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Climate Variation Assessment Based on Rainfall and Temperature in Ilorin, Kwara State, 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 Ilorin based on the variations in rainfall and temperature within the period 1980-2015. Time Series Analysis was used to determine the trend of rainfall and temperature within the period 1980-2015. 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 MAKESEN software was used to determine the temporal trend of rainfall indices 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 downward trend of 0.814 mm per year in the annual mean rainfall and also there is an upward trend of 0.029 per year in average annual minimum temperature and total annual maximum temperature has an upward trend of 0.01 mm per year. Thus, the rainfall is decreasing and temperature tends to increase.

Key word: Climate variability, Rainfall, Temperature, Period, Temporal trend, Kwara state

INTRODUCTION

Climate variability and change are among the major environmental challenges of the 21st century. It is a known fact that our climate is changing and these changes are taking place very sensibly. Climate change seems to be the foremost global challenge facing humans at the moment. The growing intensity and frequency of droughts, floods, extreme whether events and other impacts speak loudly for the need to deal with the real and serious threat (Fatile, 2013; Osakede *et al*., 2016; Olubanjo and Adebolu, 2018). The Earth's climate is dynamic and naturally varies on seasonal, decadal, centennial and longer time scales. Each "up and down" fluctuation can lead to conditions which are warmer or colder, wetter or drier and stormier. These changes in climate may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (Bates *et al*., 2008; IPCC, 2014). One of the most significant climatic variations in the African Sahel since the late 1960s has been the persistent decline in rainfall. The Sahel is characterized by strong climatic variations and an irregular rainfall that ranges between 200 mm and 600 mm with coefficients of variation ranging from 15 to 30% (Yunusa *et al*., 2017).

According to IPCC, a rainfall decrease of 29-49% has been observed in the 1968-1997 period compared to the 1931-1960 baseline period within the Sahel region (Abaje *et al*., 2010). The West Africa region has experienced a marked decline in rainfall from 15 to 30%

depending on the area (Niasse, 2005;Udo-Inyang and Edem, 2012). The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994 which was considered to be the wettest year of the past 30 and was thought to perhaps indicate the end of the drought. Unfortunately, dry conditions returned after 1994 (Abaje *et al*., 2010). The pattern of rainfall in middle belt Nigeria (Kwara State inclusive) is highly variable in spatial and temporal dimensions with inter-annual variability. As a result of the large inter-annual variability of rainfall and temperature, it often results in climate hazards, especially floods and severe and widespread droughts with their devastating effects on food production and associated calamities and sufferings (Simane *et al*., 2016; Olubanjo and Adebolu, 2018). Rainfall and temperature are the key climatic variable. Crops and animals derived their water resources largely from rainfall. It is considered as the main determinant of the types of crops that can be grown in an area and also the period of cultivation of such crops and the farming systems that can be practiced.

In many parts of the world, climate variability is already having serious impacts especially on the environment and agriculture (Muhkeeber and Sparks, 2005; Onu and Ikehi, 2016; Olubanjo and Adebolu, 2018), Climate above or below a long term average value, occur over seasons and years (Innocent *et al*, 2016). It is the variation in the mean state and other statistics of climate on all temporal and spatial scales beyond that of individual weather events (Herrere *et al*, 2018). Bates *et al.* (2008) in IPCC report argued that changes in the total amount of precipitation, its frequency and intensity directly affect the magnitude and timing of run – off and the intensity of floods and droughts. This can have major impacts on water resources, affecting both ground and surface water supply require for various purposes such as domestic, industrial, irrigation, hydropower generation, navigation among others. Climate variability refers to the temporary fluctuations in climate conditions (Madhusoodhanan *et al*., 2016) while climate change refers to a permanent alteration to the observed climate characteristics. The changes can be due to natural factors or anthropogenic factors. In other words, climate change refers to the deviation from the mean climate that is statistically significant. On the other hand, Climate change and climate variability have significant impacts on many sectors of the society such as on health, agriculture, water resources and energy. Weather and climate extremes are associated with loss of life, destruction of property and many other socioeconomic activities miseries around the world (Mathuku, 2016).

Developing countries are more vulnerable to the effects of climate change than developed countries because of their low adaptive capacity. Africa’s human existence and development is therefore under threat from the adverse impacts of climate change because most African nations are poor hence limited adaptive capacity to climate extremes. Malawi is also vulnerable to the impacts of climate change because of its limited adaptive capacity. On a global scale, climate extremes have been observed to increase in frequency. This has been reported by the IPCC. It is very likely that over the past 50 years, cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It is likely that heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level has increased worldwide (IPCC, 2014). The IPCC projects that on the African continent, average temperatures will increase by 1.5 to 3°C by the year 2050. World over, climate extremes such as frequent droughts and floods are not uncommon. There are issues of shifts of onset and cessation of rainfall and poor distribution of seasonal rainfall. There is no doubt that globally, climate is changing as supported by many research findings such as those by IPCC. The changing climate has been attributed to natural and anthropogenic causes. Natural causes are a result of the changes in the climate system (i.e. changes in the land surface processes, atmospheric processes, cryospheric processes and oceanic processes). Alteration in the structure of the earth‘s surface may lead to changes in the observed climate or weather characteristics. For instance, forest fires due to lightning can inject gaseous pollutants and particulates into the atmosphere, such as carbon dioxide and smoke. The ejection may change the atmospheric composition, thereby affecting the amount of radiation received on the surface. Forest fires may also cause deforestation, which may alter the earth‘s reflectivity (Madhusoodhanan *et al*., 2016). On the other hand, anthropogenic processes include such activities like land use practices, nuclear activities, atmospheric pollution leading to changes in ozone concentration and the release of greenhouse gases into the atmosphere (Madhusoodhanan *et al*., 2016). As reported by the IPCC (2013), there is evidence that some climate extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases.

