International Journal of Environment and Climate Change

Volume 12, Issue 12, Page 926-935, 2022; Article no.IJECC.77158
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Analysis of Rainfall Trend and Pattern in Owerri, Imo State, Nigeria

Agidi Victor Akamuga [a*], Uchechukwu Isaac Ogbonnaya [a] and Ulor Chukwuemeka [a]

[a] Department of Environmental Management, School of Environmental Science, Federal University of Technology, Owerri, Imo State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i121532

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/77158

Original Research Article

Received: 09/10/2021
Accepted: 16/11/2021
Published: 26/12/2022

ABSTRACT

The study analyzed the rainfall trend and pattern for Owerri municipal, Imo state. The data collected is secondary. A remote sensing daily rainfall data from 1981 to 2020 from CHIRPS data archive given in millimeter (mm) was downloaded. In order to achieve the aim of the research, data analysis was conducted on the rainfall data. Some of the statistical methods used includes mean, variance, standard deviation, coefficient of variation, and standardized anomaly index (S.A.I). The annual rainfall and monthly rainfall for Owerri municipal, Imo state were analyzed and charts were presented which show fluctuation in rainfall trend and pattern. The least annual rainfall happened to be in 1983 of about 1662.9mm, which is followed by that of 2001 of 1828mm. The wettest annual rainfall occurred in the year 1995 of 2962.2mm which happened to be the peak of the study, followed by 1999 of 2837.9mm. It was shown that the month July from 1981 to 2020 experienced more rainfall than that of August. The four decadal rainfall presented for the study shows; near normal condition to very wet condition (1981 – 1990), near normal condition (1991 – 2000), extremely dry conditions to near normal condition (2001 – 2010), and near normal condition to extremely dry condition (2010 - 2020). The hypothesis was tested using chi-square, the results shows there is no significant difference in trend and pattern of rainfall in owerri, thus, the null

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**Corresponding author: E-mail: victor.agidi@gmail.com;*

hypothesis was accepted. The study generally show there is a little or no singnificant change in the rainfall pattern and trend in Owerri from 1998-2020 and hence recommend that there should be more monitoring of rainfall activities in order to curtail it excesses in flooding and agricultural loss.

Keywords: Rainfall; trend; pattern.

1. BACKGROUND TO STUDY

Globally, investigation on rainfall variability and trend analysis has been in practice over the years; determining the sudden changes of rainfall pattern in different regions. Rainfall is the most critical meteorological phenomenon on earth for the natural environment and human life, making it the most vital ecological factor [1] cited in [2]. Rainfall is categorized as a form of precipitation in the hydrological (water) cycles. Rainfall can be described as the droplet of water on the earth's surface due to over-saturation of condensed water vapour in the atmospheric cloud [3].

Over the years, researchers have shown that climate change constitutes to earth's system variability in different regions. Thus, it was discovered that the hydrological process of water cycle has being affected by climate change. In addition, the Intergovernmental Panel on Climate Change [4] quoted that Precipitation and temperature are the two most importance variable in the field of climate sciences and hydrology frequently used to trace extent and magnitude of climate change and variability. However, the increase in air temperature and variability in precipitation are already evident in different parts of the world and their impacts on the environment (e.g., ecosystem and biodiversity) and human system are becoming evident [5]. The study on precipitation has received much attention as understanding rainfall patterns is necessary for assessment of climatic change, managing agricultural issues and also water resources management over the past few decades [6] cited in (Mekonnen et al. 2021); [7] cited in [8].

