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Research Article

Exploring Spatial and Temporal Temperature Trends and Characteristics for Sustainable Agricultural Planning in Southern Taraba

Patrick Sunday Asa[1, *], **Luka Yohanna**[2]

[1]Geography Department, Federal University, Wukari, Nigeria

[2]Geography Department, Modibbo Adama University, Yola, Nigeria

Abstract

Knowledge of the past, present and current temperatures in all parts of the atmosphere are crucial for weather forecasting and agricultural practices. Air temperature is one of the most sensitive indicators of the dynamical and physical processes in the atmosphere. It is affected by interactions between air and land or ocean, by the radiation received from the Sun and emitted by the atmosphere and the Earth's surface, by chemical interactions among others. This paper examined trends and characteristics of temperature in Southern Taraba. Temperature data for the period 1993-2022 were obtained from WorldClim.org. Statistical Packages for Social Sciences was used to determine descriptive statistics of the temperature; linear trend analysis was used to determine the trend of the changes while Fisher's F-test was employed to determine the statistical significance of the changes. The result of the study shows that average values of mean temperature for the period 1993-2022 vary from 27.64 ℃ at Ussa station to 28.17 ℃ while average mean temperature range for the period of study was 2.60 ℃. Linear trend analysis results of temperature shows positive values indicating a significant general rise in temperature over the study period in all the stations. The study recommends proper dissemination of agro-climatic information for appropriate adjustment and adaptations by farmers in the study for sustainable agricultural development.

Keywords

Spatial, Temperature, Linear Trend, Range and Analysis

1. Introduction

Temperature is one of the important variables that affect agricultural production besides relative humidity, precipitation, wind and sunshine in southern Taraba. Agricultural production in southern Taraba area is seasonal predominantly rain-fed. As such, understanding the trend and changes in temperature is important for sustainable agricultural planning in the study area. This is because temperature plays important role in cropping from planting to harvest and storage and animal rearing. It has also impacted on domestic and international economies in the area. Southern Taraba is highly vulnerable to climate change and variability as evident in rampant poverty, rapidly increasing population, and low levels of technological development. The increasing variability of temperature has the ability of destabilizing the fragile eco-

*Corresponding author: asa@fuwukari.edu.ng (Patrick Sunday Asa)

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system affects thermal comforts and threatens agricultural production and livelihoods in the area.

The spatial variability, intensity, seasonality and trends of temperature over Nigeria have been established focusing on different parts of the country in studies such as ([1-4]). Some of these studies revealed visibly the trend of increasing droughts and decreasing precipitation as well as rising temperatures in Nigeria from the end of the 20th century and the beginning of the 21st century.

Weather observation network in southern Taraba is characterized by low density, skewed distribution, short-term records, and significant data gaps. The available stations which generate information for weather and climatic conditions are located beyond the <50 Km^2 recommended by World Meteorological Organization (WMO). Most stations in southern Taraba are in the main urban centers (local Government headquarters), resulting in inadequate coverage of rural areas where agricultural activities take place.

Inadequate weather observation networks hamper timely and accurate rainfall forecasts or predictions that can guide farmers on cropping calendar decisions and post harvest activities. Without proper understanding the trends in temperature and precipitation, agro-meteorological planning, forecasting, and services cannot properly assist agricultural practitioners to optimally meet the ever-increasing demands for food and agricultural by-products.

This paper therefore, analyzed the annual temperatures changes and trends in Southern part of Taraba State Nigeria. The relevance and the importance of this study are underscored by the latest trends in the annual precipitation and temperatures in Nigeria by the Nigeria Meteorological Agency (NIMET).

2. Study Area

The study area is made up of five Local Government Areas (LGA) comprising Ibi, Wukari, Donga, Takum and Ussa that made up the southern senatorial zone of Taraba State in Northeastern Nigeria. The classification of the study area as southern zone of Taraba is based on political divisions of senatorial districts in Taraba State. The area is located between Latitude 6° 30’ 56’’N and 8° 46’ 26’’N and longitude 9° 06’25’’E and 10° 45’ 39’’ E with a total land area of about 14195.8km^2 [5], as seen in figure 1.

