BRAZILIAN SOIL HEALTH PARTNERSHIP

SOIL HEALTH NEWS

THEME: LIVING SOIL

CCARBON
CENTER FOR CARBON RESEARCH IN TROPICAL AGRICULTURE
UNIVERSITY OF SÃO PAULO

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CCARBON
CENTER FOR CARBON RESEARCH IN TROPICAL AGRICULTURE
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BRAZILIAN SOIL HEALTH PARTNERSHIP

LIVING SOIL

Soil is much more than just a substrate: it is a living, dynamic ecosystem, full of invisible interactions that sustain life as we know it. In this edition, we celebrate "Living Soil" soil that is rich in organisms, resilient to climate stresses, productive, balanced, and highly capable of regeneration.

We will discuss soil health, its bioindicators, and the role of sustainable practices in keeping this essential resource active and productive. Living soil is the foundation of resilient agriculture, food security, and environmental preservation.
Enjoy the read!

Restoring Soil Health with Legume-Based Integrated Farming Systems

Ana Clara Santos Duarte[1], Jaqueline de Cássia de Oliveira, Warley Rodrigues de Oliveira, Igor Costa de Freitas, Álissam de Sá Cardoso, Alex José Silva Couto, Walter José Rodrigues Matrangolo, Karina Toledo da Silva, Rodinei Facco Pegoraro and Leidivan Almeida Frazão

[1]Instituto de Ciências Agrárias, Universidade Federal de Minas Gerais, Montes Claros.

Soil health is essential for sustaining agricultural productivity and ecosystem sustainability. In the Brazilian Cerrado, conventional practices such as continuous maize cultivation and degraded pastures have contributed to soil quality decline. In this context, agricultural systems that integrate legumes with annual crops or pastures emerge as promising strategies to reverse this degradation. Therefore, this study aimed to evaluate how the introduction of legumes into integrated agricultural systems can contribute to restoring soil health.

The experiments were conducted in two areas of the Cerrado region in Minas Gerais, Brazil (Figure 1).

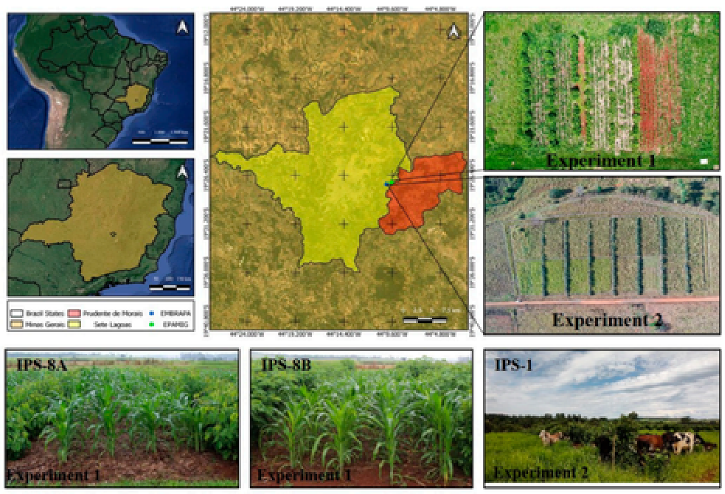


Figure 1. Integrated production system experiments conducted in Sete Lagoas and Prudente de Morais, in the Cerrado region.

The experiments evaluated different land uses, including native vegetation (NV), pastures with different *Urochloa* species, and integrated systems with tree legumes *Cratylia argentea* and *Gliricidia sepium* — intercropped with maize or pasture.

Carbon (C) stocks were similar between pasture and NV. Integrated systems showed reductions of 29% and 23% in C stocks compared with NV, but increased C stocks by 24% and 18% compared with conventional cultivation in the surface soil layer (Figure 2).

The variables qMIC and β-glucosidase were positively correlated with each other and, in contrast, were negatively correlated with urease activity.

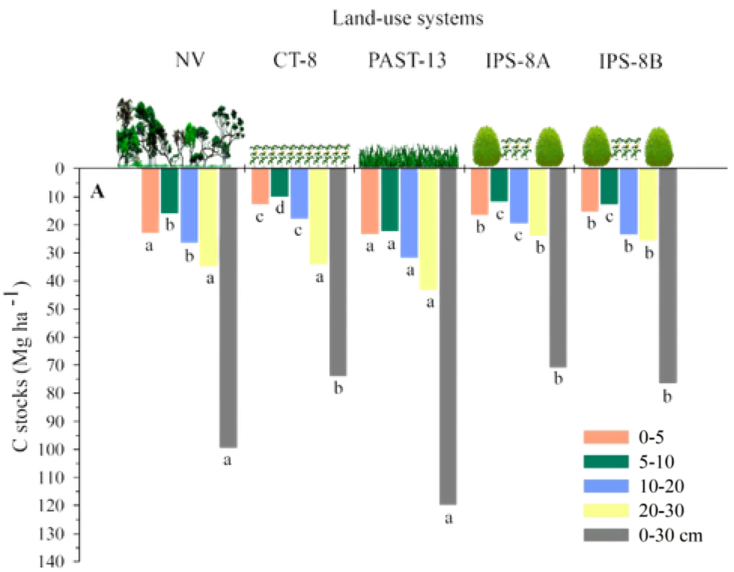


Figure 2. Soil carbon stocks. Native vegetation (NV); conventional tillage with maize (CT-8); two pasture systems with Urochloa decumbens (PAST-13); and three integrated production systems arranged with Cratylia argentea + maize (IPS-8A) and Gliricidia sepium + maize (IPS-8B).

