Social Science, Humanities and Sustainability Research
ISSN 2690-3628 (Print) ISSN 2690-3636 (Online)
Vol. 1, No. 1, 2020
www.scholink.org/ojs/index.php/sshsr

Original Paper

Trend Analysis of Maximum and Minimum Temperature over Ebonyi State, Nigeria

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Received: February 29, 2020 Accepted: March 21, 2020 Online Published: March 27, 2020

doi:10.22158/sshsr.v1n1p36 URL: http://dx.doi.org/10.22158/sshsr.v1n1p36

Abstract

This study examined the trend in annual maximum and minimum temperature data in Ebonyi State using data collected from the Nigerian Meteorological Agency of Nigeria. The aim is to reveal the spatial and temporal variation in maximum and minimum temperature from 1984-2015. The study made use of statistical tool like linear regression to depict the trend in annual maximum and minimum temperature over time. Results indicate that maximum temperature possesses steepness in slope of 0.0046℃ and minimum temperature 0.002℃. The maximum temperature equation shows a positive time trend which suggests that maximum temperature of Ebonyi State of Nigeria tends to increase over time. Decadal analysis of the climate variable revealed that the 1994-2003 decade has the highest maximum temperature followed by 2004-2015 decade and then 1984-1993. This shows that the 1984-1993 decade was cooler than the later decade which is a pointer to the increasing temperature being experienced in form of global warming with its attendant environmental consequences. The study therefore recommends that proactive measure like making accurate and appropriate weather and climate data available for planning should be encouraged by all to mitigate these consequences especially on population whose livelihood depends on agriculture that is temperature sensitive.

Keywords

trend, maximum temperature, minimum temperature, analysis, ebonyi

1. Introduction

Climate change has become one of the defining issues of recent times. Climate change has resulted to changes in long term weather conditions on both local and global scale. The climate of the world is changing at an alarming rate, and so far nothing suggests that this will not continue to happen continuously (Ahrens, 2006). This change in climate is an indication of a significantly high fluctuation in mean condition of climate or its variability with continuous trend for decades or more (Vijayavenkata, Raman, Iniyan & Goic, 2011). The impacts of this change in climate is already experienced the world over such as melting of ice cap and even changes in weather patterns (IPCC, 2007). All these events have provided strong evidence of rapid change in climate of the world. As a result of this change in climate, there has been increase in global temperature resulting in warming of the earth. This warming which has occurred largely since the 1970s is due to increase in industrial activities all over the world. Also, in recent decades there has been a diminishing arctic sea ice; both in sizes and in depths. In the past 100 years, global sea levels have increased to about17cm. This magnitude of increase in the past decade is almost twice compared to the century before now (IPCC, 2007). Based on available evidence, it is now more certain than ever, that humans are changing Earth's climate due to several activities embarked upon by man in the search to satisfy its needs (Diagi, 2017). This change has resulted in the warming of the atmosphere and ocean, accompanied by sea-level rise, a strong decline in Arctic sea ice and other climate related changes. One of the most significant evidence available of man-induced changes in climate is the continual rise in carbon dioxide (CO_2) as measured at the Mauna Loa Observatory in Hawaii, where the observation of CO_2 has been going on since 1958. In December 2008, the concentration of CO_2 in earth's atmosphere was about 386 parts per million (ppm), with a steady new increase rate of about 2 ppm per year. However, of recent the atmospheric concentration of CO_2 is about 30% higher than what it was about 150 years ago before the industrialization period. In other words, the level of CO_2 present in the atmosphere is more than they have been in the last 400 millennia. This situation has become many topics of debate both at national, regional and world level. Nearly a quarter of the emission of carbon dioxide that comes from man's activities is absorbed by land areas; another quarter is absorbed by the ocean.

