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Climate Change in Kwara State, Nigeria: Evidence of Rainfall and Temperature Variations

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Abstract

Factors such as temperature, precipitation, humidity, etc. affect the climate of a place.. Both temperature, and rainfall are necessary for environmental change and economic growth as well. The Nigerian Meteorological Agency (NIMET) provided the mean annual rainfall and maximum and lowest temperature from 2002 to 2022. The climate data was analyzed using both inferential and descriptive statistics. The results indicated that 2002 (75.2mm) was the driest year and 2008 had the most rainfall (122.5mm). The average rainfall in 2002 was 63%. The highest temperature ever recorded in a single year was 44.47°C, while the lowest was 28.28°C. In 2010, the mean annual temperature reached its highest peak of 40.26°C, whereas in 2014, the mean annual maximum temperature dropped to 24.25°C. A sequence of negative anomalies ranging from -3.5 to 31.7mm were found in the anomaly test results for the years 2002, 2003, 2010, 2011, 2012, 2013, 2014, and 2016, indicating that these were dry years. In Ilorin, the weather alternated between nearly normal rainfall and extreme dryness. The year 2008 was noted for optimal rainfall, which indicated positive significance on agricultural production as well as negative effects such as submerging of flood-prone areas, and manifesting of waterborne disease that affect people's health in the study area. The year 2002 was noted for having the highest dry spell, indicating possible drought and low productivity of agriculture. The study concluded that variations in temperature and rainfall had a big impact on the socio-economic status of the people living in Ilorin.

Keywords: Climate Change, Rainfall, Temperature, Atmosphere, Agriculture

1.1 Introduction

Climate is one of the major components in the earth system. Climate is the average atmospheric condition over a long period of years usually not less than 35years that varies from place to place and region to region. There are many variables such as temperature, rainfall, atmospheric pressure, humidity that constitute weather and climate (Intergovernmental Panel on Climate Change, IPCC, 2013). In broad sense, it is the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC, 2007). The analysis of long-term changes in climatic variables is a fundamental task in the studies on climate change detection. The understanding of past and recent climate

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change has received considerable attention through improvements and extensions of numerous datasets and more sophisticated data analyses across the globe (Kumar et al., 2010). Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods (Pal and Mishra, 2017). The rainfall and temperatures are the most important fundamental physical parameters among the climatic elements, as these parameters determine the environmental condition of a particular region which affects the agricultural productivity, energy, security, health and other sectors in any socioeconomic region (Singh et al., 2013).

In common usage, climate change describes global warming the ongoing increase in global average temperature and its effects on Earth's climate system. Climate change in a broader sense also includes previous long-term changes to Earth's climate. The current rise in global average temperature is more rapid than previous changes, and is primarily caused by humans burning of fossil fuel (Houlton, 2021). Fossil fuel use, deforestation, and some agricultural and industrial practices increase greenhouse gases, notably carbon dioxide and methane (IPCC, 2014). Greenhouse gases absorb some of the heat that the Earth radiates after it warms from sunlight. Larger amounts of these gases trap more heat in Earth's lower atmosphere, causing global warming.

Due to climate change, deserts are expanding, while heat waves and wildfires are becoming more common (IPCC, 2014). Increased warming in the Arctic has contributed to melting permafrost, glacial retreat and sea ice loss. Higher temperatures are also causing more intense storms, droughts, and other weather extremes. In the context of climate change, the physical event are weather-related phenomena such as floods, droughts, storms, extreme temperature and excess rainfall, among others (IPCC, 2022).
Climate change threatens people with food and water scarcity, increased flooding, extreme heat, more disease, and economic loss. Human migration and conflict can also be a result (Catteneo et al, 2019). The World Health Organization (2005) calls climate change the greatest threat to global health in the 21st century. Communities may adapt to climate change through efforts like coastline protection or expanding access to air conditioning, but some impacts are unavoidable. Poorer countries are responsible for a small share of global emissions, yet they have the least ability to adapt and are most vulnerable to climate change.

