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Article

Assessing the Dynamics of Green Areas in Tashkent Using Satellite Imagery and Ways to Preserve Them

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Abstarct: This article examines the formation, spatial distribution, and long-term change of green areas in Tashkent using satellite imagery. Population growth, intensifying construction, the expansion of transport infrastructure, and other anthropogenic pressures are directly affecting the condition of green spaces in the city. Remote sensing and geographic information systems (GIS) are of great scientific and practical importance for identifying these processes. The study considers the potential of Landsat and Sentinel-2 satellite imagery, the Normalized Difference Vegetation Index (NDVI), and GIS technologies, and it summarizes the available evidence on green cover and its cooling role in Tashkent. In addition, proposals are developed for protecting green areas, expanding their extent, and ensuring ecological sustainability.

Keywords: Tashkent city, green areas, satellite imagery, remote sensing, geographic information systems, NDVI, Landsat, Sentinel-2, urbanization, ecological monitoring, green infrastructure, GPS, GNSS, urban ecology.

1. Introduction

Today, the intensification of urbanization in the world's large cities is increasing pressure on the natural environment. As a result of population growth and the construction of new residential areas, industrial facilities, and transport routes, natural green areas are shrinking, and certain changes are occurring in the ecological balance of cities. A study of European cities, for example, showed that the amount of green space per inhabitant declined in many cities as they became denser [1]. Under these conditions, preserving green areas and using them rationally is one of the key priorities of urban planning policy.

The city of Tashkent is no exception to these processes. The expansion of construction and urban improvement works in the capital, changes in land use, and the high air temperatures observed in the summer months are further increasing the ecological importance of green spaces. At the national level, this importance is reflected in Presidential Decree No. PF-199 of 23 November 2023, which aims to increase the level of greenery throughout the country through the nationwide “Yashil makon” (“Green Space”) project [2].

Green areas not only improve the aesthetic appearance of a city but also play an important role in reducing airborne dust, absorbing carbon dioxide, producing oxygen, lowering noise, and regulating the microclimate. A systematic review of the empirical evidence found that urban parks are, on average, cooler than surrounding non-green areas during the day [3]. Urban trees and shrubs also remove substantial quantities of air pollutants [4]. Access to urban green space has further been associated with a range of benefits for physical and mental health [5]. In particular, the large crowns of trees limit the amount of direct sunlight reaching the ground in summer, helping to create a cooler environment. In a 2024 study, Mukhamedjanov, Isamukhamedova, and Tang examined the microclimatic characteristics of 30 green areas in Tashkent and found that the cooling effect was stronger in places where tree shade covered more than 75 percent of the area [6]. For this reason, it is necessary to study systematically not only the existing area of green spaces but also their condition, density, location, and how they change over time.

Today, satellite imagery makes it possible to monitor large areas in a short time, compare images from different years, and map changes in green cover. Vegetation indices derived from satellite data, above all the Normalized Difference Vegetation Index (NDVI), have become a standard tool for assessing the response of vegetation to environmental change [7]. This supports a scientifically grounded assessment of green areas in Tashkent and the adoption of effective decisions on their protection. One of the main problems related to preserving green areas in Tashkent is the shrinking of some green spaces as a result of construction and the expansion of urban infrastructure, along with changes in the ecological condition of existing tree stands.

When studying this problem, special attention should be paid to the following issues:

- determining the current state of green areas in the city of Tashkent;
- assessing the dynamics of change in green areas by comparing satellite images from different years;
- determining the impact of construction, road infrastructure, and other anthropogenic factors on green cover;
- assessing the density and condition of vegetation cover using the NDVI index;
- identifying areas where green spaces have decreased or become ecologically weakened;
- developing proposals for preserving existing green areas and establishing new green spaces.

Another important aspect of the problem is that assessing the condition of green areas through ground-based observations alone does not make it possible to detect all changes. In some areas, a decrease in the number of trees, a thinning of vegetation cover, or the replacement of green spaces with built structures may go unnoticed for a long time. For this reason, the combined use of remote sensing data and geographic information systems (GIS) is one of the effective solutions to this problem.

