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RAINFALL AND THE LENGTH OF THE GROWING SEASON IN NIGERIA

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ABSTRACT

This study examines the length of the growing season in Nigeria using the daily rainfall data of Ikeja, Ondo, Ilorin, Kaduna and Kano. The data were collected from the archives of the Nigerian Meteorological Services, Oshodi, Lagos. The length of the growing season was determined using the cumulative percentage mean rainfall and daily rainfall probability methods.

Although rainfall in Ikeja, Ondo, Ilorin, Kaduna, and Kano appears to commence around the end of the second dekad of March, middle of the third dekad of March, mid April, end of the first dekad of May, and early June respectively, its distribution characteristics at the respective stations remain inadequate for crop germination, establishment, and development till the end of the second dekad of May, early third dekad of May, mid third dekad of May, end of May, and end of the first dekad of July respectively. Also, rainfall at the various stations appears to retreat starting from the early third dekad of October, early third dekad of October, end of the first dekad of October, end of September, and early second dekad of September respectively, but its distribution characteristics only remain adequate for crop development at the respective stations till around the end of the second dekad of October, end of the second dekad of October, middle of the first dekad of October, early October, and middle of the first dekad of September respectively. Thus, the active lengths of the growing season are approximately 5 months, 5 months, 4 months, 4 months, and 2 months respectively. Plants that are short-dry-spell tolerant may thrive early in the rainy season, i.e. from the end of the second dekad of March to the end of the second dekad of May (in Ikeja), middle of the third dekad of March to the early third dekad of May (in Ondo), mid April to the middle of the third dekad of May (in Ilorin), end of the first dekad of May to end of May (in Kaduna), and early June to the end of the first dekad in July (in Kano), but other less tolerant plants should be planted starting from the end of the second dekad of May, early third dekad of May, mid third dekad of May, end of May, and end of the first dekad of July respectively. The daily rainfall probability method is recommended as more efficient in the assessment of the nature and length of the growing season. Copyright © 2004 Royal Meteorological Society.

KEY WORDS: length of the growing season; rainfall onset; rainfall cessation; rainfall probability; cumulative percentage mean rainfall; Nigeria

1. INTRODUCTION

'Growing season' can be defined as the period of the year during which rainfall distribution characteristics are suitable for crop germination, establishment, and full development. It is the period of the year categorised as the rainy or wet season, the length of which varies spatially, temporally, and with crop type.

In a typical tropical country like Nigeria, rain falls in different months of the year at different places, as the rainbelt appears to follow the relative northward and southward movements of the sun. In this tropical situation of a marked seasonal rainfall regime, variability of the onset and retreat of rain is highly significant, and its estimation and prediction are necessary. A delay of 1 or 2 weeks in the onset is sufficient to destroy the hopes of a normal harvest (Olaniran, 1983; Jackson, 1989). A false start of planting, encouraged by a false start of rainfall, may be followed by prolonged dry spells whose duration of 2 weeks or more

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may be critical to plant germination and/or growth (Olaniran, 1983). For instance, in 1973, the onset was earlier in Nigeria, which encouraged early planting and animal migration. However, this was a false onset, resulting in both crop and animal loss (Oguntoyinbo and Odingo, 1979). Also, as pointed out by Odumodu (1983), greater variability is experienced at the onset and retreat of rainfall than in the mid-season. Particularly notorious in this regard is the onset, as it is usually foreshadowed by a succession of isolated showers of uncertain intensity accompanied by dry periods of varying duration (Walter, 1968). As noted by Omotosho *et al.* (2000), the variations in the onset date could be up to 70 days (10 weeks) from one year to another at a single station. Thus, the rainfall distribution characteristics during the course of a year in a typical wet-and-dry climate region like Nigeria (Koppen, 1918) dictate the schedule of agricultural activities from the land preparation, through the crop variety selection and planting, to the time of harvesting. In other words, reliable prediction of rainfall onset and cessation times, and thus the length of the growing season, will greatly assist on-time preparation of farmlands, mobilization of seed/crops, manpower, and equipment and will also reduce the risk involved in planting/sowing too early or too late (Omotosho *et al.*, 2000).

The literature reveals that the length of the growing season can be determined in a variety of ways. Some people, notably Thornthwaite (1948), Thornthwaite and Mather (1955), Cocheme and Fraquin (1967) and Benoit (1977), have employed a rainfall–evapotranspiration relation model to determine the onset and cessation of the growing season. Others have based their prediction method on upper wind data (e.g. Beer *et al.*, 1977; Omotosho, 1990, 1992). Recently, Omotosho *et al.*, (2000) made another attempt, using daily mean values of surface pressure, temperature, and relative humidity. More recently, Omotosho (2002) used the Theta-E technique, which is dependent on the equivalent potential temperature. However, most workers (Dagg, 1965; Walter, 1968; Ilesanmi, 1972; Igeleke, 1973; Kowal and Adrews, 1973; Olaniran, 1983, 1984; Adejuwon *et al.*, 1992; Bello, 1995; Nnoli, 1996; Ati *et al.*, 2002) have employed rainfall alone to determine the onset and cessation of the growing season. Rainfall totals are more widely used mainly because they are more readily available (Olaniran, 1983). Also, this author believes that the use of rainfall data is a more direct approach rather than the use of some other related factors from which to make inferences. Although Thornthwaite and Mather (1955) employed rainfall and temperature (both of which are readily available data) to estimate their climatic water budget for agriculture, the model has not found wide use in West Africa for three main reasons. First, it has been found that temperature is not a good indicator of the available energy for evaporation or potential evapotranspiration, since it lags behind solar radiation (Ojo, 1977). Second, the model does not take into consideration the effect of advection (Ojo, 1977). Third, in the tropics, temperatures are relatively uniform and seasonal variations are small, thereby allowing a wide range of suitable crops in relation to temperature conditions (Nieuwolt, 1982). Thus, as noted by Nieuwolt (1982), temperatures are not a critical factor in tropical agriculture. Therefore, rainfall is the principal controlling element in tropical agriculture (Nieuwolt, 1982; Stern and Coe, 1982). In the use of rainfall data alone, there are two main approaches found in the literature: an absolute definition, based on a certain threshold value; and a relative definition, based on a certain proportion relative to the total rainfall (Adejuwon, 1988). The most widely accepted is the relative definition method (e.g. Ilesanmi, 1972). Thus far, however, rainfall probability, especially daily rainfall probability, which is the most direct method of rainfall reliability estimate, has been relatively neglected in the determination of the length of the growing season. No matter how variable the rainfall distribution characteristics of a given region at the onset and cessation periods are, there is a certain period of the year during which it would be adequate for crop germination, establishment, and development in any given year. Such a period would not exhibit significant variation from year to year. It is exactly this kind of period that the daily rainfall probability is meant to detect in this study. Even the recent prediction models proposed by Omotosho *et al.* (2000; Omotosho, 2002), which are meant to address year-to-year variation in the rainfall onset and retreat periods, still turned out to fail in some years (27% of the cases tested). In fact, in the years of failure, the error terms are as high as 24–37 days. This study aims at determining the length of the growing season in Nigeria, and also assesses the relative efficiency of the daily rainfall probability and the relative definition methods.

