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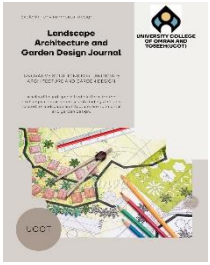

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Evaluating the Ecological Functions of Vegetation Cover in Enhancing Citizens' Health and Quality of Life in the Masoudieh and Nezamieh Gardens, with an Emphasis on the Baharestan District of Tehran

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Detailed abstract

Introduction

Rapid urbanization has significantly altered the ecological structure of cities, often resulting in the reduction of vegetation cover, expansion of impervious surfaces, and deterioration of air quality. These impacts are particularly evident in megacities such as Tehran, where intense physical growth has conflicted with environmental capacity, especially in central and historic districts like District 12. High building density, aging infrastructure, and limited green spaces have intensified urban heat island effects and air pollution, with concentrations of $PM_{2.5}$ and PM_{10} exceeding World Health Organization guidelines. Prolonged exposure to these pollutants has been strongly associated with increased respiratory and cardiovascular diseases, particularly among vulnerable populations, positioning air pollution as a major public health challenge in Tehran.

Urban vegetation plays a critical ecological role in mitigating these challenges through pollutant absorption, particulate deposition, carbon sequestration, and microclimate regulation. However, historic urban areas have experienced a substantial decline in green cover due to dense urbanization and land-use changes, as evidenced by the Negarestan Garden, where vegetation coverage has decreased from approximately 65–70% in the 1940s to less than 30% in recent years. This study examines long-term changes in vegetation cover in the Baharestan area of Tehran and evaluates two vegetation enhancement scenarios (35% and 70%) to assess their potential impacts on air quality improvement and public health. The research is grounded in the hypothesis that targeted restoration of vegetation in historic urban fabrics can reduce particulate matter concentrations, enhance environmental quality, and promote urban health, sustainability, and environmental justice.

Materials and Methods

This study employed a mixed-methods research design integrating historical analysis, field observations, spatial analysis, and scenario-based environmental modeling to evaluate the ecological performance of vegetation cover in the Baharestan area of Tehran. Historical maps, aerial photographs, and archival documents from 1942 to 2025 were analyzed to quantify long-term changes in vegetation cover, with a particular focus on Negarestan Garden and its surrounding urban fabric. Field surveys were conducted to document current land use, vegetation types, and spatial distribution of green elements, while Geographic Information Systems (GIS) were used to digitize land-cover classes and

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calculate vegetation coverage ratios. These data formed the baseline for assessing temporal trends and establishing current ecological conditions in the study area.

To evaluate the impacts of vegetation on air quality and urban health, two development scenarios were formulated and modeled: a moderate enhancement scenario increasing vegetation cover to 35% and an optimal restoration scenario increasing it to 70%. Scenario parameters were defined based on historical evidence, field observations, and findings from previous studies on the air purification and cooling capacities of urban vegetation. Modeling focused on estimating changes in particulate matter concentrations ($PM_{2.5}$ and PM_{10}) under each scenario, incorporating vegetation-related mechanisms such as pollutant deposition, carbon sequestration, shading, and evapotranspiration. Spatial analysis was applied to examine the distribution of ecological benefits across the study area and to compare scenario outcomes with the current condition.

Model validation and reliability assessment were conducted through triangulation with empirical data and existing literature. Modeled pollutant reduction rates were compared with observed air quality measurements from nearby monitoring stations and with reduction ranges reported in peer-reviewed studies. Sensitivity analysis was performed to assess the robustness of model outputs to variations in vegetation density and spatial configuration. Additionally, consistency checks between historical vegetation levels and modeled optimal conditions were used to evaluate the plausibility of scenario assumptions. Together, these validation procedures enhanced the credibility of the modeling approach and ensured that the results provide a reliable basis for ecological assessment and urban planning recommendations.

