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RESEARCH PAPER

SEASONAL PREDICTION OF PRECIPITATION OVER NIGERIA

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ABSTRACT
The availability of quantitative means of probing anticipated rainfall is essential for the purpose of planning and policy formulation everywhere in the world. However reliable prediction of rainfall remains a challenge over West Africa and Nigeria in particular. This paper predicts seasonal rainfall in Nigeria with the hope of increasing the reliability of predicted seasonal rainfall. Seasonal rainfall data (June-September) from 21 Nigerian stations and monthly Extended Reconstructed Sea Surface Temperature (ERSST) of the tropical Oceans spanning 1960-2012 constituted the input data for the formulation of prediction equations using regression analysis. Cross-validation was applied with training period of 1960-1985, verification period of 1986-2012 and vice versa. The correlations between the predicted and the observed seasonal rainfall of the training and verification periods of 1960-1985 were all significant at 5 % level except for one station. While for the training and verification periods of 1986-2012, correlations are not generally significant although some were found to be above the significant level of 5%. For the reconstructed seasonal precipitation, correlations of ten stations were found to be significant at 5 %, but at 10 % level, their number increased to 13. The t-test analysis revealed that there is no significant difference between the means of predicted and observed seasonal rainfall amount for all stations except for only three stations (Osogbo, Calabar and Enugu). This suggests some degree of skill which is also an indication that Sea Surface Temperature (SST) is a good predictor of June, July, August and September (JJAS) seasonal rainfall in Nigeria.

Keywords: *Rainfall, Prediction, Tropical Ocean, Cross-validation, Sea Surface Temperature*

INTRODUCTION

Rainfall has a profound impact on agriculture, air and road transport, hydroelectric power generation, construction, water resources, among others. Normal rainfall is beneficial for agriculture and other economic activities. However, when it is excessive, it may result in flooding and the associated negative impacts. Also the effects of below normal amount of rainfall are also not desirable. The past droughts over West Africa affected the economy, agriculture, live stock and human population (Shanahan *et al.*, 2009; Batterbury, 2001). The timely information in seasonal rainfall prediction is therefore vital for planning and decision making in these key sectors of the economy.

Apart from its relevance to life, tropical rainfall is also important for global climate and weather. Over two thirds of global precipitation falls in the tropics (Simpson *et al*., 1988). A notable feature of tropical rainfall is its inter-annual variability, which on occasions can lead to prolonged dry (drought) and wet (flood) periods.

Many studies have established a correlation between SST and rainfall in Africa (e.g. Folland *et al*., 1991; Berte and Ward, 1998; Colman et al., 2000). Over Nigeria in particular, correlation between the global SST and rainfall has been established e.g. Adedoyin (1989) and Omogbai (2010). Omogbai (2010) did not only correlate SST with rainfall over Nigeria but also predicted rainfall with SST. Thus, SST is a good predictor of rainfall in Nigeria.

Various research works on rainfall climatology in Nigeria focused attention on rainfall trends, variability, periodicities, onset and retreat e.g. Odekunle et al. (2005), Walter (1967), Olaniran (1983) and Adejuwon *et al*. (1990). Adedoyin (1989) established a correlation between the global SST anomalies and rainfall of northern Nigeria but did not make any rainfall prediction. Prediction of rainfall in Nigeria with SST has been embarked upon by Omogbai (2010) using Principal Component Analysis (PCA). The PCA according to Maraun *et al*. (2010), does not account for any information about the predictand, and the predictor/predictand correlation might thus not be optimal. According to Omogbai (2010) and Agboola *et al*. (2013) little attention has been paid to prediction of rainfall in Nigeria, hence the importance of the current study.

Study Area

Nigeria is located within Latitudes 4 –14° N and Longitude 3 –15° E and it covers a total area of 923,768 km^2. It shares border with Republic of Niger, Cameroon, Republic of Benin and the Gulf of Guinea in the north, east, west and south respectively.

Due to its location just north of the equator, Nigeria enjoys a tropical climate characterized by the hot and wet conditions associated with the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator. The climate of Nigeria is dominated by the influence of two major wind currents, namely: the southwesterly maritime tropical (mT) air mass which is prevalent during the wet season because it is moisture laden as a result of its traverse through the Atlantic ocean where it acquires moisture and the north easterly continental tropical (cT) air mass that prevails during the dry season because of its dryness since there is no ocean along its continental path (Adeniyi, 2014; Odekunle, 2004). Two main seasons; that is wet (April-October) and dry (November- March) result from the two major wind currents.

