Measuring and Modeling Greenhouse Gas Dynamics from Wet Tropical Forest Soils under Contrasting Redox Treatments

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Wet tropical forest soils frequently oscillate between fully oxygenated and anoxic conditions, which can differentially influence the dynamics of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) across landscape topography. To gain a better understanding of in situ processes, we mimicked the dynamic redox oscillations in a laboratory incubation study using soil samples collected from the valley and slope topographic locations in the El Verde site, Luquillo Experimental Forest, Puerto Rico. Sixty grams of fresh soil was incubated under static oxic, static anoxic, and alternating redox conditions (every 4 days) over 76 days. The dynamics of greenhouse gases, redox-sensitive elements (total/reduced iron, ammonium, nitrite, and nitrate), extractable organic acids, pH, microbial biomass, hydrolytic enzymes, dissolved organic carbon, and organic/inorganic phosphorus were monitored on periodic destructive harvests. Overall, net CO_2, CH_4, and N_2O fluxes followed the pattern of alternating≥oxic>anoxic, anoxic>alternating>oxic, and oxic>alternating>anoxic treatments, respectively. We observed higher reduced iron concentrations and lower pH under the anoxic treatment and in the valley soils. Valley soils had greater nitrate than slope soils, especially under the oxic treatment. Landscape topography exerted an opposite effect on microbial biomass phosphorus, valley>slope, and phosphorus-degrading enzymes phosphatase and di-phosphatase, slope>valley. However, microbial biomass phosphorus and phosphorus-degrading enzymes followed a similar pattern under redox treatments (oxic>alternating>anoxic). Hence, both redox conditions and landscape topography influenced soil biogeochemistry and altered greenhouse gases dynamics. We used a geochemical modeling framework, PHREEQC, to represent the tight coupling and rapid dynamics of carbon, nitrogen, phosphorus, and iron cycles and associated greenhouse gases dynamics in wet tropical forest soils. This research will aid in understanding and predicting the high degree of variability of greenhouse gas emissions in tropical climates.