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TREND ANALYSIS OF TEMPERATURE AND HUMIDITY IN KWARA STATE, NIGERIA

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Abstract

This paper examines the trend analysis of temperature and relative humidity in Kwara State. Climatic data on annual mean temperature (minimum and maximum) and relative humidity for 40 years (1978- 2017) were collected from Nigerian Meteorological Agency (NIMET) Ilorin. Semi-Average method, Mann- Kendull statistics and regression method were used to analyse the trend in temperature and relative humidity. The Standardized Anomaly Index (SAI) was also used to examine the changes in temperature and humidity over the period of 1978 -2017. The result of the analysis indicates that temperature (minimum and maximum) and relative humidity exhibit an upward trend. This implies that temperature and relative humidity increase over the period of 1978 -2017. The Mann-Kendull statistics values show that there is no significant difference in the values of temperature (minimum and maximum) and relative humidity. The result of the Standardized Anomaly Index (SAI) also revealed that the values of temperature and humidity fluctuated around the long –term mean. About 50% of the annual average relative humidity falls above the long term average while 40% of the annual mean maximum temperature falls above the long term average. It can therefore, be deduced that there is the possibility of increment in the values of temperature and relative humidity which could cause a serious challenge to human health and climate change. The study therefore, suggests that increase and fluctuations in temperature and relative humidity should be a critical factor in designing strategies to mitigate the effect of climate change on the environment and human health.

Keywords: Trend Analysis, Minimum and Maximum Temperature, Relative Humidity, Fluctuations

INTRODUCTION

A trend is a pattern of gradual change in a data gathered sequentially at equal spaced time interval. It is an increase or decrease in the value of a variable occurring over a period of several years. Trend is a long-term change (increase or decrease) in a time series (Ragatoa, 2018). Trend analysis is a technique for extracting an underline pattern of a behavior in a data collected over time, and the science of studying changes in pattern in a time series. Trend analysis is generally used to estimate uncertain events in the past and to predict future outcome of an events. Trends have become the most frequently used technique to identify climatic variability in regional and local basis (Amadi et. al., 2014).

Many studies in climate literature have employed trend analysis to examined pattern of changes in climatic parameters, especially variations in temperature. Some examined changes in global and regional mean temperature (Olofintoye and Sule, 2010; Jain and Kumar, 2012; Jones et al., 2013) while some studied trends in temperature on different spatial and temporal scales (Ogolo and Adeyemi, 2009). According to Karaburun et al. (2011) majority of these studies have found an increasing trend in temperature, although the variations differ slightly from one region to another. Xu et al. (2017) reported that temperature has increased more than 0.3 °C/decade in most areas in north China and 0.1–0.3 °C/decade in most of south China. Similarly, Ahmad (2015) also reported that variations of temperature over most part of Iran from 1961–2010 show a positive trend with the rate of change varying from 0.09°C to 0.38°C per decade. Historical evidences have shown that, since 1880, global mean temperature has increased about 0.85 ± 0.2 ºC (IPCC, 2014). Similarly, the general trend of minimum and maximum temperature in Nigeria was found to be increasing (Ragatao et. al., 2018).

Temperature and humidity are essential elements in the study of weather and climate forecasting. They are basic environmental factors influencing thermal comfort which is a fundamental concept for climate control systems. Variations and fluctuations in climatic elements, especially temperature and humidity, and its consequential effect on the environment and human health has become a global concern. Understanding climatic patterns is of great importance when several global challenges such as food insecurity, water crisis, biodiversity loss, and health issues are tied to climate change (IPCC, 2014). Changes in surface air temperature are a fundamental indicator of climate change. Hansen et al. (2012) examined the trend of global temperature change and reported that the increasing temperature may influence sea level and the extermination of species. Similarly, Vicente-Serrano et al. (2014) and Xie et al.

(2011) reported that understanding patterns and trends in relative humidity will reduce uncertainties in the estimation of future climatic changes. Therefore, assessment of the characteristics of climatic elements is vital for understanding of both the temporal and spatial variability at local, regional or global scales and their effect on the environment and human health.

