Sky Brightness Measurement for the Construction

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Sky Brightness Measurement for the Construction of the Astronomy Observatory Branch of Universitas Muhammadiyah Sumatera Utara (OIF UMSU) in Barus, Central Tapanuli Regency, Indonesia

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Abstract

Light pollution at **Astronomy Observatory of UniversitasMuhammadiyah Sumatera Utara (OIF UMSU)** has spread in all directions so that OIF UMSU plans to build a branch of it in Barus, Central Tapanuli Regency, Indonesia. This research is an experimental study in the form of observing the level of sky brightness using the Sky Quality Meter (SQM). Data was collected at KedaiTiga Beach, Barus District, CentralTapanuli Regency since 24 until 29 February, 2020. The average value of maximum sky brightness obtained was 21.67 mpsas and had level of difference at 2.65 mpsas with the sky at OIF UMSU. So it can be said that the sky in Barus is 11.5 times darker than the sky at OIF UMSU. The sky's brightness in Barus falls into the first category on the Bortle scale (> 21.3 mpsas) which is an ideal location for an observatory location because it has less light pollution so it can observe celestial bodies better than at the current UMSU OIF location.

Keywords: *Sky brightness, observatory, Barus*

I. Introduction

The Astronomy Observatory, UniveritasMuhammadiyah Sumatera Utara (OIF UMSU) is one of the observatories in Indonesia. OIF UMSU is located on the 7th floor of the UMSU postgraduate building which is located at coordinates 3^{o}34'N and 98^{o}43'E**.** OIF UMSU has different kinds of astronomical instruments ranging from classical to modern instruments.In general, OIF activities include research, service, public service, national and international seminars, and internal discussions.Research that has been conducted for this is righteous and dawn observation, observation beginning of the month (new moon), the observation of celestial bodies, and global Hijra calendar research [1]. In the Islamic study, the observatory has three main functions as a study of center sky, as institutions of science, and as a means of deciding the times of worship [2].

The best place to make the observatory used to study the sky is very rare.The stable atmosphere, clear, and dry are important factors in making the observatory.Criteria required to create an observatory that is ideal consists of several factors including a location free from light pollution, free of clouds during the night, and also the availability

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of infrastructures such as electricity, water, and roads are impassable for vehicles [3] .

Light pollution is a problem that is happening around the world resulting in the dilution of celestial objects visible in the night sky.Besides, light pollution also disrupts ecosystems and even harms health [4]. This problem is felt by observatories around the world including the Bosscha Observatory, which is one of the largest and oldest observatories in Indonesia. Bosscha night sky brightness value is currently about 18 magnitude at which time it was first built Bosscha night sky brightness value reached 22 magnitudes. This means that the sky around the Bosscha Observatory is currently 40 times brighter than when the new Bosscha observatory was founded. This prompted the National Institute of Aeronautics and Space (LAPAN) to establish a National Observatory in Kupang, East Nusa Tenggara [5].

The level of light pollution in a place can be detected by measuring the brightness of the night sky in that place. Several tools can be used to measure the brightness of the night sky one of which is the Sky Quality Meter (SQM) [6].SQM is an instrument used to measure the illumination of the night sky with a pocket-size and affordable price.This tool allows the public to measure the quality of the night sky whenever and wherever [7].

The brightness of the sky is divided into nine classes, namely excellent dark-sky site, typical truly dark site, rural sky, rural/suburban transition, suburban sky, bright suburban sky, suburban/urban transition, city sky, and inner-city sky. The nine classes are known as the Bortle scale [8]. The Bortle's scale can be simplified into five categories. First category (> 21.3 mpsas) is the ideal observatory location. The Milky Way Galaxy and the zodiacal lights are still visible. Second category (between 20.4 - 21.3 mpsas), light pollution has started to be seen and the appearance of the Milky Way galaxy and the zodiacal light is only a certain time. Third category (between 19.1 - 20.4 mpsas), the Milky Way galaxy is only visible in the zenith direction, the zodiacal light is difficult to see, and light pollution has reached 35 degrees from the horizon. Fourth category (between 18.0 - 19.1 mpsas), the zodiacal light is not visible, the Milky Way galaxy looks zenith direction at certain times, and light pollution has spread in all directions. Fifth category (<18.0 mpsas), light pollution is already dominant, only bright planets are visible, sky conditions in big cities without a solution to tackle light pollution [9].

