Analysis of rainfall Trends and changes for Sustainable Agricultural Planning in Southern Taraba, Northeast Nigeria

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ABSTRACT

This paper examined trends and changes in annual precipitation. Precipitation data for the period 1993-2022 were obtained from WorldClim.org. Onset, cessation and length of rainy season were analyzed to determine the changes in the rainfall characteristics using relevant equations. SPSS was used to determine the descriptive statistics of precipitation; linear trend analysis was used to determine the trend of the changes while Fisher's F-test was used to determine the statistical significance of the change. The result of the study shows that annual precipitation amounts between the periods 1993-2022 vary from 733.85 mm to 2238.4. Rainy days in the study area also vary from 164 days to 262 days. Onset of rain in the last decade (2012-2022) has change from March-April to April-May in Ibi, Wukari and Donga while at Takum and Ussa, the shift was observed from March to April. Cessation on the other has no significant changes. Rainfall trend analysis shows that Ibi, Donga and Takum were characterized by negative values of the linear trend (Takum -217 mm/10 years, Donga -64.5 mm/10years and Ibi-25 mm/10years) indicating decrease in the precipitation amount in the period (1993-2022). The study recommends proper dissemination of agro-climatic information for appropriate adjustment and adaptations by farmers in the study for sustainable agricultural development.

1. Introduction

The most developed topical issues of 20th Century in most parts of the world have been climate change issues. Thus, in recent times, researches' related to the issues of climate change are focused on changes in air temperature and precipitation and the possible consequences of these changes. Emphasis is placed on the changing amount and regime of precipitation and temperature, which are important components, determining the development of climate systems, in order to facilitate the adaptation.

Rainfall is an important variable that affect agricultural production in southern Taraba. This is because agricultural production in the area is predominantly rain-fed. As such, understanding the trend and changes in rainfall is important for sustainable agricultural planning in the study area. This is because rain-fed agriculture practice plays important role in cropping and animal rearing and it also has impact on domestic and international economies in the area. Southern Taraba is highly vulnerable to climate change and variability as evident in rampant poverty, rapidly increasing population, and low levels of technological development. The increasing variability of rainfall amount and seasonality destabilize the fragile ecosystem and threatens agricultural production and livelihoods in the area.

The spatial variability, intensity, seasonality and trends of precipitation over Nigeria have been established focusing on different parts of the country in studies such as Thambyahapillay (1979); Adebayo (2001); Olaniran (2002); and Sawa and Adebayo, (2010). Some of these studies revealed visibly the trend of increasing droughts and decreasing precipitation in Nigeria from the end of the 20th century and the beginning of the 21st century.

Weather observation network in southern Taraba is characterized by low density, skewed distribution, short-term records, and significant data gaps. The available stations which generate information for weather and climatic conditions are located beyond the <50 Km2 recommended by World Meteorological Organization (WMO). Most stations in southern Taraba are in the main urban centers (local Government headquarters), resulting in inadequate coverage of interior rural areas where the bulk of agricultural activities take place.

Inadequate weather observation networks hamper timely and accurate rainfall forecasts or predictions that can guide farmers on cropping calendar decisions and post harvest activities. Without proper understanding the trends in temperature and precipitation, agro-meteorological planning, forecasting, and services cannot properly assist agricultural practitioners to optimally meet the ever-increasing demands for food and agricultural by-products.

This paper therefore, analyzed the annual rainfall changes and trends in Southern part of Taraba State Nigeria. The relevance and the importance of this study are underscored by the latest trends in the annual precipitation and temperatures in Nigeria by the Nigeria Meteorological Agency (NIMET)

The study area is made up of five Local Government Areas (LGA) comprising Ibi, Wukari, Donga, Takum and Ussa that made up the southern senatorial zone of Taraba State in Northeastern Nigeria. The classification of the study area as southern zone of Taraba is based on political divisions of senatorial districts in Taraba State. The area is located between Latitude 6° 30’ 56’’N and 8° 46’ 26’’N and longitude 9° 06’25’’E and 10° 45’ 39’’ E with a total land area of about 14195.8km2 as seen in figure 1.