Rainfall in Nigeria falls within a distinct period (Adeniyi *et al*., 2009). These periods vary from the northern part to the southern part of the country because of their relative distance from the Atlantic Ocean. Rainfall starts earlier and ceases late in the southern parts while it starts late and ceases earlier in the north. The onset month in the south varies between March and April while the cessation month is October. In the North, however, rainfall starts in May and ends in September (Adeniyi, 2014). There is rainfall occurrence all over the country during June to September. However, in August, there is a period of little dry season in the southern part of the country (Adejuwon and Odekunle, 2006). Overall two rainfall peaks occur in the south whereas only one rainfall peak occurs in the north. This makes the climate to be humid in the south with annual rainfall over 2000 mm and semi arid in the north with annual rainfall less than 600 mm (Ojo, 1977).

MATERIALS AND METHODS

The observed rainfall data, reanalysis SST data, regression models and their validation used in this study are described in this section.

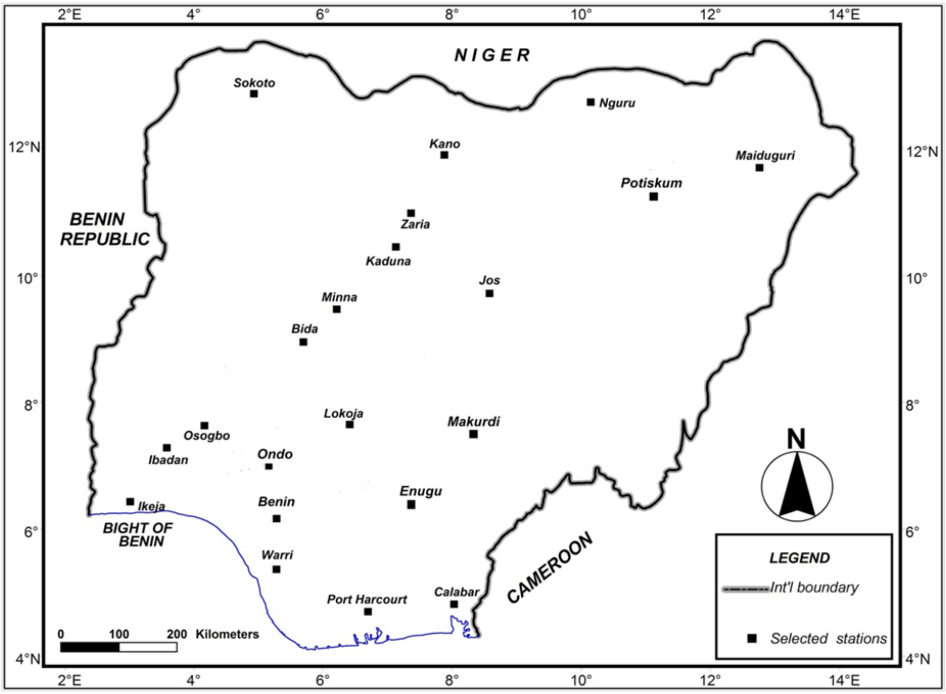

Fig. 1: **Synoptic rainfall stations in Nigeria**

Data

The monthly rainfall database consisting of 21 stations in Nigeria with 53 years of monthly rainfall records, covering the period of 1960 to 2012, were obtained from the archives of the Nigeria Meteorological Agency (NIMET), Oshodi Lagos, Nigeria. These stations were selected from various parts of the country covering its six geopolitical zones. These stations are indicated in the map of Nigeria as shown in Fig.1.

The monthly SST of the tropical Ocean for a period of 53years (1960 to 2012) were extracted from the "National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Centre (NCDC) Extended Reconstructed SST version 3b" which is available at: ftp://ftp.ncdc.noaa.gov/pub/data/cmb/ersst/erss/v3b/netcdf .

Methods

Predictor Selection

The predictors were selected based on the grids of SST that had the highest correlation coefficients (r ≥ 0.3) with the observed seasonal precipitation in a particular station. Table 1 shows the ocean and the months selected as predictors for seasonal precipitation in the different stations. Medium to high correlations were found to exist between tropical SST and the averaged JJAS Seasonal rainfall in Nigeria which led to the choice of the predictors in the different oceans (Table 1). This is in agreement with various research works e.g. Adedoyin (1989) and Omogbai (2010). The Indian Ocean has more impact on the Sahel while the Atlantic Ocean has more influence on the Guinea coast and Savanna regions of Nigeria than the other regions. However the effect of the tropical Pacific is felt all over the country.

