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The role of soil Microbiomes in Carbon Sequestration and Climate Change Mitigation

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ABSTRACT

Soil microbiomes, encompassing diverse microbial communities, play a critical role in the global carbon cycle and have the potential to mitigate climate change by sequestering carbon in soils. This essay explores the complex interactions between soil microbiomes, soil organic carbon (SOC) storage, and climate change, emphasizing the importance of understanding these relationships in the context of the Paris Climate Agreement and global climate change strategies. By examining the diversity and functionality of soil microbiomes, their contribution to carbon sequestration, and the latest technological advances in microbiome research, this essay highlights the need for further research to optimize soil management practices that enhance carbon sequestration and support climate change mitigation efforts.

Keywords: Soil Microbiomes, Carbon Sequestration, Climate Change Mitigation, Soil Organic Carbon (SOC), Microbial Diversity.

INTRODUCTION

This essay discusses why it is important to understand soil microbiomes and climate change in relation to the larger governing systems of the planet. Climate change is here to stay. This is no longer up for debate. Simple, elegant and simple empirical models show this to be true. Why one may want to study soil, microbiomes and how these can help in aiding carbon sequestration is an important and interesting endeavor. A valuable outline has been proposed in essay I [1, 2, 3]. With the onset of the 2015 Paris Climate Agreement, the importance of soil microbiomes has been thrust into the public domain amidst urgent discussions on climate change and strategy and how to adapt in increasingly uncertain times. Ultimately, climate change and systems once thought static become alive when considering the ever-increasing range of possible human interventions carried out across the earth. Thus, climate change is a non-deterministic problem. Given this, it is necessary to consider ever-larger governing systems that deficits in knowledge and generative models exist. This is why moving across scales, from the local to the global soil system, and reciprocally moving up, from the molecular to the functional taxonomic to the holistic system is essential [4, 5, 6].

SOIL MICROBIOMES: DIVERSITY AND FUNCTIONALITY

Soils host a complex community of diverse microorganisms, including bacteria, archaea, fungi, protists, and viruses. Bacteria and fungi are two of the best-studied microbial groups influencing ecological processes in soils. Bacterial communities and the taxa present in soil can change with community composition, tending to vary in response to edaphic factors. Bacteria are primarily responsible for decomposition and the release of nutrients from organic matter, which can be allocated towards the growth of organisms like plants and fungi. Apart from acting as the primary drivers of organic matter decomposition, fungi fulfill other important roles such as decomposer and interactions with other compounds related to phosphorus and anthropogenic influence than bacteria [7, 8, 9]. Protists and bacteria have long been known to share intricate and multifaceted relationships in soil. Researchers have speculated a role for soil viruses in the ecological regulation of microbial and mesofaunal communities. Microarthropods and nematodes have been shown to affect microbial parameters and may contribute a small fraction of nitrogen to plants. Rhizobia are known to establish a mutualistic partnership with plants, fixing atmospheric nitrogen and developing a system to help furtively benefit the rhizobia. Actinomycetes produce numerous useful bioactive compounds with various applications such as antibiotics, enzymes, and bioactive compounds for plant growth and protection. Understanding this biodiversity, how it operates, and the influence on soil processes are fundamental to comprehend how the microbiome will lock up carbon and offer a way of mitigating climate change [10, 11, 12].

CARBON SEQUESTRATION IN SOILS

Soils serve as one of the world's most substantial reservoirs of organic carbon. Approximately two-thirds of global soil carbon is in the form of soil organic matter (SOM) in which carbon resides. The carbon can be stored in various forms of varying lifetimes. The bulk of soil organic carbon (SOC) in soils is stored in the form of humus, or humic substances, which have residence times ranging from tenths to thousands of years. The accumulation of carbon in soils is part of a biological formation and decomposition process which fluctuates over various time scales, dubbed soil heterotrophic cycling. The resultant slow accumulation of carbon in these forms is a key terrestrial carbon sink [13, 14, 15]. The atmosphere cannot absorb the surplus of carbon created by anthropogenic CO_2 emissions: as a result, higher concentrations of CO_2 are observed in the atmosphere because concentrations of free atmospheric oxygen are slowly increasing. In the last century, soil can be identified as the prominent carbon sink source which removes up to three Gt of surplus carbon from the atmosphere. Increasing the amount of carbon buried in soil may be a simple and economical way of significantly decreasing atmospheric CO_2, as well as having an additional environmental advantage: offsetting the influence of the greenhouse effect and mitigating global climate change. Providing an in-depth understanding of the specific contribution of bacteria, archaea, and microfungi in carbon sequestration and greenhouse gas emissions processes in soil, as well as the roles they play in these processes and how it can be improved, plays a vital part in determining the role of soil as a carbon sink [16, 17, 18].

