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Determining rainy season onset and retreat over Nigeria from precipitation amount and number of rainy days

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With 3 Figures

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Summary

This study assesses the relative efficiency of the use of rainfall amount and rainy days in the determination of rainfall onset and retreat dates in Nigeria based on rainfall data for the period 1961 to 2000. Daily rainfall data were sourced from the archives of the Nigerian Meteorological Services, Oshodi Lagos. The specific locations for which data were collected are: Ibadan, Ilorin, Kaduna and Kano. The method of percentage cumulative mean rainfall values was employed in the determination of the rainfall onset and retreat dates.

The results obtained show that both rainfall amount and rainy days are equally effective in the determination of the mean rainfall onset and retreat dates in Nigeria. With regards to the rainfall onset and retreat dates of the individual years however, the method based on the rainy days is more effective than that based on rainfall amount, as the former yielded more realistic dates than the latter. It is thus recommended that studies investigating rainfall onset and retreat dates within a series of individual years in Nigeria, should be based on rainy days rather than rainfall amount.

1. Introduction

Several methods have been formulated for determining the onset and retreat of the rains in West Africa in general and Nigeria in particular. The various methods can be classified into five main categories, namely: (a) Intertropical Discontinuity (ITD) – rainfall model, (e.g. Ilesanmi, 1972a; Kowal and Knabe, 1972), (b) rainfall-evapotranspiration relation model (Cocheme and Franquin, 1967; Benoit, 1977), (c) percentage cumulative mean rainfall model – based on rainfall data alone (Ilesanmi, 1972b; Adejuwon et al., 1990), (d) wind shear model (Omotosho, 1990) and (e) the theta – E technique (Omotosho, 2002). The percentage cumulative mean rainfall appears to be one of the most frequently adopted of these methods (e.g. Ilesanmi, 1972b; Olaniran, 1983; Adejuwon, 1988; Adejuwon et al., 1990; Bello, 1995). This method is widely adopted because, as observed by Olaniran (1983), it provides mean onset of the rains that do not differ significantly from the mean start of the growing season for all locations in the country. The overall advantage of this method is that it uses rainfall data, a readily available direct measurement, rather than some other rainfall-associated factor.

Previous studies, where this method has been adopted in Nigeria, have involved the use of rainfall amount alone. This is in spite of the fact that rainfall frequency (in terms of rainy days), another component of rainfall, appears to be relatively more important to agriculturalists than the amount. The 'rainy days' parameter reflects rainfall amount since a rainy day can only be defined using a certain rainfall threshold. Both the use of rainfall amount and the number of rainy days may produce similar mean onset and retreat dates, as the mean proportion of the two parameters may approximate each other in the long-term. There may however, be the need to generate the rainfall onset and retreat dates of individual years. Such data may be required to generate onset and retreat dates time series for the purpose of prediction, or for verifying the onset and retreat dates forecasts of individual years. The problem is that one or two large isolated showers at the beginning or end of the year may meet the specified rainfall onset/retreat criteria, thus producing unrealistic rainfall onset and retreat dates. However, rainy day frequency can only be high when rainfall has truly commenced and low only when rainfall has retreated.

This study therefore investigates the relative efficiency of the use of rainfall amount and the number of rainy days in the determination of rainfall onset and retreat dates in Nigeria, using the percentage cumulative mean rainfall.

2. Study area

The study area, Nigeria (approximately latitudes 4°–14° N north of the equator and Longitudes 3°–15° east of the Greenwich meridian), lies at the southeastern edge of the West African region (Fig. 1). The country has an area of approximately 923,300 km^2.

The climate of Nigeria is more varied than any other country in West Africa. This is due to the fact that the latitudinal extent of the country is relatively large (1,100 km) and thus covers virtually all of the climatic belts of West Africa (Iloeje, 1981). The climate is dominated by the influence of three main wind currents: the tropical maritime (mT) air mass, the tropical continental (cT) air mass and the equatorial easterlies (Ojo, 1977). The mT air mass originates from the southern high-pressure belt located off the Namibian coast, while the cT air mass originates from the high-pressure belt north of the Tropic of Cancer. This latter air mass picks up little moisture along its path and is thus dry. These two air masses (mT and cT) meet along a slanting surface called the Intertropical Discontinuity (ITD). The third air mass, equatorial easterlies, is a rather erratic cool air mass, which comes from the east and flows in the upper atmosphere along the ITD. This air mass descends occasionally to actively undercut the mT or cT air mass and gives rise to line squalls or dust devils (Iloeje, 1981).

The specific locations of the country selected for the study are: Ibadan, Ilorin, Kaduna and Kano (see Fig. 1). These locations which are found along a trajectory of southwesterlies, are at such distances from each other that rainfall onset and retreat dates would clearly reflect the latitudinal order of the locations.

