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Non-Astronomical Aspects of the Success of *Rukyatul Hilal* in East Java

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Abstract: The success of rukyatul hilal (moon sighting) is not only influenced by the physical aspects of the hilal (the crescent moon) but also depends on non-physical (non-astronomical) aspects. In the last 5 years, 7 out of 23 locations in East Java have contributed to sighting the hilal while other locations have experienced failures due to various constraints and obstacles. This paper evaluates these locations using geographical and topographical theories to delve into three main questions: the implementation of rukyatul hilal activities in East Java, the influence of geographical and topographical conditions of the locations, and the mapping of rukyatul hilal locations in East Java. Research data were measured and observed directly and indirectly using Google Earth with area sampling and non-probability sampling techniques. Research findings reveal that: first, rukyatul hilal is carried out at the beginning of each Hijri month by most observers at several locations during important months such as Ramadan, Shawwal, and Dhul Hijjah with the naked eye, while other locations use optical aids with low success rates; second, geographically, most rukyatul hilal locations in East Java are located near the equator with the main obstacle being disturbances from fog pollution, dust, clouds, rain, and other atmospheric particles; and third, out of 23 active rukyatul hilal locations in East Java mapped: a) locations categorized as observatories, with two observatories that do not fully contribute to moon observations, b) other hilal observation locations categorized as locations located on the north and south coast, with five locations that do not fully contribute to hilal observations, and c) other hilal observation locations categorized as locations located at high altitudes, with seven locations contributing to the implementation of hilal sighting and three locations dominating the production of hilal visibility more than once.

Keywords: Non-Astronomical Aspects, Topographical-Geographical, Hilal Observatory

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Abstrak: *Keberhasilan rukyatul hilal tidak hanya dipengaruhi oleh aspek-aspek fisis hilal, akan tetapi juga bergantung pada aspek-aspek non-fisis hilal (non-astronomi). Secara faktual, 5 tahun terakhir, 7 dari 23 lokasi di Jawa Timur berkontribusi melihat hilal. Sementara lokasi-lokasi lainnya menemukan kegagalan dengan beberapa faktor kendala dan hambatan. Artikel ini mengevaluasi lokasi-lokasi tersebut menggunakan teori geografis dan topografis untuk mendalami 3 pertanyaan utama yaitu pelaksanaan kegiatan rukyatul hilal di Jawa Timur, pengaruh kondisi geografis dan topografis lokasi, dan pemetaan lokasi-lokasi rukyatul hilal di Jawa Timur. Data penelitian ini diukur dan diamati secara langsung dan tidak langsung menggunakan aplikasi google earth dengan metode area sampling dan teknik nonprobability sampling. Temuan penelitian menunjukkan bahwa pertama, rukyatul hilal dilaksanakan setiap awal bulan hijriyah oleh mayoritas perukyat di beberapa lokasi pada bulan-bulan penting, Ramdahan, Syawal dan Dzulhijjah dengan kasat mata. Sementara lokasi-lokasi lainnya menggunakan alat bantu optik dengan tingkat keberhasilannya yang rendah, kedua, secara geografis, lokasi rukyatul hilal di Jawa Timur mayoritas berada dekat dengan katulistiwa dengan hambatan utamanya adalah gangguan polusi kabut, debu, awan dan hujan serta partikel-partikel atmosfer lainnya, dan ketiga, dari 23 lokasi rukyatul hilal yang aktif di Jawa Timur dipetakan: 1. lokasi dengan kategori observatorium, ditemukan 2 observatorium yang tidak seluruhnya berkontribusi dalam pengamatan hilal, 2. lokasi-lokasi pengamatan hilal lainnya dikategorikan sebagai lokasi yang terletak di pesisir pantai utara dan selatan, 5 lokasi yang tidak seluruhnya berkontribusi dalam pengamatan hilal dan 3. lokasi-lokasi pengamatan hilal lainnya dikategorikan sebagai lokasi yang terletak di tempat tinggi, 7 lokasi yang berkontribusi dalam pelaksanaan rukyatul hilal dan 3 lokasi diantaranya mendominasi produksi ketampakan hilal lebih dari 1 kali.*
Kata Kunci: *Aspek Non-Astronomis, Topografis-Geografis, Observatorium Hilal*

Introduction

Theoretically, the success of hilal (the crescent moon) sightings is significantly influenced by two primary factors: scientific/astronomical and non-astronomical elements.[1] From an astronomical standpoint, the visibility of the hilal is contingent upon the moon's physical properties, twilight sky brightness, horizontal parallax, atmospheric refraction, horizon dip, angular distance between the moon and sun, and the moon's altitude above the horizon.[2] Conversely, non-astronomical factors influencing the success of hilal sightings include the observer's condition, sighting equipment and media, and the observation site.

[1] Farid Ruskanda, *100 Masalah Hisab Dan Rukyat Telaah Syariah, Sains Dan Teknologi* (Jakarta: Gema Insani Press Ruskanda, 1996). p. 53-54.

[2] Syarifuddin Yusmar, "“Penanggalan Bugis-Makasar Dalam Penentuan Awal Bulan Kamariah Menurut Syaria'ah Dan Sains," *Hunafa* 5, no. 3 (2008), p. 281.

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These three factors constitute the primary elements of hilal sighting. Among these three factors, the observation site is the most challenging to control during a moon sighting.[3] The Indonesian Agency for Meteorology, Climatology, and Geophysics (Badan Meteorologi Klimatologi dan Geofisika/BMKG) has established regulations outlined in Law No. 31 of 2009 regarding environmental requirements for observations.[4] While these regulations were initially designed for astronomical observations conducted by the BMKG, they can be applied by other institutions involved in hilal sighting activities in Indonesia. On the other hand, Nahdlatul Ulama (NU), an organization that adheres to the traditional method of *rukyat* in determining the beginning of the Hijri/Islamic month, has also established guidelines for selecting observation sites,[5] as detailed in PBNU Decision No. 311/A.II.03/I/1994 on Operational Guidelines for *Rukyat bil Fi'li* within NU dated 1 Sya'ban 1415 H/13 January 1994 M.[6] The NU criteria are quite general, prompting Gazali Masroeri (Chair of the LFPBNU) to provide additional clarification, stating that a suitable observation site is one that faces the western topocentric horizon and is free from obstructions, with the ideal site being one that faces the open sea.[7]

From the context, it can be understood that the criteria for hilal observation sites have been established by both BMKG and NU, but the criteria from each of these regulations are still very general. However, in reality, the Hisab and Rukyat Team of Ministry of Religious Affairs, the NU Rukyat Implementation Team, and other institutions often encounter obstacles and challenges in conducting hilal observations. As a result, it is reported that more observations fail to see the hilal compared to those that are successful.[8] This issue, coupled with the problems of hilal observation activities over the past 5 years, reveals the following: firstly, the Indonesian Ministry of Religious Affairs has recorded 105 hilal observation sites spread across Indonesia from Sabang to Merauke. The breakdown is as follows: 21 sites on Sumatra, 9 on Kalimantan, 7 on Sulawesi, 5 on Maluku, 4 on Papua,

[3] Kementerian Agama RI, *Almanak Hisab Rukyat,* (Jakarta: Direktorat Bimas Islam, 2010). p. 51-52.

