

# Night Restoration in Urban University Campuses: A Simulation-Based Engineering Approach for YTU Davutpaşa

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## ABSTRACT

This study aims to quantify night sky brightness at Yıldız Technical University (YTU) Davutpaşa Campus, mapping it using a Geographic Information System (GIS) to identify light pollution hot spots. Sky brightness values were collected across 18 measurement points using a Sky Quality Meter (SQM) with 10 repetitions per point (at 10-second intervals), while horizontal and vertical illuminance levels were simultaneously measured at eye level using a lux meter to correlate both datasets on a common graphical plane. The Magnitudes Per Square Arcsecond (MPSAS) across the campus ranged between 16.08 and 17.56 mag/arcsec<sup>2</sup> (approximately corresponding to urban/Bortle 8–9 conditions), with the lowest values observed around central pathways and open athletic fields, and relatively darker pockets located along peripheral zones. These findings suggest the adverse impacts of high correlated color temperature (CCT) sources and floodlights exhibiting flux spill into the upper hemisphere. Accordingly, to embody the improvement potential at the critical point where light pollution reached its maximum across the campus, a typical calculation (design simulation) was performed; within this framework, design parameters such as luminaire type, mounting height, spacing, positioning, and tilt angle were thoroughly addressed to present a comprehensive design proposal. Potential mitigation strategies include full cut-off luminaires, CCT 3000 K, smart controls via timers/sensors, and periodic GIS-based monitoring. The proposed methodology is repeatable and can provide decision support for energy-efficient lighting retrofits at the campus scale. Future studies will aim to develop lighting designs tailored to the campus's spatial and cultural identity, alongside strategies to mitigate the identified light pollution.

**Keywords:** Light Pollution, Artificial Lighting, Energy Conservation, Sky Quality

## Introduction

Light pollution, defined as the degradation of the natural night sky brightness by anthropogenic artificial lighting, has emerged as a significant issue today with both environmental and societal dimensions. Particularly in rapidly urbanizing regions, inappropriate luminaire selection, excessive use of light, and high correlated color temperature (CCT) light sources are among the primary causes of light pollution [1,2]. Global satellite-based studies reveal that night sky brightness increases by approximately 2% each year, and more than 80% of the world's population lives under artificial light-polluted skies [1].

The impacts of light pollution are not limited to astronomical observations alone. From an ecological perspective, the natural rhythms of many species are disrupted; the navigational behaviors of migratory birds and the nesting and sea-finding

behaviors of sea turtles are adversely affected [3-5]. Regarding human health, effects linked to melatonin suppression, sleep disorders, and chronic disease risks have been reported [6-7]. Socially, light pollution also negatively impacts urban aesthetics and nighttime spatial experiences.

In terms of the energy dimension, misdirected light leads to severe resource waste. A study conducted in the US estimates that approximately 30% of annual exterior lighting energy is lost due to unnecessary light straying into the sky [8]. These losses not limited to increasing energy bills, also create an additional burden in the fight against climate change by increasing carbon emissions. Studies conducted specifically on Turkey also reveal the intensity of light pollution in residential areas and establish a direct correlation with energy efficiency policies [9,10].

University campuses are suitable study areas for light pollution research due to both their high lighting demand and sustainability visions. Measurement studies conducted in various campuses in

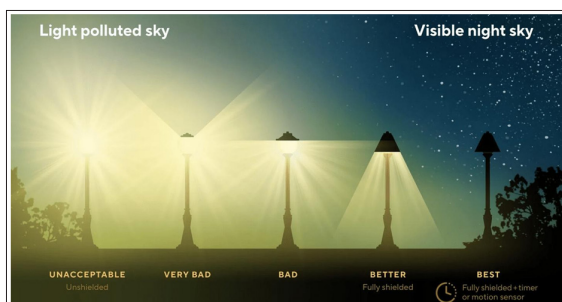
the literature provide data for examining and reducing the spatial distribution of light pollution [10,11]. In addition, the use of GIS-based methods (IDW, Kriging, etc.) enables the creation of spatial decision support systems [12].

