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Contributed Paper

Suvarnabhumi-Gregorian Rule to Determine Whether Thai Lunar Calendar Year 2012 is a Leap-month Year

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Abstract

Following a widespread disagreement on whether the Thai lunar calendar year 2012 is a leap-month year, qualitative and quantitative analyses were conducted to determine where the inaccuracy lies. Through in-depth studies of the Thai lunar calendar, we discovered an ancient rule used by the *Suvarnabhumi* civilization to determine leap-month lunar years. By observing natural occurrences, the *Suvarnabhumi* people were able to develop a calendar that synchronized with the seasons. This calendar is believed to have been the origin of the current Thai lunar calendar, as the two share similar characteristics. We restore the *Suvarnabhumi* rule and adapt it to the internationally recognized and accepted Gregorian calendar and name the resulting adaptation the "*Suvarnabhumi-Gregorian*" rule. We then apply the rule to reveal that the year 2012 is not a leap-month lunar year. The rule provides a more accurate way to predict leap-month lunar years while maintaining the same characteristics as the Thai lunar calendar, which should make it a welcome alternative for both academic scholars and practitioners of traditional Thai astrology.

Keywords: Thai lunar calendar, leap-month lunar year

1. Introduction

The Thai calendars (Buddhist calendar, BE, or *Phuttha Sakarat*) typically provide both solar (*Suriyakhati*) and lunar (*Chanthrakhati*) calendars. The former is the globally-used Gregorian calendar, while the latter is the Thai lunar calendar based on *Culasakaraj*. All Thai Buddhist holidays and festivals are set according to the Thai lunar calendar. The following examples are well known ones and how they are referred to in the Thai lunar calendar: *Magha Puja* Day, which is on full-moon 3rd month; *Visakha Puja* Day (the holiest day of all Buddhist days marking the birth, enlightenment and death of the Gautama Buddha), which is on full-moon 6th month; *Loy Krathong* Festival, which is on full-moon 12th month. Furthermore, local farmers rely on the Thai lunar calendar for their rice cultivation. Thus, it is important that the Thai lunar calendar must be accurately represented, especially as to when it is a leap-month year. We will first describe in this section about astronomical aspects related to a lunar calendar. Then we will review the history of the Thai lunar calendar. We, finally, point out why there exists a conflict whether the year 2012 is a leap-month lunar year and propose our astronomical rule to correct the calendar.

1.1 Astronomical Aspects

Important astronomical aspects described here will be regarded throughout the arguments in this paper.

Tropical year (also solar, equinoctial, natural, or seasonal year) is the time required for the Sun (or apparently, the Earth) to pass from the vernal equinox (the Sun crosses the Equator, which occurs in spring) back to the vernal equinox. Four important moments of the Sun's annual passage through the sky are the two equinoxes (vernal and autumnal) and the two solstices (summer and winter). The equinoxes are days on which the Sun rises due east and sets due west. The summer solstice ("**north solstice**") is the day on which the Sun rises and sets at its northernmost points on the horizon, whereas the winter solstice ("**south solstice**") is the day on which the Sun rises and sets at its southernmost points on the horizon.

The length of the mean tropical year is 365.242199 days [1].

Sidereal year or star year is the period of time during which the Earth makes a complete revolution around the Sun with respect to a specific star.

The sidereal year equals 365.25636 days for the J2000.0 epoch [2].

Thus, the difference between the sidereal year and the mean tropical year is $365.25636 - 365.242199 = 0.014161$ days. Therefore, the accumulated difference between the two over a period of 200 years is $200 \times 0.014161 = 2.8322$ days.

Synodic month or lunar month is the period of a complete revolution of the Moon around the Earth with respect to the Sun (full moon to full moon or new moon to new moon). Its averaged length is 29.530588 days. However, the length of any one synodic month can be vary from 29.26 to 29.80 days due to perturbing effects of the Sun on the Moon's eccentric orbit [3]. The period of 12 lunar months is called a "**lunar year**."

A period of one lunar year is 354.367056 days.

The difference between the solar year and the lunar year is $365.242199 - 354.367056 = 10.875143$ days per year, *i.e.*, $10.875143 \times 3 = 32.625429$ days per three years (which is greater than one lunar month).

The system of dividing time into convenient periods of days, months and years is called the "**Calendars**." Due to the fact that the astronomical years have a fraction (instead of a whole number) of days, all derived calendars will eventually be out of sync over a period of accumulated cycle. Adding extra days or months to the cycle can preserve synchronization with the solar year, a method known as intercalation. To date the Gregorian calendar is the closest approximation to the solar year and is internationally used calendar. A common year for the Gregorian calendar has 365 days. An intercalary year or a "leap year" has 366 days by adding one day to the month of February for the year that is divisible by 4 but years divisible by 100 are not leap years unless they are also divisible by 400. In other words, centurial years that are not divisible by 400 (*e.g.*, the year 1700, 1800 and 1900) are not leap years [4]. Similarly, intercalation cycle every two or three years is applied to a lunar (lunisolar) calendar in order to synchronize the lunar year to the solar year. A lunar year that adds one extra month will have 13 months, which is called a "**leap-month year**." A lunar year that adds one extra day to a month will be called a "**leap-day year**."

1.2 Background on Thai Lunar Calendar

The Thai lunar calendar is believed to have its origins in the "***Suvarnabhumi***" lunar calendar [5]. *Suvarnabhumi* refers to a region including Myanmar (formerly Burma), Cambodia, Laos, Xishuangbanna (in the south of Yunnan Province, southwest China), Central Thailand, Northern Thailand, Northeastern Thailand and Vietnam [6]. This region is also known as *the Rice Bowl of the world* because it is believed that the first agricultural civilization was established here approximately 15,000-10,000 years ago [7-9]. Evidences such as rice husk and pottery artifacts were discovered in Northern Thailand and Northeastern Thailand indicating the first attempts at rice cultivation [10-11]. In order to precisely keep track of the seasons for agricultural purposes, the *Suvarnabhumi* lunar calendar must have been developed at that same time.

