

Night Time Satellite Imagery for Assessment the Dynamics of Touristic Zones in Tashkent Region of Uzbekistan

Lola Gulyamova¹, Risolat Nizomova¹, Sunatilla Gaibnazarov¹, Nasiba Shamsiyeva¹, Nargiza Abdullaeva¹, Muxlisa Raximova¹, Doston Maxmadiyev¹, Ilkhomjon Abdullaev².

¹ TSTU, Geology-prospecting and mining - metallurgy faculty, Tashkent Uzbekistan - lolagulyam@gmail.com, risolatnizomovatdtu@gmail.com, sgaibnazarov@tdtu.uz, nasiba.shamsiyeva1980@gmail.com, gkik_in@mail.ru, muxlisa.xasanovna.tstu@gmail.com, doston.maxmadiyev@gmail.ru

²NUU, Geography and geoformation systems faculty, Tashkent Uzbekistan, ilkhomjon.abdullaev@gmail.com

Keywords: Night-time Satellite Imagery, VIIRS, Suomi NPP, Tourism Dynamics, Tashkent Region, Remote Sensing, Spatiotemporal Analysis

Abstract

The assessment of tourism dynamics is essential for sustainable regional development, particularly in emerging tourism markets like Uzbekistan. This study applies night time satellite imagery from the Suomi National Polar Partnership (Suomi NPP) and the VIIRS radiometer to evaluate spatial and temporal changes between 2012 and 2023 in 17 touristic zones comprising 1,008 touristic objects of the Tashkent region. 2,448 cases of Radiance growth, frequency, and intensity distributions were analyzed to understand seasonal variations and categorize zones by tourism capacity. Results indicate strong correlations between radiance values and touristic activity, enabling classification into low, moderate, high, and very high tourism capacity categories. This method offers a cost-effective, scalable, and reliable tool for assessing tourism potential, particularly in areas where official statistics are limited. The findings provide a foundation for integrating remote sensing data with socio-economic indicators, supporting improved decision-making in tourism planning, infrastructure development, and resource management.

1. Introduction

Study the dynamic of the touristic zones is an important in the planning of touristic economy in Uzbekistan when the tourism becomes one of the priorities for future prosperity of nation. This paper describes the using night time satellite imagery as one of the effective ways to assess the trends of the touristic zones' capacity development.

The night time satellite imagery is the essential source of information widely used for analysis the trends of the spatial and temporal human activity dynamics. The efficiency of “estimating human activity on the Earth’s surface at various spatiotemporal scales” is demonstrated by using Defense Meteorological Satellite Program Operational Line System (DMSP-OLS) nighttime light (NTL) data in many studies (Wang, Sutton & Qi, 2019; Dong, 2020; Levin, Phinn, 2016).

Such features of the Nighttime light (NTL) as its variability of extent and intensity help “the identifying the patterns of

economic development and environmental conditions” (Mokhtari, Bergantino & Intini 2025). Researchers (Li, He, Wang, Ma & Ye, 2022) show through an “in-depth analysis of the NTL’s change the dependence of brightness on the trends of economic activity” and argue “the higher increase amount and growth rate of NTL are detected in more developed economies”. This approach is used to assess the capacity of touristic zones in the Tashkent Region of the Republic of Uzbekistan (Figure 1). The choice of the object of study is dictated by the fact that this region is located in a variety of natural zones and the resulting diversity of forms and types of tourism. This region is divided into 5 main zones of the capacity of the recreational tourism (Gulyamova, et, al, 2023). Assessment of 2, 448 cases of the radiance variability of its extent and intensity was conducted for 17 touristic zones comprised 1008 touristic objects. Nighttime satellite imagery of the Tashkent region is represented in (Figure 2).



Figure 1. Location of the Tashkent region. (Compiled by authors).

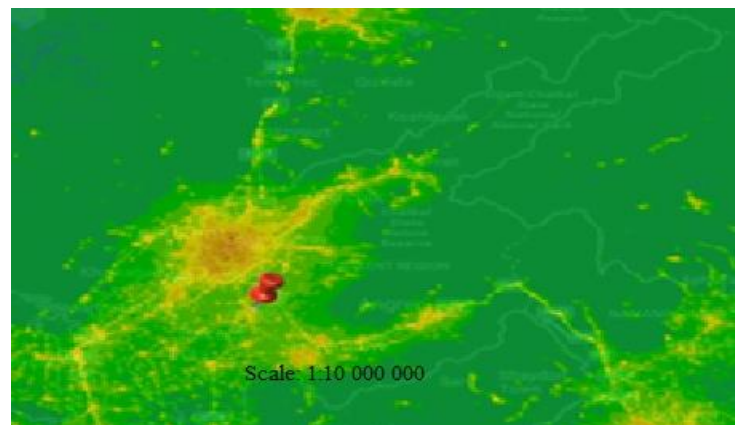


Figure 2. Night time satellite imagery from satellite SNPP and radiometer VIIRS 2023.
 (Source: <https://lighttrends.lightpollutionmap.info/#zoom=0&lon=0.00000&lat=33.78523>)