2. STUDY AREA

The study area is Nigeria (Figure 1), 3–15 °E, 4–14 °N. The area is bordered in the northern, eastern, western, and southern parts by the Republic of Niger, Cameroon, the Republic of Benin, and the Gulf of Guinea respectively. The total land area is about 923 300 km^2.

The specific locations where data were collected are Ikeja, Ondo, Ilorin, Kaduna, and Kano. Each of the five locations was selected as being representative of a zone comprising an area of similar climatic tendency in Nigeria. For instance, Ikeja is chosen to represent the coastal climatic zone; Ondo, Ilorin, Kaduna, and Kano represent forest, Guinea, and the southern and northern Sudan climatic zones respectively (see Figure 2).

Nigerian climate is dominated by the influence of three major atmospheric phenomena, namely: the maritime tropical (mT) air mass, the continental tropical (cT) air mass and the equatorial easterlies (Ojo, 1977). The mT air mass originates from the southern high-pressure belt located off the coast of Namibia, and in its trajectory it picks up moisture from over the Atlantic Ocean, crosses the equator and enters Nigeria. The cT air mass originates from the high-pressure belt north of the Tropic of Cancer. It picks up little moisture along its path, and thus is dry. The two air masses (mT and cT) meet along a slanting surface called the intertropical discontinuity (ITD). The equatorial easterlies are rather erratic, cool air masses that come from the east and flow in the upper atmosphere along the ITD. Occasionally, however, the air mass dives down, undercuts the mT or cT air mass and gives rise to a line of squalls or dust devils (Iloeje, 1981).

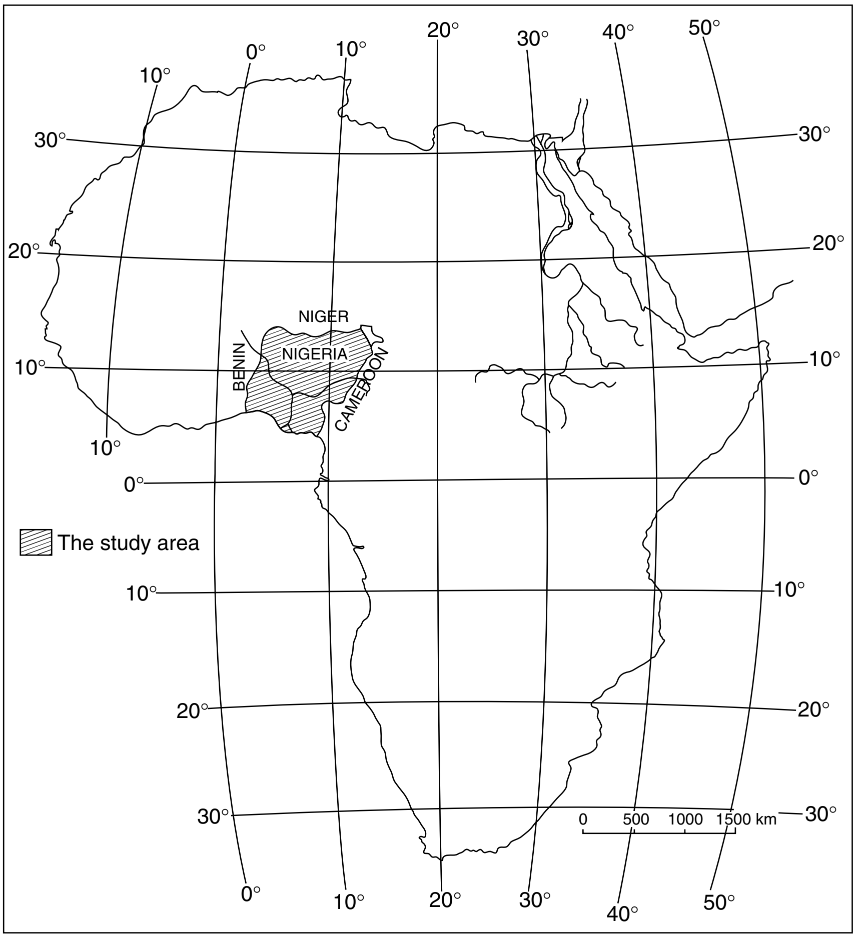

Figure 1. Map of Africa, showing the study area (Nigeria). Source: Balogun (2002)

