SPATIO-TEMPORAL ANALYSIS OF RAINFALL PATTERN AND VEGETATION DYNAMICS IN KOGI STATE, NIGERIA

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ABSTRACT

The spatio-temporal analysis of rainfall and vegetation dynamics of Kogi State have been studied over 33years (1983-2016). These years was divided into three intervals, viz: 1983-1990, 1991-2000, and 2001-2016 denoted as 80s, 90s and 00s respectively. The Tropical Application of Meteorology Using Satellite and ground based Observation (TAMSAT) monthly RFE (Rainfall Estimate) and Anomaly data and monthly GIMMS (Global Inventory Modeling and Monitoring Studies) NDVI monthly data all covering the period 1983-2016 was used in this study. The aim of the study is to ascertain how the spatial and temporal changes in rainfall pattern have affected vegetation over the years in Kogi State. The spatial distribution of rainfall over the years was analyzed using ARCGIS 10.3 and maps were produced for the respective intervals stated above. Also, the spatial distribution of rainfall anomaly was analyzed with ARCGIS 10.3 and maps were as well produced. The GIMMS NDVI data was equally subjected to ARCGIS in order to know the spatial distribution and dynamism of vegetation over the years in the study area. The relationship between rainfall and vegetation indices of the State was determined using regression analysis. Results shows that the extreme north western and southern part of the state experienced high rainfall in the 80s ,the central region of the state had moderate rainfall, while the northern part experienced low rainfall. In the 90s, only the southern part experienced high rainfall (1241.09-1410.29mm), the north eastern experienced a reduction (as they had moderate rainfall unlike the 80s where they had high) having moderate rainfall with the central region (1025.06-1123.26mm). In the 00s, almost all the Local Government Areas experienced the same rainfall amounts with the 90s except an increase experienced by Yagba East and West. In the 80s, North western, Central and Northern experienced positive anomaly (-30.03-30.46mm) while the South eastern, Southern and Northern part experienced negative anomaly (-81.68 – -30.03mm). In the 90s, Southern, South-eastern and Central experienced positive (-11.52-25.17mm) while the North-western had negative (-43.62 – -11.52mm). In the 00s, the North-western, Northern and South-eastern experienced positive (20.60-50.52mm) while the Southern and Central region experienced negative (2.686-26.60mm).

Keywords: Dynamic Rainfall Pattern, and Vegetation.

1.0 INTRODUCTION

Rainfall events are of crucial focus to the existence of man. The occurrence of rain results from several complex atmospheric processes. Falling rains comes with difference spatio-temporal dimension but rainfall distribution is closely related to the topographical features of the surrounding area (Kassim and Kottegoda, 1991). At the global level temperature and rainfall have widely been focused because of their direct effect on several earthly variables such as Agriculture and hydrology. Several studies have also linked rainfall and evapotranspiration occurrence (Koster*et al.,* 2006; Teuling*et al.,* 2006; Alessandri*et al.,* 2007) while other associated rainfall with vegetation (Liu *et al.,* 2006; Notaro*et al.,* 2006). According to Noori (2014) the occurrence of rainfall has temporal and spatial variability as well as discontinuity with notable impacts on defining climate regions. In recent times, the changes in the dynamics of several atmospheric variables have introduced the idea of climate change into environmental order and rainfall variable including pattern is expected to experience statistically significant index. As stated by IPCC(2001; 2007;2014) variability of climate parameter and pattern will be paramount in the new climate change event.

The erratic nature of rainfall in space and time in view of the importance has made several researchers to indulge in its study (Freison 2002;Tayeb 2010; Bostan 2010;Yitea 2012; Sawant *et al.* 2015;Bamba 2015) particularly with respect to vegetation dynamics (Yitea, 2012). The spatial temporal response of vegetation to rainfall incidence has a positive attribute over regions (Nicholson *et al,* 2010) and negative in some cases due to geographical position, geomorphology, vegetation type, climatic condition and other factors (Zhong *et al.,* 2010). Thus more studies are initiated at all scales to understand dynamic nature of vegetation with rainfall because climatic condition are the most unpredictable elements affect vegetation (Yitea, 2012) However few studies exist for Nigeria (particularly for Kogi State) which has its vegetation belts determined by rainfall (Oyenuga 1967; Iloeje, 2001).Therefore, understanding the interaction between rainfall elements and vegetation condition in response to climate variability and change in global or regional scales would have scientific and agricultural importance.This becomes crucial as studies have confirmed that Nigeria is already facing the perils of climate change and variability (Boko *et al.,* 2007; Adesina and Odekunle, 2011; PANSDI, 2014)

Satellite data has become useful in relating vegetation indices to climatic parameters, and to provide quantitative description of vegetation growth (Roerink *et al.,* 2003). Studies have followed approaches to estimate the spatial occurrence of rainfall over regions using direct meteorological data (Notaro *et al.,* 2006; Naoum and Tsanis, 2014; Chu *et al.,* 2008). In china, Li *et al* (2006) used data from 2114 stations for 30 years spanning between 1961 and 1990 to view spatial temporal dimension of rainfall but the problems associated with data gathering in Africa propelled approaching the analysis of the spatial distribution of rainfall over Kogi State using a satellite data. According to Tarnavsky, (2014), sparse density of stations and infrequent reporting rate present heated challenges to data access in Africa. However the state can only boast of a single functioning meteorological station in Lokoja, the state capital which may not provide a suitable coverage and representation of the rainfall pattern over the entire state. Understanding the spatio-temporal pattern of rainfall in Kogi State like every state in Nigeria is therefore, very critical and must attract all stakeholders including Researchers and Farmers seeking appropriate measures to the impacts of climate change. According to Michaelides *et al.,* (2009) the spatial and temporal characteristics of rainfall has multidimensional influence on planning, management and providing client information for several environmental assessment such as of water resources, monitoring of climate, vegetation dynamics. The objectives of this study, therefore, are to:

(i) examine the spatial and temporal pattern of rainfall trends and variability across Kogi State;

(ii) examine the rainfall anomaly of the State from 1983-2016;

(iii) assess the relationship between rainfall pattern and vegetation dynamics of the state.

