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Climate Variation Assessment Based on Rainfall and Temperature in Ibadan, South-Western, Nigeria

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Abstract
In recent times and across the globe, the concept of climate has gained much relevance because of its dynamic and complex nature and the significant influence it has on various aspects of the environment, including the increasing threat of global climate change. This study focuses on the assessment of climatic variation in Ibadan region based on the variations in rainfall and temperature within the period 1970-2012. Time Series Analysis was used to determine the trend of total rainfall and average minimum temperature within the period 1970-2012. The 5-Year Moving Average was used to smoothen the time series and to eliminate unwanted fluctuations. Linear Regression was used to estimate the value of variable Y (total rainfall or average minimum temperature), corresponding to a given value of variable X (time), while Correlation Analysis was used to determine the relationship between total rainfall and average minimum temperature within the study period. Furthermore, the study focused on the spatial variations of total rainfall and average minimum temperature in the study area. The result revealed that there is an upward trend in total rainfall within the period under study. And also there is an upward trend in average minimum temperature. Additionally, there is a positive relationship between total rainfall and average minimum temperature.
Keywords: Climate variation, rainfall and temperature, Correlation, Linear Regression, 5-year moving average

1. Introduction

In recent times and across the globe, the concept of climate has gained much relevance because of its dynamic and complex nature and the significant influence it has on various aspects of the environment, including the increasing threat of global climate change. The environment and biological system are similar in that an alteration in any component of the environmental system (like the biological) will lead to a disturbance in the whole system. A fundamental component of the environment is the climate. A change in climate will result to a change in the environment consequently affecting other components.

The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP) to "*provide authoritative information about climate change"*. The panel has since then produced enough evidence in their first report in 1990 to show that climate change is a reality and that it is being caused by anthropogenic activities. The IPCC predicts that climate change, will cause drought in some parts of the world and flooding in other parts and the poor countries will be hit the most because of their low capacity to cope with the changes" (Uyigue and Agho 2007). The IPCC (1990), with the aid of climatic records of over 100 years, have shown that there is a strong relationship between the emission of greenhouse gases and climate change and also between rise in sea level and global temperature. Per decade global temperature has been projected to rise by between 0.2^0C to 0.5^0C. The increase in temperature will definitely result to thermal expansion of sea and melting of polar ice. The resultant consequence is that the sea level will rise per decade in the next century for about 3-10 cm. While temperature or rainfall decreases over time in a given area, the trend at another place may be opposite (Adelekan, 2011). Local climate changes may be out of tune with regional or continental overall pattern of climate fluctuations. Therefore, the effects and evidences of climate change vary over space and across latitudes. In the tropics and specifically in Nigeria, the effect of climate change will be experienced in various climatic elements, especially rainfall and temperature. The ultimate effect will be an alteration of the "normal climate" of such environment.

Nigeria is within a tropical climate with distinct regional differences as a result of rainfall. Temperature is high throughout the year, averaging from 25° to 28°C. The various seasons in Nigeria are controlled by the movement of the Inter-tropical Discontinuity. However, this typical climate of the country may be altered as a result of various processes such as global warming resulting from increasing levels of greenhouse gases in the atmosphere. Thus, it is expected that climate change may cause variations in rainfall and temperature patterns which can be intensified or weakened. Therefore, using Ibadan (Nigeria) as a case study, this research focuses on localized climatic change assessment based on rainfall and temperature variations.

The variability in Global climate indicates an alteration in either the mean state of the climate or in its variability, occurring for many decades or more. Changes in individual weather events will eventually contribute considerably to changes in climate variability. The environment will greatly be affected by climate change, and also climate change will affect socio-economic and related sectors which include water resources, biodiversity, food security, human health, terrestrial and aquatic ecosystems. Changes in the pattern of rainfall will possibly lead to drought and/or flooding. Climate change will geometrically increase threats to food security. It will increase the frequency and intensity of natural disasters. It will result to scarcity of water and make lands difficult to access. The implications of the impact of Climate change are more immense in the poorest nations in Africa and Asia. According to kolawale *et al,* (2011) "Globally, the economic cost of extreme weather and flood catastrophes is severe, and if it rises as a result of climate change, it will hit poorest nations the hardest".

1.1 Aim

To assess climatic variation in the city of Ibadan based on the variations in rainfall and temperature patterns, as well as the relationship between them.

1.2. Objectives

- To determine the temporal variations in rainfall and temperature patterns in the study area by using the mean monthly and mean annual rainfall values for 43 years.
- To determine the relationship between total rainfall and average minimum temperature in the study area.
- To determine the nature of climatic variation in the study area and its possible effects.

1.2 Hypotheses

1. There is an upward trend in rainfall within the period under study.
2. There is an upward trend in temperature within the period under study.
3. There is a positive relationship between total rainfall and average minimum temperature within the period under study.

2. Research Methodology

2.1: Study Area

Ibadan was founded in the 1820's (Mabogunje, 1968) and lies between Latitude 7° 02' 49″ and 7° 43′ 21″ N longitude 3° 31′ 58″ and 4° 08′ 20″ E. Ibadan is the capital of Oyo state and has been an important administrative centre since colonial times. In terms of geographical expansion, Ibadan has almost doubled in spatial size over nine years, 1982 to 1991, from 130.5 square kilometres to 240 square kilometres (Areola 1994). By the year 2000, it expanded covering an area of about 400 km^2. The expansion of the urban area in terms of its growth during the latter half of the 20th century (from 40 km^2 to 250 km^2 in the 1950s and 1990s respectively) reveals that there has been an underestimation of the total growth of the region, and its locational advantage made it a favourable city for educational, socio-political, commercial and industrial activities. The climate of Ibadan is tropical with distinct wet and dry seasons and a mean minimum annual temperature of 21^0C (68.8^0f) but in consonance with seasonal variations in radiation, sunshine and cloud cover, the mean annual temperature, could change. Between March and October, the prevalent winds in the city is the moist maritime South-west monsoon which blows inland from the Atlantic Ocean, this is the period of rainy season. November to February is the period of dry season when the dry dust laden winds blow from the Sahara desert. The mean annual rainfall of about 1,205 mm, falling in approximately 109days with two rainfall peaks in June and September.