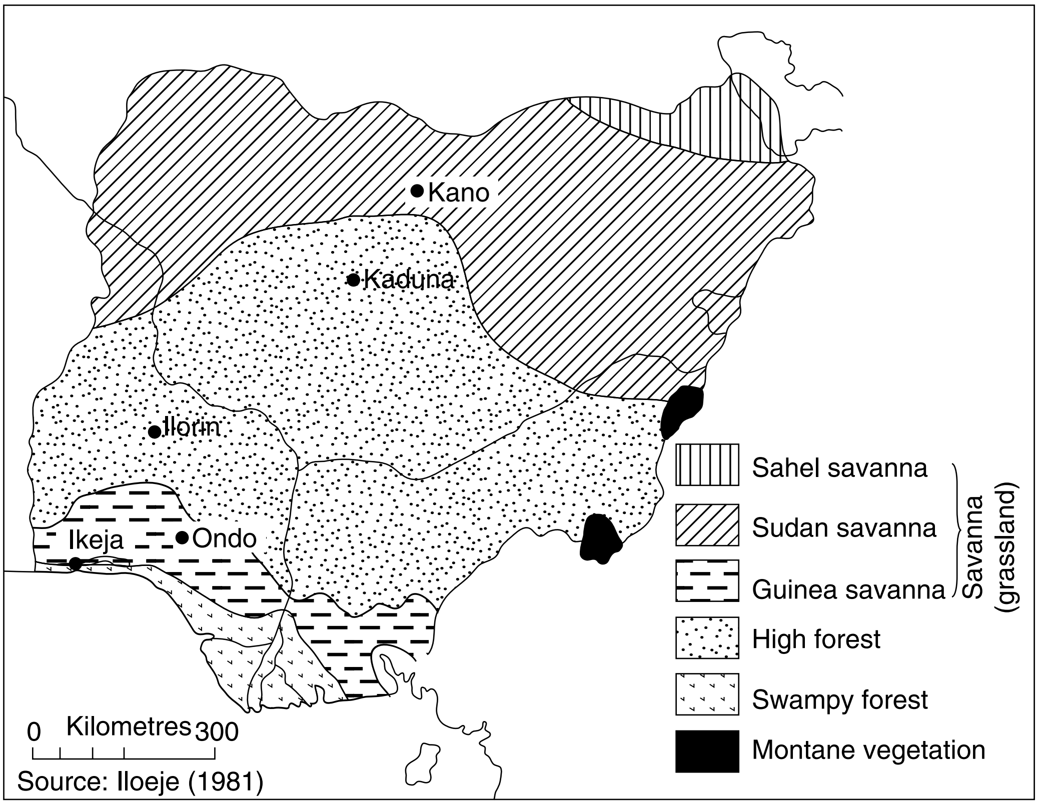

Figure 2. Map of Nigeria showing the vegetation belts and the selected rainfall stations. Source: Iloeje (1981)

Over the country, temperature varies from place to place. The most clearly marked differences are between the coastal areas and the interior and between the high plateaux and the lowlands. On the plateaux, the mean annual temperature figures vary between 21 and 27 °C. On the interior lowlands, the mean annual temperatures registered are over 27 °C. The coastal fringes have lower means than the interior lowlands (Iloeje, 1981). The seasonal temperature range, as in other tropical countries, is low, with an average value of 6 °C. In fact, at some southern stations it may be as low as 3 °C (Iloeje, 1981). In this tropical situation of relatively uniform temperatures and small seasonal variations, there is a wide choice of suitable crops in relation to temperature conditions and thus, as already noted, temperatures are not a critical factor in tropical agriculture (Nieuwolt, 1982).

Whereas in the mid-latitudes the growing season and the timing of agricultural activities are dictated by the temperature conditions, in Nigeria, like any other tropical country, rainfall is the principal controlling element in agriculture (Nieuwolt, 1982; Stern and Coe, 1982). As noted by Stern and Coe (1982), in the tropics the rainfall is often the only input that varies markedly from year to year, so the predicted variability in crop index or water balance is due only to the variability in rainfall. The southern two-thirds of the country has a double peak in rainfall, whereas the northern third has a single peak (Iloeje, 1981). Rainfall generally begins first in the south, spreading through the middle belt, and eventually reaching the northern part. The rains may be unduly prolonged in some years, and their onset may be delayed by as much as a month (Iloeje, 1981).

Figure 3 shows the general relief of the country of Nigeria. The country is highest in the east, north, and west, where the land is generally over 1500 m, 600 m, and 300 m respectively. The low-lying areas are found in the centre and south and are generally below 300 m. The Udi plateau, however, attains a height of over 300 m, which breaks the monotony of the surface in the low-lying areas of the south (Iloeje, 1981).

