PROGRESS REPORT

A) SUMMARY

During the period covered by this report, the Principal Investigator traveled to the Pennsylvania State University and the Columbia University, USA for consultations with mentors and collaborators and to access necessary literature. The most important subject discussed by the research group during the period was the format of the final report. We came to the conclusion that given the multiplicity of project objectives and approaches, the purpose of the report will be best served in a volume divided into sections, each with its own objectives and findings. Also during the period, field surveys were extended to the Sahel Zone in the northeastern corner of Nigeria. Four of our papers earlier submitted to journals in the United Kingdom, India and Singapore respectively were accepted for publication. Analysis of the impacts of climate variability and climate change progressed satisfactorily. Six project reports were emerging from the participation of students. During the next eight months, our intention is to continue work along the present lines. However emphasis will shift to the preparation of drafts of final report.

B) TASKS PERFORMED AND OUTPUTS PRODUCED

REPORT OUTLINE

One important subject discussed during the period under review is the format of the final report. We came to the conclusion that given the multiplicity of project objectives, the purpose of the report will be best served in a single volume divided into sections, each with its own structure, approaches and findings. There is an introductory chapter in which we present in an outline the conceptual framework, giving the historical details of how the initial biophysical conceptualization focused on crop productivity, acquired a significant human dimension and a focus on food security. The main body of the report will consist of nine sections, (A – I) each divided into chapters.

Section A, which consists of chapters 1 and 2, outlines the regional and global contexts of the issue of food security. Chapter 2 represents an attempt to link the problems of food security to other issues of global concern including social and economic development and environmental degradation. In chapter 3, the focus shifts to the subcontinent of West Africa, which is presented as the least developed of such regions in the world. Here, food insecurity is associated with a nexus compounding incessant civil disruption, environmental degradation, unsustainable agricultural production, endemic underdevelopment, a high rate of population growth in addition to the problems with global dimensions.

The concern in Section B is with climate variability. This section is designed to set the stage for making inferential judgment through analogy. The basic hypothesis necessitating a foray into climate variability is that existent practices developed to mitigate the problems of climate variability could be profitably adopted in solving the problems posed by the negative impacts of climate change. Thus in chapter 4, inter-annual variability in the climate of Nigeria in presented as a template for such changes in the sub continent. Extremes of weather are discussed in chapter 5. There is no doubt that crop productivity is sensitive to climate variability. However, as would be demonstrated later, the real impacts of climatic variability are related to the extremes especially those pertaining to sub- optimal and supra- optimum rainfall. In chapter 6, we attempt to present the causal basis of climate variability in terms of the dynamics of general atmospheric and oceanic circulations.

Extended weather forecasting is the subject matter of Section C, which consists of chapters 7, 8, 9 and 10. In chapter 7, we assess the skill levels of the existing weather forecasting tools. In chapters 8, 9, and 10 we present our own suggestions for improving the regional skill levels of extended weather forecasting.

In Section D we shift the focus to agriculture, crops and food production. At one stage the focus is on the entire sub-continent, while at another resolution the focus is on Nigeria, a country that extends from the coasts of the Gulf of Guinea to the southern margins of the Sahara Desert. In chapter 11 we present the systems of crop production while in chapter 12, we discuss the patterns of crop productivity using the major staple crops. In addition, in chapter 13, we examine the nutrition values of the staple foods to create an approach for the assessment of the food available given the per capita food requirements in the sub-continent. By relating population to such measures of food as calories, protein energy, and micronutrients, we are able to compute the adequacy or otherwise of the food produced. All of these are projected into the future with increased food requirements as a result of a much larger population.

Section E brings together for the first time, the crops and the climate using observed data covering the period from 1961 to 2000 in the case of climate and the period from 1971 to 2000 in the case of crop production. In chapter 14 we relate the geographical patterns of crop production to climatic zones. This is followed in chapters 15, 16 and 17 by attempts to discern the relationship between crop yield and climate variability. In Chapter 15, the analysis is at the national level. In chapters 16 and 17 we direct attention respectively to humid and semi arid regions.

'Baseline vulnerability' is the issue considered in section F. In this section, we discuss how the existing situation in the various sectors, predispose the human and agricultural exposure units to further damage or incapacitation by possible unfavorable changes in climate. In other words we have tried in the chapters under this section to establish the baseline against which to measure future changes in both human and agricultural exposure units. Chapter 18 takes up the issue of baseline vulnerability of the human system at the household scale, while chapter 19 assesses the baseline vulnerability of the crop production systems. In chapter 20 we discuss the major disasters resulting from weather events such as bush burning, rainstorms and floods, using examples drawn from various parts of Nigeria.

In section G, we provide multiple scenarios of the 21st Century in terms of land use changes (chapter 21), socio-economic changes (Chapter 22), and climate changes (chapters 23, 24 and 25). The land use changes are based on projections using remotely sensed data available from 1963 to 1995. The socio-economic scenarios start with a discussion of the economy as observed during the last decade of the 20th Century. The main driving forces of the economy come from demography, oil and gas and agriculture. The possible changes in these sectors are used to develop the socio-economic scenario developed in chapter 22. The climate change scenarios reported in chapters 23 and 24 were based on GCM experiments conducted with Hadley M2 models. While chapter 23 provides a climate scenario assuming a high rate of carbon dioxide emission, the scenario reported in chapter 24 assumes a relatively lower rate of carbon dioxide emission. SRES emission scenarios, MAGICC/SCENGEN and GIS downscaling provide the technical approach to the projections reported in chapter 25.

In section H we analyze the potential impacts of climate change on crop yield as the 21st Century progresses. The suitability of the crop model (EPIC) used for the assessment of the impacts is the subject of chapter 26. In chapters 27 to 32, we consider respectively, the six major staple food crops including: sorghum, rice, maize, millet, cassava and yam. Chapter 33 is a summary of the potential impacts of climate change on food productivity based on the three ecological zones, namely: Forest Coastal, sub humid Middle Belt and Semi-arid Sudano-Sahelian Zones.

Section I is designed to assess strategies for improving crop productivity in general and in particular for coping with the expected changes in climate. Chapter 34 addresses in a general form, the farm practices used to mitigate and ameliorate the impacts of inadequate rainfall. In chapter 35 we discuss the use of extended weather forecasting as a strategy for anticipating and forestalling negative changes in crop yield and production. Chapter 36 considers the specific strategy of changing planting dates in order to derive maximum benefits from whatever rain is received. The subject treated in chapter 37 is 'Building a Resilient Crop Production System'. This involves evaluating the biophysical and socio-economic constraints to crop production and suggesting measures to reduce them. One of such measures separately considered in chapter 38, is the development of improved cultivars. In this chapter, we review the efforts of breeders in the improvement of crop varieties in Nigeria, highlight breakthroughs and successes achieved so far on some of the important crops and discuss the problems and hindrances to achieving breeding objectives. Remedies that could be achieved through institutional reforms is the subject of chapter 39. In this chapter we review possible contributions by institutional stakeholders such as: government at all levels, Non Governmental Organizations, Farmers Organizations, International Development Agencies, Extension Institutions, Research Institutions and Community-based Organizations. 'Risks and Disaster Management' is the subject matter of chapter 40. Under the title: 'Residual Vulnerabilities', the limitations of the adaptation strategies suggested are discussed in Chapter 41.

Regional case studies designed primarily to profile farming and farmlands in the recognized ecological zones are presented in section J. One of such studies, chapter 42, focuses on the semi arid Sudano-Sahelian zones. Two others, chapters 43 and 44, focus on the Forest and the Guinea Savanna zones respectively. A fourth regional case study, chapter 45, is an economic analysis of farming activities.

Data illustrating various climate change scenarios will be presented as appendices in a separate volume. We are still considering the option of a report consisting of pamphlet-size volumes. In such a case the sections outlined above will constitute the contents of each volume.

PUBLICATIONS

The following manuscripts forwarded to the journals indicated have now been accepted for publication:

- ✓ Assessing the suitability of EPIC Crop Model for use in the study of Climate Variability and Climate Change in West Africa: *Singapore Journal of Tropical Geography.*
- ✓ Rainfall and the length of the growing season in Nigeria: *International Journal of Climatology.*
- ✓ The Relative efficiency of the use of rainfall amount and rainy days in the determination of rainfall onset and retreat dates in Nigeria: *Indian Journal of Human Ecology.*

- ✓ Skill Assessment of the existing capacity for extended weather forecasting in Sub-Saharan West Africa: *International Journal of Climatology.*

We have received acknowledgement of receipt of the following manuscript earlier submitted for publication in the journal indicated:

- ✓ On the prediction of rainfall onset and retreat dates in Nigeria: *Theoretical and Applied Climatology*

BORNU FIELD SURVEY

The fieldwork undertaken during the report period was in Bornu State. It is a case study covering the Sudan and Sahel Ecological Zones. Thus it a continuation of earlier studies conducted in the Forest and the Guinea Savanna Ecological Zones. Two local government areas were selected for this exercise, one in the south and the other in the north of the state. The Local Government Area in the north is Konduga. It is located in the Sahel Savanna Ecological Zone. The Local Government Area in the south is Askira. It is located within the Sudan Savanna Ecological zone. From each of the LGAs, five rural communities were selected for intensive coverage. From each community, ten farming households were selected for the application of a pre-prepared questionnaire. The questionnaire was applied by informal discussions and interactions over a couple of days with the members of each household, not just with the household head.

<u>Askira/Uba Local Government Area</u>

The Askira/Uba LGA is located in the southern part of state. It is centered approximately on latitude 10^{o}26N and longitude 13^{o}13E. The rural communities visited include: Giwa Higgi, Samuwa, Yamue, Walafa and Sabon Gari. The northern boundary of the Local Government Area is with Damboa LGA the western boundary is with Biu LGA, while the southeast boundary is with Adamawa state.

This local government area is situated within the Sudan Savanna Ecological Zone. The vegetation, flora and fauna are those characteristic of this zone. The climate has considerable influence over crop farming, livestock rearing and indeed almost all human activities in the area. The most important climate elements are rainfall and temperature. The rainfall is highly seasonal with marked wet and dry seasons. The wet seasons are usually associated with southwesterly monsoon winds while the dry season is associated with the dry northeasterly winds from the Sahara Desert. Normally the rainy season begins in June and terminates in September or early October (between 4 - 5 months) while the dry season begins in October and terminates in May (between 7-8 months). The heaviest rainfall and the highest number of rainfall days are normally recorded in August. The dry northeasterly winds are typically dust-laden and associated with low nighttime temperatures. Mainly as a result of the dust, visibility is limited, posing considerable hazard to aviation. The area is also characterized by extremes of temperature with relatively high diurnal and annual ranges. The coolest months of the year are December, January and February during which mean temperatures fall to the range between 20^{o} C to 25^{o} C. A sudden rise in temperature is noted during the succeeding months of March, April, May and June with mean temperatures of between 34^{o}C 38^{o}C. The typical vegetation in the Local Government Area consists of fine-leaved thorn trees predominantly of *Acacia* genus. These are mixed with broad-leaved elements that are usually found in the wetter Guinea zones to the south. There is a more or less continuous grass-cover, the grasses being short and feathery contrasting with the tall, coarse, tussocky grasses typical of the Guinea zones. Valley bottom locations are lined with fringing forests consisting of a dense tangle of dry zone species with isolated larger trees and patches of tall grasses. The soil is derived from sedimentary rocks belonging to the Chad Basin Formation. They are among the best soils in the country.

As is often the case in the Middle Belt of Nigeria people of different ethnic backgrounds mix. Even though one tribal group is usually in the majority, members of other tribes are present, not as strangers but as indigenes within each village. Invariably people who profess to be Christians are in the majority and churches outnumber mosques. The people associate on the basis of family, religious, economic and social affinities. Thus in each village there is a football or sports club, farmers associations, thrift societies, many age grade associations, many clan associations, Boy's and Girl's Brigades, Church Choir etc. By national standards, the home and environment infrastructure are grossly inadequate. There is generally no pipe-borne water. The main source of water is shallow wells augmented by stream and river sources. Health facilities are few, usually at the level of dispensaries.

The people are quite conscious of the weather factor in their lives. When the seasonal rains are early, they come in May and crop performance is high. When seasonal rain onset is delayed until July however, crop yield is low. This is because unless cessation of rain is delayed, the growing season is shortened and there is insufficient time for crops to mature. Rain coming in June is judged to be favorable and is associated with good yields of crops. Most crop failures are however associated with premature cessation of the rainy season. There could also be low yield of crops when there are prolonged dry spells within the growing season. Very few years can really be described as having rainfall patterns that are altogether unsuitable. During the past thirty years, the people can remember only 1974 and 1987 as the years with poor harvests associated with unfavorable weather. Crop pests include birds, grasshopper, caterpillar and butterflies.

Konduga Local Government Area

Konduga Local Government Area lies close to the state capital, Maiduguri, between 11^o 15N and 12^o 30N and between 12^o 25E. The communities selected for study include: Auno, Dalori, Wanori, Katari and Kotori. As stated earlier, the LGA is located within the Sahel Ecological Zone. As is the case in the Sudan, the Sahel zone is characterized by extremes of temperature with high diurnal and annual ranges. The coolest months of the year are December, January and February during which mean temperatures fall to the range between 15^oC and $22.^oC$. A sudden rise in temperature is noted during the succeeding months of March, April, May and June with mean temperatures of between $35.^oC$ 40^oC. The main difference is in the rainfall, which is less in the Sahel than in the Sudan. Mean annual rainfall in the Sahel is less than 500 mm compared with between 500 mm and 750 mm in the Sudan. The dry seasons lasts about 8 months from October to May, while the wet seasons lasts about 4 months, from June to September. Typically the Sahel vegetation consists of open thorn savanna, some 3 – 6 meters high and with a short sparse grass cover on the ground. *Acacia seyal* forms almost pure stands in low-lying sites. By comparison, at similar locations in the Sudan Zone, the vegetation could be described as woodlands consisting of *Acacia albida, Acacia seyal,* in addition to *Tamarindus indica.* Compared with the situation in the Askira Local Government Area,The soils of Konduga are highly degraded. When such soils are associated with sparse vegetation, the situation is described as desert encroachment.

The Local Government Area is located in the heartland of Kanuri Kingdom, headed by the Shehu of Bornu. Almost everybody is a Kanuri professing the Moslem religion. There are mosques within every community. Each village has its own Almajiri group. The group consists of children sacrificed to the faith by their parents. They follow a leader who teaches them Arabic and the Quoran. They live by begging for food and money in the streets. They always make themselves available for whatever their leaders consider necessary to promote the Moslem religion. Almost every community has its own sports club and football team. Each clan is organized into a development association. In case of disaster or misfortune, the members come together to render help or commiserate. People born within two or three years of one another usually come together to form age-grade associations. It is usual for members to assemble in the evenings to share a drink or two. They could use the occasion to discuss matters of mutual interest or of interest to the community as a whole. By national standards, the home and environment infrastructure are grossly inadequate. There is no pipe-borne water. The main source of water is shallow wells augmented by stream and river sources. Health facilities are few, usually at the level of dispensaries.

When the seasonal rains are early, they come in June and high-level crop yields are expected. When seasonal rain onset is delayed until August, crops are adversely affected and crop yields are low. This is because unless cessation of rain is delayed, the growing season is shortened and there is insufficient time for crops to mature. In normal years the monsoon rains arrive in July, which affords sufficient time for the crops to grow and produce high yields. Most crop failures are however associated with premature cessation of the rainy season. There could also be low yield of crops when there are prolonged dry spells within the growing season. Very few years can really be described as having rainfall patterns that are altogether unsuitable. During the past thirty years, the people can remember only 1974, 1987 and 1987 as the years with poor harvests associated with unfavorable weather. Supplemental irrigation is applied at sites near streams or ponds. The ponds are easy to construct and maintain where there is a layer of impermeable clay close to the surface. This helps to hold the water in the ponds for longer periods than would have otherwise been the case. Crop pests include birds, grasshopper, caterpillar and butterflies.

Community Profiles

Short profiles of four of the communities selected for study are as follows:

1. Giwa Higgi (Askira Local Government Area)

Goji Ngripa founded Giwa Higgi in 1905. The name Giwa Higgi is derived from the name of the tribe of the founding population. ‘Giwa Higgi’ simply translates in their language as the ‘community of Higgi tribe’. The founder was formerly residing in Dille about 4 km from the present site of Giwa Higgi. Most of the people of Dille belonged to the Marggi tribe at that time. Because of tribal differences, Ngripa could not secure a farmland at Dille, so with his own tribesmen, he moved away and settled at the place now called Giwa Higgi. Within one year of their arrival at the site, Goji was installed as the chief of the new community. After his death in 1976 his son Drambi succeeded him and he is still the chief of the community. There is one primary school called Giwa Higgi primary School, no good roads, no clean water, no electricity, and no health facilities within the community land area. Members of the community go to Lassa General Hospital, which is more than 10 km to receive medical attention.

Giwa Higgi is a community of farmers practicing mixed farming, and mixed cropping. Their major crops are guinea corn, maize, millet, beans, g/nuts, and cassava. The minor crops include:

okro, tomatoes, and vegetables. Community members also engaged in animal husbandry keeping such animals as cattle, sheep, goats, horses and donkeys. They engage in fishing during the dry season in the Yadzeram River that flows across the area. There are, in addition to the farmers, nomadic herdsmen who take care of community herds. Each nomadic family controls a herd of up to a hundred assorted animals, which have been contributed by owners within the community and others. Benefits to the herdsmen include milk of the cows, share of the litter, as well as cash monthly payments. This practice is common throughout the Local Government Area and indeed throughout the savanna ecological zones. The people could recall bad harvests in 1973, and 1987 which resulted from early cessation of the rains. It was not only crops that were affected by droughts. Animals also suffered when the grass dried up for prolonged periods. Apart from those two years, their recollection is of good harvests during the past thirty years. The total population of the community in 1991 was about two thousand five hundred.

The main recurring community problem is the unpredictable delay in the onset of the rainy season. In the past, goats, rams and cows were slaughtered as sacrifices to appease or secure favor with the tribal gods, who they believed could cause rain to fall in good time. However in 1967, the community adopted the Christian religion and the practice was discontinued. However, the belief persists, that it is only by divine intervention that the problems of variable dates of arrival of the life giving monsoon rains could be solved. Thus, intercessory prayers in the churches replaced sacrifices to tribal gods.