Table 1: Stations and their corresponding oceans combined in formulating each model

Station	Ocean (Month)
Sokoto	Indian (Feb)
Zaria	Indian (March) Pacific (Feb)
Kano	Pacific (Jan) and Atlantic (Feb)
Kaduna	Pacific (April)
Makurdi	Atlantic (January)
Jos	Atlantic (March) and Indian (Jan)
Bida	Atlantic (May) and Pacific (March)
Nguru	Atlantic (Jan) and Pacific (Feb)
Potiskum	Indian (Feb) and Pacific (March and Feb)
Maiduguri	Pacific (February)
Minna	Pacific (March and April)
Lokoja	Atlantic (May)
Enugu	Atlantic (March) and Pacific (May)
Ikeja	Atlantic (Feb) and Pacific (Jan)
Ibadan	Atlantic (May)
Osogbo	Atlantic (May) and Pacific (Feb)
Ondo	Atlantic (April)
Benin	Atlantic (May) and Pacific (Jan)
Warri	Atlantic (Feb and May) and Indian (April)
Port-hacourt	Atlantic (Jan) and Pacific (Jan)
Calabar	Indian (March and May)

The selection of suitable predictors is crucial when developing a statistical model. The most basic requirement for a predictor is that it should be informative; that is, it should have a high predictive power. Informative predictors can be identified by statistical analyses, typically by correlating possible predictors with the predictands (Maraun *et al*., 2010).

Regression

One of the most widely used methods for statistical analysis of precipitation is linear regression (Maraun *et al*., 2010). The averaged JJAS seasonal rainfall and SST data were subjected to regression analysis based on a linear relation of the form:

$$R = \beta_0 + \beta_1 X_1(M) + \beta_2 X_2(M) + \qquad (1)$$

Where R represents the predictand (averaged JJAS rainfall of the station), X_i is the predictor (SST) which is a function of month (M) of the appropriate Ocean, while β_i is a constant representing the strength of the influence of X_i as explained by Maraun *et al*. (2010).

Some stations took the simple form of the model (i.e. only X_1 is involved) while others were in multiple forms (i.e. i = 1, 2, 3….). The tropical ocean was partitioned into Atlantic, Pacific and Indian oceans where SST was treated separately. Thus, a separate SST domain is determined for each predictor–predictand combination. In these models, data dimensionality was restricted to a region within the ocean where the magnitude of correlation patterns of SST (January to May) with seasonal rainfall is greatest within the tropics.

Validation

The available data were divided into training and verification periods of 1960-1985 and 1986 -2012 respectively and vice versa, after which cross-validation was applied for the whole length of the two verification periods (1960-2012). The predicted seasonal precipitations for the two periods were concatenated to reconstruct the seasonal precipitation. The reconstructed data were then compared with the observed data in order to test for significant discrepancies between the predicted and the observed values.

Let x and y represent the reconstructed and the observed seasonal rainfall respectively and let n be the number of years (53).

The ratio of the standard deviation of the observed to the reconstructed seasonal rainfall is given by Standard Deviation Ratio,

$$SDR = \sigma_y / \sigma_x \tag{2}$$

where σ_y and σ_x are standard deviation of the observed and reconstructed seasonal rainfall respectively.

The Root Mean Square Error,

$$RMSE = \sqrt{\left[\sum_{i=1}^{n}(x_i - y_i)^2\right]/n} \tag{3}$$

$$bias\ percentage = \frac{\overline{rs}}{\bar{y}} * 100 \tag{4}$$

$$\overline{rs} = \left[\sum_{i=1}^{n}(x_i - y_i)\right]/n \tag{5}$$

Where $\overline{rs}$ =the mean of residual

$\bar{x}_i$ = arithmetic mean of x and

$\bar{y}_i$ = arithmetic mean of y

The observed and reconstructed seasonal precipitation are mostly normally distributed (range of skewness is from 0.22 to 0.83) except in a few stations. The reconstructed data set is negatively skewed (skewness = -1.782) while the observed dataset is positively skewed (skewness = 1.714) at Ikeja. At Osogbo and Bida the reconstructed seasonal rainfall are positively and negatively skewed respectively (1.09,-2.078) while the observed are normally distributed. At Markurdi the observed data is positively skewed (skewness = 1.35). The significance of the difference between the reconstructed and observed precipitations was tested using the parametric Student t-test and its non parametric counterpart Wilcoxon Signed Ranks Test (WSRT) because of the few data sets that are not normally distributed.

