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Research Article

Variability Of The Onset And End Dates Of The Rainy Season In Owerri, Imo State, Nigeria.

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Abstract

The paper assessed the onset and end dates of the rainy season in Owerri Imo State, Nigeria using daily rainfall data from 1987 to 2016. The study employed the Hybrid method derived from Walter's and Anyadike's methods to determine the dates of the onset and end of the rainy season. The mean dates of the onset are 23rd Feb., 8th April, and 17th March for Walter, Anyadike, and Hybrid methods respectively. The end dates of the rainy season are the 28th, 19th, and 24th of October for Walter, Anyadike's, and hybrid methods respectively. The area is experiencing early dates of the onset of the rainy season in recent years with later dates of the end of the rainy season. The end dates of the rainy season also significantly impact the rainfall regime in the State. The hybrid method proved better than Walter and Anyadike's method of prediction in that it attenuated the underestimation associated with Anyadike's method and the overestimation associated with Walter's method. Therefore, it should be utilised in the assessment of the onset and end dates of the rainy season in the rainforest ecological zones. The study contributes to the body of knowledge in determining the onset and end dates of the rainy season in Owerri Imo State which is useful to rain-fed agriculture and other hydro-climatic planning.

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Rainfall, Onset dates,End dates, Farming season, Nigeria, Climate variability.

1. Introduction

There is a rising interest in changes in rainfall patterns across the globe especially in the tropics where, unlike temperature, it has challenged researchers with much uncertainty (Byakatonda et al., 2019). Rainfall analysis is vital as several environmental phenomena including floods, soil erosion, waterlogging, and debris flow/landslides are a function of its temporal dynamics and irregularity (Vyshkvarkova et al., 2018). Tropical rainfall being principally seasonal implies that most of the annual rainfall is concentrated within a particular time of the year. Its distribution within this period is critical to every aspect of life. Thus, city planners, hydro-climatologists, agriculturists, and transporters among others take interest in its temporal irregularity and distribution.
Additionally, it is posited that climate change affects rainfall patterns, especially in Africa (Hulme, 1992; Salack et al., 2011; Muller et al., 2011; Alexander et al., 2013). It affects the dates of the onset and end of the rainy season, making the growing season irregular and difficult to predict as rainfall

becomes increasingly erratic. For instance, delayed onset of about 5 weeks (Byakatonda et al., 2019) and variations in the dates of onset of up to 70 days (Odekunle, 2004; Odekunle et al., 2005) have been reported. Interannual variability is greater at the onset than at the end (Camberlin & Diop, 2003). Dunning et al (2016) find the onset dates for coastal regions of West Africa are from 18th March to 24th April. The rainforest part of Ghana has onset dates of 10th March to 15th April while the cessation dates range from 15th October to 5th November (Amekudzi et al., 2015). The dynamics of the onset and cessation of the rainy season necessitate a changing length of the growing season and pose challenges to farmers (Mugalavai et al., 2008; Ndomba, 2010). The implication is that farmers' income is threatened as crop failures and low production becomes probable (Usman & AbdulKadir, 2013; Sattar et al., 2017). Yet, food production needs to be boosted to feed the rising world's population (Foley et al., 2011). Hence, the indispensability of accurate prediction of the onset of the rainy season to avert or minimise losses due to crop failures.

Additionally, knowledge of rainfall characteristics at the local level is very instrumental to agricultural planning for sustainable food production from the rain-fed agriculture of the tropics (Laux et al., 2008; Adelekan & Adegebo, 2014). The length of the growing season is correlated with the onset dates of the rainy season (Sivakumar, 1988; Chiduza, 1995) such that early onset entails a longer growing season (Omotosho, 2002). However, a lengthening growing season of about 2.5 days per decade has been reported in Xinjiang China due to a delay of end in autumn rather than early-onset in Spring (Jiang et al., 2011). Furthermore, studies in the extra-tropics and mid-latitudes equally indicate an increasing length of the growing season in some parts of Europe (Carter, 1998; Menzel & Fabian, 1999; Moonen et al., 2002), America (Robeson, 2002). The observed variations in the length of the growing season significantly impact not only agriculture but also ecosystem function (Robeson, 2002; Jiang et al., 2011). The onset, end and length of the growing season remain critical attributes related to effective rainfall (Ati et al., 2002; Odekunle et al., 2005).

Similarly little is known about the interannual variations in the components of rainy seasons (onset, cessation, frequency of rain events etc) and how they individually contribute to the longer or shorter rainy season and the varying rainfall amounts in a place (Camberlin et al., 2009). Imo State has a rainforest climate but is experiencing changes due to anthropogenic influences on land cover. Nonetheless, little to no similar studies have been done in the State to identify the changing length of the growing season and the related climate variability. Therefore, this study employed 30 years of rainfall data from the Nigerian Meteorological Agency (NIMET) to assess the variations in the rainfall characteristics of the State and determine the onset and cessation dates using a hybrid method. Walter's and Anyadike's methods were reported to perform well in Nigeria and are simple to use (Laux et al., 2008; Walter, 1967; Adelekan & Adegebo, 2014; Matthew et al., 2017). However, they were found to overestimate and underestimate the onset and end dates respectively (Ezeh et al., 2021). The hybrid method outperformed Walter's and Anyadike's methods in the Savanna region (Ezeh et al., 2021). Therefore, it was employed to learn its performance in a rainforest belt of Nigeria.

