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# ECO-GEOGRAPHICAL MAPPING OF URBAN GREEN BIOMASS DYNAMICS USING NDVI, EVI, AND LAND SURFACE TEMPERATURE: A CASE STUDY OF TASHKENT

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**Abstract**

Urban green biomass plays a critical role in regulating the ecological and thermal environment of rapidly urbanizing cities. This study aims to assess the spatio-temporal dynamics of urban green biomass and its relationship with land surface temperature (LST) in Tashkent using remote sensing techniques. Multispectral satellite data from Landsat 8/9 were processed within the Google Earth Engine platform for the period 2015–2025. Vegetation indices, including the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), were calculated to quantify green biomass distribution and dynamics. Additionally, LST was derived to evaluate the thermal environment of the study area. The results indicate a general decreasing trend in NDVI and EVI values over the study period, suggesting a gradual reduction in urban green biomass. In contrast, LST exhibits an increasing trend, highlighting intensifying urban heat island effects. The correlation analysis between NDVI and LST reveals a negative relationship ($R^2 \approx 0.10$), indicating that areas with higher vegetation density tend to have lower surface temperatures. However, the relatively weak correlation suggests that additional factors, such as urban structure and land use patterns, also influence thermal dynamics. The findings demonstrate the importance of integrating vegetation indices and thermal data for urban ecological monitoring and provide valuable insights for sustainable urban planning and green infrastructure development.

**Key words:** Urban green biomass, NDVI, EVI, Land Surface Temperature (LST), Urban Heat Island (UHI), Remote sensing, Google Earth Engine, Spatio-temporal analysis, Tashkent.

**Аннотация**

Зеленая биомасса городской территории играет важную роль в формировании экологического и теплового режима быстро урбанизирующихся городов. В данной работе проведена оценка пространственно-временной динамики зеленой биомассы и ее взаимосвязи с температурой поверхности земли (LST) на примере Tashkent с использованием методов дистанционного зондирования. Исследование выполнено на основе спутниковых данных Landsat 8/9 за период 2015–2025 гг. в среде Google Earth

Engine. Для оценки состояния растительности были использованы индексы NDVI и EVI, а также рассчитана температура поверхности земли. Результаты показали снижение значений NDVI и EVI, что свидетельствует о сокращении зеленой биомассы. Одновременно наблюдается рост LST, отражающий усиление эффекта городского теплового острова. Корреляционный анализ выявил отрицательную зависимость между NDVI и LST ($R^2 \approx 0,10$), что указывает на охлаждающий эффект растительности. Однако слабая корреляция свидетельствует о влиянии дополнительных факторов, таких как структура застройки и типы землепользования. Полученные результаты подчеркивают важность комплексного использования спектральных и тепловых данных для мониторинга городской среды и поддержки устойчивого градостроительного планирования.

Ключевые слова: Зеленая биомасса, NDVI, EVI, Температура поверхности земли (LST), Городской тепловой остров, Дистанционное зондирование, Пространственно-временной анализ, Ташкент.

## 1. Introduction

Urbanization has significantly transformed natural landscapes, leading to the reduction of vegetation cover and alteration of ecological processes in cities worldwide. The rapid expansion of built-up areas often results in the degradation of urban green spaces and contributes to environmental challenges such as increased land surface temperature and the formation of urban heat islands (UHI) (Oke, 1982; Voogt & Oke, 2003).

Vegetation plays a crucial role in regulating urban microclimates by reducing surface temperatures through evapotranspiration and shading effects (Gill et al., 2007). Therefore, monitoring the dynamics of urban green biomass is essential for understanding ecological sustainability and climate resilience in cities. Remote sensing techniques have become a powerful tool for analyzing vegetation and thermal characteristics due to their ability to provide continuous spatial and temporal data (Weng, 2009).

Among vegetation indices, the Normalized Difference Vegetation Index (NDVI) is widely used to assess vegetation health and density (Rouse et al., 1974). However, NDVI may be sensitive to soil background and atmospheric conditions, especially in urban and semi-arid environments. To address these limitations, the Enhanced Vegetation Index (EVI) has been introduced, offering improved sensitivity in areas with high biomass and better correction for atmospheric influences (Huete et al., 2002).

