A ROBUST UNIFIED ISLAMIC CALENDAR PROPOSAL FOR THE WORLD

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Abstract. To date, there is no single global Islamic calendar that is in use for the community. The computation of the Islamic calendar has become a subject of discussion. In this paper, we propose a Unified Global Islamic Calendar (UGIC) based on expected visibility of the youngest crescent moon, the International Dateline, the global lunar visibility curves and a single calendar for the whole world. Two different visibility criteria were applied to two regions of the globe. An unconventional visibility test is proposed that is based on a line instead of a point on the globe. A topocentric crescent illumination threshold criterion of 0.52% at local sunset is set for the Western region and tested at longitude 60° W along a line between latitudes ±20°. A second test criterion is based on the lunar conjunction event that has to occur before local sunset at any point on the globe. This criterion is applied at the Eastern extreme, longitude of 180° E, and tested along a line between latitudes 15° N and 35° S. We embrace the International Date Line as a day separator, and UTC as the standard clock. A 515 year calendar has been generated and tested for robustness. A 12-year calendar is produced based on the above method.

Keywords: Islamic Calendar, Unified Islamic Calendar, Time-keeping, Robust Lunar Calendar

INTRODUCTION

Apart from the Gregorian calendar, which serves as an international standard for civil employ, there are other calendars that are used for religious and cultural purposes. One of them is the Islamic calendar which is also a strictly lunar calendar. The Quran specifies that the months start with the new crescent sighting. Every year consists of 12 lunar months without leap months (Al-Quran 9: 36-37). The lunar months are Muharram, Safar, Rabiulawal, Rabiulakhir, Jamadilawal, Jamadilakhir, Rejab, Syaaban, Ramadan, Syawal, Zulkaedah, and Zulhijjah respectively. The Islamic Calendar is also referred as the Hijri Calendar.

Any calendar to be used for planning or as record of events must, essentially, be based on a mathematical system that can be calculated for the past, current and future times. It may be a simple alternate months of 29 and 30 days with systematic arrangements for leap years or an intensely mathematical formulation of the Moon's orbit and synodic periods through which months of 29 or 30 days long are determined using visibility rules. What is important for a robust Islamic calendar has to be its average duration of a month over a long period must converge to the observed synodic period of the Moon's orbit around the Sun.

The new lunar month in the Islamic calendar begins after first sighting of a thin crescent with naked-eye (i.e. shortly after lunar-solar conjunction). This crescent can be observed after sunset in the western area of sky. The beginning of a new month by this method (i.e. sighting) cannot be predicted precisely because it depended on variables that are not predictable in advance, such as the atmospheric conditions which accompany a sighting site (Guessoum & Mezziane, 2001). The lunar month has a long term mean period of 29.53088 days (Britannica, 2022). Hence, the central problem in the preparation of Islamic calendars in advance is to formulate computational procedures for determining the youngest visible phase of the moon (Abdali, 1979). The Hijri Calendar thus far has remained a regional calendar with regional variations and governed by regional governing bodies.

In recent years, serious and comprehensive attempts have been made towards an global Hijri calendrical system. Much work has been done on refining the lunar-visibility prediction criterion (Ilyas, 1991). Discussions at the *fiqh* or jurisprudence level were also taking place. A landmark achievement amongst Muslim scholars, astronomers and calendar practitioners of the world took place on 30 May 2016 in Istanbul, Turkey. A single global hijri calendar has been agreed by the participants from nearly 50 countries. Even though much details are to be determined and agreed upon, the agreement has opened the door for astronomers to toil on this matter. This paper is an attempt at consolidating the efforts made thus far into a practical Unified Global Islamic Calendar (UGIC). It is a refinement with extensions to an earlier paper on UGIC (Abdul Halim & Ahmad Kamil, 2014).