2 Yamue (Askira Local Government Area)

The community has been in existence since the 19th century. Apart from the hazards posed by the variable onset and cessation of the rainy season, what linger in the collective memory of the community from the earliest times are the activities of terrorists from across the border in Adamawa State. There was a particular one with the name Harmayan who could come with his lawless band of marauders to steal, kill, rape and lay waste the farmlands. While he was at his business of destruction, the inhabitants would abandon their homes and farms, and escape to the mountains and caves to hide. It was the colonial masters in the early 20th century that came and captured Harmayan and restored peace to the area. It was the restoration of peace that encouraged the founding of the Yamue community at its present site

The Yamue people are chiefly Kamue by tribal origin. Their culture is similar to that of the Higgis. Most of the people practice blacksmithing as secondary occupation. In this respect, they serve the farming population, not only in their village, but also in villages throughout the Local Government area and beyond. They make hoes, cutlasses, and other metal farm implements. They also specialize in crafts and and in providing music at burial, marriage and any kind of ceremony to which they are invited. Most of the people follow traditional African Religion. However there is a minority of Christians with their own church. There is no mosque in the village, evidence the relatively few adherents of Islam among the population. There is only one primary school called Yamue primary school, no good roads, no safe water supply, and no electricity. There are also no health facilities except at Lassa about 7 Kilometre away, where there is a general hospital.

Yamue is also a community of subsistence farmers practicing mixed farming, and mixed cropping. Their major crops are guinea corn, maize, millet, beans, g/nuts, and cassava. The minor crops include okro, tomatoes, and leaf vegetables. The farmers also engage in animal husbandry, rearing cattle, sheep, goats horses and donkeys. They also engage in fishing and irrigation farming during the dry season along River Yadzeram. There are, in addition to the farmers, nomadic herdsmen who take care of community herds on a litter-sharing basis. They could remember the bad harvests in 1973, and 1987. Among the pests of crops they fear are grasshoppers and quila birds which are especially damaging to grain crops. They emphasize that during most years they have good harvests.

3. Kalari (Konduga Local Government Area)

In 1951 the emir of Borno delegated one of his sons Mallah Dangel to go and establish a new settlement, which was named Kalari. This community is closer to Maiduguri Metropolitan than the headquarters of the Konduga Local Government Area. However, for administrative purposes, the community is grouped with Konduga L.G.A. council. The soil of this area is reputed to be relatively fertile and suitable for irrigation farming during the dry season. There are naturally occurring ponds in which water is stored during the rainy season, to be used for drinking, irrigation and watering farm animals during the dry season. Members of the community are predominantly of Kanuri and of Shua Arab extraction. Unlike other tribes in the state they speak only their tribal language. Notwithstanding its nearness to Maiduguri, the community lacks behind in development There is only one primary school, There is no electricity and no good drinking water apart from the water taken directly from the ponds and from few hand-dug wells. Also, basic health facilities are not available. This may not constitute much problem since Maiduguri the state capital is only a few kilometers away. However, there are no good access roads. The population of this community is about 2000 people and 99% are Moslems., there have two mosques in the area.

Kalari is also a community of subsistence farmers practicing mixed farming and mixed cropping. Their major crops include: maize, millet, beans, g/nuts, bambara nuts and cassava. The minor crops are: onions okro, tomatoes, and vegetables. The minor crops are produced, under irrigation during the dry season.. They farmers also engage in rearing of animals such as cattle, sheep, goats, camels, horses and donkeys. The same farmers also engage in fishing and irrigation farming using the available ponds during the dry sessions. There are, in addition to the farmers, nomadic herdsmen who take care of community herds. During the dry season, the herdsmen usually move out of the community land in search of green pastures. Such migration may take them over thousands of kilometers. The animals may not return to the area until they are sold on the hoof. The community experienced bad harvests in 1973, 1984 and 1987 because of early cessation of rains in the area. The worst scenario is when droughts occur, and pests such as birds and grasshoppers appear during the same growing season. When such happens, there is crop failure on a large scale. However there are control measures that could be adopted through government intervention.

4 Kotori (Konduga Local Government Area)

The area now occupied by the Kotori community was under the influence of Dalori until in 1920 when Bulama Aji was installed as the new chief of the area through the influence of his brother the chief of Dalori. The distance between the two villages is only 5 kilometers. As in the other communities in Konduga LGA, Kotori community is predominantly Moslem and Kanuri by ethnic affiliation. The usual social, cultural, economic and religious organizations are present. However socio economic infrastructures are poorly developed at Kotori compared with Dalori, the mother community. For example there is no primary school and no dispensary or any other basic health institutions within the community. Water for domestic use usually comes from shallow wells and the seasonal and ephemeral streams.

Kotori land is located in the general area where the soil has become degraded as a result of intensive cultivation. This notwithstanding, the community is well known as the largest supplier of onion, carrots, garden eggs, and vegetables to Metropolitan Maiduguri during the dry season. These are products of irrigated farming based on water supplied from the Alau Reservoir. To be able to bring these products to the urban markets, the farmers make good use of their location on the Federal Government's highway leading out of the city of Maiduguri. Individuals also come from the city to buy their needs of these products directly from the farmers. During the rainy season, farmers in the community operate as subsistence farmers engaged in the production of maize, millet, guinea corn, cassava, beans groundnuts and bambara nuts as the major crops, and melon, okro, pepper, tomatoes, leaf vegetables garden eggs, onions and carrots as the minor crops. The major crops are usually planted as sole crops. However the minor crops are planted as subsidiary crops on the same plots as the major crops. Farm animals used for farm work include horses, donkeys and camels. Cattle, sheep and goats are assets to be sold for cash during the annual festivals. Nomadic herdsmen taking care of the community's herds of cattle, sheep and goats are also present.

People in the community remembered the droughts of 1973, 1984 and 1987 as well as their impacts on the people's general well being. There were prolonged periods of inadequate food and water supply in the community. According to the people, these major disruptions to life were the consequences of early and abrupt cessation of rainfall. However, there were other anxieties related to delayed onset of the rainy season and unusually long dry spells within the main rainy season. Occational appearances of quila birds and grasshoppers are also causes for concern within the community.

ANALYSIS OF IMPACTS OF CLIMATE VARIABILITY

In our last report, we outlined a methodology for the analysis of the impacts of *climate variability* on crop yield and production. The methodology was based on a set of linear models that we hoped would not only give a measure of the response of crops to climate as it varies from one year to the other, but that could be employed in the prediction of crop yield and production when reliable tools for seasonal weather forecasting were available. However the low level of significance of the resulting measures of impacts has put a question mark on the suitability of the methodology. Thus there is the need to explore another approach. The failure of the linear models to capture the essence of the relationship between crop yield and *climate variability* could be due to inadequacies in the data employed. It is appreciated that the type of data available were not among the ideal for such exercises. For example neither climate nor crop yield data were available at farm site levels. Most of the data available were obtained through a survey of households conducted over several years throughout the country. The possibility of significant human errors creeping into the data collected over a period of thirty year is conceivable. There are farm level data available on experimental farms of research institutions. These are invariably outputs from research projects designed with objectives quite unrelated to climate variability. One such research project objective is trials to assess the performances of crop varieties bred for higher yields or tolerance of various environmental stresses. Pertaining to inadequacy of climate data is the fact that the most reliable sets are collected at meteorological stations, which are widely spaced and for most part are at some distance from the farm sites at which the crops were planted and harvested.

The inadequacy of linear models for the analysis of crop response to *climate variability* is a possibility, which is often overlooked. One basic requirement of linear models is that both the independent and the dependent variables must be continuous. This requirement essentially is that there must be a range in magnitude of each that the available data spread over. However, even where both the dependent and the independent data are separately continuous, the relationship may not be continuous. For example the relationship between the variability of crop yield and the weather or climate is not always continuous. The sensitivity of crop yield to soil moisture and rainfall will be more easily observed when moisture supply is approaching the critical minimum for optimum yield. Whenever moisture supply is adequate, change in crop yield will cease to depend on this variable. Imagine a situation in which in our area of interest the rainfall is adequate for optimum crop yield for our crop of interest over a period of thirty years. Whatever may be the moisture variability over those thirty years will have no impact on changes in crop yield. The reciprocal is that over the thirty years, whatever may be the variability in crop yield observed could not be explained in terms of changes in moisture supply.

We have started to apply another strategy for the assessment of the impacts of *climate variability* on crop yield. For this, we define impact as any significant departure from a normal year's yield. The first step is to ask and answer the question whether there has been any drastic negative or positive change in the yield. In other words, we need to determine whether there has been any impact that needs to be assessed. The second question is to determine the years during such impacts were observed. The third question relates to the type of weather that resulted in the impacts observed. If over the period of interest no significant anomaly can be observed for any one growing season, the conclusion is that there has been no serious impact of the *climate variability*, or any other factor with inter-annual time resolution on crop yield. If there has been a year with anomalous level of crop yield, we can go to examine the climate of such a year to identify the basis of such anomaly. The ultimate objective of our analysis is to determine the threshold in terms of the appropriate climate parameter at which impacts on yield could be observed.

The first set of analyses of climatic impacts was based on the data on yield for the period from 1971 to 2000. We measured impact by a Variability Index computed as annual yield minus mean annual yield divided by the standard deviation. The results produced a Z- distribution with values varying from –3 to + 3. Values lower than –1.7 or higher than + 1.7 indicate impacts that are significant at 95 percent confidence levels. Higher confidence limits can be set. For example values of –2 and +2 define impacts that are significant at 99 %. The interpretation is that the anomalies in yield observed during the years with significant V.I.s could not have happened by chance.

We observed in Fig 1A significant negative yield anomalies in 1992 and 1993. The respective variability indices were significant at 98 percent confidence limits. These could be interpreted as the impact of the nationwide drought period of 1992 – 93. We also noticed significant positive yield anomaly for 1990 (significant at 95 percent confidence limits). We are yet to identify the climate happenstance that was responsible. In Fig 1B we observed a significant negative millet yield anomaly which appeared to have resulted from the impact of early cessation of the rains in certain areas of Borno state during the year 1990.

AF 23

FIG 1A: NIGERIA VARIABILITY OF YAM YIELD 1972 - 2000

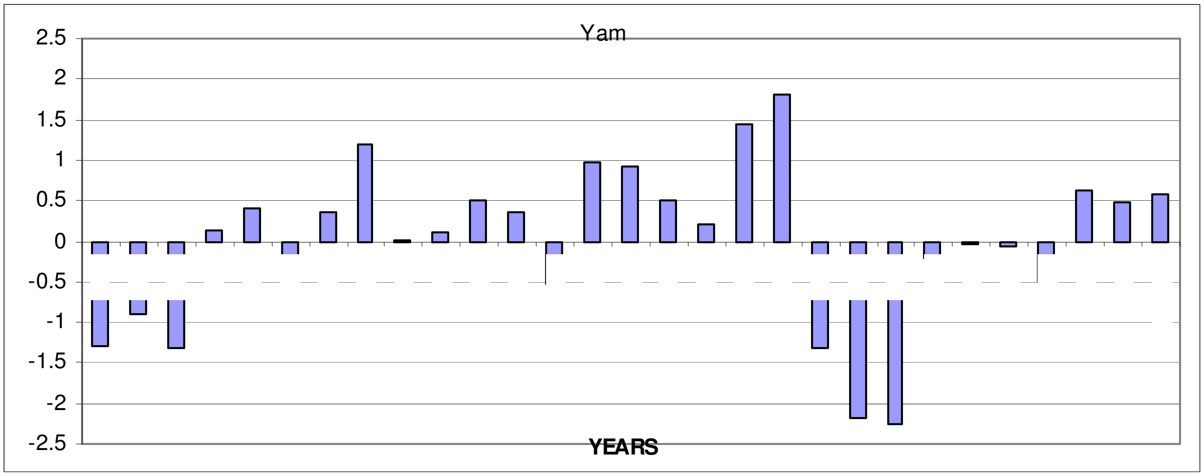
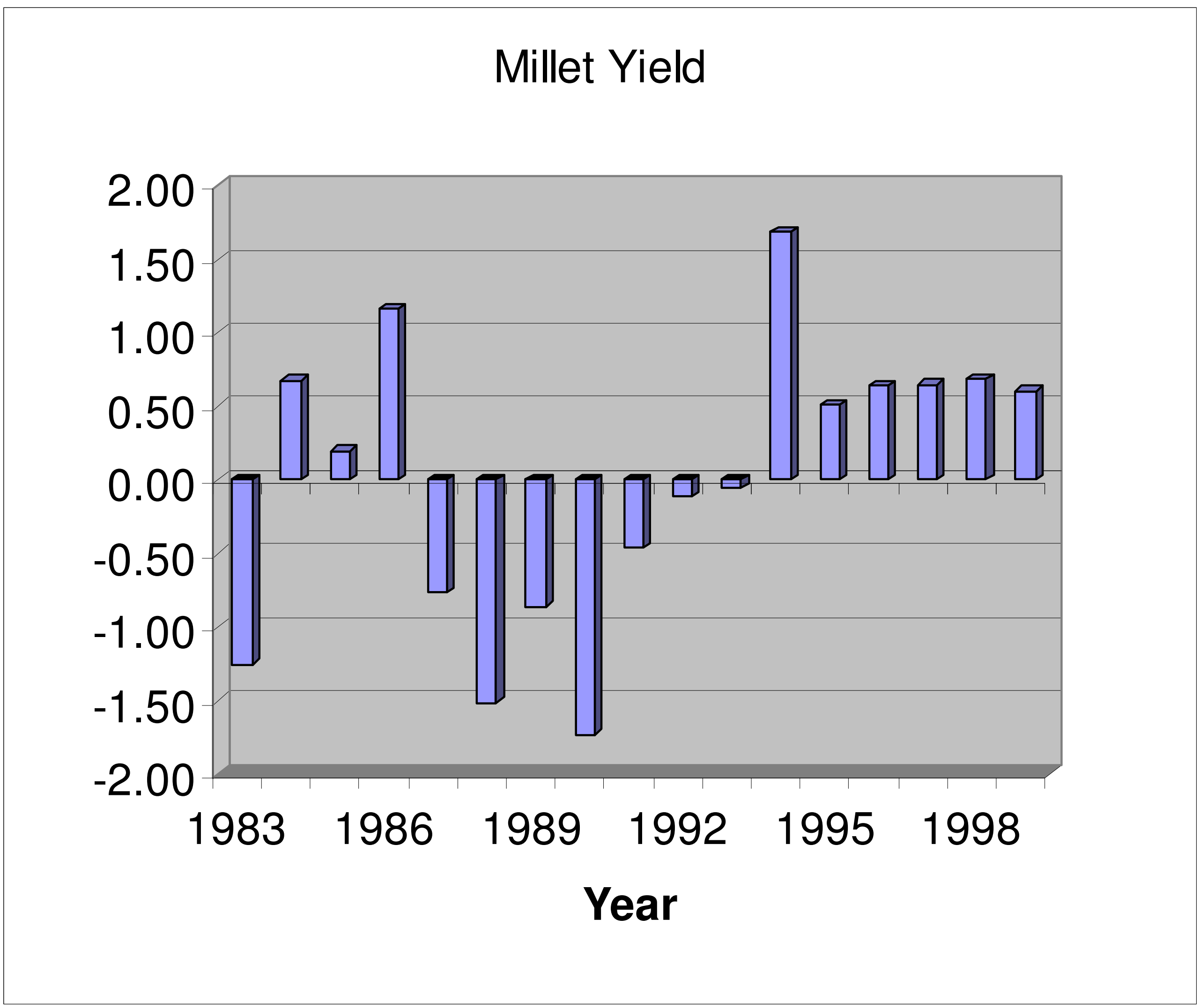


FIG 1B: BORNU STATE VARIABILITY OF MILLET YIELD 1983 1989



TRAVELS

The visit of Professor G.G. Knight of Pennsylvania State University to Obafemi Awolowo University, Ile-Ife, Nigeria for purposes of capacity building has been rescheduled for the first week in March 2004.

Within Nigeria, travels were undertaken to identify potential sites for the conduct of field surveys in Bornu and Yobe states.

We did secure AIACC funding for one of our students to visit Columbia University in New York to learn about the IBNASAT Crop Model. Up till now, the student has not been able to travel. Initially the problem had to do with visa. Now the student's study program will not permit her to travel until April 2004.

The Principal Investigator visited the Pennsylvania State University and the University of Columbia, New York in September. During the visit, the PI discussed the progress of the work with Dr Paul Desanker who was recently assigned to the project as a mentor. The PI met Desanker as he was settling down after shifting base from The University of Virginia to the Department of Geography, Pennsylvania State University. He made available a handful of copies of most recent publications that are relevant for the project. Professors Greg Knight and Bill Easterling of the same Department were similarly helpful. At the Columbia University, New York, the PI met with Dr Cynthia Rosenzweig of the GISS who is also a renowned AIACC mentor. The subject of discussion was how to acquire capability of the use of the IBNASAT Crop model for the research group. However, the most important aspect of the visit was literature search and review, using the PSU Library.

STUDENT PARTICIPATION

In our last report, we indicated that six students at the undergraduate level, one at the masters level and two at the doctorate level were participating in the AIACC Project. The undergraduate students have each submitted the draft of the first three chapters of their respective reports. The masters student is yet to clearly define his methodology. One of the doctoral students is leading the department seminar this week (13^{th} January). This will afford us the opportunity to assess her progress. Unfortunately the other doctoral student had an accident and is spending his fourth month in the hospital.

C) DIFFICULTIES ENCOUNTERED.

We did not encounter any difficulty during the period under review that is worthy of reporting

D) PREPARATION OF NATIONAL UNFCCC COMMUNICATIONS

We provided the information in our last semi annual report that our manuscript on Climate Change scenario was accepted for inclusion as chapter four of Nigeria's national communication to the UNFCCC. We are now in a position to report that the communication has now been published.

