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Assessment of Crescent Moon Observation Potential at Pemedengan Hill Based on Geographical, Meteorological, and Astronomical Data in 2024

Siti Rabi'atul Adawiyah[1*]
[1]*Department of Information Technology*
Universitas Islam Negeri Mataram
Ana Saswati[2]
[2]*Department of Islamic Astronomy*
Universitas Islam Negeri Mataram
*Corresponding author: *sradawiyah@uinmataram.ac.id*

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Abstract

This study evaluates the potential of Pemedengan Hill, East Lombok, Indonesia, as a site for rukyatulhilal (crescent Moon observation) by integrating geographical, meteorological, and astronomical analyses. This field study uses data collected through observation and documentation. Geographically, the site offers a western horizon view within an azimuth range of $240°$˘$300°$, although Mount Agung obstructs views around azimuth $272°$. Meteorological analysis indicates generally low rainfall conditions during the analyzed period, supporting the site's potential for crescent observation. Astronomical analysis used SunCalc and MoonCalc to determine the Sun and Moon azimuth and altitude at local sunset on six observation dates. The results show that the Moon was below the horizon in June and August, while it remained above the horizon in May, July, September, and October. Based on the altitude parameter, July and October showed more favorable geometric conditions, with lunar altitudes of $3.97°$ and $4.81°$, respectively. These findings indicate that Pemedengan Hill has potential for crescent observation, although a comprehensive visibility assessment requires additional astronomical and observational parameters, particularly elongation and atmospheric conditions.

Keywords:Rukyatulhilal; SunCalc; MoonCalc; Azimuth; Altitude.

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INTRODUCTION

Like crescent moon sightings in other countries, in Indonesia, they are most often performed to determine the beginning of Ramadan, Shawwal, and Zulhijjah, months directly associated with major Islamic religious observances. Indonesians have practised the crescent moon sighting method since the arrival of Islam in the archipelago. They typically flock to the beaches or hills on the 29th of Sha'ban and Ramadan to observe the appearance of the crescent moon on the western horizon at sunset. They observe the crescent moon with the naked eye, without the use of any aids (Jayusman, 2021). However, along with the development of Science and Technology, rukyatulhilal activities in Indonesia have gradually used supporting infrastructure, such as binoculars, telescopes, compasses, clinometers/inclinometers, cameras, GPS, and various other astronomical applications and software.

Modern advances have not only brought technological convenience but also created complexities in crescent moon observation, particularly those related to environmental factors such as increasing light pollution, particularly in urban areas and large cities. This light pollution originates from streetlights, housing developments, buildings, billboards, and other sources, all of which are increasing in number (Subhan, 2021). High levels of light pollution make the horizon too bright, so that even very faint crescent moons can be obscured by backlighting (Alawiya, 2023). Furthermore, current weather conditions are increasingly unstable and often change rapidly. This condition can be challenging, given that the success of crescent sighting is highly dependent on the weather's luck (Ahsani & Maliha, 2021).

Furthermore, the increasing number of tall buildings and structures can also hinder the observation of the crescent moon. These factors can pose a significant challenge, given that the crescent moon's first appearance after ijtimak (conjunction) is very faint and very thin; its thickness is only a few arc seconds. In other words, the crescent moon's visibility is highly sensitive to even the slightest disturbance.

To address these challenges, Indonesian society, particularly Islamic institutions, mass organizations, and astronomy experts, generally conduct preparations before conducting a rukyatulhilal (crescent moon sighting). This preparation is crucial and involves several key steps to maximize the chances of a successful observation. They meticulously conduct these preparations, starting with monitoring weather conditions, selecting an observation site free from obstructions, preparing equipment, and conducting astronomical calculations (hisab) (Machzumy, 2018).

Furthermore, numerous studies have been conducted to test the feasibility of crescent moon observation sites in Indonesia, often involving geographical and meteorological analysis, as these two factors are the most crucial in determining the success of direct crescent moon observations. These include those conducted by Maslihah in 2022 and Hidayati in 2024. There is also research that combines this with separate astronomical calculations. Existing methods tend not to comprehensively integrate the various factors that determine crescent visibility (geographical, meteorological, and astronomical) into a single, systematic, and predictive analytical framework. This approach is often limited to partial analysis for decision-making.

Advances in information technology, the availability of accurate astronomical data, and modern computing tools, such as SunCalc and MoonCalc, can aid in predicting the positions of celestial bodies. SunCalc and MoonCalc are websites that enable easy access to crucial astronomical parameters, such as altitude, azimuth, and sunrise/set times of the Sun and Moon, which are highly relevant for sightings. These applications can be used to calculate the positions of the Sun and Moon at a specific time and location.

However, although SunCalc and MoonCalc provide precise astronomical data, few studies in Indonesia have methodologically integrated these three types of data-geographic data, meteorological data, and astronomical simulations from SunCalc and MoonCalc-into a single spatial mapping framework to identify the best points or zones within a given location for crescent moon observation. Most studies are still discrete, focusing solely on crescent moon calculations or solely on weather analysis, without a straightforward method for mapping visual potential based on the combination of these factors in an integrated manner.

