Review of potential astronomical optical observatory sites in the Philippines

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Abstract: The Philippines is an archipelago of more than 7,600 islands with many geographical features such as mountain ranges, seas, and plains. The country has fairly developed cities that are now experiencing various kinds of pollution at different levels and intensities. Highly developed urban areas are brightly lit and are currently experiencing worsening light pollution. Despite this, the two biggest telescopes in the country are still installed in two observatories right in the country’s capital city where light pollution is at its worst. This paper aims to identify several locations away from light pollution in the islands of Luzon, the biggest island in the Philippines, and the island of Palawan, where optical astronomical observatories may be built. The locations are chosen by studying the comparative light pollution scales in the various locations. The topography of the place and meteorological data such as temperature, humidity, and precipitation are likewise studied and considered as factors. Included in these factors is the fact that both the islands of Luzon and Palawan experience several typhoons every year, while earthquakes occur anywhere in the archipelago. For this reason, the observatories to be built must be designed to withstand Category 5 typhoons and strong magnitude 7 to 8 earthquakes. The results of the study identify the places on the island of Palawan and in northern Luzon which are good dark sites for the establishment of optical astronomy observatories. These locations can be declared as protected and developed as dark-sky sites dedicated to the study of Astronomy.

Keywords: Light Pollution, Optical Observatory, Astronomical Observatory

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from December to February when the weather is cool and pleasant especially in the northern regions. The archipelago is in the Pacific Ring of Fire and experiences frequent earthquakes and volcanic eruptions. All these phenomena should be considered when constructing observatories anywhere in the Philippines and it is not possible to meet every criterion as earlier mentioned.

This review was done to identify locations where astronomy facilities - specifically optical telescopes and observatories, can be placed. This is significant due to the country’s relatively small size, which emphasizes finding such sites before they are taken up for other purposes. As it is right now, the Philippines has fairly developed cities and urban areas but also has plenty of relatively untouched land in Luzon alone that would make suitable observatory sites. In doing this, the identified locations can be protected and developed to increase their effectiveness in the purpose of astronomy.

The Philippines is a developing country with a tropical climate. Due to this, there are challenges to constructing an optical observatory in the country - still, its geography and rural areas afford its locations where the night sky was visible with minimal light pollution. This is in contrast to its major cities and capital region where light pollution drastically reduces the visibility of astronomical objects.

The vicinity of these observatories has to be preserved and protected from the encroachment of light brought about by establishments or agricultural practices which might cause light pollution. Government regulations must be made clear on this matter. The designation of observatories as protected preserves and may help in mitigating the effects or the progress of climate change.

2. Background of the Study

2.1 Astronomical Observatories

Observatories using optical telescopes use the light emitted or reflected by an astronomical object to produce images of the object. Due to this, they are affected by several factors that may obscure visible light from the observed object. These factors include the artificial brightness of the night sky, the atmospheric conditions of the area, and whether the view of the telescope is obstructed by physical objects such as geographical features.

A favorable location for an observatory, in terms of topography, would be where the surrounding land does not rise high enough to obstruct a significant portion of the night sky. Often, these locations are the tops or peaks of hills and mountains, or areas where the terrain is mostly flat such as deserts. Higher elevations are made even more advantageous, because light from an astronomical object travels through less atmosphere to reach a more elevated observatory, reducing atmospheric effects on the image [1]. Aside from distorting the image, atmospheric conditions can also reduce visibility in more direct ways - the biggest example being cloud cover. While clouds can simply block out objects from view, they can also reflect light from nearby sources of light pollution on the ground [2]. Not only that, but the atmosphere can also affect the equipment itself. Humidity can cause condensation, which can deteriorate reflective and refractive surfaces or even contribute to fungal growth [3]. Temperature can also affect equipment, as high temperatures can overheat electronics such as DSLRs and computers while cold temperatures cause the build-up of frost - both of these can limit observational periods [4].

Lastly, artificial night sky brightness, from sources of light pollution, can outshine much of the night sky. This is especially evident within the vicinity of cities where sources of light pollution are numerous and close together [5]. This makes placing optical observatories in the proximity of urban environments unfavorable as the bright night sky becomes a detriment to the visibility of astronomical objects. Most of the population is concentrated in urban areas, the biggest of which is the urban sprawl of Metropolitan Manila, which extends in a wide area from the province of Batangas south of Luzon to its central plains up to the Lingayen Gulf in the province of Pangasinan. This is where light pollution generally affects the night sky, the light emitted from urban areas brightens up the night sky making it non-conducive for astronomical observations.

