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Urban Soil Dynamics: The Relationship Between Soil Health and Urbanization

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Abstract: Urbanization, combined with unsustainable agricultural practices, climate change, and pollution, poses a significant threat to soil health, leading to degradation with far-reaching impacts on ecosystems and human well-being. This article explores these challenges and specifically focuses on how urbanization affects soil health by degrading its quality and limiting its ability to sustain life. The study examines the dynamics of soil humification, the potential of urban soils to store carbon, and the critical impacts on food production and public health. Through a comprehensive analysis that includes geographical perspectives on soil-related issues, the article highlights innovative management strategies that can enhance the productivity and sustainability of urban soils. It emphasizes the urgent need to integrate soil science into environmental and urban planning to mitigate these negative impacts and promote a sustainable future.

Keyword: urban soil; humification; carbon sequestration; sustainable agriculture; health

1.0 Introduction

Soils are vital for our planet, forming the basis for life and maintaining the balance of ecosystems. However, they are increasingly threatened by rapid urbanization, unsustainable agricultural practices, climate change, and pollution. These challenges pose significant risks to food security, biodiversity, and human health, requiring urgent attention (Kishore et al., 2024; Gupta, 2019). Urban expansion often converts fertile land into cities, reducing the availability of land for food production (Lal, 2016). Additionally, modern agricultural practices that rely heavily on chemicals lead to soil leaching and pollution, further exacerbating climate change as stored carbon is released into the atmosphere (Nielsen et al., 2015; Fess & Benedito, 2018).

Although often overlooked, urban soils have the potential to play a crucial role in carbon sequestration, urban agriculture, and ecosystem services. However, they are also exposed to contamination risks and require careful management to remain productive (Yang & Zhang, 2015). Recent research stresses the importance of urban soils for sustainable urban development. Studies have shown that urban soils provide essential ecosystem services such as carbon storage, climate regulation, and water flow management, but they are increasingly degraded by urbanization. This degradation affects soil quality and pollution levels, which, in turn, impacts their ability to sustain life (O'Riordan et al., 2021). Urban growth often targets high-value soils, leading to a gradual deterioration of soil quality, as seen in regions such as Athens, Greece, and Emilia-Romagna, Italy (Nickayin et al., 2021).

Urban soils are also increasingly contaminated with pollutants such as heavy metals and organic compounds, posing significant health risks. There is a growing need for risk assessments based on bioavailability and improved management measures to mitigate these threats (Li et al., 2018). Furthermore, urbanization leads to the homogenization of soil properties, such as carbon content and particle size, which can affect the ability of soils to provide various ecosystem services (Herrmann et al., 2020). The complexity of managing urban soils is increased by their considerable horizontal and vertical heterogeneity resulting from different land uses and human activities. This variability affects soil properties such as pH, calcium carbonate content, and contaminant levels, complicating assessment and management (Greinert, 2015).

The health of urban soils is directly related to human health, both through exposure to contaminants and the benefits provided by urban green spaces. Future research needs to link health risk assessments with soil properties to better understand these relationships (Li et al., 2018). Effective urban planning must consider the multifunctionality of urban soils, recognize the historical and current impacts of urbanization on soil properties, and integrate soil management into broader urban strategies (Giampieri & Vialle, 2020). Recent research findings emphasize the crucial role of urban soils in providing ecosystem services and supporting sustainable urban development. Urbanization often degrades soil quality and increases pollution, highlighting the need for improved management and policy measures. The diverse characteristics and multi-functionality of urban soils should play a central role in urban planning to ensure the sustainable use of soil resources in growing cities.

In this article, we explore the complex relationships between soils, environmental issues, and human health. We also examine the processes of soil humification, the role of urban soils in carbon storage and food production, and the impact of soil on human health. We will emphasize the importance of incorporating soil science into environmental and urban planning to effectively address these challenges. In the following sections, we will discuss how sustainable soil management can mitigate the negative impacts of urbanization and climate change, improve food security, and promote human well-being. We will also explore the roles of policy, technology, and community engagement in maintaining soil health and advocate for a holistic approach to soil management as the cornerstone of a sustainable future.

2.0 Soil Humus

Soil humus, a critical component of soil organic matter, plays a vital role in soil fertility, structure, and ecosystem functions (Andreux, 1996). Understanding the formation and characteristics of humus requires examining various geographical factors, such as slope steepness and altitude, which can significantly influence soil properties. For example, slope steepness affects water runoff and erosion rates, which in turn impact organic matter accumulation and decomposition. Altitude influences temperature and precipitation patterns, leading to variations in soil moisture and biological activity that are crucial for humus formation (Figure 1) (Defersha et al., 2011).

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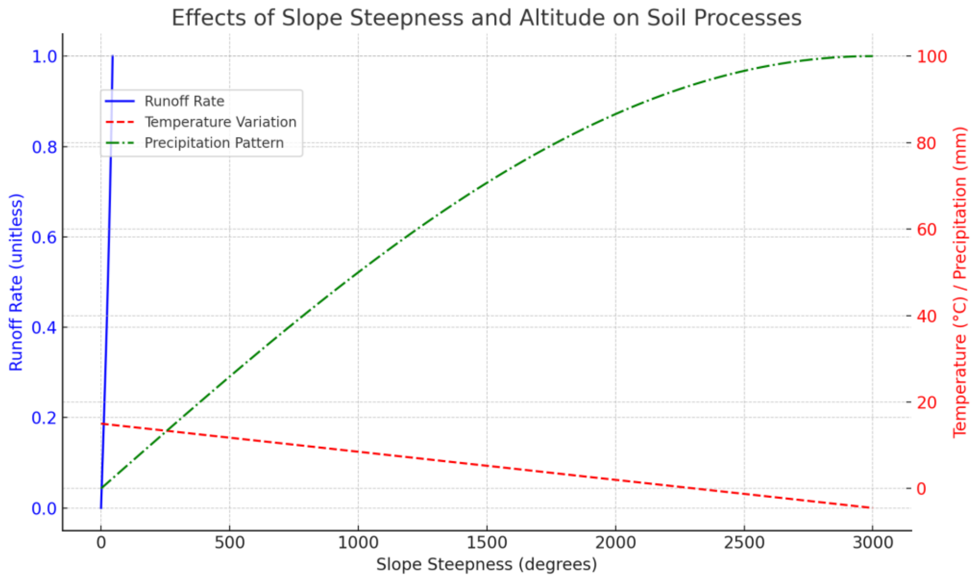

Figure 1: Effects of Slope Steepness and Altitude on Soil Processes.