In the dry season (July 2022), NV and pasture showed higher values of microbial carbon (Cmic), qMIC, labile carbon, and urease activity, whereas the integrated system with *Gliricidia sepium* and maize stood out for its higher β-glucosidase activity.

Principal component analysis (see Figure 7 in Duarte et al., 2025) showed that, in the rainy season, the highest values of Cmic, qMIC, and β-glucosidase occurred in the pasture systems and in the integrated system with *Cratylia argentea* and *Urochloa brizantha* cv. BRS Piatã, with a strong

Karina Toledo da Silva

correlation among them.
Overall, the results show that integrated agricultural systems with legumes helped restore soil health by improving its chemical, physical, and biological properties. Compared with pasture cultivated for 13 years, legume-based integrated systems showed important improvements in soil quality.
For example, the integrated system with *Gliricidia sepium* and maize increased soil N content, highlighting the key role of legumes in improving soil fertility in the Cerrado. In addition, integrated systems reduced soil compaction in deeper layers, probably due to greater plant diversity within the system. Higher β-glucosidase enzyme activity was also observed in the integrated systems with *Cratylia argentea* and maize, as well as with Gliricidia sepium and maize, indicating better biological soil quality.
This result was further supported by a 25% increase in microbial biomass carbon (Cmic) in the 5–10 cm soil layer compared with the pasture system.

Conclusion

Even in the short term, the integrated system with Gliricidia sepium and maize increased soil carbon stocks by up to 24% in the surface layer compared with annual cropping under conventional management. This system also showed potential to restore carbon stocks in degraded pasture areas,

Karina Toledo da Silva

reaching levels similar to those of well-managed pastures.

Long-term studies are needed to better assess the effects of adopting agroforestry systems on increasing soil C and N stocks.

Climate seasonality had a stronger influence on soil microbial attributes than the land-use systems themselves. Despite the short implementation period of one year, microbial carbon was similar between the integrated system and the pasture. Integrated systems increased β-glucosidase enzyme activity compared with pasture.

This study indicates that introducing legumes into integrated production systems significantly contributes to restoring soil health, representing a viable alternative to pasture monocultures or annual cropping systems in the Cerrado biome.

Walter J. R. Matrangolo

Read the full article!

Master's degree from the Graduate Program in Plant Production at the Federal University of Minas Gerais (UFMG). Holds a degree in Agronomy from UFMG (2020). Member of the Crop-Livestock-Forest Integration Study Group at ICA/UFMG.

Ana Clara Santos Duarte

Engª agrônoma | MSc. em Produção Vegetal

Degree in Agronomic Engineering from UFSCar (2004), Master's degree in Sciences — Chemistry in Agriculture and the Environment — from CENA/USP, and PhD in Sciences — Soil and Plant Nutrition — from ESALQ/USP, in partnership with Colorado State University through a sandwich PhD program.

Coordinator of the Study Group on Crop-Livestock-Forest Integration Systems at ICA/UFMG. She is also a member of the Management Committee of the Center for Carbon Studies in Tropical Agriculture — CCARBON/USP — and a scientific member of the Brazilian Soil Health Partnership (BSHP).

Leidivan Almeida Frazão

Professora Asssociado III da Universidade Federal de Minas Gerais (UFMG)

Caatinga Microbiome Initiative: disentangling the soil microbiome across areas under desertification and restoration in the Brazilian drylands

Ademir S. F. Araujo[1], Erika V. de Medeiros, Diogo P. da Costa, Lucas W. Mendes, Mauricio R. Cherubin, Francisco de Alcantara Neto, Raphael M. Beirigo, George R. Lambais, Vania M. M. Melo, Gabriel N. Nobrega, Humberto A. Barbosa, Jaedson C. A. Mota, Rodrigo M. Santana, Vanessa N. Kavamura, Wardsson L. Borges, Arthur P. A. Pereira

[1] Universidade Federal do Piauí (UFPI)

Soil microorganisms, such as bacteria, fungi, archaea, nematodes, viruses, and protists, are essential for keeping soils alive and functioning. They help decompose organic matter, recycle nutrients, and even store carbon. These processes are fundamental to soil health and environmental balance, especially in vulnerable regions such as the Brazilian semiarid region.

In the Caatinga, one of the most unique and threatened biomes in the Brazil, soil degradation is a growing problem. With naturally low fertility, limited organic matter, and a dry climate, these areas are highly susceptible to desertification, which currently affects about 19% of the territory. Pressure on water, firewood, and pasture resources, combined with social vulnerability, further intensifies this process.

To better understand how to restore these areas effectively, the Caatinga Microbiome Initiative (CMI) was created. This initiative brings together researchers from across

Brazil with the aim of studying how the soil microbiome responds to desertification and restoration strategies.

Figure 1 shows the location of the four main desertification nuclei in the northeastern semiarid region: 1) Irauçuba (CE), 2) Gilbués (PI), 3) Seridó (PB and RN), and 4) Cabrobó (PE). These areas are critical sites for soil restoration studies. The main conservation practices applied in the region include pasture exclusion, terracing, green manuring, and agroforestry systems.