Student's t test

This takes the actual difference between the arithmetic means of the two samples and divides it by the standard error of the difference (SED).

$$t = \frac{\bar{x} - \bar{y}}{\sigma_d} \tag{6}$$

SED, $$\sigma_d = \sqrt{\frac{{\sigma_x}^2}{n} + \frac{{\sigma_y}^2}{n}} \tag{7}$$

where $\bar{x}$ = the mean of predicted rainfall.

$\bar{y}$ = the mean of observed rainfall.

The degrees of freedom = 2n-2

For this test, the null hypothesis is: there is no difference between the means of the predicted and the observed while the alternative hypothesis is: there is a difference between the means of the predicted and the observed seasonal rainfall.

This was done at 95% confidence level.

Wilcoxon Signed Ranks Test

Null hypothesis set for this test is: there is no difference between the medians of the reconstructed and the observed seasonal precipitation.

The differences in medians are ranked regardless of the sign of the difference. All zero differences are ignored and the original signs are affixed to the rank numbers. All pairs with equal absolute differences are given the same rank but finally ranked with the mean of the rank numbers that would have been assigned if they would have been different.

Ranks with the same signs are summed (*W+; W-*) and the total number of pairs (*N*) is finally determined.

The level of significance is calculated by dividing the number of all distributions of signs over the ranks that have a SUM <= *W+* (if *W+* < *W-*) by 2^N.

Alternatively, if N > 15, then

$$Z = [W - 0.5 - N(N+1)/4] / \sqrt{[N(N+1)(2N+1)/24]} \quad (7)$$

where *W* is the larger of *W+* and *W-*.

Z has a distribution that can be approximated by the standard normal distribution so the calculated Z is compared with the standard normal distribution and if calculated Z is less than the tabulated Z, the null hypothesis cannot be rejected.

RESULTS AND DISCUSSION

Cross-validation and Reconstruction

The correlations between the predicted and the observed seasonal rainfall of the training and verification periods of 1960-1985 were all significant at 5% level for all stations. This ranged from 0.34 to 0.75. In the case of training and verification periods of 1986-2012, correlations are not generally significant although some were found to be above significant level of 5%. These ranged from 0.12 to 0.55 (Table 2). This is an indication that the period of 1960-1985 performed better than the period of 1986-2012 and this is probably showing climate change effects.

The correlations between the reconstructed and the observed seasonal rainfall of ten stations were found to be significant at 5%, but at 10% level, their number increases to thirteen (table 2). This suggests some degree of skill which is also an indication that SST is a good predictor of JJAS seasonal rainfall in Nigeria.

Test of Fit

The t-test and Wilcoxon Signed Ranks Test analyses yielded the same result (table 3), no significant difference was found between the reconstructed and the observed seasonal rainfall in almost all stations except for Calabar, Enugu and Osogbo. The stations are in the south. This is another indication of good prediction over the entire northern Nigeria but difficulty in reliable prediction over the south, especially at the coast.

As the RMSE values on test data of almost all the stations considered in Nigeria are relatively low and there is a little deviation of the predicted rainfall value from the actual as indicated by the SDR values obtained, majority of prediction models obtained are reliable in line with Gholam *et al*. (2009). The accuracies of majority are also above average as obtained by Agboola *et al*. (2013) in their own prediction.

The percentage deviation of the predicted from the observed 2012 seasonal rainfall amount found by NIMET shows normal (-10% to 10%) seasonal precipitation in only 3 stations while the rest 19 were above normal (>10%) (*NIMET -SRP*, 2013). In comparison, the percentage deviations obtained in this study are all less than 10% (table 3) over the 53 years considered. This reveals better reliable seasonal prediction from this study than that of *NIMET* (2013).

