Quantification of key factors driving the microbial metabolism in the vadose zone – A microscale-modelling perspective

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Organic carbon (C), either originated from soil organic carbon or introduced externally from anthropogenic sources, is the main pool for providing microorganisms with materials for biosynthesis (anabolism) and energy for catabolism. Routing the carbon source between catabolic and anabolic pathways eventually decides over the fate of C; either if it leaves the system as inorganic carbon (i.e. CO₂) or, it stays in it due to anabolism and cell synthesis processes. The microbial carbon use efficiency (CUE) – and thus the proportion of the C that (potentially) remains in soil – depends on various factors. Physio-chemical condition of the hosting environment, the composition and activity of the microbial community and in extreme cases, climatic changes can cause a high spatio-temporal variability in microbial activity and CUE. At microscale, also the pore-size distribution, pore connectivity and pore water-content can (directly or indirectly) alter the distribution of carbon and energy fluxes in soils. Across different soil types and conditions, the evolution of microbial community and of their CUE in the simultaneous presence of various factors are poorly understood.

In order to capture the in-situ dynamics of microbial activity and CUE in the dynamically changing environment of the vadose zone, we apply a pore-scale reactive transport modelling approach to disentangle the interplay of physio-chemical factors in the evolution of the soil carbon pool. Our modelling framework is capable providing a resolution of unsaturated water flow and solute transport at the microscale combined with capturing the underlying biogeochemical processes for tracking the evolution of microbial communities along with C pools in soil. Physical properties of the porous structure (such as pore geometry, pore size distribution and their connectivity) are accounted for via using digitized -CT images. Variable water flow and distribution is achieved by solving the Navier Stokes equation. A full set of advective-diffusive-reactive transport equation is solved for all chemical and microbial species to investigate their evolution in time and space. Model simulation cover various scenarios differing in properties of the solid matrix, imposed flow conditions and considered organic carbon substrates. Sensitivity simulations are performed to single out the effect of different bio-physio-chemical factors on evolution of microbial biomass and CUE.