Light Pollution: A Preliminary Study in Kundasang, Sabah Based on Sky Quality Meter System

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Abstract. Night sky brightness is one of the important parameters to be considered in determining the quality of a site for astronomy observation. However, light pollution acts as a major contributor to sky brightness at night. We measure the night sky brightness at Kundasang, Sabah to obtain the first preliminary sky brightness reading. In order to measure light pollution in Kundasang Sabah, Unihedron Sky Quality Meter (SQM-LU-DL) was used for the measurement with a fixed position and oriented towards the zenith. The measurements have been done during the period of July 2018 to February 2019. The measurement is taken between approximately 7 p.m. to 5.30 a.m. everyday. The best night sky brightness reading is on January 5\textsuperscript{th}, 2019 with a value of 21.34 ± 0.7 mag/arcsec\textsuperscript{2}. The preliminary average reading of sky brightness is 20.71 ± 0.2 mag/arcsec\textsuperscript{2}. Comparison with previous similar studies for the same condition of astronomy sites in Malaysia and other locations indicate that Kundasang, Sabah is a suitable location for astronomical observation.

1. Introduction

Night sky brightness is one of the important parameters to be considered in determining the quality of a site for astronomy observation. The night sky brightness caused by airglow, scattered starlight and light pollution which anthropogenic by-product of human activity, is a major contributor to the noise in astronomical observations made from Earth (Faid, Shariff, & Hamidi, 2019). The brightness of night sky limits the depth of telescope detection - the more the faint stars can be observed and the more astronomical information and details can be obtained if the sky brightness in the lower value. The best sky condition required by astronomers is the clear sky, hence light pollution became the most influential factor affecting the astronomers and astronomical observation (Hamidi, et al., 2011).

All the best observations around the world are subject to comprehensive studies of night sky brightness measurements at their locations (Faid, et al., 2016). The prevalent ways that have been used to carry out sky brightness monitoring is through satellite measurement or from ground measurement (Shariff et al., 2016). In Malaysia, several studies have been conducted to ensure the location of the study remains suitable to be the place for observation of celestial objects to either optical or radio astronomy. For example, from January to March 2016 at PERMATApintar Observatory, (Azhar, et al., 2016) have measured the night sky brightness using an SQM-LU with a position pointing zenith to
obtain the first preliminary sky brightness reading. As a result, the acquired data are within the range of the sky brightness for suburban area, which is 19.5 to 20.7 mag/arcsec² after compared to previous similar measurement for the same type of area (suburban area).

Next, night sky brightness study by (Tahar, 2017) found that the average of sky brightness over the entire Langkawi island is 21.45mag/arcsec², and it is an indication that the island is, overall, still relatively dark. The study was carried out at 16 selected locations which are at least 100m from the nearest light source while the devices used are SQM and SQM-L for measuring the sky brightness on the moonless night and the cloudless sky. In addition, Geographic Information System (GIS) was used to interpolate and analyze the obtained sky brightness data in this study, hence generating a spatial model of sky brightness in Langkawi Island that clearly shows the bright and dark sky areas.

Besides, (Umar et al., 2018) showed that night sky brightness reading at KUSZA Observatory is 19.65 mag/arcsec². This night sky brightness study conducted at 10 locations around Merang Terengganu including the KUSZA Observatory using SQM devices. Then, the results were used to compare with the simulation data generated from Earth Observation Group (EOG) of National Oceanic and Atmospheric Administration (NOAA), National Geophysical Data Center, which indicate a significant difference between simulation data and observation data, but, both the simulation results and the SQM results of the level of light pollution around the KUSZA Observatory still in the level that allow the astronomy activities carried out there.

Meanwhile, a study by (Ngadiman, Ahmad, & Wahab, 2018) has performed the night sky measurement at Langkawi National Observatory (LNO) using photometry technique through charge-coupled device (CCD) device with KAF-1001 image sensor attached with telescope. The value obtained, which is 20.65 mag/arcsec², shows that LNO has a good quality of night sky and astronomical observation is suitable to be carried out there.

In addition, Bosscha Observatory located in Bandung, Indonesia (6.82444°S, 107.61556°E, 1300m above the sea level), which has the same climate and season with Malaysia, showed that 17.67 mag/arcsec² and 19.41 mag/arcsec² are the average and maximum magnitudes after midnight. Bandung and Lembang, which are cities around the observatory, clearly give a strong contribution to light pollution and affects SQM readings (Herdiwijaya, 2019). This study was conducted using a portable photometer pointing at zenith direction during years 2011-2012. While, observation in Yogyakarta cities (7.7956° S, 110.3695° E) in years from 2014 to 2016, SQM readings indicated the darkest night could reach 22.61 mag/arcsec² only in few seconds, with mean value 18.8 mag/arcsec² (Herdiwijaya, 2016).

Therefore, this research used Sky Quality Meter (SQM) device and monitored the sky brightness of Islamic Training Centre Kundasang Sabah. The estimation and quantification of sky brightness have considerable benefits and advantages, chiefly to preserve as well as conserve the Kundasang, Sabah from light pollution and as a systematic effort for surveying and mapping local night sky brightness.