INTERACTIONS BETWEEN SOIL MICROBIOMES AND CARBON SEQUESTRATION

Soil microbiomes play a key role in determining belowground soil carbon (C) storage and loss following land use and management changes. Soil microorganisms mediate numerous processes in the soil organic C (SOC) pool that together determine the soil's capacity to store and protect C against decomposition. discusses the interactions between soil microbiomes and carbon sequestration in soils. The article provides an overview of how different microorganisms can influence soil organic matter (SOM) accumulation and presents the main underlying processes and drivers. Furthermore, the article outlines the implications of SOC properties and SOM composition and stabilization form for land use change and climate change mitigation, discusses concepts of microbial social-ecological tipping points related to soil C storage, and outlines future research needs to move this field forward [19, 20, 21]. The increase in the Earth's temperature is driving important changes in climate and ecosystems through different types of phenomena, including the intensification of extreme climate events, global biological shifts, or impacts on socio-economic activities. A key driver of such climate change is the increase of atmospheric greenhouse gases (GHGs) due to human activities such as the combustion of fossil fuels, deforestation, or disruptive soil management, with the logarithmic increase in CO_2 concentration being the main driver of global warming. As the most abundant terrestrial store of carbon, soil carbon (C) - notably in the form of soil organic carbon (SOC) - is gaining increasing scientific and political attention. The role of soil C in climate is not only related to the potential for C uptake in the soils as a function of soil management but also to considerations of the release of previously stored C, should management destabilize the balance between the natural inputs (plant residues, root exudates, etc.) and removal pathways (microbial respiration or leaching) [22, 23].

TECHNOLOGICAL ADVANCES IN STUDYING SOIL MICROBIOMES

In the past decade, multiple technological advances have revolutionized the study of the soil microbiome. The soil microbiome, a complex microbial community that lives in close relationship with plants, is vital to the health and functioning of soil ecosystems. Scientists used to have a much simpler view of these microscopic power-players. They initially examined their populations through sequencing and plate culturing. However, in the last decade, methods for analyzing microbes have expanded. Rather than looking at them individually, researchers can now obtain the entire gene pool from an entire soil population via DNA sequencing, a procedure known as Whole Metagenomic Sequencing (WMG). By using Illumina's NextSeq or MiSeq or PacBio's high-sequencing tools, scientists can read individual DNA sequences, known as base pairs, to reconstruct an organism's genomes [24, 25]. On its own, this procedure takes no time at all. The interpretation and analysis of the data, on the other hand, are time-consuming. Researchers can identify the taxonomic identity of individual members, gain insights into their functional and identity traits, and gauge the results of different management practices on the microbiota – for example, add or remove small heterologous amendments (biological, biochar, etc.), fungal networks, or organic matter. Treatments such as cover cropping have been reported to enhance soil carbon sequestration. With any intervention, the ecological part of interest and the microbiota beneath need to be recognized to gain a comprehensive picture of what is taking place in the root realm [26, 27].

