



## Understanding the Trends and Patterns of Rainfall Variability and Its Implications for Climate-Resilient Development in Osogbo, Nigeria

Olugbenga A. Adewoye



Department of Surveying and Geoinformatics, Osun State College of Technology, Esa-Oke

\*Corresponding Author's email: [waleadewoye@gmail.com](mailto:waleadewoye@gmail.com)

### KEYWORDS :

Climate-resilient,  
Development Pattern Rainfall Variability,  
Trend.

### ABSTRACT

The study examined rainfall patterns in Osogbo for 30 years to identify changes in the variability and their implication for sustainable environmental management. The study aimed at understanding rainfall variability trend and pattern. Data for the study is from a secondary source. It was sourced from the Nigeria Meteorological Agency (NiMet). The data was analyzed using statistical technique. The study revealed variability in the rainfall pattern across the seasons, with a significant difference between the wet and the dry seasons. The Men –Kendal test revealed that the S value is equal to 83, the Z Value equals 1.46, and the p value is equal to 0.143. The seasonality index shows a fluctuating dry season, which is more intense with a reduction in corresponding reductions in rainfall. The ARIMA analysis showed a stationary value of 0.6171, forecasting an increasing trend with fluctuation around 5.69mm by 2026. The standard precipitation index showed an average standard precipitation index of a wetter than expected condition. The dry years are 2014, 2000, and 2016, while the wet years are 1991, 1997, and 2012. There are alternatives between wet and dry years, but it revealed wet than dry years. It also revealed the increase in frequency and intensity of rainfall extremes like floods, droughts, etc. The study concluded that there is a need for proactive and adaptive strategies to mitigate the effects and risks of extreme rainfall events. Therefore, it recommends strengthening climate monitoring, developing climate-resilient infrastructures.

### CITATION

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### INTRODUCTION

There is a spatial-temporal variation of Earth's climate with seasons, decades, centuries, and even longer times. The variations may be hot or wet, cold or dry, stormy or quiet, etc.; they are generally known as climate change. Climate change is a contemporary global challenge that humanity is currently facing. World leaders have called for action to curtail the threat of climate change and its consequences. Measures have been implemented to mitigate the effects and ameliorate the consequences.

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

Olaniran (2002) concluded that the mean annual rainfall in Ilorin, Nigeria, using 1971-2000 rainfall data, is 1200mm. Any other years at Ilorin will be described as a departure from the normal. The 1999 annual rainfall of 1530mm is 27.5% above normal while the year 2000 990.3mm of 17.5% below normal are departures known as variability. Rainfall

trends, therefore, show the pattern of deviation from the normal over a given period. A persistent deviation constitutes some climatic fluctuations, which are usually referred to as climate change. (Olaniran 2002)

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

Rainfall is one of the key climatic elements that determine the pace of economic activities in Osogbo; for instance, rainfall, the primary source of water resources, determines the types of crops to grow, the period of cultivation of crops, the post-harvest practices, and the kind of farming system to be practised in the region. Statistical evidence has shown that rainfall varies, affecting economic activities in the area. Invariably, the scientific explanation needs to provide an in-depth study of the current trend of events in the city's rainfall characteristics.

Osogbo is the capital city of Osun state and the headquarters of Olorunda and Osogbo Local Government Area. It is located within Lat  $7^{\circ} 46^{\prime}. 74^{\text{ii}}\text{N}$  and Long  $4^{\circ} 33^{\prime} 25^{\text{ii}}\text{E}$ . The climate of Osogbo, Nigeria, is tropical; it is hot and cold. The rainy season begins from April to October, while the dry season begins in November and ends in March. The mean temperature is  $27^{\circ}\text{C}$ , while the mean annual rainfall is about 13000mm. The rainfall in the city is influenced by the intertropical convergence zone (ITCZ), which brings moisture from the Atlantic Ocean and the Gulf of Guinea. The southwest monsoon wind also influences it. (Ileoje,2000)

The average relative humidity in the rainy season is around 75 to 85%. The temperature in the rainy season is around  $22^{\circ}\text{C}$  to  $32^{\circ}\text{C}$ , while in the dry season, it is around  $17^{\circ}\text{C}$  to  $27^{\circ}\text{C}$ .