2.0 MATERIALS AND METHODS

2.1 Study Area

Kogi State is a state in the central region of Nigeria. It lies on 7°30'N 6°42'E and 7.500°N 6.700°E with geological features depicting young sedimentary rocks and alluvium along the riverbeds, which promotes agricultural activities. It was created on 27th August, 1991. It has a total area of 29,833km² (11,519 sq mi) and it is ranked the 13th largest area in Nigeria.

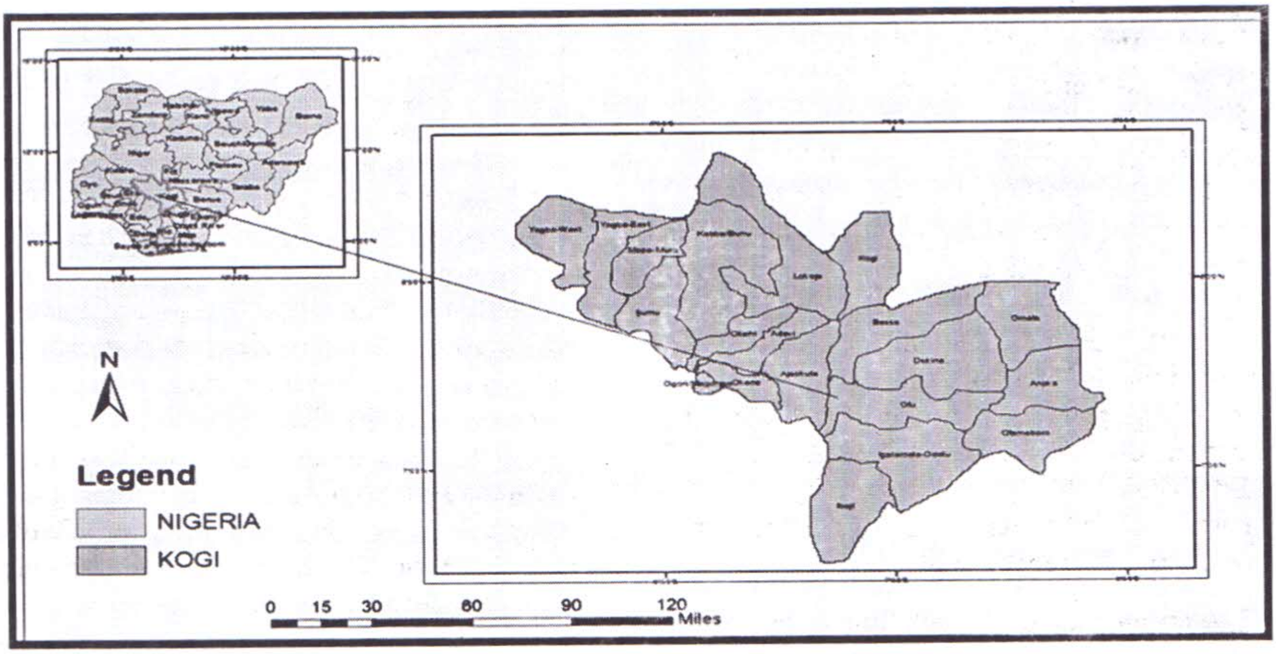

Figure 1: The study area
Source: Author's data analysis

2.2 Data

The research data includes; Tropical Application of Meteorology Satellite data (TAMSAT) monthly imageries (Rfe and Anomaly) from 1983-2016 and Global Inventory Modeling and Monitoring Studies (GIMMS) NDVI monthly data collected from NASRDA repository which were also from 1983-2016. The TAMSAT is a rainfall products designed for Africa, calibrated with ground measurements with dekadal and monthly estimation at 1km resolution which make it a suitable data for the study area. The GIMMS data set is an NDVI corrected data derived from the Advanced Very High Resolution Radiometer (AVHRR) instrument onboard the NOAA satellite series 7, 9, 14, 16, and 17.

