



Bortle scale: A way to assess and monitor the urban night sky

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Abstract

The skylines of the cities in Metro Manila are towering buildings. Each city in it is peppered with high-rise buildings for business, commercial and residential purposes. The nighttime in these cities is as busy as daytime, the nighttime in these cities became as bright as daytime. A large percentage of the observers hail within Metro Manila. These respondents have scaled their night sky as BS7 which is characterized as City/Suburban Transition where light pollution makes the entire skylight gray, strong light sources are evident in all directions and the Milky Way is nearly or totally invisible. There's also a big percentage of respondents coming from the outskirts of Metro Manila, these respondents have scaled their night sky as BS6 which is characterized as Bright Suburban Sky wherein the zodiacal light is invisible, clouds anywhere in the sky are fairly bright, and high clouds (cirrus) are brighter than the sky background. Also, there was a fairly large percentage of the respondents from provinces like Bulacan and Pampanga 2.5 to 3.5 hours away from Metro Manila who scaled their night sky as BS which is characterized as Suburban Sky that can be described with light pollution that is visible in most directions, clouds are brighter than the sky, the light coming from the Milky Way is very weak near the horizon. Provinces that are 4 to 7 hours or more away from Metro Manila were scaled significantly lower or with darker night skies than provinces near Metro Manila.

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Introduction

It is always a welcoming idea to enjoy the beauty of the night sky even if one is located in the heart of a busy and progressive city. The skylines of the cities in Metro Manila are towering buildings. Each city in it is peppered with high-rise buildings for business, commercial and residential purposes. Living in the two of the most progressive cities in Metro Manila has many advantages, people get to work inside or near these cities, one can enjoy the amenities like proximity to the malls, businesses and commercial hobs, and other recreational places.

The nighttime in these cities is as busy and as bright as daytime. There is a notion that bright lights ensure safety and security in an area, streetlights were installed in every corner of these cities. Businesses utilize the airspace to promote products and services through huge billboards with glaring lights at night so that people can see them easily. Bright lights are somehow associated with festivities, fun, and progress. It seems like the people from various parts of the country are attracted to these cities' urban appeal. As a result, there is a concentration of population from different parts of the Philippines in these cities. City dwellers tend to forget that beyond the colorful and bright city lights lie the jewels of the night skies. These astronomical objects are hidden through total exposure to artificial light in the ground. This has been the main problem arising since the mid-1900s for observational astronomy.

The excessive, misdirected, or obtrusive use of artificial lights result in Light Pollution (LP). Street lights not only lit up the street but also the space above it, lights are not used efficiently. Progressive countries already have different measures to lessen light pollution, for instance, South Korea, Hong Kong, and Britain. According to Hong Soo Lim (2018), to avoid light pollution caused by excessive ALAN (Artificial Lighting At Night), in February 2013 South Korea enacted the Light Pollution Prevention Act. At present, there is no law or ordinance to help address light pollution in Hongkong but in order to address the side effects created alongside light pollution, the

government has provided guidelines and tips to save the environment (Lau S.Y., 2014). In Britain, in an attempt to preserve the darkness of the night sky detailed interactive maps were created to show districts, counties, National Parks and Areas of Outstanding Natural Beauty (AONBs) and, at a wider scale, National Character Areas for England while Scotland and Wales have high-level maps that allow Britain to present the most accurate picture of how much light is spilling up into its night sky. (Night Blight: Mapping England's light pollution and dark skies.)

Measuring Night Sky Condition

Chalkias et al. (2006) noted that various scientists have modeled light pollution in different ways, sky glow at different altitudes, and azimuths from several observation sites were mapped. There is a growing interest in light pollution in different fields of science, for instance, astronomy, environmental sciences, and even human sciences.