Land Surface Temperature (LST) derived from thermal satellite data is a key parameter for analyzing the thermal environment of urban areas and detecting UHI effects (Weng et al., 2004). The relationship between vegetation indices and LST has been extensively studied, revealing a generally negative correlation, where higher vegetation density is associated with lower surface temperatures (Zhou et al., 2011).

Despite numerous global studies, there is still limited research focusing on Central Asian cities, particularly Tashkent, where rapid urban growth and climatic conditions create unique environmental challenges. Therefore, this study aims to (1) analyze the spatio-temporal dynamics of urban green biomass using NDVI and EVI, (2) assess LST variations, and (3) investigate the relationship between vegetation and thermal patterns using correlation analysis.

## 2. Methodology

### 2.1 Study Area

The study was conducted in Tashkent, the capital of Uzbekistan, characterized by a continental climate with hot summers and relatively low precipitation. Rapid urban expansion and increasing anthropogenic pressure have significantly influenced the spatial distribution of vegetation and thermal conditions within the city.

### 2.2 Data Sources

This study utilized multispectral and thermal satellite data from the Landsat 8 and Landsat 9 missions (Collection 2, Level 2), accessed via the Google Earth Engine (GEE) cloud computing platform. The analysis covered the period from 2015 to 2025, focusing on the summer season (June–August) to capture peak vegetation activity and maximum surface temperature conditions. Surface reflectance data were used to compute vegetation indices, while thermal infrared bands were used to derive Land Surface Temperature (LST). All datasets were preprocessed using standard scaling factors provided by the dataset.

### 2.3 Image Preprocessing

Clouds, cloud shadows, and cirrus effects were removed using the QA_PIXEL quality assessment band. Only cloud-free pixels were retained for further analysis. Surface reflectance values were scaled according to Landsat specifications, and thermal bands were converted from digital numbers to temperature values in degrees Celsius. Annual composite images were generated using the median reducer to minimize noise and residual atmospheric effects.

### 2.4 Vegetation Indices Calculation

To assess urban green biomass, two widely used vegetation indices were calculated:

NDVI (Normalized Difference Vegetation Index)

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

NDVI was used to evaluate vegetation density and spatial distribution.

EVI (Enhanced Vegetation Index)

$$EVI = 2.5 \cdot \frac{NIR - Red}{NIR + 6 \cdot Red - 7.5 \cdot Blue + 1}$$

EVI provides improved sensitivity in areas with dense vegetation and reduces atmospheric and soil background effects.

2.5 Land Surface Temperature (LST) Retrieval

Land Surface Temperature was derived from the Landsat thermal infrared band (ST_B10) using the standard scaling and conversion formula:

$$LST(^{\circ}C) = DN \cdot 0.00341802 + 149.0 - 273.15$$

This allowed the estimation of spatial temperature variations across the urban environment.

2.6 Temporal Analysis

Annual median values of NDVI, EVI, and LST were calculated for each year from 2015 to 2025. Time-series analysis was performed to identify trends in vegetation dynamics and thermal conditions. Linear regression was applied to evaluate the direction and magnitude of changes over time.

2.7 Correlation Analysis

To investigate the relationship between vegetation and temperature, a pixel-wise Pearson correlation analysis was conducted between NDVI and LST. Additionally, scatter plot analysis at the city level was performed to quantify the strength of the relationship. The coefficient of determination ($R^2$) was used to assess the explanatory power of vegetation indices in predicting temperature variations.

2.8 Statistical Analysis and Visualization

All spatial analyses were performed in Google Earth Engine, while statistical summaries and visualization (time-series graphs and scatter plots) were generated using built-in charting tools. The results were exported for further interpretation and presentation.

**3. Results and discussion**

3.1 Spatio-Temporal Dynamics of Vegetation Indices

The temporal analysis of vegetation indices reveals a gradual decline in urban green biomass in Tashkent during the study period (2015–2025). The annual mean NDVI decreased from approximately 0.31 in 2015 to 0.24 in 2025, while EVI exhibited a similar trend, declining from 0.22 to 0.17.

