PREDICTING THE VARIABILITY AND THE SEVERITY OF THE "LITTLE DRY SEASON" IN SOUTHWESTERN NIGERIA

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Abstract

This study evaluates the variability and severity of the 'Little Dry Season' (LDS) in southwestern Nigeria. Being an important climatic phenomenon that impacts agricultural practices in the West African sub-region, a fore knowledge of the LDS characteristics for any given year should enable farmers to plan with greater confidence and mitigate the negative consequences and exploit its beneficial opportunities. The study therefore examines the relationship between the LDS rainfall characteristics of southwestern Nigeria and the sea surface temperatures (SSTs) of the Gulf of Guinea, and of the source locations of the Guinea and Benguela currents, and generates models for the prediction of the LDS characteristics. Rainfall data of Ikeja, Benin City, Ibadan and Ilorin in southwestern Nigeria are used in the analysis.The data were sourced from the archives of the Nigerian Meteorological Service, Oshodi, Lagos. The two sets of data are for a 38-year period (1961-1998). The data of 10 of the 38 years (1961-1970) were used for testing the model, while the remaining data (1971-1998) were used for building the prediction model. Linear regression algorithm and K-means cluster analyses were employed to generate the models.

Results show that LDS rainfall amount and rainy days have significant positive relationship with SSTs of the Gulf Guinea and the source locations of the Guinea and Benguela currents. Very Cold, Cold, Average, Warm and Very Warm SST conditions promote Very Dry, Dry, Average, Wet and Very Wet LDS rainfall conditions, respectively. The time lag between the SSTs of the source locations of the Guinea and Benguela currents and SST of the Gulf of Guinea and thus LDS rainfalls, are 1-2 and 6-7 months, respectively. There is no time lag between the SST of the Gulf of Guinea and the LDS rainfalls. All the correlation values obtained are statistically significant. However, the 'goodness of fit' assessment (by comparing the observed with the forecast) indicated that the model generated, using the SST of the source locations of the Guinea current, has a poorer 'fit' than the model based on the source locations of the SST of the Benguela current. Given that both the statistical and real time tests of 'goodness of fit' indicate the SST of the Benguela current origin as having the most coherent relationship, the study concludes that, the Benguela current is having preponderant influence on the dynamics of the Gulf of Guinea, and thus the LDS rainfall in southwestern Nigeria. Thus the SST of the Gulf of Guinea and the LDS rainfall in southwestern Nigeria can be reliably predicted with 6-7 months lead period, using the SST of the Benguela current origin.

Keywords: Southwestern Nigeria; Gulf of Guinea; Benguela current; Guinea current; "Little Dry Season" (LDS); Sea Surface Temperature (SST); LDS rainfall amount; LDS rainy days.

1. Introduction

The "Little Dry Season" (LDS) is a climatological phenomenon, which occurs in southwestern Nigeria. It is manifested in form of a decline in both the frequency and amount of daily rainfall for a number of weeks half way through the rainy season (Hamilton and Archbold, 1945, Ilesanmi 1972; Adejuwon and Odekunle, 2006). The reduction in rainfall becomes noticeable from mid-July, intensifying through August, and terminates early in September (Adejuwon and Odekunle, 2006). A recent study (Adejuwon and Odekunle, 2006) shows that the LDS characteristics of rainfall amount, number of rain-days, length of the LDS and LDS rainfall intensity, exhibit considerable inter-annual variability. The study further shows that, although over most of the years the LDS rainfall is enough to meet the water needs of the various crops, in some other years, rainfall is and drought conditions prevail. Variability in the severity of the LDS was thus noted as having mixed implications for agricultural practices in southwestern Nigeria. For instance, Osunade (1994) observed that when the LDS occurs with normal intensity the period is put to good use in the agricultural calendar in three main ways: (a) as a period of the growing season during which conditions are favourable for weeding; (b) it is a period when conditions are favourable for the application of pesticides, and (c) it is perceived as a phenomenon that favours good yield of yam. However, when the LDS comes up too early during

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the growing season, it could spell disaster for early crops. In other years, when the LDS persists too late into the second half of the growing season, the length of the growing season is reduced, resulting in widespread crop failure. Given the variable severity of the LDS and its attendant mixed implications for agricultural practices in southwestern Nigeria, a predictive capacity of the LDS characteristics should enable farmers to plan with greater confidence to forestall its negative consequences and exploit its benefits.

Several explanations have been advanced for the occurrence of the LDS in Nigeria. These include: (a) a pronounced subsidence inversion found in the 850mb-800mb layer (Hamilton and Archibold, 1945); (b) the deflections of the southwesterlies (Ojo 1977); (c) drastic change in the St. Helena anticyclone in the South Atlantic, which produces the southeasterly air stream, that extends to the northern hemisphere as southwesterlies to affect the West African coast (Ireland, 1962); (d) the effect of the rainfall between May and June that promotes a stabilized lower atmosphere (Ojo 1977); (e) northward displacement of the Intertropical Discontinuity (ITD) and its associated rainfall band (Ilesanmi, 1972); (f) coastal alignment (Dines,1922; Ilesanmi, 1972); and (g) static stability, brought about by SST dynamics in the Gulf of Guinea which, prevent the development of convection.

It is generally believed that a strong cold-water upwelling in the Gulf of Guinea, promotes a strong Walker Circulation, which in turn strengthens the mT air mass to push the ITD maximally. In such years, the ITD goes further north than usual thereby generating severe LDS in the southern region. Conversely, a weak cold-water upwelling would be associated with a weak Walker Circulation. This condition is believed to promote a limited ITD incursion into the region. Such years are characterized by mild LDS in the southern region. The Low SST (upwelling) in the Gulf of Guinea is believed to be effected by the combined action of cold under current – the Benguela current, and a two-sided divergence of the Ekman transport (Flohn, 1971). Therefore, since the thermal inertia of the coupled climate system rests in the upper ocean, the SST around the Gulf of Guinea should be a valuable predictor of the LDS rainfall. Also, given the fact that the Benguela current has a long trajectory over the Atlantic Ocean, the SST of its Source location may indicate the nature of the LDS rainfall characteristics some couples of months earlier than that of the Gulf of Guinea. The Guinea current is another important current known to have a direct significant effect on the hydrography of the Gulf of Guinea (Longhurst, 1962). This study therefore attempts to develop prediction models for LDS rainfall characteristics, based on the perceived relationships between the LDS rainfall and the SSTs of the Gulf of Guinea and the source locations of theGuinea and Benguela currents.

2. Study Area

The study area is the southwestern region of Nigeria. The area lies approximately between longitudes 3° E and 7° E, and latitudes 5° N and 9° N, and thus, west of the lower Niger and south of the Niger Trough (Figure 1). The total land area is about 191, 843 square kilometres (Iloeje, 1981). The rural population is high and a large proportion of the people are peasant farmers. A large proportion of the most populous States and cities in the country are located in this area. The most populous State is Lagos, having a total population of 5,685, 781 (1991; 6.42% of the total national population).

As in the other parts of the country, the climate of southwestern Nigeria is dominated by the influence of three major wind currents, namely: the tropical maritime (mT) air mass, the tropical continental (cT) air mass and the equatorial easterlies (Ojo, 1977; Iloeje, 1981). 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 southwestern 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, which are rather erratic cool air masses, come from the east and flow in the upper atmosphere along the ITD. Occasionally however, the air mass moves down, to undercut the mT or cT air mass and give rise to line squalls or dust devils (Iloeje, 1981).