However, one way to understand these changes in climate is to carry out a study on global warming which is the main cause of these changes. Temperature is not a static phenomenon as has been observed over time. On a global scale, the surface temperature of the earth has increased by 0.74 ± 0.18^{o}C during the last 100 years ending in 2005 (IPCC, 2007); although this figure has been discovered to vary from one place to another depending on how its manifest in a particular place. Numerous studies have shown that there has been a steady increase in temperature across Nigeria. Audu et al. (2004) observed that there is a general rise in mean minimum temperature of 3℃ per decade based on 40 years data from Nigeria. Bello (2010) observed temperature increases of about 0.2℃-0.3℃per decade at various locations in the rainforest of Nigeria. Adakayi (2009) also asserted that there is a general rise in annual minimum temperature in Katsina from 1971-2006. Several other studies conducted on regional basis

have also found a positive trend in temperature, even though the changes slightly vary from region to region (Karaburun et al., 2012; Karaburun et al., 2011; Abudaya, 2013; Ustaoglu, 2012). To be able to measure the degree of warming arising from these changes in climate, changes in global temperature has to be studied which is a fundamental factor according to Ikenna et al. (2017). Amadi et al. (2014) asserted that one of the most commonly used parameters that indicate climate change is temperature. Temperature is a climatic variable that informs us the degree of hotness or coldness of a place.

Therefore, in order to ascertain the impact of climate change over Ebonyi, the study of changes in the degree of hotness or coldness of the state is necessary. Audu (2012) also pointed out that one of the climatic variables mostly affected by global warming, climate change and variability is temperature. Notable researches carried out to investigate changes in temperature include that of Mohiuddin et al., (2014) who understudied the pattern of change of temperature of Dhaka, in this study maximum temperature was observed to be having a decreasing trend. Also, Jain and Kumar (2012) on investigation of Indian cities discovered that most cities had rising trends although there were records of cities with falling trends in the maximum temperature. Other studies include Amadi et al. (2014); Ogolo and Adeyemi (2009) and Jackson et al. (2012).

This study has become necessary bearing in mind the importance that temperature changes plays in almost every aspects of man's life ranging from energy supply, water supply, flood and drought, thermal comfort, work output and especially agriculture, through rainfall (Arora et al., 2005). Ebonyi State being an agricultural state is a very important state in Nigeria in terms of food production and since temperature variation plays a crucial role in crop productivity it is therefore necessary to undertake a study to ascertain its impact in the state especially because farming in this State is majorly based on rain-fed agriculture which can be impacted upon by these changes in temperature.

2. Method

The study area Ebonyi State, displayed as Figure 1, is located in South-Eastern part of Nigeria which lies approximately within latitudes 5° 40' and 6° 45' North and longitudes 7°30' and 8°30' East (Figure 2). The mean temperature range within the study area is usually between 27 ° to 30^0C over the year (Ogbuene, 2010). Temperature is highest from February to April and it is about 31^0C (Ogbodo, 2013). The prevalent climatic condition in the area is noted for having two main regimes of rainy and the dry seasons. The rainy season is from April to October, while the dry season begins from October through February. Although with climate change, there exists variation in values in the months presently. The major industry in Ebonyi State is agriculture, as an estimated 8 to 5 people derive their source of living from agriculture activity (Ogbodo, 2013).