In this context, light pollution has become a common topic not only for astronomy communities but also for a wide range of researchers interested in energy efficiency, ecology, and human health. Factors such as excessive lighting, inappropriate light colors, or improper use of timers and sensors trigger light pollution, creating negative impacts on the environment, wildlife, and human health. Components of light pollution include glare, skyglow, light trespass, and clutter. Unnecessary lighting and the use of inappropriate luminaires lead to the waste of natural resources and jeopardize environmental sustainability.

In this study, measuring and analyzing light pollution was carried out specifically for Yıldız Technical University (YTU) Davutpaşa Campus as a university already advancing in line with green campus and global sustainability goals [13]. Night sky brightness was quantitatively measured, mapped using a Geographic Information System (GIS), and light pollution "hot spots" were identified across the campus. This study is directly related to the United Nations Sustainable Development Goals (particularly Goal 7: Affordable and Clean Energy and Goal 13: Climate Action), Turkey's 11th Development Plan, and TUBITAK 2024–2025 R&D and Innovation Topics. Contributing to Turkey's energy efficiency targets, this study serves as a decision support tool for sustainable lighting transformations to be developed at the campus scale.

The primary objective of this research is to minimize light pollution and increase energy efficiency in exterior lighting systems, taking Yıldız Technical University as a model. Accordingly, the findings obtained through campus-wide measurements, GIS-based analyses, and comparisons with the literature both reveal the current situation and guide future improvements.

The types and placement layouts of luminaires used in artificial lighting design have a direct impact on night sky brightness. While full cut-off luminaires limit the upward dispersion of light, poorly directed or optically weak luminaires increase light pollution, leading both to energy loss and unfavorable conditions for astronomical observations. The impact of exterior lighting luminaire design and usage on the sky is given in Figure 1.



**Figure 1:** Sky Impact of Exterior Lighting Luminaires [14]

### Current Lighting Conditions at the Campus

Field observations conducted at YTU Davutpaşa Campus revealed that the existing luminaires used at many points cause both

energy inefficiency and light pollution. It was observed that these luminaires disperse light into the sky and the horizontal plane, thereby reducing environmental quality. As an example, two commonly encountered luminaire types are presented in Figure 2.



**Figure 2:** Examples of Luminaires Commonly Used on Campus

### Measurement of Night Sky Brightness and SQM

Sky brightness is frequently expressed in astronomy using the unit magnitudes per square arcsecond ( $\text{mag}/\text{arcsec}^2$ ). The larger the value, the darker the sky is considered to be. Average sky brightness values were calculated from the data obtained at each measurement point and processed onto the sky brightness map.

The device used in this study is the Sky Quality Meter, model SQM-Le. The SQM device measures the collected light energy in  $\text{mag}/\text{arcsec}^2$  and performs this measurement from an area within a  $20^\circ$  cone relative to the normal of the Earth's surface [12]. Measurements were taken using a tripod positioned at a height of 1.5 meters from the ground. Ten repetitions were performed per point, with fixed intervals left between measurements.



**Figure 3:** Sky Quality Meter (SQM)

### Qualitative Assessment of Night Sky Darkness: The Bortle Scale

The Bortle Dark-Sky Scale was used to qualitatively define night sky darkness. This scale classifies the night sky based on the types and visibility levels of celestial bodies visible to the naked eye, enabling the comparison of sky quality across different regions.

### GIS-Based Interpolation (IDW)

IDW interpolation was used to estimate night sky brightness values for the regions between the measurement points. In this method, the value at the target point is derived from surrounding measurements using distance-inversely proportional weighting. The IDW method is an effective, easily interpretable, and reliable method, particularly for local-scale studies with dense and regular sampling.