Having said this, the Philippines has two major observatories - the Manila Observatory which is located at the Loyola Heights campus of the Ateneo de Manila University. The PAGASA Astronomical Observatory is sited inside the campus of the University of the Philippines, Diliman, Quezon [6]. Both are located in the National Capital Region, the most light-polluted region in the country. While these
locations make them easily accessible, the conditions in these locations are detrimental to their effectiveness and purpose.

3. Methodology

The Philippines is a tropical country in Southeast Asia. It is on the western edge of the Pacific Ocean. In almost all months of the year, the archipelago is visited by typhoons which often spawn in the Pacific Ocean through some form in the South China Sea. These typhoons average about 20 per year. For most of the year, the weather is hot and humid, relieved only by a few months from December to February when the weather is cool and pleasant especially in the northern regions and during the rainy season brought by the southwest monsoon from May to be replaced by the northeast monsoon in September. The archipelago is in the Pacific Ring of Fire and experiences frequent earthquakes and volcanic eruptions. These earthquakes are often caused by shifting tectonic plates. The country also has a number of active volcanoes. All these phenomena should be considered when constructing observatories anywhere in the Philippines and it is not possible to meet every criterion as earlier mentioned. Despite all of these challenges, observatories can and should be built and there are locations that can offer the optimum advantages for an observatory.

Light pollution map is acquired from the Visible Infrared Imaging Radiometer Suite (VIIRS) 2019 Day Night Band [20] which has been propagated through the atmosphere using the radiative transfer code reported in [21]. The upward emission function and the radiance calibration were obtained using data from Sky Quality Meters [22] [23].

Topographical maps of Luzon were taken from National Mapping and Resource Information Authority (NAMRIA), a government agency that provides geospatial services to the public. The overlaid topographic map has a scale of 1:250,000 to decide the initial list of locations. These locations were chosen by their night sky brightness, proximity to light pollution, and highest area elevation. Furthermore, the average annual temperature, humidity, dew point, precipitation, and visibility of the locations from 2005-2015 were taken using the third-party website but data is from the PAGASA Science Garden Station. Each location’s data were compared to each other to find the most suitable locations.

Using this method several sites around the northern areas of Luzon and the island of Palawan were located. The southeast of Luzon also had several potential sites but was considered too susceptible to typhoons compared to the other considered sites.

4. Results and Discussion

Table 1. Atmospheric data and the highest elevation of different locations.

| Location     | Elevation (m) | Yearly Precipitation (mm) | Humidity (%) | Dew Point (°C) | Visibility (km) | Mean Temperature (°C) |
|--------------|---------------|---------------------------|--------------|----------------|-----------------|-----------------------|
| Cagayan      | 701           | 209.9                     | 84           | 25             | 15              | 28                    |
| Camarines Sur| 921           | 212.4                     | 84           | 25             | 15              | 28                    |
| Apayao       | 2344          | 145                       | 77           | 24             | 19              | 29                    |
| Quzon        | 315           | 155.1                     | 79           | 23             | 6               | 28                    |
| Sibuyan Island| 1780         | 205.9                     | 83           | 25             | 15              | 28                    |
| Palawan      | 1260          | 109.5                     | 80           | 24             | 23              | 28                    |
| Averages     | 1233.5        | 172.967                   | 81.167       | 24.33          | 15.833          | 28.167                |
Table 1 shows data taken from timeanddate.com and elevation was taken from topographical maps lifted from the government site of NAMRIA. The averages are listed in the lowest row, light green cells are above average while light red cells are below average. Mean Temperature is disregarded as there is no significant variation. The included locations were those initially chosen through their topography and night sky brightness.

\textit{a. Palawan}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{A mosaicked true-color SMI image of Palawan. © PHL-Microsat.}
\end{figure}

Palawan is an island province of the Philippines located in the MIMAROPA region. It lies between the South China Sea and the Sulu Sea, it stretches from Mindoro in the northeast to Borneo in the southwest. This island is said to be the largest province in the country with an area of jurisdiction measuring 450 kilometers (280 mi) long, and 50 kilometers (31 mi) wide. Professional astronomers travel to different places just to experience an astronomical phenomenon. These and many other people travel to different places just to chase eclipses as well as to gather in dark-sky sites for a few nights under stars and by attending ‘star party’, these people can enjoy the beauty of the stars and at the same time learn a lot about the sky. Natural phenomena like solar eclipses gather millions of nature-based tourists in many destinations that are appropriate for observations [24].