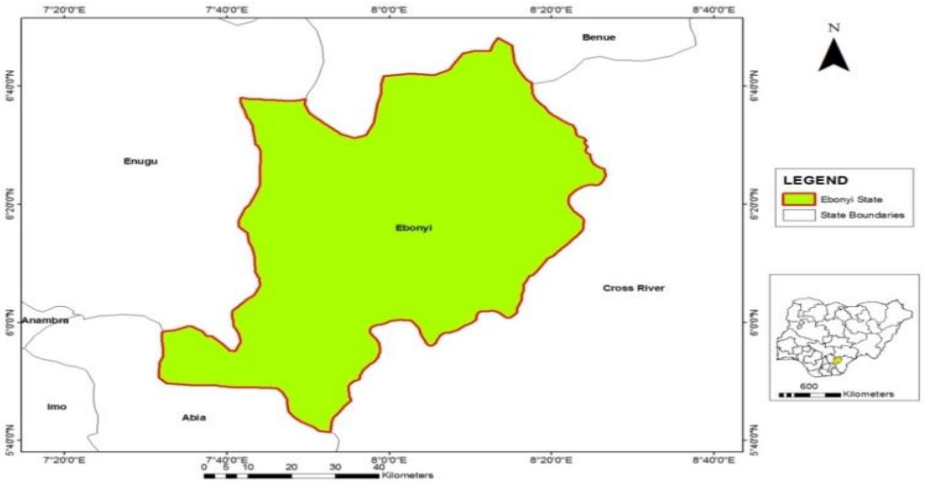

Figure 1. Map of Ebonyi State, Southeastern Nigeria

Monthly average minimum and maximum temperature covering a period of 31 years were used for this study. The temperature data is changed to average monthly temperature before transforming to yearly temperature for the 31 years period (1984-2015). The least squares regression is used in the study to model the trends in temperature data over the 31 years period. The result helps to determine the overall average rates of change in trends of annual temperature in the study area. Trend analysis is a tool used to fit a general trend model to time series data and provide forecast. The trend analysis for a time series data can take different forms such as linear quadratic or cubic but in this analysis linear trend model was used. In this case, a standard regression model is used to describe the relation between temperature and time. The keyword "Trends", in this study is a term that is commonly used in climatic studies to describe a general increase or decrease in climatic phenomena over time.

However, in order to determine the degree of significance of the observed trend, the coefficient of correlation R^2 was used to test for significance. The correlation coefficient is a statistical measure that calculates the strength of the relationship between the relative movements of two variables. R-square shows how much of the change in the dependent variable can be explained by the independent variable. The values range between -1.0 and 1.0 therefore, any variable with R^2 less than 0.5 shows that the trend is statistically not significant but if the value of R^2 is greater than or equal to 0.5, the trend could be said to be statistically significant.

The equation for least square regression is as follows:

$$y = a + bx \quad (1)$$

Where

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x)^2} \quad (2)$$

And

$$a = \frac{\sum y}{n} - \frac{b\sum x}{n} = \bar{y} - b\bar{x} \quad (3)$$

Thus, a is the intercept; b is the regression coefficient or slope; y is the temperature values (dependent variable); x is the time in years (independent variable); $\bar{x}$ is the mean time; and $\bar{y}$ is the mean temperature value.

3. Result

In Figure 2, it shows the average annual maximum and minimum temperature variation over the 31 years period (1984-2015). Thus, maximum temperature was observed to be very high in 1987, 1998, 2003 and 2010. The lowest maximum temperature occurred in the year 1985 while the highest maximum temperature was in 1987. The highest minimum temperature was recorded in the year 2010, while the lowest minimum temperature was in 2012. This shows that the warmest year was 1987 while the coolest year was 2012. In Figure 3, it shows the variability in maximum temperature for the three decade. Figure 3 revealed that the 1994-2003 decade recorded the highest maximum temperature followed by 2004-2015 decade and then 1984-1993. This shows that the 1984-1993 decade was cooler than the other decade which is a pointer to the increasing temperature being experienced in the study area with its attendant environmental consequences. In Figure 4, average annual maximum temperature shows a decline up to 2000, and increased suddenly in 2003 showing some fluctuation. Figure 4 depicts the trend of average annual maximum temperature for the study period.

Generally, there is an upward trend 0.004℃ with a tendency for further increase over time. Although the R_2 value of 0.013 is very low as it signifies a very weak statistical significance in trend but it still shows evidence of an increase. Figure 5 also revealed that the trend for the 1984-1993 decade shows a downward trend in average maximum temperature at a rate of 0.021℃ per annual. Figure 6 shows decade of a positive increasing trend of maximum temperature over time at the rate of 0.065℃ with a coefficient of determination of 0.254. Figure 7 revealed that maximum temperature from 2004-2015 over the study area has a positive trend increasing at the rate of 0.031℃ per year.

