Volume 3 No. 2 December 2024
P-ISSN: 2986-1675 E-ISSN: 2963-0290
Page: 135-155
DOI: https://doi.org/10.47766/astroislamica.v3i2.3369

ASTROISLAMICA
Journal of Islamic Astronomy

Correlation Between *Hilal* Age and Altitude at the Beginning of the Lunar Month (A Critique of the Calculation System in *Fath ar-Rauf al-Mannan*)

[1]Rahma, [2]M. Ihtirozun Ni'am
[1]rahmaajoa83@gmail.com [2]ihtirozun_n@walisongo.ac.id
[1,2] Universitas Islam Negeri Walisongo Semarang, Indonesia

ARTICLE INFO

Article history:

Submitted Aug 10, 2024
Accepted Oct 26, 2024
Published Dec 10, 2024

Keywords:

Hilal age
Hilal altitude
Fath ar-Rauf al-Mannan
Lunar month

ABSTRACT

The hilal altitude formulation in the book Fath ar-Rauf al-Mannan is 0.5 of its age value. However, in the practice of modern theory, the calculation of hilal altitude is not that simple but uses a complex formulation of spherical trigonometry. Therefore, it is necessary to conduct research related to the correlation of hilal age and altitude at the beginning of the lunar month to determine the relationship between the two variables as a criticism of the Fath ar-Rauf al-Mannan hilal altitude formulation. The approach used is quantitative with the type of library research. This research uses data on the new moon at the beginning of the lunar month in 1444 H for twelve months (coordinates 6°59'30" N and 110°20'53" E). The hilal age (x variable) and altitude (y variable) were analyzed using simple regression resulting in a correlation equation y = 0.444103449 x – 0.34109308. The result shows that the hilal altitude formulation in the book Fath ar-Rauf al-Mannan is not representative enough, so it has the potential to cause errors in predicting the hilal position.

ABSTRAK

Formulasi tinggi hilal dalam kitab Fath ar-Rauf al-Mannan ialah 0,5 dari nilai umur hilal. Namun dalam praktik teori modern perhitungan tinggi hilal tidak sesederhana itu, melainkan menggunakan *formulasi kompleks segitiga bola. Karena itu, perlu dilakukan penelitian korelasi umur dan tinggi hilal untuk mengetahui hubungan kedua variabel tersebut sebagai kritik formulasi ketinggian hilal Fath ar-Rauf al-Mannan. Pendekatan yang digunakan ialah kuantitatif dengan jenis penelitian pustaka. Penelitian ini menggunakan data hilal awal bulan kamariah tahun 1444 H selama dua belas bulan (koordinat 6°59'30" LS dan 110°20'53" BT). Umur hilal (variabel x) dan tinggi hilal (variabel y) dianalisis menggunakan regresi sederhana sehingga menghasilkan persamaan korelasi y = 0,444103449 x -0,34109308. Berdasarkan hal tersebut, diketahui bahwa formulasi tinggi hilal dalam kitab Fath ar-Rauf al-Mannan tergolong belum cukup representatif (karena kenyataannya ada kasus tinggi hilal Jumadil Akhir 1444 H nilainya negatif padahal umur hilal positif) serta belum akurat sehingga berpotensi menimbulkan kesalahan prediksi posisi hilal.*

I. INTRODUCTION

The age of *hilal* (new crescent moon observed after conjunction on the 29th day of Hijri month) is one of the key variables in determining the beginning of lunar month. The moon's age is the interval between conjunction and the subsequent observation of the moon.[1] Conjunction, also referred to as *ijtima'*, is the condition in which the Moon and Sun occupy the same ecliptic longitude.[2] The age of the new crescent moon (*hilal*) specifically signifies the time span from the occurrence of *ijtima'* to the moment of sunset when the *hilal* is observed. The moon's age can assume a positive value if conjunction occurs prior to sunset, whereas it is deemed negative if conjunction occurs post-sunset.[3] The age of the *hilal* data, in accordance with

[1]Mohammad SH. Odeh, "New Criterion for Lunar Crescent Visibility," *Experimental Astronomy* 18 (2004): 41, https://doi.org/10.1007/s10686-005-9002-5.

[2]Muhyiddin Khazin, *Kamus Ilmu Falak* (Yogyakarta: Buana Pustaka, 2005), 32.

[3]N Sopwan and M Raharto, "Umur Bulan Sebagai Parameter Visibilitas Hilal," in *Seminar Nasional Fisik (SNF) 2019:"Menghilirkan Penelitian-Penelitian Fisika Dan Pembelajarannya"* (Surabaya, 2019), 28.

the *hilal* visibility criteria, facilitates the assessment of whether the moon is observable during the *rukyat al-hilal* process at the inception of the lunar month. This process involves the observation of the western horizon at sunset to see the first crescent moon that appear after conjunction.[4]

Additionally, the altitude of the new moon represents another critical variable in identifying *hilal* presence. Altitude, also referred to as *irtifa'*, is defined as the arc along a vertical circle extending through a celestial object, measured from the horizon to the celestial object.[5] The altitude of a celestial object is regarded as positive when it is situated above the horizon and negative when it lies below. The moon's altitude is the vertical angle between the moon's position and the horizon line as perceived by the observer.[6]

The altitude of the new moon is mentioned in the MABIMS (Minister of Religion of Brunei, Indonesia, Malaysia, and Singapore) new crescent visibility criteria employed by Indonesia for lunar month determination.[7] The most recent criterion instituted by the Indonesian government since 2022 is the MABIMS's *Hilal* Neo Visibility, which stipulate the moon's altitude of 3° and elongation of 6.4°.[8] If the moon's altitude doesn't meet the criteria, it can be inferred that the new crescent moon will not be visible, thereby leading to the rejection of the testimony from the *hilal* observer. This variable is significant in establishing the beginning of the lunar month.[9]

---

[4]Ahmad Lutfi Afifi Bin Mohd Nasir et al., "Hisab Rukyat in the Light of the Quran and Sunnah," *Al-Hisab: Journal of Islamic Astronomy* 1, no. 1 (2024): 26.