E) TASKS TO BE PERFORMED IN THE NEXT EIGHT-MONTH PERIOD

IMPACTS OF CLIMATE VARIABILITY

Analysis of climate variability on crop yield will continue. This will be undertaken at individual-farm, state, zonal and national levels. Crop yield data are available for the whole country for the period 1971 to 2000. These will be analyzed to demonstrate, for each major crop, the significant yield anomalies, both positive and negative. Attempts will then be made to identify the particular weather events or patterns that correspond to the anomalies and which could be held responsible. Crop yield data on the North East Arid Zone for the period 1983 to 2001 for millet, sorghum, maize, ground nut, beans and cassava will be analyzed and interpreted in the same way. The crop yield data for the Guinea Savanna Zones of Oyo State, which will be subjected to analysis in the same way, cover the period from 1988 to 1999. Using the 19-state structure, there are crop yield data for each state covering the period from 1983 to 1992.. These will be used to show the regional contrasts in crop yield response to climate variability.

IMPACTS OF CLIMATE CHANGE

EPIC Crop Model data files have been created for each of the 28 weather stations adopted for the project. We are conducting EPIC runs to simulate crop yields for four time slices, namely: 1961-90, 2010-39, 2040-69, and 2070-99. The results will be interpreted to demonstrate the probable changes in crop yield over the period from 1961 to 2099.

FIELD SURVEYS

The last field survey exercise will be conducted in Ekiti State located in the forest zone. The primary objective of the survey is economic analysis of the farm operations. The survey will::

- Identify the farm inputs, operations and activities necessary for the production of each crop.
- Collect data on the costs of the inputs and operations.
- Collect data on the total costs of establishing a unit area to each crop.
- Collect data on market and farm gate prices of farm products
- Analyze the costs and benefits of crop farming as a business and specifically determine the level of yields required to offset the costs of production.

FIRST DRAFT OF REPORT

We hope to start in earnest to prepare the first draft of the final report of the project based on the outline agreed on as outlined earlier in this report.

PUBLICATIONS

Our attempts at preparing manuscripts for publication in peer reviewed journals will continue. However, priority will now shift to the first draft of project report. We are aware that the bulk of our contributions through peer-reviewed publications will be produced after the project report has been submitted and accepted.

STUDENT PARTICIPATION

The undergraduate students participating in the project are due to complete and submit their dissertations at the end of the current semester in April. The doctoral student is scheduled to conduct her fieldwork during the eight-month period

F) ANTICIPATED DIFFICULTIES

We are not anticipating any difficulty at this point in time

G) PAPER ATTACHED

- ✓ Rainfall and the length of the growing season in Nigeria: Accepted for publication in the *International Journal of Climatology.*
- ✓ On the prediction of rainfall onset and retreat dates in Nigeria: submitted to *Theoretical and Applied Climatology*

RAINFALL AND THE LENGTH OF THE GROWING SEASON IN NIGERIA

BY

T.O. ODEKUNLE
DEPARTMENT OF GEOGRAPHY
OBAFEMI AWOLOWO UNIVERSITY
ILE-IFE, NIGERIA

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 appear to commence around the end of the second decade of March, middle of the third decade of March, mid April, end of the first decade of May and early June respectively, its distribution characteristics in the respective stations remain inadequate for crop germination, establishment and development till the end of the second decade of May, early third decade of May, mid third decade of May, May ending and end of the first decade of July. Also, rainfall in the various stations appear to retreat starting from early third decade of October, early third decade of October, end of the first decade of October, September ending and early second decade of September respectively, but its distribution characteristics only remain adequate for crop development in the respective stations till around the end of the second decade of October, end of the second decade of October, middle of the first decade of October, early October and middle of the first decade of September. Thus the active lengths of the growing season are approximately 5, 5, 4, 4 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 decade of march to the end of the second decade of May (in Ikeja), middle of the third decade of March to the early third decade of May (in Ondo), mid April to the middle of the third decade of May (in

Ilorin), end of the first decade of May to May ending (in Kaduna) and early June to the end of the first decade in July (in Kano), but other less tolerant should be planted, starting from the end of the second decade of May, early third decade of May, mid third decade of May, May ending and end of the first decade 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.

KEY WORDS: *Length of the Growing Season; Rainfall Onset; Rainfall Cessation; Rainfall Probability; Cumulative Percentage Mean Rainfall; Nigeria*

INTRODUCTION

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

In a typical inter-tropical country like Nigeria, rain falls in different months of the year at different places, as the rain-belt appears to follow the relative northward and southward movements of the sun. In this tropical situation of marked seasonal regime, variability of the onset and retreat of rain is highly significant and its estimation and prediction necessary. A delay of one or two 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 two or more weeks may be critical to plant germination and/or growth (Olaniran, 1983). For instance, in Nigeria, in 1973, the onset was earlier, which encouraged early planting and animal migration, but was a false onset, thereby 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 (ten weeks) from one year to another at a single station. Thus, rainfall distribution characteristics during the course of a year, in a typical wet-and-dry climate region like Nigeria (Koppen, 1918) assume prominence particularly in the schedule of the activities of the agricultural calendar – 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 revealed that, the length of growing season can be determined in a variety of ways. Some scholars, notably Thornthwaite (1948), Thornthwaite and Mather (1955), Cocheme and Fraquin (1967) and Benoit (1977) employed a rainfall-evapotranspiration relation model to determine the onset and cessation of the growing season. Also, some scholars based their prediction method on upper wind data (see for example 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) made further attempt, using Theta-E technique, which is dependent on the equivalent potential temperature. However, most scholars (Dagg, 1965; Walter, 1968; Ilesanmi, 1972; Igeleke, 1973; Kowal and Adrews, 1973; Olaniran 1983; 1984; Adejuwon et al, 1992; Bello, 1995; Nnoli, 1996) employed rainfall alone to determine the onset and cessation of the growing season. The use of rainfall data alone is found widely in use mainly because it is more readily available (Olaniran, 1983). Also, the author believes that the use of rainfall data is a more direct approach rather than the use of some other related factors 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 been found widely in use in West Africa for three main reasons. One is that, 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). Two, the model did not take into consideration the effect of advection (Ojo, 1977). Three, in the tropics, temperatures are 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, namely: (absolute definition – based on a certain thresold value, and (b) relative definition – based on a certain proportion relative to the total rainfall (see Adejuwon, 1988). The most widely accepted is the relative definition method (see e.g. Ilesanmi, 1972) but so far, 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, it would have 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) and Omotosho (2002), which are meant to address year–to-year variation in the rainfall onset and retreat periods, still turned out to be failures 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.

STUDY AREA

The study area is Nigeria (figure 1), which is located within Longitudes 3^o and 15^{o}E and Latitudes 4^o – 14^{o}N. The area is bordered in the northern, eastern western and southern parts by the Republic of Niger, Cameroon, Republic of Benin and Gulf of Guinea, respectively. The total land area is about 923, 300sq, km.

The specific locations where data were collected are Ikeja, Ondo, Ilorin, Kaduna and Kano. Each of the five locations was selected as representative of zones comprising areas of similar climatic tendencies in Nigeria. For instance, while Ikeja is chosen to represent the coastal climatic zone, Ondo, Ilorin, Kaduna and Kano represent forest, Guinea, 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, 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 is thus 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 give rise to line squalls or dust devils (Iloeje, 1981).

Over the country, temperature varies from place to place. The most clearly marked difference 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 21^0C and 27^0C. On the interior lowlands, the mean annual temperatures register over 27^0C. The coastal fringes have lower means than the interior, lowlands (Iloeje, 1981). The intra-annual temperature range, as in other tropical countries, is low with an average value of 6^0C. In fact, in some Southern stations, it may be as low as 3^0C (Iloeje, 1981). In this tropical situation of uniform temperatures and small seasonal variations, the choice of suitable crops in relation to temperature conditions is normally wide (Nieuwolt, 1982). Thus as noted by Nieuwolt (1982), temperatures are not a critical factor in tropical agriculture

While 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 countries, rainfall is the principal controlling element in agriculture (Nieuwolt, 1982; Stern and Coe, 1982). As noted by Stern and Coe (1982), in the tropics rainfall is often the only input that varies 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 double peak rainfall while the northern third has a single peak (Iloeje, 1981). Rainfall generally commences from south, spreading through the middle belt, to eventually reach 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 1500m, 600m and 300m respectively. The low-lying areas are found in the centre and South and are generally below 300m. The Udi plateau, however, attains a height of over 300m, which appear to break the monotony of the surface in the low-lying areas of the south (Iloeje, 1981)

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. The data available for all the rainfall stations in this study are between 1961 and 2000 (40years)

The rainfall data were collected using the British Standard Raingauge and the Dine's tilting siphon rainfall recorder. Data collected using these instruments are samples in space, and are subject to errors including instrumental and observer errors, and problems of data homogeneity. On the latter, Adejuwon (1988) shows that the Nigerian Meteorological stations whose data are employed in this study have not suffered from relocation of site. Notwithstanding this useful historical information, the author assessed the consistency of the data and confirmed its homogeneity. 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 reposed in the data reliability could not be determined.

There are however reasons to believe that the data are of adequate quality. For instance, the intra-annual distribution of the data reflects important 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 at 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, while 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 to 8 percent of the annual rainfall totals has been obtained, while that of rainfall cessation is 90 percent. This study adopts the latter method – onset and cessation periods are taken as the time when an accumulated 7 to 8 percent and 90 percent of the annual rainfall totals are obtained respectively.

Varieties of methods have been devised to ensure meaningful probability and reliability values with which to qualify rainfall events. This study determines the overall probability of rain, and the method chosen is that proposed by Garbutt et. al. (1981). According to these authors, 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 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), 0.85mm was found appropriate for West Africa countries. Therefore, a threshold value of 0.85mm is employed in this study. This implies that, any day with rainfall amount below this threshold value is assumed to be rainless.

RESULTS

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

Figures 9-13 show the rainfall onset and retreat periods and the length of the growing season in Ikeja, Ondo, Ilorin, Kaduna and Kano respectively, using the daily rainfall probability/reliability method. The results of the analysis show that rainfall in the respective stations become more reliable starting from the end of the second decade of May (with probability value of 0.50), early third decade of May (with probability value of 0.51), mid third decade of May (with probability value of 0.50), May ending (with probability value of 0.53) and end of the first decade of July (with probability value of 0.50). Rainfall in the respective stations become less reliable from the end of the second decade of October (with probability value of 0.50), end of the second decade of October (with probability value of 0.52),middle of the first decade of October (with probability value of 0.50), early October (with probability value of 0.55) and middle of the first decade 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 5,5,4,4 and 2 months respectively. In 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 probability of rainfall that is less than 0.50 during the growing season. This period, which is between the end of the second decade of July and middle of the first decade 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. 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. This period, which comes up between the end of the first decade and middle of the second decade of August, is also visualised 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 decade of July to August ending) 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. The maximum number of consecutive days of rainfall probability that is less than 0.50 during the growing season in Kaduna and Kano is 8. As shown in Figures 12 and 13, the daily rainfall probability values reflect single maximum regime intra-annual rainfall distribution.

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 decade of March to the early third decade of October), 7 moths (middle of the third decade of March to the early third decade of October), 5 months (mid April to the end of the first decade of October), 5 months (end of the first decade of May to the September ending) and 3 months (early June to the early second decade of September) respectively. All the results obtained – rainfall onset and retreat periods and the length of the growing season, compare well with the works already done by some scholars in the region (e.g., Ilesanmi, 1972; Olaniran , 1983; Adejuwon, 1988; Adejuwon, et.al., 1992; Bello, 1995). In contradiction to the above results obtained (using the relative definition method) however, the analysis of rainfall probability shows that on the average, there are 5 months (end of the second decade of May to the end of the second decade of October), 5 months (early third decade of May to the end of the second decade of October), 4 months (mid third decade of May to the middle of the first decade of October), 4 months (May ending to the early October) and 2 months (end of the first decade of July to the middle of the first decade 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 revealed that in all of the stations studied, the disparity between the first date of reliable rainfall, using rainfall probability method, and that revealed by the relative definition method is large. The differences in the onset period in Ikeja, Ondo, Ilorin, Kaduna and Kano are approximately 2,2,1,1 and 1 months, respectively. However there is no significant difference between the two methods with regards to the rainfall cessation periods in all the stations studied. None of the differences in the retreat periods in all the stations studied is up to a week.

It is known that the frequency of rainfall during the course of a year within the tropics appears to be mostly governed by the movement of the ITD (Intertropical Discontinuity) and the critical depth of the warm, moist tropical maritime (mT) air required for a location to regularly experience rainfall (> 1500m; see Ojo, 1977). This implies that, as the ITD advances northward, any newly invaded place that is less than 4 degrees of latitude south of the ITD may at best experience isolated showers of uncertain amount and intensity (see Flohn, 1960; Adedokun, 1981). A similar but converse situation prevails during the retreat period. The disparity 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 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 ITD, as the rainfall onset in Nigeria takes approximately 3 months to spread from Ikeja (end of the second decade of March) to Kano (early June), while it takes approximately only 1 month to retreat from Kano (early second decade of September) to Ikeja (early third decade of October). The implication of this gradual advanced and rapid retreat of 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 experience sufficient warm, moist tropical maritime (mT) air depth between the end of the second decade of May and end of the second decade of October, early third decade of May and end of the second decade of October, mid third decade of May and middle of the first decade of October, May ending and early October and end of the first decade of July and middle of the first decade of September, respectively, during the course of a year, since rainfall during these periods appear 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 are approximately 5,5,4,4 and 2 respectively.

This connotes that, crops planted between the end of the second decade of March and end of the second decade of May in Ikeja, middle of the third decade of March and early third decade of May in Ondo, mid April and middle of the third decade of May in Ilorin, end of the first decade of May and May ending in Kaduna and early June and end of the first decade 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 decade of March, middle of the third decade of March, mid April, end of the first decade 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 decade of May, early third decade of May, mid third decade of May, May ending and end of the first decade of July in the respective stations.

CONCLUSION

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

REFERENCES

Adedokun, J.A. (1981): "Potential Instability and precipitation Occurrence Withing Intertropical Discontinuity". Arch. Met. Geoph. Biokl., Ser. A, 30, 69-86.

Adefolalu, D.O. (1983): "Rainfall Patterns in the Coastal Areas of Nigeria". Nigerian Geographical Journal, Vol. 26, Pp. 15 3-170.

Adejuwon, S.A. (1988): "An Assessment of the Patterns of Rainfall Fluctuations Between 1922 and 1985 in Nigeria". Unpublished Ph.D. Thesis, Obafemi Awolowo University, Ile-Ife.

Adejuwon, J.O., Balogun, E.E., and Adejuwon, S.A. (1992): "On the Annual and Seasonal Patterns of Rainfall Fluctuations in Sub-Saharan West Africa". International Journal of Climatology, Vol. 10, Pp. 839-848.

Adejuwon, J.O. and Jeje, L.K. (1976): Land Elements of Ife Area. Publication No. 2, Department of Geography, University of Ife, Ile-Ife, 106 pp.

Ati, O.F. , Stigter, C.J. and Oladipupo, E.O. (2002) "A Comparison of Methods to Determine the Onset of Growing Season in Northern Nigeria". International Journal of Climatology, Vol. 22, No 6, pp. 731-742.

Ayoade, J.O. (1974): "A Statistical Analysis of Rainfall Over Nigeria". Journal of Tropical Geography, Vol. 29, Pp. 11-23.

Balogun, Y.O. (2000) Senior Secondary Atlas. Longman, Second Edition. 161 pp.

Beer, T., Greehut G.K. and Tandeh, S.E. (1977): "Relations Between Z-Criterion for the Subtropical High, Hadley Cell Parameters and the Rainfall in Northern Ghana". Monthly Weather Review, Vol. 105, Pp. 849 – 855.

Bello, N.J. (1995): "On the Reliability of the Methods of Predicting the Onset and Cessation of the Rains in a Tropical Wet-and-dry Climate: Ondo as a Case Study". Journal of the Nigerian Meteorological Society (NMS), Vol. 1, No. 1, Pp. 41-55.

Benoit, P. (1977): The Start of the Growing Season in Northern Nigeria". Agric. Met., 18, Pp. 91-99.

Cocheme, J. and Franquin, P. (1967): "An Agroclimatological Survey of a Semi-arid Area in Africa, South of the Sahara, W.M.O., 86 No. 210, TP 110, 13 6.

Dagg, M. (1965): "A Rational Approach to the Selection of Crops for Areas of Marginal Rainfall in East Africa". East African Agric. J. 30, Pp. 286-295.

Fasheun, A. (1983): "Modelling of Daily Rainfall Sequences for Farm Operating Planning in Ibadan". Nigerian Met. Journal, Vol. 1, Pp. 102-109.

Flohn, H. (1960): "Intertropical Convergence Zone and Meterological Equator". W.M.O. Tropic', Munitalp/WMO Joint Symposium on Tropical Meterological in Africa, Munitalp, Nairobi.

Garbutt, D. J., Stern, R.D., Dennett, M.D., and Elston, J. (1981): "A Comparison of the Rainfall Climate of Eleven Places in West Africa, Using a Two-Part Model for daily Rainfall". Arch. Met. Geoph. Boikl, Ser. B., 29, 137-155.

Igeleke, G.A. (1973): "Determining the Duration of Available Water Periods at Some Selected Stations in Nigeria for the Period 1972". In: Agro. Met. Bulletin (January, 1973), Pp. 6-11.

Ilesanmi, O.O. (1972): "An Empirical Formulation of the Onset, Advance, and Retreat of Rainfall in Nigeria". Journal of Tropical Geography, Vol. 34, Pp. 17-24.

Iloeje, N.P. (1981): A New Geography of Nigeria. New Revised Edition, Longman, Great Britain.

Jackson, I.J. (1989): Climate, Water and Agriculture in the Tropics. Singapore, Longman.

Koppen, W. (1918): "Klassification de Klimate nach Temperature Niederschlag Und Jahreslauf". Pattermanns Geographishe Mitteilungen, Vol. 64, Pp.193 – 203, 2 43 – 248.

Kowal, J.M. and Adrews, D. J. (1973): "Pattern of Water Requirements for Grain Sorghum Production at Samaru, Nigeria". Tropical Agriculture, Vol. 50(2), Pp. 89-100.