This is in line with other studies carried out in Nigeria by Olofintoye and Sule (2010) who found significant increasing trend in minimum and maximum temperature in Owerri between 1983 and 2008 which indicate a change in climate. Figure 8 indicates that there is a stable rise in annual minimum temperature.

Therefore, the general trend with respect to time can be established. However, we will get a clearer view of these changes when we compare these figures with maximum temperature which gives a picture of a higher increase (0.0046℃) than minimum temperature with a trend of 0.0029℃. Figure 9 revealed that the decade 2004-2015 recorded the highest maximum temperature followed by 2004-2015 decade and then 1984-1993. This shows that the 1984-1993 decade was cooler than the other decade which is a pointer to the increasing temperature being experienced in the study area with its attendant environmental consequences. Figure 10 indicates a negative decreasing trend in the 1984-1993 decade

in minimum temperature at the rate of -0.2℃ with a coefficient of determination of 0.025. Figure 11 depicts the variability in minimum temperature for the decade 1994-2003 indicating a positive trend in the decade 1994-2003 with R2 of 0.225. Figure 12 shows a decreasing trend in minimum temperature of -0.007℃ per annual and a weak coefficient of determination of 0.001 while within the same decade maximum temperature experienced a positive trend increasing by 0.031℃ per year with a coefficient of determination of 0.114.

The study revealed that the greatest warming was observed in the decade between 1994 and 2003. This study agrees with the studies of Amadi, Udo and Ewona (2014) and Abiodun et al. (2011) on the rising trend in temperature over southeast Nigeria. However, the study revealed that minimum temperature increased more than maximum temperature which is in conformity with the findings of Amadi, Udo and Ewona (2014) who noted that minimum temperature in southeast Nigeria has a higher trend coefficient than the maximum temperature.

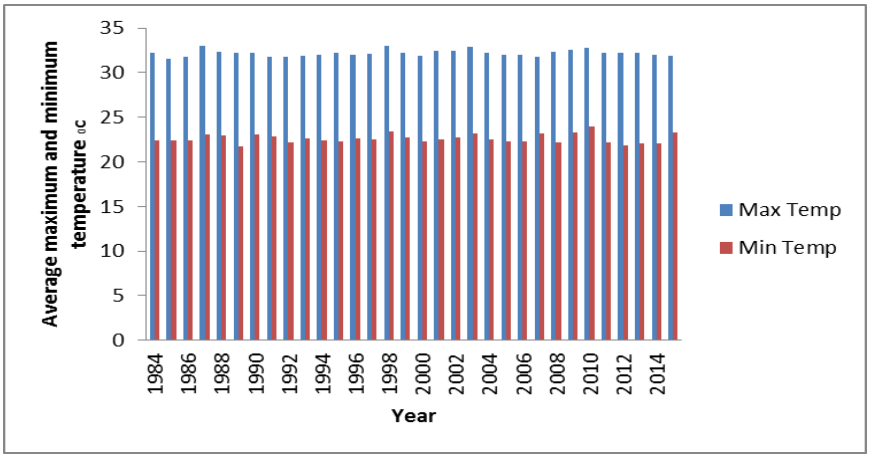

Figure 2. Average Annual Maximum and Minimum Temperature from 1984-2015

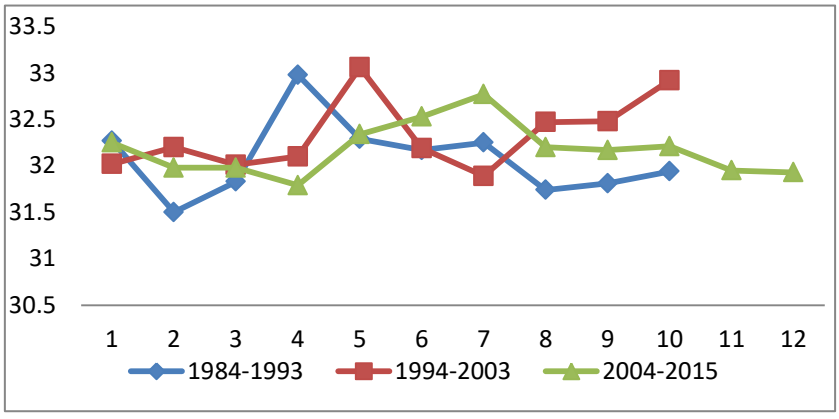

Figure 3. Variability of Maximum Temperature for the Three Decade 1984-1993, 1994-2003 and 2004-2015