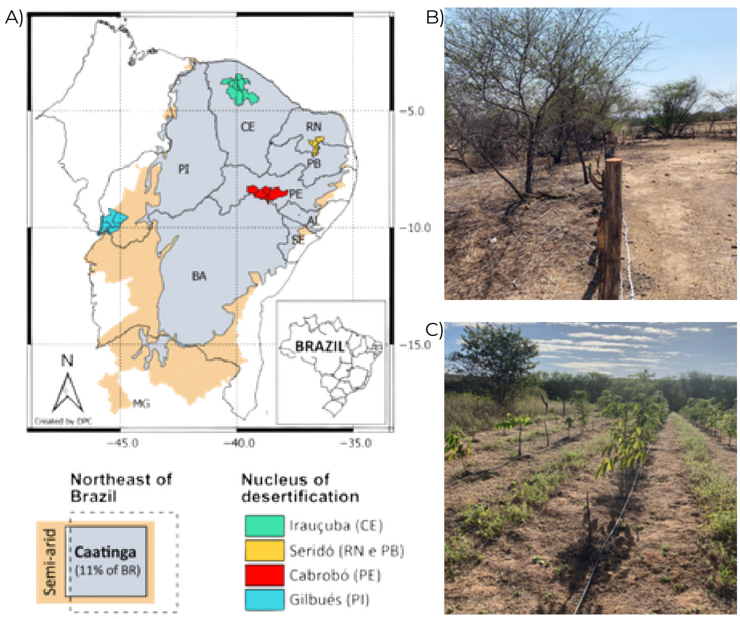


Figure 1. (A) Northeastern Brazil, a semiarid region, showing the Caatinga biome and the four main desertification nuclei; (B) pasture exclusion; and (C) green manure or agroforestry system.

Evidence suggests that soil restoration and sustainable management practices, such as increasing organic matter and reducing physical disturbance, support the recovery of microbial biodiversity and enhance ecosystem services such as water retention and nutrient mineralization.

Groups such as actinobacteria, algae, viruses, protozoa, and nematodes perform complementary and often critical functions in soil functioning, contributing to processes such as aggregate formation, pathogen regulation, nutrient solubilization, and the balance of microbial food webs (Figure 2).

Read the full article!

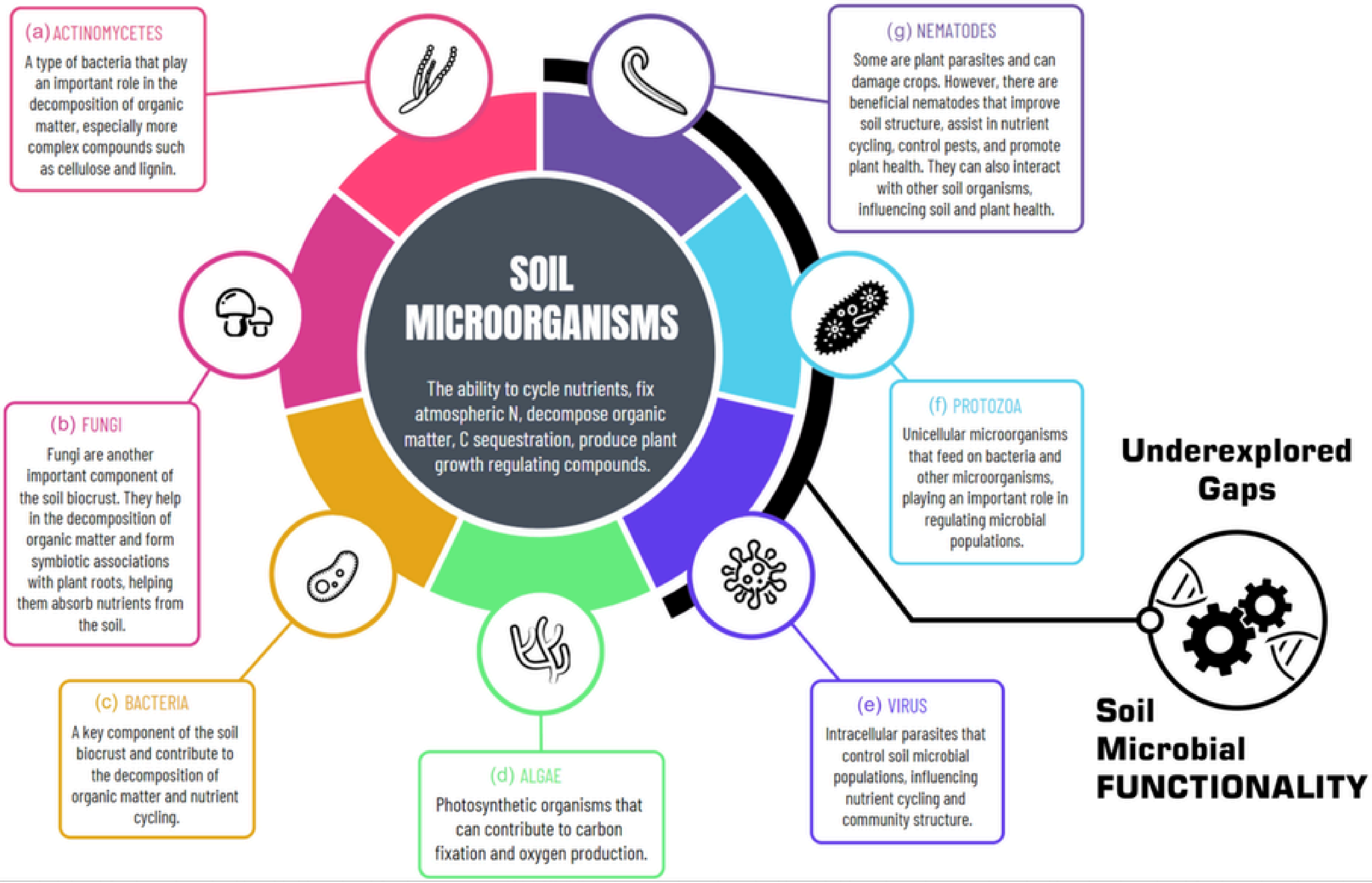


Figure 2. Main biological groups studied in the soil and understudied knowledge gaps in the Caatinga biome.

