American International Journal of Contemporary Research
ISSN: 2162-139X (Print), 2162-142X (Online)

Original Article | Open Access | Peer Reviewed

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Long Term Trends and Patterns of Rainfal: Implications on Climate Resilience and Water Resources Management in Osogbo, Nigeria

ADEWOYE, Olugbenga Adewale[1]

[1] Department of Surveying and Geoinformatics, Osun state College of Technology, Esa-oke; waleadewoye@gmail.com; Phone: 07036916399.

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Address for Correspondence:

ADEWOYE, Olugbenga Adewale, Department of Surveying and Geoinformatics, Osun state College of Technology, Esa-oke. (waleadewoye@gmail.com)

Article History:

Published: 28 August 2025

Abstract Rainfall as major element of climate is varying due to the anthropogenic effect and climate change. to understand the implication on climate resilience and water resources management. it is appropriate to review the trend and pattern. Data for the study was obtained from the secondary source. Rainfall data from (1992-2023) collected from the Nigeria Meteriological Agency (NiMet) was the major data for the study. The data was analysed using Timeseries analysis and histogram. From the analysis, it was revealed that 2021 has the highest annual rainfall while 2005 has the least. The time series has a skwewness value of 0. 226426. It also revealed that the dry season is becoming wetter and the raining season is experiencing rainfall anomaly. The study recommended a sporadic action on early warning system to improve the quality of weather forcast to assist in climate resilience and water management.

Keywords Pattern, Rainfall, Resilience Trend, and water Resources

Volume 15, 2025

Publisher: The Brooklyn Research and Publishing Institute, 442 Lorimer St, Brooklyn, NY 11206, United States.

DOI: https://doi.org/10.30845/aijcr.v15p4

Reviewers: Opted for Confidentiality

Citation: Adewoye, O. A. (2025). Long Term Trends and Patterns of Rainfal: Implications on Climate Resilience and Water Resources Management in Osogbo, Nigeria. *American International Journal of Contemporary Research*, *15*, 34-42. https://doi.org/10.30845/aijcr.v15p4

Background to the Study

There is a spatial-temporal variation of earth climate with seasons, decades, centuries and even longer times. The variations may be hot or wet, cold or dry, stormy or quiet etc. This is generally known as climate change. Climate change is a contemporary global challenge that is currently facing humanity. There has been a call for action among the world leaders to curtail the threat of climate change and its consequences. Measures have been put in place to mitigate the effects and adaptive measures are also put in place to ameliorate the consequences.

Rainfall is one of the major elements of climate. It is the total amount of rain that falls within a particular region within a period of time. It is normal when it falls within one standard deviation above or below long term it varies mean; otherwise. (Ayoade, 2004)

Olaniran (2002) found out that the mean annual rainfall in Ilorin, Nigeria using 1971-2000 rainfall data is 1200mm. any other years at Ilorin will be described in terms of departure from the normal. The 1999 annual rainfall of 1530mm is 27. 5% above normal while year 2000 990. 3mm of 17. 5% below normal are departures known as variability. Rainfall trend therefore shows the pattern of deviation from the normal over a given period of time. A persistent deviation constitutes some climatic fluctuations which usually refer to as climate change.

In Osogbo, Nigeria, the trend and the pattern of rainfall is noticeable through rainfall variability. This is the change in the frequency, occurrences, intensity of extreme weather events like flood, drought, erosion etc.

Rainfall is one of the key climatic elements that determine the space of economic activities in Osogbo, Economic activities are affected by the rainfall characteristics of the region. For instance, rainfall the main source of water resources determines the types of crops to grow, the period of cultivation of crop, the post-harvest practices and the type of farming system to be practiced in the region. Statistical evidences have shown that rainfall is varying with a consequence effect on the economic activities in the area. Invariably with the current trend of event in rainfall characteristics of the area, it is very important for scientific explanation to provide in-depth study.

Osogbo is the capital city of Osun and the headquarter of Olorunda and Osogbo local Government Area. It is located within Lat 7^0 46^i. 74^{ii}N and Long 4^0 33^i 25^{ii}E. The climate of Osogbo, Nigeria is tropical; that it is hot and cold. The raining season begin from April to October while the dry session begins from November and end in March. The mean temperature is 27°c while the mean annual rainfall is about 13000mm. the nrainfall in the city is influenced by the inter tropical convergence zone (ITCZ) that bring moisture from the Atlantic Ocean and the Gulf of Guinea and also influenced by the southwest monsoon wind.