Many climate change impacts are already felt at the current 1.2 °C (2.2 °F) level of warming. Additional warming will increase these impacts and can trigger tipping points, such as the melting of the Greenland ice sheet. Under the 2015 Paris Agreement, nations collectively agreed to keep warming "well under 2 °C". However, despite the pledges made under the Agreement, global warming would still reach about 2.7 °C (4.9 °F) by the end of the century. Limiting warming to 1.5 °C will require halving emissions by 2030 and achieving net-zero emissions by 2050. Some effects of climate change, clockwise from top left are wildfire intensified by heat and drought, worsening droughts compromising water supplies, and bleaching of coral caused by marine heat waves. Reducing emissions requires generating electricity from low-carbon sources rather than burning fossil fuels. This change includes phasing out coal and natural gas fired power plants, vastly increasing use of wind, solar, and other types of renewable energy, and reducing energy use. Electricity generated from non-carbon-emitting sources will need to replace fossil fuels for powering transportation, heating buildings, and operating industrial facilities (United Nation Environmental Program, 2019). Carbon can also be removed from the atmosphere, for instance by increasing forest cover and by farming with methods that capture carbon in soil (Fischer, et al., 2002).

Rain is liquid water in form of droplets that have been condensed from atmospheric water vapour and then becoming heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. It provides suitable conditions for many types of ecosystems, as well as water for hydroelectric power, plants and crop irrigation (Alexa, 2009). Rainfall is the most imperative weather parameter in the tropical region. The rainfall in this region is highly variable both in space and time and the amount of rainfall in a given region is influenced by many factors such as relief, wind speed and direction (relative to coastal orientation) and distance from the ocean. Seasonal rainfall patterns are very important for continuous supply of water for domestic, industrial and agricultural uses. Rainfall leads to surface and sub-surface recharge, and for rain-fed agricultural production (Tarhule, 2002).

The major cause of rain production is moisture moving along three-dimensional zones of temperature and moisture contrasts known as weather fronts (Kempler, 2008). If enough moisture and upward motion is present, precipitation falls from convective clouds (those with strong upward vertical motion) such as cumulonimbus (thunder clouds) which can organize into narrow rain bands. In mountainous areas, heavy precipitation is possible where upslope flow is maximized within windward sides of the terrain at elevation which forces moist air to condense and fall out as rainfall along the sides of mountains. On the leeward side of mountains, desert climates can exist due to the dry air caused by downslope flow which causes heating and drying of the air mass (National geographic society, 2015). The movement of the monsoon trough, or inter tropical convergence zone, brings rainy seasons to savannah climes (National research council, 1998).

Many scholars have studies the trends of hydrometeorological variables in Nigeria (odjugo, 2005, Itiowe et al 2019.akinsanola and Ogunjobi, 2016) and given their implication on agriculture and water resources. Therefore the aim of this study is to assess the effects of variability in rainfall and temperature on the socioeconomic activities of the people of Ilorin with a view to proffering management options.

1.2 The Study Area

The region of Nigeria, known as North Central is home to Kwara State. With an area of 765 km³ (295 sq mi), Kwara State is situated between latitudes 8° & 100 4′N and longitudes 2° 45′E & 60 12′E (National Bureau of Statistics, 2016). Situated on the Lagos-Kaduna highway, the city is 500 kilometres from Abuja, the Federal Capital of Nigeria, and 360 km from Lagos (World Gazetteer Ilorin, 2015). Ilorin has a total land of 0.8sqkm when it was first founded but today it has grown in size to about 765sqkm. The climate of Ilorin is humid tropic type and is characterized by both dry and wet seasons, each lasting for about six months. The raining season starts from March and ends in October while the dry season begins in November and ends in early March. The total annual rainfall in the state ranges from 800mm to 1,200mm in the Northwest and 1,000mm to 1,500mm in the Southeast. The state has a mean annual temperature ranging between 300-350°C and a relative humidity of 60% on the average. The landscape consists of a relatively flat and undulating land with interspersed hills and valleys in parts of Baruten, Kaiama and Moro Local Government areas. (Ifabiyi & Omoyosoye, 2011). It is situated in what is known as the Guinea Savanna, a region that is a transition between a rain forest and the north's southwest savanna grassland (Oyegun, 1982). The area is covered in vegetation, which includes, among other trees, locust, shear butter, acacia, and beans trees. The basement complex rocks that underlie Ilorin are primarily made of metamorphic rocks, particularly resistant quartzite and gneiss. The soil belongs to the soil category known as ferruginous soil and is composed of rocks from the Precambrian basement complex (Jimoh, 1997).