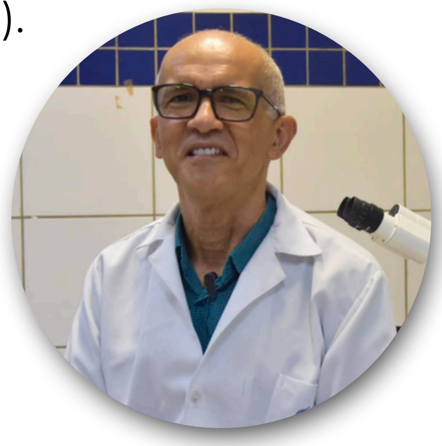
Studies from the CMI already indicate that restored areas harbor healthier and more diverse microbial communities. In addition, strategies such as the inoculation of native microorganisms have the potential to accelerate soil recovery. The initiative also highlights the importance of studying less well-known groups, such as viruses and nematodes, which may play important ecological roles.

Based on this, the CMI proposes practical actions to restore Caatinga soils and make production systems more resilient and sustainable, benefiting both the environment and the communities that depend on it.

Agronomist (UFRPE, 1998), PhD in Soil Microbiology (ESALQ/USP, 2004), and Postdoctoral Researcher in Soil Microbial Ecology at the University of California, Davis (2015).

Permanent faculty member of the Graduate Programs in Agronomy and Agricultural Sciences. He has experience in Agronomy and Soil Science, with an emphasis on Soil Microbiology and Biochemistry.

Leader of the research group "Soil Microbial Ecology of the Mid-North Region" (UFPI/CNPq), Coordinator of a CNPq and FAPEPI Center of Excellence, and scientific member of the Brazilian Soil Health Partnership (BSHP).



Ademir S. F. Araujo

Professor at the Federal University of Piauí (UFPI).

Agronomist from the Federal Rural University of Pernambuco, Garanhuns campus (2012). He holds a Master's degree, PhD, and postdoctoral experience in Sciences from the Graduate Program in Soil and Plant Nutrition at the "Luiz de Queiroz" College of Agriculture (ESALQ/USP, 2013–2019).

During his PhD, he completed a sandwich period at the Hawkesbury Institute for the Environment, University of Western Sydney, Australia (2018).

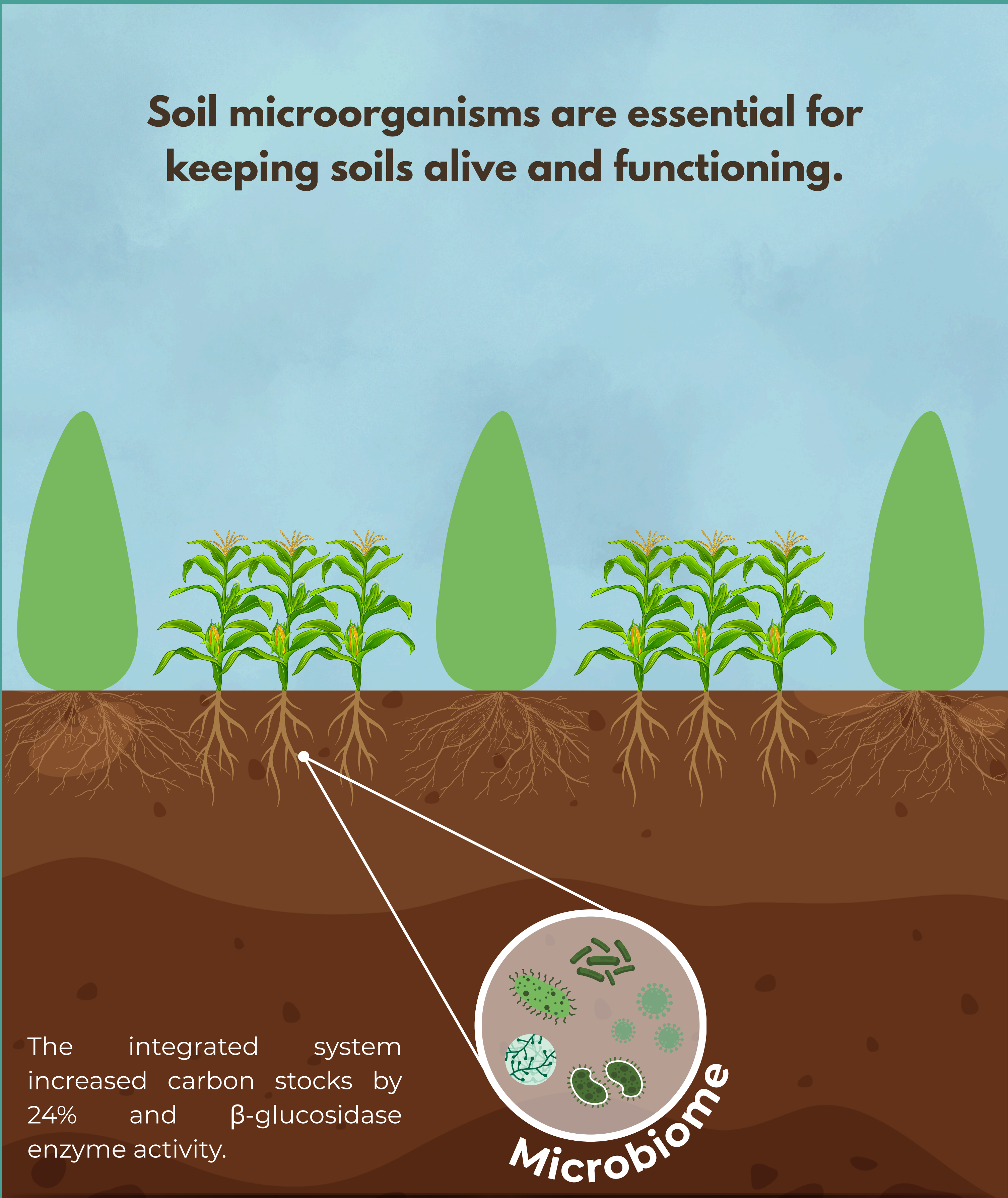
He coordinates GEMBioS — the Study Group on Soil Microbiology and Biotechnology — and is a scientific member of the Brazilian Soil Health Partnership (BSHP)