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THE UGIC PROPOSAL

This proposal is built upon the following premises:

1. The Hijri Calendar Union Congress's unanimous agreement on 30 May 2016 in Istanbul in favour of a unified Islamic Calendar for the world is taken here as the *fiqh* (Islamic jurisprudence) justification for a unified calendar (Mehmet Çelik, 2016).
2. Accepts the International Date Line (IDL) as the day separator.
3. Accepts UTC and its time zone classification as the standard clock measure of time.
4. A Hijri calendar need to be robust and reproducible for dates well into the future. Despite monthly variations of 29 and 30 days, the long term calendar must agree with the average synodic period of the Moon's orbit around the Earth.
5. This global calendar relies heavily on the concept of International Lunar Date Line (ILDL) as reported by Ilyas (1984).
6. No habitable location on the globe must begin its new Hijri month before lunar conjunction at the time of its local sunset.
7. No habitable location on the globe should experience a new month which is one whole day late. Meaning a new month must not begin on a day when the new moon
8. was already casually visible with the naked eye on the day before.
9. Given that one day is 24 hours, the age of a new moon that began at the start of IDL will be 24 hours old when the Sun sets at the end of IDL, seasonal and latitudinal variations is noted. The age of the moon is measured from the instance of conjunction to the time of local sunset.
10. Noted that very young cresent, aged < 24 hours, have been sighted by trained observers. For untrained or casual obervers sighting after 24 hours is more likely. Our calendar design will bias towards naked-eye casual observers rather than trained observers.
11. The calendar will make use of two criteria based on the concept of ILDL. They are tested at two different regions on the globe. One criterion is based on an expected visibility criterion (Ilyas, 1984) and tested at longitude 60^{o} W along a longitude line in between latitudes ±25^{o}. The other criterion is tested at the IDL, longitude 180^{o} E, in between latitudes 15^{o} N and 35^{o} S (for Tonga and Fiji islands), the Moon has to past conjunction during its local sunsets. Both criteria must be met for the beginning of a new month.

THE INTERNATIONAL LUNAR DATE LINE (ILDL)

The ILDL was first unveiled by Ilyas (1984). It represents a natural partition line that divides the globe into two regions, in one region the new crescent Moon is expected to be visible and in the other it is not expected to be visible. This natural pattern occurs usually on the 29th day of a Hijri month. Its shape and location is not fixed but varies from month to month. Figure 1 illustrates the concept of ILDL. The figure shows a Mercator projection of world with the ILDL superimposed. The ILDL is the line separating two areas of the globe. On one side is an area of expected visibility of the new crescent Moon and on the other is its non-visibility. The white circles sizes indicate the probability of sighting a new crescent Moon. The larger size indicate a higher probability of sighting. Conversely, the dark circles representing increasing probability of not sighting, with the larger sizes indicating its higher probability. The figure also show the probability of sighting is generally higher to the West of the ILDL.