2. METHOD

2.1. Study area

Imo is one of the States in southeastern Nigeria. The State is located between Latitudes 5.15° and 6.00° North of the equator and Longitudes 6.60° E and 7.35° E (Figure 1) with an area of about 5,500 km^2. The State is bounded by Abia State to the East, Anambra to the North and Rivers State to the West and South. It has 27 Local Government Councils with an administrative headquarters at Owerri, a tourist town. Owerri comprises four Local government areas-Owerri Municipal, Owerri North, Owerri West and part of Mbaitoli (Figure 1). Its climate is the Af climate of Koppen's classification (rainforest) though some areas are having derived Savanna due to anthropogenic activities. It has two distinct seasons, namely the rainy and dry seasons. The total rainfall decreases from 2500 mm in the south to 2200 mm in the north (Okorie, 2015). It has a single rainfall peak with a somewhat normal distribution though with a little skewness towards the right (Figure 2). This indicates that the heaviest of the rains fall in the latter half of the year in the area. It rose progressively from January reaching a peak in August, after which it decreased steadily to December (Figure 2). The hottest months are January to March when the mean temperature is above 27°C (Okorie, 2015).

The main drainage is River Otamiri and its main tributary, the Nwaorie Stream. The geology of the area is principally the Imo clay shale and the Benin formation comprising friable sands intercalated with clay (Amangabara, 2015). The topography is a near-flat terrain with an elevation of less than 100m. The city has a population of about 215,000 while the State is about 5,408,756 (NBS, 2018). The area is cosmopolitan with a majority of Igbo people. The major trades in the capital city are commerce and administrative jobs while the majority of the neighbouring communities engage in agriculture and fishing. The principal grown crops are *Elaeis guineensis* (Oil palm), *Treculia africana* (African breadfruit), *Mangifera indica* (Mango tree), *Citrus spp* (Orange), *Bambussa spp* (Bamboo tree), *Dioscorea spp* (yam), *Colocasia esculenta* (Cocoyam), *Manihot spp* (cassava), *Zea mays* (maize), *Solanum tuberosum* (potatoes), *Musa spp* (Banana), *Musa paradisiaca* (plantains), *Cocos nucifera* (coconut).

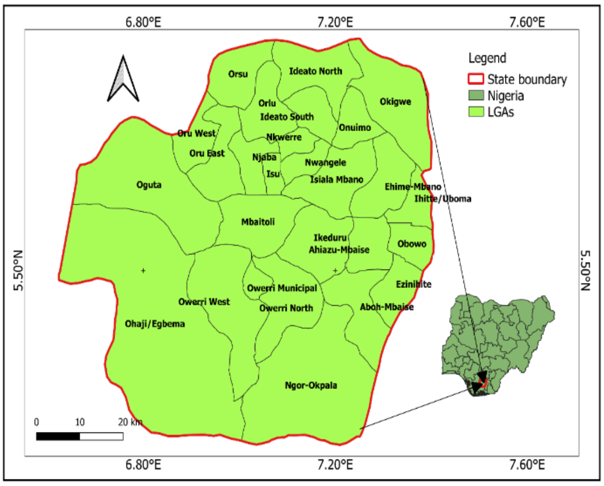

Figure 1. Imo State and the Local Government Areas
Source: DivaGis 2020

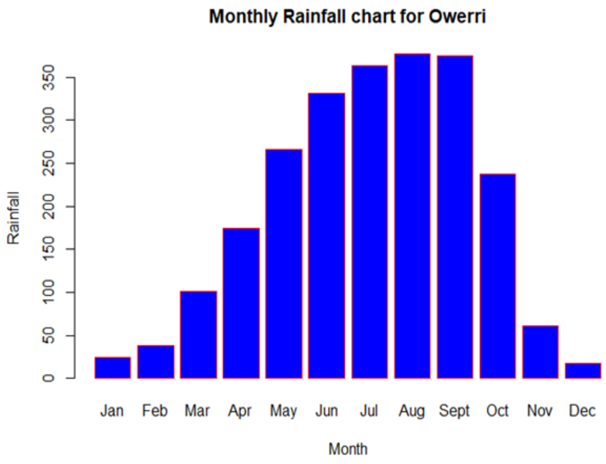

Figure 2. Mean monthly rainfall distribution

2.2. Analysis

The analyses of the data comprised some steps. The data was first subjected to descriptive statistics and presented in charts. The analysis of the onset and end (retreat) of the rainy season was done using a Hybrid method (eq. 31) by adjusting the Walter (1967) (eq. 1) and Anyadike (1993) (eq.2) methods.

