# Pore-scale wetting patterns and antecedent soil moisture alter carbon dynamics at every scale

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Soils are the Earth's largest terrestrial reservoir of carbon. It is important to know how soil carbon is stored in a "sink" and how it is released into the atmosphere as a "source."

Understanding that requires studying soil microorganisms, including where they live, and their access to stored carbon for food. When microbes have access to carbon and oxygen, they decompose those elements into carbon dioxide, or CO2, a process called "mineralization."

Water is required for this and other microbial activity. When water fills the conduits between soil pores, it connects microbes to resources by creating a three-dimensional network of aqueous highways.

## Pore Spaces

But not all soil carbon is available as microbial food. Some of it is protected within microscopic pore spaces within soil, whose tiny diameters restrict access to carbon-hungry microbes. Will soil carbon be food or not? Its fate depends on the hydrologic activity and connectivity in the soils.

A new paper in Nature Communications, a collaboration by lead author A. Peyton Smith and others at the Pacific Northwest National Laboratory and EMSL, investigates the importance of pore-scale wetting patterns, antecedent soil moisture conditions and other factors affecting soil carbon dynamics at every scale, from pore to core to field. (Core scale might be a shovel full. Field scale can be as big as an ecosystem.)

Smith and her co-authors argue that earth system models should treat soil moisture as more than a single number. It is better, they say, to think of soil as a three-dimensional framework-one that emphasizes the moisture conditions that form the hydrologic conduits that diffuse carbon and other soil resources.

## Banishing Uncertainties

Acknowledging the three-dimensional character of soil, in addition to its hydrology, is a significant step towards resolving uncertainties about soil carbon in current earth system models. Such models predict whether soils will be sinks or sources of carbon.

Droughts and other extreme events related to precipitation continue to increase in intensity, duration and extent. This has implications for carbon storage in soils at both the ecosystem and global scale.

In soil, the fate of carbon can go one of two ways, said Smith, a PNNL postdoc, "It's eat or keep."

So far, studies show that drought-affected soils pulse CO2 into the atmosphere when they are rewet, a phenomenon known as the "Birch effect." The longer the drought, the bigger the pulse of this greenhouse gas.

But the Birch effect is rarely investigated at multiple spatial and temporal scales. As a result, present models limit our ability to predict how cycles of drying and rewetting influence soil carbon.

## Wetting Direction, Down to the Molecule

In the new paper, researchers set out to develop a molecular-level understanding of wetting direction and antecedent soil moisture. In a laboratory setting, they used 16 experimental cores of sandy soil from the Florida Everglades to investigate the capacity of soils to be either a carbon sink or a carbon source in response to drought and rewetting direction.

We already know that when soils are wet from above, by precipitation, the larger pores fill in first. We also know that when soil is wet from below, by groundwater, capillary action saturates the finest pores first.

This above-below dynamic creates distinctive conditions. It affects the type of carbon available for microbial decomposition; the size of pores that get filled with water, enhancing hydrologic connectivity; and the size of pores that get filled with air, which provides the oxygen needed for decomposition.

"The connectivity is important," said Smith, "not just pore size."

## 'Drought Legacy'

The paper demonstrates that a soil's "drought legacy" and wetting direction are more important to carbon storage than its current moisture content. In particular, when rewetting comes from rising groundwater it produces a more rapid core-to-ecosystem carbon loss than precipitation events from above.

Still, at the field scale, both precipitation and groundwater fluctuations interact to destabilize soil carbon.

Models that simulate carbon fluxes at an ecosystem scale have to account for the dynamics of these directional wetting events, the authors say-not as a single number but as a three-dimensional framework.

**More information:** A. Peyton Smith et al. Shifts in pore connectivity from precipitation versus groundwater rewetting increases soil carbon loss after drought, *Nature Communications* (2017). DOI: 10.1038/s41467-017-01320-x

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