2.1 Data Collection and Analysis

This study employed the use of secondary data obtained from the Nigerian Meteorology Agency (NIMET) weather station. The major climatic parameters used in this study are rainfall and temperature. To understand the nature of rainfall and temperature variations, as well as the relationship that exists between these variations, rainfall data and temperature data for 1970-2012 (43 years) were collected and analyzed for one weather station within the study area. Descriptive statistical methods such as; mean and standard deviation, were utilized. Furthermore, Time Series was used for the analysis of rainfall and temperature trend over time (Terence, 2006) and the Moving Average technique was also used in the analyses of the data. This study employed the use of the 5-Year Moving Average. The moving average has the characteristics of reducing the amount of variation in a set of data. This property in the time series is used mostly to remove fluctuations that are not needed. The use of moving average result in the formation of new artificial series in which each of the actual value of the original series is replaced by the mean of itself and some of the values immediately preceding it and directly following it Ayoade (2008). To estimate the value of a variable Y (i.e. rainfall or temperature), corresponding to a given value of a variable X (i.e. time), Regression Analysis was applied. This was accomplished by estimating the value of Y from a least-squares curve that fits the sample data. The resulting curve is a regression curve.

The Curve Fit was used to express the relationship between temperature and rainfall in mathematical form, by determining an equation that connects the variables, after drawing the scatter diagram. Correlation Analysis was then used to explain the degree of relationship between total rainfall and average minimum temperature. Correlation helps to determine how well a linear equation describes or explains the relationship between variables. From this analysis, the coefficient of determination was obtained, this is given by $r^{2.}$ Finally, statistical hypotheses were formulated for the purpose of rejecting or accepting them, and the maximum probability of being wrong in rejecting an hypothesis was determined by testing the level of significance (at 0.05).

3.0 Results and Discussion

3.1 Variations in Rainfall and Temperature in Ibadan

3.1.1 Rainfall Trend

Rainfall data of 43 years (1970-2012) for the study area was subjected to various statistical techniques to arrive at valuable results. The Time Series analysis was used to determine the trend in total rainfall over time for the weather station in the study area, and the 5-year moving average was used to smoothen out the variations present within data sets. The results of this study show that rainfall variations and trends in Ibadan is worthy of close examination, as its variations over time is remarkable.

Analysis of rainfall data reveals that rainfall in Ibadan has been highly varied. Table 2.1, shows the mean total rainfall, minimum and maximum values as well as the mean rainfall range for the weather station in Ibadan. Figure 2.1 reveals the trend of total annual rainfall for the periods 1970-2012, while figure 2.2 is the 5-years smoothing graph (5-Year Moving Average) for total rainfall. The mean total annual rainfall for the area was 9233.60 mm; with a mean minimum of 14.67mm recorded in 1974 and a mean maximum of 499.67mm in 2005 (Figure 2.3). Total rainfall of the area was characterized by two distinct peaks: one in 1980 and the other (highest) peak in 2005. This shows that these years were the wettest years within the period under study (1970-2012). In general, total rainfall of the area increased in the period 1970-1973 and declined in 1974. There was also a slight decline in 1983, 1994, 1998, 2004 and 2006 (figure 2.1). There was a sharp increase after 1974, this was more experienced in 1980, which continued till about 2011 with a sharp decline in 2012. Within this period there was an interesting variation of rainfall as it experienced a rise and fall. The total rainfall continued to increase and decline in the period 1980-2012 with an overwhelming sharp rise in 2005. Rainfall amount in the period of study has shown a slight rise since 1981. Figure 2.4 shows that the mean total annual rainfall is highest for 2005 (499.67) while it is lowest for 1974 (14.67). This result supports the result in figure 2.3 that reveals the minimum and maximum annual mean rainfall for the period under study. The implication of this is that rainfall in Ibadan varies in amount from 1970 to 2012. Therefore, it is not expected that equal amount of rainfall can fall from one year to another.

Annual rainfall range indicates the variability of annual rainfall and hence denotes how reliable the rainfall is in terms of its persistence as a constant and stable replenishing source of water in Ibadan metropolis. The figure 2.5 shows rainfall range which signifies the difference between the highest rainfall and the lowest in each year. The result shows that the difference between the highest and the lowest rainfall for 1980 is 604.00mm and for 2005 is 3543.09mm. This result shows the level of variability between the years.

The coefficient of variation expressed as a percentage was determined by dividing the standard deviation by the mean. 2005 had the highest coefficient of variation of 98% for rainfall in the period 1970-2012. This indicates that rainfall is highly varied in 2005 and this is supported by its minimum and maximum mean value of 0.60mm and 3,543.69mm respectively, as well as a mean value of 499.67mm, 2002 had the lowest coefficient of variation of 12.725%, which indicates that rainfall is less varied in this year.

3.2: Temperature Trend

In many disciplines, fitting a trend is of great value. Fitting trends are used in determining the current and recent trend in temperature in the discipline of Climatology. This is because it provides major indication of the presence or absence of global warming. To establish the temperature trend in the study area, Time Series analysis was carried out using minimum temperature data of 43 years (1970-2012) to determine the variations in temperature in Ibadan. Figure 2.7 shows the temperature of the station with the lowest value of average minimum temperature within the period under study; with an average minimum temperature of 13.0^{0}C in 1979. The minimum value of 18.68^{0}C, 17.16^{0}C, 18.71^{0}C and 17.53^{0}C was recorded in 1971, 1975, 1989 and 1994 respectively, which shows that these years were relatively cooler. The maximum value of 22.48^{0}C was however recorded in 2002, indicating that it was a relatively warmer year. According to the 5-year moving average graph in figure 2.8, average minimum temperature decreased in 1970 with a slight increase in 1981 to 1989. It dropped in 1990 and increased in 1995 and remains steady from 2008-2012.