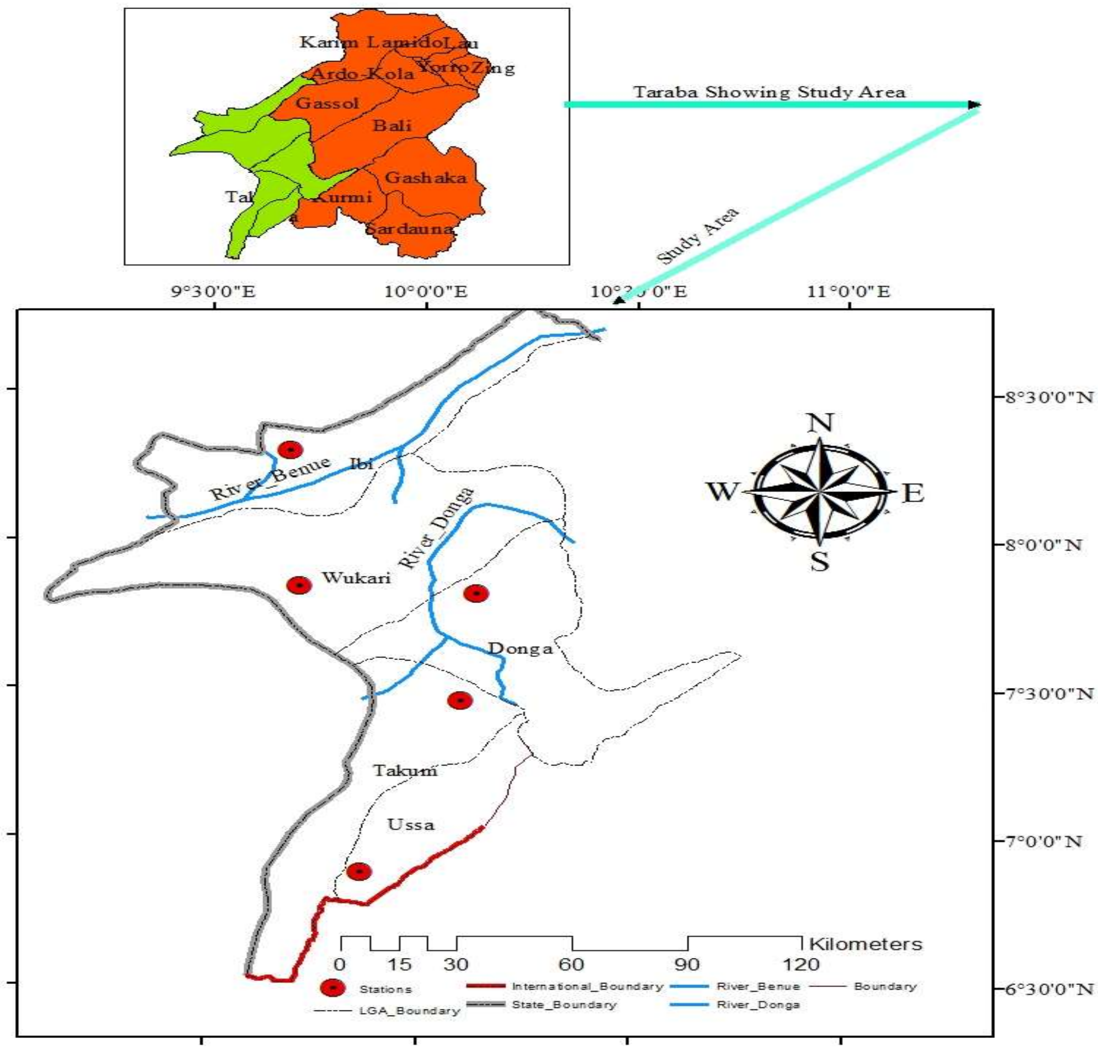

Fig. 1 Study Area

Southern Taraba is unarguably the most agricultural products producing zone in Taraba State and the northeastern Nigeria as a whole. The area is known for tuber crops such as yam and cassava, cereals such as maize, guinea corn, millet sorghum etc and cash crops like groundnuts, soya beans, and sesames among others. The area is divided into two climatic zones; tropical continental and the tropical rainforest climate which falls within the Koppen's climate classification scheme corresponds to the Aw and Af type of climate respectively. These climates are characterized by two distinct seasons (Rainy/wet and dry seasons) with a relatively brief period of harmattan compared to other parts of the state. The seasons are influenced by two local air masses; the northeast trade wind otherwise called the tropical continental air mass and southwest trade wind otherwise known as the tropical maritime air masses. The northeast trade wind is usually dry and desiccated, originating from the northeastern part of the country bringing along dusts from the Sahara desert resulting to harmattan dust. The advent of the northeast trade wind signifies the end of rainy season and the beginning of dry season. Rainy season in the study area begins from late March and last till early November. Rainfall varies from 1200 mm in Ibi, Wukari and Donga to 2500mm in Takum and Ussa annually. Mean annual temperature ranges between 27.5oC and 32 oC with the lowest temperatures in Takum and Ussa. The vegetation of the area is basically of two distinctive vegetation zones; the tropical rainforest-cum Savanna in Takum and Ussa and derived Savanna in Ibi, Wukari and Donga. The vegetation type in the area has significant influence in the modification of the climate of the area (Asa and Zemba, 2023).

Southern senatorial zone of Taraba has a well drained soil with coarse texture surface horizons with different types of minerals in the parent rock. The soil types are generally well suitable for agricultural production.

Thus, agriculture is the single largest occupation of the inhabitants of the study area. The inhabitants of the study area cultivate mostly tuber crops such as Yam and cassava; cereal crops such as rice, maize and Guinea corn as well as leguminous crops such as beans, groundnut, soya beans etc. The tropical rainforest climatic condition of Takum and Ussa favour the cultivation of tree crops such as palm trees, cashew, banana, plantain, mango oranges and other perennial crops.

The relief of the area shows that Wukari and Ibi are generally on low and undulating land with elevations less than 174m above sea level (a.s.l) with the lowest at Ibi while Donga, Takum and Ussa are generally above 174m a.s.l with highest point reaching up to 1440m asl particularly Fikyu, Rukwen-Rufu areas and Lissam in Ussa and Takum at the extreme southern end along the international border with Cameroun around. Two major rivers (River Benue and River Donga) with their tributaries such as the Shemanker drain the study area (Figure 2).

