

**Lola Gulyamova¹, Nargiza Abdullaeva², Ilkhomjon Abdullaev³,
Risolat Nizomova⁴, Sattarbergan Avezov⁵**

EVALUATING THE POTENTIAL OF NIGHTTIME SATELLITE IMAGERY TO ANALYZE URBAN DYNAMICS: A CASE STUDY OF THE TASHKENT REGION, UZBEKISTAN

ABSTRACT

Assessing urban dynamics is a critical prerequisite for fostering sustainable regional development, particularly in rapidly urbanizing areas experiencing intense demographic and economic transformation. This study investigates the potential of nighttime satellite imagery — specifically data from the Suomi National Polar-orbiting Partnership (Suomi NPP) and its Visible Infrared Imaging Radiometer Suite (VIIRS) — to serve as a proxy for tracking spatial and temporal patterns of urban growth in the Tashkent Region of Uzbekistan, a key economic hub in Central Asia undergoing significant structural change. Drawing on a comprehensive dataset comprising 11 664 radiance observations across 81 urban settlements between 2012 and 2023, we analyze metrics of radiance growth, intensity distribution, temporal frequency, and variability to characterize urban trajectories. Our findings reveal robust correlations between nighttime light radiance and both economic activity and urban expansion, enabling the classification of settlements into three distinct categories of urban dynamism: low, moderate, and high. Notably, in some cases — such as Bekabad — radiance aligns more closely with industrial output than with population size, underscoring the method’s sensitivity to economic structure. The approach demonstrates high scalability, cost-efficiency, and reliability, especially in contexts where official socio-economic statistics are sparse, inconsistent, or delayed. By validating radiance as a robust indicator of urban vitality, this research establishes a foundation for integrating remote sensing data with conventional planning tools to support evidence-based decision-making in regional policy, infrastructure investment, and sustainable urban management. The developed methodological framework is readily transferable to other regions facing similar data limitations, offering a replicable model for monitoring urban change in the Global South.

KEYWORDS: night-time satellite imagery, VIIRS, Suomi NPP, urban dynamics, Tashkent Region, remote sensing

INTRODUCTION

Nighttime satellite imagery is an essential source of information widely used to analyze spatial and temporal human activity dynamics. By leveraging Geographic Information Systems (GIS) and remote sensing methodologies, this study investigates the spatiotemporal variations in radiance intensity, utilizing it as a surrogate indicator for urban growth and economic activity.

¹ Tashkent State Technical University named after Islam Karimov, 2, Universitetskaya str., Tashkent, 100174, Uzbekistan, *e-mail*: lolagulyam@gmail.com

² Tashkent State Technical University named after Islam Karimov, 2, Universitetskaya str., Tashkent, 100174, Uzbekistan, *e-mail*: abdullaeva.nargiza@tdtu.uz

³ National University of Uzbekistan named after Mirzo Ulugbek, 4, Universitetskaya str., Tashkent, 100174, Uzbekistan, *e-mail*: ilkhomjon.abdullaev@gmail.com

⁴ Tashkent State Technical University named after Islam Karimov, 2, Universitetskaya str., Tashkent, 100174, Uzbekistan, *e-mail*: risolatnizomovatdtu@gmail.com

⁵ Urgench State University named after Abu Rayhan Biruni, 14, Kh. Alimdjana str., Tashkent, 220100, Uzbekistan, *e-mail*: avezovsattarbergan@gmail.com

The spatial and temporal urban changes in the rapidly developing Tashkent Region of Uzbekistan are evaluated through analysis of nighttime satellite imagery from the Suomi National Polar Partnership (Suomi NPP) and the Visible Infrared Imaging Radiometer Suite (VIIRS). The analysis of variations in the intensity of radiance over time is used to identify the rate of urban dynamics and their differentiation across cities. This study contributes to a better understanding of urban expansion patterns in Uzbekistan and offers a framework for rating urban dynamics to facilitate more effective and sustainable urban management.

Urbanization studies in Uzbekistan have primarily focused on general urban planning issues [Narziev, 2021], discussing trends such as the “stabilization or even stagnation of the population in individual small urban settlements”, as well as demographic shifts [Muxtarov et al., 2024]. Salimova [2022] emphasizes “the need to develop a concept for the development and regulation of urbanization in Uzbekistan”. Geographers [Tashtaeva et al., 2022] argue that the “agroindustry and resource functions” are still preserved in the development of small cities. Madrimov et al. [2024] highlight that medium-sized cities and monofunctional cities in the Tashkent agglomeration face stagnation, with populations moving out in all directions and urban functions not improving. However, limited studies have been conducted to rank the level of urban dynamics in small and medium towns in the Tashkent Region.

The research is consistent with the broader applications of GIS, as exemplified by the National Geographic Information System (NGIS), which integrates multi-sectoral datasets to facilitate informed decision-making in resource management and urban planning [Abdullaev et al., 2022]. Analogous to NGIS, which supports the sustainable management of natural resources, GIS-driven remote sensing methodologies provide vital data for monitoring and managing urban dynamics, particularly in rapidly urbanizing regions such as Tashkent.

Remotely sensed imagery is an efficient source of information for monitoring social and economic processes such as urban sprawl [Sutton et al., 2001; Manesha et al., 2021]. Nighttime light imagery [Doll et al., 2006] has been found to correlate with Gross Regional Product (GRP) across various spatial scales. Studies have proven that the intensity of nighttime light is related to resource use, economic output, carbon emissions, and population size [Sutton et al., 2012; Shi et al., 2015]. Nighttime satellite imagery offers opportunities for modeling, evaluating, and predicting social dynamics. Numerous studies demonstrate that analyzing the “location and intensity of nocturnal lighting” provides a unique perspective on humanity’s presence [Sutton, 2003; Bagan, Yamagata, 2015; Coscieme et al., 2016]. It has been shown that nighttime satellite observations of nocturnal lighting can be used as a spatial indicator for other variables that are more difficult to observe on a global scale [Elvidge et al., 1999]. The efficiency of estimating human activity on Earth’s surface at various spatiotemporal scales has been demonstrated using Defense Meteorological Satellite Program Operational Line System (DMSP-OLS) nighttime light (NTL) data in many studies [Levin, Phinn, 2016; Wang et al., 2019; Dong, 2020].