Interestingly, there are some ties between the *Suvarnabhumi* and the Maya civilization. The Maya civilization developed within the Mesoamerican cultural area, which gave rise to a series of cultural developments that included complex societies, agriculture, cities, monumental architecture, writing, and calendrical systems [12]. The Maya developed the calendar by recording lunar and solar cycles, eclipses and movements of planets [13]. In addition, the Maya and Cambodia counting systems are alike, *i.e.*, both counted 6 as 5|1; 7 as 5|2; and 8 as 5|3. According to DNA research study on the domestication of chickens from their wild progenitors, all domestic chickens have the same ancestor (about 7,000 years ago) originating from Fang (Northern city of Chiang Mai, Thailand) [14]. Thus, it is not surprising that the Maya, Thai, Cambodia, and Laos all have a sport with cockfighting as one of their traditions [15]. These connections suggest that the Maya may originate from the *Suvarnabhumi* region before migrating to Mesoamerican cultural area.

1.2.1 *Suvarnabhumi* lunar calendar

The *Suvarnabhumi* lunar calendar is merely a name suggested by Yodintra [5] in order to collectively refer to all lunar calendars developed by different nomadic groups (with names like Tai, Khmer, Mon, Jean, Muser, Laos, Shan and Lua) in the *Suvarnabhumi* region. Each nomadic group developed its own calendar with a common rule as to match a lunar cycle to natural surroundings in each area. The *Suvarnabhumi* lunar calendar described here, therefore, reflects the natural occurrence within Thailand which we have gathered from the elders.

One regular year of the *Suvarnabhumi* lunar calendar consists of 12 lunar months. Each lunar month has 15 days of waxing moon in the first half of the month. The second half has either 14 days (for odd month) or 15 days (for even month) of waning moon. As a result, the 1st, 3rd, 5th, 7th, 9th, and 11th month have 29 days each, whereas the 2nd, 4th, 6th, 8th, 10th, and 12th month have 30 days each [16]. The full moon day is the last day (15th) of waxing moon and is called "***Wan Pen***." The last day (14th or 15th) of waning moon is called "***Wan Dub***" meaning a "**dark moon day**." When signs from nature—*i.e.*, blossoming of certain trees, arrival of transitional rain, and moon appearance related to sunrise—occur at odd times, the *Suvarnabhumi* farmers will add one extra 8th month (30-day month). The year that has a "***Double*-8th month**" is called an "***Adhikamat* year**" (a leap-month year). This adjustment will synchronize the calendar with the seasons and retain a nominal length of twelve months. Every two or three years, the ancient farmers had to adjust their calendar to the *Adhikamat* year. They became experts in predicting an *Adhikamat* year using the *Suvarnabhumi* land as their observational field.

They even developed a rule which has been passed down through generations and known to today's elders as "***13 Dub Bungkub 13 Pen***" (***13-dark moon impending 13-full moon***) detailed in *Section 2.3.3*. An indicator resulting from this rule is that whenever the dark moon of the 1st month appears before the south solstice (December 22); the year will be an *Adhikamat* year. Since a full moon is obviously observed, they can use the full moon of the 12th month that appears before November 9 as the indicator of an *Adhikamat* year to come.

Not only did the ancient people of *Suvarnabhumi* know when to add a month, they also recognized the need to add a day. Due to the fact that they alternated the hollow month (29-day odd-month) and the full month (30-day even-month), their full moons and dark moons sometimes were misaligned with the actual phases of the Moon. The *Suvarnabhumi* full moon, *i.e.*, the 15th waxing moon, often appears before the actual one. In observing the *Suvarnabhumi* full moon days, they noticed that when the Sun was setting, the Moon had already risen in the East for 1-2 hours. If they observed that the *Suvarnabhumi* full moon (or dark moon) appears more than one day before the actual one and if that year is not an *Adhikamat* year, then they will add one extra day to the 7th month (from 29 days to become 30 days) in order to coincide the calendar with the appearance. The lunar year that adds one day is called an "***Adhikavara* year**" (a leap-day year). An *Adhikamat* year and an *Adhikavara* year will never be the same year [17-18].

1.2.2 *Culasakaraj* calendar

The *Culasakaraj* calendar or the *Makaranta* reckoning calendar is adapted from the *Suvarnabhumi* calendar with the *Double*-8th month for an *Adhikamat* year and the 30-day 7th month for an *Adhikavara* year. The Burmese era, known in Thai by the name *Culasakaraj* era (CS), was announced by King Popa Saw Yahan who usurped the throne of Pagan from the Burmese on Saturday March 25, 638 AD (*Gregorian date*). The day marks the beginning of New Year as the Sun enters the first point of Aries and is regarded the start of *Culasakaraj* (0 CS) [19]. He matched the *Suvarnabhumi* calendar to the Indian sidereal calendar because he believed that the Indian sidereal calendar which has the average year length of 365.25875 days (292,207 ÷ 800) was the most accurate calendar at the time as it reflected the actual moon in the sky. Therefore, the *Culasakaraj* calendar is based upon the *Suvarnabhumi* calendar matching with 800-year Indian sidereal calendar (*i.e.*, from 0 CS to 800 CS) in order to locate an *Adhikavara* year. He also acquired the rule based on the Indian sidereal calendar to predict an *Adhikamat* year instead of using the nature observation method, which he found troublesome.

The *Culasakaraj* calendar considers "***Tithi***" on the New Year of CS to identify an *Adhikamat* year. The *Tithi* is the angle of the Moon with respect to the Sun considering the Earth as a vertex. There are 30 *Tithis* in total. *Tithi* 0 represents the Sun and the Moon in alignment on the same side; hence it is a dark moon day. *Tithi* 15 represents the Sun and the Moon in alignment but on the opposite side; thus it is a full moon day. An *Adhikamat* year is then determined, for example the *Culasakaraj* New Year's Day on April 16, if the *Tithi* on that day is 26, 27, 28, 29, 0, 1, 2, 3, 4, 5 or 6. The prediction of an *Adhikamat* year by this rule is not all correct. We will discuss the problem of using the Indian sidereal calendar as a reference more in details in *Section 2.1.2*.