The average relative humidity in the raining season is around 75 to 85%. while temperature in the raining season is around 22°c to 32°c while in the dry season; the temperature is around 17°c to 27°c.

The city has a diverse geology which is composed of rocks from the pre-Caribbean Paleozoic and cretaceous periods, the rock types include granite, gneiss, schist and quartzite.

The topography of the city is characterized by low-lying plains and hills. And the vegetation of the city is primarily rainforest with patches of savanna in the north. it is a highly diverse city with a wide range of socio-economic activities. The most significant socio-economic activities include: Agricultural production, especially food crops like cassava, yams, rice and maize. Cultural tourism is also very important.

Research Questions

What is the trend and pattern of rainfall in the southwest Nigeria in the last thirty years?

Trend and pattern of rainfall in Osogbo, Nigeria

Rainfall is water droplet from the atmosphere condensed from the atmospheric cloud. It is very important in water cycle because it is the source of freshwater deposited in the earth surface. It is a major factor in the existence of the natural ecosystem.

There are many factors that influence trend and pattern of rainfall Osogbo, Nigeria. This includes EI Nino, and movement of inter tropical discontinuity. EI Nino and La Nino are two phases of EI Nino Southern Oscillation (ENSO) which is recurring climate pattern around the world. The inter-tropical discontinuity (ITD) is the commonest

accepted mechanism that affects rainfall distribution in Africa. (Clackson 1960; Obasi 1965; Mbele Abong 1974; Ayoade 1988; Ilesanmi 1981; Lamb 1983; Adejuwon Balogun and Adejuwon 1990).

In Osogbo, Nigeria, rainfall is of two regimes, the Bi-modal maximum South of 10^{o}N and a single maximum North of this latitude. The distribution is as a result of seasonal movement of inter-tropical discontinuity (ITD).

The knowledge of rainfall over a period of study in temporal and spatial scale is very important in studying. (Abiodun; and Gunnar 2016). In Nigeria, rainfall patterns have also become more varied in recent years. In the southern part, rainfall has become less reliable with frequent drought and floods. In the north rainfall has become more intense, leading to increased flooding and damage to infrastructure. Studies for rainfall variability have been realized in some part of the world.

Gonzalez Hidalgo and Deluis (2010) found out in the analysis of Woler planning Division confirmed that precipitation trends over the period of 1946-2005 with very low significant level for the total annual amount and for the wet and dry seasons. Consequently, significant and spatially current trends were identified on a monthly scale.

Jayawardere, Sonnadara and Jayewondere (2010) observed rainfall trend in Sri Lanka with centenary data. They confirmed that some part experiencing decreasing trend, some on the increase while some indifference. This shows that trend characteristics varies with the duration of the analyzed data.

Smadi and Zghol (2010) studied trend analysis of rainfall in Jordan using three variations. The study was done using a dataset of 81 years (1922-2003). They observed different trend for different seasons across different locations. For example, one of the locations shows different in raining days and total amount of rainfall after the mid-11950s.

Partal and Kahya (2016) examine trend within 64 years' period (1929-1993) of rainfall for 96 stations, the result they obtained confirm that the trend in precipitation is downward, with some increasing trend. Aji, stigler and Oladapo (2012) studying rainfall data from nine stations for 50 years (1963-2012) in Northern Nigeria found out that Ilela' 5 year running showed rainfall in the increase up to 1970. However, it is decreasing from 1970s-2010. For Kaduna station, rainfall is on the increase but from early 1980s to 2010 rainfall was below the long-term mean.

Zaria station showed annual rainfall above long term mean from 1970s to 2010. It was below the mean. The Potiskum's leadings showed annual rainfall above the long term mean around 1970s and declining from 1970s. Kano zone also has a similar trend with slight increase before 1970 and consequent declining from 1970s to 2010.

Ologunorisa (2016) assessing the annual trend of rainfall in Makurdi for 77 years (1927-2014) using spearman rank correlation coefficient statistics confirmed that the annual rainfall trend on the period of consideration have a negative correlation coefficient of -0. 3-0. 31. The significance of the trend was also tested by the student's T test and was found to be at 95% confidence level.