This study aims to analyze the urban dynamics of small and medium towns in the Tashkent Region using nighttime imagery. The analysis of growth dynamics in small cities through nighttime imagery provides critical insights into urbanization processes. Various characteristics of nighttime satellite imagery can serve as a proxy for studying population growth, economic activity dynamics, infrastructural expansion, and urban vitality. The economic activities of small and medium-sized cities also include services, which are key determinants of a city’s attractiveness as a tourism destination. This approach enables a better understanding of the spatial and temporal patterns of urban development, crucial for predicting the future trajectory of urban economies. Moreover, integrating nighttime imagery with other socio-economic data allows for the identification of regions that may require targeted interventions to promote sustainable urban growth while mitigating potential negative impacts on local communities and ecosystems.

Nighttime satellite imagery from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS), "providing the ability to image human activity on the Earth's surface by observing artificial nighttime lighting" [Liu et al., 2011], is widely used in urban studies as a tool "to estimate the population of cities around the world at the regional level" [Sutton et al., 2001]. It is also used to measure the level of development in modern cities [Elvidge et al., 2012]. Sutton et al. [2001] showed that the total national population for each nation can be efficiently calculated by using a percentage of the population in cities, establishing "a linear relationship between area and population for each country in the world by aggregating estimates and using a single large city to fit the regression" for the 20 out of 60 most populous countries. A comparison of the results of this study with those of other researchers [Elvidge et al., 2017] shows that the spatialized population density map constructed from nighttime images reflects the nature of population distribution more accurately and in greater detail.

To predict energy consumption, eight years of data were collected from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB) satellite imagery and the Brazilian Energy Research Corporation [Fonseca Flores et al., 2023]. The Suomi National Polar Orbiting Partnership (NPP) conducted the first assessment of the VIIRS NPP-VIIRS nighttime light imagery in economic modeling by analyzing total nighttime light (TNL) and gross regional product (GRP) in 2010 for 31 provinces and 393 counties in China. This study calculated GRP and total nighttime light data based on linear regression, showing that TNL from NPP-VIIRS differed significantly from the relationship between TNL from DMSP-OLS F-16 and F-18 satellites, with R^2 values of 0.86 and 0.85 for the region and district, respectively. The study found that NPP-VIIRS data were more predictive of GRP than DMSP-OLS data.

Measurements of nighttime light, such as its extent and intensity, are widely used to detect the spatial dimension of human activity dynamics, while the concentration of light sources serves to assess the capacity of urban objects [Bennett, Smith, 2017; Chen et al., 2023; Mokhtari et al., 2025]. The study by Levin & Zhang [2017] shows that "the variety of light pollution and artificial lighting in space and time is a function of population and economic activity". A positive relationship has been detected between "nighttime lights per capita" [Wang et al., 2019] and "proximity to large cities for administrative units" [Morales-Arilla, Gadgin Matha, 2024]. Researchers [Mellander et al., 2015] conducted a correlation analysis and geographically weighted regression experiment to test whether light could act as a proxy for economic activity at a more granular level. In this research, [Li et al., 2022] found that "the relational grade between nighttime light (NTL) and all socioeconomic factors in the Regional Comprehensive Economic Partnership (RECP) region was greater than 0.6". The future application of this technology lies in introducing "higher spatial resolution and multispectral sensors covering the range from blue to NIR" [Levin et al., 2020], which will widen the range for monitoring and assessing economic processes. By combining nighttime light (NTL) data [Xu et al., 2021] and natural city (NC) data, this study [Yang et al., 2021] compares the differences between urban centers. The efficiency of "estimating human activity on the Earth's surface at various spatiotemporal scales" has been demonstrated by using DMSP-OLS NTL data in many studies [Elvidge et al., 2013; Mellander et al., 2015; Levin, Zhang, 2017; Li et al., 2021].

Features of nighttime light (NTL), such as its variability in extent and intensity, help "identify the patterns of economic development and environmental conditions" [Martínez et al., 2007]. Researchers argue that "an in-depth analysis of NTL's change shows the dependence of brightness on the trends of economic activity" and that "higher increases in the amount and growth rate of NTL are detected in more developed economies" [Sutton et al., 2001; Li et al., 2022].

The objectives of this study are to investigate the relationships between radiance and urban growth dynamics in the Tashkent Region. The research question is whether radiance variability

and intensity reflect the trends in urban and economic activity growth. Additionally, how can nighttime imagery help capture spatiotemporal patterns and rate urban dynamics?

RESEARCH MATERIALS AND METHODS

Research area

This study investigates selected settlement systems within the Tashkent Region of Uzbekistan, which function as critical nodes in regional development and comprise a mix of urban and semi-urban environments.

Located in the northeastern part of the country, the Tashkent Region is one of Uzbekistan's most economically and demographically significant areas. It borders Kazakhstan to the north and west, Kyrgyzstan to the east, and Tajikistan to the south, encircling the capital city, Tashkent, which is administratively distinct (Fig. 1). The region covers approximately 15 300 km² and exhibits diverse topographical features, ranging from the foothills of the Tien Shan mountains to expansive irrigated lowland plains. The region's continental climate, marked by hot summers and cold winters, supports a wide range of agricultural and industrial activities. The settlement systems selected for this research — Angren, Almalyk, Chirchik, Akkurgan, Bekabad, Buka, and Pskent — were chosen based on a combination of factors, including population size, economic function, and spatial distribution within the region.



Fig. 1. Location of the Tashkent Region

These criteria provide a robust foundation for examining the relationship between nighttime light intensity, population dynamics, and economic activity. Urban centers such as Angren and Almalyk are prominent for their heavy industries, including energy production, metallurgy, and mining, while smaller towns like Buka and Pskent feature more localized economies and

exhibit lower population densities. These settlements are undergoing rapid industrialization within the framework of the “Uzbekistan — 2030” national development strategy. The expansion of their industrial sectors plays a crucial role in reshaping the regional economic landscape and significantly contributes to the sustainable development goals of the Tashkent Region. Furthermore, these urban systems are part of a larger, interconnected network, where patterns of nighttime lighting serve as a proxy for assessing the intensity of economic activity and the spatial dynamics of urbanization.

Materials and methods

To analyze the trends in light emissions observed by satellites, the data was derived using the web app called “Radiance Light Trends”¹, guided by Christopher Kyba from the GFZ German Research Centre for Geosciences in Potsdam. This internet resource was produced as part of the GEO Essential project, funded by the EU’s Horizon 2020 programme, with the coding done by Jurij Stare of Deneb Geoinformation Solutions.