Table 2.2, shows the minimum temperature values, as well as the minimum and maximum values of temperature for the weather station in Ibadan. Temperature in Ibadan has been highly varied. The mean annual temperature for the area was 27.08^{0}C; with the lowest mean minimum of 13.0^{0}C in 1979 and the highest mean maximum of 39.82^{0}C in 2000 (Table 2.2) The mean minimum temperature for the area from 1970-2012 was 22.5. The mean maximum temperature of the area was characterized by two distinct peaks: one in 2005 (32.45^{0}C-highest) and the other peak in 1988 (33.39^{0}C). This shows that these years were the hottest years within the period under study (1970-2012). In general, Mean annual temperature of the area was stable with slight fluctuations from 1970 up until 1993 where it declined (figure 2.9) and has remained stable with slight fluctuation from 1994 to

2012 within the period.

The coefficient of variation of average minimum temperature for the weather station was also calculated. The result indicated that the station had a coefficient of variation of 20.9% in 1994 making it the year with the highest variation in average minimum temperature, and this is evident in its minimum and maximum value of 17.53^{0}C and 36.63^{0}C respectively. The year 1999 had the lowest coefficient of variation of 2.72%, which is further reflected in its minimum and maximum values of 21.77^{0}C and 23.52^{0}C respectively.

3.3: Relationship Between Total Rainfall And Average Minimum Temperature

The relationship between total rainfall and average minimum temperature was determined using various statistical techniques. For example, the curve fit was used to express the relationship between temperature and rainfall in mathematical form. Also, correlation analysis was carried out to explain the degree of this relationship. Figure 2.11 is scatter diagrams with fitted regression lines showing the relationship between total rainfall and average minimum temperature for the period under study (1970-2012). According to the scatter diagram, there is a direct relationship between average minimum temperature and total rainfall in the period under study.

3.4: Linear Regression Analysis (Total Rainfall)

This type of analysis involves predicting a dependent variable (Y) by one independent variable (X). It is given by the equation:

$$Y= f(X)$$

Where:

Y=Rainfall;
X= Time;
$Y= b_0 + b_1 X_1$

Where:

b_0= Intercept/Constant; which is part of rainfall not due to time.
b_1= Slope; which is the magnitude of change in rainfall due to a unit change in time.
When b_1 is positive, then rainfall has increased over time.
When b_1 is negative, then rainfall has decreased over time.

According to table 2.3 b_1 is positive, indicating that rainfall has increased over time. The table also shows that rainfall in the study area has a very steep slope with a magnitude of change of 47.187.

3.4.1: Testing The First Hypothesis

Figure 2.12 reveals that an upward trend in rainfall is evident during the period under study (1970-2012), table 2.3 also shows that this is statistically significant at the 0.05 level. Thus, H_1, which states that, there is an upward trend in rainfall within the period under study, is accepted; and H_0 is rejected.

3.5: Linear Regression Analysis (Average Minimum Temperature)

3.5.1: Testing the Second Hypothesis

Table 2.4, as well as figure 2.13, clearly proves that there has been an upward trend in average minimum temperature within the period under study (1970-2012). It shows an upward trend that is significant, since $P < 0.05$ (this result is statistically significant). Therefore, H_1, which states that there is an upward trend in temperature within the period under study (1970-2012), is accepted and H_0 is rejected. The result also shows a steady growth in average minimum temperature within the study area (Fig. 2.13)

3.6: Correlation Analysis (Testing the Third Hypothesis)

Pearson's correlation analysis was conducted to establish the relationship between total rainfall and average minimum temperature. According to this analysis (table 2.5), a correlation coefficient of 0.348 indicates that the relationship between total rainfall and average minimum temperature is positive. This means that, as average minimum temperature is increasing, total rainfall is increasing. However, P is > 0.05 which shows that this result is not statistically significant. Therefore, the third hypothesis, which states that there is a positive relationship between total rainfall and average minimum temperature, is accepted, and H_0 is rejected.

3.7: Analysis of Monthly Variations in Rainfall and Temperature

The monthly analysis of total rainfall and average minimum temperature patterns in the area of study is characterized by marked variations, more pronounced than the annual trends. This is why it is crucial to separate the monthly analysis from the annual analysis

3.71: Monthly Rainfall Pattern

The monthly rainfall pattern (figure 2.14) indicates that the highest average rainfall of 124.83mm was recorded in the month of June. This means that June was the wettest month in study area. This was followed by September, July and August with average rainfall of 114.33mm, 107.67mm and 101.37mm respectively. The lowest average rainfall of 17.52mm was recorded in January and this shows that January was the driest month. The total mean monthly rainfall for the study area was 78.3825mm, which indicates that January, February, March, April and November fall below the total mean monthly rainfall while May, October and December are slightly above total mean monthly rainfall of the study area.

3.8: Monthly Minimum Temperature Pattern

The monthly temperature pattern (figure 2.15) shows that the highest average monthly temperature of 23.8^{0}C was recorded in the month of February July and September had the lowest value of 21.9^{0}C each. This indicates a clear range, (difference between the highest and lowest value) of 1.9^{0}C.

4.0 Conclusion and Recommendation

The results of this study show that the variations and trends in total rainfall and average minimum temperature do not conclusively indicate climate change in the region under study. However, one cannot underestimate the possibility of climate change in the study area and possible human impact on the 'local' climate. Also, data of a much longer period or duration (e.g. 100years) and spatial data will be needed to provide more accurate information on climatic change in the area. This will however be difficult or impossible to obtain from the appropriate weather monitoring agencies. Therefore, it will be correct to state that the total rainfall and average minimum temperature of Ibadan region is characterized by considerable variations.