FUTURE DIRECTIONS

The purpose of this article is to emphasize the importance of soil microbiomes in carbon sequestration and climate change mitigation. Specifically, this essay has highlighted the varied composition and factors influencing microbiome abundance in different soil types, as well as the efficacy of soil carbon sequestration in mitigating climate change. The unique and variable microbiomes in different soils are of interest to researchers studying their interaction with the ecosystem. Studies suggest that an increased diversity and abundance of weakly antagonistic microbial species in the soil benefit plants. Further research is needed to determine the potential impact of managing or increasing soil carbon on these organisms [28, 29]. Soil carbon sequestration is vital for reducing atmospheric carbon. While the soil's ability to store carbon decreases after fifteen years, it remains an effective strategy for combating climate change. Small-scale changes in soil microbial communities have positive effects for global warming and farmers. Future research aims to tailor microbial communities for specific environments and maximize carbon sequestration. This research can help reverse climate change impacts and address nitrogen use in agriculture [28, 30].

CONCLUSION

Understanding the role of soil microbiomes in carbon sequestration is crucial for developing effective strategies to mitigate climate change. The diversity and functionality of these microbial communities significantly influence the soil's ability to store carbon and reduce greenhouse gas emissions. Technological advances have provided new insights into these complex interactions, revealing the potential for targeted soil management practices to enhance carbon sequestration. As the global community continues to seek solutions to climate change, further research into soil microbiomes and their role in the carbon cycle will be vital in optimizing land-use practices and achieving climate goals.

REFERENCES

1. Arora P, Chaudhry S. Microbial mediated soil carbon sequestration and mitigation of green house gases. COJ Rev. Res.. 2021. researchgate.net
2. Kumari A, Dash M, Singh SK, Jagadesh M, Mathpal B, Mishra PK, Pandey SK, Verma KK. Soil microbes: a natural solution for mitigating the impact of climate change. Environmental Monitoring and Assessment. 2023 Dec;195(12):1436. [HTML]
3. Sellappan R, Krishnan A, Thangavel K. Role of plant microbiome in carbon sequestration for sustainable agriculture. Core Microbiome: Improving Crop Quality and Productivity. 2022 May 10:190-205. researchgate.net
4. Greenhough B, Read CJ, Lorimer J, Lezaun J, McLeod C, Benezra A, Bloomfield S, Brown T, Clinch M, D'Acquisto F, Dumitriu A. Setting the agenda for social science research on the human microbiome. Palgrave Communications. 2020 Jan 31;6(1):1-1. nature.com
5. Adeleke BS, Babalola OO. The endosphere microbial communities, a great promise in agriculture. International Microbiology. 2021. researchgate.net
6. Terribile F, Renella G, Ajmone Marsan F, Ciampalini R, Comolli R, Ferraris S, Freppaz M, Gardi C, Mileti FA, Padoan E, Said-Pullicino D. The Future of Soil Science in Italy. InSoil Science in Italy: 1861 to 2024 2024 May 4 (pp. 135-181). Cham: Springer International Publishing. [HTML]
7. Islam W, Noman A, Naveed H, Huang Z, Chen HY. Role of environmental factors in shaping the soil microbiome. Environmental Science and Pollution Research. 2020 Nov;27:41225-47. researchgate.net
8. Jiao S, Peng Z, Qi J, Gao J et al. Linking bacterial-fungal relationships to microbial diversity and soil nutrient cycling. Msystems. 2021. asm.org
9. Gschwend F, Hartmann M, Mayerhofer J, Hug AS, Enkerli J, Gubler A, Meuli RG, Frey B, Widmer F. Site and land-use associations of soil bacteria and fungi define core and indicative taxa. FEMS Microbiology Ecology. 2021 Dec;97(12):fiab165. oup.com
10. Kumar N, Srivastava P, Vishwakarma K, Kumar R, Kuppala H, Maheshwari SK, Vats S. The rhizobium–plant symbiosis: state of the art. Plant microbe symbiosis. 2020:1-20. researchgate.net
11. Basu S, Kumar G. Nitrogen fixation in a legume-rhizobium symbiosis: the roots of a success story. Plant microbe symbiosis. 2020. researchgate.net
12. Westhoek A, Clark LJ, Culbert M, Dalchau N, Griffiths M, Jorrin B, Karunakaran R, Ledermann R, Tkacz A, Webb I, James EK. Conditional sanctioning in a legume–Rhizobium mutualism. Proceedings of the National Academy of Sciences. 2021 May 11;118(19):e2025760118. pnas.org
13. Rodrigues CID, Brito LM, Nunes LJR. Soil carbon sequestration in the context of climate change mitigation: A review. Soil Systems. 2023. mdpi.com
14. Walker WS, Gorelik SR, Cook-Patton SC, Baccini A, Farina MK, Solvik KK, Ellis PW, Sanderman J, Houghton RA, Leavitt SM, Schwalm CR. The global potential for increased storage of carbon on land. Proceedings of the National Academy of Sciences. 2022 Jun 7;119(23):e2111312119. pnas.org