[4] "Indonesian Law Number 31 of 2009 Concerning Meteorology, Climatology, and Geophysics, Article 51 & Government Regulation of the Republic of Indonesia Number 46 of 2012 Concerning the Implementation of Observation and Management of Meteorological, Climatol" (n.d.).

[5] Ahmad Fadholi, "Pandangan Ormas Islam Terhadap Draf Kriteria Baru Penentuan Kalender Hijriah Di Indonesia," *Istinbath* 17, no. 1 (2018), p. 205.

[6] Pengurus PBNU, *(Pengantar), Pedoman Hisab Dan Rukyat Nahdlatul Ulama*, ed. Lajnah Falakiyah PBNU, 2006. p. 12-19.

[7] Gazali Masroeri, "'Manajemen Rukyat' in Gazali Masroeri, Pendidikan Dan Pelatihan Nasional Pelaksana Rukyat Nahdlatul Ulama on 17-23 December 2006," p. 2.

[8] Muhtar Salimi, "'Visibilitas Hilal Minimum: Studi Komparatif Antara Kriteria Depag RI Dan Astronomi,'" *Jurnal Penelitian Humaniora* 6, no. 1 (2005), p. 1–13.

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6 on Nusa Tenggara, and 51 on Java and Madura.[9] Not all of these observation sites have reported successful hilal observations. This can be seen from the Ministry of Religious Affairs' compiled data, which shows that over a 10-year period (1431 H/2010 M - 1440 H/2019 M), only 23 locations reported the most successful hilal sightings compared to the other 80 locations. Secondly, of the total number of locations, 51 observation points were in Java and Madura. This can be broken down as follows: East Java and Madura recorded 23 locations (with 7 successful observations at Bukit Condrodipo Gresik, Pantai Gebang Bangkalan, Pantai Tanjung Kodok Lamongan, Bukit Wonocolo Bojonegoro, Masjid Jamik Denanyar Jombang, Pantai Kalbut Situbondo, and LAPAN Watu Kosek Pasuruan), Central Java and Yogyakarta Special Region recorded 15 locations (with 7 successful observations in unspecified sites at Semarang, Tegal, Kebumen, Yogyakarta, Brebes, and Kudus) and West Java, Jakarta, and Banten had 13 observation points (with 2 successful observations at Pelabuhan Ratu Sukabumi and a site in North Jakarta). Thus, only 16 locations in Java and Madura reported successful hilal observations. Among these 16 locations in Java and Madura, Bukit Condrodipo Gresik reported the most successful observations with 16 times, followed by Pelabuhan Ratu Sukabumi with 3 times, Pantai Tanjung Kodok with 3 times, Pantai Gebang Bangkalan with 2 times, and North Jakarta (unnamed location) with 2 times.

The remaining 11 observation locations had 1 successful observation each. Thirdly**,** the Ministry of Religious Affairs also recorded 105 observers who had taken an oath and testified to having successfully seen the hilal. Among them were 60 observers from Java and Madura. Of these observers, 9 individuals successfully observed the hilal at the beginning of Ramadan, Shawwal, and Dhul Hijjah more than once without the aid of observation tools and had been sworn in by the local Religious Court judge. These individuals include K.H. Inwanuddin (16 times at Bukit Condrodipo Gresik, East Java), H. Ahmad Azhar (11 times at Bukit Condrodipo Gresik, East Java), K.H. Yahya (3 times at Pelabuhan Ratu, West Java), Syamsul Ma'arif (3 times at Bukit Condrodipo Gresik, East Java), K. Khotib Asmoni (3 times at Pantai Tanjung Kodok Lamongan, East Java), H. Muhammad Moa (2 times in Kupang, East Nusa Tenggara), H. Abd. Said Sajran (2 times in Kupang, East Nusa Tenggara), M. Irfan (2 times in Kupang, East Nusa Tenggara), and M. Yusuf (2 times in Lampung, East Nusa Tenggara).[10]

From the findings, it can be concluded that: firstly, the East Java locations that have successfully contributed to hilal observations are seven locations with two observers who consistently succeeded in sighting the hilal with the naked eye. Secondly, the three main non-astronomical factors significantly influence the

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[9] "Directorate General of Islamic Guidance, Ministry of Religious Affairs of the Republic of Indonesia," .

[10] Bimas Islam, *Keputusan Menteri Agama RI, 1 Ramadan, Syawal Dan Zulhijjah 1381-1440 H/1962 M – 2019 M.*, 2019, p. 520-525.

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success of observing the hilal at the beginning of the Hijri month. Based on these findings, previous studies have explored the suitability of hilal observation locations in terms of the sunset point, the moon, other obstructions, and access to the location.[11] However, these studies were very partial. Hence, this study provides a comprehensive examination of non-astronomical aspects. In this context, the study presents a novel aspect with the following in-depth research questions: first, how is the hilal observation activity carried out in East Java? second, how do geographical, topographical, and meteorological conditions affect the success of hilal observation locations in East Java? and third, how is the mapping of hilal observation locations in East Java? To answer these questions, the study employed geographical, topographical, and meteorological theories. The data were collected through direct and indirect observation using Google Earth, using area sampling and non-probability sampling methods, and supplemented with documentary data from organizations, institutions, and relevant literature. Thus, this study can provide solutions to the challenges faced in successful hilal observations in East Java, identify the main factors contributing to its success, and map the observation locations that have been used in East Java, Indonesia.