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FIG 1.1. MAP OF IBADAN SHOWING THE WEATHER STATION
Source: Department of Geography, University of Ibadan

TABLE 2.1: TOTAL RAINFALL VALUES FOR THE WEATHER STATION (1970-2012)

LOCATION	MEAN TOTAL RAINFALL (mm)	ANNUAL MEAN MINIMUM RAINFALL (mm)	ANNUAL MEAN MAXIMUM RAINFALL (mm)	RAINFALL RANGE (mm)
NIMET (IBADAN)	9,233.60	14.67	499.67	485

TABLE 2.2 MINIMUM TEMPERATURE VALUES FOR THE STATION (1970-2012)

LOCATION	MEAN MINIMUM TEMPERATURE (1970-2012, Celsius)	MEAN MINIMUM VALUE (Celsius)	MEAN MAXIMUM VALUE (Celsius)	MEAN ANNUAL TEMPERATURE (Celsius)
NIMET	22.5	13.00	39.82	27.08

TABLE 2.3: LINEAR REGRESSION

CURVE FIT – PREDICTING TOTAL RAINFALL OVER TIME							
LOCATION	**R^2**	**d.f**	**F-Test**	**Significance**	**b_0**	**b_1**	**Decision**
NIMET	0.371	42	24.813	0.000	-92613.187	47.817	RISING

TABLE 2.4: LINEAR REGRESSION

CURVE FIT – PREDICTING AVERAGE MINIMUM TEMPERATURE OVER TIME							
LOCATION	**R^2**	**d.f**	**F-Test**	**Significance**	**b_0**	**b_1**	**Decision**
NIMET	0.192	42	9.772	0.03	-68.906	47.817	RISING

Table 2.5: CORRELATION ANALYSIS

		Minimum Annual mean Temperature	Total annual Rainfall
Average minimum Temperature	Pearson Correlation	1	.348*
	Sig. (2-tailed)		.000
	N	43	43
Total annual rainfall	Pearson Correlation	.348*	1
	Sig. (2-tailed)	.022	
	N	43	43

*Correlation is significant at the 0.05 significant level (2-tailed)

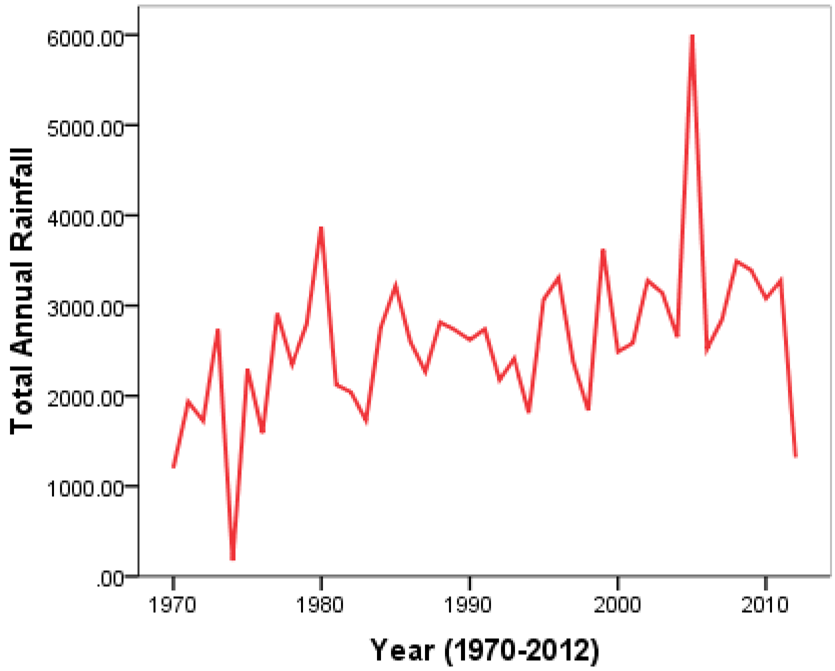


Figure 2.1: INTERACTIVE GRAPH OF TOTAL RAINFALL FOR IBADAN (1970-2012)