Geospatial and Statistical Analysis

The methodology component of the study included both spatial and statistical analysis. The spatial extraction of Kogi State extent was done with tools ARCGIS 10.3.The extraction tools that is clipping feature was used to allow for the subsetting of cells Kogi State from the main TAMSAT (rainfall and anomaly) and GIMMS NDVI image for Africa. The locational and the cells attributes were captured in the resulting database after initiating the cell statistics analysis. Each of the

respective years between the intervals was added together and their average was found. The imagery was classified into 3 classes, viz; high, medium and low rainfall respectively.
The clip tool creates one new feature class that contains only the parts of the original features that fall within the polygons in the clip feature class. Spatial interpolation of one thousand (1000) random points generated within Kogi State shapefile was done using the extract raster value to point tool in ARCGIS 10.3 spatial analyst option. The Inverse Distance Weighting (IDW) interpolation method was employed to generate an estimated surface from a scattered set of points from the extracted value to point tools. The method is simple and effective with dense data. It has been used for climate data (Legates and Willmont, 1990; Stallings *et al.*, 1992; Noori, 2014).The examination of the spatial and temporal pattern of rainfall trends and variability across Kogi State after geospatial process was done using line graph on Microsoft excel. The mean monthly value of rainfall was extracted from the analysed maps on ARCGIS. Also, to examine the rainfall anomaly of the Kogi State from 1983-2016, the mean monthly rainfall of the analysed data was computed using an excel sheet which was latter plotted against some selected years on a line graph to show how rainfall pattern has deviated from the normal trend. Time Series Analysis and Linear Regression Analysis were used in assessing the relationship between rainfall pattern and vegetation dynamics in the study area. Normalised Difference Vegetation Index (NDVI) from Global Inventory Monitoring and Modelling Studies (GIMMS) was correlated with the Linear Regression, LR and Correlation values obtained from equation (1) and equation (2).

Mathematically, linear regression method, least square regression is given as:

$$Y = a + bx \qquad (1)$$

While the coefficient of correlation is given as:

$$R = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2] - [n\sum y^2 - (\sum y)^2]}} \qquad (2)$$

3.0 RESULTS

The spatial and temporal pattern of rainfall trends and variability across Kogi State

(a) Spatial distribution

Figure 2 represents the spatial (average) distribution of rainfall over the years from 1983-1990, 1991-2000 and 2001- 2016.

3.1 Average Rainfall pattern for the Nineteen Eighties (1980s) ranging from 1983-1990

From figure 2 (a) indicating average rainfall pattern in the Nineteen eighties (1980s), Yagba-West, Yagba-East and part of Ijumu and Mopa in the North Western region and Ibaji, Igalamela, Olamoboro in the extreme south of the state received high rainfall as shown by the green colour on the map. Local Government Areas with colour yellow including Dekina, Okene, Ankpa, Ofu and parts of Ajaokuta, Kabba, MopaMurro, Igalamela, Olamaboro experienced a medium rainfall while the northern region of the state including Lokoja, Kogi, Bassa, Okehi, parts of Omala, Kabba/ Bunnu, and Adavi represented by red has low rainfall.

3.2 Average Rainfall pattern for the Nineteen Nineties (1990s) ranging from 1991-2000

Figure 2 (b) is showing the average rainfall pattern in the 1990s from years 1991-2000. There was a decline in rainfall in the northwestern region of Kogi State as Yagba-West and Yagba-East, parts of Ijumu and Mopa which received medium rainfall instead of the high rainfall received in the 80s. Also there was a decline in rainfall in areas of Okene, Okehi, Ajaokuta, Adavi and others from medium to low rainfall as shown by red colour. Dekina, Ofu, Ankpa and parts of Igalamela maintained their rainfall distribution of medium value. Similarly, the extreme southern region including Ibaji, Olamaboro and part of Igalamala still has the high rainfall value (see 2 b).

3.3 Average Rainfall pattern for the early twenties (2000s) ranging from 2001-2016

Figure 2 (c) indicates average rainfall pattern in the twenties (2000s) from 2001-2016. Parts of Yagba-East and Yagba-West had an increased rainfall and Dekina, Olamaboro, Ibaji and also part of Igalamela maintained their usual high rainfall indicated by green colour. Some parts of Mopa, Ijumu, Kabba etc. and Ofu, Ankpa as well as part of Igalamela still received medium rainfall. The central part extending to the north such as Lokoja, Kogi, Okene, Ajaokuta, Okehi, Adavi etc represented by red also received low rainfall as received in the 90s. In all, there was no much change in the amount of rainfall received across Kogi State between 1991-2000 and 2001-2016 except the increased rainfall amount in Yagba-East and Yagba-West.

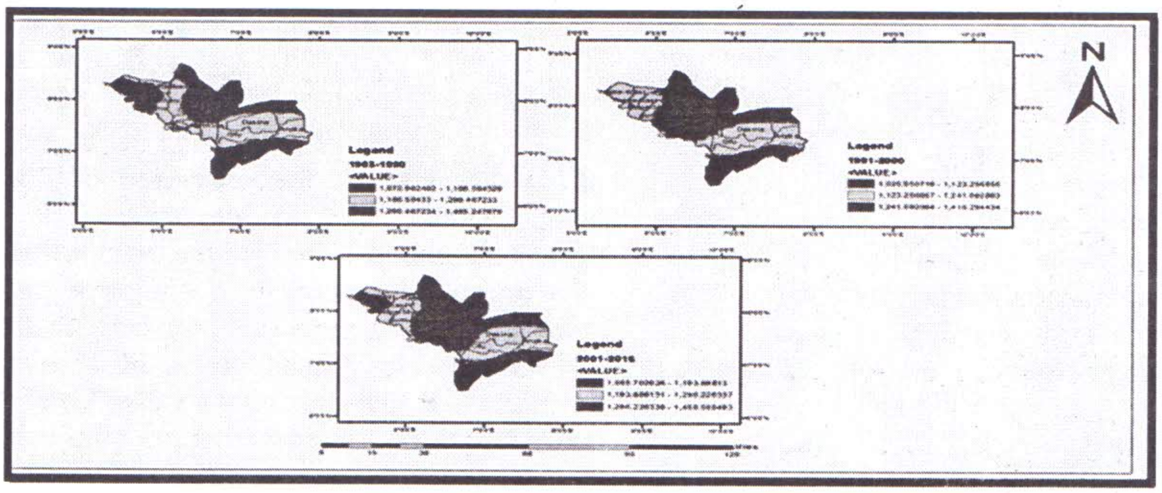

Figure 2: Spatial Analysis of Average Rainfall Pattern from 19808-1990, 1991-2000 and 2001-2016

