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Shifting resource availability, plastic allocation to exoenzymes and the consequences for heterotrophic soil respiration

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The rate of decomposition of soil organic matter (SOM) is influenced by the availability of substrates in the soil matrix, the chemical composition of organic matters substrates, and the reaction kinetics of exoenzymes secreted by microbes. Predicting carbon (C) flow from SOM into respired CO_2 is predicated on knowledge of feedbacks between substrate availability and microbial resource allocation. It is critical to understand physiological responses of microbes to their environments because it is the feedbacks between the abiotic conditions and resource availability that govern exoenzyme synthesis. Without mechanistic knowledge, it is difficult to project how warming and changing edaphic characteristics will influence respiratory CO_2 losses from soils.

Here, we apply a general theoretical framework that describes the consequences of interactions between exoenzymes, SOM substrates, microbial resource allocation and microbial stoichiometry to explore how different edaphic conditions give rise to different microbial niches. Our approach incorporates the kinetics of exoenzyme-substrate interactions, the costs and benefits associated with producing different exoenzymes, regulation of biomass C:N, and substrate availability in the soil matrix. We explore how shifting resource availability forces microbes to alter their strategies for synthesizing exoenzymes to promote acquisition of C and N that satisfies demand. In particular, we study how changing relative C and N availability constrain the degree to biomass C:N can be maintained with plastic allocation to different exoenzymes. Using reaction rate data from purified enzyme-substrate experiments, we conclude that shifts in both the absolute and relative availability of substrates with different C:N give rise to clear niches in C and N allocation space. These niches correspond to environments that are typically associated with soil microbes exhibiting different biomass C:N. Finally, we show that the allocation changes required to maintain relatively constant biomass C:N over a range of edaphic conditions can directly lead to changes in mass specific respiration rates. Our results highlight some important implications for gross CO_2 production for fixed and adaptive decomposition strategies in response to changes temperature and pH in soils.