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HEAT WAVE AND ITS IMPACT IN NORTHEASTERN NIGERIA: A CASE STUDY OF YOBE STATE, NIGERIA.

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ABSTRACT

Heatwaves are significant natural disaster that is caused primarily by extreme temperatures. The extreme heat events associated with heatwaves often cause severe health complications and deaths. In view of the environmental hazards associated with heatwaves, this study investigated the impact of heatwaves in Yobe State, northeast Nigeria. Temperature and humidity data of thirty years (1991-2020) for the hot season (March-June), were obtained from the Nigerian Meteorological Agency (NiMet) Abuja. Time series analysis and basic statistical tools were used to analysis the data which was used to evaluate the trend of heatwaves and their impact in the study area. The results of the study showed that 2010 was extremely hot with an average maximum temperature anomaly of 2.18, while 2013 and 2015 have an average maximum temperature anomaly of 1.93 respectively, and were very hot. The trend in the average maximum temperature anomaly of the study area showed a continuous increase in extreme heat for about a decade (2009-2020). The positive temperature trend and the average maximum temperature anomaly showed that the intensity of heatwaves in the study area will increase in the future as a result of global warming caused by the continuous emission of anthropogenic greenhouse gases. The results also showed that the heatwaves were exacerbated by the drought which occurred between 2010 and 2014. The annual heat index which range from 29.4^{o}C - 34^{o}C in the study area showed that the heatwaves have impacted both human and animals negatively in the area.

Keywords: Heatwave, Temperature, Anomaly, Heat-index, Global warming.

INTRODUCTION

When visible light and high frequency infrared radiation are absorbed by the surface of the Earth, it gets hotter, the absorbed radiant energy from the Sun is being re-radiated in all directions on the Earth's surface in the form of long-wave infra-red radiation which are also known as heat radiation. Infrared light from the Sun accounts for 49% of the heating of Earth, with the rest being caused by visible light that is absorbed and then re-radiated at longer wavelengths (Griffin *et al.*, 1947). Heatwave is a period of unusual hot weather which may last for three or more days (NOAA, 2020). For a heat event to qualify to be called a heatwave, the recorded temperature of the area under consideration must exceed the average temperature (NOAA, 2020). The World Meteorological Organization (2015) refers to heatwave as a situation where the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5^{o} C (Rothfusz, 1990). Heatwaves are associated with negative environmental and economic impacts. Several studies have shown that heatwave normally cause health problems that may lead to death (Larsen, 2003; Fischer et al., 2012; Haider, 2019; NOAA, 2021). The United States Agency for Health Care Research and Quality, reported that about 6,200 Americans are hospitalized every summer due to extreme heat (Haider and Anis, 2015).

Heatwaves occur when a static high pressure is formed in the upper atmosphere and it remains over a region for several days or weeks. Under the high pressure situation, the air sinks towards the Earth surface and the wind gets minimized thereby making the air to be cut off from circulation. The air warms and dries adiabatically, preventing conventional movement of air parcels and cloud formation, and thereby increasing the amount of solar radiation reaching the Earth's surface. During the extreme heat event, there is always a geometric increase in hospital admissions caused by increased prevalence of heat-related diseases (Van Loenhout *et al*., 2016). Karl and Knight (1997) reported that a heatwave which lasted for three days killed about 700 people in Chicago, in 1995. Heatwaves could be dangerous when the public is uninformed and unprepared. Aditya *et al.*, (2021) reported that the heatwave which occur in Russia in 2010 led to the death of 55,000 people. Garcia-Herrera *et al*., (2010) reported that about 70,000 people died in Europe, in 2003 due to heatwave. WHO (2018) reported that 2,200 people died in India in 2015 as a result of heatwave. In Nigeria, the British Broadcasting Corporation (BBC) on Thursday 11 June 2002, reported that more than 60 people died due to heatwave that lasted for three days in Maiduguri. In northeastern Nigeria, the hot weather runs from March to June. The year 2020 ranked one of the three warmest years on record globally (NiMet, 2020). Olagunju (2015) reported that extreme heat can cause heat exhaustion, cardiovascular diseases (heart attacks and strokes). He also observed that over exposure to high ultra-violet radiation can suppress the immune systems of both human and animals. The hazards of extreme heat or heat waves are largely ignored and in most times misrepresented, especially in developing countries such as Nigeria. Extreme heat has been affecting the northeastern part of Nigeria seriously in the past decade, but due to lack of awareness, most of the events were under-reported. The prominent cause of heatwave death are cardiovascular, respiratory and cerebrovascular diseases (Basu, 2015). People with pre-existing illness such as heart