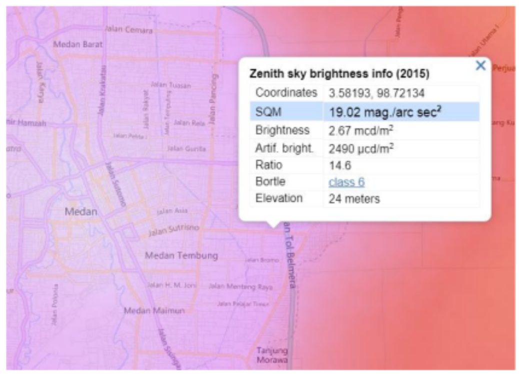

Figure 1.OIF UMSU Sky Brightness Value, based on lightpollutionmap.info

Sky brightness level in OIF UMSU is in four categories based on lightpollutionmap.info as seen in Figure 1. Therefore OIF UMSU intends to open new branches in places that have a low level of light pollution. OIF UMSU plans to open a branch by establishing an observatory in Barus, Tapanuli Tengah district. Barus city selected as they are by the beach away from the hustle of the city, and Barus also inaugurated by the president of Indonesia Mr. JokoWidodo as Zero Point of Islam Nusantara in 2018. This study was conducted to determine the level of light pollution in Barusas branch development of OIF UMSU.

II. OBSERVATORY

In terminology, an observatory is a building used to observe celestial bodies, and these observations are recorded. In the Islamic study, observatories have three main functions, namely as a center for celestial studies, as a scientific institution, and as a

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means of determining times of worship. Observation of celestial objects existed long before the arrival of Islamic civilization because observation is a daily human activity. Almost all parts of medieval Islam had observation activities (observatories) which were generally private and led by an astronomer, and these observatories ended when the character died. Initially, many observation activities were carried out in mosques because of the connection between these mosques and the prayer timing system, especially prayer times [2]. In today's modern era, observatories have a strategic function and position in social and intellectual life in society. Among them, the observatory has values or educational aspects. In the context of education, the observatory has educational values, namely as a means of accurate times and positions of Muslim worship (especially prayer and fasting), as an institution for scientific studies, and as a scientific-educational institution [10].

The best places to build an observatory used for sky study are very rare. A stable, clean, and dry atmosphere is an important factor in making an observatory.
The criteria needed to make an ideal observatory consist of:

a. The location of the observatory should be in an area away from street lighting and traffic lights. The location of the observatory is not in the city center due to its relation to light pollution, but the location is also not too far from the city center. The observatory can be accessed at least by a two to three-hour drive from the city center.
b. Infrastructure such as roads, electricity, water, and telephone must be available. The road must be accessible by vehicles to the city center.
c. Seeing is a form of the term used for determining astronomical imagery. Locations with "poorly observed" will result in unclear recording and low-resolution data.
d. The most basic and very important criterion for an observatory is a night sky that is free of clouds so that it does not interfere with the observation. Strong winds can also interfere with observations because they can cause vibrations in the telescope [3].

III. LIGHT POLLUTION

Light pollution is a worldwide problem resulting in less visible celestial bodies in the night sky. Light pollution also disrupts ecosystems and even harms health. Light pollution is usually divided into two, namely distracting light and excessive light. Light pollution can also be divided into indoor and outdoor light pollution [4]. Outdoor lighting is an indispensable element of modern society for safety, recreation, and decoration purposes. However, a poorly designed lighting system and excessive lighting levels have resulted in a huge waste of money and energy. Common sources of outdoor light pollution are such as street lamps, fluorescent lamps, and lit billboards [11]. Many countries do not yet have an official body regulating light pollution control [12]. There are many ways to reduce the level of light pollution, one of which is holding an Earth Hour activity, which is turning off the lights for one hour on a certain date [13]. Light pollution are included as follows.

a. Skyglow
   Skyglow is caused by the increasing brightness of the sky above residential areas. The scattering of light from the settlements by air particles makes the sky brighter and the stars invisible.
b. Glare
   Excessive brightness which results in discomfort visually and can lower the ability to see.
c. Light trespass
   Disturbing light around the light that illuminates the place unwanted or unneeded.
d. Over illumination
   Excessive number of light sources in quality and quantity could exacerbate light

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pollution.Excessive use of light is also spending more energy.

e. Light clutter

Excessive grouping of the light sources in one place. Light clustering can produce confusion, take your eyes off obstacles, and can cause accidents [4].