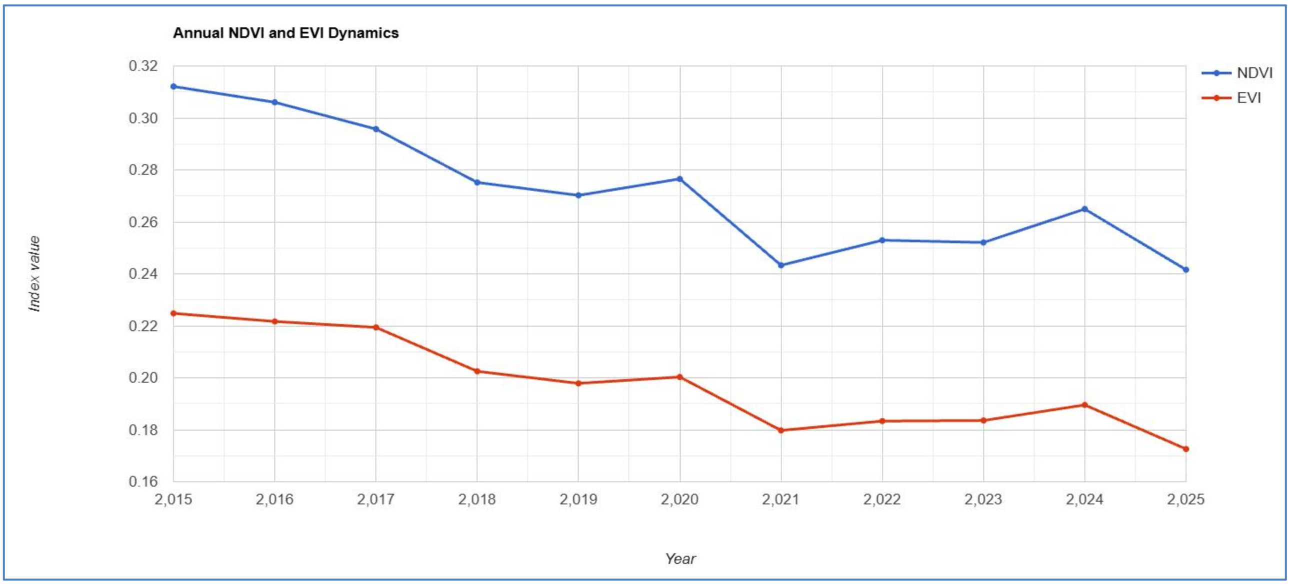


**Figure 1.** Annual dynamics of NDVI and EVI in Tashkent from 2015 to 2025. Both indices demonstrate a decreasing trend, indicating a gradual decline in urban green biomass. Temporal fluctuations reflect changes in vegetation cover associated with urban development and environmental factors.

This consistent reduction in both indices indicates a progressive loss of vegetation cover, likely associated with urban expansion, land-use transformation, and increasing anthropogenic pressure. The sharper decline observed between 2017 and 2021 suggests a period of intensified urban development or environmental stress.

These findings are consistent with previous studies demonstrating that urbanization leads to fragmentation and reduction of green spaces, particularly in rapidly developing cities (Weng, 2009; Seto et al., 2012). The observed patterns also align with research indicating that vegetation indices are effective indicators of urban ecological degradation (Zhang et al., 2013).

3.2 Land Surface Temperature (LST) Dynamics

The analysis of Land Surface Temperature shows a general increasing trend, with values rising from approximately 44.3°C in 2015 to over 46.0°C in 2025. This increase highlights the intensification of the Urban Heat Island (UHI) effect in the study area.

