Biosphere 2 experiment reveals that soils in drought stress leak more volatile organic compounds into the atmosphere

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A fisheye view of the enclosed rainforest at Biosphere 2. Credit: Laura Meredith

Microbes are doing a lot under the soil surface that can't be seen with the naked eye—from sequestering carbon to building the foundation of Earth's crust. But even tiny microbes are feeling the stress of a hotter, drier future.

According to a new study by University of Arizona researchers, published in *Nature Microbiology*, soil microbes release more volatile organic compounds into the atmosphere in response to drought stress.

The study is just one part of the B2 Water, Atmosphere, and Life Dynamics project, which brought over 90 researchers from around the world to the University of Arizona's enclosed rainforest at Biosphere 2 to conduct a controlled drought experiment and better understand what happens to the world's ecosystems when water is scarce.

Uncovering how soil microbes process carbon and interact with the atmosphere under environmental stress helps scientists predict and support how ecosystems will adapt in the face of increasing temperatures and prolonged drought.

Volatile isn't what you may think

When most people think of volatile organic compounds, they think of aerosols—which can contribute to warming and have negative impacts on air quality—but the term "volatile" simply refers to how easily a chemical or compound can change from a liquid to a gas phase, explained lead study author Linnea Honeker, a postdoctoral researcher who worked with associate professor of environmental science Malak Tfaily in the College of Agriculture and Life Sciences during the B2 WALD project.

Many volatile organic compounds are naturally produced and are released in our breath, from trees or by microbes that live in the soil. Microbes naturally consume carbon as part of their life cycle and, in turn, produce volatile metabolites.

As part of the B2 WALD project—led by Laura Meredith, an associate professor and ecosystem genomics expert in the School of Natural Resources and the Environment—Honeker and a team of international soil and atmospheric scientists used a labeled carbon isotope to track the movement of carbon and water throughout the rainforest ecosystem during the simulated drought experiment. Using soil flux chambers, the team was able to measure the consumption and release of volatile organic compounds in the soil.

The Biosphere 2 facility in Oracle, Arizona, at sunset. Credit: Laura Meredith

Less CO_2, more VOCs

While microbes worked to break down volatile organic compounds produced in the soils during ambient or pre-drought conditions, these same microbes appeared to ramp up production and decrease consumption of volatile metabolites under drought stress.

"What we found is microbial production of CO_2 decreased during drought, but there was a net increase of emissions of the volatile metabolites acetate, acetone and diacetyl," said Honeker, who recently accepted a postdoctoral position in soil microbiome bioinformatics at the Lawrence Livermore National Laboratory.

Overall, the study revealed soil carbon cycling efficiency decreased during drought, and that may be a result of microbes diverting more of their resources to producing volatile organic compounds and other protective compounds to help support themselves during the drought, she said.

It is not yet clear what specific role the volatile organic compounds found in the study play in soil-atmosphere dynamics, but the findings are an important step toward understanding how small but mighty microbes beneath the surface are responding to environmental stress.

"These results bring us one step closer to understanding how droughts, which are expected to increase in frequency and duration, can impact microbial carbon cycling in the soil, which, in turn, can have large-scale impacts on ecosystem services and even atmospheric processes," Honeker said.

More information: Linnea K. Honeker et al, Drought re-routes soil microbial carbon metabolism towards emission of volatile metabolites in an artificial tropical rainforest, *Nature Microbiology* (2023). DOI: 10.1038/s41564-023-01432-9

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