**Table 1: Bortle Dark-Sky Scale**

| Level/Class | Title                             | NELM      | SOM mag/arcsec <sup>2</sup> |
|-------------|-----------------------------------|-----------|-----------------------------|
| 1           | The high dark sky area            | 7.60–8.00 | 21.70–22.00                 |
| 2           | The typical truly dark area       | 7.10–7.50 | 21.50–21.70                 |
| 3           | Rural sky area                    | 6.60–7.00 | 21.30–21.50                 |
| 4           | The rural or suburban area        | 6.10–6.50 | 20.40–21.30                 |
| 5           | Suburban sky area                 | 5.60–6.00 | 19.10–20.40                 |
| 6           | Bright with the suburban sky area | 5.10–5.50 | 18.00–19.10                 |
| 7           | Suburban or urban transition area | 4.60–5.00 | 18.00–19.10                 |
| 8           | City sky area                     | 4.10–4.50 | Less than 18.00             |
| 9           | Inner-city sky area               | ≤ 4.00    | Less than 18.00             |

This theoretical framework brings together field data, GIS analysis, photometric examination, and simulation methods at the campus scale. The objective is to develop evidence-based design and operational recommendations to support an energy-efficient and low-environmental-impact lighting retrofit.

### Methodology

The study area was selected as Yıldız Technical University Davutpaşa Campus. The campus accommodates a combination of intensive construction, buildings with various functions, extensive green spaces, and sports facilities. Due to the diversity of lighting sources (sodium vapor luminaires, LED retrofits, floodlights, etc.) and varying usage intensities, the campus forms a suitable sample area for light pollution analysis. The distribution of measurement points was determined according to the following criteria:

- Representation of different functional zones (clubs valley, dormitory surroundings, main roads, green spaces, sports areas),
- Inclusion of open and obstructed horizon conditions,
- Reflection of the variability in luminaire density and light source types,
- Ensuring homogeneous coverage across the campus by maintaining an average interval of 200–250 m between points.

**Figure 4:** Satellite image of the campus map and selected points

Consequently, 18 different measurement points were determined, and these points were recorded using GPS coordinates. The coordinates are given in meters under the UTM (Universal Transverse Mercator)/Gauss-Kruger projection. The study area is located in Zone 39, based on the 30° East central meridian. The terms Northing and Easting are parameters used in GIS to

express the Cartesian coordinates of a point, typically measured in meters. Northing values express the distance northward from the equator, while Easting values express the distance eastward from the central meridian of the relevant UTM zone. Thus, the measurements were made directly positionable within the GIS environment. The points selected on the campus map are presented in Figure 4.

### GIS and IDW Interpolation

The acquired point data were imported into the QGIS environment and plotted onto the campus map using the latitude and longitude coordinates of the points. Interpolation was performed using the IDW (Inverse Distance Weighting) method. IDW is a deterministic interpolation technique that calculates each cell value in spatial estimations by weighting surrounding observation points inversely proportional to their distances raised to a power. This method strongly reflects the spatial correlation of the data by ensuring that nearby points have a more dominant influence on the estimation. The IDW interpolation function is defined as follows:

$$f(p) = \frac{\sum_{i=1}^N d_i^{-u} z_i}{\sum_{i=1}^N d_i^{-u}}, \quad d_i \neq 0$$

Here,  $z_i$  represents the values of the data points,  $d_i$  represents the Euclidean distance between the interpolation point  $p$  and the data point, and  $u$  represents the power parameter, which is generally chosen to be greater than 1 [17].

The parameters were set such that the power value = 2 and the maximum number of neighbors = 12. As a result, a spatial distribution map of night sky brightness was obtained across the campus. This map enabled a visual comparison between bright/polluted areas and relatively dark areas.

### Findings and Discussion

#### General Overview of Measurement Results

The measurement results obtained from different points of the campus within the scope of the study are given in Table 2.