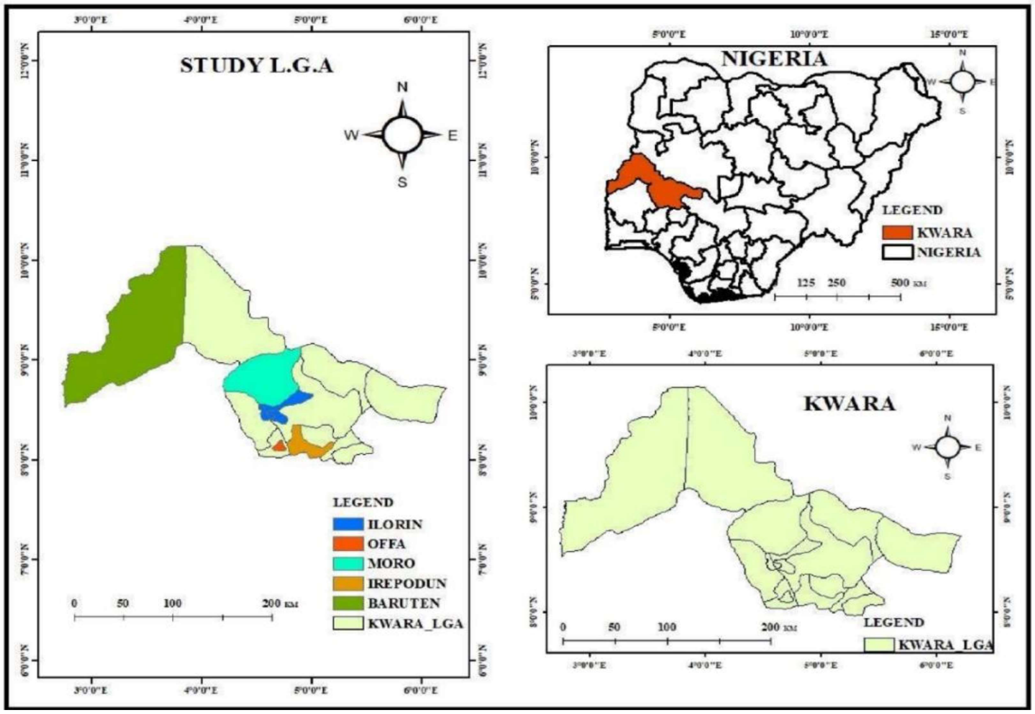

Figure 1: Kwara State Nigeria.

2. Materials and Methods

Monthly records of rainfall and temperature for the years 2002–2022 (20 years) are the secondary data used for this study. The required data for this study were collected from the Nigeria Meteorological Agency (NIMET), Ilorin, Kwara state. Descriptive (mean, standard deviation, tables, and charts) and inferential statistical methods (time series analysis) were used to analyze the data.

3. Presentation of Results

3.1 Description of Annual Rainfall Variable in Ilorin 2002 - 2022

The pattern of annual rainfall was presented in Table 1. It was shown that the highest mean rainfall amount (122.5mm) was recorded in 2008 and the lowest mean rainfall amount (75.2mm) was recorded in 2002. The highest median value (117.53mm) of rainfall was recorded in 2003 while the lowest median value (26.38mm) was in 2010. The highest variability (189.76mm) was in 2019 and the least (85.50) was in 2013. On the whole, minimum score (0.001mm) was in 2007 and the maximum score (490.6mm) was in 2003. The skewness was greatest (19.0mm) in 2017 and the least (-0.2831) of the skewness was in 2003. On the other hand, Figure 2 presented the pattern of the mean annual rainfall that 2006, 2014 and 2019 recorded which are 118.5mm, 118.7mm and 119.7mm respectively in the study area.