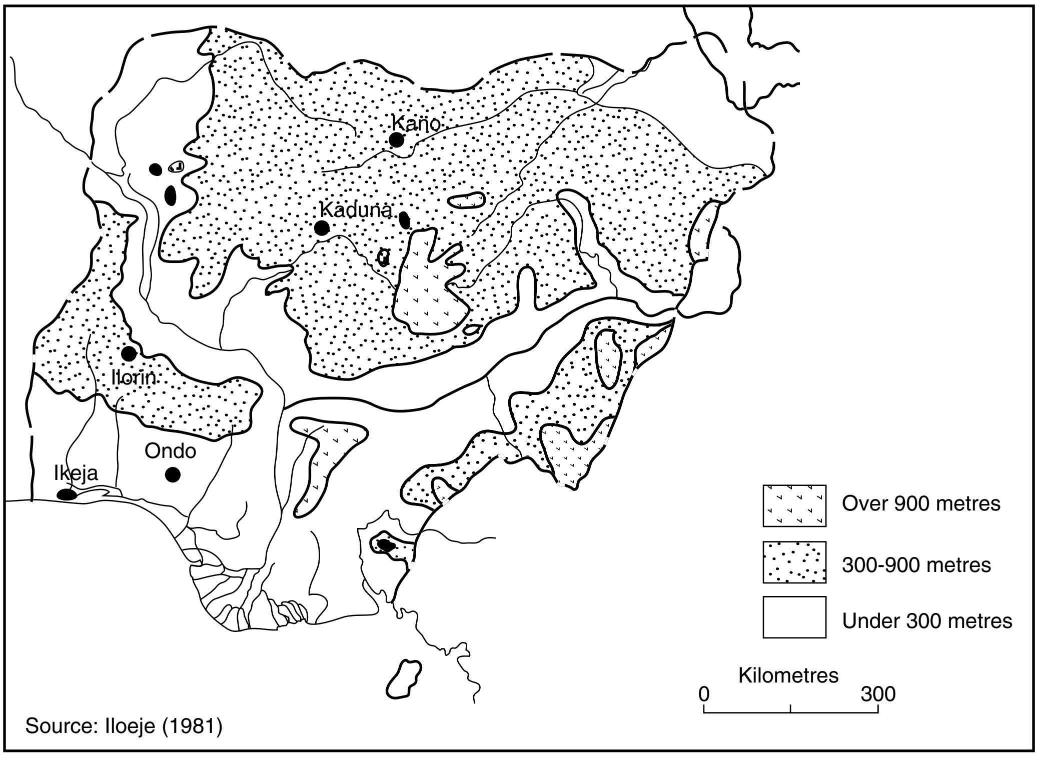

Figure 3. Map of Nigeria showing the relief and the selected rainfall stations. Source: Iloeje (1981)

3. STUDY METHODOLOGY

The data used for this study are the daily rainfall data collected from archival sources, namely the Library of the Nigerian Meteorological Services, Oshodi, Lagos. Data for all the rainfall stations in this study are available between 1961 and 2000 (40 years).

The rainfall data were collected using the British Standard rain gauge and a Dines' tilting siphon rainfall recorder. Data collected using these instruments are samples in space, and so are subject to errors, including instrumental and observer errors, and problems of data homogeneity. On the latter, Adejuwon (1988) has shown that the Nigerian meteorological stations whose data are employed in this study have not been affected by site relocation. Notwithstanding this useful historical information, the data consistency has been assessed and the homogeneity confirmed. The existence of other errors in the rainfall data of the various stations could not be determined, and error terms associated with the data could not be assessed. Furthermore, the confidence placed in the data reliability could not be determined. However, there are reasons to believe that the data are of adequate quality. For instance, the seasonal distribution of the data reflects well known tropical rainfall phenomena, such as the double rainfall maxima and the 'little dry season' of southwestern Nigeria and the single maximum rainfall regime of northern Nigeria.

The relative definition method employed in this study to determine the onset and cessation of the growing season is that proposed by Ilesanmi (1972). The first essential step of this method is to derive the percentage mean annual rainfall that occurs for each 5 day interval. This is followed by accumulating the percentages of the 5-day periods. When the cumulative percentage is plotted against time through the year, the first point of maximum positive curvative of the graph corresponds to the time of rainfall onset, and the last point of maximum negative curvature corresponds to the rainfall cessation. Ilesanmi (1972) noted that the point of onset on the graph corresponds to the time when an accumulated 7–8% of the annual rainfall totals has been obtained, whereas that of rainfall cessation is 90%. This study adopts this method: onset and cessation periods are taken as the times when an accumulated 7–8% and 90% of the annual rainfall totals respectively are obtained.

A variety of methods have been devised to ensure meaningful probability and reliability values with which to determine rainfall events. This study determines the overall probability of rain; the method chosen is that proposed by Garbutt *et al.* (1981), whereby the probability of rain on any given date can be estimated by the proportion of rainy days on that date. In other words, the process of estimating the probability of rainfall for each day of the year is to express the number of rainy days as a proportion of the total number of days considered for each day of the year. On the basis of this rainfall probability estimate of each day of the year, a comprehensive tabulation can be arrived at for all the days of the year. Furthermore, since probability values range between 0 and 1, with success and failure breaking even at 0.50, a day with reliable rainfall may be taken as a day with a probability value that is greater than or equal to 0.50.

There is, however, a need to define the threshold value of rainfall amount required for a day to be counted as rainy. Several thresholds have been tried by Garbutt *et al.* (1981), and 0.85 mm was found appropriate for West African countries. Therefore, a threshold value of 0.85 mm is employed in this study. This implies that any day with a rainfall amount below this threshold value is assumed to be rainless.

4. RESULTS

Figures 4–8 respectively show the rainfall onset and retreat periods and the length of the growing season in Ikeja, Ondo, Ilorin, Kaduna, and Kano using the relative definition method. The period of the year when 7–8% mean cumulative rainfall of the 5-day periods is attained (corresponding to the time of rainfall onset) in Ikeja is around the end of the second dekad of March (with percentage cumulative rainfall of 7.47%). The corresponding periods for Ondo, Ilorin, Kaduna, and Kano are respectively around the middle of the third dekad of March, mid April, end of the first dekad of May, and early June, with cumulative percentage rainfall values of 8.61%, 8.14%, 7.14%, and 9.28% respectively. The periods of the year when over 90% of the mean cumulative rainfall for the 5-day periods is attained (corresponding to the time of rainfall retreat) are respectively around the early third dekad of October, early third dekad of October, end of the first dekad of October, end of September, and early second dekad of September for Ikeja, Ondo, Ilorin, Kaduna, and Kano. Their respective cumulative percentage rainfall values are 90.08%, 91.76%, 90.71%, 92.56%, and 92.09%. The mean length of the growing season for Ikeja is approximately 7 months, and for Ondo, Ilorin, Kaduna, and Kano this is approximately 7 months, 6 months, 5 months, and 3 months respectively.

