Using Command-Line and Graphical User Interfaces Program in Determining Dawn in Pollutive and Non-Pollutive Area

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Abstract

This study aims to reveal early true dawn light's characteristics, both its physical character and the ideal location's character to observe it. The presentation was elaborated by using command-line and graphical user interfaces program of GNUPlot to determine dawn in pollutive and non-pollutive area. The study was carried out with an astronomical approach and field observations. The theory of categorization of sky brightness proposed by John E. Bortle is used to determine the characteristics of the ideal location implied by the shari'a text. Meanwhile, observations in Banyuwangi, Masalembu Island Sumenep, Bawean Island Gresik, and Timau Hill in West Nusa Tenggara were ideal locations to reveal the physical characteristics. As a comparison, observations were also made in less than ideal locations in Semarang, Depok, and Pasuruan. The results of this study indicate that the early true dawn light is thin like threads and spreads across the eastern horizon with dim brightness or a value of around 21.74 ± 0.45 mpsas. Meanwhile, the ideal location for observation is characterized by easily seeing the zodiacal light, which is a location with clear weather and no light pollution or at least it is included in category 3 on the Bortle scale with a sky brightness of more than or equal to 21.3 mpsas because the appearance of the low light of true dawn is affected by light pollution. Based on observations at an ideal location, early true dawn light is detected when the Sun is around -19.6 ± 0.52 degrees below the horizon.

Keywords

GNUPlot, Bortle Scale, Astronomy, Dawn.

Introduction

The study of dawn is interesting to discuss considering that in the last decade the criteria for sunrise as a marker of the early dawn set by the Ministry of Religious Affairs of the
Republic of Indonesia are doubted by several parties because it is judged that the determination of these criteria is not based on adequate observational data and is only based on historical data, namely on the ideas of Saadoe'ddin Jambek and Abdur Rachim (Herdiwijaya, 2016; Bahali et al., 2018; Butar-butar, 2018). In 2010, the lawsuit against the -20° criteria set by the Ministry of Religion of the Republic of Indonesia and has been used in general by Muslims in Indonesia, has become a hot topic of discussion in various circles of society, especially after the publication of several series of writings in Qiblati Magazine with the title "wrongly misguided at fajr time" which stated that the call to prayer for the dawn prayer in Indonesia was sounded around 24 minutes before dawn (Haryono, 2010; Museum Astronomi Islam, 2013; al-Buhairi, 2009).

Early dawn discourse in Indonesia resurfaced after The Islamic Science Research Network (ISRN) Universitas Muhammadiyah Prof. Dr. Hamka (UHAMKA) explained that the start of Fajr time in Indonesia according to the Indonesian Ministry of Religion's version of the prayer time schedule is 26 minutes earlier than when the dawn appears, which is the reference for the early dawn. This is based on the results of most of the dawn observations in Depok near Jakarta with additional observations in the Medan, Cirebon and Makasar areas (Rizqo, 2019). In addition, ISRN also stated that based on the results of his research, there was no significant correlation between light pollution and sunrise.

On the other hand, the Ministry of Religion of the Republic of Indonesia dismissed the results of the ISRN study and stated that the current time for the Fajr prayer was correct (Fadhil, 2019). Djamaluddin confirmed the statement from the Ministry of Religion of the Republic of Indonesia by saying that thin clouds and light pollution could block the light of dawn on the eastern horizon, so that the thin white astronomical dawn could not be seen. Dawn measurement with a Sky Quality Meter (SQM) from the center of a city with moderately strong light pollution can be misleading, thus concluding a slower dawn. It's normal for dawn to be detected when the sun's position is -20 degrees in Indonesia because the equatorial atmosphere is higher than other regions (Djamaluddin, 2017).