1.2.3 Thai lunar calendar

Between the 11th and the 13th centuries, the *Culasakaraj* calendar was adopted in the Pagan Empire and first came to be used in peripheral regions. The adoption of this calendar had spread to Siamese kingdoms initially from the *Lanna* Kingdom in the mid-13th century, to the *Sukhothai* Kingdom in the following century, and eventually to the *Ayuddhaya* Kingdom in the 16th century [17]. Subsequently, Siamese kingdoms retained this calendar as the official calendar under the name of *Culasakaraj* era (CS) until 1889 AD. Although, the *Culasakaraj*-based Thai lunar calendars have been encountered several adjustments to coincide with the seasons, but the local farmers prefer to use the *Suvarnabhumi* calendar for their crop cultivation. This *Culasakaraj*-based Thai lunar calendar, therefore, is only favored among Thai astrologers. The *Culasakaraj* dates remain the most commonly used and preferred form of entry by the academia for Thai history and Thai astronomy studies, even after Thailand has moved on to Buddhist calendar (BE) since 1941 AD. As a result, the current Thai lunar calendar still has an average year length of 365.25875 days.

1.3 Conflicting Results in Determining *Adhikamat* Year of 2012

The inaccuracy in predicting an *Adhikamat* year of the *Culasakaraj*-based Thai lunar calendar becomes imminent when the two following sources determine the year 2012 differently. According to Chunphongthong [20] (the scholar who designed the 5000-year lunar calendar which was published by the National Astronomical Research Institute of Thailand), when data from the National Aeronautics and Space Administration (NASA) were applied, the year 2012 on the Thai lunar calendar was shown to be a regular year. The Astrological Association of Thailand, published 150 Thai lunar calendars for citizen by Burajaraya [21], along with the Thai official calendar year 2012 stated otherwise that it is an *Adhikamat* year. In fact, these conflicting results can be expected every 150-200 years because the Thai lunar calendar is synchronized to the Indian sidereal year, which gradually drifts apart from the solar year as shown in *Section 1.1*.

In *Section 2*, we describe why the use of *Culasakaraj* in the Thai lunar calendar is no longer valid. We re-establish the wisdom of our *Suvarnabhumi* ancestors and incorporate it into the Gregorian calendar in order to determine an *Adhikamat* year. We name the resulting combination the ***Suvarnabhumi-Gregorian* rule** which provides two advantages: The Thai lunar calendars, like the Gregorian calendar, will be closely synchronized with the seasons; and we can maintain the traditions. An *Adhikavara* year can be assigned using the NASA information.

2. MATERIALS AND METHODS

Before we can apply the *Suvarnabhumi-Gregorian* rule to determine the *Adhikamat* year of 2012, we must demonstrate how the *Culasakaraj*-based Thai lunar calendar is no longer valid; and how continuing to use it will cause more harm than good. Qualitative analysis of information will be conducted based on the following questions:

I. Is it suitable for the Thai lunar calendar to be synchronized with the Indian sidereal calendar?
II. Is there any drawback in using a year length of 365.25875 as in *Culasakaraj* calendar in the Thai lunar calendar?
III. Why does the Thai lunar calendar add a leap month to the 8th month?
IV. How accurate when using data of new moon and full moon from NASA to set an *Adhikavara* year?
V. What advantages to employ the *Suvarnabhumi-Gregorian* rule for an *Adhikamat* year?

Once the above questions are answered, we will establish the four *Suvarnabhumi-Gregorian* conditions as a rule to determine an *Adhikamat* year, which combine rules from the Thai astrologer group and the scholar group.

2.1 Synchronization of Thai Lunar Calendar with Indian Sidereal Calendar

The *Suvarnabhumi* calendar was synchronized with the seasons corresponding to the length of the tropical year. The *Culasakaraj*-based Thai lunar calendar matched the *Suvarnabhumi* calendar with the sidereal year as used in the *Darakhati India* calendar. We will determine and compare the accumulating drift in 800 years when synchronize the *Suvarnabhumi* year with the tropical year in *Section 2.1.1* and with the Indian sidereal year in *Section 2.1.2*.

2.1.1 Synchronize *Suvarnabhumi* year with tropical year

The Gregorian calendar, an internationally accepted calendar for civil and scientific purposes, is a solar calendar that has the closest approximation of year length to the mean tropical year of 365.242199 days. It has a cycle of 400 years (146,097 days). The average year length is 146,097 ÷ 400 = 365.2425 days [4]. One synodic month is 29.530588 days on average. The length of the lunar month is not an even fraction of the length of the tropical year. As a result, a purely lunar calendar will quickly drift away from the seasons [22].

Throughout history, the *Suvarnabhumi* people used their calendar to help them plan for rice cultivation by observing astronomical phenomena cycles. One *Suvarnabhumi* lunar year has 354 days. They regularly noticed that the rising of the Moon did not precisely match with their calendar and also shorter than a solar year, *i.e.*, 11 days shorter of the 365-day solar year. Therefore, in approximately three years there is a difference of more than one synodic month between the lunar and the solar year. In this case, every two or three-year intervals, the ancient *Suvarnabhumi* added a thirteenth intercalary month (a leap month of 30 days) to the lunar year to form the 11-year-cycle (<u>3332</u>: as the 3rd, 6th, 9th, and 11th year each has 13 months) and the 8-year-cycle (<u>332</u>: as the 3rd, 6th, and 8th year each has 13 months). The years outside these cycles are regular years with 12 months each. Occasionally, previous two cycles form a 19-year Metonic cycle (<u>3332</u> <u>332</u>: equivalent to seven leap-month-lunar-years).