Table 1: Description of Annual Rainfall Variable in Ilorin 2002 - 2022

Years	Mean	Median	Std. Dev.	Mini.	Maxi	Skewness
2002	75.2	60.43	121.00	0.16	294.18	0.3661
2003	103.4	117.53	149.72	0.15	490.56	-0.2831
2004	117.6	57.67	123.00	0.09	359.48	1.4617
2005	108.8	27.70	141.24	0.16	460.10	1.7226
2006	118.5	27.71	119.62	0.47	176.83	2.2769
2007	113.5	85.91	98.48	0.01	294.25	0.8405
2008	122.5	25.48	136.66	0.20	404.57	2.1298
2009	111.9	55.78	96.82	0.25	298.95	1.9867
2010	86.7	26.38	112.37	0.06	336.62	1.6104
2011	95.9	38.83	98.45	0.03	313.72	1.7390
2012	87.2	57.28	111.39	0.39	329.17	0.8058
2013	101.1	74.62	85.50	0.18	247.87	0.9291
2014	118.7	34.56	121.89	025	278.0	0.0708
2015	110.9	110.67	150.08	0.25	341.8	0.0046
2016	101.9	89.02	131.67	0.35	401.88	1.2431
2017	119.7	75.94	164.47	0.12	345.87	19.0386
2018	109.8	47.34	99.78	0.15	256.09	1.8779
2019	112.1	98.67	189.76	0.61	321.93	0.2123
2020	107.6	111.95	123.54	0.31	456.43	-0.1056
2021	109.1	59.75	114.87	0.11	286.34	1.2888
2022	113.3	58.88	124.34	0.45	342.76	1.3130

Source: Author's Computation, 2023

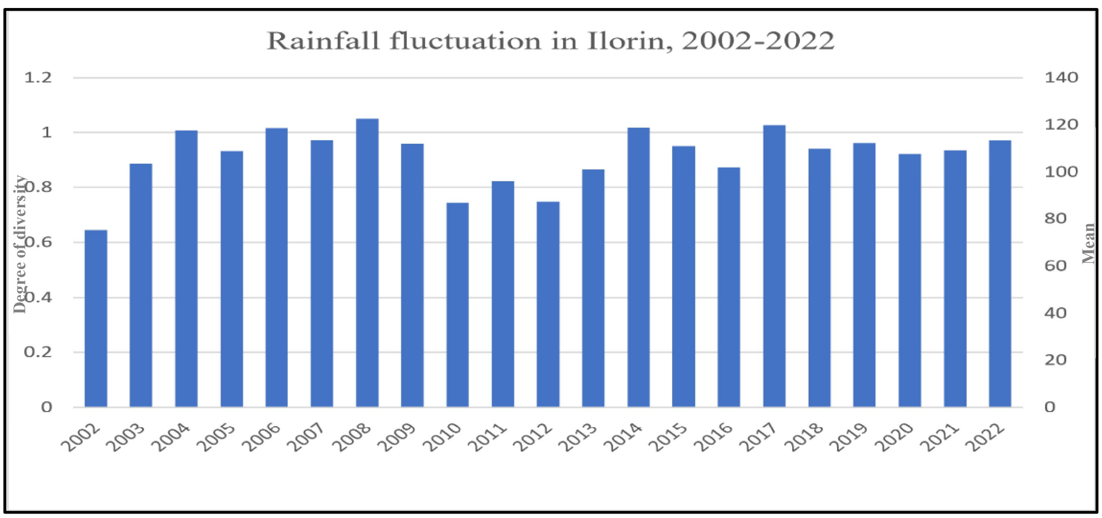

Figure 2: Mean Annual Rainfall from 2002 – 2022 in Ilorin

3.2 Fluctuations in the Annual Maximum Temperature (°C) in 2002 - 2022

In the same vein, Table 2 presented the results of mean annual temperature between 2002 and 2022 in the study area. The mean lowest temperature (24.35°C) was recorded in 2014 while the mean highest temperature (40.26 °C) was in 2010. The highest median value (38.63 °C) was recorded in 2005 while the lowest median value (31.42 °C) was recorded in 2014 and the minimum temperature (28.26 °C) was in 2007 while the maximum temperature (44.47 °C) was recorded in 2003.