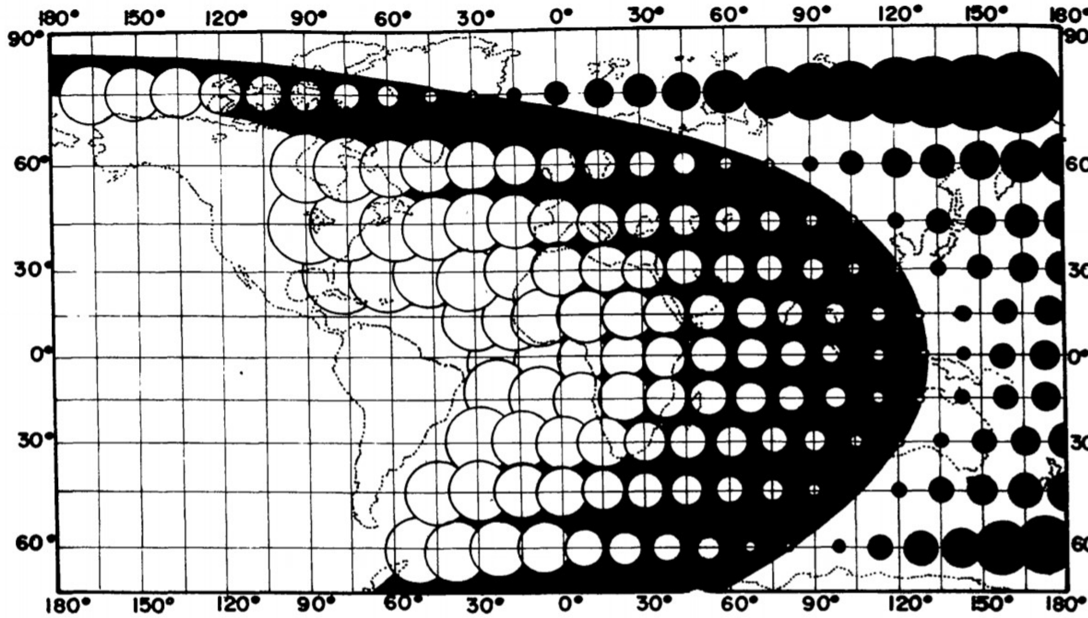

Fig 1 shows the ILDL, a line separating areas of new crescent Moon's visibility probability across the globe. The white circles sizes indicate the probability of sighting a new crescent Moon. The larger size the higher probability of sighting. Conversely, the dark circles representing increasing probability of not sighting, with the larger sizes representing higher probability. The figure also show the probability of sighting is generally higher to the West of the ILDL (Courtesy Ilyas, 1984)

The ILDL line profile across the globe is a reflection of the crescent visibility criterion in use. A Calendar Commission (*Mu'tamar Tahdid Awa'il asy-Syuhur al-Qamari*), 1978 (Hamdun, 2017) held in Istanbul has introduced a criterion method called *imkanur rukyah* for determining new crescent Moon visibility. It is evidence based and sets a minimum condition for new crescent Moon's visibility based on its altitude and elongation. It is a sighting-based criterion, namely the new crescent Moon must not only be 'born' (i.e. past its conjunction), but must also be sightable at a given location. It is an statistically based condition for sighting a new crescent Moon, hence the term *imkanur-rukyah*.

THE NEW CRESCENT MOON VISIBILITY CRITERIA

A 'sighting-based' global calendar require constraints so that the fullfilment of criteria do not include areas outside populated land masses. In this proposal the constraints are in the form of two criteria tests at two regions on the globe. An *imkanur rukyah* visibility criterion that is based on crescent illumination is adopted for one test, and the other is lunar conjunction test. Lunar illumination is based on a ratio of the illuminated fraction maximum angular width of the Moon to the Moon's semi-diameter angular width, expressed as percentage. The *imkanur rukyah* illumination value adopted is 0.52% (Ahmad Kamil & Abdul Halim, 2014). This expected visibility criterion was derived from 52 different-months observation collected at various sites in Malaysia (Ahmad Kamil & Abdul Halim, 2014).

The expected visibility criterion is tested at longitude 60^o W along a line ±25^o in latitude. The conjunction criterion is simultaneously tested at the beginning of IDL, which is a line along 180^o E near the Tonga and Fiji Islands. It is a line from latitude 15^o N to 35^o S.

The 0.52% illumination criterion is almost an equivalent of the composite criteria 5^o latitude and 8^o elongation which requires two parameters as suggested at the 31 May 2016 Istanbul conference (Hamdun, 2017). Figure 2 is a display of the a number of ILDLs using different criteria on a Mercator world map projection. As can be seen the 0.52% illumination (magenta coloured) line and the Istanbul 2016 (red coloured) line are close to each other.

