



MEASURING LUMINANCE AND SUN DEPRESSION ANGLE OF DAWN

Kassim Bahali and Abdul Latif Samian

Institute of the Malay World & Civilization, Universiti Kebangsaan Malaysia

Nazri Muslim

Pusat Citra, Universiti Kebangsaan Malaysia

Nurul Shazana Abdul Hamid

School of Applied Physics, Faculty of Science and Technology

ABSTRACT

Dawn are difficult to be seen when it first rises due to weather conditions and the low intensity of dawn light along with the factor of low visual acuity of the observer. In that case, the detection of the early emergence of dawn by using photometry is very important. The photometric device can detect and measure the dawn luminance, the moment it starts emerging. This study aims to measure the luminance of dawn, L_D and the sun depression angle, D_{\odot} when the dawn began to appear by using a photometer, Sky Quality Meter (SQM) and Digital Single Lens Reflex (DSLR). The result of the measurement using these two tools were compared in terms of the luminance value and the measured value of the sun depression angle. The study was conducted from June to December 2017 in seven locations around Malaysia and Indonesia. The study found that the average value of L_D is $19.47 \text{ mag arcsec}^{-2}$ and $20.85 \text{ mag arcsec}^{-2}$ with a DSLR and SQM, respectively. On the other hand, the average value obtained for D_{\odot} is -17.00° and -16.56° with DSLR and SQM, respectively. We therefore propose that L_D is between $19.50 \text{ mag arcsec}^{-2}$ and $20.90 \text{ mag arcsec}^{-2}$ while D_{\odot} of the dawn is -17.00° .

Keywords; Instrumentation: Photometer, Methods: Observational, Techniques: Image processing, Techniques: photometric

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1. INTRODUCTION

Dawn has special significance in some cultures and religions since ancient times. In Islam, dawn indicates a sign of morning prayers, while in other religions such as Judaism, dawn also

plays an important role in their worship. From an astronomical point of view, dawn occurs due to the scattering of sunlight by the atmosphere surrounding the Earth's atmosphere when the sun is still below the horizon. The atmosphere contains air molecules and aerosol particles that would scatter sunlight which occurs in the upper atmosphere. Due to the scattering of sunlight, it causes the sky near the horizon to brighten up.

According Helmuth (2014), twilight is produced by sunlight scattering in the upper atmosphere, illuminating the lower atmosphere so that Earth's surface is not completely dark. Note that, the light of dawn is soft and diffuse. A similar situation occurred in the evening during the sunset, and the sky still bright. If the earth had no atmosphere, the sky will immediately turn dark when the sunset. The light scattering occurs when the sun is at a certain angle below the horizon. The angle limit of the sun below the horizon that could cause light scattering occurs at 18° . If the sun is below the indicated angle, the light scattering does not occur (Ilyas 1984).

Sun depression angle, D_\odot refers to the dawn light that began to appear when the sun is at a certain angle below the horizon. Light of dawn that began to appear looks like a dim light positioned horizontally. This dawn light is difficult to be seen with naked eyes due to the low luminance of dawn and the weather in the eastern horizon during the time of the observation. To overcome this problem, the usage of photometric observation may help to detect and determine the time of dawn began to rise.

Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. The SI unit for luminance is candela per square meter (cd m^{-2}) (Kolláth et al. 2017; Kocifaj 2015). In other words, luminance is the amount of visible light leaving a point on a surface in a given direction.

Several methods and instruments that have been used by researchers to measure the sky brightness or luminance. Among the tools used are a DSLR camera and a photometer, SQM. Many studies have been conducted using a DSLR for example the study to measure the brightness of the sky by the Mumpuni (2009), Hanel. et al. (2017) and Desmukh (2015). Also, Jechow (2017) and Vitek (2017) used a DSLR to measure light pollution. Meanwhile Kollath. Z. (2010) measured and modelled light pollution at Zselic Starry Sky Park. Apart from that, Rohmah (2016) used a DSLR in the study the effect of atmosphere dampening on the appearance of the dawn and morning prayers. Also, Bahali et al. (2018b) used a DSLR to study the luminance of dawn.

A commercial DSLR camera may provide quantitative information on luminance of the whole upper hemisphere with a single exposure. The DSLR cameras are easily accessible and are transportable (Hänel et al. 2017). The DSLR has been proven to be an effective tool in characterizing potential dark sky parks (Kolláth 2010).

However, the DSLR camera should be calibrated first before could be used for measurements. The precision of the measurements depends on the calibration procedure and on the camera itself (Hänel et al. 2017).

While for SQM, it was used by Dhani (2016) to measure the sky brightness and dawn measurement in Jogjakarta and also by Bahali et al. (2018b) to measure the value of D_\odot in Malaysia. Furthermore, Jechow (2016) used SQM to measure the brightness of the sky in summer and Plauchu (2017) measured the night sky brightness in San Pedro Martir, Mexico. Similarly, Biggs et al. (2012), Kyba et al. (2013) and Sánchez et al. (2017) used SQM to observe the global night sky luminance.