The aim of this study is to develop and substantiate a satellite-based approach for assessing the dynamics of green areas in Tashkent, to summarize the available quantitative evidence on green cover and its ecological role in the city, and to propose measures for preserving and expanding Tashkent’s green spaces.

2. Materials and Methods

2.1. Study area and research design

The study area is the city of Tashkent within its official administrative boundaries. The research combines two components: a synthesis of published studies on the green cover and microclimate of Tashkent, and the design of a reproducible remote sensing and GIS workflow for long-term monitoring of the city's green areas. Published studies were included if they used satellite imagery, the NDVI, or field microclimatic measurements for Tashkent or the Tashkent region. For each study, the area covered, the years and data sources used, the method, and the main quantitative results were extracted and compared.

2.2. Satellite data

Open data from the Landsat 8, Landsat 9, and Sentinel-2 satellites can be used for the study. Landsat 8 carries the Operational Land Imager, which continues the long Landsat record of multispectral observations at a spatial resolution of 30 m [8]. Landsat imagery is therefore convenient for comparing long-term changes. Sentinel-2 provides multispectral imagery with several spectral bands at a spatial resolution of 10 m and a short revisit time [9]. The main technical characteristics of the mission are summarized by the European Space Agency [10]. The 10 m resolution of Sentinel-2 provides an important opportunity for identifying green cover within the urban area.

To obtain the data, it is recommended to use the following platforms:

- USGS EarthExplorer;
- Copernicus Data Space Ecosystem;
- Google Earth Engine.

Google Earth Engine also makes it possible to process large collections of images in the cloud without downloading individual scenes [11]. Atmospherically corrected surface reflectance products (Landsat Collection 2 Level-2 and Sentinel-2 Level-2A) should be used so that images from different dates are radiometrically comparable. Clouds and cloud shadows should be masked using the quality bands supplied with the products or an automated algorithm such as Fmask [12]. To limit the influence of seasonal differences, images should be selected from the same phase of the growing season, preferably the summer months when deciduous trees are in full leaf, and with minimal cloud cover over the city.

2.3. Calculation of the NDVI vegetation index

The NDVI is used to determine the condition of green areas. The index was proposed in the 1970s for monitoring vegetation from satellite data [13]. Its physical basis is the strong contrast between the absorption of red light by chlorophyll and the high reflectance of near-infrared radiation by the internal structure of leaves [14]. NDVI is calculated using the following formula:

$$NDVI = (NIR - RED) / (NIR + RED)$$

Here, NIR is the reflectance value in the near-infrared part of the spectrum, and RED is the reflectance value in the red part of the spectrum. For Landsat 8 and Landsat 9, NDVI is calculated from band 5 (near-infrared) and band 4 (red) [15]. For Sentinel-2, the corresponding bands are band 8 and band 4. NDVI values range from −1 to +1. High positive values most often indicate dense and healthy vegetation cover, while low values represent sparse vegetation or surfaces with no vegetation. In sparsely vegetated parts of the city, where the soil background strongly affects reflectance, soil-adjusted indices such as the SAVI can be used as a complement to the NDVI [16].

2.4. Classification of green cover and accuracy assessment

To convert continuous NDVI values into green-cover classes, threshold values are applied, and pixels are grouped into non-vegetated surfaces and areas of low, moderate, and high greenness. The threshold values should be calibrated for Tashkent using reference points rather than adopted from other regions without verification. The accuracy of the resulting maps should be assessed with independent reference points interpreted from very-high-resolution imagery and checked in the field, and reported as a confusion matrix with overall, user's, and producer's accuracies [17]. The areas of change should be

estimated with error-adjusted area estimators and confidence intervals rather than by simple pixel counting [18].

2.5. Analysis using GIS technologies

The acquired satellite images are processed in ArcGIS or QGIS. In this process, the study area is extracted based on the administrative boundaries of the city of Tashkent, cloud-covered portions of the images are removed, and NDVI maps are produced. Subsequently, maps from different years are compared with one another to determine the expansion and shrinkage of green areas and the directions of their change. The results are also summarized by administrative district so that changes can be linked to the bodies responsible for managing green spaces.