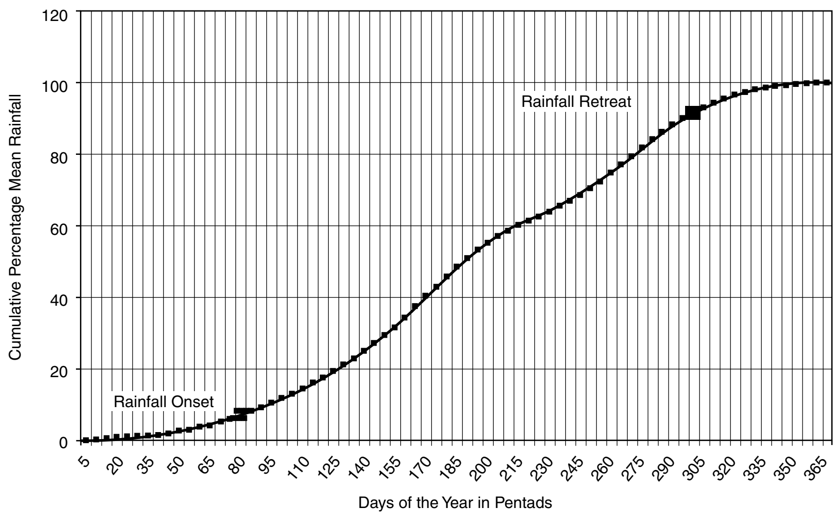

Figure 4. Rainfall onset, rainfall retreat, and length of the growing season in Ikeja (using the relative definition approach)

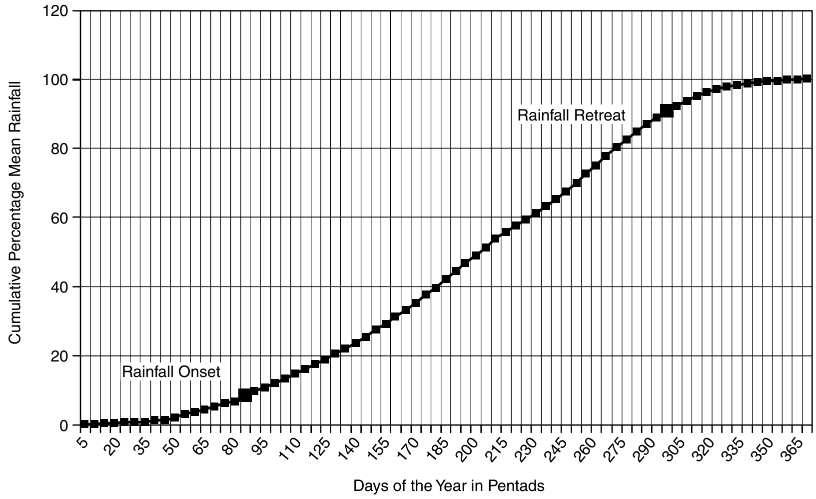

Figure 5. Rainfall onset, rainfall retreat, and the length of the growing season in Ondo (using the relative definition approach)

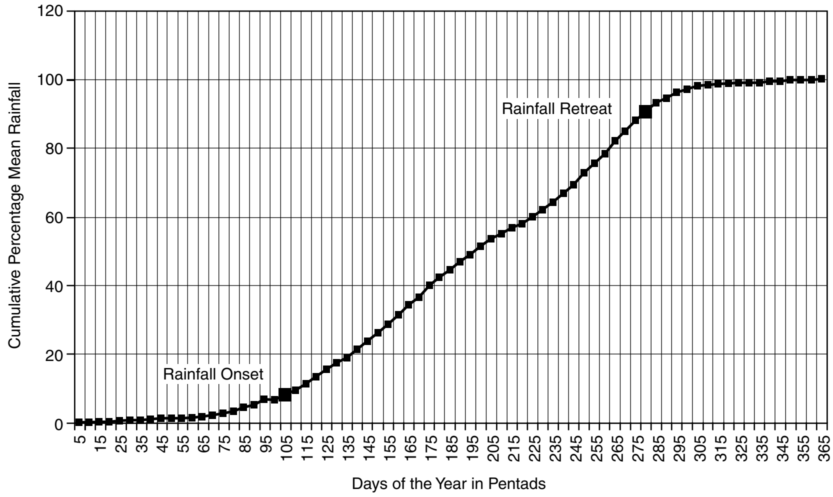

Figure 6. Rainfall onset, rainfall retreat, and the length of the growing season in Ilorin (using the relative definition approach)

Figures 9–13 respectively show the rainfall onset and retreat periods and the length of the growing season in Ikeja, Ondo, Ilorin, Kaduna, and Kano using the daily rainfall probability/reliability method. The results of the analysis show that rainfall at the respective stations becomes more reliable starting from the end of the second dekad of May (with probability value of 0.50), early third dekad of May (with probability value of 0.51), mid third dekad of May (with probability value of 0.50), end of May (with probability value of 0.53), and end of the first dekad of July (with probability value of 0.50). Rainfall at the respective stations becomes less reliable from the end of the second dekad of October (with probability value of 0.50), end of the second dekad of October (with probability value of 0.52), middle of the first dekad of October (with probability value of 0.50), early October (with probability value of 0.55), and middle of the first dekad of September (with probability value of 0.50). Thus, judging by the rainfall probability and reliability method, the lengths of the growing season in Ikeja, Ondo, Ilorin, Kaduna, and Kano are 5 months, 5 months, 4 months, 4 months, and 2 months respectively. In the southwestern part of the country, Ikeja, Ondo, and Ilorin, the rainfall probability values reflect the influence of the July–August rainfall minimum (see Figures 9–11). In Ikeja for instance, there were 48 consecutive days having a probability of rainfall that is less than 0.50 during