Trend analysis of ambient air temperature and humidity are essential in assessing environmental heat stress on human health (Ogbonmwan et al., 2016). Field et al. (2012) opined that extremely high air temperatures have a profound effect on human and natural systems while Wehner et al. (2017) reported that human health and welfare are mainly affected by the combination of high heat and relative humidity. Wehner et al. (2017) also noted that the highly cited literature on the impacts of climate change (Smith et al., 2014) considers both variations in temperature and humidity on future occupational heat stress. Hot and moist air makes people feel uncomfortable, while extremely dry air cause discomfort on human body. High humidity leads to continuous sweating and also cause overheating or heat exhaustion which can lead to dehydration, chemical imbalances in the body and ultimately death. Patz et al. (2005) opined that the reproduction and survival rates of bacteria and viruses, which are devoid of thermostatic mechanisms, are greatly affected by temperature variability. According to Ye et al. (2013) understanding changes in the surface air temperature and humidity are vital because they can have severe impacts on the hydrological cycle and the surface energy budget. Furthermore, Lewis and King (2016) also reported that knowledge about the specific characteristics of changes in temperature distributions in response to background warming is an essential aspect of fully understanding changes in heat extremes and their related impacts on human and ecosystem health.

From the ongoing discussion, it is clear that knowledge about changes in temperature and humidity are critical to human comfort, climate change and other contemporary environmental problems. Understanding the uncertainties associated with temperature and humidity patterns will provide a knowledge base for better management of heat stress, climate change and other related environmental hazards. According to Meshram et al. (2018) trend analysis of temperature on different spatial scales will help in the construction of future climate scenarios. Therefore, the objectives of the study is to examine the pattern of temperature and humidity in Kwara State with the aim of creating awareness on the changes in temperature (minimum and maximum) and humidity which are useful information in developing strategies to mitigate the impact of heat stress on human comfort, its impact on climate change and other related environmental problems.

STUDY AREA

Kwara State is located on longitude 2°6’E and 5°2’E and latitude 7°30’N and 9°40’N. It is situated within the North Central geopolitical zone of Nigeria. Kwara State shares boundary with Republic of Benin and with five states in Nigeria. These states are Niger in the North, Oyo, Osun and Ekiti in the South, and Kogi in the East. Kwara State comprises of sixteen local government areas. In term of population, according to 2006 population census, the population of Kwara state was 2,365,353 (NPC, 2006). Figure 1 shows the map of Kwara State showing the topography and the location of weather station.