Lately, this phenomenon has been increasingly discussed after Muhammadiyah decided to correct the dawn time for Indonesia, which was originally the position of the Sun at an altitude of -20 degrees to -18 degrees. This decision was based on the findings of ISRN UHAMKA, Astronomy Center of Ahmad Dahlan University (Pastron UAD), and Astronomy Observatory of Muhammadiyah University of North Sumatra (OIF UMSU) which specifically observed changes in morning light in several cities in Indonesia for several years (Suara Muhammadiyah, 2021).
Related to this, National Institute of Aeronautics and Space (LAPAN) and the Ministry of Religion of the Republic of Indonesia stated that the dawn time used so far is correct and does not need to be corrected (Mufarida, 2020; Hutabarat, 2020). This is based on observations made by the Indonesian Ministry of Religion's Falakiyah Team in Labuan Bajo using SQM tools and DSLR cameras and the results obtained at -20 sun position have found the light of dawn. Furthermore, data from the Nahdlatul Ulama Team in Banyuwangi also found that at a sun position of -20 degrees dawn was also detected.

The emergence of these problems cannot be separated from the absence of a comprehensive study of the characteristics of dawn light. Studies on dawn that have been carried out by several previous researchers, on the one hand, focus more on the theoretical aspect and do not involve collecting and processing field data. For example, research conducted by Odeh (2010), Raihana et al. (2016 and Azhari (2018). Meanwhile, other researchers focus more on the study of empirical data by involving the collection and analysis of observational data, they pay less attention to a strong theological basis. For example, research by Ngadiman et al. (2020), Herdiwijaya (2016), Rohmah (2016), and Bahali et al. (2018).

Furthermore, related to the character of the early dawn light, which is soft white and elongated like a thread on the horizon, it will be explored further and correlated with observation data in ideal (non-polluting) locations as the conditions of the brightness of the sky at the time of the Prophet SAW, and in less-than-ideal (polluting) locations, as shown in Table 1.

### Table 1 Locations for observing the dawn of fingerprints

<table>
<thead>
<tr>
<th>No</th>
<th>Location</th>
<th>Time</th>
<th>Criteria</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Banyuwangi (-7.97S, 114.42T, 1 masl)</td>
<td>24/08/2020–25/10/2020</td>
<td>Non-polluting</td>
<td>M. Basthoni &amp; LF PWNU Jatim</td>
</tr>
<tr>
<td>2</td>
<td>Masalembu Island (-5.59S, 114.44T, 1 masl)</td>
<td>14–25 Sept 2020</td>
<td>Non-polluting</td>
<td>Thiflan (IF FSH UIN Walisongo)</td>
</tr>
<tr>
<td>3</td>
<td>Bawean Island (-5.79S, 112.74T, 1 masl)</td>
<td>5 – 9 July 2019</td>
<td>Non-polluting</td>
<td>M. Basthoni &amp; LFNU Gresik</td>
</tr>
<tr>
<td>4</td>
<td>Bukit Timau NTT (-9.6S, 123.8T, 1.282 masl)</td>
<td>19, 23, 24 July 2018</td>
<td>Non-polluting</td>
<td>Evan I. Akbar (FMIPA ITB)</td>
</tr>
<tr>
<td>5</td>
<td>Semarang (-6.97S, 110.29T, 1 masl)</td>
<td>25/9/2020 – 25/10/2020</td>
<td>Polluting</td>
<td>M. Basthoni</td>
</tr>
<tr>
<td>7</td>
<td>Pasuruan (-7.57S 112.67T, 57 masl)</td>
<td>May–Oct 2019</td>
<td>Polluting</td>
<td>LAPAN Watukosek Pasuruan</td>
</tr>
</tbody>
</table>

* Observations were made with the SQM-based Dawn Observation Automation System (SOOF) tool and a digital camera that was developed in conjunction with this research process (Basthoni, 2020).
Based on some of these backgrounds, this study aims to explore more deeply about the characteristics of the early dawn light. For this reason, in this literature review as well as field research, we will explore the meaning of dawn in Islamic literature which includes the Qur'an, Hadith and the opinions of scholars. The results of this search are then correlated with one of the astronomical theories about the categorization of sky brightness proposed by John E. Bortle. The characteristics of the early light of dawn in the perspective of Al-Quran-hadith and Bortle are then used as a reference to determine the ideal location for making observations, so it is hoped that the analysis of the appearance of the early light of dawn on the observation data in this study is in accordance with the previously determined characteristics.