In the 19-year-cycle, the lunar and the solar can be perfectly matched at the length of 6,939 or 6,940 days[1]. Since an *Adhikamat* year has 384 days, whereas a regular year has 354 days, after adding seven leap months to this cycle (which is found to be 6,936 days[2]), it is still three or four days shorter than the

[1] 19 solar years = 19 x 365.242199 = 6,939.601781 days
235 lunar months = 235 x 29.530588 = 6,939.68836 days
[2] (12 regular years x 354) + (7 Adhikamat years x 384)

solar cycle. In order to match the full moon in the *Suvarnabhumi* calendar (Thai lunar calendar before 638 AD) with the actual full moon, the ancient people also added a leap day (known as an *Adhikavara* year) three or four times per cycle. Thus, the *Suvarnabhumi* calendar always coincides with a solar (tropical) year. Continuing the calculation for 800 years, it was found that there is a total of 292,194 days (= 800 × 365.2425) by Gregorian calendar covering 294 *Adhikamat* years and 155 *Adhikavara* years in the *Suvarnabhumi* calendar [23].

2.1.2 Synchronize *Suvarnabhumi* year with *Darakhati India* sidereal year

"***Darakhati India***" called by Thai people refers to the Burmese calendar that adapted from the *Surya Siddhanta* system of ancient India and merged with a 19-year intercalation schedule (Metonic cycle) [24]. It is unclear from where, when or how the Metonic system was introduced. However, it is believed that this system came from the *Suvarnabhumi* calendar system. This Burmese calendar, thus, used a "strange" combination of sidereal years from the Indian calendar with the Metonic cycle [25]. King Popa Saw Yahan then synchronized the *Suvarnabhumi* calendar to this 800-year *Darakhati India* as he believed it was the most accurate one for holy days, harvest, and so on.

As mentioned previously in *Section 1.1*, a sidereal year length is equal to 365.25636 days, which is a small amount longer than the solar year. Before the discovery of the precession of the equinoxes by Hipparchus in the Hellenistic period, the difference between the sidereal and the solar year was unobserved by ancient people. For naked-eye observation, the shift of the constellations relative to the equinoxes only becomes apparent over centuries. However, the fact that the sidereal year is nearly 24 minutes longer than the tropical year, eventually all sidereal-based calendars will slowly drift away from the seasons. Synchronizing the *Suvarnabhumi* calendar, by inserting intercalary months and days on the Metonic cycle, with the 800-year sidereal yields a total of 292,205 days (≈ 800 × 365.25636) which includes 295 *Adhikamat* years and 155 *Adhikavara* years. The total number of days in the 800-year sidereal are only 11 days longer than that in the 800-year solar (292,205 − 292,194 = 11), but there is one more *Adhikamat* year. In other words, there are at least 30 days that the Thai lunar calendar does not coincide with the seasons.

Synchronizing the Thai lunar calendar to the sidereal year will gradually shift the calendar away from the actual seasons, with potentially disastrous consequences for farmers. This may be the reason why the *Sukhothai* Period, when the *Culasakaraj* calendar was initially introduced, saw many famines. The *Sukhothai* people had adjusted their calendar frequently to coincide with the *Suvarnabhumi* calendar in order to set the right time for rice-planting. It is therefore better to synchronize the Thai lunar calendar to the solar year and to avoid the sidereal year calendar altogether.

2.2 Effect of Applying 365.25875-day Year in Thai Lunar Calendar

Most Thai astrologers follow the *Culasakaraj* system, which is influenced by and therefore has to reconcile with the 800 *Darakhati India* years as tabulated in comparison in Table 1.

Table 1. Comparison on the New Year's Day between the *Culasakaraj* calendar and the *Darakhati India* calendar for 800 years.

CS (BE)	Gregorian Dates and Times for New Year's Day (in AD)	
	Culasakaraj calendar	*Darakhati India* calendar
0 (1181)	March 25, 638 at 11:11:24	March 25, 638 at 11:11:24
1 (1182)	March 25, 639 at 17:24:00	March 25, 639 at 17:20:34
⋮	⋮	⋮
775 (1956)	April 6, 1413 at 23:56:24	April 5, 1413 at 3:32:30
⋮	⋮	⋮
799 (1980)	April 7, 1437 at 4:58:48	April 5, 1437 at 7:12:25
800 (1981)	April 7, 1438 at 11:11:24	April 5, 1438 at 13:21:35

From Table 1, the 800-year *Culasakaraj* calendar is about two days longer than the 800-year *Darakhati India* calendar. As the total days in 800-year CS (292,207) is two days more than that in the *Darakhati* (292,205), resulting in 365.25875 days per CS year. Therefore, the *Culasakaraj*-based Thai lunar year is longer than the sidereal year causing even more drifts from the solar year. Furthermore, King Popa Saw Yahan used this number to calculate the New Year's Day, which moved towards May. In the long term, the calendars are drifting one day approximately every 60 years and 4 months. As a result, the CS New Year will move towards the rainy season. We might have to celebrate the *Songkran* Festival in the rain. Consequently, it was suggested that the Thai lunar calendar must avoid using *Culasakaraj* system to be any reference or to adjust an *Adhikamat* and *Adhikavara* year.

2.3 Adding a Leap Month to the 8th Month

Although the ancient *Suvarnabhumi* people did not have any calendars or adjusting instruments that we do today, the ancient astronomers used a variety of methods that can be applied across cultures and time periods. They connected the sky with the cycles of nature for its relationship with agriculture. As previously mentioned, the timing between the Moon and the Sun are different. To keep the lunar years in sync with the actual seasons, these people added an extra 30-day month to the 8th month or added an extra day to the 7th month. Why they had to add a leap month only to the 8th month in an *Adhikamat* year? Is it possible or suitable to add to another one? For a better understanding, we compared the dates by converting to the Gregorian calendar. The answers to why it has to be the *Double*-8th month in an *Adhikamat* year are discussed in the next section.