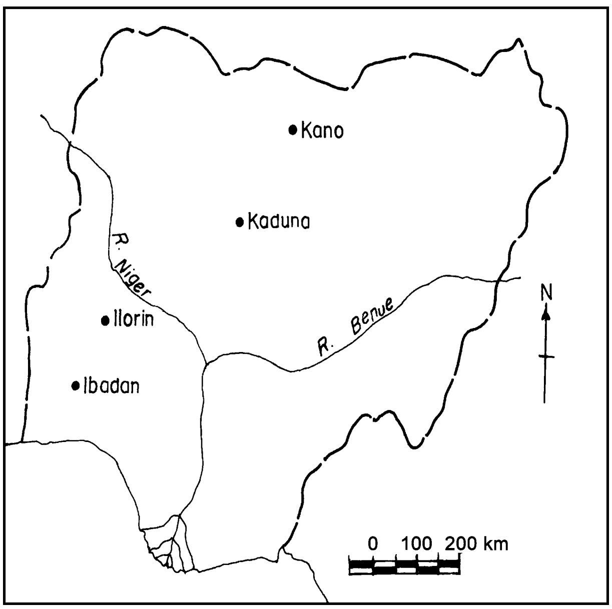


Fig. 1. Map of Nigeria, showing the selected rainfall stations

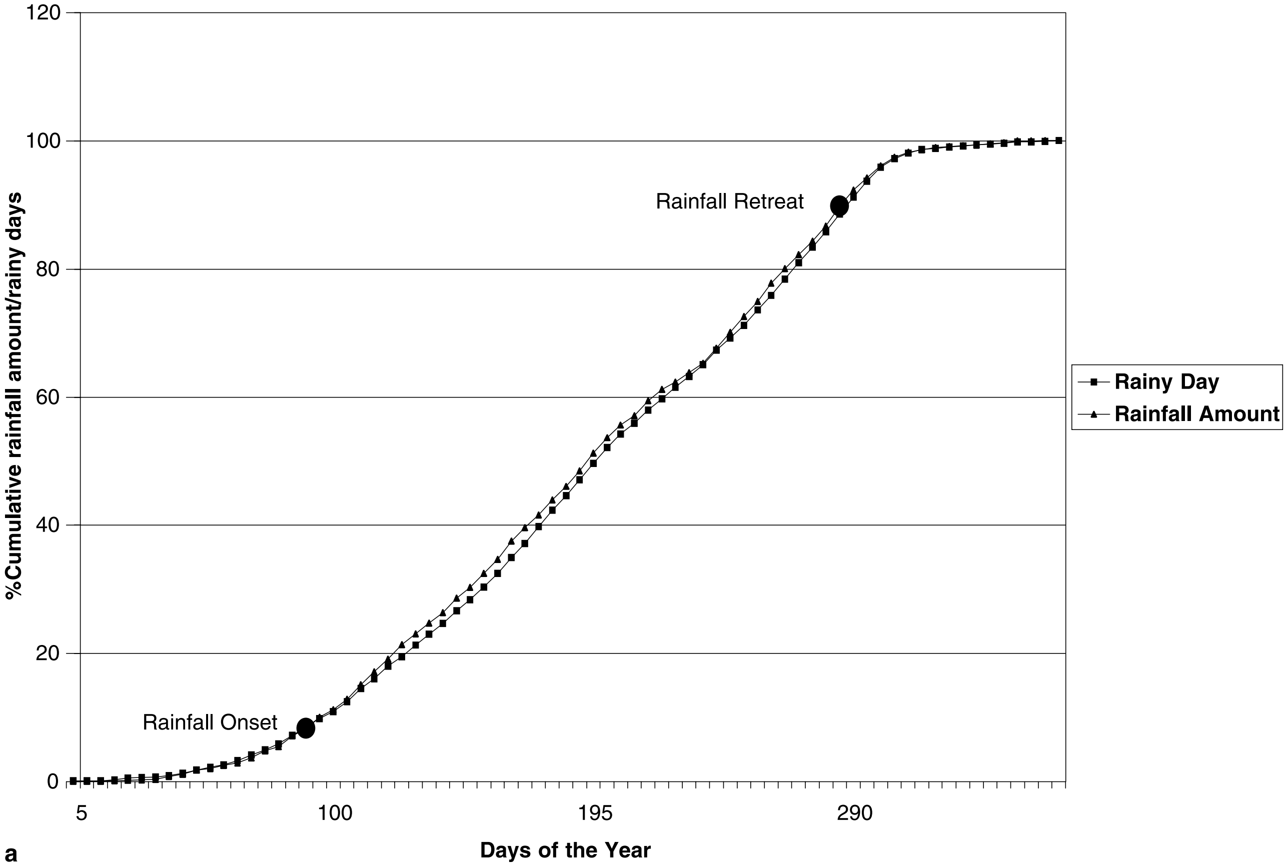
3. Study methodology

3.1 Data collection

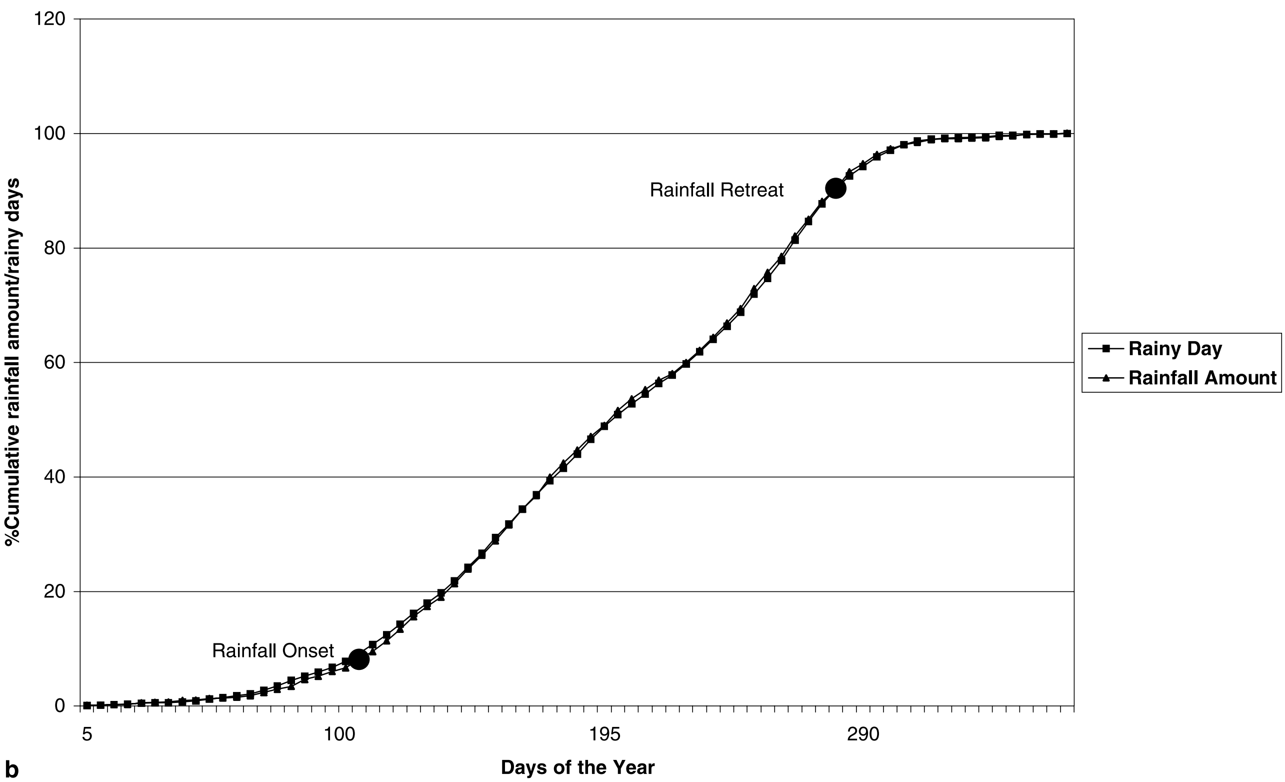
The data required for this study are daily rainfall. The data were sourced from the archives of the Nigerian Meteorological Services, Oshodi, Lagos. The data were collected at four synoptic meteorological stations in the country – Ibadan, Ilorin, Kaduna and Kano between 1961 and 2000. The mean rainfall onset date was determined using the daily rainfall data between 1961 and 2000, while the onset dates of individual years were determined using the daily rainfall data between 1971 and 2000.

3.2 Percentage mean cumulative rainfall

The proponents of the method of percentage cumulative mean rainfall for determining rainfall onset and retreat dates include Ilesanmi (1972a; 1972b), Rao (1976), Adejuwon (1988)

