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Predicting the response of soil organic matter microbial decomposition to moisture

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Next to temperature, soil moisture is a main driver of soil C and N transformations in soils, because it affects microbial activity and survival. The moisture sensitivity of soil organic matter decay may be a source of uncertainty of similar magnitude to that of the temperature sensitivity and receives much less attention. The basic concepts and mechanisms relating soil water to microorganisms were identified early (i.e. in steady state conditions : direct effects on microbial physiology, diffusion substrates, nutrients, extracellular enzymes, diffusion of oxygen, movement of microorganisms). However, accounting for how moisture controls soil microbial activity remains essentially empirical and poorly accounts for soil characteristics. Soil microorganisms live in a complex 3-D framework of mineral and organic particles defining pores of various sizes, connections with adjacent pores, and with pore walls of contrasted nature, which result in a variety of microhabitats. The water regime to which microorganisms are exposed can be predicted to depend the size and connectivity of pores in which they are located. Furthermore, the spatial distribution of microorganisms as well as that of organic matter is very heterogeneous, determining the diffusion distances between substrates and decomposers.
A new generation of pore scale models of C dynamics in soil may challenge the difficulty of modelling such a complex system. These models are based on an explicit representation of soil structure (i.e. soil particles and voids), microorganisms and organic matter localisation. We tested here the ability of such a model to account for changes in microbial respiration with soil moisture.

In the model MOSAIC II, soil pore space is described using a sphere network coming from a geometrical modelling algorithm. MicroCT tomography images were used to implement this representation of soil structure. A biological sub-model describes the hydrolysis of insoluble SOM into dissolved organic matter, its assimilation, respiration and microbial mortality. A recent improvement of the model was the description of the diffusion of soluble organic matter. We tested the model using the results from an experiment where a simple substrate (fructose) was decomposed by bacteria within a simple media (sand). Separate incubations in microcosms were carried out using five different bacterial communities at two different moisture conditions corresponding to water potentials of -0.01 and -0.1 bars. We calibrated the biological parameters using the experimental data obtained at high water content and we tested the model without any parameters change at low water content.
Both the experiments and simulations showed a decrease in mineralisation with a decrease of water content, of which pattern depended on the bacterial species and its physiological characteristics. The model was able to correctly simulate the decrease of connectivity between substrate and microorganism due the decrease of water content.

The potential and required developments of such models in describing how heterotrophic respiration is affected by micro-scale distribution and processes in soils and in testing scenarios regarding water regimes in a changing climate is discussed.