Using Lasers to Measure Soil Carbon

Long-term storage of carbon (C) in soils is a potential strategy to mitigate rising CO_2 concentrations in the atmosphere. Management options for enhancing soil C in agroecosystems include reduced tillage, crop rotations, improved grazing strategies, and residue incorporation. Such practices could sequester large amounts of C during the next century. Quantifying changes in soil C due to land management has, however, proven problematic and will continue to be met with mixed success until methods are developed to measure and verify changes in soil C.

A team of scientists at Oak Ridge National Laboratory, the University of Tennessee, and Los Alamos National Laboratory has explored the use of laser-induced breakdown spectroscopy (LIBS) as a rapid and potentially field-deployable technique for measuring C in soils. While the technique has proven useful in earlier studies, an obstacle to widespread use of LIBS has been the lack of a consistent calibration for use across different soils. Scientists have now addressed this challenge and demonstrated that reliable measurements of soil C can be achieved using LIBS regardless of soil characteristics. Results from the study were published in the January–February issue of the *Soil Science Society of America Journal*.

A hammer-driven coring device is commonly used to sample soils. Extracted soil cores are contained within a plastic sleeve and transported to the laboratory for analysis.

The difficult and elusive goal of obtaining a single calibration model with LIBS was tackled by analyzing soils with different sand, silt, and clay compositions. With LIBS, a small portion of a sample is subjected to a high-energy laser. Light emitted from the resulting plasma provides an elemental fingerprint of the material. In the case of soil C, the novelty of the method resides in the use of multivariate analysis to determine the best experimental conditions to collect LIBS data on soils and to construct robust calibration models independently of the type of soils. In addition, the multivariate technique allows the whole spectral fingerprint to be used instead of just specific emission lines assigned to C.

Madhavi Martin, a laser spectroscopist who led the study, has applied LIBS to topics that range from criminal forensics to food-web dynamics.

"LIBS is a powerful technique, one that has many applications in the soil sciences," Martin says. "Based on the results of our current investigation, LIBS provides a robust method for soil C detection. Soil scientists, land managers, and instrument developers should find these results encouraging."

The potential of LIBS for analysis of soil C was first noted in 2001 by scientists at Los Alamos National laboratory and colleagues from the USDA. The difficulties of calibrating LIBS for quantitative analysis of soil C were identified and are related to microscopic and macroscopic heterogeneity in all soils. In applying LIBS to soil C analysis, Michael Ebinger, a co-author on the study, notes that "the analytical signal from C in soils is small and is masked by absorption of that signal by the ever-changing soil matrix." Martin says her team's research solves these issues.

Carbon concentrations were determined using laser-induced breakdown spectroscopy on replicated compressed disks of soil. Evidence of laser ablation can be seen as diagonal lines across the sample disks.

Scientists at Oak Ridge and Los Alamos National Laboratory, in partnership with the University of Tennessee, continue to explore the potential application of laser-based techniques in the environmental sciences. With methodologies like LIBS to assist them, soil scientists hope they can eventually identify the agricultural practices that provide maximum benefits to farmers and the climate alike.

Adapted from Martin, M.Z., N. Labbé, N. André, S.D. Wullschleger, R.D. Harris, and M.H. Ebinger. 2010. Novel multivariate analysis for soil carbon measurements using laser-induced breakdown spectroscopy. Soil Sci. Soc. Am. J. 74:87–93. View the full article online at http://soil.scijournals.org/content/vol74/issue1

Madhavi Martin uses laser-induced breakdown spectroscopy to measure carbon in compressed disks of soil.