Restoration of degraded areas in semi-arid region contributes to 'return' of soil microorganisms, study shows

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The researchers conducted a review of 18 studies of the semi-arid region, focusing on the Caatinga. Credit: Arthur Prudêncio de Araújo Pereira/UFC

Strategies deployed for the restoration of degraded land have had promising results in Brazil's semi-arid region, improving the microbial

properties of the soil and contributing to a return of native ecosystem services. The techniques include removal of cattle or restriction of their access to specific areas of pasture; cultivation of cover crops; and terracing to control erosion. Recovery of soil microbial properties maintains biodiversity and raises crop yields, contributing to agricultural sustainability.

These are the main findings of a study reported in the *Journal of Environmental Management* by a Brazilian research group comprising scientists affiliated with the University of São Paulo (USP), the Federal University of Piauí (UFPI), the Federal University of Ceará (UFC), and the Federal University of the Agreste of Pernambuco (UFAPE). The review article encompasses 18 studies conducted in the semi-arid region, especially the Caatinga, a local biome consisting mainly of deciduous thorn forest.

The area susceptible to desertification corresponds to 70% of the Northeast region, or about 16% of Brazil's total land mass. It contains more than 1,400 municipalities (out of a nationwide total of 5,570) and spans nine states with an aggregate population of 35 million.

Biodiversity is high in the Caatinga, with some 600 species of birds, 240 species of fish and 170 species of mammals, among others. Family farmers are very much in the majority and are particularly exposed to climate risk. The main family farming municipalities have suffered severe production losses in the past three decades.

According to a study by the Climate Policy Initiative at the Pontifical Catholic University of Rio de Janeiro (CPI/PUC-Rio), the increase in drought events in the Caatinga correlates with higher yield losses for beans (16%) and corn (35%) compared with other biomes (6% and 16% respectively). In the case of cattle raising, productivity falls 9% in the Caatinga but rises 1% elsewhere.

"We set out to understand the soil microbiome and its functions in order to identify tools that can help restore degraded areas in the semi-arid region. We found that restoration techniques have led to a return of microbial diversity and hence a resumption of ecosystem services and functions similar to what they were naturally," Lucas William Mendes, last author of the article, told Agência FAPESP. Mendes is a professor at the University of São Paulo's Center for Nuclear Energy in Agriculture (CENA-USP).

About the soil microbiome

The soil microbiome is the community of microorganisms—bacteria, fungi, archaea, protists and viruses—that live in soil, along with their genetic material, functions, and relationships with the environment. It plays an important role in nutrient cycling, organic matter decomposition, greenhouse gas emissions, and plant health.

Microorganisms are involved in the formation and stabilization of carbon-rich organic matter, contributing to carbon sequestration and mitigating the effects of climate change. "By understanding how some microorganisms live in drought-ridden areas and contribute to plant growth there, we can discover novel inoculants for use in developing vegetation in semi-arid regions," Mendes said.

An analysis of the effects of restoration techniques on the soil microbiome highlights land quality as a basis for reducing synthetic inputs and leveraging biotechnological potential to implement sustainable practices.

Sustainability is the current focus for the G20 Agriculture Working Group. With 19 member countries, the European Union and the African Union, the G20 is chaired by Brazil this year. The summit for heads of state and government will be held in November in Rio de Janeiro.

For Erika Valente de Medeiros and Diogo Paes da Costa, professors at UFAPE and co-authors of the article, research of this kind can provide vital knowledge for policymakers to devise sustainable development strategies and combat desertification. "These initiatives are fundamental, especially insofar as they make use of the concept of global health, which acknowledges the interconnectedness between ecosystem health, soil microbiome diversity and human well-being," Medeiros said.

Natural and anthropogenic factors

In the article, the researchers show that desertification in Brazil's semi-arid region is influenced both by natural factors, such as low rainfall, high evaporation and fragile soil, and by anthropogenic factors, such as non-sustainable livestock production and crop growing without adequate land management.

"The study is important because it highlights the negative effects of desertification and points to effective practices to restore soil microbial diversity," said agronomist Ademir Sérgio Ferreira de Araújo, first author of the article, a researcher with CENA-USP and a professor of soil microbiology at UFPI.

The group used molecular techniques such as metagenomics and metatranscriptomics to measure and assess the effects of soil microbiome restoration projects. Some areas were restored with new plant cover, such as Sunn hemp (Crotalaria juncea) and Guinea grass (Panicum maximum). The latter, a plant of African origin found throughout the tropical and subtropical regions, is an excellent cattle forage crop thanks to its high green mass yield and elevated crude protein content

"With plant cover changing soil chemistry, improvements in pasture were sufficient to support an increase in head of cattle per hectare and in

productivity," Mendes said.

Terracing helps control erosion, conserves water and facilitates farming. "It's important to bear in mind that restoration of soil microbial properties is a complex process that takes time, requiring long-term commitment and monitoring. Hence the need for more research in this field," Mendes added.

Mendes is also a co-author of an article published in January in the journal *Plant and Soil*, advocating a systems-based approach to land restoration that integrates biological approaches with environmental variables such as ecosystem properties, climate and soil types. Led by Brajesh Singh, a researcher at Western Sydney University in Australia, and with a global purview, the study supported this approach by integrating novel computational tools and satellite imaging to facilitate implementation of ecosystem management, monitoring and restoration.

According to Arthur Prudêncio de Araújo Pereira, a professor at UFC and a co-author of both articles, next steps will involve the Caatinga Microbiome Initiative (CMI), launched in 2022 with more than 20 professors and researchers from Brazil and abroad to study the Caatinga microbiome and its links to soil health.

"We know very little about the role of the soil microbiome in the Caatinga, especially in desertifying areas. Hence the importance of the experiments conducted as part of the project," he said.

More information: Ademir Sergio Ferreira Araujo et al, From desertification to restoration in the Brazilian semiarid region: Unveiling the potential of land restoration on soil microbial properties, *Journal of Environmental Management* (2023). DOI: 10.1016/j.jenvman.2023.119746

Alexandre Pedrinho et al, Soil microbial diversity plays an important role in resisting and restoring degraded ecosystems, *Plant and Soil* (2024). DOI: 10.1007/s11104-024-06489-x