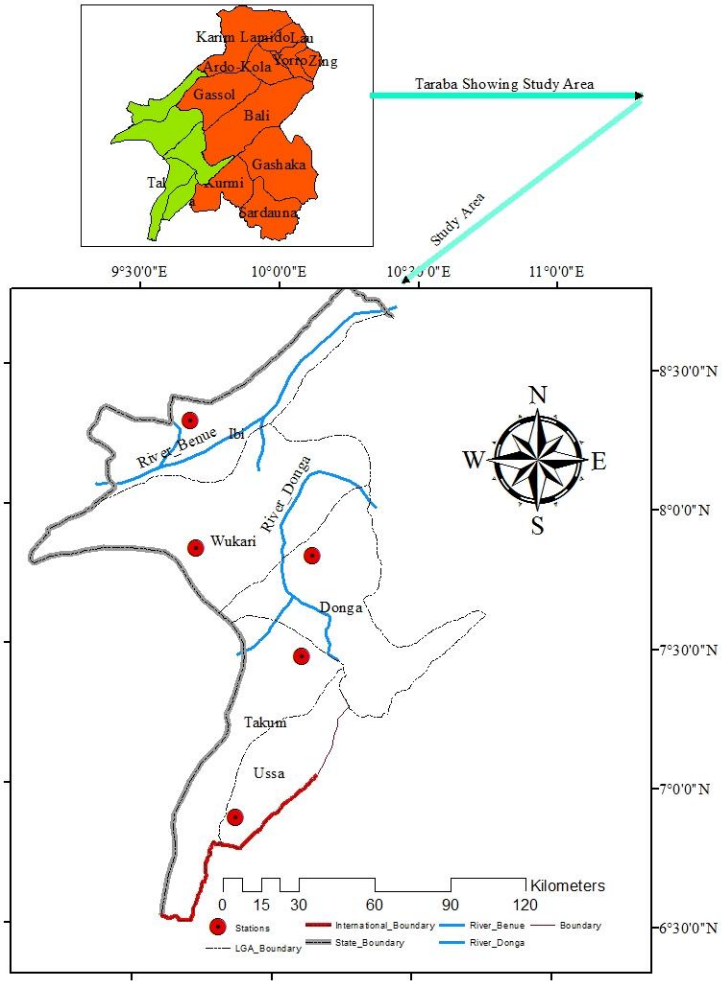


Figure 1. *Study Area.*

The study area is divided into two climatic zones; tropical continental and the tropical rainforest climate which falls within the Koppen's climate classification scheme corresponds to the A_w and A_f type of climate respectively. These climates are characterized by two distinct seasons (Rainy/wet and dry seasons) with a relatively brief period of harmattan compared to other parts of the state. The seasons are influenced by two local air masses; the northeast trade wind otherwise called the tropical continental air mass and southwest trade wind otherwise known as the tropical maritime air masses. The northeast trade wind is usually dry and desiccated, originating from the northeastern part of the country bringing along dusts from the Sahara desert resulting to harmattan dust. The advent of the northeast trade wind signifies the end of rainy season and the beginning of dry season. Rainy season in the study area begins from late March and last till early November respectively. Rainfall varies from 1200 mm in Ibi, Wukari and Donga to 2500mm in Takum and Ussa annually. Mean annual temperature ranges between 27.5^{o}C and 32^{o}C with the lowest temperatures in Takum and Ussa. [6]. The vegetation of the area is basically of two distinctive vegetation zones; the tropical rainforest-cum Savanna in Takum and Ussa and derived Savanna in Ibi, Wukari and Donga. The vegetation type in the area has significant influence in the modification of the climate of the area.

Southern senatorial zone of Taraba has a well drained soil with coarse texture surface horizons with different types of minerals in the parent rock. The soil types are generally well suitable for agricultural production. Thus, agriculture is the single largest occupation of the inhabitants of the study area. The inhabitants of the study area cultivate mostly tuber crops such as Yam and cassava; cereal crops such as rice, maize and Guinea corn as well as leguminous crops such as beans, groundnut, soya beans etc. The tropical rainforest climatic condition of Takum and Ussa favour the cultivation of tree crops such as palm trees, cashew, banana, plantain, mango oranges and other perennial crops.