Thus, this study aims to apply an integrative method using geographic data, meteorological data, and astronomical simulations from SunCalc and MoonCalc to determine the optimal observation time. The research location was at Pemedengan Hill, Sajang Village, Sembalun District. The selection of this location was based on the results of initial observations that Pemedengan Hill in Sajang Village, East Lombok is located at an altitude of 750 meters above sea level and coordinates $-8°18'25.41''$ South Latitude and $116°28'55.41''$ East Longitude, and is separated from village settlements which allows for minimal light pollution and obstructions to view the western horizon at that location. Based on these findings, Pemedengan Hill has the potential as a crescent moon observation location. This study was conducted to enhance the accuracy of determining the location of the rukyatulhilal, providing more objective, data-driven guidance for

observers and related institutions, optimizing resources and time used in hilal observation, and contributing to the development of a more modern and scientific rukyatulhilal methodology in Indonesia.

RESEARCH METHODS

This research is a field study. The primary data for this research include data on the western horizon of Pemedengan Hill obtained through direct observation, geographical data of Pemedengan Hill collected from Google Earth, and data on the positions of the moon and sun obtained from the SunCalc and MoonCalc websites. Meanwhile, the secondary data for this research are meteorological data from Pemedengan Hill, Sajang Village, obtained from the Mataram Meteorology, Climatology, and Geophysics Agency (BMKG). Additionally, this research utilizes supporting data obtained from various sources, including books, theses, and scientific articles that discuss related topics. The data analysis stage of this research encompasses data reduction, data presentation, and conclusion.

RESULT AND DISCUSSION

Geographical Analysis of Pemedengan Hill, Sajang Village, Sembalun District, East Lombok Regency as a Place for Rukyatulhilal

Sajang Village is a village located in East Lombok Regency, West Nusa Tenggara Province, Indonesia. East Lombok Regency, as one of ten regencies/cities in West Nusa Tenggara Province, is located at the eastern tip of Lombok Island, bordered to the north by the Java Sea, to the east by the Alas Strait, to the south by the Indian Ocean, and to the west by Central Lombok Regency and North Lombok Regency.



Figure 1: The View of Hill Tourism

Geographically, this district is located at coordinates $8°$-$9°$ South Latitude and $116°$-$117°$ East Longitude. In general, the East Lombok district area is situated at an altitude of 0-3,726 meters above sea level (Pemerintah Kabupaten Lombok Timur, 2024). Pemedengan Hill is situated at the foot of Mount Rinjani, located in Sajang Village, Sembalun District, East Lombok Regency. The trip to the Pemedengan Hill location can be reached in approximately one hour from the centre of Selong city by car or motorbike. This hill is located at a Latitude of $8°18'25.41''$ South and a Longitude of $116°28'55.41''$ East, with an altitude of approximately 750 meters above sea level. It has a field of view facing west, where the sun sets, without being obstructed by any buildings or trees. The appearance of Pemedengan Hill Tourism is presented in Figure 1.

Altitude affects the horizon's view. While a specific altitude is not the primary criterion, higher elevations minimize obstructions such as buildings, trees, and other obstacles. Therefore, Pemedengan Hill, located 750 meters above sea level, ensures it is free from buildings and trees.



Figure 2: Road to the Location

Access to Pemedengan Hill is also quite good. The hill is located approximately 1,200 meters from the main road and residential areas, allowing visitors to reach it by private vehicle. Figure 2 above shows the road to Pemedengan Hill. Sajang Village also has electricity from PLN. Meanwhile, internet access in Bukit Pemedengan is available via cellular network. The internet connection in Bukit Pemedengan is stable enough for communication and data transfer.

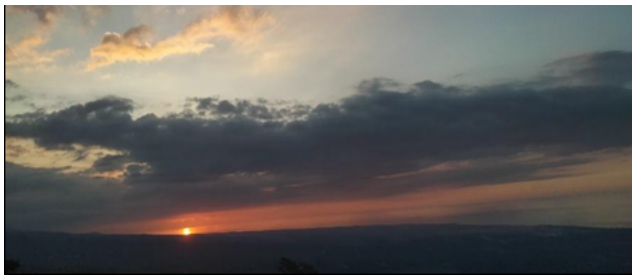


Figure 3: View of the Western Horizon of Pemedengan Hill

According to the location suitability criteria by the Meteorology, Climatology and Geophysics Agency, the location for rukyatulhilal is an open area free from obstructions such as buildings or trees (Alfarisi, 2023). The ideal location for rukyatulhilal faces the horizon and must be clear of any obstructions at an azimuth of $240^\circ - 300^\circ$, which is the angle between north and west. This area is needed if rukyatulhilal is carried out throughout the season, taking into account the shifts of the moon and sun from time to time. Figure 3 above shows the western horizon of Pemedengan Hill.



Figure 4: View of Mount Agung from the Pemedengan Hill Observation Site Toward The Western Horizon

As shown in Figure 4, Mount Agung is visible on the western horizon from the observation point at Pemedengan Hill and may obstruct views when the Sun or Moon is near the mountain's azimuth, approximately 272°. Therefore, crescent observation is expected to be less affected when the solar and lunar azimuths are

located to either side of this direction rather than directly aligned with Mount Agung. However, this study does not include measurements of the local horizon's angular elevation. Consequently, Mount Agung is considered a potential azimuthal obstruction rather than a quantitatively confirmed visibility barrier.

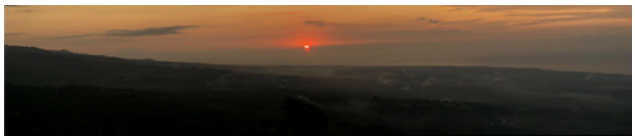


Figure 5: Sky View at Pemedengan Hill

Another criterion is that Pemedengan Hill is far from the city, meaning the location has minimal light pollution and supports activities such as observing the crescent moon. As shown in Figure 5, the observation site at Pemedengan Hill provides a relatively open view toward the western horizon, which is relevant for observing the crescent Moon after sunset. Observations indicate that the average travel time from Selong, the capital of East Lombok Regency, to Pemedengan Hill by motorized vehicle is approximately one hour, suggesting that the hill is quite distant from the city centre. Furthermore, good road access and adequate internet access at Pemedengan Hill are other factors contributing to the success of crescent moon observation activities at this location.