2.3.1 Conditions for continuity of *Suvarnabhumi* seasons

The intended use of the *Suvarnabhumi* lunar calendar is to keep track with the seasonal year for their agriculture cultivation, rice in particular. Therefore, the common year of the *Suvarnabhumi* lunar calendar coincides with the seasons as follows: The end of the 1st month is in mid-winter; the waning moon of the 3rd month is the start of summer; the waxing moon of the 5th month is in mid-summer; the waning moon of the 6th month is the start of the rainy season; the waning moon of the 8th month is during heavy rainfall (desirable for rice cultivation); the waning moon of the 12th month is the start of winter. The 8th month is the most important month for rice cultivation. Rice seedlings need to be exposed to the heavy rainfall in order to be ready for harvesting by the mid-11th month. Figure 1 shows dates in the Gregorian calendar that are related to the Sun's declination. In order to ensure that each lunar month falls during the same *Suvarnabhumi* season every year, all three specific lunar dates—that can precisely be observed with the particular angles of sunrise at south solstice (23.5° S), equinox (0°), and north solstice (23.5° N)—must meet the following conditions as shown in Table 2.

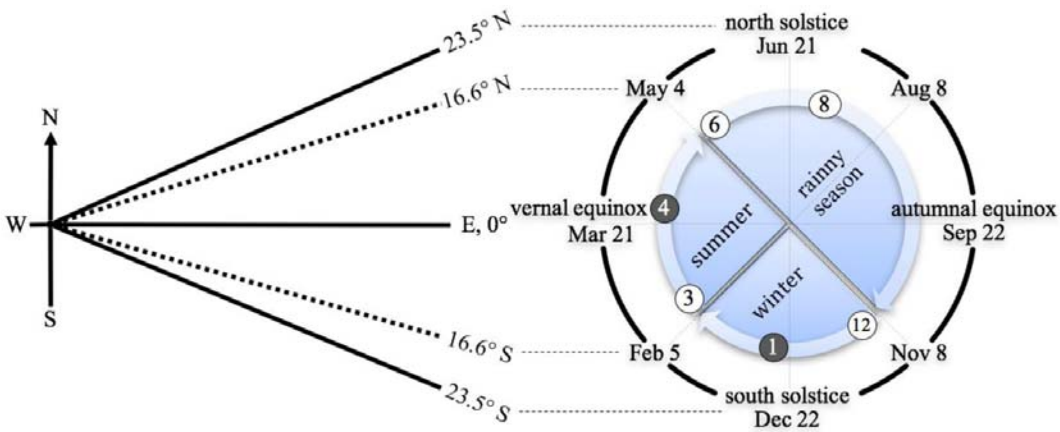

Figure 1. Diagram shows the Sun's declination and the *Suvarnabhumi* seasons with corresponding to Gregorian date. The circled number indicates the lunar month, while ◯ and ⬤ represent full moon and new moon, respectively. (❶, ❹ and ⑧ referred in Table 2; and ⑫, ③, ⑥ and ⑧ referred in Table 3).

Table 2. The Conditions to determine the lunar calendar hold on to the seasons.

Date of lunar calendar	Sunrise at	Gregorian date Conditions	
		Satisfied	Unsatisfied
14th waning moon and new moon, 1st month	south solstice	After December 22	Before December 23
15th waning moon, 4th month	vernal equinox	After March 21	Before March 22
15th waxing moon and full moon, 8th month	north solstice	After July 2	Before July 3

2.3.2 Signs of natural occurrence for *Adhikamat* year

To synchronize the signs of nature in *Suvarnabhumi* seasons with their calendar, they observed various natural events occurring at the full moon day of each month as detailed in Table 3. The data in Table 3 also provide conditional dates to determine an *Adhikamat* year in the Gregorian calendar.

Table 3. Nature signs of the *Suvarnabhumi* seasons with Gregorian date conditions.

Full moon of	Corresponding season	Nature phenomena with Gregorian date condition	
		Regular year	*Adhikamat* year
12th month (a year before)	rainy season ends then winter or northeast monsoon season begins	- occurs after November 8 (a year before) - north-easterly wind, cold air from China, begins	- occurs before November 9 (a year before) (sign #1) - happens in advance of winter - north-easterly wind does not blow yet
3rd month	winter ends then summer or pre-monsoon season begins	- occurs after February 5 - mango tree or "*Mamuang Kalon*" (*Mangifera caloneura* Kurz) flowers in full bloom - a rain (of January-March period) during the flowering season to wash off the flowers	- occurs before February 6 (sign #2) - happens in advance of summer - mango tree is not in full bloom - no rain washes the flower off
6th month	summer ends then rainy (southwest monsoon) season begins	- occurs after May 4 - soapberry (*Sapindus emarginatus* Wall) flowers	- occurs before May 5 (sign #3) - happens in advance of the rainy season - soapberry does not begin flowering
8th month (first full moon after south solstice)	during the peak of rainy season (heavy rainfall)	- occurs after July 2 - bungor or "*Ta Bek*" (*Lagerstroemia floribunda* Jack which is the tropical flowering tree) flowers in full bloom - during heavy rainfall	- occurs before July 3 (sign #4) - happens in advance of heavy rainfall - bungor flower is not fully bloom

The *Suvarnabhumi* people observed these natural events for their rice cultivation. In *Suvarnabhumi*, there are varieties of rice, which are based on hydrological characteristics, such as upland rice, lowland rice, dry (off)-season rice, wet-season rice [26]. Especially for wet-season rice, the seeding must start in seeding beds before the full moon of the 6th month which have been flooded by rain. Seedlings later on are transplanted by hand to the fields before the full moon of the 7th month and must finish before the full moon of the 8th month. After that there are heavy rainfalls; the rice plant then grows in flooded soil during the green season through to September (from booting stage in the 9th month to heading and flowering stage in the 10th month). The rice turns from emerald to darker green and finally to dry gold under the strong sunray. Between the full moon of the

11th and the 12th month, it is ready to be harvested. One of the most important factors for rice cultivation is to have enough water in rice fields by observing a heavy rainfall in the 8th month. Rainy season is the most important nature signs for the farmers. They had noticed lunar phases, seasons, and trees as four full-moon signs shown in Table 3. It is worth noting that these signs are simply derived from the three conditions in a regular year given in Table 2. The four full-moon signs here triggered the farmers to add an extra 8th month in an *Adhikamat* year. The Buddhist festivals would be moved to one month later; for example, *Visakha Puja* Day would be moved to the full moon of the 7th month instead. The *Double*-8th month would then fall on the heavy rain season as desired.

