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Carbon Sequestration Potential of Urban Green Spaces: A Natural Solution for Climate-Resilient Cities

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Rapid urbanization has led to the reduction of natural vegetation and increased greenhouse gas emissions, contributing significantly to climate change. Urban green spaces such as parks, avenue plantations, urban forests, green roofs, vertical gardens, institutional landscapes, and residential gardens play a crucial role in mitigating these environmental challenges. Through the process of photosynthesis, plants absorb atmospheric carbon dioxide (CO₂) and store carbon in their biomass and soil, a process known as carbon sequestration. Well-designed urban landscapes not only enhance the aesthetic value of cities but also function as important carbon sinks, helping to offset emissions generated from transportation, industries, and buildings. In addition to carbon storage, urban green spaces provide numerous ecosystem services, including temperature regulation, air purification, biodiversity conservation, stormwater management, and improved human well-being. With growing concerns over global warming and urban heat islands, integrating carbon-conscious landscape planning into urban development has become increasingly important. This article explores the concept of carbon sequestration, the role of different urban green spaces in capturing atmospheric carbon, factors affecting sequestration potential, and strategies to enhance carbon storage in urban environments. Strengthening urban greening initiatives can contribute significantly toward sustainable, climate-resilient, and environmentally healthy cities.

Keywords: Carbon sequestration, Urban green spaces, Climate change mitigation, Urban forestry.

Introduction

Climate change has emerged as one of the most pressing environmental challenges of the twenty-first century. Rising atmospheric concentrations of greenhouse gases, particularly carbon dioxide (CO₂), have intensified global warming, resulting in extreme weather events, rising sea levels, biodiversity loss, and ecosystem degradation (IPCC, 2023). Urban areas are major contributors to greenhouse gas emissions because of rapid industrialization, transportation activities, energy consumption, and expanding infrastructure. As cities continue to grow, natural ecosystems are often replaced by buildings, roads, and other impervious surfaces. This transformation reduces the capacity of landscapes to absorb atmospheric carbon. Consequently, urban planners and environmental scientists are increasingly recognizing the importance of urban green spaces as nature-based solutions for climate mitigation. Parks, gardens, urban forests, green belts, roadside plantations, green roofs, and vertical gardens can capture and store carbon while simultaneously improving urban environmental quality (Nowak and Crane, 2002).

Understanding Carbon Sequestration

Carbon sequestration refers to the process by which carbon dioxide is removed from the atmosphere and stored in plant biomass, soils, and other carbon reservoirs. Plants absorb CO₂ during photosynthesis and convert it into organic compounds that become part of leaves, stems, roots, and woody tissues. The carbon captured by vegetation remains stored until plant material decomposes, burns, or is otherwise disturbed. Long-lived trees are particularly effective carbon sinks because they accumulate large quantities of biomass over many years. Soil beneath vegetation also stores substantial amounts of organic carbon through root growth and decomposition processes (Lal, 2004). Urban green spaces therefore function as miniature carbon reservoirs within cities, helping to balance some of the carbon emissions generated by urban activities.

Types of Urban Green Spaces and Their Carbon Storage Potential

1. Urban Forests

Urban forests comprise trees growing in parks, streets, institutional campuses, residential areas, and peri-urban regions. They represent one of the most effective forms of urban carbon sequestration. Large canopy trees such as neem, rain tree, banyan, peepal, gulmohar, and pongamia can store considerable amounts of carbon in their trunks, branches, and root systems. Studies indicate that urban forests can sequester significant quantities of carbon annually while simultaneously reducing air pollution and urban temperatures (Nowak et al., 2013). Besides carbon storage, urban forests improve biodiversity by providing habitats for birds, pollinators, and beneficial insects.

2. Parks and Recreational Landscapes

Public parks serve as important green lungs within cities. The combination of trees, shrubs, lawns, and ornamental plants contributes to carbon capture through continuous biomass production. Well-maintained parks can store carbon both above and below ground. Mature trees contribute the largest share of carbon storage, while grass-covered areas and landscape beds enhance soil organic carbon accumulation. The environmental benefits of urban parks extend beyond carbon sequestration to include recreation, mental health improvement, and community well-being.

3. Green Roofs and Vertical Gardens

With increasing land scarcity in urban areas, green roofs and vertical gardens are becoming innovative solutions for expanding green cover. Green roofs consist of vegetation established on building rooftops, while vertical gardens utilize walls and facades for plant growth. Although their carbon sequestration capacity is lower than that of mature urban forests, these systems provide additional environmental benefits such as thermal insulation, reduced building energy consumption, and mitigation of urban heat islands (Getter and Rowe, 2006). Furthermore, widespread adoption of green infrastructure can significantly contribute to sustainable urban development.