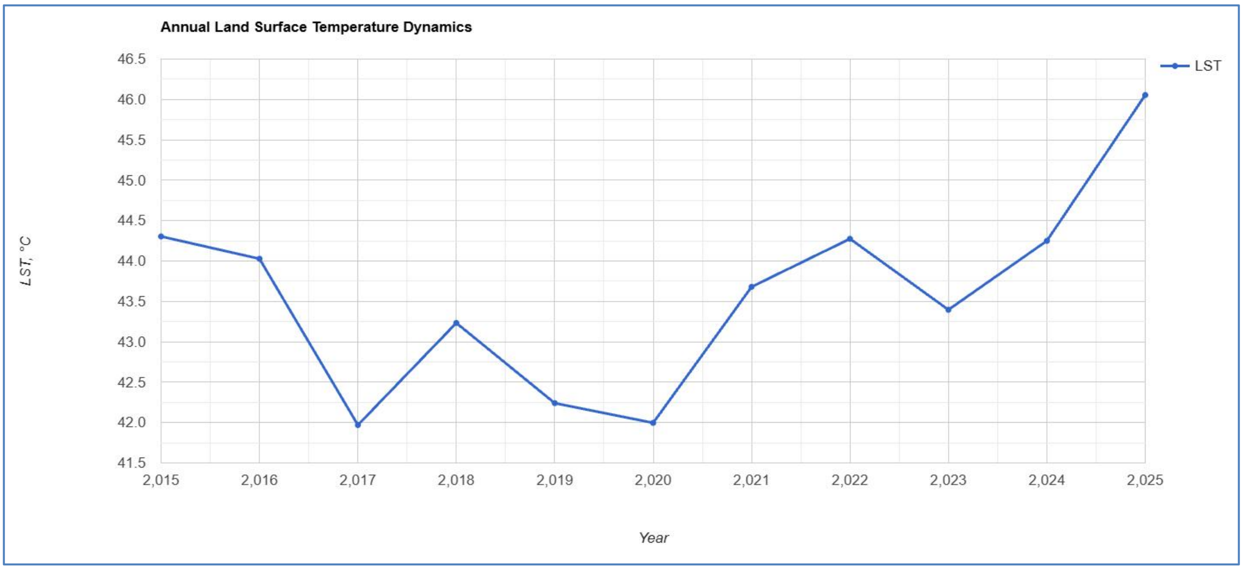


**Figure 2.** Annual variation of Land Surface Temperature (LST) in Tashkent from 2015 to 2025. The increasing trend highlights the intensification of the urban heat island effect, with higher temperatures observed in recent years.

Notably, the temporal fluctuations in LST correspond inversely with vegetation dynamics. Periods of lower NDVI/EVI values tend to coincide with higher LST, indicating reduced cooling capacity of the urban landscape. The lowest LST values were observed around 2017–2020, which corresponds to relatively higher vegetation levels during those years.

These results are consistent with established findings that vegetation plays a critical role in regulating surface temperature through evapotranspiration and shading mechanisms (Oke, 1982; Gill et al., 2007). The increasing LST trend suggests that the loss of urban greenery is contributing to thermal stress within the city.

3.3 Relationship Between Vegetation and Temperature

The relationship between vegetation and thermal conditions was evaluated using correlation analysis between NDVI and LST. The results indicate a negative linear relationship, with a coefficient of determination of approximately $R^2 \approx 0.097$.