Source: Author's analysis, 2017

3.4 Temporal distributions

From Figure 2, it is clear that there have been variability in rainfall distribution over the years. From 1983-1990, the blue line showed that rainfall amount was about 45 mm in January and in February, it dropped to about 40 mm it then increased in March reaching about 70 mm. In April, there was a rapid decline after which there was a continuous increase in May, June, July and a decline in August popularly known as August Break. It then increased reaching its peak in September and subsequently declined from October, November and December.

From 1991-2000 (the red line), January received about 20mm and a sharp decline to about 5mm in February. It then increased through March, April, May and declined in June, maintaining a rainfall amount of 150 mm throughout after which there was an increase in July and the Peak was reached in August (there was no August Break here rather it breaks in June). It then rapidly drops throughout the remaining months of the years as shown in Figure 2.

It increased rapidly in March and gradually in April, May, June, July and reached its peak also in August after which it dropped gradually in September, October and reached its minimum in November and then a slight increase in December.

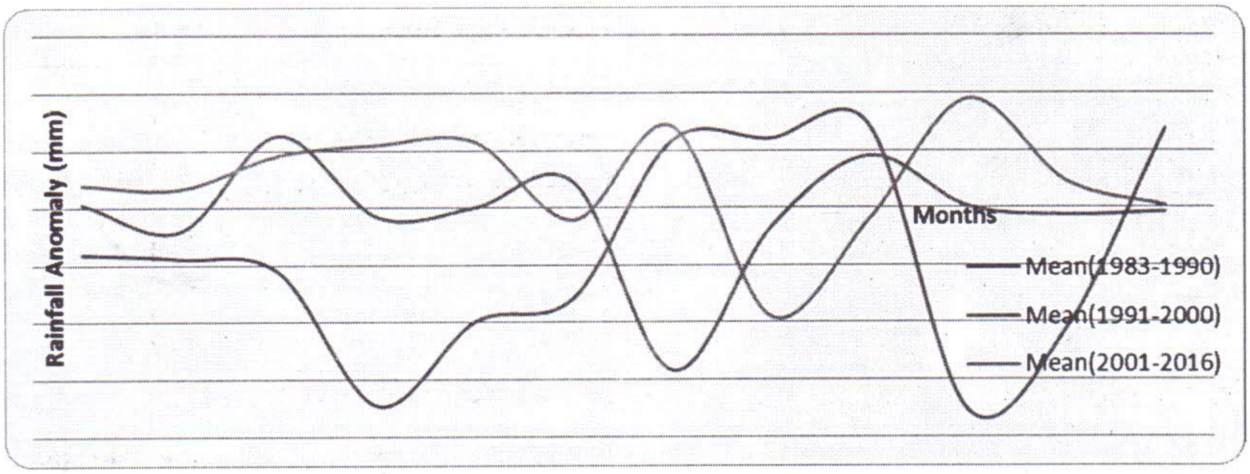

Figure 3: Temporal Analysis of Rainfall Pattern and Variability

To gain more insight on the temporal distributions of rainfall, a normal, i.e. 30 years mean was computed and the result was compared with the average of the intervals as shown in Figure 3. There was no much deviation from Normal in the years 1983-1990. A slight decline was experienced in February and some days in March. The remaining days of March maintained the same trend with the Normal. From April to May, there was a decline and this falls back to the trend in June after which it increased in later days of June and early July, it dropped again towards the end of July. In August and September, it increased. It then maintain the trend in October and declined in November and December.

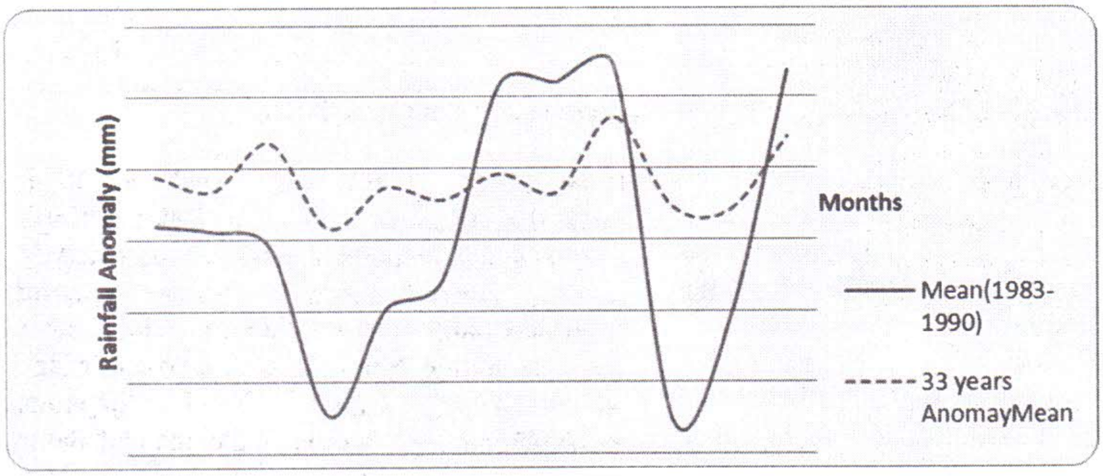

Figure 4: Comparison between the Normal (30 years mean) and mean (1983-1990)

From Figure 4, the years 1991-2000 did not receive much deviation from the Normal except a reduction experienced in January, February, November and December. Rainfall increased in May and declined in the early days of June after which it increased reaching its peak in August. It then follows the Normal and a slight decrease in September and October.