Evidently, analysis on rainfall trend and pattern in Imo state have shown the following problems associated with such as increase in amount of rains, increased number of rainy days, flooding occurring at shorter intervals, landslide especially in erosion prone areas, formation of gullies, increase rate of pest and disease, and waste pollution in the environment [9-12] cited in [13]. The need to analyze rainfall trends and patterns for this sectional area in Imo state is to provide answers on the variation of rainfall in Owerri municipal that is, to the duration and intensity of rainfall in the area. And also prevent future hazard such as gullies formation, flooding etc, established the need for drainage system and measure to utilize the water supply. For instance, agriculture which is the primary source for livelihood communities, people living in the area will be of interested to understand the rainfall trend and pattern there. However, there is little or no work of such in Owerri municipal of Imo state hence necessitates the study. Therefore aim for the study is to analyze rainfall trend and pattern in Owerri municipal.

1.1 Hypothesis

There is no significant different in rainfall trend analysis from 1981 to 2020 in Owerri Municipal.

1.2 The Study Area

Owerri municipal is a Local Government Area in Imo state, located at the southeastern region of Nigeria. It has an area of 58 km² and a population of 127,213 according to the 2006 census. According to Imo State [14], the state lies within latitudes 4°45'N and 7°15'N, and longitude 6°50'E and 7°25'E with an area of around 5,100 sq km, estimation on population as for 2016 stand at about 1,401,873. It has intersection of roads from Port Harcourt, Onitsha, Aba, Orlu, Okigwe and Umuahia. Fig. 1 illustrates the geographical area of Owerri municipal, Imo state. It is known as the trading center for palm products, corn [maize], yams and cassava [manioc]. This region experiences two seasons every year which are Dry (Harmattan) Season and Wet (Rainy) Season. Having an average annual temperature of above 20°c (68.0°f), creates an annual relative humidity of 75%, with humidity reaching 90% in the rainy season. Rainy season begins in April and last till October [14].

The Southeast region is said to be hot and wet, dry in the Southwest and a steppe climate with little precipitation is found in the far North over the years, the length of the rainy season decreases from South to North.

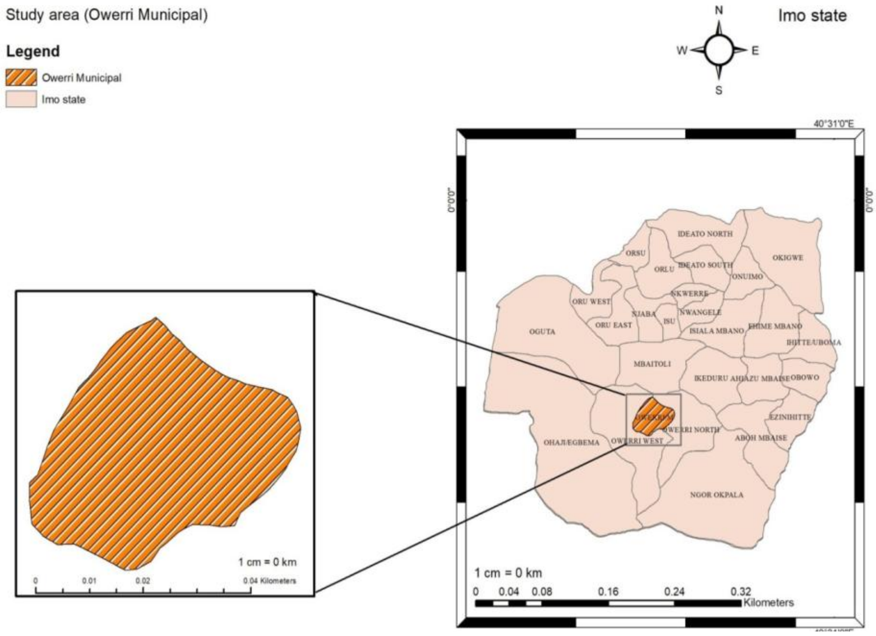


Fig. 1. The Geographic Location of Owerri municipal, Imo State Nigeria

There is a marked interruption in the rains which occurs in August in the Southern region, resulting in a short dry season often referred to as the "August break". This break enables the region to harvest and plant in crop for the next period of rainfall, making it to have a double period of rainy season ("*Nigeria – climate*", 2020). Thus, it is known that the Southern regions (Owerri inclusive) of Nigeria experience more rainfall than the far North [15].