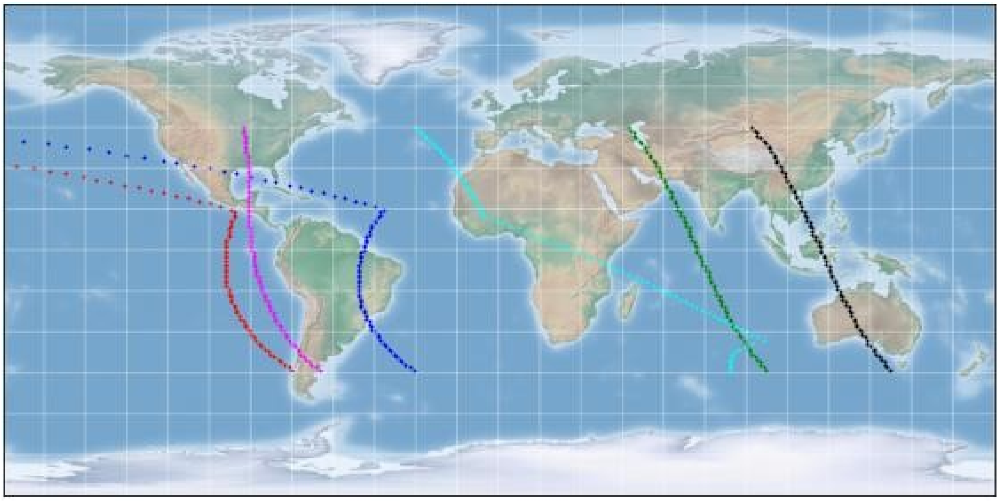

Fig 2 shows ILDL patterns of various criteria on date 23 Dec 2022. The black line is conjunction at local sunset. The green line is Moon's age at 3 hours. The turqoise is the older MABIMS criteria known as 2-3-8 (Bayan al-Falak, 2018), the blue line is ILDL of current MABIMS criteria (Kamarddin Amin, 2022), the pink line is 0.52% illumination and the red line is the Istanbul 2016 proposed 5-8 line.

As explained earlier, by using the *imkanur rukyah* criteria any location to the West of the ILDL is expected to sight the new crescent Moon. The conjunction and age criteria in figure 2 are not *imkanur rukyah* criteria. The conjunction criterion is used as a constraint to ensure no region on the globe experience new month before lunar conjunction at their local sunset.

A ROBUST CALENDAR

The synodic period of a lunar cycle varies slightly from month to month due to pertubations in the Moon's orbit. However, there is a long term stability, the average of which is 29 days 12 hours 44 minutes and 3 seconds or 29.530588 days (Britannica Online, 2022). Early hijri calenders used the istilahi system of fixed alternate 29 and 30 days in a month with leap year corrections in a 30-year cycle (Sharifah Shazwani *et. al.*, 2016). The hijri calendar built on *imkanur rukyah* show a more random distribution of 29 and 30-day months, following its natural cycle. It follows that a calendar which follows the natural lunar cycle, over a long period, must also exhibit an average number of days in a month approaching the lunar synodic period of 29.530588 days. I will take this as a measure of calendar robustness. Figure 3 is a result of a 515 year hijri calendar generated using the constrained global criteria described above. It reveals a diminishing oscillation average around the average synodic period, the last value after 6181 months averaged at 29.530573, which is a 0.00005% deviation from the accepted synodic period. The early istilahi system achieved a good value of 0.0001% deviation. Thus, the calendar developed is considered robust, which means it will not deviate away from the Moon's natural orbital period over time. The istilahi calendar, despite being robust, does not reflect the short-term monthly new crescent Moon's visibility.

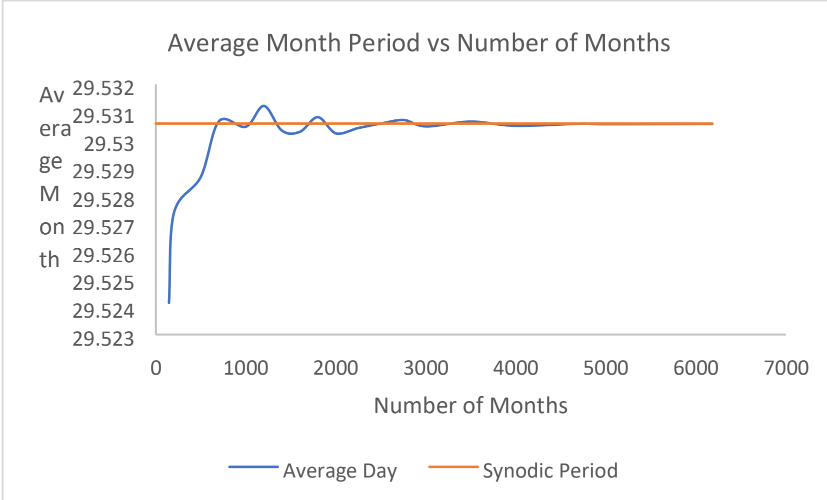

Figure 3 show the convergence of average days in a month over a long term.