For this study, the data was obtained using the annual radiance light map from the Suomi National Polar Partnership (SNPP) satellite, specifically the VIIRS (Visible Infrared Imaging Radiometer Suite) system. Annual and monthly light intensity (in W/cm^2) data from 2012 to 2023 were obtained from the “Radiance Light Trends” web app. A sample of such data is represented in Fig. 2–3.

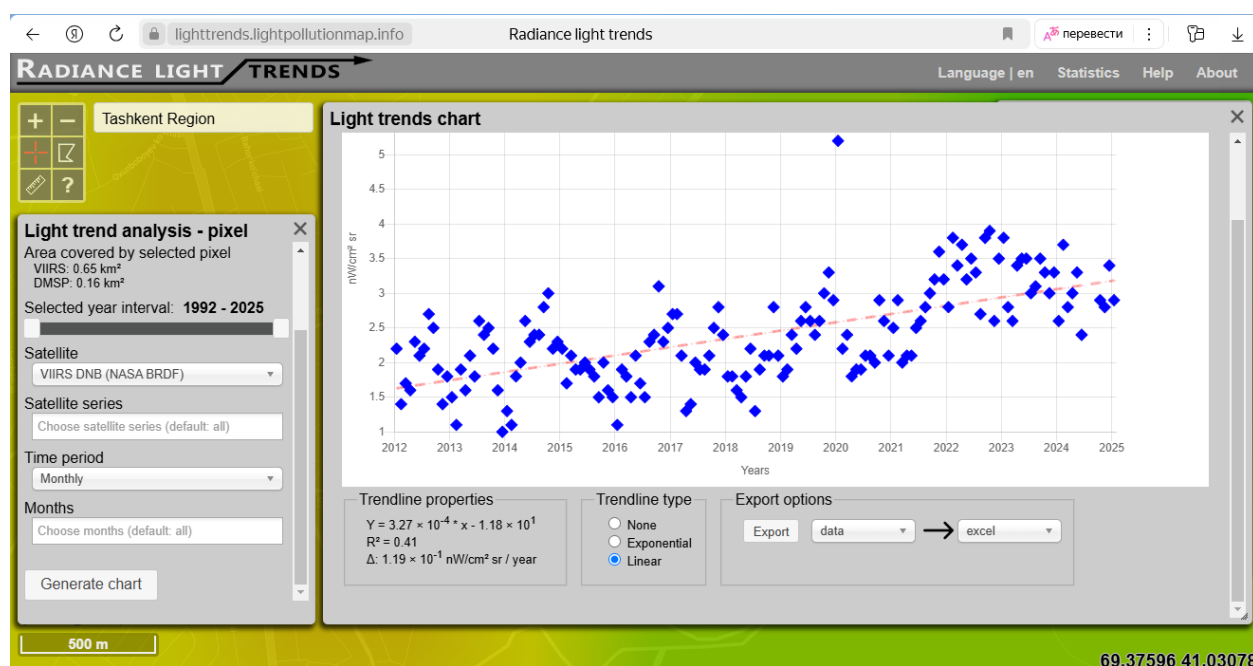


Fig. 2. Data view from the Radiance web application of Tashkent Region 2023

The additional dataset includes:

- population: annual population data from official statistics for the period from 2012 to 2023;
- industry: city-level industrial output based on local economic reports for the period from 2012 to 2023.

¹ Web resource: <https://www.eurekalert.org/news-releases/689072> (accessed 07.07.2025)

The tools for statistical analysis include:

- simple linear regression;
- multiple linear regression;
- Pearson correlation coefficient.