Arthur P. A. Pereira

Professor at the Federal University of Ceará (UFC).

From science to practice:

Figure 3. Soil organisms: essential for maintaining fertility, increasing carbon, and sustaining agricultural productivity.



Dr. Ieda de Carvalho Mendes

Researcher at Embrapa Cerrados

Agronomist graduated from the University of Brasília, with a PhD in Soil Science from Oregon State University, United States.

Her work focuses mainly on:

- Biological nitrogen fixation
- Soil microbial ecology
- Soil quality bioindicators

With extensive experience in soil microbiology, her career has made significant contributions to advancing knowledge on soil health in Brazil, especially through the development and application of biological indicators, such as BioAS.

1) What motivated you to work with soil microbiology and soil quality bioindicators?

My motivation has always been the conviction that soil is alive and functions as a "superorganism." From the beginning, it was clear that chemical analyses alone were not sufficient to understand how our soils function. The absence of the biological component in routine soil analyses represented an important gap — and if we truly wanted to understand soil dynamics and functioning, we also needed to look at its biology. The more biology, the more life in the soil — and the healthier it is. The less biology, the less life — and the more degraded the soil becomes.

2) How do you see the contribution of BioAS to sustainable soil management practices in Brazil?

With soil bioanalysis, BioAS, Brazil became the first country in the world to incorporate two biological indicators into routine soil testing: the enzymes β-glucosidase and arylsulfatase.

These bioindicator enzymes are more sensitive than organic matter content in detecting changes in the soil resulting from the adoption of different management practices. Because they occur in all biological components of the soil — microorganisms, plants, and fauna — they reflect the functioning of the soil's "biological machinery," especially regarding nutrient cycling.

When analyzed together with organic matter content and soil texture, these enzymatic activities allow us to classify soil into four different health conditions: healthy, becoming degraded, degraded, and recovering.

The great merit of BioAS is that it translates this technical knowledge into useful and applicable information for farmers' daily decision-making, helping them choose more sustainable and efficient management practices.

3) In your view, what are the main current challenges to expanding large-scale biological soil monitoring?

On July 23, 2025, we will celebrate five years since the launch of BioAS. It is, therefore, a technology that is still in the early stages of adoption. For its application to expand and become consolidated in the field, it is essential to intensify technology transfer and rural extension efforts.

We need to overcome the knowledge gap regarding soil health and its monitoring through BioAS — especially among students, agronomy professionals, and farmers. In addition, it is essential to raise awareness of the value of biological indicators as practical tools to guide sustainable soil management.

It is necessary to show farmers, technical advisors, and decision-makers that soil biology provides essential information about soil health — and that soil testing should go beyond detecting nutrient deficiencies or excesses.

These analyses also need to become more accessible, both logistically and economically. Currently, the Embrapa Network of commercial laboratories authorized to perform BioAS includes 33 laboratories. This number needs to be expanded. Demonstration projects across different regions and agroecological conditions are also essential to clearly show the practical value of biological diagnosis, especially in terms of productivity and sustainability.

Another key point is financial support — subsidies, strategic partnerships with stakeholders in the agricultural sector, and the integration of biological analyses with precision agriculture tools can facilitate large-scale adoption. Finally, the development of user-friendly interfaces and integrated digital platforms can also expand the use of biological monitoring, making it a practical and effective tool within agricultural management routines.

Adopting an integrated approach — involving education, practical demonstration, financial support, partnerships, and technology — is essential to overcome these challenges and consolidate biological soil monitoring as a common and strategic practice in Brazilian agriculture.

4) Could you share a recent result or success story that demonstrates the positive impact of using bioindicators?

Agriculture is one of the sectors most affected by climate change. Extreme events, including heat and cold waves, long drought periods, and changes in rainfall patterns, directly affect crop performance.

However, farms that adopt management systems capable of maintaining healthy soils have shown greater resilience to these challenges, sustaining high productivity levels with greater input-use efficiency.