Table 2 : Correlation of predicted with the observed seasonal rainfall

Station	Training period (1960-1985)	Verification period (1986-2012)	Training period (1986-2012)	Verification period (1960-1985)	Reconstruction
Sokoto	0.55	0.38	0.38	0.55	0.39
Zaria	0.62	0.31	0.35	0.52	0.21
Kano	0.56	0.53	0.32	0.56	-0.23
Kaduna	0.41	0.16	0.16	0.41	0.32
Makurdi	0.40	0.23	0.23	0.40	0.22
Jos	0.54	0.22	0.30	0.34	0.37
Bida	0.53	0.12	0.12	0.53	0.18
Nguru	0.72	0.36	0.38	0.70	0.33
Potiskum	0.58	0.26	0.29	0.49	0.28
Maiduguri	0.39	0.27	0.27	0.39	0.05
Minna	0.45	0.19	0.19	0.45	0.16
Lokoja	0.51	0.39	0.39	0.51	0.46
Enugu	0.61	0.23	0.25	0.57	0.28
Ikeja	0.69	0.22	0.25	0.62	0.23
Ibadan	0.54	0.49	0.49	0.54	0.50
Osogbo	0.75	0.21	0.22	0.73	0.25
Ondo	0.42	0.38	0.38	0.42	0.39
Benin	0.63	0.36	0.37	0.62	0.36
Warri	0.60	0.31	0.39	0.37	0.29
Port Harcourt	0.70	0.12	0.13	0.70	0.25
Calabar	0.60	0.15	0.22	0.49	0.26

Table 3: Tests of fitness between the predicted and the observed of the cross-validated seasonal rainfall

Station	RMSE (mm)	SDR	Bias %	WSRT p-value	(t-test) p-value
Sokoto	32.45	1.49	2.24	0.40	0.48
Zaria	40.73	1.99	4.24	0.22	0.15
Kano	100.00	0.51	2.80	0.87	0.76
Kaduna	30.28	3.80	-1.19	0.25	0.50
Makurdi	44.03	2.30	-0.71	0.45	0.81
Jos	33.47	2.39	-1.20	0.47	0.54
Bida	34.46	2.44	-2.39	0.31	0.30
Nguru	27.78	1.61	1.65	0.62	0.66
Potiskum	37.66	1.95	3.31	0.47	0.34
Maiduguri	46.32	1.88	-1.80	0.85	0.70
Minna	36.01	0.54	1.88	0.52	0.49
Lokoja	35.80	2.28	0.15	0.84	0.95
Enugu	49.59	1.35	6.66	0.01	0.01
Ikeja	80.98	1.54	-8.81	0.23	0.11
Ibadan	48.68	1.80	2.55	0.15	0.51
Osogbo	50.66	1.34	9.39	0.02	0.02
Ondo	51.34	2.17	2.75	0.10	0.38
Benin	60.71	1.97	0.48	0.71	0.86
Warri	77.11	0.66	0.26	0.73	0.69
Port Harcourt	49.67	2.78	0.65	0.71	0.75
Calabar	77.24	2.06	6.45	0.01	0.01

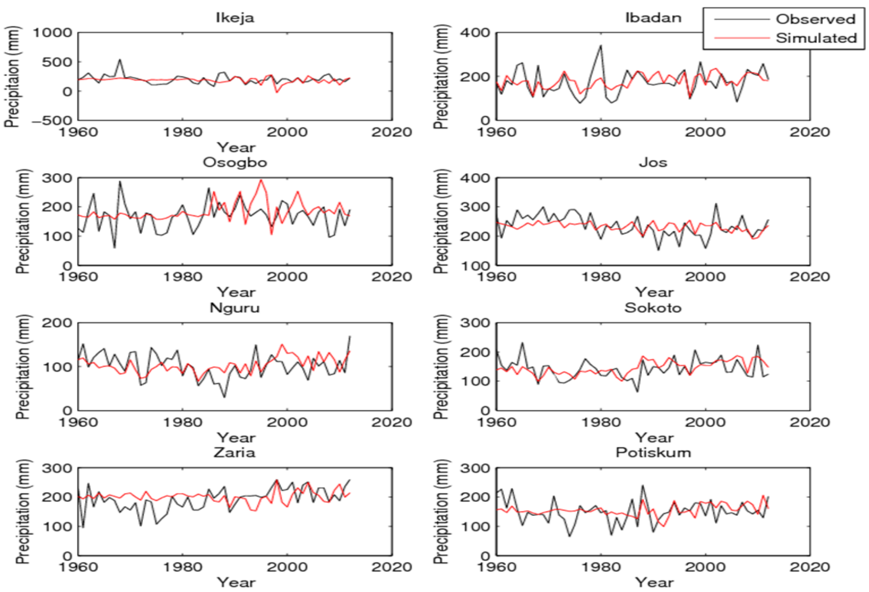

Fig. 2: Observed and reconstructed seasonal (JJAS) precipitation for some selected Nigerian stations