The monthly visibility, and hence, the number of days in a month is not regular as implemented in the istilahi system. If sighting is at all going to be practiced, then the imkanur rukyah system offers better conformity with sighting results. Table 1 illustrate the irregular nature of this calendar in comparison to the istilahi. However, it can be argued that the istilahi calendar, after recalibration, can become a simple yet effective and practical global hijri calendar, especially when there is no longer a requirement for sighting the new crescent Moon any more. A systematic calendar is seen as the overiding Qur'anic expectation, understood from the holy Quran 9:37. This is easily complied by the istilahi calendar and the UGIC system.

Table 1 illustrate the irregular length of months using the proposed calendar vs the regular nature of the istilahi calendar. The 30 day months are coloured. For the istilahi system Zulhijjah is either 29 days (normal years) or 30 days (leap years).

Month/Year	1443 H	1444 H	1445 H	1446 H	1447 H	Istilahi
Muh	29	30	30	30	29	30
Saf	30	29	29	29	30	29
Raw	29	30	30	30	29	30
Rak	30	29	30	30	30	29
Jaw	29	30	29	30	30	30
Jak	29	29	30	29	29	29
Rjb	30	30	29	30	30	30
Sbn	30	29	30	29	30	29
Rmd	29	29	29	30	29	30
Syw	30	30	29	29	30	29
Zkd	29	29	30	29	29	30
Zhj	30	30	29	30	29	29/30

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THE UNIFIED GLOBAL ISLAMIC CALENDAR

It can be said that a global unified Islamic calendar must be systematic so that dates can be calculated for the future by any one who follows the rules, and people from the future can confidently trace past dates accurately. The calendar proposed here, unlike the istilahi system, complies (theoretically) with sighting requirements. For a global calendar, the choice of visibility criteria is not so critical since sighting anywhere on the globe is accepted and we understand the systematics of sighting. The use of criteria and test sites acts as constraints put in place, as mentioned in the premises, to maintain the concept of *imkanur rukyah* somewhere on the globe on the day which conjunction has taken already place.

A 12-year global hijri calendar is presented that follow all the premises, rules and criteria mentioned in this paper. This is followed by a 2-year daily calendar of the same, presented with global criteria lines for quick visual reference each month. The simplicity of this method lies in the locations of the two criteria lines on the world maps. A Gregorian calendar is always accompanied for comparison and checks. Note that the Gregorian calendar correspondence is valid only during daylight hours since the two calendar use different dark or night times for date change. The hijri calendar takes local sunset as the mark for new day whereas the Gregorian calendar takes 12 midnight (local time) as its new day. Since the hijri calendar adopts UTC as its time reference there will be discrepencies with regard to when the hijri day begins. That is because local sunset times varies throughout the season. This aspect requires deeper toil. The 12-year calculated calendar in full is in Appendix 1. A truncated and enhanced section is shown in Table 2.

Referring to Table 2, the first column is the final visibility verdict after taking into account the lunar crescent illumination value at 60^{o}W at any point in between latitudes ±25^o is not less than 0.52% (column 6 is coloured green when this condition is met), that conjunction has taken place at longitude 180^o E anywhere between latitudes 15^{o}N and 35^o S (also coloured green if the condition is met). Only when the two conditions are met will a "YES" verdict be given in column 1 (coloured pink when met). Column 2 is the day of sighting, the 29th day of the month. Column 3 is the name of the new month while column 4 tells the starting date of the new month (daylight equivalence) in relation to the well established Gregorian calendar. Column 5 is the number of days the new month will carry. Columns 8 and 9 are the date and times of lunar conjunctions.