The city has a diverse geology composed of rocks from the pre-Caribbean Paleozoic and Cretaceous periods. The rock types include granite, gneiss, schist, and quartzite. (Ileoje,2000)

The city's topography consists of low-lying plains and hills. The vegetation 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 include Agricultural production, especially food crops like cassava, yams, rice, and maize. Cultural tourism is also vital.

### Research Questions

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

#### ***Trend and pattern of rainfall in Osogbo, Nigeria***

Rainfall is water droplets from the atmosphere condensed from the atmospheric cloud. It is essential in the water cycle because it is the source of freshwater deposited on

the Earth's surface. It is a significant factor in the existence of the natural ecosystem.

Many factors influence the trend and pattern of rainfall in Osogbo, Nigeria. These include El Nino and the movement of the intertropical discontinuity. El Nino and La Nino are two phases of the El Nino Southern Oscillation (ENSO), a recurring climate pattern worldwide. Intertropical discontinuity (ITD) is the most accepted mechanism affecting African rainfall distribution. (Clackson 1960; Obasi 1965; Mbele Abong 1974; Ayoade 1988; Ilesanmi 1981; Lamb 1983; Adejuwon Balogun and Adejuwon 1990). In Osogbo, Nigeria, rainfall has two regimes: a Bimodal maximum South of  $10^{\circ}\text{N}$  and a single maximum North of this latitude—the distribution results from the seasonal movement of intertropical discontinuity (ITD).

Knowing rainfall throughout the study on temporal and spatial scales is essential. (Abiodun; and Gunnar 2016). In Nigeria, rainfall patterns have also become more varied in recent years. They have become less reliable in the southern part, with frequent droughts and floods in the north. They have become more intense, leading to increased flooding and damage to infrastructure. Studies of rainfall variability have been conducted in some parts of the world.

Gonzalez Hidalgo and Deluis (2010) found in the analysis of the Woler Planning Division that precipitation trends throughout 1946-2005 had very low significant levels for the total annual amount and the wet and dry seasons. Consequently, significant and spatially current trends were identified on a monthly scale.

Jayawardene, Sonnadara, and Jayewondere (2010) observed rainfall trends in Sri Lanka with centenary data. They confirmed that some parts are experiencing a decreasing trend, some are increasing, and some are indifferent. This shows that trend characteristics vary with the duration of the analyzed data.

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

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

Zaria station showed annual rainfall above the long-term mean from the 1970s to 2010. It was below the mean. The Potiskum's readings showed annual rainfall above the

long-term mean around the 1970s and declining from the 1970s. Kano zone also has a similar trend, with a slight increase before 1970 and a consequent decline from the 1970s to 2010.

Ologunorisa (2016), assessing the annual rainfall trend in Makurdi for 77 years (1927-2014) using Spearman rank correlation coefficient statistics, confirmed that the yearly rainfall trend in the consideration period has a negative correlation coefficient of -0.3031. The significance of the trend was also tested by the student's T-test and was found to be at a 95% confidence level.

This confirmed a downward trend in the annual rainfall in Makurdi town. Abaje, Isahaya, and Usman (2015) studied the mean ( $\bar{x}$ ) standard deviation (SD) coefficient of variation (CV) standard coefficient of skewness (Zi) kurtosis (Zz) of rainfall for Kafanchan from April to October and annually, the result shows 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, except Zi and Zz.

Ogolo and Adeyemi (2009), in their study of the variation and trends of meteorological parameters 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) conducted a study on Enugu and observed 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), Olivia (2004), Babalolu (2010), Fowler and Kilsby (2013), Odekunle (2010), and Ologunorisa (2010, 2014). Other studies, like Olaniran (1993), Ologunorisa (2013), and Dayi (2015), focused majorly on the causes of floods, including rainfall variability, intensity, duration, frequency seasonally, variability trend, and fluctuation.