Land and sea breezes are another set of air masses found in southwestern Nigeria, but because they are confined to the coastal zones, they assume a relatively minor role in the climate of the area.

The latitudinal position of the ITD is a function of the season although there are also considerable short period fluctuations. Generally however, it is situated well to the north of Nigeria in July and August thereby allowing southwestern Nigeria to be totally under the influence of mT air mass. It is located along the coastal part of Nigeria during January, with the effect that most of southwestern Nigeria is covered by the cT air mass during this period. As a result, southwestern Nigeria is subject to marked wet and dry seasons associated with the moist and dry air currents, respectively. In most of the study area, the wet season extends from April to October and rainfall is characteristically bimodal in distribution (Hamilton and Archbold, 1945; Ireland, 1962). The

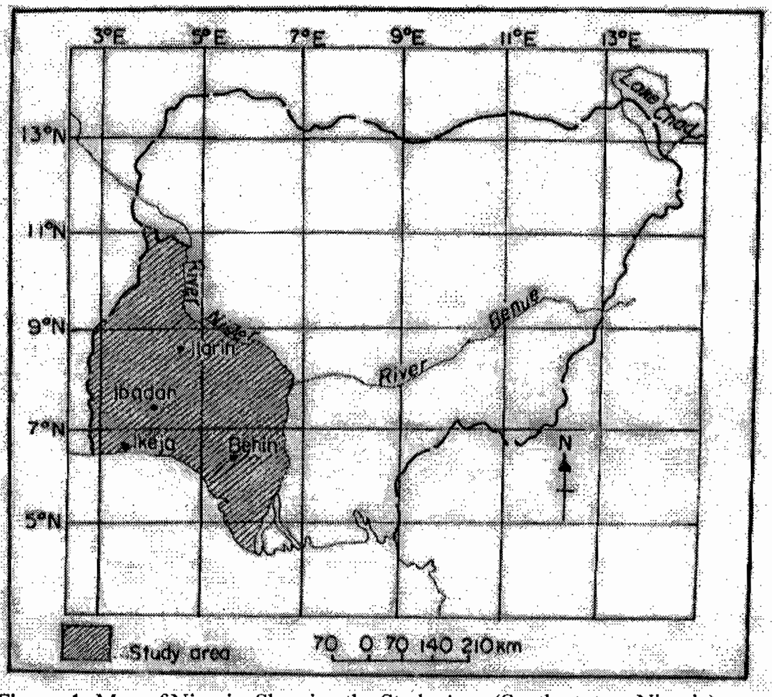

Figure 1: Map of Nigeria, Showing the Study Area (Southwestern Nigeria)

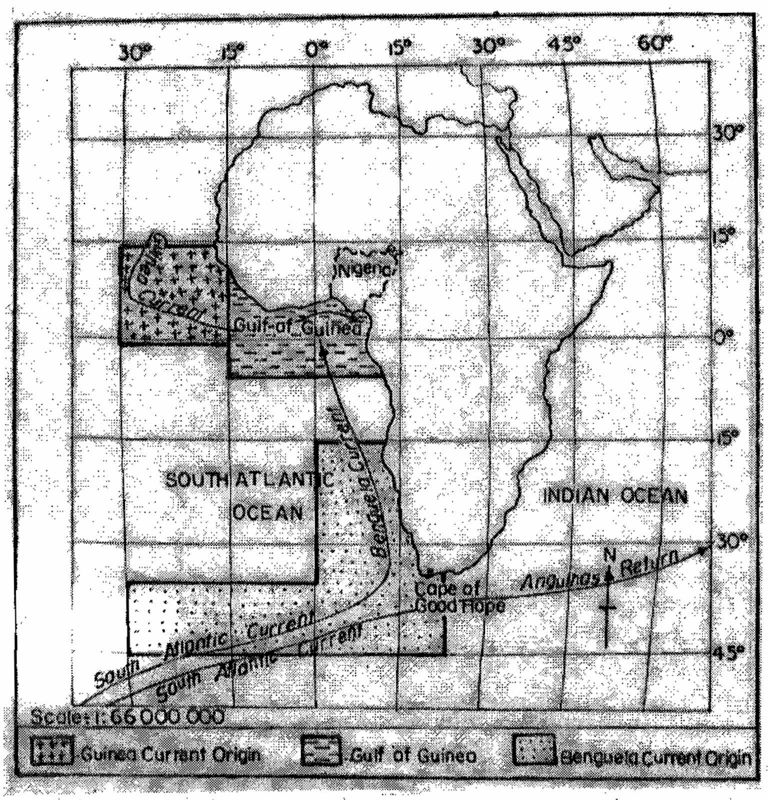

Figure 2: Map of Africa, showing Nigeria, Gulf of Guinea, and Guinea and Benguela currents origin.

primary rainfall maximum is usually in the mid-September, while the secondary rainfall maximum occurs in mid-July. The LDS is sandwiched between the two rainfall maxima. The mean annual rainfall varies from about 1200mm along the northern boundary of the area of study to over 2000mm along the coast.

The mean annual maximum temperature is about 35° C in Ilorin, in the north, and 30° C in Ikeja, in the south, while the mean minimum temperature is about 24° C in Ikeja and 21° C in Ilorin. The intra-annual temperature range, as in other tropical countries, is low, with an average value of 6° C. In fact in some southern stations, it may be as low as 3° C (Iloeje, 1981). The mean relative humidity decreases from the south to the north, with the maximum of 88 % occurring around Ikeja (Adejuwon and Jeje, 1976). The specific locations where data were collected to represent southwestern Nigeria are Ikeja, Benin City, Ibadan and Ilorin (see Figure 1). Each of the four locations chosen to represent southwestern Nigeria was selected as representative of zones comprising areas of similar climatic tendencies. For instance, Ikeja represents the coastal climatic zone, Benin City represents the forest zone, while Ibadan and Ilorin represent the Guinea Savanna zone.

3. Methodology

(a) Data Collection

The data required for this study are the daily rainfall for each of the selected rainfall stations and the mean monthly SSTs at specific locations in the Gulf of Guinea, and the source locations of the Benguela and Guinea currents (see Figures 1 and 2). The rainfall data were sourced from the archives of the Nigerian Meteorological Service, Oshodi, Lagos. The SST data were obtained from the International Research Institute for Climate Prediction. The spatial resolution of the SST data is 2° x 2° (Toure, 2000). The study therefore made use of the rainfall and SST data for the period 1961-1998. Of the 38-year period, 10 years (1961-1970) were set aside for calibrating generated models, leaving twenty-eight years (1971-1998) for developing the predictive models for the LDS rainfall in Southwestern Nigeria.

(b) Data Analysis

The mean durations of the LDS at the selected rainfall stations were recently determined by Adejuwon and Odekunle (2006), using 40-year (1961-2000) daily rainfall data. The mean duration of the LDS at Ikeja, Benin, Ibadan and Ilorin are July 15th-September 8th, July 20th-September 3rd, July 20th-August 29th, and July 25th-August 29th respectively. The rainfall that occurred in Ikeja between 15th July and 8th September, between 20th July and 3rd September in Benin, between 20th July and 29th August in Ibadan, and between 25th July and 29th August in Ilorin in any specified year, is taken as the respective annual LDS rainfalls.