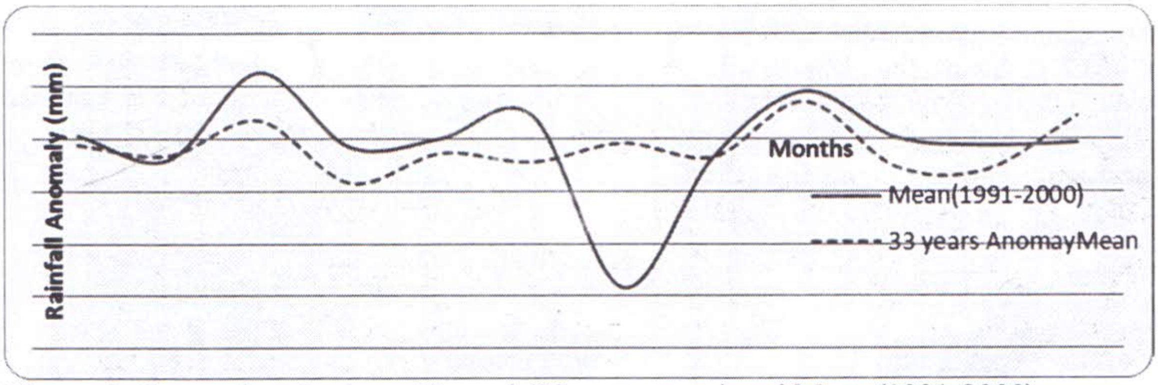

Figure 5: Comparison between Normal (30 years mean) and Mean (1991-2000)

From the Figure 5, there was an increase in rainfall in January and February and a slight increase in March/April and also decreased slightly in May/June. It further decreased in July, August and September, maintained the normal trend in October and increased rapidly in November and December.

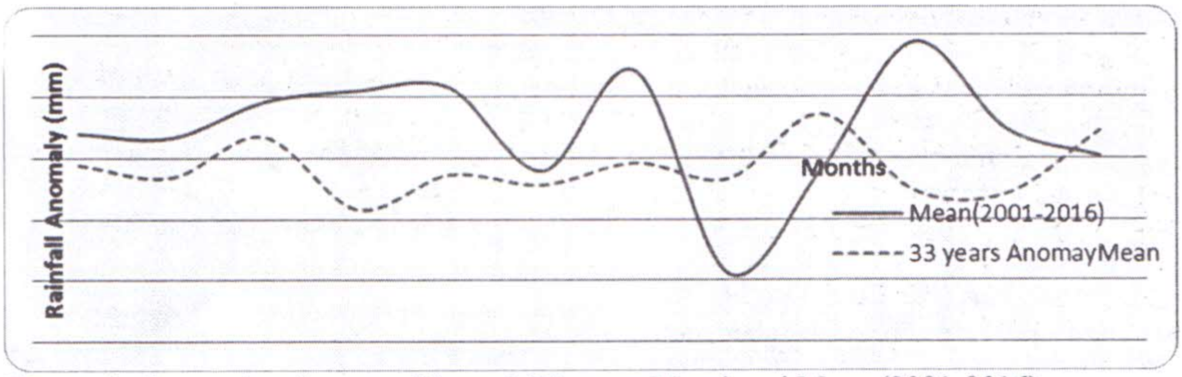

Figure 6: Comparison between Normal (30 years Mean) and Mean (2001-2016)

In general, there has been variation in rainfall both spatially and temporally over the years. As analyzed above, some areas have increased rainfall while others is decreased.

3.5 Examination of rainfall anomaly of the Study area from 1983-2016

Two colours were used for Rainfall Anomaly (i.e. deviation from Normal), these are: the red and green. The red represents **negative anomaly,** i.e. reduction in rainfall amounts while the green represents **positive anomaly** i.e. increased rainfall amounts.

From Figure 7 (a), areas such as Ibaji, Igalamela, Olamaboro, Ankpa, Dekina, Kogi, Omale and some parts of Bassa as indicated by red experienced negative anomaly ranging from -81.6805 – -30.0260mm. while other areas including Yagba-East and West, Mopa Muro, Adavi, Okene, Okehi, Ajaokuta, Kabba/Bunnu, parts of Ofu, Dekina and Bassa experienced positive anomaly ranging from -30.0260 – 30.4583.

From Figure 7(b), the reverse was the case as the areas that experienced positive anomaly now have negative anomaly and vice versa.

Yagba-West and East, Ijumu, MopaMuro, Kabba/Bunnu, parts of Okehi, Okene, Lokoja and Adavi had negative anomaly ranging from -43.6206–11.5180 mm. while others including Ibaji, Olamaboro, Igalamela, Ofu, Ankpa, Dekina, Bassa, Omala, Kogi, parts of Lokoja, Okene, Okehi and Adavi experienced increased rainfall (positive anomaly) ranging from -11.5180 – 25.1707 mm as indicated by green.

