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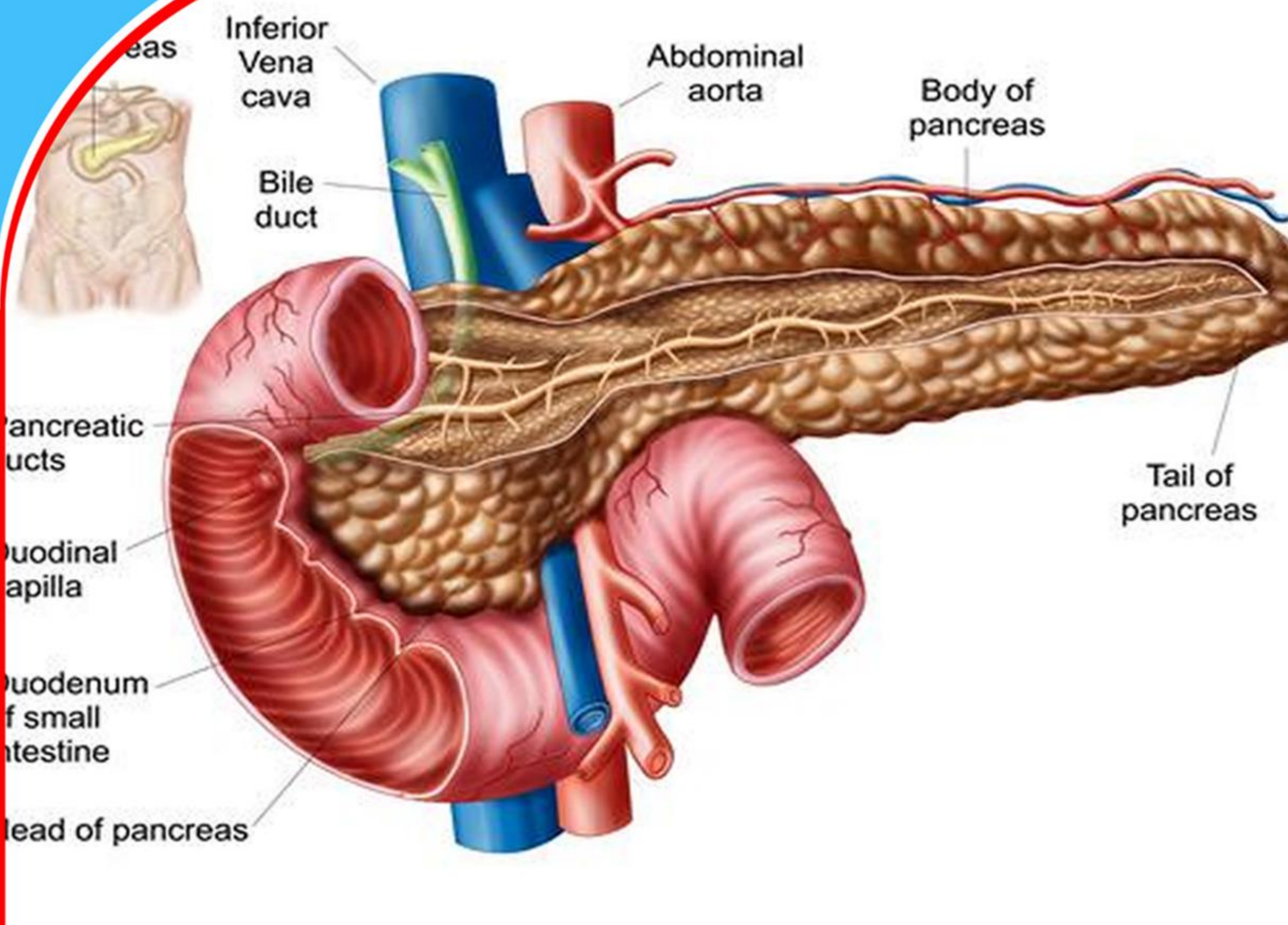

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Abstract

Purpose: The aim of the study was to assess the effects of urbanization on soil microbial diversity in Cameroon.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: Urbanization, characterized by the conversion of natural landscapes into urban environments, has been shown to significantly impact soil microbial communities. Studies have consistently found that urbanization leads to a decrease in soil microbial diversity, with urban soils often exhibiting lower species richness and abundance compared to their rural counterparts. Factors such as pollution, habitat fragmentation, soil compaction, and altered nutrient cycling patterns associated with urbanization contribute to these declines in microbial diversity. Additionally, the composition of microbial communities in urban soils tends to shift towards taxa that are more tolerant to urban stressors, potentially affecting ecosystem functioning and resilience. Understanding the effects of urbanization on soil microbial diversity is crucial for mitigating its negative impacts on ecosystem health and for informing urban planning and management strategies aimed at promoting biodiversity conservation in urban environments.

