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Assessment of Night Sky Brightness and Light Pollution Around the UTM Observatory, Johor, Malaysia

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Abstract

This study investigates the influence of artificial lighting on night sky brightness in the vicinity of the UTM Observatory, Johor, Malaysia. Measurements were conducted using a Sky Quality Meter (SQM) at twelve locations representing different land-use environments, including residential zones, road networks, commercial areas, and a stadium. Recorded values ranged from 16.66 to 19.07 mag/arcsec², indicating noticeable spatial variation caused by surrounding artificial light sources. The brightest sky conditions (16.66 mag/arcsec²) were detected near stadium floodlights, while the darkest measurements (19.07 mag/arcsec²) were obtained close to UTM Tropical Park, where artificial lighting is limited. A statistical evaluation was performed to identify the dominant contributors to sky brightness degradation. Results indicate that the observatory is exposed to moderate to high levels of light pollution relative to dark-sky standards, potentially reducing the visibility of celestial objects and affecting astronomical observations. The findings highlight the need for targeted mitigation, particularly involving stadium and roadway lighting, and provide baseline information for long-term monitoring and observatory protection.

Keywords: artificial light, Sky Quality Meter, night sky brightness, astronomical observations, light pollution

1. Introduction

In the modern era, artificial lighting is driving a global surge in night-sky brightness. Defined as the misuse or overabundance of outdoor illumination—such as skyglow, glare, and light trespass (Lyytimäki, 2025; Ścieżor, 2019) where light pollution is expanding rapidly. While earlier estimates noted a 2.2% annual growth in artificially lit areas (Kyba et al., 2017), more recent data indicate a 9.6% yearly increase from 2011 to 2022, meaning sky brightness doubles roughly every eight years (Kyba et al., 2023) This steady rise is further supported by VIIRS satellite data, which shows a continuous spread of light-polluted zones (Gyenizse et al., 2022; Yerli et al., 2021). As a result, more than 80% of people worldwide now live under skies where artificial glow obscures the stars and other celestial events (Linares Arroyo et al., 2024).Within Malaysia, High-Pressure Sodium (HPS) streetlights have been pinpointed as a major driver of this brightening trend (Tahar et al., 2020). This worsening light pollution substantially degrades local sky quality and limits the visibility of celestial bodies (Faid et al., 2016); Hailmy & Musa, 2024). Consequently, these patterns underscore a critical need for localised research to identify the specific sources of artificial light. Evaluating these environmental conditions is crucial for sustaining astronomical activities, a point echoed in various regional case studies (Aksaker et al., 2020; Kurt et al., 2024).

The increase of artificial illumination poses an escalating challenge for the astronomical community, obscuring celestial bodies and degrading the overall fidelity of nocturnal viewing. Consequently, the expanding footprint of urban infrastructure now exposes even the most isolated research facilities to disruptive levels of anthropogenic glare (Aboushelib et al., 2019; Komarova et al., 2025; Wesołowski, 2023). In Malaysia, Bely et al. (2024) stressed the need to consistently track zenithal sky brightness to monitor these changes, noting that even designated dark-sky areas are succumbing to significant brightening. Maintaining ideal conditions for astronomy remains a major challenge, underscoring the need to thoroughly evaluate night-sky quality and pinpoint specific light pollution sources at sites like the UTM Observatory in Johor (Bely et al., 2024; Kurt et al., 2024; Umar et al., 2018, 2023).Consequently, this research evaluates nocturnal sky luminance by examining the extent of light pollution surrounding the Universiti Teknologi Malaysia (UTM) Observatory in Johor. The overarching goal is to determine the correlation between artificial illumination and overall night sky conditions by quantifying local emissions and identifying the predominant artificial light sources within a 2-kilometre radius of the facility.