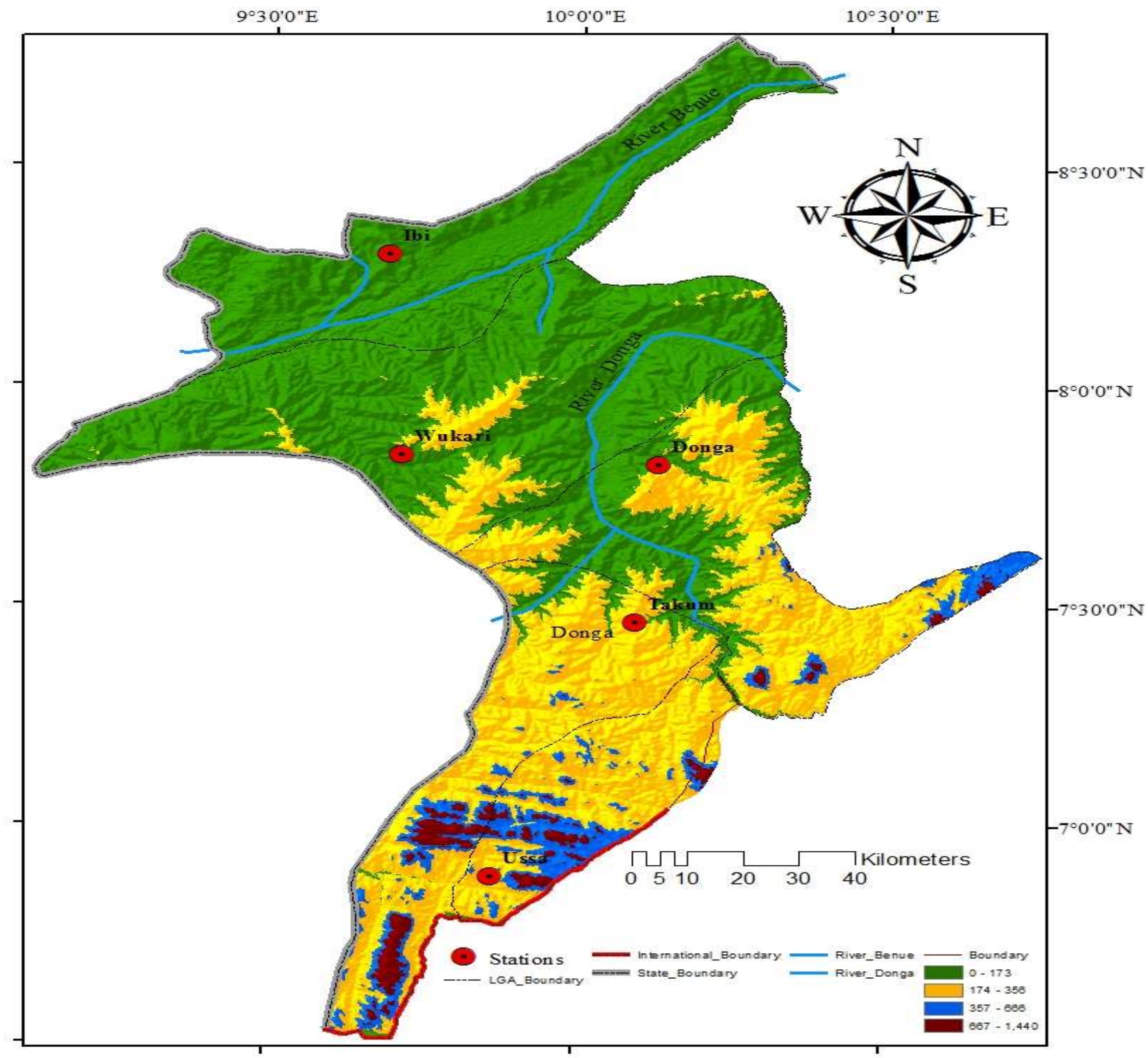

Fig. 2: Relief and Drainage of the Study area

2. Methodology

Data on precipitation and temperature for the periods 1993-2022 were obtained from WorldClimate database at http://www.worldclim.org. WorldClim contains long term global climatic database of daily maximum, minimum and average temperature and daily rainfall as well as sunshine, Relative humidity and wind speed of 30,000 stations

Station	Location	Mean Elevation (m)
Ibi	Lat: 8°14’23’’ to 8°20’40’’ Long: 9°38’31’’ to 9°46’50’’	150.000
Wukari	Lat: 7°47’17’’ to 8°00’11’’ Long: 9°40’30’’ to 9°50’17	147.000
Donga	Lat: 7°38’25’’ to 7°45’06’’ Long: 9°51’33’’ to 10°00’30’’	152.000
Ussa (Lissam)	Lat: 6°59’00’’ to 7°08’39’’ Long: 9°56’48 to 10°06’08’’	278.000
Takum	Lat: 7°11’16’’ to 7°25’10’’ Long: 9°51’02’’to 10°08’01’’	302.000

spread across the globe with a spatial resolution of 0.86 km2 (Hijman et al. 2005). WorldClimate has six (6) meteorological stations distributed within the study area situated at Ibi, Wukari, Rafin-Kada, Donga, Takum and at

Sources: http://www.worldclim.org

Lissam (Ussa). However, for the purpose of this study, five (5) stations were used excluding Rafin-Kada. This is because Rafin-kada is between Wukari and Donga with a distance of less than 15km, which falls within the average distance between meteorological stations recommended by WMO. The data was retrieved on 14/3/2023 7:04 PM. Out of the six stations in southern Taraba, three (Takum, Donga and Lissam) were located above 250m above sea level, while the remaining are below 250 m asl. This means that all the stations are located on a relatively low and undulating land. The descriptions of the station’s locations are presented in Table 1.

Table 1: WorldClim stations in southern Taraba

Data were also collected from the meteorological yearbook of NIMET and Upper Benue River Basin Development Authority (UBRBDA) meteorological stations in the study area (Wukari, Ibi, Donga, Lissam and Takum) as seen in Figure 1, the study area formed part of the UBRBDA.