Table 2: Fluctuations in the Annual Maximum Temperature (°C) in 2002 - 2022

Years	Mean	Median	Std. Dev.	Mini.	Maxi	Skewness
2002	37.33	37.47	3.31	31.58	43.45	-0.13
2003	30.72	37.47	7.56	29.99	42.80	-2.72
2004	36.80	38.42	3.85	30.57	42.33	-1.29
2005	37.39	38.63	3.76	32.42	43.08	-0.73
2006	37.26	35.82	5.10	29.29	44.47	-0.94
2007	36.63	36.52	4.59	28.29	42.38	0.08
2008	35.77	37.50	4.19	28.78	42.64	-1.21
2009	35.95	36.34	4.30	29.71	43.58	-0.22
2010	40.26	34.98	5.38	30.22	42.38	2.94
2011	35.76	37.00	4.28	28.82	43.71	-0.87
2012	35.46	38.39	3.64	28.26	41.95	-2.41
2013	31.89	34.87	3.18	29.84	43.67	-2.81
2014	24.35	31.42	3.26	30.00	40.39	-6.49
2015	32.60	34.73	4.01	28.28	39.89	-1.06
2016	33.41	34.28	3.91	30.33	40.62	-0.68
2017	32.70	31.64	2.86	29.66	40.78	1.11
2018	32.52	35.42	3.08	30.25	41.66	-0.90
2019	33.20	35.64	4.01	31.33	42.25	-1.83
2020	31.41	33.24	3.65	29.62	40.15	-1.52
2021	32.5	35.36	3.21	31.64	39.66	-2.67
2022	33.6	31.88	2.87	29.66	42.87	-1.80

Source: Author's computation, 2023

Figure 3 shows a gentle decrease pattern of temperature with linear equation Y = 0.154x-698.315 and gradient value R^2 = 0.4326.

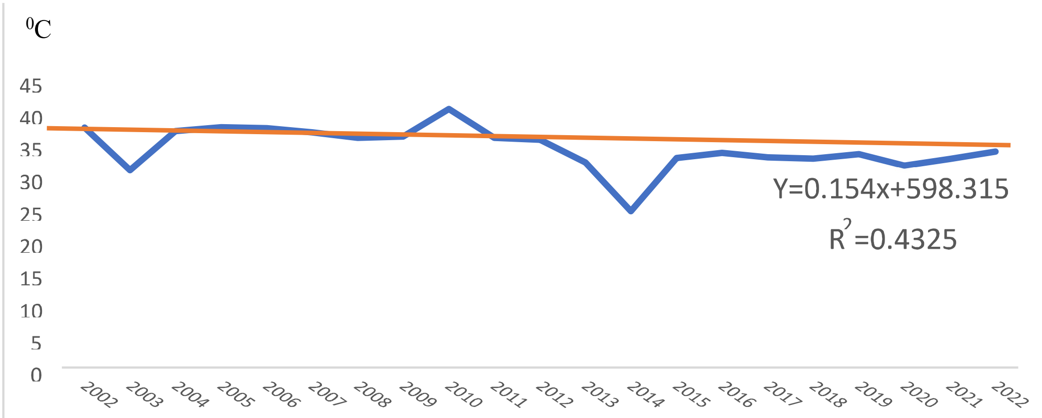

Figure 3: Mean Annual Temperature from 2002 - 2022 in Ilorin

However, there was a significant increase in the annual rainfall with linear equation Y = 7.88x+321.67 and slope value $R^2 = 0.4932$ (Figure 4).