**Bortle Scale, Sky Brightness and Astronomic Observations**

The principle of observation in astronomy is a matter of contrast, namely the comparison of the brightness of the object being observed and the brightness of the background light (Narisada & Schreuder, 2004). The more contrast, the easier the object is to be recognized. Likewise, the observation of early dawn light as one of the faint and very thin astronomical objects such as a white thread that crosses the eastern horizon also requires environmental conditions that are free of artificial light or light pollution so that sunrise can be detected validly.

Based on 50 years of observational experience, John E. Bortle proposed a 9-point brightness measurement in the February 2001 issue of Sky & Telescope magazine (The Astronomical League, 2013). According to him, this categorization can be used by observers to assess the level of brightness of the sky at the observation site so that they can estimate what astronomical objects are possible to be observed optimally because they can estimate the level of light pollution in that location. The scale ranges from grade 1 (darkest sky) to grade 9 (brightest sky). This scale uses a reference or unit of naked-eye limiting magnitude (NELM), which is a unit that refers to the ability of the naked eye to see the faintest star near the zenith on a moonless night. In addition to this reference, the Bortle scale also uses the appearance of the Milky Way galaxy, the M33, M31, Orion, Pleiades, and zodiacal light (false dawn/\textit{al-fajr\ al-kazib}) galaxies as well as the appearance of the constellations of stars.

For the purposes of this study, the Bortle scale will be simplified by only looking at indications of the appearance of the zodiacal light (\textit{al-fajr\ al-kazib}) because based on the previous description, the Prophet Muhammad gave a signal that it was quite easy to see false dawn/\textit{al-fajr\ al-kazib} (Bortle, 2016). The simplification of the Bortle scale is described in Table 2 below.
Table 2 Bortle scale summary

<table>
<thead>
<tr>
<th>No</th>
<th>Category</th>
<th>NELM</th>
<th>Sky Brightness (mpsas)</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excellent dark-sky</td>
<td>7,6–8.0</td>
<td>21,7–22.0</td>
<td>The color of <em>al-fajr al-kazib</em> is clear and stretches across the sky</td>
</tr>
<tr>
<td>2</td>
<td>Typical truly dark</td>
<td>7,1–7,5</td>
<td>21,5–21,7</td>
<td>The light of <em>al-fajr al-kazib</em> is still bright enough</td>
</tr>
<tr>
<td>3</td>
<td>Rural sky</td>
<td>6,6–7,0</td>
<td>21,3–21,5</td>
<td><em>Al-fajr al-kazib</em> is visible in spring and fall (extending 60° above the horizon before dawn prints rise) and are weak in color</td>
</tr>
<tr>
<td>4</td>
<td>Rural/suburban transition</td>
<td>6,1–6,5</td>
<td>20,4–21,3</td>
<td><em>Al-fajr al-kazib</em> is still visible but disappears when its altitude is 45° at the beginning of dawn due to light pollution that begins to appear around the horizon</td>
</tr>
<tr>
<td>5</td>
<td>Suburban sky</td>
<td>5,6–6,0</td>
<td>19,1–20,4</td>
<td><em>Al-fajr al-kazib</em> looks very weak on the best (clear) night of every season</td>
</tr>
<tr>
<td>6</td>
<td>Bright suburban sky</td>
<td>5,1–5,5</td>
<td>18,0–19,1</td>
<td><em>Al-fajr al-kazib</em> not seen at all</td>
</tr>
<tr>
<td>7</td>
<td>Suburban/urban</td>
<td>4,6–5,0</td>
<td>≤ 18,0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>City sky</td>
<td>4,1–4,5</td>
<td>≤ 18,0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Inner-city sky</td>
<td>≤ 4,0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As described above, the appearance of the light of *al-fajr al-kazib* is one of the indicators in this categorization. The light of *al-fajr al-kazib* was quite easy to observe at the time of the Prophet. Thus, if it is correlated with the Bortle scale, it can be said that the sky brightness at the time of the Prophet was in the 3rd, 2nd or 1st category, namely a very dark area with a sky brightness greater than or equal to 21.3 mpsas. This is quite reasonable because the estimated population at that time was not much. According to Philip K. Hitti, the population at that time was around 8 million who occupied the area of the Arabian Peninsula which had an area of about 3.2 million sq km or with a density of about 1 person per 2 sq km (Hitti, 1951). So that the artificial light of the residents at that time did not affect the brightness of the sky because the level of population density was directly proportional to the level of light pollution in an area (Pariona, 2018; Herdiwijaya, 2019; Malasan et al., 2001).