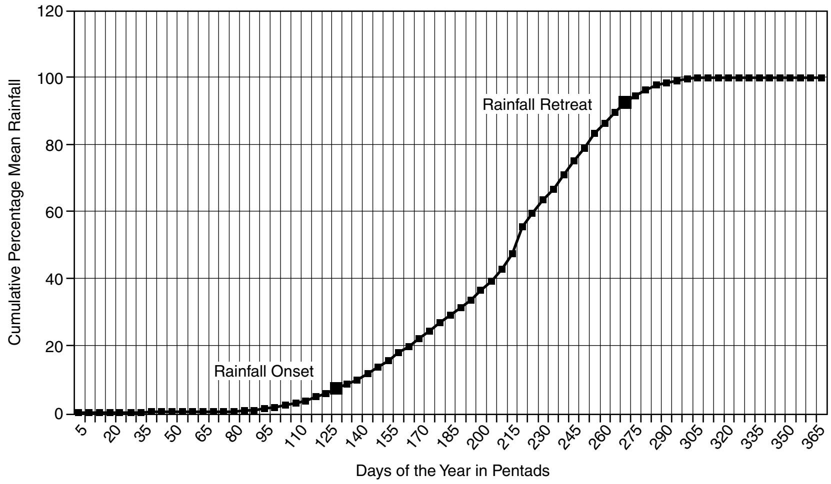

Figure 7. Rainfall onset, rainfall retreat, and the length of the growing season in Kaduna (using the relative definition approach)

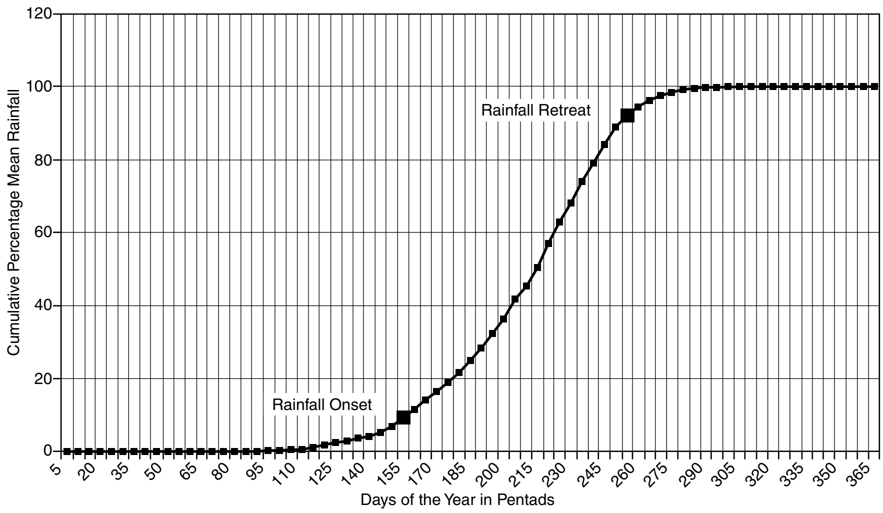

Figure 8. Rainfall onset, rainfall retreat, and the length of the growing season in Kano (using the relative definition approach)

the growing season. This period, which is between the end of the second dekad of July and middle of the first dekad of September, represents the July–August rainfall minimum of the region. The maximum number of consecutive days of rainfall probability that is less than 0.50 in the remaining part of the growing season in Ikeja is 5 days. During the growing season in Ondo, the maximum number of consecutive days during which the probability of receiving rainfall is less than 0.5 is 7 days. This period, which comes between the end of the first dekad and middle of the second dekad of August, is also visualized to fall within the July–August rainfall minimum. The July–August rainfall minimum phenomenon is also noted in Ilorin's daily rainfall probability graph (Figure 11). The phenomenon manifests itself as 43 consecutive days (end of the second dekad of July to end of August) of rainfall probability values of less than 0.50 during the growing season in the region. The maximum number of consecutive days of rainfall probability that is less than 0.50 in the remaining part of the growing season in Ilorin is 8 days. The maximum number of consecutive days of rainfall probability that is less than 0.50 during the growing season in Kaduna and in Kano is 8 days. As shown in Figures 12 and 13, the daily rainfall probability values reflect a single maximum in the seasonal rainfall regime.

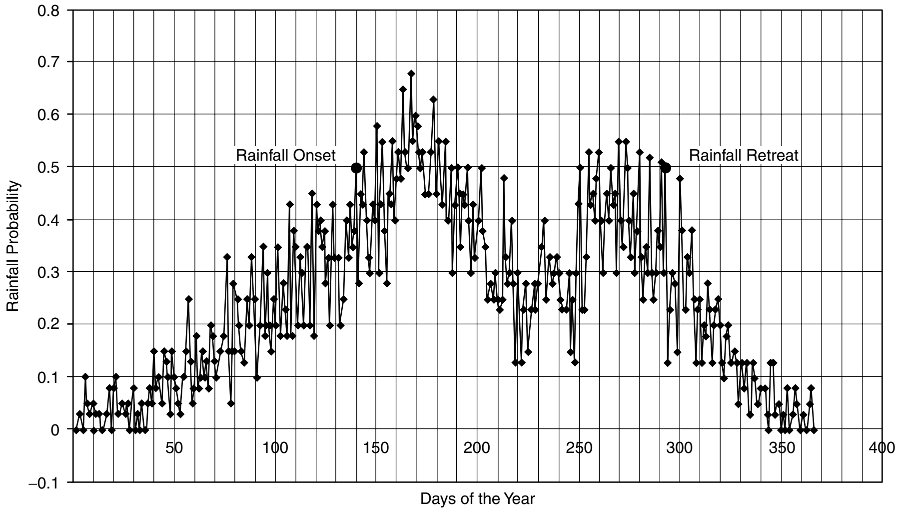

Figure 9. Rainfall onset, rainfall retreat, and the length of the growing season in Ikeja (using the rainfall probability/reliability approach)