The dawn angle measurement, D_\odot , have been previously carried out by researchers such as by Dhani (2016), Hassan et al (2013), Hassan et al (2016) and Khalifaa et al. (2018). Dhani (2016) used SQM to measure the angle D_\odot , in Jogjakarta Indonesia and the results of his

research found that the D_{\odot} angle = -17° . Meanwhile Hassan et al., (2016) measured the angle D_{\odot} of dawn using a photometer at Matrouh and the results of his research found that the D_{\odot} angle is between -18° and -20° . Furthermore, Hassan et al., (2016) used naked eyes to determine the angle of dawn, D_{\odot} in Assiut and Sinai in Egypt with the angle D_{\odot} obtained is -14.61° and -13.67° , respectively. Similarly, Khalifaa et al., (2018), in Hail, Saudi Arabia, found the angle of D_{\odot} to be -14.01° . D_{\odot} angle measurements have been also carried out by Bahali et al., (2018a).

In the present study, both DSLR and SQM tools were used to measure the L_D and D_{\odot} of dawn simultaneously each time during data collection on the location of the observations. The findings of the L_D and D_{\odot} angle values measured with DSLR are compared to the values measured by using SQM.

2. METHODOLOGY

Dawn phenomenon study was conducted at seven locations in Malaysia and Indonesia to collect the data observation by using DSLR camera and SQM photometer. The parameters measured and collected in this study are L_D and the angle of D_{\odot} . The site chosen for this study are those location facing the eastern horizon either the sea horizon or land horizon which can be clearly observed without any obstructions such as islands, tree or building. The locations chosen are also far from any light pollution which can interfere with the results of the observations. Also, those locations are close to the road and can be reached by vehicle.

Observations were conducted for 47 days between June and December 2017 as shown in Table 1. The dates chosen are moonless nights after midnight until morning. The presence of moon light causes a slight brightness in the sky and could interfere the observed results. Time of the observations were carried out between 30 to 60 minutes before dawn and 30 minutes after dawn. Due to Malaysia's latitude being close to the equator, the condition of horizon and the sky is always cloudy. Therefore, observations will be conducted under two circumstances; good weather and bad. Good weather conditions are such that the eastern horizon and the sky is not cloudy or less meanwhile unfavorable weather conditions are such that the eastern horizon and the sky are covered with clouds on a scale of 3-8 Okta.

Table 1 Dates and locations

Dates	Location	Lat.	Long.	Horizon
3-5Jun 17	Pekan	3°24'29 "	103°21'22 "	Sea
3-7 Jul. 17	Pekan	3°24'29 "	103°21'22 "	Sea
24-26 Jul. 17	Pekan	3°24'29 "	103°21'22 "	Sea
1-5 Aug 17	Dungun	4°47'42 "	103°25'34 "	Sea
19-21Oct. 17	Jasin	2°20'04 "	102°18'57 "	Land
23-31Oct. 17	Penarik	5°35'52 "	102°47'49 "	Sea
23-25Nov.17	Langkawi	6°18'23 "	99°51'45"	Sea
1-3 Dec. 17	Merlimau	2°18'45 "	102°23'31 "	Land
20-29 Dec.17	Sabang	5°52'34 "	95°20'22"	Sea

DSLR camera used in this study is the Canon 60Da camera dedicated for astronomical observation. This camera has a sensor of size 22.30 mm x 14.90 mm, with 18 megapixels, outputs of 14-bit RAW and JPEG file image format and has an aperture range between f/3.5-f/22.

The camera is equipped with a Tamron 28-300 mm aspherical lens. While the photometer used is Unihedron Sky Quality Meter, model SQM LU. SQM has been widely used by present researchers as the sky brightness photometer due to its low price and its small size which makes it easy to be handled. The SQM-LU has an integrated lens which measures luminance for a patch of the sky with an opening angle of 20°. The combination of a silicon photo diode, TSL237S and a band-pass filter, HOYA CM-500 results in a spectral response between 320-720nm roughly similar to that of scotopic human vision. The SQM provides luminance in unit of magnitude per square arc second (mag arcsec^{-2}), which is a logarithmic scale that decreases with the increase in brightness (Jechow 2016).

DSLR camera works by recording the images formed on the light detector, which contains a number of specific pixels. In the recorded images, each pixel contains a pixel value representing a particular pixel brightness. To make DSLR camera as a means of measuring luminance, the camera has been calibrated beforehand. The purpose of calibration is to obtain the calibration constant, K_c connecting the luminance pixels with the pixel value of each image. Calibration is performed by using a known light source to be used as a source of standard luminance.