2.3.3 *13-dark moon impending 13-full moon*

As the Moon orbits the Earth, its position relative to the Earth and Sun changes, and the Moon appears to go through phases. When the Earth sits between the Moon and Sun, people on Earth see a full moon at night. On the other hand, when the Moon sits between the Earth and the Sun or when the Moon and Sun are in conjunction, people on Earth will see no moon at night. This lunar phase according to the NASA is called **new moon**, which we will refer to as "**dark moon**" according to the *Suvarnabhumi* people.

In addition to the previous observations, the ancient people also noticed for 13 dark moons in one tropical year in between two south solstices, which in turns resulted in the 13 full moons in between two north solstices that followed. This nature rule is known as "***13-dark moon impending 13-full moon***", and is the most important rule to abide, as the ancient *Suvarnabhumi* people believed that nature had given back the missing month. In practice, there are normally 12 dark moons in between two successive south solstices (from December 23, Y−1 to December 22, Y, see bold line in Figure 2), but sometimes there is another observed dark moon of the 1st month within 11 days before the south solstice (December 12-22, Y) as shown graphically in Figure 2. Then, the full moon of the 8th month must be observed within 11 days after the north solstice and this 8th month is set as a leap month for an *Adhikamat* year. Thus, this full moon is referred as the 13th full moon of a tropical year starting from an 11-day-after-north solstice to the next one (from July 3, Y to July 2, Y+1, see bold dashed line in Figure 2), which already has 12 full moons.

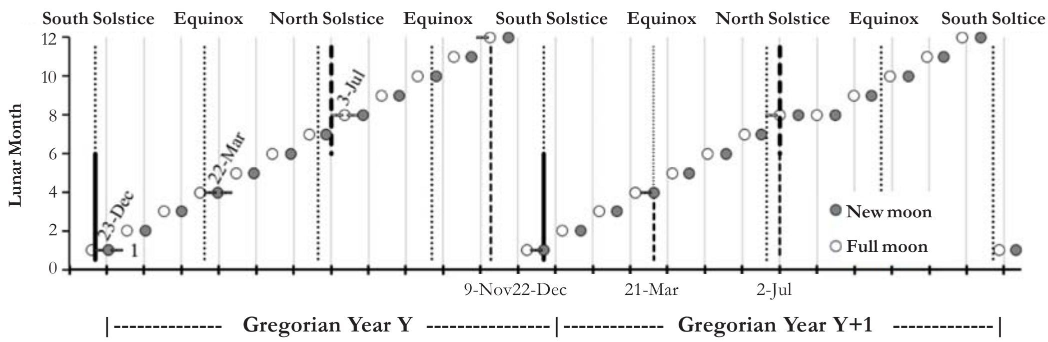

Figure 2. Graphic representation of the event of *13-dark moon impending 13-full moon*. Three specific lunar dates referred in Table 2 must occur after those three dates as shown diagonally. The full or new moons that occur before those four dates as shown in the horizontal axis are the *Suvarnabhumi-Gregorian* conditions (referred in Table 4).

The Lua, an ancient *Suvarnabhumi* tribe, made use of the *Inthakin* Pillar (city pillar) and *Chaeng Sri Phum* (northeast corner of Chiang Mai city wall) as the instruments for adjusting their calendar to synchronize with the solar year by observing the north solstice. If they saw a full moon appeared after that within 11 days, this lunar year must add a leap month. These ancient astronomers can predict the 13 full moons coming in the next two successive north solstices as they already counted a total of 13 dark moons occurred that year.

Attempts to retain the appropriate season for rice cultivation at each stage and the fact that the most desirable season is the heavy rainfall season which falls on the 8th month are the reasons why the focus is on the 8th lunar month. More importantly, nature itself as described in the *13-dark moon impending 13-full moon* rule do give back an extra full moon around the 8th month as well. It is thus natural and undeniable why the leap month is the 8th month. Nonetheless, some tribes in *Suvarnabhumi* had chosen other leap month instead of the 8th depending upon which rice stage they gave more priority.

2.4 Using NASA Data for Calculating of *Adhikavara* Year

The ancient *Suvarnabhumi* civilization developed in the tropics. Examples of this civilization include Angkor Wat in Cambodia [27]; Wat Pra Yeun in Lamphun [5]; the *Inthakin* Pillar and *Chaeng Sri Phum* in Chiang Mai; and Wat Xieng Thong in Luang Prabang, Laos. These cultures had zenith passages that only occur in the tropics [28]. These ancient *Suvarnabhumi* were able to see the Moon and the Sun all year round. Thus, these ancient timekeepers were able to differentiate between the actual full moon in the sky and the one on their calendar. Moreover, these people had witnessed lunar eclipses at least twice a year and found that this phenomenon only occurred on a perfect full moon, while a solar eclipse occurred only on a perfect new moon. A full moon is the lunar phase that occurs when the Moon is completely illuminated as seen from the Earth. It rises in the East almost the same time that the Sun is setting.

The observers noticed that a full moon in the sky did not appear as it should because the *Suvarnabhumi* lunar calendar has alternating months of 29 days in the odd months and 30 days in the even months, yielding the average lunation length equals to 29.5 days which is slightly shorter than the mean synodic month by 29.530588 − 29.5 = 0.030588 day. When they found that their calendar's full moon (15th waxing moon) occurred before the actual one by more than one day and that year was not an *Adhikamat* year then they would add one extra day to a hollow month (29-day month). As mentioned in *Section 2.3.2*, the *Suvarnabhumi* people were rice farmers who linked their calendar with the seasons by adding the leap month to the 8th month. Thus, in order to adjust their full moon of the 8th month to be coincide with the actual full moon, the extra day of 15th waning moon was added to the 7th month as it is the closest month to the 8th month. The year, which the hollow 7th month become a full month of 30 days, is then called an *Adhikavara* year.