2. METHODOLOGY

2.1 Type of Data

The rainfall data from 1981-2020 used for this study is purely secondary, downloaded and extracted from a remote sensing file.

2.2 Source of Data

The rainfall datasets were obtained from the CHIRPS data archive. The data were downloaded from these web archived saved in Network Common Data File (Net CDF) format. This Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) was developed by the United State Geological survey (USGS), which uses a Cold Cloud Duration from thermal infrared with a similar approach to the one of the TAMSAT. The station data is blended through two phase processes, which yields a preliminary rainfall product with 2-day latency, sparse World Meteorological Organization's Global Telecommunication System (GTS) gauge data are blended with CCD-derived rainfall estimates at every pentad. In the second phase, which yields a final product with an average latency of about 3 weeks, the best available monthly (and pentadal) station data are combined with monthly (and pentadal) high resolution CCD based rainfall estimates to produce fields that are similar to gridded monthly station [16].

2.3 Methods for Analysis

Descriptive statistics such as charts, tables were used for the studies, as well as inferential statistics such as mean, range, variance, standard derivation, coefficients of variation and standardized anomaly index. Simple regression analysis was carried out on the data to show the trend analysis of the annual and decadal data. Wettest and driest years were also analysed and represented in charts. The hypothesis was tested using chi-square. The model used are explained as follows;

2.4 Coefficient of Variation

This is used to compare the variability of any two distributions which may be measured in different units. It is expressed as a percentage of the standard deviation to the arithmetic mean.

In mathematical notation;

Coefficient of variation = $\frac{standard\ deviation \times 100\%}{Mean}$ *Equation1*

The model method gives answer to objective 1, 2, & 3, which determines the amount of rainfall experience in each month of the years.

2.5 Standardized Anomaly Index (S.A.I)

Standardized Anomaly Index calculates the difference between the annual total of a particular year and the long term average rainfall records divided by the standard deviation of the long term data.

In mathematical notation;

$$X_j = \frac{r_{ij} - \bar{r}_j}{\delta_i} \quad \textit{Equation 2}$$

Where,

X_j = Normalized departure
δ_i= Standard deviation
r_{ij} = Annual rainfall for the station in the year j
$\bar{r}_j$= Mean annual rainfall for the station i

Table 1. Standardized anomaly index (McKee, 1993)

S.A.I Value	Category
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely wet

The table above provides the index of rainfall intensity in any geography area. This model provides answer to objective 3 by determining the wettest rainfall from 1981 to 2020.

2.6 Hypthosis

Null hypothesis was tested using chi-square.

$$X^2 = \sum \frac{(OR - ER)^2}{ER} \quad \textit{Equation 3}$$

Where,

OR= the observed rainfall outcomes
ER= the expected rainfall outcomes
$\sum$ = the sign of summation.
X^2 = Chi square

For further analysis using the critical value or chi-square tabulated X^2, we deduce;

$$Df = (r - 1)\,(C - 1) \quad \text{Equation 4}$$

Where,

Df = degree of freedom
r = the number of rows
c = the number of columns
Alpha ($\propto$) = the level of significance or confidence limit (0.05, 0.01 and 0.001).

3. RESULT PRESENTATION AND DISCUSSION

3.1 Decadal Rainfall

This analysis revealed decadal rainfall trend and pattern of the study area with their standardized anomaly index values.

