

PROCESSES CONTROLLING CARBON MINERALIZATION WITHIN PERIODIC WETLAND SOILS

Michael Schaefer¹, Marco Keiluweit¹, Kristin Boye¹, Tom Regier², Jay Dynes²,
Shawn Benner³, Scott Fendorf¹

¹Stanford University, ²Canadian Light Source, ³Boise State University

Soil contains the largest carbon stock on Earth, with approximately one-third of soil carbon stored in the tropics. An important control on soil organic matter (SOM) quantities is the mineralization (oxidation) rate, which ranges from days to millennia. The rate of SOM mineralization is affected by climatic factors influencing microbial metabolic rates in combination with SOM chemistry, mineral-SOM stabilization, and physical protection. What remains elusive is to what extent constraints on microbial metabolism induced by the respiratory pathway, and specifically the electron acceptor in respiration, control overall rates of carbon mineralization in soils. Here we sought to determine how aerobic-anaerobic cycling in soils contributes to SOM mineralization rates and thus storage.

The major factors contributing to SOM accumulation (e.g., precipitation, clay content, temperature, biological activity) are often at extremes in the tropics. We therefore used the accelerated (potential) rate of carbon processing to examine the factors controlling carbon turnover within the mega deltas of Asia, specifically focusing on the Mekong Delta, using a combination of laboratory and field experiments. We compared the abundance and chemical state of SOM at three sites having varying degrees of saturation (uncultivated seasonal wetlands, cultivated wetlands, and permanent lakes) by measuring total carbon content and chemistry, the latter deduced with bulk C (1s) near-edge x-ray absorption fine structure (NEXAFS) spectroscopy. Permanganate oxidizable carbon (POXC) measurements suggest that microbially oxidizable C is concentrated in the top 50-100 cm of the deltaic wetland soils, even when normalized to bulk C content, and that deeper SOM is minimally available for microbial oxidation.

To assess the impact of soil saturation on SOM we monitored CO₂ flux, porewater chemistry, and soil moisture content at a seasonal wetland through flooding and draining periods. Surface sediment cores (10 cm diameter) collected from the same wetland were manipulated in the laboratory to deduce the relative effects of drying, O₂ influx, and Fe mineral precipitation on observed CO₂ fluxes. We compared the following drying conditions: oxic, anoxic, and oxic with additional Fe(II) addition. In each of these treatments we monitored CO₂ flux and porewater chemistry as a function of water content during a drying cycle. After complete drying, the top 3 cm of the cores were separated into density fractions of <1.6, 1.6-2.4, and >2.4 g cm⁻³ using sodium polytungstate solutions, and the two denser fractions were analyzed using scanning transmission x-ray microscopy (STXM). Drying under oxic conditions stimulates SOM oxidation and CO₂ flux relative to anoxic drying, and we observed increased mass in the <1.6 and 1.6-2.4 g cm⁻³ fractions of the anoxic core. The formation of Fe(III) oxides during oxic drying protects SOM from mineralization as indicated by close C-Fe associations in STXM analysis. These associations are less pronounced in anoxic cores. Soils exposed to seasonal oxygen incursions accumulate less SOM than permanently flooded soils and sediments owing to oxygen-induced microbial degradation pathways; however, metal-organic matter associations provide an important preservation pathway.