The objectives of this study are investigating regional relationships between radiance and touristic zone capacity in Tashkent region. Research question is whether the radiance variability and intensity show the relationship between the capacity of touristic zone in the different natural regions? And how may they help in capturing spatiotemporal patterns?

2. Literature Review

According to research (Elvidge 2013, p.62) “VIIRS data are superior to DMSP for mapping nighttime lights”. This is the reason to use VIIRS data in this study. Elvidge and colleagues (Elvidge et al., 2012) argue that nighttime light can be used to measure the level of development of modern cities, it was found that the number of people living in unlit areas is highly correlated with the electrification rate. This population model has a coefficient of determination (R^2) ranging from 0.80 to 0.95 in the study area, which has remained consistent over the years. A comparison of the results of this study with those of other researchers (Elvidge, Zhou & Cao, 2017) shows that the spatialized population density map constructed from nighttime images reflects the nature of population distribution more accurately and in greater detail. It is possible to estimate the illumination of night-lights through the radiance value (Elvidge, 2007). Researches (Sutton & Costanza, 2002) estimated global marketed and non-marketed economic value from two classified satellite images with global coverage at 1 km² resolution. GDP as a measure of marketed economic output is correlated with the amount of light energy (LE) emitted by that nation as measured by nighttime satellite images. Researches (Mellander, Lobo, Stolarick & Matheson, 2015), conducted a correlation analysis and a geographically weighted regression experiment to test whether light could act as a proxy for economic activity at a more granular level. They found that the relationship between NTL (night-time light) and economic activity was strong enough to make it a relatively good proxy for population and institutional density. Night-time light imagery (Doll, Muller & Morley, 2006) was found to correlate with Gross Regional Product (GRP) across a range of spatial scales. Maps of economic activity at 5 km resolution were produced based on the derived relationships. Such measurements of nighttime light as its extent and intensity are widely used to detect the spatial dimension of human activity’s dynamics while the concentration of light source serves for assessment the capacity of objects (Mokhtari, et.al., 2025; Bennett & Smith, 2017; Chen et al. 2023). The study (Levin &

Zhang, 2017) shows “the variety of the light pollution and artificial lighting in space and in time is a function of population and economic activity”. A positive relationship is detected between “nighttime lights per capita” (Wang et al. 2019) and “proximity to large cities for administrative units” (Morales-Arilla, Gadgin, 2024). The future of application of this technology is in introducing “higher spatial resolution and multispectral sensors covering the range from blue to NIR” (Levin et al., 2020) that widen the range of monitoring and assessment the economic processes. By combining nighttime light (NTL) data and the natural city (NC) this study (Yang et al., 2021) compares the differences between urban centers. This research (Xu et al., 2021) shows that the combining night time lights is efficient in prediction of poverty incidence at the county level and points out a higher temporal and spatial resolution of satellite remote-sensing data compared with traditional poverty measurement methods. The spatiotemporal patterns of urbanization were defined by using continuous time-series NTL data from 2000 to 2018 combined with land-use images (Li et.al., 2021).

3. Materials and Methods

For this study the images were obtained using the radiance light annual map SNPP (the Suomi National Polar Partnership) from the satellite VIIRS (Visible Infrared Imaging Radiometer Suite system). Annual and monthly data was derived from 2012 to 2023 in excel and graphic formats. Sample of such data is represented in (Figures 3, 4).

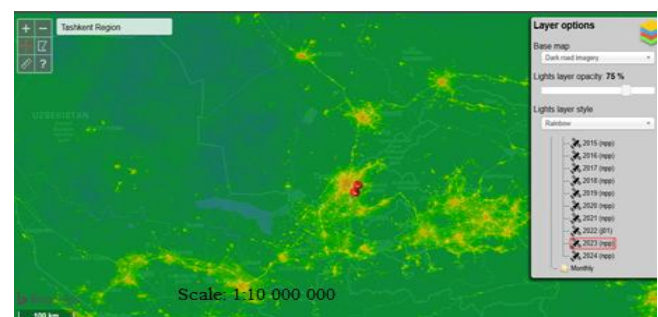


Figure 3. Appearance of the Radiance web application of Tashkent region 2023. (Source: <https://lighttrends.lightpollutionmap.info/#zoom=0&lon=0.00000&lat=33.78523>)

OLS (Operational Linescan System) and VIIRS acquire low-light imagery data only in a single, broad, visible near-infrared band. Spectral information about the illumination type is available for 17 touristic zone of Tashkent region. Radiance dynamic is calculated based on its annual and monthly frequency and amount.