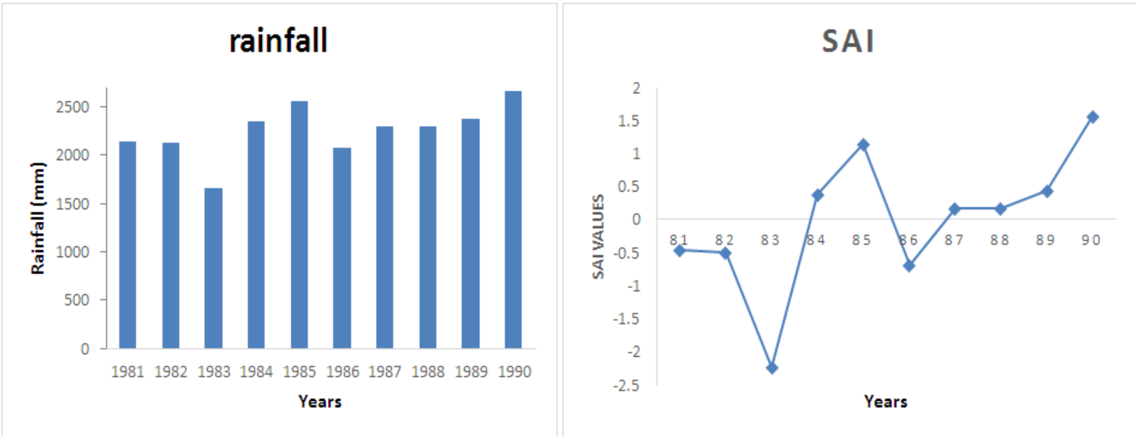
Fig. 2a shows 1981 to 1990 decadal rainfalls fluctuations with an increase in trend analysis of 2133.5mm in 1981 and 2667.4mm in 1990. According to S.A.I value (Fig. 2b), 1981 rainfall is said to be -0.4 (meaning “near normal” condition) while 1990 rainfall is said to be 1.56 (i.e “very wet”). However, 1983 is recorded to have the lowest rainfall of about 1662.9mm.

3.1.1 Decadal rainfall from 1991 TO 2000

Fig. 3a shows decadal fluctuation in rainfall from 1991 to 2000 with a slight increase in trend pattern of about 2413.7mm to 2454.5mm and the S.A.I value (Fig. 3b) are -0.1 and 0.03 respectively (i.e. “near normal”). The peak of rainfall on this chart is 1995 of about 2962.2mm with the S.A.I value of 2.03 (extremely wet). Also, 1992 accounted as the lowest rainfall on the chart having 2040.4mm.

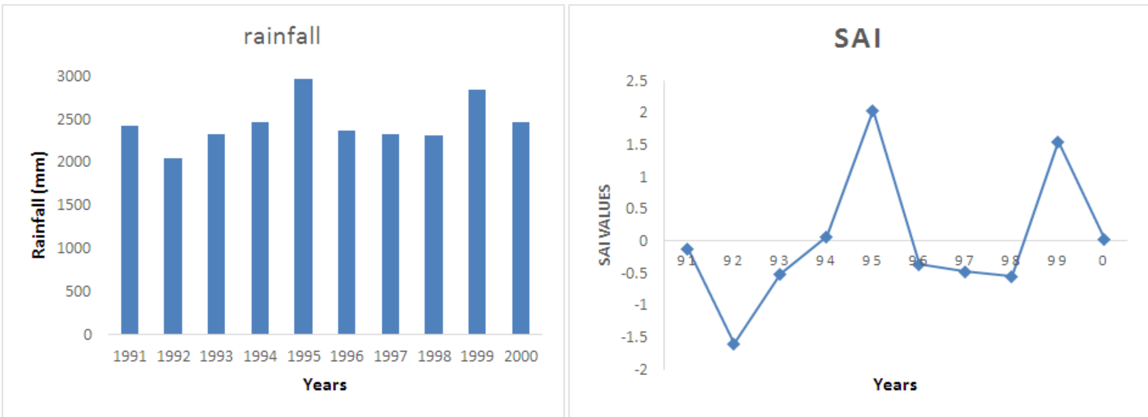
Fig. 4.a shows fluctuation in decadal rainfall from 2001 to 2010 with an increase in rainfall trend analysis of 1828.9mm to 2579.7mm. The S.A.I values (Fig. 4b) presented that -2.6 in 2001 (extremely dry) and 2010 as 0.99 (near normal). Thus, 2001 has the lowest rainfall while the peak happened to occur in 2008 of 2623mm with the S.A.I value of 1.19 (moderately wet).