Statistical analyses were carried out using SPSS version 10.2 to show the trend and changes in the rainfall of the study area for the period of study. Rainfall onset, cessation and length of rainy days were also calculated. The formulae used in all the calculations are described in equations (1) to (5).

i. Monthly rainfall amount: This was computed for the study area from the daily rainfall amount using the equation;

$$M_R = \frac{1}{n}\sum_{i=1}^{n} R_i \qquad (1)$$

Where: MR = monthly rainfall amount (mm);

Ri = daily rainfall amount at the study area;

n = number of days in a month;

i = the days of the months.

ii. Annual total rainfall amount: The annual rainfall total was calculated for the study area from the monthly rainfall amount using equation (2).

$$A_R = \frac{1}{12}\sum_{i=1}^{12} R_i \qquad (2)$$

Where: AR = monthly rainfall amount (mm);

Ri = daily rainfall amount at the study area;

n = number of days in a month;

i = the days of the months.

iii. Mean monthly rainfall amount: The mean annual rainfall amount for the period of 36 years was computed for the study area by equation (3).

$$\overline{\mathrm{RRj}} = \sum_{j=1}^{30} {}^{R_j}/_{36} \tag{3}$$

Where: RR j = the mean monthly rainfall amount for the period.

iv. Arithmetic Mean: Arithmetic Mean or the mean of a set of n-numbers: X1, X2 X3 , , , ,Xn denoted by $\bar{x}$ is the sum of these variables divided by n. mathematically expressed as equation (4).

$$\text{Mean, } \bar{x} = \sum x / n \tag{4}$$

Where x = Mean of daily rainfall amount;

Σx = sum of daily rainfall for the month (X1 + X2+ X3 , , , +Xn);

n = number of days in a month.

The same equations were used for temperatures also but amount of rainfall.

v. Linear trend: Linear trend method was used to determine the trends in the annual precipitation and temperature amounts. Fisher's F-test was used to determine their statistical significance

Seasonality index, (rainfall onset, cessation and number of rainy days were determined using the Walters formula as modified by (Olaniran, 1988). The method is expressed in equation (5):

$$\text{Onset /End}=\frac{\mathrm{DM}}{\mathrm{TM}}\mathrm{x}(51-\mathrm{AP}) \tag{5}$$

Where, DM = number of days in the month containing the onset;

TM = total rainfall for the month in which accumulated rainfall exceeds 51 mm;

AP = accumulated rainfall of previous months just before the month in reference;

51 mm = the threshold of rainfall for both Onset/End month.

Where such onset date was followed by rainfall amount less than 51 mm, the next rain day date that is up to 51 mm or more was chosen.

3. Results and Discussion

Studies of rainfall provide a more precise insight regarding precipitation changes of a place (Popov and Svetozarevich, 2021). Therefore, in this study the precipitation of Southern Taraba Senatorial zone for the period 1993-2022 which was further classified into three decadal periods; 1993-2002, 2003-2012 and 2013-2022 has been analyzed, compared and presented. The results were discussed to show rainfall trends and changes over the study period. Average annual rainfalls for the periods studied are presented in Table 2 while the statistical characteristics were presented in Table 3.

Table 2: Annual rainfall for the period of the study (1993-2022)

YEARS	IBBI	WUKARI	DONGA	TAKUM	USSA	Total
1993	1259.508	1205.837	1577.078	1543.409	1834.587	7420.419
1994	1428.168	1042.896	2189.351	2238.411	1043.234	7942.06
1995	1765.322	1703.778	1291.165	1317.426	1043.234	7120.925
1996	1191.068	963.3516	1863.384	1955.212	1615.825	7588.8406
1997	1763.866	1295.804	1761.35	1709.685	1382.438	7913.143
1998	1674.519	1112.966	1304.185	1477.349	1142.071	6711.09
1999	1107.499	1716.75	1983.547	1995.228	1675.843	8478.867

2000	1630.735	1506.621	1883.684	2076.488	1673.265	8770.793
2001	1438.228	1341.444	1596.219	1640.201	1317.507	7333.599
2002	1606.408	1682.465	1859.142	2105.259	1792.469	9045.743
2003	1339.468	1522.563	1527.434	1830.375	1839.416	8059.256
2004	1363.09	1314.377	1511.489	1773.282	1510.713	7472.951
2005	1457.579	1678.94	1411.72	1668.095	1723.357	7939.691
2006	1241.304	1236.84	1227.762	1468.86	1346.535	6521.301
2007	1299.994	1462.026	1414.226	1793.913	1611.596	7581.755
2008	1265.284	894.6909	1268.885	1459.049	1114.754	6002.6629
2009	1480.981	1473.536	1561.657	1820.944	1604.484	7941.602
2010	1330.569	1176.272	1368.046	1462.806	1337.995	6675.688
2011	1254.983	1211.346	1331.914	1542.973	1452.883	6794.099
2012	794.1098	733.8516	755.5246	944.5008	819.4643	4047.4511
2013	938.9774	958.879	1027.54	1205.937	1210.406	5341.7394
2014	1321.633	1351.497	1491.791	1042.496	1643.526	6850.943
2015	1683.378	1301.787	1781.841	1707.738	1669.91	8144.654
2016	1632.854	1496.005	1815.535	983.3716	1802.306	7730.0716
2017	1304.44	1229.055	1335.426	1265.304	1429.477	6563.702
2018	1159.818	1122.863	1311.178	1114.933	1369.769	6078.561
2019	1392.485	1480.672	1599.824	1716.75	1727.203	7916.934
2020	1606.55	1724.332	1926.091	1509.661	2090.739	8857.373
2021	2012.899	1779.946	2087.785	1381.494	2167.451	9429.575
2022	1319.823	1507.246	1562.117	1782.467	1841.986	8013.639

Station	Years	Range	Min.	Max.	Sum	Mean
IBI	30	1218.79	794.11	2012.90	42065.54	1402.1847
WUKARI	30	1046.09	733.85	1779.95	40228.64	1340.9546

Sources: Calculated from WorldClim.org

From the result presented in Table 3, it shows that annual rainfall amounts for the period 1993-2022 vary from 733.85 mm at Wukari station to 2238.41 mm at Donga station. The year with least annual rainfall was 2012 while the year with highest rainfall was 2021 exactly ten (10) years later (Table 2). A decadal analysis was conducted to show the trend and changes over period of three decades. The analyses of the three periods show that rainfall in the study area is decreasing. The largest decrease in the annual amount of precipitation was observed at Donga and Ussa in the last decade. This could be attributed to increase human anthropogenic activities particularly deforestation and over grazing in the area, the decrease was also evident in Takum and Ibi with Wukari recording the lowest decrease in the precipitation amounts according to the data for the third studied period (Table 3 and Figure 3).