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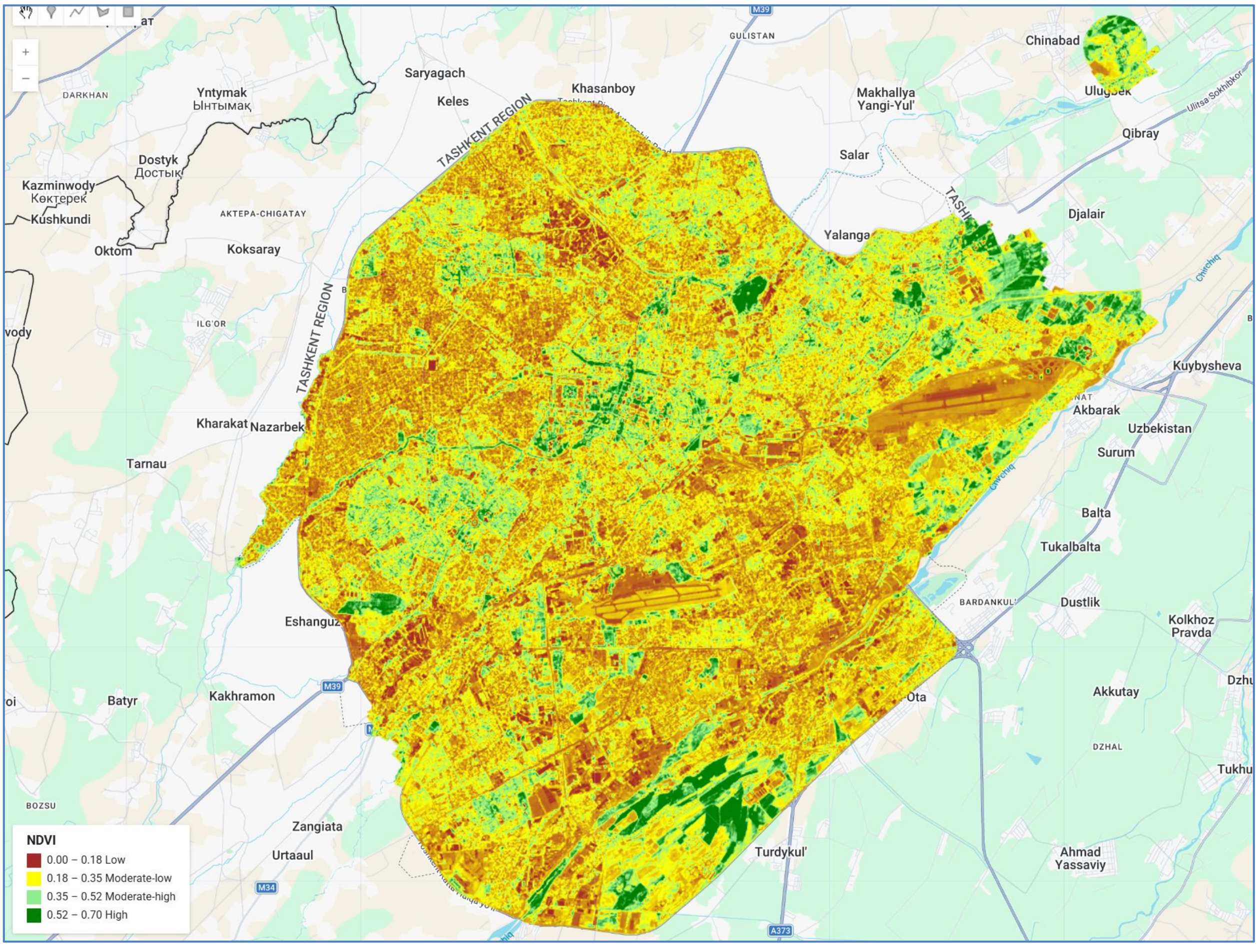


**Figure 3.** Relationship between NDVI and Land Surface Temperature (LST) in Tashkent during the summer season (2015–2025). The scatter plot shows a negative linear relationship, indicating that areas with higher vegetation density tend to exhibit lower surface temperatures. The fitted regression line ($R^2 \approx 0.097$) suggests a weak but consistent inverse correlation between vegetation cover and thermal conditions.

Although the correlation is relatively weak, the negative slope confirms that higher vegetation density is associated with lower surface temperatures, supporting the well-established cooling effect of vegetation. Similar relationships have been widely reported in urban climate studies (Zhou et al., 2011; Li et al., 2014).

The relatively low $R^2$ value suggests that LST variability cannot be explained solely by vegetation indices, and other factors must be considered. These include:

- Urban morphology (building density and height)
- Surface materials (asphalt, concrete)
- Anthropogenic heat emissions
- Spatial heterogeneity of land use

This observation is consistent with previous studies indicating that urban thermal dynamics are influenced by multiple interacting factors beyond vegetation cover alone (Voogt & Oke, 2003).

3.4 Spatial Patterns of Urban Green Biomass and Thermal Environment

Spatial analysis further confirms the inverse relationship between vegetation and temperature. Areas with higher NDVI and EVI values, such as parks and peripheral green zones, exhibit lower LST, while densely built-up areas show elevated temperatures.