Two methods were employed to determine the degree of the relationships between the LDS rainfall and the various SSTs. These are the linear regression and K-means cluster analyses. The regression algorithm facilitated the determination of the direction and the strength of the relationship and the models for predicting LDS rainfall in southwestern Nigeria. K-means cluster analysis is a procedure that facilitates the identification of relatively homogeneous groups of cases based on selected characteristics. The LDS rainfalls of each station and SST of each location were classified into five groups, using a thirty-year period (1969-1998). The rainfall classes are: Very Dry, Dry, Average, Wet and Very Wet (Table 1a), while the SST classes are: Very Cold, Cold, Average, Warm and Very Warm (Table 1b). These classes were adopted given the known positive relationship between SST and coastal rainfall (see Adedokun, 1978; Hayward and Oguntoyinbo, 1987). It is thus assumed that Very Cold, Cold, Average, Warm and Very Warm SST conditions will promote Very Dry, Dry, Average, Wet and Very Wet LDS rainfall conditions respectively. On this basis, an assessment table was designed to rate the relationship between LDS rainfall and the SSTs (Table 2). Excellent relationships are those situations in which SST and the expected LDS rainfall conditions are exact. The relationship is assessed as poor when the SST and the expected LDS rainfall conditions are substantially different.

4. Results

The results show that there exist strong positive relationships between SSTs of the Gulf of Guinea, and the source locations of the Guinea and Benguela currents, and the LDS rainfall amount and rainy days (see Table 3). It is however, the spatial average SST of location 4° W-4° E and 3° N-5° N in August that has the most significant influence (80 % of the correlation values obtained are equal to or greater than 0.50 (some of them are above 0.70; and significant at 99 % level of confidence. The remaining 20 % are significant at 95 %). Of the source locations of the Guinea current, it is the SST spatial average of location 20° W-25° W; 5° N in June that has the most significant relationship (50 % of the correlation values obtained are equal to or greater than 0.50 and significant at 99 % level of confidence. The remaining 50 % are significant at 95 %). Of the source locations of the Benguela current, it is the SST average of location 15° E and 35° S in November-December of the previous year that has the most significant relationship (90 % of the correlation values obtained are equal to or greater than 0.50 and

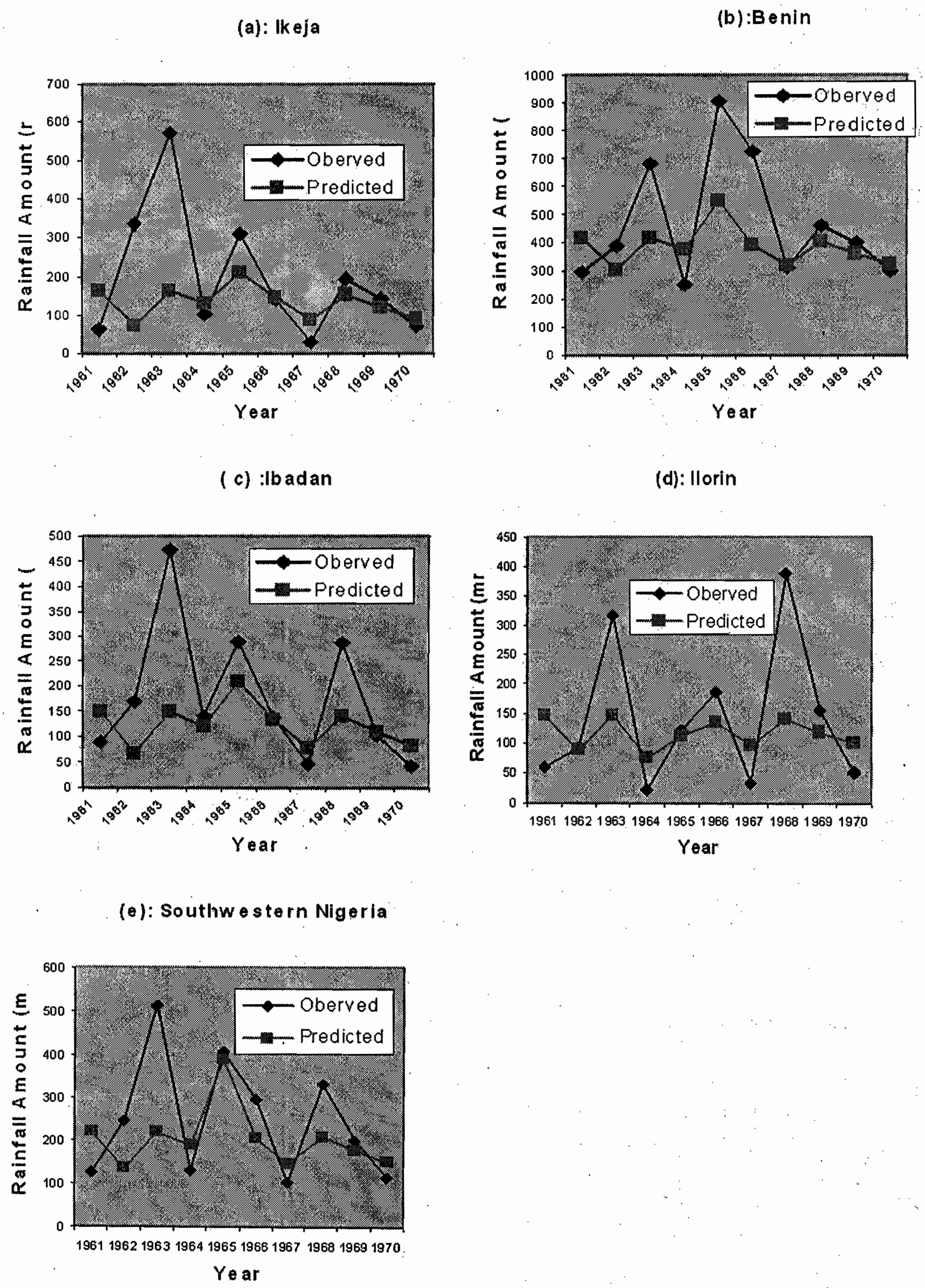

Figure 3: Observed and Predicted LDS Rainfall Amount Between 1961 and 1970 (Using the SST of Benguela current Origin)