15. Moinet GY, Hijbeek R, van Vuuren DP, Giller KE. Carbon for soils, not soils for carbon. Global Change Biology. 2023 May;29(9):2384-98. wiley.com
16. Meena RS, Kumar S, Yadav GS. Soil carbon sequestration in crop production. Nutrient dynamics for sustainable crop production. 2020:1-39. researchgate.net
17. Abbas F, Hammad HM, Ishaq W, Farooque AA, Bakhat HF, Zia Z, Fahad S, Farhad W, Cerdà A. A review of soil carbon dynamics resulting from agricultural practices. Journal of environmental management. 2020 Aug 15;268:110319. [HTML]
18. Farooqi ZU, Sabir M, Zia-Ur-Rehman M, Hussain MM. Mitigation of climate change through carbon sequestration in agricultural soils. InClimate Change and Agroforestry Systems 2020 Feb 14 (pp. 87-118). Apple Academic Press. [HTML]
19. Jansson JK, Hofmockel KS. Soil microbiomes and climate change. Nature Reviews Microbiology. 2020. osti.gov
20. Keuper F, Wild B, Kummu M, Beer C, Blume-Werry G, Fontaine S, Gavazov K, Gentsch N, Guggenberger G, Hugelius G, Jalava M. Carbon loss from northern circumpolar permafrost soils amplified by rhizosphere priming. Nature Geoscience. 2020 Aug;13(8):560-5. aalto.fi
21. Berkelmann D, Schneider D, Meryandini A, Daniel R. Unravelling the effects of tropical land use conversion on the soil microbiome. Environmental Microbiome. 2020 Dec;15:1-8. springer.com
22. Bruhwiler L, Basu S, Butler JH, Chatterjee A, Dlugokencky E, Kenney MA, McComiskey A, Montzka SA, Stanitski D. Observations of greenhouse gases as climate indicators. Climatic Change. 2021 Mar;165(1):12. springer.com
23. Malyan SK, Singh O, Kumar A, Anand G, Singh R, Singh S, Yu Z, Kumar J, Fagodiya RK, Kumar A. Greenhouse gases trade-off from ponds: An overview of emission process and their driving factors. Water. 2022 Mar 19;14(6):970. mdpi.com
24. Uritskiy G. Microbial community adaptations and dynamics in extremophile microbiomes of the Atacama Desert. 2020. jhu.edu
25. Ransom CS. EcoHealth survey of Herpetofauna in South Africa. 2023. nwu.ac.za
26. Blanco-Canqui H. Cover crops and carbon sequestration: Lessons from US studies. Soil Science Society of America Journal. 2022. [HTML]
27. Adetunji AT, Ncube B, Mulidzi R, Lewu FB. Management impact and benefit of cover crops on soil quality: A review. Soil and Tillage Research. 2020. academia.edu
28. Elbasiouny H, El-Ramady H, Elbehiry F, Rajput VD, Minkina T, Mandzhieva S. Plant nutrition under climate change and soil carbon sequestration. Sustainability. 2022 Jan 14;14(2):914. mdpi.com
29. Amelung W, Bossio D, de Vries W, Kögel-Knabner I, Lehmann J, Amundson R, Bol R, Collins C, Lal R, Leifeld JJ, Minasny B. Towards a global-scale soil climate mitigation strategy. Nature communications. 2020 Oct 27;11(1):5427. nature.com
30. Tiefenbacher A, Sandén T, Haslmayr HP, Miloczki J, Wenzel W, Spiegel H. Optimizing carbon sequestration in croplands: A synthesis. Agronomy. 2021 Apr 29;11(5):882. mdpi.com

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