While it is undeniable fact that climate is changing, there is a need to provide information to support this fact. Thus studies should be carried out to provide evidence of significant changes in climate variables to answer the question of whether the climate, in general, has become more or less extreme (IPCC, 2014). However the challenge lies in that, the terms ‘more extreme’ and ‘less extreme’ can be defined in different ways, resulting in different characterizations of observed changes in extremes. IPCC (2014) observes that many weather and climate extremes result from natural climate variability (including phenomena such as El Niño). Even if there were no anthropogenic changes in climate, a wide variety of natural weather and climate extremes would still occur due to changes in the natural climate system. Therefore, there is need to provide objective evidence rather than use subjective conclusion that climate is changing. In recent literatures, it has been observed that climate variability and climate change are discussed hand in hand; this is because so many researchers claimed that it is difficult to separate a swing in climatic mean that is caused by natural forcing which is termed climate variability and climate change brought about by anthropogenic activities. Therefore it is better to discuss the two together because an understanding of climate variability would give an insight into climate change which is usually on a longer term. Climate varies overtime in any one geographical area and also varies from one geographical area to another. According to Xu *et al*. (2017) and Olubanjo and Adebolu (2018) climate varies on time scales ranging from months to Millennia. The seasonal cycle is the most regular of all climate variations. Seasonal changes in precipitation and temperature greatly influence variations in stream flow, lake, reservoir, and ground water levels, and groundwater recharge. However, for water supply studies climate variations from months to centuries are most relevant. Climate varies from place to place depending on latitude, distance to the sea, vegetation, orography and other factors. Climate variability also occurs at different time scale. While climate change is known to be a global environmental problem, mainly caused by the world’s biggest carbon dioxide emitters: China (28%), the United States (16%), the European Union (10%), India (6%) and the Russian federation (6%) (Fatile, 2013; Osakede *et al*., 2016).This shows that climates are not the same all over the world but varies from one place to another and from one season to another.

According to Michael (2002), climate varies on all time scales, from one year to the next, as well as from one decade, century or millennium to the next. The complex nature of this variability is a major obstacle to the reliable identification of global changes brought about (in the past, present or future) by the presence and activities of humanity on this planet. Climatic change is the natural variability of climate. How can person discern long-term climatic change, given the notorious variability of local weather and climate from day to day and year to year? This question according to Hansen *et al.* (2011) assumes great practical importance, because of the need for the public to appreciate the significance of human made global warning. According to the NASA’s earth science division, carbon dioxide laves in the air are at the highest in 650,000 years, Arctic sea ice is shrinking at 13.3 percent per decade and shrank to the lowest extent on record in 2012. Actions to stem emissions of the gases that cause global warming, mainly CO_2, are unlikely to approach what is needed until the public perceives that human - made climate change is underway and will have disastrous consequences if effective actions are not taken to short, circuit the climate change. Climate change is global in nature but the potential change has to be investigated at all level of the global subdivision which include countries and even states. As a result climatic data of Ilorin the capital of Kwara State needs to be analyzed so as to know its climate variability and the risk of vulnerability due to climate change. Farmers need to know the onset of the raining season so as to help them in early season farming and must have the knowledge of cessation so as to know the time for late farming. Climate change is no longer something to happen in future but rather an ongoing phenomenon. It is now univocally established that climate change is a reality as noted by the intergovernmental panel on climate change (IPCC, 2013). While data on the global impacts of climate variability and change are available, those at regional levels are scanty and scattered. This prompted this study that took a general overview of climate variability in Ilorin to determine the temporal variations in rainfall and temperature patterns by using the mean monthly and mean annual rainfall and temperature values for 35 years thereby determining the nature of climatic variation and its possible effects is known for future occurrence.

MATERIALS AND METHODS

Study location

Ilorin, the Kwara State capital is located between latitude $08^o36'$N of the equator, and longitude $04^0 33^1$E of the Greenwich Meridian. It is situated at a strategic point between the densely populated South-Western and the sparsely populated middle belt of Nigeria. Ilorin is located in the transitional zone between the deciduous woodland of the South and dry savannah of North Nigeria (Ajadi *et al.*, 2016). Figure 1 shows the map of Kwara State and the study area. It covers about 100 km^2. The landscape ranges in elevation in the western part from 273 m to 333 m and in the eastern part from 273 m to 364 m. Sobi hill is the dominant landform, it is an Inselberg, and it is the highest point in the city (394 m above sea level) (Ajadi *et al.*, 2016).

Climate of Ilorin

The climate of Ilorin is characterized by both wet and dry seasons. The rainy season begins towards the end of April and last till October while the dry season begins in November and ends in April. The temperature of Ilorin ranges from 33^0C to 35^0C from November to January while from February to April; the value ranges between 34^0C to 37^0C. Days are very hot during the dry season. The total annual rainfall in the area ranges from 990.3 mm to 1318 mm. the rainfall in Ilorin city exhibits the double maximal pattern and greater variability both temporarily and spatially. The relative humidity at Ilorin city ranges from 75% to 88% from May to October while in the dry season it ranges from 35% to 80% (Ajadi *et al.*, 2016)

Collection of data

The data used for this research is basically secondary in nature and it include; Meteorological data such as Rainfall (mm), maximum temperature (^{0}C), and minimum temperature (^{0}C)

(Table 1). The meteorological data were obtained from NIME office, Ilorin (Nigeria Meteorological Agency, the agency responsible for the measurement, control and storage of meteorological data in Nigeria) as well as meteorological unit lower Niger River Basin Development Authority, Ilorin. The climatic variables used for this work are rainfall, minimum and maximum temperature. The data collected on all these climatic variables span for 35 years i.e. (1980-2015) this is because the World Meteorological Organization, (2013) suggested 30-35 years as the minimum period for averaging climatic variables before variability and changes can be ascertained.

Figure 1: Map of Nigeria showing Kwara state and study area (Ilorin Metropolis)

Table 1: Types of Climatic data

Variables	Period
Rainfall (mm)	1980-2015
Minimum temperature (^{0}C)	1980-2015
Maximum temperature (^{0}C)	1980-2015

Methods of data analysis

The analysis of the data were carried out by using arithmetic mean, median, skewness, standard deviation, trend analysis, Pearson product moment correlation and regression analysis. The temporal trend of rainfall indices was carried out using MAKESEN software.

RESULTS AND DISCUSSION

Descriptive pattern of rainfall of the study area

The beginning of the raining season in Ilorin, the Kwara State capital is observed to be March/April which is usually characterized by little down pour of rain which last for a short duration depositing about 20 mm to 36 mm of rain. For all the years, a steady increase in rainfall occurs from January to June, and then decrease from July to August, then peak at September, then reduces from October to December. The annual rainfall statistics showed that rainfall has not been consistent especially with reference to its volume, both annual and decadal, for the past 35 years from 1980 to 2015. The peak annual rainfall occurs in 1994 depositing 1750.42 mm. 2013 has the lowest recorded amount of rainfall depositing 733.3 mm. The range of rainfall for the year under study is 1027.12 mm. Table 2 shows monthly data obtain for each month and the summation for each year. Figure 2 gives the pictorial view i.e. bar chart showing total yearly Rainfall of the study area. January/February of all the years under study shows little or no rainfall at all except for year 1994 which has 70.12 mm amount of rainfall. As from March to October the rain was observed to be relatively heavy and then decrease from November to December with little or no rainfall except for 1994 which has 289.9 mm of rain in the month of November all these were shown in table 2. Figure 3 shows the graph of annual mean rainfall against year. From the graph it was observed that the annual mean rainfall exhibits a decline in the trend with the trend line equation suggesting a reduction in the amount of rainfall by about 0.82 mm These results are consistent with Ayanshola and Sule (2006) and Agboola and Emmanuel (2016).