2. Materials and Methods

2.1 **Study Area:**Because it directly aligns with the study's goals, the UTM Observatory in Johor, Malaysia, was selected as the principal research location. To thoroughly evaluate the area's environmental and viewing conditions, the investigation analysed a 2-kilometre zone around the facility (as depicted in FIGURE 1). This boundary was established to monitor factors nearby that significantly affect observation quality, including atmospheric conditions and light pollution. By limiting the analysis to this radius, the research achieves an optimal balance between depth and broader coverage, which enables highly precise assessments of local effects. Ultimately, tailoring the study's scope to align with the observatory's operational parameters strengthens the research framework, ensuring that the findings will benefit both ongoing and future astronomical projects at the UTM facility.

2.2 **Methodology:** To ensure accuracy and environmental consistency, data collection was strictly limited to clear, cloudless nights during moonless or new moon phases, with observation windows scheduled between 9:00 pm and 11:00 pm. Night sky brightness was quantified in magnitudes per square arcsecond (mag/arcsec²) using a Sky Quality Meter (SQM). This instrument is extensively validated in the astronomical community for evaluating light pollution and characterizing sky conditions at diverse observation sites (Bará et al., 2020; Cinzano, 2005). Specifically, this study utilised the SQM-LE model (illustrated in FIGURE 2), which was pointed directly at the zenith. The device features a front lens that restricts the measurement angle to a 20-degree cone, and its portable design, combined with consistent sensitivity. Furthermore, the SQM-LE features Ethernet connectivity to support real-time data logging and seamless transfer during field surveys. This functionality is vital for maintaining the strict temporal coordination and synchronisation required to guarantee robust, consistent, and reliable environmental data collection (Musa et al., 2019).

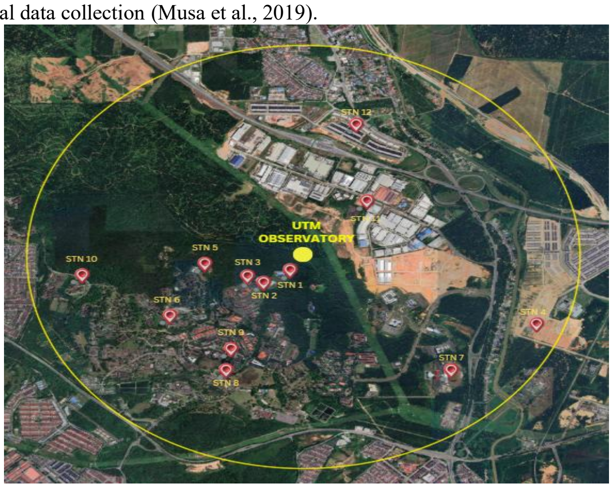

FIGURE 1. Spatial coverage of the research area, encompassing a 2-kilometer boundary around the UTM Observatory in Johor. The central observatory serves as the primary node for recording sky brightness, with the yellow outline marking the exact limits of the study (Source: Google Earth).

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FIGURE 2. The Sky Quality Meter–LE (SQM-LE) was employed in this study to measure night sky brightness, expressed in magnitude per square arcsecond (mag/arcsec^2).

3. **Results and Discussion:** The study was carried out within a clearly defined area consistent with the research objectives, following a structured workflow that encompassed data collection, processing, analysis, and interpretation.

3.1 **Sky Brightness Data:** The impact of artificial light was evaluated by recording sky brightness across 12 distinct monitoring sites. Each selected location featured unique environmental conditions and lighting profiles, and its precise geographical coordinates were documented. Results revealed significant spatial variation within the 2-kilometre study area (TABLE 1), with average night sky brightness ranging from 16.66 to 19.07 mag/arcsec^2 a notable difference of 2.41 mag/arcsec^2. Furthermore, these brightness levels are categorised using equivalent classes: the Bright band encompasses measurements between 18.25 and 20.24 mag/arcsec^2, whereas the White band designates brighter, more polluted skies with readings less than 18.25 mag/arcsec^2 (Crumey, 2014).

TABLE 1. Sky brightness at each station.