Meteorological Analysis of Pemedengan Hill, Sajang Village, Sembalun District, East Lombok Regency as a Place for Rukyatulhilal

Weather conditions at the observation site significantly affect the visibility of the crescent moon. If a location experiences significant rainfall, it will limit visibility to the horizon during the crescent moon sighting (Oktaviani, 2018).

Periods of high rainfall are often associated with increased cloudiness and reduced horizon visibility, which may limit crescent Moon observation. Heavy rainfall can cause water vapour to condense in the atmosphere. Condensation is the process by which a substance changes from a gas to a liquid. Condensing water vapour in the atmosphere forms clouds that can obscure the observer's view, making the crescent moon difficult to observe. Therefore, relatively dry conditions may provide more favorable meteorological circumstances for observation. However, rainfall data alone cannot represent actual sky clarity (Rafi'i, 1995).

Table 1: Average Rainfall Data in Sembalun District 2021-2023

Month	2021	2022	2023
January	897 mm	374 mm	399 mm
February	910 mm	391 mm	681 mm
March	217 mm	149 mm	364 mm
April	32 mm	50 mm	333 mm
May	5 mm	49 mm	8 mm
June	19 mm	130 mm	6 mm
July	14 mm	31 mm	35 mm
August	5 mm	33 mm	-
September	32 mm	11 mm	-
October	44 mm	150 mm	-
November	361 mm	222 mm	124 mm
December	184 mm	341 mm	100 mm

Table 1 above displays the average rainfall data in Sembalun District from 2021 to 2023, obtained from the BMKG in Mataram City. Normal rainfall is divided into three categories: low (0-100 mm), moderate (100-300 mm), and high (300-500 mm) (BMKG - Badan Meteorologi, Klimatologi, dan Geofisika, 2024). Thus, based on Table 1 in the data presentation above, the rainfall conditions in Sembalun District are presented in Table 2 below.

Based on Table 2 above, rainfall in Sembalun District from 2021 to 2023 is categorized as relatively low. In 2021, rainfall was low from April to October. High rainfall occurred in January, February, and November.

Table 2: Rainfall Categories in Sembalun District (2021-2023)

Month	2021		2022		2023	
	Rainfall	**Category**	**Rainfall**	**Category**	**Rainfall**	**Category**
January	897 mm	High	374 mm	High	399 mm	High
February	910 mm	High	391 mm	High	681 mm	High
March	217 mm	Moderate	149 mm	Moderate	364 mm	High
April	32 mm	Low	50 mm	Low	333 mm	High
May	5 mm	Low	49 mm	Low	8 mm	Low
June	19 mm	Low	130 mm	Low	6 mm	Low
July	14 mm	Low	31 mm	Low	35 mm	Low
August	5 mm	Low	33 mm	Low	-	No Rainfall
September	32 mm	Low	11 mm	Low	-	No Rainfall
October	44 mm	Low	150 mm	Moderate	-	No Rainfall
November	361 mm	High	222 mm	Moderate	124 mm	Moderate
December	184 mm	Moderate	341 mm	High	100 mm	Moderate

Meanwhile, rainfall in March and December was moderate. Furthermore, 2022 data shows that heavy rainfall occurred in January, February, and December. Moderate rainfall occurred in March, October, and November. Meanwhile, in 2023, heavy rainfall occurred primarily at the beginning of the year, specifically from January to April. Rainfall decreased drastically in the following three months, May, June, and July, with no rain at all in August, September, and October. Rain fell again in November and December, although it was moderate in intensity.

Thus, historical rainfall data indicate that Bukit Pemedengan experiences relatively drier conditions during certain months of the year, which may provide favorable meteorological conditions for hilal (new moon) observation. However, rainfall data alone are insufficient to determine the actual sky conditions affecting hilal visibility; factors such as cloud cover and horizon visibility must also be considered. As cloud cover data were unavailable for this study, the meteorological assessment was limited to historical rainfall characteristics. Months with relatively high rainfall, such as January and February, may have meteorological conditions less conducive to observation.

Astronomical Analysis of Pemedengan Hill as a Place for Rukyatulhilal Based on Simulations from the SunCalc and MoonCalc Websites

The astronomical analysis in this study focuses on the relative positions of celestial objects. Knowing the position of the crescent moon is expected to help determine the best times to observe the crescent moon at Pemedengan Hill throughout the year. The position of the crescent moon's height is one of the criteria that must be taken into account in crescent moon observation activities (Machzumy, 2018).

The Indonesian government has set a minimum altitude requirement for the crescent moon during rukyatulhilal (crescent moon sighting) of 3°. In other words, the new moon, or the beginning of a lunar month, is declared to have arrived when the crescent moon's altitude is at least 3°. The Ministers of Religious Affairs agreed upon the altitude of this crescent moon in the new MABIMS (Islamic Centre for Islamic Studies), and it serves as the basis for determining the beginning of a lunar month for the government (Irfan & Latuconsina, 2023; Aini & Azkarrula, 2024; Wahyuningsih, 2024).