2.6. Dynamic analysis

To assess the dynamics of green areas, satellite images from 2015, 2020, 2022, and 2025 that belong to the same vegetation season can be compared. In this process, the following indicators are taken into account:

- the total area of green cover;
- the share of areas with high NDVI values;
- areas where vegetation cover has decreased;
- newly established green areas;
- the spatial distribution of green areas.

The change in green area between two dates is calculated as $\Delta A = A_2 - A_1$, and the relative change as $\Delta A\% = (A_2 - A_1) / A_1 \times 100$, where A_1 and A_2 are the areas of green cover in the earlier and later years. A pixel-by-pixel comparison of classified maps produces a change matrix that shows which areas remained green, which were converted to built-up or bare surfaces, and which became newly green. To link changes in green cover with the thermal environment of the city, the thermal infrared band of Landsat can also be used to derive land surface temperature and to examine its relationship with NDVI [19].

2.7. Comparative and cartographic analysis

Based on the results of the study, green cover maps of Tashkent for different years are compiled. These maps make it possible to identify changes in green areas, ecologically vulnerable places, and areas in need of protection. The map layers are combined with data on new construction and road projects to identify the anthropogenic factors associated with the loss of green cover.

3. Results

3.1. Evidence on green cover and microclimate in Tashkent

The use of satellite imagery and GIS makes it possible to carry out a comprehensive assessment of the condition of green areas in Tashkent, and the studies available for the city confirm the practical significance of this approach. In 2026, Pulatov, Aminov, and Xakimova examined the green cover of Yakkasaray district using NDVI and GIS technologies and Sentinel-2 images from 2020, 2022, and 2024 [20]. They report that the share of low-greenness areas rose from 57 percent in 2020 to 61 percent in 2024, while the share of high-greenness areas fell from 9 percent to 8 percent. An NDVI-based assessment of the dynamics of green cover has also been carried out for the Mirzo Ulugbek and Yangihayot districts [21]. At the regional scale, NDVI indicators have been used to assess the natural geographical conditions and vegetation dynamics of the Tashkent region [22].

The study by Mukhamedjanov, Isamukhamedova, and Tang discussed in the Introduction provides field evidence of the ecological role of green areas in the city. Based on observations of 30 green areas, the authors showed that tree shade is decisive for summer cooling, with the strongest effect where shade covers more than 75 percent of a site. The main characteristics of these studies are summarized in Table 1.

Table 1. Published studies on green cover and microclimate in Tashkent

Study	Area	Data and method	Main result
Pulatov, Aminov, Xakimova (2026)	Yakkasaray district	Sentinel-2 (2020, 2022, 2024); NDVI and GIS	Low-greenness areas rose from 57% to 61%; high-greenness areas fell from 9% to 8%
Aminov, Xakimova, Aminova (2026)	Mirzo Ulugbek and Yangihayot districts	NDVI-based assessment of green-cover dynamics	Dynamics of green cover assessed under climate change conditions
Shariatov, Samatova (2025)	Tashkent region	NDVI indicators	Vegetation dynamics and natural geographical conditions assessed
Mukhamedjanov, Isamukhamedova, Tang (2024)	30 green areas in Tashkent	Field microclimatic observations	Cooling effect strongest where tree shade covers more than 75% of the site

The Yakkasaray results show a shift towards lower greenness over four years, which illustrates the need to monitor spatial changes in green cover regularly. However, these figures cannot be generalized to the whole of Tashkent, because they are specific to a particular district, period, and research methodology.

3.2. Proposed monitoring framework

On the basis of the methods described above, a monitoring framework for Tashkent is proposed that produces four types of output. The first is a series of NDVI maps for 2015, 2020, 2022, and 2025 for the same season. The second is a set of classified green-cover maps with documented thresholds and accuracy assessments. The third is a set of change indicators, namely the absolute and relative change in green area, the share of high-greenness areas, and the areas of loss and gain, calculated for the whole city and for each district. The fourth is a map of hotspots where green cover has been lost or weakened, which identifies the areas that require priority protection or restoration.