This confirmed that there was a downward trend in the annual rainfall in Makurdi town. Abaje; Isahaya and Usman (2015) studied mean (x) standard deviation (SD) coefficient of variation (CV) standard coefficient of skewness (Zi) kurtosis (Zz) of rainfall for Kafanchan from April to October and annual, the result show that standard variation coefficient of skewness (Zi) and Kurtosis (Zz) showed that all the months and annual were accepted as indicative of normality of the 95% significant level, with the exception of Zi and Zz).

Ogolo and Adeyemi (2009) in their study in the variation and trends of meteorological parameter in Ibadan observed a downward trend of rainfall between 1988-1990 with a slight increase around 1991-1993 followed by a drought year of 1994 which dropped to the minimum.

Enete and Izuchukwu (2009) carried out a study on Enugu and observed that there is a decline in rainfall values in recent times. The values varied between 265. 37 and 320. 21mm.

The studies include Gobo (1998), Mc Ewen (1999), Orivia (2004), Babalolu (2010); Fowler and Kilsby (2013) Odekunle (2010) and Ologunorisa 2010, 2014). Other studies like Olaniran 1993; Ologunorisa 2013, Dayi 2015) focused majorly on causes of flood by rainfall variability, intensity, duration, frequency seasonally, variability trend and fluctuation.

Theoretical framework

The Inter-tropical discontinuity (ITD)

The term Inter-Tropical discontinuity (ITD) proposed by World Meteorological Organization (W. M. O) Provisional Guide to Meteorological practices aptly describes this moisture boundary on land. Nigeria receives rainfall from the southwesterly which invade the country from the Gulf of Guinea coast, i. e. the tropical Atlantic. This moist airstream is overlaid by the northeast trade wind which originate from above the Sahara and are thereby dry and dust laden. The zone of contact of the two air masses at the surface is a zone of moisture discontinuity and it is known as the Inter Tropical Discontinuity (ITD) zone.

The ITD advances inland as far as 22-25^{0}N in August at the margin of the Sahara i. e. considerably beyond Nigeria's northern border (Adejokun 1964; Adedokun, 1978) while it does not retreat equator-ward beyond 4^{0}N latitude during the "Harmattan" dry season (Adefolalu, 1983).

Five weather zones are associated with the ITD. Zone "A" to the north of the ITD is rainless as well as Zone "B" to the immediate south because they do not contain rain-producing clouds. Rainfall in the ITD occurs in zones "C" and "D" where conditions favor the development of clouds of great vertical extent. Thunderstorms and squall lines are associated with zone "C" weather and monsoon rains with Zone "D" weather. Consequently, rainfall is spatially discontinuous when Zone "C" weather prevails. On the other hand, the monsoon system gives continuous rains which may last 12 hours or more (Olaniran, 1995).

Overall, rainfall occurs at a distance of about 500km south of the surface location of the ITD, 4-6 weeks behind it in its annual cycle. When the fifth weather type associated with the ITD i. e. zone "E", prevails over an area, light rainfall usually results because Zone "E" weather is dominated by layered strati-form clouds.

The position of the ITD fluctuates seasonally and the different ITD zones affect different areas of the country at various times. Between January/February and August, the ITD migrates northward and there is a corresponding shift northward of the area of rainfall activity, and from the end of August when the ITD is at its most northerly position, zone "E" weather migrates a short distance inland causing a period of reduced rainfall in the coastal area, a phenomenon known as the "little dry season" or the "July/August break". During this period the southwester-lies become deflected into westerlies which bring little or no rain. This causes rainfall to increase eastward over southern Nigeria during the July-August period (Olaniran, 1988 a, b).

The account of the rainfall-producing systems presented for Nigeria, depicts rainfall activity over the country as a function of the migration pattern of the ITD (Ayoade, 1970; Kowal & Knabe, 1972; and Olaniran, 1985; 1988 a; 1988 b). Accordingly, droughts in Nigeria, and indeed over West Africa, are associated with a restricted northward advance of the ITD. On the other hand, wet years result from a considerable northward advance of the ITD. Different from this simplistic picture, the ITD itself is erratic in its south-north advance and north-south retreat. It moves in a series of surges, retreats and stagnations.