Solar and lunar data obtained from the SunCalc and MoonCalc websites enable us to determine when the moon sets and where it will rise. This data makes it easier for observers to map the positions of celestial bodies during the rukyatulhilal (crescent moon sighting) operation. The data taken is for May to October 2024. Data collection in this range refers to the results of analyzing Pemedengan Hill meteorological data, as previously carried out in point 2, which found that the rainfall conditions from May to October 2024 fall within the low category. No rain occurred in the last year, namely in 2023. In other words, meteorologically, the chance of success in observing the crescent moon in these months is relatively high due to the minimal presence of rain, which could otherwise hinder the sighting of the crescent moon.

Thus, after determining the best months for observing the crescent moon from a meteorological perspective, this astronomical analysis is expected to be a follow-up study that can strengthen the results of the previous analysis to identify the optimal times to observe the crescent moon at Pemedengan Hill. The following is the sun and moon data obtained from the SunCalc and MoonCalc websites at Pemedengan Hill.

1. Sun and Moon Data on May 8, 2024

Solar data for the Location		**Geo data for the Location**		
Dawn:	05:55:33	Height:		750m
Sunrise:	06:17:07	Latitude:	S 8°18'25.41"	-8.30706°
Sun peak level:	12:10:33	Longitude:	E 116°28'55.41"	116.48206°
Sunset:	18:03:55	Timezone:	Asia/Makassar	WITA
Dusk:	18:25:30			
Duration:	11h46m48s			
Altitude:	-0.09°			
Azimut:	287.37°			
Shadow length:	n/a	at an object level: 1m		

Figure 6: Solar Positional Parameters Obtained from Suncalc for the Pemedengan Hill Observation Site on 8 May 2024.

Figure 6 above shows the sun's azimuth on May 8, 2024, at an azimuth of 287.37° at an altitude of -0.09°. Figure 7 below shows the moon's azimuth at 291.76° at an altitude of 0.87°.

Lunar data for the selected location		**Geo data for the selected location**		
Moon rising:	06:07:20	Height:		750m
Moon peak:	12:08:58	Latitude:	S 8°18'25.41"	-8.30706°
Moonset:	18:09:02	Longitude:	E 116°28'55.41"	116.48206°
Moon distance:	367,677km	Timezone:	Asia/Makassar	WITA
Moon elevation angle:	0.87°			
Moon horizontal angle:	291.76°			
shadow length:	66.12m	at an object level: 1m		
Moonphase/Fraction:	New Moon/0.2%			
Moon Age:	0.28 out of 29.39 days			
Next New Moon:	06.06.2024 20:37:55	Next Full Moon:	23.05.2024 21:53:23	

Figure 7: Lunar Positional Parameters Obtained from Mooncalc for the Pemedengan Hill Observation Site on 8 May 2024

Figure 8 illustrates the apparent positions of the Sun and Moon at sunset on 8 May 2024, based on azimuth and altitude coordinates at Pemedengan Hill, as shown in Figure 6 and 7.

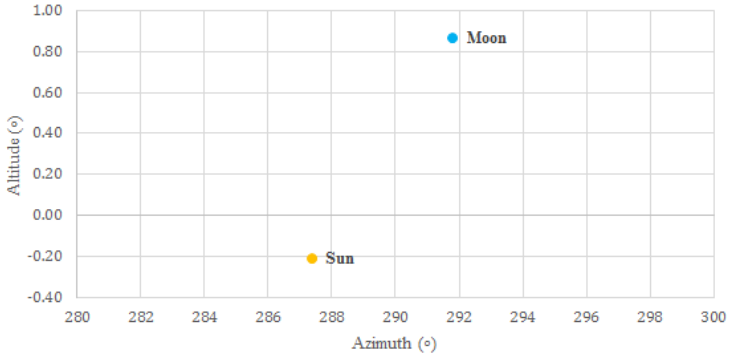


Figure 8: Apparent Positions of the Sun and Moon at Sunset on 8 May 2024

The horizontal axis represents azimuth, while the vertical axis represents the altitude of the celestial objects relative to the local horizon. The graph shows that the Sun was at an azimuth of 287.35° with an altitude of -0.21°, indicating that it had already set at the time of observation. Meanwhile, the Moon was located at an azimuth of 291.76° with an altitude of 0.87°. The small difference between the Sun and Moon azimuth values (approximately 4.41°) indicates that both objects were located in a similar direction near the western horizon. The Moon altitude value of 0.87° indicates that the crescent position was very close to the horizon after sunset. Although the Moon was still theoretically above the horizon,

its low altitude suggests that the crescent observation conditions were limited due to its proximity to the horizon. Therefore, the positional relationship between the Sun and Moon shown in Figure 8 provides an overview of the geometric conditions affecting crescent visibility on 8 May 2024.

2. Sun and Moon Data on June 6, 2024

Solar data for the Location		**Geo data for the Location**		
Dawn:	06:00:30	Height:		750m
Sunrise:	06:22:50	Latitude:	S 8°18'25.41''	-8.30706°
Sun peak level:	12:12:48	Longitude:	E 116°28'55.41''	116.48206°
Sunset:	18:02:45	Timezone:	Asia/Makassar	WITA
Dusk:	18:25:05			
Duration:	11h39m55s			
Altitude:	-0.24°			
Azimut:	292.85°			
Shadow length:	n/a	at an object level: 1m		

Figure 9: Solar Positional Parameters Obtained from Suncalc for the Pemedengan Hill Observation Site on 6 June 2024.