## THEORETICAL FRAMEWORK

### The Inter-tropical discontinuity (ITD)

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

The ITD advances inland as far as 22-25°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°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, and "E" to the immediate south because it is rainless and does not contain rain-producing clouds. Rainfall in the ITD occurs in zones "C" and "D", where conditions favour the development of clouds of great vertical extent. Thunderstorms and squall lines are associated with zone "C" weather, and monsoon rains are associated with Zone "D" weather. Consequently, rainfall is spatially discontinuous when Zone "C" weather prevails. On the other hand, the monsoon system causes continuous rains that may last 12 hours or more (Olaniran, 1995).

Overall, rainfall occurs 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, zone "E," prevails over an area, light rainfall usually results because layered strati form clouds dominate Zone "E" weather.

The position of the ITD fluctuates seasonally, and the different ITD zones affect other 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. 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 southwesterlies become deflected into westerlies, which bring little or no rain. It causes rainfall to increase eastward over southern Nigeria during July-August (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 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. Unlike this simplistic picture, the ITD 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°E in that year, the ITD advanced up to 11°N latitude in January but retreated southward to 6° 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 that is subsequently followed by a prolonged dry spell or late onset of rains, which a prolonged wet spell may follow.

The Inter-Tropical Discontinuity (ITD) is the most popularly accepted medium that influences rainfall distribution in Nigeria (Clackson, 1969; Obasi, 1965; Mbele-Abong, 1974; Ayoade, 1988; Ilesanmi, 1972a; Lamb, 1983; Adejuwon, et al. 1990). It is established that in the southern part of ITD, varying degrees of convective activity and precipitation occur. In contrast, the northern part has little cloud development or precipitation. In other words, rain falls mainly when an area is overlain by the Continental Tropical (cT) air mass. This makes the position of ITD a significant determinant of most rainfall attributes in southwest Nigeria. It has been argued that the convergence of trade wind and monsoonal airflow in the ITD region cannot ITD region, cannot produce sufficient vertical motion (and depth of clouds) to induce rainfall (Hulme & Tosdevin, 1989).

Therefore, the ITD's relevance in this study lies in its provision of a framework for following the south/north motion of the rain-bearing maritime air mass (mT). Several rainfalls producing systems within the mT air mass are enclosed, such as the disturbance lines (especially the easterly waves), squall lines, and the two tropospheric jet streams.

Long-term rainfall variability in southwest Nigeria is accounted for not by the ITD mechanism alone but by 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 valuable in understanding the effects of rainfall variability on sustainable economic growth in Southwest Nigeria. The ITD is a significant source of rainfall variability, and the region experiences dry and wet seasons. The ITD can affect the regional rainfall distribution, with the area experiencing a greater drought risk during the dry season, a massive crop yield, and a food security crisis. The agricultural practices and farming methods depend on the rainfall pattern, which is affected by the change due to the ITD and makes the practices less effective.

## MATERIALS AND METHODS

The study's data was collected from a secondary source. Rainfall data was collected from the Nigeria Meteorological Agency (NiMet) for 30 years under review. The trends and patterns of rainfall in Osogbo, Nigeria, were analyzed using descriptive and inferential statistics methods. The trend of rainfall was determined using time series analysis. The trend and rainfall pattern were determined using the Man-Kendall (MK) test, where S statistics (SS) represent the sum of signs of all pairwise differences in the dataset. A positive (SS) indicates an increasing trend, and a negative SS indicate a decreasing trend. The variance SS accounts for tied values in the

dataset and z-score (ZZ) standardized SS to determine the trend significance where a higher ZZ value indicates a stronger trend. The P-value measures the probability of obtaining the observed trend by chance. A p-value of <0.05 suggested a statistically significant trend. The seasonality index was also used, where the dry season index stayed below 50% and the wet season index was below 100%. ARIMA model equation was also used to capture the trends, seasonality, and randomness in time series forecasting. AR(P-1) suggests rainfall depends on the previous value, and MA (Q-1) indicates past errors.

