

GIS-BASED ASSESSMENT OF URBAN GREEN INFRASTRUCTURE IN TASHKENT

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Abstract. *This study focuses on the GIS-based assessment of Urban Green Infrastructure (UGI) in Tashkent, aiming to evaluate its spatial distribution, accessibility, and ecological effectiveness in the context of rapid urbanization. The research examines the role of green infrastructure in mitigating environmental challenges such as air pollution, urban heat island effects, and uneven distribution of green spaces. Using Geographic Information Systems (GIS) technologies, including spatial analysis and remote sensing techniques, the study integrates satellite imagery and vegetation indices such as NDVI to quantify and analyze urban greenery. The findings reveal significant spatial disparities in the distribution of green infrastructure, with central areas having relatively higher green coverage compared to peripheral districts. The study also highlights issues related to fragmentation and limited accessibility of green spaces, which reduce their ecological and social benefits. Based on GIS-based analysis, the research proposes strategic recommendations for improving the planning, connectivity, and sustainability of urban green infrastructure.*

Keywords: *Urban Green Infrastructure (UGI), Geographic Information Systems (GIS), spatial analysis, remote sensing, NDVI, urban sustainability, green space distribution, environmental management, urban ecology.*

Introduction

Rapid urbanization has significantly intensified environmental challenges in major cities, including Tashkent. Population growth, expansion of transport networks, and increasing industrial activity have contributed to rising air pollution, the urban heat island effect, and the reduction of green spaces. These challenges highlight the urgent need for sustainable urban planning strategies, among which Urban Green Infrastructure (UGI) plays a crucial role. Urban Green Infrastructure refers to a strategically planned network of natural and semi-natural areas such as parks, urban forests, green corridors, and water bodies that provide a wide range of ecosystem services. These include improving air quality, regulating urban microclimates, enhancing biodiversity, and supporting the physical and mental well-being of residents. In rapidly developing cities like Tashkent, the effective management and expansion of green infrastructure are essential for maintaining ecological balance and ensuring long-term urban sustainability.

In recent years, Geographic Information Systems (GIS), particularly tools such as ArcGIS and QGIS, have become indispensable in assessing and managing urban green infrastructure. GIS-based approaches enable spatial analysis, integration of remote sensing data, and evaluation of vegetation indices such as NDVI (Normalized Difference Vegetation Index). These techniques allow researchers to accurately map, quantify, and analyze the distribution and condition of green spaces across urban environments. The primary objective of this study is to conduct a GIS-based assessment of urban green infrastructure in Tashkent, evaluating its current spatial distribution,

accessibility, and ecological effectiveness. The research utilizes satellite imagery, geospatial datasets, and statistical analysis to examine the extent and quality of green areas in relation to population density and urban development patterns.

Relevance

The relevance of assessing Urban Green Infrastructure (UGI) using GIS technologies is increasing in rapidly urbanizing cities such as Tashkent. Accelerated population growth, land-use changes, and infrastructure expansion have led to the fragmentation and reduction of green spaces, negatively affecting ecological stability and public health. Urban areas are experiencing intensified environmental issues, including air pollution, increased surface temperatures, and reduced ecosystem services.

Objective

The main objective of this study is to evaluate the spatial distribution, quality, and ecological effectiveness of Urban Green Infrastructure in Tashkent using GIS-based methods.

Specifically, the study aims to:

- Analyze the spatial patterns and extent of green areas using geospatial data and remote sensing techniques;
- Assess vegetation health and density through indices such as NDVI;
- Evaluate accessibility of green spaces in relation to population distribution;
- Identify gaps and inequalities in the distribution of urban green infrastructure;
- Provide practical recommendations for improving green infrastructure planning and sustainable urban development.

The ultimate goal is to support evidence-based decision-making processes by integrating GIS technologies into urban environmental management and planning systems.