The model of Radiance data processing consists of three stages (Figure 5) when dynamic of R_i is calculated based on its annual and monthly frequency.

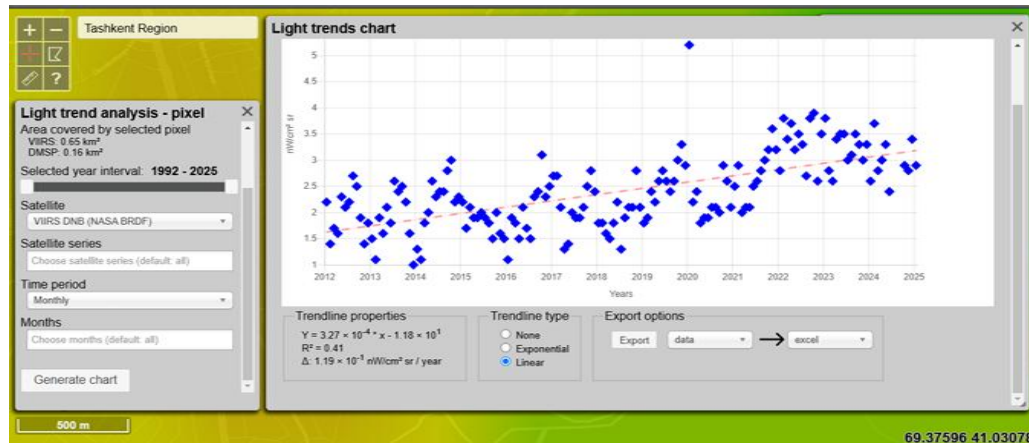


Figure 4. Data view from the Radiance web application of Tashkent region 2023.
(Source: <https://lighttrends.lightpollutionmap.info/#zoom=0&lon=0.00000&lat=33.78523>)

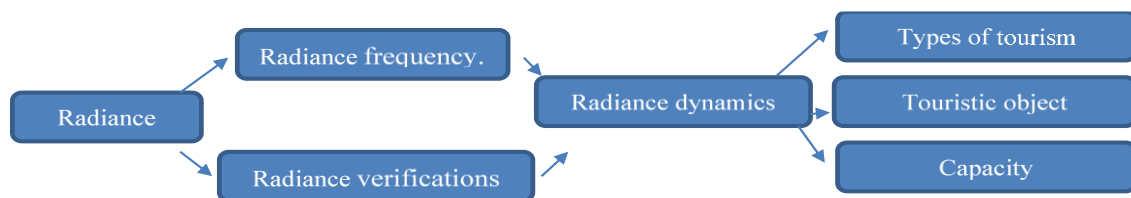


Figure 5. Radiance data processing model. (Compiled by authors).

4. Results and Discussion

VIIRS monthly data as of 2012 -2023 years of 17 touristic zones totaling 2448 cases were analyzed. Several characteristics of radiance were applied to define the trends of variability of its extent and intensity: 1. Radiance growth R_i ; 2. Radiance probability R_p ; 3. Radiance R_g growth factor is grouping in acceding Radiance probability of its intensity.

Radiance growth is calculated (1):

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

Here, R_g is the Radiance growth factor.

The frequency of repeating numbers is calculated (2):

$$\Omega_i = N_i / N_t \quad (2)$$

Ω_i - Frequency of rapidly repeating numbers, N_i = number of cases, N_t – Total number of cases.

This study shows if the light decreases, it indicates a decrease in activity in the touristic zone. This is another evidence of the dependence of radiance on an economic activity shown by Sutton, Elvidge and Ghosh (2007). The radiance growth coefficient of 17 touristic zones was calculated, a sharp decrease was observed in the touristic zones of Aktash, Khumson, Charvak, Dukent, Yangiabad, Zarkent, Ahangaron, and Chirchik (Table 1).