## DISCUSSION OF FINDINGS

The Men-Kendal test revealed that the S value is equal to 83, the Z Value equals 1.46, and the p value is equal to 0.143. the seasonality index shows a fluctuating dry season, which is more intense with a reduction in the corresponding reduction in rainfall. The ARIMA analysis showed a stationary value with a p-value of 0.6171, forecasting an increasing trend with fluctuation around 5.69mm by 2026. the standard precipitation index showed an average standard precipitation index of a wetter than expected condition. The dry years are 2014, 2000, and 2016, while the wet years are 1991, 1997, and 2012. There are alternatives between wet and dry years, but revealed wetter than dry years.

Rainfall is a crucial component of the hydrological cycle, and its trends and patterns are significant for sustainable environmental management. (Oyebande, 2018) Understanding the rainfall pattern is crucial for developing effective climate-resilient strategies in Osogbo. Osogbo rainfall has been irregular, with a significant decrease in amount in recent years (Olaniran, 2021). The trend is consistent with the findings from other researchers who submitted a submission on the declined rainfall amount in Osogbo, Nigeria. The season in Osogbo is divided into two: the dry season from November to March and the rainy season from April to October. There has been a general increase in precipitation levels from 1992 to 2024. This pattern indicates that the dry season has become progressively wetter.

Critically, while the overall pattern shows increased precipitation, there are fluctuations within each period. For example, there are fluctuations in precipitation levels from November to March every five years. These fluctuations could be attributed to various factors such as climate variability, weather patterns, and environmental changes (Figures 1.0. and 2.0). Moreover, the data indicates that February and March typically experience the highest precipitation levels during the dry season.

However, it is essential to note that despite the pattern, there are instances of variability in precipitation levels between the years within each period. The data suggested increasing precipitation during the dry season in Osogbo, Nigeria, over the years.

Fluctuations and variations within each period indicate 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 rainy season in Osogbo, Nigeria, reveals notable patterns and fluctuations over the years. From April to October, which constitutes the rainy season, there is a general pattern of fluctuating precipitation levels across different periods from 1992 to 2024. While there are fluctuations, there has been no consistent increase or decrease in precipitation levels.

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

The implications of the trend for developing effective climate-resilient strategies in Osogbo are far-reaching and significantly impact the environment, agriculture, and water resources. A decreased rainfall reduces water availability, affecting agricultural productivity and food security (Oyebande, 2015). Irregular rainfall patterns can increase the risk of flooding, erosion, and landslides, which can have devastating consequences on human settlements and infrastructure (Nwagwu,2021)

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Critically, while the overall pattern shows increased precipitation, there are fluctuations within each period. For example, there are fluctuations in precipitation levels from November to March every five years. These fluctuations could be attributed to various factors such as climate variability, weather patterns, and environmental changes (Figures 3.0 and 4.0). Moreover, the data indicates that February and March typically experience the highest precipitation levels during the dry season.

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There is an increased occurrence of extreme weather events due to the change in rainfall patterns with severe floods, drought and storms, which damage infrastructures, displace communities and affect water resources. A sharp reduction in water availability has consequences on water quality, irrigation water and portable water for drinking. This has led to increased water demand, with a shift in economic activities affecting production food, food security and economic development. Similarly, there will be an increase in the risk of vector-borne diseases and consequences on the ecosystem, leading to biodiversity loss and species migration due to limited access to quality water.

The study corroborated the findings of Adetunji Ogunwale and Adepelumi (2015), who concluded that rainfall in Osogbo, Southwest Nigeria, is seasonal. The intertropical convergence zone (ITCZ) influences the rainy season between April and October.