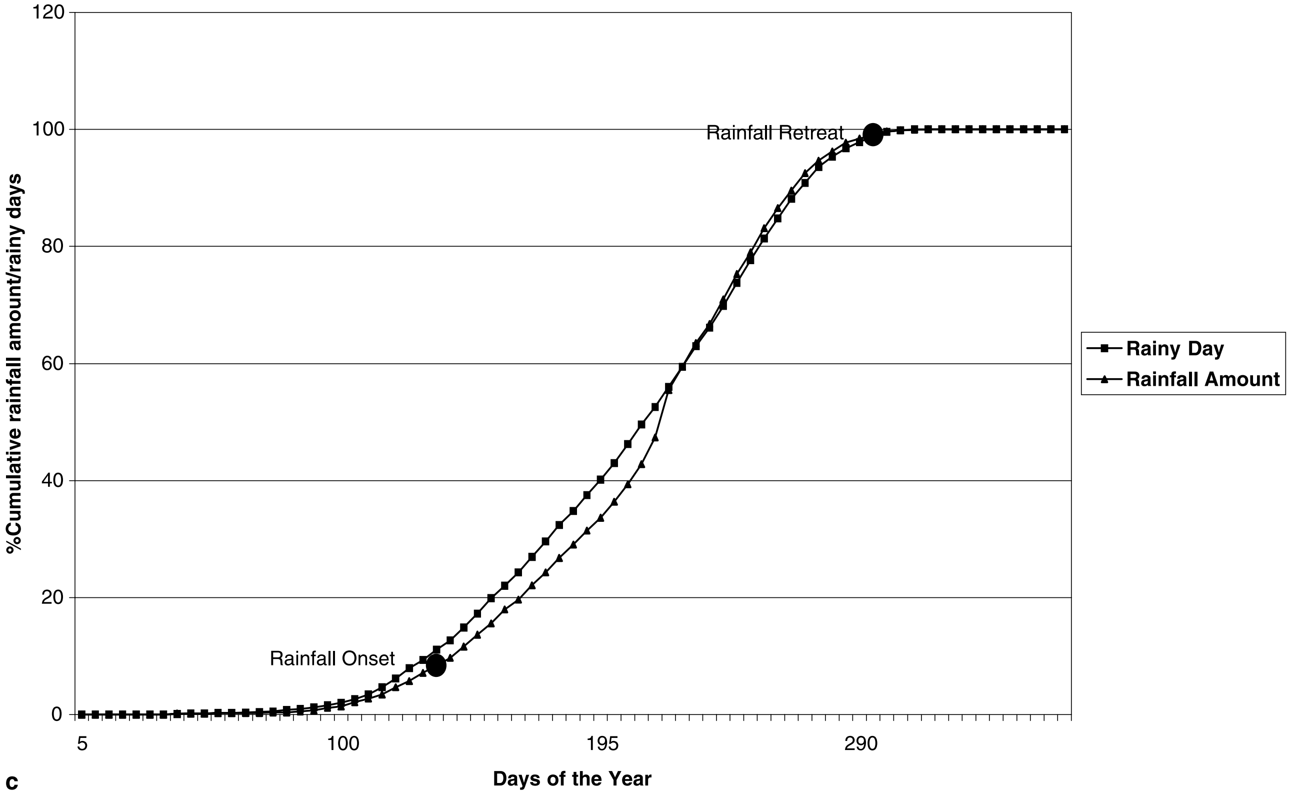


a



b

Fig. 2a–d. Mean rainfall onset and retreat dates in (**a**) Ibadan, (**b**) Ilorin, (**c**) Kaduna and (**d**) Kano between 1961 and 2000



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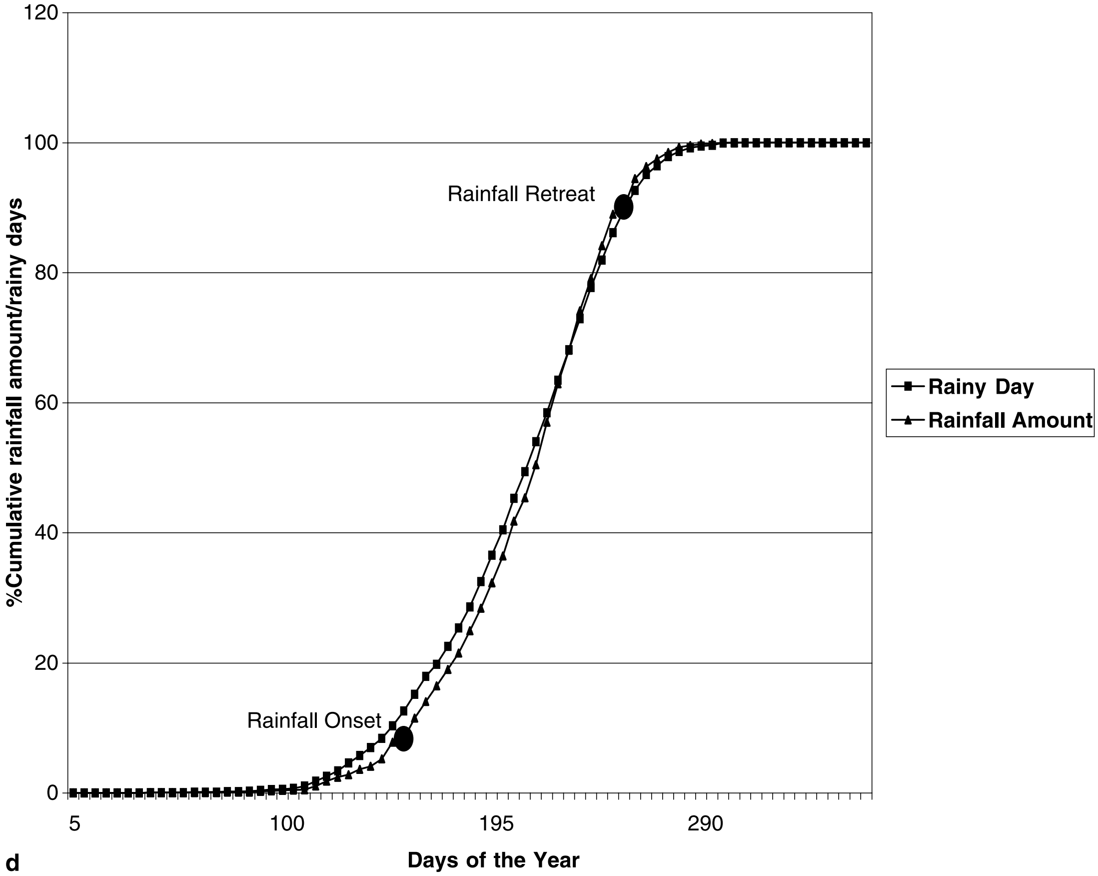

d

Fig. 2 (*continued*)

and Adejuwon et al. (1990). The first essential step of this method is to derive the mean annual rainfall that occurs at each 5-day interval of the year. This is followed by computing the percentage of the mean annual rainfall that occurs at each of the 5-day intervals throughout the year. The next step involves cumulating the percentages of the 5-day periods. Finally, when the cumulative percentage is plotted against time through the year, the first point of maximum positive curvature of the graph corresponds to the time of rainfall onset, while the last point of maximum negative curvature corresponds to the rainfall retreat. These points of maximum curvature which correspond to the onset and retreat of rainfall are respectively 7–8 percent and over 90 percent of the annual rainfall. In this study, the graphical method is used to determine the mean proportion, which is then used to estimate the rainfall onset and retreat dates for each year.