Station	Lat.	Long.	Mean SQM (mag/ arcsec^2)	SD	Sky Class (Crumey, 2014)	Dominant Light Source
1	1°34′03.26″	103°38′35.52″	18.54	0.012	Bright	Road lighting
2	1°33′58.67″	103°38′27.24″	18.55	0.043	Bright	Housing area lights
3	1°34′00.35″	103°38′23.64″	18.57	0.032	Bright	Commercial lighting
4	1°33′43.23″	103°39′48.96″	17.18	0.101	White	Street illumination
5	1°34′05.96″	103°38′09.60″	18.08	0.110	White	Street illumination
6	1°33′45.73″	103°37′59.16″	17.00	0.038	White	Road lighting
7	1°33′23.67″	103°39′23.04″	16.66	0.100	White	Stadium floodlights
8	1°33′24.16″	103°38′16.44″	19.07	0.011	Bright	Streetlights
9	1°33′32.68″	103°38′17.52″	17.84	0.043	White	Commercial lighting
10	1°34′01.70″	103°37′32.52″	18.10	0.038	White	Housing area lights
11	1°34′30.38″	103°38′58.10″	18.00	0.057	White	Housing area lights
12	1°35′00.58″	103°38′55.27″	18.09	0.012	White	Housing area lights

Analysis of the data reveals clear geographic disparities in night-sky luminance across the observation sites, with some locations maintaining steady, dark conditions while others experience intense, fluctuating brightness. Maximum light pollution was recorded at Station 7 (FIGURE 3), primarily driven by the severe glare from nearby transportation infrastructure and stadium floodlights. Conversely, the darkest measurements were obtained at Station 8 (FIGURE 4), situated adjacent to UTM Tropical Park, an area largely shielded from direct artificial illumination.

Overall measurement conditions remained largely consistent, as evidenced by standard deviation values ranging from 0.011 to 0.110. Within this spectrum, Station 8 provided the most stable data, whereas Station 5 (adjacent to the cafeteria) recorded the greatest fluctuations. This high variance at Station 5 was presumably caused by temporary light emissions from shifting building lights and passing vehicles. Ultimately, these findings verify that stadium and transportation networks act as the primary catalysts for local light pollution, significantly outweighing the impacts of commercial or housing area light emissions

FIGURE 3 Night sky brightness was recorded using the SQM-LE installed on a tripod near a stadium with strong illumination, illustrating how nearby artificial lighting affects local sky conditions.

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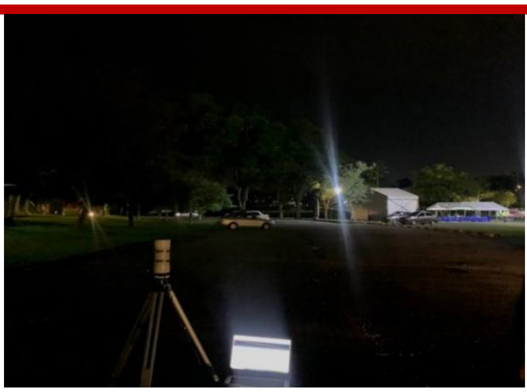

FIGURE 4 Among all monitoring locations, Station 8—located adjacent to UTM Tropical Park showed the darkest conditions with a recorded value of 19.07 mag/arcsec². The elevated magnitude suggests reduced skyglow and minimal impact from nearby urban illumination.

3.2 Statistical Analysis of Sky Brightness Measurement

Data collected from the 12 observational sites demonstrated significant geographic disparities in artificial light pollution. Measurements spanned from 16.66 to 19.07 mag/arcsec², reflecting a substantial divergence in nocturnal sky quality across the surveyed zone. Because the magnitude scale is inverted, higher values indicate darker environments with minimal interference, while lower values indicate more illuminated, highly polluted skies. Specifically, Station 8 recorded the darkest, optimal measurements (19.07 mag/arcsec²), indicating a negligible impact from nearby artificial sources. Conversely, maximum luminance was detected at Station 7 (16.66 mag/arcsec²), an outcome directly attributed to severe glare from adjacent stadium floodlights.Furthermore, analysing the error bars' standard deviations reveals critical insights into the environmental stability of each location (FIGURE 5). Sites such as Stations 1, 3, 8, and 12 showed high stability during the observation periods, yielding negligible standard deviations of < 0.02 mag/arcsec². On the other hand, a pronounced data spread emerged at Stations 4, 5, 6, and 7, where standard deviations surpassed 0.10 mag/arcsec². Such heightened variance indicates a greater vulnerability to dynamic lighting disruptions, presumably driven by inconsistent vehicular traffic, unpredictable commercial illumination, or temporary high-intensity glare