Note: The graphic above illustrates the effects of slope steepness and altitude on soil processes, specifically focusing on how these factors influence water runoff, erosion rates, temperature, and precipitation patterns.

The graphic above illustrates the relationship between slope steepness, altitude, and their effects on soil processes. The blue line shows that as slope steepness increases, the rate of water runoff also increases, which can lead to higher erosion rates. This increase in erosion impacts the accumulation and decomposition of organic matter, as steeper slopes typically result in less organic matter retention. The red dashed line depicts how temperature decreases with increasing altitude, based on the typical environmental lapse rate, where temperature decreases by approximately 6.5°C per 1000 meters of altitude. Meanwhile, the green dotted line represents the simplified pattern of precipitation changes with altitude (e.g., Nottingham et al., 2015). In general, precipitation increases with altitude to a certain point due to orographic lift but can vary depending on local geographic and climatic conditions. Increased runoff and erosion on steeper slopes lead to less organic matter accumulation, which affects soil fertility and humus formation. Additionally, changes in temperature and precipitation with altitude influence soil moisture levels and biological activity. These factors are crucial for organic matter decomposition and humus formation, impacting soil structure and fertility. Understanding these relationships is essential for managing soil resources effectively, particularly in regions with varying topography and climate (e.g., Defersha et al., 2011). Sustainable land management practices can help mitigate the adverse effects of these factors, promoting soil health and resilience.

Humus forms are classified based on the transformation and accumulation of organic matter in soil, reflecting distinct phases of plant litter and soil organic matter decomposition. In Russian forest soils, twelve humus forms have been identified in xeric and mesic soils, five in hydric soils, and six in histic soils, correlating with forest types and productivity. These classifications highlight the importance of understanding how different environments contribute to soil characteristics and humus development (Chertov & Nadporozhskaya, 2018; Chernova et al., 2021). The study of soil humus involves interpreting the outcomes of scholarly inquiry, modeling, and experimentation. The classical humification theory encompasses stages of organic matter decomposition and transformation into humic substances by soil microorganisms. However, the theory of physical protection focuses on the functional parameters of organic matter components, separated by their mineralization rates. This theory has limitations in explaining the formation of recalcitrant organic matter (Hayes and Swift, 2020).

From a chemical perspective, humus is viewed as a complex of natural carbonaceous compounds, with ongoing research into its specific chemical structure and formation mechanisms (e.g., Piccolo, 2002). The ecological perspective emphasizes the role of humus in soil ecology, advocating for the preservation of traditional concepts while integrating new findings (Salmon, 2018). Recent debates challenge the polymerization theory, suggesting that a significant portion of soil organic carbon may be attributed to fire-affected black carbon (e.g., Ottou et al., 2016). Despite these controversies, humic substances are recognized for their role in nutrient availability and soil reactions. Humus improves soil structure, drainage, aeration, water-holding capacity, and nutrient supply, making soils rich in humus generally more productive. It serves as a source of nitrogen, phosphorus, and sulfur for plants and enhances the dissolution of silicate minerals. Recent models, such as ROMUL and “Romul_Hum,” simulate soil organic matter dynamics based on the functional roles of soil biota in different humus forms (Komarov et al., 2017). These models represent a synthesis of traditional and innovative approaches, advancing our understanding of how humus forms and functions within diverse environmental contexts.

3.0 Humification

Humification is a fundamental process in soil science, involving the transformation of organic matter into humus, which significantly impacts soil structure, fertility, and carbon sequestration. Geographical factors such as slope steepness, altitude, and climatic conditions play a crucial role in humification processes. Slope steepness affects erosion rates and water drainage, which can influence organic matter retention and decomposition rates. Altitude impacts temperature and precipitation, affecting microbial activity and the decomposition of organic materials. In tropical regions, for instance, higher temperatures and increased rainfall can accelerate the decomposition of plant litter, leading to rapid humification and distinct soil characteristics (Bednář & Šarapatka, 2018).

Humification leads to a decrease in O-alkyl carbon and an increase in alkyl and carboxyl carbon with soil depth and decomposition. Despite variations in soil type, the aromatic carbon content remains constant at about 25%. In deeper soil layers, humic acids exhibit increased aromatic carbon and decreased methoxyl and phenolic groups (Figure 2), indicating oxidative degradation of lignin, a key component of plant cell walls (Han et al., 2016; Katsumi et al., 2016).