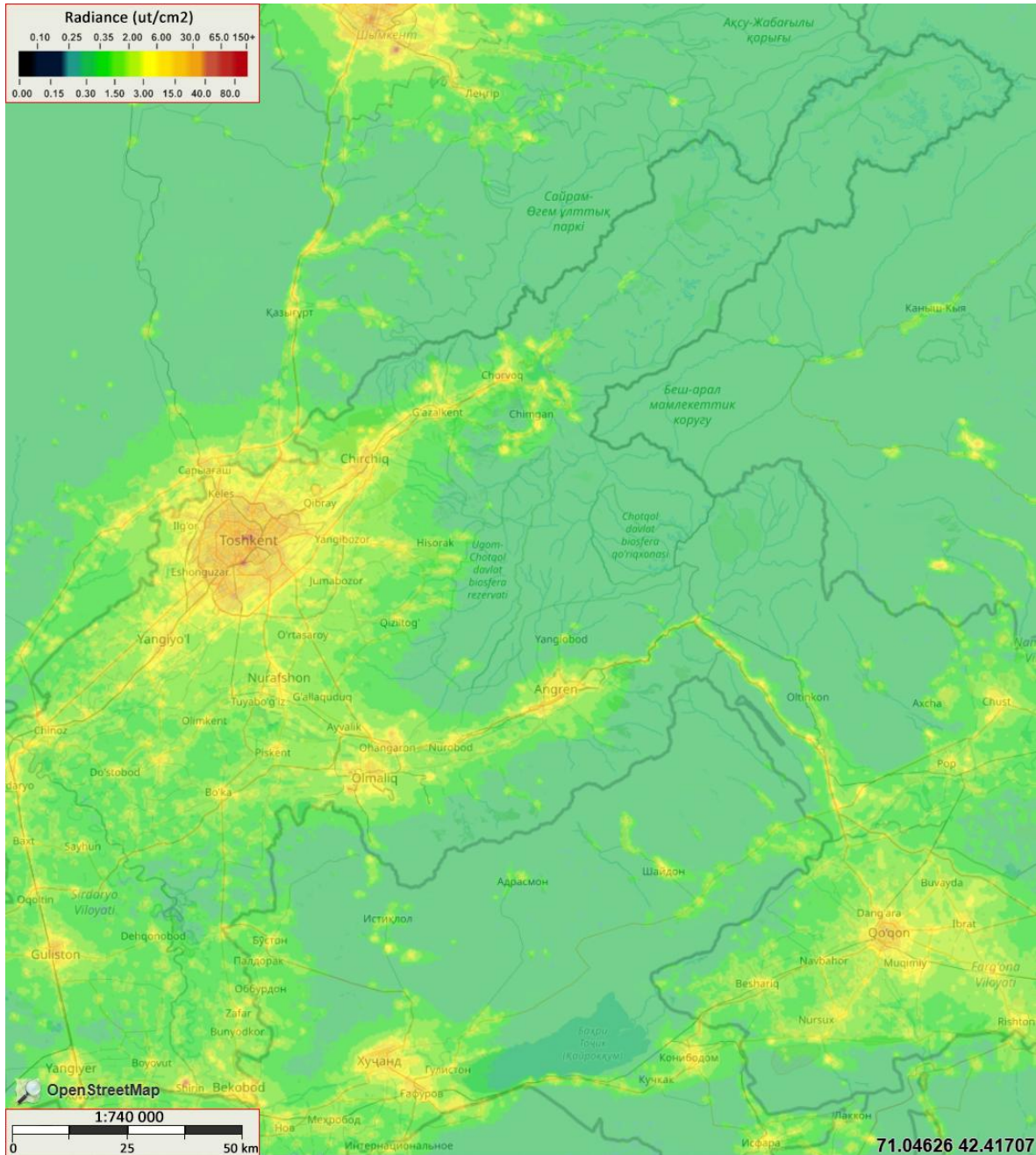


Fig. 3. Appearance of the Radiance web application of Tashkent Region 2023

Data were processed using ArcGIS Pro, Microsoft Excel, and Python libraries. The outputs were visualized through graphs and tables for comparative analysis across cities and time periods. Operational Line scan System and VIIRS acquire low-light imagery data only in a single, broad, visible near-infrared band. The model for radiance data processing consists of three stages, with the dynamics of R_i calculated based on its annual and monthly frequency. The urban dynamics assessment through nighttime lighting was performed in the following sequence (Fig. 4).

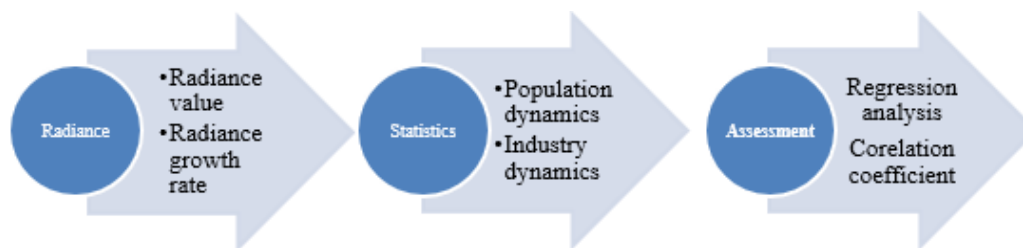


Fig. 4. Steps of assessment the urban dynamics by nighttime satellite imagery

RESEARCH RESULTS AND DISCUSSION

VIIRS monthly data from 2012 to 2023 for 81 local settlement systems, totaling 11 664 cases, were analyzed. Several characteristics of radiance were applied to define the trends of variability in extent and intensity:

- radiance growth rate;
- correlation coefficient of the relationship between Radiance (R_i), urban dynamics (U_i), and industry (I_i);
- the frequency of repeating numbers.

The radiance growth rate is calculated using the following formula (1):

$$R_g = R_i / R_{i-1} \quad (1),$$

where R_g represents the radiance growth factor.

The frequency of repeating numbers is calculated using the following formula (2):

$$\omega_i = N_i / N_t \quad (2),$$

where ω_i — frequency of rapidly repeating numbers,

N_i — number of cases,

N_t — total number of cases.

This study demonstrates that if the light intensity increases, it indicates an increase in activity in the population centers. This provides additional evidence of the relationship between radiance and economic activity, as shown by Sutton, Elvidge, and Ghosh (2007). The radiance growth coefficient for 7 major cities was calculated, revealing a sharp decrease in the local settlement systems of Bekabad (2016–2017), Buka (2017–2018), Akkurgan (2016–2018), Pskent (2018–2022), Angren (2017–2019), Almalyk (2016–2017), and Chirchik (2016–2017) (Table 1).

Table 1. The annual trends of radiance in the local settlement systems of the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

Year	Angren	Almalyk	Chirchik	Pskent	Akkurgan	Buka	Bekabad
2012	15.3	17.3	14.4	11.6	8.2	17.1	9.5
2013	11.7	17.8	12.3	11.1	9.1	16.1	7.5
2014	10.9	14.8	12.9	11.3	8.7	14.6	7.9
2015	9.8	13.2	12.5	10.1	7.9	13.5	5.7
2016	7.5	12.6	11.1	8.4	6.2	13.5	4.2
2017	7.7	11.6	11.5	7.6	6.9	12	4.3
2018	7.3	22.5	13.7	5.9	6.9	10.8	7.1
2019	7.2	30.1	24	5.5	14.3	21.6	14.2

Year	Angren	Almalyk	Chirchik	Pskent	Akkurgan	Buka	Bekabad
2020	9.3	31.6	22.8	5.2	16.6	20.3	12.8
2021	14.4	40.6	29.7	6.7	15.7	23	14.6
2022	16.5	37.3	26.3	7.3	18.2	19.5	15.3
2023	15	29.1	23.9	8.7	12.6	16.6	13.9

The monthly and annual trends of radiance for the local settlement systems were calculated to evaluate the rate of radiance growth. A sample of the results is presented for the Bekabad local settlement system (Table 2). A sample of the annual trend of radiance R_i for Bekabad is shown in Fig. 5.

Table 2. Annual trends of radiance for the Bekabad local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

Year Month	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
January	5.5	4.6	7.4	3.8	4.5	4.6	7.5	11.4	14.4	14.5	8.2	9.2
February	8	8.1	6.3	4.1	4.5	4.5	5.8	16.3	14.5	17.3	19.3	9.2
March	7.6	7	8.3	5.5	4.3	4.4	5.8	15.4	14.7	10.7	16.4	11
April	11.6	8.1	7.4	6.3	3.7	3.4	5.9	13.1	11.5	12.3	15.8	13.6
May	10.7	10.1	9.3	6.4	3.9	3.3	6.2	14.4	12	13	15.8	14.8
June	9.1	9.5	8.7	6.2	3.7	3.8	6.6	15.9	12.5	12.2	19.7	12.3
July	10.2	6.8	9.9	4.7	3.7	4.4	7.1	12.2	11.9	12.3	16.3	13.4
August	10	5.2	8.7	5.7	3.8	4.3	7.1	13.9	11.9	13.6	18	13.4
September	10.2	8.8	8.3	5.6	4.5	4.8	8.1	15	13.4	16.1	15.3	14.9
October	8.6	8.3	5.7	6.4	4.7	4.7	10.1	15	12.8	16.2	14.8	16.4
November	7.9	7.6	5.2	5.4	5.1	5.5	8.9	14.6	15.2	19.3	13.5	18.5
December	7.3	7.6	5	5.3	5.8	5.3	8.3	15.3	9.2	19.5	8	14.3