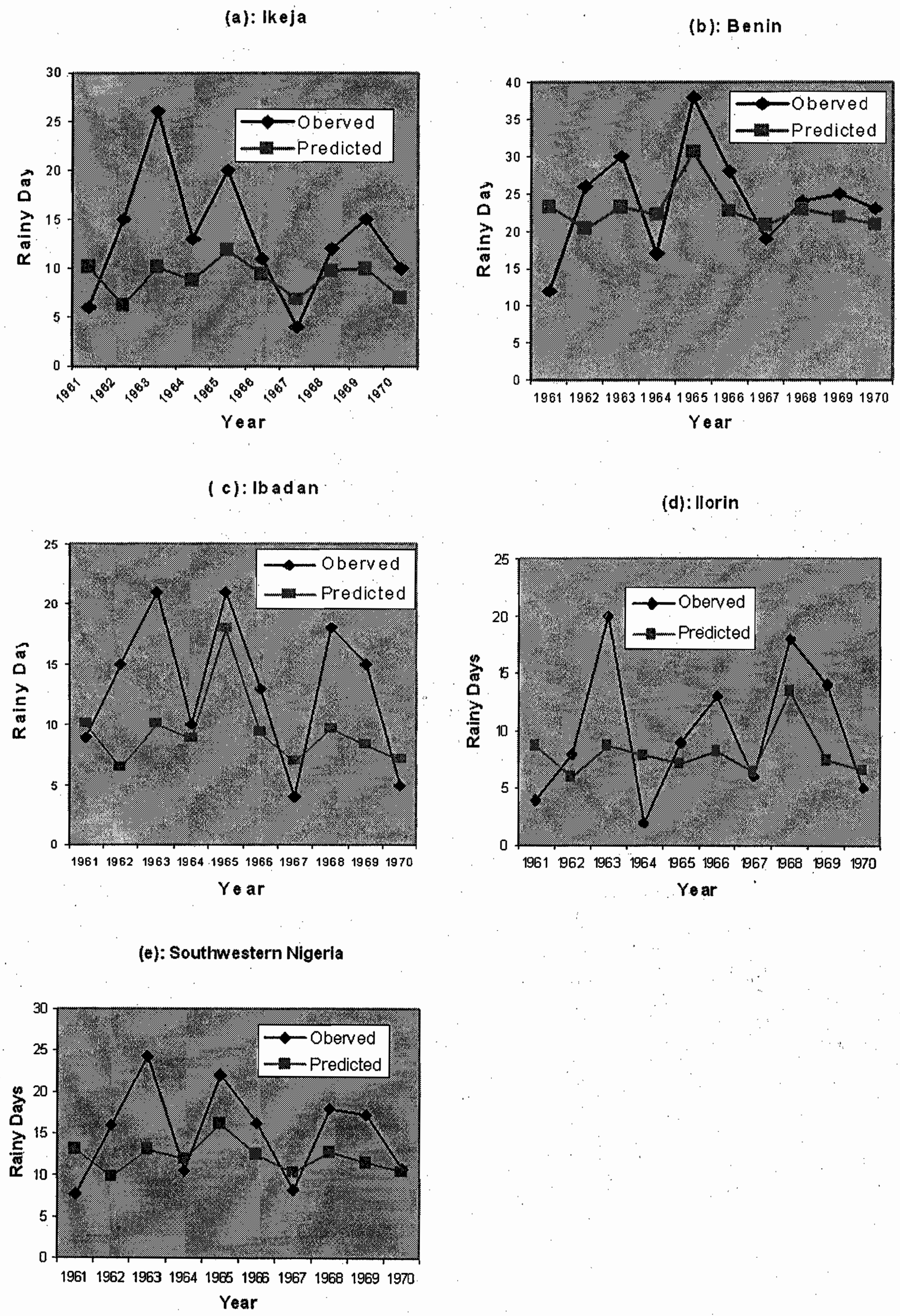

Figure 4: Observed and Predicted LDS Rainy Days Between 1961 and 1970 (Using the SST of Benguela Current Origin)

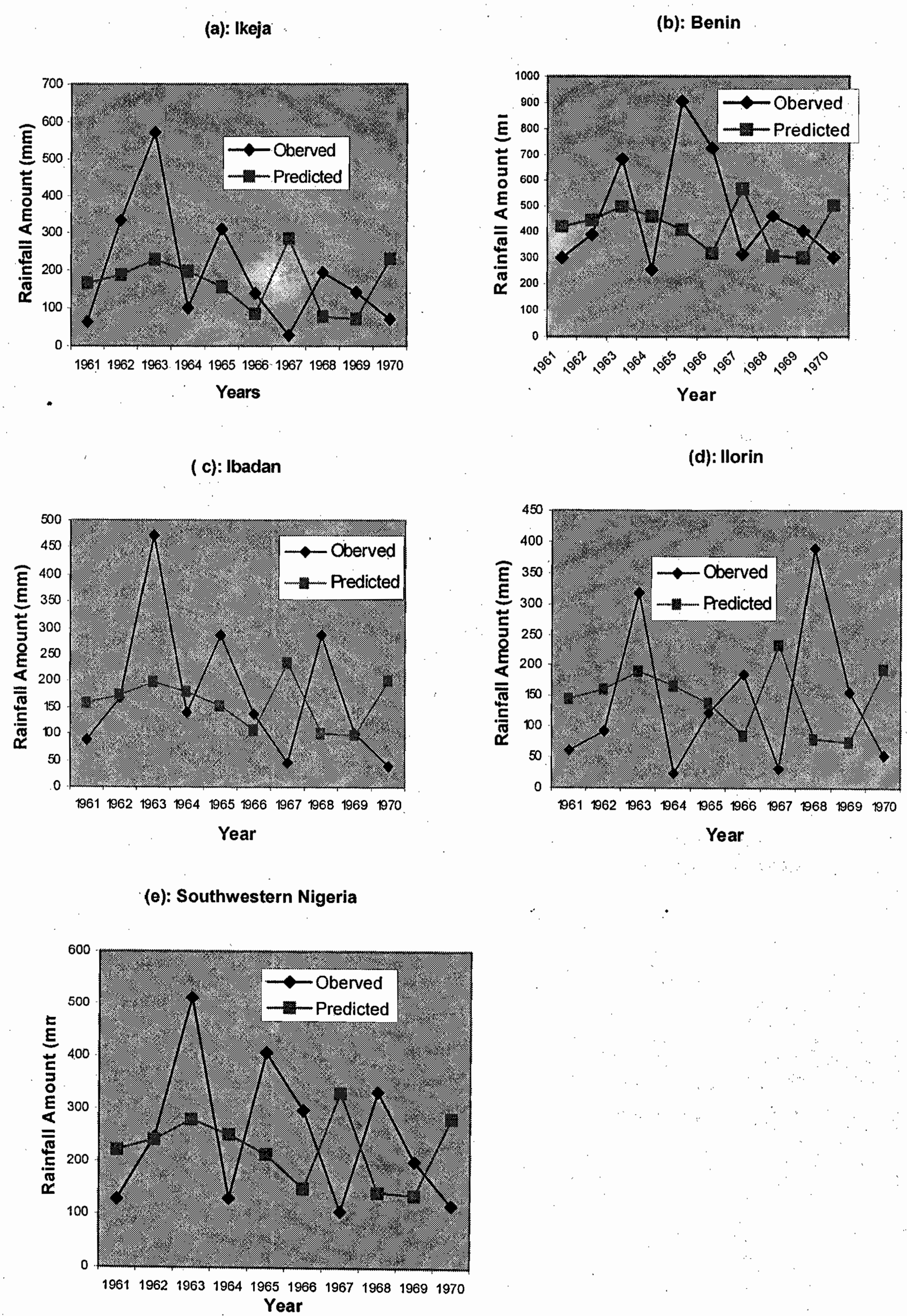

Figure 5: Observed and Predicted LDS Rainfall Amount Between 1961 and 1970 (Using the SST of Guinea Current Origin)