and lung diseases are at higher risk of dying during heatwave (Wolf, 2009). Stafoggia *et al*., (2006) observed that people with diabetes, fluid or electrolyte disorder and some neurological disorders are at much risk of heat related death. The effect of climate change is now evident in the extreme temperature events in northeastern Nigeria, particularly in Yobe and Borno States. The Word Health Organization predicted that by 2030, about 92,000 people will be dying of heatwave every year, such that, Sub-Saharan Africa, Latin America and Southeast Asia will be mostly affected (WHO, 2014). The World Meteorological Organization (WMO) reported that the last decade (2011-2020) was the warmest decade so far, and the last six years starting from 2015-2020 was the warmest (NiMet, 2020). The Nigeria Meteorological Agency reported in 2020, that temperatures of 45º C and above were recorded in Maiduguri, Borno state and in Potiskum, Yobe State. Temperatures above 40º C were recorded for eighty (80) days in Nguru Yobe State, Nigeria (NiMet, 2021). Nigeria Meteorological Agency also reported that Maiduguri experienced daily maximum temperatures of 41- 45º C in 28 consecutive days in the year 2020 (NiMet, 2021). Heat waves can cause significant bushfires and wildfires during drought or dry season. Bell *et al*., (2003) reported that an extreme heatwave occurred in Europe and there was an outbreak of wildfire which destroyed about 3,010 square kilometers of forest and 440 square Kilometers of agricultural land. Heatwaves are potential health risk and they are likely to increase in frequency, duration and intensity as a consequence of climate change. The impacts of heatwave in northeastern Nigeria deserve attention. Prolonged extreme heat event can cause water scarcity due to reduction in groundwater table, drought, famine and poor agricultural production. Animals are also much affected during prolonged heatwave especially when it is accompanied by drought (Figure 1).

Figure 1. Effect of heat wave on livestock (Source: Abdullahi, 2018).

Heatwave exacerbated by drought can lead to a severe situation that could cause sudden mass death of livestock and great loss to farmers (Figure 1). The United Nation Office for Disaster Risk Reduction observed that heatwave fatalities is the fourth among the top 10 natural disasters with highest fatalities (UNODRR, 2016). Heatwaves affect the functioning of automobiles and thereby causing wear and tear of automobile parts and frequent mechanical failures. Much stress is always imposed on the cooling systems due to excess heat. Periods of heatwaves are often associated with high demand of electricity power supply to power air conditioning systems in order to assuage the effect of stress caused by heat. Sometimes the increase in pressure on the power grid can lead to the explosion of transformers, which is a common phenomenon in the study area. There is huge economic loss associated with heatwaves. The unusual expansion of rails on the railway system sometimes leads to kinking and buckling of the rails which leads to cancellation of railway services with a consequence of great economic loss. Hassan et al., (2017) investigated the trends of rainfall and temperature over northeastern Nigeria and they observed that the frequency of drought might increase in the future as a result of climate change. Kehinde et al., (2021) in their study of temperature pattern in Yobe State, northeast Nigeria, observed that there is variation in both monthly and yearly temperatures, and April remains the hottest month in the area. They therefore concluded that the variation in the temperature pattern in the study area are due to global warming. Eze, (2017) observed that there is a high incidence of drought in Yobe State and its frequent occurrence has negatively impacted both human and the environment. Global warming is predicted to increase the frequency of heatwaves as well as global mean temperatures and health risks (Easterling *et* al., 2000; NASA, 2020; NOAA, 2020). The need for this study is necessitated by the fact that there has been very little or no research on the impact of heatwaves in Nigeria. The aim of this study is to evaluate the impacts of heatwaves in northeastern Nigeria, using Yobe States as a case study.