Nieuwolt, S. (1982) Tropical Climatology: An Introduction to the Climates of the Low Latitudes. John wiley & sons 207 pp.

Nnoli, N.O. (1996): "Mean Onset and Cessation Dates of Rainy Season in Nigeria". Proceedings of the 11th Nigerian Meteorological Society Conference on Climate Change and its Impact on Agriculture, IITA – International Institute for Tropical Agriculture, Pp. 24-125, October 1996, Ibadan, Nigeria.

Odumodu, L.O. (1983): "Rainfall Distribution, Variability and Probability in Plateau State, Nigeria". Journal of Climatology, 3, 385-393.

Oguntoyinbo, J.S. (1978): "Drought and the Nigerian Farmer". Unpublished Staff/Postgraduate Student's Seminar Presented at the University of Ibadan.

Oguntoyinbo, J.S. and Odingo, R.S. (1979): "Climate Variability and Landuse" Proceedings of the World Climate Conference, W.M.O. Publication No. 537, Pp. 5 52-580.

Ojo, O. (1977): The Climate of West Africa. Heineman, London, Ibadan, Nairobi, Lusaka.

Olaniran, O.J. (1983): "The Start and End of the Growing Season in the Niger River Basin Development Authority Area of Nigeria" Malaysian Journal of Tropical Geography, Vol. 9, Pp. 49-58.

Omotosho, J.B. (1990): "Onset of Thunderstorms and Precipitation over Northern Nigeria". International Journal of Climatology", Vol. 10, Pp. 849-860.

Omotosho, J.B. (1992): "Long-Range Prediction of the Onset and End of the Rainy Season in West African Sahel.

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. Vol 3 No 2, pp. 81-89

Omotosho, J.B., Balogun, A.A. and Ogunjobi, K. (2000): "Predicting Monthly and Seasonal Rainfall, Onset and Cessation of the Rainy Season, in West Africa, Using Only Surface Data". International Journal of Climatology, Vol. 20,Pp. 865-880.

Stern, R.D. Denett, M.D., and Garbutt, D.J. (1981): "The Start of the Rains in West Africa". J. of Climatology, Vol. 1, No. 1, Pp. 59-68.

Stern, R.D. and Coe R. (1982) "The use of Rainfall Models in Agricultural Planning" Agricultural Meteorology, vol. 26,pp 35-50

Thornthwaite, C.W. (1948) "An Approach Toward a Rational Classification of Climate" Geogr. Rev. Vol. 38, pp, 55-94.

Thornthwaite, C.W. and Mather J.R. (1955) "The Water Balance" Centerton, N.J.: Laboratory of Climatology.

Walter, M.W. (1968): "Length of the Rainy Season in Nigeria", Institute of Agriculture Rsearch, Ahmadu Bello University, Samaru, Zaria, Nigeria.

Fig. 1: Map of Africa, Showing the Study Area (Nigeria)

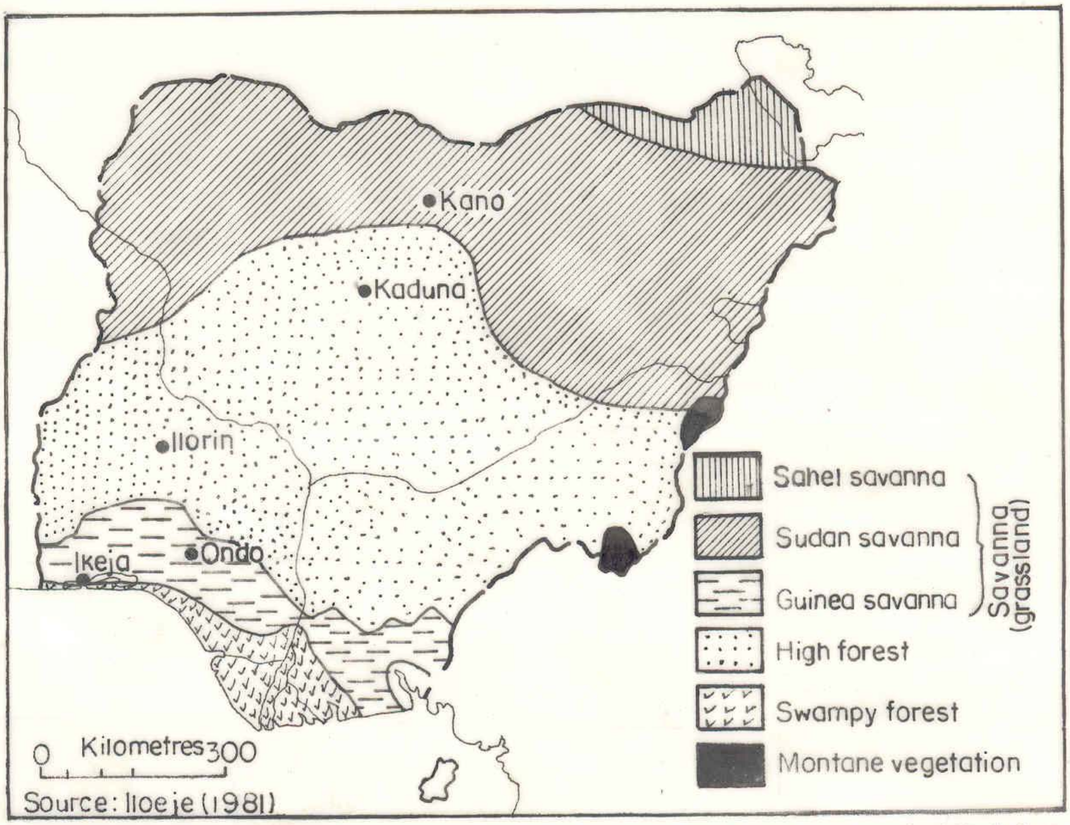


Fig. 2: Map of Nigeria, Showing the Vegetation Belts and the Sellected Rainfall Stations

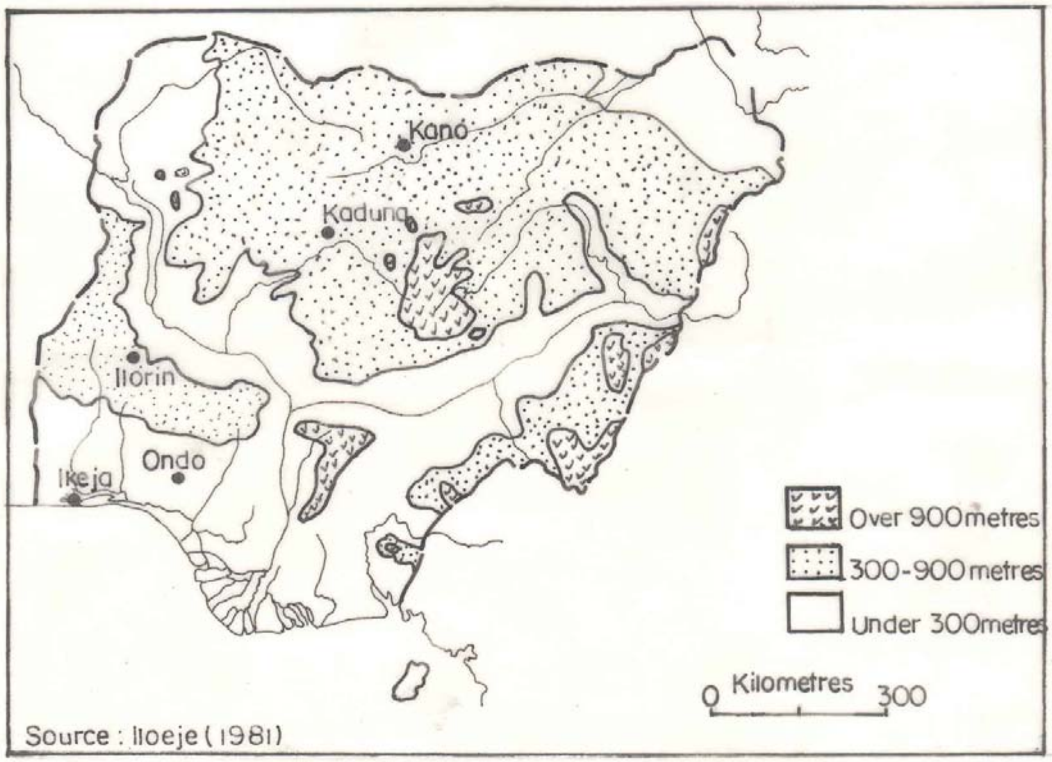


Fig. 3: Map of Nigeria, Showing the Relief and the Sellected Rainfall Stations·

Fig 4 : Rainfall Onset, Retreat and Length of the Growing Season in Ikeja (Using the Relative Definition Approach)

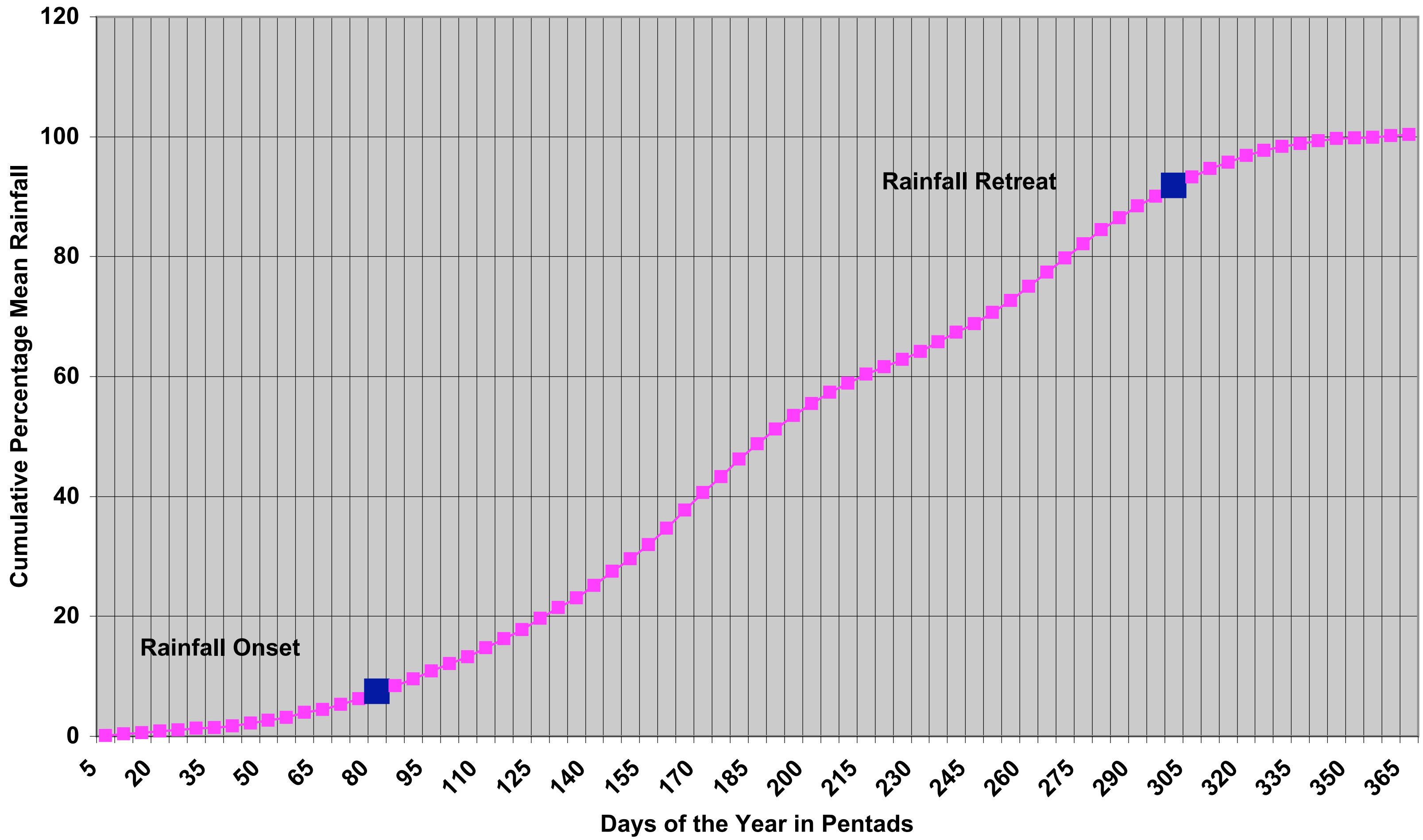


Fig 5 : Rainfall Onset, Retreat and the Length of the Growing Season in Ondo (Using the Relative Definition Approach)

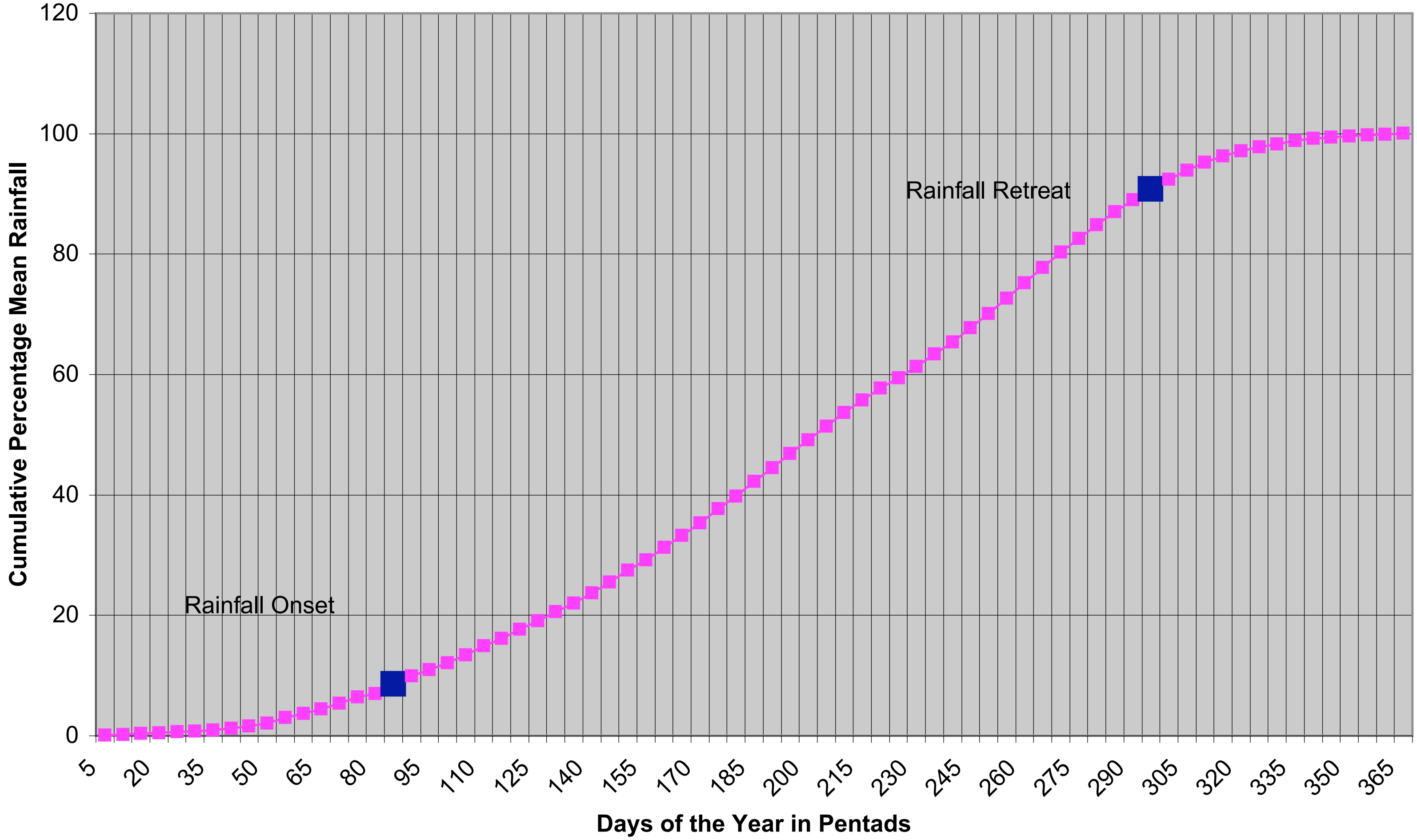


Fig 6 : Rainfall Onset, Retreat and the Length of the Growing Season in Ilorin (Using the Relative Definition Approach)