2. Methodology
The night sky brightness measurement was carried out at the Islamic Training Centre Kundasang which located at a coordinate of 5.904 N 116.038 E. Kundasang is a town in the district of Ranau in Sabah, Malaysia that lies along the bank of Kundasang Valley. Ranau is noted for its hilly geographical structure and known as the largest producer of highland vegetables in the state of Sabah. Tourism and highland agriculture are the major industries in Kundasang, as its elevation is almost 1900m (6200ft) which is the highest settlement in Malaysia. From light pollution map, the distribution of sky brightness can be seen clearly as illustrated in Figure 1. Higher magnitude indicates by darker color on the map and the magnitude decreases as the color becomes brighter (which indicates greater light pollution). Red regions are mostly city areas and capital of the districts such as Kota Kinabalu, Ranau and Tuaran. Meanwhile, Kundasang has been in the area of light green colour which means it is in a region that is still in high magnitude and relatively dark.
The measurement was taken during July 2018 to February 2019. In order to measure light pollution in Kundasang, Sabah, Unihedron Sky Quality Meter (SQM-LU-DL) was used for the measurement with a fixed position pointing zenith (Figure 2). This is due to focus the maximum point which less polluted. This SQM-LU-DL comes with USB that enabled continual data-logging and will provide the brightness of night sky readings in magnitude per square arcsecond (mag/arcsec²) – the brighter an object visible in the dark sky, the lower the measured magnitude. For this study, the SQM comes with weatherproof housing and powered by an external battery pack for field data logging. The author makes the correction for glass offset value; subtract 0.03 from “Light calibration offset” value using calibration software or subtract 0.03 from all new readings. A crystalline silicon (c-Si) photodiode TSL237 which is electrically connected to a current-to-frequency converter is the detector for this device. The c-Si photodiode is covered by HOYA CM-500 filter, with reported non-zero spectral transmittance between 350 and 750 nm, therefore it sensitive to visible light only. The output frequency is proportional to the intensity of the incident light, thus giving a reliable and precise measurement even at minimum values of brightness. In addition, the SQM-LU-DL is equipped with a narrow 20-degree lens used for capturing light. This provides much more accurate readings than the standard SQM by averaging sky glow magnitude in a smaller portion of the sky, effectively filtering out most of the light that is close to the ground.

3. Result and Discussion

Figure 3 shows the data of the average magnitude of sky brightness for each month when moon illumination <10% (new moon, waxing and waning crescent phases), 10%-60% (first and last quarter moon phases) and >60% (full moon, waxing and waning gibbous phases). The measurement was taken everyday, starts 7:30 pm until 5:30 am, from July 2018 until February 2019. Our results, such as shown in Figure 3 shows that magnitude of the night sky at Kundasang Sabah lies between 20.32 ± 0.4 to 20.97 ± 0.2 mag/arcsec² with 20.71 ± 0.2 mag/arcsec² as the average value when moon illumination less than 10%. In the meantime, the average magnitude decreases to 20.2919 ± 0.1 mag/arcsec² when moon illumination at 10% to 60% range. And, Kundasang, Sabah night sky brightness shows significant difference when moon illumination more than 60%, which is the average magnitude become 18.82 ± 0.1 mag/arcsec². It is noticeable that the magnitude value of night sky brightness becomes diminished as the illumination of the moon increases.
Figure 3. Average magnitude of sky brightness when moon illumination <10%, between 10% - 60% and >60%.

Based on the sky brightness data in Figure 4 and Table 1, the best sky brightness reading is on January 5\textsuperscript{th}, 2019 with a value of $21.34 \pm 0.7$ mag/arcsec\(^2\) while the lowest is on November 16\textsuperscript{th}, 2018 with a value of $18.54 \pm 1.2$ mag/arcsec\(^2\). The data shown are at the moonless night.
Figure 4. The highest and lowest night sky brightness values graph for each month.

Table 1. The best and the lowest sky brightness readings each month.

| MONTH       | MAXIMUM SKY BRIGHTNESS (mag/arcsec²) | MINIMUM SKY BRIGHTNESS (mag/arcsec²) |
|-------------|-------------------------------------|--------------------------------------|
| July        | 20.73 ± 0.5                         | 19.6 ± 1.0                           |
| August      | 21.04 ± 0.6                         | 19.66 ± 0.7                          |
| September   | 20.89 ± 0.7                         | 19.57 ± 1.2                          |
| October     | 21.09 ± 0.7                         | 19.29 ± 0.8                          |
| November    | 21.06 ± 0.6                         | 18.54 ± 1.2                          |
| December    | 21.16 ± 0.6                         | 19.67 ± 0.8                          |
| January     | 21.34 ± 0.7                         | 18.66 ± 1.0                          |
| February    | 21.18 ± 0.7                         | 18.98 ± 1.2                          |

The graph on the left shows a high reading night sky magnitude while the graph on the right side indicates lower magnitude of night sky. The differ in sky brightness value, in this case, mainly due to...
cloud distribution that scattered any artificial light throughout the sky thus causing the brightening of the sky. This can be seen clearly in the graph of July 20th, August 5th, September 9th, October 2nd, November 16th, December 29th, January 14th and February 1st where the brightness fluctuates in certain period of time. The difference range between the lowest and highest night sky brightness magnitude in Kundasang is approximately 2.7978 mag/arcsec².

4. Conclusion
In conclusion, the preliminary average reading of night sky brightness in Kundasang, Sabah is 20.71 ± 0.2 mag/arcsec². Meanwhile, the best night sky brightness reading is on January 5th, 2019 with a value of 21.34 ± 0.7 mag/arcsec². Comparison with previous similar studies for the same condition of astronomy sites in Malaysia indicates that Kundasang, Sabah is a suitable location for astronomical observation. By conducting continuous study about night sky brightness, a more comprehensive assessment of light pollution over the entire Sabah can be produced and it helps to identify areas which currently have low-light backgrounds, but which may be at future risk.

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