IV. SKY BRIGHTNESS

The night sky will never be completely dark. This is because there is the contribution of natural light affects the brightness of the night sky.Six factors contribute to the brightness of the night sky: (1) the combination of the light from distant galaxies;(2) the combination of starlight in the Milky Way;(3) zodiac light; (4) night airglow; (5) aurora; (6) the twilight emission line [14].In addition, the moon phases can also affect the brightness of the sky [15]. As a result of pollution and global warming, the brightness of the sky in Indonesia increasingly dims.Sky brightness levels in a region heavily dependent on the composition of the aerosol particles and cloud particles present in the atmosphere of a region [16].The brightness of the sky is divided into nine classes: excellent dark-sky site, typical truly dark site, sky rural, rural/suburban transition, suburban sky, bright suburban sky, suburban/urban transition, city sky, and inner-city sky.Ninth grade stretcher was known Bortle scale [8].

The Bortle's scale can be simplified into five categories. The first category (> 21.3 mpsas) is an ideal observatory location. The Milky Way Galaxy and the zodiacal lights are still visible. The second category (between 20.4 - 21.3 mpsas), light pollution is starting to look and appearance of the Milky Way and the zodiac light only a certain time.The third category (between 19.1 - 20.4 mpsas), the Milky Way galaxy is only visible in the direction of the zenith, the Zodiac is difficult to see the light, and light pollution has already reached 35 degrees from the horizon.In the fourth category (between 18.0 - 19.1 mpsas), the light Zodiac is not visible, the Milky Way visible toward the zenith at a certain time, and light pollution has spread to all directions.In the fifth category (<18.0 mpsas), light pollution is already dominant, only planets visible light, sky conditions in big cities without a solution to light pollution [9].

V. SKY QUALITY METER

The level of light pollution in a place can be detected by measuring the brightness of the night sky in that place. Several tools can be used to measure the brightness of the night sky, one of which is the Sky Quality Meter (SQM) [6]. SQM is a tool used to measure the illumination of the night sky at a pocket-size and low price. This tool makes it possible for the general public to measure the quality of the night sky anytime and anywhere [7]. SQM measures the brightness of the night sky in terms of magnitudes per square arc second or mathematically it can be written mag / arcsec^2 (mpsas). A magnitude is an astronomic unit for measuring the brightness of an object. One arcsecond is the area of a celestial rectangle whose sides are one arc second. The higher the value read SQM, the darker the object. Every 5 mag / arcsec2 change means the sky is 100 times brighter. The light sensor (TSL237) provides a microcontroller with a light level, and the temperature sensor readings are used to compensate for the light sensor readings through the temperature range when the instrument is operating [17]. The spectral response of SQM is in a fairly wide range, namely the visual range 400 - 650 nm for 0.5 transmissions with a peak of about 540 nm. Thus the SQM spectral range corresponds to the spectral sensitivity of the human eye [18].

VI. RESEARCH METHODS

This research was conducted at KedaiTiga Beach, Barus District, Central Tapanuli Regency with a coordinate point of 2^{o}0'53" N 98^{o} 24'27" E. The research was conducted on 24-29 February 2020.

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Technique of Data Analysis

a. Determination of the maximum night sky brightness value

The brightness value of the night sky can vary up and down due to many factors, one of which is the weather factor. To determine the level of light pollution in the research area is needed maximum sky brightness value can be obtained on-site.Sky brightness maximum brightness value is determined by selecting the highest of the night sky from midnight until morning.

b. Determination of the degree of difference in sky brightness

The level of difference in sky brightness is obtained by finding the difference between the brightness value of the night sky at OIF UMSU and in Barus using equation 1. Sky brightness at OIF UMSU is obtained using lightpollutionmap.info

$$\left| m_{Barus} - m_{OIF} \right| = \Delta m \qquad (1)$$

Pogson determined that the difference in magnitude 5 means there is a difference in brightness by 100 times. With this difference, it can be determined that the brightness of the night sky in Barus has a difference of the number of times the brightness of the night sky in OIF using equation 2.

$$\frac{I_{Barus}}{I_{OIF}} = 2{,}512^{\Delta m} \qquad (2)$$

Research Procedure

Sky brightness measurements using SQM follow the following procedure:

a. SQM is inserted into the holder to be easy to retrieve data and directed facing the zenith and is not hindered by trees or other objects that obstruct SQM against the sky.

b. SQM is connected to a laptop using a cable connector.

c. SQM is run using the Unihedron Device Manager software. SQM is set to read the brightness of the sky every two seconds.