$$OE1 = \frac{D(50.8-F)}{R} \qquad 1$$

$$OE2 = \frac{DM(0.083Tr-Ac)}{RM} \qquad 2$$

$$OE = \frac{OE1 + OE2}{2} \qquad 3$$

where OE is the onset, end date of the rainy season, D is the number of days in the first month with effective rain, with accumulated rainfall of 50.8mm, F is the total accumulated rain in the month before 50.8mm rainfall was reached, R is the total rainfall in the month with the threshold rainfall amount. The end is the date after which no more than 50.8 mm of rain is expected. The formula is applied in reverse order by accumulating total rainfall backwards from the end of the year to obtain the actual date of the end of the season. DM is the number of days in the month containing the rain amount >= (Tr x 0.083), Ac is the accumulated rains in the months before the month that the value of (Tr x 0.083) falls in, Tr is the total annual rainfall and RM is the total amount of rain in the month that (Tr x 0.083) falls in. The period between the onset and cessation of the rainy season represents the length of the rainy season (LOS). It was obtained using the formula after Anyadike, (1993) (eq. 4):

$$LOS = Cessation\ date(\ days) - \ Onset\ date\ (Days) + \ 1 \qquad 4$$

The Hybrid method was the mean of Walter's method and Anyadike's method. The two methods were assessed because they are among the best methods for rainforest regions (Matthew et al., 2017). Furthermore, a classification was devised for the onset and cessation of the rainy season based on its yearly pattern into three namely: early, normal and late (Bello, 1996). Using the same method, the LOS was classified into short, normal and long (See Table 1). Thus, based on the characterisation of the onset and the cessation dates of the rainy season in Table 1, it can be deduced that a normal season fit for agricultural purposes should be one of these classes: normal onset/normal cessation NN, early-onset/normal cessation EN and early or normal onset/late cessation EN. The LOS is adjudged unsuitable if it possesses any of the following classes; late-onset/early cessation LE, late-onset/normal cessation LN and normal onset/early cessation LL. The classes are extracted from the deviations from the mean onset- and cessation dates of the rainy season.

Table 1: Scale for classifying the onset, cessation and LOS in Owerri

Class	Onset Range (days)	Cessation Range (days)	Duration Class	Range (days)
Early	=< 74	=< 293	Short	=< 218
Normal	75-79	294-298	Normal	219-223
Late	>= 80	>= 299	Long	>= 224

The result obtained for various years were grouped into eleven indices in Table 2. This depicts the prevailing pattern of onset, cessation and duration of rains in Imo State.

Table 2: Composite scale for categorising rainfall years

Indices	**Meaning**
EEL	Early Onset Early Cessation Long Duration
EEN	Early Onset Early Cessation Normal Duration
ELL	Early Onset Late Cessation Long Duration
LNS	Late-Onset Normal Cessation Short Duration
LES	Late-Onset Early Cessation Short Duration
LNN	Late-Onset Normal Cessation Normal Duration
LNS	Late-Onset Normal Cessation Short Duration
NEN	Normal Onset Early Cessation Normal Duration
NES	Normal Onset Early Cessation Short Duration
NLL	Normal Onset Late Cessation Long Duration
NLS	Normal Onset Late Cessation Short Duration
ELN	Early Onset Late Cessation Normal Duration
ENS	Early Onset Normal Cessation Short Duration
NNS	Normal Onset Normal Cessation Short Duration
LLS	Late-Onset Late Cessation Short Duration
LLN	Late-Onset Late Cessation Normal Duration
NLN	Normal Onset Late Cessation Normal Duration

Source; Adapted from Bello (1996)

Furthermore, biases in the onset, end and LOS were calculated for the different methods following Matthew's approach (Matthew et al., 2017). It is represented in equation 5.

$$\sum_{i=1}^{n} {ESM-OBS}/{n} \quad (5)$$

where ESM is the estimated value, OBS is the actual value and n is the sample size.
The relationship between the dates of the onset, and end of the rainy season and the LOS in the State was assessed using the non-parametric Mann-Kendall test and Spearman rho test. It was applied to search for trends within the onset, cessation and duration of the growing season in the area while Sen’s slope was used for slope estimates (Salmi et al., 2002; Önöz & Bayazit, 2003). The Mann-Kendall is a widely applied test mainly because it is simple, robust and requires no conformity to a particular distribution (Drápela & Drápelová, 2011). Additionally, it is fairly insensitive to missing data values or data inhomogeneity (Tabari et al., 2011). It is expressed in equation 6 while equation 7

is Spearman's rho.

$$S = \sum_{j=k+1}^{n-1} sgn\,(x_j - x_k \qquad 6$$

$$rho = 6 \sum_{i=1}^{n} d^2 / _{n^3 - n} \qquad 7$$

where rho is Spearman's rank correlation coefficient, n is the number of observations and d is the difference between the ranks of two different sets of observations. The Mann-Kendall test tests the null hypothesis of no trend against the alternate hypothesis of the existence of either a positive or negative monotonic trend. A positive value indicates an increasing trend but a negative value signifies a decreasing trend. The tau explains the strength and direction of the relationship between the independent (Time) and the dependent value. The standard Z statistic is expressed in equation 8.