MATERIALS AND METHODS

Study Area

Yobe state is located within latitudes 10º 30´ N and 13º 25´ N and on longitudes 9º 35´E and 12º 30´E. It has a population of about 2.6 million according to the National Population Census (NPC) results of 2006. Yobe State was carved out of old Borno State on August 27, 1991. It is located in the semi- arid region of Nigeria (Figure 2). The climate of the area is characterized by long dry season and short rainfall. Its annual rainfall ranges from 500 mm – 1000 mm (Agada *et al*., 2011), and it is the first to experience the hot northeast trade wind that blows

across the Sahara Desert into Nigeria (Agada *et al*., 2011). The study area is susceptible to drought and desertification by the virtue of its geographical location.

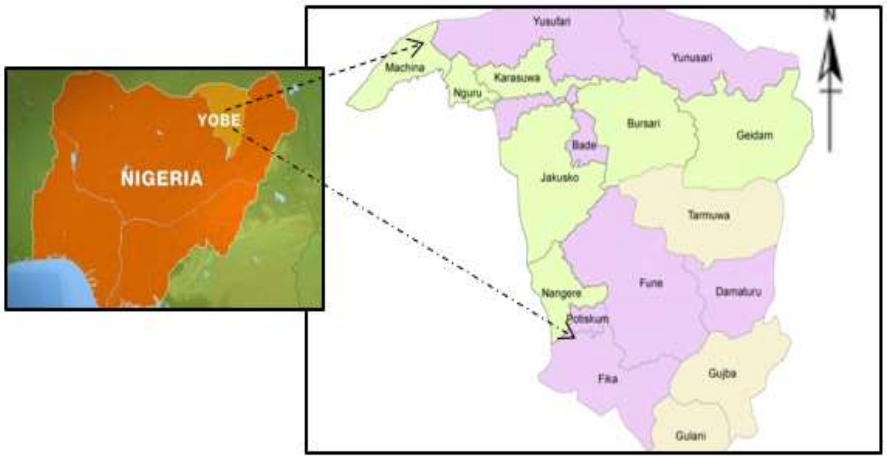

Figure 2. Map of Nigeria showing the study area.

Data Collection

Maximum temperature and relative humidity records for thirty years (1991-2020) were collected from Nigeria Meteorological Agency in Abuja and Potiskum station. The data obtained were computed and used for the assessment of the extreme heat events which normally occur between the months of March and June annually. The months of March, April, May and June are characterized by series of heatwaves in this part of Nigeria.

Data Analysis

Time series analysis and basic statistics such as maximum, minimum, mean and standard deviation were used to evaluate the data obtained. The simple linear regression technique was employed to analyze the temperature data in order to establish trends in the heatwaves. Three or more daily consecutive temperatures greater than 37ºC and the average relative humidity of the periods were used to evaluate the heatwaves. The mean annual maximum temperature was used to evaluate the Standardized Temperature Index (STI). The standardized temperature anomaly index was calculated using,

$$STI = \frac{x_i - x_m}{\sigma} \quad (1)$$

Where, x_i is the mean temperature of the year and x_m is the long-term mean temperature. σ is the standard deviation of the annual maximum temperature for the long-term. Periods below the long-term average were considered cooling periods and periods above the long-term average were considered warming periods. The standardized temperature index was compared to the threshold risk levels (Table 1).