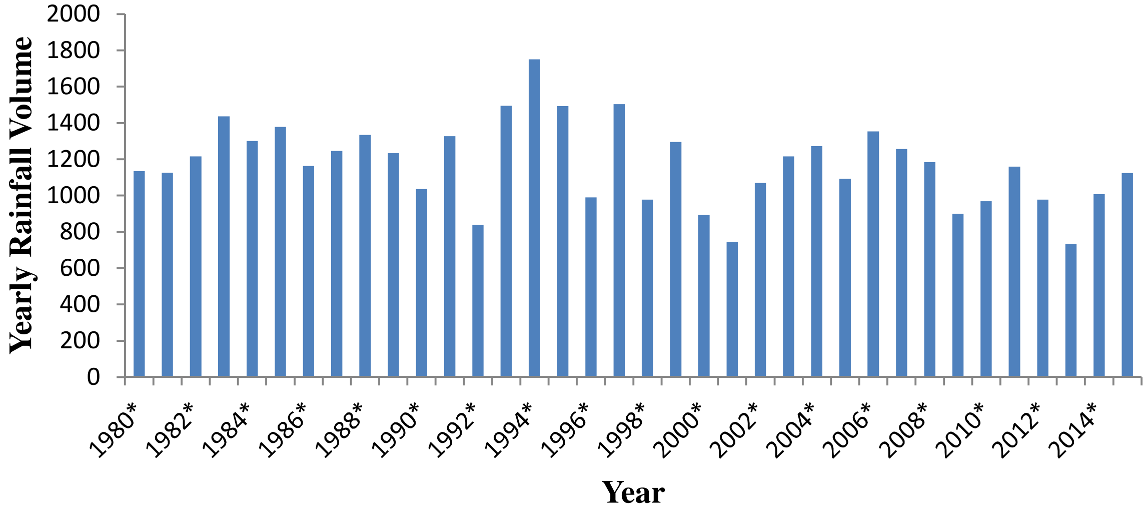

Figure 2: Bar chart showing total Yearly Rainfall in Ilorin

Table 2: Summary of annual rainfall at Ilorin in the year 1980 – 2015

YEARS	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1980		13	53	74	135.7	215	235	143.37	124.28	98	43		1134.35
1981		36	45	115	126.42	147.2	173.85	129.63	169.7	135.34	35.17	12	1125.31
1982			12	98	136.14	227.4	195.2	148	166.63	181.7	51.2		1216.27
1983	13	27	71	106.56	213.4	198	234.17	183.28	187.66	162.3	39		1435.37
1984			51.8	103	147.4	125	240.42	187.21	236.4	187.9	21		1300.13
1985		11	47.6	126	254.2	267.9	193.8	137.1	162.5	123.7	54		1377.8
1986			62.3	79.8	135.3	198.4	216.9	134.62	181.3	154.32			1162.94
1987			43	59	173.2	169	186.7	283.4	171.9	128.6	11	19	1244.8
1988		21	34	127.21	145.8	197.3	201.3	212	198.4	177.8	19		1333.81
1989			56.2	96.5	106.8	239.93	111.32	199.94	233.8	188.94			1233.43
1990		8.5		158.2	130.74	129.7	149.98	116.8	225.05	98.73	17.37		1035.07
1991	17.15	17.57	37.76	67.45	340.79	135.9	319.52	138.78	124.78	127.01			1326.71
1992			2	46.7	166.62	90.1	134.72	75.9	129.4	193.2			838.64
1993		102.5	79	35.2	176.07	220.55	100.4	333.6	362.8	84.86			1494.98
1994	70.12		7.9	161	168	168.1	283.1	83.4	201	317.9	289.9		1750.42
1995			79	79	234	186.5	140.5	245.06	372.5	133	11.5	12	1493.06
1996			56.52	67.1	165.3	154.2	96.4	154.6	199.8	96.3			990.22
1997			93.1	206.4	207.4	375.2	158.8	107.6	224.4	115.3	15		1503.2
1998		0.75	17.1	73.9	159.6	132.3	58.5	170.9	224.8	140			977.85
1999		32.5	54.9	67.1	143.3	244.9	195.6	85.7	265.6	182.5	22.8		1294.9
2000		2.2	2.4	22.8	68.2	262.2	93.4	163.9	268	9			892.1
2001			18	45	139	121.8	138.7	44.5	176.4	60.8			744.2
2002			59.4	163.2	57.2	97.8	180.8	182.7	144.5	176.7	6.5		1068.8
2003		14	12.4	93.9	124.54	360.7	123.2	130.9	176.2	133.4	46.7		1215.94
2004	18.2	33.1	4	67	260.5	159.2	211.4	145.4	243.5	98.1	31.6		1272
2005		5.5	25.5	75.5	187.6	171	130.2	93.6	282.6	109.8	10.5		1091.8
2006	1.2	16.1	27.5	106.6	163.7	259.6	224.1	88.2	276.2	190			1353.2
2007		29.3	37.6	115.2	150.3	235	198.1	124.7	203.6	137.9	23.8		1255.5
2008		39.4	47.3	87.6	106.7	131.5	151.4	193.2	199	186.7	41.7		1184.5
2009		13	17.5	123.4	98	127.3	126.7	139.3	162.4	92			899.6
2010		9	21	115	74	91.6	132.3	186.2	201	117.3	22		969.4
2011			13	74	124	179.6	146	260.3	178.5	155.3	29		1159.7
2012			43	35.3	134.7	77.6	144.7	228	179.1	134.5			976.9
2013				29.5		67.3	163.9	172.8	189.1	98.7	12		733.3
2014		35	37	45	66.4	124.3	173.6	193.8	207	79.6	45		1006.7
2015	17	31	23	63.2	121.7	148.7	154.8	224.2	181.7	127.3	31.3		1123.9
Average		13.7	35.88	89.14	148.4	178	169	206	137	105.67	25.83		1300