Data presented by Walker (1958) showed that along longitude 3^{0}E in that year the ITD advanced up to 11^{0}N latitude in January but retreated southward to 6^0 N latitude in February i. e. the following month, a retreat of 500 km. Oguntoyinbo and Richards (1977) also reported a similar situation for southern Nigeria during 1972/73. Such irregular movements of the ITD have implications for determining the rainfall characteristics of southwest Nigeria. Often, they cause a false start of the rainy season i. e. early onset of rainfall at a location which is subsequently followed by a prolonged dry spell or late onset of rainfall which may be followed by a prolonged wet spell.

The Inter-Tropical Discontinuity (ITD) is the most popularly accepted medium that influence rainfall distribution in Nigeria (Clackson 1969; Obasi 1965; Mbele-Abong 1974; Ayoade 1988; Ilesanmn 1972a; Lamb 1983; Adejuwon et al. 1990). It is established that to the southern part of ITD, varying degrees of convective activity and precipitation takes place, whereas, little or no cloud development or precipitation occur to the northern part. In other words, rain fall mostly when an area is over-lain by the Continental Tropical (cT) air mass. This makes the position of ITD a great determinant of most rainfall attributes in southwest Nigeria. It has been argued that the convergence of trade wind and monsoonal airflow, in the region of the ITD, is unable to produce sufficient vertical motion (and depth of clouds) to induce rainfall (Hulme & Tosdevin, 1989).

The relevance of the ITD in this study therefore lies in its provision of a framework for following the south/north motion of the rain bearing maritime air mass (mT). Within the mT air mass is enclosed a number of rainfalls

producing systems, such as the disturbance lines (especially the easterly waves), squall lines and the two tropospheric jet streams.

Long-term rainfall variability in southwest and Nigeria as a whole is accounted for, not by the ITD mechanism alone, rather, other local climatic factors such as heat flow, sea surface temperature anomaly (SSTA), heat budget and the hydrological cycle. Overall, rainfall anomalies especially in southern Nigeria are caused by both tropical and extra tropical factors (Ayoade, 1988). The theory of inter-tropical discontinuity is a useful tool in understanding the effects of rainfall variability on sustainable economic growth in Southwest Nigeria. The ITD is a major source of rainfall variability with the region experiencing both dry and wet seasons. The ITD can affect the regional distribution of rainfall, with the region experiencing greater disk of drought during dry season with huge crisis on crop yields and food security. The agricultural practices and farming method depends on the rainfall pattern which is affected by the change due to the ITD and make the practices less effective. The understanding of this theory will assist the policy makers in Southwest Nigeria to design policies and programmes that will support sustainable economic growth in the region.

Research methods.

The data for the study was collected from the secondary source. Rainfall data was collected from the Nigeria Meteorological Agency (NiMet) for a period of 30 years under review

Analysis of trends and pattern of rainfall in Osogbo, Nigeria was done in the following order. Trend of rainfall was analysed by using descriptive statistics and time series analysis. The seasonal variation of rainfall in Southwest region was analysed using descriptive analysis of simple bar-chart while mean monthly analysis of the year under review was analysed using multiple bar chart.

Findings and the interpretation of Results

Trend of Rainfall in Soutwest Nigeria from (1992-2024)

In Osogbo, April and October across the entire time series chart experience higher annual value with the highest in 2021 and the least in 2005 as shown in figure 1. 0 with the skewness of 0. 226426 closer to zero, as contained in **Table 1. 0 and evenly distributed boxplot, the normal probability plot in figure 1. 2 also affirmed that the distribution is approximately normal**