From Figure 7(c), Ofu, Ajaokuta, Adavi, Ibaji, Igalamela, parts of Bassa, Lokoja, Dekina, Olamabro, Igalamela, Okene, Okehi, and Kogi has negative anomaly ranging from 2.6867-26.604 mm while other areas of the state had positive ranging from 26.6041-50.5215 mm

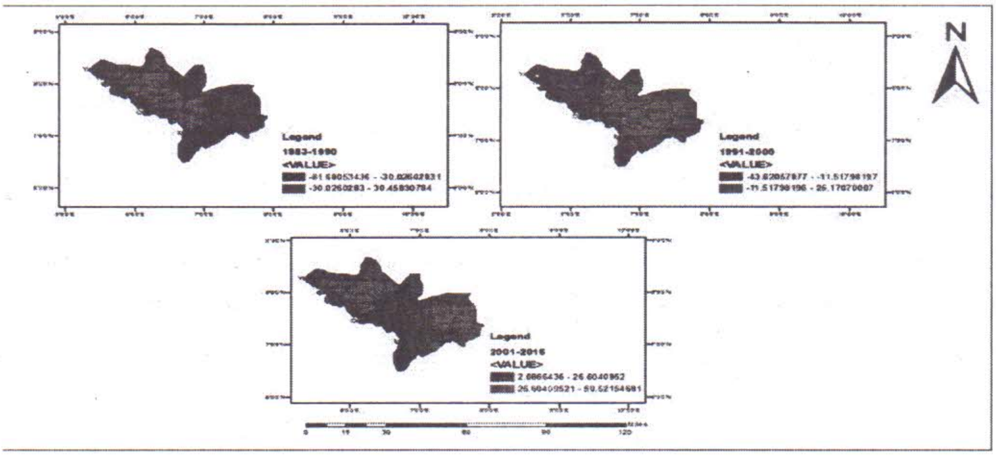

Figure 7: Spatial distribution of rainfall anomaly of the state

From Figure 8, years 1983-1990 had negative anomaly from January to June, positive from July to September, negative from October to November and positive in December as depicted by the blue line. Years 1991-2000 had positive anomalies in the months March, June, August to October. Negative in January, February, April, May, July to August, October, November and December had slight negativity as in red.

Years 2001-2016, positive anomaly was experienced in almost all the months except in June and between August and September where negative anomaly was recorded as in green.

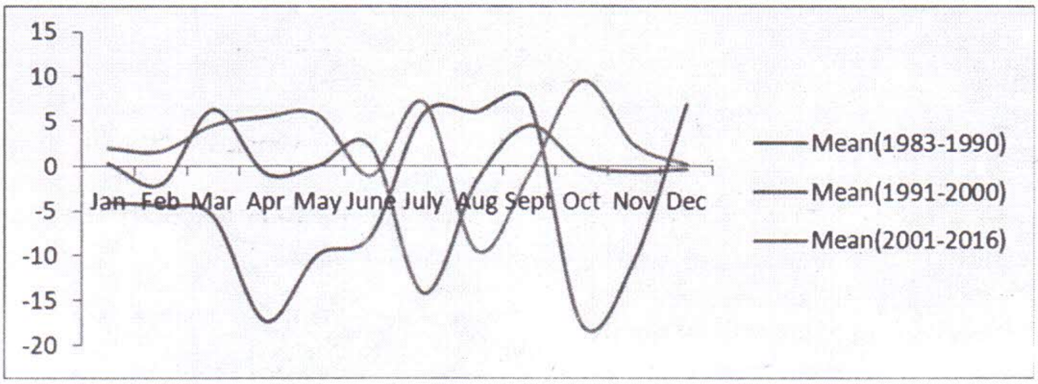

Figure 8: Temporal Analysis of Rainfall Anomaly

From Figure 9, the Anomaly mean indicates negativity throughout the months except March and December where a positive was recorded. The average of years 1983-1990 (in blue) also indicated negativity in all the months except from July to September where positive anomaly was experienced.

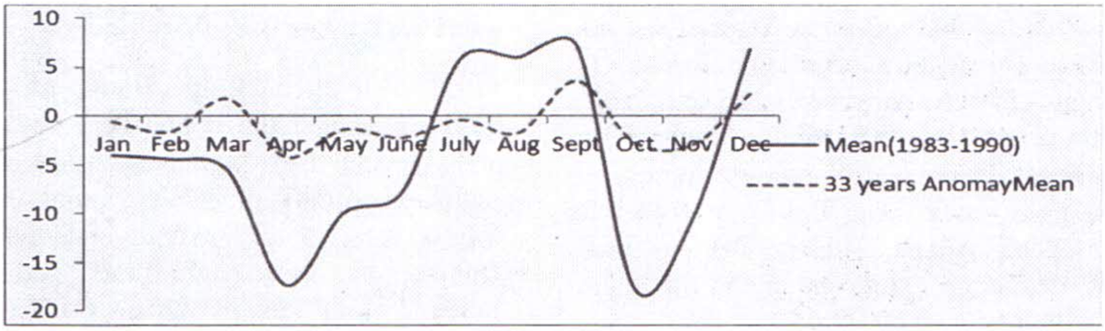

Figure 9: Comparison of Normal Anomaly (33years Anomaly Mean) and mean (1983-1990)

From Figure 10, the mean (1991-2000) followed the trend as the Anomaly Mean but with more positivity in May/June and negativity from June to August.