Source: Lower Niger River Basin Development Authority, Ilorin (2017)

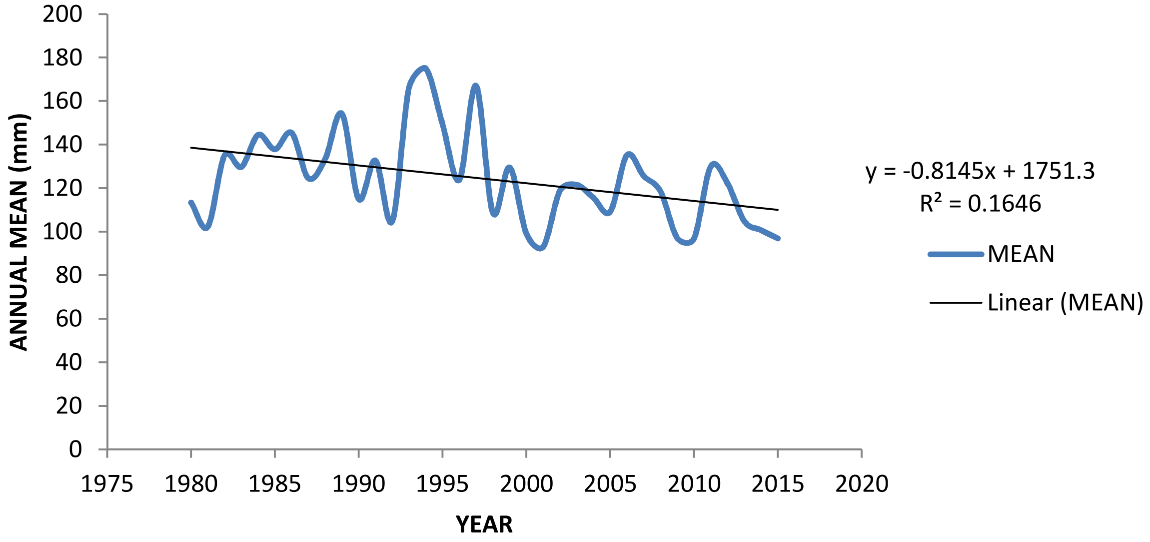

Figure 3: Graph of annual mean rainfall against year.

Descriptive pattern of minimum temperature

Figure 4 and Table 3 show distribution of minimum temperature recorded between 1980 and 2015. The study shows that the year 1998 recorded the lowest mean minimum temperature at the station, while the year 1984 recorded the highest minimum temperature.

Annual minimum temperature of the study area shows that 1997 has the lowest annual minimum temperature total of 229°C while 2012 has 276°C as the year with the highest annual minimum temperature has shown in table 3. Figure 5 is a graph showing the average minimum temperature against years of the study. From the graph, a positive trend of 0.029°C increase in minimum temperature and R^2 value of 0.137 shows slight increase in minimum temperature with an increase in years (i.e slight increase in climatic trend or climatic variation). This is in accordance with IPCC (2014).

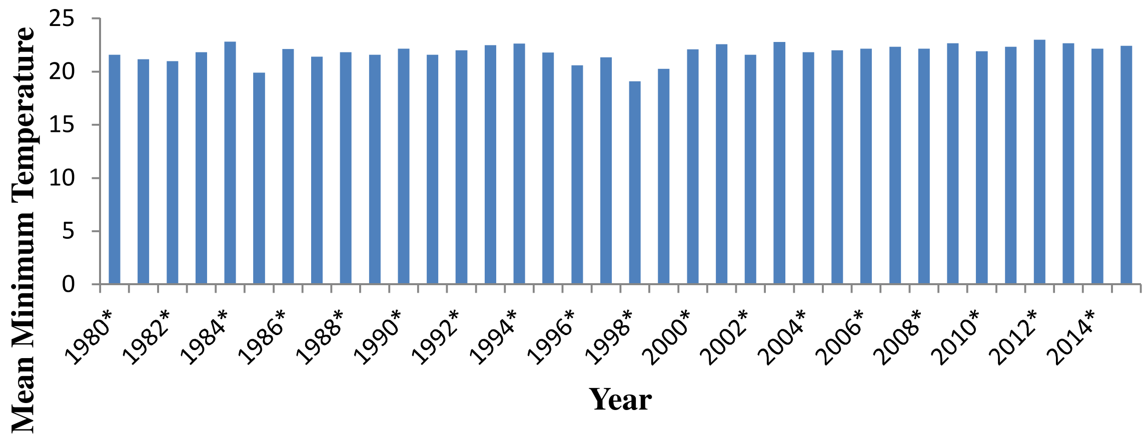

Figure 4: Bar chart showing descriptive pattern of minimum temperature between 1980–2015