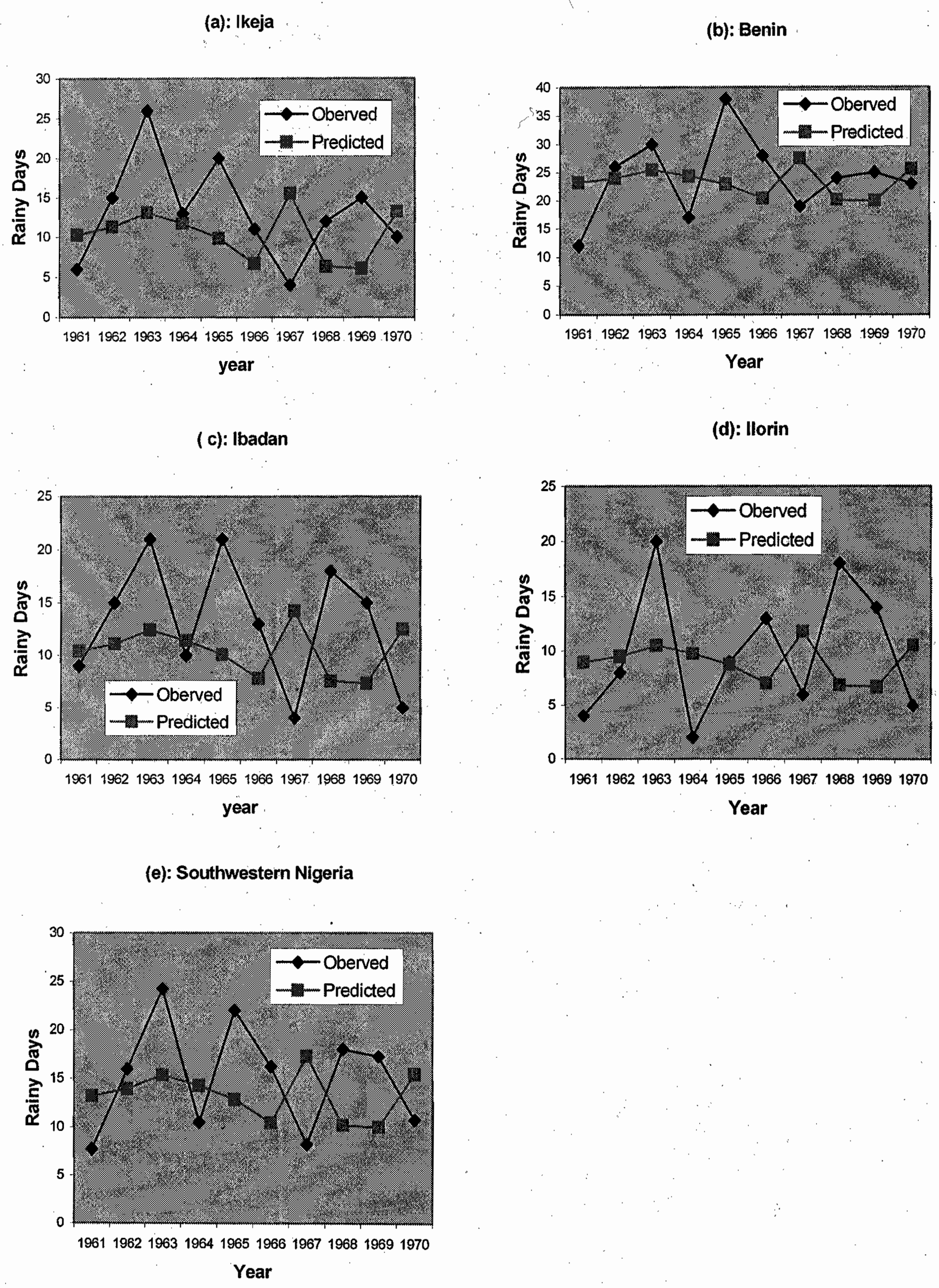

Figure 6: Observed and Predicted LDS Rainy Days Between 1961 and 1970 (Using the SST of Guinea Current Origin)

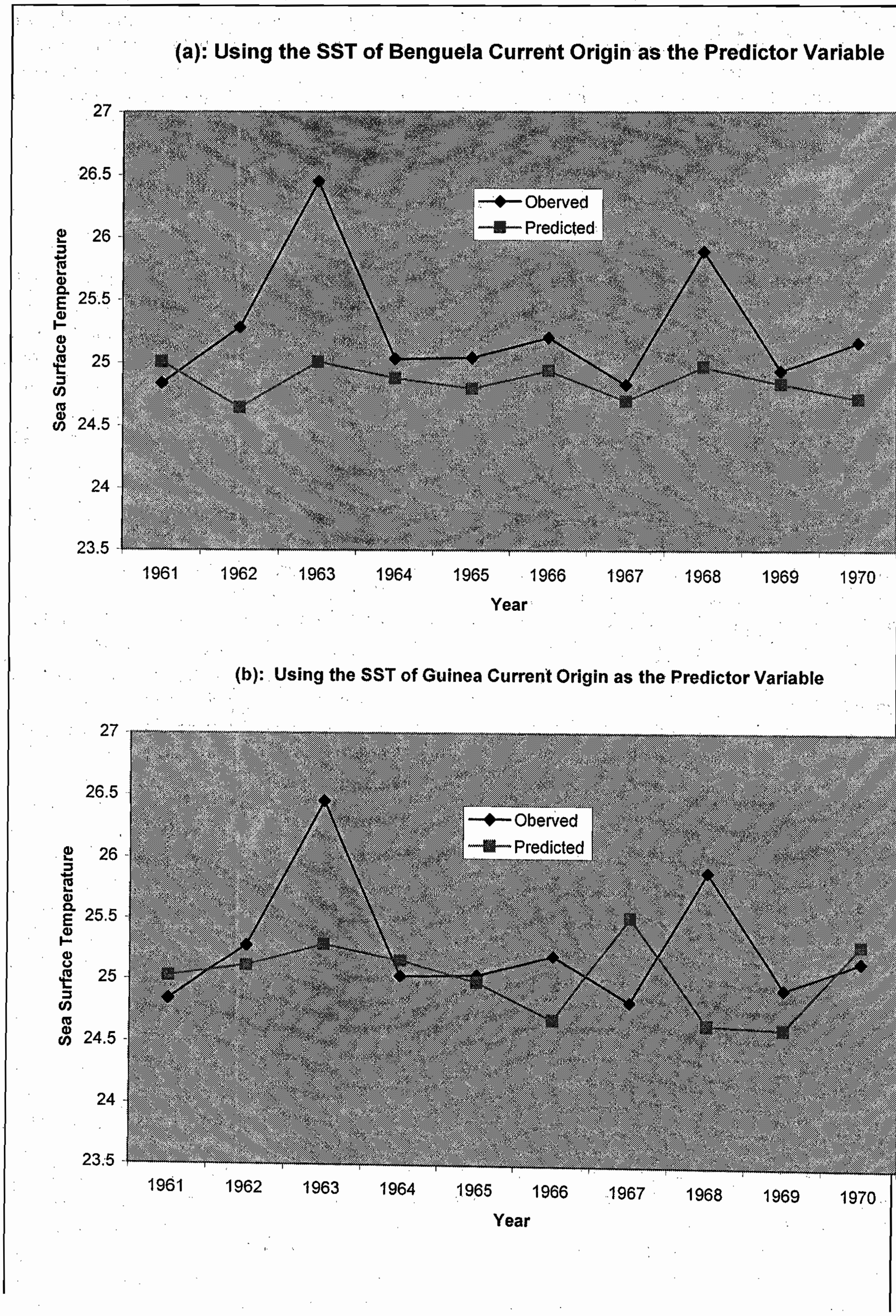

Figure 7: Observed and Predicted SST of the Gulf of Guinea Between 1961 and 1970

significant at 99 % level of confidence. The remaining 10 % are significant at 95 % level of confidence). The correlation values obtained between SSTs of the Gulf of Guinea and those of the source locations of the Guinea and Benguela currents are 0.60 and 0.70, respectively (significant at ±= 0.01). The results thus show that the lower the SSTs of the Gulf of Guinea in August, and those of the source locations of the Guinea in June of the current year and Benguela current in November-December of the previous year, respectively, the lower the rainfall amount and rainy days of the LDS in southwestern Nigeria.