The reliability of the quantitative indicator, the most repeated monthly and annual indicators were determined (Table 2)

	Chinarkent	Aktash	Khumson	Chimgan	Amirsay	Charvak	Yusuphona	Beldirsay
2012	4.6	1.7	4.2	1.8	0	8.7	4.6	0
2013	4.5	1.7	4	2.1	0	7.5	4.8	0
2014	5.1	1.8	3.7	2.2	0	7.7	4.6	0.98
2015	4.2	1.1	3.2	2.1	0	6.5	4.5	0.78
2016	3.3	1.1	3.1	1.8	0	5.6	4.4	0.45
2017	3	1.2	3.2	2.1	0	5.9	3.3	0.58
2018	2.9	1	3.4	1.8	0	6.6	5.1	0.98

	Chinarkent	Aktash	Khumson	Chimgan	Amirsay	Charvak	Yusuphona	Beldirsay
2019	3.6	1.3	3.8	1.6	0.9	10.9	5.5	0.89
2020	3.5	1.2	4.6	1.4	14.9	11.6	4.7	0.85
2021	4.5	1.7	8.1	1.9	15.8	15	6.5	1
2022	5.7	3.5	9.9	2.1	18.3	23	7	0.66
2023	4.9	4.3	10.7	2.4	15.1	28.2	6.6	1.22

Table 1. The annual trend of radiance of touristic zones Tashkent region, ut/cm2. 2012-2023. (Compiled by authors by using data from <https://lighttrends.lightpollutionmap.info/#zoom=0&lon=0.00000&lat=33.78523>)

Years Months	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
January	8.1	6.6	7.4	6	5.3	6.3	3.9	7.8	22.8	16.3	19.3	28.2
February	7.9	6.9	4.6	4.5	5	4.9	5.4	6.6	14.2	11.7	19.7	21.9
March	6.9	5.9	3.2	5.4	4.9	3.9	5.1	6.4	10.1	11.1	14.4	19.2
April	6.6	5.9	4	5.5	5.1	3.8	4.6	9.1	11	12.3	21	21.3
May	8	7.3	6.7	5.9	4.8	4.8	5.2	10.1	11.2	12.8	23.2	24.4
June	10.7	9.5	9.2	9	6	5.7	8.1	9.8	13.1	18.3	30.7	29.9
July	11.3	8.7	10.7	8.1	7.1	8.4	9.2	12.6	11.5	15.9	27.1	34.7
August	9.2	8.7	9.5	7.3	7.2	6.8	7.8	12.7	12.9	16.2	22.7	29.9
September	9.2	7.9	8.2	5.3	5.2	5.3	6.5	11.8	10.9	16.4	24.4	26.7
October	7.7	7	5.4	4.3	4.8	5	6.8	11.2	11.6	13.7	23	30.4
November	6.3	5.4	4.6	6	4.3	5.7	6.4	12.9	11.1	13.8	29.6	30.8
December	5.4	6.9	4.6	3.8	4.3	7.6	7.4	13.5	14.4	15.9	29.7	33.8

Table 2. The monthly trend of most repeated Radiance of the Chorvak touristic zone, ut/sm2, 2012-2023 (Compiled by authors).

The radiance dynamics was calculated of all touristic zones. The change of annual dynamics is detected for all touristic zones by growth of radiance. Sample is in Figure 6.

The growth rate of Radiance R_g was calculated for all touristic zones. Sample is in Figure 7.

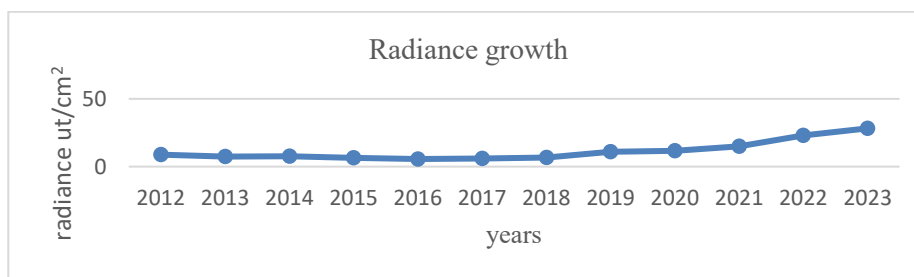


Figure 6. Charvak touristic attraction radiance growth. (Compiled by authors).