The relief of the area shows that Wukari and Ibi are generally on low and undulating land with elevations less than 174m above sea level (asl) with the lowest at Ibi while Donga, Takum and Ussa are generally above 174m asl with highest point reaching up to 1440m asl particularly Fikyu, Rukwen-Rufu areas and Lissam in Ussa and Takum at the extreme southern end along the international border with Cameroun around. Two major rivers (River Benue and River Donga) with their tributaries such as the Shemanker drain the study area (Figure 2).

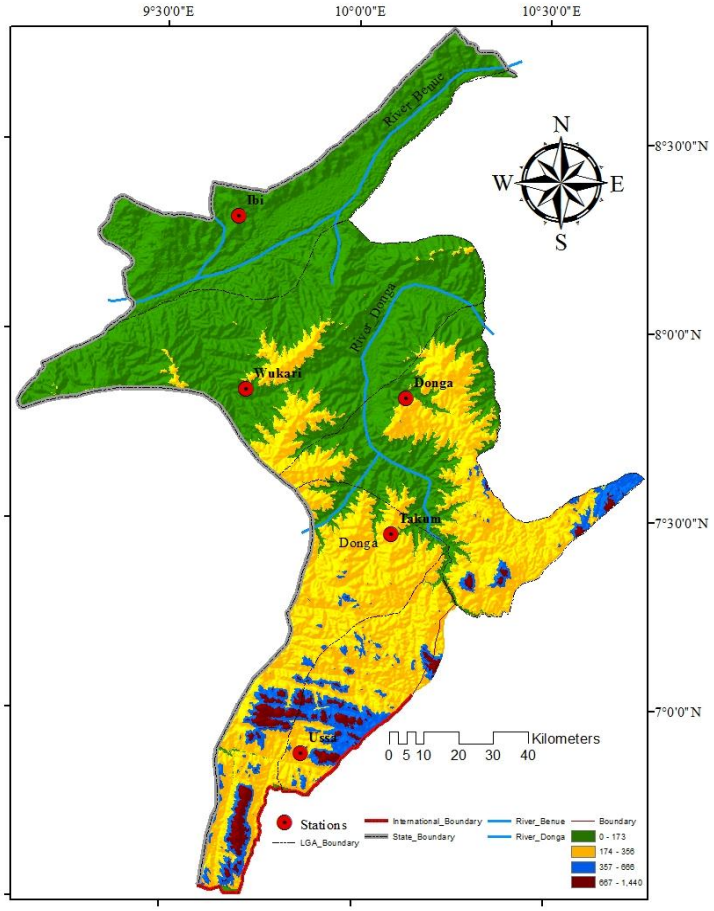


Figure 2. *Relief and Drainage of the Study area.*

3. Materials and Methodology

3.1. Materials

Data on temperature for the periods 1993-2022 were obtained from WorldClimate database at http://www.worldclim.org. WorldClim contains long term global climatic database of daily maximum, minimum and average temperature and daily rainfall as well as sunshine, Relative humidity and wind speed of 30,000 stations spread across the globe with a spatial resolution of 0.86 km^2 [7]. WorldClimate has six (6) meteorological stations distributed within the study area situated at Ibi, Wukari, Rafin-Kada, Donga, Takum and at Lissam (Ussa). However, for the purpose of this study, five (5) stations were used excluding Rafin-Kada. This is because Rafin-kada is between Wukari and Donga with a distance of less than 15km, which falls within the average distance between meteorological stations recommended by WMO. The data was retrieved on 14/3/2023 7:04 PM according to ([8, 9]). Out of the six stations in southern Taraba, three (Takum, Donga and Lissam) were located above 250m above sea level, while the remaining are below 250 m asl. This means that all the stations are located on a relatively low and undulating land. The descriptions of the station's locations are presented in Table 1.