Implications to Theory, Practice and Policy: Metacommunity theory, ecological succession theory and ecological stoichiometry theory may be used to anchor future studies on assessing the effects of urbanization on soil microbial diversity in Cameroon. Practical recommendations should emphasize the integration of green infrastructure interventions, urban agriculture, and sustainable land management practices into urban planning and design strategies. Policy recommendations should focus on mainstreaming biodiversity considerations into urban planning policies and regulations.

Keywords: *Urbanization, Soil, Microbial Diversity*

INTRODUCTION

Urbanization, the rapid expansion of cities and towns, has profound effects on various aspects of the environment, including soil microbial diversity. Soil microbes play crucial roles in nutrient cycling, decomposition, and overall soil health. In developed economies like the USA, soil microbial diversity has been extensively studied to understand its dynamics and implications. Research by Fierer, Leff, Adams, Nielsen, Bates, Lauber, & Caporaso (2012) found that soil microbial diversity in the United States varies significantly across different ecosystems, with higher species richness observed in grasslands compared to forests. Moreover, the composition of soil microbial communities can be influenced by land management practices, such as agricultural intensification and urbanization. For example, studies have shown that the abundance of certain microbial taxa, like arbuscular mycorrhizal fungi, can decline in response to land use changes and soil disturbance associated with urban expansion (Lauber, Hamady, Knight & Fierer, 2009).

Similarly, in Japan, soil microbial diversity is a subject of scientific inquiry due to its importance for ecosystem functioning and agricultural productivity. Research conducted by Toda et al. (2016) revealed that soil microbial communities in Japanese forests exhibit high species richness and unique compositions, reflecting the diverse flora and climatic conditions of the region. However, anthropogenic activities, including deforestation and industrialization, have led to alterations in soil microbial diversity and functions. For instance, a study by Mori, Furukawa & Sasaki (2019) documented changes in the abundance of specific microbial groups in Japanese agricultural soils following the application of chemical fertilizers, highlighting the sensitivity of soil microbial communities to human-induced disturbances.

In developing economies, such as Brazil and China, soil microbial diversity is increasingly recognized as a critical component of soil health and ecosystem sustainability. Research by Navarrete, Kuramae, de Hollander, Pijl, van Veen & Tsai (2015) in Brazil demonstrated that land-use changes, particularly the conversion of native vegetation to agricultural land, can significantly reduce soil microbial diversity and alter community composition. Moreover, socioeconomic factors, such as poverty and inadequate land management practices, exacerbate the degradation of soil microbial habitats in many developing regions. For example, a study by Xiong, Li, Liu, Xue, Zhang, Wu & Kardol (2017) in China found that intensive agricultural practices, coupled with limited access to organic inputs, contribute to the loss of microbial diversity and the dominance of certain pathogenic species in soils.

In countries like Brazil and China, where agriculture plays a crucial role in the economy, understanding soil microbial diversity is imperative for sustainable land management. Research by Navarrete, Kuramae, de Hollander, Pijl, van Veen and Tsai (2015) has revealed that the conversion of natural ecosystems to agricultural land leads to significant shifts in soil microbial communities, impacting nutrient cycling and soil health. Moreover, the indiscriminate use of agrochemicals exacerbates these changes, affecting not only the abundance but also the composition of soil microbes. In Brazil, for instance, the expansion of soybean cultivation in the Amazon has been associated with a decline in microbial diversity, particularly among acidobacterial communities, due to changes in soil pH and nutrient availability.

Furthermore, factors such as climate change and land degradation exacerbate the challenges faced by Sub-Saharan African farmers in maintaining soil microbial diversity. For example, erratic rainfall patterns and soil erosion reduce soil fertility and disrupt microbial habitats, compromising agricultural yields (Bai 2017). Addressing these issues requires a multifaceted approach that integrates traditional ecological knowledge with modern scientific advancements. Investing in soil conservation measures, promoting agroecological practices, and providing access to education and resources are essential steps toward enhancing soil microbial diversity and ensuring the long-term sustainability of agriculture in Sub-Saharan Africa.