The complexity of calendars arises because astronomical cycles are neither constant nor perfectly commensurable with each other. The acceptance of the Gregorian calendar as a worldwide standard has spanned more than three centuries, however, astronomical cycles are not absolutely constant, and they are not known exactly. In the long term, only a purely observational calendar maintains synchrony with astronomical phenomena, even though it exhibits short-term uncertainty, because the natural phenomena are complex and the observations are subject to error. To adjust the Thai lunar calendar using the lunar phases data from NASA, we set the 14th waning moon of the 7th month every year as a dark moon that must occur before the new moon as defined by NASA data; except for an *Adhikamat* year, we set the 15th waxing moon of the first 8th month instead. This way we will have dark moons and full moons matches with actual ones and they are necessary for utilizing the *13-dark moon impending 13-full moon* rule as well.

Moreover, using the new moon data from NASA and using the same characteristic with *Suvarnabhumi* calendar as a reference will be more acceptable for both astrologers and academic scholars.

2.5 *Suvarnabhumi-Gregorian* Rule for *Adhikamat* Year

Regarding the Gregorian calendar as the most internationally accepted for its synchronization with the seasons, we adapt it in accordance with the observations discovered by the ancient *Suvarnabhumi* (as listed in Table 2 and 3) and arrive at the criteria to determine an *Adhikamat* year. We call these sets of criteria the ***Suvarnabhumi-Gregorian* rule**. In order to determine whether the year is an *Adhikamat* year, all four conditions as listed in Table 4 must be satisfied in successive orders. The lunar dates or the lunar phases in Table 4 refer to the actual ones in the sky.

Table 4. Four conditions of the *Suvarnabhumi-Gregorian* rule.

Condition	Thai lunar date/ NASA lunar phase	Gregorian date conditions for *Adhikamat* year
1	15th waxing moon, 12th month/ full moon	Before November 9 (a year before)
2	14th waning moon, 1st month/ new moon	Between December 12 and 22 (a year before)
3	15th waning moon, 4th month/ new moon	Before March 22
4	15th waxing moon, 8th month/ full moon	Between June 22 and July 2

Condition 3 is to mark the 15th waning moon of the 4th month must occur after the vernal equinox (March 21) as the first new moon. The Gregorian calendar also marks this equinox as the reference for adjusting their calendar every year including a leap year. **Condition 2** and **4** are the conditions that retain the *Suvarnabhumi* calendar with the astronomical seasons. These criteria have cropped the new moon of the 1st month and the full moon of the 8th month always occurs within 11 days before the south solstice and after the north solstice, respectively.

We have demonstrated and pointed out drawbacks of using the *Culasakaraj*-based Thai lunar calendar to determine an *Adhikamat* and an *Adhikawara* year. The calendar does not match the actual seasons because it is synchronized to the sidereal year rather than the solar year. It will eventually drift away from the natural seasons and no longer serve as a useful reference for agricultural cultivation. The ancient wisdom of *Suvarnabhumi* is much more suited for cultivation purposes because the region's people have synchronized their calendars with the natural seasons for generations. By combining this ancient knowledge with modern knowledge and the globally accepted Gregorian calendar, we have a rule for determining an *Adhikamat* year, which we name the *Suvarnabhumi-Gregorian* rule. We suggest that the NASA information is used for determining an *Adhikawara* year.

3. RESULTS AND DISCUSSION

The *Suvarnabhumi-Gregorian* rule for *Adhikamat* year provides two advantages: The Thai lunar calendar will be closely synchronized with the solar seasons similar to the Gregorian calendar, and we can hold onto the traditions for Thai astrologers. The rule harmoniously combines rules from both Thai astrologers and academic scholars. The rules maintained from the former group are 1) setting 29-day odd month and 30-day even month, 2) adding a leap month to the 8th month and 3) adding a leap day to the 7th month. For the latter group, the calculation is based on the new moon and full moon data sourced from NASA referring to the Gregorian calendar.

3.1 Determine *Adhikamat* Year in 2012

We will demonstrate how to apply the four ***Suvarnabhumi-Gregorian*** conditions to determine the year 2012 for *Adhikamat*. By using the Thai Calendar year 2011 and 2012, those conditions can be examined in Table 5.

Table 5. Identify the year 2012 to the four *Suvarnabhumi-Gregorian* conditions.

Condition	Thai lunar date / NASA lunar phase	Gregorian date / Date and time (Universal Time)	Satisfy condition
1	15th waxing moon, 12th month	November 10, 2011	No
	full moon	November 10, 2011 at 20.16	(Before November 9?)
2	14th waning moon, 1st month	December 24, 2011	No
	new moon	December 25, 2011 at 6.10	(Between December 12-22?)
3	15th waning moon, 4th month	March 22, 2012	No
	new moon	March 22, 2012 at 14.37	(Before March 22?)
4	15th waxing moon, 8th month	July 3, 2012	No
	full moon	July 3, 2012 at 18.52	(Between June 22-July 2?)

The results show that none of the conditions are satisfied. So, it can be concluded that the year 2012 is not an *Adhikamat* year. This answer coincides with the academic group and is confirmed by the mango tree (referred in Table 3) as the *Suvarnabhumi* people have been using signs from nature, sunray, and lunar phase to check for an *Adhikamat* year since several thousand years ago.

3.2 Discussion of Conditions Defining *Adhikamat* Year

The conditions to be an *Adhikamat* year can only be fulfilled with evidence of the event of *13-dark moon impending 13-full moon*. For all four conditions presented, each can be discussed as follows:

– **Condition 1** is a warning condition if the full moon of the 12th month occurs before November 9. This will force the new moon of the coming 1st month to be before the mid-winter. Then, the full moon of the 3rd month will occur before the beginning of summer. This is why some years the Thai lunar calendar moves the *Magha Puja* Day (full moon, 3rd month) to the next one of the 4th month.

– **Condition 2** is the condition that fixed the Thai lunar calendar with the seasonal year (using Gregorian calendar). If the new moon of the 1st month occurs between December 12 and 22 (before or on the south solstice). It shows that the calendar is faster than the seasonal year then it needs to add one more month to that lunar year.