Fig. 5a shows the decadal rainfall distribution chart from 2011 to 2020 which is said to be 2640.4mm to 745.1mm. Thus, the data analysis for 2020 were calculated from January to June. However, 2013 rainfall is said to have the lowest rainfall of about 1927.2mm and its peak in 2019 of 2711.4 mm. Fig. 5b shows SAI valve fluctuations that 2013 having -0.45 and 2019 of -0.99 (near normal).



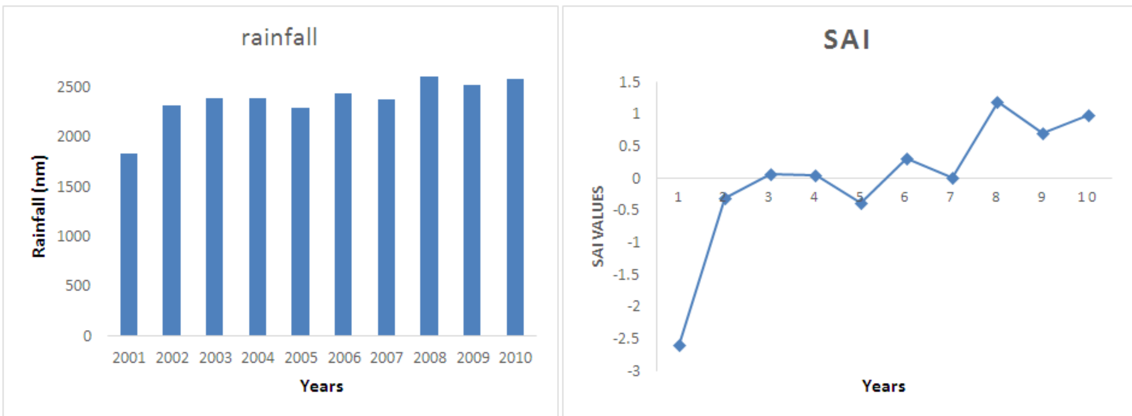
2(a) 2 (b)

Fig. 2. Decadal rainfall from 1981 to 1990



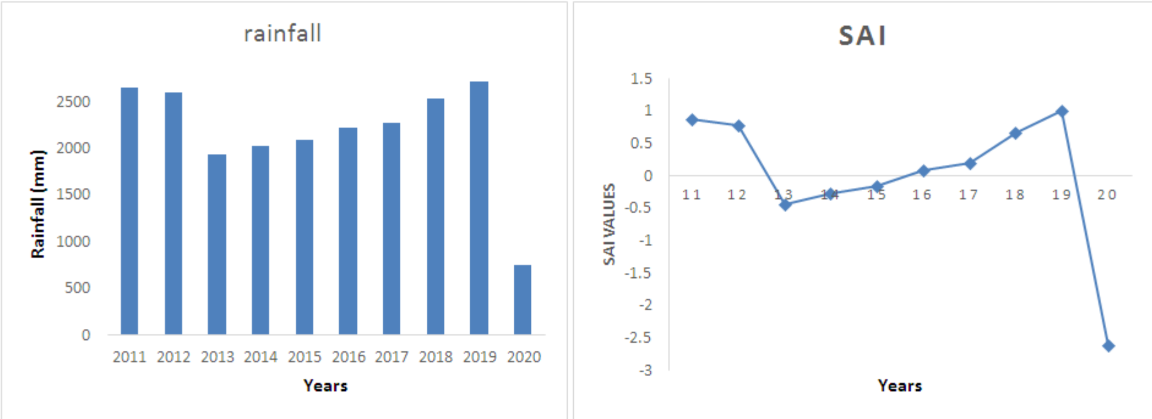
3(a) 3 (b)