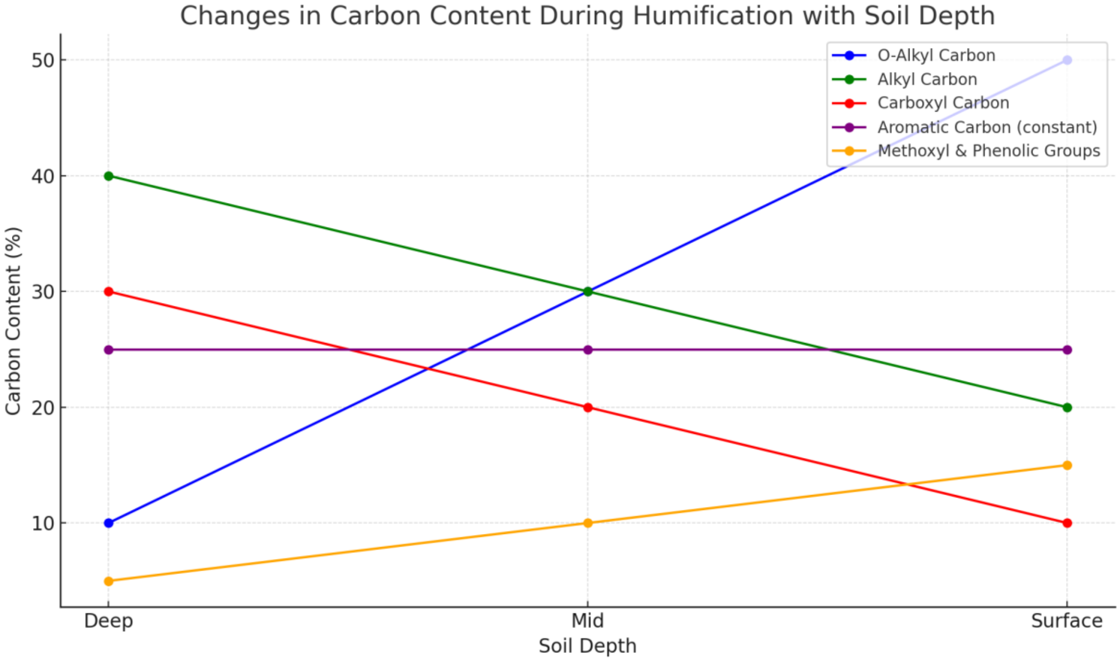

Figure 2: Changes in Carbon Content During Humification with Soil Depth.

Different forest humus types emerge from varying rates of litter decomposition, involving the preferential mineralization of carbohydrates and the alteration of lignin. Composting shares secondary biochemical reactions with natural humification, forming humic substances that enhance soil quality. For instance, reclaimed post-mining sites demonstrate faster accumulation of organic carbon and nitrogen, as well as higher humification rates compared to “unreclaimed” sites; however, these differences diminish as the site ages (e.g., Han et al., 2016). Suspended soils in tropical forests, which are isolated from the forest floor, exhibit higher nitrogen, phosphorus, and potassium contents but lower moisture levels compared to forest soils (e.g., Abakumov et al., 2018). Humification in these soils results in deeply humified organic matter with significant aromatic content, highlighting the role of environmental conditions in shaping soil properties. Recent advancements in humification techniques include the creation of artificial soil through hydrothermal processes. These methods enhance soil organic matter, water retention, and nutrient conservation by mimicking natural humus-clay complexes, demonstrating potential for improving soil health, particularly in degraded or nutrient-poor areas.

Humified materials are crucial for soil aggregation, improving soil structure, nutrient supply, and water-holding capacity. Practices utilizing exogenous organic material, such as composting, can enhance these properties and reduce soil erosion. In temperate climates, humification involves the formation of various organo-mineral complexes, which differ in biodegradation resistance and chemical properties. The degree of organic matter transformation varies with soil type and climate, highlighting the need for tailored soil management strategies (e.g., Piccolo, 2002; Katsumi et al., 2016).

In Karst regions—characterized by barren, rocky terrain, caves, sinkholes, underground rivers, and the absence of surface streams and lakes—humic acids and fulvic acids show low content and degrees of humification. However, more transformations occur between humic acids and fulvic acids than between fulvic acids and humin, indicating regional variations in humification pathways (e.g., Abakumov et al., 2018). Fluorescence spectroscopy has emerged as an effective tool for measuring the degree of humification in soil humic acids, providing a simpler alternative to electron spin resonance spectroscopy. This technique offers valuable insights into the humification process, aiding in the development of strategies for soil management and restoration (e.g., Zacharioudaki et al., 2022).

4.0 Urban Soil Carbon Storage

Urban soil carbon storage is a critical component of the global carbon cycle, especially as urbanization continues to expand. Understanding how urban soils store carbon and the factors influencing this storage is essential for developing strategies for climate change mitigation and urban land management. Urban soils offer a unique opportunity to capture carbon in places where it is often overlooked, but this potential is frequently underutilized due to policy and management challenges (Yang & Zhang, 2015).

From a scientific perspective, soil organic carbon (SOC) densities vary significantly across different cities and land uses (Figure 3). For example, residential soils in Baltimore have lower SOC densities compared to those in Moscow (Chernova et al., 2021) or Chicago (Scharenbroch et al., 2017), while park soils in Baltimore have higher SOC densities (Schwarz et al., 2016) than those in Hong Kong (e.g., Zhang et al., 2007). Urban green spaces generally store less carbon than natural habitats, but the capacity varies with climate and vegetation types. Urbanization can lead to both increases and decreases in SOC pools. In the northeastern U.S., cities like Boston and Syracuse have seen a reduction in SOC following urban development, whereas cities in warmer and drier climates, like Oakland and Chicago, have experienced slight increases in SOC (Sarzynski & Vicino, 2019). Urban soils in South Korea have lower carbon storage compared to other countries due to lower soil carbon concentration and smaller land areas under urban green spaces (Bae & Ryu, 2020).