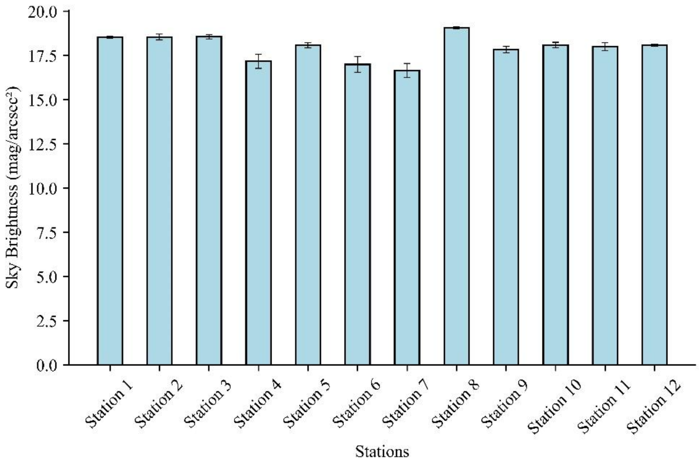

FIGURE 5 Average night sky brightness was calculated for 12 monitoring stations located within a 2 km radius of the UTM Observatory, with standard deviation shown as error bars. These error bars indicate the spread of measurements at each station.

Classifying monitoring stations by their dominant artificial light sources reveals distinct environmental patterns. Locations subjected to commercial illumination and public streetlamps typically recorded moderate sky luminance, ranging from 17.80 to 18.60 mag/arcsec². Conversely, observation points situated near transportation networks and stadium floodlights persistently registered the lowest quality of dark skies. Furthermore, sites dominated by housing area light emissions yielded intermediate measurements, suggesting that domestic lighting has a localised, relatively minor impact compared to the extensive glare of large-scale infrastructure. Ultimately, these findings strongly suggest that future light pollution interventions must prioritise high-intensity emissions—specifically from transit networks and sports stadiums because these specific sources drive the most profound deterioration of nocturnal sky conditions.

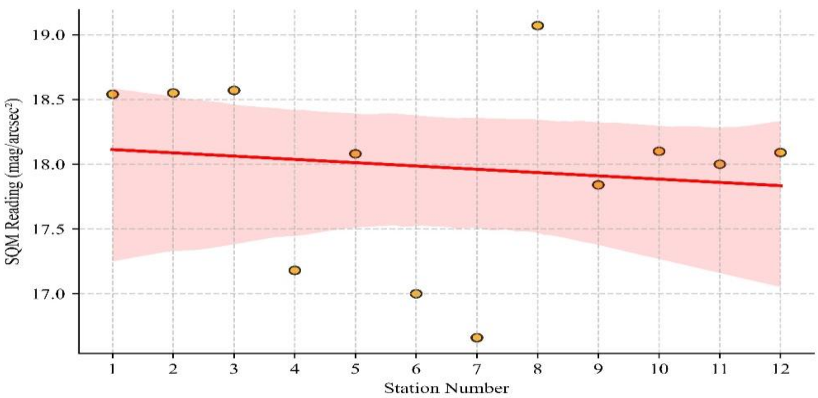

FIGURE 6 Scatter plot showing the relationship between individual monitoring stations and the measured night sky luminance (mag/arcsec²). The visualisation includes a fitted linear regression line, with the shaded area representing the 95% confidence interval.