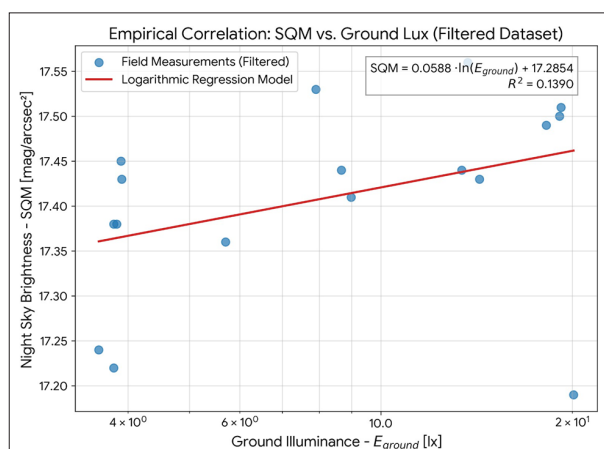
**Table 2: YTU Davutpaşa Campus SQM and Luxmeter Measurement Results (Selected Points)**

| POINT | LOCATION     | SQM AVERAGE OF 10 MEASUREMENTS | LUX   |
|-------|--------------|--------------------------------|-------|
| 1     | Clubs Valley | 17.19                          | 20.10 |

|    |                              |       |       |
|----|------------------------------|-------|-------|
| 2  | Center                       | 17.41 | 8.98  |
| 3  | Kışla Mosque                 | 16.08 | 12.50 |
| 4  | Faculty of Civil Engineering | 17.44 | 8.67  |
| 5  | Technopark                   | 17.43 | 14.30 |
| 6  | Technopark                   | 17.50 | 19.10 |
| 7  | Gate B                       | 17.49 | 18.20 |
| 8  | Computer Engineering         | 17.44 | 13.40 |
| 9  | Yıldız Cafe                  | 17.56 | 13.70 |
| 10 | Nation's Garden              | 17.43 | 3.91  |
| 11 | Faculty of Arts and Sciences | 17.45 | 3.90  |
| 12 | Bus Stop                     | 17.24 | 3.60  |
| 13 | Guest House                  | 17.36 | 5.70  |
| 14 | İhan Varank Library          | 17.53 | 7.90  |
| 15 | Technopark                   | 17.51 | 19.20 |
| 16 | Gate A                       | 17.22 | 3.80  |
| 17 | Gate A                       | 17.38 | 3.84  |
| 18 | Gate A                       | 17.38 | 3.80  |

As seen from the table, the lowest value was determined as 16.08 mag/arcsec<sup>2</sup> (No: 3, northeast region), and the highest value as 17.56 mag/arcsec<sup>2</sup> (No: 9, southwest region). These values indicate that the campus is in the Bortle 8–9 class, meaning that urban lights exert a prominent dominance over the night sky.

In order to bring these data obtained in different units to a common ground and formulate the mathematical relationship between them, SQM and lux values were subjected to correlation analysis on the same graphical plane. Since surface brightness is a logarithmic scale, a trend curve was fitted by taking into account the inverse and exponential/logarithmic relationship between illuminance and surface brightness. Accordingly, an attempt was established to derive a meaningful common coefficient and conversion relationship between the two parameters.



To quantitatively formulate the empirical relationship between the ground illuminance and the night sky brightness obtained from field measurements, a numerical regression procedure was implemented. Accordingly, the data were first imported into a numerical analysis software environment (Microsoft Excel),

where a scatter plot was constructed by assigning ground illuminance values to the independent variable (X-axis) and night sky brightness values to the dependent variable (Y-axis).

To model the non-linear relationship among the data points on the plot, Excel's **Logarithmic Trendline** algorithm was utilized. In accordance with the characteristics of photometric units, this algorithm fitted the data to a logarithmic equation in the format  $y=a \cdot \ln(x)+b$

Through the **Least Squares Method** optimization executed by the software's backend, the sum of squared vertical residuals between each measurement point and the curve was calculated, mathematically deriving the optimal slope coefficients that minimize this total to a global minimum.