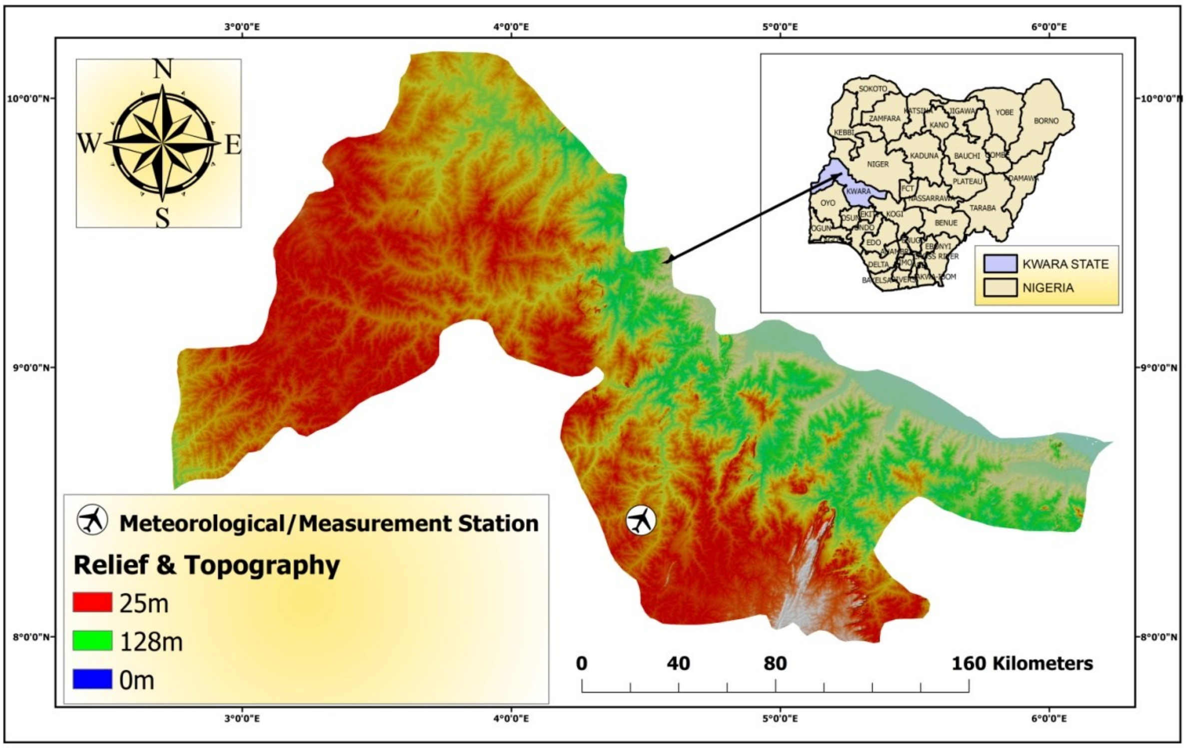

Fig.1 Map of Kwara State showing the Topography and Location of Weather Station

The climate of Kwara State exhibits both wet (rainy) and dry seasons in response to the South West Monsoon wind and the North East continental wind which are the major prevailing winds that blow across the state. The wet or rainy season begins towards the end of April and last till October. The dry season begins in November and end in April. The temperature of the state ranges from 33°C to 35°C from November to January and from 34°C to 37°C from February to April. The total annual rainfall ranges from 990.3mm to 1318mm. The rainfall exhibits double maximal pattern. Relative humidity ranges from 75% to 88% from May to October and 35% to 80% during the dry season (Ajadi and Adeniyi, 2017).

MATERIALS AND METHODS

Power series polynomial model and trigonometric polynomial or fourier series model are the basic models of trend surface analysis. However, the power series model is used in this study because it is the most frequently used model of trend surface analysis. Monthly data on temperature (minimum and maximum) and relative humidity were collected from 1978–2017 from Nigerian Meteorological Agency, (NIMET) Ilorin. The liquid-in-glass thermometer was used to collect data on minimum and maximum temperature while hygrometer was used to collect data on humidity. These instruments are the most common instruments used for measuring temperature and humidity with high accuracy. These data were collected from the weather station in the Ilorin International Airport. The 5 year Moving average was used to calculate short term fluctuations. Semi-Average method was used to analyse the trend in temperature (minimum and maximum) and relative humidity. The method was employed because it is more objective than fitting a line by eye to the plotted series. Regression method was also used to analyse trend in temperature and humidity. The study period was 40 years 1978–2007 and it was divided into four equal parts to examine the deviation of decadal means from the long term mean. The study period was also sub-divided into two sub periods, 1978–2017 and 1978–2007 based on climatic normal that is 30 years (1978–2007). The essence of the sub-division is to investigate the trend in the climatic elements in relation to the percentage change from 1978–2017. Mann-Kendall test was used for the analysis of trend (increasing or decreasing) in temperature and humidity. Mann Kendal test was employed because it is a non parametric test which does not require the data to be normally distributed and also has low sensitivity to short breaks due to inhomogeneous time series (Tabari et al. 2011). In addition, it is the most generally used methods and appropriate method of detecting trends. The Mann Kendall trend test have been extensively used and adapted several times especially in diverse studies on trend analysis (Ragata et al. 2018). The method was employed by Adeniyi (2016) in the study of spatio- temporal variations of wind flow and its implications for energy generation in the Sudano-Sahelian Zone, Nigeria and also by Birhanu et al. (2017) in the study of temperature and precipitation trend over 30 years in Southern Tigray, regional State, Ethiopia.