[5]Khazin, *Kamus Ilmu Falak*.

[6]Odeh, "New Criterion for Lunar Crescent Visibility."

[7]Novi Sopwan and Moedji Raharto, "Karakteristik Parameter Posisi Hilal Elongasi Dan Tinggi Bulan Saat Matahari Terbenam Di Pelabuhan Ratu Jawa Barat," in *Seminar Pend. IPA Pascasarjana UM Vol.2* (Malang: Universitas Malang, 2017), 51.

[8]Nuril Farida Maratus, "Implementasi Neo Visibilitas Hilal MABIMS Di Indonesia (Studi Penentapan Awal Bulan Ramadan Dan Syawal 1443 H)," *Jurnal Al-Ahkam* 10, no. 2 (n.d.): 229.

[9]Cahyo Puji Asmoro et al., "DIY Photometer in Determining the Beginning of Dawn Time in Cimahi City," *Gravity : Jurnal Ilmiah Penelitian Dan*

Both traditional and modern lunar calculation systems incorporate the moon's age employing diverse formulations. A notable text on Falak Science in Indonesia, still widely utilized today, is the Book of *Fath ar-Rauf al-Mannan*. This text uniquely uses the age of the new crescent moon to calculate its altitude. The author, Abdul Djalil Hamid, characterizes the age of the crescent moon through the phrase "*sa'ah al-bu'di minal ijtima' ila al-ghurub*" (the moon's age since *ijtima'* until the time of sunsets). According to Abdul Jalil, the altitude of new crescent moon (*irtifa' al-hilal*) can be derived by multiplying the moon's age by half a degree.[10] This conceptual approach also appears in comparable *haqiqi taqribi* books such as *Sullam Nayyiroin*.

In practice, the calculation of the *hilal* altitude and age is not as simple, particularly within contemporary calculation systems. Modern theoretical calculations for *hilal* altitude do not use the simplistic formula that directly relates to moon's age, but rather use a more complex formulation based on the spherical trigonometry.[11] The Ephemeris algorithm, recognized as a high-accuracy contemporary calculation system, computes the *hilal* age in with a series of calculations related to the lunar phases. The formulation used in the Ephemeris algorithm contrasts with the simplistic approach found in the *Fath ar-Rauf al-Mannan* book. According to this book, the altitude of the *hilal* is calculated as half of its age value. In reality, however, there are instances where the *hilal* age is relatively high, yet the altitude remains negative, indicating that the *hilal* is still below the horizon.[12]

Consequently, it is imperative to conduct research on the correlation between *hilal* age and altitude at the beginning of the lunar month. Understanding this correlation has the potential to offer deeper insights into how the age of the *hilal* can influence

---

Pembelajaran Fisika 10, no. 1 (April 28, 2024): 17–26, https://doi.org/10.30870/GRAVITY.V10I1.22873.

[10]Abdul Djalil Hamid, *Fath Al-Rauf Al-Manan* (Kudus, n.d.).

[11]Muhammad Dimas Firdaus et al., "Pengamatan Hilal Siang Hari Di OIF Cabang Barus," *Astroislamica: Journal of Islamic Astronomy* 1, no. 2 (2022), https://doi.org/10.47766/astroislamica.v1i2.965.

[12]Sopwan and Raharto, "Umur Bulan Sebagai Parameter Visibilitas Hilal."

its altitude. This research aims to know the correlation between *hilal* age and altitude as a critique of the calculation system presented in *Fath ar-Rauf al-Mannan* regarding its altitude formulation. Through this correlation, it can be analyzed whether the *hilal* age and altitude formulation within the *Fath ar-Rauf al-Mannan* book remains relevant for contemporary use.

Research related to the *hilal* age, altitude, and the calculation system in the *Fath ar-Rauf al-Mannan* can be grouped into three categories. First, studies on the moon's age within the criteria for determining the beginning of the lunar month. Judhistira Aria Utama and Hilmansyah examined the post-conjunction moon's age as a physical parameter of the *hilal*, focusing on its potential as a visibility criterion specifically for tropical regions.[13] In another article, Judhistira Aria Utama and S. Siregar proposed *hilal* visibility criteria for Indonesia using the Kastner model, which suggests that the moon's age post-conjunction should be greater than 15 hours, the elongation should be greater than 8°, and the *hilal* altitude should be a minimum of 3°.[14] Additionally, there are studies by N. Sopwan and Raharto, which explored the *hilal* age as a visibility parameter and noted that the MABIMS visibility criteria, which set the moon's age at 8 hours, do not encompass all possible *hilal* parameters.[15]

Second, research on the *hilal* altitude at the beginning of the lunar month. M. Ilyas stated that the minimum distance between the *hilal* altitude and the setting sun for the new crescent visibility criterion is approximately 4°.[16] Slamet Ridwan compared *hilal* altitude in determining the beginning of the lunar month

---

[13]Judhistira Aria Utama and Hilmansyah, "Penentuan Parameter Fisis Hilal Sebagai Usulan Kriteria Visibilitas Di Wilayah Tropis," *Jurnal Fisika Unnes* 3, no. 2 (2013): 122–27, https://doi.org/10.15294/jf.v3i2.3821.

[14]J. A. Utama and S. Siregar, "Usulan Kriteria Visibilitas Hilal Di Indonesia Dengan Model Kastner," *Jurnal Pendidikan Fisika Indonesia* 9, no. 1 (2013): 204.

[15]Sopwan and Raharto, "Umur Bulan Sebagai Parameter Visibilitas Hilal."