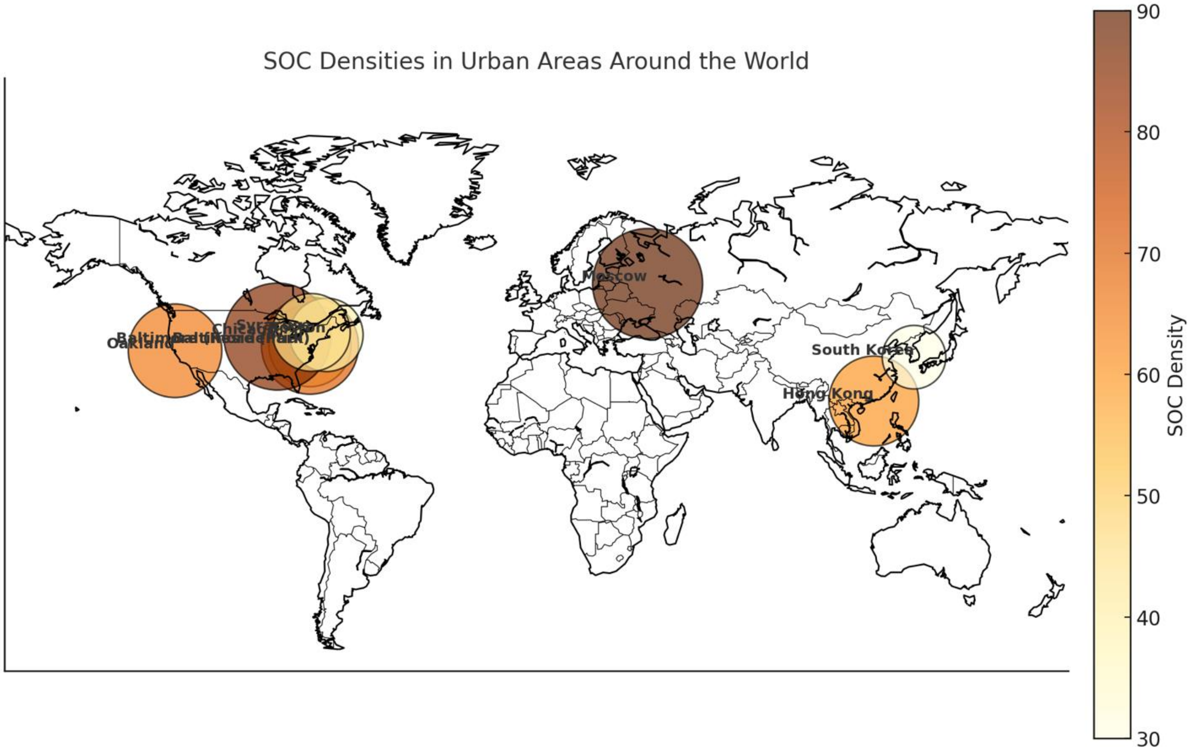

Figure 3: SOC Densities in Urban Areas Around the World.

Urban soils under impervious surfaces can still store significant amounts of carbon, although typically less than soils in green spaces. For instance, urban soils in the U.K. store more organic carbon than regional agricultural lands (Figure 4), even under impervious surfaces (Han et al., 2016). However, soil sealing in cooler climates, such as Finland, results in substantial losses of carbon and nitrogen storage (Figure 4) (Gilg et al., 2013). These differences highlight the importance of tailoring urban land management practices to specific environmental conditions to maximize carbon storage.

Management practices, such as the application of green waste compost, can significantly enhance carbon storage in urban soils. Adding compost to newly created urban soils can triple carbon densities compared to existing urban soils. Allotment gardens in the U.K. also demonstrate high soil quality and significant carbon storage due to effective management practices. Urban soils often contain high levels of black carbon (BC), a product of the incomplete combustion of fossil fuels and biomass. In the Northeast of England, BC contributes significantly to the total organic carbon stocks in urban soils, with its proportion increasing with soil depth. Engineered urban soils can capture and store atmospheric carbon through the formation of carbonates, involving the weathering of calcium and magnesium-bearing minerals, which can sequester substantial amounts of carbon dioxide (see: Batey, 2009; Jones et al., 2009).

From a political and legislative perspective, urban soil management is often overlooked in policy-making processes. The potential of urban soils to sequester carbon is significant but frequently underestimated in climate policies. This oversight can be attributed to the complexity of measuring urban soil carbon storage and the lack of standardized methodologies for incorporating urban soils into carbon accounting frameworks. Legislation and regulations that promote the development of urban green spaces and encourage sustainable soil management practices, such as composting and the use of engineered soils, can enhance urban carbon sequestration and contribute to broader climate change mitigation efforts (Yang & Zhang, 2015).

Regulatory frameworks should incentivize the use of green infrastructure and the protection of existing urban soils to prevent carbon losses due to development. Additionally, policies that promote community involvement in urban gardening and composting initiatives can help increase awareness and participation in sustainable soil management practices (Carvalho et al., 2022). These efforts can transform urban areas into vital components of climate change mitigation strategies.

Urban soils, therefore, have considerable potential for carbon storage, influenced by factors such as land use, climate, vegetation, and management practices. While urbanization can have both positive and negative effects on SOC pools, strategic management practices—such as the use of compost and the creation of green spaces—can improve carbon storage. Moreover, urban soils play a crucial role in black carbon sequestration and carbonate formation, further contributing to their carbon sequestration potential. Understanding these dynamics is essential for effective urban soil management and climate change mitigation strategies. We believe that greater attention should be paid to the untapped potential of urban soils for carbon sequestration.

