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Microbial community outgrowth in a controlled and monitored soil column – A lysimeter experiment

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Soils are complex ecosystems that support agriculture, pollutant remediation and water quality. The diverse and rich soil microbiome mediates most of these processes through metabolic activity fueled by organic matter degradation [1]. To develop efficient microbiome-based soil engineering strategies, we need to decipher the biological and physicochemical parameters shaping the compositional trajectory and function of soil communities. However, isolating and identifying the key factors controlling soil microbiome change over time is not a trivial task. A systematic, controlled approach is needed. To that end, we developed an in-lab experimental setup allowing to study the establishment and outgrowth of a soil microbial community in a continuously monitored soil column (lysimeter).

A soil microbiome inoculum was homogeneously mixed into straw-amended sterile soil columns with a controlled water table. Sterile artificial rainwater was applied twice a week. Physicochemical parameters along the vertical gradient (pH, redox potential, water tension, dissolved oxygen) as well as CO_2 and CH_4 emissions were continuously monitored throughout the experiment. Porewater samples were also taken regularly to measure dissolved organic carbon & nitrogen, Fe^{2+}, Fe^{3+}, NH_4^+, NO_2^-, NO_3^- and SO_4^{2-}. Sacrificial sampling was performed after 38, 108 and 196 days to study microbial succession using multiple methods (amplicon sequencing, metagenomics, metaproteomics).

Data reveal that the redox potential fluctuates between a reduced and oxidized state in the top layer (~4 cm) while the rest of the soil column is in a reduced state. The geochemical data indicate high organic matter degradation and an active nitrification process during the first ~15 days in this top layer. A subsequent decrease in the redox potential resulted in a drop of the nitrate concentration which could indicate an active denitrification process. Microbial analyses will help identify the physicochemical parameters shaping the soil microbiome and to delineate the microbial succession from the initial inoculum to a fully grown soil microbiome. Our work aims at giving a better understanding of the complex mechanisms controlling microbiome dynamics and geochemical cycling in an organic matter-amended soil.

[1] Philippot, L. *et al.* (2024) The interplay between microbial communities and soil properties. *Nat Rev Microbiol* **22**, 226–239