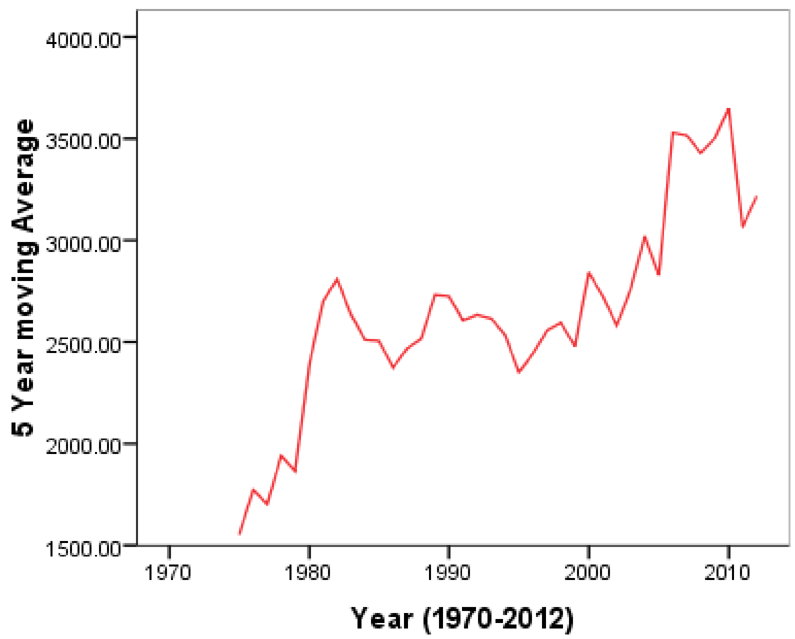


Figure 2.2: 5-YEAR MOVING AVERAGE FOR IBADAN RAINFALL

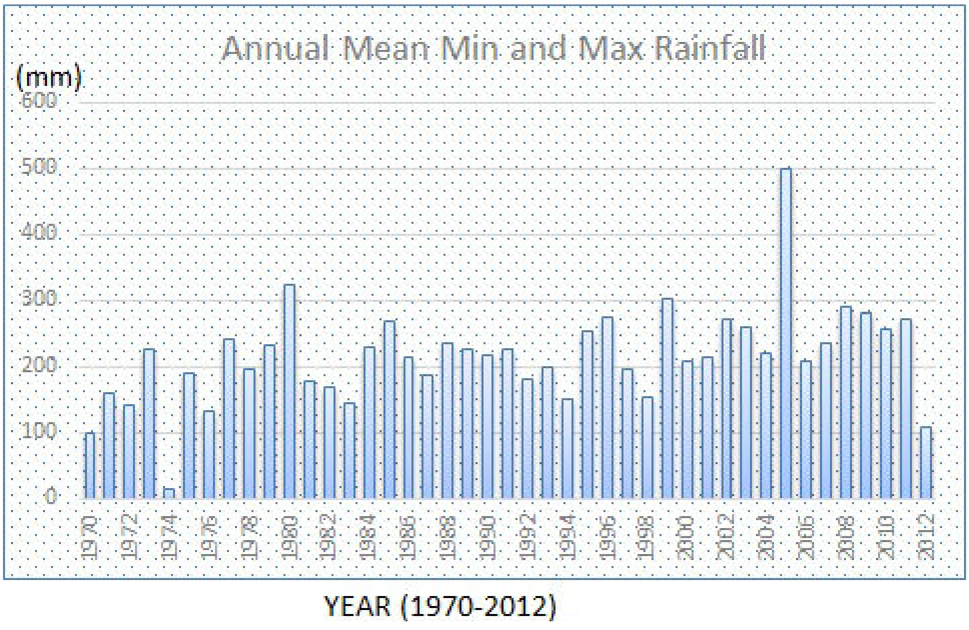


FIG 2.3: MAXIMUM AND MINIMUM MEAN ANNUAL RAINFALL (1970-2012)