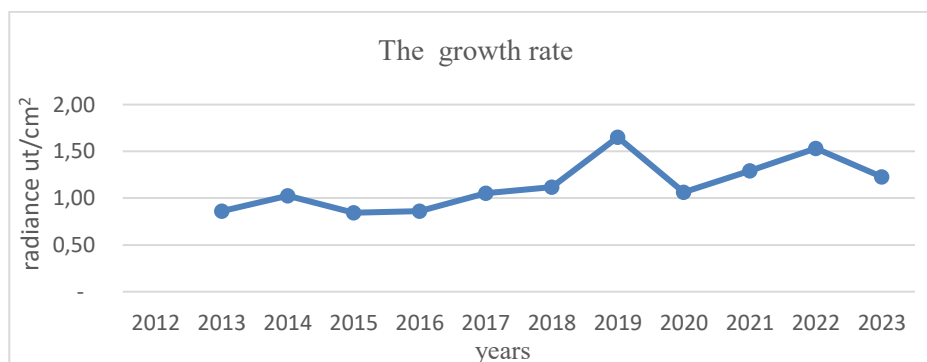


Figure 7. The growth rate of Radiance R_g of the Charvak touristic attraction radiance. (Compiled by authors).

Due to the presence and frequent repetition of fractional numbers of R_i between 2 and 3, 5 and 7, 9 and larger numbers in the Radiance index, these numbers were selected as the limiting numbers when dividing into stages. The sequence of stages was

determined as follows: the number of repeating numbers between 0-3, 3-6, 6-9, 9-12 and their intervals was determined in the stages (Table 3).

Radiance value (ut/sm ²)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
0-3	7	8	8	8	5	3	1	2	3	3	3	4
3-6	4	2	3	3	4	4	6	6	6	5	5	4
6-9		1	1	1	1	6	3	1	0	1	1	1
9-19	1	1			2	1	2	3	3	2	3	3

Table 3. Number of cases observed on monthly base, Charvak touristic zone 2012- 2023. (Compiled by authors)

Verification of quality of radiance is performed according to the standard evaluation metrics (Table 4).

Name	Equation
Mean Squared Error (MSE)	$MSE = \frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2$
Root Mean Squared Error (RMSE)	$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2}$
Coefficient of Determination (R^2)	$R^2 = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2}$
Mean Absolute Error (MAE)	$MAE = \frac{1}{n} \sum_{i=1}^n y_i - \hat{y}_i $

Table 4. The evaluation metrics of Radiance data.

Temporal change of radiance was investigated for detecting its variety and frequency. By identifying the numbers in this range, the frequency of frequently recurring numbers was determined. Dynamics of monthly change of radiance $R_{(i)}$ probability $P_{(i)}$ is set for the grouping.

Four groups of radiance R_i change with the probability P_i and frequency Ω_i were identified (Table 5):

1. R_i 0-3(ut/cm²) $P_i=0.08-0.17$
2. $R_i=3-6$ (ut/cm²) $P_i=0.17-0.33$
3. $R_i= 6-9$ (ut/cm²) $P_i=0.33-0.50$
4. $R_i= 9-20$ (ut/cm²) $P_i=0.50-0.67$

Charvak touristic zone												
Radiance value (ut/cm ²)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
0-3	0.58	0.67	0.67	0.67	0.42	0.25	0.08	0.17	0.25	0.25	0.15	0.33
3-6	0.33	0.17	0.25	0.25	0.33	0.33	0.50	0.50	0.50	0.42	0.25	0.33
6-9	-	0.08	0.08	0.08	0.08	0.50	0.25	0.08	-	0.08	0.05	0.08
9-20	0.08	0.08	-	-	0.17	0.08	0.17	0.25	0.25	0.17	0.15	0.25
Aktash touristic zone												
0-3	0.08	0.38	0.17	0.08	0.08	-	-	-	-	-	-	-
3-6	0.17	0.72	0.25	0.25	0.08	-	-	-	-	-	0.17	0.08
6-9	0.25	0.48	0.17	0.17	0.33	0.25	0.42	0.33	0.17	0.25	0.33	0.50
9-21	0.42	0.89	0.42	0.50	0.58	0.75	0.58	0.67	0.83	0.75	0.50	0.42

Table 5. Trend of probability of frequencies detected on monthly base, 2012-2023.

The average frequency value was found for each touristic zone (Table 6).

