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ABC of the Sukuma Calendar

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Abstract: The aim of this study had been to document and to astronomically mimic in an algorithm the undocumented ancient lunar calendar of the Sukuma and that of the Nyamwezi sibling tribe of Tanzania which is at the verge of perishing due to the perishing of living memory about that calendar. It had been found that the Sukuma calendar marks its end of the sidereal year at the Sukumaland "Jidiku" position of Earth in its trajectory around the Sun which is the December Solstice astronomically fitting on the Gregorian 23rd December. The stereotype is that the ancient Sukuma of Kishapu tallied up the elapsing days since the first appearance of the "ndimila" on the horizon day-to-day using 64 pebbles to get to the "Jidiku" and later developed that method of tallying days into the fully fledged "isolo" game of counting pebbles. Subsequent to the determination of the "Jidiku" position, the algorithm to compute the Sukuma lunar New Year was developed basing on the technique of computing the Jewish calendar in essence whereby the number of lunar-tagged days elapsed to the beginning of a 19-year lunar cycle since 01st January year 0000 get compared with the number of solar days elapsed to the beginning of a 19-year Gregorian cycle since 01st January year 0000 to get the difference in number of days short to the next new moon which mark the Sukuma lunar New Year lying between 23rd December and 22nd January. By adding the number of days short to the next new moon at the beginning of a 19-year Gregorian cycles to a series-tagged increment of days - which is a product of 19 and a within-cycle-relative year of the running year (lying between 0 and 18) - the within-cycle lunar New Year gets computed. The lengths of the consecutive lunar months between two consecutive Sukuma lunar New Years were found to fit in a model of repeating 30-to-29 days. It was further found that the Nyamwezi lunar New Year falls one lunar month before the Sukuma lunar New Year and that a Nyamwezi lunar New Year within a 19-year Gregorian cycle is gotten by adding a series-tagged decrement of days - which is a product of 11 and a within-cycle-relative year of the running year - to the begin-of-cycle number of days short to the next new moon.

Keywords: Ndimila, Sukuma, Sukumaland, Sukuma Calendar, Sukuma New Year, Nyamwezi, Unyamwezi, Nyamwezi Calendar

1. Introduction

The Sukuma or Wasukuma, a folk which inhabits Sukumaland, speak Sukuma or Kisukuma. They are the ethnic majority of Tanzania and a sibling tribe to the Nyamwezi or Wanyamwezi, the tribe neighboring the Sukuma in the South. As to the difference and similarity between these two tribes, some authors describe the difference between the two by saying that the Nyamwezi speak a soft accent of Sukuma (Bukurura et al., 1995). The two tribes differentiate from each other basically relying on the geographic location of the other, e.g. the Nyamwezi call the Sukuma as people of the North which is the real meaning of the name of the tribe being referred to in Kisukuma or Kinyamwezi (Bukurura et al., 1995). The two tribes belong to the Bantu group which is believed to have migrated from Central Africa to settle in Tanzania about 3000 years ago (Adler et al., 2007).

Geographically, on the map of Tanzania, Sukumaland extends southwards from Lake Victoria to cover 4 administrative regions: Geita, Mwanza, Shinyanga and Simiyu whereas the Nyamwezi inhabit the Tabora administrative region South of Sukumaland (Law et al., 2015).

In terms of culture, the Sukuma and the Nyamwezi share an inclination to a camaraderie behavior of organizing big festivals which attract attention beyond the borders of an administrative district. Food and shelter is a communal issue during a Sukuma-Nyamwezi festival. They like harmonious singing alongside harmonious dancing and swaying as well as flavoring their festivals with harmonious drum beats for recreation and for purposes like thanks giving during and after the harvest season as well as for flavoring wedding ceremonies, etc.

Speaking about Sukumaland alone, a festival is a grand slam – it is a fight for spectators. There are about 7 established dancing lines namely: “beni”, “bugobogobo”, “bugoyangi”, “bununguli”, “buyeye”, “mahia”, and “wigashe”. The pallet of flavor of the offers from these dancing lines is very diverse, for example: the “bununguli” line will mimic the porcupine in their stage costume with spikes and will mimic the hunting of the porcupine during their performances whereas the “bugoyangi” line will stage their best skills to play with snakes in terms of commanding them and keeping them as well as petting them to attract as many spectators as possible during the competition. The “bugobogobo” line will portray a show of twirling the hoe whereas the “buyeye” line will stage a master work in playing the monochord (“ndono” in Kisukuma) and the xylophone (“malimba” in Kisukuma) as well as stage a flamboyant sort of belly dance of whirling their lower backs in the rhythm of their playing instruments.