Table3: statistical characteristics of Rainfall (mm) in the Study Area (1993-2022)

DONGA	30	1433.83	755.52	2189.35	46626.89	1554.2297
TAKUM	30	1293.91	944.50	2238.41	47533.62	1584.4539
USSA	30	1347.99	819.46	2167.45	45834.44	1527.8148

Source: Calculated from data obtained at WorldClim.org

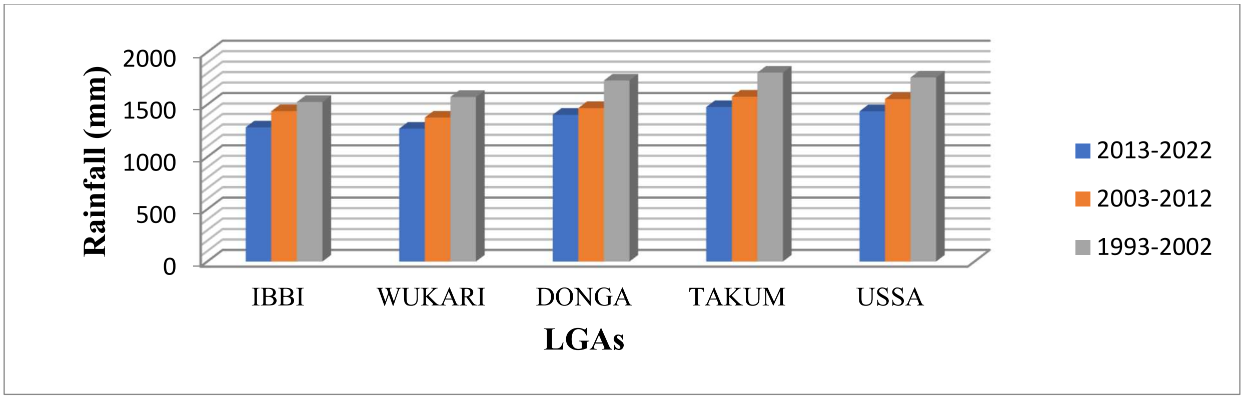

Fig. 3: Decadal changes in the annual amount of precipitation

Higher amount of rainfall is typical for areas at higher altitudes and tropical rainforest zones (Milovanoviæ, Schuster, Radovanoviæ, Vakanjac and Schneider, 2017). Takum and Ussa stations are at higher altitude and tropical rainforest zones respectively altitudes, and therefore, they were observed to have between 20-25 % higher rainfall (4859.63228 mm 4748.393 mm) respectively compared to the lower altitude areas (Wukari 4220.03371 mm, Ibbi 4244.554 mm and followed by Donga 4601.062 mm). The reasons for the high rainfall in Takum cannot be unconnected with its latitudinal location towards the Atlantic Ocean. The area is located on a higher altitude and surrounded by numerous hills. Thus, higher amount rainfall is typical of higher altitude areas while Ussa is at the fringe of the tropical rainforest zones of southeastern Nigeria it is the transitional zone between the southern Guinea savanna zone and the tropical rainforest. The tropical rainforest zone in Nigeria is characterized by heavy rainfall and longer rainfall duration. Table 3 revealed that the maximum precipitation received within the period of study was 2238.41mm at Takum in the year 1994 while the minimum precipitation was recorded at Wukari in 2012. Lowest mean precipitation was received at Wukari while the highest mean was at Takum. The results of this study are another clear indication of climate change and variability in the area besides other evidences.

The analysis of linear trend for the decadal period; 1993-2002, 2003-2012 and 2013-2022 was performed and the result is presented in Table 4 and Figure 4a-e.

Table 4: Average annual amount of precipitation (mm) and linear trend for the period 1993-2022.

Station	Average Annual Precipitation 1993-2002	Average Annual Precipitation 2003-2012	Average Annual Precipitation 2013-2022	Equation of linear trendline 1993-2022	Significance of trend
IBI	1282.7362	1437.2857	1524.5321	Yt = 1451 - 24.6232*t	insignificant
WUKARI	1270.44425	1376.2282	1573.36126	Yt = 1303 + 19.0*t	insignificant
DONGA	1402.866	1467.286	1730.911	Yt = 1691 - 68.4990*t	significant
TAKUM	1730.911	1576.480	1805.8668	Yt = 2019.3 - 217.426*t	significant
USSA	1436.12	1553.047	1759.226	Yt = 1285 + 122*t	significant

The results show negative changes of precipitation amount at (Takum -217 mm/10 years, Donga -68.5 mm/10years and Ibi -25 mm/10years). The remaining two stations Wukari and Ussa exhibit a positive linear trend, with the least increase being observed at Wukari stations followed by Takum station (217.426 mm/10 years) and then Ussa station (122 mm/10 years).

The high annual amount of precipitation is a result of many factors, one of the most important of them being the terrain (the presence of mountains). Mountains represent an Orographic barrier for air masses. Therefore, windward slopes usually receive more rainfall than leeward sites. After crossing the mountains, the air masses descend and heat up. Hence, the difference in the amount of rainfall on the mountainous areas of Takum and Ussa, and the valleys of Ibi and Wukari.