Non-Physical Problems of the Moon in the Hilal Observation at the Beginning of the Hijri Month

The beginning and end of lunar months are inevitable for those who practice and use the Hijri calendar, especially regarding the holy months of Ramadan, Shawwal, and Dhul Hijjah. These three months involve more ritualistic and vertical dimensions of worship, as they pertain to the spiritual fortitude of a servant in their relationship with their Creator, thus feeling more bound by the provisions of ritual *fiqh* (Islamic jurisprudence) textbooks.[12] On the other hand, the beginning of Eid al-Fitr and Eid al-Adha, while related to ritualistic and vertical worship, are more predominantly categorized as social-horizontal worship, as they involve the collective merriment and joy in celebrating the greatest holidays for Muslims.[13] The problems in determining the beginning of

[11] Ismail Khudari, "Analisis Tempat Rukyat Hilal Di Jawa Tengah (Studi Analisis Astronomis dan Geografis.," https://eprints.walisongo.ac.id/id/eprint/7504/

[12] Ali Abubakar et al., "The Postponement of the Implementation of Inheritance Distribution in The Seunuddon Community, North Aceh In The Lens Of 'Urf Theory and Legal Pluralism," *El-Usrah: Jurnal Hukum Keluarga* 6, no. 2 (December 30, 2023), p. 416. Fauzi Fauzi, "'Urf and Its Role in The Development of Fiqh: Comparative Study of Famliy Law Between Egypt and Indonesia," *El-Usrah: Jurnal Hukum Keluarga* 7, no. 1 (June 30, 2024), p. 346.

[13] Nasaruddin Umar, "Memahami Hal Itsbat Dalam Perspektif Fiqh Siyasah, Paper Presented at Diklat Nasional Pelaksana Rukyat Nahdlatul Ulama on 17-23 December 2006 in Masjid Agung Semarang Jawa Tengah," See also Susiknan Azhari, *Hisab & Rukyat: Wacana Untuk Membangun Kebersamaan Di Tengah Perbedaan* (Yogyakarta: Pustaka Pelajar, 2007), p. 53-65.

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the month of Ramadan are common issues related to determining the beginning of the Hijri month, especially those related to the implementation of worship. These problems have become crucial to be resolved, particularly non-physical problems related to the moon, such as: the observer (the person performing the *rukyat*/observation), the media and tools used for observation, and the observation location.

1) The Observer

The practice of sighting the hilal (*rukyatul hilal*) requires techniques that align with the scientific process of observation. Technically, there are two methods of conducting hilal observations: using the naked eye and using aids, e.g., telescopes and other modern equipment.[14] Naked-eye observations are directly related to the observer, while the use of observational aids involves not only the observer but also the instruments used. Testimonies of sighting the hilal are often accepted as valid if they meet the visibility criteria set by MABIMS (the Ministers of Religious Affairs of Malaysia, Brunei Darussalam, Indonesia, and Singapore) and the Indonesian Ministry of Religious Affairs. If the sighting is below the criteria, then the observation is rejected as a valid testimony[15] even though each person is endowed with different levels of visual acuity. Therefore, to ensure that an observer has truly seen the hilal, their testimony must meet specific criteria for acceptance in hilal observations. There are four aspects to consider: age, knowledge about the hilal, techniques for observing the hilal, and visual acuity.[16] The hilal is very faint and difficult to identify as it may only appear as a thin line. Therefore, these four aspects become essential to possess.

Of these two techniques, the majority of observers in East Java use the first method, which is naked-eye observation, as it is easier and more efficient. However, the success of this method is highly subjective. Therefore, as a verification step, it needs to be complemented by the second technique to produce verifiable and objective results.

The criteria for the observer's acceptance in hilal observations:

a) Age

According to Tarwaka a person's physical abilities increase over several years from the beginning until they peak at the age of 25-30 years. The age group of 25-30 years is the age group with the best physical abilities in the human life cycle. Therefore, there is a relationship between age and the ability of bodily functions. A person's physical abilities will increase over several years from the beginning until they peak at the age of 25-30 years. This age range is the age

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[14] Riza Afrian Mustakim, "'Teknologi Rukyatul Hilal Dalam Tinjauan Maslahah Mursalah,'" *Jurnal Al-'Ibrah,* 14, no. 1 (2018), p. 18.

[15] Muhammad Faisal Amin, *"Ketajaman Mata Kriteria Visibilitas Hilal,"* 2020, p. 28-40.

[16] Riza Afrian Mustaqim, "Pandangan Ulama Terhadap Image Processing Pada Astrofotografi Di BMKG Untuk Rukyatul Hilal," *Al-Marshad: Jurnal Astronomi Islam Dan Ilmu-Ilmu Berkaitan* 4, no. 1 (June 30, 2018), p. 78–115.

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group with the best physical abilities in the human life cycle. Physical abilities will gradually decline with increasing age after physical abilities peak, and this decline is due to physiological changes that occur in every human being who has reached adulthood.[17] One of the physical organs that experiences a decline is visual acuity. A decline in organ function also occurs in the visual organs. At the age of 35 and above, a person will begin to experience a decrease in visual acuity.[18] Visual acuity is defined as the eye's ability to see an object clearly and depends heavily on the eye's ability to accommodate. Visual acuity is influenced by changes in target angular velocity, vibration, luminance, contrast, tracking head and eye movements, reaction time, learning factors, and fatigue.[19]

Therefore, one factor that affects visual acuity is age. As age increases, firstly, the lens becomes larger, flatter, yellowish, and harder. This condition causes the lens to lose its flexibility and reduce its ability to curve. Secondly, the near point moves away from the eye, while the far point generally remains the same.[20] This theory suggests that the productive age for observing the crescent moon is below 35 years, whereas the age of observers who have successfully observed the crescent moon in East Java is above 35 years. This reality indicates a greater degree of subjectivity among observers in producing the appearance of the crescent moon in East Java.

b) Knowledge on the Hilal

Every year, Muslims in Indonesia often encounter differences in determining the beginning of the Hijri month, although this difference is most keenly felt due to the possibility of multiple holidays. Experts, including Islamic jurists, astronomers, and government officials, have been trying to find a common ground for its determination.[21] Astronomically, determining the exact position of the moon is indeed possible. Therefore, some Muslims believe that calculations alone are sufficient to accurately determine the beginning of the month. However, it must be understood that this factor is not scientifically accurate enough because the position of the moon is only one of several variables in the visibility of the hilal. Although the position of the moon above the horizon is a prerequisite, other variables such as the moon-sun elongation angle and the age of the moon after

[17] Dedy Setiawan, "Hubungan Antara Umur Dan Intensitas Cahaya Las Dengan Kelelahan Mata Pada Juru Las Pt. X Di Kabupaten Gresik," *The Indonesian Journal Of Occupational Safety And Health* 5, No. 2 (2017), p.142-152.