In this study, the standard luminance source used is an integrating sphere at National Space Agency of Malaysia as in figure 1. It is a custom designed integrating sphere that produces stable and uniform light sources with known spectral radiance from 300nm to 2400nm. The integrating sphere provides a diffuse light property exit the port at 14" and 16" in diameter. The calibration test was carried out in an ISO class 8 cleanroom-controlled environment with temperature controlled at $22 \pm 3^\circ\text{C}$ and relative humidity at $55 \pm 10\%$. During the measurement, the room was completely in dark to avoid stray light entering into field of view of the camera. In this calibration test, the 100w tungsten-halogen lamp was switched on, in order to simulate the scene to be captured by the DSLR. The nominal output luminance produced by this lamp is about 4.5 Nit. For shooting, the DSLR camera was placed in center position relative to the integrating sphere exit port at distance between the integrating sphere exit and the camera is 1340 mm. A set of images were captured using various combination of exposure, ISO and aperture setting. The images were saved in RAW and JPEG format. The camera captures the images in a two-dimensional pixel array. Each pixel has a certain pixel value, N_d which describes the light intensity. The N_d of the pixel is determined from an analysis of the image, using the Astronomical Image Processing for Windows 2.0, AIP4Win 2.0 an image processing software.

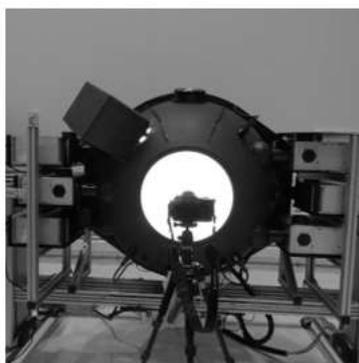


Figure 1 Integrating sphere

The amount of the luminance of the image is proportional to the number of electrons released by the photons of light falls on the sensor, where the luminance (in lux-seconds) is proportional to illuminance (in lux) times the exposure time (in seconds). Invoking the parameter of the camera, the formula can be derived as follows (Hiscocks 2014):

$$N_d = K_c \left(\frac{tS}{f_s^2} \right) L_s \tag{1}$$

$$K_c = \frac{N_d f_s^2}{L_s t S} \tag{2}$$

where

- N_d Digital number (pixel value) of the pixel in the image
- K_c Calibration constant for the camera
- t Exposure time
- f_s Aperture number (f/stop)
- S ISO Sensitivity of the film
- L_D Luminance of the dawn (cd m^{-2})

The unit of cd m^{-2} converted to unit of mag arcsec^{-2} using the formula given below;

$$1 \text{mag arcsec}^{-2} = \frac{\log_{10} \left(\frac{1 \text{cd m}^{-2}}{108000} \right)}{-0.4} \tag{3}$$

Table 2 shows the DSLR and SQM setting were used throughout this study.

Table 2: DSLR and SQM setting

DSLR Operation Modes	Setting	SQM Operation Mode	Setting
Camera mode	Manual	Mode	continuous
Exposure	8 – 13 s	Exposure	1 s
Aperture	f/3.5 – f/4.5	Duration	60 min.
ISO sensitivity	2000 - 2500		

Before images are recorded, the camera is directed horizontally towards the position of the sun rising on the eastern horizon. The camera automatically records the images starting from two hours before sunrise. Images are recorded every minute within 60 minutes of the observations. To ensure that the time of dawn is recorded accurately, the clock setting of the camera has been determined in accordance with the standard Malaysian time. Recorded images are saved in RAW and JPEG format with dimensions of 5148 x 3456 pixels in the camera's memory card.

In the image processing, raw images recorded needs to be calibrated. For image calibration, few dark images are taken at the end of the observation session. Dark images were set as same as the raw images recorded. A series of raw images were recorded, beginning with the first image up to the end of images taken. The images show increasing in brightness, starting from dark turning to bright gradually. From the series of images of dawn captured sequentially, comparison of the brightness of the images were conducted. The brightness of the images is shown by the pixel value of image. In digital image, each of the pixel has a pixel value which describes how bright the pixel is. For a greyscale images, the pixel value, N_d is a single number that represents the brightness of the pixel.

In a calibrated image, the minimum pixel value or value of zero means the sky is dark. The pixel value starts to increase when the sky starts to brighten. The dark sky starts to brighten at

the moment dawn starts emerging. The first image that starts to brighten is the dawn (Bahali et al. 2018b). The first dawn image recorded is referred to as the time of dawn rise. To determine the angle of D_{\odot} of dawn, the time of dawn rise is converted to angle by using the following formula;

$$D_{\odot} = \sin^{-1}(\sin \varphi \sin \delta + \cos \varphi \cos \delta \cos H) \tag{4}$$

where,

φ right ascension of the Sun

δ declination of the Sun

H Hour angle

In order to measure L_D , the RAW images were analyzed using AIP4Win 2.0 software. The pixel values, N_d of dawn were read from RAW images. Then, the Pixel Tool function in AIP4win was used in reading the pixel values, N_d by selecting a rectangle region above the horizon on the image of dawn. The pixel values of N_d are then plugged into formula (1) to calculate L_D .

Next, SQM LU was used to measure the luminance of dawn every minute. For the purpose of protection from rain or dew, SQM LU has been fitted with a semi water-proof housing which is attached to the tripod. SQM LU is directed horizontally toward the sunrise azimuth and is connected to a laptop with a USB cable. SQM LU records the L_D of dawn and ambient temperature in the unit of magnitudes per square arc second and degree Celsius, respectively. Both SQM LU and DSLR camera are pointed towards the azimuth on the horizon and data is recorded simultaneously at the same time.