Table 3: Summary of annual minimum temperature at Ilorin in the year 1980-2015

YEARS	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	Average
1980*	18	23	25	24	24	23	19	20	21	21	22	19	259	21.58333
1981*	19	23	24	24	23	23	20	20	20	20	20	18	254	21.16667
1982*	21	22	22	23	24	23	21	21	21	21	18	15	252	21
1983*	21	21	23	23	22	23	22	22	22	22	22	19	262	21.83333
1984*	24	25	24	25	24	23	22	22	22	22	22	19	274	22.83333
1985*	17	18	18	17	17	23	22	22	22	23	23	17	239	19.91667
1986*	20	22	23	23	21	22.5	22	24	22	23	22	21	265.5	22.125
1987*	20	19	22	22	21	22	22.5	22.6	22.3	23.1	21.5	18.7	256.7	21.39167
1988*	19	20	22	22	22	22	23	23	22	23	23	21	262	21.83333
1989*	19	20	26	24	22	22	23	22	22	20	20	19	259	21.58333
1990*	22	20	23	25	24	22	23	21	23	23	20	20	266	22.16667
1991*	18	21	25	25	24	21	23	23	22	23	18	16	259	21.58333
1992*	20	23	23	21	24	20	23	23	23	23	22	19	264	22
1993*	21	24.3	25.2	25.2	24.3	19	23	23	22	22	21	20	270	22.5
1994*	20	23	23	25	24	22.5	22	24	22	23	22	21	271.5	22.625
1995*	18	21	25	21	24	22	22.5	22.6	22.3	23.1	21.5	18.7	261.7	21.80833
1996*	20	22	23	23	21	21	21	21	21	21	18	15	247	20.58333
1997*	19	20	22	22	22	22	22	22	22	22	22	19	256	21.33333
1998*	17	18	18	17	17	20	19	20	21	21	22	19	229	19.08333
1999*	20	19	22	22	21	21	20	20	20	20	20	18	243	20.25
2000*	22	20	23	25	24	22	22	22	22	22	22	19	265	22.08333
2001*	18	21	25	25	24	23	23	23	22	23	23	21	271	22.58333
2002*	20	23	23	21	24	22	23	22	22	20	20	19	259	21.58333
2003*	21	24.3	25.2	25.2	24.3	22.8	22.5	22.6	22.3	23.1	21.5	18.7	273.5	22.79167
2004*	19	20	26	24	22	22	22	22	22	23	23	17	262	21.83333
2005*	21	22	22	23	24	22	23	21	23	23	20	20	264	22
2006*	24	25	24	25	24	22	22	22	22	22	18	16	266	22.16667
2007*	18	23	25	24	24	24	22	23	21	23	22	19	268	22.33333
2008*	21	21	23	23	22	24	23	23	23	22	21	20	266	22.16667
2009*	19	23	24	24	23	24	23	23	23	23	22	21	272	22.66667
2010*	17	20	26	24	22	22	23	23	23	22	22	19	263	21.91667
2011*	20	22	22	23	24	23	22	22	24	22	23	21	268	22.33333
2012*	16	25	24	25	24	23	24	23	23	23	22	24	276	23
2013*	19	23	25	24	24	23	24	23	23	23	23	18	272	22.66667
2014*	20	21	23	23	22	23	22	23	23	23	22	21	266	22.16667
2015*	21	23	24	24	23	22	23	22	22	24	22	19	269	22.41667

Source: Lower Niger River Basin Development Authority, Ilorin (2017)

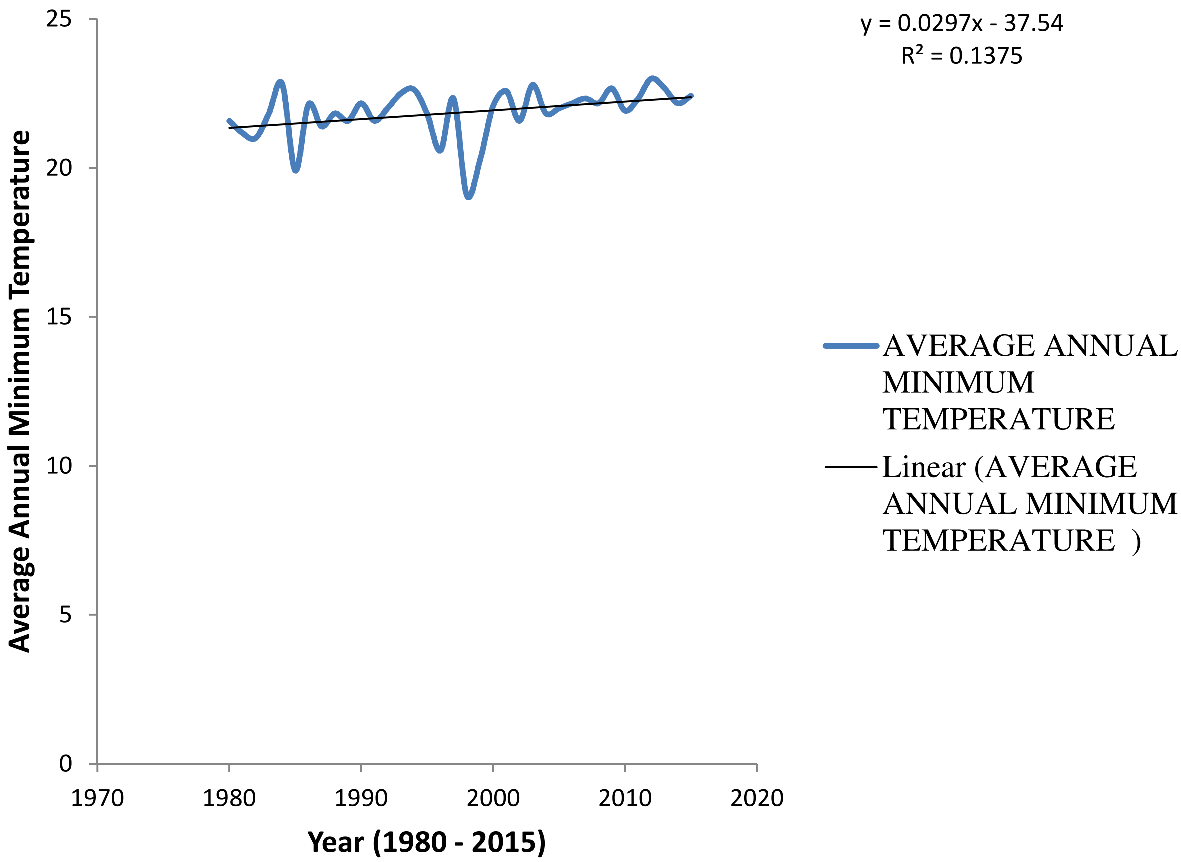

Figure 5: Graph of average minimum temperature against year

Descriptive pattern of maximum temperature

Figure 6 and Table 4 show yearly maximum temperature recorded from January to December for the period of 1980 – 2015. The month of February as shown in table 4 has the highest maximum temperature with a mean record of 35.64^{o}C. This is due to intense insolation from the sun received coupled with the light cloud cover around this time. During this period the sun is overhead in the area around the equator while in the course of its northward movement to the tropic of cancer in the northern Hemisphere. This makes areas here come under intense insolation from the sun with longer day time resulting into higher temperature. The maximum temperature total for all the years is very low in the month of August with a mean record of 28.53^{o}C. During this period, the effect of the temperature is ameliorated by the wet season. The mean maximum temperature has a range of 3.6^{o}C over the period of the study. Figure 6 shows that the year 1998 has the lowest maximum temperature with a mean of 30.5^{o}C while 1985 received the highest maximum temperature with a mean of 34.1^{o}C. Figure 7 shows the graph of total annual maximum temperature against year from which it can be seen that gentle slope rising across the years which indicate that maximum temperature is increasing. The positive trend is consistent with the earlier result from the trend analysis and the findings of Nouaceur *et al*. (2016).