[16]M. Ilyas, "Limitting Altitude Separation in the New Moon's First Visibility Criterion," *Astronomy and Astrophysics* 206 (1988): 133–35.

between the Ephemeris method and the Nautical Almanac method. Both methods use the same altitude formula: $\sin h = \sin \varphi \sin \delta_{moon} + \cos \varphi \cos \delta_{moon} \cos t_{moon}$.[17] Furthermore, Muhammad Syarief Hidayatullah examined *hilal* altitude references from the perspectives of Nahdlatul Ulama and Muhammadiyah.[18] Novi Sopwan and Moedji Raharto also studied the *hilal* altitude, analyzing the characteristics of the *hilal* elongation and altitude parameter at sunset in Pelabuhan Ratu, West Java.[19]

T. B. Ramadhan conducted a re-evaluation of *hilal* visibility criteria (including the *hilal* altitude and age) in Indonesia using national and international observational data, finding that the moon's age was 9.4 hours after conjunction with a Moon-Sun altitude difference of 3° when the azimuth difference was ≥ 5°.[20] Moreover, Imas Musfiroh and Hendri suggested that the best *hilal* visibility criteria are based on the topocentric altitude and elongation, or topocentric altitude combined with topocentric *hilal* width.[21] A similar study was conducted by Nazhatul Shima Ahmad, who analyzed the criteria for the beginning of the month using a circular regression model between *hilal* elongation and altitude, resulting in an elongation of 7.28° and an altitude of 3.33° at sunset.[22]

---

[17]Slamet Ridwan, "Studi Komparasi Ketentuan Ketinggian Hilal Antara Metode Ephemeris Dan Almanak Nautika Dalam Penentuan Awal Bulan Qomariyah" (STAIN Pekalongan, 2013).

[18]Muhammad Syarief Hidayatullah, "Acuan Tinggi Hilal Perspektif Nahdlatul Ulama Dan Muhammadiyah," *Bilancia: Jurnal Studi Ilmu Syariah Dan Hukum* 13, no. 2 (2019): 275–303, https://doi.org/10.24239/blc.v13i2.496.

[19]Novi Sopwan and Raharto, "Karakteristik Parameter Posisi Hilal Elongasi Dan Tinggi Bulan Saat Matahari Terbenam Di Pelabuhan Ratu Jawa Barat."

[20]T. B. Ramadhan, T. Djamaluddin, and J. A. Utama, "Re-Evaluation of Hilaal Visibility Criteria in Indonesia by Using Indonesia and International Observational Data," in *Proceeding of International Conference On Research, Implementation And Education Of Mathematics And Sciences 2014* (Yogyakarta: Yogyakarta State University, 2014), 81–72.

[21]Imas Musfiroh and Hendri, "Analisis Regresi Non Linier (Polinomial) Dalam Pembentukan Kriteria Visibilitas Hilal Di Indonesia," *Al-Marshad: Jurnal Astronomi Islam Dan Ilmu-Ilmu Berkaitan* 4, no. 1 (2018): 46–66.

[22]Nazhatulshima Ahmad et al., "A New Crescent Moon Visibility Criteria Using Circular Regression Model: A Case Study of Teluk Kemang,

Third, studies on the calculation system for the beginning of the lunar month in the *Fath ar-Rauf al-Mannan*. The calculation system in this book uses the Dahlan Table data, which refers to the *Tadzkirah Ikhwan* manuscript by Sheikh Ahmad Dahlan.[23] Additionally, there is research by Solikha comparing the calculation system between the *Fath ar-Rauf al-Mannan* and the Ephemeris method. She mentioned that there are differences in the results of the two methods because *Fath ar-Rauf al-Mannan* is based on a permanent table, whereas Ephemeris data is updated annually, with more corrections as it refers to astronomical data.[24]

The various studies related to *hilal* age and altitude mentioned above have not specifically addressed the relationship between these two variables. Moreover, no studies have discussed the *hilal* altitude formulation in the *Fath ar-Rauf al-Mannan*, where altitude is linked to its age. This problem needs to be critically examined, making it essential to first understand the actual correlation between *hilal* age and altitude. In line with this, the current study aims to complement previous research by contributing a scientific examination of moon's age and altitude.

II. METHOD

This reseach uses a quantitative approach with a library research design. The research object is the *hilal* (the crescent moon on the 29th day of the lunar month) at sunset over one Hijri year in the year of 1444 H, encompassing twelve months. The focus of the research is on the variations in *hilal* altitude and age. The *hilal* age serves as the independent variable (x variable), while the altitude is treated as the dependent variable (y variable).

Malaysia," *Sains Malaysiana* 49, no. 4 (2020), https://doi.org/10.17576/jsm-2020-4904-15.

[23]Iin Safarina, "Penentuan Awal Bulan Qamariyah Menurut Kitab Fathur Raufil Mannan" (Institut Agama Islam Negeri Sunan Kalijaga Yogyakarta, 2001).

[24]Solikha, "Studi Perbandingan Sistem Penentuan Awal Bulan Metode Kitab Fathur Al-Ra'uf Al-Manan Dan Metode Ephemeris" (Uiniversitas Islam Negeri Malang, 2008).

Data on *hilal* age and altitude were obtained through calculations using the Ephemeris method, analyzed with Microsoft Excel. The astronomical data for the Moon and Sun used in these calculations were sourced from the Ephemeris Hisab Rukyat published by the Indonesian Ministry of Religious Affairs.[25] The geographic coordinates used were the Planetary and Observatory at UIN Walisongo Semarang, located at a latitude of 6°59'30" S and a longitude of 110°20'53" E, with an elevation of 109 meters above sea level.[26]

After collecting data on *hilal* age and altitude, the relationship between these two variables was analyzed using simple regression analysis. The objective was to identify a linear relationship between the independent and dependent variables, thereby enabling the independent variable to be used in predicting the dependent variable. The correlation equation result will be used to analyze the *hilal* altitude formula in the *Fath ar-Rauf al-Mannan* book.