Figures 3 and 4 show the observed and predicted LDS rainfall amount and rainy days respectively (between 1961 and 1970), using the SST of the source locations of the Benguela current. The results indicate a close association between the observed and predicted LDS rainfall amount and rainy days, though the shape and direction of the two curves (observed and predicted) do not fully approximate each other. This may indicate that the SST of the source locations of the Benguela current influences the characteristics of the LDS rainfall in southwestern Nigeria. Figures 5 and 6 show the observed and predicted rainfall amount and rainy days of the LDS, respectively, using the SST of the source location of the Guinea current. The results indicate a relatively weak association between the observed and predicted rainfall amount and rainy days of the LDS. The shape and direction of the twocurves (observed and predicted) are largely dissimilar. Figures 7a and b show the observed and predicted SST of the Gulf of Guinea (between 1961 and 1970). The SSTs were predicted from the values of those of the source locations of the Benguela and Guinea currents. There is much closer association between the observed and predicted SST, when data of the Benguela Currents are adopted. Thus, it is appears that the SST of the source locations of the Benguela current significantly influences both the SST of the Gulf of Guinea and the LDS rainfall in southwestern Nigeria.

Using the weather and SST classification schemes in Tables 1a and b, another table, Table 4, was created. The new table shows the nature of the LDS rainfall amount and rainy days and the SST of the source locations of the Benguela and Guinea currents for the period between 1969 and 1998. Tables 5a and b were created using the assessment scheme of the relationship between the rainfall and the SST in Table 2. The tables show the results of the assessment of the relationship between the LDS rainfalls and the SSTs of the Benguela and Guinea currents. With respect to the Benguela SST, the results show that in all cases, 70 % or more of the relationship are excellent/good (with some of them exceeding 90 %), while in the case of the Guinea current SST, the results show that in most cases, 50 % or more of the relationship are excellent/good (with some of them exceeding 70 %). These results corroborate those obtained using the regression algorithm in two ways: (a) It also demonstrates that the relationship is significantly highly correlated and (b) that the SST of the source location of the Benguela current exerts a strong influence on the LDS rainfall in southwestern Nigeria.

5. Discussion

The results obtained show that the LDS rainfall amount and rainy days have significant coherent positive relationship with the SSTs of the Gulf of Guinea (in August) and Guinea (In June) and Benguela (in November-December of the previous year) currents origin. The results also show that Very Cold, Cold, Average, Warm and Very Warm SST conditions over the Gulf of Guinea and source locations of the Guinea and Benguela currents largely promote Very Dry, Dry, Average, Wet and Very Wet LDS rainfall conditions respectively.

The Gulf of Guinea part of the Atlantic Ocean has long been identified as an important upwelling area (see for example, Adedokun, 1978; Adamec and O'Brien, 1978). As observed by Adamec and O'Brien (1978), the upwelling in the area is evident in every summer from July through to early September. Upwelling refers to cold, nutrient rich water rising to the surface of the ocean from depths of 50 meters or more. As indicated in the results, low SST in the Gulf of Guinea is inhibitory/antagonistic to rainfall formation. In other words, the LDS may be more or less severe, or perhaps, turn into wet spell (see Adejuwon and Odekunle, 2006) depending on how high or low the SST of the Gulf of Guinea is. However, as suggested by Adedokun (1978), the effect of the SST on the rainfall during the period of the LDS may not be through moisture availability but rather, on the stability of the atmosphere. As observed by Adedokun(1978), there is sufficient precipitable water in the atmosphere during the period. Low SST may generate thick temperature inversion layer that may be inhibitory to convection and consequently antagonistic to rainfall. Most explanations that have been provided to account for the upwelling phenomenon in the Gulf of Guinea are rather unsatisfactory and somewhat confusing. However, studies have established that neither the local winds nor the ocean circulation provide an adequate forcing mechanism (Houghton, 1976). The results obtained in this study further corroborate Houghton's view by identifying remote ocean circulations as the primary forcing mechanism of the upwelling in the Gulf of Guinea. The two oceanic circulations are the SSTs of Guinea (In June) and Benguela (in November-December of the previous year) currents origin.

The Benguela Current has been observed as the cold eastern boundary current of the South Atlantic subtropical gyre, which begins as a northward flow off the Cape of Good Hope, where it skirts the western African coast equatorward until around 24° S-30° S, where most of it separates from the coast towards the northwest (Peterson and Stramma 1991, Wedepohl et al., 2000). Near the surface, South Atlantic Current (SAC) flows eastward across the Atlantic at approximately 40° S, but beneath, it feeds into the Cape basin from the southwest after crossing the Mid-Atlantic ridge. As the SAC approaches the prime meridian it bifurcates (Garzoli and Gordon, 1996) into eastward and northward branches. The former sustains passage through the south of the Cape of Good Hope at approximately 40°S, into the Indian Ocean. The latter turns northwards, feeding into the Agulhas Current system. It is this latter part of the SAC that forms the Benguela current, which becomes the key conduit by which the water from the South Atlantic and the Indian Ocean flows across the equator. In other words, Benguela current constitutes the main conduit by which cool waters are advected into the tropics from cold southern latitudes (Peterson et al. 1996). Observations of the Benguela current at a depth of about 750m have indicated latitude 35°S as its maximum southern extension (Garzoli et al., 1996; Richardson and Garzoli, 2002). The results obtained in this study indicated the SST of longitude 14° E position along the maximum southern extension of the Benguela current as a significant driver of interannual variability of the SST of the Gulf of Guinea and thus the LDS rainfall in southwestern Nigeria. The

Table 1a: Classification of the LDS Rainfall Into Five Probable Weather Categories (1969-1998)

Rainfall Stations	LDS Rainfall Parameters	Category Limits (Rainfall in mm)				
		Very Dry	Dry	Average	Wet	Very Wet
Ikeja	Amount	≤ 88	> 88-174	> 174-292	> 292-512	> 512
Benin	Amount	≤ 166	> 166-342	> 342-506	> 506-707	> 707
Ibadan	Amount	≤ 101	> 101-197	> 197-327	> 327-428	> 428
Ilorin	Amount	≤ 86	> 86-155	> 155-234	> 234-336	> 336
Southwestern Nigeria	Amount	≤ 130	> 130-226	> 226-323	> 323-466	> 466
Ikeja	Rainy Days	≤ 4	> 4-8	> 8-13	> 13-17	> 17
Benin	Rainy Days	≤ 16	> 16-20	> 20-27	> 27-34	> 34
Ibadan	Rainy Days	≤ 4	> 4-7	> 7-11	> 11-17	> 17
Ilorin	Rainy Days	≤ 6	> 6-9	> 9-12	> 12-14	> 14
Southwestern Nigeria	Rainy Days	≤ 9	> 9-14	> 14-17	> 17-22	> 22

Table 1b: Classification of the SST Into Five Probable Temperature Categories (1969-1998 for the Guinea Current; 1968-1997 for the Benguela Current)