The most exciting line out of the Sukuma dancing lines is the “beni” line. “Beni” is so well organized and outraging in that it has got two rival groups “bugika” and “bugalu” which actually stage a competition of the two within a grand slam. The structure of “beni” is so well organized with a conductor (“ningi” in Kisukuma) at the helm. “Beni” is performed in harmonious singing alongside dancing and swaying with a flavor of drum beats escorted with episodes of acrobatic performances and a show of grotesque masks and magic rituals. Whereas the drum master (“mahalila” in Kisukuma) will keep the order of the drum orchestra and command the gig of the biggest drum called ‘ihama’ in Kisukuma, his subordinates will command the other relatively small drums called “ndundu” and “lugeto”. Whereas “beni” is played by the teens and the middle-aged including single ladies in standing, “wigashe” is an affiliated line of “beni” played by the elderly in sitting hence the name “wigashe” to mean in sitting style. “Beni” is customary staged on the 5th day of a lunar month to culminate into a stunningly exciting competition on the 14th day to be in line with the Sukuma rule of lunar festivals which provides that a climax of a festival should take place a day before the moon starts to raise (dread monkeys). That rule has moon light implications as to the tradition of “chagulaga” especially whereby an opportunity for the single girls and lads to court publicly after the dancing sessions shortly before dusk offers itself – the girls will start running wildly heading for home knowing that the lads will be after them to start the morally accepted Sukuma-art-of-courting competition when they finally compromise a way to attract the crowd of lads crying “chagulaga mayu” to mean “select me madam”.

It is believed that the Sukuma developed the Sukuma calendar primarily to track the rain season as well as to track time for their cultural festivals about 5776 solar years ago. Quite astronomical and notable, the Sukuma developed the skill to track the end of the sidereal year by tracking the position of the Sukumaland-famous constellation of stars called “ndimila” to mark the Sukuma lunar New Year at the earliest new moon at “Jidiku”. It is because of the “ndimila” that the given name “Ndimila” has become widespread in Sukumaland. In his book "Moral Power - The Magic of Witchcraft", Koen Stroeken is implicitly describing the sidereal New Year of the Sukuma calendar to primarily be anchored to a predetermined position of the “ndimila” in the course of its movement in the firmament since its first appearance on the horizon in October (Stroeken et al., 2012).

Between science, superstition, and magic practices of the Sukuma: the ancient Sukuma of Kishapu in the administrative region of Shinyanga are said to have strongly believed in the supernatural powers of magic practitioners to conjure rainfall and thunder. Although the state of the horizon and the firmament is relative with respect to location and period of the year, but as soon as the “ndimila” appears on the horizon of Sukumaland in October / November, the ancient rainfall conjurers (called “nfuti o mbula” or “o magobho” in Kisukuma) are said to have begun to assemble their traditional utensils to track that cluster of star as it was a great honor to them to tell when the rain season would start as well as a great honor to them to conjure rainfall when the society believed it was long overdue. They are reported to have reliably used a shadow clock (fig. 1) and a row of 12 clay pots filled with water to make pots of a distinct chronological array in water level (fig. 2) to track the turn of the solar likewise sidereal year towards the beginning of the rain season believed to be at around 23rd December on the Gregorian calendar.

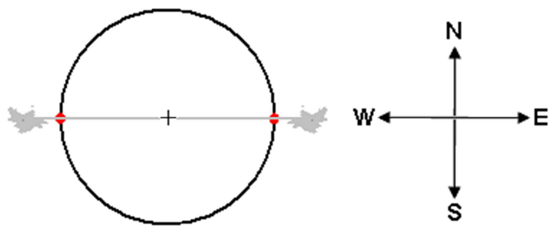

Fig. 1. *Sukuma Shadow Clock with the “Nsingisa” tree at Center and Stone Pegs in Red.*

The Sukuma of Kishapu in the Shinyanga region are reported to have used the shadow of the tall, slender, long-living “nsingisa” tree for the shadow clock whereby observations were carried out amid magic rituals by rain conjurers in animal hide attire at sunrise and sunset to confirm the conditions for the turn of the solar year when the shadow of the “nsingisa” dovetails with the stone pegs set firmly on the ground. Animal hide attire (in Kisukuma "ngobo") and a whisk made of a tail of an animal are said to be the typical utensils of a magic practitioner in Sukumaland.

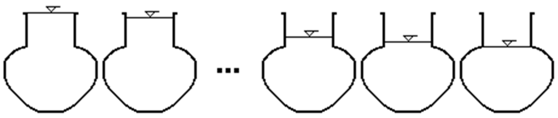

Fig. 2. *Sukuma Array of Magic Pots.*

As far as the array of pots is concerned, the observations are reported to have been carried out after the fall of the dark amid magic rituals as well. It is said that as long as the "ndimila" would be viewed above the horizon in Sukumaland transiting through the sky, magic power would pull and catch it up to be seen transiting through the array of pots to reach the "wija" port at the turn of the sidereal year coinciding with the beginning of the rain season. It is said that the conjurer in full action will flash his/her wet whisk hither thither several times as well as curse several times to drive away the witches and demons in that ritual when the turn of the sidereal year would be due.