Table 2 is a short section of the 12-year Unified Global Islamic Calendar. It shows the two criteria in play, coloured green for clarity. When both criteria are conplied (illumination not less than 0.52% coloured green and "YES" for Eastmost conjunction, green too) then the visinility verdict will indicate the new crescent Moon is sightable, "YES" and coloured pink.

Visibility Verdict	Sighting Day	Hijri Month	Start New Month	Number of Days	Illumination at 60^o W (%)	Easternmost Conjunction	Conjunction	
							Date	Time
NO	2021/8/8	Muh	2021/8/10	29	0.26	NO	2021/8/8	09:50:04
YES	2021/9/7	Saf	2021/9/8	30	0.99	YES	2021/9/6	20:51:42
NO	2021/10/6	Raw	2021/10/8	29	0.29	NO	2021/10/6	07:05:20
YES	2021/11/5	Rak	2021/11/6	30	1.39	YES	2021/11/4	17:14:34
NO	2021/12/4	Jaw	2021/12/6	29	0.44	NO	2021/12/4	03:42:59
YES	2022/1/3	Jak	2022/1/4	29	1.89	YES	2022/1/2	14:33:28
YES	2022/2/1	Rjb	2022/2/2	30	0.72	YES	2022/2/1	01:45:58
NO	2022/3/2	Sbn	2022/3/4	30	0.15	NO	2022/3/2	13:34:43
NO	2022/4/1	Rmd	2022/4/3	29	0.43	NO	2022/4/1	02:24:21
YES	2022/5/1	Syw	2022/5/2	30	0.95	YES	2022/4/30	16:28:02

NO	2022/5/30	Zkd	2022/6/1	29	0.16	NO	2022/5/30	07:30:13
YES	2022/6/29	Zhj	2022/6/30	30	0.59	YES	2022/6/28	22:52:12

A 2-year daily calendar is presented in Appendix 2 to illustrate the ideas above as a full calendar with the relevant date lines drawn in. This provide a visual of how the system operates. When used together with Appendix 1 they provide deeper insights into the strengths and weaknesses of this system

STRENGTHS AND WEAKNESSES

This is a robust system, but not the only one system to choose from. The constrained approach avoids a totally floating sighting, which will not care about the Eastern region. It ensures that the whole globe will not begin a new month before lunar conjunction. It makes use of the same IDL for day change and it is a UTC based time system. It is easy to use with the help of software, but without which casual computation may not be possible.

For a global lunar based calendar like the Hijri calendar, a unified calendar must accept an acceptable level of compromises. One forseeable compromise is the *imkanur rukyah* criterion applied at a 60º W, ±25º latitudes. The criterion is not the tightest or lowest possible. There have been positive sighting at 0.39% illumination. However, these are rare and made by professional or trained observers, sometimes with the aid of good quality instruments, including the use electronic detection and image processing. A 0.39% illumination approximately equivalent to the new MABIMS criteria (Kamarddin Amin, 2022). A 0.52% illumination new crescent Moon, in my opinion, is also not easy with casual sighting, it is in the realms of professional or trained observers. If 0.52% ILDL just misses the test area (meaning a 'not visible' verdict given) the land mass that may possibly sight the new crescent Moon is a little in South Ameraka but mostly in the North America at higher latitudes. This is an open question whether at high latitudes the new crescent Moon is less sightable given the extra atmospheric absorption (in winter) or the bright background sunlight (in summer) which reduces contrast and, thus, visibility. It is open for research and discussion.

CONCLUSION

A robust Unified Global Islamic Calendar has be proposed for the community. It is built on clear premises, its strengths and weakness have been discussed. A 12-year calendar has been produced based on the method discussed. A 2-year daily calendar following ILDL drawn on a Mercator projection world map has been produced to aid its appreciation and use.

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