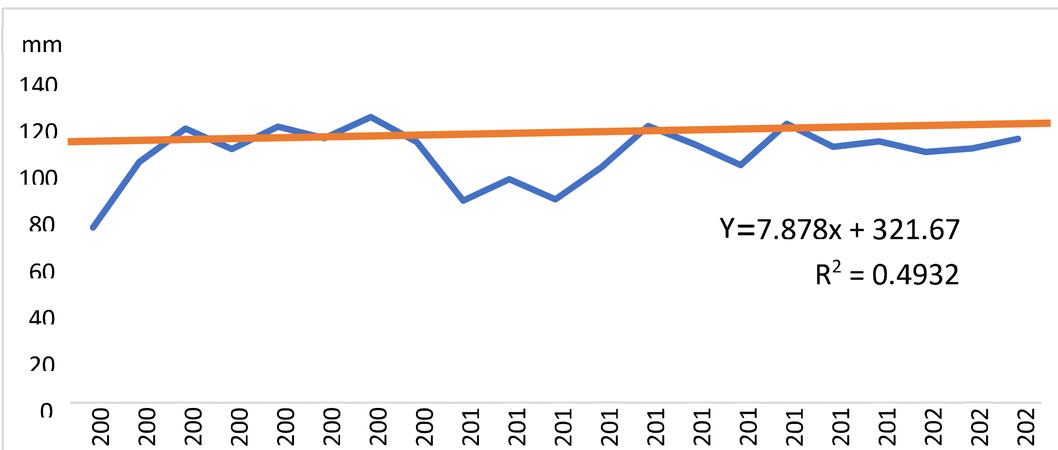

Figure 4: Rainfall Trend in Ilorin 2002 -2022

3.3 Mean Annual Rainfall Anomaly of Ilorin

The results of annual rainfall anomaly index in Figure 5 shows that highest amount of rainfall was recorded in 2008 and lowest rainfall anomaly was recorded in 2002.

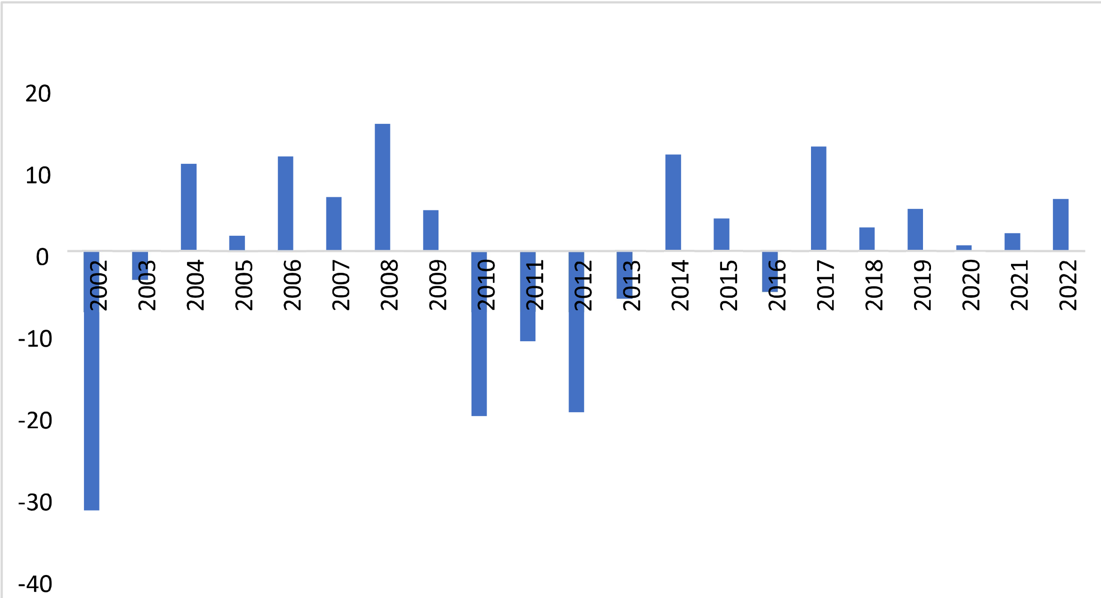

Figure 5: The Mean Annual Rainfall Anomaly of Ilorin

4.1 Discussion of Results

4.1.1 Result of the Fluctuations in the Level of Annual Rainfall in Ilorin

The result showed that there was a significant variation in the distribution of rainfall in Ilorin across the period of twenty years (2002 to 2022) under consideration. It was observed that the heaviest rainfall level was 490mm in 2003, while, the lowest amount of rainfall was recorded in 2006 (0.03mm) (Table 1 and Figure 1). However, from 2004, the rainfall level has remained unstable with fluctuating rainfall levels across the years; 2005 (108.8mm), 2006 (118.5mm), 2007 (113.5mm) and 2017 (119.7mm) respectively. However, rainfall level decreased to 86.7mm from 2010 to 2012 but later increased up to 118.7mm in 2014. Since then, it has kept on fluctuating till 2022. About 55% of the rainfall lies above the total average rainfall level. The longest consecutive years when annual rainfall peaks above long-term mean was recorded from 2003 to 2009 and 2014 to 2022, while the longest consecutive years when rainfall level falls below long-term mean (dryness level) were recorded from 2010 to 2013. The range for the annual total rainfall is from 490mm-0.03mm which implies a significant level of variability in the distribution of rainfall in the study area. Impliedly, the dry years suggested low output of farm produce in the study area. This is because during the period of dry spells, majority of farmers would not enjoy double maxima because of late onset and early cessation of rainfall. Food shortage is bound and increased cost of agricultural production is inevitable due to erratic behavior of rainfall.

