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Insights into Soil Organic Matter Dynamics and Stability in a Temperate Deciduous Forest

Soil ecologists have long argued that models of global carbon dynamics may not be accurately capturing soil organic matter dynamics and the response of soil carbon pools to changes in temperature, precipitation, or land use. Because soils contain more than three times as much as carbon as the atmosphere, and four and a half times more carbon than the world's biota, small changes in soil organic matter stability could result in a large effect on atmospheric carbon pools. Although carbon sequestration in soil is often suggested as a management technique to reduce the rate of atmospheric CO_2 increases, mechanisms of soil carbon sequestration, the amounts of carbon that may potentially be sequestered in soils, and the long-term dynamics of carbon sequestered in soils are poorly understood.

Soil carbon pools have been shown to be sensitive to soil texture and mineralogy, as well as to disturbances such as tilling or forest harvest, and most global models try to capture these dynamics. However, most models also assume a strong positive relationship between plant detrital inputs and carbon sequestration in soils, even though several studies have suggested that this relationship might be complex and non-linear. Research in agricultural systems has shown that soils have finite capacities to sequester C and might "saturate," or achieve maximum equilibrium levels under different combinations of soil texture, mineralogy, and climate. Similarly, increases in labile carbon inputs to soil can cause disproportionate increases in microbial respiration rates, known as positive priming, causing a paradoxical decrease in soil carbon pools with increases in high quality litter inputs.

Collecting soil respiration data in a DIRT (Detritus Input and Removal Treatment) experimental plot. *Photo by Aleta Wiley, Harvard Forest Archives.*

In a special supplemental issue of the *Soil Science Society of America Journal* containing articles from the 12th North American Forest Soils Conference, Kate Lajtha, Richard Bowden, and Knute Nadelhoffer present results of 20 years of litter manipulations in The Detritus Input and Removal Treatment (DIRT) experiment at the Harvard Forest Long-Term Ecosystem Research (LTER) site in Petersham, MA. This experiment was designed to assess how rates and sources of plant litter inputs control accumulation and dynamics of organic matter in soils over decadal time scales. Soil organic matter quantity and quality were measured in O horizon and mineral soil in five treatments: Control, Double Litter (DL), No Litter (NL), No Roots (NR), and No Inputs (NI). After 20 years of manipulation, doubling litter inputs did not increase surface soil C content in contrast to model predictions. Similarly, doubling litter inputs did not increase either light or heavy density fraction pools of carbon or any measures of labile soil carbon. However, the activities of two key enzymes (β-glucosidase and phosphomonoesterase) increased 30% with litter additions, suggesting that litter additions stimulated microbial activity and likely caused significant priming of old soil carbon by labile carbon inputs. Exclusion of either aboveground litter or root inputs resulted in sharp declines in O-horizon carbon content but smaller decreases in total mineral soil carbon. Aboveground leaf litter exclusion resulted in a 19% decline in total profile mineral soil carbon whereas root exclusion resulted in a 9% decline, indicating the importance of aboveground inputs to long-term carbon pools. This was unexpected, as many studies—and many models—suggest that root inputs are more important to soil carbon sequestration than are aboveground inputs since aboveground inputs are more efficiently respired than stabilized.

The authors concluded that soil carbon pools in forests may not respond linearly or immediately to aboveground or belowground litter inputs, and thus efforts to sequester carbon by managing productivity and associated litter inputs will not likely result in increased carbon storage over short time frames.

Adapted from Lajtha, K., R.D. Bowden, and K. Nadelhoffer. 2014. Twenty years of litter and root manipulations in a temperate deciduous forest: Insights into soil organic matter dynamics and stability. Soil Sci. Soc. Am. J. 78(S1). doi:10.2136/sssaj2013.08.370. View the full article online at http://dx.doi.org/doi:10.2136/sssaj2013.08.370

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