3.3 Rainy days

A first step in the use of this method is to define the threshold value of rainfall amount required for a day to be counted as rainy. The Nigerian Meteorological Services Oshodi, Lagos usually employs two thresholds 0.3 mm or 1 mm. However, several thresholds have been investigated by Garbutt et al. (1981) and 0.85 mm was found appropriate for agricultural purposes in West Africa. Therefore, a threshold value of 0.85 mm is employed in this study. This implies that, all days with rainfall below this threshold value are not included as rainy days.

4. Results

Figure 2a–d show the cumulative percentage of both the mean annual rainfall amount and the number of rainy days that occur at each 5-day period between 1961 and 2000 respectively in Ibadan, Ilorin, Kaduna and Kano. Both the cumulative percentage of the mean annual rainfall amount and rainy days that occur at each 5-day period were plotted concurrently on the same figure for each station. The results of the graphs obtained show that the two series (using rainfall amount and rainy days) approximate each other

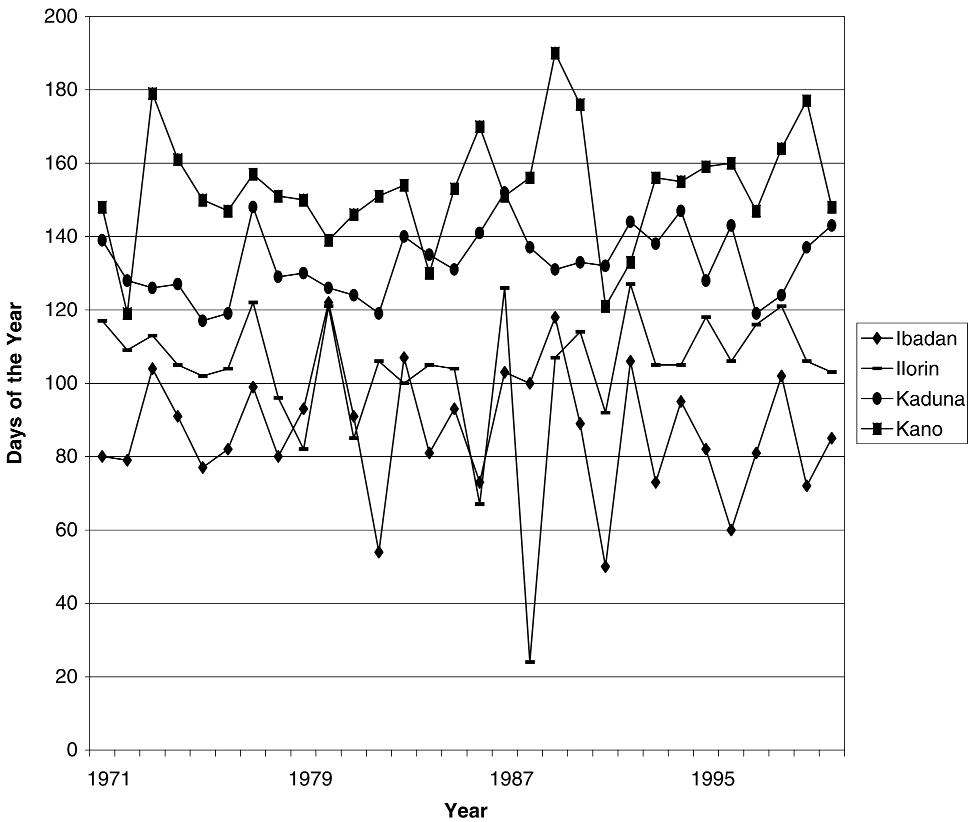

Fig. 3a. Rainfall onset dates, using rainfall amount (1971–2000)