3. RESULTS AND DISCUSSION

The camera value of the calibration constant, K_c , was computed with the steps that have been discussed in section 2.0 above. In this study, we are using 100 measurement with the combination of the setting of exposure, ISO and aperture to measure the calibration constant, K_c of Canon 60Da. The sample calculation of K_c is as follows;

The known quantities in the equation (2) are:

N_d Digital number (Pixel value) in the image:	789
t Exposure time, seconds:	0.1 sec
f _s Aperture number (f-stop):	f/3.5
S ISO setting:	400
L _s Luminance of the scene:	3.26 cd m ⁻²

$$K_c = \frac{N_d f_s^2}{L_s t s}$$

$$K_c = \frac{789 \times 3.5^2}{0.1 \times 3.26 \times 400} = 74$$

From the calculation conducted, average K_c value obtained is 74 and this value is used throughout the study was conducted.

Figure 2 shows calibrated images recorded on December 28, 2017 in Sabang, Indonesia where the eastern horizon here is the horizon of the sea. Images are recorded with a DSLR camera, the Canon 60Da model with the setting; exposure: 8 "; aperture: f / 3.5 and ISO: 2500. The images were recorded everyone minute automatically within 60 minutes. The images were first recorded at 5:09 am. The sky above was observed when the stars and constellations seem like a constellation of Scorpio, but the eastern horizon was cloudy with two degrees of altitude horizon. Clouds present on the horizon have cracks or fissures in the cloud.

At the start of observation, the sky of the horizon looks dark and the clouds on the horizon are invisible. At 05:31 am, the emergence of early morning light could be seen through the gaps in the clouds of the recorded image but the light is very dim. Dawn began to appear dim due to the scattering of light near the horizon moving across larger distances in the Earth's atmosphere compare to the light across the zenith. In such cases, dawn at horizon becomes dimmer.

Figure 2 (a, b) shows the calibrated image of the eastern horizon at 05:29 and 05:30 (local time) each still showing darkness. Brightness of image is shown in the pixel value, N_d . The N_d depicts the tonal brightness of each pixel in a digital image.

Table 3 shows the mean N_d and luminance of figure 2. The N_d and luminance was measured and calculated using AIP4Win software. Figure 2 (a, b) have same mean N_d which is lower compared with Figure 2 (c). The mean N_d of Figure 2 (a, b) is 114 while Figure 2 (c) are 124. The figure 2(c) shows the mean N_d starts increase that indicate the dark sky starts brighten with soft light. The values of N_d converted to L by using the formula (1). This visible light is known as the early morning light (dawn) that appeared at 05:31 and its value of L_d is 20.055 mag arcsec⁻². The increase in the tone of light implies that dawn began to appear. Figure 2 (d,e,f) shows that the sky horizon gradually becomes brighter. While table 3 shows the increase in the brightness of the image is shown by the increase of the luminance.

The time of dawn is at 5:31 and is converted to D_{\odot} by using formula (4). Calculation shows that D_{\odot} value when dawn began to appear is at -18.15° .

. The calculated L_d of the figure 2(c) was 0.00103 cd m⁻² (20.055mag arcsec⁻²). Meanwhile the night dark sky luminance is 0.001 cd m⁻² (Hiscocks 2014). It shows that the value of L_d is agree with the night dark sky luminance.

Table 3 Mean N_d and Luminance of figure 2

Figure	Time	N_d	L (cd m ⁻²)	L (mag arcsec ⁻²)
2(a)	05:29	114	0.00094	20.147
2(b)	05:30	114	0.00094	20.147
2(c)	05:31	124	0.00103	20.055
2(d)	05:32	130	0.00108	20.004
2(e)	05:37	153	0.00127	19.827
2(f)	05:48	423	0.00350	18.723