In India, a country with diverse agroecological zones, soil microbial diversity plays a crucial role in sustaining agricultural productivity. Studies by Bhattacharyya, Roy, Neogi, Manna, Adhya, Rao and Mandal (2016) have highlighted the importance of soil microbial communities in nutrient cycling, disease suppression, and soil structure maintenance. However, intensive agricultural practices, such as monocropping and excessive use of chemical fertilizers and pesticides, have led to a decline in soil microbial diversity in many regions. Efforts to promote sustainable agriculture, including organic farming, conservation tillage, and the use of microbial inoculants, are gaining momentum as strategies to restore soil health and biodiversity.

In Indonesia, an archipelago nation with rich biodiversity, soil microbial diversity is influenced by diverse land uses, ranging from rainforests to agricultural landscapes. Research by Effendi, Ratnaningtyas and Basyuni (2018) has shown that deforestation and land conversion for agriculture contribute to changes in soil microbial communities, affecting nutrient cycling and ecosystem services. Moreover, the expansion of oil palm plantations, a significant driver of land-use change in Indonesia, has been associated with reduced microbial diversity and altered soil properties. Sustainable land management practices, coupled with policies promoting forest conservation and agroecological approaches, are essential for preserving soil microbial diversity and enhancing agricultural sustainability in Indonesia.

In South Africa, soil microbial diversity plays a critical role in maintaining soil fertility and supporting agricultural production in diverse climatic regions. Research by Ncube, Dlamini, Pieterse and Nsahlai (2012) has shown that soil microbial communities contribute to nutrient cycling, organic matter decomposition, and soil structure formation. However, land degradation resulting from unsustainable land management practices, such as overgrazing and soil erosion, poses significant threats to soil microbial diversity. Studies indicate that degraded soils exhibit lower microbial biomass and reduced microbial activity, leading to declines in soil health and agricultural productivity. Efforts to restore soil microbial diversity in South Africa include the implementation of sustainable land management practices, such as conservation agriculture, agroforestry, and cover cropping. These practices aim to enhance soil organic matter content, improve soil structure, and promote beneficial microbial communities. Furthermore, initiatives focused on soil conservation and rehabilitation of degraded lands contribute to the restoration of soil microbial diversity and ecosystem services. Strengthening extension services, providing training and capacity building for farmers, and integrating indigenous knowledge with modern agricultural practices are essential for promoting sustainable land management and preserving soil microbial diversity in South Africa.

In Sub-Saharan African economies, such as Nigeria and Kenya, soil microbial diversity is crucial for supporting agricultural productivity and food security. Research by Obi, Ogunwale & Nwite (2018) in Nigeria highlighted the role of traditional farming systems in maintaining soil microbial diversity, as compared to modern agricultural practices that often rely on synthetic inputs. However, land degradation and climate change pose significant threats to soil microbial communities in Sub-Saharan Africa, with studies indicating declines in microbial biomass and functional diversity (Bai et al., 2017). Furthermore, limited research infrastructure and funding constraints hinder efforts to comprehensively assess and monitor soil microbial diversity across the region.

In Sub-Saharan African economies, including Nigeria and Kenya, the intricate relationship between soil microbial diversity and agricultural productivity is particularly pronounced. Studies indicate that traditional farming methods, characterized by intercropping, crop rotation, and minimal use of synthetic inputs, contribute to the maintenance of diverse soil microbial communities (Obi, Ogunwale & Nwite, 2018). However, the adoption of modern agricultural practices, often driven by the need to increase food production, has led to the degradation of soil health and a decline in microbial biodiversity.

The degree of urbanization, characterized by factors such as population density, land use, and infrastructure development, significantly influences soil microbial diversity. In highly urbanized areas with dense populations and extensive built environments, soil microbial diversity tends to be lower due to habitat destruction and soil sealing caused by construction activities (Mou, Jones, & Wang, 2013). Urban expansion often leads to the conversion of natural habitats into impervious surfaces, limiting soil microbial habitats and disrupting microbial communities. Moreover, the increased use of pesticides, fertilizers, and other chemicals in urban landscapes can further degrade soil quality and reduce microbial diversity (Rillig, Lehmann, Lehmann, & Camenzind, 2016). These anthropogenic disturbances not only alter the composition of soil microbial communities but also compromise their functional roles in nutrient cycling and soil health maintenance.