Regarding the observation of *al-fajr al-kazib*, the experience of astronomers shows that the light of *al-fajr al-kazib* can only be seen in a very dark, bright location and without interference from the Moon's light (James et al., 1997; Gaherty, 2012; King, 2015). Thus, when the Prophet gave a signal for the appearance of dawn (both dawn fingerprint and *al-fajr al-kazib*) it was strongly suspected that it was in bright conditions and without interference from moonlight and the brightness of the sky was very dark.
Dawn in Pollutive and Non-Pollutive Area

After knowing the criteria for the ideal location for observing dawn, then in this section we will explore the characteristics of early dawn light through observations in ideal locations with minimal light pollution as hinted by the Prophet in the previous description and in locations with high light pollution.

As described earlier, the observations in this study used a Sky Quality Meter (SQM) to record data on the brightness of the eastern sky before dawn until the sun rises. Changes in the intensity of the brightness of the sky due to the apparent movement of the Sun which is getting closer to the horizon, which was initially dark and then turned into light, which was read from the SQM data recorded as a benchmark for the appearance of dawn.

The sky brightness data recorded by SQM is displayed in units of magnitude per square arc second (mag/arcsec² or mpsas). What is meant by mpsas is the magnitude of the value of the brightness of the sky which is spread per unit square arcsecond from the sky. In reading the data, the greater the magnitude value, the darker the brightness of the sky. Vice versa, if the magnitude value is indicated by a smaller value, the sky conditions will be brighter (Unihedron, 2020).

The sky brightness data obtained with SQM is processed into an $x$, $y$ curve using the GNUPlot application. The $x$-axis contains the Sun depression angle data obtained by converting a.dat file from SQM to a.csv file using the Unihedron Device Manager (UDM) application. The $y$-axis is in the form of sky brightness data. Furthermore, by visually analyzing the curve, it is easy to know the change in the intensity of the brightness of the sky, which was initially dark and then became consistently bright. The beginning of this increase in light intensity is used as a benchmark for the emergence of dawn.

Figure 1 One of the results of the SQM data plot in Banyuwangi (25/8/2020) which was processed with GNUPlot
Based on Figure 1 it can be easily read that the condition of the night sky brightness can be identified with a constant light intensity with a sky brightness value of 21.48 mpsas (y axis) to the position of the Sun's altitude at -54.54 degrees below the horizon (x axis). Furthermore, the value of the intensity of the brightness of the sky began to increase slowly forming a linear line with a constant slope or gradient at the position of the Sun -53.85 to -19.98 degrees. The increase in light intensity in this range is identified as the emergence of al-fajr al-kazib. Over time, the intensity of light increases from the position of the Sun -19.96 degrees and continues to increase drastically and exponentially. The beginning of this exponential increase in light intensity is identified as the beginning of the dawn of the fingerprint.