Lunar data for the selected location		**Geo data for the selected location**		
Moon rising:	05:52:12	Height:		750m
Moon peak:	11:49:50	Latitude:	S 8°18'25.41''	-8.30706°
Moonset:	17:46:36	Longitude:	E 116°28'55.41''	116.48206°
Moon distance:	375,950km	Timezone:	Asia/Makassar	WITA
Moon elevation angle:	-4.01°			
Moon horizontal angle:	296.81°			
shadow length:	n/a	at an object level: 1m		
Moonphase/Fraction:	New Moon/0.2%			
Moon Age:	29.28 out of 29.39 days			
Next New Moon:	06.06.2024 20:37:55	Next Full Moon:	22.06.2024 09:08:00	

Figure 10: Lunar Positional Parameters Obtained from Mooncalc for the Pemedengan Hill Observation Site on 6 June 2024

Figure 11 illustrates the apparent positions of the Sun and Moon at sunset, based on their azimuth and altitude coordinates shown in Figures 9 and 10. The graph shows the Sun at an azimuth of $292.85°$ and an altitude of $-0.24°$, indicating that it had already set at the time of observation. Meanwhile, the Moon was positioned at an azimuth of $291.76°$ with an altitude of $-0.41°$. The similar azimuth values of the Sun and Moon indicate that both celestial objects were located in almost the same direction near the western horizon. However, the Moon's altitude was negative, showing that it was already below the local horizon when the observation was conducted. The Moon was positioned approximately $0.41°$ below the horizon, while the Sun was approximately $0.24°$ below the horizon. This condition indicates that the Moon was not geometrically visible after sunset because it had already set or was below the observer's horizon.

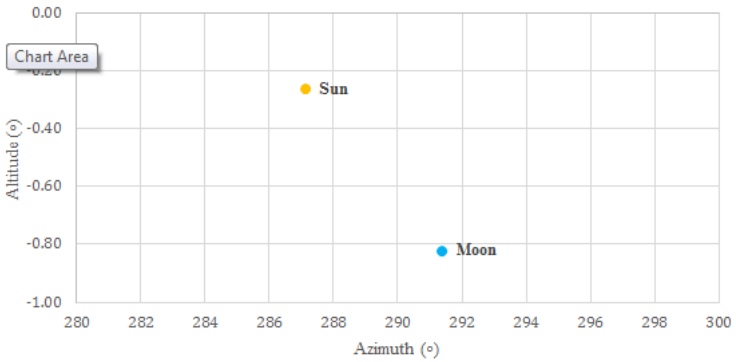


Figure 11: Apparent Positions of the Sun and Moon at Sunset on 6 June 2024

The proximity between the Sun and Moon positions in azimuth indicates a small horizontal separation, but the negative lunar altitude represents an unfavorable geometric condition for crescent observation. Therefore, based on the positional parameters shown in Figure 11, the crescent visibility condition was not fulfilled at the observation location on this date.

3. Sun and Moon Data on July 6, 2024

Solar data for the Location		**Geo data for the Location**		
Dawn:	06:06:35	Height:		750m
Sunrise:	06:28:55	Latitude:	S 8°18'25.41''	-8.30706°
Sun peak level:	12:18:54	Longitude:	E 116°28'55.41''	116.48206°
Sunset:	18:08:54	Timezone:	Asia/Makassar	WITA
Dusk:	18:31:14			
Duration:	11h39m59s			
Altitude:	-0.21°			
Azimut:	292.74°			
Shadow length:	n/a	at an object level: 1m		

Figure 12: Solar Positional Parameters Obtained from Suncalc for the Pemedengan Hill Observation Site on 6 July 2024

Lunar data for the selected location		**Geo data for the selected location**		
Moon rising:	06:38:19	Height:		750m
Moon peak:	12:33:56	Latitude:	S 8°18'25.41''	-8.30706°
Moonset:	18:30:06	Longitude:	E 116°28'55.41''	116.48206°
Moon distance:	388,817km	Timezone:	Asia/Makassar	WITA
Moon elevation angle:	3.97°			
Moon horizontal angle:	297.94°			
shadow length:	14.41m	at an object level: 1m		
Moonphase/Fraction:	New Moon/0.4%			
Moon Age:	0.47 out of 29.51 days			
Next New Moon:	04.08.2024 19:13:12	Next Full Moon:	21.07.2024 18:17:20	

Figure 13: Lunar Positional Parameters Obtained from Mooncalc for the Pemedengan Hill Observation Site on 6 July 2024

Figure 14 illustrates the apparent positions of the Sun and Moon at sunset, based on their azimuth and altitude coordinates shown in Figures 12 and 13. The graph shows the Sun at an azimuth of 292.74° and an altitude of -0.21°, indicating that the Sun had already set and was slightly below the western horizon at the observation time. Meanwhile, the Moon was at an azimuth of 297.94° with an altitude of 3.97°, showing that it remained above the horizon after sunset.

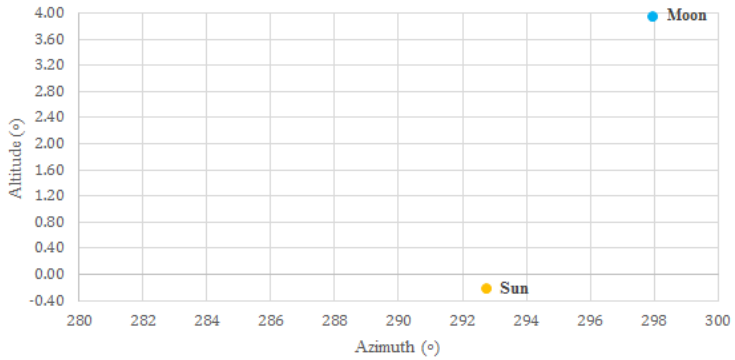


Figure 14: Apparent Positions of the Sun and Moon at Sunset on 6 July 2024

The difference between the Sun and Moon azimuth values was approximately 5.20°, indicating that both celestial objects were located in a relatively close direction near the western horizon. The Moon altitude of 3.97° indicates that the crescent position met the minimum altitude criterion commonly considered in

crescent visibility assessments. Therefore, the geometric position of the Moon in Figure 14 indicates more favorable conditions for crescent observation compared with cases where the Moon altitude is below the horizon.