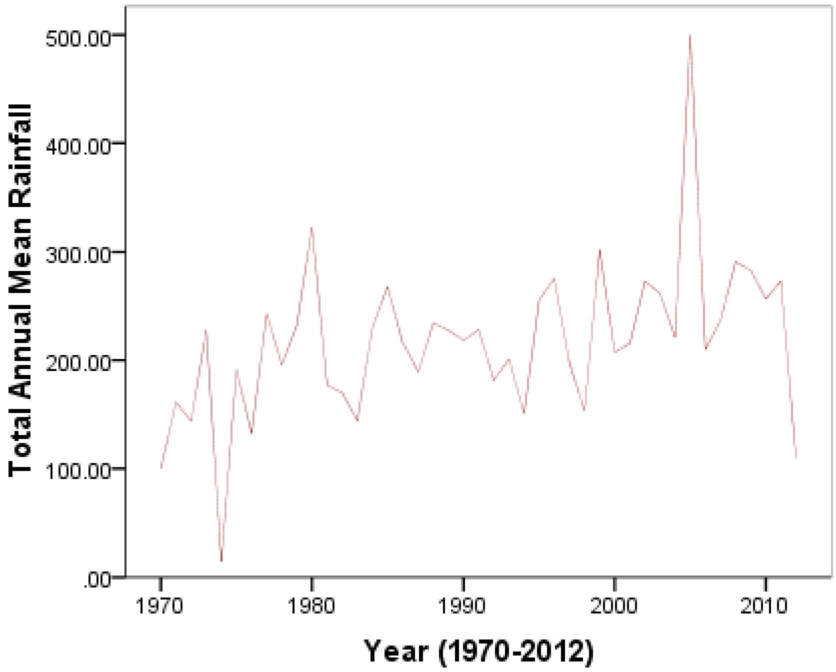


FIGURE 2.4: TOTAL MEAN RAINFALL VALUES FOR THE WEATHER STATION

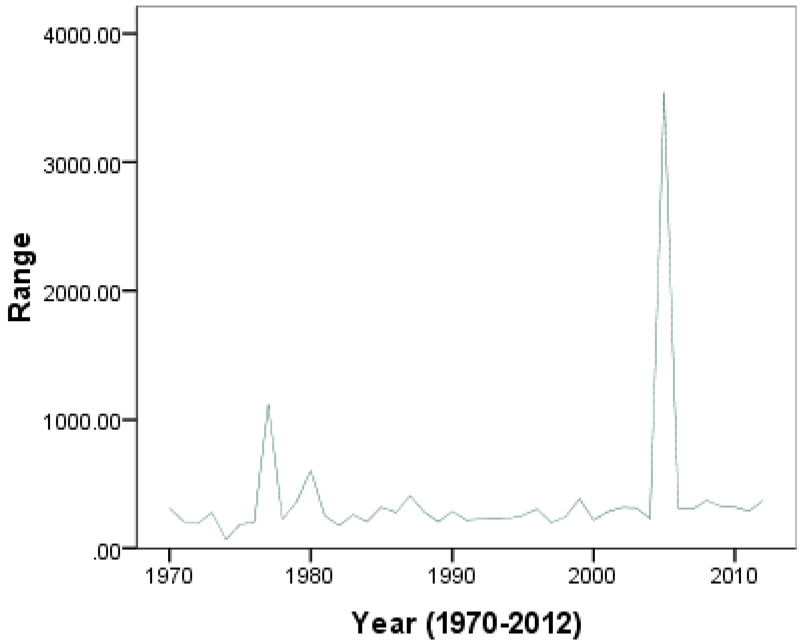


FIG 2.5 ANNUAL RAINFALL RANGE

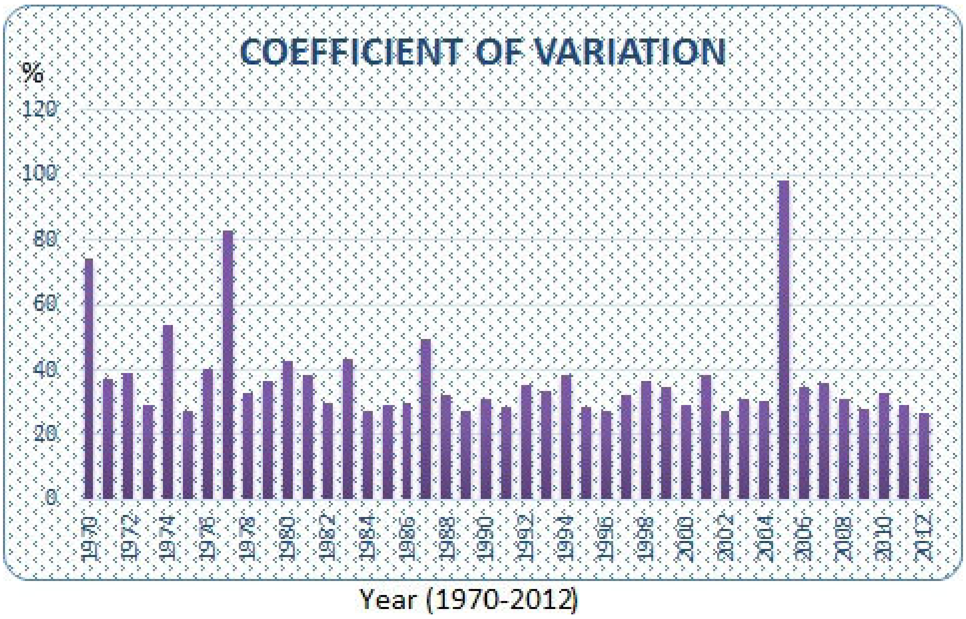


FIG 2.6: COEFFICIENT OF VARIATION

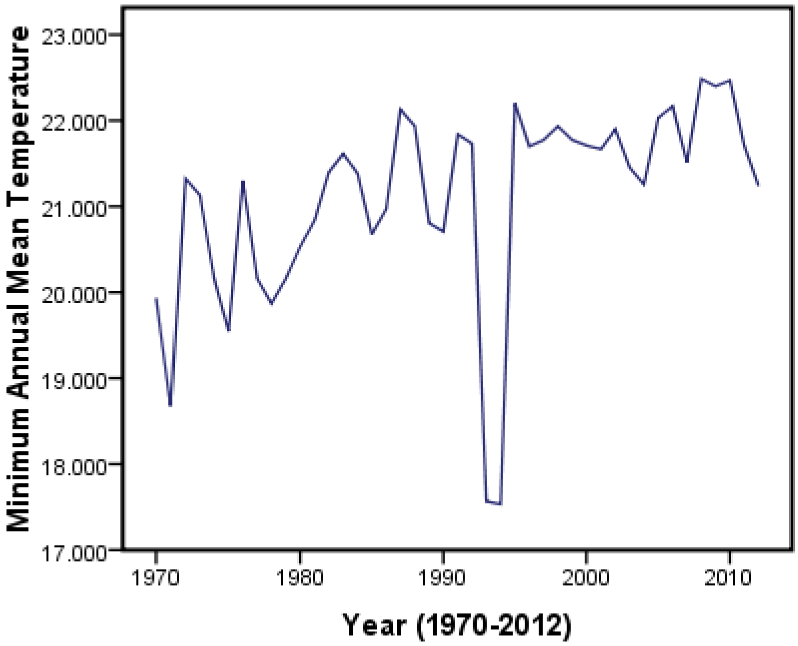


Figure 2.7: INTERACTIVE GRAPH OF AVERAGE MINIMUM TEMPERATUREFOR IBADAN

Figure 2.8: 5-YEAR MOVING AVERAGE FOR IBADAN MINIMUM TEMPERATURE

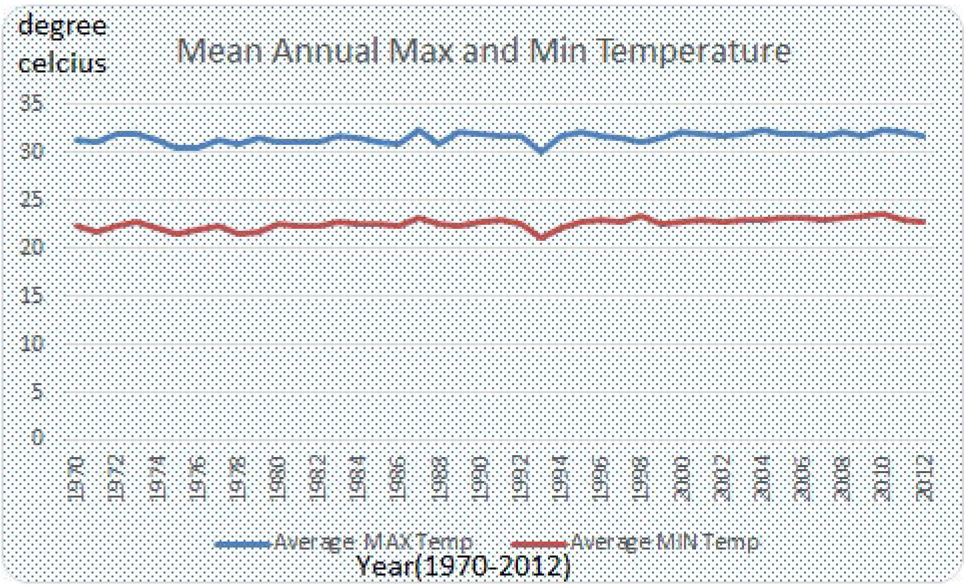
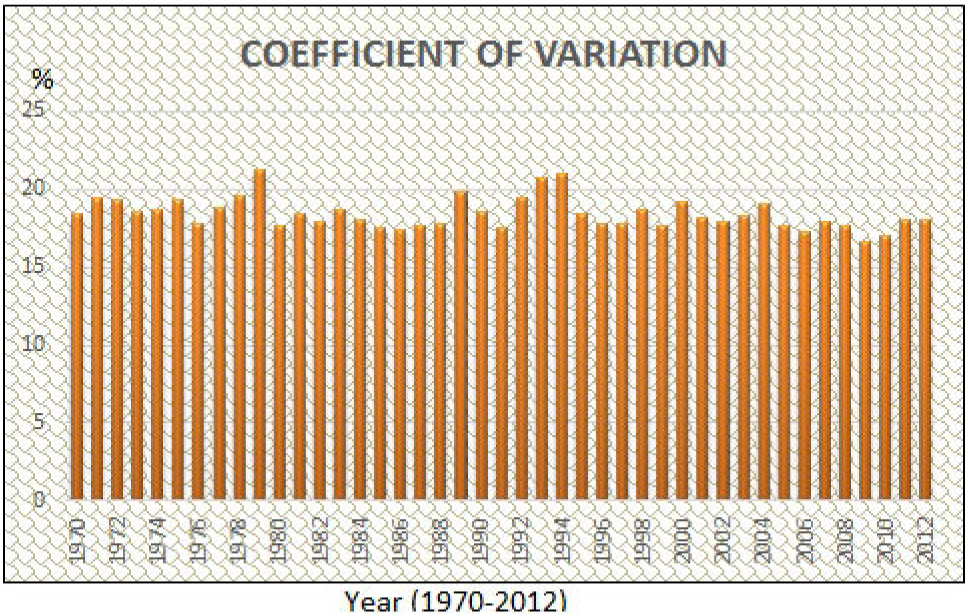