[18] Ian Grierson, *The Eye Book: Eyes And Eye Problems Explained,* (Liverpool: Liverpool University Press, 2000), p .175-176.

[19] Nur Ulfah, Sitijurusan Harwanti, And Ngadiman, "Pengaruh Usia Dan Status Gizi Terhadap Ketajaman Penglihatan," *Jurnal Kesmasindo* 6, No. 1 (2013).

[20] Ulfah, Harwanti, And Ngadiman.

[21] Nur Quma Laila And Irwan Abdullah, "Questioning Fiqh Muamalah Of Toleration: Religious Spatial Segregation In The Urban Area Of Yogyakarta," *Al-Ihkam: Jurnal Hukum Dan Pranata Sosial* 17, No. 1 (2022), p. 28-59.

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conjunction must still be calculated.[22] Therefore, an observer must understand the meaning of the hilal to minimize the finding of the appearance of the hilal.

The hilal is not the moon. The hilal, which looks like a crescent on the western horizon at sunset at the beginning of each Hijri month, is the appearance of the moon. Thus, the hilal is not "the moon". The hilal is a phenomenon of light, or rather, the reflection of sunlight by the moon to the earth. The existence of the hilal depends on the presence or absence of light, because the hilal is an object attached to the moon. Misunderstanding occurs because the word "moon" is a translation of the word "*qamar*", so there is almost no longer any difference between whether the term "*ru'yah al-hilal*" means seeing the hilal or seeing the moon. However, on the other hand, the sharia evidence related to this matter indicates a difference between the two. The Qur'an, for example, in Surah Al-Baqarah verse 189, mentions the *hilal* - even if only once - using the plural form, namely *al-ahillah*, but mentions *qamar* - 26 times - using the singular (*mufrad*) form. This pattern of mention can be understood as an indication that the hilal is related to many phenomena, while *qamar* is not. The hadiths also indicate this difference by mentioning *ru'yah al-hilal* many times, but never once mentioning *ru'yah al-qamar*. This indication of difference is then reinforced in the formulation of the concept of the hilal proposed by the majority of Islamic jurists, who place the visibility variable as the main element in the ontology of the hilal.[23] In fact, from the earth, the hilal appears to change. When it first appears, it is shaped like a young crescent, then it becomes full, and then it changes back into an old crescent.

Therefore, an observer must understand that the hilal is the first visible crescent phase of the moon observed on the western horizon after sunset, appearing as a thin line of light. When using a telescope with image processing, it may appear as a thin line of light at the edge of the moon's disk facing the sun.[24] The fact is that the visibility of a young crescent moon is a physical reality of extraterrestrial and atmospheric hilal that is very difficult to observe when the intensity of twilight (*syafaq*) is brighter than the light of the hilal. Thus, the light of the hilal is outshone by the light of twilight. Hence, for an observer, understanding the hilal is a necessity. Illustrated in the following is a photo of the hilal:

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[22] Jayusman, "Kajian Ilmu Falak Perbedaan Penentuan Awal Bulan Kamariah: Antara Khilafiah Dan Sains," *Jurnaliainpontianak*, 2015.

[23] Abdus Salam Nawawi, "Tradisi Fiqh NU: Analisis Terhadap Konstruksi Elit NU Jawa Timur Tentang Penyatuan Awal Bulan Islam, Dissertation" (Postgraduate of IAIN Surabaya, 2008).

[24] T. Djamaluddin, *Menggagas Fiqh Astrononi Telaah Hisab-Rukyat Dan Pencarian Solusi Perbedaan Hari Raya* (Bandung Kaki Langit, 2005). p. 108.

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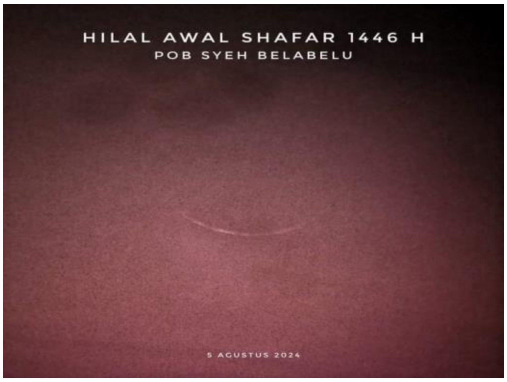

Picture of Hilal in the Beginning of Safar 1446 H, 5 August 2024.[25]

c) Hilal Observation Techniques

Experience in hilal observation is necessary for an observer. Moon observation must be carried out through several procedures, namely planning, preparation, and implementation. These processes will provide greater confidence for an observer to testify to the appearance of the hilal. In the planning stage, observers must consider the location, time, calculated data, equipment, and costs. In the preparation stage, observers must have already selected and determined the location, determined the time and its accurate indicator, have calculated data, and brought equipment and other facilities. In the implementation stage, an observer or team of observers must already be at the location several hours before the observation. The moon (hilal) which is the object of observation is located around the sun in a certain place, and that place is expressed in altitude and azimuth. The altitude of celestial bodies, such as the moon and the sun, is measured perpendicularly from the horizon to the center of the celestial body. The altitude is measured in degrees; therefore, a protractor is needed to indicate the direction to the intended target. Altitude measurement can be done in a simple way or with a more precise instrument. A simple way, for example, is by using an object placed in front of the observer, perpendicular to the direction of his gaze.[26]

Hilal observation requires knowledge of techniques and strategies, as well as field experience, in order for its implementation to be very productive. Without knowledge and experience, hilal observation will always face obstacles and failure. Observing the hilal must begin by looking towards the setting sun on the western horizon. Many variables must be considered, one of which is that the setting sun is influenced by the thickness of the atmosphere along the horizon, so that the sun and the sky around it appears red. The sun sets exactly when the top of its arc passes over the horizon. After that, the influence of sunlight does not

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[25] "The Image Was Successfully Captured by the Observatory Team of POB Syekh Belabelu on August 5, 2024, at 5:59 PM WIB.,"

[26] Departemen Agama RI, *Pedoman Tehnik Rukyat* (Jakarta: DEPAG RI, 1995). p. 11-27.