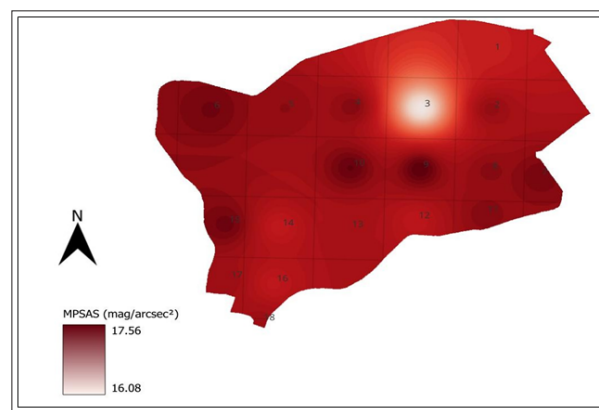
As a result of this optimization and iteration process, the best-fit empirical correlation for the data set was obtained:

$$SQM=0.0588 \cdot \ln(E_{ground})+17.2854 \text{ (Equation 1)}$$

### GIS-Based Distribution Map and Typical Calculation Design

As a result of the IDW interpolation performed in the QGIS environment, central and roadside areas (e.g., No: 3) indicate high levels of light pollution with lower SQM values. In contrast, higher SQM values obtained in the peripheral areas of the campus (e.g., No: 6, 7, 15) demonstrate areas where light pollution is relatively low and the night sky can be observed in a darker state.

When the map is examined, it is observed that the night sky brightness is higher around the main roads and open sports areas located in the center of the campus. The light pollution map obtained as a result of the measurements is given in Figure 5.



**Figure 5:** Light Pollution Map of the Campus

As a focal point selected in alignment with the project's primary objectives of mitigating light pollution and achieving night restoration, the walkways around Kışla Mosque—identified through field measurements and GIS-based mapping as the zone with the highest light pollution density across the campus—were subjected to a typical calculation design in DIALux evo.

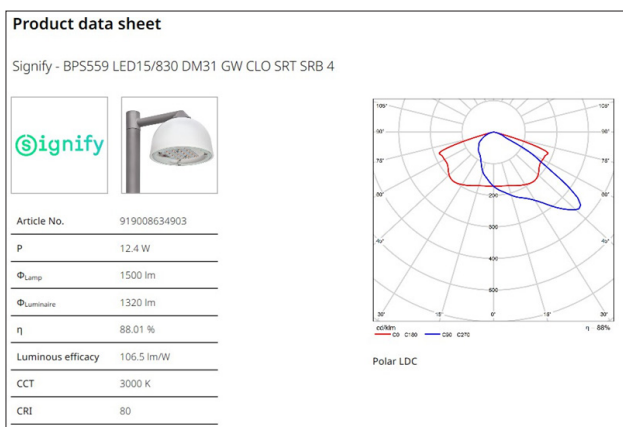
To preserve the dark sky integrity of the campus ecosystem and completely eliminate harmful luminous flux directed toward the sky, the Signify Copenhagen LED gen2 mini (BPS559) luminaire model featuring full-cutoff and asymmetric light distribution was chosen.

To preserve the dark sky integrity of the campus ecosystem and completely eliminate harmful luminous flux directed toward the sky, the Signify Copenhagen LED gen2 mini (BPS559) luminaire model featuring full-cutoff and asymmetric light distribution was chosen, with the product visual provided in Figure 6.