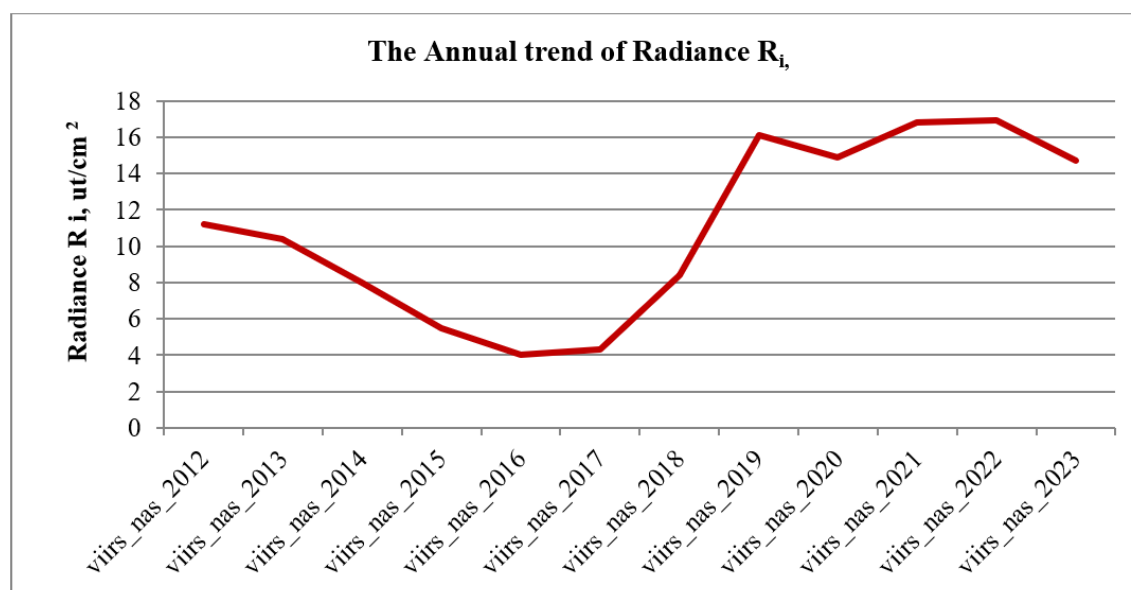


Fig. 5. Annual trend of radiance for the Bekabad local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

The highest, average, and lowest values of radiance intensity for the Bekabad local settlement system during 2012–2023 were calculated to detect temporal variation (Table 3).

Table 3. Variation in radiance intensity for the Bekabad local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

Months	Radiance max	Radiance average	Radiance min
January	16.30	8.88	3.60
February	22.00	10.94	3.90
March	20.60	10.45	4.20
April	16.80	10.18	3.80
May	16.60	11.22	3.50
June	20.30	10.93	3.60
July	17.50	10.59	4.00
August	18.60	10.91	3.70
September	18.40	11.39	3.90
October	19.50	11.83	4.40
November	21.60	11.80	5.00
December	21.70	10.53	5.10

The reliability of the quantitative indicator was determined by identifying the most frequently repeated monthly and annual values. A sample of the most repeated monthly and annual radiance intensities for the Bekabad settlement system is presented in Table 4.

Table 4. Monthly trend of the most repeated radiance values for the Bekabad settlement system, ω_i — frequency of rapidly repeating numbers, 2012–2023

Radiance value ($\mu\text{t}/\text{cm}^2$)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10–14.9	0.33	0.33	0.5	0.42	0.33	0.33	0.25	0.25	0.17	0.25	0.33	0.08
15–19.9	0.08	0.17	0.08	0.17	0.25	0.25	0.33	0.25	0.33	0.17	0.17	0.42
20–24.9	0.25	0.17	0	0.08	0	0.08	0	0.08	0	0.08	0	0.17
25–29.9	0	0.08	0.08	0.08	0.08	0	0.25	0.08	0.17	0.08	0.25	0
30–34.9	0	0	0.08	0.08	0.17	0.17	0.08	0.17	0.17	0.17	0.08	0.08
35–39.9	0.17	0	0.17	0.08	0.17	0.17	0.08	0.17	0.17	0.08	0.08	0.08
40–44.9	0.08	0	0	0.08	0	0	0	0	0	0.17	0	0.08
45–50	0.08	0.25	0.08	0	0	0	0	0	0	0	0.08	0.08

The temporal variation in radiance is used to define the character of urban dynamics (a sample for Bekabad is shown in Fig. 6). A variety of radiance intensity over time is measured by ω_i (the frequency of rapidly repeating numbers) to identify the rate of dynamics in cities and their differentiation.

At the next stage of the analysis, the relationship between radiance (R_i) and population (U_i) was calculated to identify the rate of dynamics in cities and their differentiation. Simple linear

regression, multiple linear regression, and Pearson correlation coefficient were applied to define strong, medium, and weak relationships.