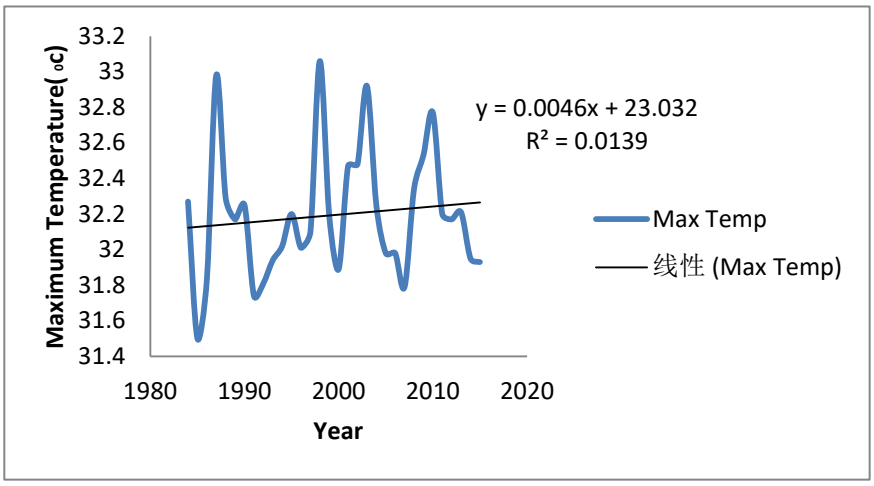

Figure 4. Trend in Average Maximum Temperature 1984-2015

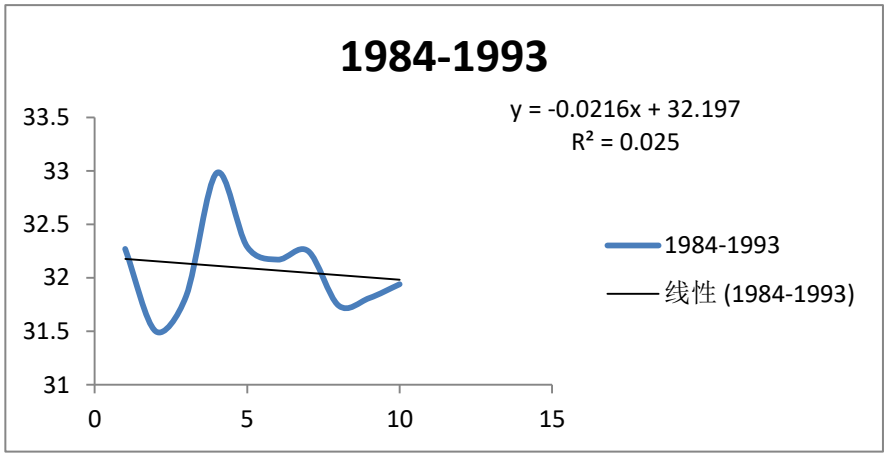

Figure 5. Trend in Average Maximum Temperature for the 1984-1993 Decade

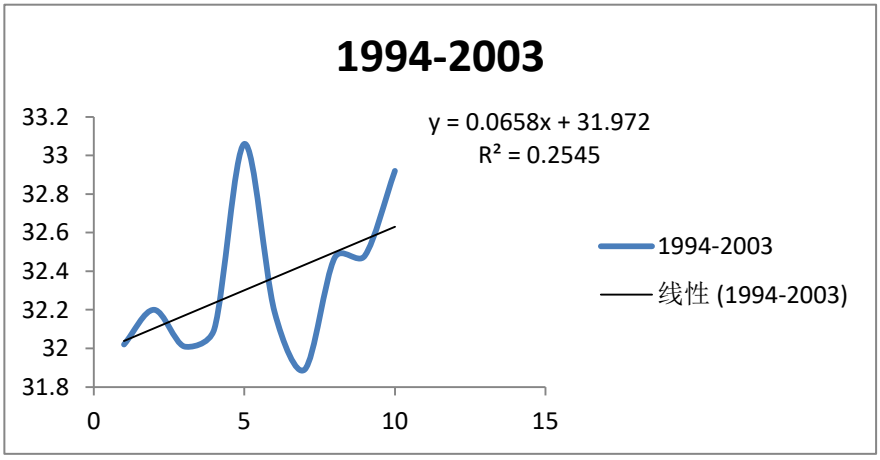