$$Z = \begin{cases} \frac{s-1}{\sqrt{VAR(s)}} & if\ s > 0 \\ 0 & if\ s = 0 \\ \frac{s+1}{\sqrt{VAR(s)}} & if\ s < 0 \end{cases} \qquad 8$$

It reveals whether the trend is statistically significant or not. The statistical significance of the trend is also manifest in the Z value. Hence, if the calculated p-value is greater than the alpha value of 0.05, the H0 is rejected. A negative S is associated with a negative Z denoting decreasing trend and vice versa. Also, if a linear trend is present in a given time series, the slope which denotes the rate of change per unit is computed according to Sen's method (Sen, 1968). The trend analysis was carried out in the R environment using the trend package (Pohlert, 2016) and the wq package (Jassby et al., 2016).

3. RESULTS

3.1. Onset, cessation, and length of the rainy season in the study area

The variations in the dates of the onset and end of the rainy season are shown in Figure 3. The onset dates vary from 18th January to 2nd April for the Walter method with a mean of 23rd February. It then ranged from 5th March to 1st May for the Anyadike method with a mean date of 8th April (Figure 3). The hybrid method has a mean onset date of 17th March (Figure 3). The mean end dates are 28th October (Walter's method) and 19th October (Anyadike's method). The end dates vary with the method such that the Walter method has a mean of Oct. 28th varying from Sept 30th to Dec. 31st, the Anyadike method has a mean of Oct. 19th varying from Sept 29th to Nov. 27th and the hybrid has a mean of Oct. 4th varying from Oct. 5th to Dec. 6th.

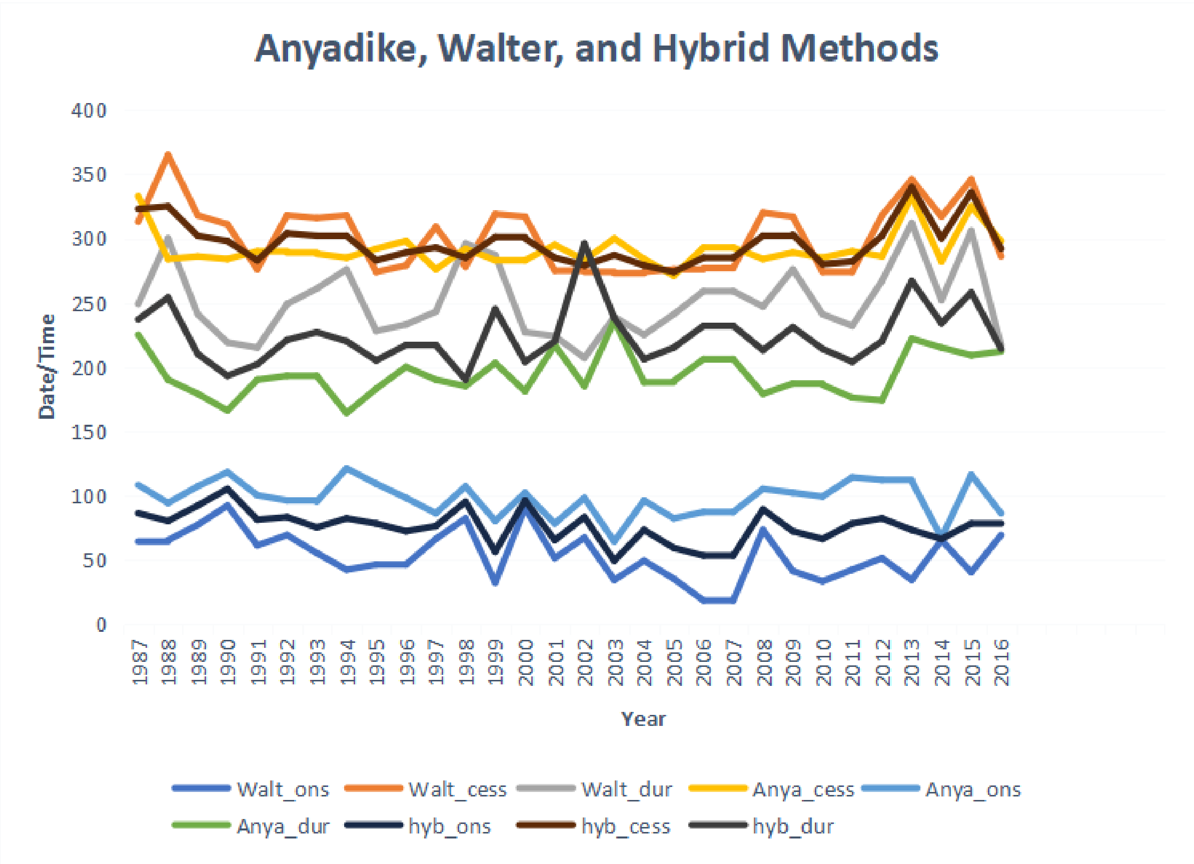

Figure 3. Fluctuations in the onset, end dates and LOS.