The variation in sky brightness among the 12 stations is shown in FIGURE 6, where a fitted linear trend and a confidence interval accompany the plotted values. However, the expansive confidence band accompanying this regression line indicates that this linear correlation remains weak and lacks robust statistical significance. Specifically, observation nodes 4 through 7 yielded distinctly diminished magnitude values, an anomaly likely driven by intense, localised artificial lighting rather than a broader systemic trend. Even with these regional fluctuations, most empirical data points converge near the 18.0 mag/arcsec² threshold, indicating a largely stable nocturnal luminance profile across the broader study area. Ultimately, these observational patterns demonstrate that accurate assessments of night sky conditions must rigorously evaluate both localised lighting anomalies and overarching spatial heterogeneities.

3.3 Distribution of Sky Brightness Percentiles

Percentile analysis of the sky brightness data (FIGURE 7) was performed to examine the distribution of light pollution across the 12 monitoring locations. The recorded measurements ranged from 16.66 to 19.07 mag/arcsec², with 16.66 and 19.07 representing the lowest and highest values, respectively. The quartile analysis showed that the first quartile (Q1) occurred at 17.68 mag/arcsec², while the third quartile (Q3) was identified at 18.54 mag/arcsec². These values yield an interquartile range of 0.86 mag/arcsec², indicating moderate variation in sky brightness across the observation stations. Consequently, this metric demonstrates that the vast majority of monitored locations fall strictly within a moderately polluted, bright-sky classification. Furthermore, a median (50th percentile) reading of 18.09 mag/arcsec² establishes a clear dividing line; exactly half of the surveyed areas benefit from darker atmospheric conditions, while the other half endure more intense artificial illumination. Finally, examining the statistical extremes reveals that the lower tail (10th percentile at 17.02 mag/arcsec²) characterises zones afflicted by severe light intrusion. In contrast, the upper tail (at the 90th percentile, 18.57 mag/arcsec²) highlights the regions most shielded from urban glare.

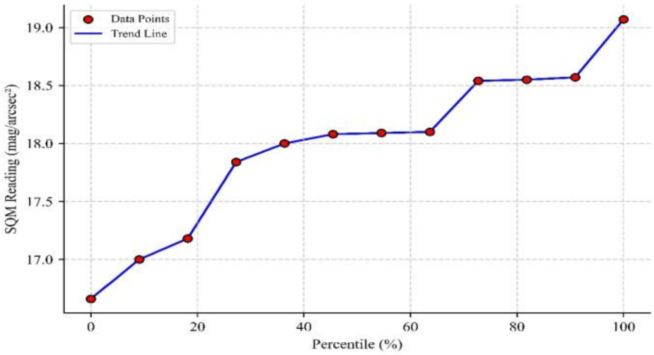

FIGURE 7 The percentile distribution of sky brightness (mag/arcsec²) across all observation stations is presented. The data points correspond to the recorded sky brightness measurements. At the same time, the blue trend line indicates a progressive increase in magnitude with higher percentiles, highlighting the variation in sky quality from brighter to darker locations.

4. Conclusion

This study evaluated night sky brightness within a 2 km radius of the UTM Observatory to examine the impact of artificial light sources on sky quality. The data revealed substantial geographic disparities in luminosity, with measurements ranging from 16.66 to 19.07 mag/arcsec². Maximum artificial glare was concentrated near the stadium and transit infrastructure, whereas the darkest atmospheric conditions were preserved near the minimally lit UTM Tropical Park. Subsequent statistical analysis confirmed that intense commercial and infrastructural emissions act as the primary catalysts for light pollution, driving a moderate yet clear degradation of the viewing environment around the facility.Mitigating these adverse effects requires the immediate implementation of rigorous light management protocols. Recommended interventions include deploying fully shielded lighting fixtures, lowering overall emission intensities, and transitioning toward warm-colour temperature LEDs. Furthermore, instituting regulated lighting zones and strictly enforcing outdoor illumination policies near the observatory will substantially curtail excess skyglow. Subsequent research must combine sustained ground-level tracking with remote satellite data collection, thereby enabling precise evaluations of temporal shifts and the long-term efficacy of these proposed regulatory frameworks.

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