Figure 6. Trend in Average Maximum Temperature for the 1994-2003 Decade

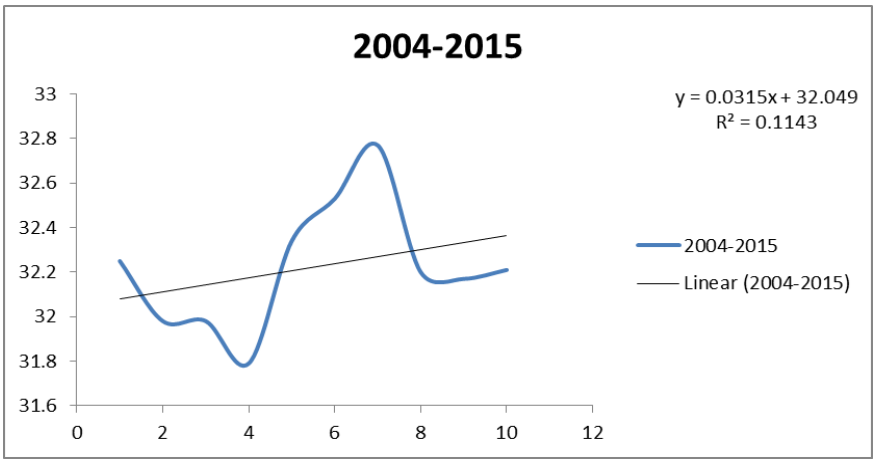

Figure 7. Trend in Average Maximum Temperature for the 2004-2015 Decade

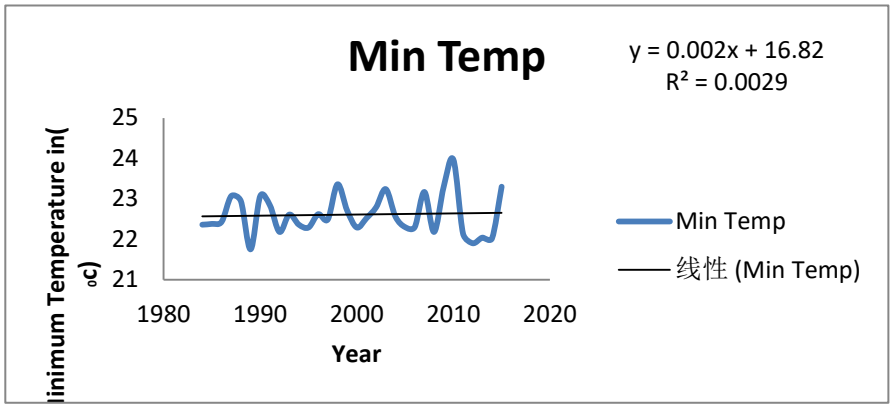

Figure 8. Trend in the Average Minimum Temperature from 1984 to 2015