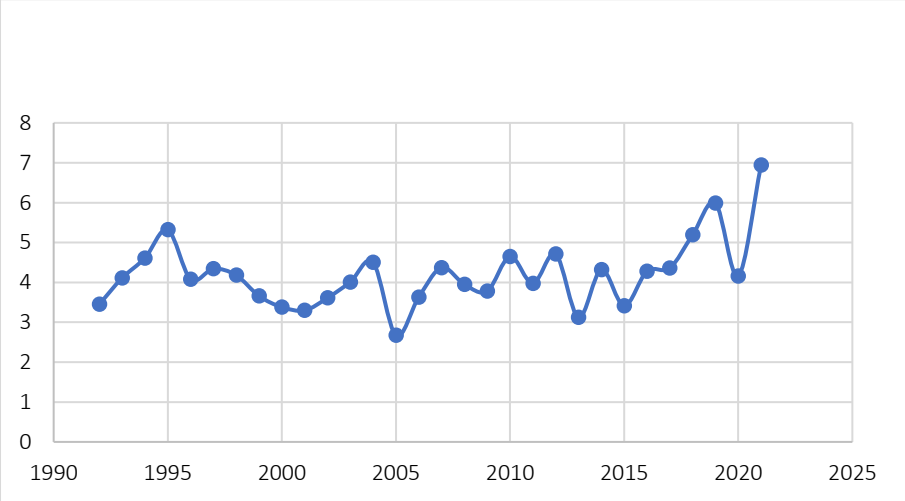

Figure 1. 0: Time series analysis of annual rainfall in Osogbo Osun State (1992-2024) mm

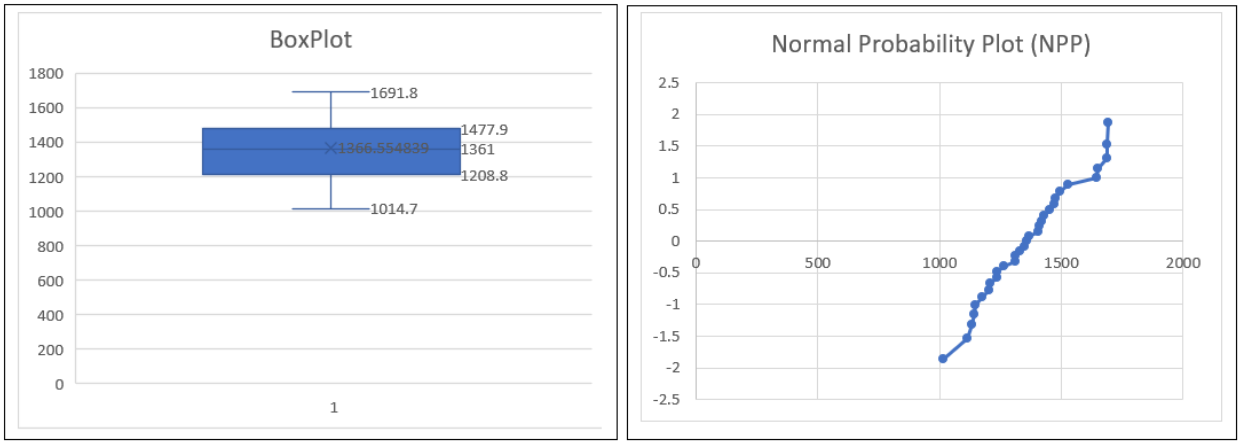

Figure 2. 0: Normal distribution analysis of annual rainfall in Osogbo Osun State (1992-2024) mm

Table 1. 0: Descriptive analysis of annual rainfall in Osogbo Osun State

Descriptive Index	Value
Mean	1366. 555
Standard Error	33. 28159
Median	1361
Mode	#N/A
Standard Deviation	185. 304
Sample Variance	34337. 58
Kurtosis	-0. 68804
Skewness	0. 226426
Range	677. 1
Minimum	1014. 7
Maximum	1691. 8
Sum	42363. 2
Count	31

Pattern of Rainfall in Osogbo, Nigeria from (1992-2023)

Seasonal Analysis

The season in Osogbo is divided into two, they are the dry season from November to March and the raining season from April to October. There is a general increasing in precipitation levels across the different time periods from 1990 to 2024. This pattern indicates that the dry season has become progressively wetter over the years.

Critically, while the overall pattern shows an increase in precipitation, there are fluctuations within each time period. For example, there are fluctuations in precipitation levels from November to March within each five-year period. These fluctuations could be attributed to various factors such as climate variability, weather patterns, and environmental changes. Figure4. 0. and 5. 0. Moreover, the data indicates that February and March typically experience the highest levels of precipitation during the dry season. However, it's essential to note that despite the pattern, there are instances of variability in precipitation levels between the years within each time period. The data suggested an increasing precipitation during the dry season in Osogbo Nigeria over the years.

However, there are fluctuations and variations within each time period, indicating the influence of multiple factors on seasonal precipitation patterns. Further analysis incorporating additional environmental and climatic factors would provide a more comprehensive understanding of these trends.

Analyzing the seasonal data for the raining season in Osogbo Nigeria reveals notable pattern and fluctuations over the years. From April to October, which constitutes the rainy season, there is a general pattern of fluctuating precipitation levels across the different time periods from 1990 to 2024. While there are fluctuations, there is no consistent increasing or decreasing trend in precipitation levels over the years.