3.2. Variability of onset and cessation dates

Table 3 describes the mode of interannual variability in the dates of the onset and cessation of the rainy season over the study area. For the onset of the rainy season, about 87 percent of the period falls under the early onset category for the Walter method while for Anyadike's method, about 90% fell under the late onset category (Table 3). Walter and Anyadike's methods produce extremes for the onset dates at varying directions. That is, Walter tends to overestimate while Anyadike's method underestimates (Table 3). The hybrid had about 40% each for the late and early onset of the rainy season. For the end dates, the Walter method had about 47% in the early category and 53% in the late category. Anyadike’s method had about 77% in the early category and 1.3% in the late category. The hybrid method had about 50% in the early category and 47% in the late cessation category.

Table 3: Classification of years into different categories of Onset and cessation

Classes	Onset			Cessation		
	Walter	Anyadike	Hybrid	Walter	Anyadike	Hybrid
Early	26	2	12	14	23	15
Normal	1	1	6	-	3	1
Late	3	27	12	16	4	14

Furthermore, in Table 4, following the classification of the dates of the onset and cessation of the rainy season of Bello (1996), the rainfall regime in Imo State was categorised into classes. Table 4 reveals a complex pattern. The Walter method has the highest (13) in the ELL category followed by the hybrid with 4. Anyadike's method had 22 in the LES. The hybrid method had a greater spread into diverse classes.

Table 4: Composite pattern of rainfall years obtained in Imo State

Category	Walter	Anyadike	Hybrid
ELL	1987,88,92-94, 97,99, 2008,09,12-15		1999, 2009,13,14
EEL	1995,96,2001,2003-2007,10,11		2003,06,07
EEN		2003	
ELN	2016		
ENN			2001
EES	1991,2002	2014	1996,2004,05,10
LEL	1998		2002
LES		1988-95,97-2000,02,04-12	1991,1998
LNS			1990
LLL	2000	1987,2013,2015	1987,1988
LLN	1990		1992,1994,2012
LNN		1996,2016	
LLS			1989,2000,08
NES			1995,97,2011,16
NLL	1989		1993,2015
NNN		2001	

3.3. Trends in the onset, end dates and LOS.

The trend analysis was carried out to identify the direction and magnitude of the relationships in the onset, end and LOS. It showed the existence of a significant trend in the assessed parameters. The onset of the rainy season has a negative trend for the 3 methods while the LOS has a positive trend for the 3 methods. However, the end of the rainy season shows negative trends for Walter and hybrid methods but a positive trend for the Anyadike method (Table 5). At a 95% confidence level, only the onset of the rainy season is significant for Walter's method and hybrid method. The rate of change in the trend of onset of the rainy season in the Walter method is 9 days earlier onset date per decade and for the hybrid method is 5 days earlier dates per decade. This implies nearly a day early onset of the season for the Walter method (Table 5). Table 5 shows also that the onset of the rainy season had a greater influence on the length of the growing season in Walter and hybrid methods. Anyadike's method has no significant difference between the onset and the cessation.

Table 5. The result of the Mann-Kendall trend analysis

	Walter			Anyadike			Hybrid		
	onset	end	LOS	onset	end	LOS	onset	end	LOS
tau	-0.26	-0.05	0.09	-0.06	0.09	0.12	-0.27	-0.12	0.12
Z	-1.98	-0.36	0.71	-0.46	0.66	0.91	-2.04	-0.88	0.88
S	-112	-21	41	-27	38	52	-115	-50	50
Sen Slope	-0.92	0.00	0.53	-0.23	0.11	0.53	-0.54	-0.20	0.48
p-value	0.047	0.72	0.48	0.64	0.51	0.36	0.04	0.38	0.38

*LOS is the length of the rainy season

3.4. Comparison of the performance of the methods of assessment

The result of the biases in the estimation of the dates of the onset, end and LOS was shown in Table 6. It shows that the hybrid method performed better in the estimation of the onset dates. For the cessation dates, the Walter and the hybrid methods did better than Anyadike's method (Table 6) while for the LOS, the hybrid method was the better performer followed by the Walter method. Since the LOS is dependent on the onset and end dates, it showed that the hybrid method is the best method for the assessment of the onset and end dates of the rainy season in Imo State (Table 6).