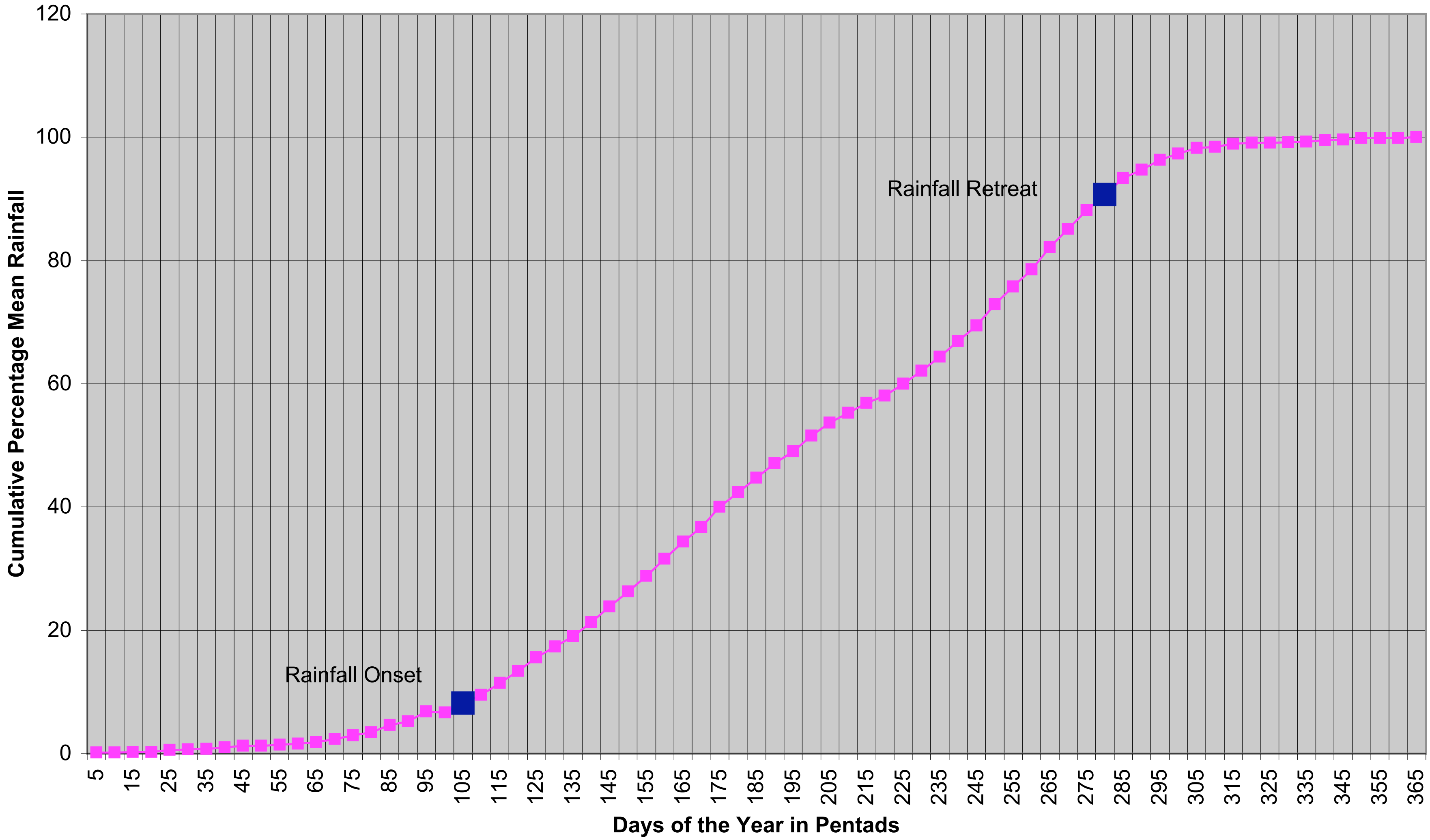


Fig 7 : Rainfall Onset, Retreat and the Length of the Growing Season in Kaduna (Using the Relative Definition Approach)

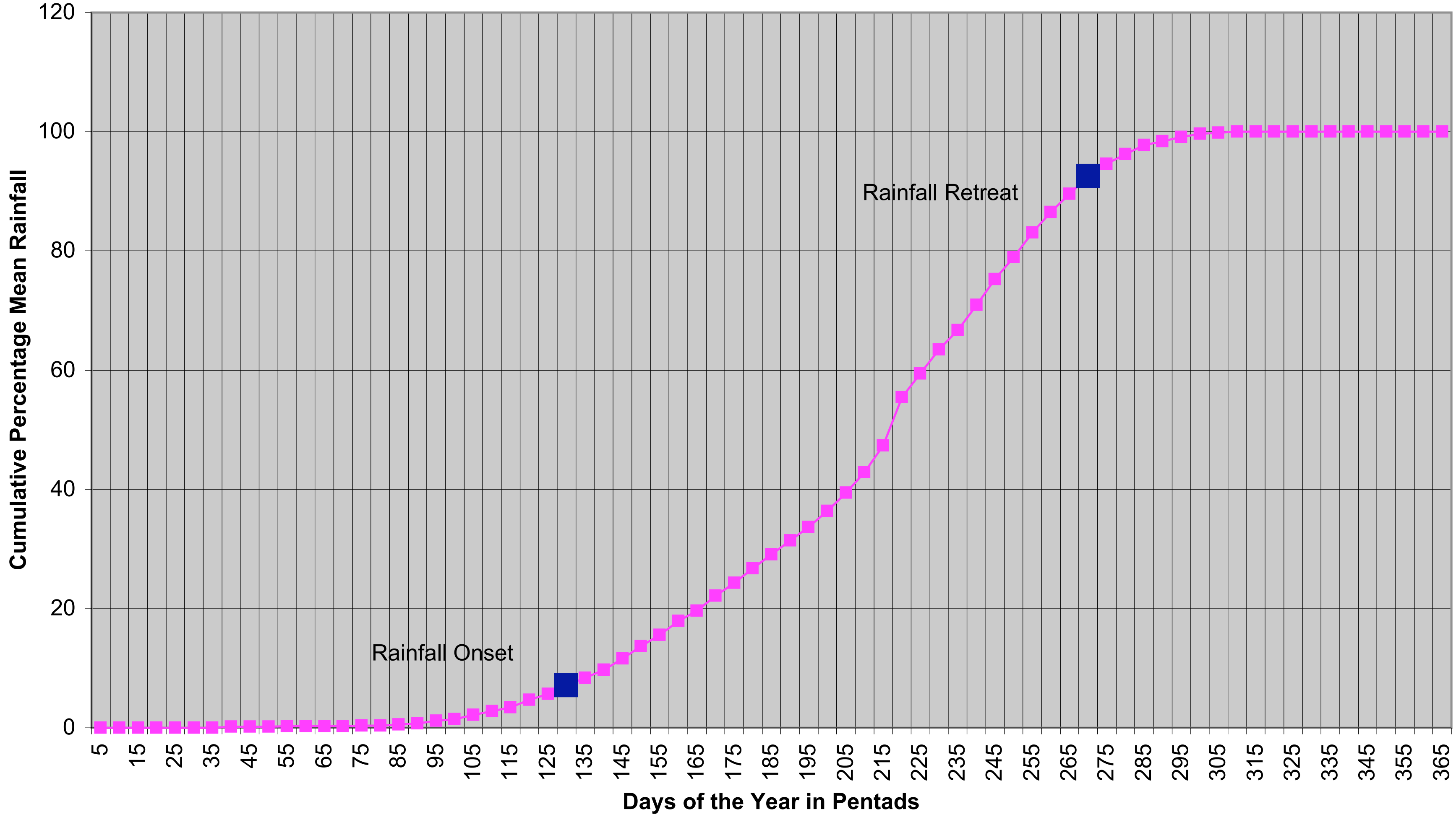


Fig 8: Rainfall Onset,Retreat and the Length of the Growing Season in Kano (Using the Relative Definition Approach)

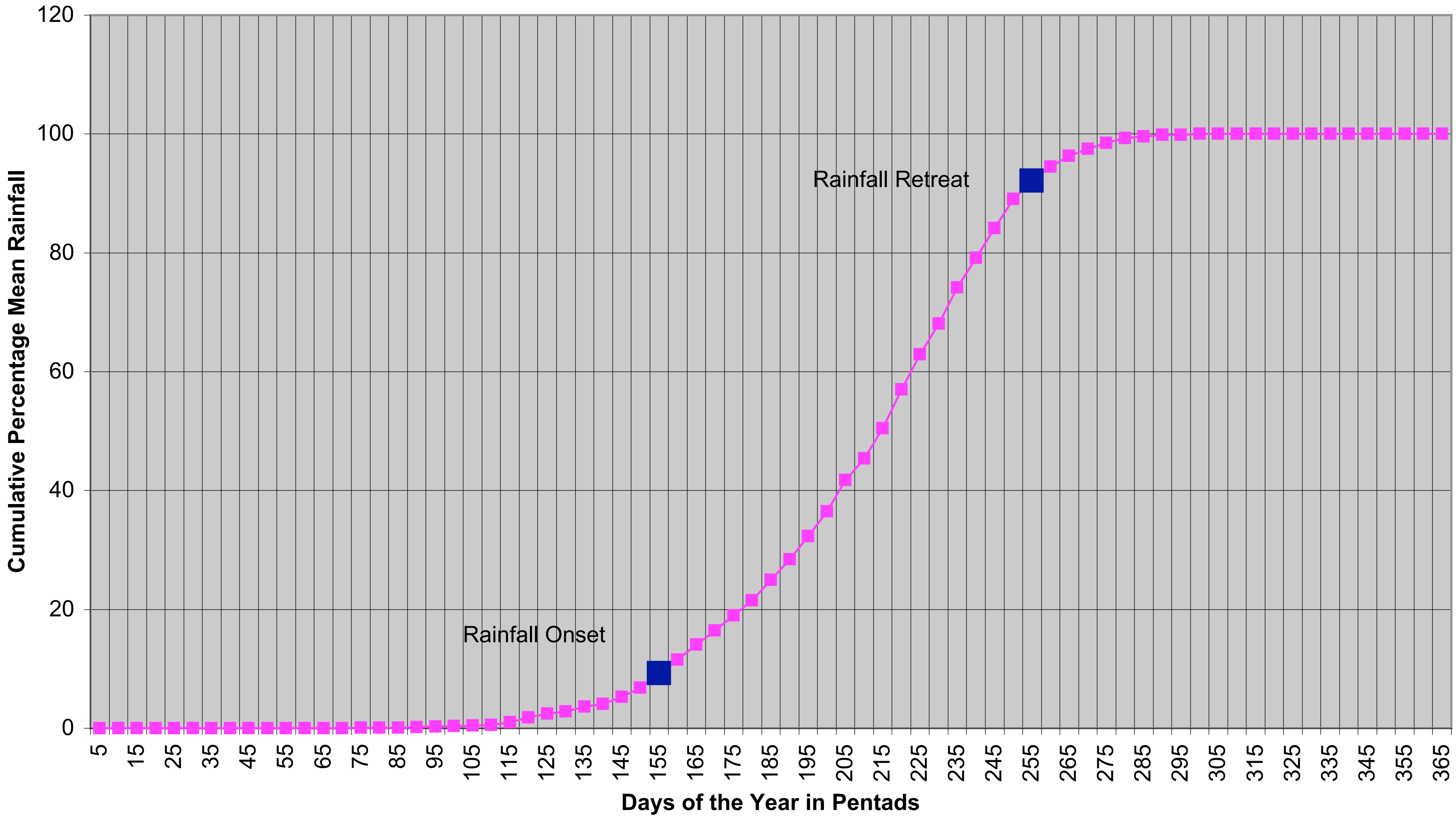


Fig 9: Rainfal Onset, Retreat and the Length of the Growing Season in Ikeja (Using the Rainfall Probability/Reliability Approach)

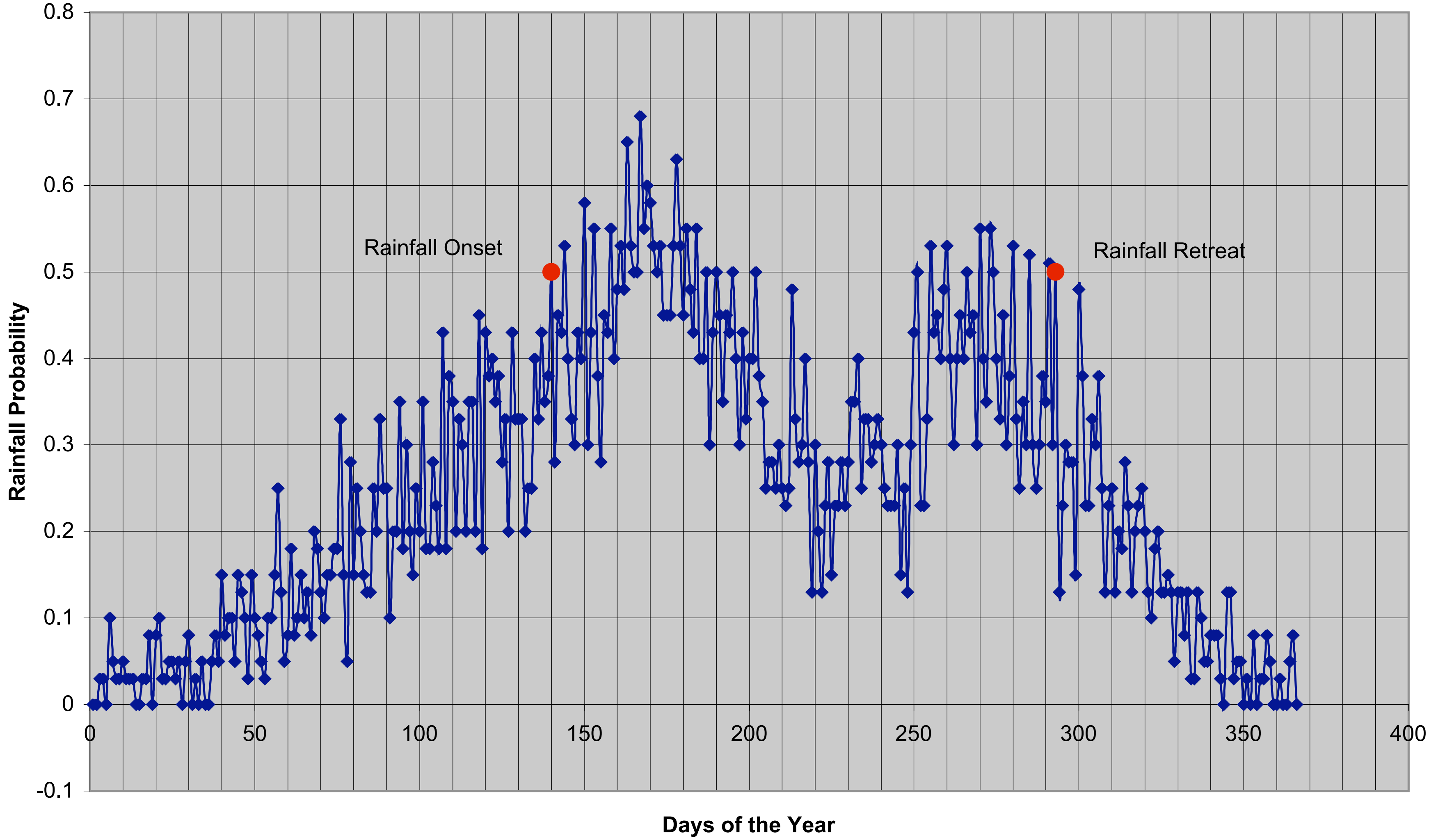


Fig 10 : Rainfall Onset, Retreat and the Length of the Growing Season in Ondo (Using the Rainfall Probability/Reliability Approach)

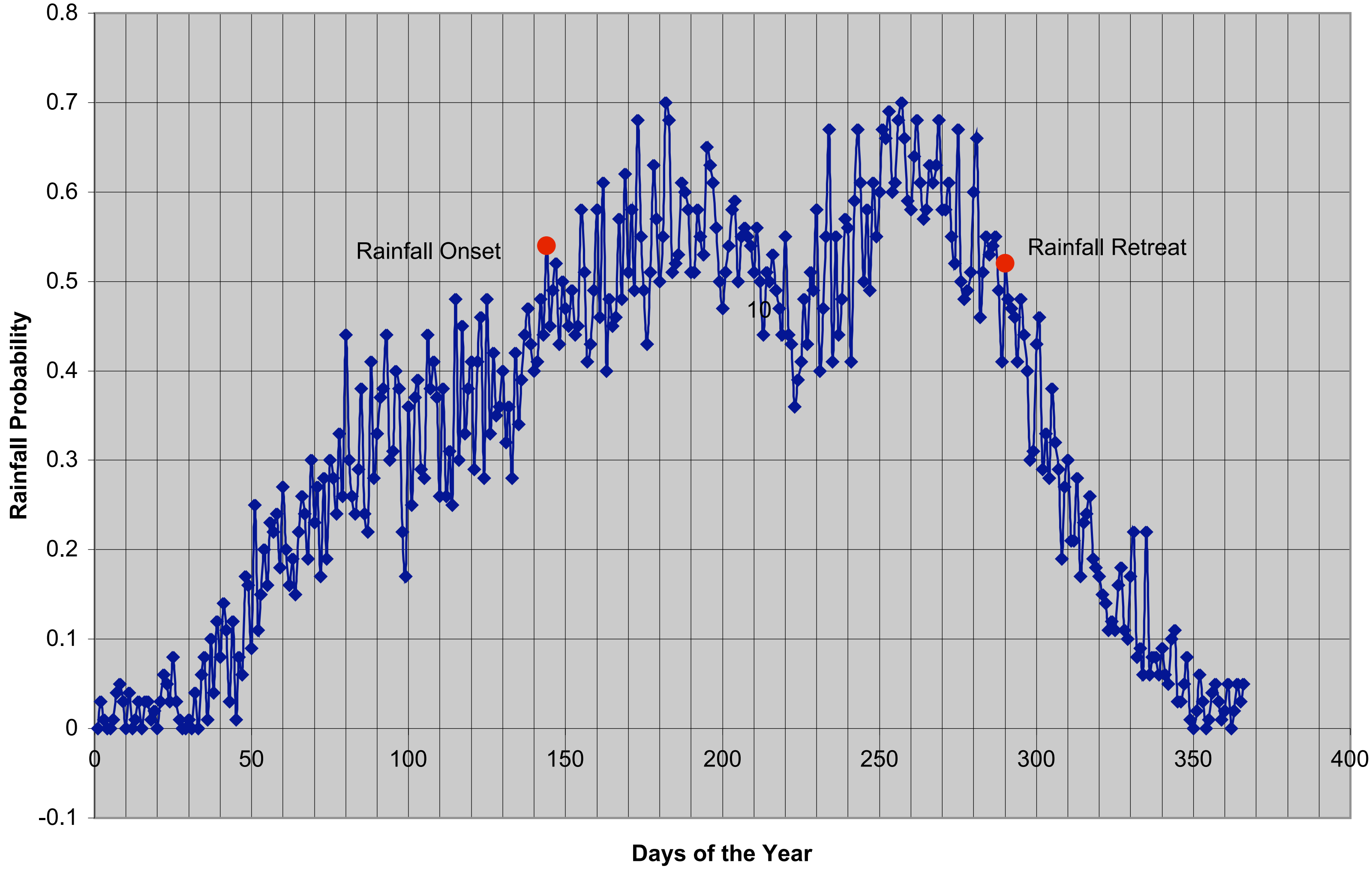


Fig 11 : Rainfall Onset, Retreat and the Length of the Growing Season in Ilorin (Using the Rainfall Probability/Reliability Approach)