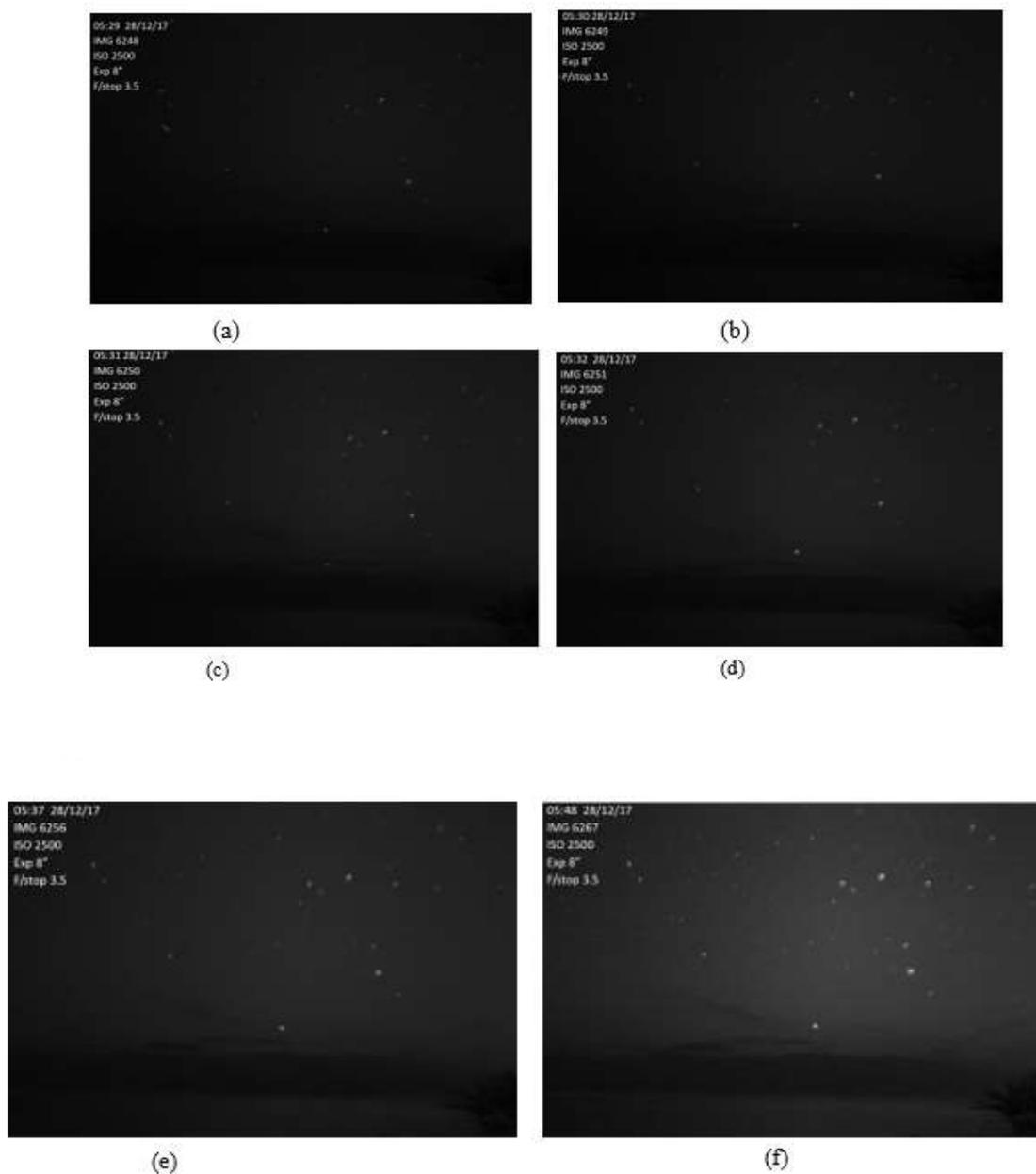


Figure 2 The Sky before dawn (a, b); dawn (c, d, e, f)

On the other hand, Figure 3 shows the graph of dawn luminance against the time of observation by SQM. L_D values recorded starts at 05:09 local time (LT) with a reading of 20.84 mag arcsec⁻² which is uniform until 05:27 LT. Starting from 05:28 LT, L_D readings began to decrease by 20.67 mag arcsec⁻². The values of SQM continues to decrease gradually until sunrise. When the reading began to decrease, it indicates a starting point of light appearance on the eastern horizon. The light that began to appear is known as the light of dawn.

To calculate the value of D_{\odot} when dawn began to appear, 05:28 LT is converted to angle by using formula (4). The value of D_{\odot} obtained is -18.83° and the corresponding luminance dawn is 20.67 mag arcsec⁻².

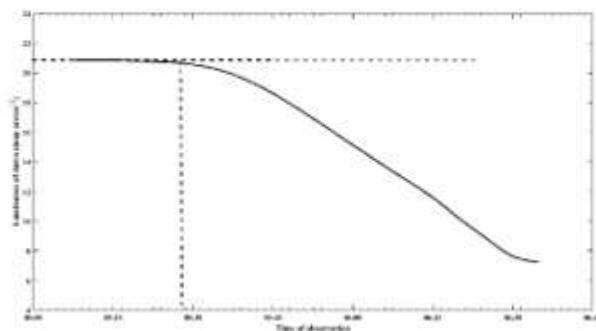


Figure 3. Luminance of dawn, L_D by SQM

Furthermore, the table 4 shows the comparison of the average value of the L_D recorded with cloudy horizon for SQM and DSLR. The average of L_D of DSLR and SQM were $19.47 \text{ mag arcsec}^{-2}$ and $20.32 \text{ mag arcsec}^{-2}$ respectively. The difference of the average value of the L_D is relatively small that is $0.85 \text{ mag arcsec}^{-2}$. While the standard deviation of the L_D recorded with DSLR is lower compared to the SQM.