An excellent example is farmer Maira Lelis, from Santa Helena Farm, located in Guaíra, São Paulo. The farm has adopted no-till farming for more than 30 years and systematically uses cover crops. This history of good agricultural practices is directly reflected in the BioAS reports carried out on the farm: all indicators are in the green range, indicating healthy soil, high enzymatic activity, and high organic matter content. In other words, the soil has a high capacity for nutrient cycling.

In the 2022/23 growing season, several fields on the farm reached 6000 kg ha of soybean without the need for potassium and phosphorus fertilization, a direct result of well-functioning soil biology. This performance was repeated in the 2023/24 season, which was an extremely challenging year from a climate perspective, with irregular rainfall and high temperatures at the beginning of planting. The adoption of no-till planting "on green cover," with cover crops rolled down before soybean sowing, was essential to maintain soil moisture and temperature at suitable levels for crop establishment.

The case of farmer Maira Lelis shows that investing in soil health is beneficial in every aspect, not only for environmental value or increased farm value, but especially for agronomic and economic gains. Biologically active soils are more productive, more efficient in nutrient use, have greater capacity to store water, and can help bioremediate pesticide residues. Ultimately, all of this translates into greater production stability, resilience, and profitability, even under climate adversity.

5) What message or recommendation would you give to technical advisors, farmers, and young researchers interested in soil biology and soil health?

We are living through an extraordinary moment in Brazilian agriculture. With BioAS, we have entered a new era in soil testing in the country, not only because we can now assess soil health, but also because we have begun to establish a true “biochemical dialogue” with the soil, mediated by the enzymes β-glucosidase (GLU) and arylsulfatase (ARYL).

These enzymes allow us to access something that once seemed intangible: the “memory of the soil”, that is, the stories it has to tell us as a result of the management practices it has undergone. For us, as researchers, this reading is clear. Our hope is that this understanding will also become increasingly evident to farmers, technical advisors, and young scientists, promoting profound changes in the way we relate to soil.

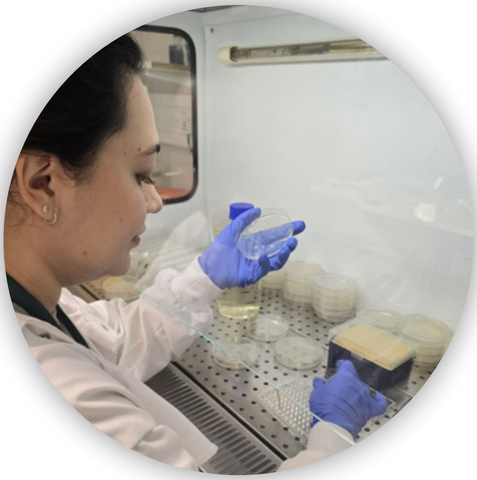
Agricultural systems that maintain healthy soils are more productive, resilient, and sustainable. The recipe for achieving this lies in imitating nature: avoiding soil disturbance, promoting plant diversity through crop rotation and the use of cover crops, keeping the soil continuously covered with living plants and crop residues, and, whenever possible, integrating trees and animals into the system.

My message is simple and direct: let us be inspired by nature when designing our agricultural systems. Success will follow. Soil health is directly linked to soil biology, and this biology is the key to climate-smart agriculture, adapted to today’s challenges and committed to the future.

The Microbiome Associated with Carnauba Palm Plants (*Copernicia prunifera*): Ecology and Biotechnological Applications

Elane Bezerra; Arthur P. A. Pereira

Elane Bezerra



Elaine Bezerra

The carnauba palm is a typical palm species of the Brazilian semiarid region, with great economic, social, and environmental importance for the region. One of its natural resistance mechanisms may be related to its interaction with associated microorganisms, which contribute to its survival in adverse environments. These microbial communities represent a promising potential for the bioprospection of organisms with applications in inducing stress tolerance in agricultural crops. Therefore, this study aims to study microorganisms of biotechnological interest associated with carnauba palm, with a focus on soil and leaves, using classical analyses and next-generation sequencing techniques. The proposal also investigates their ecological aspects and biotechnological applications for mitigating stress in cultivated plants. The research is being developed at the Federal University of Ceará, with part of the analyses also conducted at Rothamsted Research, in the United Kingdom, during a sandwich PhD period.

Evaluation of Biostimulants and Biological Inoculants in Soybean/Maize and Soybean/Cotton Production Systems

Larissa Bortolo

In the 2025/26 growing season, Fundação MT will launch an exclusive project focused on biological products, mainly inoculants, plant biostimulants, and biological soil conditioners. The project will bring together several companies interested in generating reliable and applicable data under real field conditions, covering strategic regions of Mato Grosso.

The trials will be conducted by the Fundação MT team, with technical monitoring throughout the crop cycle. A key feature of the project is the participation of leading farmers from Mato Grosso, who will act as project ambassadors, closely following the results.

The proposal is simple: to evaluate, compare, and understand the real potential of biological technologies in an independent and practical way, with a focus on those who make decisions in the field.

Larissa Bortolo

Larissa Bortolo

Larissa Bortolo

Nature Program by NINHO®: Scaling Regenerative Agriculture and Sustainability in Milk Production

The Nature Program by NINHO®, led by Nestlé Brazil, aims to support the transition of milk production in Brazil toward sustainable and regenerative practices. The program involves more than 800 farming families in Minas Gerais, Goiás, and São Paulo, encouraging care for the soil, water, people, and animals.