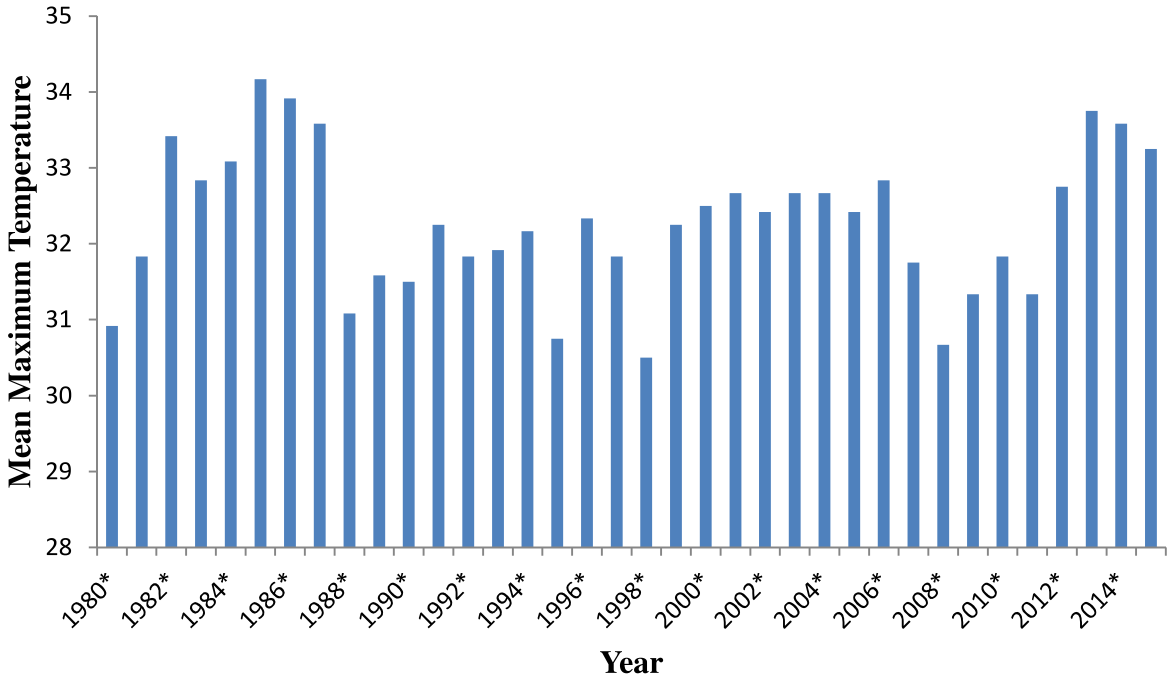

Figure 6: Bar chart showing descriptive pattern of maximum temperature between1980 – 2015