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Comparison of Light Pollution Map of Palawan Island and Metro Manila Light Pollution Map.}
\end{figure}
As seen in the Figure 2, Palawan has much less light pollution compared to the mainland of Luzon, where in light increases night sky brightness, which causes celestial bodies with lower magnitudes to be less or not visible [19]. The possibility of observing celestial bodies is greatly affected also by climate and weather. High humidity can lead to dewing, reducing viewing or imaging time, strong winds can knock over equipment or blow debris, extreme cold can cause frost to form on optical/structural pieces, and extreme heat can affect the sensitivity of imaging equipment, as well as negatively impact equipment that require cooling [13]. Another factor that affects observation is cloud coverage. Aside from obscuring the sky, clouds can amplify sky luminance, increasing night sky brightness [2]. Palawan, as a good location is farthest away from the Pacific, where typhoons originate. It has relatively low annual precipitation at -109.5 mm, it is the lowest out of the initially chosen locations. Not only that, but it also has the most visibility at 23 km. This gives it very favorable conditions for placing an observatory, especially considering its topography as mountains such as Mt Mantalingahan provide high elevations upwards of 1 kilometer on which an optical observatory can be constructed. The main source of light pollution on the island is the city of Puerto Princesa, which is the most populated and urbanized city in Palawan. However, the magnitude of its artificial sky brightness is not as intense as in other areas like Manila. Multiple elevated locations are not in proximity to light-polluted areas that are suitable.

b. Apayao

Figure 3. Cordillera Administrative Region Topography.

Cordillera Administrative region has a high mean elevation of 9,606 ft (2,928 m). Provinces such as Apayao, Mt. Province, Ifugao and Kalinga are within the third climatic type where seasons are not pronounced but are relatively dry from November to April and wet for the rest of the year.
Figure 4. Light Pollution Map of Cordillera Administrative Region compared to Metro Manila.

Apayao has an area of 4,413.35 square kilometers (1,704.00 sq. mi). It is also the least densely-populated province in the Philippines. It is another of the locations chosen that was proven viable by the region’s mountainous terrain providing elevations of 1,921 m (6,302 ft). It also has the second-lowest amount of yearly precipitation at 145mm as well as the second-highest visibility at 19 km. Not only that, but Apayao also has the lowest humidity out of the chosen locations – 77 %. Perhaps one caveat of the location, however, is its proximity to light-polluted areas such as Tuguegarao and Laoag, as well as the populated pockets of light present in the mountains of the region. However, the negative impacts of these on night sky visibility can be minimized by appropriate placement of the facility.

5. Summary of Findings

Several years have passed, the Philippines have established astronomy education and research. It may still be behind neighboring Southeast Asian countries, especially those who have established far way back and have established advanced space technologies. At that time, it was very evident that there was the scarcity of trained professional Filipino astronomers [12]. Observation is a part of studying astronomy, choosing a site location for an Astronomical Observatory is one of the first considerations of the entire process. Certainly, before any building takes place, a site must be chosen and confirmed, which requires site-scouting to be an essential first step in observatory planning. Often, the location will dictate certain parts of the telescope design.

Steps can be taken to prepare a facility for events such as typhoons and earthquakes, while it can also be built with the equipment to handle daily conditions such as high humidity. Equipment such as dehumidifiers can be used within the facility or heaters to keep the facility above the dew point. The structure of the facility can be built to withstand or minimize the damage caused by typhoons and earthquakes. Doing so would make the facility less costly to repair after these events.

Not only that, but sites suffering from bright night skies can be improved by implementing behaviors, ordinances, and technologies to reduce light pollution in the area. These can include using specific streetlights that minimize light being shone upward.

It should also be noted that due to the relatively short work period of this review, the researchers were not able to personally visit the sites for evaluation - this is more important to note for artificial night sky brightness. More accurate data may be taken by visiting the noted locations for first-hand accounts.
6. Conclusion

The Philippines has several viable locations within Luzon where an observatory may be constructed, mainly avoiding areas such as NCR where light pollution can be a major detriment to optical observation.

Although there are plenty of dark, elevated areas, as stated earlier, it is very difficult to find a location in the Philippines with the ideal atmospheric conditions due to the country’s tropical climate. A prime example of this is the high humidity. Although Apayao had 77% relative humidity, the lowest among the chosen locations, it is still high enough to be problematic for equipment [4].

Thus, as mentioned above, extra considerations should be taken when constructing a major observatory in the country regardless of the location. Not only that but selected locations viable for optical observations of the night sky should be protected from light pollution to retain their effectiveness as astronomy sites.

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