant to carbon and nutrient cycling. The DEB enables an explicit representation of the intracellular metabolic reserves and structural pools, while the TBM explicitly describes the distribution of microbial guilds and functional pathways across spatial and temporal environmental gradients. This formulation allows us to dynamically model changes in microbial stoichiometry in response to changes in substrate diversity and availability. We have integrated this DEB-TBM framework with an equilibrium chemistry approximation approach. The coupled model framework allows for a generic model structure that can consistently simulate microbial functional diversity and fitness under the influence of abiotic mineral adsorptive surfaces and other subsurface protection mechanisms.

We applied this model structure to simulate aerobic organic matter decomposition by a few different microbial functional guilds. By explicitly representing the extracellular-enzyme regulated cascade between different organic polymers and organic monomers, we formed an organic matter decomposition model that can model the close feedback between organic matter chemical composition and microbial ecology. Preliminary analysis indicates (i) the model reasonably simulates the often-observed two-phase behavior of litter decomposition and (ii) the chemical composition of the long-term decomposed organic matter becomes a function of both the initial organic matter chemical composition and the associated microbial community structure. We also discuss issues associated with integration of the approach in larger-scale biogeochemistry models.