Fig. 3. Decadal rainfall from 1991 to 2000



4(a) 4 (b)

Fig. 4. Decadal rainfall from 2001 to 2010



5(a) 5 (b)

Fig. 5a and 5b. Decadal rainfall from 2010 to 2020

Therefore, the following rainfall patterns were observed for the different decade analysis;

- 1981 – 1990 were near normal to very wet conditions rainfall distribution.
- 1991 – 2000 were near normal conditions in rainfall distribution.
- 2001 – 2010 were extremely dry to near normal condition in rainfall distribution.
- 2010 – 2020 were near normal to extremely dry conditions in rainfall (based on 2020 data were from January to June).

3.2 The Wettest Annual Rainfall

Based on the Standardized Anomaly Index from 1981 to 2020, 10 wettest years that occur during the period were observed to illustrates the interval of which the years experienced high rainfall.

Fig. 6a shows the SAI of rainfall fluctuations from 1981 to 2020 where the 10 wettest rainfall were selected. Fig. 6b present the wettest years; 1985, 1990, 1995, 1999, 2008, 2010, 2011, 2012, 2018, & 2019. Their S.A.I index illustrate the following "near normal", "moderately wet", & "extremely wet" in respective to their values. Thus, from the chart (Fig. 6b) 1985, 1990& 1995 were 5years, 1995 to 1999 was 4years, 1999 to 2008 was 9years, 2008 to 2010 took 2years, 2010, 2011 &2012 were a year, 2012 to 2018 was 6years while 2018 to 2019 was a year interval to experience their wettest rainfall.

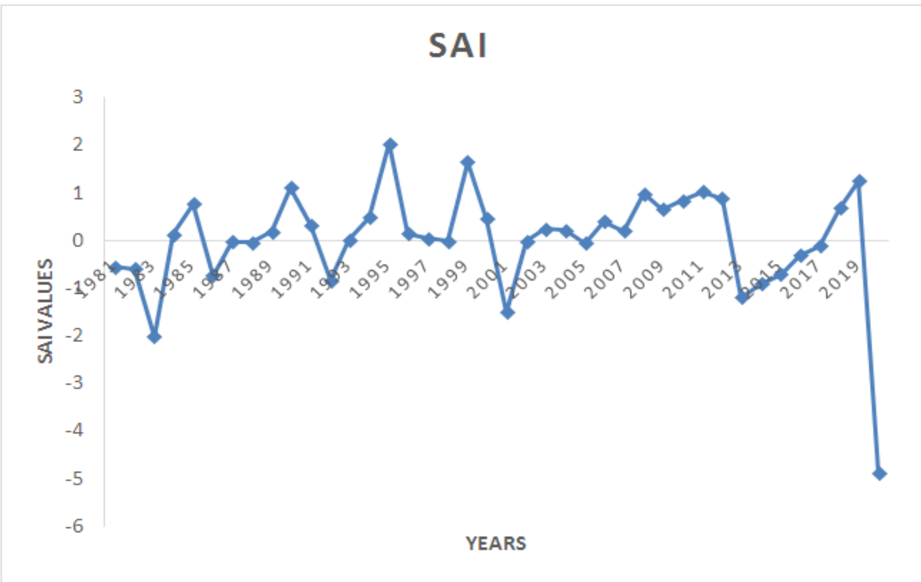


Fig. 6a. Wettest rainfall analysis

Table 2. Chi square test from 1981 to 1990

Decadal rainfall	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Observed value (O)	177.79	176.81	138.58	196.08	212.99	172.76	191.73	191.41	197.58	222.28
Expected value (E)	187.80	187.80	187.80	187.80	187.80	187.80	187.80	187.80	187.80	187.80
O – E	-10.01	-10.99	-49.22	8.28	25.19	-15.04	3.93	3.61	9.78	34.48
$(O - E)^2$	100.20	120.78	2422.61	68.56	634.54	226.20	15.44	13.03	95.65	1188.87
$(O - E)^2/E$	0.5335	0.6431	12.900	0.3651	3.3788	1.2045	0.0822	0.0694	0.5093	6.3305

Total = 26.016; Using the mean annual rainfall with the interval of ten (10) years we are able to determine, the hypothesis was determined; Degree of freedom, Df= (r-1) (c-1); = (2-1) (10-1); = (1) (9); = 9; At confidence limit 0.001 (99.999%), X^2_t = 27.878; According to Table 1 since 27.878 > 26.016; we therefore, accept the null hypothesis (Ho).