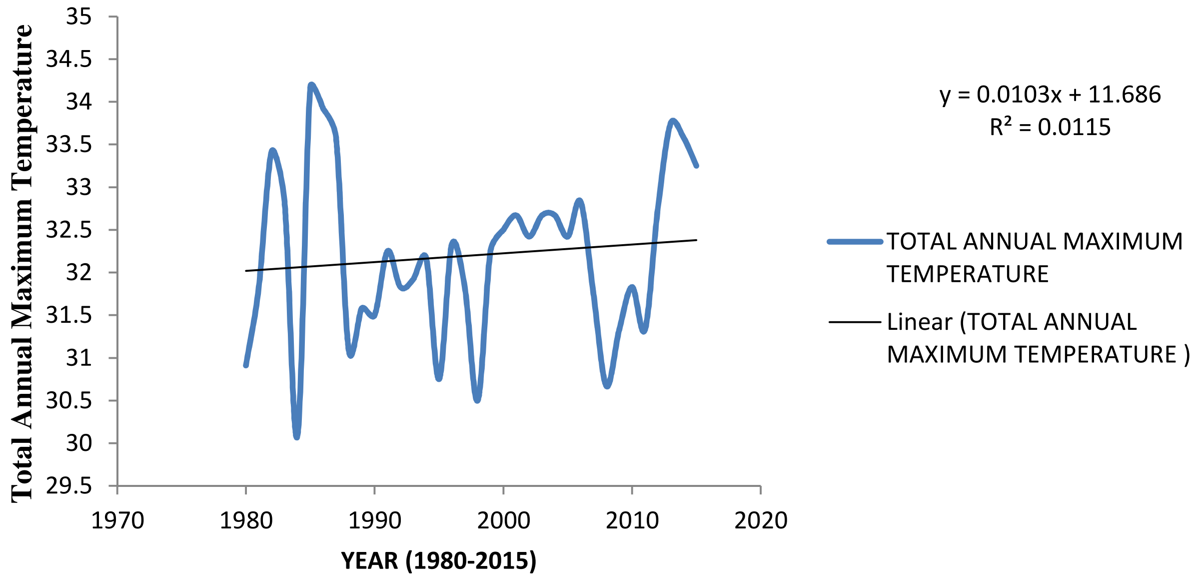

Figure 7: Graph of total annual maximum temperature against year

Table 4: Summary of annual maximum temperature at Ilorin in the year 1980-2015

YEARS	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	Average
1980*	32	32	31	32	31	31	32	30	31	30	32	27	371	30.91666667
1981*	34	37	36	30	28	29	29	32	28	32	33	34	382	31.83333333
1982*	34	35	34	34	35	35	35	34	32	31	31	31	401	33.41666667
1983*	35	33	32	33	36	35	32	31	30	31	33	33	394	32.83333333
1984*	34	37	36	37	33	32	32	28	29	31	34	34	397	33.08333333
1985*	35	35	37	34	35	35	34	34	31	32	34	34	410	34.16666667
1986*	33	35	34	34	33	37	35	34	30	32	35	35	407	33.91666667
1987*	32	34	33	35	35	37	35	32	31	31	34	34	403	33.58333333
1988*	32	31	32	32	33	30	33	30	29	29	30	32	373	31.08333333
1989*	30	31	31	33	32	31	32	31	35	30	31	32	379	31.58333333
1990*	34	32	31	32	33	31	31	30	28	30	32	34	378	31.5
1991*	31	33	32	34	37	32	31	31	31	32	30	33	387	32.25
1992*	32	33	35	34	33	33	30	31	29	30	31	31	382	31.83333333
1993*	33	35	34	31	32	35	30	31	32	29	30	31	383	31.91666667
1994*	32	34	33	31	32	33	31	31	31	34	30	34	386	32.16666667
1995*	31	32	32	31	31	31	31	29	30	28	31	32	369	30.75
1996*	34	35	35	35	34	32	31	31	32	30	32	27	388	32.33333333
1997*	33	36	35	32	31	30	28	29	29	32	33	34	382	31.83333333
1998*	37	33	32	32	28	29	27	27	28	31	31	31	366	30.5
1999*	34	35	35	34	34	31	29	29	29	31	33	33	387	32.25
2000*	34	33	37	35	34	30	29	29	30	31	34	34	390	32.5
2001*	35	35	37	35	32	31	30	28	29	32	34	34	392	32.66666667
2002*	32	32	31	36	32	32	30	31	31	32	35	35	389	32.41666667
2003*	34	37	36	34	34	30	29	29	30	32	33	34	392	32.66666667
2004*	34	35	34	38	35	33	30	29	29	30	32	33	392	32.66666667
2005*	35	33	32	34	31	32	31	35	30	31	32	33	389	32.41666667
2006*	34	37	36	36	32	31	30	28	30	32	34	34	394	32.83333333
2007*	31	32	31	32	32	31	31	31	32	30	33	35	381	31.75
2008*	33	30	31	29	31	30	31	29	30	31	31	32	368	30.66666667
2009*	32	31	32	32	33	30	31	32	29	30	31	33	376	31.33333333
2010*	30	31	31	33	32	31	31	31	34	30	34	34	382	31.83333333
2011*	34	32	31	32	33	31	29	30	28	31	32	33	376	31.33333333
2012*	31	33	32	34	37	32	33	31	32	31	33	34	393	32.75
2013*	32	33	35	34	33	33	32	34	33	35	36	35	405	33.75
2014*	33	35	34	31	32	35	33	32	34	33	35	36	403	33.58333333
2015*	32	34	33	31	32	33	34	34	34	35	33	34	399	33.25
Average	**33**	**35.64**	**33.417**	**33.222**	**32.803**	**32.055**	**31.167**	**28.53**	**30.555**	**31.166**	**32.556**	**33.0277**		

Source: Lower Niger River Basin Development Authority, Ilorin (2017)

Statistical analysis of rainfall (mm) from 1980 to 2015

Analysis was carried out on the rainfall and temperature data to determine mean, median, standard deviation, minimum, maximum and skewness of the sets of data. The statistical monthly summary obtained for rainfall is presented in Table 5.

Table 5: Monthly Summary of the Statistical Analysis of Rainfall (mm) 1980-2015

Months (mm)	Mean	Median	Std.Dev.	Min.	Max.	Skewness
January	6.19	0.00	15.82	0.00	73.30	3.33
February	6.21	0.01	17.19	0.00	90.70	4.43
March	43.43	39.20	28.61	0.00	109.20	0.56
April	93.34	90.30	50.55	19.60	223.90	1.07
May	163.32	147.85	90.21	42.30	457.80	1.42
June	190.05	184.20	64.67	89.30	370.80	0.85
July	159.12	140.15	76.76	69.20	323.00	0.84
August	159.26	148.85	76.76	16.50	334.60	0.19
September	219.47	238.25	81.56	61.40	400.10	-0.19
October	136.22	140.50	71.54	16.40	250.70	-0.12
November	10.50	2.35	16.09	0.00	55.60	1.72
December	6.97	0.00	27.43	0.00	148.5	5.08

Table 5 shows that the maximum monthly rainfall received was 457.80 mm and the minimum was 0.00 mm over the 35 years period. Figure 8, shows the mean monthly rainfall, it revealed that the months of September and June recorded the highest rainfall over the 35 years period of study. The month of September recorded a mean of 219.47 mm and June recorded a mean of 190.05 mm, it can be said that rainfall is at its' peak between these months. The months of November to March recorded the lowest amount of rainfall over the period of study which is the period of low flow. Range of value for standard deviation was 15.82-90.21 mm.

Variation of mean monthly rainfall

Table 5 shows the monthly rainfall distribution of Ilorin. The month with the highest rainfall amount was September while rain rarely falls in the month of December. A steady increase in rainfall occurs from January to June, then decreases in June and July, then peaks at September, then reduces from October to December. Averagely, 1202.7 mm of rainfall falls over Ilorin annually over the study period.

Annual rainfall distribution at the station

The annual rainfall over the stations is shown in Figure 9. At Ilorin, the wettest year was 1994 with rainfall exceeding 1700 mm while the driest year was 2001 with rainfall less than 800 mm. The smoothened 5-year moving average clearly shows the inter-decadal variability of rainfall over this station. It was observed that the last decade of the study period, between 2001 and 2010, received the least amount of rainfall