Celebrating the Beginning of the Lunar New Year. The ancient Sukuma are said to have slaughtered a black sheep to celebrate the beginning of the lunar New Year at the event of the turn of the sidereal year's earliest new moon to honor the work of the rain conjurer.

Because of the vast size of Sukumaland in terms of area, administrative regions as well as the number of chieftaincies, the palette of its cultural festivals is relatively wide. Besides lunar festivals anchored to the lunar calendar, Sukumaland has solar festivals anchored to the Gregorian calendar as provided in table 1 and 2 respectively. Whereas the lunar festivals go through stages to last 10 days, the organizers of solar festivals go about sparingly with time.

Table 1. *Sukumaland Lunar Festival Days on the Lunar Calendar by Administrative Region.*

Lunar Month	Festival Name	Day(s)	Admin Regions
Nsoolo	Ng'waka Mpya	01	Geita, Mwanza, Shinyanga, Simiyu
Nsaatu	Ijika	05-14	Geita, Mwanza, Shinyanga, Simiyu
Nhandatu	Jigano	05-14	Shinyanga, Simiyu
Mhungati	Shikome	05-14	Geita, Mwanza
Nane	Igembe Sabo	05-14	Geita, Mwanza, Shinyanga, Simiyu
Ng'henda	Jahuda	05-14	Geita, Mwanza, Shinyanga, Simiyu
Ng'humi	Bulabu Weelu	05-14	Shinyanga
Ng'humi na Mo	Lombo	05-14	Shinyanga, Simiyu
Ng'humi na Mo	Ihuema	05-14	Geita, Mwanza
Ng'humi na Mbili	Isolo	05-14	Shinyanga, Simiyu
Ng'humi na Mbili	Isumbi	05-14	Geita, Mwanza

Table 2. *Sukumaland Solar Festival Days on the Gregorian Calendar by Administrative Region.*

Gregorian Month	Festival Name	Day(s)	Admin Regions
July	Bulabo	07	Geita, Mwanza
July	Bulabu	07	Shinyanga, Simiyu
July	Igesa	07	Shinyanga (Kahama District)
August	Balimi	08	Geita, Mwanza, Shinyanga, Simiyu

Some facts about the festivals: although with a bit of differing accent, the story telling of the Sukuma of Geita and Mwanza on one camp and the Sukuma of Shinyanga and Simiyu on the other camp share the season which manifests itself with the cold of June to August. The very famous Sukuma fairy tale called the "Shing'weng'we o Mitwe Kenda" in Mwanza accent or "Jing'weng'we o Mitwe Kenda" in Shinyanga accent to mean the monster with nine heads in which "Masala Gulangwa" is portrayed to be the brave boy to kill the monster, is shared across Sukumaland. The custom and tradition to attract the children around the fire place for story telling alongside the roasting of pea nuts, cassava and sweet potatoes is shared across Sukumaland as well. The "Shikome" and "luganga" to mean the fire place as well as "Shigano" and "Jigano" to mean a fairy tale manifest the phonetic difference between the Sukuma of Mwanza and Shinyanga respectively. There is a sharing of hunting inclinations "Ihuema" in Mwanza accent vis-à-vis "lombo" in Shinyanga accent as well as sharing in the hunting season, the period approaching the beginning of the rain season. The Sukuma also have got a favorite chess-like game of counting pebbles which is played by two opponents in the season towards the beginning of the rain season as well. The game is called "isolo" likewise "isumbi" in Shinyanga likewise Mwanza accents of Sukuma. The game sets off with two pebbles resting in each of the 32 notches cut on the ground or on a chunk of wood to make 4 arrays of 8 holes each. It is believed that "isolo" emerged out of the practice of rain conjurers to tally up the days elapsing day-to-day since the first appearance of the "ndimila" on the horizon until the beginning of the rain season.

As to solar festivals: whereas the Sukuma of Mwanza celebrate "bulabo" on July the 7^{th}, the Sukuma of Shinyanga will celebrate "bulabu" on the very same July the 7^{th}. The difference between the two festivals is actually phonetic so to speak and it actually means the blossom festival. It is actually a mirror image of the "bulabu weelu" lunar festival which depicts the blossoming of the savanna-climate-predominant acacia and the flamboyant baobab (adansonia digitata) trees in Sukumaland at the beginning of the north hemispheric fall or the “Jahuda” season in Sukumaland. The other part of Shinyanga in Kahama district will celebrate “igesa” on the same July the 7th to mean the harvesting festival. There is a synchronization of names however as to the “balimi” festival of August the 8th to celebrate the peasants day.