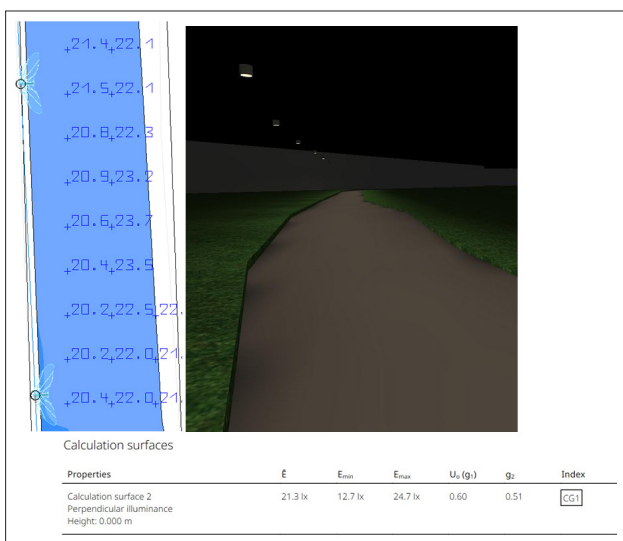


**Figure 6:** Appearance and technical details of the Signify Copenhagen LED gen2 mini (BPS559) luminaire

The technical data sheet of these efficient luminaires with a system power of 12.4 W and a luminous flux of 1320 lm is presented in Figure 7; by positioning the luminaires at a 4-meter mounting height with 8-meter pole spacings (Figure 8), compliance with the required illuminance levels of international road lighting standards ( $E = 21.3 \text{ lx}$ ,  $U = 0.60$ ) was flawlessly achieved while preventing unnecessary luminaire density and over-lighting.



**Figure 7:** Technical data sheet of the Signify Copenhagen LED gen2 mini (BPS559) luminaire



**Figure 8:** DIALux evo lighting layout plan for the Kışla Mosque walkway

Restricted solely to circulation axes, this engineering intervention maximizes photometric efficiency across the campus, concretely proving through simulation data the applicability of sustainable lighting strategies that are environmentally conscious and effectively neutralize light pollution, which forms the core vision of the project.

### Comparison with Literature

When compared with similar studies, SQM values obtained in the center of Istanbul are generally reported within the range of 16.8–17.5 mag/arcsec<sup>2</sup>. The maximum value of 17.56 mag/arcsec<sup>2</sup> found on the YTU campus indicates that certain areas of the campus remain relatively darker compared to the city center. However, the average values fall quite short of the international "dark sky park" criteria (21 mag/arcsec<sup>2</sup>). The measurement ranges for school campuses and districts in various provinces are given in Table 3.

**Table 3: Comparison of SQM measurement ranges across various studies**

| Study                                                               | Measurement Location               | SQM Measured Value Range |
|---------------------------------------------------------------------|------------------------------------|--------------------------|
| Yeşiltaş vd., 2023 [10]                                             | Çukurova University Campus         | 13,19- 19,16             |
| Nasıroğlu vd., 2020 [11]                                            | Atatürk University Campus          | 16,66- 19,51             |
| Nilüfer İlçesi Işık Kirliliğini Araştırma Projesi Sonuç Raporu [15] | Nilüfer District, Bursa Province   | 17,38- 20,90             |
| Özyurt Ökten vd., 2023 [16]                                         | Hatay ili İskenderun ilçesi        | 12,74- 18,30             |
| This Study                                                          | Yıldız Technical University Campus | 16,08- 17,56             |

### Conclusion and Recommendations

This study has revealed the status of light pollution on the YTU Davutpaşa Campus through sky brightness (SQM) measurements, GIS-based distribution maps, and photometric simulations.

The SQM values obtained across the campus range between 16.08 and 17.56 mag/arcsec<sup>2</sup>. These values indicate that the campus generally falls within the Bortle 8-9 class, meaning city lights have a strong impact on the night sky. The lowest value was recorded in the vicinity of the Kışla Mosque in the northeast of the campus (16.09 mag/arcsec<sup>2</sup>), while the highest value was recorded near the Yıldız Café in the southwest (17.56 mag/arcsec<sup>2</sup>). GIS-based interpolation maps demonstrated that light pollution concentrates particularly around main roads and open sports areas, whereas relatively darker pockets exist in the peripheral regions of the campus.