Critically, each month within the raining season exhibits variations in precipitation levels both within and between the five-year periods. For example, while April and May generally show varying levels of precipitation across the years, June and July tend to have higher precipitation levels, indicating peak rainfall during these months. However, there are instances of lower precipitation levels in some years compared to others within the same time period.

Moreover, August, September, and October typically experience decreasing precipitation levels towards the end of the rainy season. However, there are exceptions, with some years showing higher precipitation levels during these months. Figure 4. 0 and 5. 0.

The trend and pattern of rainall in Osogbo, have a consequence on climate resilience and water resources management. There is increased occurrence of extreme weather events due to the change in rainfall pattern with severe floods, drought and storms which damage infrastructures, displace communities and affect water resources. There is a sharp reduction in water availability with concequence on water quality, irrigation water and portable water for drinking. this led to increased water demand, with a shift in economic activities as its effect crop production food security and economic development. Similarly, there will be increase in the risk of vecto-borne diseases due to limited access to quality water.

There will be a consequence on the ecosystem leading to biodiversity loss and species migration.

The data suggested a mixed pattern of precipitation levels during the rainy season in Osogbo Nigeria over the years. While there are fluctuations and variations within each time period.

The study corroborated the findings of Adetunji Ogunwale and Adepelumi (2015) where it was concluded that rainfall in the Southwest Nigeria is seasonal, with raining season between April to October with influences from the Atlantic Ocean, the inter-tropical convergence zone (ITCZ) and the topography of the region.

Adeyemi, Oje Adepelumi and Awosika (2017) also confirmed the seasonality of rainfall pattern in the region thereby also altitudinal the downward trend and cases of variability due to anthropogenic effect and that of climate change the study of the trends and pattern of rainfall will have direct consequences on the impact of

Environmental effect of flooding during the period much rainfall and problem of water shortages which inhibit water availability for uses in the industry and for domestic uses will affect economic activities thereby affect sustainability. The impact of heavy rainfall on the available infrastructures cannot be over emphasized. Infrastructures like roads, bridges etc. are badly affected during heavy rainfall and this affect economic activities and also increases the cost of doing business