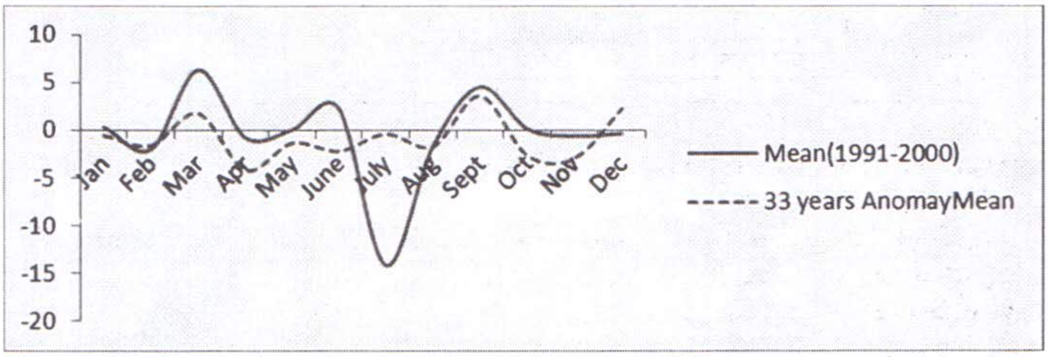

Figure 10: Comparison between Normal Anomaly (33 years Anomaly Mean) and the Anomaly mean (1991-2000)

From 2001-2016, there were more positive anomaly months, negative was experienced only in middle of June and from August to September.

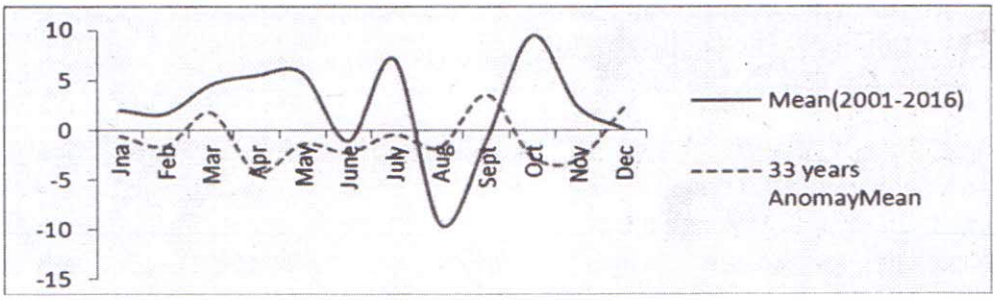

Figure 11: Comparison between Normal Anomaly (33years Anomaly Mean) and the Anomaly mean (2000-2016)

3.6 Relationship between rainfall pattern and vegetation dynamics of the State

Figure 12 shows the spatial distribution of vegetation across the study Area. From 1983-1990, vegetation index ranged from 0.56-0.65. Areas such as Mopa-Muro, Yagba-East and Ijumu had the highest vegetation index with the range 0.59-0.65 as indicated in dark green in Figure 4.1.1(1983-1990). Yagba-West, Kabba/Bunu, Bassa , Olamaboro, in light green had medium index with the range 0.56-0.59 while Okehi, Ankpa, Adavi, Dekina, Ibaji, Lokoja, Okene in lighter green had the lowest index with a range 0.50-0.56.

From 1991-2000, vegetation index of the state ranged from 0.48-0.68. Ijumu, Mopa-Muro, Yagba East had high index with a range 0.60-0.68. Okene, Kabba/Bunu, Yagba West, Bassa, Omala, Igalamela as in light green had medium index with range 0.56-0.60 while Dekin, Ofu, Ibaji, Okehi, Lokoja in lighter green has low index with range 0.49-0.56.

From 2001-2016, Kabba/Bunu, Mopa-Muro, Yagba East and the boundary between Bassa and Dekina had high vegetation index as indicated in dark green with range 0.62-0.70. Yagba West, Kogi, Okene, Igalamela-Odolu, Dekina, etc. as in light green had medium Index while Ibaji, Ofu, Okehi, Adavi, Ajaokuta, Ankpa in lighter green had the lowest index with the range 0.53-0.58.

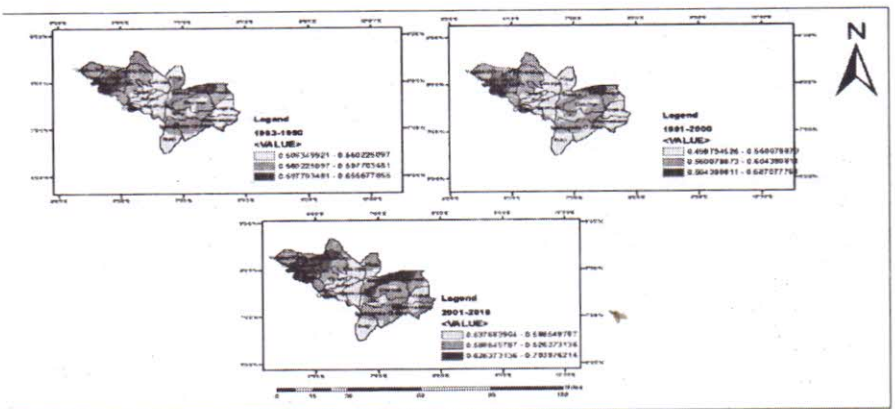

Figure 12: Spatial Analysis of the vegetation index of the study area

Figure 12 shows the scatter plot of monthly Rainfall estimation (Rfe) and Normalized Difference Vegetation Index. The Scatter gram shows that a positive relationship exists between the two variables. The coefficient of r-square is 0.50 (50%). This implies that 50% of the change in vegetation can be accounted for by Rainfall Estimation (Rfe). The linear regression equation for this relationship is:

$$Y = 394.7x - 132.6$$

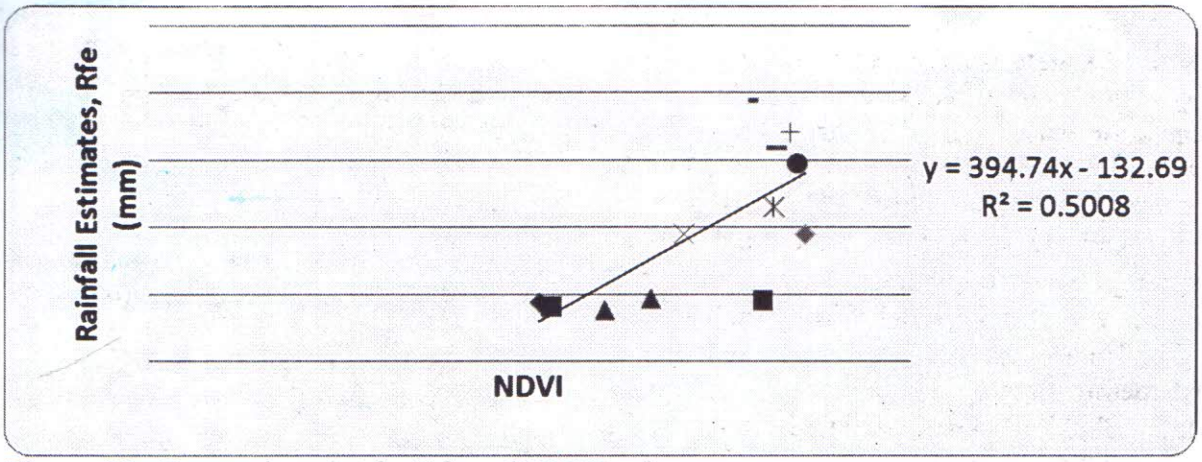

Figure 13: Regression plot for Rfe and NDVI values

Table 1: Analysis of Variance Result

Research Statistics	
Multiple R	0.707649837
R Square	0.500768292
Adjusted R Square	0.450845121
Standard Error	0.076235673
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	Sig F
					0.01 it is significant
Regression	1	0.058298	0.058298	10.0307	<0.05
Residual	10	0.058119	0.005812		
Total	11	0.116416			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.461563962	0.045411	10.16405	1.37E-06	0.360381	0.562747
X Variable	0.001268613	0.000401	3.167141	0.010036	0.000376	0.002161

The one-way analysis of variance result shows that there is a significant difference between the mean rainfalls across the study area between the Local Government Areas as the observed p-value (approximately 0.010036) is less than 0.05. This means that at least one LGA (Local Government Area) is significantly different from others. Again, there is a significant difference between the mean rainfalls across the years revealing that at least mean rainfall in a particular year is significantly different from others.

4.0 DISCUSSION OF RESULTS

This research employed the use of remote sensing techniques in the examination of spatial and temporal pattern of variables. The research proved enough reliance by showing spatial and temporal changes in rainfall pattern as well as vegetation dynamics. Study of the climate of the state shows that the annual rainfall ranges from 1016 mm to 1524 mm and this research did not dispute that fact as its annual range is 1025 mm to 1485 mm. Although there were fluctuation in the rainfall amount in the respective intervals used in this research. Years from 1983-1990 had the high annual range, 1991-2000 had the low and 2001-2016 had the medium.

The research also shows a spatial variation in the vegetation and about 50% of the variation in vegetation is accounted for by rainfall. In summary, rainfall pattern has changed over the years and there exist a significant relationship between rainfall and vegetation of the state.

4.1 Conclusions

In conclusion, the following were drawn from the Analysis:

1. For Spatial distribution of Rainfall, it was discovered that the state received maximum rainfall in the years 1983-1990, followed by 2001-2016s while the 90s received the minimum rainfall distribution. For temporal patterns, years from 1983-1990 had a peak in rainfall in September and the minimum rainfall in February. 1991-2000 had its peak in August and the minimum in February and 201-2016 peak in August and the minimum in March.
2. The Rainfall Anomaly, years 1991-2000 experienced deviation of rainfall the most as the areas that experienced positive Anomaly in years 1983-1990 changed to negative in 1991-2000 and vice versa. However, the rainfall anomaly reverted itself following the trend of 1983-1990 in the years 2001-2016.
3. From the correlation analysis, the rainfall pattern accounted for about 50% of the Dynamics in Vegetation over the years. This implies a significant relationship between the two variables.

4.2 Recommendations

In the course of the study a lot were seen and in lieu of these the study recommends that:

i. There is the need for the establishment of more meteorological stations as those available were not enough for the reasons for which satellite data were utilized.

ii. It is also important for agro-industries to make use of the available information from the study. The study thereby recommends that the findings of this study should be inculcated in the agricultural planning in the area.

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