Findings

The analysis of historical maps, aerial imagery, and i-Tree Canopy outputs reveals substantial long-term changes in the landscape structure and ecological performance of Masoudieh and Nezamieh historic gardens in the Baharestan area of Tehran. Between 1867, 1999, and 2025, both gardens experienced significant reductions in vegetation cover, tree density, and ecological functionality, largely driven by urban expansion, land-use change, and physical fragmentation. Although recent restoration efforts have led to partial recovery of green cover, current conditions remain far below historical ecological baselines. These transformations have weakened the gardens' roles in air purification, carbon sequestration, and microclimate regulation, reducing their contribution to urban environmental quality and livability.

Findings related to Nezamieh Garden indicate the most severe ecological decline. Once covering approximately 3.8 hectares with dense vegetation and high ecological capacity, the garden has been reduced to a small remnant of green space. Annual carbon sequestration decreased dramatically from about 42.5 tons in 1867 to less than 0.1 ton by 1999, with only marginal recovery to 0.25 tons by 2025. Similarly, total annual air pollutant removal declined from over 381 kg to less than 1 kg during the same period, while the annual economic value of ecosystem services dropped from more than USD 163,000 to under USD 400. Although limited restoration initiatives have slightly improved these indicators in recent years, the results demonstrate that the ecological functions of Nezamieh Garden remain critically compromised and far from their historical capacity.

Masoudieh Garden shows a comparatively more resilient but still fluctuating ecological trajectory. Tree-covered area decreased from 0.9 hectares in 1867 to 0.61 hectares in 1999, followed by partial recovery to 0.74 hectares in 2025. Correspondingly, annual carbon sequestration declined by approximately 32% during the period of maximum degradation and later increased by about 21% with recent restoration efforts. A similar pattern was observed in air pollutant removal, which dropped from

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nearly 885 kg to 600 kg before rising again to over 727 kg. Despite this improvement, the economic value of ecosystem services in 2025 remains notably lower than historical levels, indicating that current restoration measures have not fully restored ecological integrity or ecosystem service provision.

Scenario-based modeling highlights the substantial potential benefits of targeted vegetation expansion in both gardens. Increasing tree cover to 35% and 70% leads to marked improvements in carbon sequestration, air pollutant removal (particularly $PM_{2.5}$, PM_{10}, and O_3), and the economic value of ecosystem services. In both gardens, higher vegetation scenarios consistently outperform current conditions, with the 70% scenario yielding the greatest ecological and economic gains. These results confirm a strong, positive relationship between vegetation cover and ecological performance, underscoring the role of historic gardens as strategic green infrastructures capable of enhancing air quality, urban health, and quality of life in dense historic districts.

Survey findings further support the modeling results, revealing high public awareness of the links between vegetation loss, air pollution, and declining health and well-being. A majority of respondents strongly associate the degradation of historic gardens with increased air pollution, respiratory problems, and reduced quality of life, while emphasizing the necessity of governmental and municipal intervention for green space restoration. Together, the empirical data, modeling outcomes, and social perceptions provide convergent evidence that restoring and expanding vegetation cover in Masoudieh and Nezamieh gardens can play a critical role in improving environmental quality, public health, and environmental justice in the Baharestan area of Tehran.

Discussion and Conclusion

The results show that Masoudieh and Nezamieh historic gardens, despite differences in size and degradation, significantly influence environmental quality and public health in the Baharestan area. Severe vegetation loss in Nezamieh Garden has largely eliminated its ecological functions, illustrating the negative impacts of intensive urban development on historic green spaces. In contrast, Masoudieh Garden demonstrates that even moderately sized and partially preserved green areas can effectively improve air quality and support residents' physical and mental well-being.

Scenario-based modeling confirms that increasing vegetation cover substantially enhances ecosystem services in both gardens. Higher green coverage leads to reduced particulate matter concentrations, increased carbon sequestration, and lower respiratory-related health risks, with the 70% restoration scenario producing the greatest benefits. The findings emphasize that even degraded or small historic green spaces can yield meaningful health and environmental gains when properly restored.

Overall, the study highlights that restoring historic gardens is not only a heritage conservation measure but also a vital strategy for promoting public health, environmental justice, and sustainable urban development in dense and polluted historic districts.

Keywords : Nezamieh Garden; Masoudieh Garden; Air Pollution; Mortality Rate; Vegetation Cover