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Accounting for microbial dynamics to simulate soil functions under agricultural management

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Mechanistic simulation models are an essential tool for predicting soil functions such as nutrient cycling, water filtering and storage, productivity and carbon storage as well as the complex interactions between these functions. Most soil functions are driven or affected by soil organisms. Yet, biological processes are often neglected in soil function models or implicitly described by rate parameters. This can be explained by the high complexity of the soil ecosystem with its dynamic and heterogeneous environment, and by the range of temporal and spatial scales these processes are taking place at.

Here, we meet these challenges and present our approach for integrating biological microscale processes into soil modelling. We introduce our systemic soil model BODIUM which simulates relevant microbial processes at the profile scale to analyse the impact of different agricultural management and climatic conditions on soil functions. For this, BODIUM includes different microbial pools as well as C:N stoichiometric considerations but does not explicitly account for microbial community structure or composition dynamics. In our approach, soil structure dynamics at the pore scale is a critical factor for controlling the availability of carbon and nutrients as well as the distribution of water and oxygen, which in turn jointly drive microbial growth and activity. To explore the potential advantage of BODIUM, we compare our model approach with traditional modelling approaches without explicit microbial activity under different simulation scenarios. We further analyse the impact of changing microclimatic conditions of water, oxygen and nutrient availability as dedicated by a dynamic soil structure on microbial activity and the corresponding soil functions.

Finally, we discuss ongoing developments to additionally consider, e.g., microbe-fauna-interactions, microbial feedback on soil structure dynamics, and phosphor dynamics.