Table 6. The biases in the estimation-performances of the different methods

	onset	end	LOS
Walter	-0.77	-0.30	0.60
Anyadike	0.70	-0.60	-1.30
Hybrid	-0.03	-0.43	-0.27

4. DISCUSSION

The Walter method had the highest overestimation in the dates of the onset of the rainy season (Figure 3, Table 3). This is because it gives early dates of onset (Ati et al., 2002; Adelekan & Adegebo, 2014). This is in line with Matthew et al. (2017) that it performed poorly in the forest region (Warri) though it does in the Sudan zone. It had the highest number of false starts (1987, 1988, 1990, 1991, 1995, 1997, 1998, 2000, 2006, 2007, 2009, 2016). The Hybrid method had only two false starts (2002, 2004) while the Anyadike method did not have a false start but it is bedevilled with underestimation (late onset) for most of the years. The Walter method had the highest number of early onset dates of the rainy season (87 %) (Table 3) while the hybrid method performed better than the Anyadike's method (Table 3). The results show that the area is indeed an equatorial climate where the rains are expected most of the days throughout the year. This is reflected inn the dynamics of the onset and end of the rainy season which ranges from Feb to April. This corroborates the findings that the onset dates in the forest region range from mid-March to mid-April and end from mid-October to early November (Amekudzi et al., 2015; Matthew et al., 2017).Its rainy season spans from eight to ten months (Figure 3). However, Anyadike's metrhod performed worse than the others as the mean length of the growing season is barely six months due to underestimation of the onset dates of the rainy season. This falls short of the actual length of growing season in a rainforest region (Laux et al., 2008; Amekudzi et al., 2015; Matthew et al., 2017; NIMET, 2018). The Hybrid method has a mean onset of the the rainy season about mid-March which is similar to what other researchers found(Laux et al., 2008;

Amekudzi et al., 2015; Matthew et al., 2017; NIMET, 2018). Interannual variability in the end dates is greater in the Walter method, unlike the other methods where it is greater in the onset dates. This is at variance with the findings of Camberlin & Ooola (2003).

The onset dates influence the LOS (Table 5). In line with studies, the length of the growing season is correlated with the onset dates (Sivakumar, 1988; Chiduza, 1995) such that an early onset dates entails a longer growing season (Omotosho, 2002). The Walter and Hybrid methods show signs of early onset dates. However, Anyadike's method shows signs of increasing late end dates. These dynamics in the onset and end dates lead to the varying lengths of the rainy season which pose challenges to farmers (Mugalavai et al., 2008; Ndomba, 2010) and significantly impacts their income (Usman & AbdulKadir, 2013; Sattar et al., 2017). Good knowledge of these dynamics is necessary at the local level for susatainable food production (Laux et al., 2008; Adelekan & Adegebo, 2014). There is an increasing trend in the LOS in the area.

It also indicated that the early onset and late end of the rainy season seen to prevail in the later part of the study period. This might be attributed to the changing rainfall pattern (Salack et al., 2011; Muller et al., 2011; Alexander et al., 2013). This indicates that the dates of the onset of the rainy seasonfall in the early to normal category but the majority of the years experienced later dates of the end of the rainy season except for the Walter method. The varying dates imply diverse influences on agriculture and ecosystem functions in the area (Robeson, 2002; Jiang et al., 2011). However, it reveals the study area has ample rainfall quite sufficient to carry out multiple or double growing seasons with little to no need for irrigation. This is because water stress is drastically low considering the range between the onset and end provide cues effective rainfall (Adefolalu, 1986; Ati et al., 2002; Odekunle et al., 2005). Though the late end of the rainy season is not a prominent feature of the rainfall regime in Imo state (Table 3), the years with later dates significantly had longer growing seasons. Therefore, although the date of onset of the rainy season is very important, it shows that the end dates of the rainy season significantly impacted the LOS in the study area. Also, though the tau is weak, it showed that the end dates of the rainy season, unlike the onset date. A similar finding was reported in Ibadan (Adelekan & Adegebo, 2014).

It has been opined that rain-fed agriculture and farmers' income are threatened by highly variable dates of onset and end of the rainy (Usman & AbdulKadir, 2013). However, in Imo state, the farmers' income and food production can be boosted via sustainable planning with little supply of irrigation to ensure multiple crop growing seasons annually. This is necessary to bolster food production to feed the burgeoning population (Foley et al., 2011). The area can support intensive crop farming with minimal water stress which is important to forestall land degradation due to slash and burn form of agriculture in the developing world.

5. CONCLUSION

The study investigated the variability in the dates of onset and end of the rainy season in Imo State, Nigeria using a Hybrid method. Findings indicate that the dates of onset and cessation of the rainy season are changing with early dates of onset and later dates of end of season persisting in the latter part of the study period. This implies an extension in the length of the growing season in recent years. This is good for rain-fed agriculture though with little challenges as harvest periods of certain crops may be affected as well, also the risk of certain pests might increase too. It might affect the storability of some seed crops due to likely pest invasion and rotting. However, it can be harnessed for some annual crops which can now be grown twice with little to no water stress. Therefore, the early onset and late cessation dates of the rainy season are good predictors for the long or normal length of the rainy season. Hence, the LOS in the area is a function of the dates of onset and end of the rainy season. Also, the delineation into eleven different rainfall composite patterns revealed a complex pattern. However, it shows that though early onset is critical to the length of the rainy season, early cessation neutralises it. Hence, most early-onset with early cessation had a short duration of the season.