Main part

Urban Green Infrastructure (UGI) is recognized in contemporary scientific research as an integrated approach aimed at ensuring ecological sustainability within urban environments. It represents a network of natural and semi-natural elements interconnected across the city landscape, including parks, green spaces, urban forests, street trees, green corridors, and water bodies. These components function not as isolated units but as a cohesive ecological system that supports the overall functionality of the urban ecosystem. The theoretical foundation of UGI is closely linked to the concept of ecosystem services, which emphasizes the benefits that natural systems provide to human society.

Within this framework, green infrastructure contributes significantly to environmental regulation. Vegetated areas play a crucial role in carbon sequestration, oxygen production, and the reduction of airborne pollutants, thereby improving urban air quality. In addition, UGI helps regulate urban microclimates by lowering surface and air temperatures, particularly during warmer seasons, thus mitigating the urban heat island effect. Hydrologically, green spaces support water infiltration, reduce surface runoff, and enhance natural filtration processes, contributing to flood prevention and water resource management.

UGI also plays a vital role in supporting biodiversity by providing habitats for various plant and animal species, thereby maintaining ecological balance. From a social perspective, green infrastructure enhances public health by encouraging physical activity, reducing stress, and improving overall well-being. Moreover, it contributes to the aesthetic value of urban areas and increases their economic attractiveness. Urban Green Infrastructure represents a multidisciplinary

and integrated system that combines ecological, social, and economic dimensions. It serves as a fundamental component of sustainable urban development and provides a scientific basis for improving environmental quality and human well-being in cities.

The rapid pace of urbanization in modern cities has led to a significant increase in environmental challenges, making sustainable urban management a critical global concern. Cities such as Tashkent are experiencing intensified pressure on natural resources due to population growth, industrial expansion, and increased transportation activities. These processes have resulted in deteriorating air quality, reduction of green spaces, and growing environmental risks. One of the most prominent urban environmental issues is the urban heat island effect, where built-up areas experience significantly higher temperatures than surrounding rural regions. This phenomenon negatively impacts human health, increases energy consumption, and exacerbates climate-related risks. In this context, Urban Green Infrastructure serves as an effective mitigation strategy.

Green spaces contribute to improving air quality by absorbing pollutants and releasing oxygen, thereby creating a healthier urban environment. They also regulate temperature by providing shade and facilitating evapotranspiration processes. Furthermore, green infrastructure supports sustainable water management by enhancing infiltration and reducing the risk of urban flooding. Beyond environmental benefits, green infrastructure has important social implications. It provides recreational spaces, promotes physical activity, and enhances the quality of life for urban residents. The presence of accessible green areas is also associated with improved mental health and community well-being. The development and management of green infrastructure have become essential components of addressing environmental challenges in modern cities. Integrating UGI into urban planning strategies is crucial for achieving long-term sustainability and resilience.

Geographic Information Systems (GIS) are advanced technological tools designed for the collection, storage, analysis, and visualization of spatial data. GIS plays a crucial role in environmental and urban studies by enabling researchers to analyze complex spatial relationships and patterns. The system integrates various types of data, including satellite imagery, maps, and statistical datasets, into a unified analytical framework. The fundamental components of GIS include hardware, software, data, and users, all of which interact to facilitate spatial analysis and decision-making. From a theoretical perspective, GIS is grounded in disciplines such as cartography, geodesy, computer science, and spatial analysis. These interdisciplinary foundations allow GIS to support a wide range of applications in urban planning and environmental management.

In the context of urban green infrastructure, GIS is particularly valuable for assessing the spatial distribution, extent, and condition of green spaces. It enables the mapping and quantification of vegetation cover, identification of spatial inequalities, and evaluation of accessibility to green areas. Through techniques such as overlay analysis, buffer analysis, and spatial modeling, GIS provides insights that are essential for evidence-based planning. Furthermore, GIS supports predictive analysis and scenario modeling, allowing urban planners to simulate the impact of different development strategies. This capability enhances the effectiveness of decision-making processes and contributes to more sustainable urban management. GIS represents a powerful analytical framework that facilitates the integration of spatial data into urban

environmental studies. Its application in assessing green infrastructure provides valuable scientific insights and supports the development of sustainable and resilient cities.