The Standardized Anomaly Index (SAI) was also used to examine the changes in the values of temperature and humidity over the period of 1978-2017. The Standardized Anomaly Index was calculated using the following equation:

$$SAI = \frac{X_i - \bar{X}}{S.D}$$

Where:

X_i = annual total of the parameter

$\bar{X}$ = mean value of the parameter for the period of study

S.D = standard deviation from the mean value of the parameter for the period of study.

RESULTS AND DISCUSSION

Fluctuations in Annual Temperature and Relative Humidity (1978 – 2017)

The graphs in Figures 2–4 revealed the fluctuations of minimum temperature, maximum temperature and relative humidity in Kwara state (1978–2017). The annual minimum temperature (Fig. 2) in the state falls below the long term average in the years from 1978 to 1979, 1981 to 1982, 1984 to 1986, 1990, 1992 to 1998, 2000 to 2001, 2011 and 2015 to 2017. About 43% of the annual minimum temperature falls above the long term average. The longest consecutive years when annual minimum temperature falls below the long term mean were recorded from 1992 to 1998 while the longest consecutive years when minimum temperature falls above the long term mean were recorded from 2003 to 2005 and 2012 to 2014. The annual maximum temperature (Fig. 3) in the state falls above the long term average in the years from 1987, 1996, 1998, 2000 to 2003, 2006 to 2011 and 2015 to 2017. Fifty percent (50%) of the annual mean maximum temperature falls below the long term average while 40% of the annual mean maximum temperature falls above the long term average. The longest consecutive years when annual mean maximum temperature falls below the long term mean was recorded from 1979 to 1984 while the longest consecutive years when minimum temperature falls above the long term mean was recorded from 2006 to 2011. Figure 4 revealed that the annual relative humidity in the state falls below the long term average in the years from 1982 to 1985, 1987 to 1990, 1992 to 1998, 2000 to 2002 and 2008. About 50% of the annual mean relative humidity falls above the long term average. The longest consecutive years when annual relative humidity falls below the long term mean was recorded from 1992 to 1998 while the longest consecutive years when minimum temperature falls above the long term mean was recorded from 2009 to 2005 and 2017. The above findings show that temperature (minimum and maximum) and relative humidity varies from year to year and fluctuated around the long term mean.

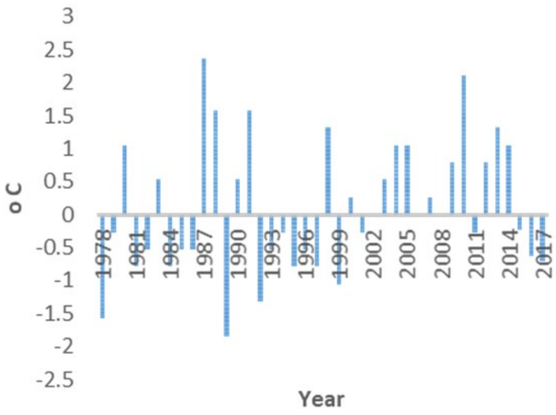

Fig.2 Annual Minimum Temperature Fluctuations for Kwara State

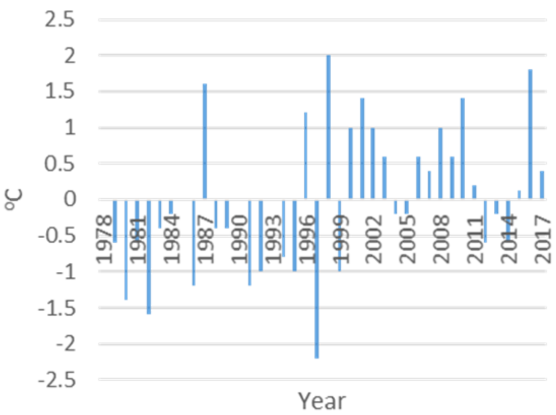

Fig.3 Annual Maximum Temperature Fluctuations for Kwara State

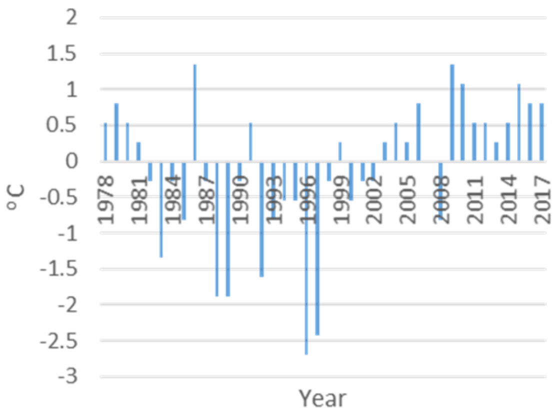

Fig.4 Annual Relative HumidityFluctuations for Kwara State

Deviation of Decadal Means of Climatic Parameters in Kwara State (1978–2017)