Also, the assessment of the different techniques showed that the hybrid method is better. It had the best performance on the onset dates. However, the Walter method did well in the cessation dates as shown by the bias assessment. In conclusion, it is recommended that planning for rain-dependent sectors of the economy such as crop farming should be based on the knowledge of both the onset and the end dates of the rainy season for sustainable development planning in the State. Hence, farmers and water managers can utilise this important knowledge to adequately prepare for their yearly water demand/supply budget and farming activities. Also, for the assessment of the onset and end of the rainy season, the Hybrid method is preferable.

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Author Contributions

First Author: Conceptualisation, Investigation. **Second Author:** Data curation, draft preparation. Third **Author**: Supervision, Reviewing and Editing.

Conflicts of Interest

The authors declare no conflict of interest.

References

Adefolalu, D. O. (1986). Rainfall trends in Nigeria. *Theoretical and Applied Climatology*, *37*(4), 205–219

Adelekan, I. O., & Adegebo, B. O.. (2014). Variation in onset and cessation of the rainy season in Ibadan, Nigeria. *Journal of Science Research*, *13*, 13–21

Adefolalu, D. O. (1986). Rainfall trends in Nigeria. *Theoretical and Applied Climatology*, *37*(4), 205– 219.

Adelekan, I. O., & Adegebo, B. O. (2014). Variation in onset and cessation of the rainy season in Ibadan, Nigeria. *Journal of Science Research*, *13*, 13–21.

Alexander, L., Allen, S., & Bindoff, N. L. (2013). *Working group I contribution to the IPCC fifth assessment report climate change 2013: The physical science basis summary for policymakers*. OPCC.

Amangabara, G. T. (2015). Drainage morphology of Imo basin in the Anambra–Imo river basin area, of Imo state, southern Nigeria. *Journal of Geography, Environment and Earth Science International*, *3*(1), 1–11.

Amekudzi, L. K., Yamba, E. I., Preko, K., Asare, E. O., Aryee, J., Baidu, M., & Codjoe, S. N. (2015). Variabilities in rainfall onset, cessation and length of rainy season for the various agro-ecological zones of Ghana. *Climate*, *3*(2), 416–434.

Anyadike, R. N. C. (1993). Seasonal and annual rainfall variations over Nigeria. *International Journal of Climatology*, *13*(5), 567–580.

Ati, O. F., Stigter, C. J., & Oladipo, E. O. (2002). A comparison of methods to determine the onset of the growing season in northern Nigeria. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *22*(6), 731–742.

Bello, N. J. (1996). An investigation of the characteristics of the onset and cessation of the rains in Nigeria. *Theoretical and Applied Climatology*, *54*(3–4), 161–173.

Byakatonda, J., Parida, B. P., Kenabatho, P. K., & Moalafhi, D. B. (2019). Prediction of onset and cessation of austral summer rainfall and dry spell frequency analysis in semiarid Botswana. *Theoretical and Applied Climatology*, *135*(1–2), 101–117.

Camberlin, P., & Diop, M. (2003). Application of daily rainfall principal component analysis to the assessment of the rainy season characteristics in Senegal. *Climate Research*, *23*(2), 159–169.

Camberlin, P., Moron, V., Okoola, R., Philippon, N., & Gitau, W. (2009). Components of rainy seasons' variability in Equatorial East Africa: Onset, cessation, rainfall frequency and intensity. *Theoretical and Applied Climatology*, *98*(3–4), 237–249.

Carter, T. R. (1998). Changes in the thermal growing season in Nordic countries during the past century and prospects for the future. *Agricultural and Food Science*, *7*(2), 161–179.

Chiduza, C. (1995). Analysis of rainfall data and their implication on crop production: A case study of northern Sebungwe. *The Zimbabwe Journal of Agricultural Research (Zimbabwe)*.

Drápela, K., & Drápelová, I. (2011). Application of Mann-Kendall test and the Sen's slope estimates for trend detection in deposition data from Bílý Kříž (Beskydy Mts., the Czech Republic) 1997-2010. *Beskydy*, *4*(2), 133–146.

Dunning, C. M., Black, E. C., & Allan, R. P. (2016). The onset and cessation of seasonal rainfall over Africa. *Journal of Geophysical Research: Atmospheres*, *121*(19), 11,405-11,424.

Ezeh, C. U., Ekwezuo, C., Emeribe, C. N., & Butu, A. W. (2021). Enhanced prediction methods for the onset and cessation dates of the rainy season over the Guinea Savanna, Nigeria. *Arabian Journal of Geosciences*, *14*(3), 1–11.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., & West, P. C. (2011). Solutions for a cultivated planet. *Nature*, *478*(7369), 337–342.

Hulme, M. (1992). Rainfall changes in Africa: 1931–1960 to 1961–1990. *International Journal of Climatology*, *12*(7), 685–699.

Jassby, A. D., Cloern, J. E., & Jassby, M. A. (2016). *Package 'wq'*.