Table 1. Standardized Temperature Index (Source: Marck, 2015)

S/N	Event	Interpretation
1	STI ≥ 2.0	Extremely hot
2	STI $\geq 1.5 < 2$	Very hot
3	STI $\geq 1.0 < 1.5$	Moderately hot
4	STI $< 1.0 > -1.0$	Near normal
5	STI $\leq -1.0 > -1.5$	Moderately hot
6.	STI $\leq -1.5 > -2.0$	Very cold
7.	STI ≤ -2.0	Extremely cold

Heat Index

The heat index was calculated using the average maximum temperature and the relative humidity data obtained from the Nigeria Meteorological Agency. The heat index measures the heat evaporative between the human body and the environment. The heat index was determined using the formula developed by the United States National Weather Service (Rothfusz and Headquarters, 1990).

$$Heat\ Index = -42.379 + 2.04901523\,x\,T + 10.1433312\,x\,R - 0.22475541\,x\,Tx\,R - 0.00683783\,x\,T^2 - 0.05481717\,x\,R^2 + 0.00122874\,x\,T^2\,x\,R + 0.00085282\,x\,T\,x\,R^2 - 0.00000199\,x\,T^2\,x\,R^2 - K.$$

Where T= temperature (ºF) and R = relative humidity and

$$K = \begin{cases} \left(\frac{13-RH}{4}\right) x \sqrt{\frac{17(T-95)}{17}} & , RH \geq 85\%\ and\ 80 \leq T \leq 112 \\ \left(\frac{RH-85}{10}\right) x \left(\frac{87-T}{5}\right) & , RH \geq 85\%\ and\ 80 \leq T \leq 87 \end{cases} \quad (2)$$

The calculated heat index was compared with the standards established by the United States National Weather Service (Rothfusz, 1990).

Table 2. Heat index threshold and their implications (Source: Orimoloye et al, 2017)

Threshold Index (°C)	Severity	Possible Adverse Effect
21- 25	Less evident	Fatigue with prolonged exposure
26- 32	Caution	Fatigue possible
33 -37	Extreme caution	Muscle cramps, sun stroke, heat exhaustion
38 – 48	Danger	Sun stroke, heart failure, sun burn, fainting, and skin rashes.
> 49	Extreme danger	Heat stroke, heart failure, skin rashes.

RESULTS AND DISCUSSION

The study showed that during the heatwaves the average maximum temperature of the study area range from 38.15 ºC – 41.25 º C (Figure 3a). This high temperature range is a clear indication of the effects of the unwavering heat on the study area which is responsible for the prevalence of diseases such as heat edema, heat rashes, heat cramps, heat syncope and heat exhaustion. Heat syncope is caused by over-exposure to heat waves which produces orthostatic hypotension (Orimoloye et al, 2017). It occurs as a result of intense sweating which leads to dehydration. Excessive dehydration and electrolyte depletion are responsible for heat exhaustion, which is characterized with symptoms such as diarrhea, headache, nausea, vomiting, dizziness, malaise and myalgia. The annual average maximum temperature growth is 0.3%.