The aim of this study is to document and preserve the Sukuma calendar which is at the verge of perishing because of 5 reasons: the lack of documentation as to the calendar, the perishing of living memory to transfer the knowledge about the calendar from mouth to mouth through generations, the ever growing individualism which is accelerating the perishing of the Sukuma-calendar-dependent festivals, the lack of economic viability and sustainability of the Sukuma festivals which is driven by the fast growing market economy, and the intrusion of foreign influence.

The approach of this study is to get to an astronomical Sukuma calendar through mimicking the ancient Sukuma calendar by anchoring the Sukumaland’s turn of the sidereal year to a fixed date on the Gregorian calendar in the first place. Such an accepted and most favorable date is taken by the Sukuma of Kishapu to be December the 23rd. In the second place, an algorithm to determine the Sukuma lunar New Year will be developed basing on the principle of Metonic cycles which prescribes nearly equal lengths of lunar against solar years in days every 19 solar years (Ng’hwaya Masule et al., 2015). In the third place, a simple way will have to be developed to get the dates of the beginning of the 12 or 13 lunar months of the Sukuma calendar (for a normal or leap year respectively) between two consecutive lunar New Years. Here are the names of the thirteen lunar months of the Sukuma calendar in a row: “Nsoolo”, “Miili”, “Nsaatu”, “Nne”, “Nsaano”, “Nhandatu”, “Mhungati”, “Nane”, “Ng’henda”, “Ng’humi”, “Ng’humi na Mo”, “Ng’humi na Mbili” and “Ng’humi na Ndatu”. In the fourth place the study will critically analyze the methods said to have been used by the ancient Sukuma to track the beginning of the rain season likewise the turn of the sidereal year since the first appearance of the “ndimila” on the horizon in order to come up with a stereotype.

The study also aims to draw a comparison between the Sukuma calendar and the Nyamwezi calendar, a calendar of the sibling tribe to the Sukuma.

2. Approach

This section primarily pursues to determine the number of days short to the new moon on the 01st of January by calculating the difference between the number of lunar-tagged days and the number of solar days out of elapsed 19-year Gregorian cycles since a predetermined reference date which will set the basis for the computation of the Sukuma lunar New Year on the Gregorian calendar. Once the number of days short to the next new moon on the 01st January (at the beginning of a 19-year Gregorian cycle) is known, the number of days short to the next new moon for the cases of the relative years within the running cycle can algorithmically be fixed. The subsequent setting of the Sukuma calendar in terms of the day dG, month mG and the year yG of the lunar New Year on the Gregorian calendar as well as in terms of the dates of the beginning of lunar months between two consecutive lunar New Year dates can then follow.

2.1. Determining the References Points

An accepted and favorable date on the Gregorian calendar to serve as an algorithmic or astronomical anchor of the position of the Sukumaland’s “ndimila” in the firmament to mark the Sukumaland’s end of the sidereal year which coincides with the point of time marking the beginning of the rain season in Kishapu of Shinyanga called “Jidiku” in Kisukuma and which coincides with the wide accepted ancient Sukuma lunar calendar in Kishapu and which coincides with the wide accepted practices of rain conjuring in Kishapu is the December the 23rd. It is also opportune to set the 2nd reference of the algorithm to be the 01st January because the computation of Gregorian days elapsed since the 01st of January year 0000 using a single line mathematic expression is possible.

A challenge is still to be resolved as to the other helper reference points: the date of the new moon shortly after the 23rd December year -0001 and the new moon around the 22nd January year 0000. The technique is to determine the non-postponed Jewish molad Tishri (Jewish new moon on the month of Tishri) of the relevant years by working backwards since the molad Tishri of the year 1900 or 1971 first as provided in table 3 (Rich et al., 2011). The abbreviations in table 3: the d stands for the day of the week with 1 to 7 for Sunday to Saturday respectively, the h stands for hours, and the p stands for “parts” – there are 18 p in a minute and 1080 p in an hour - (Rich et al., 2011). With the molad Tishri of the year minus 0001 known, and with length of the moon set to be the 29 days, 12 hours, and 793 "parts" for short 29d 12h 793p (Rich et al., 2011), the challenge gets resolved as provided in table 4:

Table 3. *Selected Molad Tishri. (New Moons).*

Gregorian Date	Jewish Notation	Status	Worked out Julian Day Number
+1971 September 20	2d 07h 743p	provided	2441215
+1900 September 24	2d 11h 009p	provided	2415287
+0359 September 10	5d 08h 029p	provided	1852434
+0108 September 22	7d 08h 957p	provided	1760771
+0000 September 15	6d 11h 989p	worked out	1721318
-0001 August 28	7d 14h 400p	worked out	1720934
-3760 September 07	2d 05h 204p	worked out	0347998

Source: (Rich et al., 2011; McCarthy & Guinot, et al 2013)

Table 4. *Dates of the 3 consecutive New Moons around the December Solstice of the Year -0001.*

Gregorian Date	Jewish Notation	Worked out Julian Day Number
-0001 November 25	5d 04h 619p	1721023
-0001 December 24	6d 17h 332p	1721052
+0000 January 23	1d 06h 045p	1721082

Source: (McCarthy & Guinot, et al 2013)

2.2. Determining Solar Versus Lunar-Tagged Days Since Reference

2.2.1. Solar Days Since 01st January Year 0000 at the Beginning of a 19-Year Gregorian Cycle

The very first step is to get the number of 19-year Gregorian cycles, nCycles, elapsed since 01st January year 0000 for a Gregorian year y:

$$\text{nCycles} = \text{y div } 19 \tag{1}$$

Since the number of years elapsed to the beginning of the running cycle, yCycles, will be needed to calculate the number of elapsed number of solar days ultimately, it must be calculated from the number of elapsed Gregorian cycles, nCycles, thus:

$$\text{yCycles} = \text{nCycles} * 19 \tag{2}$$

The relative year, n, in the running cycle, which will be needed to calculate the number of days short to the new moon on 01st January for the years within a 19-year cycle in the next steps, is provided as a remainder in the following modulus division:

$$\text{n} = \text{y mod } 19 \tag{3}$$

Since the century, c, to the year before the beginning of the running cycle is needed in the ultimate computation of the elapsed solar days, it must be calculated out of the number of years elapsed to the beginning of the running cycle, yCycles, thus:

$$\text{c} = (\text{yCycles} - 1) \text{ div } 100 \tag{4}$$

The number of solar days, iSolar, elapsed since the 01st January year 0000 on the 01st of January of a particular cycle is given by:

$$\text{iSolar} = ((\text{yCycles} + 3) \text{ div } 4) + (365 * \text{yCycles}) - \text{c} + (\text{c div } 4) \tag{5}$$

2.2.2. Lunar-Tagged Days Since 01st January Year 0000 at the Beginning of a 19-Year Gregorian Cycle

Since a 19-year lunar cycle has 235 lunar months (Rich et al., 2011), and since the length of a lunar month is taken to be 29d 12h 793p (Rich et al., 2011), and since a 19-year Gregorian cycle can be taken to be equivalent to a 19-year solar cycle, and since the length of a 19-year solar cycle in days is said to be approximately equal to a 19-year lunar cycle as the two cycles constitute a Metonic cycle (Ng'hwaya Masule et al., 2015), the number of presumptive lunar-tagged days, iLunar, elapsed since 01st January year 0000 can be calculated as follows:

$$\text{Parts} = (\text{nCycles} * 235 * 793) + 0 \tag{6}$$

$$\text{Hrs} = (\text{nCycles} * 235 * 12) + (\text{Parts div } 1080) + 0 \tag{7}$$

$$\text{iLunar} = (\text{nCycles} * 235 * 29) + (\text{Hrs div } 24) + 0 \tag{8}$$

In calculating iLunar, it was assumed that since there is no new moon on the 01st January year 0000 (table 4), the presumptive start of the running of the lunar-tagged days is synchronous to the start of the running of the solar days at the start of the solar day.

2.3. Determining the Number of Days Short to the Next New Moon on the 01st January

As there is no new moon on the 01st January year 0000, the hypothetical number of days short to the new moon on the 01st January can be gotten as follows:

$$\text{i} = (19 * \text{n}) + \text{iLunar} - \text{iSolar} \tag{9}$$

Some explanation: At the beginning of a 19-year Gregorian cycle the value of n will be zero. Since the length of the lunar year is taken to be 11 days short to the Gregorian year in average, the 19 x n series will provide a way to determine the number of days short to the next new moon on the 01st January within the running cycle as there exists a moon of the same age plus 11 days in approximately one Gregorian year since reference and there exists a next new moon of the same age in 19 days in approximately one solar year since reference (Ng'hwaya Masule et al., 2015; Seidelmann et al., 1992).