III. RESULTS AND DISCUSSIONS

A. Correlation Between *Hilal* Age and Altitude at the Beginning of the Lunar Month

1. Significance of *Hilal* Age Variations on *Hilal* Altitude

Based on the calculations of *hilal* age and altitude at the beginning of the lunar month using the Ephemeris system, the data obtained is presented in the following table:

Table 1. Data of *Hilal* Age and Altitude at the Beginning of the Lunar Month

No	***Lunar Month (1444 H)***	***Hilal Age***	***Hilal Altitude***
1	*Muharram*	16,71182106	6,674422388
2	*Shafar*	2,335138378	0,992732498
3	*Rabiul Awal*	12,63355797	5,304705973

[25]Kementerian Agama RI, *Ephemeris Hisab Rukyat 2022* (Jakarta: Direktorat Jenderal Bimbingan Masyarakat Islam, 2022); Kementerian Agama RI, *Ephemeris Hisab Rukyat 2023* (Jakarta: Direktorat Jenderal Bimbingan Masyarakat Islam, 2023).

[26]Google, "Planetarium Dan Observatorium UIN Walisongo Semarang," Google Earth, 2023.

4	*Rabiul Akhir*	23,70254054	10,63960397
5	*Jumadil Awal*	11,68203688	4,784618876
6	*Jumadil Akhir*	0,590454758	-0,097328555
7	*Rajab*	14,15458724	7,939685781
8	*Sya'ban*	3,902820863	2,567211834
9	*Ramadhan*	17,40330282	7,981776675
10	*Syawal*	6,357996723	1,600826737
11	*Dzulqo'dah*	18,68134574	6,141148537
12	*Dzulhijjah*	5,879394889	0,902883191

To determine the overall significance of the regression model relating *hilal* age to *hilal* altitude based on the data above, an Analysis of Variance (ANOVA) was performed. The results are as follows:

Table 2. ANOVA Output

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	116,029553	116,0296	95,773797	1,9367E-06
Residual	10	12,11495797	1,211496		
Total	11	128,144511			

Explanation:

Df : degrees of freedom for regression

SS : sum of squares for regression

MS : mean square of regression

F: F-statistic or F-test for the zero hypothesis

Significance F: statistical significance of the model

Based on the table above, the F significance value of the model is 1.9367E-06, indicating that the regression model is statistically significant overall. This means that the model effectively explains the variation in the independent variable. The F statistic value of 95.773797 exceeds the 5% significance level, leading to the conclusion that the independent variable has a significant effect on the dependent variable. This also suggests that the use of the independent variable (*hilal* age) better predicts the dependent variable (*hilal* altitude) than using only the intercept (without the independent variable).

Next, the proportion of the contribution of *hilal* age to *hilal* altitude was calculated using the equation $R^2 = (\Sigma xy)^2 / \Sigma x^2 \Sigma y^2$. The results are as follows:

Table 3. Output of Regression Statistics

Regression Statistics	
Multiple R	0,951555898
R Square	0,905458627
Adjusted R Square	0,89600449
Standard Error	1,100679698
Observations	12

The table shows that the correlation coefficient (Multiple R) is 0.951555898, which is close to 1, indicating a strong linear relationship between age and altitude. Additionally, the coefficient of determination (R Square) is 0.905458627, meaning that approximately 90% of the variation in *hilal* altitude can be explained by the observed variation in *hilal* age. Moreover, the Standard Error value is 1.100679698, indicating the absolute average distance of data points from the regression line. This suggests that if the regression equation is used to estimate values beyond the existing data, there may be an error margin of up to 1.100679698.

2. Regression Equation Between *Hilal* Age and *Hilal* Altitude for the Year 1444 H

Data on *hilal* age and altitude at the beginning of the lunar months in 1444 H were analyzed using a simple regression equation with the following formula:

$$X = \Sigma X / n$$
$$\bar{Y} = \Sigma Y / n$$
$$x = X - \bar{X}$$
$$y = Y - \bar{Y}$$
$$b = \Sigma xy / \Sigma x^2$$
$$a = \bar{Y} - b \bar{X}$$

Explanation:

B: gradient

a : intercept

X : independent variable

Y : dependent variable

n : number of data points
$\bar{X}$: mean value of the independent variable
$\bar{Y}$: mean value of the dependent variable
x : deviation of the independent variable from its mean value
y : deviation of the dependent variable from its mean value

The equation was processed using regression data analysis, yielding the following values:

Table 4. Output of Regression Analysis

	Coefficients	***Standard Error***	***t Stat***	***P-value***
Intercept	-0,34109308	0,598227854	-0,57017	0,5811441
Hilal Age	0,444103449	0,045379613	9,786409	1,937E-06

The regression coefficient for *hilal* age, called gradient, is 0.444103449. This positive and significant regression coefficient indicates a correlation between *hilal* age and altitude, meaning that as the *hilal* age increases, the altitude also increases.