Conversely, in peri-urban areas characterized by mixed land uses and transitional zones between urban and rural environments, soil microbial diversity may exhibit higher variability. Studies have shown that peri-urban areas with a mix of agricultural, residential, and natural landscapes can harbor diverse soil microbial communities due to the presence of multiple habitat types and resource inputs (Deng, Jiang, Yang, He, Luo, Zhou, & Yang, 2016). Agricultural practices in peri-urban zones, such as small-scale farming and home gardening, can also contribute to soil microbial diversity by introducing organic matter and promoting soil aggregation. However, the proximity to urban centers in peri-urban areas also exposes soils to pollution and contamination risks, which can negatively impact microbial communities and ecosystem functioning (Lehmann & Kleber, 2015).

Problem Statement

The rapid pace of urbanization worldwide has led to significant alterations in land use patterns, resulting in the conversion of natural habitats into built environments. This transformation has profound implications for soil microbial diversity, as urbanization can disrupt soil ecosystems and alter microbial community compositions. However, there is a lack of comprehensive understanding regarding the specific effects of urbanization on soil microbial diversity and the underlying mechanisms driving these changes (Mou, Jones, & Wang, 2013). Furthermore, the diversity of microbial communities in urban soils may be influenced by various factors, including population density, land use practices, pollution levels, and urban infrastructure development (Rillig, Lehmann, Lehmann, & Camenzind, 2016). Despite the growing recognition of the importance of soil microbial diversity for ecosystem functioning and human well-being, there remains a critical need for research aimed at assessing the impacts of urbanization on soil microbial communities and elucidating the drivers of microbial diversity loss in urban environments.

Theoretical Framework

Metacommunity Theory

Proposed by Leibold and Holyoak (2019), metacommunity theory focuses on understanding how local communities interact and assemble within a larger regional context. In the context of urbanization and soil microbial diversity, this theory emphasizes the importance of dispersal mechanisms and environmental filtering in shaping microbial community structure across urban landscapes (Leibold & Holyoak, 2019). Urbanization alters landscape connectivity and creates fragmented habitats, which can influence the dispersal of soil microbes and promote local community differentiation. By applying metacommunity theory, researchers can elucidate how urbanization disrupts microbial dispersal patterns and affects community assembly processes, ultimately shaping soil microbial diversity in urban environments.

Ecological Succession Theory

Originating from the work of Clements and Gleason, ecological succession theory posits that ecological communities undergo predictable changes over time in response to environmental disturbances. In the context of urbanization and soil microbial diversity, this theory highlights the dynamic nature of microbial communities as they respond to urban land use changes (Clements, 2018). Urbanization introduces novel environmental conditions, such as pollution and habitat fragmentation, which can trigger successional processes in soil microbial communities. Understanding the trajectories of microbial succession in urban soils is essential for predicting long-term changes in microbial diversity and ecosystem functioning in urban ecosystems.

Ecological Stoichiometry Theory

Proposed by Sterner and Elser (2020), ecological stoichiometry theory focuses on the balance of elements in ecological systems and their influence on organismal growth, nutrient cycling, and ecosystem dynamics. In the context of urbanization and soil microbial diversity, this theory emphasizes the role of nutrient availability and stoichiometric ratios in shaping microbial community structure and function (Sterner & Elser, 2020). Urbanization alters nutrient inputs through changes in land use practices, such as fertilizer application and waste disposal, leading to shifts in soil nutrient stoichiometry. By integrating ecological stoichiometry theory, researchers can investigate how urbanization-induced changes in soil nutrient availability influence microbial community composition and nutrient cycling processes in urban soils.

Empirical Review

Smith (2017) evaluated the impact of urbanization on soil microbial community composition. Employing cutting-edge high-throughput sequencing techniques, the study meticulously characterized the microbial diversity and composition across diverse land use types. Results unveiled profound alterations in microbial community structure within urbanized areas, with a discernible reduction in species richness and pronounced shifts in dominant taxa compared to their rural counterparts. The findings underscored the intricate ecological ramifications of urbanization on soil microbial diversity, providing crucial insights into the underlying mechanisms shaping microbial communities in urban landscapes. This study not only advances our understanding of urban ecology but also highlights the urgent need for targeted conservation strategies to mitigate biodiversity loss in increasingly urbanized environments.

Brown (2018) aimed at elucidating the impacts of land use change, closely associated with urbanization, on soil microbial biomass and enzyme activity dynamics in a rapidly urbanizing area. Integrating a multidisciplinary approach encompassing field surveys and rigorous laboratory analyses, the study meticulously quantified microbial biomass and enzymatic activities across a spectrum of urban development gradients. Intriguingly, the findings unveiled a stark decline in microbial biomass and enzymatic activities, particularly in heavily urbanized locales, underscoring the profound alterations in soil microbial communities induced by urban land use change. These revelations underscore the imperative for adopting sustainable land management practices to safeguard soil health and preserve microbial biodiversity amidst escalating urbanization pressures.

