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Urban Soils: Feature and Impacts

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The term "urban" is defined as "in relating to, or characteristic of a town or city". Therefore, an urban soil, must be impacted and/or influenced by human activities within a town or city. Soils used in large-scale agricultural production are not included as urban soils. This definition suggests some criteria relating an established population, a density of a human population, various structures, and human activities impacting the native soil environment.

'Urban soils' is a class of Anthropic soils, a term already used in several classification systems. Urban soils are soils extensively influenced by human activities, found mostly but not only in urban areas. They include: (1) soils that are composed of a mixture of materials differing from those in adjacent agricultural or forest areas, and that may present a surface layer greater than 50 cm, highly transformed by human activity through mixing, importing, and exporting material, and by contamination; (2) soils in parks and gardens that are closer to agricultural soils but offer different composition, use, and management than agricultural soils; and (3) soils that result from various construction activities in urban areas and that are often sealed. According to this definition, urban soils are essentially under strong human influence in urban and suburban environments; they may exert a strong effect on human health, on plants and soil organisms, and on water infiltration. They are differentiated from other strongly influenced soils such as those found in quarries, mines, and mine tailings, and airfields away from cities. However, it is sometimes difficult to set a clear boundary between urban soils and agricultural soils (Figure 1).

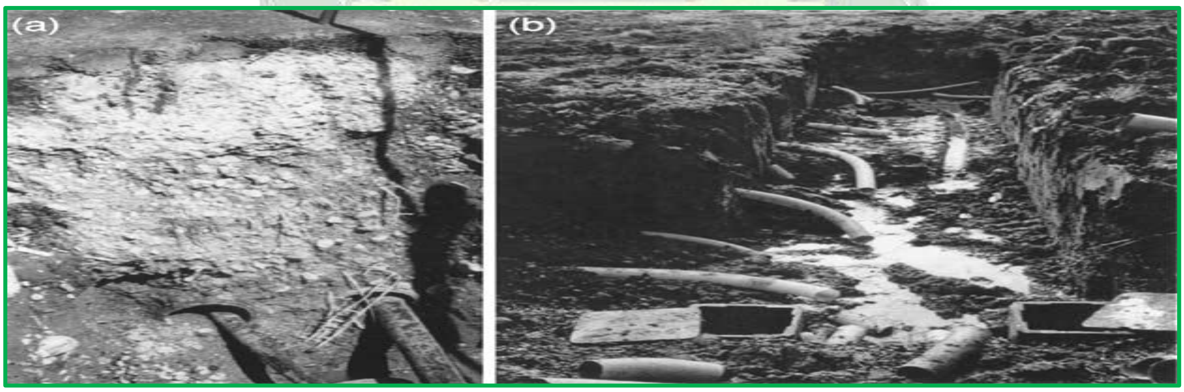

Figure 1: Urban soils and agricultural soils: (a) urban soil profile showing a sealed surface, imported soil materials, and electric wires; (b) agricultural soil profile showing strong perturbation induced by the incorporation of plastic drains.

The definition and extent of urban areas described by Liu et al. (2014) suggest that urban areas include the "administrative city boundary." This boundary includes satellite cities, suburban fringe or peri urban areas with a lower development density that are contained in an established city limit. Other concepts of urban areas are based on population density or legal geopolitical names such as town, village, township, or borough. Due to inconsistent and overlapping criteria at the local, national, or global scale for these definitions, those names are generally unreliable indicators of a city's geographic extent or a city's population and do not effectively differentiate the degree and extent of soil alterations related to human activity in those areas.

Characteristics of urban soils and ecological services

Soils in urban and built areas provide many of the same ecosystem services as soils in undeveloped areas with additional functions to support urban infrastructure or activities. Soil functions and processes deliver services such as the provision of food, fuel and fiber, water infiltration and groundwater recharge, water storage, nutrient cycling to support vegetation, climate regulation, filtering and cleaning of water, and immobilization (sorption)

Pedogenic processes in urban soils

Widely accepted models of soil forming factors were suggesting five critical factors which impact soil formation: parent material, topography, time, climate, and organisms. More recently a sixth, independently acting factor has been discussed as critical for anthropogenic environments, such as urban areas.

These soils differ significantly from natural soils due to various factors such as construction, pollution, and artificial landscaping. Below are key features and impacts of urban soils:

Physical Properties of Urban Soils

Soil Compaction: Urban activities like construction, heavy machinery movement, and pedestrian traffic lead to severe compaction. This reduces the soil's porosity, limiting water and air movement, which is crucial for root growth and microbial activity. Compacted soils often create drainage problems and increase runoff.

Surface Sealing: Paved surfaces such as roads, sidewalks, and parking lots seal the soil, preventing natural water infiltration and gas exchange. Sealing not only disrupts natural soil functions but also accelerates runoff, contributing to urban flooding and water quality degradation.

Artificial Layers: Many urban soils have stratified, unnatural layers due to construction activities or debris deposition. These layers may consist of materials like concrete, bricks, or metal fragments, disrupting natural root growth patterns and soil development.

Chemical Properties of Urban Soils

Alkalinity: Urban soils often have higher pH levels, leaning toward alkalinity. This can be due to the use of materials like concrete, which releases calcium carbonate into the soil. High pH can affect nutrient availability, especially for plants that prefer acidic soils.

Pollutants and Heavy Metals: Heavy metals such as lead (from old paints or gasoline), mercury, cadmium, and zinc are common in urban soils. These elements can accumulate over time, posing risks to human health through direct exposure or food grown in contaminated soils. Pollution from vehicle emissions, industrial activities, and waste dumping also adds toxic substances to the soil.

Reduced Organic Matter: Urban soils often lack organic material, which is essential for supporting soil life, nutrient cycling, and water retention. Organic matter is crucial for the formation of humus, which helps improve soil structure, water-holding capacity, and microbial diversity.

