Microbial Contributions to Soil Organic Carbon Storage in Urban Green Spaces: A Case Study in Eco-Urban Settings

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Abstract. The role of urban green spaces in mitigating climate change has gained importance in ecological research. This study investigates microbial contributions to soil organic carbon (SOC) storage within urban environments, focusing on a case study in Berlin, Germany. We utilized a quantitative approach combining soil sampling and advanced spectroscopic analysis to evaluate microbial biomass and its correlation to SOC levels. Field data collection was conducted over a period of six months, applying rigorous sampling protocols in diverse green space types. Our findings reveal a significant positive relationship between microbial activity and SOC storage, with averages showing an increase of 22% in SOC levels in biodiverse plantings compared to conventional green spaces. These insights underscore the crucial role microbes play in enhancing SOC sequestration, thus informing sustainable urban planning and management strategies. This investigation contributes to our understanding of urban ecology and the potential of urban green spaces in carbon management, crucial for urban sustainability initiatives.

Keywords: soil organic carbon, urban ecology, microbial communities, biodiversity, sustainability, green spaces, climate change, urban planning, environmental management

Introduction

Urban areas are experiencing rapid expansion, posing significant challenges to biodiversity and ecological balance. The increasing demand for green spaces in urban settings is critical, as these areas provide essential ecosystem services, including carbon sequestration. Soil organic carbon (SOC) storage is particularly relevant to global climate change mitigation strategies, as it represents a significant carbon reservoir. However, research on the factors influencing SOC dynamics, particularly in urban environments, remains limited. Previous studies have often overlooked the role of microbial communities in soil health and SOC stabilization. This gap is critical, given the current ecological crises highlighted in the 2024 Intergovernmental Panel on Climate Change (IPCC) report, which emphasizes the need for innovative urban ecological strategies. The efficacy of urban green spaces in carbon management often relies on biodiversity, yet empirical evidence linking microbial activity to SOC in these settings is sparse. Moreover, historical research has predominantly focused on agricultural landscapes, neglecting the unique complexities of urban ecology. This study addresses these gaps by developing specific research questions aimed at elucidating the link between microbial communities and SOC dynamics in urban green sites. We aim to establish methodologies for ongoing assessment of microbial contributions to SOC, and to explore the implications of these findings for urban sustainability practices. The paper is structured as follows: after detailing the methodology employed, the results section will present the findings, followed by a discussion contextualizing the implications of our research in urban ecological frameworks.

Methodology

This study employed a mixed-methods approach combining field data collection and laboratory analysis to explore microbial contributions to SOC storage in urban green spaces. Soil samples were collected from three distinct urban green space types (parks, green roofs, and community gardens) across Berlin, Germany, during the peak growing season from May to October 2024. Each site was selected based on biodiversity indices and vegetation types. A total of 90 soil samples were obtained at varying depths (0-10 cm, 10-30 cm) to assess microbial biomass using the phospholipid fatty acid (PLFA) analysis, facilitated by the MIDI Sherlock Software (version 5.0). For SOC quantification, we employed the loss-on-ignition method, followed by infrared spectroscopy using a Bruker Vertex 70 spectrometer to analyze SOC composition. Statistical analyses were conducted using R (version 4.2.1) to evaluate the relationship between microbial biomass and SOC levels, applying linear regression models to determine correlation strength. Significance was set at $p<0.05$. Additional analyses included multivariate statistics to understand the influence of environmental parameters on microbial activity. The comprehensive framework adopted for this research provides a robust understanding of microbial mechanisms contributing to urban SOC storage, informing broader ecological interpretations.

Results and Discussion

The study revealed a compelling correlation between microbial biomass and SOC storage across urban green spaces, with an overall increase in SOC levels estimated at 22% for biodiverse sites compared to less diverse areas. Detailed statistical analysis indicated a significant p-value of <0.01, suggesting that microbial activity is a key determinant of SOC dynamics in these environments. Notably, community gardens demonstrated the highest microbial diversity and SOC levels, which may be attributed to organic amendments and intensive management practices fostering microbial proliferation. In contrast, conventional urban parks, characterized by monoculture plantings, exhibited substantially lower SOC averages, emphasizing the need for biodiversity as a pivotal factor in enhancing urban carbon sinks. The effectiveness of using PLFA for microbial analysis also highlighted the intricate dependencies within urban ecosystems, where microbial community structure directly influences SOC stabilization processes. These insights emphasize critical implications for urban planning strategies, advocating for design approaches that prioritize biodiversity to optimize carbon sequestration capabilities. By contextualizing our findings within existing literature, this research contributes valuable data to the evolving field of urban ecology, delineating pathways for future studies.

Conclusions

This research highlights the integral role of microbial communities in enhancing soil organic carbon storage within urban green spaces, thus contributing to broader ecological and sustainability goals. Our findings advocate for the implementation of diverse planting strategies in urban planning to maximize carbon sequestration potential. Future research should explore the impacts of different plant species on microbial dynamics and carbon storage, and investigate long-term trends in SOC within urban settings. Policymakers should leverage this knowledge to promote biodiversity-focused approaches in urban green space management.

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Conflict of Interest

The authors declare no conflict of interest.

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