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Linking Water Table Dynamics to Carbon Cycling in Artificial Soil Column Incubations

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The biogeochemistry of wetlands soils is closely tied to their hydrology. Water table fluctuations that cause flooding and drying of these systems may lead to enhanced degradation of organic matter and release of greenhouse gasses (e.g. CO_2, CH4) to the atmosphere. However, predicting the influence of water table fluctuations on the biogeochemical functioning of soils requires an understanding of the interactions of soil hydrology with biogeochemical and microbial processes. To determine the effects of water table dynamics on carbon cycling, we are carrying out state-of-the-art automated soil column experiments with fully integrated monitoring of hydro-bio-geophysical process variables under both constant and oscillating water table conditions. An artificial, homogeneous mixture consisting of minerals and organic matter is used to provide a well-defined starting material. The artificial soils are composed of quartz sand, montmorillonite, goethite and humus from a forested riparian zone, from which we also extracted the microbial inoculum added to the soil mixture. The artificial soils are packed into 60 cm high, 7.5 cm wide columns. In the currently ongoing experiment, three replicate columns are incubated while keeping the water table constant water at mid-depth, while another three columns alternate between drained and saturated conditions. Micro-sensors installed at different depths below the soil surface record time-series redox potentials (Eh) varying between oxidizing ($\sim$+700 mV) and reducing ($\sim$-200 mV) conditions. Continuous O_2 levels throughout the soil columns are monitored using high-resolution, luminescence-based, Multi Fiber Optode (MuFO) microsensors. Pore waters are collected periodically with MicroRhizon samplers from different depths, and analyzed for pH, EC, dissolved inorganic and organic carbon and ion/cation compositions. These measurements allow us to track the changes in pore water geochemistry and relate them to differences in carbon cycling between the contrasting water table regimes. Particular attention is given to the mobilization and redistribution of iron from the initially homogeneously distributed goethite. In addition, small solid-phase samples are collected monthly from the saturated and unsaturated zones of the soil columns to characterize the microbial communities and changes in soil microstructure and organo-mineral associations. Headspace gas measurements are used to derive the effluxes of CO_2 and CH4 during the experiment. Together, the experimental data will provide a comprehensive picture of the early development of the soil and the accompanying establishment of biogeochemical gradients under dynamic hydrological conditions. They will allow us to relate the degradation of soil organic matter and greenhouse gas emissions to the saturation conditions and redox chemistry under controlled conditions. The experiment is in progress with an expected total duration of 6 months.