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immediately disappear and the brightness of the sky, which is called twilight, is still visible. As long as there is twilight, the horizon can still be seen, but the light gradually fades.[27]

Under good weather conditions, twilight completely fades when the center of the sun has reached about 18 degrees below the horizon, and from that moment on, the horizon can no longer be seen. Other celestial bodies such as stars and planets that are near the horizon usually begin to appear after the sun reaches 12 degrees below the horizon. At that time, the horizon may still be visible. Thus, for about an hour after sunset, the sky is still influenced by twilight. The light of the very thin crescent moon, especially when the moon is less than 16 hours old, is very difficult to distinguish from the brightness of the twilight sky. In addition, the surface of the moon itself is uneven, consisting of mountains and craters, so that the part that reflects light to the earth is even less. If the sky is clear, sometimes the crescent of the moon appears to be segmented because it is interrupted by places that do not reflect light towards the earth. The length of the arc depends on the angular distance between the sun and the moon. The closer it is to the sun, the shorter the arc, and with the influence of the uneven surface, it can be even shorter.[28]

In an effort to observe the hilal, the observation team should be prepared at the observation site before sunset while paying attention to the sky around the sun. By continuously following the changes in the sky's light, it gives the eyes a chance to adjust to the conditions of the object to be seen. The point of change, caused by the Earth's atmosphere, for example, the condition of dark or light clouds, determines the brightness of the sky from time to time and makes observers more familiar with the conditions around the sun and moon.

d) Visual Acuity

In hilal observation, there are two methods that can be used: the naked eye and observation aids. Thus, how can the eye capture the form of the hilal, or how is the form of the hilal captured by the eye? In accordance with its function, the eye and its sharpness of vision are important and urgent to understand. The eye is one of the most vital organs of the human body in terms of function and use. The eye generally functions as the organ of sight that detects light and is used to provide visual understanding. The human eye has a perfect automatic working mechanism; the eye is formed with 40 different main elements and all these parts have important functions in the process of seeing. In fact, what the eye does is capture the reflection of light on an object. Light is reflected by the object into the eye, passing through the cornea and continuing through the pupil. Then the light is continued to the lens of the eye. The lens of the eye adjusts its curvature so that the light can fall exactly on the retina. The image that falls on the retina is inverted

[27]Departemen Agama RI. p. 36.
[28]Departemen Agama RI. p. 37.

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and reduced. At the retina, light is received by the visual cells in the yellow spot and transmitted by the nerve to the brain. The brain will process and interpret the light stimulation and produce a visual impression so that we know the type of object seen.[29]

On the surface of the back of the eye, the retina contains receptors that are sensitive to light. These motor receptors are the first stage of visual perception. Motor receptors can be effectively considered as "transducers" that convert light energy into electrical impulses (neurological signals). Photoreceptors are functionally classified into rods and cones. Rods are sensitive to dim light and night vision (achromatic), while cones respond to brighter chromatic light or daylight vision. The retina contains about 120 million rods and 7 million cones.[30]

In terms of its structure, the eye has both external and internal structures. The external structures of the eye are: (1) eyebrows, which function to protect the eyes from sweat, (2) eyelids, which function to protect the eyes from dirt and dust, (3) tear glands, which function to keep the eyes from drying out by producing tears, and (4) eyelashes, which function to protect the eyes from light and dust. The internal structures of the eye are: (1) cornea, which functions to receive light from a light source and helps focus the image of an object on the retina, (2) pupil, which functions to determine the quantity of light that enters the deeper part of the eye, (3) lens, which functions to adjust the focus of light so that the light falls exactly on the yellow spot of the retina. When looking at a distant object/light, the lens of the eye will thin. While when looking at a nearby object, the lens of the eye will thicken, (4) retina, the function of the yellow spot on the retina is to receive light and transmit it to the brain.[31] All aspects of its structure influence the sharpness of human vision.

Visual acuity, or resolving power, is the "ability to distinguish fine detail" and is a property of the cone cells. Visual acuity is often measured in cycles per degree, measuring angular resolution, or how far the eye can distinguish one object from another in terms of visual angle. Resolution in cycles per degree can be measured using a bar chart with varying numbers of white/black line cycles. For example, if each pattern is 1.75 cm wide and placed 1 m from the eye, it will form an angle of 1 degree, so the number of white/black line pairs in the pattern will be the measure of cycles per degree of that pattern. The highest number that the eye can see as separate lines, or that distinguishes it from a gray block, is a measure of visual acuity.[32]

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[29]M. F. Fernald, *"The Evolution of Eyes". Annual Review of Neuroscience"*, 1992, 1–29.

[30] Andrew T. Duchowski, *Eye Tracking Methodology: Theory and Practice*, ed. Springer, 3rd ed (London, 2017).

[31] Grierson, *The Eye Book: Eyes and Eye Problems Explained*,. p. 6-8. Leo M. Chalupa and Robert W. Williams (editors), *Eye, Retina, and Visual System of The Mouse*, (Hongkong: Massachusetts Institute of Technology, 2008). p. 685.

[32] *Eye, Retina, and Visual System of The Mouse*,. p. 685.

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For the human eye with very good acuity, the maximum theoretical resolution is 50 cycles per degree[33] (1.2 minutes of arc per line pair, or 0.35 mm of line pairs at a distance of 1 m). A rat can only separate about 1 to 2 cycles per degree. A horse has higher acuity through most of its visual field than humans, but not as high as the acuity of the fovea at the center of the human eye. Spherical aberration limits the resolution of a 7 mm diameter pupil to about 3 minutes of arc per line pair. At a 3 mm diameter pupil, spherical aberration is greatly reduced, increasing resolution to about 1.7 minutes of arc per line pair. A resolution of 2 minutes of arc per line pair, equivalent to a 1-minute arc gap on an optotype, corresponds to 20/20 (normal vision) in humans.[34]

The elaboration above indicates that the eye is a very essential medium in observing the hilal. The sharpness of the eye is important to be trained to match the capabilities of other media created by humans. Thus, in the context of eye sharpness in particular, an observer is categorized as having sharp eyesight if, firstly, they have high accommodation ability (adjustment to the object being viewed), secondly, visual acuity (the ability to accurately distinguish an object from its background), thirdly, sensitivity to contrast (contrast sensitivity), and fourthly, having the ability to adapt or adjust to the lighting conditions of the information source.[35] For East Java observers, the process of sharpening and sensitizing the eyes to recognize the hilal object is done through monthly observation exercises at one location. Observers mark the place where the sun and moon set, as well as the position of the eyes at the observation location. This technique is very effective for localizing the position of the hilal at the beginning of each month so that this strategy becomes an effective way to hone the sharpness of the eyes and can more easily recognize the hilal when observing the hilal is carried out.