FIG: 2.9 AVERAGE MIN AND MAX TEMPRATURE



FIGT 2.10: COEFFICIENT OF VARIATION OF AVERAGE MINIMUM TEMPERATURE

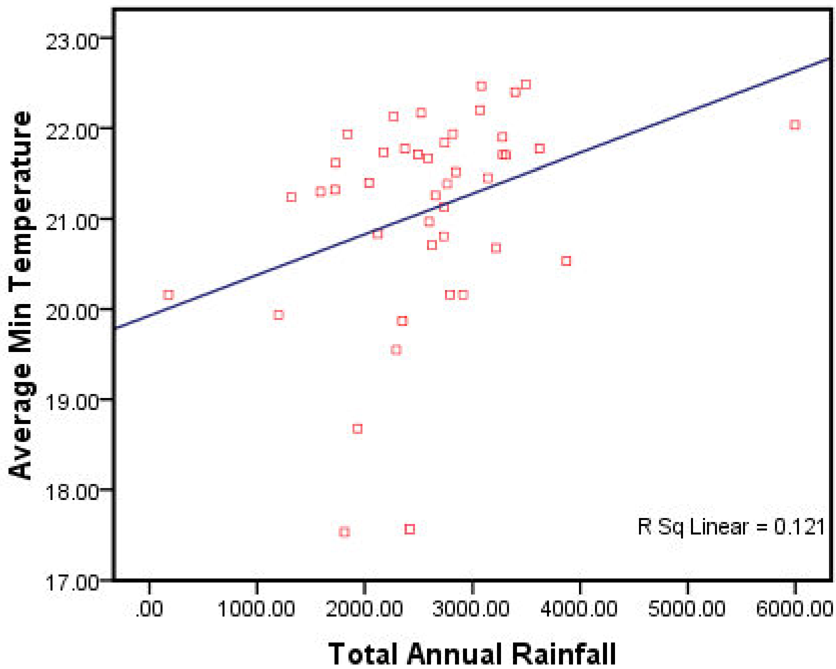


FIG 2.11: SCATTER DIAGRAM WITH FITTED REGRESSION LINES FOR AVERAGE MINIMUM TEMPERATURE AND TOTAL RAINFALL WITHIN THE STUDY AREA