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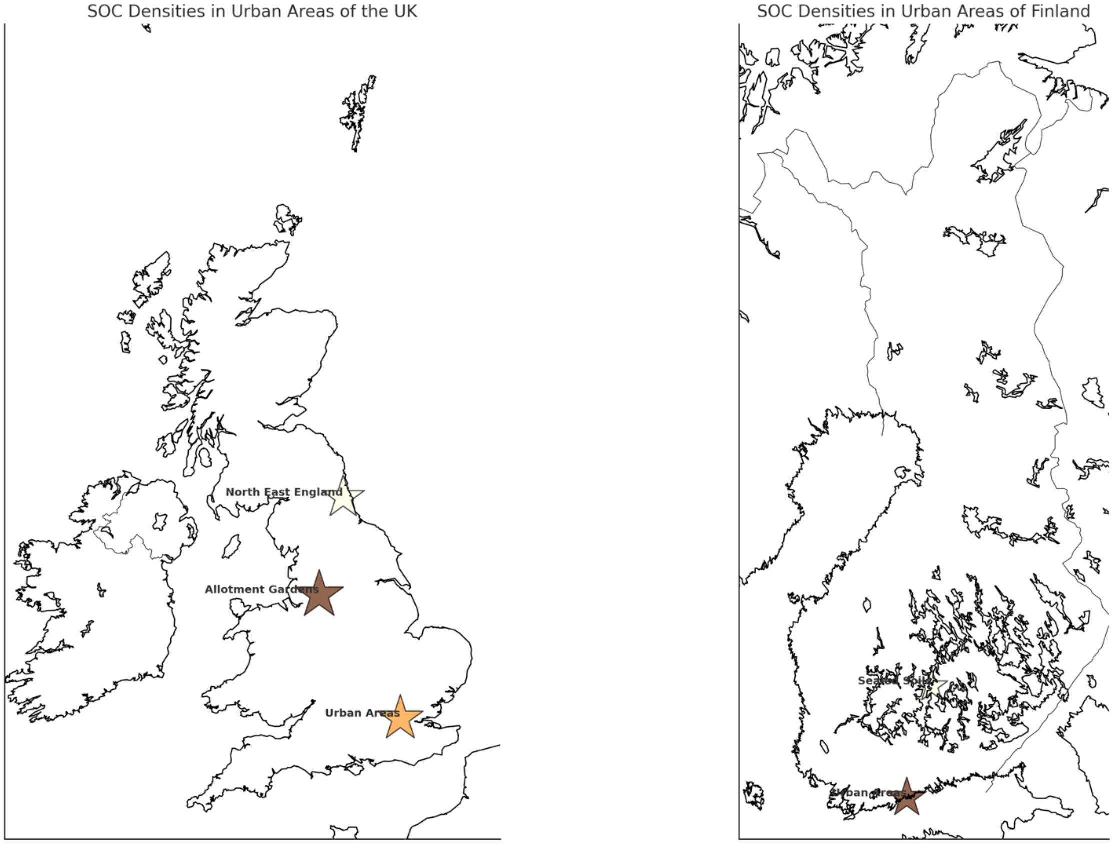

Figure 4: SOC densities in urban areas of the UK and Finland.

5.0 Urban Soils for Food Production

Urban agriculture is increasingly recognized as a vital component of food security and sustainability in cities. However, the quality and management of urban soils are critical factors that influence the success and safety of urban food production. The potential of urban agriculture is immense, but its success hinges on effectively managing soil quality and addressing the unique challenges posed by urban environments. Urban gardeners can significantly influence soil quality through their cultivation techniques, such as incorporating organic matter and avoiding chemical treatments (Yang & Zhang, 2015). However, there is often a lack of awareness among gardeners about how to protect and enhance soil fertility.

Different soil management practices and nutrient sources can lead to varying impacts on soil quality and productivity. Sustainable intensification and the use of locally sourced materials, such as compost and clean sediments, can enhance soil health and productivity without degrading soil quality (Batey, 2009). Research has shown that urban soils often face contamination from past industrial activities, posing risks to food safety. The use of raised beds with introduced soils can mitigate these risks and support cleaner production (Adimalla, 2020). Constructing urban agricultural soils using clean, locally sourced materials, such as municipal composts and excavated sediments, promotes sustainable food production while enhancing ecosystem services and reducing greenhouse gas emissions.

From a political and legislative standpoint, urban agriculture faces challenges and opportunities that require strategic planning and regulation. Urban development often leads to significant land loss from agricultural areas, reducing the overall capacity for food production. This loss of agricultural land can have substantial impacts on food security, as seen in Europe, where urbanization has led to a notable decrease in agricultural productivity. The competition between urbanization and food production for land necessitates strategic planning to protect fertile croplands and promote urban resilience through sustainable urban agriculture practices (Table 1).

Policies that encourage urban agriculture and protect existing agricultural lands are essential to ensure food security in rapidly urbanizing areas. Governments and local authorities can play a crucial role by implementing zoning laws that designate urban farming areas, providing incentives for urban farmers, and supporting community gardening initiatives. Additionally, regulations to prevent soil contamination and promote the use of safe, sustainable materials in urban agriculture can enhance food safety and environmental health (see Carvalho et al., 2022).

Soil suitability varies significantly across different urban and peri-urban areas, affecting the potential for growing specific crops. For instance, in the peri-urban Niayes zone of Senegal, soils were found to be highly suitable for groundnut production but less so for cassava and rice. This variability underscores the importance of site-specific soil assessments and tailored management practices to optimize crop yields (Diack et al., 2017). Globally, soil degradation through unsustainable agricultural practices poses a significant threat to long-term food security (e.g., Bednář & Šarapatka, 2018). There is a pressing need for policies that promote soil conservation and sustainable management to ensure the continued provision of essential ecosystem services. Urban soils, with their unique challenges and potential, are at the forefront of this issue.

Urban soils play a crucial role in supporting food production within cities, but their management requires careful consideration to ensure sustainability and safety. As someone passionate about soil science and its role in food security, I believe that addressing the challenges of urban agriculture is vital for creating resilient, sustainable cities. Effective soil management practices, educational support for urban gardeners, and strategic urban planning are essential to mitigate the impacts of urbanization on agricultural land and enhance the productivity and health of urban soils.

