Energy-stability relationships in soil organic matter: Implications for agriculture

WILLIAM C. HOCKADAY[1], ZACHARY P. VALDEZ[1], CAROLINE A. MASIELLO[2], G. PHILLIP ROBERTSON[3]

[1]Baylor University, Institute for Ecological Earth & Environmental Sciences, william_hockaday@baylor.edu, zack_valdez@baylor.edu
[2]Rice University, Department of Earth, Environmental and Planetary Sciences, masiello@rice.edu
[3]Michigan State University, Kellogg Biological Station, robert30@msu.edu

Soil-dwelling organisms which provide many ecosystem services derive energy from the oxidation of soil organic matter (SOM). The quanitiy of energy available for soil heterotrophs is the Gibbs free energy, $\Delta G°$. The required energy input for SOM oxidation, $\Delta G°_{ox}$, exhibits a linear relationship with carbon oxidation state, C_{ox} [1]. The $\Delta G°$ of SOM oxidation also depends greatly upon energy from the reduction, $\Delta G°_{red}$, of the teminal electron acceptor (TEA). For the typical TEAs and C_{ox} values found in soils, the Gibbs free energy of SOM mineralization [$\Delta G° = \Delta G°_{red} + \Delta G°_{ox}$] can range from -3 to -44 kJ/g C. In highly oxidizing agricultural soil environments where the dominant TEAs are O_2, Mn^{4+}, and NO_3^-, the energy yield of SOM decomposition can be approximated as $\Delta G°$ (kJ/g C) = $7.85 \times C_{ox} - 35.9$.

We used carbon-13 NMR spectroscopy to measure C_{ox} and several chemical structure-based indices of SOM stability and decomposition (lignin/N and alkyl/O-alkyl ratios). We combined these with estimates of free energy, ($\Delta G°$), of root tissues and SOM in an agricultural grassland to obtain energy-stability relationships. We then quantified the extent to which energy and chemical quality of soil organic matter can be managed through the agricultural practices of biomass harvesting and nitrogen fertilizer application. The effects upon root systems were were most apparent in the depthwise distribution of Gibbs free energy, and as energy-for-stability tradeoffs in root tisues. This exhibited a predictable response in the unprotected (light fraction) SOM where plots with low energy biomass input have SOM pools in state of low energy, and extensive decomposition. Understanding the energy-stability trade-off in SOM and that it can be affected by cultural practices has implications for managing agricultural systems as well as implications for our understanding of the fundamental controls on soil organic matter storage.

[1] LaRowe & Van Capellen (2011) Geochimica et Cosmochimica Acta, 75, 2030-2042.

This abstract is too long to be accepted for publication. Please revise it so that it fits into the column on one page.