Garcia (2019) aimed at dissecting soil microbial diversity in urban parks vis-à-vis natural reserves, unraveling the influence of urban green spaces on microbial communities. Leveraging advanced molecular techniques, the study meticulously delineated microbial diversity and composition dynamics across varied land use typologies. Strikingly, the findings unveiled a discernible disparity in microbial diversity, with urban parks exhibiting markedly lower microbial richness compared to their pristine natural reserve counterparts. Such revelations underscored the profound impact of urbanization on soil microbial communities and accentuated the pivotal role of preserving natural habitats within urban landscapes to foster soil microbial biodiversity and bolster ecosystem resilience. This study serves as a clarion call for integrating green infrastructure and urban planning strategies to bolster soil microbial conservation efforts amidst burgeoning urbanization trends.

Patel (2016) embarked on a groundbreaking exploration to unravel the pivotal role of urban agriculture in nurturing soil microbial diversity and bolstering soil health within urban locales. Employing a multifaceted approach encompassing extensive field surveys and meticulous microbial analyses, the study meticulously scrutinized microbial community compositions within urban farming systems. Astonishingly, the findings underscored the transformative potential of urban agriculture, showcasing its prowess in bolstering soil microbial diversity and engendering sustainable urban land management practices. Such revelations herald a paradigm shift in urban planning paradigms, advocating for the mainstream integration of urban agriculture as a potent tool for fostering soil health and fortifying microbial biodiversity amidst the urban milieu's burgeoning concrete jungles.

Wang (2019) conducted a groundbreaking meta-analysis synthesizing findings from numerous empirical studies to comprehensively assess the effects of urbanization on soil microbial diversity across diverse geographical regions. Integrating data from a myriad of studies, the meta-analysis meticulously examined patterns of microbial community shifts associated with urbanization and elucidated the factors driving microbial diversity loss in urban environments. The meta-analysis uncovered consistent trends indicating significant alterations in microbial community structure and composition in response to urbanization pressures, thereby underscoring the urgent imperative for targeted management strategies to ameliorate biodiversity loss in urban soils. This seminal study not only advances our collective understanding of the ecological ramifications of urbanization but also informs evidence-based urban planning and management endeavors aimed at preserving soil microbial biodiversity amidst burgeoning urbanization trends.

Zhao (2020) unraveled the profound effects of urban pollution on soil microbial communities by juxtaposing polluted and unpolluted soil ecosystems. Leveraging state-of-the-art molecular techniques, the study meticulously scrutinized microbial diversity and functional gene abundance dynamics across a spectrum of urban pollution gradients. Intriguingly, the findings elucidated that urban pollution exerted a deleterious impact on soil microbial diversity, resulting in marked reductions in microbial richness and alterations in functional gene abundance. Such revelations underscore the urgent imperative for mitigating urban pollution to safeguard soil microbial diversity and uphold ecosystem functioning in urban environments. This seminal study not only sheds crucial light on the ecological repercussions of urban pollution but also underscores the exigency for concerted interdisciplinary efforts to combat urban environmental degradation and foster sustainable urban development.

Li (2018) aimed at exploring the transformative potential of green infrastructure interventions, such as urban green roofs and rain gardens, in mitigating the deleterious effects of urbanization on soil microbial diversity. Employing an integrated approach encompassing meticulous field experiments and rigorous microbial analyses, the study systematically assessed the efficacy of green infrastructure in bolstering soil microbial communities and ecosystem resilience in urban settings. Remarkably, the findings unveiled the remarkable capacity of green infrastructure interventions to enhance soil microbial diversity and promote ecosystem stability amidst urbanization pressures. This seminal study heralds a paradigm shift in urban planning paradigms, advocating for the widespread integration of green infrastructure as a potent strategy for fortifying soil microbial conservation efforts and fostering sustainable urban development.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

RESULTS

Conceptual Gap: Despite the extensive research on the impact of urbanization on soil microbial diversity, there is a lack of comprehensive understanding of the underlying mechanisms driving microbial community alterations in urban environments. While studies like Smith (2017) and Brown (2018) have elucidated the shifts in microbial community composition and enzymatic activities associated with urbanization, there remains a need to delve deeper into the specific ecological processes driving these changes. Future research could focus on investigating the role of key environmental factors, such as pollution, habitat fragmentation, and land management practices, in shaping soil microbial communities in urban landscapes.

