Increased droughts are disrupting carbon-capturing soil microbes, concerning ecologists

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A photo of an outdoor structure that was built to reduce rainfall at the Loma Ridge Global Change Experiment in Irvine, CA, USA, where researchers are studying how drought affects soil microbial communities and carbon storage. Credit: Steven Allison

Soil stores more carbon than plants and the atmosphere combined, and soil microbes are largely responsible for putting it there. However, the increasing frequency and severity of drought, such as those that have been impacting California, could disrupt this delicate ecosystem.

In a perspective published in the journal *Trends in Microbiology* on April 12, microbial ecologist Steven Allison warns that soil health and future greenhouse gas levels could be impacted if soil microbes adapt to drought faster than plants do. He argues that we need to better understand how microbes respond to drought so that we can manage the situation in both agricultural and natural settings.

"Soil microbes are beneficial, and we couldn't live without their cycling of carbon and nutrients, but climate change and drought can tweak that balance, and we have to be aware of how it's changing," says Allison of the University of California, Irvine.

Some soil microbes take carbon from decomposing plants and store it in the soil, while others release plant carbon back into the atmosphere. The carbon that ends up in the soil is beneficial in multiple ways. "The carbon in the soil has these reverberating effects out to the rest of the world in terms of the infrastructure in our natural and managed ecosystems," says Allison. "Carbon-rich soils hold more nutrients, so plants growing in those soils tend to be more productive, and the carbon changes the physical properties of the soil, which prevents erosion."

"In California now, we have this system where the droughts are more intense, and then the rainfall is more intense," he says. "So, if you're losing your soil carbon, when it rains really hard it could carry away your soil and cause erosion, landslides, mudslides, sediments, and all kinds of problems that we're actually seeing right now."

The carbon that is released back into the atmosphere is another story.

"From a climate mitigation standpoint, what we want is for more carbon to be in plants and soils and less carbon to be in the atmosphere, so the more carbon we can absorb into plants through photosynthesis and the more we can transfer and keep in the soil, the better off we're going to be in terms of climate change," says Allison. "That's why it's really important to know how the balance of incoming versus outflowing carbon changes with drought, or warming, or any other climate factor."

Plants and microbes will both be impacted by the increasing frequency of drought, but Allison suspects that microbes will be able to bounce back faster. "Microbes are really adaptable—they can change their physiology, they can change their abundances so that more drought-adapted microbes take over, and they can potentially evolve—so we expect that they are going to resist or bounce back from drought," says Allison. "All those different processes can happen pretty quickly with microbes, and much more quickly than with plants."

If more carbon-releasing microbes survive than carbon-sequestering microbes, we could end up with carbon-depleted soils, which would have serious negative implications for plant productivity and future greenhouse gas levels.

We may be able to nudge the balance in the right direction, Allison says, but more research is needed first. "There's still a lot to be done. Right now, we have data that suggests that when we have drought, something changes that results in carbon loss, but we don't understand exactly how or why that's happening, whether drought's changing the abundance of beneficial plant associated microbes versus the carbon releasing microbes, or if it's causing the evolution of one of the microbe groups, or if it's more determined by changes to their immediate physiology," says Allison.

Some microbes could actually help plants cope with drought. If we knew

which microbes were most beneficial to plants, and most likely to retain carbon in soil, we could try to tip the balance in their favor.

"There's a lot of potential for us to manage or engineer soil microbes," says Allison. "In agricultural systems, we can look into manipulating the soil or adding beneficial microbes back in. In more natural systems, management would probably be on the plant side: soil microbes are often closely intertwined with plants, so managing the plants can also benefit the microbial part of the ecosystem."

"We also need more measurements to get a good sense of how drought affects soil carbon change in different ecosystems," says Allison. "There's a lot of landscape out there—from the Arctic tundra to the deserts—and we could use more research across those diverse habitats."

More information: Steve Allison, Microbial drought resistance may destabilize soil carbon, *Trends in Microbiology* (2023). DOI: 10.1016/j.tim.2023.03.002

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