Replacing existing high-pressure sodium and non-full-cutoff floodlights with full-cutoff LED luminaires will reduce both light pollution and energy consumption. Utilizing light sources with a correlated color temperature of 3000 K and below will both minimize adverse effects on biological rhythms and limit sky glow. During hours of low pedestrian density, motion sensors and dimming switch systems should be utilized to

prevent unnecessary energy consumption. The GIS-based light pollution map generated for the campus should be updated at regular intervals so that change trends can be monitored in the long term.

The findings obtained on the YTU campus serve as an example for conducting similar measurement campaigns throughout Istanbul and integrating them with the Istanbul Lighting Master Plan. Light pollution awareness events targeting campus users, especially students and personnel, should be organized to provide direct experience through sky observations.

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### References

1. Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, et al. The new world atlas of artificial night sky brightness. *Sci Adv*. 2016. 2: e1600377.
2. Kyba CCM, Kuester T, de Miguel AS, Baugh K, Jechow A, et al. Artificially lit surface of Earth at night increasing in radiance and extent. *Sci Adv*. 2017. 3: e1701528.
3. Aksay CŞ, Ketenoğlu O, Kurt L, et al. Işık kirliliği. *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*. 2007. 7: 231-236.
4. Gauthreaux SA, Belser CG. Effects of artificial night lighting on migrating birds. In: Rich C, Longcore T, editors. *Ecological consequences of artificial night lighting*. Washington, DC: Island Press; 2006. 67-93.
5. Witherington B, Martin RE. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. Tallahassee (FL): Florida Marine Research Institute. 2003.
6. Cho YM, Ryu SH, Lee BR, Kim KH, Lee E, et al. Effects of artificial light at night on human health: a literature review of observational and experimental studies applied to exposure assessment. *Chronobiol Int*. 2015. 32: 1294-1310.
7. Chepesiuk R. Missing the dark: health effects of light pollution. *Environ Health Perspect*. 2009. 117: A20.
8. Cinzano P, Falchi F, Elvidge CD. The first World Atlas of the artificial night sky brightness. *Mon Not R Astron Soc*. 2001. 328: 689-707.
9. Küçük ZK, Ekren N. Light pollution and smart outdoor lighting. *Balkan J Electr Comput Eng*. 2021. 9: 191-200.
10. Yeşiltaş HK. Light pollution measurements at Çukurova University Balcalı Campus. *Journal of Çukurova University Faculty of Engineering*. 2023. 38: 359-373.
11. Nasıroğlu İ, Güney Y, Kılıç Y, Niaei MS, Tozoğlu B. Sky quality measurement (light pollution) of Atatürk University campus. *Türk J Astron Astrophys*. 2020. 1: 431-432.
12. Türk Ö, Yavuz M. Measurement and evaluation of light pollution in Atakum district using an unmanned aerial vehicle. *Journal of Science of Süleyman Demirel University Faculty of Arts and Sciences*. 2023. 18: 99-109.
13. Yıldız Technical University. Sustainability report 2023. Istanbul: Yıldız Technical University; 2023.
14. DarkSky International. What is light pollution? [Internet]. [cited 2025 Sep 23]. Available from: <https://darksky.org/resources/what-is-light-pollution>
15. Nilüfer District Light Pollution Research Project Final Report. Bursa; 2017.
16. Korkut O, Sinem Ö, Ökten Ö, Kapan AA. Investigation of the impact of light pollution on urban quality of life: The case of İskenderun/Hatay. *Journal of the Institute of Science and Technology of Osmaniye Korkut Ata University*. 2023. 6: 2123-2135.
17. Shepard D. A two-dimensional interpolation function for irregularly spaced data. In: *Proceedings of the 1968 23rd ACM National Conference*; 1968 Aug 27-29; Washington, DC. New York: Association for Computing Machinery; 1968. 517-524.