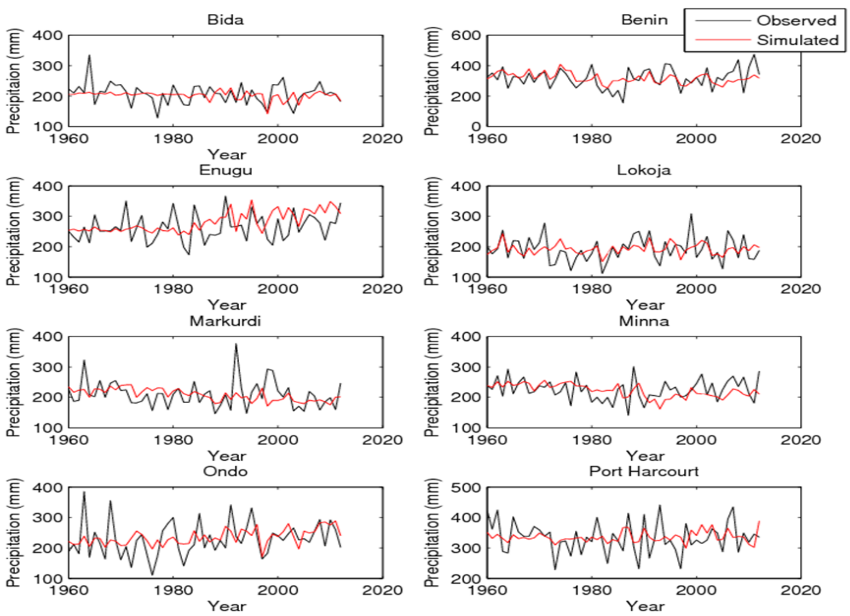

Fig 3: Observed and reconstructed seasonal (JJAS) precipitation for some selected Nigerian

Figs. 2, 3 and 4 show the trend of observed and reconstructed seasonal (JJAS) precipitation while fig. 5 shows the bias percentage between observed and reconstructed JJAS precipitation of all selected stations in Nigeria.

CONCLUSIONS

In this paper, seasonal rainfall data from twenty -one Nigerian stations and monthly Sea Surface Temperature of the tropical Oceans constituted the input data for the formulation of prediction equations using regression analysis. The rainfall data and SST indices are for the period of 53 years ranging from 1960-2012. Models that can predict seasonal rainfall in Nigeria have been generated. Cross-validation was also applied with training period ranging from 1960-1985 while its verification period is from 1986 to 2012 and vice versa.

The reconstructed seasonal rainfall for each station was later correlated with the observed seasonal rainfall amount. In addition to this, the reconstructed seasonal rainfall was subjected to test of fitness to know the level of confidence in the predictions.

Results from this study reveal that, there are linear relationships between the Sea Surface Temperature (SST) of the tropical oceans and the averaged JJAS seasonal rainfall amount in Nigeria. This is in agreement with various research works e.g Omogbai (2010) and Adedoyin (1989).

The correlations between the predicted and the observed seasonal rainfall of the training and verification periods of 1960-1985 were all significant at 5% level except for one station, while in the case of period of 1986-2012, the