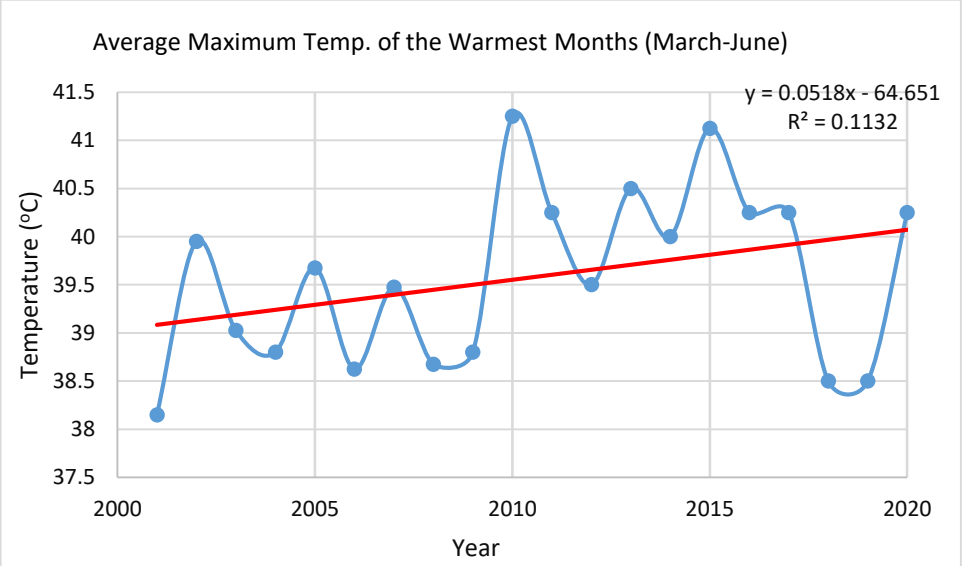

Figure 3a. The average maximum temperature of Yobe State during the warmest months (March –June).

The trend in the average maximum temperature anomaly of the study area (Figure 3a) indicates a continuous increase in extreme heat for about a decade (2009 -2020). The positive temperature trend (Figure 3a) shows that the intensity of heatwaves in the study area in the future, might increase as a result of global warming caused by the continuous emission of anthropogenic greenhouse gases such as carbon dioxide, chlorofluorocarbon, nitrous-oxides and methane. The heatwave duration in the early part of last decade (2010-2013) was prolonged (Table 3). A comparison of the standardized maximum temperature (Table 1) with the results obtained (Figure 3b) showed that 2010 was extremely hot with an average maximum temperature anomaly of 2.18, while 2013 and 2015 have an average maximum temperature anomaly of 1.93 respectively, and were considered very hot (Figure 3b).

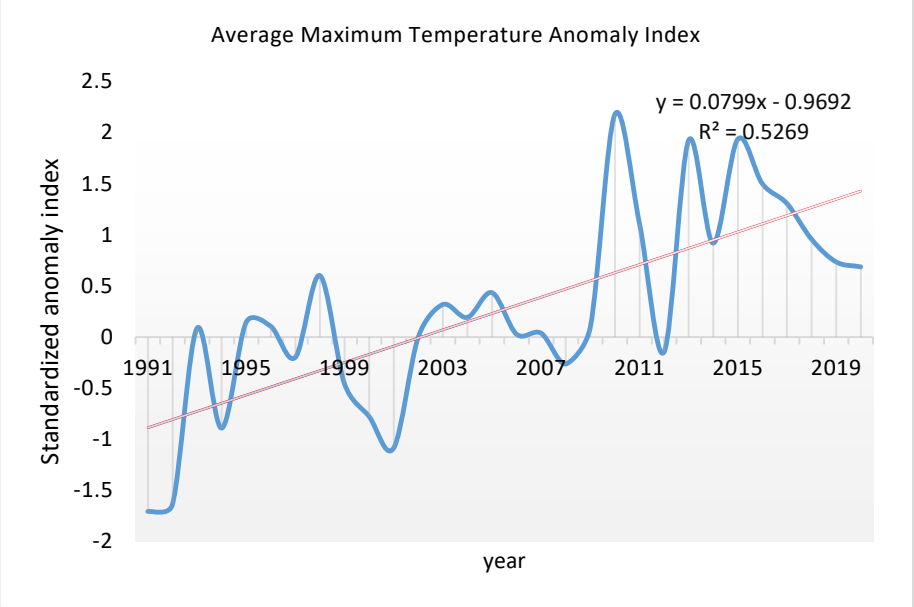

Figure 3b. Trend in the average maximum temperature anomaly in Yobe State (1991-2020)

Table 3. Average number of heat waves and number of days

S/N	Year	Number of Heat waves	Average Number of Days
1	2010	4	10
2	2011	3	9.5
3	2012	5	12.7
4	2013	4	9.8
5	2014	1	9.8
6	2015	2	5
7	2016	1	5
8	2017	1	3
9	2018	1	3
10	2019	1	9
11	2020	2	3

There were four heatwave events in 2010 with an average duration of 10 days, and in 2011 there were three heatwave events with an average duration of 9.5 days (Table 3). The durations of the heatwaves were more pronounced during the period between 2010 and 2014 (Figure 4a). During those periods there were evidence of drought in the study area (Eze, 2017). The heatwave duration in 2019 was prolonged due to the fact that the year 2019 was excessively hot throughout the world (NASA, 2020; NOAA, 2020).