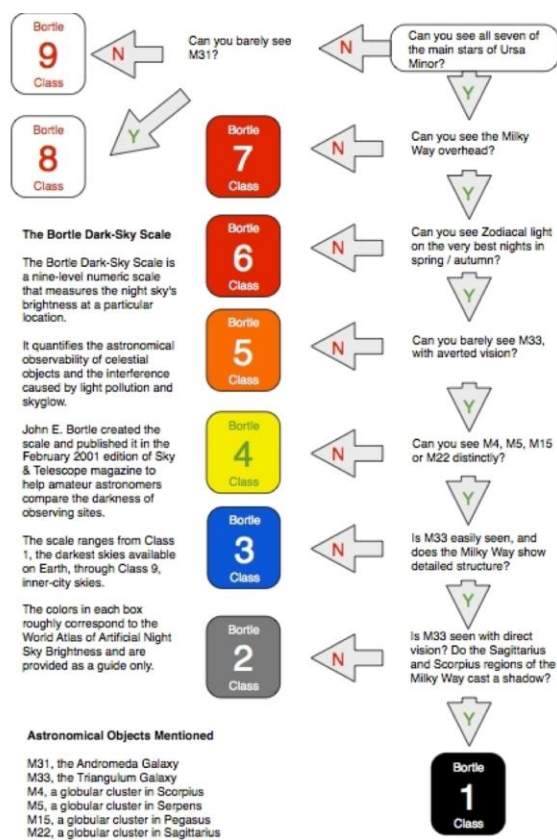
According to darksky.org, there are a variety of ways to approach making a survey of the quality of the night sky. First is the Sky Quality Meter Survey. The Unihedron Sky Quality Meter (SQM) device is used to take scientific-quality measurements of the sky's brightness. To measure the night sky using this device the observer must report all of the measurements where there should be at least 6 measurements per site per visit, disregarding the first measurement.

The device is counterintuitive, the darker the sky the higher the number it will yield. The second approach is the Bortle Scale interpretation. This scale interprets the sky's brightness and how light pollution affects the observer's view of the night sky phenomenon.

Bortle Scale flowchart by Steve Owens, International Dark Sky Places Committee member.

This flowchart can be used to easily interpret the Bortle scale, it is supported by questions to reveal the quality of the night sky. According to the Bortle scale, the best night sky quality has the lowest number. Compared to the Sky quality measurement using a

device, the Bortle scale is less quantitative. A combination of the two or more methods to measure the quality of the night sky will be more accurate. Lastly, the Photographic Evidence. This method can be useful to support the Bortle Scale method. It can also be a way to document the night-sky phenomena. The images' information like exposure time, ISO, Focal length, and date and time should be taken into account. This method is also less quantitative compared with Sky Quality Measurement. It should be used with other methods to accurately document the quality of the night sky.



There is a need to preserve the night sky for mental and physical health, the environment, and for people to enjoy the beauty of the night sky. Unlike air pollution and water pollution, light pollution is not one of the primary concerns in the Philippines. This is the reason why there are no existing rules and guidelines in placing and usage of lighting infrastructure in public areas.

This study may show the extent of light pollution in the cities of Metro Manila, it may become the basis

for setting standards on the proper and efficient utilization of night light in the city to lessen and eventually avoid light pollution in urban cities. Cities can reconsider how the different outdoor lighting will be used effectively and efficiently. The Local government can save a lot of street lights are placed on strategic areas so that its full potential can be utilized. The LGUs should be encouraged to invest money in building sustainable and efficient lighting infrastructures. Guidelines about lighting public areas can be placed. When light pollution in these urban cities is addressed and controlled it would be possible to make Astronomical Observation sites in it for bright objects.

Materials and methods

A descriptive research design was utilized in this study to allow the researchers to observe and study the normal behavior of the subjects without interfering with it. The research design also allowed the researcher to measure and test large samples for the qualitative part.

Light pollution is referred to as changes in natural light levels (Hollan, 2009; Falchi, Cinzano, Elvidge, Keith & Haim, 2011) due to excessive and poorly-designed artificial light (Bashiri & Che Hassan, 2014; Jiang, He, Long, Guo, Yin, Leng, Liu & Wang, 2018). Light pollution appears in different forms such as glare, sky glow, and light trespass (Chepesiul, 2009). Skyglow takes place when light is reflected in the atmosphere (Bennie, Davies, Cruse & Gaston, 2016) which will cause an increase in the brightness of the sky.

This study utilized the raw data gathered from the survey to measure the quality of the night sky in Metro Manila.