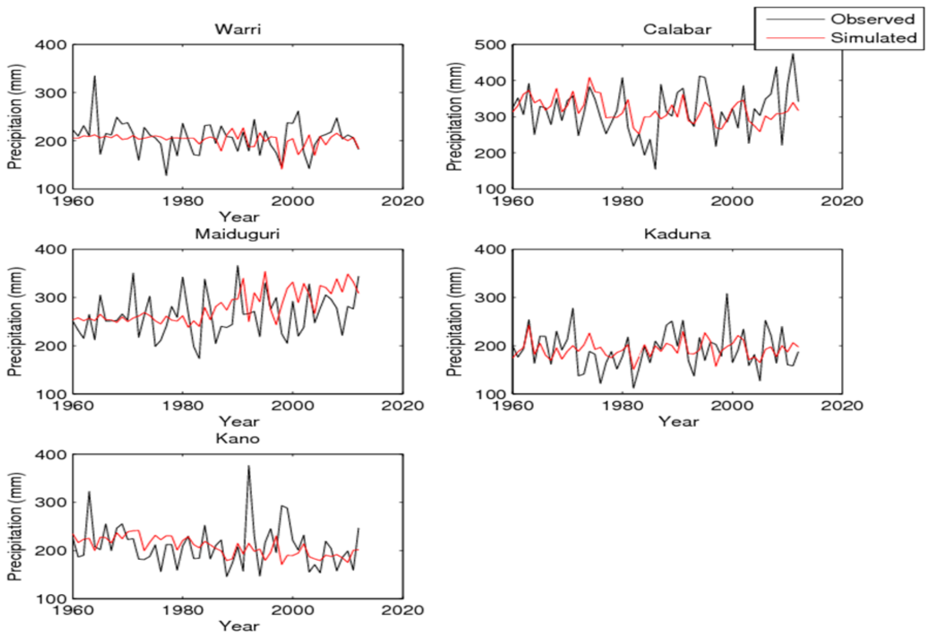

Fig. 4 : Observed and reconstructed seasonal (JJAS) precipitation for some selected Nigerian stations

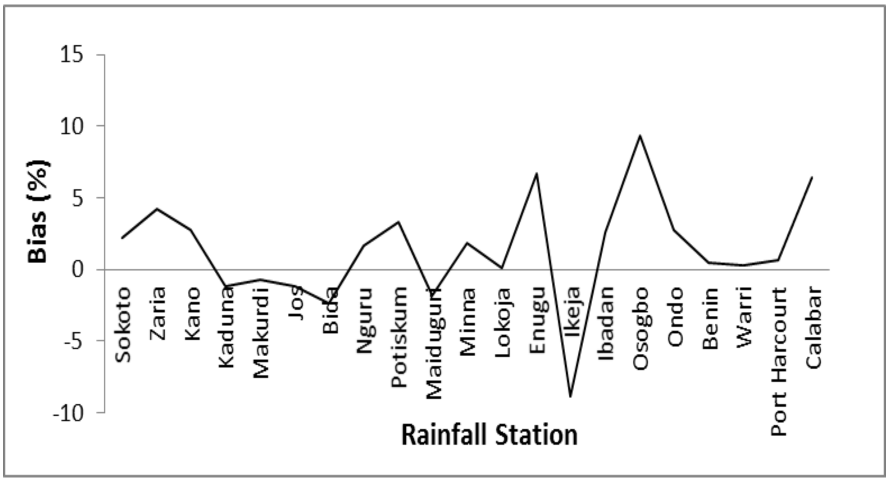

Fig 5 : Bias (%) between the predicted and the observed cross-validated seasonal rainfall

correlations are significantly low although some were found to be above significant level (5%). This indicates that the period of 1960-1985 performed better than the period of 1986-2012 probably due to the effect of climate change on the latter period.

The reconstructed seasonal precipitation, has significant correlation with the observed in only ten stations at 5% level, but the number increased to thirteen at 10% level.

Both the t-test and the WSRT analyses show that there is no significant difference between the predicted and the observed seasonal rainfall in almost all the stations except in Calabar, Enugu and Osogbo. This suggests some degree of skill which is also an indication that SST is a good predictor of rainfall in Nigeria in line with the context of Folland *et al*. (1991), Ward *et al*. (1993) and Omogbai (2010).

The result obtained from the deviation of predicted from the observed 2012 seasonal rainfall amount indicates that our prediction model performed better compared with the 2012 prediction of NIMET (NIMET-SRP, 2013). Also, we were able to predict for a period of 53 years unlike one-year prediction of Omogbai (2010).

The results of this study have implications for more reliable forecast of seasonal rainfall amount, which is applicable for governmental planning in agriculture, water resources, climate adaptation, air and land transportations, hydroelectric power generation and also in the prevention of flooding and its associated negative impacts. Therefore, this work is highly useful and thereby recommended for the Federal government of Nigeria.