4. Sun and Moon Data on August 4, 2024

Solar data for the Location		**Geo data for the Location**		
Dawn:	06:05:12	Height:		750m
Sunrise:	06:26:46	Latitude:	S 8°18'25.41''	-8.30706°
Sun peak level:	12:20:10	Longitude:	E 116°28'55.41''	116.48206°
Sunset:	18:13:40	Timezone:	Asia/Makassar	WITA
Dusk:	18:35:13			
Duration:	11h46m54s			
Altitude:	-0.26°			
Azimut:	287.10°			
Shadow length:	n/a	at an object level: 1m		

Figure 15: Solar Positional Parameters Obtained from Suncalc for The Pemedengan Hill Observation Site on 4 August 2024

Lunar data for the selected location		**Geo data for the selected location**		
Moon rising:	06:14:10	Height:		750m
Moon peak:	12:11:32	Latitude:	S 8°18'25.41''	-8.30706°
Moonset:	18:10:03	Longitude:	E 116°28'55.41''	116.48206°
Moon distance:	396,714km	Timezone:	Asia/Makassar	WITA
Moon elevation angle:	-0.82°			
Moon horizontal angle:	291.37°			
shadow length:	n/a	at an object level: 1m		
Moonphase/Fraction:	New Moon/0.1%			
Moon Age:	29.47 out of 29.51 days			
Next New Moon:	04.08.2024 19:13:12	Next Full Moon:	20.08.2024 02:26:06	

Figure 16: Lunar Positional Parameters Obtained from Mooncalc for The Pemedengan Hill Observation Site on 4 August 2024

Figure 14 illustrates the apparent positions of the Sun and Moon at sunset, based on their azimuth and altitude coordinates shown in Figures 12 and 13. The graph shows the Sun at an azimuth of 292.74° and an altitude of -0.21°, indicating that the Sun had already set and was slightly below the western horizon at the observation time. Meanwhile, the Moon was at an azimuth of 297.94° with an altitude of 3.97°, showing that it remained above the horizon after sunset.

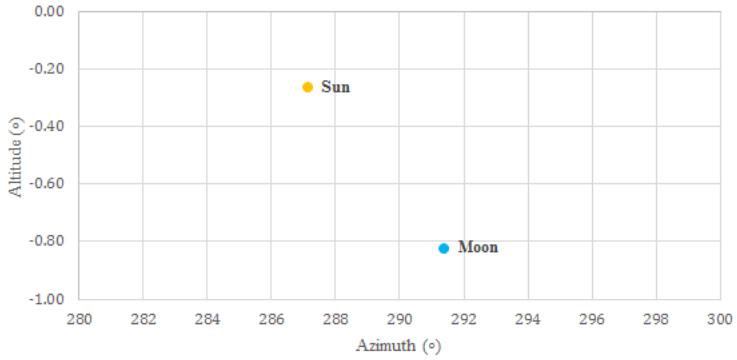


Figure 17: Apparent Positions of the Sun and Moon at Sunset on 4 August 2024

The difference between the Sun and Moon azimuths was approximately 4.27°, indicating that both objects were in a similar direction near the western horizon. However, the Moon altitude was negative and lower than the Sun altitude, meaning the Moon had already set before or around sunset. This condition indicates that the Moon was not in a geometrically observable position after sunset. Therefore,

based on the azimuth and altitude parameters in Figure 17, the crescent observation condition was unfavorable because the Moon was below the horizon at the time of observation. The close azimuthal separation between the Sun and Moon alone was insufficient to support crescent visibility because the Moon altitude parameter did not meet the required condition for visibility.

5. Sun and Moon Data on September 3, 2024

Solar data for the Location		**Geo data for the Location**		
Dawn:	05:53:24	Height:		750m
Sunrise:	06:14:12	Latitude:	S 8°18'25.41''	-8.30706°
Sun peak level:	12:13:22	Longitude:	E 116°28'55.41''	116.48206°
Sunset:	18:12:39	Timezone:	Asia/Makassar	WITA
Dusk:	18:33:27			
Duration:	11h58m27s			
Altitude:	-0.26°			
Azimut:	277.24°			
Shadow length:	n/a	at an object level: 1m		

Figure 18: Solar Positional Parameters Obtained from Suncalc for The Pemedengan Hill Observation Site on 3 September 2024

Lunar data for the selected location		**Geo data for the selected location**		
Moon rising:	06:17:03	Height:		750m
Moon peak:	12:20:51	Latitude:	S 8°18'25.41''	-8.30706°
Moonset:	18:26:15	Longitude:	E 116°28'55.41''	116.48206°
Moon distance:	404,454km	Timezone:	Asia/Makassar	WITA
Moon elevation angle:	2.75°			
Moon horizontal angle:	278.21°			
shadow length:	20.81m	at an object level: 1m		
Moonphase/Fraction:	New Moon/0.1%			
Moon Age:	0.34 out of 29.70 days			
Next New Moon:	03.10.2024 02:49:39	Next Full Moon:	18.09.2024 10:34:52	

Figure 19: Lunar Positional Parameters Obtained from Mooncalc for The Pemedengan Hill Observation Site on 3 September 2024

Figure 20 illustrates the apparent positions of the Sun and Moon at sunset, based on their azimuth and altitude coordinates shown in Figures 18 and 19. The graph shows that the Sun was at an azimuth of 277.24° with an altitude of -0.26°, indicating that it had already moved below the western horizon at the observation time.