Table 1. *WorldClim stations in southern Taraba.*

Station	Location	Mean Elevation (m)
Ibi	Lat: 8°14'23'' to 8°20'40'' Long: 9°38'31'' to 9°46'50''	150.000
Wukari	Lat: 7°47'17'' to 8°00'11'' Long: 9°40'30'' to 9°50'17	147.000
Donga	Lat: 7 °38'25'' to 7 °45'06'' Long: 9 °51'33'' to 10 °00'30''	152.000
Ussa (Lissam)	Lat: 6°59'00'' to 7°08'39'' Long: 9°56'48 to 10°06'08''	278.000
Takum	Lat: 7°11'16'' to 7°25'10'' Long: 9°51'02''to 10°08'01''	302.000

Sources: http://www.worldclim.org

The other data were collected from the meteorological yearbooks of NIMET and Upper Benue River Basin Development Authority (UBRBDA) meteorological stations in the study area (Wukari, Ibi, Donga, Lissam and Takum) as seen in Figure 1.

3.2. Methodology

Statistical analyses were carried out using SPSS version 10.2 to show the trend and changes in the temperature and rainfall of the study area for the period of study. Rainfall onset, cessation and length of rainy days were also calculated based on [10]. The formulae used in all the calculations are described in equations (1) to (5).

i. Monthly temperature amount: This was computed for the study area from the daily rainfall amount using the equation;

$$M_R = \frac{1}{n}\sum_{i=1}^{n} R_i \quad (1)$$

Where: M_R = Temperature (℃);
Ri = daily Temperature;
n = number of days in a month;
i = the days of the months.

ii. Annual Temperature amount: The annual rainfall total was calculated for the study area from the monthly rainfall amount using equation (2) as found in [4].

$$A_R = \frac{1}{12}\sum_{i=1}^{12} R_i \quad (2)$$

Where: A_R =;
Ri = daily Temperature (℃);
n = number of days in a month;
i = the days of the months.

iii. Mean monthly Temperature amount: The mean Temperature (℃); amount for the period of 36 years was computed for the study area by equation (3).

$$\overline{RRj} = \sum_{j=1}^{30} {}^{R_j}/_{36} \quad (3)$$

Where: *RR j* = the mean monthly Temperature for the period.

iv. Arithmetic Mean: Arithmetic Mean or the mean of a set of n-numbers:

X_1, X_2 X_3,,,, X_n denoted by $\bar{x}$ is the sum of these variables divided by n. mathematically

Expressed as (equation (4)).

$$\text{Mean, } \bar{x} = \sum x / n \quad (4)$$

Where x = Mean of daily rainfall amount;

Σx = sum of daily temperatures for the month (X_1 + X_2+ X_3…… +X_n);

n = number of days in a month.

v. Linear trend: Linear trend method was used to determine the trends in the annual temperature amounts. Fisher's F-test was used to determine their statistical significance

4. Results

Studies temperature trends and changes has provide a more precise insight regarding the temperature changes of a place ([11, 12]) Therefore, in this study the temperature of Southern Taraba Senatorial zone for the period 1993-2022 which was further classified into three decadal periods; 1993-2002, 2003-2012 and 2013-2022 has been analyzed and compared and presented. The results were discussed in two sections; the first section presents and discusses to show temperature changes and trend.

Mean Annual Temperatures

Annual mean temperatures for the study area under the study period were calculated and the temperature characteristics were analyzed, the results were presented in Tables 2 and 3 respectively.