The regression analysis graph showing the correlation between *hilal* age and altitude is as follows:

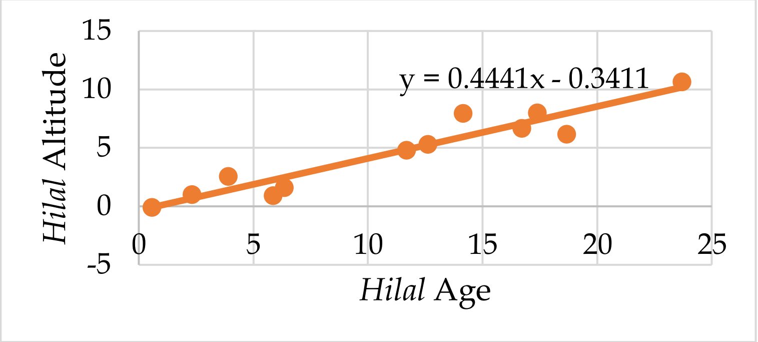

Figure 1. Correlation between *Hilal* Age and *Hilal* Altitude based on Regression

The intercept value (a) of the model is -0.34109308. This indicates that if the *hilal* age is zero, the altitude would be -0.34109308. When written in the equation form y=bx+ay = bx + ay=bx+a, this can be expressed as y=0.444103449x−0.34109308. This implies that for each hour increase in the independent variable (*hilal* age), the altitude increases by approximately 0.44 degrees.

If this equation is used to calculate *hilal* altitude based on its age (x value) for the beginning of the lunar months in 1444 H, the resulting *hilal* altitude values are as follows:

Table 5. Comparison of Ephemeris *Hilal* Altitude Data and Regression Equation Results

No	***Lunar Month (1444 H)***	***Hilal Age (x)***	***Ephemeris Hilal Altitude (y)***	***Hilal Altitude based on Regression Equation (y = 0,4441x - 0,3411)***
1	*Muharram*	16,71182106	6,674422388	7,080684293
2	*Shafar*	2,335138378	0,992732498	0,695949928
3	*Rabiul Awal*	12,63355797	5,304705973	5,269513589
4	*Rabiul Akhir*	23,70254054	10,63960397	10,18528693
5	*Jumadil Awal*	11,68203688	4,784618876	4,846939792
6	*Jumadil Akhir*	0,590454758	-0,097328555	-0,078870086
7	*Rajab*	14,15458724	7,939685781	5,945007934
8	*Sya'ban*	3,902820863	2,567211834	1,392163126
9	*Ramadan*	17,40330282	7,981776675	7,387773729
10	*Syawal*	6,357996723	1,600826737	2,482515195
11	*Dzulqo'dah*	18,68134574	6,141148537	7,955357001
12	*Dzulhijjah*	5,879394889	0,902883191	2,269966469

Based on this data, the correlation between *hilal* age and altitude can be visualized as shown in the following curve:

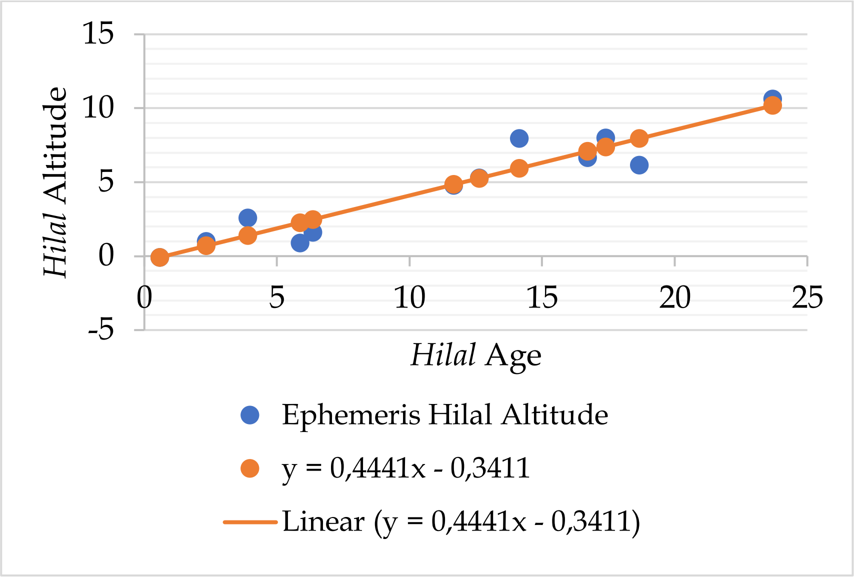

Figure 2. Correlation between *Hilal* Age and *Hilal* Altitude based on Ephemeris and Regression Analysis

B. Critical Discussion on the *Hilal* Altitude Formula in *Fath ar-Rauf al-Mannan*

1. The Case of Positive *Hilal* Age but Negative *Hilal* Altitude

In the *Fath ar-Rauf al-Mannan*, the definition of *hilal* altitude is the distance between the setting of the Sun and the conjunction (*ijtima'*), divided by two. In other words, the *hilal* altitude is calculated as half of the *hilal* age (altitude = *hilal* age × 0.5°). This formula bases the *hilal* altitude solely on its age, with the assumption that each unit of *hilal* age will contribute an increase of 0.5° in altitude. According to the formula y=0.5x as presented in the book, the *hilal* should always be above the horizon if the conjunction occurs before sunset.

However, the reality case is different, as exemplified by the *hilal* altitude in Jumadil Akhir 1444 H, where the calculated altitude was negative despite the positive *hilal* age of 0.590454758 hours. According to Ephemeris calculations, the *hilal* altitude in Jumadil Akhir 1444 H was -0.097328555 degrees, while the altitude calculated using *Fath ar-Rauf al-Mannan*'s method was 0.295227379 degrees. This discrepancy indicates that according to *Fath ar-Rauf al-Mannan*, the *hilal* should have been above the horizon, while the Ephemeris calculation shows it was still below.

Meanwhile, simple regression analysis using empirical data demonstrates that the relationship between *hilal* age and altitude is not strictly linear with a constant increment of 0.5° per unit of *hilal* age. Instead, the relationship is more complex and can be better represented by the regression equation derived from the analysis. The simple regression analysis revealed a significant positive regression coefficient between the altitude and age, indicating a positive relationship between the two variables. The resulting equation is as follows:

$$y = 0{,}444103449\ x - 0{,}34109308$$

$$hilal\ \text{altitude} = 0{,}444103449 \times hilal\ \text{age} - 0{,}34109308$$

According to this formula, the *hilal* altitude for Jumadil Akhir 1444 H would be -0.078870086, which is closer to the Ephemeris-calculated altitude. This regression-based formula includes the *hilal* age coefficient of 0.444103449 and an intercept value of -0.34109308, whereas the formula in *Fath ar-Rauf al-Mannan* only includes the *hilal* age coefficient of 0.5.