After all the data in Table 1 is reduced and selected according to predetermined criteria, the data is analyzed using the steps as in analyzing the curve in Figure 1. The results of data analysis for each location are then taken the average and standard deviation using Microsoft Excel. To find out the pattern in polluting and non-polluting areas, the data from the analysis was calculated the average value and standard deviation according to the category of each category. A recap of the results of the data analysis can be seen in Table 3, while the detailed analysis results for each location can be seen in the appendix.

### Table 3 Data analysis at seven observation locations when the weather is clear and there is no interference from moonlight

<table>
<thead>
<tr>
<th>No</th>
<th>Location</th>
<th>Data (days)</th>
<th>Category</th>
<th>Sky brightness (mpas)</th>
<th>Position of the Sun (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Evening</td>
<td>Dawn</td>
</tr>
<tr>
<td>1</td>
<td>Banyuwangi</td>
<td>18</td>
<td>Non-polluting</td>
<td>21.4 ± 0.09</td>
<td>21.2 ± 0.08, -19.8 ± 0.29</td>
</tr>
<tr>
<td>2</td>
<td>P. Masalembu</td>
<td>7</td>
<td>Non-polluting</td>
<td>21.9 ± 0.38</td>
<td>21.8 ± 0.4, -19.6 ± 0.45</td>
</tr>
<tr>
<td>3</td>
<td>P. Bawean</td>
<td>1</td>
<td>Non-polluting</td>
<td>21.79</td>
<td>21.57, -19.68</td>
</tr>
<tr>
<td>4</td>
<td>Bukit Timau</td>
<td>2</td>
<td>Non-polluting</td>
<td>22.2 ± 0.01</td>
<td>22.2 ± 0.0, -19.3 ± 0.73</td>
</tr>
<tr>
<td></td>
<td>Total data</td>
<td>28</td>
<td></td>
<td>21.82 ± 1.03</td>
<td>21.74 ± 0.45, -19.6 ± 0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polluting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Semarang</td>
<td>12</td>
<td>Polluting</td>
<td>17.1 ± 0.20</td>
<td>16.8 ± 0.20, -13.5 ± 0.80</td>
</tr>
<tr>
<td>6</td>
<td>Depok</td>
<td>12</td>
<td>Polluting</td>
<td>18.7 ± 0.24</td>
<td>18.6 ± 0.24, -13.8 ± 0.44</td>
</tr>
<tr>
<td>7</td>
<td>Pasuruan</td>
<td>42</td>
<td>Polluting</td>
<td>19.5 ± 0.21</td>
<td>19.5 ± 0.15, -15.0 ± 0.59</td>
</tr>
<tr>
<td></td>
<td>Total data</td>
<td>66</td>
<td></td>
<td>18.43 ± 1.12</td>
<td>18.33 ± 1.11, -14.1 ± 0.99</td>
</tr>
</tbody>
</table>

Table 3 shows that 4 non-polluting locations fall into categories 1 and 2 on the Bortle scale because they have a night sky brightness of 21.5 mpsas or more. Meanwhile, 3 polluting
locations are categorized as 5-9 on the Bortle scale. Semarang, which has a night sky brightness less than 18.0 mpsas, is in the 8-9 category, while Depok is in category 6-7 and Pasuruan is in category 5. If we take the average difference in night sky brightness between polluting and non-polluting areas, it is around 3.35 mpsas or it can be said that polluted areas are 8.38 times brighter than non-polluting areas. The difference in the value of 1 mpsas means the difference in brightness is 2.512 (Satyaningsih, 2007).