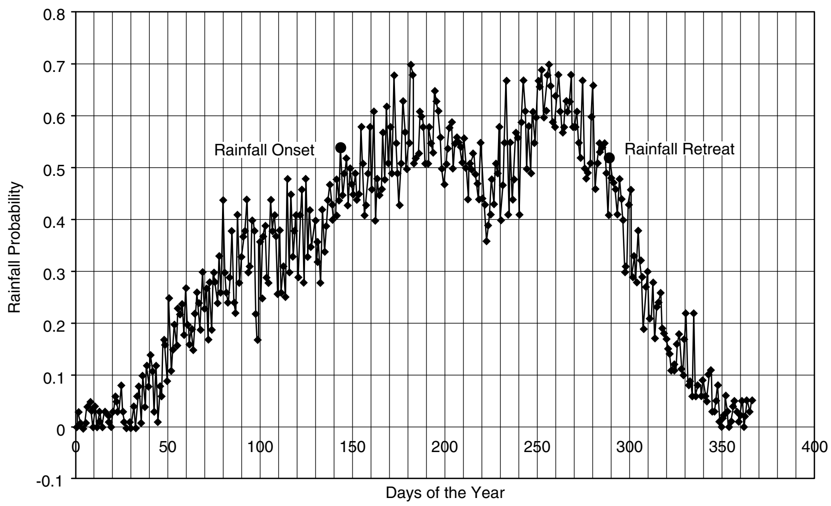

Figure 10. Rainfall onset, rainfall retreat, and the length of the growing season in Ondo (using the rainfall probability/reliability approach)

5. DISCUSSION

Judging by the relative definition method of determining the length of the growing season, the growing seasons in Ikeja, Ondo, Ilorin, Kaduna, and Kano extend over 7 months (end of the second dekad of March to the early third dekad of October), 7 months (middle of the third dekad of March to the early third dekad of October), 5 months (mid April to the end of the first dekad of October), 5 months (end of the first dekad of May to the end of September) and 3 months (early June to the early second dekad of September) respectively. All the results obtained (rainfall onset and retreat periods and the length of the growing season) compare well with other studies carried out in the region (e.g. Ilesanmi, 1972; Olaniran, 1983; Adejuwon, 1988; Adejuwon *et al.*, 1992; Bello, 1995). However, in contradiction to the above results (obtained using the relative definition method), the analysis of rainfall probability shows that, on average, there are 5 months (end of the second dekad of May to the end of the second dekad of October), 5 months (early third dekad of May to the end of the second dekad of October), 4 months (mid third dekad of May to the middle of the first dekad of

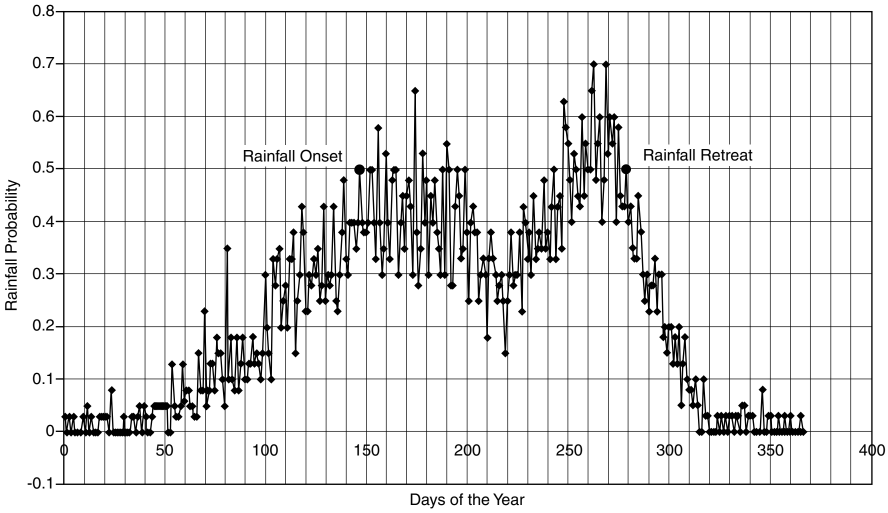

Figure 11. Rainfall onset, rainfall retreat, and the length of the growing season in Ilorin (using the rainfall probability/reliability approach)

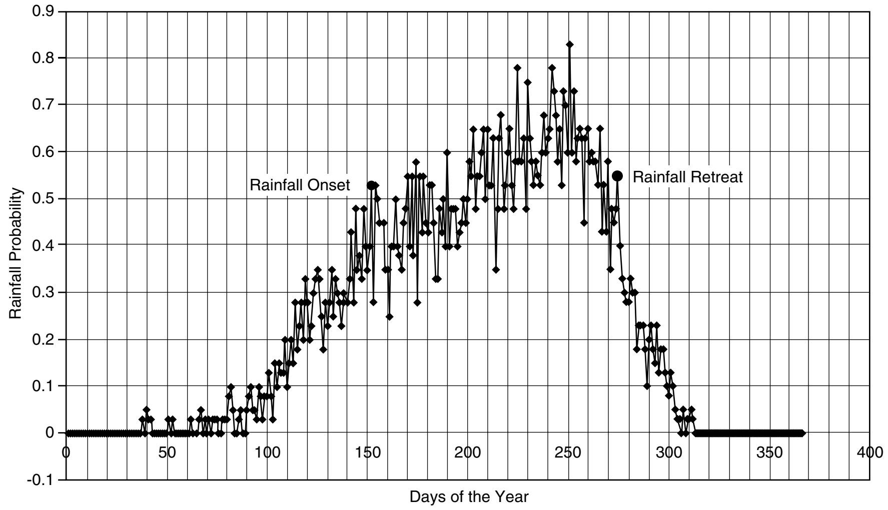

Figure 12. Rainfall onset, rainfall retreat, and the length of the growing season in Kaduna (using the rainfall probability/reliability approach)

October), 4 months (end of May to early October) and 2 months (end of the first dekad of July to the middle of the first dekad of September) in the year, in Ikeja, Ondo, Ilorin, Kaduna, and Kano respectively, during which rainfall is reliable for crop germination, establishment, and full development. A careful observation of the results obtained reveals that, for all of the stations studied, the disparity is large between the first date of reliable rainfall using the rainfall probability method and that revealed by the relative definition method. The differences in the onset period at Ikeja, Ondo, Ilorin, Kaduna, and Kano are approximately 2 months, 2 months, 1 month, 1 month and 1 month respectively. However, there is no significant difference between the two methods with regard to the rainfall cessation periods for the stations studied. None of the differences in the retreat periods at any of the stations studied is up to a week.