Table 1 shows the deviation of the decadal mean values of minimum temperature, maximum temperature and relative humidity from the long term 1978–2017. The highest deviation of decadal mean of minimum temperature was in 2008 to 2017 (+0.2) while that of maximum temperature was in 1998 to 2007. The lowest deviation of decadal mean of relative humidity (+0.6)

Table 1 Deviation of Decadal Means of Climatic Parameters in Kwara State (1978-2017)

Period	Deviation of Decadal Mean		
	Minimum Temperature	**Maximum Temperature**	**Relative Humidity**
1978 – 1987	0.00	-0.2	+0.6
1988 – 1997	-0.1	-0.3	-4.1
1998 – 2007	+0.1	+0.3	+0.7
2008 – 2017	+0.2	+0.2	+2.7

Table 2 Deviation of the 1978 – 2017 Means of Climatic Parameters from 1978-2007 in Kwara State

Climatic Elements	**1978 - 2017**	**1978 - 2007**	**Change**	**Change [%]**
Minimum Temperature [^{0}C]	21.7	21.6	-0.1	-0.46
Maximum Temperature [^{0}C]	32.5	32.4	-0.1	-0.31
Relative Humidity [%]	74.0	73.0	-1.0	-1.35

was in 1978 to 1987. Temperature (minimum and maximum) and relative humidity exhibit positive deviation of decadal mean in 1998–2007 and 2008–2017. This implies that there is an increase in the values of temperature and relative humidity from 1998–2017. The negative signs show a decrease in the values of the climatic parameters.

Deviation of the 1978–2017 Means of Climatic parameters from 1978–2007

The period under study, 1978 to 2017 was divided into two sub- periods, 1978–2017 and 1978–2007 to show the deviation of the means of temperature (minimum and maximum) and humidity of 1978–2017 from 1978–2007. Table 2 shows a decrease in percentage change of minimum temperature, maximum temperature and relative humidity. There was a decrease of –0.46% of minimum temperature and -0.31% decrease of maximum temperature. Relative humidity has -1.35% decrease in percentage change. The negative change in the percentage of change implies that there were declines in the values of minimum temperature, maximum temperature and relative humidity in the state from 1978 -2007, though the rates of deviation were small.

Variation of Temperature and Relative Humidity (1978–2017)

Figures 5–7 show the variation of the mean and the 5-year Moving average of minimum temperature, maximum temperature and relative humidity in Kwara state from 1978 to 2017. The annual values of minimum temperature fluctuated from 21.0°C in 1989 to 22.6°C in 1987 (Fig. 5). Figure 6 shows that maximum temperature fluctuated from 31.4°C in 1997 to 33.5°C in 1998 while that of relative humidity fluctuated from 71% in 1985 to 79% in 2009 (Fig. 7). This implies that there were little variations in the values of temperature (minimum and maximum) and relative humidity. Similarly, the smoothed by running averages for the period of 5 years also revealed that there is little variation in the values of temperature and relative humidity.