Table 2. *Mean annual Temperature for the study Area (1993-2022).*

YEARS	IBI	WUKARI	DONGA	TAKUM	USSA
1993	27.27	27.62	27.47	27.72	27.24
1994	26.79	27.15	26.76	26.58	26.46
1995	27.07	27.44	27.03	26.54	26.86
1996	27.55	27.79	27.52	27.50	27.30
1997	27.82	27.48	26.95	26.70	26.36
1998	27.53	28.27	27.53	27.38	27.52
1999	27.83	27.85	27.81	27.67	27.07
2000	27.60	27.85	27.57	27.45	27.20
2001	26.72	27.80	27.76	26.49	27.61
2002	27.97	28.25	27.90	27.81	27.71
2003	27.88	28.11	27.86	27.75	27.38
2004	27.86	27.08	26.69	26.78	26.36
2005	27.41	27.82	27.57	28.05	27.46
2006	27.36	27.65	27.33	27.17	27.15
2007	27.42	27.75	27.39	27.22	27.20
2008	27.35	27.55	27.33	27.38	27.11
2009	27.15	27.53	27.11	27.23	27.13
2010	28.25	28.47	28.23	28.11	27.48
2011	28.69	29.09	28.65	28.45	28.49
2012	28.19	28.67	28.15	28.12	28.81
2013	27.95	28.31	27.92	27.74	27.43
2014	28.55	29.04	28.51	28.26	27.72
2015	28.66	29.01	28.63	28.48	27.99

YEARS	IBI	WUKARI	DONGA	TAKUM	USSA
2016	28.76	29.15	28.74	29.76	28.48
2017	29.13	29.42	29.10	28.95	28.90
2018	28.84	28.97	28.82	28.76	28.51
2019	28.11	28.42	28.08	28.33	28.74
2020	28.04	28.36	28.01	27.85	28.55
2021	28.42	28.43	28.42	28.42	28.95
2022	28.82	28.86	28.81	28.79	28.05
Mean	27.90	28.17	27.85	27.78	27.64

Source: Fieldwork (2023)

Table 3. *Mean Temperature characteristics for the periods of Study.*

Stations	Range	Min.	Max.	Mean	Std. Dev.
IBI	2.41	26.72	29.13	27.8997	.63937
WUKARI	2.34	27.08	29.42	28.1730	.64012
DONGA	2.41	26.69	29.10	27.8550	.65348
TAKUM	3.27	26.49	29.76	27.7813	.78292
USSA	2.59	26.36	28.95	27.6407	.75267

Source: Fieldwork (2023)

From the result presented in Table 3, it shows that the average values of mean temperature for the period 1993-2022 vary from 27.64 ℃ at Ussa station to 28.17 ℃ at Donga station. However, the station with the highest maximum mean temperature is Wukari. The average mean temperature range for the period of study was 2.60 ℃ with the lowest mean temperature range of 2.34 ℃ recorded at Wukari Station while the highest range was recorded at Takum (3.27 ℃). this is similar to findings in ([13, 2, 11]) The statistical values of the mean maximum and minimum temperatures reached during the period of study in the study area by stations shows that, Ibi has 29.13 ℃, as mean maximum temperature while 26.72 ℃ as mean minimum temperatures, Wukari has 29.42 as maximum temperature reached while 27.08 ℃ as the minimum temperature during the period under review. Donga station has 29.10 ℃ as the maximum mean and 26.69 ℃ as the minimum mean, Takum on the other hand has 29.76 ℃ as the maximum mean and 26.49 ℃ as the minimum. Lastly, Ussa has 28.95 ℃ as the maximum and 26.36 ℃ minimum. The results of the standard deviation of the temperatures show significant deviations from the means of all the stations.

Temperature Trends and Changes

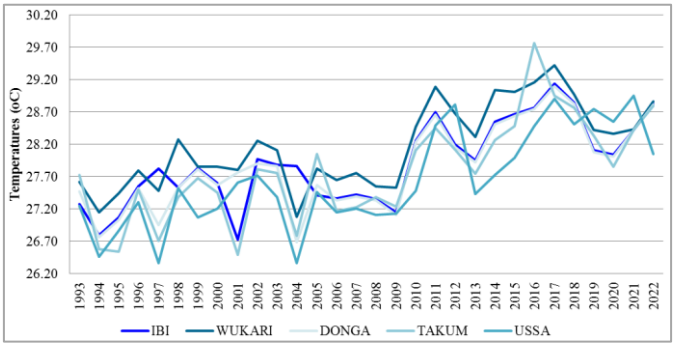


Figure 3. *Trend of Annual Temperature.*

An annual analysis was conducted to show the trend and changes over period of thirty years. The analyses of the period show that temperature in the study area fluctuates as seen in Figure 3.