The formula used in the manuscript fails to account for situations where the *hilal* altitude is negative, even if the conjunction occurs before sunset. Simply halving the *hilal* age is insufficient to produce accurate results. The altitude formula requires the addition of an intercept constant. Thus, it can be concluded that the formula in *Fath ar-Rauf al-Mannan* is somewhat inadequate and not fully representative in accurately determining the *hilal* altitude.

2. Accuracy of Data Calculations in *Fath ar-Rauf al-Mannan*

When the *hilal* altitude calculated using the formula from *Fath ar-Rauf al-Mannan* is compared to the altitude obtained from the regression analysis equation, the data can be summarized in the following table:

Table 6. Comparison of *Hilal* Altitude Data

Lunar Month (1444 H)	***Hilal* Age (x)**	**Ephemeris *Hilal* Altitude (y)**	***Hilal* Altitude based on Regression Equation**	***Hilal* Altitude based on**

			(y = 0,4441x - 0,3411)	*Fath ar-Rauf al-Mannan* (y=o,5x)
Muharram	16,71182106	6,674422388	7,080684293	8,355910528
Shafar	2,335138378	0,992732498	0,695949928	1,167569189
Rabiul Awal	12,63355797	5,304705973	5,269513589	6,316778984
Rabiul Akhir	23,70254054	10,63960397	10,18528693	11,85127027
Jumadil Awal	11,68203688	4,784618876	4,846939792	5,841018441
Jumadil Akhir	0,590454758	-0,097328555	-0,078870086	0,295227379
Rajab	14,15458724	7,939685781	5,945007934	7,077293619
Sya'ban	3,902820863	2,567211834	1,392163126	1,951410431
Ramadan	17,40330282	7,981776675	7,387773729	8,701651409
Syawal	6,357996723	1,600826737	2,482515195	3,178998362
Dzulqo'dah	18,68134574	6,141148537	7,955357001	9,340672872
Dzulhijjah	5,879394889	0,902883191	2,269966469	2,939697445

According to the table, the maximum discrepancy between the empirical *hilal* altitude (based on Ephemeris) and the altitude calculated using the formula from *Fath ar-Rauf al-Mannan* is 3.199524335°, which occurs in the month of Shawwal 1444 H. The maximum discrepancy between the empirical *hilal* altitude and the altitude derived from the regression equation is 1.994677846°, occurring in the month of Rajab 1444 H. This indicates that the *hilal* altitude data calculated using the formula from *Fath ar-Rauf al-Mannan* is still inaccurate, with discrepancies reaching up to 3°.

The formula, which links *hilal* altitude directly to *hilal* age, fails to provide an accurate approach. This is because the *Fath ar-Rauf al-Mannan* only offers a rough estimate of the *hilal* altitude based on its age, without accounting for the more complex variations in this relationship. In contrast, the regression equation from the data analysis provides a more accurate approach because it is based on actual empirical data.

Essentially, the calculation system used in *Fath ar-Rauf al-Mannan* falls under the category of *haqiqi taqribi*. A *haqiqi taqribi* astronomy text is one that approaches the study of astronomy with simpler, more practical methods. This approach is intended to facilitate the use of astronomical knowledge in everyday life, particularly in determining the beginning of the lunar month or other religious observances based on astronomical calculations. Astronomical texts categorized as *haqiqi taqribi* typically provide practical rules or formulas that are easy for the general public to understand and apply, without requiring in-depth astronomical knowledge. An example is the simple formula for determining *hilal* altitude based on its age, as mentioned in *Fath ar-Rauf al-Mannan*. While this formula does not always yield astronomically accurate results, it is sufficient for providing a general estimate.

3. The Impact of the *Hilal* Altitude Formula in *Fath ar-Rauf al-Mannan* on Potential Differences in the Beginning of the Lunar Month (Case Study of Shawwal 1444 H)

It is well known that the lunar month begins with the *hilal* (the first crescent moon) in the sky. The condition of the *hilal* that makes it visible to the human eye is referred to as *imkanur rukyat* or, in astronomical terms, new crescent visibility.[27] The criteria for *hilal* visibility used in Indonesia are the Neo MABIMS *Hilal* Visibility Criteria, commonly known as the new MABIMS criteria, which require a minimum moon altitude of 3° and an elongation of 6.4°.[28] One of the most crucial variables in the *hilal* visibility criteria is the altitude.

A *hilal* altitude that meets the visibility criteria indicates that the *hilal* can be seen by the human eye. Accurate *hilal* altitude data are essential to ensure that calculations align with what can be directly observed. However, the *hilal* altitude calculations in *Fath ar-Rauf al-Mannan* are considered inaccurate, which raises the potential for errors in predicting the *hilal* position. The following curve illustrates the data on *hilal* altitude and the *hilal* altitude criteria according to the Neo MABIMS *Hilal* Visibility criteria:

---

[27] Khazin, *Kamus Ilmu Falak*.

[28] Maskufa et al., "Implementation of the New MABIMS Crescent Visibility Criteria: Efforts to Unite the Hijriyah Calendar in the Southeast Asian Region," *Ahkam: Jurnal Ilmu Syariah* 22, no. 1 (2022), https://doi.org/10.15408/ajis.v22i1.22275.