Table 1: Impact of urban soils.

Food	Soil Suitability/Importance
Groundnut	Highly suitable in certain urban areas
Cassava	Less suitable in some urban soils
Rice	Variability in soil suitability
Urban Vegetables	Dependent on soil quality and management
Peri-Urban Crops	Requires site-specific soil assessments

6.0 Soil and Human Health Trends

The relationship between soil and human health is multifaceted, encompassing both direct and indirect effects. Soil influences human health through its physical, chemical, and biological properties, impacting everything from nutrient supply to exposure to harmful elements and pathogens (Steffan et al., 2018). Understanding these complex interactions is essential for safeguarding human health and ensuring sustainable development. Recent research highlights the dual role of soil in human health (Lal, 2016). On one hand, soils are a source of essential nutrients and beneficial microorganisms that support healthy ecosystems and food production. On the other hand, they can harbor pollutants and pathogens that pose significant health risks. Urban soils often contain high levels of organic and inorganic pollutants due to industrialization and urbanization (Ahn et al., 2024). This contamination can lead to exposure to heavy metals, such as lead and cadmium, which are linked to various health issues, including neurological disorders and kidney damage. Soil can also harbor pathogens that cause diseases such as tetanus, hookworm, and geohelminth infections through ingestion, inhalation, or dermal absorption (Table 2) (e.g., Li et al., 2018; Adimalla, 2020; Zhang et al., 2021)..

Table 2: Soil impacts – diseases and their causes.

Disease	Cause
Tetanus	Pathogens in soil
Hookworm Infection	Pathogens in soil
Geohelminth Infections	Pathogens in soil
Lead Poisoning	Heavy metals in soil
Cadmium Poisoning	Heavy metals in soil
Neurological Disorders	Heavy metals in soil
Kidney Damage	Heavy metals in soil

Soil biodiversity plays a crucial role in suppressing disease-causing organisms and providing clean air, water, and food. Maintaining soil biodiversity through sustainable management practices can enhance these health benefits, emphasizing the importance of soil conservation measures (Nielsen et al., 2015). One of the biggest challenges currently facing soil and human health is the impact of climate change on soil properties and functions. Climate change can alter temperature and moisture regimes in the soil, affecting nutrient cycling and the survival of pathogens. These changes may impact nutrient availability in soils and the incidence of soil-borne diseases, potentially threatening food security and public health. Another pressing issue is the degradation of soil quality due to unsustainable agricultural practices, deforestation, and urban expansion (e.g., Bednář & Šarapatka, 2018; Stefan et al., 2018). Poor soil management can lead to nutrient-poor harvests and contaminated water supplies, which indirectly affect human health. Addressing these challenges requires a multidisciplinary approach involving soil science, agronomy, toxicology, epidemiology, and medical sciences (Table 3) (e.g., Lal, 2016)).

Table 3: Soil management and possible effects.

Affects	Cause
Nutrient Deficiency	Poor soil management
Soil-borne Diseases	Pathogens in soil
Contaminated Water Supplies	Pollutants in soil
Crop Yield Reduction	Degraded soil quality
Food Insecurity	Degraded soil quality
Public Health Risks	Climate change effects on soil

As someone deeply invested in soil science, I believe that understanding and managing the relationship between soil and human health is crucial for ensuring the well-being of current and future generations. Healthy soils provide essential ecosystem services, including food production, climate regulation, and cultural benefits like stress reduction and recreation. These services are vital for overall human well-being and should be a priority in policymaking and land management strategies. By adopting sustainable soil management practices and enhancing soil biodiversity, we can mitigate health risks and maximize the positive contributions of soil to human health. This requires collaboration across disciplines and sectors, with scientists, policymakers, and communities working together to protect and restore our soils.

7.0 Conclusions

This article has explored the complex and multi-layered relationship between soils and important aspects of ecological and human well-being, emphasizing the crucial role of soils in urban, agricultural, and health contexts. The findings underline the importance of humification—a process in which organic matter is converted into humus—in improving soil structure, fertility, and carbon storage. This process is critical for maintaining soil health and productivity, especially in urban and agricultural areas, and is a key component of climate change mitigation strategies.

Urban soils are essential for carbon storage and agricultural productivity. Despite the challenges posed by urbanization, which often reduce soil organic carbon levels, the application of strategic management practices—such as the use of compost, biochar, and engineered soils—can significantly improve soil quality and increase carbon sequestration. Urban agriculture, supported by healthy urban soils, plays a crucial role in promoting food security, biodiversity, and community well-being while providing vital ecosystem services in densely populated areas.

The dual impact of soils on human health—as they can serve as a source of nutrients and beneficial microbes while also harboring pollutants and pathogens—underscores the need for sustainable soil management practices. These practices are essential for reaping the benefits of soils for human health while minimizing the risks associated with contamination and degradation. The geographical dimensions of soil-related challenges, such as erosion and contamination, require coordinated efforts across scientific, policy, and regulatory domains. Tools such as Geographic Information Systems (GIS) and the adoption of sustainable land management practices are crucial for maintaining soil health and strengthening ecosystem resilience.

From a conceptual perspective, this study proposes viewing soil management through a holistic lens, recognizing soils as dynamic systems that interact with broader ecological, social, and economic networks. Practical recommendations for sustainable soil management include promoting organic farming practices, restoring degraded soils through afforestation and reforestation, and integrating green infrastructure into urban planning. Policies should also focus on conserving existing green spaces and remediating contaminated soils, with an emphasis on promoting soil biodiversity as a means of improving ecosystem services.