Arinde et.al (2017) had a similar opinion with this finding that climatic changes around us and its effects on agricultural productivity and urban livelihood cannot be over emphasized. They agreed that Climatic fluctuation is putting Nigeria's agriculture system under serious threat and stress. The study of the effect of climate change on agricultural productivity is critical, given its impact in changing livelihood patterns in the country (Ayinde O. et al, 2017)

4.1.2 Statistical Analysis of Annual Temperature (℃) in Ilorin 2002-2022

The mean annual analysis for maximum temperature in Table 2 and Figure 2 shows that the highest annual maximum temperature recorded is 44.47℃ and the minimum is 28.28℃ over the twenty year period. Furthermore, the highest mean annual temperature of 40.26℃ was recorded in 2010 while the lowest mean annual maximum temperature of 24.25℃ was recorded in 2014. However, 2.86-5.38℃ was observed as the range of values for standard deviation. This implies that the temperature over the years could significantly determine rate of evaporation and condensation of air to form rain which was received in the study area.

The result in the Table 2 showed that there is a high level of variation in temperature level of the area under study. It can be observed that in 2002, the temperature level was at 37℃ and declined in the following years to 30℃. The temperature level sprang higher in 2003 to 40℃ and also declined in four subsequent years that follows to 24℃. The fluctuation persists in the temperature as at 2006, when the temperature level fluctuated between 31℃ and 33.6℃ between 2015 and 2022. The fluctuation implies that farmers will have to adapt their planting and harvesting schedules accordingly to maximize agricultural yield.

Yaro (2010) indicated that climate variability may be the leading cause of the decline in food crop production amongst other constraints of urban agriculture, and that farmer's adaptive behaviour and coping strategies revolve around the knowledge of climate rather than human environmental variables. Ajadi et al. (2011) showed that variation in some climatic parameters suggests variation in crop yield. Others noted that farmers are aware of climate change and its impacts on their livelihood and their perceptions greatly influence the coping strategies employed. For instance, Adelekan & Bolarinwa (2001) revealed that arable farmers were more aware of climate change and its impacts on their livelihood, but the techniques of coping and mitigating the impact of the scourge is still crude owing to poverty and ignorance. Similarly, Apata et al. (2009) revealed that fall in temperature influences the probability of changing from mono-cropping to mixed cropping systems.

4.2 Pattern of Rainfall and Temperature in Ilorin

Time series or trend analysis is a method that enables researchers to observe the pattern of variation in rainfall and temperature over time. Generally, the variables are plotted against year (time) and the trend equation is stated to statistically evaluate either the increase or decrease in the observed climatic variables.

4.2.1 Rainfall Trend from 2002-2022 in Ilorin

Rainfall trend was analyzed to observe the pattern of rainfall in Ilorin. Rainfall was plotted against time in Figure 3. The result showed a positive trend line with gentle slope indicating that rainfall increased with time at very low rate during the study period. From the trend line equation, $y=7.878x + 321.67$ it can be observed that rainfall increased at 43.50mm every year over the twenty year period, showing that the rainfall period was not steady. This implies that the increase in rainfall will lead to an increase in the availability of water, which is beneficial for agriculture, and supports growth of crops and vegetation. However, excessive rainfall can lead to flooding and water logging that can damage crops and can contribute to soil erosion. According to the United State Global Change Research Program (USGCRP, 2014) climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity.