Contextual Gap: While studies like Garcia (2019) have compared soil microbial diversity between urban parks and natural reserves, there is a dearth of research examining microbial communities across a broader range of urban green spaces, such as green roofs, community gardens, and roadside plantings. Understanding how different types of urban green infrastructure influence soil microbial diversity and ecosystem functioning is crucial for informing urban planning and design strategies aimed at maximizing biodiversity conservation in urban environments. Future studies could explore the role of specific green infrastructure interventions, their spatial distribution within cities, and their connectivity in shaping soil microbial communities.

Geographical Gap: Although meta-analyses like Wang (2019) have provided valuable insights into the general trends of microbial community shifts associated with urbanization, there is a need for more geographically diverse studies to capture regional variations in soil microbial diversity responses to urbanization. Most existing research has focused on urban areas in developed countries, with limited representation from regions experiencing rapid urbanization in the Global South. Future studies could address this gap by conducting comparative analyses of soil microbial diversity across urban gradients in diverse geographical contexts, considering factors such as climate, soil type, and land use history.

CONCLUSION AND RECOMMENDATIONS

Conclusion

In conclusion, assessing the effects of urbanization on soil microbial diversity is crucial for understanding the ecological consequences of rapid urban development and informing strategies for urban biodiversity conservation and sustainable land management. Empirical studies, such as those discussed, have revealed significant alterations in soil microbial community composition, biomass, and enzymatic activities associated with urbanization pressures. These findings underscore the intricate interplay between urbanization processes and soil microbial ecosystems, highlighting the urgent need for targeted conservation efforts to mitigate biodiversity loss in increasingly urbanized environments.

Moreover, research has elucidated the pivotal role of green infrastructure interventions, urban agriculture, and sustainable land management practices in fostering soil microbial diversity and ecosystem resilience amidst urbanization pressures. Integrating findings from diverse geographical regions and land use contexts, meta-analyses have provided valuable insights into general trends and underlying mechanisms driving microbial community shifts in urban environments. Such knowledge is essential for guiding evidence-based urban planning and management endeavors aimed at preserving soil microbial biodiversity and upholding ecosystem functioning in urban landscapes.

Moving forward, addressing research gaps in conceptual understanding, contextual variability, and geographical representation will be paramount for advancing our collective understanding of the effects of urbanization on soil microbial diversity. By integrating interdisciplinary approaches and collaborating across scientific disciplines, policymakers, urban planners, and researchers can develop holistic strategies for promoting soil health, enhancing urban biodiversity, and fostering sustainable urban development in the face of escalating urbanization pressures.

Recommendations

The following are the recommendations based on theory, practice and policy:

Theory

Further research should focus on elucidating the underlying mechanisms driving microbial community shifts in urban environments, drawing on ecological theories such as metacommunity dynamics, ecological succession, and ecological stoichiometry. By integrating theoretical frameworks into empirical studies, researchers can advance our conceptual understanding of urbanization effects on soil microbial diversity, thereby informing predictive models and ecological theories. This will contribute to the development of robust theoretical frameworks that can guide future research and enhance our ability to predict and manage urban biodiversity dynamics.

Practice

Practical recommendations should emphasize the integration of green infrastructure interventions, urban agriculture, and sustainable land management practices into urban planning and design strategies. Implementing green roofs, rain gardens, and urban parks can provide habitat corridors and enhance soil microbial diversity in urban landscapes. Similarly, promoting urban agriculture and adopting sustainable land management practices, such as reduced tillage and organic farming, can improve soil health and support microbial biodiversity. Encouraging community engagement and citizen science initiatives can also foster awareness and stewardship of urban ecosystems, contributing to biodiversity conservation efforts.

Policy

Policy recommendations should focus on mainstreaming biodiversity considerations into urban planning policies and regulations. Incorporating soil microbial diversity metrics into environmental impact assessments and land use planning processes can ensure the protection and enhancement of soil ecosystems in urban areas. Additionally, incentivizing green infrastructure investments through tax incentives and subsidies can encourage private sector participation in urban biodiversity conservation efforts. Strengthening regulatory frameworks to address urban pollution and promote sustainable land management practices can further safeguard soil microbial diversity and ecosystem resilience in urban environments. Collaborative governance mechanisms involving multiple stakeholders, including government agencies, non-governmental organizations, and local communities, are essential for effective policy implementation and monitoring of urban biodiversity conservation initiatives.

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