Table 3. Chi square test from 1991 to 2000

Decadal rainfall	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Observed value (O)	201.14	170.03	192.88	205.34	246.85	196.23	193.58	192.06	236.49	204.54
Expected value (E)	203.91	203.91	203.91	203.91	203.91	203.91	203.91	203.91	203.91	203.91
O - E	-2.77	-33.88	-11.03	1.43	42.94	-7.68	-10.33	-11.85	32.58	0.63
$(O - E)^2$	7.70	1148.13	121.75	2.03	1843.50	59.04	106.79	140.52	1061.20	0.3919
$(O - E)^2/E$	0.0377	5.6304	0.5971	0.0100	9.0406	0.2896	0.5237	0.6891	5.2041	0.0019

Total = 22.0242; Table 2 has the same interval with Table 1; Thus, at confidence limit of 0.005 (99.995%), X^2_t = 23.589; Therefore, Table 2: 23.589 > 22.0242, we therefore, accept null hypothesi

Table 4. Chi square test from 2001 to 2010

Decadal rainfall	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Observed value (O)	152.41	192.26	198.88	198.38	191.1	203.12	197.92	218.58	210.08	214.98
Expected value (E)	197.77	197.77	197.77	197.77	197.77	197.77	197.77	197.77	197.77	197.77
O – E	-45.36	-5.51	1.11	0.61	-6.67	5.35	0.15	20.81	12.31	17.21
$(O - E)^2$	2057.53	30.36	1.2321	0.3721	44.49	28.62	0.022	433.06	151.54	296.18
$(O - E)^2/E$	10.4036	0.1535	0.0062	0.0019	0.2250	0.1447	0.0001	2.1897	0.7662	1.4976

Total = 15.3886; Table 3 has the same interval with Tables 1 & 2; Thus, at confidence limit 0.05 (95%), X^2_t = 16.92; Therefore, Table 3, 16.92 > 15.3886, we accept Ho

Table 5. Chi square test from 2011 to 2019

Decadal rainfall	2011	2012	2013	2014	2015	2016	2017	2018	2019
Observed value (O)	220.03	216.1	160.6	168.35	173.77	184.4	189.39	210.63	225.95
Expected value (E)	194.36	194.36	194.36	194.36	194.36	194.36	194.36	194.36	194.36
O – E	25.67	21.74	-33.76	-26.01	-20.59	-9.96	-4.97	16.27	31.59
$(O - E)^2$	659.06	472.72	1139.59	676.40	423.86	99.16	24.68	264.79	998.07
$(O - E)^2/E$	3.3910	2.4322	5.8633	3.4802	2.1808	0.5102	0.1270	1.3624	5.1352

Total = 24.4823; From Table 4, using nine (9) interval from 2011 to 2019, due to 2020 we have data of six (6) month, in order to prevent error in the hypothesis test, 2020 data analysis is omitted from the test; Degree of freedom, Df = (r-1) (c-1); = (2-1) (9-1); = (1) (8); = 8; Thus, at confidence limit 0.001 (99.999%), X^2_t = 26.125; Table 4: 26.125 > 24.4823, we accept Ho