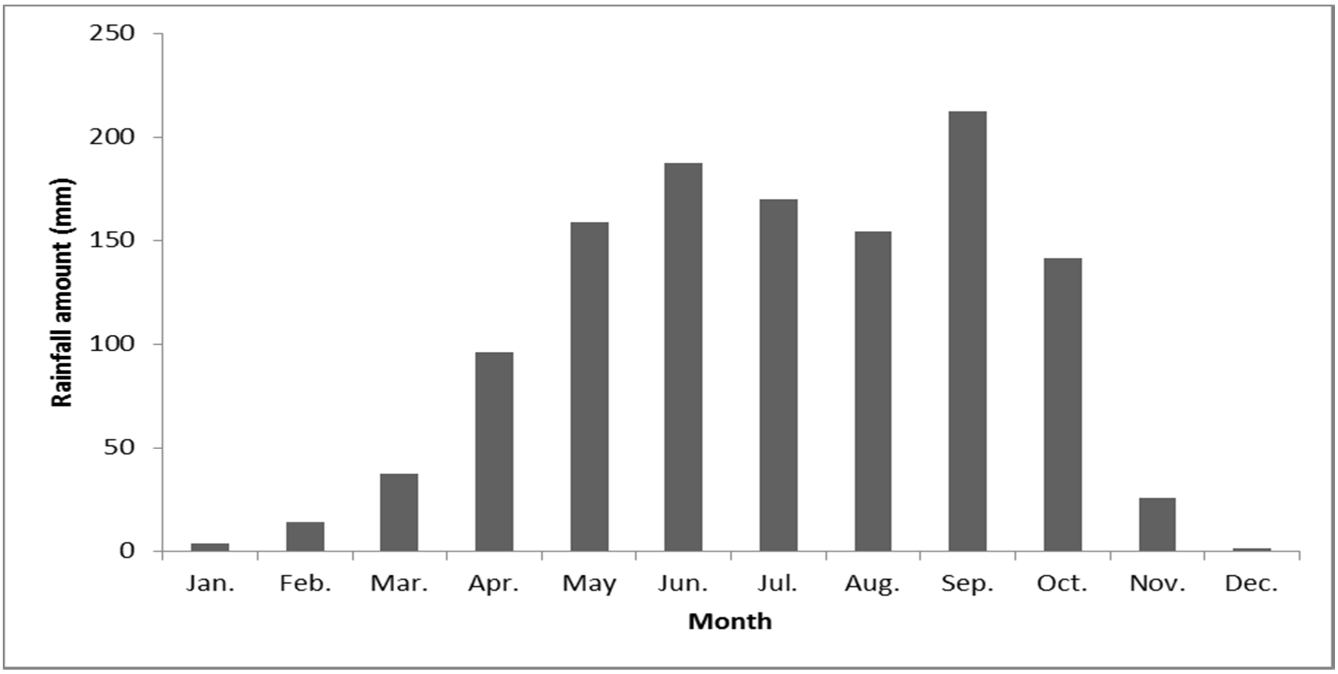

Figure 8: Mean monthly rainfall for Ilorin

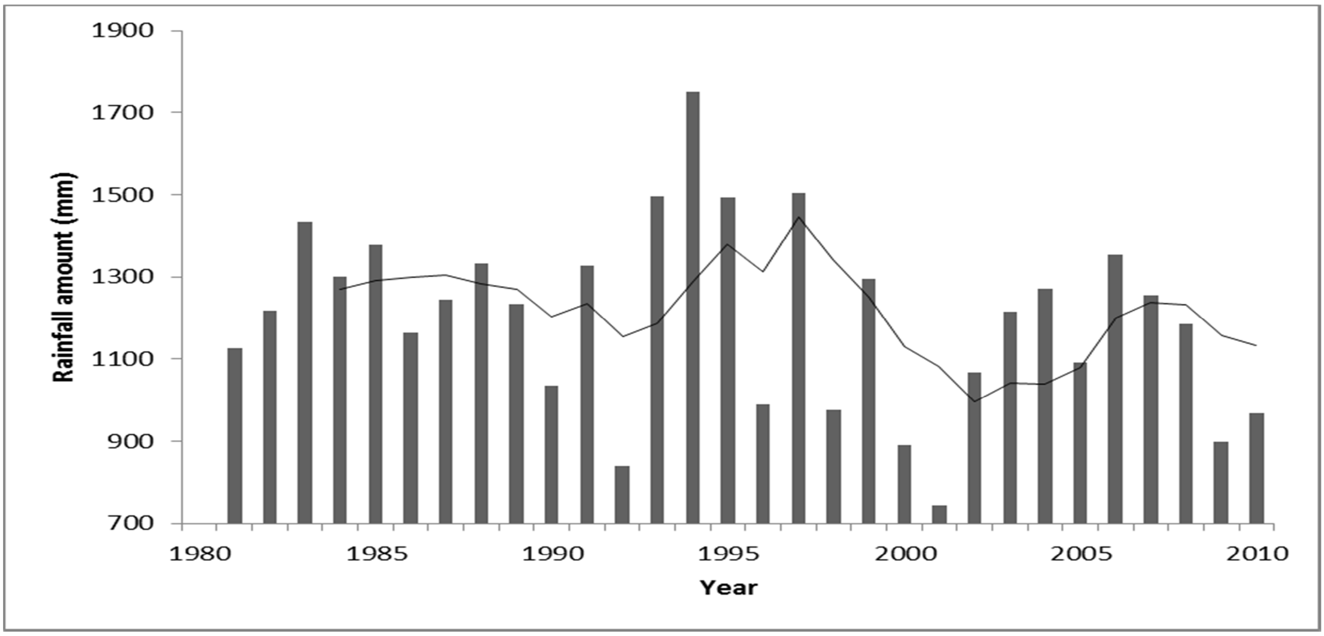

Figure 9: Annual rainfall for Ilorin with trend line showing 5 year moving average

Monthly and annual rainfall trend analysis

The temporal trend of rainfall indices was carried out using MAKESEN software. The symbol "***", "**", "*", and "+" represents 0.1% (most significant), 1% (highly significant), 5% (more significant) and 10% (significant) significance level respectively, while a blank cell means significance level is greater than 10%, that is, 'not significant'. The magnitude of trend (Q) is expressed in per decade (10 years).Trend analysis of monthly and annual rainfall observed over Ilorin station was first assessed. The results showed that there were no significant changes in rainfall over the study area. However, it was observed that almost all the months except September showed negative trend. January and December showed no trend. July showed the highest reduction with about 18.9 mm of rainfall reduction per decade over the study period. This emerging trend if sustained tends to be worrisome for farmers who depend on rainfall for their farming activities as this may lead to low productivity and change of planting seasons. Overall, the annual rainfall trend showed that rainfall was reducing and at a rate of about 81mm per decade over this location.

Table 6: Trend analysis result for monthly and annual rainfall over Ilorin Station.

S/N	Time Series	Test Z	Significance	Q(mm/decade)
1	January	0		-2.2
2	February	-0.45453		-2.5
3	March	-1.27577		-8.8
4	April	-0.21416		-0.7
5	May	-1.46296		-15.6
6	June	-0.74932		-8.9
7	July	-1.64137		-18.9
8	August	-0.82069		-11.8
9	September	1.302603		13.0
10	October	-1.14183		-11.2
11	November	-0.76968		-4.4
12	December	0		0
	Annual	-1.46296		-71.3

***Trend is significant at $\alpha = 0.001$. **Trend is significant at $\alpha = 0.01$. *Trend is significant at $\alpha = 0.5$. +Trend is significant at $\alpha = 0.1$.

CONCLUSIONS

The research work revealed an increase of 0.029^{o}C in average annual minimum temperature and 0.01^{0}C increase in the linear trend of total annual maximum temperature. On the other hand rainfall decreased annually at the rate of 0.814 mm across the years. Climate of the study area was accessed to be varying remarkably which may be due to climate change. The research had established the temporal variations in annual, monthly, and seasonal rainfall and temperature amounts in Ilorin, Kwara State, Nigeria. It is recommended that farmers should overcome the problem of declining rainfall by planting drought resistance crops and as a matter of urgency the government should continually sensitize the public on the challenges of the climate variation and change. Also feasible adaptation measures to be adhered to in order to avert the detrimental effects of climate variation and change must be disseminated to the famers and community dwellers through agricultural extension agents.

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