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A mechanistic soil biogeochemistry model with explicit representation of microbial and macrofaunal activities and nutrient cycles

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The potential of a given ecosystem to store and release carbon is inherently linked to soil biogeochemical processes. These processes are deeply connected to the water, energy, and vegetation dynamics above and belowground. Recently, it has been advocated that a mechanistic representation of soil biogeochemistry require: (i) partitioning of soil organic carbon (SOC) pools according to their functional role; (ii) an explicit representation of microbial dynamics; (iii) coupling of carbon and nutrient cycles. While some of these components have been introduced in specialized models, they have been rarely implemented in terrestrial biosphere models and tested in real cases. In this study, we combine a new soil biogeochemistry model with an existing model of land-surface hydrology and vegetation dynamics (T&C). Specifically the soil biogeochemistry component explicitly separates different litter pools and distinguishes SOC in particulate, dissolved and mineral associated fractions. Extracellular enzymes and microbial pools are explicitly represented differentiating the functional roles of bacteria, saprotrophic and mycorrhizal fungi. Microbial activity depends on temperature, soil moisture and litter or SOC stoichiometry. The activity of macrofauna is also modeled. Nutrient dynamics include the cycles of nitrogen, phosphorous and potassium. The model accounts for feedbacks between nutrient limitations and plant growth as well as for plant stoichiometric flexibility. In turn, litter input is a function of the simulated vegetation dynamics. Root exudation and export to mycorrhiza are computed based on a nutrient uptake cost function. The combined model is tested to reproduce respiration dynamics and nitrogen cycle in few sites where data were available to test plausibility of results across a range of different metrics. For instance in a Swiss grassland ecosystem, fine root, bacteria, fungal and macrofaunal respiration account for 40%, 23%, 33% and 4% of total belowground respiration, respectively. Root exudation and carbon export to mycorrhizal represent about 7% of plant Net Primary Production. The model allows exploring the temporal dynamics of respiration fluxes from the different ecosystem components and designing virtual experiments on the controls exerted by environmental variables and/or soil microbes and mycorrhizal associations on soil carbon storage, plant growth, and nutrient leaching.