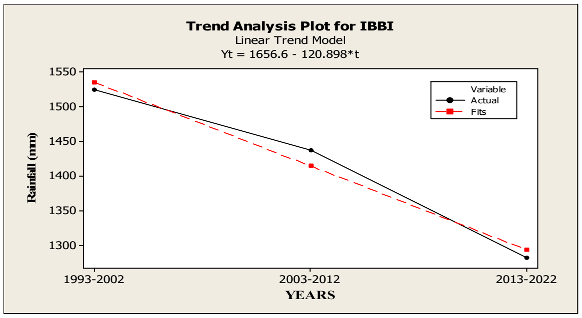

Fig.4a Annual precipitation and trends 1993-2022 Ibi

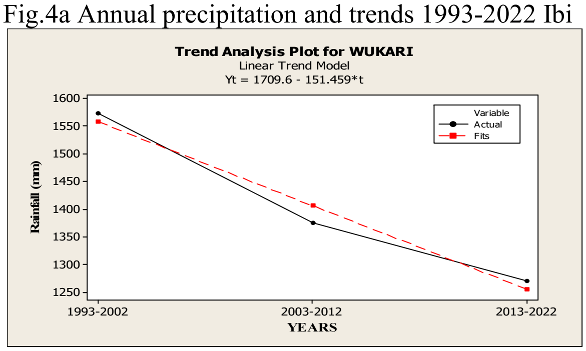

Fig.4b Annual precipitation and trends 1993-2022 Wukari

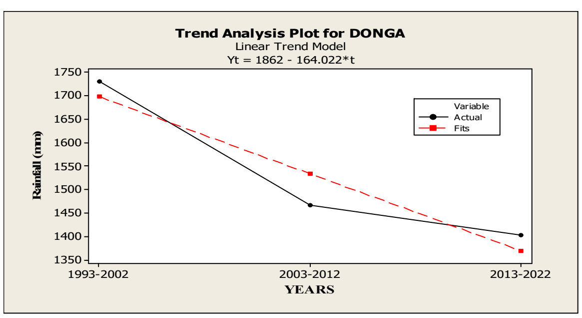

Fig.4c Annual precipitation and trends 1993-2022 Donga

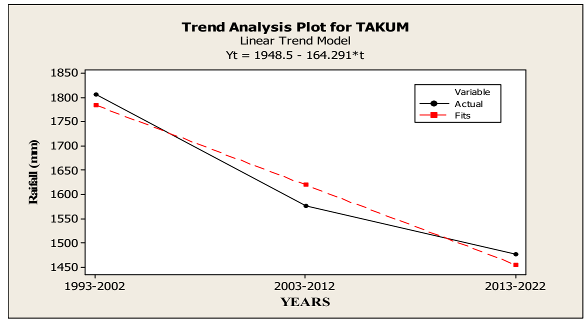

Fig.4d Annual precipitation and trends 1993-2022 Takum

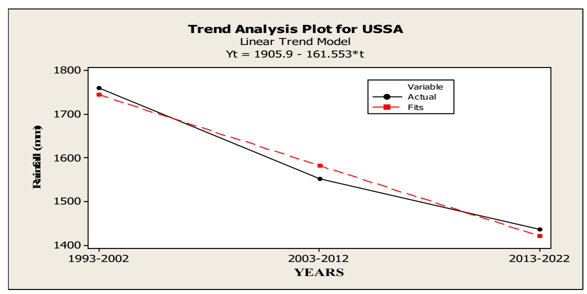

Fig. 4e Annual precipitation and trends 1993-2022 Ussa

Fig 4. Annual precipitation and trends for the period 1993-2022.

Rainfall onset and cessation dates were also calculated in order to analyze the changes and trend in the length of rainy days in the study area for the period 1993-2022 for agricultural planning and the result is presented in Table 5. Results presented in table 5 shows that rainfall onsets date in the study area vary from 5th march to 30th May. The earliest onset of rain was recorded in Takum and Ussa stations while late onset was recorded at Donga station in 2012. Generally, based on the results of this research, it is safe to say onsets of rain in Takum and Ussa is March while for Donga, Wukari and Ibi is April. As the rainfall onset varies, so also is the cessation in the study area. From the Table 5, it can be deduced that cessation is between October and November with an isolated cessations in dates in December at Takum and Ussa stations. Perhaps this explains why the two stations recorded high average annual precipitations. Cessation in Ibi, Wukari and Donga stations varies between October and November while Takum and Ussa varies between November and December