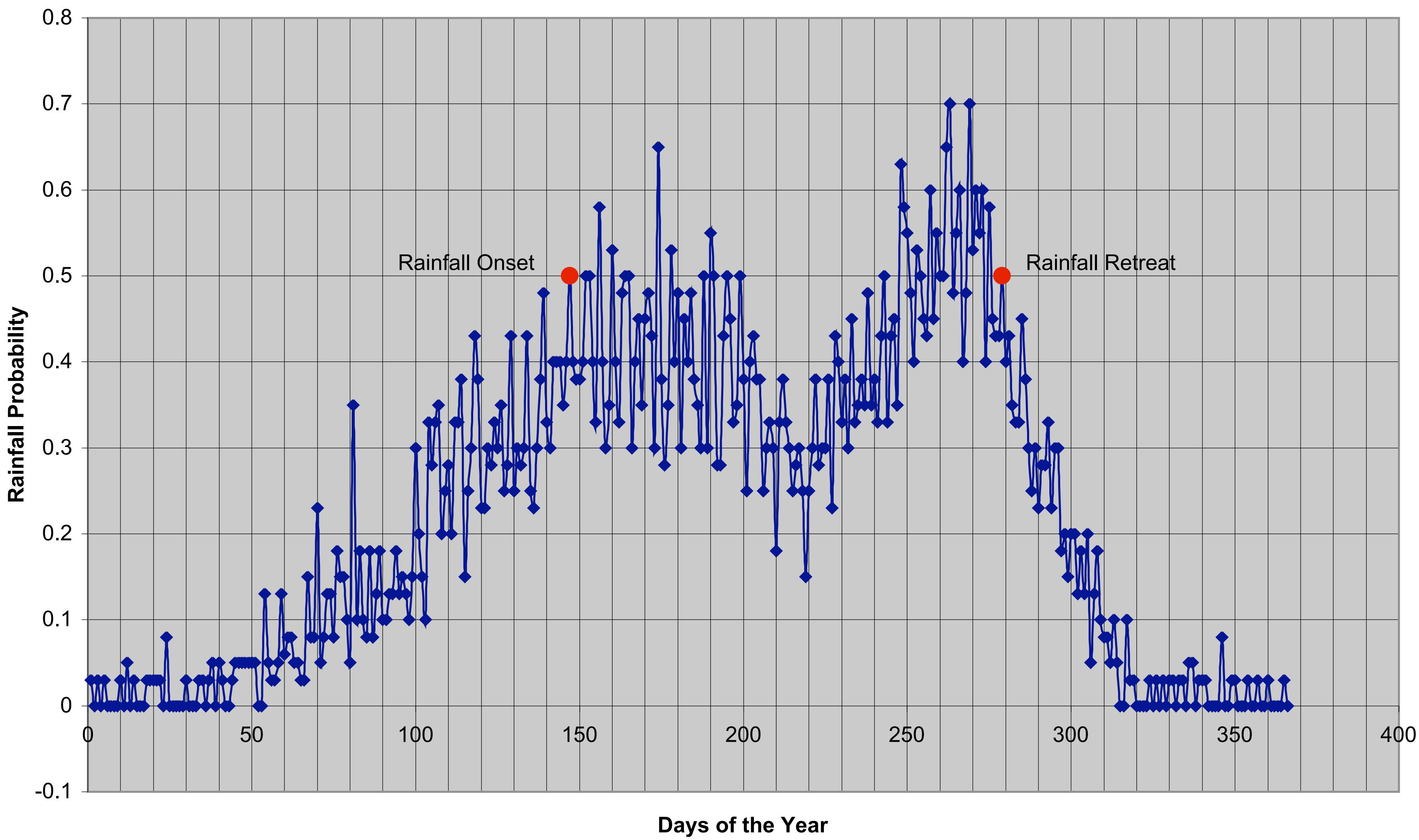


Fig 12 : Rainfall Onset, Retreat and the Length of the Growing Season in Kaduna (Using the Rainfall Probability/ Reliability Approach)

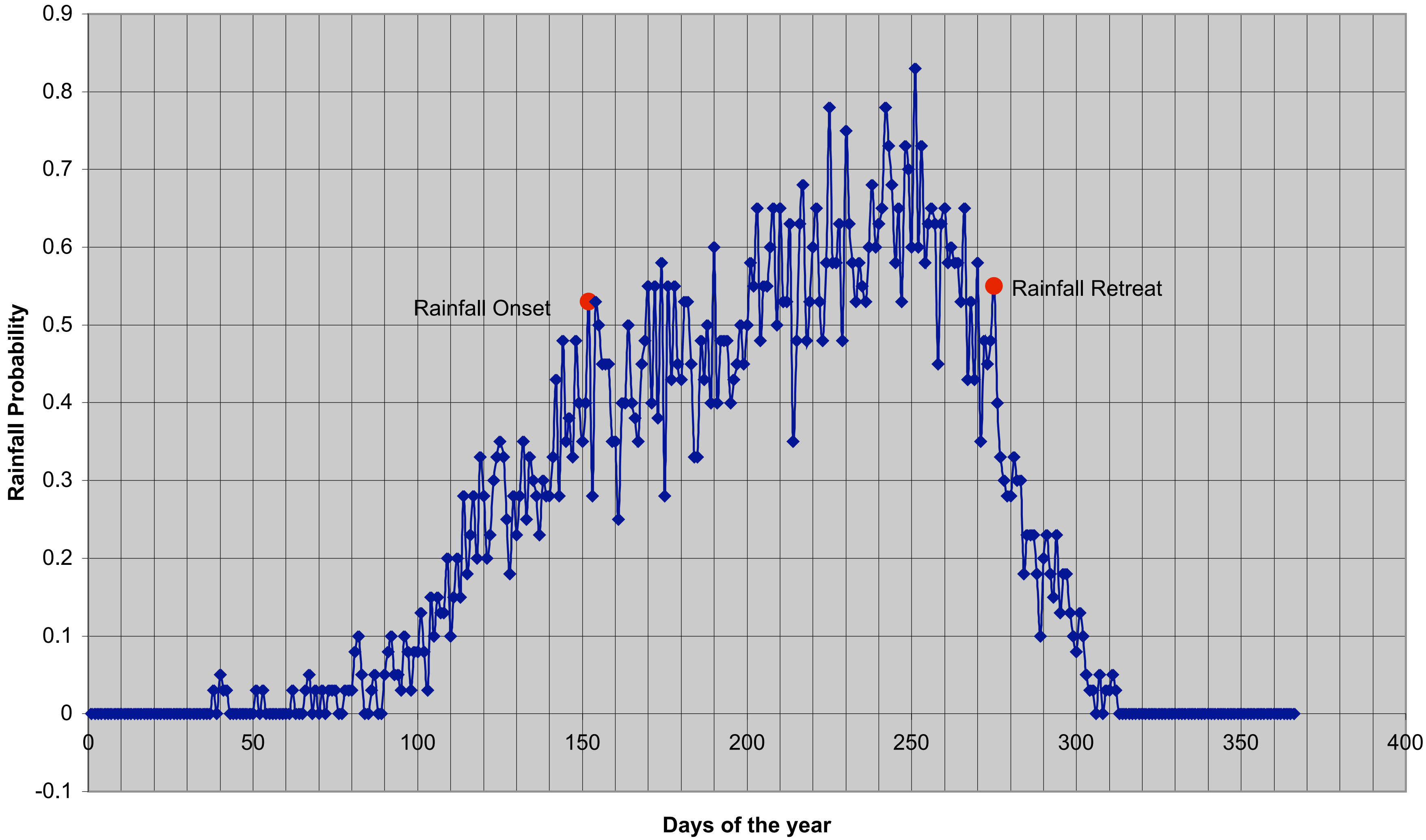
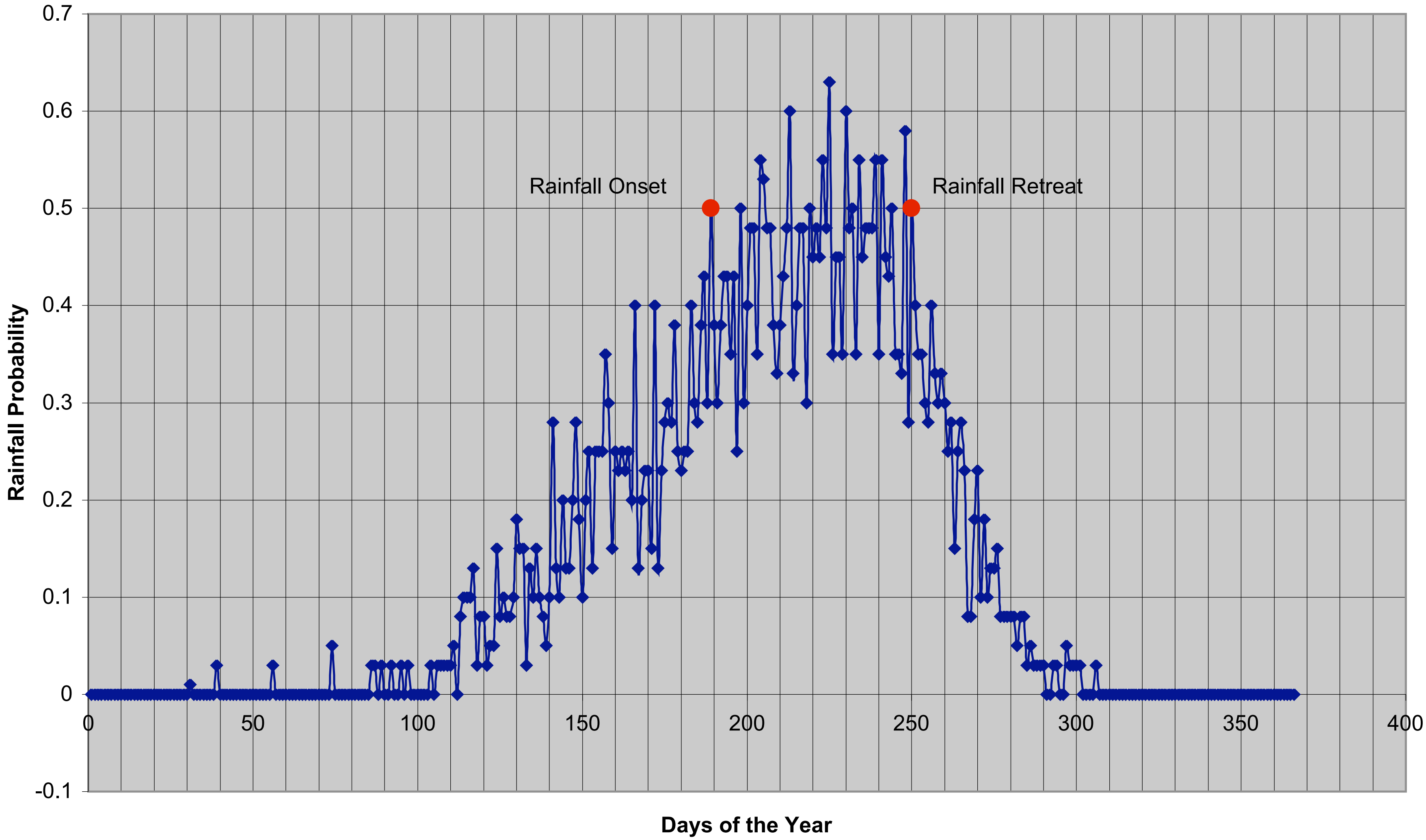


Fig 13 : Rainfall Onset, Retreat and the Length of the Growing Season in Kano (Using the Rainfall Probability/Reliability Approach)



ON THE PREDICTION OF RAINFALL ONSET AND RETREAT DATES IN NIGERIA

BY

T.O. ODEKUNLE

Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria.

E.E. BALOGUN

Department of Physics, Obafemi Awolowo University, Ile-Ife, Nigeria.

And

O.O. OGUNKOYA

Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria.

ABSTRACT

The study examined the rainfall onset and retreat dates in Nigeria (1970-1996) and generated models for their prediction. The study used the composite of the rainfall engendering factors of the sea surface temperature of the tropical Atlantic ocean, land/sea thermal contrast between some selected locations in Nigeria and the tropical Atlantic ocean, the surface location of intertropical Discontinuity and the land surface temperature in the selected locations in Nigeria. Data were collected from Ikeja, Benin, Ibadan, Ilorin, Kaduna and Kano, to represent Nigeria. Cumulative percntage mean rainfall was employed to generate the rainfall onset and retreat dates series, while the method of stepwise multiple regression analysis was used to construct the required prediction models.

The results obtained showed that the hypothesized rainfall-engendering factors are efficient in predicting rainfall onset and retreat dates in Nigeria. The correlation coefficients obtained (R^2) are in 75% of the cases higher than 0.50 (with several of them approaching 0.90). Sea surface temperature and land/sea thermal contrast as observed in the study, are the most significant predictor variables. The two factors solely constituted 93% of the total factors found significant in the various regression equations. The results also indicated that all the areas of the tropical Atlantics-ocean, from the Gulf of Guinea, through St Helena and Ascension Island, up to the Benguela current region, have bearing to the interannual variabilities in the rainfall onset and retreat dates of the country. Further still, the study demonstrated that different parts of the ocean becomes relevant to the rainfall onset and retreat dates at different time of the year and that the direction of the relationship between the explanatory variables and rainfall onset and retreat dates could change from time to time and from location to location.

INTRODUCTION

Rainfall onset can be taken as the period when rainfall commences, in earnest at the beginning of the season, while rainfall retreat refers to the cassation of the rain at the end of the rainy season. In an intertropical country like Nigeria, rainfall commences, reaches peak and retreats in different days of the year at different places. This emanates from the fact that he rain-belt follows the northward and southward movements of the Intertropical Discontinuity (ITD), which in turn is sun-synchronous (Walter, 1967; Ayoade, 1988; Hayward, 1987; Adejuwon et al, 1990).

Of all the seasonal component, rainfall onset and retreat periods appear to be the most important (Walter, 1967, Olaniran, 1983, Adejuwon et al, 1990). They are paramount because they significantly affect regional economics. Droughts are regional in nature and critical drought conditions occur when there is extreme shortage of water for long duration over large areas (Gustard et al, 1997). The most notorious seasonal component in this regard in West Africa, appears to be the rainfall onset, as it is usually foreshadowed by a succession of isolated showers of uncertain intensity with intervening dry periods of varying duration (Walter, 1967). A failure in the establishment t of rainfall onset usually indicates a drought in the early part of the rainy season. Agriculturists require a reasonable guarantee that, after a given dates the rain will become fairly continuous and sufficient to ensure enough moisture in the soil after planting commences and that such moisture level would be maintained and even increased as the season advances.

Numerous attempts have been made to estimate and forecast the rainfall onset and retreat dates in the tropics. The existing methods include: (a) rainfall-based models – method based on rainfall data alone (e.g. Ilesanmi, 1972a; Fasheun, 1983, Nnoli 1996), (b) ITD-rainfall models (e.g. Ilesanmi, 1972a; Kowal and Knabe, 1972), (c) rainfall- evapotranspiration relation model (e.g. Cocheme and Fraquin, 1967; Benoit, 1977), (d) model based on upper air data (Omotosho, 1990; 1992) and Theta – E technique – method based on the daily mean values of surface pressure temperature and relative humidity (Omotosho et al , 2002). But as observed by Omotosho et al (2002), most of these methods of determining or predicting rainfall onset and retreat dates give the same dates every year, which is clearly far from reality. According to these authors, the methods that are capable of addressing the problem of year to year (interannual) variabilities in the rainfall onset and retreat dates are; (a) wind shear scheme, and (b) the Theta-E technique. The major problem confronting the method that is based on the wind shear scheme is that of scarcity of the network of the required upper-air data over the entire West African region. As noted by Omotosho et al (2002), a new method (probably, most recent) of predicting rainfall characteristics in the tropics is the use of sea surface temperature (SST) (e.g. Falland et al, 1991; Fountain and Janicot, 1996; Colman et al, 2000 Chiang et al 2002). However the method has so far been applied to June to July to September" and annual rainfall totals only (Omotosho et al, 2002). Also the correlation coefficient of the prediction model generated using SST for the above rainfall parameters are rather too weak (mostly 0.30 – 0.40) (Omotosho et al, 2002). It is thus apparent that the model (SST) has not been attempted for the prediction of rainfall onset and retreat dates.

So far, West Africa rainfall characteristics have been explained in terms of three main factors, namely; intertropical discontinuity (e.g. Ilesanmi, 1972a, Kowal and Knabe, 1972), sea surface temperature (Adedokun; 1978 Folland et al, 1991; Colman et al, 2000) and land/sea thermal contrast (Carlson, 1969; Adedokun, 1978). ITD is the boundary zone separating the tropical maritime (mT) air mass from the tropical continental (CT) one. As noted by Ilesanmi (1972b) and Adedokun (1981), although this boundary zone is not a rain-producing phenomenon in itself, yet it is very important because weather zones occur in a latitudinal – spatial relationship to it. Well to the north of it, a rainless clear-sky climate and the northeasterly Harmattan winds prevail. The vicinity of its surface is a region of fair weather with scarce cloudiness (Hastenrath, 1985). At a distance of between 400km and 1000km south of ITD, where the layer of moist, cool monsoon airstreams is deep (at least 1,500m deep, Ojo, 1977) frequent storms and showers are observed. Thus, as observed by Ayoade (1974), whatever kind of weather types occurring at a particular place – the Harmattan, the steady rain and drizzle, the disturbance line thunderstorms and the 'Little dry season', their time of occurrence their onset, duration, intensity and retreat, are primarily determined by the location of that place relative to the moving ITD. Thus the movement of ITD into the sub-continent marks the onset on rain, while its withdrawal means the retreat of rainfall from sub-continent.