Scope and Delimitation

The study is limited to the BS Astronomy students enrolled in the subjects Astronomy Observation I and II. The focus of this study was intended in Metro Manila but due to the pandemic, respondents were scattered in their respective home provinces which are located in the different parts of the Philippines.

Data Gathering

This study utilized the Bortle Scale that was modified to fit the observation condition in the Philippines. The survey of the Modified Bortle Scale was disseminated with the use of Facebook. The reason for the utilization of social media specifically Facebook is its accessibility to the respondents. The respondents of the survey questionnaire were the BS Astronomy students enrolled in the subjects Astronomy Observation I and II. These subjects require the students to conduct a survey of the night sky for the quality of astronomical observations they will make throughout the semester.

Sampling

Part of the requirements of subjects Astronomical Observation 1 and 2 of the students taking up Bachelor of Science in Astronomy is to measure the brightness of the night skies. The Bortle scale survey was modified to fit the present conditions of the target locations and a standard or guidelines was set for the students to follow. The data based on the Bortle scale gathered by the students from different locations will be collected, analyzed, and plotted into a light pollution map.

Mapping

This research used a developmental method that a process and graph the data into the map. The researchers made use of the python programming language to write the codes to be able to read the input file from the pollux device. This input file contains series of data which composed of the date(Date), time(t), latitude (lat), longitude(lon), relative humidity(RH), temperature (degC, degF), light spectrum (FullSpectrum), visible light(visible light), infrared(IR), luminance(LUX), air pressure (mmHG), altitude(alt), total volatile organic compound(TVOC), equivalent carbon dioxide(eCO₂), hydrogen(H₂), gas (LPG), methane (CH₄), carbon monoxide(CO), alcohol(ROH), carbon dioxide(CO₂), toluene(ToL), nitrate(NH₄), and acetone(Ace). These data will be gathered using the pollux device at an interval of one (1) second, which will be saved simultaneously to the microSD card installed in the

pollux device under the file name of “Mandaluyong.csv” and “Pasig.csv” for the data in Mandaluyong and Pasig city respectively.

The program reads the CSV files which also prepares the data for graphing. The user had a chance to choose which data from the list above he wanted to show at a range of times. The program filtered out all of the data from the CSV file based on the user selection which will then be graphed into the map. The program uses several python packages such as pandas which were used to read the CSV file, open street maps which provide the map, plot, and politely express which renders the data into the map. The program rendered the user-selected data at a particular date range, the data were plotted onto the interactive map based on the geographic location to where the data was gathered. A scale bar was also produced showing the color-coded range of intensity of the selected data, the data represented by a color-coded circle whose radius varied depending on the numerical value of the data.

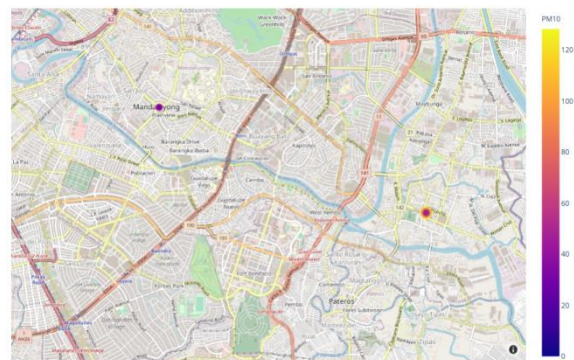


Fig. 1. The PM₁₀ data of Mandaluyong and Pasig City, overlapping data in two points are caused by the same latitude and longitude provided in the PM₁₀ data of DENR which also turns out to be the same observing point in Mandaluyong and Pasig City.

A GitHub account was created using the e-mail address of CARD. The program will then be uploaded to github.com, a software development platform that hosts different software using Git, by this means, the program runs online inside GitHub which enables the user to access the program using the web browser through the “cosmologi” website.

This interactive map will enable the user to zoom in and out of the map to see the available plotted data. The figure below shows the PM10 data of Mandaluyong and Pasig City.

Results and discussion

1. The instrument was used to measure the extent of light pollution

Bortle Scale, the survey using the Modified Bortle Scale was disseminated with the use of social media, the reason for the utilization of social media was its accessibility to the respondents.

