Long residence times of rapidly decomposable soil organic matter: a mechanistic modeling study

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To investigate how mechanisms interact to influence SOM dynamics, we developed a SOM model based on a reaction network integrated in a three-dimensional, multi-phase reactive transport solver. The model represents bacterial and fungal activity, archetypal polymer and monomer carbon substrate groups, aqueous chemistry, gaseous diffusion, aqueous advection and diffusion, and adsorption and desorption. With these mechanisms, rapid rates of microbial transformation yielded SOC turnover times up to several thousands of years at depth because of transformation of plant material to microbial necromass protected on mineral surfaces and low concentrations of dissolved, assimilable substrate. The model results reasonably matched depth-resolved SOM and dissolved organic carbon stocks in grassland ecosystems and behaved consistently with expectations of depth-resolved profiles of lignin content and fungi:aerobic bacteria ratios. Observed organic carbon stocks $\Delta^{14}C$ vertical profiles were explained by a model with relatively labile carbon compounds, equilibrium protection on mineral surfaces, and vertical transport. While vertical transport was important in moving SOC below the zone of plant production, it did not explain the long residences times at depth. Thus, the persistence of theoretically labile substrates and increase in SOC turnover times with depth in soils was due to microbial activity and transformation and sorption kinetics.