Biological Properties of Urban Soils

Reduced Microbial Activity: Due to contamination, compaction, and lack of organic matter, urban soils typically have lower microbial populations. Microbes play a critical role in nutrient cycling, decomposition of organic matter, and overall soil health. Poor microbial activity limits these functions, reducing soil fertility.

Lower Earthworm Populations: Earthworms are vital for aerating the soil and improving its structure. However, their populations are often reduced in urban soils due to compaction, pollution, and lack of organic matter. Fewer earthworms lead to poorer soil structure and reduced infiltration rates.

Limited Vegetation: Vegetation in urban areas is often limited to lawns, ornamental plants, or small trees. The root systems of such plants are often shallow and restricted, unable to penetrate compacted or contaminated soils. This limits the amount of biomass input and reduces the potential for natural soil regeneration.

Environmental and Societal Impacts

Urban Heat Island Effect: Soils in urban areas contribute to the urban heat island (UHI) phenomenon, where cities experience higher temperatures than surrounding rural areas. Sealed surfaces (asphalt, concrete) and low vegetation cover reduce cooling effects. Exposed, bare soils absorb and radiate heat, further contributing to temperature rise.

Flooding and Erosion: Poor water infiltration in urban soils leads to increased surface runoff during rain events. This can overwhelm drainage systems, causing urban flooding. Erosion of soil on slopes or construction sites can wash sediments into waterways, causing sedimentation and water pollution issues.

Soil Degradation: Urban development causes significant soil degradation, which is often irreversible. Soil sealing, pollution, and removal of topsoil reduce the land's ability to recover naturally. Degraded soils have limited capacity to support vegetation, making it harder to establish green spaces or urban forests.

Features of Urban Soils

Disturbed Structure: Urban soils are often compacted due to construction activities, roads, and foot traffic. This compaction reduces pore space, which affects water infiltration and root growth.

Heterogeneous Composition: Urban soils may contain a mix of natural soil, debris (like concrete, asphalt, glass), and foreign materials. They often show high variability in texture and composition, even within small areas.

Contamination: Urban soils frequently contain pollutants, including heavy metals (lead, arsenic, cadmium), petroleum products, chemicals from industrial activities, and pesticides. This is especially common near roads, industrial sites, and old housing structures.

Poor Nutrient Content: Due to a lack of organic matter and biological activity, urban soils often have low levels of essential nutrients such as nitrogen, phosphorus, and potassium.

Altered Hydrology: The structure of urban landscapes (e.g., buildings, pavement) affects natural water flow, leading to increased surface runoff and reduced soil moisture retention. This can impact the soil's ability to support vegetation.

Increased Temperature: Urban soils experience higher temperatures due to the urban heat island effect. This elevated heat can impact microbial activity and soil chemistry.

Impacts of Urban Soils

Reduced Vegetation Growth: The compaction, lack of nutrients, and pollution in urban soils can limit plant root growth, reduce biodiversity, and hinder the success of urban green spaces like parks and gardens.

Stormwater Management Issues: Urban soils, due to compaction and reduced infiltration capacity, contribute to higher surface runoff during rainfall, which increases the risk of flooding and erosion in urban areas. This can also lead to poor water quality as pollutants in the soil are carried into waterways.

Human Health Risks: Contaminants in urban soils, such as lead and other toxic substances, pose health risks, particularly to children who may be exposed through direct contact or through dust particles. Contaminated soils in urban agriculture can affect food safety.

Carbon Sequestration Challenges: Urban soils generally have lower organic matter content, limiting their ability to sequester carbon. This reduces their role in mitigating climate change compared to natural soils.

Heat and Climate Regulation: Urban soils have a reduced capacity for natural cooling through evapotranspiration due to their altered structure and composition. This contributes to the urban heat island effect, further exacerbating temperature rise in cities.

Biodiversity Loss: Urban soils support less biological activity (such as microbes, earthworms, and insects) compared to natural soils. This reduces biodiversity and the ecological services provided by soil organisms.

Management and Restoration of Urban Soils

Soil Remediation: Phytoremediation (using plants to absorb contaminants) and bioremediation (using microorganisms to break down pollutants) are strategies to clean contaminated soils. These methods are increasingly used in urban brownfields (abandoned or underused industrial sites) to restore soil functionality.

Composting and Organic Amendments: Adding organic materials such as compost, mulch, or manure can improve urban soil health. These materials increase organic matter, enhance microbial activity, and improve soil structure, helping to restore soil fertility and support plant growth.

Permeable Pavements: Urban planning now incorporates green infrastructure solutions like permeable pavements that allow water to infiltrate the ground, reducing runoff and improving groundwater recharge. This helps maintain the natural hydrological cycle in cities.

Green Roofs and Urban Greening: Urban soils can be improved through greening initiatives such as green roofs, green walls, and community gardens. These projects not only enhance aesthetic and recreational value but also help in cooling the environment, improving air quality, and supporting urban biodiversity.

Soil Monitoring and Testing: Regular soil testing can help assess the level of contamination and degradation in urban areas. It also informs soil management practices, such as the need for amendments or remediation efforts.

Stormwater Management Systems: To counter the problems caused by surface runoff, cities often implement stormwater management systems like retention ponds, bioswales, and rain gardens. These features enhance infiltration, filter pollutants, and reduce erosion in urban soils.

Conclusion

Urban soils are a vital yet often overlooked resource in cities. By understanding their unique properties and impacts, urban planners and environmental scientists can develop strategies to manage them sustainably, creating healthier urban environments. Restoration techniques, soil remediation, and careful management of green spaces all play a critical role in enhancing urban soil quality and mitigating negative impacts.

References

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