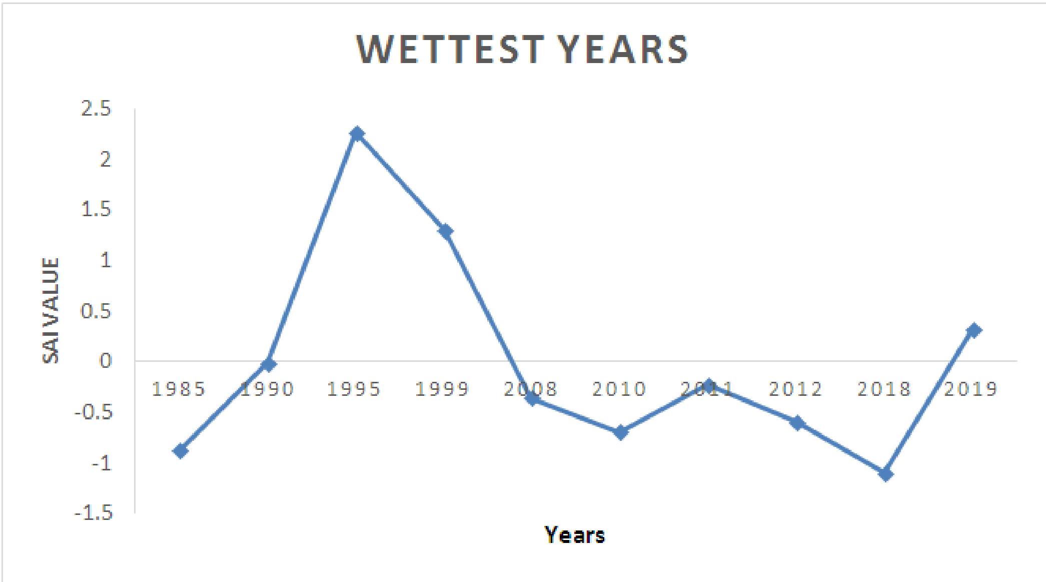


Fig. 6b. Wettest rainfall analysis

3.3 Hypothesis

The observed rainfall values obtained for 1981 to 2020 and the expected rainfall values obtained using moving average were used to determine the hypothesis.

Using decadal data to check the viability of trend, for all the three decades of 19-80-1990, 19191-2000, 2001-2020 the null hypothesis need to be accepted. Thus it can be said that there is no significance difference in rainfall trend in Owerri from 1980 to 2020.

4. SUMMARY, CONCLUSION AND RECOMMENDATION

The study assessment analyzed the rainfall trend and pattern in Owerri municipal, Imo state. The result shows fluctuations in the monthly rainfall, annual rainfall, decadal rainfall, and wettest rainfall variation in respect to the climatic conditions. The standardized anomaly index (SAI value) determine the rate at which rainfall occur in the area. This result implied that Owerri municipal had a significant increase in rainfall trend and pattern from 1981 to 2019. Chi-Square test provides the hypothesis test which prove that there is no significant different in rainfall trend analysis from 1991 to 2019.

However, with reference to rainfall distribution chart, the month with the higher rainfall is said to be July, which experienced high variations between 210mm and 637mm from 1981 to 2019. The month of August which is known for short dry season experienced more rainfall than June. Thus, the month of December from 1981 to 2019 is said to have the lowest rainfall.

4.1 Conclusions

Analysis of rainfall trend and pattern is increasingly becoming important owing to the fact that most people in the study area rely on rainfall for farming and also for the precarious nature of the area to flood. The study has found out that the rainfall trend from 1981 to 2020 is almost the same thus farmers and government need to take note and developed mechanism to take the advantage of this.

4.2 Recommendation

Based on the analysis done on the rainfall trend and pattern in Owerri municipal, the following should be taken into consideration;

- More studies should be done and perhaps annually to help both Government and Farmers to plan effectively.
- More careful attention should be given to the perennial flooding in the town because the rainfall trend is not decreasing.
- Farmers should account on the month of April - October for the cultivation of crop. These months experience a minimum rainfall of 100mm. Thus, the rainfall condition of these months is favourable in cultivating crop

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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