The program provides technical support, training, and a differentiated payment system for producers, classifying them as Bronze, Silver, Gold, or Diamond according to the level of sustainable practices adopted.

In addition to improving farm efficiency and profitability, the program seeks to reduce carbon emissions and contribute to the decarbonization of Nestlé's milk supply chain, in line with the company's commitment to achieving carbon neutrality by 2050.

The program also promotes women's engagement and leadership in rural areas, as well as family succession through the training of young people and women. Partnerships with institutions such as EMBRAPA, among others, are essential to guide the implementation of new technologies and knowledge.

needed to advance regenerative livestock farming in the field.

Since the foundation of regenerative agriculture is Living Soil, the Nature Program by NINHO® encourages practices that promote soil health. Over the past three years, the company has tripled the number of hectares under regenerative agriculture management, increasing from 9,200 to 28,600 football fields. These practices include plant diversity, soil cover, crop rotation, no-till or minimum tillage, the use of organic fertilizers and bioinputs, and the preservation of native areas.

Nestlé

In addition, the program supports the preservation of more than 17,000 hectares of natural habitat, encouraging the conservation of biodiversity, including the fauna and flora of participating farms.

The program also promotes belowground biodiversity through the implementation of cover crops in more than 60% of cultivated areas and the incorporation of liquid and solid manure as organic fertilizer.

Nestlé

Nestlé

Composting Project – Nescafé Plan

The Nescafé Plan is Nestlé's main global sustainability program for the coffee supply chain. Launched in 2011 and known in Brazil as "Cultivated with Respect", the program is present in 18 countries. In Brazil, it supports more than 2,500 partner producers and invests heavily in training and technical assistance.

In addition, Cultivated with Respect is responsible for promoting more than 70,000 hectares under sustainable practices. Its central goal is to ensure long-term sustainable coffee production by promoting responsible agricultural practices, professional development for producers, and ensuring high product quality according to sustainability criteria.

In this context, one of the initiatives supported by the program is the implementation of composting practices on farms. Initially, 30 properties will participate over a two-year period, with 20 in the first year and 30 in the second year.

The project provides technical support to producers through monthly consulting and training, as well as assistance throughout the entire organic composting process, from the acquisition of raw materials to its application on the farm, in a customized way.

The project is aligned with the pillars of regenerative agriculture, bringing direct and essential benefits to soil health. It promotes an increase in soil organic matter, supplies macro- and micronutrients from an organic source, and enhances the use of residues already available on the farm, such as coffee husks.

Nestlé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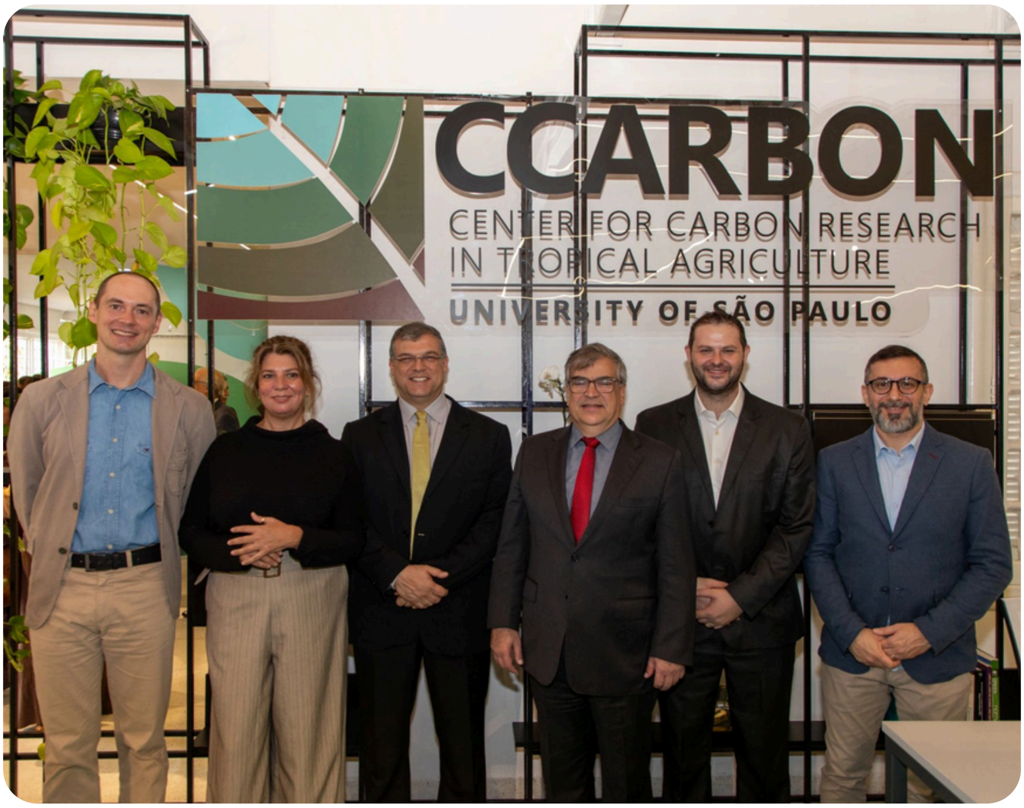
News

Inauguration of the Administrative Headquarters of the Center for Carbon Research in Tropical Agriculture (CCARBON)