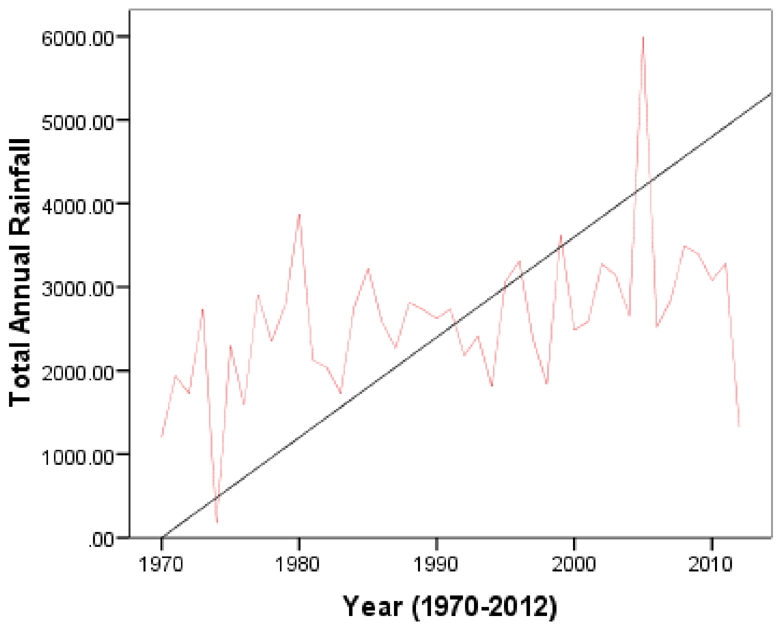


FIG 2.12: TOTAL RAINFALL

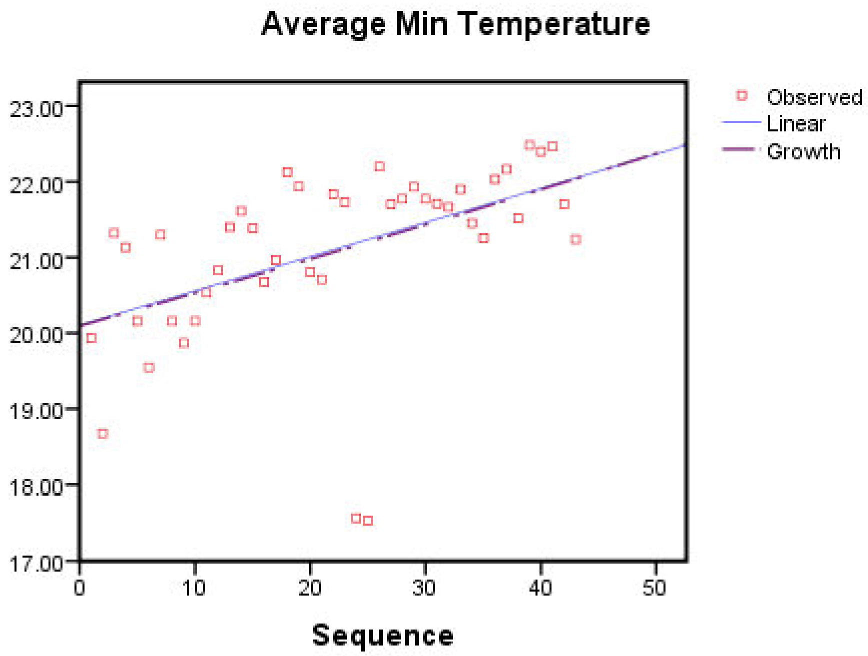


FIG 2.13: AVERAGE MINMUM TEMPERATURE

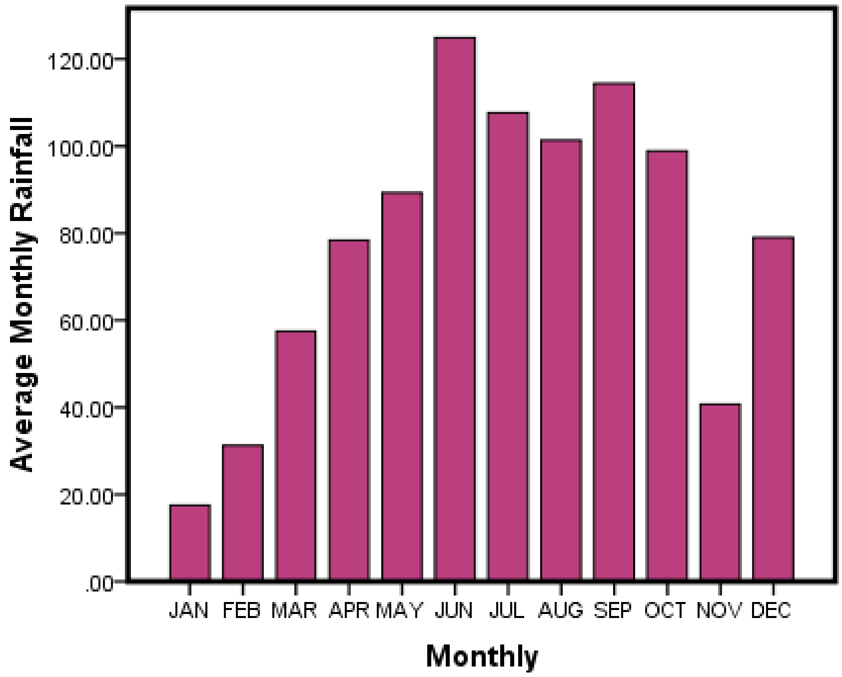


FIGURE 2.14: AVERAGE MONTHLY RAINFALL

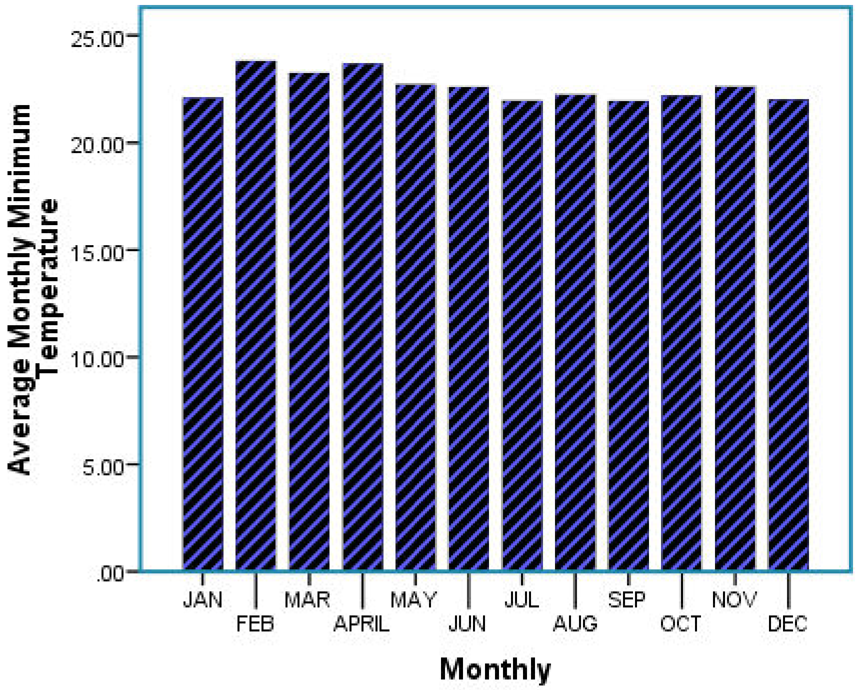


FIGURE 2.15: AVERAGE MONTHLY MINIMUM TEMPERATURE(^{0}C)