Research Instruments

Instruments in this study include hardware and software to support the attainment of the objectives of this study as desired.

a. Hardware
   1) SQM-LU to detect the brightness of the sky and use a USB cable to connect to the laptop.
   2) Laptop, is a means of obtaining research data obtained from SQM.
   3) Holder, is a protector of SQM so that it can retrieve data when it rains.
   4) Cable connector, as a liaison between SQM and laptop.

b. Software
   1) MicrosoftExcel.
   2) Unihedron Device Manager.

VII. Result and Discussion

The brightness of the sky in Barus from midnight to early morning since 24 until 29 February 2020 was shown in Figure 2. Because it is influenced by clouds, the obtained night sky brightness value does not always have the same value so that the graph looks uneven. However, before sunrise, there are no more clouds, so the resulting graph looks flatter. In figure 2 can be seen the graph impaired sky brightness gradually. This is because the night sky is influenced by sunlight which is refracted by the atmosphere and indicates that the sun will rise.

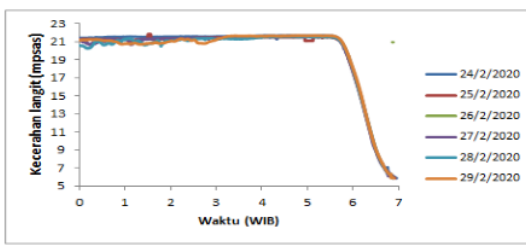

Figure 2. The brightness of the sky Barus zenith direction

The highest sky brightness value during observation from 24-29 February 2020 can be seen in table 1. From this value, the average value is 21.67 mpsas. Based on the Bortle scale, Barus is in the first category (> 21.3 mpsas).

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Table 1 Themaximum sky brightness value in Barus on 24-29 February, 2020

Date	The maximum sky brightness value (mpsas)
24/02/2020	21.72
25/02/2020	21.87
26/02/2020	21.56
27/02/2020	21.62
28/02/2020	21.56
29/02/2020	21.69
Average	**21.67**

With an average maximum brightness value of 21.67 mpsas, Barus is included in the first category (> 21.3 mpsas) on the Bortle scale. This shows that Barus is an ideal place to build an observatory. Due to the small level of light pollution, more celestial bodies can be observed at night. Even the Milky Way galaxy can be seen using the naked eye when the weather is clear. In addition to measuring the brightness of the sky, researchers have also documented the Milky Way galaxy as seen in Figure 3.

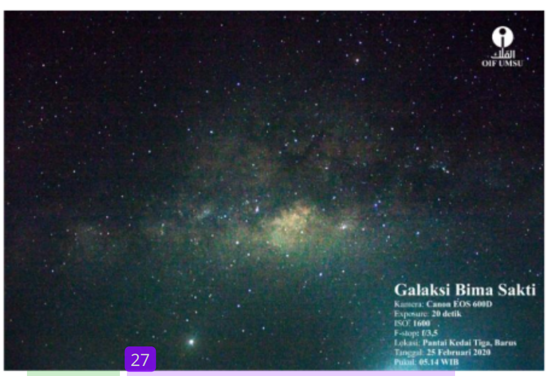

Figure 3. The Milky Way Galaxy seen in Barus

The current location of the OIF UMSU based on lightpollutionmap.info has a sky brightness value of 19.02 mpsas. Based on the Bortle's scale, the location is in category four where the zodiac light is not visible, the Milky Way galaxy is visible in the zenith direction at a certain time, and light pollution has spread in all directions. Meanwhile, the sky's brightness in Barus has a value of 21.67 mpsas. The sky brightness at OIF UMSU and in Barus has a difference in sky brightness of 2.65 mpsas as shown in table 2.

Table 2. Difference in sky brightness OIF UMSU and Barus

OIF UMSU sky brightness (mpsas)	Barus sky brightness (mpsas)	The difference in sky brightness (mpsas)
19.02	21.67	2.65

Using equation 2, it is found that the sky in Barus is 11.5 times darker than the sky at the current OIF UMSU location. Therefore Barus is a suitable place for the construction of an observatory which will become the current branch of the UMSU OIF. Judging from the level of sky brightness, Barus is an ideal location for the observatory location because it has less light pollution so that it can observe celestial bodies better than at the current OIF UMSU location.

VIII. CONCLUSION

The selection ofBarus as a location to build OIF UMSU branch is the right thing. The sky in Barus is 11.5 times darker than the sky at OIF UMSU at this time. Judging from the level of sky brightness, Barus is included in the first category on the Bortle scale which is an ideal location for an observatory location because it has less light pollution so that it can observe celestial bodies better than at the current OIF UMSU location.

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