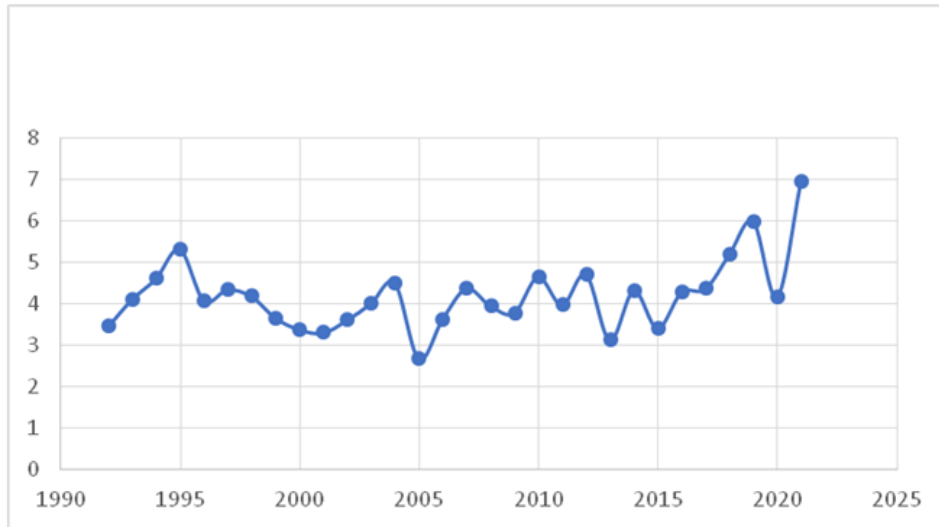


Figure 1: Time series analysis of annual rainfall in Osogbo Osun State (1992-2024)mm