Since the number of elapsed lunar-tagged days in equation (6 to 9) was based on a presumptive new moon on the 01st January year 0000, to get to the new moon of 23rd January year 0000 (table 4) 23 days must be added in equation (9), thus:

$$\text{i} = (19 * \text{n}) + \text{iLunar} - \text{iSolar} + 23 \tag{10}$$

Since the number of days short to the next new moon out of equation (9) happens to exceed 30 days with increasing Gregorian years as it will be shown in section 2.4, the modulus division must be used to get a number of such days which is less than 30 (Ng'hwaya Masule et al., 2015; Seidelmann et al., 1992), thus:

$$\text{i} = \text{i mod } 30 \tag{11}$$

Since the new moon should not fall after the 22nd January, dividing i by 23 will create a selector, iShifter, to hold a value of 0 or 1 which means that a new moon in December will have to be taken if iShifter will have the value of 1, thus:

$$\text{iShifter} = \text{i div } 23 \qquad (12)$$

$$i = i - \text{iShifter} * 31 \qquad (13)$$

Day, Month and Year of the Sukuma Lunar New Year on the Gregorian Calendar: Since the number of days short to the next new moon on the 01st January, i, will take the minimum value of 0 for the Sukuma lunar New Year to fall in January, it follows that for that case of the Sukuma lunar New Year falling in January the value of "(32 + i) div 32" must churn out 1 and 0 otherwise for the Sukuma lunar New Year in December. That is to say, that the month of the Sukuma lunar New Year, mG, on the Gregorian calendar is consequently given by:

$$mG = 12 + (32 + i) \text{ div } 32 \qquad (14)$$

The value of mG out of equation (14) can still be tolerated to be 13 for now when the Sukuma lunar New falls in January until the issue of the day and the year has been resolved.

Since mG still has the value of 13 when the Sukuma lunar New Year falls in January, and since i has got the value of 0 when the Sukuma lunar New Year falls on the 01st of January, 31 days must be subtracted from 32 to fix the day in January. A negative value of i will fix the day in December as it will be subtracted from 32, thus:

$$dG = 32 + i - 31 * (mG \text{ div } 13) \qquad (15)$$

The Sukuma lunar New Year will fall in the previous Gregorian year if the month in mG happens to be December, thus:

$$yG = y - (12 \text{ div } mG) \qquad (16)$$

The month in mG can at this point be set from 13 to 1 for the case of the Sukuma lunar New Year in January in the following step since the modulus operator will churn out 0 whereas the integer division operator will churn out 1 in the following instruction:

$$mG = mG \text{ mod } 13 + ((32 + i) \text{ div } 32) \qquad (17)$$

2.4. Simplifying the Sukuma Lunar New Year Algorithm

Since the number of lunar-tagged days raging out of the number of solar days on the 01st January reflected in equation (9) happens to progressively increase since year 0000 from the value of 0 to the value of 77 in the year 17993 (table 5), it can be deduced that the number of days short to the next new moon on the 01st January in equation (10) will increase by 1 every 12 19-year Gregorian cycles as vouched by these examples of integer division: dividing 17993 by 77 and then by 19 churns out 12 likewise dividing 06992 by 29 and then by 19 churns out 12.

Table 5. *Progression of the Number of Days Short to the Next New Moon on the 01st January with increasing 19-year Gregorian Cycles.*

Gregorian Year	**Number of Days Short to the Next New Moon on the 01st January**
00000	00
00988	03
01995	08
02983	12
03990	16
04997	20
05985	25
06992	29
07999	34
08987	38
09994	42
10982	46
11989	51
12996	55
13984	60
14991	64
15998	68
16986	72
17993	77

Equation (10) gets modified as follows in the first step:

$$i = (19 * n) + (\text{nCycles div } 12) + 23 \qquad (18)$$

By introducing a rounding-off technique, equation (18) gets modified as follows:

$$i = (19 * n) + (\text{nCycles div } 12) + ((\text{nCycles mod } 12) \text{ div } 6) + 23 \qquad (19)$$

The simplified algorithm in a row:

$$\text{nCycles} = y \text{ div } 19 \qquad (20)$$

$$n = y \text{ mod } 19 \qquad (21)$$

$$i = (19 * n) + (\text{nCycles div } 12) + ((\text{nCycles mod } 12) \text{ div } 6) + 23 \qquad (22)$$

$$i = i \text{ mod } 30 \qquad (23)$$

$$\text{iShifter} = i \text{ div } 23 \qquad (24)$$

$$i = i - \text{iShifter} * 31 \qquad (25)$$

$$mG = 12 + (32 + i) \text{ div } 32 \qquad (26)$$

$$dG = 32 + i - 31 * (mG \text{ div } 13) \qquad (27)$$

$$yG = y - (12 \text{ div } mG) \qquad (28)$$

$$mG = mG \text{ mod } 13 + ((32 + i) \text{ div } 32) \qquad (29)$$

2.5. Sukuma Calendar Lunar Months

Three steps are needed to determine the Gregorian dates at the beginning of the lunar months of the Sukuma lunar calendar. The first step is to determine the dates of two consecutive Sukuma lunar New Years with full qualified Julian Day numbers. The second step is to determine whether the span of the year in days qualifies to be a leap year or not. A normal year has 12 lunar months whereas a leap year has 13 lunar months. The third step is to set the consecutive lunar months in a fashion of repeating 30-to-29 days in length taking into consideration the length of the year in days in terms of their differing lengths of 353 or 354 or 355 days for a normal year likewise 383 or 384 or 385 days for a leap year as provided in table 6:

Table 6. *Lunar Months of the Sukuma Calendar.*

Occurrence Sequence	Month Name	Length in Days
01st month	"Nsoolo"	30
02nd month	"Miili"	29
03rd month	"Nsaatu"	30
04th month	"Nne"	29
05th month	"Nsaano"	30
06th month	"Nhandatu"	29
07th month	"Mhungati"	30
08th month	"Nane"	29
09th month	"Ng'henda"	30
10th month	"Ng'humi"	29
11th month	"Ng'humi na Mo"	30 or 29 for normal of 353
12th month	"Ng'humi na Mbili"	29 or 30 for 355 and 385
13th month	"Ng'humi na Ndatu"	30 or 29 for leap of 383

3. Discussion

3.1. Mirror Image of the "Ndimila" in the "Wija" Pot vis-à-vis the Method of Tallying-up Elapsing Days Since Appearance of "Ndimila"

Assuming the period taken by the "ndimila" to transit through the firmament over Sukumaland to be 182 days (about 6 months) to cover an angular displacement of about 180°, the angular displacement of the position of the "ndimila" relative to the horizon, θ, after Δd number of days can be approximated as follows:

$$\theta = \Delta d * (180 / 182) \tag{30}$$

That is to say, for the image of the "ndimila" to be seen in the "wija" pot of radius r (fig. 3), the level of water in that pot relative to the brim can geometrically be approximated as follows:

$$h = r * \tan(\theta) \tag{31}$$

By substituting equation (30) into equation (31), it follows that:

$$h = r * \tan(\Delta d * 180 / 182) \tag{32}$$

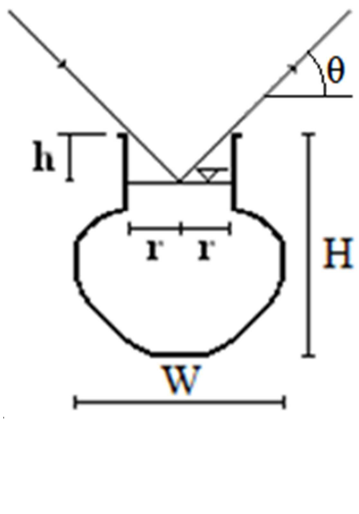

Fig. 3. *Optics behind the "Wija" Pot.*

It can therefore be said that, in order for the mirror image of the "ndimila" to be visible in the "wija" pot of 0.3 m brim radius and height of about 1.3 m at around December 23rd - about 53 days after the presumptive first appearance of the "ndimila" on the horizon on the 1st November - the water level in the pot must be about 0.38 m below the brim.

The method of tallying-up the elapsing days since the first appearance of the "ndimila" looks somewhat accurate than the method of the "wija" port in that the tallying does not involve any sort of measuring and it is easy to be repeated. It can therefore be said that in order to exhaust the 64 pebbles of the "isolo" game through the tallying of elapsing days; the "ndimila" must be observed on the horizon on October 20th to get the beginning of the rain season at around December 23rd.

3.2. Unyamwezi Lunar New Year Algorithm

Since Unyamwezi and some parts of Sukumaland get the beginning of their rain season towards the end of November (somewhat earlier than the rest of Sukumaland) and since the "ndimila" enters into the position of the Unyamwezi end of the solar likewise sidereal year relatively earlier in this region, the lunar New Year of the Nyamwezi must in principle fall one lunar month behind the lunar New Year of the Sukuma.