2) *Rukyat* Media and Equipment

Efforts to improve and facilitate the success of *rukyatul hilal* require the use of *rukyat* aids or media in accordance with current developments and technological advances. Historically, this observation has been part of the observation of other celestial bodies that have been carried out since prehistoric times. In practice, in several hilal observation sites, it is often the case that trained observers can see a hilal, which is less than 18 hours old, using the naked eye. The use of the naked eye will only be successful if the air is very clear. The possibility of this success is even smaller if the age of the moon is smaller or the distance between the sun and the moon is smaller. The limitation of the naked eye is that it cannot see the complete shape of the moon in detail and if there is no

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[33] Russ John C, *The Image Processing Handbook* (CRC Press, 2006). p. 94.
[34] H. B. Barlow, *"The Size of Ommatidia in Apposition Eyes,"* 1952. p. 667–674
[35] Muhammad Faisal Amin, *"Ketajaman Mata Kriteria Visibilitas Hilal."* p. 30-31.

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reference to the actual location of the moon, it can be mistaken for another object.[36]

Natural conditions that make visual observation difficult are the bright sky around the moon, while the moon itself is not a good reflector of light. This makes the contrast between the moon's environment and the sky very small. The proximity of the moon to the sun means that the moon has a small altitude above the horizon at sunset. Therefore, the time for observation is relatively short before the moon sinks below the horizon. In addition, the view in the direction of the Earth's horizon is influenced by dirty air, clouds or fog, and the light of lamps on the Earth's surface. Certainly, observers must try to find a place that has a view free of obstacles such as trees, buildings, or other celestial objects that stand on the Earth. The natural conditions mentioned cannot be avoided and therefore must be able to be penetrated by visual means that make observation more likely to succeed. Hence, the effort to obtain details of the observation object is through the use of a telescope.[37]

The telescope used can be a stargazing telescope or a long-range telescope such as binoculars, theodolite, and other telescopes that can bring the viewing angle closer.[38] The requirements for *rukyat* aids that need to be met are, firstly, the ability to see distant and small objects. This function can be useful by using a telescope with optical components such as lenses, mirrors, and prisms. Secondly, the ability to see objects with weak light. To see weak light, light amplification technology or light intensification is used with a component called an image intensifier. This component can intensify light up to 50,000 times. Thirdly, it can block twilight. This twilight can be overcome using a filter called a subtraction filter so that all colors with twilight can be blocked. Fourth, it can strengthen the image of the hilal. To perform this function, the telescope must be equipped with a lens with a focal length of 500 m or 200 mm with apertures of f/8.0 and f/1.7 respectively. With both objectives and an 18 mm image intensifier tube, the hilal will be seen as a quarter and one-tenth of the view, respectively.[39]

Based on the object being observed, telescopes are divided into three types. The first is refractor or dioptric telescopes, having a system that works using two objective lenses; the main lens will collect the image and light which will then be forwarded to the eyepiece and received by the eye when viewing an object and to the image object. The second is reflector or catoptric telescopes, having a working system that uses a concave mirror, which will reflect light and image images. The third is catadioptric telescopes, having a working system that is not much different from the two telescopes, which absorbs light and images of objects that will be

[36] Dirjen Bimas Islam Kemenag RI, *Pedoman Teknik Rukyat*, p. 17-18

[37] Kementerian Agama RI, *Almanak Hisab Rukyat,* p. 205.

[38] Dito Alif Pratama, "Ru'yat Al-Hilāl Dengan Teknologi: Telaah Pelaksanaan Ru'yat Al-Hilāl Di Baitul Hilal Teluk Kemang Malaysia," *Al-Ahkam* 26, no. 2 (December 2, 2016), p. 274.

[39] Mustakim, "'Teknologi Rukyatul Hilal Dalam Tinjauan Maslahah Mursalah, p. 28."

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received in the eye.[40] All types of telescopes have the same performance and function, which is to observe objects that are very large and far away, such as small objects and celestial bodies. However, the function of the newly discovered telescope is the Hubble telescope, which is installed in space to send images using electromagnetic waves. These waves will be captured by the earth with clear results.[41]

Thus, telescopes help observers to observe objects in outer space. Telescopes can see celestial objects such as the hilal which is very dim and very far away through optics, either mirrors or lenses, which are very large. Therefore, the larger the lens, the lighter the telescope collects. The light that comes and hits the objective lens will form an image of the hilal on the focal plane, the plane where the objective lens forms an image. This image of the hilal will be the basis for objective verification of the hilal produced from the sharpness of the naked eye of the observers.

3) Locations of Hilal Observations in East Java

The locations of hilal observations are known by several names, such as the moon observation post, *rukyat* hall, laboratory, observatory, planetarium or musollatorium, the location of *rukyatul hilal*, and *baitul hilal* of celestial bodies.[42] In East Java, there are three main terms, namely Balai Rukyat e.g., Condrodipo Gresik, Observatory e.g., Jokotole Observatory Pamekasan, and Rukyatul Hilal Location e.g., Tanjung Kodok Lamongan.

In terms of the location, if the observer selects the wrong *rukyat* location, it will affect the success of seeing the hilal. This suggests that *rukyat* in a place that is obstructed by mountains or buildings will certainly not be able to see the hilal at all, even though according to astronomical calculations (visibility theory) the hilal is very likely to be seen. Failure to see the hilal can be caused by an observer not being able to see the horizon directly. Therefore, the implementation of *rukyatul hilal* in East Java need to consider the physical, geographical, topographical, and meteorological elements.

Physical geographical factors have a significant influence on the success of implementing *rukyatul hilal*, especially those related to the place as the main reference for the success of *rukyatul hilal* in East Java. In this context, several concepts in geography need to be studied, including the concepts of location, distance, accessibility, and geomorphology. In the concept of location, two concepts are known, absolute location and relative location. Absolute location is

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[40] James L. Chen, *A Guide to Hubble Space Telescope Objects* (London: Springer, 2015), p. 15-18.