δ_i - monthly average value of radiance frequency
 Ω_t - monthly total value of radiance frequency

$$\delta_i = \Omega_t / 12 \quad (3),$$

Radiance value (ut/sm ²)	Touristic zone								
	Chinorkent	Aktash	Khumson	Chimgan	Amirsoy	Chorvak	Yusuphoxona	Beldirsoy	Kumushkon
0-3	0.06	0.01	0.02	0.04	0.72	0.04	0.02	0.06	0.08
3-6	0.02	0.01	0.05	0.01	0.12	0.06	0.04	0.33	0.09
6-9	0.01	0.02	0.01	-	-	0.06	0.01	0.15	-
9-19	-	0.03	0.01	-	0.28	-	0.01	-	-
Radiance value (ut/sm ²)	Touristic zone								
	Sokok	Nevich	Krasnogorsk	Dukent	Yangiobod	Zarkent	Ohangaron	Urtachirchiq	
0-3	0.06	0.08	0.04	0.03	0	0.06	0	0	
3-6	0.06	0.08	0.04	0.03	0	0.06	0	0	
6-9	0.03	-	0.02	0.02	0	0.02	0	0	
9-19	-	-	0.01	0.01	0	-	0	0	

Table 6. Average monthly total value of radiance frequency Ω_t of Radiance R_i for each touristic zone, 2012-2023. (Compiled by authors)

The probability of frequency of the calculated radiance values shows the maximum values of most its frequent repetition in the intervals between 0-3 ut/cm² and 9-20 ut/cm². In Charvak, these radiance values of ut/cm² correspond to December, January, February, March and April. In the intervals 3-6, 6-9, the highest values were in June, July, August, September and almost all years have low values. Data was verified according the probability of frequency of radiance. The data of higher probability is accepted reliable for further analysis. From this perspective all touristic

zones were determined as throughout the year, seasonal (summer, winter), special. All touristic zones are divided depending on radiance value on 4 major groups of tourism type and form: 1. Low capacity of touristic activities, radiance between 0-3ut/cm². 2.Moderate capacity 3-6 ut/cm². 3. High capacity 6-9 ut/cm². 4. Very high capacity 9-20 ut/cm² (Table 7). The variation of the monthly Radiance R_i level (Figure 8) demonstrates the change of its intensity over the year and serves as an indicator of the type and the form of touristic services.

Assessment categories	Radiance value (ut/cm ²)	Average probability of frequencies of recorded radiance	Tourism type
1. Low capacity of touristic activities	0-3	0.02	Seasonal (summer, winter),
2. Moderate capacity	3-6	0.07	Seasonal (summer, winter), special.
3. High capacity	6-9	0.11	throughout the year, seasonal (summer, winter), special.
4. Very high capacity	9-20	0.28	throughout the year, seasonal (summer, winter), special.

Table 7. Assessment of touristic zones through the probability of frequencies of radiance values. (Compiled by authors).

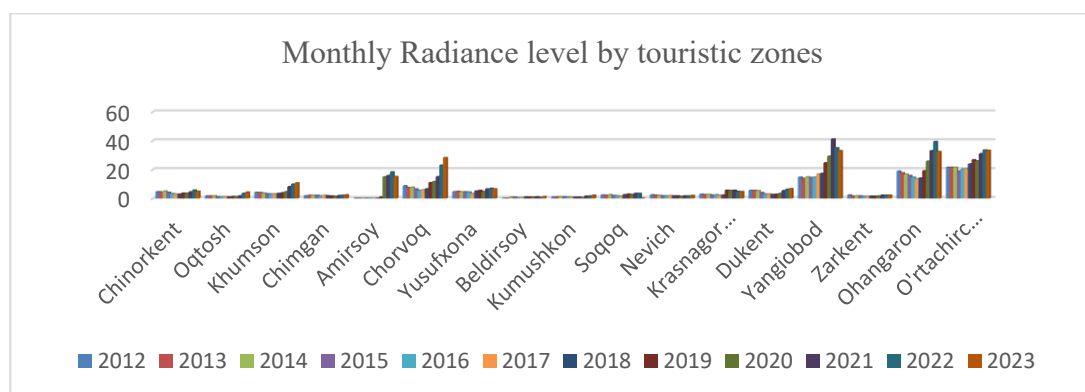


Figure 8. Monthly Radiance level by touristic zones. (Compiled by authors).

Based on an average probability P_i of frequencies of recorded radiance R_i all touristic zones are characterized by their capacity of touristic activities (Table 8).