Based on the analysis, the following results can be identified. First, satellite imagery makes it possible to detect changes in green areas over the years and to map their extent. Second, the NDVI index makes it possible to detect changes in the density and condition of vegetation cover. Third, GIS technologies make it possible to identify places where green areas are shrinking, analyze their location, and create ecological monitoring maps. Fourth, the ecological effectiveness of green areas is determined not only by their size but also by the species, age, crown structure, location, and maintenance condition of the trees. Fifth, combining remote sensing results with field observations increases the accuracy and reliability of the assessment.

4. Discussion

The available evidence suggests that green areas in Tashkent are under pressure, at least in the central districts that have been studied. The increase in the share of low-greenness areas in Yakkasaray between 2020 and 2024 is consistent with the experience of other densifying cities, where new construction often occupies former green spaces and reduces the amount of green space per inhabitant. At the same time, district-level results cannot be extrapolated to the whole city, because Tashkent's districts differ in building density, the age of their tree stands, and the scale of new development. A city-wide assessment using a consistent method is therefore needed before firm conclusions about the overall trend can be drawn.

The loss or thinning of green cover has consequences that go beyond the reduction of area. The Tashkent field evidence shows that summer cooling depends strongly on tree shade, which means that replacing mature trees with young saplings or lawns cannot

restore the microclimatic function quickly. Studies of urban heat islands have similarly found that land surface temperature decreases as vegetation abundance increases, which supports the combined use of NDVI and thermal data proposed in this study. The air-quality and health benefits of green spaces described in the Introduction also depend largely on mature trees with large crowns. For these reasons, the protection of existing tree stands should be given higher priority than the number of new plantings.

The method also has limitations that must be taken into account when interpreting the results. NDVI tends to saturate in dense vegetation, so it may not distinguish between moderately dense and very dense tree canopies. At a resolution of 10–30 m, many urban pixels are mixed and contain trees, roofs, roads, and lawns at the same time, which makes it difficult to detect individual street trees and small green spaces. NDVI values are also affected by the season, irrigation, and drought, so comparisons between years are reliable only when images from the same phenological period are used. Finally, NDVI does not directly show the species, age, or health of trees, and these attributes require field inventories.

From a policy perspective, the results support a shift from counting planted saplings to monitoring outcomes. The "Yashil makon" project has created a framework for large-scale planting, but its long-term ecological effect depends on the survival and growth of the planted trees and on the protection of existing mature stands. A regularly updated, satellite-based monitoring system with field validation would allow the city authorities to track both. Such a system could be integrated into urban planning documents, used when construction permits are issued, and made publicly accessible so that residents can follow changes in their own neighborhoods.

Specifically, the following measures can be proposed: establishing a digital inventory of green spaces and individual trees; restricting the felling of mature trees to cases justified by an expert assessment; requiring compensatory planting with species adapted to local climatic conditions and available irrigation; maintaining the irrigation network that supplies street trees; creating green corridors that link parks with river and canal banks; and carrying out annual satellite-based monitoring with publication of the results. Future research should apply the proposed workflow to the whole city for 2015–2025, validate the classification with field data, and combine NDVI with land surface temperature and population data to identify districts where a shortage of green space and heat stress coincide.

5. Conclusion

Assessing the dynamics of green areas in Tashkent using satellite imagery is a modern and effective approach to studying the city's ecological condition, because Landsat and Sentinel-2 imagery, the NDVI vegetation index, and GIS technologies make it possible to determine the spatial distribution of green cover and its change over time. The available studies show a decline in greenness in Yakkasaray district between 2020 and 2024 and confirm that tree shade is decisive for summer cooling in the city, although district-level results cannot yet be generalized to the whole of Tashkent. The proposed workflow, which combines same-season image selection, cloud masking, calibrated NDVI classes, accuracy assessment, change indicators, and hotspot mapping, provides a reproducible basis for city-wide monitoring. Preserving green areas in Tashkent should not be limited to planting saplings; it should go hand in hand with protecting existing mature trees, assessing their ecological condition, and introducing regular satellite-based monitoring that makes it possible to detect negative changes at an early stage and ensure the ecological sustainability of the city.

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