[41] David J. Shayler and David M. Harland, *The Hubble Space Telescope: From Concept to Success* (New York: Springer, 2016), p.153-156.

[42] Nihayatur Rahmah, "Observasi Dan Observatorium (Peluang Dan Tantangan Rukyatul Hilal Di Indonesia)," *Jurnal Al-Mabsut: Jurnal Studi Islam Dan Ilmu Sosial* 12, no. 2 (2018), p. 153–65.

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the location according to latitude and longitude, which is fixed. The latitude of a place is the distance of the place calculated from the equator as a point of 0 towards the north and south, while longitude is the line connecting the north and south poles of the earth and intersecting perpendicular to the equator whose 0 point is in Greenwich, such as the location of Indonesia is between 6 degrees north latitude to 11 degrees south latitude, and between 95 degrees east longitude to 140 degrees east longitude and the location of East Java is between 7 degrees to 8 degrees south latitude and between 111 degrees to 114 degrees east longitude.[43] The relative location is the location that depends on the influence of the surrounding area, and its nature changes, such as the position of Indonesia located between the continents of Asia and Australia.[44]

The concept of distance, geographically, can be measured in two ways: geometric distance expressed in units of kilometers, and time distance measured in units of time (travel time). The concept of accessibility is a concept based on how easy or difficult a location is to reach, which is influenced by location, distance, and site conditions. The concept of geomorphology elaborates on the forms of the earth's surface. The concept of geomorphology is needed to know the forms of the earth's surface, such as mountains, hills, valleys, and plains.[45]

From the concepts of location, distance, accessibility, and geomorphology, observers of *rukyatul hilal* in East Java must pay attention to the position and condition of their observation location. Basically, a good early-month observation site is a place that has an unobstructed field of view around the place where the sun sets, so that the horizon will appear straight in an area that has an azimuth[46] between 241.5° and 298.5°.[47] This area is needed, especially if the moon observation is carried out throughout the season, considering the shift of the sun and moon from time to time.[48] From this concept, not all *rukyatul hilal* locations in East Java meet this field of view. This concept is used to predict the farthest position of the moon or sun's movement as the object of observation when the observation is carried out. If the observer's position is at the equator with a geographic position value of 0° (zero degrees), then when the observer faces the west direction, that place must leave a field of view of the horizon of about 28.5° (twenty-eight and a half degrees) to the right point (north) and 28.5° to the left

[43]Ahmad Musonnif, *Ilmu Falak* (Yogyakarta: Teras, 2011), p. 33-34. Salamun Ibrahim, *Ilmu Falak* (Surabaya: Pustaka Progressif, 2000), p. 33.

[44]P. Kenneth, *Explanatory Supplement to The Astronomical Almanac*, (California: University Science Books, 2006), p. 202-203.

[45]I Wayan Treman, *Geomorfologi* (Yogyakarta: Graha Ilmu, 2014), p. 2-3.

[46].Heafner Paul J, *Fundamental Ephemiris Computations*, ed. Willmann-Bell (Virginia, 1999), p. 49.

[47] Muhyiddin Khazin, *Ilmu Falak Dalam Teori Dan Praktek* (Yogyakarta: Buana Pustaka, 2005), p. 51.

[48] Kementerian Agama RI, *Almanak Hisab Rukyat*, p. 51-52.

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point (south).[49] Twenty-eight degrees is the result of the calculation of the sun's declination to the north and south of 23°26' 21.48" plus 5° of the moon's declination, with detailed values being the farthest declination of the sun of 23°26' 21.48" [50] plus the farthest declination of the moon of 5°8' with a result of 28°34'21.49" each for the north and south directions.[51]

In addition, topographically, the observation site should meet the requirements of being free of obstacles and located in a location that faces the horizon,[52] and far from the city to avoid pollution. This pollution can be in the form of smoke that can change the thickness of the protons in the air or light pollution that can change air pressure and light deviation. This pollution will also change the value of refraction of a place, especially for air pollution. This is because the bending or refraction of light from an object towards the observer's eye will be increasingly dense, so that polluted places not only hinder the quality of observation in its implementation, but can also change the predicted calculation of *hisab* (calculation) with the use of refraction (if no research is conducted on the magnitude of refraction of a place).[53] This condition will make the position of the *rukyat* location in mountainous areas better than the *rukyat* location in urban areas. This is because the quality of the place and air with air and light pollution is greater in urban areas than in mountainous areas. In addition to places that need to be avoided, they are also beaches around which factories are built that can cause pollution. In the context of this theory, several *rukyatul hilal* locations in East Java do not fully meet this theory.

Meteorologically, the Earth has an atmosphere that is very friendly to living things, partly because of its distance that is not too close and not too far from the sun. The Earth's atmosphere is 78% nitrogen, 21% oxygen, and 1% is a mixture of other gases.[54] Although the atmosphere is beneficial to the Earth because it can protect against solar radiation, it is one of the hindering factors that affect the possibility that the position of the hilal cannot be observed, including due to the

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[49] Khazin, *Ilmu Falak Dalam Teori Dan Praktek*, p. 51

[50] Anton Ramdan, *Islam Dan Astronomi*, (Jakarta: Bee Media Indonesia, 2009), p. 106. Agus Mustofa, *Jangan Asal Ikut-Ikutan Hisab & Rukyat*, (Surabaya: PADMA Press, 2013), p. 100

[51] Agus Fanny Chandra Wijaya, , *"Gerak Bumi Dan Bulan"* (Jayapura: Digital Learning Studi, 2010), http://file.upi.edu.

[52] BJ. Habibi, *Pengantar Rukyah Dengan Teknologi: Upaya Mencari Kesamaan Pandangan Tentang Penentuan Awal Ramadhan Dan Syawal*, (Jakarta: Gema Insani, 1994), p. 75

[53] Thomas Djamaluddin, *Astronomi Memberi Solusi Penyatuan Umat* (Jakarta: Lapan, 2011), p. 13

[54] Bayong Tjasyono, *Ilmu Kebumian Dan Antariksa* (Bandung: UPI dan Rosdakarya, 2006); 122-123; Tono Saksono, *Mengkompromikan Rukyat Dan Hisab* (Jakarta: Amythas Publicita in collaboration with CIS, 2007), p. 25-26.