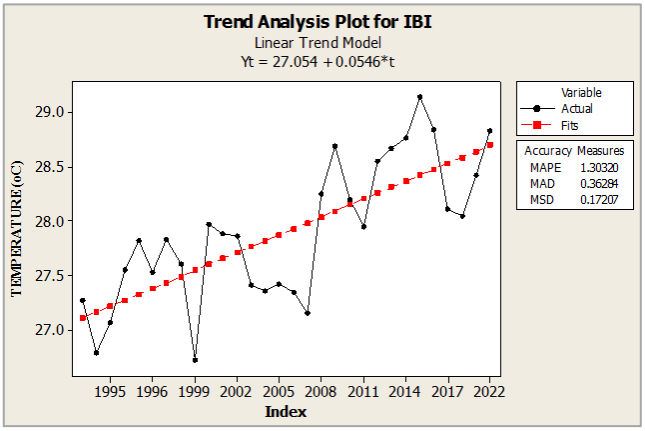
From the graph above it can be seen and that temperature rise and fall with time. The graph revealed a sharp decline in 1994, 1997, 2001 and 2004 before maintaining a steady increase. The largest increase in annual mean temperature began in the year 2016 when there was an abrupt rise in the mean temperature of the study area. The reason for the sharp rise can be attributed to global rise in temperature (Global warming) and the increased human anthropogenic activities particularly deforestation through lumbering activities commonly called (Madrid) in the area and over grazing occasioned by large influx of nomadic Fulani headers in the area which was also reported by [14]. Furthermore, linear trend analysis of temperature for the period 1993-2022 was conducted and the results were presented in Table 4 and Figure 4a-e.

Table 4. *Annual Average Temperature (℃) and Linear Tend for the Period 1993-2022.*

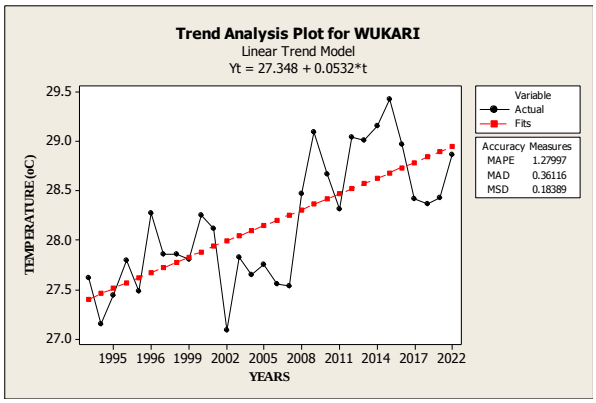
Station	1993-2002	2003-2012	2013-2022	Mean	Equation of Linear Trend Line 1993-2022	Significance of trend
Ibi	27.3 ℃	28.20 ℃	28.5 ℃	28.0 ℃	Yt = 27.054 + 0.0546*t	significant
Wukari	27.78 ℃	28.40 ℃	28.80 ℃	28.3 ℃	Yt = 27.348 + 0.0532*t	significant
Donga	27.44 ℃	27.97 ℃	28.50 ℃	28.0 ℃	Yt = 26.990 + 0.0558*t	significant
Takum	27.35 ℃	27.8 ℃	28.53 ℃	27.9 ℃	Yt = 26.766 + 0.0655*t	significant
Ussa	27.53 ℃	27.61 ℃	27.89 ℃	27.7 ℃	Yt = 26.608 + 0.0666*t	Significant

Source: Fieldwork (2023)