Geographic Information System (GIS) platforms such as ArcGIS and QGIS are essential tools in the analysis and management of urban green infrastructure. These software systems enable the integration of multiple data sources, including satellite imagery, aerial photographs, land-use maps, and statistical datasets, into a unified analytical environment. Through this integration, researchers can perform detailed spatial analysis of green areas within urban landscapes. GIS tools allow for the identification, classification, and quantification of vegetation cover, making it possible to determine the extent and distribution of green infrastructure across different urban zones. Advanced analytical functions such as overlay analysis facilitate the comparison of multiple spatial layers, enabling the assessment of relationships between green spaces and other urban elements, such as population density or infrastructure development. Buffer analysis is particularly useful for evaluating accessibility, as it helps determine how easily residents can reach parks and green areas within a specified distance. Additionally, spatial statistics and modeling tools provide insights into patterns and trends, allowing for the identification of areas with insufficient green coverage.

ArcGIS offers a comprehensive suite of professional tools for large-scale and complex spatial analysis, while QGIS provides an open-source alternative with flexible customization options. Both platforms support visualization techniques that generate high-quality thematic maps, which are critical for communicating findings to policymakers and stakeholders. The application of GIS tools significantly enhances the accuracy, efficiency, and scientific validity of urban green infrastructure assessments. These technologies support evidence-based planning and contribute to the development of sustainable and environmentally resilient urban systems.

Remote sensing is a powerful technique that enables the observation and analysis of the Earth's surface without direct physical contact, primarily through satellite or aerial sensors. This technology plays a crucial role in monitoring environmental changes and assessing urban green infrastructure. By capturing data across different spectral bands, remote sensing provides detailed information about land cover, vegetation, and surface conditions. One of the most widely used indicators derived from remote sensing data is the Normalized Difference Vegetation Index (NDVI). NDVI is calculated using the reflectance values of near-infrared (NIR) and red light bands, which are sensitive to vegetation characteristics. Healthy vegetation reflects more NIR and absorbs more red light, resulting in higher NDVI values. The index typically ranges from -1 to +1, where values closer to +1 indicate dense and healthy vegetation, while lower values represent sparse or degraded vegetation. When integrated with GIS, NDVI allows for spatial and temporal analysis of vegetation patterns in urban areas. Researchers can monitor changes in green cover over time, detect areas experiencing vegetation loss, and evaluate the effectiveness of urban greening initiatives. Furthermore, remote sensing enables large-scale data collection, making it possible to assess entire cities or regions efficiently and cost-effectively. This approach also supports environmental decision-making by providing objective, quantifiable data on vegetation health and distribution. As a result, remote sensing and NDVI-based methods are indispensable tools in the scientific assessment and management of urban green infrastructure.

The current state of urban green infrastructure in Tashkent reflects a complex interaction between historical urban planning and recent patterns of rapid development. The city has traditionally been recognized for its tree-lined streets, parks, and green public spaces, which

contribute to its environmental quality and aesthetic appeal. However, in recent years, increasing urbanization and construction activities have placed significant pressure on these green resources. Spatial analysis reveals that green infrastructure in Tashkent is unevenly distributed across different districts. Central areas generally retain a higher concentration of parks and landscaped spaces, while peripheral and newly developed areas often lack sufficient green coverage. This disparity leads to environmental inequalities, affecting air quality, temperature regulation, and overall living conditions in different parts of the city. Moreover, the reduction of green spaces due to infrastructure expansion has contributed to the intensification of the urban heat island effect. Areas with limited vegetation tend to experience higher temperatures, reduced air quality, and lower levels of environmental comfort. At the same time, some existing green spaces are not efficiently maintained or integrated into a broader ecological network. GIS-based assessments provide valuable insights into these challenges by mapping green space distribution, identifying gaps, and evaluating accessibility for residents. Such analyses are essential for guiding urban planning strategies aimed at restoring ecological balance and enhancing sustainability. Tashkent still possesses significant green infrastructure assets, there is a clear need for strategic planning and management to ensure their preservation, equitable distribution, and long-term contribution to urban resilience.