Table 5: Onset and Cessation Dates for the Period 1993-2022

	IBI		WUKARI		DONGA		TAKUM		USSA	
YEARS	Onset	Cessation	Onset	Cessation	Onset	Cessation	Onset	Cessation	Onset	Cessation
1993	12-Apr	8-Nov	4-Apr	11-Nov	22-Apr	23-Nov	5-Mar	20-Nov	5-Mar	20-Nov
1994	23-Apr	30-Oct	21-Apr	6-Nov	3-May	4-Nov	1-May	2-Nov	20-Apr	23-Nov
1995	21-Mar	1-Nov	21-Apr	3-Nov	10-Apr	19-Nov	10-Apr	14-Dec	5-Mar	3-Nov
1996	10-Apr	4-Nov	21-Mar	19-Nov	31-Mar	12-Dec	31-Mar	12-Oct	26-Mar	4-Nov
1997	24-Mar	12-Oct	10-Apr	3-Dec	3-Apr	10-Oct	3-Apr	18-Oct	31-Mar	14-Dec
1998	2-Apr	28-Oct	24-Mar	23-Oct	26-Mar	11-Nov	26-Mar	11-Nov	26-Mar	28-Oct
1999	24-Apr	31-Oct	2-Apr	18-Nov	29-Apr	2-Nov	29-Apr	1-Nov	11-Apr	6-Nov
2000	1-Apr	11-Nov	24-Apr	11-Nov	12-Mar	5-Nov	21-Mar	14-Nov	12-Mar	3-Nov
2001	18-Apr	27-Nov	19-Apr	12-Nov	10-Apr	14-Dec	19-Apr	5-Nov	19-Apr	6-Dec
2002	4-May	28-Nov	5-Apr	27-Nov	5-Apr	25-Dec	14-Apr	10-Dec	22-Apr	9-Nov
2003	17-Apr	29-Oct	18-Apr	5-Nov	16-Mar	5-Nov	16-Mar	6-Nov	5-Mar	11-Nov
2004	13-Apr	4-Nov	16-May	19-Nov	14-Apr	25-Nov	14-Apr	5-Nov	20-Apr	23-Nov
2005	14-Mar	1-Dec	6-May	8-Nov	15-Mar	22-Nov	15-Mar	2-Dec	3-May	5-Nov
2006	4-May	28-Oct	21-Apr	5-Nov	6-Apr	1-Nov	6-Apr	1-Nov	27-Mar	4-Nov
2007	22-Apr	1-Nov	3-May	26-Oct	18-Apr	5-Nov	18-Apr	5-Nov	31-Mar	16-Nov
2008	14-Apr	26-Nov	11-May	31-Oct	1-Mar	27-Oct	1-Mar	27-Oct	27-Mar	28-Oct
2009	30-Apr	22-Oct	28-Apr	18-Nov	12-Apr	7-Nov	12-Apr	7-Nov	12-Apr	4-Nov
2010	12-May	29-Oct	4-Apr	4-Dec	29-Apr	24-Oct	30-Apr	24-Oct	12-Mar	3-Nov
2011	25-May	8-Oct	5-Apr	14-Nov	28-Apr	31-Oct	28-Apr	31-Oct	19-Apr	5-Nov
2012	10-May	21-Oct	23-Apr	10-Nov	30-May	29-Oct	19-Apr	29-Oct	14-Apr	15-Nov
2013	24-Apr	23-Oct	18-Apr	18-Oct	27-Apr	10-Nov	26-Apr	10-Nov	13-Apr	3-Nov

2014	17-May	9-Nov	16-May	4-Nov	23-Apr	26-Nov	23-Apr	26-Nov	15-Apr	26-Nov
2015	20-May	8-Nov	6-May	8-Nov	10-Apr	27-Nov	10-Apr	12-Dec	2-Apr	12-Dec
2016	14-May	12-Nov	21-Apr	5-Nov	10-May	7-Nov	4-May	5-Nov	11-May	7-Nov
2017	3-May	30-Oct	3-May	20-Oct	27-Apr	4-Nov	27-Apr	4-Nov	22-Apr	1-Nov
2018	15-May	28-Oct	11-May	31-Oct	7-May	2-Nov	7-May	2-Nov	27-Apr	2-Nov
2019	26-Apr	14-Nov	28-Apr	18-Nov	3-May	19-Nov	3-May	19-Nov	6-Apr	19-Nov
2020	23-Apr	28-Oct	4-Apr	29-Oct	2-Apr	12-May	2-Apr	5-Dec	3-Apr	15-Dec
2021	5-Apr	9-Nov	5-Apr	14-Nov	1-Apr	10-Nov	1-Apr	10-Nov	5-Apr	16-Nov
2022	23-Apr	31-Oct	23-Apr	10-Nov	7-May	14-Nov	5-May	14-Nov	24-Apr	11-Nov

Source: Computed from the data obtained at UBRBDA

The results revealed that onset of rain in the last decade (2012-2022) has changed from March-April to April-May in Ibi, Wukari and Donga while at Takum and Ussa, the shift was observed from March to April from the previous decades. These findings are slightly different from Adebayo (2002). However, one striking situation observed in all the stations is that, as onset date shifts upward, cessation remains unchanged. This may be connected with changes in the movement of the two Air masses the continental air mass and the maritime air mass over the country over the last decade as the advent and of the two air masses remain unchanged. The implication of this finding is that farmers in the area need to plan their schedules from planting and harvesting and to adjust their planting dates so that they won't be caught up went rainfall ceases.

3.2 Length of Rainy Season

The length of rainy season in the study area was calculated and the result is presented in Table 6.

Table 6: Descriptive Characteristics of the Length of Rainy Days

	Years	Range	Minimum	Maximum	Sum	Mean	Std. Deviation
IBI	30	87	164	251	5909	196.97	21.750
WUKARI	30	74	171	245	6045	201.50	20.986
DONGA	30	78	179	257	6389	212.97	22.789
TAKUM	30	83	179	262	6455	215.17	25.696
USSA	30	76	182	258	6546	218.20	20.112

The results in Table 6 show that mean number of rainy days in the study area varies from 164 days in Ibi in the northern part of the study area to 262 days in Takum in the southern part. This leads to a significant difference of 21 days between Ibi and Ussa. The increase in the length of rainy days is progressive as one moved away from Ibi to Ussa. As such, the length of rainy days increased by 5 days representing 2.5% increase from Ibi to Wukari, while the number of rainy days in Donga increases with 11 days representing 5.2% from that of Wukari. In Takum, the rainy days increase with 2 days from that of Donga but however, in Ussa the increase is just 3 days from Takum. Although, the increases were insignificant between stations for agricultural planning, it is worthy of note that there are significant differences in the length of rainy days between Ibi and 3 stations namely; (Donga, Takum and Ussa) and the increase is the progressive southwards from Ibi. The results presented in Table 6 also revealed that mean number of rainy days in the study area were slightly above 200 days during the period under study with the exception of Ibi. Ironically, Ibi is the area that suffers from seasonal flooding. This means the flooding is unconnected with either the intensity of rain or the length of rainy days but its location along the bank of the river Benue. Figure 5 shows mean length of rainy season in the study area.