SST Stations	SST Parameters	Quint Category Limits (SST in °C)				
		Very Cold	Cold	Average	Warm	Very Warm
Bengula Current Origin	November-December SST of Location 15°E; 35°S in the previous Year	≤ 16.95	>16.95-17.39	>17.39-17.78	>17.78-18.16	>18.16
Guinea Current Origin	June SST of Location 20°W-25°W; 5°N in the Current Year	≤ 27.39	> 27.39-27.96	> 27.96-28.19	> 28.19-28.55	>28.55

Table 2: Assessment Scheme of the Relationship Between the LDS Rainfall and SST

RAINFALL / SST	VERY WET	WET	AVERAGE	DRY	VERY DRY
VERY WARM	Excellent	Good	Poor	Poor	Poor
WARM	Good	Excellent	Good	Poor	Poor
AVERAGE	Poor	Good	Excellent	Good	Poor
COLD	Poor	Poor	Good	Excellent	Good
VERY COLD	Poor	Poor	Poor	Good	Excellent

Table 3: Regression Outputs of the Relationship Between SSTs of the Gulf of Guinea, Guinea and Benguela Currents Origin and LDS Rainfalls in Southwestern Nigeria (1971-1998)

Dependent Variable	Explanatory Variable	Correlation Value	Constant	Unstandardized B Coefficients
Ikeja LDS Rainfall Amount	GG SST	0.75**	-5046.015	208.510
BeninLDS Rainfall Amount	GG SST	0.50**	-4833.402	210.414
Ibadan LDS Rainfall Amount	GG SST	0.53**	-3519.377	147.079
Ilorin LDS Rainfall Amount	GG SST	0.42*	-1814.571	78.796
Average LDS Rainfall Amount in Southwestern Nigeria	GG SST	0.68**	-3803.341	161.200
Ikeja LDS Rainy Days	GG SST	0.72**	-209.269	8.787
BeninLDS Rainy Days	GG SST	0.44*	-121.271	5.792
Ibadan LDS Rainy Days	GG SST	0.64**	-175.129	7.419
Ilorin LDS Rainy Days	GG SST	0.55**	-88.577	3.910
Average LDS Rainy Days in Southwestern Nigeria	GG SST	0.67**	-148.562	6.477
Ikeja LDS Rainfall Amount	GCO SST	0.51**	-5349.863	196.566
BeninLDS Rainfall Amount	GCO SST	0.43*	-6554.095	248.497
Ibadan LDS Rainfall Amount	GCO SST	0.37*	-344.523	128.259
Ilorin LDS Rainfall Amount	GCO SST	0.57**	-3980.713	147.012
Average LDS Rainfall Amount in Southwestern Nigeria	GCO SST	0.55**	-4831.299	180.083
Ikeja LDS Rainy Days	GCO SST	0.52**	-236.353	8.790
BeninLDS Rainy Days	GCO SST	0.39*	-174.427	7.045
Ibadan LDS Rainy Days	GCO SST	0.39*	-167.610	6.344
Ilorin LDS Rainy Days	GCO SST	0.48*	-123.856	4.734
Average LDS Rainy Days in Southwestern Nigeria	GCO SST	0.50**	-175.562	6.728
GG SST	GCO SST	0.60**	1.763	0.829
Ikeja LDS Rainfall Amount	BCO SST	0.61**	-3158.590	184.928
BeninLDS Rainfall Amount	BCO SST	0.51**	-3744.623	231.617
Ibadan LDS Rainfall Amount	BCO SST	0.57**	-2917.311	170.669
Ilorin LDS Rainfall Amount	BCO SST	0.58**	-1980.288	118.365
Average LDS Rainfall Amount in Southwestern Nigeria	BCO SST	0.68**	-2950.203	176.395
Ikeja LDS Rainy Days	BCO SST	0.62**	-136.703	8.178
BeninLDS Rainy Days	BCO SST	0.42*	-83.072	5.921
Ibadan LDS Rainy Days	BCO SST	0.59**	-123.874	7.457
Ilorin LDS Rainy Days	BCO SST	0.71**	-89.900	5.492
Average LDS Rainy Days in Southwestern Nigeria	BCO SST	0.64**	-108.387	6.762
GG SST	BCO SST	0.70**	11.467	0.754

* Correlation is significant at the 0.05 level (2-tailed);
** Correlation is significant at the 0.01 level (2-tailed)
GG SST: Gulf of Guinea Sea Surface Temperature in August
GCO SST: Seas Surface Temperature of the Gulf of Guinea Current Origin in June
BCO SST: Seas Surface Temperature of the Benguela Current Origin in November-December of the Previous Year

Table 4: The Nature of the LDS Rainfall in Southwestern Nigeria and SSTs of the Benguela and Guinea Currents Origin

Years for the Benguela SST	Years for other Variables	Rainfall Stations										SST Stations	
		Ikeja		Benin		Ibadan		Ilorin		Southwestern Nigeria		Benguela Current	Guinea Current
		AM	RD	AM	RD	AM	RD	AM	RD	AM	RD		
1968	1969	D	W	AV	AV	VD	W	D	W	D	AV	C	WA
1969	1970	VD	AV	D	AV	VD	D	VD	VD	VD	D	VC	AV
1970	1971	AV	AV	AV	AV	D	AV	D	AV	D	D	C	C
1971	1972	VD	D	D	VD	VD	D	D	D	VD	VD	C	AV
1972	1973	W	AV	W	AV	AV	W	W	W	W	AV	AV	VWA
1973	1974	AV	AV	AV	AV	VD	AV	D	AV	AV	D	C	C
1974	1975	D	D	W	D	D	AV	VD	VD	D	VD	C	C
1975	1976	D	VD	D	D	VD	D	D	D	VD	VD	C	C
1976	1977	VD	VD	D	D	VD	AV	VD	VD	VD	VD	C	C
1977	1978	AV	D	D	D	D	AV	D	D	D	D	AV	C
1978	1979	W	VW	W	VW	W	VW	AV	W	W	VW	AV	WA
1979	1980	W	VW	VW	W	VW	VW	W	VW	VW	VW	AV	WA
1980	1981	D	AV	D	AV	VD	VD	D	AV	D	D	AV	WA
1981	1982	VD	VD	VD	VD	VD	D	AV	D	VD	VD	VC	AV
1982	1983	D	D	VD	D	VD	VD	AV	D	VD	VD	C	AV
1983	1984	AV	W	D	D	D	AV	W	AV	AV	D	AV	AV
1984	1985	D	W	AV	AV	AV	VW	D	D	AV	AV	AV	C
1985	1986	VD	VD	D	VD	VD	VD	D	AV	VD	VD	AV	AV
1986	1987	VW	VW	VW	W	W	VW	W	VW	VW	VW	VWA	VWA
1987	1988	AV	AV	D	AV	VD	AV	VD	VD	D	D	C	VWA
1988	1989	AV	W	W	AV	D	W	D	AV	AV	AV	AV	VWA
1989	1990	VD	AV	VW	W	D	AV	D	AV	AV	AV	AV	AV
1990	1991	AV	W	W	VW	AV	VW	AV	AV	AV	W	C	AV
1991	1992	D	AV	D	AV	D	W	VD	VD	D	D	C	C
1992	1993	VD	D	W	W	D	AV	AV	VW	AV	AV	AV	WA
1993	1994	D	AV	W	W	VD	D	VD	VD	AV	D	C	AV
1994	1995	AV	VW	VW	W	AV	W	AV	W	W	W	WA	VWA
1995	1996	AV	W	W	AV	AV	W	D	AV	AV	AV	C	VWA
1996	1997	D	AV	D	AV	VD	D	VD	D	D	D	VC	AV
1997	1998	VD	D	D	D	VD	D	VW	D	D	D	AV	VWA