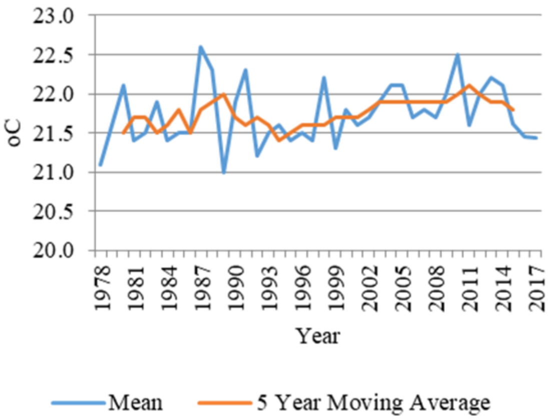

Fig. 5 Trend of 5-Year Moving average of Annual Minimum Temperature in Kwara State

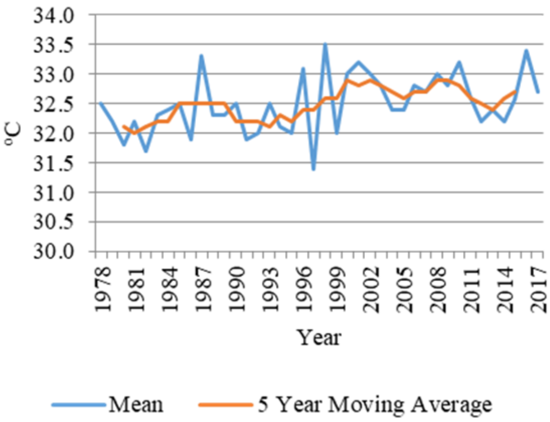

Fig. 6 Trend of 5-Year Moving average of Annual Maximum Temperature in Kwara State

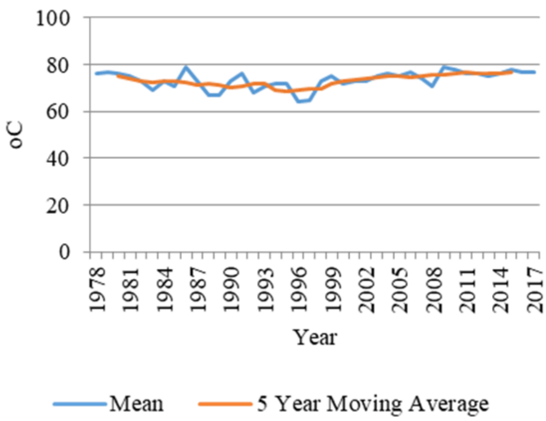

Fig. 7 Trend of 5-Year Moving average of Annual Relative Humidity in Kwara State

Trend in Temperature and Relative Humidity Using Semi Average Method

The annual value of minimum temperature, maximum temperature and relative humidity for the period of 40 years, (1978 to 2017) were analyzed for trends using semi average method (Table 3). From the table, minimum temperature, maximum temperature and relative humidity exhibit an upward trend, although the changes are very small. This implies that values of temperature (minimum and maximum) and relative humidity in the state will keep on increasing. In addition, it also indicates a warming trend. This finding of increase in temperature agreed with the report of the International Panel on Climate Change (IPCC) (2013) which state clearly that temperature trends on a global scale show a warming of 0.85 (0.65-1.06)°C, over the period 1880–2012.

Trend in Temperature and Relative Humidity Using Mann-Kendull Statistics (1978-2017)

The result of the trend analysis using Mann-Kendull statistics shows increasing (positive) trends in the values of temperature and humidity. The result of the statistics in Table 4 also shows that there is no significant difference in the values of temperature (minimum and maximum) and relative humidity at either 95% or 99% probability levels. This is because the values of the Mann-Kendull statistics (r) is less that the theoretical value $(r)_t$. This implies that no differential pattern of variation exist in the values of temperature and relative humidity in the state.

Table 3 Trend in Temperature (Minimum and Maximum) and Relative Humidity Using Semi Average Method

Climatic Elements	First Part Avg.	Second Part Avg.	Trend
Minimum Temperature [°C]	21.6	21.8	Upward Trend
Maximum Temperature [°C]	32.2	32.7	Upward Trend
Relative Humidity [%]	71.9	75.3	Upward Trend

Table 4 Trend in Temperature (Minimum and Maximum) and Relative Humidity Using Mann-Kendull Statistics

Climatic Elements	R
Minimum Temperature	0.06
Maximum Temperature	0.23
Relative Humidity	0.17

Trend Analysis of Temperature and Humidity Using Linear Regression Method

Figures 8–10 show the actual, trend lines and trend equations of temperature (minimum and Maximum) and humidity in Kwara state (1978–2017). From the figures (Figures 8–10), the trend lines show an upward trend. This implies that there is an increase in the values of temperature (minimum and maximum) and relative humidity. In addition, no definite break in the trend of temperature and humidity is observed, although the values fluctuate. The rate of increase in trend is very small. However, an increase in temperature leads to climate change which can negatively affect weather and consequently cause many climatological hazards like drought.