The distribution of urban green infrastructure in relation to population density is a critical indicator of environmental equity and urban sustainability. In many rapidly developing cities, including Tashkent, green spaces are often unevenly distributed, leading to disparities in access among different social and spatial groups. Areas with high population density frequently experience a shortage of parks, recreational zones, and tree cover, which negatively affects both environmental conditions and public health. From a spatial analysis perspective, GIS-based studies reveal that per capita green space availability varies significantly across districts. In densely populated neighborhoods, limited land availability and intensive construction reduce opportunities for developing new green areas. As a result, residents in these zones are more exposed to air pollution, higher temperatures, and reduced environmental comfort. Conversely, less populated or historically planned districts tend to have better access to green infrastructure, creating an imbalance in urban ecological benefits.

Another major challenge is the fragmentation of green spaces. Instead of forming an interconnected ecological network, many green areas exist as isolated patches, which reduces their effectiveness in supporting biodiversity and regulating urban climate. Accessibility is also a key issue, as not all residents can easily reach green areas within a reasonable walking distance. Socio-economic factors further influence the distribution of green infrastructure, often resulting in unequal environmental conditions between different communities. These disparities highlight the need for integrated planning approaches that prioritize equitable access to green spaces. Addressing these challenges requires the use of spatial analysis tools to identify underserved areas and implement targeted interventions. Ensuring balanced distribution of green infrastructure is essential for improving urban resilience, environmental quality, and overall quality of life.

The application of Geographic Information Systems (GIS) provides a powerful framework for developing effective strategies to improve and expand urban green infrastructure. By utilizing spatial data and analytical tools, planners and researchers can identify priority areas for greening, optimize land use, and design interconnected ecological networks. GIS enables evidence-based decision-making, ensuring that interventions are both efficient and sustainable. One of the key

strategies involves the identification of areas with insufficient green coverage through spatial gap analysis. This allows urban planners to prioritize regions where new parks, green corridors, or urban forests should be developed. Additionally, GIS can be used to evaluate accessibility by analyzing walking distances and transportation networks, ensuring that all residents have convenient access to green spaces.

Another important approach is the integration of green infrastructure into existing urban systems. This includes the development of green roofs, vertical gardens, and roadside vegetation, particularly in densely built environments where space is limited. GIS-based modeling can simulate different planning scenarios, helping to assess the environmental impact of proposed projects before implementation. GIS supports long-term monitoring and management of green infrastructure by tracking changes in vegetation cover and environmental conditions over time. This allows for adaptive management strategies that respond to evolving urban dynamics. GIS-based approaches play a crucial role in enhancing the planning, development, and sustainability of urban green infrastructure. By integrating spatial analysis with environmental and socio-economic data, cities can create more resilient, equitable, and environmentally sustainable urban landscapes.

Conclusion

This study demonstrates that Urban Green Infrastructure (UGI) plays a fundamental role in ensuring ecological sustainability, improving environmental quality, and enhancing the overall well-being of urban populations. In rapidly developing cities such as Tashkent, increasing urbanization has intensified environmental challenges, including air pollution, rising temperatures, and uneven distribution of green spaces. These issues highlight the necessity of integrating green infrastructure into urban planning as a strategic response to modern environmental pressures. The research confirms that the application of Geographic Information Systems (GIS) provides a scientifically robust and efficient approach for assessing, monitoring, and managing urban green infrastructure. Through spatial analysis, remote sensing integration, and indicators such as NDVI, GIS enables accurate evaluation of green space distribution, accessibility, and ecological performance. This allows for the identification of spatial inequalities and supports evidence-based decision-making processes.

Findings indicate that while Tashkent possesses significant green infrastructure assets, their distribution remains uneven, with certain densely populated areas lacking adequate access to green spaces. Additionally, fragmentation of green areas reduces their ecological effectiveness and limits their capacity to provide essential ecosystem services. These challenges underscore the need for more coordinated and data-driven planning strategies. To address these issues, the study emphasizes the importance of GIS-based planning approaches that prioritize equitable distribution, connectivity, and sustainability of green infrastructure. The integration of innovative solutions such as green corridors, urban forestry, and nature-based designs can significantly enhance environmental resilience and urban livability.

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