The role of ocean-atmosphere interaction (mainly in terms of the SST) in the climatic variability in general and rainfall variability in particular is increasingly gaining relevance and acceptability (See for example, Adedokun, 1978, Adejuwon et al 1990, Folland et al, 1991, Colman et al, 2000.) The basic tenet central to all sorts of explanations on this ocean atmospheric phenomenon is that, a lot of atmospheric disturbances result due to anomalously high or low temperature of the ocean surface. An anomalously low SST in the Atlantic ocean has long been recognized as a significant cause of interannual climatic viabilities in West Africa (Bjerknes, 1969; Krueger and Winston, 1975; Adedokun, 1978). The usually low SST is observed to take place dominantly around the Gulf of Guinea. The Low SST in this region of the Atlantic ocean is believed to be affected by the combined action of cold under current – the Benguela current, and a two sided divergence of the Ekman transport found within Guinea coast (Flohn, 1971) . Another explanation of this phenomenon of upwelling in the Gulf of Guinea is that provided by Sverdurp at al (1942) and Longhurst (1962). According to these author, the upwelling in the region is initiated by the coriolis force. More importantly a number of affects on the nature of rainfall distribution result from this factor of ocean-atmosphere interaction. All these affects are well summarized by Adedokun (1978). One such affect is that of the thermodynamic transformation the moist southwesterly winds undergo during their encounter with: (a) chilling effect at the coast – thereby acquiring negative buoyancy, and later, the warming due the land – thus acquiring positive buoyancy to effect convection inlands. Also (b), the southwesterly are strengthened by the upwelling effect of the ocean water. The strengthening of the southwesterlies, according to Adedokun (1978), enhances sahel rains but inhibitory to precipitation around the coastal area. (c) It has been argued by Carlson (1969) that low SST can effect a change in the temperature contrast between the potentially hot Sahara area and the relatively colder southern region. Increase in temperature contrast enhances easterly shear through the process described by Adedokun (1978) as “thermal – wind adjustment”. The increase in easterly shear should in turn result in increase in precipitation (but in the sahel region only; Adedokun, 1978). It is also believed that enhanced thermal contrast would make ITD to move further north, which will generate more rainfall in the north but less in the south. The above SST – rainfall relationship so far, presents the Gulf of Guinea as the only area of Atlantic ocean having influence of the nature of precipitation in West Africa. More recently however, Folland et al (1991) have found out that the relevant area of influence of SST to precipitation of the sub-region is not limited to the Gulf of Guinea alone, but extends southward to include the Benguela current region of the South Atlantic ocean. Infact, these authors have found strong coherent relationship between the SST anomalies in the tropical Atlantic (most especially, the Bengula current region) and Sahel rainfall.

This study attempts to generate models that can predict – rainfall onset and retreat dates in Nigeria. It appears that most previous studies attempted their various prediction models on rainfall characteristics using the various rainfall – engendering factors in a relative isolation. This perhaps accounts for the weak correlation coefficients obtained in most studies on the SST – rainfall relationship. Although SST – rainfall model is yet to be assessed for the rainfall onset and retreat dates so that one cannot say whether the correlation coefficients would be weak or strong, but the composite of the various rainfall – engendering factor would be better than the use of SST alone. Thus this study attempts its rainfall onset and retreat dates prediction and model, on the basis of the combined effect of the rainfall – engendering factors of the SST (right from the Gulf of Guinea up to the Benguela current region), land/sea thermal contract between some selected rainfall stations and the selected SST stations, ITD and land surface temperature.

STUDY AREA

The area chosen for the study is Nigeria, a West African sub-region (Fig. I). The country is located within Latitudes 4^0 - 14^0 and Longitude 3^0 – 15^0 E. It is bordered in the north, east, west and south by the Republic of Niger, Cameroon, Republic of Benin and the Gulf of Guinea respectively.

Nigerian climate is principally governed by the influence of three wind currents. These wind currents include: the maritime tropical (mT) airmass, the continental tropical (cT) air mass and the equatorial easterlies (Ojo, 1977). The first two air masses constantly coverage around a boundary zone popularly called Intertropical Discontinuity (ITD). The movement of ITD is sun-sychronous (Ayoade, 1974), but there is six-week lag between the ITD's movement and the solar cycle (Adedokun, 1978). It reaches its northern extremity, between latitudes 19.6^0N and 22.2^0N in August, and its southern extremity between latitudes $5.2^0$2 and 8^0N in February (Obasi, 1965). Over the country, rain falls mostly when an area is overlained by the mT air mass, and its becomes dryness when the area is overlained by the cT air mass. The equatorial easterlies are rather erratic cool air masses which come from the east and flow in the upper atmosphere along the ITD. Occasionally however, the air mass dives down, undercut the mT or cT air mass and give rise to line squalls or dust devils (Iloeje, 1981).

The specific locations selected to represent Nigeria and for which rainfall and temperature data were collected include: Ikeja, Benin, Ibadan, Ilorin, Kaduna and Kano. Each of the six locations was chosen to represent zones comprising area of similar climatic tendencies in the country. For instance, while Ikeja is selected to represent the coastal climatic zone, Benin, Ibadan, Ilorin, Kaduna and Kano represent forest, southern Guinea, Northern Guinea, Sudan and Sahelian zones, respectively.

STUDY METHODOLOGY

Data Collection

The data used for this study include: daily rainfall amount, the monthly surface location of ITD, the monthly land surface temperature and the monthly sea surface temperature. Data on the first three climatic parameters were sourced from the archives of the Nigerian Meteorological Services, Oshodi, Lagos. The SST data were sourced from the archives of the Hadley Center for Climatic Prediction and Research, U.K. Data on the surface location of ITD were collected along three longitudinal positions across West Africa. The three longitudinal positions which give the average position of the ITD's NNW-ESE orientation includes 5^0W, 0^0 and 5^0E. The data were collected at 0600Z chart and were only available from 1970 to 2000. Data on the SST were collected for twelve locations over the Atlantic ocean (1945-1996). The locations include: 22.5^0; 7.5^0E, 22.5^0S; 2.5^0E and 22.5^0S; 2.5^0W; in the Benguela current region of South Atlantics, 17.5^0S; 2.5^0W and 17.5^0S; 7.5^0W, near St. Helena, 7.5^0S; 2.5^0E and 7.5^0S; 12.5^0W, near Ascension Island and 2.5^0S; 2.5^0E, 2.5^0S; 2.5^0W; 2.5^0S; 7.5^0W, 2.5^0N, 2.5^0E and 2.5^0N; 2.5^0W to represent the Gulf of Guinea. Data availability on the SST and ITD appear to be the two main factors that put constrain on the length of the data used in this study. While the data availability of the former is between 1945 and 1996, that of the latter is between 1970 and 2000. Thus for the purpose of uniformity in the length of the data, the study made use of 27 years data (1970-1996). Of the twenty-seven years, two years (1995 and 1996) were set aside for testing the scheme, leaving twenty-five years for developing the required model for the rainfall onset and retreat dates predictability in the country.

Analysis

Determination of rainfall onset and retreat dates

The first set of data analysed in this study is the mean rainfall onset and retreat dates. This is followed by estimating these parameters for each years to generate rainfall onset ad retreat dates series that would constitute the dependent variables. The method employed in this study is that proposed by

Ilesanmi (1972a; 1972b) – cumulative percentage mean rainfall method. The basic procedures of the method is outlined as follows:

(a) derivation of the percentage of the mean annual rainfall that occure at each 5-day intervals;

(b) accumulation of the computed percentage at 5-day intervals;

(c) plotting the cumulative percentage at 5-day intervals through the year; and

(d) identification of the time of rainfall onset and retreat.

The point of first maximum positive curvature and last maximum negative curvature on the graph of the cumulative percentage at 5-day intervals through the year, are respectively the mean periods of rainfall onset and retreat. According to Ilesanmi alternatively, onset of the rains would be the timing of an accumulated 7 to 8 percent of the annual rainfall, and the rains ending after the accumulation of 90 percent of the annual rainfall. In this study, the second method is adopted – onset and retreat periods were taken as when 7 to 8 percent and 90 percent of the accumulated annual rainfall are attained, respectively. Then the respective mean proportion were employed to estimate the rainfall onset and retreat dates for each year.

Prediction Model

The method adopted for the construction of the prediction model in this study is multiple regression analysis. The statistical procedure employed in the selection of significant explanatory variables among the hypothesized set of explanatory variables is stepwise regression procedure. This procedure of regression analysis has been evaluated by Dripper and Smith (1966) as the best among others. The basic feature of this method of analysis is that the F- level for accepting into or deletion from the equation is set before the analysis. The level of significance chosen in this study is α = 0.05 (95% confidence level).Here, in this study,rainfall onset and retreat dates constitute the dependent variables, while SST,ITD, land/sea thermal contrast and land surface temperature constitute the explanatory variables. Data involving time series tend to move in the same direction because of the trend that is common to all of them. Thus it has been argued that trend be included among the explanatory variables so as to avoid misleading forecast (Grager and Newbolt,1974). So, time (year) is included among the explanatory variables in this study. Predictor variables of all the months preceeding the months of rainfall onset and retreat dates were used.

Models "Goodness of fit" Assessment

The values of F- level upon which the explanatory variables were added or deleted from the prediction equation, and the values of the coefficient of multiple determination (R^2), represent statistical "goodness of fit". As observed by Folland et al (1991) these statistical "goodness of fit" assessments are insufficient. These authors believed that the use a part of historical data outside that employed in the models' construction to verify forecasts, is the best way to assess the level of skill that the models were likely to achieve in real time forecasting. This study tested the forecasting power of its model, using 1995 and 1996 data. This assessment, which can be referred to as the “actual goodness of fit” and thus the reliability of the prediction models, were assessed by comparing the predicted rainfall onset and retreat dates with the observed values, using some threshold. As observed by Omotosho et al (2000) in their study over West Africa (argument was based on the decadal crop- water requirement), the predicted rainfall date is taken as correct if it is within 10 days of the actual date of rainfall onset. Given this argument of Omotosho et al, this study rated the model prediction skill performance on the rainfall onset and retreat dates in three categories. The skill is rated high,moderate and low if is within 10 days, beween 10and 20 days and above or below 20 days of the actual date, respectively.

RESULTS

Rainfall Onset and Retreat Dates

The results obtained show that Ikeja mean rainfall onset date is March 28th with cumulative percentage rainfall of 7%. Those of Benin, Ibadan, Ilorin, Kaduna and Kano are respectively on the 31th March, 14thApril,19thMay and 28th May and with cumulative percentage rainfall values of 7%,8%,8%,9% and 7%, respectively. The mean rainfall retreat dates are respectively 10th November,1st November,24th October, 14th October, 26th September and 8th September for Ikeja, Benin, Ibadan, Ilorin, Kaduna and Kano. Their respective cumulative percentage rainfall values are 96%,96%,96%,94%, 92% and 89%.From these results, March is the rainfall onset month of Ikeja, Benin and Ibadan. That of Ilorin is April while the month of May is the onset month for both Kaduna and Kano.

Modelling

The results of the analyses show that there is coherent relationships between rainfall onset and retreat dates and the hypothesised causative factors. In other words, all of the twelve regression equations that were generated are significant at $\alpha = 0.05$

Using the SST of the Atlantic ocean, land/sea thermal contrast between Nigeria and the selected SST locations in the Atlantic Ocean ,ITD, land surface temperature and time (year), there exist some coherent relationship between the explanatory variables and rainfall onset dates and retreat dates for all the six stations studies. With regards to the rainfall onset dates, the predictor variables of the months of January and February, were used for Ikeja, Benin and Ibadan. For Ilorin, it was months of January, February and March, while the months of January February, March and April were used for Kaduna and Kano. The various relationship obtained are expressed by the following equations:

Ikeja rainfall onset date = $-475.74+25.31KtM_2+40.36T_5M_1-26.78T_4M_1-17.26T_{12}M_2$ ----------(1)

$\alpha = 0.05$

$R = 0.82$

$R^2 = 0.68$

Where: KtM_2 is February land surface temperature;

T_5M_1 is January SST of location 17.5°S; 7.5°W T_4M_1 is January SST of location 17.5°S; 2.5°W and $T_{12}M_2$ is February SST of location 2.5°N; 2.5°W

Benin rainfall onset date =91.68 +17.26T_6M_2 –12.97Yt_8M_1-

31.74T_9M_1+15.82T_6M_1--(2)

α = 0.05, R= 0.75 and R^2=0.60

Where: T_6M_2 is February SST of location 7.5°S;2.5°E; Yt_8M_1 is January land/sea thermal contrast Between Benin and location 2.5°S;2.5°E; T_9M_1 is January SST of location 2.5⁰S 2.5⁰W T_9M_1 is January SST of location 7.5⁰S 2.5⁰E

Ibadan rainfall onset date = 85.11 + 11.69 Bt_{11} M_2……….. (3)

α = 0.05, R= 0.44 and R^2=0.20

Where Bt_{11} M_2 is February land/sea thermal contrast between Ibadan and location 2.5⁰N; 2.5⁰E.

Ilorin rainfall onset date = 461.89 – 13.54T_8 M1 ………………. (4)

α= 0.05, R= 0.45 and R^2=0.20

Where T_8 M_1 is January SST of location 2.5⁰S, 2.5⁰E

Kaduna rainfall onset date = -235.11 + 11.29 T_{12} M_4 + 6.31 X M_2

+ 5.35 Dt_{11} M_4 ………………………………………(5)

α = 0.05, R = 0.76 and R^2=0.58

Where: T_{12} M_2 is April SST of location 2.5⁰N, 2.5⁰W; XM_2 is February surface location of ITD and Dt_{11} M_4 is April land/sea thermal contrast between Kaduna and Location 2.5⁰N; 2.5⁰E.

Kano rainfall onset date = 317.69 + 17.44T_8M_3 – 29.51Nt_9M_3 + 24.34 Nt_{10} M_3 .. (6)

α = 0.05, R= 0.84 and R^2=0.65

Where: T_8M_3 is March SST of location 2.5^0S; 2.5^0E and Nt_9 M_3 and Nt_{10} M_3 are March land/ sea thermal contrasts between Kano and locations 2.5^0S, 2.5^0W and 2.5^0S; 7.5^0W, respectively.

With regards to the rainfall retreat dates the predictor variable of the months of January to August were used for all the stations studies. The various relationships obtained are expressed by the following equations:

Ikeja rainfall retreat date = 1242.21 + 0.94 year – $38.40T_{12}$ M_8 + $26.48T_{11}$ M_8 ……….. (7)

$\alpha = 0.05$, R= 0.81 and R^2=0.63

Where: T_{12} M_8 is August SST of Location 2.5^0N; 2.5^0W and T_{11} M_8 is August SST of Location 2.5^0N; 2.5^0E.

Benin rainfall retreat date = 1039.68 – 33.82 T_5 M_7 – 9.78 Yt_7 M_6

+ 22.78 T_4 M_7 – $14.02T_{12}$ M_8 – $8.45XM_6$ …………………………(8)

$\alpha = 0.05$, R= 0.90 and R^2=0.81

Where: T_5M_7 is July SST of location 17.5^0S, 7.5^0W; Yt_7M_6 is land/sea thermal contrast between Benin and location 7.5^0S; 12.5^0W; T_4M_7 is July SST of location 17.5^0S; 2.5^0W, T_{12} M_8 is August SST of location 2.5^0N; 2.5^0W and XM_6 is July surface location of ITD.

Ibadan rainfall retreat date = 231.08 + 12.80 $Bt_{11}M_2$ + 10.90 T_6 M_1 - 13.99 T_8 M_1 + 17.22 T_3 M6 – 6.29 T_8 M_6 ……………………………………………………(9)

$\alpha = 0.05$, R= 0.87 and R^2=0.76

Where: Bt_{11} M_2 is February SST of location 2.5^0N; 2.5^0E, T_6M_1 is January SST of location 7.5^0S; 2.5^0E, T_8M_1 is January, SST of location 2.5^0S; 2.5^0E, T_3M_6 is June SST of location 22.5^0S; 2.5^0 W and T_8 M_6 is June SST of location 2.5^0S, 2.5^0E.

Ilorin rainfall retreat date = 9.17 – 16.50 T_8M_7 +12.75$T_{10}M_2$ + 6.18$Lt_{11}M_2$+11.20T_9M_3 ………………………………………………………. (10)

α = 0.05, R= 0.94 and R^2=0.87

Where: T_8 M_7 is July SST of location 2.5^{0}S; 2.5^{0}E, $T_{10}M_2$ is February SST of location 2.5^{0}S; 7.5^{0}W, Lt_{11} M_2 is land sea thermal contrast between Ilorin and location 2.5^{0}S; 2.5^{0}E and T_9 M_3 is March SST of location 2.5^{0}S; 2.5^{0}W.

Kaduna rainfall retreat date = 143.16 – 13.06 Dt_2 M_6 – 8.73 Dt_{12} M_8 + 7.19T_9M_2 + 4.88 Dt_{10} M_7 ……………………………………………………………(11)

α = 0.05, R= 0.88 and R^2=0.78

Where: Dt_2M6 and Dt_{12} M_8 are June and August land/sea thermal contrasts between Kaduna and locations 22.5^{0}S, 2.5^{0}E and 2.5^{0}N; 2.5^{0}W, respectively; T_9M_2 is February SST of location 2.5^{0}S; 2.5^{0}W and $Dt_{10}M_7$ is July land/sea thermal contrast between Kaduna and SST of location 2.5^{0}S, 7.5^{0}W.

Kano rainfall retreat date = 292.10 + 17.21 T_5M_5 – 14.29 T_7M_8 …………… (12)

α = 0.05, R= 0.66 and R^2=0.43

Where: T_5M_5 is May SST of location 17.5^{0}S; 7.5^{0}W and T_7M_8 is August SST of location 7.5^{0}S; 12.5^{0}W.

Observation of the above prediction equations show a number of things. One is that the coefficient of multiple determination (R^2) which represents the variance explained in the dependent variable by explanatory variable (s) is above 50% (i.e R^2 = 0.50) in 75% of the regression equations. Also the relative contribution of each explanatory variable is at variant from each other. For instance, SST alone constitute 67% of the total explanatory variables found to be significant in the various equations. Land/sea thermal contrast, ITD and land surface temperature constitute 26%, 5% and 2% respectively. Thus SST and land sea thermal contrast alone constitute 93%. This means that rainfall onset and retreat dates of Nigeria can be predicted, using SST and land /sea thermal contrast alone.