Touristic zones	Radiance value (ut/cm2)				Assessment categories
	0-3	3-6	6-9	9-20	
Chinorkent	0.61	0.36	0.01	0.10	Low capacity of touristic activities
Oqtosh	0.08	0.17	0.29	0.45	Very high capacity
Khumson	0.08	0.17	0.29	0.45	Very high capacity
Chimgan	0.26	0.64	0.09	0.10	Moderate capacity
Amirsoy	0.50	0.10	-	-	Low capacity of touristic activities
Chorvoq	0.72	1.50	-	0.28	Low capacity of touristic activities
Yusufxona	-	0.19	0.52	0.37	High capacity
Beldirsoy	0.26	0.56	0.18	0.08	Moderate capacity
Kumushkon	0.81	0.88	1.77	-	Moderate capacity
Soqoq	1.00	1.09	-	-	Moderate capacity
Nevich	0.72	0.45	-	-	Low capacity of touristic activities
Krasnagorsk	1.00	-	-	-	Low capacity of touristic activities
Dukent	0.53	0.28	0.18	0.09	Low capacity of touristic activities
Yangiobod	0.35	0.30	0.19	0.08	Low capacity of touristic activities
Zarkent	-	-	-	1.00	Very high capacity
Ohangaron	0.83	0.17	-	-	Low capacity of touristic activities
O'rtachirchiq	-	-	-	1.00	Very high capacity

Table 8. Assessment of touristic zones through the probability of frequencies of radiance values. (Compiled by authors).

The assessment of the capacity of the touristic zones is aiming to define the level of the development of the touristic services. Such kind of assessment provides the base for planning and management touristic activities.

5. Conclusion

This study demonstrates the effectiveness of nighttime satellite imagery in assessing the dynamics and capacity of touristic zones in the Tashkent region. By analyzing VIIRS radiance data over a twelve-year period, clear seasonal and spatial patterns of tourism activity were detected. Higher radiance values during winter months in Chinorkent and Amirsoy, and spring peaks in Kumushkon and Oktash, Beldirsoy correspond with tourism seasonality. Touristic zones were successfully classified into four capacity levels based on radiance intensity (Gulyamova et al., 2023), providing an evidence-based framework for evaluating tourism potential.

The use of radiance frequency analysis enhances reliability in cases where statistical tourism data is lacking, allowing tourism dynamics to be monitored with greater confidence and supports the statement about efficiency of such data (Sutton & Costanza, 2002). Future integration of radiance metrics with ground-based data and the application of regression models (Schober, Boer, & Lothar, 2018; Sarstedt & Mooi, 2014) will further strengthen predictive capabilities. This approach not only supports better tourism management and planning but also contributes to broader regional development and sustainability goals by enabling data-driven decision-making.

Acknowledgment

This study was carried out under the research project, "Networking for Climate, Environmental and Social Smart Cities in Central Asia (NETSTAN)," has been approved for funding by the German Ministry of Education and Research (BMBF) under the ID 01DK25002.

Data Availability Statement

The data that support the findings of this study are openly available in <https://lighttrends.lightpollutionmap.info/#zoom=6&lon=69.11744&lat=41.34543>

The authors confirm that the data supporting the findings of this study are available within the article.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

References

- Bennett, M., & Smith, L. (2017). Advances in using multitemporal night-time lights satellite imagery to detect, estimate, and monitor socioeconomic dynamics. *Remote Sensing of Environment* (192), 176–197
- Chen, Z., Yu, S., You, X., Yang, Ch. (2023). New nighttime light landscape metrics for analyzing urban-rural differentiation in economic development at township: a case study of Fujian province, *China. Appl. Geogr.* (150), 102841
- Doll, C., Muller, J., & Morley, G. (2006). Mapping regional economic activity from night-time light satellite imagery.