Table 3 also provides information that the brightness of the night sky is positively correlated with the time of detection of dawn fingerprints. In non-polluting areas, the difference in the time of dawn between locations is not far apart. If averaged, dawn rises at the position of Matarari -19.6 ± 0.52 degrees. Or the maximum angle at -20.09 degrees (80.36 minutes before sunrise) and minimum at -18.57 degrees (74.28 minutes). Meanwhile in polluted areas, in the darkest area (Pasuruan), dawn was detected earlier by about 1.35 degrees (5.4 minutes) compared to 2 other areas that were brighter (Semarang and Depok). However, if the average time of dawn in polluted and non-polluting areas is compared, they are quite far apart, which is 5 degrees (20 minutes). Thus, light pollution can slow down the appearance of fingerprints. The curve in Figure 2 further clarifies the difference in the time of dawn in polluting and non-polluting areas.

Note: Red arrow as a marker of sunrise

Figure 3 Plot of SQM data in polluting and non-polluting areas
Based on Table 2, it can also be seen that the brightness of dawn light in polluting and non-polluting areas is also quite far apart, namely 2.75 mpsas or dawn light in polluting areas is only detected when the sky brightness is 6.875 times brighter than in non-polluting areas.

Thus, based on Table 3 and Figure 3 as well as the characteristics of dawn light and ideal locations that have been described previously, the results of observations in non-polluting locations are proposed as physical characteristics of early dawn light, namely: (1) When the position of the Sun is about -19.6 ± 0.52 degrees; (2) The brightness of the night sky at the observation location is around 21.82 ± 1.03 mpsas or at least in category 3 on the Bortle scale; (3) The early dawn light is still quite dim and thin or has a brightness of around 21.74 ± 0.45 mpsas; (4) The dim early dawn light appears to be greatly affected by light pollution.

The results of this study confirm the findings of several previous studies. Among them Herdiwijaya who stated that light pollution has a strong enough influence on the dawn of fingerprints (Herdiwijaya, 2010). Hassan's study of the 1983-1985 sky brightness observation data at Matrouh Egypt (class 2 on the Bortle scale) also found that the dawn of fingerprints rose when the Sun's position was around -18 to -20 degrees (Hassan et al., 2013). Likewise, the findings of the Hisab Rukyat Team of the Ministry of Religion of the Republic of Indonesia when conducting observations in Labuanbajo NTT which stated that the dawn of fingerprints rose when the sun's position was -20 degrees below the horizon (Djamaluddin, 2018).

The delay in detection of dawn light in less than ideal locations was also confirmed by other studies. For example, Semeida's observations at Wadi Al Natron Egypt (grade 5 on the Bortle scale) in 2014-2015 found that the dawn of fingerprints rose when the Sun's position was -14.57 degrees (Semeida & Hassan, 2018). The category of sky brightness of an area based on the Bortle scale can be known with a light pollution map via the lightpollutionmap.info web. Likewise, Hassan's research in Tubruq Libya (grade 5 on the Bortle scale) in 2010-2013 produced a value similar to that of Semeida's study, namely -14.7 degrees. A trend of delayed dawn appearance was also identified in Qusthalaani's study in Rembang (grade 4 on the Bortle scale) which found that dawn was detected at the Sun's position of -18.4 degrees when measured by SQM and -16.6 degrees when measured by a DLSR camera (Hassan & Abdel-Hadi, 2015; Qusthalaani, 2019).

**Conclusion**

Based on the previous description, it can be concluded that the characteristics of the early dawn light can be described that it is thin like a thread and spreads on the eastern horizon.
with a brightness that is still dim or the brightness value is around 21.74 ± 0.45 mpsas. The ideal location for observation requires that the dawn light of al-fajr al-kazib is easy to see, namely a location with clear weather and no light pollution or at least in category 3 on the Bortle scale, namely an area with a sky brightness greater than or equal to 21.3 mpsas. This is because the dim early dawn light appears to be strongly influenced by light pollution. Based on observations at this ideal location, the early dawn light was detected when the Sun's position was around -19.6 ± 0.52 degrees below the horizon.

References


https://skyandtelescope.org/observing/see-shoot-zodiacal-light02042105/.