– **Condition 3** is also a warning condition if the new moon of the 4th month occurs before March 22 (before or on the vernal equinox). This will force the waning moon of the 6th month to be before the beginning of the rainy season. This is why some years the Thai lunar calendar moves the *Visakha Puja* Day (full moon, 6th month) to the next one of the 7th month.

– **Condition 4** is also the condition that fixed the Thai lunar calendar with the seasons. If the full moon of the 8th month occurs between June 22 and July 2 (11 days after the north solstice), which will occur before the heavy rains start. The calendar needs to add one more lunar month to the 8th month and that is an *Adhikamat* year. This is why some years the Thai lunar calendar moves the *Asalha Puja* Day (full moon, 8th month) to the next one which is called the *Double*-8th month (or noted as "88").

By comparing the Thai lunar calendar to the Gregorian calendar, the four conditions of the ***Suvarnabhumi-Gregorian* rule** describe the relations of the timing that are easily observable and recognizable for international researchers. Three important issues can be gained from this rule.

1.) Currently, the Thai lunar calendar is based upon on *Culasakaraj*, such calendars are known as Burmese calendar, which was adapted from the Hindu calendar. As mentioned in *Question I* and *II*, its average year length is longer than the tropical (solar) year. The lunar calendar and the tropical year do not match up very well. Many times, the full and dark moon days of the Thai lunar calendar do not coincide with the actual moon. **Condition 2** and **4** can solve this variation and keep the Thai lunar calendar aligned with, and adjusted to, the tropical year. Thus, the full and dark moon days of the Thai lunar calendar will be aligned with the actual lunar phases. These two conditions will confirm when the Thai lunar calendar needs a leap month added to an *Adhikamat* year. In the long term, the average year length of the Thai lunar calendar will be equal to the mean tropical year.
2.) The goal of having **Condition 3** is to sync the Thai lunar calendar with the solar calendar (being the Gregorian calendar) by referring to the vernal equinox. If the new moon of the 4th month occurs after this equinox then it can correct the accumulating error and fix the average year length to be nearly equal to the tropical year.
3.) When the full and dark moon days of the Thai lunar calendar do not coincide with the actual moon up to two days and **Condition 2** and **4** are not satisfied, then the calendar needs a leap day added to that year as an *Adhikavara* year.

As analysis from the three issues, the Thai calendar currently is a Buddhist calendar in which the months are based on lunar months (*Culasakaraj* or Burmese calendar) and years are based on solar year (Gregorian calendar). One of its primary objectives is to synchronize the lunar part with the solar part (seasonal). Because of the inaccuracy of the calendric calculation systems, the average and the actual full and new moons rarely coincide. The lunisolar calendars are slowly drifting away from the seasons as the time goes by. The accumulating drift against the seasons means the New Year's Day (*Songkran* Day) which used to fall on March 22 (Julian calendar; near the vernal equinox) in 638 AD, but now falls on April 16 in 2012 AD, and in the long term, will fall on the rainy season or even winter. There is no known internationally concerted effort to stop this drift. Fortunately, the introduced *Suvarnabhumi-Gregorian* conditions for checking an *Adhikamat* year can stop the drift and use as a guide for developing the future Thai lunar calendar to be perfectly coincided with the seasons.

4. Conclusions

In year 2012, there was an argument between academic scholars and Thai astrology group whether that year is an *Adhikamat* year. Through in-depth studies of the calendric calculation systems and their history, we find that each group bases its argument in different systems, as discussed through the five questions. In order to settle the conflict, we arrive at the *Suvarnabhumi-Gregorian* rule. The rule is a combination of knowledge bases from both the astrology practitioners, who are accustomed to the *Suvarnabhumi* calendar, and the academics, who are engaged in present-day calculations.

The summary of our findings through five research questions are as follows:

- **Referring to *Question I*** :
  The current Thai lunar calendar should stop utilizing the *Culasakaraj*. The *Culasakaraj* is based on a sidereal calendar which slowly drifts from the seasons over times. The Thai lunar calendar should be synchronized with the solar calendar instead like in the internationally accepted Gregorian calendar.

- **Referring to *Question II*** :
  It is confirmed that the Thai lunar calendar should stop basing their festivals and holy days on the *Culasakaraj*, especially, the *Songkran* Festival. Otherwise, in the long term, Thai people would be celebrating the Water Festival during the rainy season or even winter.

- **Referring to *Question III*** :
  The ancient *Suvarnabhumi* added one extra 8th month to an *Adhikamat* year because they wanted to adjust the calendar for rice cultivation. Growing rice at appropriate conditions given by the seasons would result in high yield. The 8th month is a heavy rain season which is very important stage for rice vegetation. They observed signs from nature, lunar phases with corresponding to the north and south solstice, and the event of *13-dark moon impending 13-full moon* to determine an *Adhikamat* year.

- **Referring to *Question IV*** :
  Using the NASA new moon and full moon data as a reference for checking an *Adhikavara* year, the full and dark moon days on the Thai lunar calendar can be adjusted to coincide with the actual moon phases.

- **Referring to *Question V*** :
  The *Suvarnabhumi-Gregorian* conditions are established to confirm an *Adhikamat* year. This astronomical rule is consistent with the corrected data of lunar phases from NASA used by academic scholars; furthermore, it remains the *Suvarnabhumi* calendar system used by the Thai astrologers.

The new way to develop the future Thai lunar calendar is suggested as follows:

1.) A new version of Thai lunar calendar is recommended using the *Suvarnabhumi-Gregorian* conditions for checking an *Adhikamat* and *Adhikavara* year. It is named "international-based Thai lunar calendar" by Smai Yodintra.

2.) The *Songkran* Festival, which is assigned to the rising of Aries on the astrological chart as in the *Culasakaraj*, should be in keeping with the Gregorian calendar by fixing the April 13 as a date for *Songkran*.

In conclusion, the Thai lunar calendar has to reconcile to the *Suvarnabhumi* calendar system and make it more accepted worldwide by adding the Gregorian calendar to it. The *Suvarnabhumi* calendar combines lunar and solar calendars with observations of nature and is suitable for use in the *Suvarnabhumi* region.

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