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presence of atmospheric refraction, particles, and humidity in the air.[55] There are many particles in the air that can obstruct the view, such as fog, rain, dust, and smoke. And even in big cities, industrial centers, and dry areas, the number reaches 5 million per cm^3.[56]

The atmospheric disturbance that predominantly influences *rukyatul hilal* is the troposphere, the lowest layer of the atmosphere with an average layer thickness of 10 km at a height of 0-18 km at the equator and 0-6 km at the poles.[57] The thickness of the troposphere implies that the farther a place is from the equator, the better the position for seeing the hilal. Conversely, the closer a position is to the equator, the more difficult it is to observe the hilal.[58] Thus, there are several possibilities for predicting the success of *rukyatul hilal* in East Java, namely if the weather on the horizon is clear of clouds, and the blue sky can be seen clearly to the horizon, then there is a high possibility that the hilal can be seen; yet, if there are thin clouds on the horizon that are not even, and above it looks whitish or reddish, then there is a small possibility that the hilal can be seen.

b. Mapping the Locations of *Rukyatul Hilal* in East Java

The location of the crescent moon observation has a significant impact on whether or not the hilal can be seen. Based on the criteria of BMKG and NU, the locations of *rukyatul hilal* in East Java, both from astronomical, geographical, and topographical aspects, these observation locations are mapped and categorized into three types, namely locations with the category of Observatory, High Places, and Coasts (North and South). However, in general, these three criteria are combined into two categories, namely High Places and Coastal Locations. These locations have great potential to be used for the implementation of hilal observations because of the wide field of view of the location and the viewing distance from the observer's point to the horizon point where the hilal and sun set and rise.

First, locations categorized as observatories, there are two observatories found. These locations are under the responsibility and management of an institution, namely the Watoe Dhakon Observatory of IAIN Ponorogo located in the middle of the city at 7°51'47"S and 111°29'33"E and the Jokotole Observatory of IAIN Madura located on the outskirts of the city at 7°11'58"S and 113°28'22"E. **Second,** other hilal observation locations are categorized as locations located in high places, but not included in the observatory category. These locations are under the responsibility of an organization and one LAPAN East Java institution,

[55] Thomas Djamaluddin, *Astronomi Memberi Solusi Penyatuan Umat*. https://tdjamaluddin.wordpress.com/category/3-sains-kebumian/.

[56] Tjasyono, *Ilmu Kebumian Dan Antariksa*, p. 124.

[57] Cesare Barbieri, *Fundamental of Astronomy* (New York: CRC Press, 2007, 2007), Tjasyono, *Ilmu Kebumian Dan Antariksa*.

[58] Muh. Nashiruddin, *Kalender Hijriyah Universal,* (Semarang: El Wafa, 2013), p. 132.

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as follows: Balai Rukyat Bukit Condrodipo Gresik located in a hilly area, on the outskirts of Gresik Regency at 7°10'11.10"S and 113°37'03.50"E. The slopes of Mount Pandan Sradan Madiun are located in the mountainous area of Madiun Regency at 7°29'23.6"S and 111°42'53.3"E. Bukit Wonocolo Bojonegoro is located in the hilly area of Bojonegoro Regency at 7°3'14.6"S and 111°40'21.7"E. Jamik Denanyar Mosque is located in the middle of Jombang Regency at 7°22'58.8"S and 112°13'04.8"E. Bukit Sadeng is located in the hilly area of Jember Regency at 8°20'28"S and 113°28'22"E. Lapan Watu Kosek Pasuruan is located in the hilly area of Pasuruan Regency at 7°34'1.99"S and 112°40'33.38"E. Gumuk Klasi Indah Banyuwangi is located in the hilly area of Banyuwangi Regency at 8°17'38"S and 114°12'5.16"E. **Third,** other hilal observation locations are categorized as locations located on the coasts, both the north coast and the south coast. These locations are mostly under the responsibility of an organization. They are Gebang Beach, located on the North Coast of Bangkalan Regency at 6°59'19"S and 112°47'03"E, Tanjung Kodok Beach located on the north coast of Lamongan Regency at 6°51'50.22"S and 112°21'27.80"E, Kalbut Beach located on the north coast of Situbondo Regency at 7°37'30.88"S and 114°0'35.75"E, Taneros Ambunten Beach located on the north coast of Sumenep Regency at 6°52'59"S and 113°46'19"E, and Taddan Harbor located in the southern part of Sampang Regency at 7°13'46"S and 113°17'54.1"E.

From the mapping of these locations, three hilal observation locations dominate the productivity of the appearance of the hilal, namely Balai Rukyat Condrodipo Gresik with 16 reports, Tanjung Kodok Lamongan with 3 reports, and Gebang Beach Bangkalan with 2 reports. The dominance of the success of these hilal observations is influenced by the ideal conditions of non-astronomical aspects, i.e., the geographical-topographical factors. The locations are in a relatively high position with an ideal field of view from an azimuth of 241.35-289.65 degrees, free from disturbances from the ground surface, trees and buildings, and meet a viewing distance of 10-25 km with highly experienced *rukyat* observers.

Conclusion

The determination of the beginning of the Hijri month is highly dependent on the activity of observing the hilal. Studies of the success of observations often focus, astronomically, on the physical aspects of the moon, while non-physical aspects of the moon (non-astronomical) are often overlooked, even though these aspects have a significant influence. The majority of observers at several hilal observation locations in East Java carry out observation activities every beginning of important months, e.g., the months of Ramadan, Syawal, and Dzulhijjah with the naked eye and optical instruments with a low success rate. This is because, geographically, the majority of these locations are close to the equator, and the main obstacle of which, meteorologically, is the disturbance of fog pollution, dust,

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clouds, and rain, as well as other atmospheric particles, and topographically, the horizon view of the hilal observation locations in East Java is not free and not all of them are spread over a field of view from an azimuth of 241.5 degrees to 298.5 degrees. From the conditions of these locations, 23 active hilal observation locations in East Java are mapped as follows: 1) locations categorized as observatories, with two locations found that do not fully contribute to the observation of the hilal, 2) locations located on the north and south coasts, with five locations that do not fully contribute to the observation of the hilal, and 3) locations located in high places, although they do not fully meet the BMKG and NU criteria, with seven of these locations contribute to the observation of the hilal with the naked eye and three of them dominate. This success is stated by the *falaq* experts as subjective success. Therefore, this study considers it significant to make a verificative-objective technique with optical technology and CCD Imaging as a perfection of the birth of a verificative-objective hilal in this era.

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