Table 4. The comparison of Luminance of dawn, L_D

L_D	DSLR (mag arcsec ⁻²)	SQM (mag arcsec ⁻²)
Min.	17.65	18.44
Max.	20.52	21.98
Average	19.47	20.32
Std. Dev	0.8148	0.8911

Figure 4 shows the comparison of the scattering of the L_D with the DSLR and the SQM. The results shows that the recorded values of the L_D with the DSLR camera were between 17.65 and $20.52 \text{ mag arcsec}^{-2}$. While with the SQM were between 18.44 and $21.98 \text{ mag arcsec}^{-2}$. Its indicated that these values are nearly in agreement with the standard luminance of nautical twilight ($19.4 \text{ mag arcsec}^{-2}$) as well as the standard night sky luminance ($22.7 \text{ mag arcsec}^{-2}$) (Hänel et al. 2017; Hassan et al. 2014)

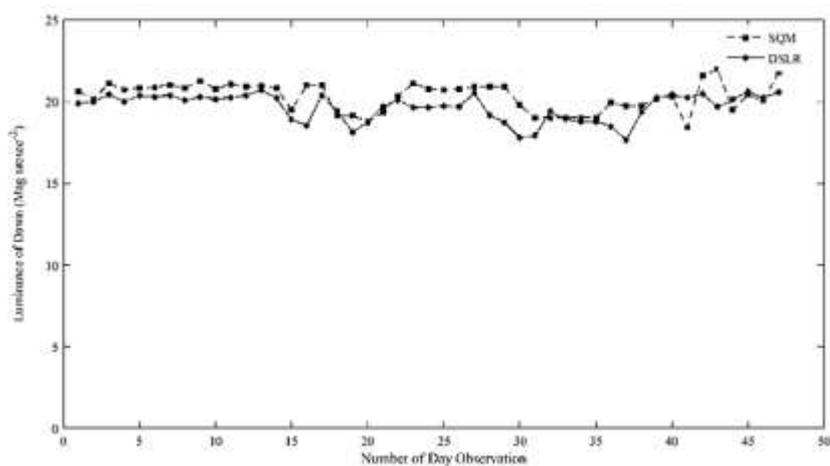


Figure 4. The comparison of the scattering of L_D On the other hand,

Figure 5 shows the frequency of the L_D for DSLR and SQM. The results show the highest frequency of the L_D is between 20.00 and 20.99 mag arcsec⁻² for both DSLR and SQM with 25- and 21-days observations have these values respectively.

On the other hand, the lowest frequency of L_D is 17.00 -17.99 mag arcsec⁻² and 18.00-18.99 mag arcsec⁻² for DSLR and SQM respectively

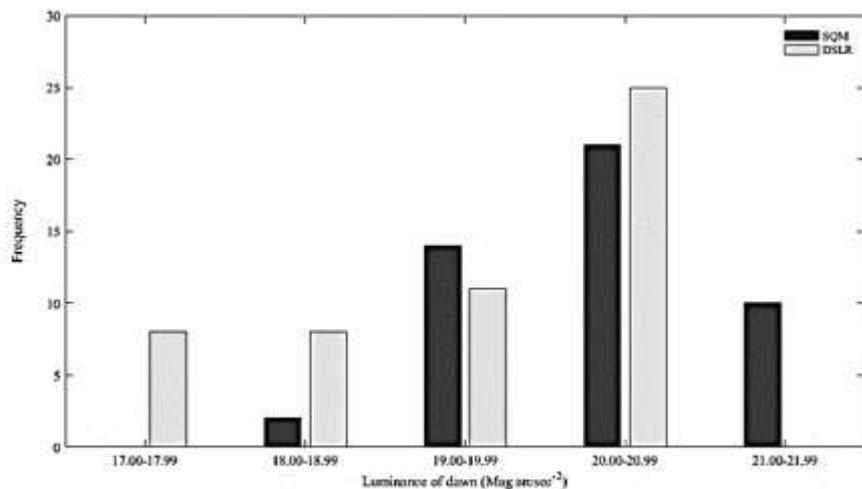


Figure 5. The comparison of frequency of L_D

The same highest frequency of L_D measured by the DSLR camera (in this study, Canon 60Da) and the SQM LU indicated that the measured luminance of dawn is a reliable result.

Thus, Canon 60Da and SQM LU can be used to measure the luminance of dawn.

Figure 6 shows the comparison of the D_{\odot} scattering throughout this study. The results indicated that there exists a small difference in the measured value of D_{\odot} between DSLR and SQM reading.