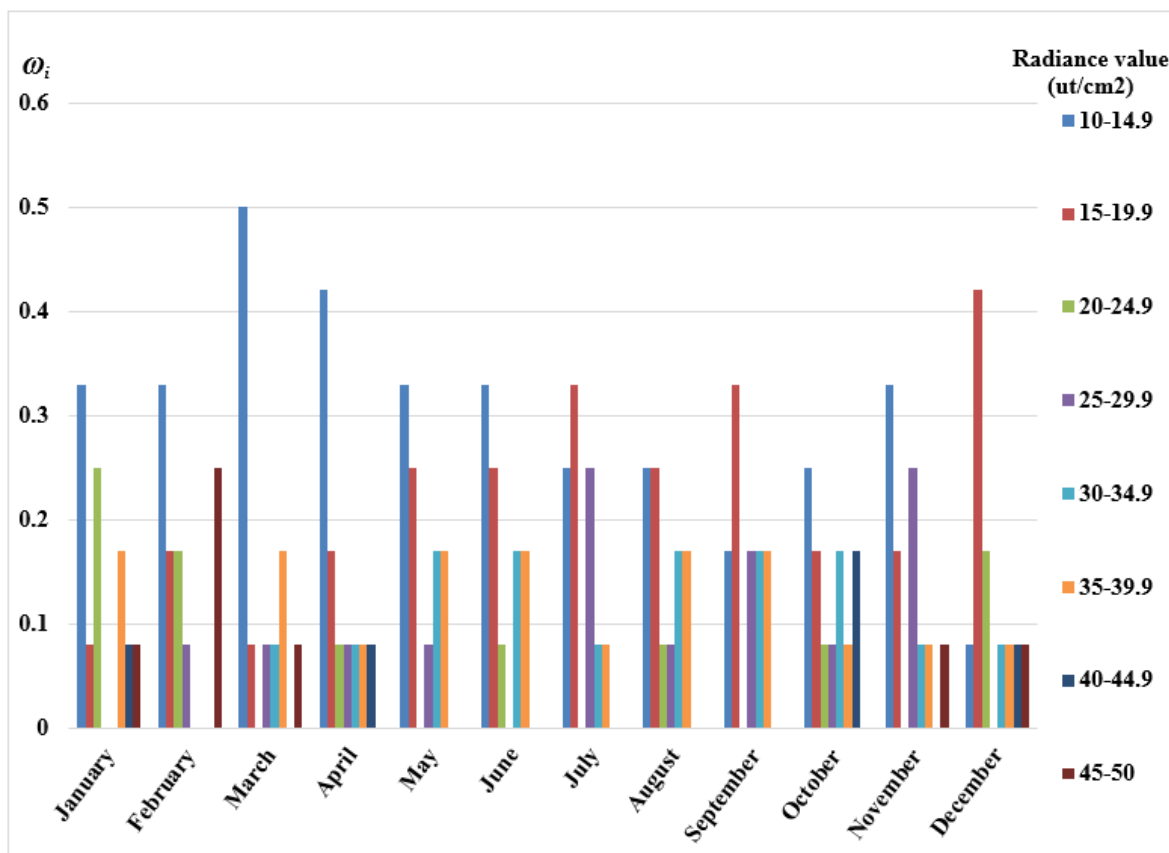


Fig. 6. Temporal variation in radiance intensity reflecting urban dynamics for the Bekabad local settlement system

The correlation coefficients between the radiance index, population, and industry for the local settlement system are presented in Table 5.

Table 5. The correlation coefficients of relation between the radiance index in the system of settlements and the population and industry

No.	City name	R ² ₁	R ² ₂
		Population and radiance	Industry and radiance
1	Angren	0.3	0.9
2	Almalyk	1	0.9
3	Chirchik	0.9	0.8
4	Pskent	0.9	0.6
5	Akkurgan	0.9	0.9
6	Buka	0.9	0.9
7	Bekabad	0.1	0.9

From 2012 to 2023, the relationship between radiance (R_i) and population (U_i) for the Bekabad local settlement system is not significant, with an R^2 value of 0.0798 (Fig. 7).

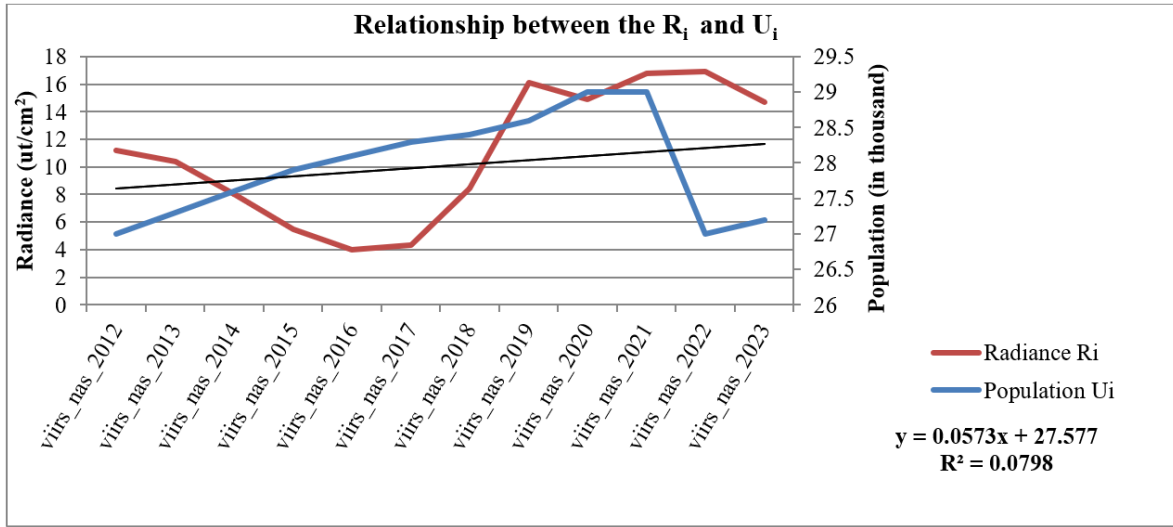


Fig. 7. The annual trend of the relationship between the Radiance and population of the Bekabad local settlements system in Tashkent Region, $\mu\text{t}/\text{cm}^2$, 2012–2023

At the same time, in 2012–2023 the relationship between the Radiance and Industry is quite significant and $R^2 = 0.9261$ (Fig. 8) demonstrating the stronger input of the manufacturing in the Night Light.