VD: Very dry; D: Dry; AV: Average; W: Wet; VW: Very wet; VC: Very cold; C: Cold; WA: Warm; VWA: Very warm

location (14°E; 35°S) appears to represent the turning point of the SAC to form the northward branch and therefore the starting point of the Benguela current. The SST in this region established the relationship as early as November-December of the previous year with the interannual variability of the SST of the Gulf of Guinea and the LDS rainfall in southwestern Nigeria of the current year (August and mid July-early September, respectively), because the water of the Benguela current that will be advected into areas as far as the Gulf of Guinea requires a relatively long period of time to travel. Thus the time lag (6-7 months) between the predictor variable (Benguela current) and the dependent variables (the SST of the Gulf of Guinea and the LDS rainfall in southwestern Nigeria) appears to be the time required to arrive the West African coast. The lower the SST of the Benguela current origin the greater is the ability of the Benguela current to propel cold water into the Gulf of Guinea. The situation is such that when the SST of the Benguela current origin is relatively warm it will affect the Gulf of Guinea not only by bringing relatively warm water but also by weakening the propelling force of the current so that its tongue is a bit distant from West African coast. The Benguela current has long been noted as one of the principal currents directly affecting the hydrography of the Gulf of Guinea (see for example, Longhurst, 1962; Adedokun, 1978). Thus variability in the SST of the Benguela current origin significantly affects SST of the Gulf of Guinea and the LDS rainfall in southwestern Nigeria. Significant interannual variability in the SST of the Benguela current origin is overwhelmingly generated by variations in the sources of its waters. The water sources include Indian and South Atlantic subtropical thermocline water; saline, low-oxygen tropical Atlantic water; and cooler, fresher subantarctic water (Garzoli et al., 1996).

Guinea current is another major current of a remote influence directly affecting the hydrography of the Gulf of Guinea (Houghton, 1962). As observed by Houghton (1962), the current is warm and flows eastwards throughout the year over its entire length but it undergoes periodical and unusual short-term reversals, which are yet to be satisfactorily explained. The reversal of the current occurs mostly in two areas: (a) from Senegal to Liberia and (b) from Togo to the Niger Delta. As indicated by the results obtained in this study, the SST of longitudes 20° W-25° W along Latitudes 5° N in June (in the vicinity of the Guinea current origin) has significant relationships with interannual variability of the SST of the Gulf of Guinea and thus the LDS rainfall in southwestern Nigeria (August and mid July- early September, respectively) because, the water of the Guinea current that will be advected into areas as far as the Gulf of Guinea requires some period of time to travel. Thus the time lag (1-2 months) between the predictor variable (Guinea current) and the dependent variables (the SST of the Gulf of Guinea and the LDS rainfall in southwestern Nigeria) appears to be the time required to arrive the West African coast. Also, the lower the SST of the Guinea current origin, the lower the SST of the Gulf of Guinea and thus the LDS rainfall. The time lag between the predictor and the dependent variables in the case of the Guinea current is considerably shorter than that of Benguela current because of the greater distance required by the latter to cover.

However, it is important to note that both the statistical and real time tests of 'goodness of fit' performed in this study clearly indicate the SST of the Bengula current origin as having preponderant influence on the hydrography of the Gulf of Guinea and thus the LDS rainfall in southwestern Nigeria. Given the relatively weak correlation values obtained in the case of the Guinea current the cluster analysis indicates relationship that is modest and a rather poor relationship, when the observations were compared with real time forecast.

6. Conclusions

The study recognized the variability and the severity of the LDS in southwestern Nigeria as important climatic phenomenon that has attendant mixed implications for agricultural practices in the West African sub-region. Given the above, a fore knowledge of the LDS characteristics is necessary so as to enable farmers to plan with greater confidence to forestall its negative consequences and exploit its beneficial opportunities. Prediction models were therefore generated for the LDS rainfall. The model was based on the relationship between the LDS rainfall and the SSTs of the Gulf of Guinea, Guinea and Benguela currents origin.

The results obtained show that the LDS rainfall amount and rainy days have significant coherent positive relationship with the SSTs of the Gulf of Guinea (in August) and Guinea (in June) and Benguela (in November-December of the previous year) currents origin. The results also show that Very Cold, Cold, Average, Warm and Very Warm SST conditions over the Gulf of Guinea and the source locations of the Guinea and Benguela currents largely promote Very Dry, Dry, Average, Wet and Very Wet LDS rainfall conditions respectively. The time lag between the predictor (SSTs of the source locations of the Guinea and Benguela currents) and dependent variables (the LDS rainfall amount and rainy days), which are 1-2 and 6-7 months for the SSTs of the source locations of the Guinea and Benguela currents respectively, is a function of the distance between the sources and destination of the predictor variables. Generally, the results from the statistical methods are encouraging as all the correlation values obtained are statistically significant and mostly high. However, the actual 'goodness of fit' assessment (by comparing the observation with the forecast) indicated the model generated, using the SST of the source locations of the Guinea current, as rather poor. The actual 'goodness of fit' assessment, using the SST of the source locations of the Benguela current, is very encouraging. However, as suggested by Ward (1992), if the SST changes significantly after the forecast has been made, statistical methods are likely to fail. Ward therefore concluded that statistical forecast should be combined with coupled Atmosphere-Ocean General Circulation Models for much more accurate forecasts. Given that both the statistical and real time tests of 'goodness of fit' clearly indicate the SST of the source locations of the Benguela current as having the most coherent relationship, the study concludes that, the Benguela current is having prepondrant influence on the dynanics of the Gulf of Guinea and thus the LDS rainfall in southwestern Nigeria.

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Table 5a: The Results of the Assessment of the Relationship Between the LDS Rainfall and Benguela Current SST Between 1969 and 1998

Rainfall Stations	LDS Rainfall Parameters	Percentages of the Degree of the Relationship		
		Excellent	Good	Poor
Ikeja	Amount	40	46.7	13.3
Benin	Amount	30	46.7	23.3
Ibadan	Amount	26.7	60	13.3
Ilorin	Amount	33.3	60	6.7
Southwestern Nigeria	Amount	46.2	46.2	6.6
Ikeja	Rainy Days	26.6	46.7	26.7
Benin	Rainy Days	33.3	46.7	20.0
Ibadan	Rainy Days	30	40	30
Ilorin	Rainy Days	36.7	53.3	10
Southwestern Nigeria	Rainy Days	43.3	43.4	13.3

Table 5b: The Results of the Assessment of the Relationship Between the LDS Rainfall and Guinea Current SST Between 1969 and 1998

Rainfall Stations	LDS Rainfall Parameters	Percentages of the Degree of the Relationship		
		Excellent	Good	Poor
Ikeja	Amount	33.3	26.7	40.0
Benin	Amount	26.7	40.0	33.3
Ibadan	Amount	20.0	26.7	53.3
Ilorin	Amount	33.3	36.7	30.0
Southwestern Nigeria	Amount	33.3	30.0	36.7
Ikeja	Rainy Days	23.3	53.3	23.4
Benin	Rainy Days	26.7	43.3	30.0
Ibadan	Rainy Days	13.3	56.7	30.0
Ilorin	Rainy Days	33.3	46.7	20.0
Southwestern Nigeria	Rainy Days	20.0	46.7	33.3

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