New predictive models developed for bacterial diversity of soils

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A new set of quantitative models that incorporates pH into the metabolic theory of ecology (MTE) has been developed by an international team that includes Penn State assistant professor of plant science Francisco

Dini-Andreote.

The work is included in a new paper published by the *Proceedings of the National Academy of Sciences*, titled, "Integrating pH into the metabolic theory of ecology to predict [bacterial diversity](link) in [soil](link)."

"Soils are the most complex and biodiverse ecosystems on Earth," said Dini-Andreote, a member of Penn State's Microbiome Center. "In soils, microbial diversity plays indispensable roles in the anabolic and catabolic cycles of carbon, nitrogen and sulfur, without which the diversity of life forms—including plants, animals and other microbes—that evolved on our planet would not have been possible. In addition, advancing our ability to predict patterns of soil biodiversity is critical to better understanding how [climate change](link) will affect soil functioning and how [soil microbes](link) will respond to shifts in temperature and precipitation regimes."

In general terms, the metabolic theory of ecology links rates of organism diversification (i.e., the [metabolic rate](link) of an organism) with the organisms' body size and body temperature, explained Dini-Andreote. Building upon the factors that are parametrized in the MTE, the researchers introduced variation in local pH as an additional variable that acts as a stringent selective filter of biodiversity in soils, impacting the species of microbes acting and surviving in the soil.

By considering all these factors—the metabolic rate, mass, and temperature as well as pH—the researchers were able to capture and account for previously unexplained variation in the relationship between soil edaphic properties (the physical, chemical, and biological properties of the soil), temperature, and biogeographical patterns of bacterial diversity. The team then continued to test and validate their models across multiple scales—such as single bacterial strain diversification rates, local and continental scale soil communities—yielding robust

results.

"By layering these models, researchers can start to better understand patterns of microbial distribution in soils and start to answer long-standing questions in this field, such as: 'What determines variation in soil biodiversity?' and "How dynamic changes in soil biodiversity can be modeled and predicted?" said Dini-Andreote.

"With that, we will be able to better harness the genomic and functional potential of these soil microorganisms to effectively manipulate them for desirable outcomes. These outcomes vary from essential ecosystem functions, such as carbon storage in soil, to the manipulation of beneficial plant-associated microorganisms to enhance crop productivity in agriculture."

This study also represents a nexus point for the integration of other variables into these quantitative models, such as variation in [soil moisture](link) and salinity, among others. The authors foresee new avenues of research ahead that will greatly improve scientists' ability to understand the distribution of soil microbial species, and the diverse ways they operate as engineers of essential ecosystem processes and services in soils.

"Dr. Dini-Andreote's scholarship shines a [bright light](link) on the abundance of the soil microbiome and the processes and mechanisms that shape soil health. From the soil on up, microbial communities connect different ecosystems as microorganisms flow from soil to hosts and back. With soil as the largest reservoir of [microbial diversity](link) on Earth, this important work raises the call to action as soils vary and degrade due to climate change, erosion, and chemical contamination," said Seth Bordenstein, director of the Penn State Microbiome Center, Dorothy Foehr Huck and J. Lloyd Huck Chair in Microbiome Sciences, professor of biology and entomology.

More information: Lu Luan et al, Integrating pH into the metabolic theory of ecology to predict bacterial diversity in soil, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2207832120

Provided by Pennsylvania State University

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