Model's Actual 'Goodness of Fit" Assessment

Tables I and 2 summarise the actual "goodness of fit" assessment of the prediction equations developed for the rainfall onset and retreat dates, respectively. With regards to the rainfall onset dates, the skill is rated high in 58%, moderate in 17% but low in 25% of the cases tested. As for the rainfall retreat dates, the skill is rated high in 50%, moderate in 33% but low in 17% of the case tested. Generally (in both the cases of rainfall onset and retreat dates), the skill is rated high in 54%, moderate in 25% but low in 21% of the cases tested. In other words, generally, both the "high skill" and "moderate skill" categories constitute 79% of the cases tested. These result thus demonstrated that the models generated for the prediction of rainfall onset and retreat dates of the sub-region are suitable enough to be relied upon.

DISCUSSION

Both the statistical "goodness of fit" (using both the R^2 and α values) and the actual "goodness of fit" (by comparing the observed rainfall onset and retreat dates and with the predicted values using 1995 and 1996 data) of the results obtained in this study have proved the prediction models generated, as adequate for rainfall onset and retreat dates in Nigeria. The results have also demonstrated that the most important factors affecting the interannual variabilities in the rainfall onset and retreat dates in Nigeria are the SST of the Atlantic ocean (right from the Gulf of Guinea, through the St. Helena and Ascension Island, up to the Benguela current region) and the land /sea thermal contrast between the selected stations in the country and the various SST locations. The land surface temperature and the surface location of ITD are relatively less important.

The above pattern of the results obtained is not unexpected because, studies have demonstrated that SST/SST anomalies is a significant cause of interannual variabilities in the tropical rainfall characteristics (Adedokun, 1978, Folland et al, 1991, Colman et al, 2000). Also the factor of land /sea thermal contrast through its effect on both the strength of southwesterlies and the frequency of easterly shear, has long been recognized as a prime factor engendering interannual rainfall variability in the sub-region (Carlson, 1969, Adedokun, 1978; Folland et al, 1991). The contribution made by the factors of ITD and land surface temperature that proved negligible are also easy to explain. As observed by Adejuwaon and Jeje (1976) and Hayward and Oguntoyinbo (1987), land surface temperature does not constitute climatological problem in the tropics because it is naturally abundant throughout the whole year. Infact the factor is brought into the study purposely to be able to estimate the land/sea thermal contrast. Also, it has been pointed out by Adefolalu (1981) that

ITD/rainfall relationship can only be used to explain the mean-state conditions of rainfall, and that interannual variabilities appear to be poorly defined in terms of the mean ITD positions.

The results obtained have also demonstrated that the relationship between SST of the tropical Atlantic ocean and rainfall onset and retreat dates is such that different part of the ocean becomes significant to the rainfall onset / retreat dates of different locations at different time. For example, the SST of location that is insignificant in February may become important in March or April. So also are the factors of land/sea thermal contrast, ITD and land surface temperature. This pattern of results as observed in this study, further corroborates the observation of Trenbeth (1993) and Kane (2000) on the SST characteristics. These authors have noticed the changes in the location, extent and time of year of SST anomalies in the tropical ocean, which results in differences in tropical rainfall.

Furthermore, the pattern of the direction of the relationships between SST, land/sea thermal contrast, ITD and land surface temperature, and rainfall onset and retreat dates, as observed in this study is rather complex. In other words the direction of the relationship is sometimes direct and sometime inverse. As for the SST, the results obtained further corroborates the observation of Gbuyiro and Olaleye (1999). These scholars have already noticed such dual-direction characteristics of the SST-rainfall relationship in Nigeria. This pattern of the result as observed in this study may be as a result of the changes in the locations, extent and time of year of SST anomalies in the tropical oceans (Trenbeth, 1993; Kane, 2000). Notwithstanding these complex relationships, the composite of the factors provide statistically (and in reality) significant prediction models. This study believes that those SST that are inversely related with the rainfall onset and retreat dates act to strengthen the southwesterlies, while those directly related act to enrich the moisture status of the southwesterlies. With regards to the land/sea thermal contrast, where it is found to be both directly and inversely related in the same equation, it may act to generated internal eddying within the southwesterlies, which will promote frequent precipitation. In fact the land / sea thermal contrast is difficult to be explained as the phenomenon is not a function of SST alone, but of the land surface temperature. The only few place (precisely, two) where ITD featured, in the equation, they are not concurrent with the dependent variable and so may assume any direction of relationship. The only place where the land surface temperature featured, it is positively related. It is found to be positively related to Ikeja rainfall onset dates in February. This means that high land surface temperature may cause delay in the rainfall onset dates in Ikeja. However, since the factor is not concurrent with the dependent variable, it may assume any direction of relationship. For instance, warm land surface temperature that appears to cause delay in the rainfall onset may suggest that the moisture status of the atmosphere is still low. In that situation, heat would be given off mostly in the sensible rather than latent form.

CONCLUSION

The study has generated model that can predict rainfall onset and retreat dates in Nigeria, using the rainfall – engendering factors of the sea surface temperature, land/sea thermal contrast between the selected stations, in the country and those of the tropical Atlantic Ocean, ITD and land surface temperature. The specific locations selected to represent Nigeria and from which rainfall data were collected include: Ikeja, Benin, Ibadan, Ilorin, Kaduna, and Kano. The method proposed by Ilesanmi (1973) – Cumulative percentage mean rainfall, was employed to obtain both the mean and individual year rainfall onset and retreat dates, while the method of stepwise multiple regression analysis was employed in the construction of the prediction model.

Results from the study show that the hypothesized rainfall engendering factors are efficient in predicting rainfall onset and retreat dates in Nigeria. At 95% level of confidence the values of coefficient of multiple determination (R^2) of most prediction models generated are above 0.50% (with some of them approaching 0.90%). SST and land/sea thermal contrast are the most two important factors, as they solely constitute 93% of the total factors found significant in the construction of the various prediction models. The results also clearly demonstrate that all the areas of the tropical Atlantic ocean, from the Gulf of Guinea, through the St. Helena and ascension Island, up to the Benguela current region, have significant bearing to the interannual variabilities in Nigeria rainfall onset and retreat dates.

Acknowledgement

To the staff members of the library of the Nigerian meteorological services, oshodi, Lagos, we say BIG thank you, for the provision of the data on the rainfall, surface location of ITD and the land surface temperature. Our appreciation also goes to the staff members of the Hadley Centre, meteorological Office, London, Bracknell, for the provision of t he required sea surface temperature data.

REFERENCES

Adedokun, J.A (1978) ‘West African Precipitation and Dominant Atmospheric Mechanism” Arch. Met. Geoph. Biokl. Ser. A Vol. 27, pp. 289-310.

Adedokun, J.A. (1981) “Potential Instability and precipitation Occurrence within an Intertropica Discontinuity’ Arch. Met. Geoph.Biokl. Ser. A, Vol.30, pp 69-86.

Adejuwon, J.O. Balogun, E.E and Adejuwon, S.A**.** (1990) “On the Annual and Seasonal patterns of Rainfall Fluctuaitns in Sub-Sahara West Africa’ International Journal of Climatology, Vol. 10. pp 839-949.

Ayoade, J.O. (1974) “A statistical Analysis of Rainfall Over Nigeria” Journal of Tropical Geography Vol. 39, pp. 11-23.

Ayoade, J.O. (1988) Introduction to Climatology for the tropics. Abiprint and Pak Limited, Ibadan.

Benoit, P. (1977) “The start of the Growing Season in Northern Nigeria” Agric Met. Vol. 18, pp. 91-99.

Bjerknes, J. (1969) “ Atmospheric Telecommunications from the Equatorial pacific” Mon Wealth Rev. Vol. 97, pp 163-172.

Carlson, T.N. (1969) “Some Remarks on African Disturbances and their progress Over the Tropical Atlantic” Mon. Wealth Rev. Vol. 97, pp 716-726.

Chiang, J.C.H. Kushnir, Y and Giannin; A .(2002) “Deconstructing Atlantic Intertropoical Convergence Zone Variability: Influence of the Local Cross – Equatorial Sea surface Temperature Gradient and Remote Forcing from the Eastern Equatorial Pacific “Journal of Geophysical Research, Vol. 107, No. D1 1029/2000 JD000307, PP. 3-1-3-19.

Cocheme, J. and Fraquin p (1967) “An Agroclimatological survey of a semi-arid Area in Africa, South of the Sahara” W.M.O Vol. 86, No. 210, pp 110-136.

Colman, A.W. Davey, M.K. Graham, R and Clark R. (2000) “Experimental Forecast of 2000 Seasonal Rainfall in the Sahel and other Regions of Tropical North Africa, Using Dynamical and Statistical Methods” The Met Office, Bracknell, Berkshire, RG 12 2SY, UK..

Draper, N.W. and Smith, H. (1966) Applied Regression Analysis Wiley, New York.

Fasheun, A (1983) “Modeling of Daily Rainfall Sequence for Farm Operations Planning in Ibadan”, Nigerian Meteorological Journal Vol. 1, pp 102-109.

Flohn, H. (1971) “Tropical Circulation Pattern” Bonnerk Meteorol. Abh. Heft. 15, 55pp.

Folland, C. Owen, J., ward, M.N. and Colman, A (1991) “Prediction of Seasonal Rainfall in the Sahel Region, Using Empirical and Dynamic methods” Journal of Forecasting vol. 10, pp 21-56.

Fontaine, G and Janicot, S. (1996) “Sea Surface Temperature Fields Associated with West Africa Rainfall Anomally Types” Journal of Climate Vol. 9, pp. 2935-2940.

Gbuyiro, S.O and Olaleye J.O. (1999) “The Telecommunication Between Nigerian Rainfall and the Southern Oscillation” Published by the Department of Meteorological Services, Oshodi, Lagos .

Grager, C.W. J. and Newbolt, P. (1974) “Spurious Regressions in Econometrics” Journal of Econometrics , Vol. 35, pp. 143-159.

Gustard, A., Novicky, O. Demith, S., Tallaksen, L. Lanen, H.V. Clausen, B., Kasparek, L. Miklanek, P., Majercakova, O., Fendokova, M. Kupszyk, E. Radick, L. and Czamara, W. (1997) “Low flows and droughts in Northern Europe” pp 132-148 in FRIEND, Project H-5-5 (IHP IV) and I.I (IHP V) Third Report; 1991 – 1997 Camagref Editions.

Hastenrath, S. (1985) Climate and Circulation of the Tropics D. Reidel Publishing Company Netherlands, 455pp.

Hayward and Oguntoyinbo, J.S. (1987) The Climatology of West Africa Barnes and Neble Books, Totowa,New Jersey.

Ilesanmi, O.O (1972a) “An Empirical Formulation of the Onset, Advance and Retreat of Rainfall in Nigeria” Journal of Tropical Geography vol. 34, pp. 17-24.

Ilesanmi, O.O. (1972b) “Aspect of the Precipitation Climatology of the July August Rainfall Minimum of Southern Nigeria” Journal of Tropical Geography Vol. 35, pp 51-59.

Iloeje, N.P. (1981) A New Geography of Nigeria New Revised Edition, Longman, Great Britain.

Kane, R.P. (2000) “Some Characteristics and Precipitation Effects of the EL Nino of 1997-1998” Journal of Atmospheric and Solar – Terrestrial Physic, vol. 61, pp 1325-1346.

Kowal, J. M and Knabe D.T. (1972) “An Agroclimatological Atlas of the Northern States of Nigeria Ahmadu Bello University press; Zaria Nigeria.

Krueger, A.F and Winston, J.S (1975) “Large Scale Circulation Anomalies Over the Tropics During 1971-1972” Mon. Weath, Rev. Vol. 103, pp. 465-473.

Lunghurst, A.R. (1962) “A Review of the Oceanography of the Gulf of Guinea” Bulletin de II F.A. N.T. XXIV Ser. A NO. 3

Nnoli, N.O. (1996) “Mean Onset and Cessation Dates of Rainy Season in Nigeria”. Proceddings of the 11th Nigerian Meteorological society conference on climate change and its impact on Agriculture, IFTA 24-25 October, 1996, Ibadan, Nigeria.

Obasi, G.O.P (1965) “Atmospheric Synoptic Climatological Features Over the West African Region” Nigerian Meteorological Services Technical Note No. 28.

Ojo, O. (1977) The climate of West Africa, Heinemann, London, Ibadan, Nairobi, Lusaka.

Olaniran, O.J. (1983) “The Onset of the Rains and the start of the Growing Season in Nigeria” Nigeria Geographical Journal Vol. 26, Nos.1and 2 pp81-88.

Omotosho, J.B. Balogun, A. A. and Ogunjobi, K. (2000) “Predicting Monthly and Seasonal Rainfall Onset and Cessation of the Rainy Season, In West Africa Using Only Surface Data” International Journal of Climatology, Vol. 20, pp 865-880.

Omotosho, J.B. (2002) “Synoptic Meteorology: Pathway to Seasonal Rainfall Prediction for Sustainable Agriculture and Effective Water Resource management in West Africa But Nigeria in particular”. Journal of the Nigerian Meteorological Society (NMS) Vol. 3 No. 2 pp 81-86.

Sverdrup, H.V., Johnson, M.W and Fleming R.H. (1942) “The Ocean, their

Physics, Chemistry and General Biology" OCW5 (Mimeographed).

Trenberth, K.E. (1993) "The Different Flavours of El. Nino" In: Proceedings of the Eighteenth Annual Climate Diagnostics Workshop, Boulder, Co, pp 50-53.

Walter, M.W. (1967) "The length of the Rainy season in Nigeria "Nigerian Geographical Journal Vol. 10, pp 123-128.

TABLE 1

Model's "Goodness of Fit" Assessment of Rainfall Onset Dates (1995 and 1996)

Stations	Year	Observed rainfall onset dates (in days of the year)	Predicted rainfall onset dates (in day of the year)	Difference between observed and predicted (in days)	Prediction skill levels
Ikeja	1995	68	64	4	High
Benin		79	102	23	Low
Ibadan		90	95	5	High
Ilorin		118	82	36	Low
Kaduna		142	144	2	High
Kano		160	171	11	Moderate
Ikeja	1996	46	102	56	Low
Benin		82	98	16	Moderate
Ibadan		62	66	4	High
Ilorin		111	107	4	High
Kaduna		144	144	0	High
kano		155	163	8	High

TABLE 2

Model's "Goodness of Fit" Assessment of Rainfall Retreat Dates

(1995 and 1996)

Stations	Yea	Observed rainfall onset dates (in days of the year)	Predicted rainfall retreat dates (in day of the year)	Difference between the observed and predicted (in days)	Prediction skill levels
Ikeja	1995	310	314	4	High
Benin		307	297	10	High
Ibadan		298	290	8	High
Ilorin		299	270	29	Low
Kaduna		264	263	1	High
Kano		252	264	12	Moderate
Ikeja	1996	287	317	30	Low
Benin		276	262	14	Moderate
Ibadan		290	303	13	Moderate
Ilorin		276	286	10	High
Kaduna		271	288	17	Moderate
kano		258	248	10	High

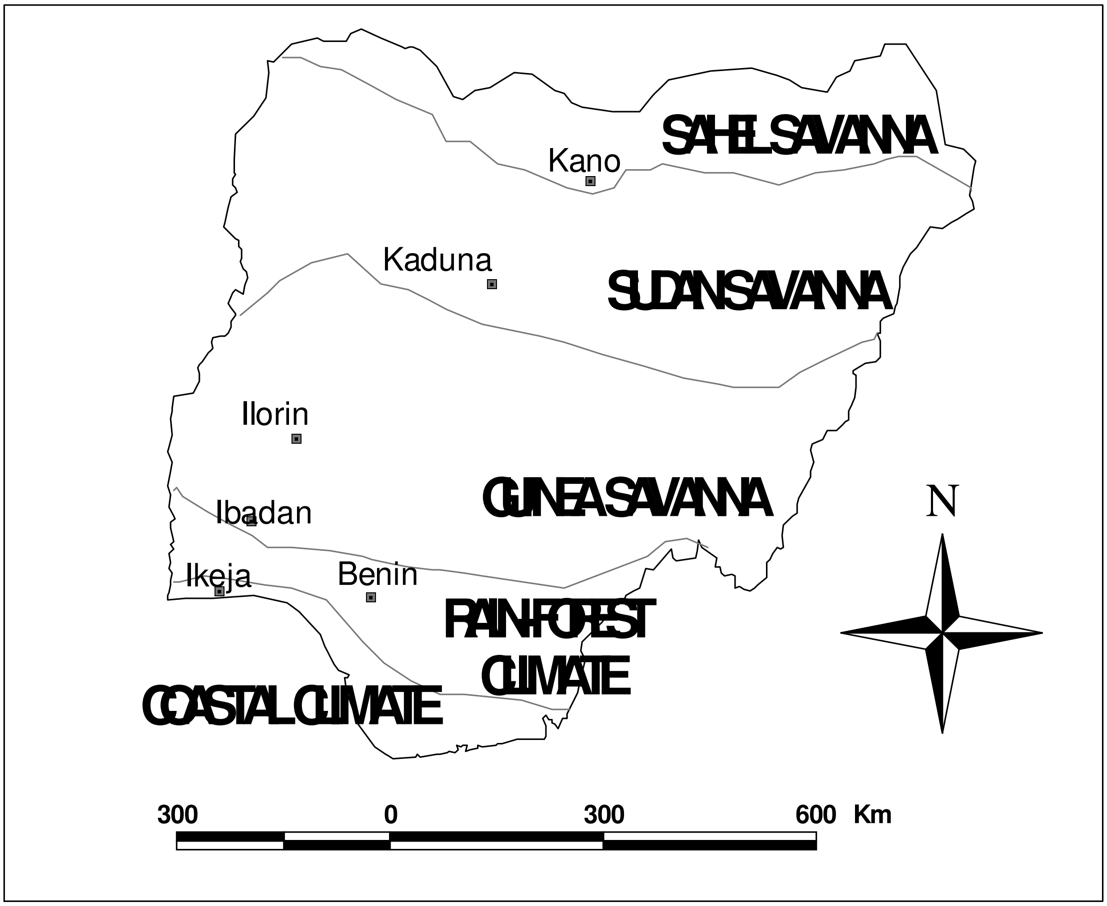


Fig1: Map of Nigeria, Showing the Selected Rainfall stations.