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REFERENCES

Adedoyin, J. A. (1989). Global-scale sea-surface temperature anomalies and rainfall characteristics in Northern Nigeria. *International Journal of Climatology, 9: 131-144.*

Adeniyi, M. O. (2014). Variability of daily precipitation over Nigeria. *Meteorology and Atmospheric Physics, 126(3-4):161-176.* DOI: 10.1007/s00703-014-0340-6

Adeniyi, M. O., Ogunsola, O. E., Nymphas, E. F., Oladiran, E. O. (2009). Food security measures during uncertain climatic conditions in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development (AJFAND) 9(2):652–677*

Adejuwon, J. O, Balogun, E. E, Adejuwon, S. A (1990). On the annual and seasonal patterns of rainfall fluctuants in Sub-Sahara West Africa. *International Journal of Climatology, 10: 839–949*

Adejuwon, J.O. and Odekunle, T. O. (2006). Variability and severity of the "Little Dry Season" in southwestern Nigeria. *Journal of Climate, 19:1-8.* DOI:10.1175/JCLI3642.1

Agboola, A. H., Gabriel, A. J., Aliyu, E.O., and Alese, B. K. (2013). Development of a fuzzy logic based rainfall prediction model. *International Journal of Engineering and Technology, 3 (4), 427-435*

Batterbury, S. (2001). The Sahel region; assessing progress twenty-five years after the great drought. Simon Batterbury, republished paper from 1998 RGS-IBG conference. *Global Environmental Change (2001), 11 (1): 1-95*

Berte, Y. and Ward, M. N. (1998). Experimental forecast of seasonal rainfall and crop index for July–September 1998 in Côte D'Ivoire. SODEXAM, Meteorologie Nationale de Côte D'Ivoire, Abidjan *CIMMS, pp 59 –62*.

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. Experimental Long-Lead Forecast Bulletin. http://grads.iges.org/ellfb/Jun001colman. 6.00.htm

Folland, C. K., Owen, J. A., Ward, M. N., and A. W. Colman, (1991). Prediction of seasonal rainfall in the Sahel region of Africa using empirical and dynamical methods. *Journal of Forecasting*, *10: 2–56*.

Gholam, A. F., Mohammad M. and Majid H. N., (2009). Annual Rainfall Forecasting by Using Mamdani Fuzzy Inference System. *Research Journal of Environmental Sciences, 3: 400-413.*

Maraun, D., Wetterhall, F., Ireson, A. M., Chandler, R. E., Kendon, E. J., Widmann, M., Rust, H. W., Sauter, T., Themeβl, M., Venema, V. K. C., Chun, K. P., Goodess, C. M., Jones, R. G., Onof, C., Vrac, M., and Thiele-Eich, I. (2010). Precipitation downscaling under climate change: recent developments to bridge the gap between dynamical models and the end user. *Reviews of Geophysics, 48, RG3003, 34*, DOI: 10. 1029 /2009RG000314

NIMET-SRP (2013). 2013 Seasonal Rainfall Prediction (SRP). Published by the Nigerian Meteorological Agency

Odekunle, T. O. (2004). Determining rainfall onset and retreat dates in Nigeria. *Journal of Human Ecology, 16(4):239–247*

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

Ojo, O. (1977). *Climates of West Africa:* Heineman Publishers, Ibadan

Olaniran, O. J. (1983). The onset of the rains and the start of the growing season in Nigeria: *Nigeria Geographical Journal. 26(1 and 2): 81–88*

Omogbai, B. E. (2010). An Empirical Prediction of Seasonal Rainfall in Nigeria. *Journal of Human Ecology. 32(1), 23-27*

Shanahan, T., Overpeck, J. T., Anchukaitis, K. J., Beck, J. W., Cole, J. E., Dettman, D. L., Peck, J. A., Scholz, C. A. and King, J. W. (2009). "Atlantic Forcing of Persistent Drought in West Africa". *Science 324 (5925): 377–380.*

Simpson, J., Adler, R. F. and North, G. R. (1988). A proposed Tropical Rainfall Measuring Mission (TRMM) satellite. *Bulletin of American Meteorological Society. 69, 278–295.*

Walter, M. W. (1967). Length of the rainy season in Nigeria. *Nigerian Journal of Geography. 10: 123-8.*

Ward, M. N., Folland, C. K., Maskell, K., Colman, A. W., Rowell, D. P., and Lane, K. B. (1993). Experimental seasonal forecasting of tropical rainfall at the U.K. Meteorological Office. Prediction of Interannual Climate Variations, J. Shukla, Ed., *Springer–Verlag. 197–216.*