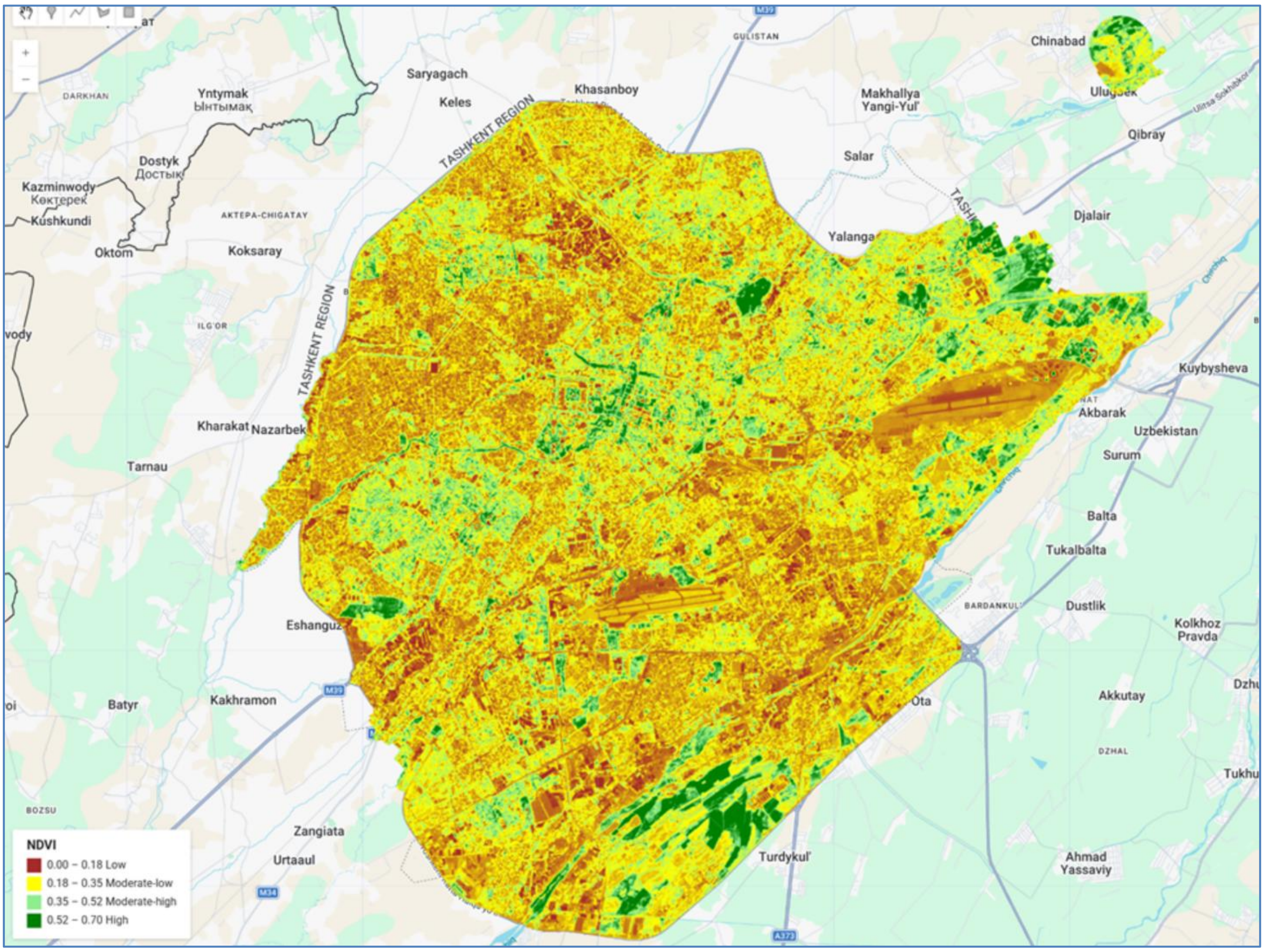


**Figure 4.** Spatial distribution of NDVI in Tashkent for the year 2025. Higher NDVI values (green tones) correspond to dense vegetation areas, while lower values (brown–yellow tones) indicate sparse vegetation or built-up surfaces.