4. Avenue Plantations and Roadside Green Belts

Trees planted along roadsides and highways play an important role in carbon capture while improving urban aesthetics. Species such as neem, pongamia, cassia, tabebuia, and polyalthia are commonly used in avenue planting programs. Roadside plantations not only absorb carbon dioxide but also trap dust particles, reduce traffic noise, and improve air quality. Strategic urban greening through avenue plantations can create continuous carbon-sequestering corridors throughout cities.

5. Residential Gardens and Institutional Campuses

Residential landscapes, school gardens, university campuses, hospital grounds, and corporate landscapes collectively occupy substantial urban land area. Although individually small, these spaces collectively contribute significantly to urban carbon storage. The incorporation of trees, shrubs, ornamental flowering plants, lawns, and native vegetation increases biomass accumulation and promotes soil carbon storage. Community participation in home gardening and urban greening programs can therefore play a valuable role in climate action.

Factors Affecting Carbon Sequestration in Urban Green Spaces

Several factors influence the carbon sequestration potential of urban vegetation:

Tree Species Selection

Different plant species vary considerably in growth rate, biomass production, longevity, and carbon storage capacity. Fast-growing and large-canopy tree species generally sequester more carbon than smaller ornamental species.

Tree Age and Size

Older and larger trees typically store greater quantities of carbon because of their accumulated biomass. Protecting mature trees is often more beneficial than replacing them with young saplings.

Soil Quality

Healthy soils rich in organic matter support vigorous plant growth and enhance below-ground carbon storage. Proper soil management practices can therefore improve carbon sequestration efficiency.

Climate and Environmental Conditions

Temperature, rainfall, sunlight, and pollution levels influence plant growth and carbon uptake. Favorable environmental conditions generally promote greater biomass accumulation.

Landscape Management Practices

Regular maintenance, mulching, compost application, efficient irrigation, and sustainable pruning practices can enhance plant health and increase carbon storage potential.

Additional Benefits of Urban Green Spaces

The significance of urban green spaces extends far beyond carbon sequestration. These landscapes provide numerous ecosystem services that contribute to sustainable urban living.

Mitigation of Urban Heat Islands: Vegetation cools surrounding areas through shading and evapotranspiration. Green spaces can significantly reduce surface and ambient temperatures in densely built environments.

Improvement of Air Quality: Trees and shrubs remove particulate matter, absorb pollutants, and release oxygen, thereby improving urban air quality.

Biodiversity Conservation: Urban green spaces provide habitats for birds, butterflies, bees, and other wildlife, helping maintain ecological balance within cities.

Stormwater Management: Vegetation intercepts rainfall and promotes water infiltration, reducing runoff and minimizing flood risks.

Human Health and Well-being: Access to green spaces has been associated with improved mental health, reduced stress levels, enhanced physical activity, and stronger community interactions.

Strategies to Enhance Carbon Sequestration in Cities

To maximize carbon sequestration potential, urban planners and landscape professionals should adopt the following approaches:

- Increase urban tree canopy cover.
- Prioritize native and long-lived tree species.
- Protect existing mature trees.
- Develop urban forests and green corridors.
- Promote green roofs and living walls.
- Encourage community-based tree planting programs.
- Improve soil health through organic amendments.
- Integrate carbon accounting into urban planning policies.
- Expand institutional and residential landscaping initiatives.
- Establish biodiversity-friendly landscapes with diverse vegetation layers.

Such measures can significantly improve the carbon balance of urban ecosystems while enhancing environmental sustainability.

Conclusion

Urban green spaces represent one of the most practical and cost-effective nature-based solutions for mitigating climate change in cities. Through carbon sequestration, trees and other vegetation remove atmospheric carbon dioxide and store it in biomass and soils, helping reduce the environmental footprint of urbanization. Urban forests, parks, roadside plantations, green roofs, vertical gardens, and residential landscapes collectively contribute to carbon storage while providing numerous ecological, social, and economic benefits. As cities continue to expand, integrating green infrastructure into urban planning will be essential for achieving climate resilience, improving environmental quality, and creating healthier living spaces for future generations. Investing in urban greening today is an investment in a sustainable and climate-secure tomorrow.

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