It is known that the frequency of rainfall during the course of the year within the tropics appears to be mostly governed by the movement of the ITD and the critical depth of the warm, moist mT air required for a location to experience rainfall regularly (>1500 m; see Ojo (1977)). This implies that, as the ITD

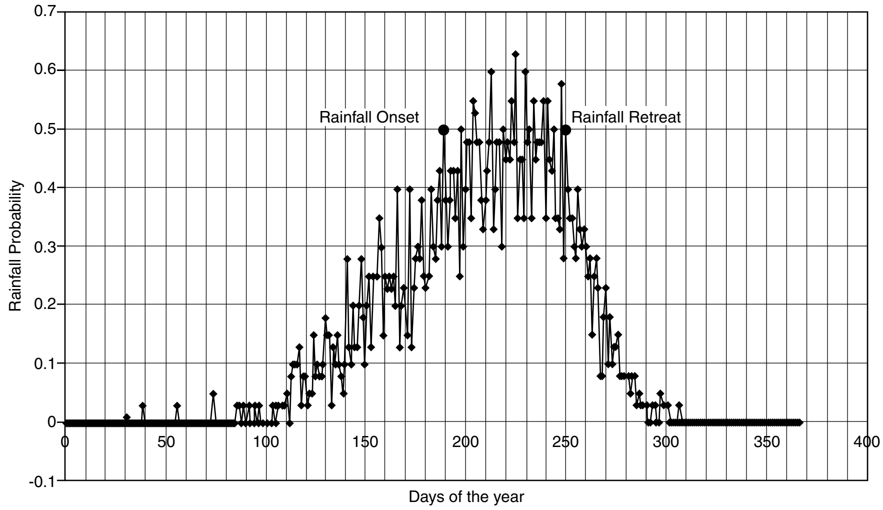

Figure 13. Rainfall onset, rainfall retreat, and the length of the growing season in Kano (using the rainfall probability/reliability approach)

advances northward, any newly invaded place that is less than 4° of latitude south of the ITD may, at best, experience isolated showers of uncertain amount and intensity (Flohn, 1960; Adedokun, 1981). A similar but converse situation prevails during the retreat period. The disparities in the dates of the start of the growing season between the two methods (relative definition and rainfall probability methods) are more than those of the cessation because the ITD advances into the continent gradually but it retreats rapidly (Ayoade, 1974; Adefolalu, 1983). The results obtained in this study (using the relative definition method) further corroborate this idea of gradual advance and rapid retreat of the ITD, as the rainfall onset in Nigeria takes approximately 3 months to spread from Ikeja (end of the second dekad of March) to Kano (early June), whereas it takes approximately only 1 month to retreat from Kano (early second dekad of September) to Ikeja (early third dekad of October). The implication of this gradual advance and rapid retreat of the ITD is that isolated showers of uncertain amount and intensity would prevail over Nigeria over a relatively longer period of time at the beginning than towards the end of the growing season. Thus, it can be established that Ikeja, Ondo, Ilorin, Kaduna, and Kano respectively experience sufficient warm, moist mT air depth between the end of the second dekad of May and end of the second dekad of October, between the early third dekad of May and end of the second dekad of October, between the mid third dekad of May and middle of the first dekad of October, between the end of May and early October, and between the end of the first dekad of July and middle of the first dekad of September during the course of the year, since rainfall during these periods appears to be more regular as suggested by the index of probability and reliability values. In other words, the reliable length of the growth season in Ikeja, Ondo, Ilorin, Kaduna, and Kano is approximately 5 months, 5 months, 4 months, 4 months and 2 months respectively.

This implies that crops planted between the end of the second dekad of March and end of the second dekad of May in Ikeja, between the middle of the third dekad of March and early third dekad of May in Ondo, between mid April and middle of the third dekad of May in Ilorin, between the end of the first dekad of May and end of May in Kaduna, and between early June and end of the first dekad in July in Kano are vulnerable to critical dry spells that may adversely affect both plant germination and establishment. Thus, plants that are tolerant to short, dry spells may be planted commencing from the end of the second dekad of March, middle of the third dekad of March, mid April, end of the first dekad of May, and early June in Ikeja, Ondo, Ilorin, Kaduna, and Kano respectively. However, plants that are less tolerant of drought at the germination and establishment stages should be planted starting from the end of the second dekad of May, early third dekad of May, mid third dekad of May, end of May, and end of the first dekad of July respectively.

6. CONCLUSIONS

The length of the growing season in Nigeria has been examined using both the daily rainfall probability method and the rainfall onset and retreat, as determined by the cumulative percentage mean rainfall values.

Although rainfall in Ikeja, Ondo, Ilorin, Kaduna, and Kano appears to commence from the end of the second dekad of March, middle of the third dekad of March, mid April, end of the first dekad of May, and early June respectively, the rainfall distribution characteristics at the respective stations remained inadequate for crop germination, establishment, and full development until the end of the second dekad of May, early third dekad of May, mid third dekad of May, end of May, and end of the first dekad of July respectively. The reliable growing seasons extend respectively from the end of the second dekad of May to the end of the second dekad of October, from the early third dekad of May to the end of the second dekad of October, from the mid third dekad of May to the middle of the first dekad of October, from the end of May to early October, and from the end of the first dekad of July to the middle of the first dekad of September. This study recommends the use of daily rainfall probability estimates for assessment of the growing season.

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