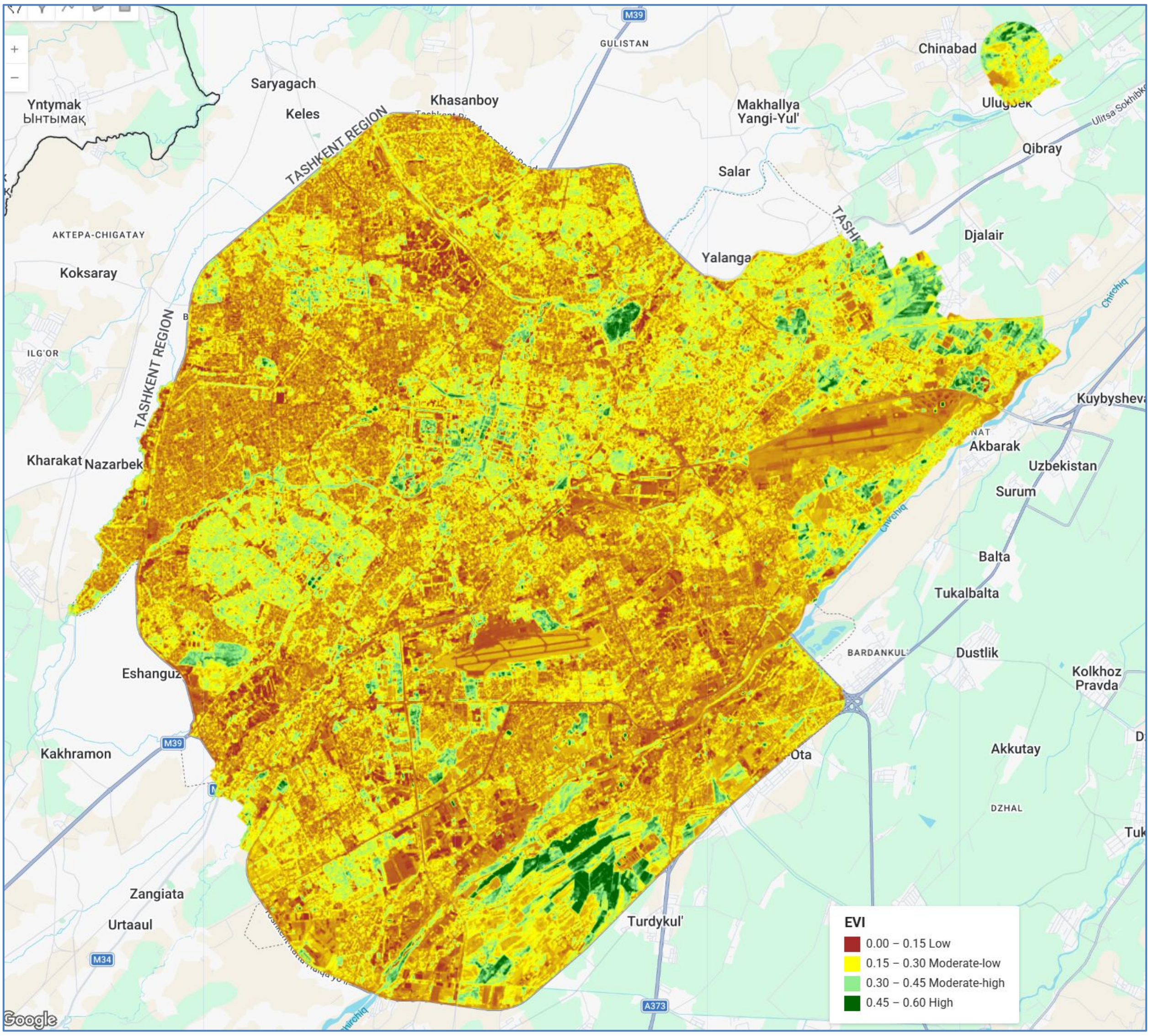


**Figure 5.** Spatial distribution of EVI in Tashkent for 2025. The map highlights vegetation structure with improved sensitivity in high biomass areas compared to NDVI, allowing better discrimination of urban green spaces.