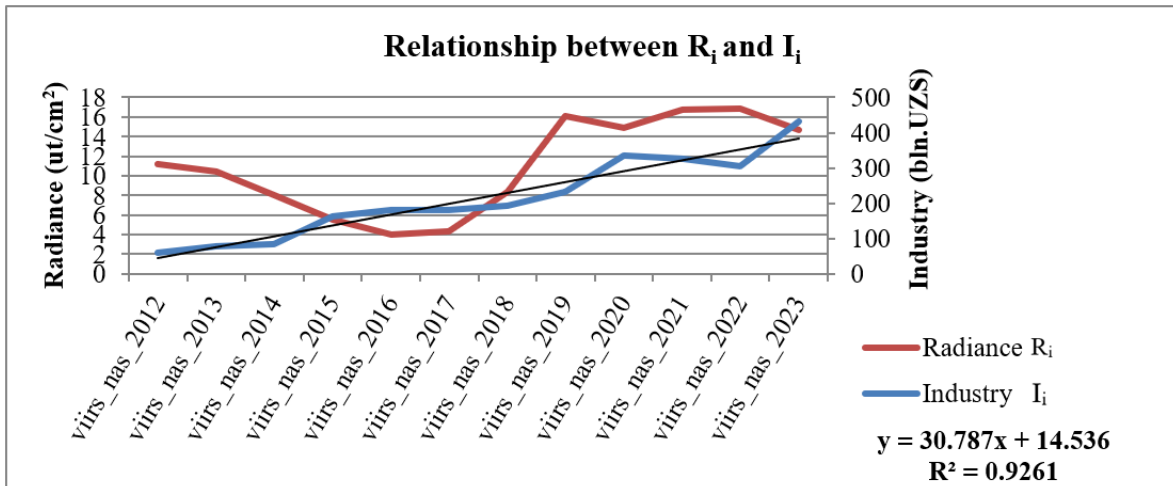


Fig. 8. Annual trend of the relationship between radiance and industry, measured as Gross Domestic Product, for the Bekabad local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

The annual trends of the relationship between radiance (R_i), population (U_i), and industry (I_i), measured as Gross Domestic Product, for the Almalyk local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, from 2012 to 2023 (Fig. 9–10), show different types of urban growth, with $R^2 = 0.9634$ and $R^2 = 0.8866$, respectively.

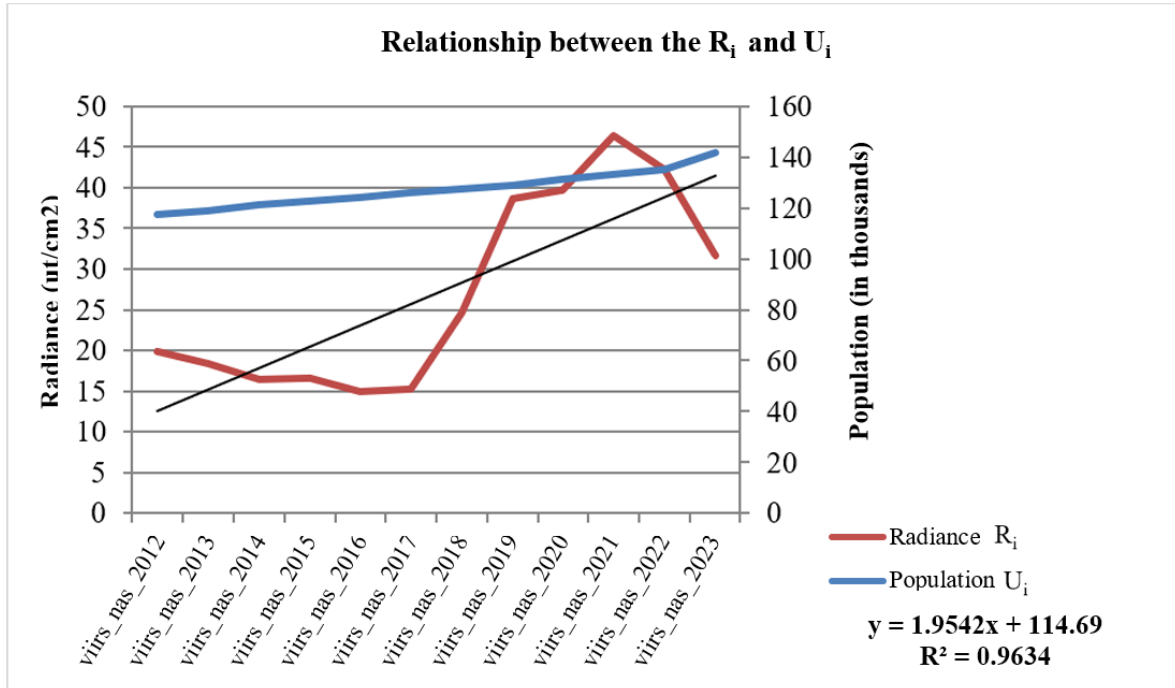


Fig. 9. Annual trend of the relationship between radiance and population for the Almalyk local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

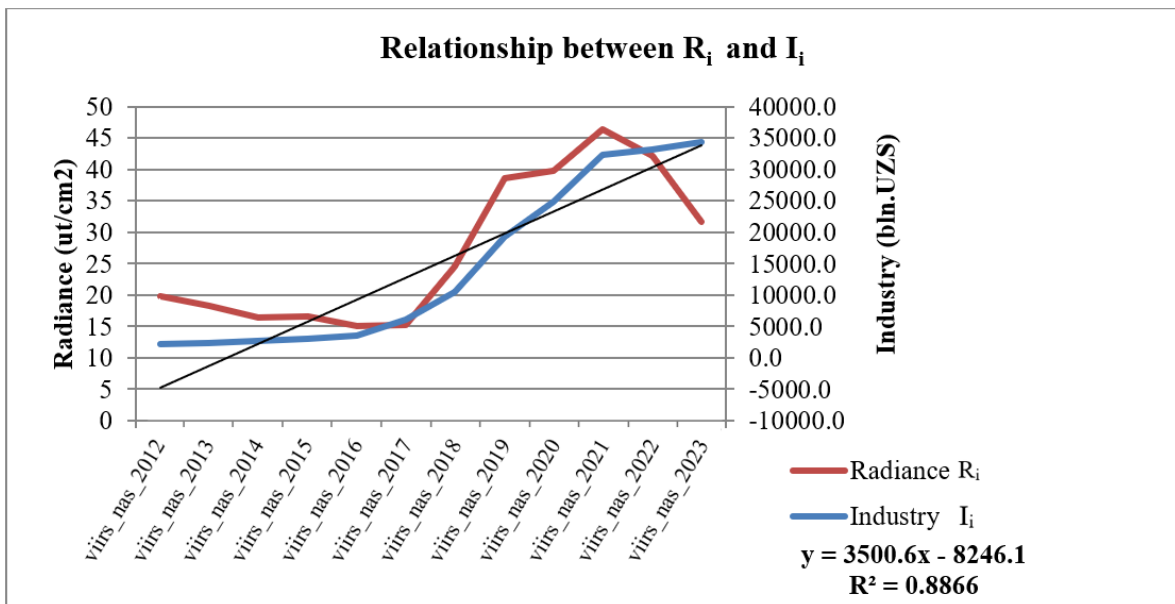


Fig. 10. Annual trend of the relationship between radiance and industry, measured as Gross Domestic Product, for the Almalyk local settlement system in the Tashkent Region, in $\mu\text{t}/\text{cm}^2$, 2012–2023

The frequency of repeating numbers (ω_i max, ω_i average, ω_i min) serves as an indicator of the dependence of radiance values on urban dynamics and is used to rate local settlement systems (Fig. 11).