Additionally, encouraging public participation in urban gardening and sustainable agricultural practices can raise awareness and increase stewardship of soil. Education and outreach programs should be developed to provide local communities with the knowledge and tools needed to protect and enhance soil health. Addressing soil contamination through regular testing, bioavailability-based risk assessments, and implementing targeted remediation strategies is also crucial for public health and environmental sustainability.

Thus, soils are fundamental to environmental sustainability, food security, and human health. A better understanding of soil processes, linking scientific knowledge to practical solutions, and promoting cooperation between different sectors can lead to more effective soil management strategies. The findings from this study underline the need for a comprehensive and integrated approach to soil management that recognizes the central role of soils in sustaining the environmental, social, and economic systems on which we all depend.

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Conflicts of Interest The authors declare that there is no conflict of interest.

References

Abakumov, E. V., Rodina, O. A., & Eskov, A. K. (2018). Humification and humic acid composition of suspended soil in oligotrophous environments in South Vietnam. *Applied and Environmental Soil Science*, *2018*(1), 1026237. https://doi.org/10.1155/2018/1026237

Adimalla, N. (2020). Heavy metals pollution assessment and its associated human health risk evaluation of urban soils from Indian cities: a review. *Environmental geochemistry and health*, *42*(1), 173-190. https://doi.org/10.1007/s10653-019-00324-4

Ahn, Y. J., Juraev, Z., & Gu, J. Y. (2024). Exploring the Interplay of Healthcare, Spirituality, and Urban Well-Being. *Pharos Journal of Theology*, 104(5), 1-12. https://doi.org/10.46222/pharosjot.104.521

Andreux, F. (1996). Humus in world soils. In *Humic substances in terrestrial ecosystems* (pp. 45-100). Elsevier Science BV. https://doi.org/10.1016/B978-044481516-3/50003-7

Bae, J., & Ryu, Y. (2020). High soil organic carbon stocks under impervious surfaces contributed by urban deep cultural layers. *Landscape and Urban Planning*, *204*, 103953. https://doi.org/10.1016/j.landurbplan.2020.103953

Batey, T. (2009). Soil compaction and soil management–a review. *Soil use and management*, *25*(4), 335-345. https://doi.org/10.1111/j.1475-2743.2009.00236.x

Bednář, M., & Šarapatka, B. (2018). Relationships between physical–geographical factors and soil degradation on agricultural land. *Environmental research*, *164*, 660-668. https://doi.org/10.1016/j.envres.2018.03.042

Carvalho, C. A., Más-Rosa, S., & Ventura, A. C. (2022). Urban Gardens and Composting: Effective Government for Strengthening Urban Resilience and Community Waste Management. In *Water-Energy-Food Nexus and Climate Change in Cities* (pp. 217-241). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-05472-3_12

Chernova, O. V., Golozubov, O. M., Alyabina, I. O., & Schepaschenko, D. G. (2021). Integrated approach to spatial assessment of soil organic carbon in the Russian Federation. *Eurasian soil science*, *54*, 325-336. https://doi.org/10.1134/S1064229321030042

Chertov, O. G., & Nadporozhskaya, M. A. (2018). Humus forms in forest soils: concepts and classifications. *Eurasian Soil Science*, *51*, 1142-1153. https://doi.org/10.1134/S1064229318100022

Defersha, M. B., Quraishi, S., & Melesse, A. (2011). The effect of slope steepness and antecedent moisture content on interrill erosion, runoff and sediment size distribution in the highlands of Ethiopia. *Hydrology and Earth System Sciences*, *15*(7), 2367-2375. https://doi.org/10.5194/hess-15-2367-2011

Diack, M., Loum, M., Guisse, A., & Sane, M. B. (2017). Dynamics of agricultural land and the risk to food insecurity in the Niayes region of Diamniadio, West Senegal. *Jambà: Journal of Disaster Risk Studies*, *9*(1), 1-7. https://hdl.handle.net/10520/EJC-8c6cdccc8

Fess, T. L., & Benedito, V. A. (2018). Organic versus conventional cropping sustainability: a comparative system analysis. *Sustainability*, *10*(1), 272. https://doi.org/10.3390/su10010272

Giampieri, M., & Vialle, A. (2020). Mapping urbanization as an anthropedogenetic process: A section through the times of urban soils. *Urban Planning*, *5*(2), 262-279. https://doi.org/10.17645/up.v5i2.2848

Gilg, H. A., Hall, A. M., Ebert, K., & Fallick, A. E. (2013). Cool kaolins in Finland. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *392*, 454-462. https://doi.org/10.1016/j.palaeo.2013.09.030

Greinert, A. (2015). The heterogeneity of urban soils in the light of their properties. *Journal of Soils and Sediments*, *15*, 1725-1737. https://doi.org/10.1007/s11368-014-1054-6

Gupta, G. S. (2019). Land degradation and challenges of food security. *Rev. Eur. Stud.*, *11*, 63. doi: 10.5539/res.vl 1n1p63.

Han, L., Sun, K., Jin, J., & Xing, B. (2016). Some concepts of soil organic carbon characteristics and mineral interaction from a review of literature. *Soil Biology and Biochemistry*, *94*, 107-121. https://doi.org/10.1016/j.soilbio.2015.11.023

Hayes, M. H., & Swift, R. S. (2020). Vindication of humic substances as a key component of organic matter in soil and water. *Advances in Agronomy*, *163*, 1-37. https://doi.org/10.1016/bs.agron.2020.05.001

Herrmann, D. L., Schifman, L. A., & Shuster, W. D. (2020). Urbanization drives convergence in soil profile texture and carbon content. *Environmental Research Letters*, *15*(11), 114001. DOI 10.1088/1748-9326/abbb00.