The respondents of the survey questionnaire were the BS Astronomy students enrolled in the subjects Astronomy Observation I and II to survey the extent of light pollution in Metro Manila.

The table shows the evaluation of respondents on the night sky during their observation based on the Bortle Scale, Out of 189 respondents 50 or 26.45% classified the night sky as BS7: City/Suburban Transition (light pollution makes the entire sky light gray, strong light

sources are evident in all directions, the Milky Way is nearly or totally invisible), 40 or 21.16% classified the night sky as BS6: Bright Suburban Sky (the zodiacal light is invisible, clouds anywhere in the sky is fairly bright, high clouds (cirrus) are brighter than the sky background), 35 or 18.51% classified the night sky as BS5: Suburban Sky (light pollution is visible in most directions, clouds are brighter than the sky, the Milky Way is very weak near the horizon),

26 or 13.75% classified the night sky as BS8/9: Inner City/City Sky (the sky is light gray or orange, the sky is brilliantly lit, no Messier objects are visible to the naked eye aside from Pleiades), 16 or 8.46% classified the night sky as BS4: Suburban/Rural Transition (the Milky Way is well above the horizon is still impressive but lacks detail, surroundings are clearly visible, even at a distance), 13 or 6.87% classified the night sky as BS3: Rural Sky (some pollution evident at the horizon, clouds are illuminated near the horizon, dark overheard, nearer surroundings are vaguely visible).

Table 1. Evaluation of the night sky using the Bortle Scale.

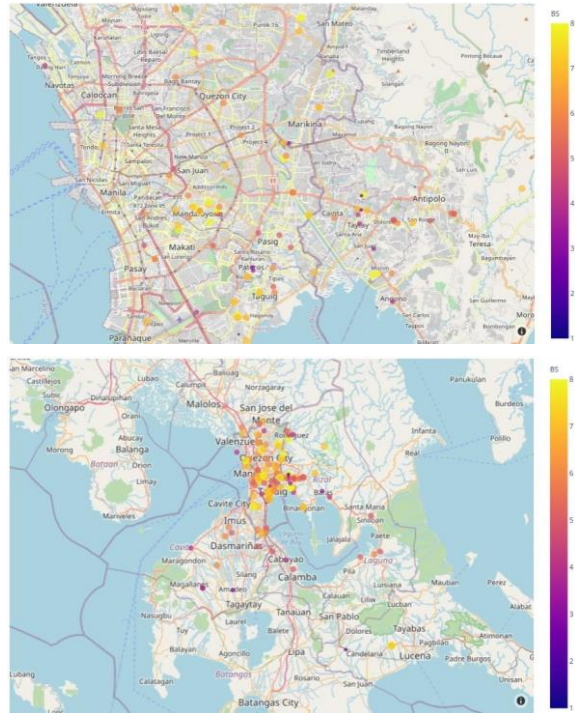
Bortle Scale	Frequency (f)	Percentage (%)
A) BS1: Excellent Dark-sky Site (Scorpius and Sagittarius regions of the Milky Way cast obvious, many constellations, Messier and globular clusters are visible via naked-eye)BS2: Dark-sky Site (zodiacal light is yellowish, clouds are visible as dark holes against the sky, many Messier objects and globular clusters are visible via naked eye)	3	1.58
B) BS2: Dark-sky Site (zodiacal light is yellowish, clouds are visible as dark holes against the sky, many Messier objects and globular clusters are visible via naked eye)	6	3.17
C) BS3: Rural Sky (some pollution evident at the horizon, clouds are illuminated near the horizon, dark overheard, nearer surroundings are vaguely visible)	13	6.87
D) BS4: Suburban/Rural Transition (the Milky Way is well above the horizon is still impressive but lacks detail, surroundings are visible, even at a distance)	16	8.46
E) BS5: Suburban Sky (light pollution is visible in most directions, clouds are brighter than the sky, the Milky Way is very weak near the horizon)	35	18.51
F) BS6: Bright Suburban Sky (the zodiacal light is invisible, clouds anywhere in the sky are fairly bright, high clouds (cirrus) are brighter than the sky background)	40	21.16
G) BS7: City/Suburban Transition (light pollution makes the entire skylight gray, strong light sources are evident in all directions, the Milky Way is nearly or invisible)	50	26.45
H) BS8/9: Inner City/City Sky (the sky is light gray or orange, the sky is brilliantly lit, no Messier objects are visible to the naked eye aside from the Pleiades)	26	13.75
Total	189	100