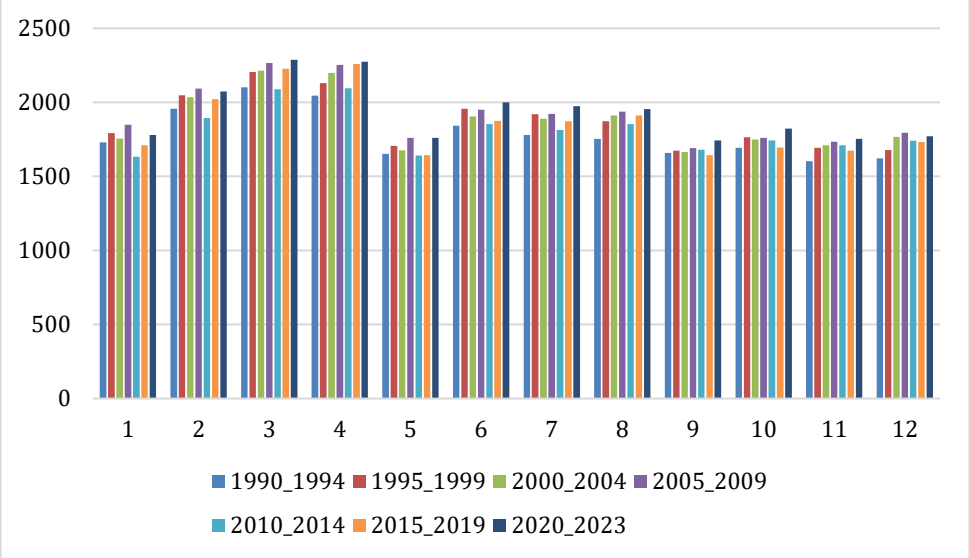

Figure 3. 0: Mean Monthly Rainfall between (1992-2023) mm

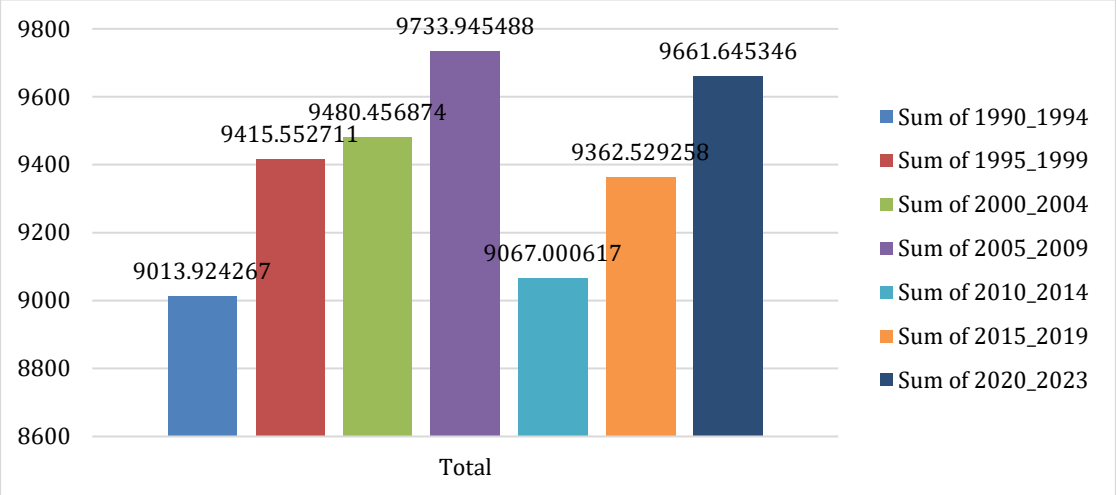

Figure 4. 0: Total Rainfall during the Dry season from (1992-2023

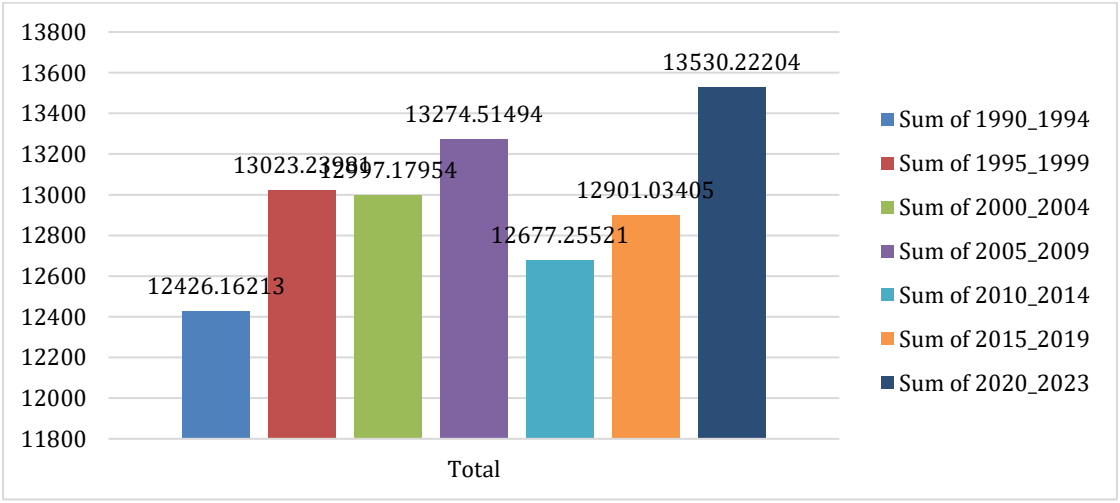

Figure 5. 0: Total Rainfall during the raining season between (1992-2024) mm

Summary and Recommendation

Osogbo, Nigeria experiences a tropical climate with a distinct dry and wet season. The raining season lasts from March to November while the remaining months is for the dry season. In Osogbo Osun State 2021 recorded the highest annual rainfall and 2005 recorded the least with the skewess value of 0. 226426

One the seasonal analysis. The dry season is becoming welter simply because the precipitation is on the increase. There are also some fluctuations in precipitation level from November to march within each five years period. The impact of trend and pattern of rainfall on climate resilience and water management in Osogbo, Nigeria must be addressed. The study recommended an early warning system to improve on the quality of weather forecast to assist in climate resilience and water management.

Conflict of Interest: None declared.

Ethical Approval: Not applicable.

Funding: None.

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