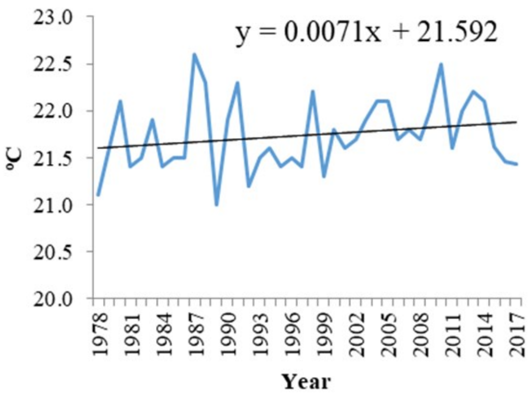

Fig. 8 Trend of Annual Minimum Temperature in Kwara State

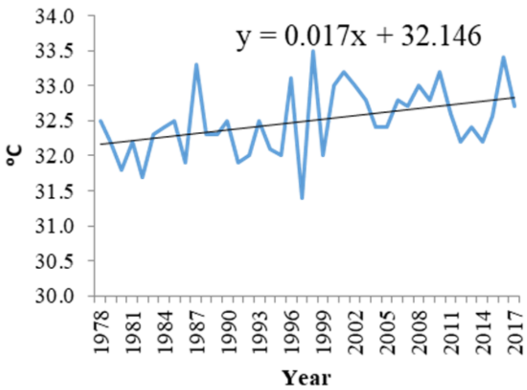

Fig. 9 Trend of Annual Maximum Temperature in Kwara State

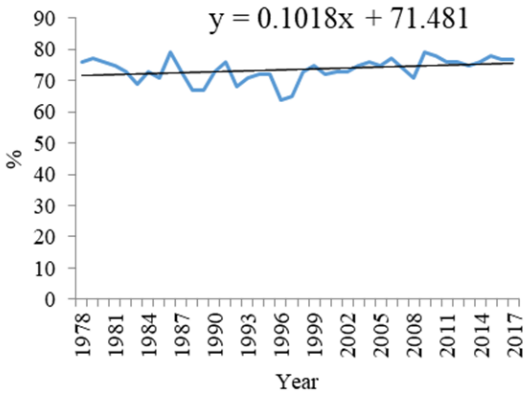

Fig. 10 Trend of Annual Relative Humidity in Kwara State

CONCLUSIONS AND RECOMMENDATIONS

The trend analysis of temperature and relative humidity for 40 years (1978–2017) in Kwara State revealed that annual mean values of minimum temperature, maximum temperature and relative humidity fluctuated around the long- term mean. Fifty percent (50%) of the annual mean maximum temperature falls below the long term average while 40% of the annual mean maximum temperature falls above the long term average. About 50% of the annual mean relative humidity falls above the long term average. This means that the identified climatic parameters in the years under review have show both below and above long term mean pattern. The deviation of decadal means of temperature and relative humidity from the long term mean shows positives in 1998–2007 and 2008–2017. The result of trend analysis shows that temperature and relative humidity exhibits an increasing trend. The increase in temperature indicates a warming trend. This implies that the state is vulnerable to the effect of global warming which is dangerous to the environment and human health. The result also suggests that the increase in temperature can lead to an increase in heat index which can lead to heat disorders such as pain, blisters, fever, headaches, heavy sweating and heat stroke or sunstroke. In addition, increase in temperature can lead to climatological hazards like drought and climate change. The increase in temperature and relative humidity could be as a result of impact of urbanization and other anthropogenic activities in the state. Therefore, the study recommends that potential increase in temperature and relative humidity should be a critical factor in designing strategies to cope with and reduce the effect of climate change on the environment and human health.

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