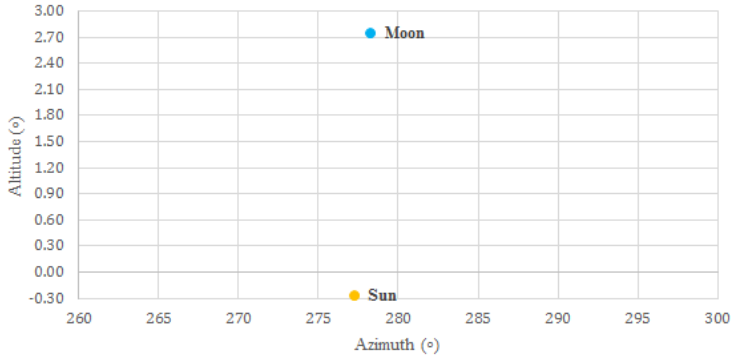


Figure 20: Apparent Positions of the Sun and Moon at Sunset on 3 September 2024

Meanwhile, the Moon was at an azimuth of 278.21° with an altitude of 2.75°, indicating that it remained above the horizon after sunset. The azimuth difference between the Sun and Moon was approximately 0.97°, showing that both objects were located in nearly the same direction near the western horizon. The Moon's altitude of 2.75° indicates that the crescent position was still above the horizon, although

relatively low. This condition suggests that the Moon had a potential geometric opportunity for crescent observation after sunset.

6. Sun and Moon Data on October 3, 2024

Solar data for the Location		**Geo data for the Location**		
Dawn:	05:36:26	Height:		750m
Sunrise:	05:57:08	Latitude:	S 8°18'25.41''	-8.30706°
Sun peak level:	12:03:02	Longitude:	E 116°28'55.41''	116.48206°
Sunset:	18:09:03	Timezone:	Asia/Makassar	WITA
Dusk:	18:29:46			
Duration:	12h11m55s			
Altitude:	-0.38°			
Azimut:	265.57°			
Shadow length:	n/a	at an object level: 1m		

Figure 21: Solar Positional Parameters Obtained from Suncalc for The Pemedengan Hill Observation Site on 3 October 2024

Lunar data for the selected location		**Geo data for the selected location**		
Moon rising:	06:04:51	Height:		750m
Moon peak:	12:17:37	Latitude:	S 8°18'25.41''	-8.30706°
Moonset:	18:32:13	Longitude:	E 116°28'55.41''	116.48206°
Moon distance:	406,397km	Timezone:	Asia/Makassar	WITA
Moon elevation angle:	4.81°			
Moon horizontal angle:	262.86°			
shadow length:	11.88m	at an object level: 1m		
Moonphase/Fraction:	New Moon/0.4%			
Moon Age:	0.64 out of 29.75 days			
Next New Moon:	01.11.2024 20:47:43	Next Full Moon:	17.10.2024 19:26:52	

Figure 22: Lunar Positional Parameters Obtained from Mooncalc for The Pemedengan Hill Observation Site on 3 October 2024

Figure 23 illustrates the apparent positions of the Sun and Moon at sunset, based on their azimuth and altitude coordinates shown in Figures 21 and 22. Graph 23 shows that the Sun was at an azimuth of 265.57° with an altitude of -0.38°, indicating that it had already moved below the western horizon at the observation time. Meanwhile, the Moon was at an azimuth of 262.86° with an altitude of 4.81°, indicating that it remained above the horizon after sunset. The azimuth difference between the Sun and Moon was approximately 2.71°, indicating that both objects were in a similar direction near the western horizon. The Moon's altitude of 4.81° shows that it was sufficiently elevated above the horizon, unlike cases where the altitude was close to or below 0°. This condition provides a more favorable geometric configuration for crescent observation because the Moon remained visible above the horizon after sunset. Therefore, Figure 23 indicates a geometrically more favorable condition for crescent observation, but does not independently confirm actual crescent visibility.

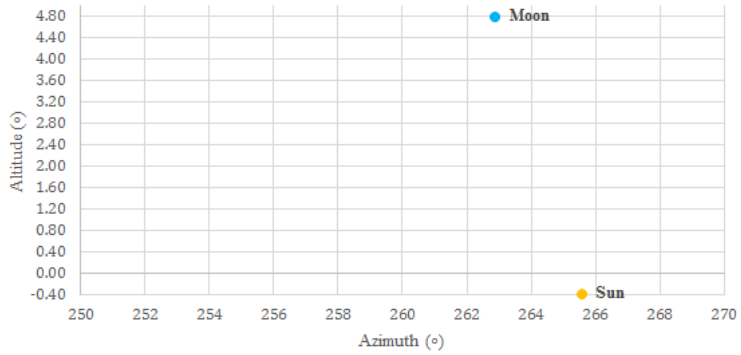


Figure 23: Apparent Positions of the Sun and Moon at Sunset on 3 October 2024

The conclusions from the mapping results are summarised and presented in Table 3 below.

