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Microbes meet Structure - Soil Ecology in Microengineered Soil Chips

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Many soil processes are governed by microbes, and biological and physical processes influence each other. We recently developed microfluidic model systems that simulate the spatial microstructure of soil microbial habitats in a transparent material, which we call Soil Chips. They allow us to study the impact of soil physical microstructures on microbes, and vice versa, the influence of microbes on soil physical properties: such as Microbial behavior and interactions in response to a spatially refined habitat, or wettability and water retention, soil aggregate formation and changes in the pore space.

We inoculated our chips with fluorescent lab cultures or natural whole soil inocula. Through the chips we observed via microscopy processes in real-time and at the scale of the microbial cells.

We could study fungi, bacteria, protists and nematodes as well as the distribution of soil minerals and soil solution in the chips. We subjected the adjacent soil to drying-rewetting processes, which was visible in water movements inside the chip. We studied the development of preferential water flow paths, and water retention in smaller pores and as a consequence of microbial exudates. Also the microbes themselves influenced the formation of microhabitats, where fungal hyphae both blocked connections and pushed through existing borders, and single-celled protozoa opened passages through existing aggregates. We found that the presence of fungal hyphae in a pore space system increased both the presence of bacteria and the likelihood of water in the pores, and thus allowing us to study fungal highways in a more realistic soil setting.

The chips act like a window into the soil, through which we can eaves-drop on a world that otherwise is largely hidden to us: Jostling protists, tsunami-like drying-rewetting events, and fungi with character. Beyond the scientific potential, the chips can also bring soils closer to people and hopefully increase engagement in soil health conservation.