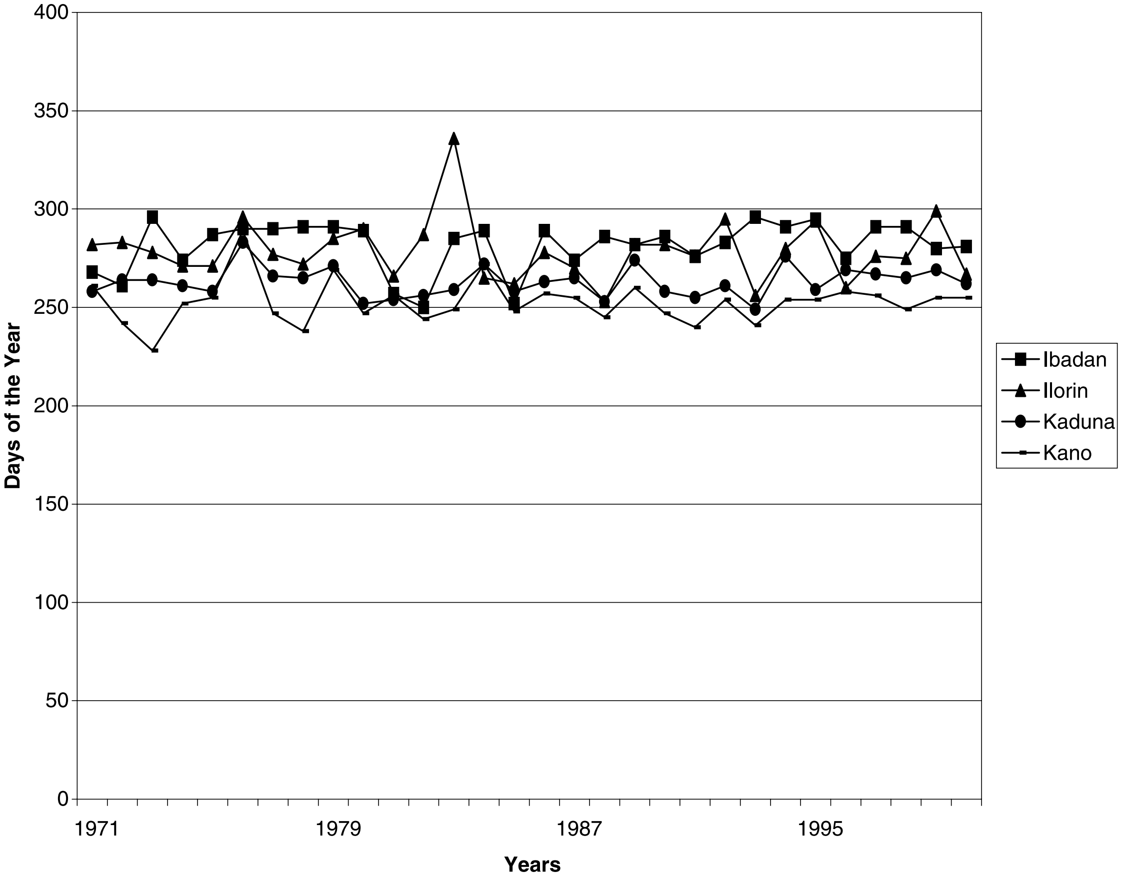

Fig. 3b. Rainfall retreat dates (in days of the year), using rainfall amount (1971–2000)

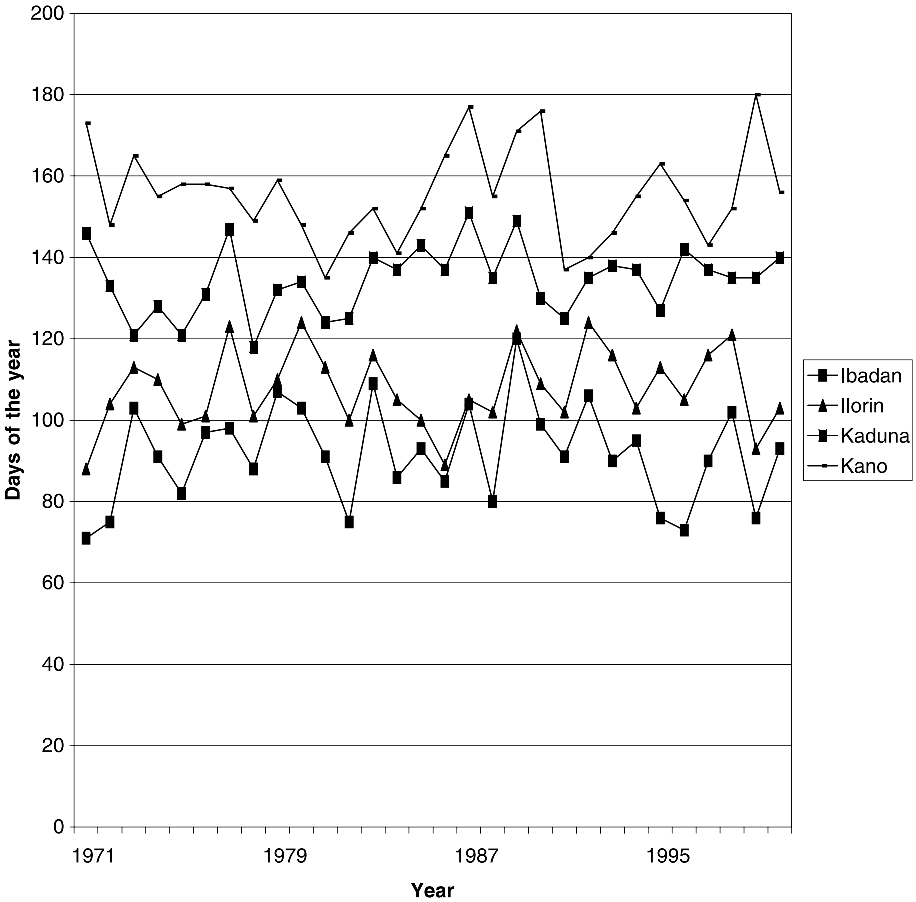

Fig. 3c. Rainfall onset dates, using rainy days (1971–2000)