Table 3: Summary of Solar and Lunar Positional Parameters at Local Sunset at Pemedengan Hill Based on SunCalc and MoonCalc Data

No.	Gregorian Date / Hijri Date	Sun Azimuth	Sun Altitude	Moon Azimuth	Moon Altitude	Geometric Condition Based on Moon Position
1	8 May 2024 / 29 Shawwal 1445 H	287.35	-0.21	291.76°	0.87°	The Moon was above the horizon after sunset; however, its low altitude indicates limited geometric conditions for crescent observation.
2	6 June 2024 / 29 Dhu al-Qa'dah 1445 H	292.85	-0.24	291.76°	-0.41°	The Moon was below the horizon at sunset, indicating unfavorable conditions for crescent observation.
3	6 July 2024 / 29 Dhu al-Hijjah 1445 H	292.74	-0.21	297.94°	3.97°	The Moon was above the horizon with a higher altitude, indicating a more favorable geometric condition for crescent observation.
4	4 August 2024 / 29 Muharram 1446 H	287.10	-0.26	291.37°	-0.82°	The Moon was below the horizon at sunset, indicating that the crescent could not be observed geometrically.
5	3 September 2024 / 29 Safar 1446 H	277.24	-0.26	278.21°	2.75°	The Moon remained above the horizon, but its altitude was relatively low for crescent observation.
6	3 October 2024 / 29 Rabi' al-Awwal 1446 H	265.57	-0.38	262.86°	4.81°	The Moon was above the horizon with a higher altitude, indicating a more favorable geometric condition for crescent observation.

Table 3 summarizes the apparent position of the Moon at sunset at Pemedengan Hill based on azimuth and altitude parameters obtained from MoonCalc. The results show considerable variation in the geometric position of the Moon across the six observation dates. The lunar azimuth ranged from 262.86° to 297.94°, while the altitude ranged from $-0.82°$ to 4.81°, indicating changes in both the horizontal direction and vertical position of the Moon relative to the local horizon.

Negative lunar altitude values were recorded on June 6, 2024 ($-0.41°$) and August 4, 2024 ($-0.82°$). These values indicate that the Moon was below the local horizon at sunset. Geometrically, these conditions are unfavorable for observing the hilal (new crescent moon). On May 8, 2024, the Moon remained above the horizon at an altitude of only 0.87°, limiting observation prospects because of its very low position. A similar situation occurred on September 3, 2024, although the Moon's position was higher, at 2.75°.

More favorable geometric conditions were found on 6 July and 3 October 2024. On 6 July, the Moon reached an altitude of 3.97° at an azimuth of 297.94°, whereas on 3 October it reached the highest altitude among the analyzed dates, at 4.81° with an azimuth of 262.86°. These findings align with previous studies emphasizing that the moon's altitude is a crucial geometric parameter for assessing hilal (new crescent moon) visibility. According to (Reskiani & Subhan, 2022) an altitude below 3° makes empirical observation extremely difficult, particularly without optical aids (Amilia et al., 2021). (Karim & Mahsun, 2024) explain that the hilal must be at a sufficient altitude to avoid being overwhelmed by twilight (syafak) glare. Furthermore, (Fitriyani et al., 2024) reported that a 10-year hisab (astronomical calculation) analysis (1443 H - 1452 H) revealed 13 instances where the determination of the start of the month could potentially differ because the hilal altitude fell within the 0° to $< 3°$ range.

However, lunar altitude alone cannot provide a comprehensive assessment of hilal visibility, as parameters such as elongation, atmospheric transparency, cloud cover, and local horizon conditions also influence observational outcomes (Soderi et al., 2024). A hilal with insufficient elongation appears too thin and is likely to be obscured by twilight glare (Fitriyani et al., 2024). (Sopwan & Raharto, 2019) explain that greater elongation increases the crescent's thickness, thereby enhancing its brightness enough to stand out against the background light of the western horizon sky. Additionally, (Munir, 2024) notes that cloud cover is a primary factor affecting atmospheric clarity.

This study has several limitations. The meteorological analysis is based on historical rainfall data from 2021 - 2023 and does not represent the actual weather conditions on the 2024 observation dates. Cloud-cover data and quantitative sky-brightness measurements were unavailable. In addition, we did not measure the angular elevation of the local horizon, and we did not include lunar elongation in the present analysis. Therefore, interpret the results as an assessment of geometric and environmental observation potential rather than confirmation of actual crescent visibility.

Consequently, based on altitude alone, 3 October showed the most favorable geometric configuration among the six analyzed dates, followed by 6 July. Nevertheless, these results reflect only the Moon's geometric position. A complete evaluation of crescent visibility should also consider additional astronomical parameters, particularly elongation, as well as relevant atmospheric and observational conditions.

CONCLUSION

Based on geographical analysis, Pemedengan Hill directly faces the western horizon with an azimuth of 240° to 300°, although it is obstructed at an azimuth of 272° by Mount Agung. However, the field of view from west to north is clear of any obstructions. From a meteorological perspective, historical rainfall data from 2021–2023 indicate relatively drier conditions during certain months, which could facilitate hilal observation. However, cloud cover data must also be included to ensure a comprehensive analysis of the atmospheric conditions conducive to rukyatulhilal. Meanwhile, the astronomical analysis indicates varying geometric conditions for observing the crescent. The Moon was below the horizon at sunset in June and August, while it remained above the horizon in May, July, September, and October. Based on the altitude parameter, July and October showed more favorable geometric conditions, when the Moon reached altitudes of 3.97° and 4.81°, respectively. These findings describe the geometric potential for crescent observation and should be complemented by other astronomical and observational parameters for a comprehensive visibility assessment.

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