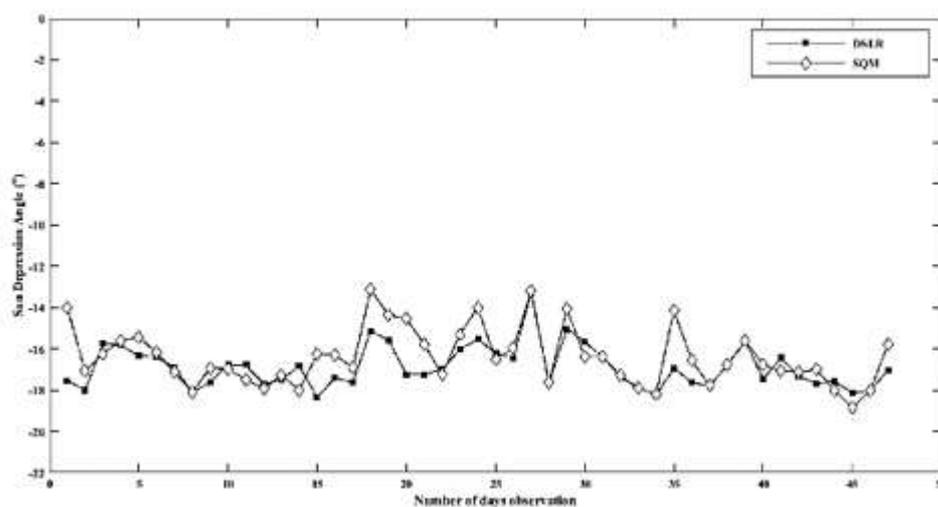


Figure 6. The comparison of scattering of D_{\odot}

Table 5 shows the comparison of D_{\odot} recorded with the DSLR and the SQM within 47 days of observation. It showed that the standard deviation of D_{\odot} recorded using the DSLR is lower compared to the SQM. The results also show that the difference between D_{\odot} values obtained from the DSLR and the SQM is 0.68°. This difference is reasonably small and can be accepted.

Table 5. The comparison D_{\odot} statistics

D_{\odot}	DSLR*	SQM*
Min.	-18.35	-18.83
Max.	-15.03	-14.00
Average	-17.01	-16.56
Std. Dev	0.8406	1.2147

Figure 7 shows the frequency of D_{\odot} throughout this study. The dawn at D_{\odot} of -17° was the high frequency for SQM and DSLR. The dawn at D_{\odot} of -15° and -19° were the lowest frequency for DSLR and SQM respectively. The result indicated that the dawn was seen at D_{\odot} of -17° was the highest frequency

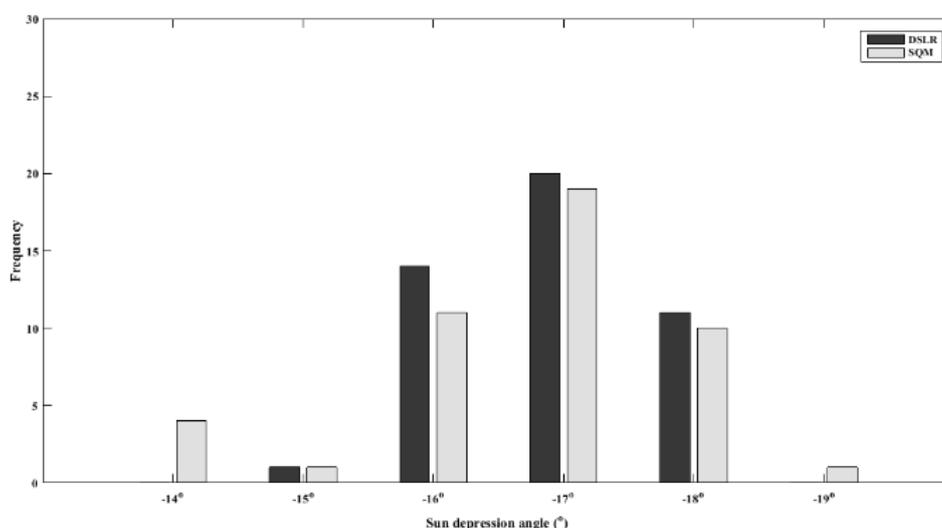


Figure 7. The comparison of frequency of D_{\odot}

The results show that the L_D recorded with the DSLR is slightly higher than the SQM. The lower number of luminance implies that the image is brighter compared with the higher number of luminance. It indicates that DSLR recorded a slightly higher amount of light in comparison with SQM.

These different values of luminance were caused by a number of factors such as sky background, weather conditions, field of view (FOV) of lens and camera setting.

The weather gave great impact on measurement of dawn luminance. Local horizon was covered with cloud from 3 to 8 okta during several days' observation. Horizon is brighter with clouds present compare with no cloud. Typically with cloud present, the average night sky brightness reaches level of 4 mcd m^{-2} compare darkest natural skies have a brightness of 0.25 mcd m^{-2} (Lolkema, D.E et al. 2010).

Furthermore, the sky background with skyglow, planets, stars and clouds also give impact in dawn measurement. The good lens of Canon 60Da with wider FOV collects light from the sky background and causes the images to be brighter. Also, the exposure setting of the DSLR were set between 8 to 10 seconds while the exposure setting of the SQM was fixed to one second. Thus, DSLR had longer exposure time and thus more light been collected. This causes the images to be brighter too.

The field of view (FOV) gives impact in sky brightness measurement (Ścieżor 2013, Salvador 2018) in which a lens with larger FOV will collect more light than a smaller one. The Canon 60Da fitted with 28mm Tamron lens gives FOV of 65.5° (horizontal) x 46.4° (vertical)

compared with SQM which gives a narrow FOV with 20° . Since Canon 60Da has a wider FOV than SQM, more light is collected. Thus, the images captured were brighter and gives a lower number of luminance.