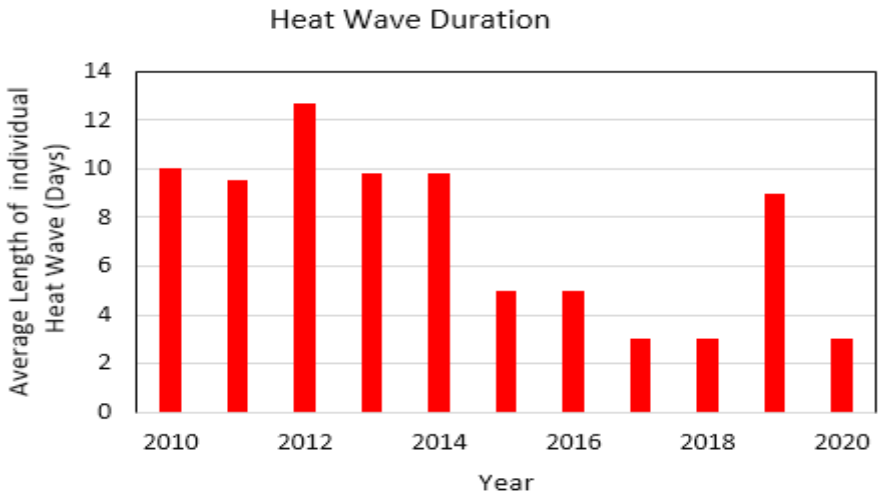

Figure 4a. Heat wave duration in Yobe State (2010-2020)

In 2012, the average length of individual heatwave was more than 12 days (Figure 4a). The heat waves were exacerbated by the drought experienced in the study area in 2012, which significantly affected crop production and livestock. The period between 2010 and 2013 witnessed high frequency of heatwaves due to drought and other climatic variabilities (Table 3). During that period, there was a significant decline in agricultural production due to livestock deaths and crop failure (Abdullahi, 2018). The situation was the same in other parts of northeastern Nigeria. Similar cases were also reported within the horns of other parts of Africa (Vicente-serrano *et al*., 2012). The period 2016 - 2019 witnessed a steady frequency of heatwave in the study area which was once per year (Figure 4b). There was a surge in the heatwave frequency in 2020.

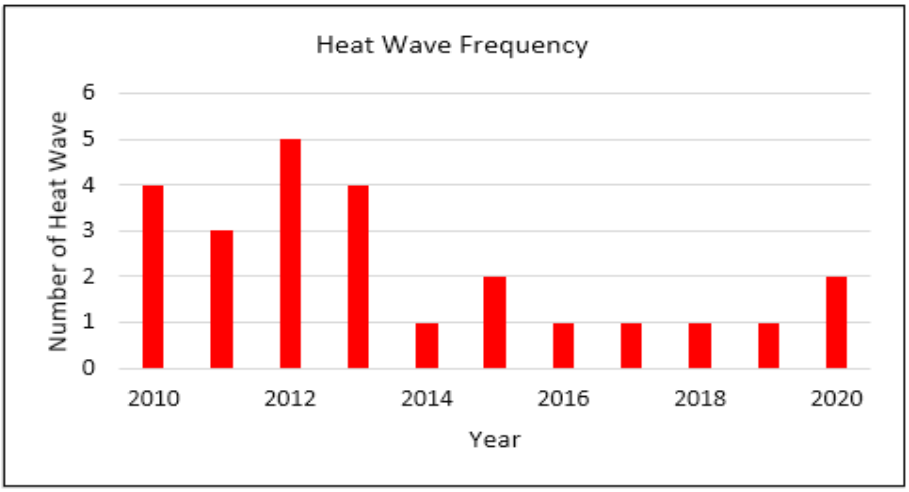

Figure 4b. Heat wave frequency in Yobe State (2010-2020).