- Ecological Economics*, 57(1), 75–92.
<https://doi.org/10.1016/j.ecolecon.2005.03.007>
- Dong, H. (2020). Study on urban spatiotemporal expansion pattern of three first-class urban agglomerations in China derived from integrated DMSP-OLS and NPP-VIIRS nighttime light data. *Journal of Geo-Information Science*. Vol.22, Issue 5, 1151
<https://doi.org/10.3390/rs13122245>
- Elvidge, C. D., Baugh, K. E., Anderson, S. J., Sutton, P. C., & Ghosh, T. (2012). The Night Light Development Index (NLDI): A spatially explicit measure of human development from satellite data. *Social Geography*, 7, 23–35. <https://doi.org/10.5194/sg-7-23-2012>
- Elvidge, Ch., Zhou, Y., Cao, Ch., Warner, T. (2017). Remote sensing of night-time light. *Remote Sensing of Environment* Volume 5855-5859.
<https://doi.org/10.1080/01431161.2017.1351784>
- Elvidge, Ch., Cinzano, P., Pettit, D., Aversen, J., Sutton, P., Small, C., Nemani, R., Longcore, T., Rich, C., Safran, J., Weeks, J., & Ebener, S. (2007). The Nightsat mission concept. *International Journal of Remote Sensing of Environment* 28(2), 2645–2670.
- Elvidge, Ch., Baugh, K., Zhizhin, M., Chi F. (2013). Why VIIRS data are superior to DMSP for mapping nighttime lights. *Proceedings of the Asia-Pacific Advanced*. (35)62-69.
<https://dx.doi.org/10.7125/APAN.35.7> ISSN 2227-3026
- Gulyamova, L., Rasulov, A., Nizomova, R., Kazakov, A., & Rakhmonov, D. (2023). Spatial assessment of natural conditions for recreational tourism in the mountains of Tashkent region. *E3S Web of Conferences*, 386, 06008.
- Levin, N., & Zhang, Q. (2017). Global analysis of factors controlling VIIRS nighttime light levels from densely populated areas. *Remote Sensing of Environment* (190), 366–382 <https://doi.org/10.1016/j.rse.2017.01.006>
- Levin, N., Kyba, Ch., Zhang, Q., Sánchez A., Román, M., Li, Xi., Portnov, B., Elvidge, Ch. (2020) Remote sensing of night lights: A review and an outlook for the future. *Remote Sensing of Environment* Volume (237) 111443
<https://doi.org/10.1016/j.rse.2019.111443>
- Levin, N., Phinn, S. (2016). Illuminating the capabilities of Landsat 8 for mapping night-lights. *Remote Sensing of Environment* (182), 27-38. DOI:10.1016/j.rse.2016.04.021
- Levin, N. & Zhang, Q. (2017). A global analysis of factors controlling VIIRS nighttime light levels from densely populated areas. *Remote Sensing of Environment* (190), 366–382 <https://doi.org/10.1016/j.rse.2017.01.006>
- Li, Y.; Ye, H.; Gao, X.; Sun, D.; Li, Z.; Zhang, N.; Leng, X.; Meng, D.; Zheng, J. (2021). Spatiotemporal Patterns of Urbanization in the Three Most Developed Urban Agglomerations in China Based on Continuous Nighttime Light Data (2000–2018). *Remote Sens.* 2021.13, 2245.
<https://doi.org/10.3390/rs13122245>
- Li, J., He, S., Wang, J., Ma, W. & Ye, H. (2022). Investigating the spatiotemporal changes and driving factors of nighttime light patterns in RCEP Countries based on remote sensed satellite images. *J. Clean. Prod.* 359, 131944
<https://doi.org/10.1016/j.jclepro.2022.131944>
- Mellander, C., Lobo, J., Stolarick, K., & Matheson, Z. (2015). Night-time light data: A good proxy measure for economic activity? *Plos one*, 10(10),
<https://doi.org/10.1371/journal.pone.0139779>
- Mokhtari, Z., Bergantino, A. S., & Intini, M. (2025). Nighttime light extent and intensity explain the dynamics of human activity in coastal zones. *Scientific Reports*, (15), 1663.
<https://doi.org/10.1038/s41598-025-85917-z>
- Morales-Arilla, J., Gadgin, M. (2024). GLocal: A global development dataset of subnational administrative areas. 11, 851
<https://doi.org/10.1038/s41597-024-03539-y>
- Sutton, P. C., & Costanza, R. (2002). Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. *Ecological Economics*, 41(3), 509–527.
- Sarstedt, M., & Mooi, E. (2014). A concise guide to market research: The process, data, and methods using IBM SPSS statistics (2nd ed.). Springer. <https://doi.org/10.1007/978-3-642-53965-7>
- Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia & Analgesia*, 126(5), 1763–1768.
<https://doi.org/10.1213/ANE.0000000000002864>
- Wang, X., Sutton, P. C., & Qi, B. (2019). Global mapping of GDP at 1 km² using VIIRS nighttime satellite imagery. *International Journal of Geo-Information (IJGI)*, 8(12), 580.
<https://doi.org/10.3390/ijgi8120580>
- Wang, X., Rafa, M., Moyer J., Li, J. (2019). Estimation and mapping of sub-national GDP in Uganda using NPP-VIIRS imagery. *Remote Sensing* 11, 163
- Xu, J., Song, J., Li, B., & Liu, D. (2021). Combining night time lights in prediction of poverty incidence at the county level. *Applied Geography* 135(7–8):102552
DOI:10.1016/j.apgeog.2021.102552
- Yang, Z., Chen, Y., Guo, G., & Zheng Z. (2021). Using nighttime light data to identify the structure of polycentric cities and evaluate urban centers. *The Science of the total Environment* 780:146586,
DOI:10.1016/j.scitotenv.2021.146586