Scientific Paper:

Soil Biology and Biochemistry 118 (2018) 42 - 50

Anoxic microsites in upland soils dominantly controlled by clay content

Marco Keiluweit[1,2], Kaitlyn Gee[2], Amanda Denney[2], Scott Fendorf[2]
[1]School of Earth and Sustainability & Stockbridge School of Agriculture, University of Massachusetts, Amherst, MA, United States
[2]Earth System Science, Stanford University, Stanford, CA, United States

Abstract:

Recent evidence suggests that oxygen limitations are a critical regulator of soil organic matter mineralization rates, even within seemingly well-drained upland soils. Oxygen limitations may arise in otherwise well-aerated soils when oxygen consumption (via microbial respiration) in soil microsites outpaces oxygen supply (through diffusion). Due to analytical limitations, attempts to parameterize oxygen limitations in models have so far been limited to measures of bulk oxygen concentrations or cm-scale gradients within larger soil structural units (e.g., aggregates or peds). Smaller anoxic microsites may thus have gone undetected, limiting our ability to accurately model and predict anoxic pore volume. Here we quantify the extent of anoxic microsites in soils held at moderate moisture and identify the soil properties that dictate their formation and persistence. Using a planar optode imaging system, we monitored oxygen dynamics during incubations of a range of soils spanning natural and artificial gradients in texture and organic matter availability. While bulk oxygen concentrations ranged from 40 to 100 % of saturation, we observed significant micro-scale variability resulting in the formation of anoxic microsites, here defined as soil spaces showing less than 5 % saturation. Anoxic microsites comprised 2 and 9 % of the total soil volume, or 14 – 85 % of the total pore volume. Bulk oxygen concentrations showed a strong negative correlation with bioavailable organic matter, presumably due to its influence on microbial oxygen consumption. In contrast, the extent of anoxic microsites was negatively correlated to clay content, an effect attributed to limited oxygen supply in clay-rich microstructures. Our results demonstrate that texture-dependent diffusion limitations at moderate moisture conditions cause an abundance of anoxic domains, not only in cm-sized macro-aggregates as current modelling approaches assume, but also within micro-aggregates. Anoxic domain size within these microstructures is at least partially decoupled from bulk oxygen concentrations, challenging the use of bulk oxygen concentrations for predicting microbially available oxygen levels and resulting OM mineralization rates and pathways in upland soils.

Keywords: Redox gradients, texture, metabolic diversity, soil carbon stabilization, soil organic matter, climate change