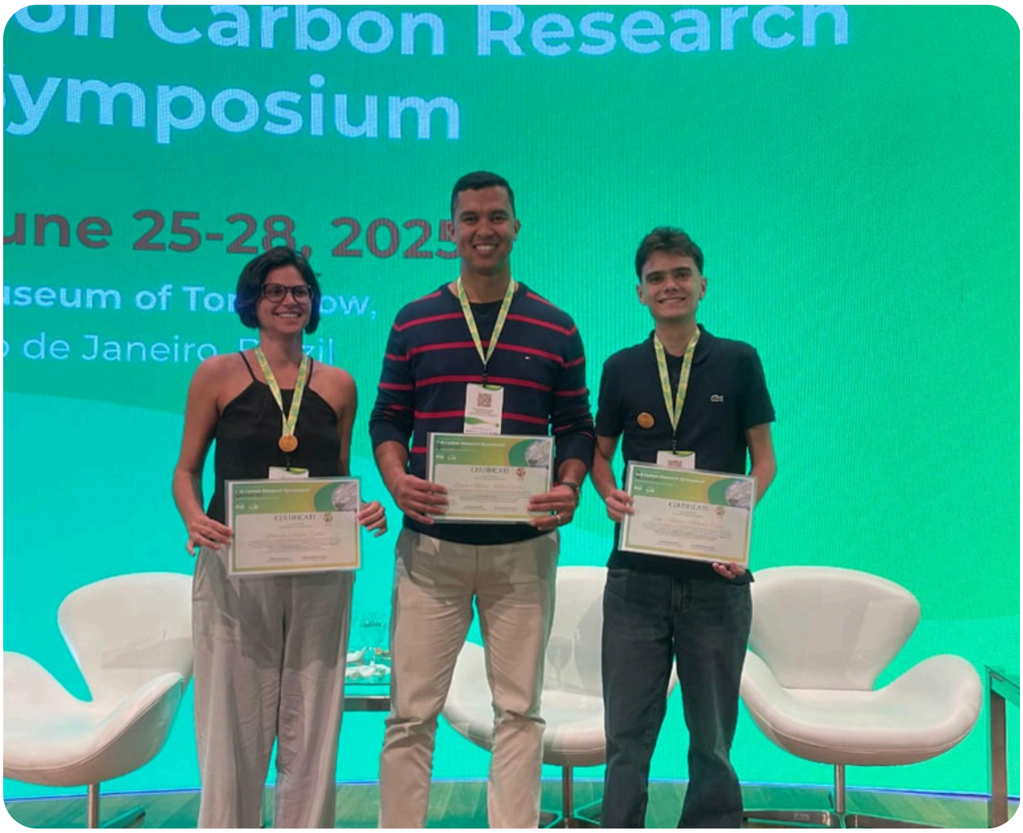


On June 6, 2025, the new administrative headquarters of CCARBON/USP was inaugurated. Based at the "Luiz de Queiroz" College of Agriculture (ESALQ/USP), the center aims to generate knowledge, develop technologies, and disseminate carbon-based solutions for tropical agricultural systems.

The ceremony included speeches by Prof. Cerri, Director of CCARBON/USP; Prof. Thais Vieira, Director of ESALQ; Prof. Carlos Gilberto Carlotti Junior, Rector of USP; and Orlando Melo de Castro, Undersecretary of Agriculture.

News

Latin American and Caribbean Symposium on Soil Carbon Research (LAC Soil Carbon) 2025



From June 24 to 28, the LAC Soil Carbon event was held in Rio de Janeiro. Prof. Dener M. S. Oliveira received the award for the third-best presentation in the professional category. His students, João Marcos M. Costa and Vanessa M. Gomes, were also recognized: João Marcos M. Costa received the award for best undergraduate presentation, while Vanessa M. Gomes received the award for best graduate presentation.

News

Excellence Award for Emerging Research Leaders at USP 2025

On June 27, 2025, Prof. Maurício Roberto Cherubin received the Excellence Award for Emerging Research Leaders at USP in the field of Agricultural Sciences. His research focuses on regenerative practices, soil health, the carbon cycle, and climate change mitigation.

The award aims to identify, encourage, and recognize the work of young researchers in their fields of knowledge.

Events

Past events

Latin American & Caribbean Soil Carbon Research Symposium.

25 a 28 de june de 2025. Rio de Janeiro, RJ.

World Conference on Carbon

June 29 to July 4, 2025. Saint-Malo, France.

XII Workshop on Forest Restoration

August 28 to 30, 2025. Piracicaba, SP, Brazil.

EUROSOIL and Iberian Congress of Soil Sciences (CICS)

September 7 to 12, 2025. Seville, Spain.

Upcoming Events

1st Brazilian Meeting on Regenerative Livestock

September 20, 2025. Ribeirão das Neves, Minas Gerais, Brazil.

XXXIX Brazilian Soil Science Congress – Soil Use and Climate Change

September 21 to 27, 2025. São Luís, MA, Brazil.

10th International Symposium on Soil Organic Matter.

May 25 to 29, 2026. São Paulo, Brazil.

Oil & Gas Decarbonisation Congress 2026.

February 9 to 10, 2026. Vösendorf, Austria.

World Congress of Soil Science

June 7 to 12, 2026. Nanjing, China.

Let’s think together

What is the impact of regenerative practices on climate change mitigation?

Find out in the next issue of Soil Health News
Special Edition: World Soil Day

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