Jones, D. L., Chesworth, S., Khalid, M., & Iqbal, Z. (2009). Assessing the addition of mineral processing waste to green waste-derived compost: An agronomic, environmental and economic appraisal. *Bioresource technology*, *100*(2), 770-777. https://doi.org/10.1016/j.biortech.2008.06.073

Katsumi, N., Yonebayashi, K., Okazaki, M., Nishiyama, S., Nishi, T., Hosaka, A., & Watanabe, C. (2016). Characterization of soil organic matter with different degrees of humification using evolved gas analysis-mass spectrometry. *Talanta*, *155*, 28-37. https://doi.org/10.1016/j.talanta.2016.04.007

Kishore, S. M., Priyadharshini, T. B., & Sowmya, K. (2024). Soil Arthropods: An Unsung Heroes of Soil Fertility. *Journal of Advances in Biology & Biotechnology*, *27*(6), 118-126. https://doi.org/10.9734/jabb/2024/v27i6872

Komarov, A., Chertov, O., Bykhovets, S., Shaw, C., Nadporozhskaya, M., Frolov, P., Shashkov, M., Shanin, V., Grabarnik, P., Priputina, I., & Zubkova, E. (2017). Romul_Hum model of soil organic matter formation coupled with soil biota activity. I. Problem formulation, model description, and testing. *Ecological Modelling*, *345*, 113-124. https://doi.org/10.1016/j.ecolmodel.2016.08.007

Lal, R. (2016). Soil health and carbon management. *Food and energy security*, *5*(4), 212-222. https://doi.org/10.1002/fes3.96

Li, G., Sun, G. X., Ren, Y., Luo, X. S., & Zhu, Y. G. (2018). Urban soil and human health: a review. *European Journal of Soil Science*, *69*(1), 196-215. https://doi.org/10.1111/ejss.12518

Nickayin, S. S., Perrone, F., Ermini, B., Quaranta, G., Salvia, R., Gambella, F., & Egidi, G. (2021). Soil quality and peri-urban expansion of cities: a Mediterranean experience (Athens, Greece). *Sustainability*, *13*(4), 2042. https://doi.org/10.3390/su13042042

Nielsen, U. N., Wall, D. H., & Six, J. (2015). Soil biodiversity and the environment. *Annual review of environment and resources*, *40*(1), 63-90. https://doi.org/10.1146/annurev-environ-102014-021257

Nottingham, A. T., Whitaker, J., Turner, B. L., Salinas, N., Zimmermann, M., Malhi, Y., & Meir, P. (2015). Climate warming and soil carbon in tropical forests: insights from an elevation gradient in the Peruvian Andes. *Bioscience*, *65*(9), 906-921. https://doi.org/10.1093/biosci/biv109

O'Riordan, R., Davies, J., Stevens, C., Quinton, J. N., & Boyko, C. (2021). The ecosystem services of urban soils: A review. *Geoderma*, *395*, 115076. https://doi.org/10.1016/j.geoderma.2021.115076

Ottou, W. N., Sardon, H., Mecerreyes, D., Vignolle, J., & Taton, D. (2016). Update and challenges in organo-mediated polymerization reactions. *Progress in Polymer Science*, *56*, 64-115. https://doi.org/10.1016/j.progpolymsci.2015.12.001

Piccolo, A. (2002). The supramolecular structure of humic substances: a novel understanding of humus chemistry and implications in soil science. *Advances in Agronomy*, *75*, 57-134. https://doi.org/10.1016/S0065-2113(02)75003-7

Salmon, S. (2018). Changes in humus forms, soil invertebrate communities and soil functioning with forest dynamics. *Applied Soil Ecology*, *123*, 345-354. https://doi.org/10.1016/j.apsoil.2017.04.010

Sarzynski, A., & Vicino, T. J. (2019). Shrinking suburbs: Analyzing the decline of American suburban spaces. *Sustainability*, *11*(19), 5230. https://doi.org/10.3390/su11195230

Scharenbroch, B. C., Bialecki, M. B., & Fahey, R. T. (2017). Distribution and factors controlling soil organic carbon in the Chicago Region, Illinois, USA. *Soil Science Society of America Journal*, *81*(6), 1436-1449. https://doi.org/10.2136/sssaj2017.03.0087

Schwarz, K., Pouyat, R. V., & Yesilonis, I. (2016). Legacies of lead in charm city's soil: Lessons from the Baltimore ecosystem study. *International journal of environmental research and public health*, *13*(2), 209. https://doi.org/10.3390/ijerph13020209

Steffan, J. J., Brevik, E. C., Burgess, L. C., & Cerdà, A. (2018). The effect of soil on human health: an overview. *European journal of soil science*, *69*(1), 159-171. https://doi.org/10.1111/ejss.12451

Yang, J. L., & Zhang, G. L. (2015). Formation, characteristics and eco-environmental implications of urban soils–A review. *Soil science and plant nutrition*, *61*(sup1), 30-46. https://doi.org/10.1080/00380768.2015.1035622

Zacharioudaki, D. E., Fitilis, I., & Kotti, M. (2022). Review of fluorescence spectroscopy in environmental quality applications. *Molecules*, *27*(15), 4801. https://doi.org/10.3390/molecules27154801

Zhang, H. B., Luo, Y. M., Wong, M. H., Zhao, Q. G., & Zhang, G. L. (2007). Soil organic carbon storage and changes with reduction in agricultural activities in Hong Kong. *Geoderma*, *139*(3-4), 412-419. https://doi.org/10.1016/j.geoderma.2007.03.003

Zhang, H., Zhang, F., Song, J., Tan, M. L., & Johnson, V. C. (2021). Pollutant source, ecological and human health risks assessment of heavy metals in soils from coal mining areas in Xinjiang, China. *Environmental Research*, *202*, 111702. https://doi.org/10.1016/j.envres.2021.111702