Anaerobic constraints imposed on organic carbon oxidation in soils

SCOTT FENDORF[1*] AND MARCO KEILUWEIT[2]

[1]Stanford University, Stanford, CA 94305, USA
[2]University of Massachusetts, Amherst, MA 01003, USA
(*correspondence: fendorf@stanford.edu)

Soils contain arguably the largest dynamic stock, changing on decadal time scales, of carbon on the planet, having approximate twice the amount stored in the surface oceans and three-times that in the atmosphere. Soil organic matter (SOM) storage, or residence time, is dominantly controlled by the mineralization (oxidation) rate, which is affected by climatic factors (particularly temperature and rainfall) influencing microbial metabolic rates as well as SOM chemistry. Geochemical factors, driving the interactions between reactive mineral phases and SOM, also have a principal control on carbon oxidation rates. An emerging view is that redox controls on metabolic rates and thermodynamic viability of carbon substrates can also be principal controls on carbon mineralization even in upland soils.

The complex physical structure of soils results in a distribution of redox environments even within seemingly aerobic systems; in fact, the majority of the soil volume may persist in an anaerobic state within an upland setting. Factors limiting oxygen diffusion such as particle size distribution, soil moisture content, organic matter input, and aggregate size (soil structure) provide central controls on microbial carbon mineralization rates. Here, combining laboratory studies with manipulations of field samples and in-field measurements, we show how soil texture and structure along with carbon availability interact to impose anaerobic conditions and associated respiratory constraints on organic matter mineralization rates and thus storage within soils. Further, we illustrate that metabolic constraints limit the carbon compounds useful in anaerobic respiration. The relative impacts of enzymantically and metabolically protected carbon within anaerobic zones rivals the magnitude imposed by mineral protection within many soils. We deduce that constraints on microbial metabolism induced by oxygen limitations act as a largely unrecognized and greatly underestimated control on overall rates of C oxidation, even in seemingly well-aeratied soils and sediments.