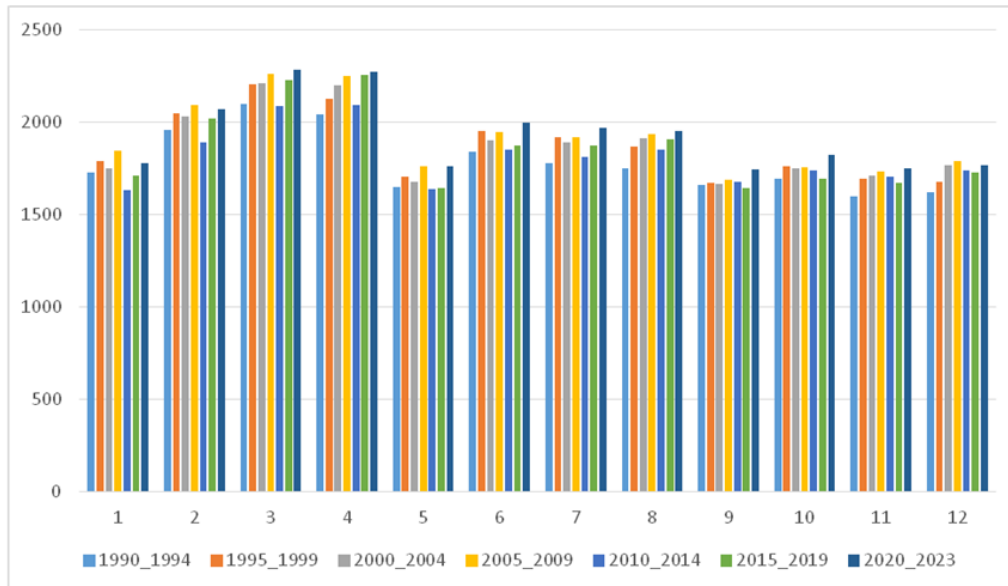


Figure 2: Mean Monthly Rainfall between (1992-2024)mm

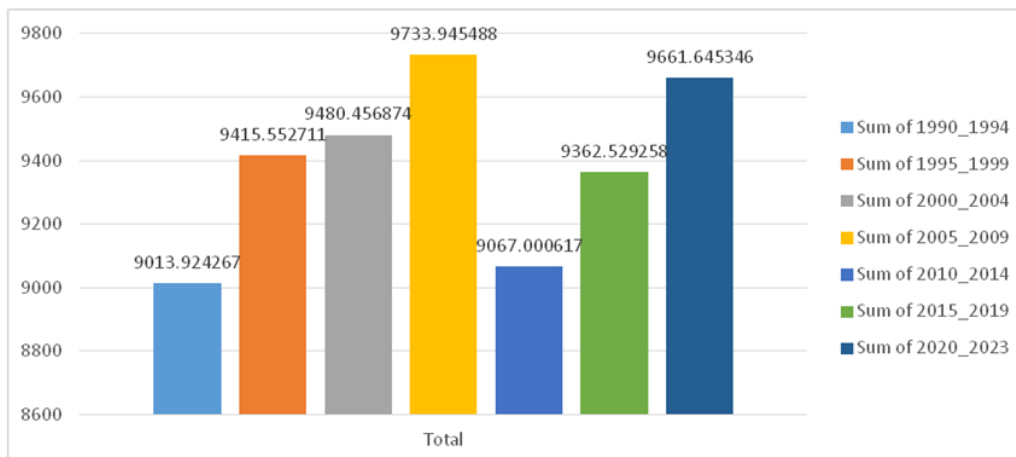


Figure 3: Total Rainfall during the Dry Season from (1992-2024)

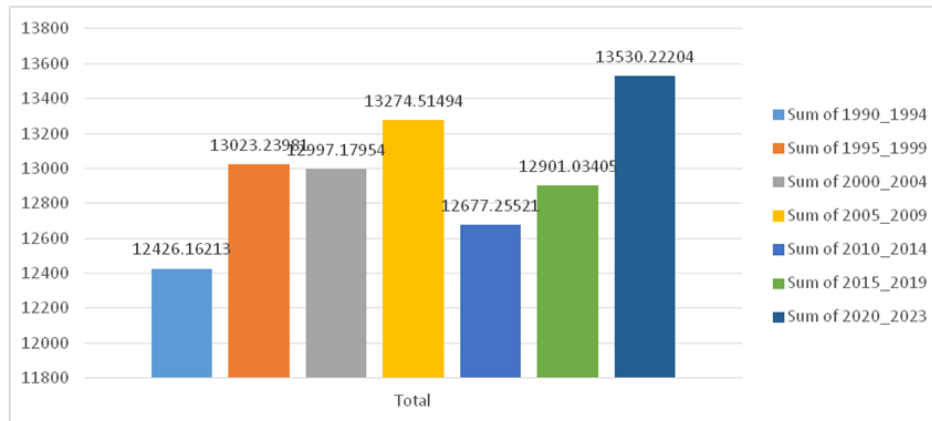


Figure 4: Total Rainfall during the rainy season between (1992-2024)mm

## CONCLUSION

In conclusion, understanding rainfall variability and its implication for climate-resilient development in Osogbo, Nigeria, is a critical step towards building a sustainable and resilient future for the city. Analyzing historical rainfall trends and patterns has highlighted the complexities and uncertainties associated with climate change and the need for proactive adaptation measures to mitigate its impacts. As the city continues to grow and develop, climate change adaptation and resilience must be integrated into development planning and policy-making. This requires a collaborative effort from government agencies, local communities and other stakeholders to develop and implement effective strategies for managing rainfall variability and its associated risks.

## RECOMMENDATIONS

By investing in climate-resilient infrastructures, promoting climate-smart agriculture, and enhancing climate monitoring and early warning systems, Oshogbo can reduce its vulnerability to climate-related shocks and stresses. Additionally, capacity building and training programmes can empower local communities and stakeholders to take ownership of climate change adaptation and resilience efforts.

Ultimately, building a climate-resilient Osogbo requires a long-term commitment to sustainable development and climate change adaptation; by working together and leveraging the knowledge and expertise of various stakeholders, we can create a more resilient and sustainable future for the city and its inhabitants. The study recommends an enhanced climate monitoring system to provide accurate and timely data on rainfall patterns and the development of climate-resilient infrastructure that can stand climate-related stresses like floods and droughts; it also recommends climate-smart agricultural practices that enhance resilience to rainfall variabilities such as drought-tolerant crops and efficient irrigation systems. Similarly, capacity building is

recommended for the stakeholders, including farmers, policymakers, and local communities, to enhance their understanding of and response to rainfall variability. The study recommends incorporating climate change adaptation into development planning and policy-making to ensure a climate-resilient future for Osogbo, Nigeria.

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