This lens also coated with a good lens coating that gives brighter images and clearer contrasts. A good lens also gives impact on the images captured. This is why the value of L_D of images captured by Canon 60Da are lower.

In this study shows the sky conditions gave impact on L_D measurement. Throughout the studies, only 10 out of 47 days the sky was clear where false dawn (zodiacal light), planets, stars and the Milky Way could be seen with naked eyes.

Table 6 shows the results of D_\odot and the L_D on clear sky nights of observations.

Table 6. D_\odot and L_D on clear sky

Date	Location	DSLR		SQM	
		D_\odot	L	D_\odot	L
07/07/2017	Pekan	-18.10	20.06	-18.10	20.83
24/07/2017	Pekan	-17.63	20.30	-16.93	21.28
31/07/2017	Dungun	-17.70	20.38	-16.53	20.91
01/08/2017	Dungun	-17.50	20.70	-17.27	20.96
05/08/2017	Dungun	-17.63	20.38	-16.92	21.00
22/12/2017	Sabang	-17.47	20.40	-16.77	18.44
26/12/2017	Sabang	-17.68	20.11	-17.00	21.41
27/12/2017	Sabang	-17.57	20.61	-18.03	20.06
28/12/2017	Sabang	-18.15	20.22	-18.03	21.76
29/12/2017	Sabang	-18.03	20.57	-18.27	21.86

The results show that the lowest L_D recorded was $20.70 \text{ mag arcsec}^{-2}$ and $21.86 \text{ mag arcsec}^{-2}$ with Canon 60Da and SQM respectively. The average of L_D was $20.37 \text{ mag arcsec}^{-2}$ and $20.85 \text{ mag arcsec}^{-2}$ with Canon 60Da and SQM respectively. On the other hand, the average of D_\odot were -17.75° and -17.35° with Canon 60Da and SQM respectively. This comparison shows that the average of L_D and D_\odot is same with both DSLR and SQM. While the value of D_\odot obtained agrees with the study done by Dani (2016) and Bahali et al., (2018a, 2018b) but differs from the study conducted by Hassan et al., (2013, 2016).

Studies has shown that by using SQM by Dani (2016) and SQM & DSLR by Bahali et al. (2018, 2018b) yields the same D_\odot that is -17° , while the study using only naked eye by Hassan et al. (2013, 2016) yields a much lower value which is of around -14° . This is due to photometer instruments are more sensitive in detecting light intensity compared to human eyes. The D_\odot value obtained from this study is also different from the D_\odot value used in the Dawn prayers in Muslim countries such as Malaysia and Indonesia which uses $D_\odot = -20^\circ$.

Table 7. Average of D_\odot and L_D on sky conditions

Sky conditions	DSLR		SQM	
	L_D (mag arcsec ⁻²)	D_\odot (°)	L_D (mag arcsec ⁻²)	D_\odot (°)
Cloudy	19.47	-17.01	20.32	-16.56
Clear	20.37	-17.75	20.85	-17.35

Table 7 shows the comparison of average D_{\odot} and L_D between cloudy and clear sky. The result shows the average of L_D on clear sky is lower compare with L_D on cloudy sky. This indicates that the luminance intensity of dawn on clear sky is lower than cloudy sky because clouds have a strong influence on natural sky brightness [Yin 2015]. In urban areas, clouds can increase the skyglow by more than an order of magnitude (Hänel et al. 2017).

The first appearance of dawn was difficult to be seen with naked eye due the dawn possessing same illumination contrast with the sky's background where the dawn is unable to be distinguished under low illumination. The dawn could be seen once the sky background illumination increases (Wa et al. 2009). According Kumari (2008), the light intensity during twilight period is very low. But in the studies the dawn could still be seen between the broken clouds on cloudy night. Due the light intensity is very low; the dawn was seen very dim with the naked eye.

4. CONCLUSION

In this study, the Canon 60Da and the SQM LU were utilized to measure the L_D and the D_{\odot} , of the dawn at first seen. Through this study, the Canon 60Da and the SQM LU can be used for measurement of the L_D and the D_{\odot} . The changes of weather conditions result in difference of our measurement.

The results of this study are given as follow;

For the measurement with the Canon 60Da, the average of the L_D is 19.47 mag arcsec⁻² during cloudy sky and 20.37 mag arcsec⁻² during clear sky. The average of the D_{\odot} , is -17.00° during cloudy and -17.75° during clear sky.

For the measurement with the SQM LU, the average of the L_D is 20.32 mag arcsec⁻² and 20.85 mag arcsec⁻² for cloudy and clear sky respectively. The average of the D_{\odot} is -16.56° during cloudy sky and -17.35° during clear sky.

Through this comparison study, shows that the average of L_D recorded with Canon 60Da and SQM LU is between 19.47 mag arcsec⁻² and 20.85 mag arcsec⁻². On the other hand, the average of D_{\odot} is nearly same with both DSLR and SQM.

Hence, we propose that the value of L_D for dawn at first appearance is between 19.50 mag arcsec⁻² and 20.90 mag arcsec⁻². While the value of D_{\odot} , is -17.00°.

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