A large percentage of the observers hail within Metro Manila. These respondents have scaled their night sky as BS7 which is characterized as City/Suburban Transition where light pollution makes the entire skylight gray, strong light sources are evident in all directions and the Milky Way is nearly or totally invisible. There's also a big percentage of respondents coming from the outskirts of Metro Manila, these respondents have scaled their night sky as BS6 which is characterized as Bright Suburban Sky wherein the zodiacal light is invisible, clouds anywhere in the sky are fairly bright, and high clouds (cirrus) are brighter than the sky background. Also, there was a fairly large percentage of the respondents from provinces like Bulacan and Pampanga 2.5 to 3.5 hours away from Metro Manila who scaled their night sky as BS which is characterized as Suburban Sky that can be described with light pollution that is visible in most directions, clouds are brighter than the sky, the light coming from the Milky Way is very weak near the horizon. Provinces that are 4 to 7 hours or more away from Metro Manila were scaled significantly lower or with darker night skies than provinces near Metro Manila.

Aside from animals, the environment has also been affected by light pollution (Falchi, Cinzano, Elvidge, Keith, & Haim, 2011). For example, the Milky Way Galaxy is a visible sight in the night sky before, which is made possible by dim natural light. But today, it vanished because of excessive light. This is caused by “skyglow”, a byproduct of light pollution where the sky is brightened by urban lights (Du, et al., 2018). This is why researchers and space observers prefer observations in locations far from urban areas. 3 or 1.58 BS1: Excellent Dark-sky Site (Scorpius and Sagittarius regions of the Milky Way cast obvious, many constellations, Messier and globular clusters are visible via naked-eye)BS2: Dark-sky Site (zodiacal light is yellowish, clouds are visible as dark holes against the sky, many Messier objects and globular clusters are visible via naked eye)

2. *The instrument that can show the extent of light pollution in Metro Manila.*

Interactive Map of Metro Manila embedded with information on light pollution.



The Bortle scale data gathered by the astronomy students and faculty of the Rizal Technological University.

Conclusion

1. The Bortle scale was a useful tool to measure the quality of the night sky, through it the extent of the light pollution can be scaled. Giving the impression of the condition of the night sky in Metro Manila and nearby provinces. Aside from the quality of the night sky, information such as location, time and day of observation, sources of light, presence of the Moon during observation, and weather conditions were part of the survey.
2. Although the respondents were scattered in different places of the Philippines. Most of them were in Metro Manila, a large number of the respondents have scaled their night sky from BS5 to BS7 this is due to several factors: location, time and day of observation, sources of light, presence of the Moon during observation, and weather conditions. Under the BS7 night sky the light pollution makes the entire skylight gray, strong light sources are evident in all directions, the Milky Way is nearly or totally invisible.
3. It is possible to develop an interactive map using python-based programming and free mapping software.

The data from the CSV file were plotted using python libraries and open-street-map to help us visualize the extent of light pollution using a scale bar from GPS tagged Bortle scale data which can also be sorted using a prescribed duration of time.

Recommendation

1. Though the Bortle scale was proven to be a useful tool, to accurately measure the quality of the night sky and the extent of light pollution affecting it. There are a variety of ways to approach making a survey of the quality of the night sky such as Sky Quality Meter Survey and Photographic evidence. A combination of the two or more methods to measure the quality of the night sky will be more accurate.

2. Night Sky observations must be consistent with the following factors: location, time and day of observation, sources of light, presence of the Moon during observation, and weather conditions.

3. The developed interactive map provides room for improvement. Future researchers may want to add features such as creating a gif plot that shows the extent of Bortle scale data in time series. A back-end program would also be a great help for automatic data retrieval and plotting if someone has uploaded their observations online. Looping codes may also be created for the interpolation of Bortle scale data to form smooth data manifolds.

Acknowledgement

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