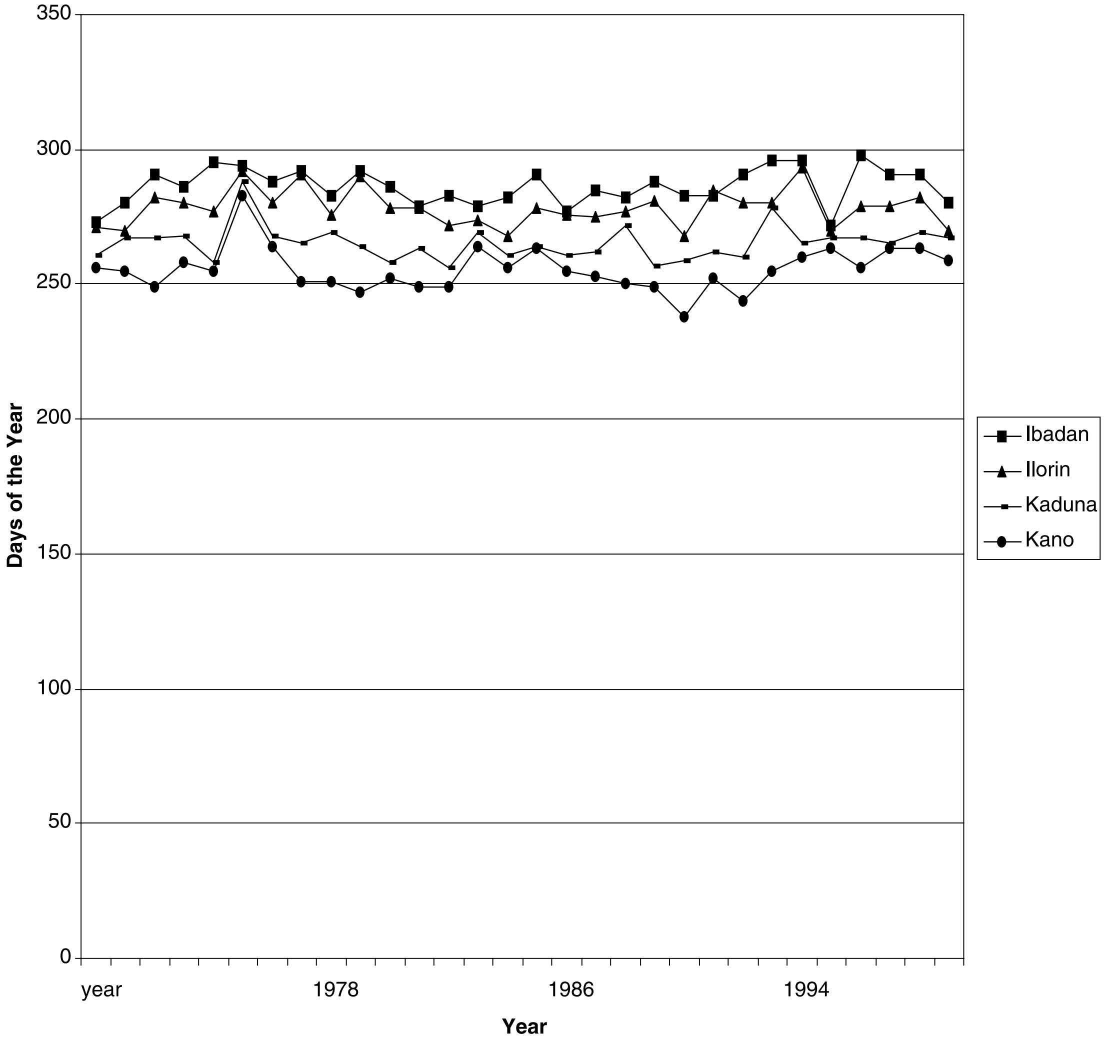

Fig. 3d. Rainfall retreat dates, using rainy days (1971–2000)

totally in terms of configuration in all the stations. In most cases, the two graphs are observed to be directly overlapped. In other words, both methods of determining mean rainfall onset and retreat dates (i.e. using rainfall amount and rainy days) produce the same mean rainfall onset and retreat periods at all the stations studied. The first point of maximum positive curvature of the graphs (corresponding to the time of rainfall onset) of Ibadan, Ilorin, Kaduna and Kano are respectively 31st March, 15th April, 15th May and 4th June. Although, both the methods based on rainfall amount and number of rainy days converge to give the same mean dates of the rainfall onset and retreat dates, the respective cumulative percentage rainfall values at which the various dates were obtained are different. For instance, while the first point of maximum positive curvature of the graph, using the rainfall amount method, had cumulative percentage rainfall value of 8% uniformly in all of the stations studied, those using the rainy days method are 9%, 9%, 11% and 13% for Ibadan, Ilorin, Kaduna and Kano, respectively. The last points of maximum negative curvature of the various graphs (corresponding to the time of rainfall retreat) are respectively 12th October, 7th October, 22nd September and 12th September. While their respective cumulative percentage rainfall values, using rainfall amount, is uniformly 90% at all of the stations studied, the rainy days method gives the cumulative percentage rainfall values of 89%, 90%, 88% and 90%, respectively.