The annual heat index ranges from 29.4ºC - 34ºC (Figure 4a). Using the heat index threshold in Table 2, it is evident that the annual heatwave might have contributed immensely to human health risk in the study area. The heat index surges from 30.8º C in 2009 to 34º C in 2012, and subsided to 31º C in 2014 and it later surges to 34º C in 2015 (Figure 5). 2012 and 2015 had the highest annual heat index of 34º C (Figure 5), which might have been facilitated by the drought during these seasons. The trend shows a continuous growth from 2009 to 2020 (Figure 5). The positive heat index trend indicates that the heat wave might increase in the future. The annual growth of the heat index is 0.22%.

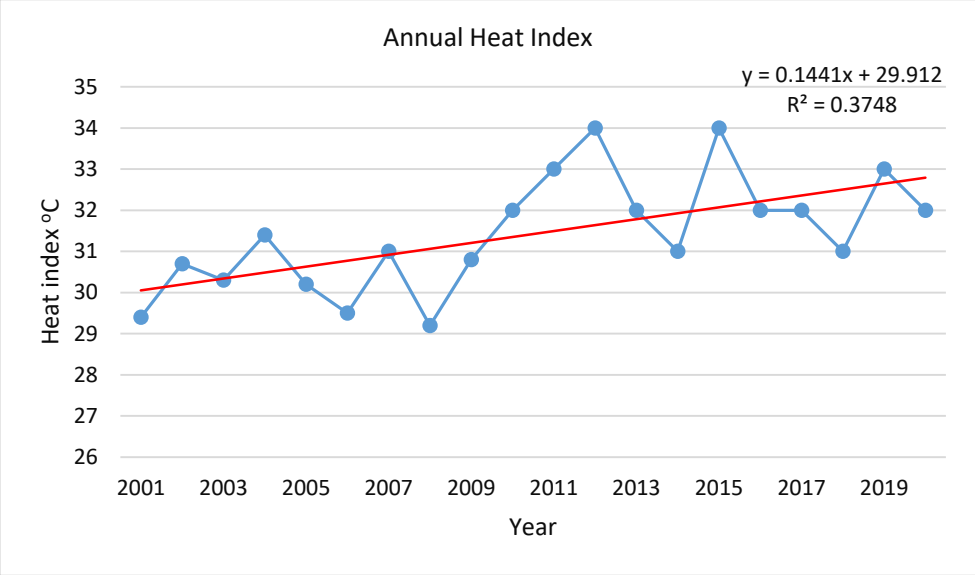

Figure. 5 Time series of annual heat index of Yobe State (2001-2020).

CONCLUSION

This study shows the impact of heatwaves in northeastern Nigeria. It reveals that duration and intensity of heatwaves in the study area were enhanced by drought, and its impacts are consequences of climate change. The values of the heat index obtained indicated that the heatwaves have impacted both human and infrastructure in northeastern part of Nigeria. The study showed variability in both the mean and maximum temperature suggesting that the frequency and intensity of heatwaves will increase in the future. The heat index values reflected the enormous stress, discomfort and health complications that people, plants, and livestock were subjected, during heatwave. Therefore, it is important to develop and adopt appropriate measures such as afforestation, public awareness, education, and early warning system alerts that will help to mitigate the impact of heatwaves in northeastern Nigeria. The results of the study agree with the observation of the Nigerian Meteorological Agency on the issue of rising temperature across northeastern Nigeria.

RECOMMENDATION

Base on the findings of this study, it is therefore recommended that deforestation should be discouraged by the government and appropriate authorities. Tree planting should be encouraged by the government and the public to provide shade and cooling in the environment through evapotranspiration. Measures which includes, a climate-based early warning system to alert the public and the farmers on the impeding danger of heatwaves should be made available at the right time in other to avert the consequences of heatwaves. The Nigeria Meteorological Agency and other weather Agencies should establish proper communication channels which includes the use of local languages to deliver information related to extreme weather conditions to the public, in order to avert their impacts and make provision for adaptation strategies.

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