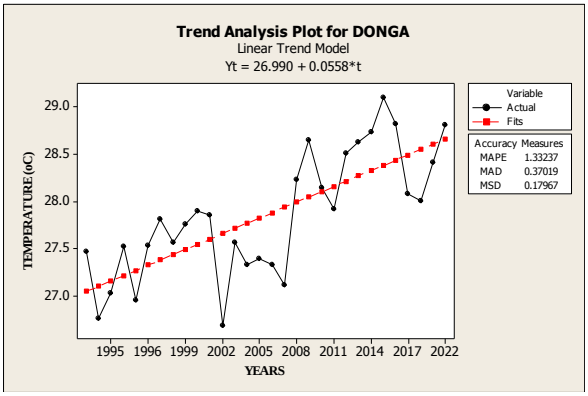
The results of the linear trend analysis show general rise in temperature over the study period in all the stations, the rise is a significant. The implication of this result is that temperature in the study area rises with time in-line with the global trend of global warming thus, the need to device means of reducing the rise in temperature to avoid reaching a threshold of thermal discomfort and unbearable temperatures and adopt mitigations and method of adapting to the rise in temperature so as to reduce the negative effects of high temperature in the area.



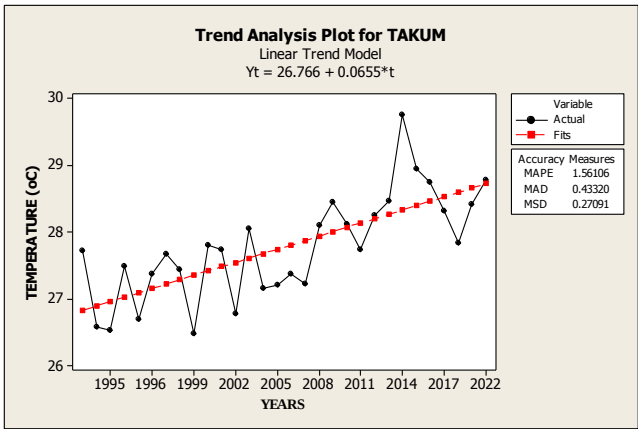
a Temperature linear trend line 1993-2022 of Ibi



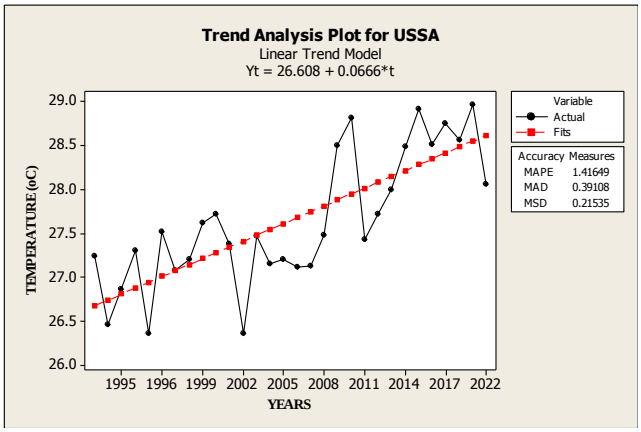
b Temperature linear trend line 1993-2022 of Wukari



c Temperature linear trend line 1993-2022 Donga



d Temperature linear trend line 1993-2022 of Takum



e Temperature linear trend line 1993-2022 of Ussa

Figure 4. *Annual Temperature and Linear trend line for the period 1993-2022.*

5. Conclusion

From the analysis of the results of this study, the following conclusions we can be drawn; that the average values of mean temperature for the period 1993-2022 vary from 27.64^{o}C at Ussa station to 28.17^{o}C at Donga station. From the linear trend analysis it can be concluded that there is general rise in temperature over the study period in all the stations the highest increase in the annual mean temperature began in the year 2016.

6. Recommendations

The research recommends a further study to cover the whole of Taraba state for better information on temperature for a sustainable agricultural planning from planting, harvest and storage. The study also recommends proper dissemination of agro-climatic information for appropriate adjustment and adaptations by farmers in the study for sustainable agricultural development.

Abbreviations

WMO	World Meteorological Organization
NIMET	Nigeria Meteorological Agency
UBRBDA	Upper Benue River Basin Development Authority
LGA	Local Government Authority
Asl	Above Sea Level
SPSS	Statistical Packages for Social Sciences

Author Contributions

Patrick Sunday Asa: Conceptualization, Formal Analysis, Methodology, Writing – review & editing

Luka Yohanna: Data curation, Investigation, Project administration, Resources

Conflicts of Interest

The authors declare no conflicts of interest.

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