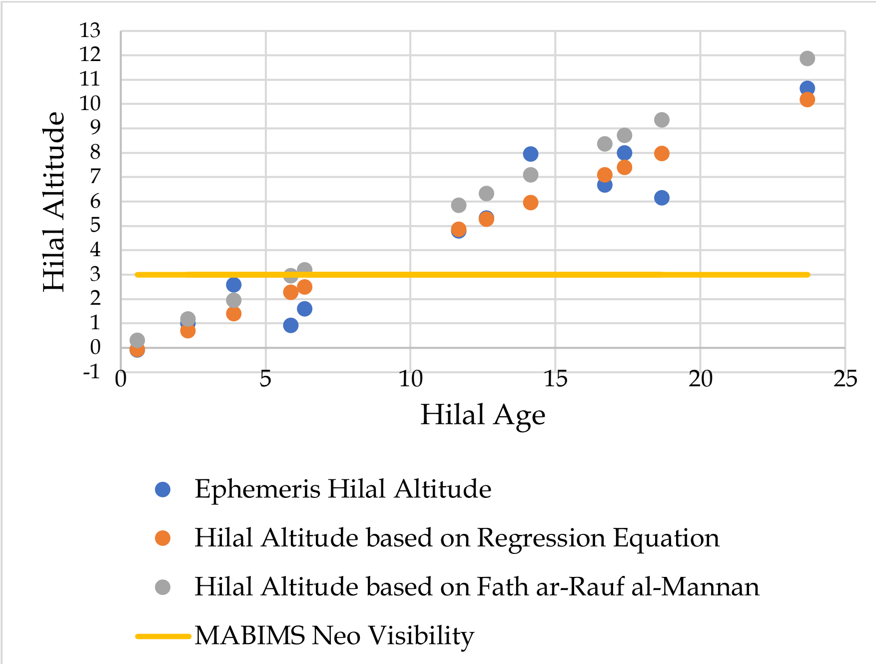

Figure 3. *Hilal* Altitude and Criteria in MABIMS Neo Visibility

From the curve, it is evident that one *hilal* altitude data point is particularly critical in determining the beginning of the lunar month, as it is close to the Neo MABIMS criteria. This data point refers to the *hilal* altitude at the beginning of Syawal 1444 H. The details are shown in the following curve:

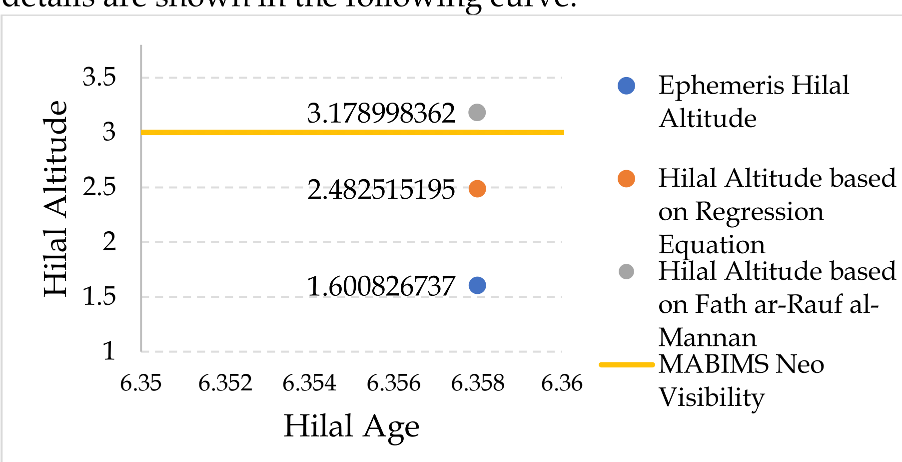

Figure 4. *Hilal* Altitude of Syawal 1444 H and MABIMS Neo Visibility Criteria

According to the calculations in *Fath ar-Rauf al-Mannan*, the *hilal* altitude at the beginning of Shawwal 1444 H is 3.178998362°. When compared to the Neo MABIMS visibility criteria, which require a minimum *hilal* altitude of 3°, this value meets the criteria for the beginning of the new month, suggesting that the *hilal* would likely be visible. However, based on the Ephemeris data (which is considered more accurate), the *hilal* altitude is only 1.600826737°, which does not meet the Neo MABIMS criteria, indicating that the *hilal* may not be visible. This significant difference highlights the potential for errors in predicting the *hilal* position.

IV. CONCLUSION

The regression equation derived from the relationship between *hilal* altitude and *hilal* age is *hilal* altitude=0.441103449×*hilal* age−0.34109308. This equation implies that the older the *hilal*, the greater its altitude. The use of the independent variable (*hilal* age) improves the prediction of the dependent variable (*hilal* altitude) compared to using only the intercept (without the independent variable).

However, the *hilal* altitude formula in *Fath ar-Rauf al-Mannan* (*hilal* altitude = 0.5 × *hilal* age) does not include an intercept constant, making it less representative in explaining the *hilal* altitude at the beginning of the lunar month. The formula used in that book fails to accommodate scenarios where the *hilal* altitude is negative, even if the conjunction occurs before sunset. The *hilal* altitude data calculated using the formula from *Fath ar-Rauf al-Mannan* remains inaccurate, with discrepancies as large as 3 degrees. Consequently, the use of the *hilal* altitude formula in *Fath ar-Rauf al-Mannan* has the potential to cause errors in predicting the *hilal* position.

BIBLIOGRAPHY

Abdul Djalil Hamid. *Fath Al-Rauf Al-Manan*. Kudus, n.d.

Ahmad Lutfi Afifi Bin Mohd Nasir, Hotnida Wakiyah Sari Hsb, Najmuddin Saifullah, and Rizqan Arya Perdana Nazara. "Hisab Rukyat in the Light of the Quran and Sunnah." *Al-Hisab: Journal of Islamic Astronomy* 1, no. 1 (2024): 24–31.