The most interesting thing to note in the set of instructions hereunder to determine the day dG, month mG, and the year yG of the Unyamwezi lunar New Year on the Gregorian calendar for a given Gregorian year y in the first place is the reference of computation of the number of solar days elapsed since November 25 year -0001 (table 4) in equation (37) which significantly differs from the reference of computation used in the sibling computation in equation (5). In the second place to note is the use of the "11 * n" series in equation (41) which is a sibling of the "19 * n" series used in equation (9), (10), (18), (19) and (22). Whereas the former works backwards, the later works forwards. In the third place to note is the difference in the technique of the shifter in equation (25) and (43) in that 30 must be added to i since the value of i is negative in the later, thus:

$$\text{nCycles} = y \text{ div } 19 \tag{33}$$

$$n = y \bmod 19 \tag{34}$$

$$\text{yCycles} = \text{nCycles} * 19 \tag{35}$$

$$c = (\text{yCycles} - 1) \text{ div } 100 \tag{36}$$

$$\text{iSolar} = 36 + ((\text{yCycles} + 3) \text{ div } 4) + (365 * \text{yCycles}) - c + (c \text{ div } 4) \tag{37}$$

$$\text{Parts} = (\text{nCycles} * 235 * 793) + 0 \tag{38}$$

$$\text{Hrs} = (\text{nCycles} * 235 * 12) + (\text{Parts div } 1080) + 0 \tag{39}$$

$$\text{iLunar} = (\text{nCycles} * 235 * 29) + (\text{Hrs div } 24) + 0 \tag{40}$$

$$i = \text{iLunar} - \text{iSolar} - ((11 * n) \bmod 30) \tag{41}$$

$$i = i \bmod 30 \tag{42}$$

$$iShifter = (i + 30) \operatorname{div} 23 \tag{43}$$

$$i = i - iShifter * 31 \tag{44}$$

$$mG = 11 + (30 + 31 + i) \operatorname{div} 31 \tag{45}$$

$$dG = 31 + i + 30 * (11 \operatorname{div} mG) \tag{46}$$

$$yG = y - 1 \tag{47}$$

4. Conclusion and Recommendations

In order to determine the turn of the sidereal year coinciding with the rain season after the first appearance of the "ndimila" on the horizon, the ancient Sukuma of Kishapu tallied-up the elapsing days using 64 pebbles day-to-day to get to the point of time at the beginning of the rain season called “Jidiku” at around December 23rd on the Gregorian calendar. That method of tallying up days later developed into the fully pledged “isolo” game of counting pebbles.

The simplification of the algorithm to compute the Sukuma lunar New Year looks somewhat simple and of light weight but loses some accuracy in the computation within ±3 days and it should therefore not be used for practical purposes. It should be worked around to find a better compromise.

To determine the day dG, month mG, and the year yG of the Sukuma lunar New Year on the Gregorian calendar for a given Gregorian year y the following set of instructions must be executed:

$$k = y \operatorname{div} 19 \tag{48}$$

$$n = y \bmod 19 \tag{49}$$

$$yCycles = k * 19 \tag{50}$$

$$c = (yCycles - 1) \operatorname{div} 100 \tag{51}$$

$$iSo = 0 + ((yCycles + 3) \operatorname{div} 4) + (365 * yCycles) - c + (c \operatorname{div} 4) \tag{52}$$

$$iLu = (k * 235 * 29) + (((k * 235 * 12) + (((k * 235 * 793)) \operatorname{div} 1080)) \operatorname{div} 24) \tag{53}$$

$$i = (19 * n) + iLu - iSo + 23 \tag{54}$$

$$i = i \bmod 30 \tag{55}$$

$$iShifter = i \operatorname{div} 23 \tag{56}$$

$$i = i - iShifter * 31 \tag{57}$$

$$mG = 12 + (32 + i) \operatorname{div} 32 \tag{58}$$

$$dG = 32 + i - 31 * (mG \operatorname{div} 13) \tag{59}$$

$$yG = y - (12 \operatorname{div} mG) \tag{60}$$

$$mG = mG \bmod 13 + ((32 + i) \operatorname{div} 32) \tag{61}$$

The following set of instructions hold for the computation of the Nyamwezi lunar New Year for a given Gregorian year y:

$$k = y \operatorname{div} 19 \tag{62}$$

$$n = y \bmod 19 \tag{63}$$

$$yCycles = k * 19 \tag{64}$$

$$c = (yCycles - 1) \operatorname{div} 100 \tag{65}$$

$$iSo = 36 + ((yCycles + 3) \operatorname{div} 4) + (365 * yCycles) - c + (c \operatorname{div} 4) \tag{66}$$

$$iLu = (k * 235 * 29) + (((k * 235 * 12) + (((k * 235 * 793)) \operatorname{div} 1080)) \operatorname{div} 24) \tag{67}$$

$$i = iLu - iSo - ((11 * n) \bmod 30) \tag{68}$$

$$i = i \bmod 30 \tag{69}$$

$$iShifter = (i + 30) \operatorname{div} 23 \tag{70}$$

$$i = i - iShifter * 31 \tag{71}$$

$$mG = 11 + (30 + 31 + i) \operatorname{div} 31 \tag{72}$$

$$dG = 31 + i + 30 * (11 \operatorname{div} mG) \tag{73}$$

$$yG = y - 1 \tag{74}$$

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