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A mechanistic model of soil biogeochemistry - a reality check

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Among the long-standing gaps in soil biogeochemistry modeling are the (i) partitioning of soil organic carbon (SOC) to its functional pools, (ii) the representation of microbial biomass and diversity, and (iii) mechanistically coupling soil carbon and nutrient cycles. Model evaluation strategies employ either soil column information or leap to global scale inferences with less attention to ecosystem scale behavior. We introduce a new soil biogeochemistry module that is integrated with a well-tested land-surface and terrestrial biosphere model (T&C). The soil biogeochemistry module distinguishes a number of litter pools and partitions SOC into particulate, dissolved, and mineral fractions. Extracellular enzymes and microbial pools are explicitly modelled and differentiated based on known functional roles of bacteria, and saprotrophic and mycorrhizal fungi (including explicit plant-mycorrhizal interactions). Soil macro-fauna is also represented. The model considers the cycles of nitrogen, phosphorous and potassium, in addition to carbon. The model was applied to 20 sites spanning a wide range of climatic conditions and different biomes, and was challenged to reproduce (i) global patterns of microbial biomass including community composition and SOC components, (ii) the observed responses to litter manipulation experiments, and (iii) ecosystem response to nitrogen addition. Model results compared favorably with observed patterns of microbial and macro-faunal biomass relations with soil organic carbon, soil respiration, and Net Primary Production (NPP). The predicted long-term responses of soil carbon pools to litter manipulation are well within the range of experimental results. The model predicts that fine roots, bacteria, fungal and macro-faunal respiration account, respectively, for 33%, 40%, 24% and 3% of total belowground respiration on average, despite large site-to-site variability. Root exudation and carbon export to mycorrhizal fungi represent about 13% of plant NPP. The model provides general and mechanistically-derived estimates of microbial biomass and its contribution to respiration fluxes and to soil organic matter dynamics thus enabling a range of virtual experiments that systematically vary effects of environmental variables on soil microbial dynamics, carbon storage, plant growth, and nutrient leaching.