Ahmad, Nazhatulshima, Mohd Saiful Anwar Mohd Nawawi, Mohd Zambri Zainuddin, Zuhaili Mohd Nasir, Rossita Mohamad Yunus, and Ibrahim Mohamed. "A New Crescent Moon Visibility Criteria Using Circular Regression Model: A Case Study of Teluk Kemang, Malaysia." *Sains Malaysiana* 49, no. 4 (2020). https://doi.org/10.17576/jsm-2020-4904-15.

Asmoro, Cahyo Puji, Hana Susanti, Judhistira Aria Utama, and Dhani Herdiwijaya. "DIY Photometer in Determining the Beginning of Dawn Time in Cimahi City." *Gravity : Jurnal Ilmiah Penelitian Dan Pembelajaran Fisika* 10, no. 1 (April 28, 2024): 17–26. https://doi.org/10.30870/GRAVITY.V10I1.22873.

Firdaus, Muhammad Dimas, Hariyadi Putraga, Muhammad Hidayat, and Arwin Juli Rakhmadi. "Pengamatan Hilal Siang Hari Di OIF Cabang Barus." *Astroislamica: Journal of Islamic Astronomy* 1, no. 2 (2022). https://doi.org/10.47766/astroislamica.v1i2.965.

Google. "Planetarium Dan Observatorium UIN Walisongo Semarang." Google Earth, 2023.

Hidayatullah, Muhammad Syarief. "Acuan Tinggi Hilal Perspektif Nahdlatul Ulama Dan Muhammadiyah." *Bilancia: Jurnal Studi Ilmu Syariah Dan Hukum* 13, no. 2 (2019): 275–303. https://doi.org/10.24239/blc.v13i2.496.

Ilyas, M. "Limitting Altitude Separation in the New Moon's First Visibility Criterion." *Astronomy and Astrophysics* 206 (1988): 133–35.

Khazin, Muhyiddin. *Kamus Ilmu Falak*. Yogyakarta: Buana Pustaka, 2005.

Maratus, Nuril Farida. "Implementasi Neo Visibilitas Hilal MABIMS Di Indonesia (Studi Penentapan Awal Bulan Ramadan Dan Syawal 1443 H)." *Jurnal Al-Ahkam* 10, no. 2 (n.d.): 227–50.

Maskufa, Sopa, Sri Hidayati, and Adi Damanhuri. "Implementation of the New MABIMS Crescent Visibility Criteria: Efforts to Unite the Hijriyah Calendar in the Southeast Asian Region." *Ahkam: Jurnal Ilmu Syariah* 22, no. 1 (2022). https://doi.org/10.15408/ajis.v22i1.22275.

Musfiroh, Imas, and Hendri. "Analisis Regresi Non Linier (Polinomial) Dalam Pembentukan Kriteria Visibilitas Hilal Di Indonesia." *Al-Marshad: Jurnal Astronomi Islam Dan Ilmu-Ilmu Berkaitan* 4, no. 1 (2018): 46–66.

Novi Sopwan, and Moedji Raharto. "Karakteristik Parameter Posisi Hilal Elongasi Dan Tinggi Bulan Saat Matahari Terbenam Di Pelabuhan Ratu Jawa Barat." In *Seminar Pend. IPA Pascasarjana UM Vol.2*, 51–56. Malang: Universitas Malang, 2017.

Odeh, Mohammad SH. "New Criterion for Lunar Crescent Visibility." *Experimental Astronomy* 18 (2004): 39–64. https://doi.org/10.1007/s10686-005-9002-5.

Ramadhan, T. B., T. Djamaluddin, and J. A. Utama. "Re-Evaluation of Hilaal Visibility Criteria in Indonesia by Using Indonesia and International Observational Data." In *Proceeding of International Conference On Research, Implementation And Education Of Mathematics And Sciences 2014*, 81–72. Yogyakarta: Yogyakarta State University, 2014.

RI, Kementerian Agama. *Ephemeris Hisab Rukyat 2022*. Jakarta: Direktorat Jenderal Bimbingan Masyarakat Islam, 2022.

———. *Ephemeris Hisab Rukyat 2023*. Jakarta: Direktorat Jenderal Bimbingan Masyarakat Islam, 2023.

Ridwan, Slamet. "Studi Komparasi Ketentuan Ketinggian Hilal Antara Metode Ephemeris Dan Almanak Nautika Dalam Penentuan Awal Bulan Qomariyah." STAIN Pekalongan, 2013.

Safarina, Iin. "Penentuan Awal Bulan Qamariyah Menurut Kitab Fathur Raufil Mannan." Institut Agama Islam Negeri Sunan Kalijaga Yogyakarta, 2001.

Solikha. "Studi Perbandingan Sistem Penentuan Awal Bulan Metode Kitab Fathur Al-Ra'uf Al-Manan Dan Metode Ephemeris." Uiniversitas Islam Negeri Malang, 2008.

Sopwan, N, and M Raharto. "Umur Bulan Sebagai Parameter Visibilitas Hilal." In *Seminar Nasional Fisik (SNF) 2019:"Menghilirkan Penelitian-Penelitian Fisika Dan Pembelajarannya"*, 26–29. Surabaya, 2019.

Utama, J. A., and S. Siregar. "Usulan Kriteria Visibilitas Hilal Di Indonesia Dengan Model Kastner." *Jurnal Pendidikan Fisika*

Indonesia 9, no. 1 (2013): 197–205.

Utama, Judhistira Aria, and Hilmansyah. "Penentuan Parameter Fisis Hilal Sebagai Usulan Kriteria Visibilitas Di Wilayah Tropis." *Jurnal Fisika Unnes* 3, no. 2 (2013): 122–27. https://doi.org/10.15294/jf.v3i2.3821.