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4.3.2 Temperature Trend from 2002-2022 in Ilorin

In order to observe the statistical distribution of temperature, the climatic variable was plotted against the years in the study area in Figure 4. There was a marked fluctuation in the statistical distribution of the temperature in the study area. The graph showed a significant increase in the temperature. The trend line equation indicated that temperature increased at the rate of 0.11°C every year over the period under study in Ilorin. The trend line equation $Y = 0.154x + 598.315$ indicated that maximum temperature decreased at the rate of 0.05°C every year over the period under study. The decrease in maximum temperature indicate cold trend in the study area. The fluctuation implies that farmers will have to adopt different adaptation strategy that will support their planting and harvesting schedules accordingly in order to maximize agricultural yield. However, majority of farmers in developing countries operate at small scale due to their poverty level and lack of capacity to engage in mechanization. For instance, Ayanwuyi (2011) revealed that farmers were more aware of climate change and its impacts on their livelihood, but the techniques of coping and mitigating the impact of the scourge is still crude owing to poverty and ignorance.

4.4 Annual Rainfall Anomaly in Ilorin

The deviation in long term mean rainfall shows the nature of rainfall pattern in Ilorin metropolis. Rainfall anomaly denotes the difference between the long term average rainfall and the rainfall that is actually occurring. However, positive anomaly value indicates that observed rainfall values are greater than the average threshold values which implies rainfall is wetter than normal, while negative anomaly indicate observed rainfall is less than average value, which means rainfall is drier than normal. In other words, positive anomaly implies wetter years which significantly increase agricultural production, availability of water for domestic and industrial use while negative anomalies indicate drier years in terms of rainfall which signifies drought and low agricultural production in the study area. According to Smith et al (2015), positive rainfall anomalies provide ample water for crops growth and increased yield, while negative anomaly can lead to drought conditions, affecting crop productivity and potentially leading to food shortages. The anomalies of rainfall in Ilorin indicates an unsteady trend of rainfall and this implies that positive anomalies increased rainfall above average. This scenario can lead to availability of water and at the same time can lead to flooding while the negative anomalies indicate drier years which implies that the negative anomalies in rainfall will lead to drought, low agricultural yield and shortage of water.

According to Figure 4, there were a number of negative anomalies in the years 2002, 2003, 2010, 2011, 2012, 2013, 2014 and 2016 with values ranging from -3.5 to 31.7mm showing that these years were dry years while some positive anomalies were noted during the period of study. This result revealed a fluctuation between a near normal rainfalls and extremely dry condition in Ilorin (Figure 4). The year 2002 is noted for the highest dry spell which indicate possible drought and low productivity of agriculture while year 2008 is noted for the optimal rainfall which could indicate positive significance on agricultural production as well as negative effects such as submerging of flood prone areas, manifesting of waterborne disease and breeding of insects such as mosquitos which affect the health of people in the study area.

5. Conclusion

This study revealed the occurrence of a significant variation in the distribution for all the investigated meteorological parameters. It was observed that there is a notable increase in the values of air temperature in the study area. Only rainfall level shows a statistically significant increasing trend during the period of observation while the trends shown in temperature are statistically on the decline. Temperature and rainfall presented tolerable values which are not life-threatening to the residents of Ilorin. However, the general increase in the level of rainfall showed a period of adequate water in the study area, which the farmers and other agricultural stakeholders should take advantage of. Further, the adaptive measures should be infused in coming years in order to reduce problems of flooding and soil erosion. This implies that the fluctuating rainfall experienced in the study area will make it difficult for farmers to determine when and what to plant and this can indirectly cause low yield in agricultural produce. The increasing level of temperature on the other hand also posited a problematic climatic condition. Although the level of declination is relatively low, it might lead to the issue of high blood pressure to farmers due to high vapor pressure and since the temperature is higher than the tolerable limit, Ilorin is subject to heat. Therefore, the residents should endeavor to provide themselves cooling systems for homeostasis to be engaged. The study therefore concluded that there is strong relationship between the two variables (rainfall and temperature) in the study area. Moreover, this significant relationship has a great effect on the socio-economic life of the residents in the study area. The fluctuation in rainfall has greatly affected the farming activities and has brought about low yield of crop production. It has also brought about water scarcity for those that depend on rain water as their source of water. The study however recommended that Government policies related to agriculture and water resources development should take into account the risks and opportunities associated with late onset and early cessation and increasing length of dry season in the study area. Moreover, the information derived should be utilized to enable farmers to plan earlier for cropping season and undertake improved land management, soil conservation, flood control method and improve farmers knowledge about proper use of weather information that apparently will minimize the risks of climate related hazard or seasonal rainfall variability.

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