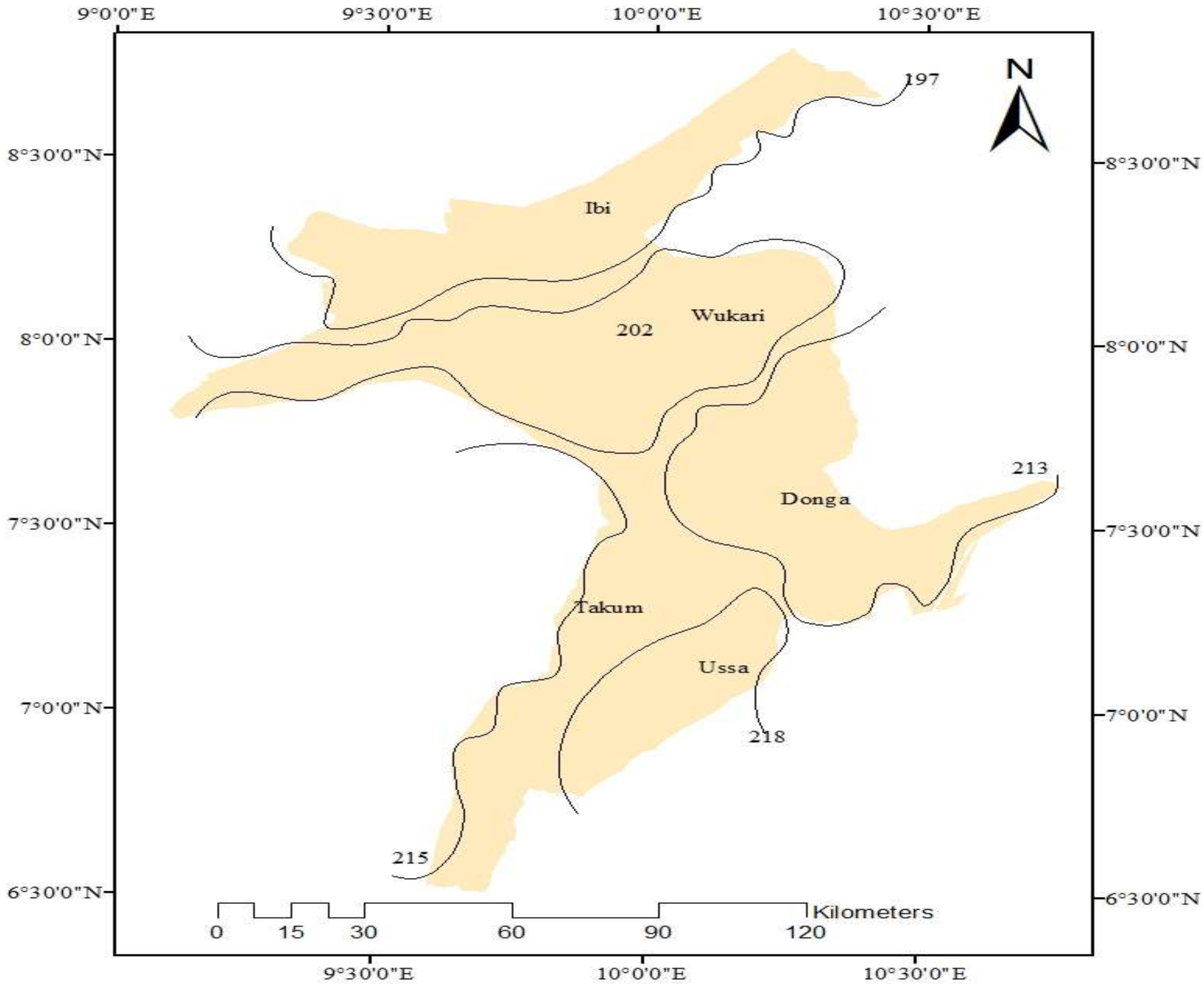

Fig.5: Mean length of rainy days

4. Conclusion

From the analysis of the results of this study, the following conclusions we can drawn; The average annual rainfall in the study area for the period 1993-2022 varied between 733.85 mm at Wukari station to 2238.41 mm at Donga station. Ibi, Donga and Takum areas are characterized by negative values of the linear trend (Takum -217 mm/10 years, Donga -64.5 mm/10years and -25 mm/10years) indicating decrease in the precipitation amount in the period (1993-2022). From the analysis of the annual precipitation amounts for the period 1993-2022, we can summarize that the year with least rainfall less than 1000 mm was 2012 while the year with the highest rainfall is 2021. It can also be concluded that onset of rain in the last decade (2012-2022) has change from March-April to April-May in Ibi, Wukari and Donga while at Takum and Ussa too, the shift was observed from March to April from the previous decades. Rainy days in the study area varies from 164 days in Ibi in the northern part of the study area to 262 days in Takum in the southern part.

Base on the results of this study the following recommendations were made :

i. Farmers should take advantage of the lengthy periods of rain in the area to cultivate early maturing crops especially crops such as maize, rice and groundnut twice in order to improve their agricultural productions

ii. Yam which is the major tubers crop cultivated in the area should be planted early to avoid heavy rainfalls received in September to avoid damages to their crops as heavy rainfall at maturity stage of yam is capable of damaging the yam

The study also recommends proper dissemination of agro-climatic information for appropriate adjustment and adaptations by farmers in the study for sustainable agricultural development. The research also recommends a further study that will cover the whole of Taraba state for better information for a sustainable agricultural planning.

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