Geophysical Research Abstracts
Vol. 18, EGU2016-7589, 2016
EGU General Assembly 2016

Texture-dependent anaerobic microsites constrain soil carbon oxidation rates

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Soil texture, which is a product of parent material, climate and other soil forming factors, is a predictor for long-term storage of soil organic carbon (SOC) storage in many soil ecosystems. Positive correlation between texture (particularly clay content) and SOC storage have long been attributed to protective associations between clay minerals and organic compounds that prevent microbial and enzymatic access – a mechanism commonly referred to as 'mineral protection'. Texture therefore acts as the primary proxy for mineral protection in terrestrial ecosystem models used to assess SOC storage and its sensitivity to global change impacts. Here we show that this protective effect of texture is not only due to mineral protection, but also to the formation of anaerobic microsites. Combining micro-scale laboratory experiments with field-scale observations, we find that oxygen diffusion limitations within clay-rich domains create anaerobic microsites within seemingly well-aerated soils, shifting microbial metabolism to less efficient anaerobic SOC oxidation pathways. Kinetic and thermodynamic constraints reduce SOC oxidation rates within these anaerobic microsites by an order of magnitude relative to aerobic rates, and caused the preservation of bioavailable, polymeric and reduced organic compounds. Lifting these metabolic constraints through increased soil aeration (e.g., through changes in precipitation patterns or land use) may stimulate microbial oxidation of this inherently bioavailable SOC pool. Models that attribute the effects of texture merely to 'mineral protection' may therefore underestimate the vulnerability of soil C to global change impacts.