Measuring carbon dioxide emissions from soils at both the soil surface and deeper down at the plants’ roots is key to understanding biological activity in soils, which offers a measure of a soil’s health, including its ability to cycle nutrients and support plant growth. Scientists have been working on techniques to quantify carbon dioxide concentrations in soils for the last century. Now, for the first time, researchers have developed an autonomous sensor that allows for constant measurements of soil and root respiration in heterogeneous soil.

The sensor is described in a recent article in *Vadose Zone Journal* (https://doi.org/10.2136/vzj2019.01.0007). According to SSSA member Detlef Lazik, a geophysicist at the Helmholtz-Centre for Environmental Research at the UFZ in Germany, and his colleagues, the primary goal of measuring both soil and root respiration is to characterize the soil in terms of plant–soil–microbe interaction. But respiration concentrations also provide information on greenhouse gas production from soils, which has implications for global climate change as well as soil–gas dynamics that affect soil fertility and plant growth, they say. “There are a lot of biological implications of knowing where that respiration occurs,” says SSSA and ASA member Tom Sauer, a soil scientist with the USDA in Iowa who was not involved with the new work.

Current techniques for measuring soil gas concentrations work, but they have flaws. Manual sampling, for example, which involves extracting soil from different depths across a field and then taking it to a lab to analyze it, is laborious and pricey, the team wrote. It and other methods, like sampling traps and diffusion probes, provide single-point measurements rather than autonomous or continuous real-time measurements across an entire field, take significant amounts of time for equilibration and calibration, require frequent maintenance, or can get clogged by biological activity. Having to frequently recalibrate the analyzers in the field is a real limitation of these techniques, Sauer says.

So Lazik and his colleagues developed a new line sensor that can be deployed prior to planting that autonomously collects real-time measurements and does so more accurately than previous technologies. “That’s progress,” Sauer notes.

The new sensor technology relies on small buried tubes that have carbon dioxide-gas-permeable walls. The team flushes the interiors of the tubes with air, which has a low carbon-dioxide content, so the pressure inside the tube increases as carbon dioxide seeps through the soil into the tube, Lazik says. “This can easily be measured, and from that, the carbon dioxide concentration in the ambience of the tube can be calculated.” Because the tubes can be buried for tens of meters beneath a field, he says, the measurements provide “meaningful averages” across a soil profile or field, despite the heterogenous environment.

The new technology also corrects for environmental factors such as soil temperature, air pressure, and water vapor without requiring additional calibration. Automatically correcting for the effect of water vapor in the soil...
Lazik says. “Our measurements provide a direct indicator for biological activity at high temporal resolution.” Thus, he says, the new sensor “allows us to analyze the relative importance and feedback processes of the various drivers—soil moisture, temperature, the supply of organic substances by plant roots, for example, and the composition and plasticity of the soil biome.”

Lazik and his colleagues set up the experiments for their new sensors using six 50-cm-by-50-cm boxes of soil, 55 cm deep, from an agricultural field test site in Germany. They installed their sensors at both 5 cm deep and 15 cm deep, planted 100 barley seeds in each box, and then started watering the soil and watching it. Throughout the growing process—sowing the seeds and harvesting the barley—the team measured carbon dioxide concentrations, water content and temperatures at both soil depths, and measured air pressure and temperatures above the soils. After harvest, they compared their sensor measurements with infrared carbon dioxide sensors, the industry standard, to confirm results.

Over the course of 20 years, Lazik and other researchers have been making “substantial developments on membrane-based gas sensors,” allowing more sensitive and accurate carbon dioxide measurements, Lazik says. The main contribution of this paper, he adds, “is a construction-based compensation of water vapor pressure,” meaning no additional measurements of humidity and temperature need to be made.

Lazik and his team have “pushed along the measurement technology,” Sauer says. “That’s a good thing.” But the other part is the diffusion coefficient—the ability of carbon dioxide to move through the soil system. Measuring that is “the hard part,” DeSutter says.

Scaling from laboratory to field is also tricky, he says. That’s the team’s next step, Lazik says. The team also plans to extend the technique to measure other gases.

Changes in carbon dioxide concentrations at the surface and at depth are part of the flux equation, says SSSA and ASA member Tom DeSutter, a soil scientist at North Dakota State University who was not part of the new study. “But the other part is the diffusion coefficient”—the ability of carbon dioxide to move through the soil system. Measuring that is “the hard part,” DeSutter says.

Dig Deeper

Read the full open access Vadose Zone Journal article, “New Sensor Technology for Field-Scale Quantification of Carbon Dioxide in Soil” at https://doi.org/10.2136/vzj2019.01.0007.