Figure 3a and 3b respectively show the rainfall onset and retreat dates obtained using rainfall amount for individual years between 1971 and 2000 in Ibadan, Ilorin, Kaduna and Kano. The results clearly show that using rainfall amount produces a lot of inconsistencies in the rainfall onset and retreat dates of the various stations. For instance, it is unrealistic to accept that rainfall commences in Ilorin earlier than Ibadan as estimated by the method for the years 1979, 1980, 1981, 1983, 1986, 1988 and 1989. Also, it is unrealistic to accept that rainfall commences in Kano earlier than Kaduna as estimated by the method for the years 1972, 1984, 1991, and 1992. The method also gives unrealistic dates of rainfall retreat at all of the four stations studied. For instance, the method shows that rainfall retreats earlier in Kaduna than Kano in the years 1971, 1976, and 1981, while it also retreats earlier in Ibadan than Ilorin in 1971, 1972, 1976, 1981, 1982, 1983, 1985, 1992 and 2000. A very peculiar case is 1984 for which the method indicates a rainfall retreat date for Ilorin earlier than at Kano. The rainfall retreat date at Ilorin for 1996 is also earlier than at Kaduna but is similar to that of Kano. Figure 3c and 3d respectively show the rainfall onset and retreat dates obtained for the individual years between 1971 and 2000 in Ibadan, Ilorin, Kaduna and Kano, using rainy days. The results clearly show that this latter method of determining rainfall onset and retreat dates produces more realistic results. Thus, rainfall is observed to commence at normally expected times at Ibadan, Ilorin, Kaduna and Kano. Rainfall also retreats consistently from Kano, through Kaduna Ilorin and Ibadan.

5. Discussion

This study has established that, between 1961 and 2000, on average, rainfall sets in at the beginning of the season from Ibadan and gradually proceeds through Ilorin, Kaduna, and Kano. These results are in agreement with the established fact in the literature. It should be noted that the largest proportion of the moisture supplied into the atmosphere over West African hinterlands appears to emanate from the Atlantic Ocean. The moisture from the ocean is embedded in the southwesterly winds, which advance from the Gulf of Guinea and moves over Ibadan to Ilorin, Kaduna and eventually Kano (see for example, Ojo, 1977; Adedokun, 1978). The converse of this situation holds for the retreat period – rainfall retreats from Kano, Kaduna, Ilorin, to eventually reach Ibadan. The results show that rainfall takes up to 65 days to spread from Ibadan to Kano during the onset period, whereas, it takes only 30 days to retreat from Kano to Ibadan. This result further corroborates the observations of Ayoade (1974) and Ojo (1977) that the ITD advances gradually and retreats rapidly from the Nigerian hinterland. This accounts for the gradual spread of the rain during onset and rapid retreat. Regarding the relative efficiency of the use of rainfall amount and rainy days, the results show that there is no difference between the two methods with respect to the mean onset and retreat dates in Nigeria. This implies that the required proportion of rainfall amount and rainy days that constitute rainfall onset and retreat dates approximate each other over the long-term.

However, the results obtained for the rainfall onset and retreat dates of the individual years suggests that the method utilising the number of rainy days is more efficient than the method based on the rainfall amount. This is a result of the unrealistic onset and retreat dates produced by the latter method. It is known that rainfall onset in Nigeria is usually foreshadowed by a succession of isolated showers of uncertain amount and intensity with intervening dry periods of varying duration (Walter, 1967). Thus, at the beginning or end of the year, one or two large isolated showers (as early as the first week in January or as late as December) may constitute the specified proportion of the total rainfall amount required for rainfall to be assumed to have commenced or retreated. This situation would definitely generate misleading onset/retreat dates. Whereas, rainfall frequency, in terms of rainy days, appears to yield more realistic onset and retreat dates mainly because the most prominent characteristic of the true rainfall onset and retreat period is rainfall frequency (Walter, 1967; Ilesanmi, 1972a; Ojo, 1977; Adedokun, 1981; Hastenrath, 1985). Thus, rainfall commences in earnest at the beginning of the season when rainfall becomes frequent and retreats at the end of the season when rainfall is infrequent.

6. Conclusion

This study has examined the relative efficiency of the use of rainfall amount and rainy days in the determination of rainfall onset and retreat dates in Nigeria. The method employed in the determination of the rainfall onset and retreat dates is the percentage cumulative mean rainfall value.

The results obtained show that both methods (the use of rainfall amount and rainy days) are equally efficient with respect to the mean rainfall onset and retreat dates. With respect to the rainfall onset and retreat dates of the individual years however, the use of rainy days is more efficient as it generates rainfall onset and retreat dates that are more realistic than those generated using the rainfall amount method.

This study recommends the use of rainy days, rather than rainfall amount, in the determination of rainfall onset and retreat dates of the individual years.

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