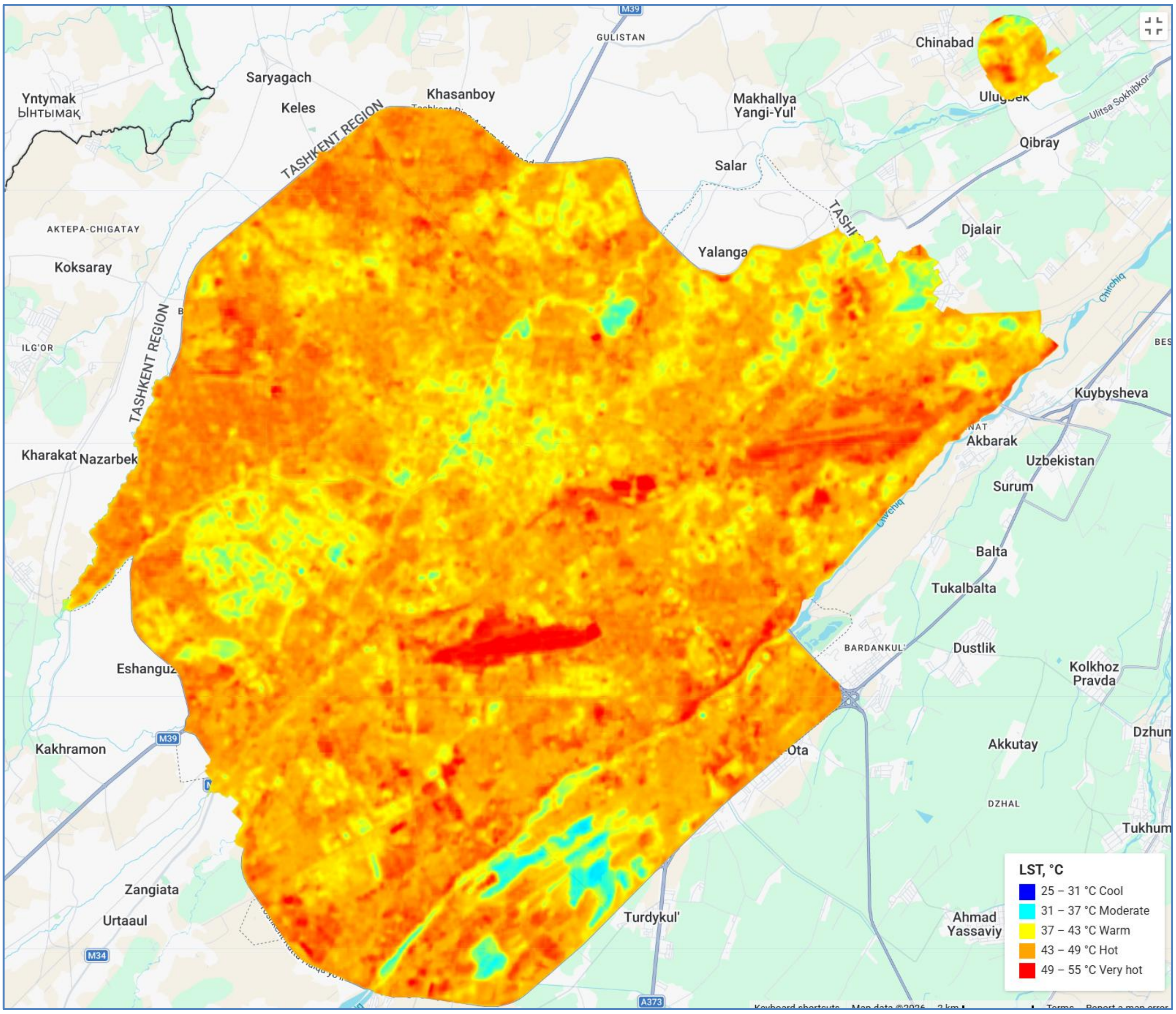


**Figure 6.** Spatial distribution of Land Surface Temperature (LST) in Tashkent for 2025. High-temperature zones (red tones) are associated with dense built-up areas, while cooler zones (blue–cyan tones) correspond to vegetated and open spaces.

The maps clearly illustrate that green spaces function as localized cooling islands, mitigating the intensity of urban heat. Conversely, areas dominated by impervious surfaces contribute to heat accumulation.

These spatial patterns are consistent with the concept of "urban ecological gradients", where vegetation density decreases and temperature increases toward the urban core (Weng et al., 2004).

3.5 Implications for Urban Sustainability

The results highlight the critical role of urban vegetation in maintaining ecological balance and thermal comfort. The observed decline in green biomass, combined with increasing LST, suggests that Tashkent is experiencing growing environmental pressure associated with urbanization.

- From a planning perspective, these findings emphasize the need to:
- Preserve existing green spaces
- Expand urban green infrastructure
- Integrate vegetation into urban design strategies

Such measures are essential for enhancing climate resilience and reducing the impacts of urban heat islands.

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