Jiang, F., Hu, R., Zhang, Y., Li, X., & Tong, L. (2011). Variations and trends of onset, cessation and length of climatic growing season over Xinjiang, NW China. *Theoretical and Applied Climatology*, *106*(3–4), 449–458.

Laux, P., Kunstmann, H., & Bárdossy, A. (2008). Predicting the regional onset of the rainy season in West Africa. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *28*(3), 329–342.

Matthew, O. J., Imasogie, O. G., Ayoola, M. A., Abiye, O. E., & Sunmonu, L. A. (2017). Assessment of prediction schemes for estimating rainfall onset over different climatic Zones in West Africa. *Journal of Geography, Environment and Earth Science International*, *9*(1), 1–15.

Menzel, A., & Fabian, P. (1999). Growing season extended in Europe. *Nature*, *397*(6721), 659–659.

Moonen, A. C., Ercoli, L., Mariotti, M., & Masoni, A. (2002). Climate change in Italy indicated by agrometeorological indices over 122 years. *Agricultural and Forest Meteorology*, *111*(1), 13–27.

Mugalavai, E. M., Kipkorir, E. C., Raes, D., & Rao, M. S. (2008). Analysis of rainfall onset, cessation and length of growing season for western Kenya. *Agricultural and Forest Meteorology*, *148*(6–7), 1123–1135.

Muller, C. J., O'Gorman, P. A., & Back, L. E. (2011). Intensification of precipitation extremes with warming in a cloud-resolving model. *Journal of Climate*, *24*(11), 2784–2800.

NBS. (2018). *National Bureau of Statistics Demographic Statistics Bulletin. Retrieved 20th March, 2020 from*. https://nigerianstat.gov.ng/download/775

Ndomba, P. M. (2010). Development of rainfall curves for crops planting dates: A case study of Pangani River Basin in Tanzania. *Nile Basin Water Science and Engineering Journal*, *3*, 13–27.

NIMET. (2018). *An overview of the 2018 Seasonal Rainfall Prediction* (p. 32).

NIMET. (2020). *Overview of the 2020 Seasonal Rainfall Prediction* (p. 41).

Odekunle, T. O. (2004). Rainfall and the length of the growing season in Nigeria. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *24*(4), 467–479.

Odekunle, T. O., Balogun, E. E., & Ogunkoya, O. O. (2005). On the prediction of rainfall onset and retreat dates in Nigeria. *Theoretical and Applied Climatology*, *81*(1–2), 101–112.

Okorie, F. C. (2015). Analysis of 30 years rainfall variability in Imo State of southeastern Nigeria. *Proceedings of the International Association of Hydrological Sciences*, *366*, 131.

Omotosho, J. B. (2002). Synoptic meteorology: Pathway to seasonal rainfall prediction for sustainable agriculture and effective water resources management in West Africa but Nigeria in particular. *Journal of the Nigerian Meteorological Society*, *3*(2), 82–88.

Önöz, B., & Bayazit, M. (2003). The power of statistical tests for trend detection. *Turkish Journal of Engineering and Environmental Sciences*, *27*(4), 247–251.

Pohlert, T. (2016). Non-parametric trend tests and change-point detection. *CC BY-ND*, *4*.
Robeson, S. M. (2002). Increasing growing-season length in Illinois during the 20th century. *Climatic Change*, *52*(1–2), 219–238.

Salack, S., Muller, B., & Gaye, A. T. (2011). Rain-based factors of high agricultural impacts over Senegal. Part I: integration of local to sub-regional trends and variability. *Theoretical and Applied Climatology*, *106*(1–2), 1–22.

Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T., & Amnell, T. (2002). Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates MAKESENS–The excel template application. *Finish Meteorological Institute, Helsinki*.

Sattar, A., Khan, S. A., & Banerjee, S. (2017). Evaluation of onset, cessation and length of rainy season for sustainable rainfed crop production in Bihar. *Evaluation*, *633*(631.57), 540.29.

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*, *63*(324), 1379–1389.

Sivakumar, M. V. K. (1988). Predicting rainy season potential from the onset of rains in Southern Sahelian and Sudanian climatic zones of West Africa. *Agricultural and Forest Meteorology*, *42*(4), 295–305.

Tabari, H., Marofi, S., Aeini, A., Talaee, P. H., & Mohammadi, K. (2011). Trend analysis of reference evapotranspiration in the western half of Iran. *Agricultural and Forest Meteorology*, *151*(2), 128–136.

Usman, M. T., & AbdulKadir, A. (2013). On determining the 'real'onset date of seasonal rains in the semi-arid and sub-humid areas of West Africa. *Natural Hazards*, *66*(2), 749–758.

Vyshkvarkova, E., Voskresenskaya, E., & Martin-Vide, J. (2018). Spatial distribution of the daily precipitation concentration index in Southern Russia. *Atmospheric Research*, *203*, 36–43.

Walter, M. W. (1967). Length of the rainy season in Nigeria. *The Nigerian Geographical Journal*, *10*(2), 123–128.