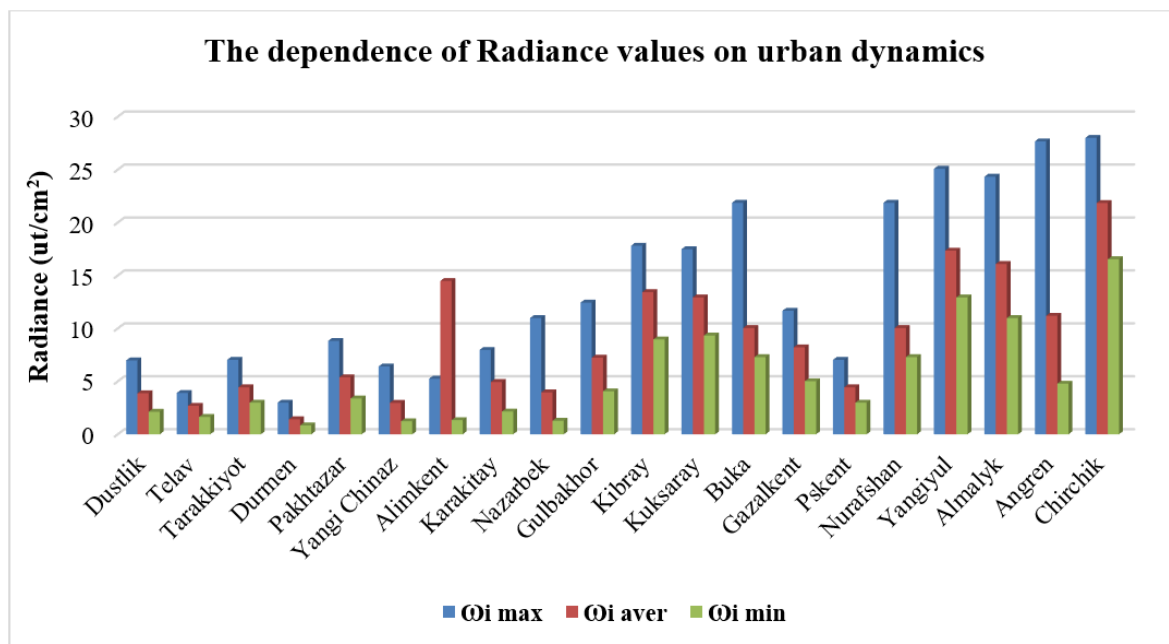


Fig. 11. Dependence of radiance values on urban dynamics for local settlement systems in the Tashkent Region

This study supports the assumption of a dependence between radiance intensity and urban dynamics. For local settlement systems with populations of up to 3 000 people, the average radiance (δ_{aver}) is measured at 3.88, while for systems with populations between 10 000 and 19 999 people, the average radiance (δ_{aver}) is 13.43. The differences in maximum (δ_{max}), average (δ_{aver}), and minimum (δ_{min}) radiance intensity within settlement systems of the same population size reflect the level of urban development and sustainability. The rating, based on the average radiance ($R_{\delta_{aver}}$) detected between 2012 and 2023, classifies settlement systems into high urban dynamics (1), medium (2), and low (3) categories, as assigned by local officials (Table 6).

Table 6. Rating of urban dynamics for the settlement systems in the Tashkent Region

Population	City name	δ _{max}	δ _{aver}	δ _{min}	Rating
Up to 3 000	Dustlik	6.98	3.88	2.13	2
	Telav	3.90	2.69	1.64	3
	Tarakkiyot	7.03	4.44	2.99	1
3 000–5 000	Durmen	2.99	1.42	0.84	3
	Pakhtazar	8.82	5.39	3.38	1
	Yangi Chinaz	6.41	2.97	1.23	2
5 000–10 000	Alimkent	5.25	14.48	1.34	1
	Karakitay	7.97	4.94	2.15	2
	Nazarbek	10.98	3.96	1.28	3
10 000–20 000	Gulbakhor	12.44	7.24	4.06	3
	Kibray	17.81	13.43	8.96	1
	Kuksaray	17.48	12.93	9.33	2

Population	City name	δ_{\max}	δ_{aver}	δ_{\min}	Rating
20 000–50 000	Buka	21.87	10.04	7.29	1
	Gazalkent	11.67	8.21	5.01	2
	Pskent	7.03	4.44	2.99	3
50 000–100 000	Nurafshan	21.87	10.04	7.29	2
	Yangiyul	25.08	17.35	12.93	1
Above 100 000	Almalyk	24.33	16.09	10.98	2
	Angren	27.67	11.19	4.78	3
	Chirchik	28.00	21.85	16.54	1

The variation in the values of $R_{\delta_{\max}}$, $R_{\delta_{\text{aver}}}$, and $R_{\delta_{\min}}$ for radiance intensity within settlement systems of the same size reflects differences in the level of urban development and sustainability. This method forms the basis for rating the dynamics of settlement systems.

CONCLUSIONS

This study demonstrates the effectiveness of nighttime satellite imagery in assessing the dynamics and capacity of settlement systems in the Tashkent Region. By analyzing VIIRS radiance data over a twelve-year period, distinct temporal and spatial patterns of urban activity were identified. Higher radiance values in settlement systems were observed across various groups of the traditional statistical classification, supporting the idea that radiance intensity can be a reliable indicator of urban dynamics.

The classification of settlement systems based on radiance intensity provides an evidence-based framework for evaluating urban capacity. Additionally, the use of radiance frequency analysis enhances the reliability of urban assessments, particularly in cases where statistical data is limited. This further supports the efficiency of nighttime light data for monitoring urban dynamics, as previously highlighted by Sutton & Costanza [2002].

Looking forward, the integration of radiance metrics with ground-based data and the application of regression models [Sarstedt, Mooi, 2014; Schober et al., 2018] will further enhance predictive capabilities. This approach not only supports more effective regional planning and management but also contributes to broader goals of regional development and sustainability by enabling data-driven decision-making.

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