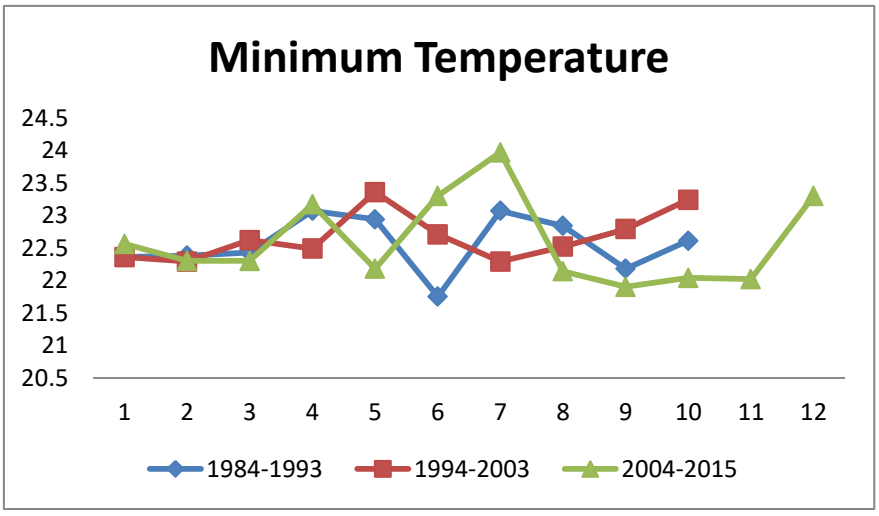

Figure 9. Decadal Variability of Minimum Temperature

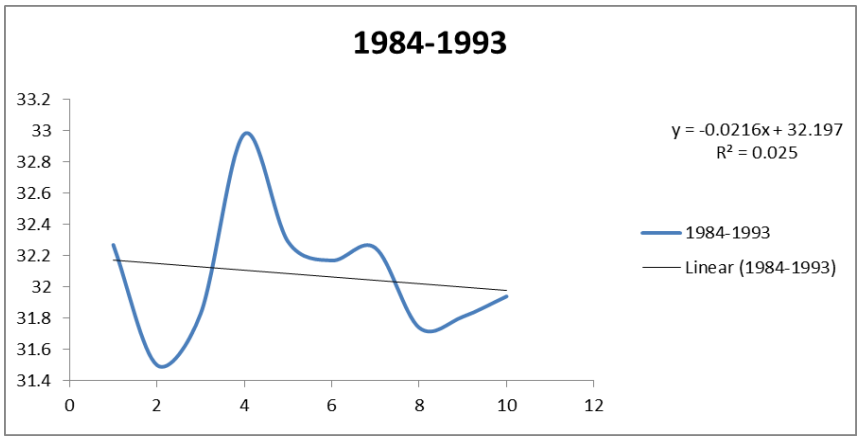

Figure 10. Trend in Minimum Temperature 1984-1993 Decade

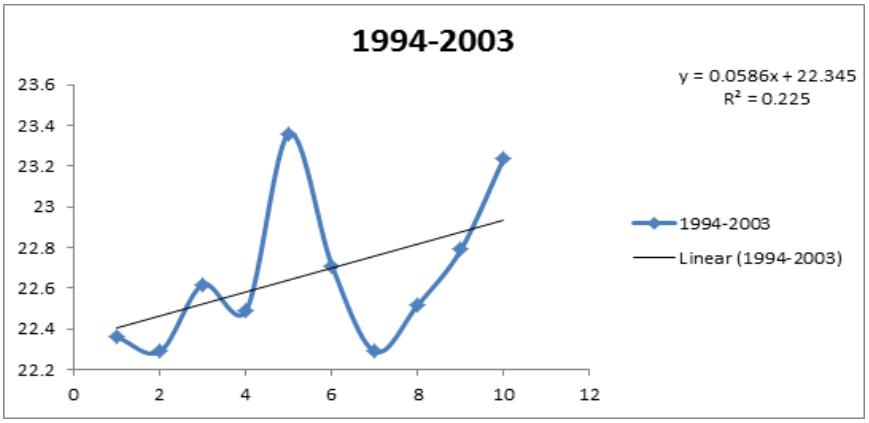

Figure 11. Trend in Minimum Temperature 1994-2003 Decade

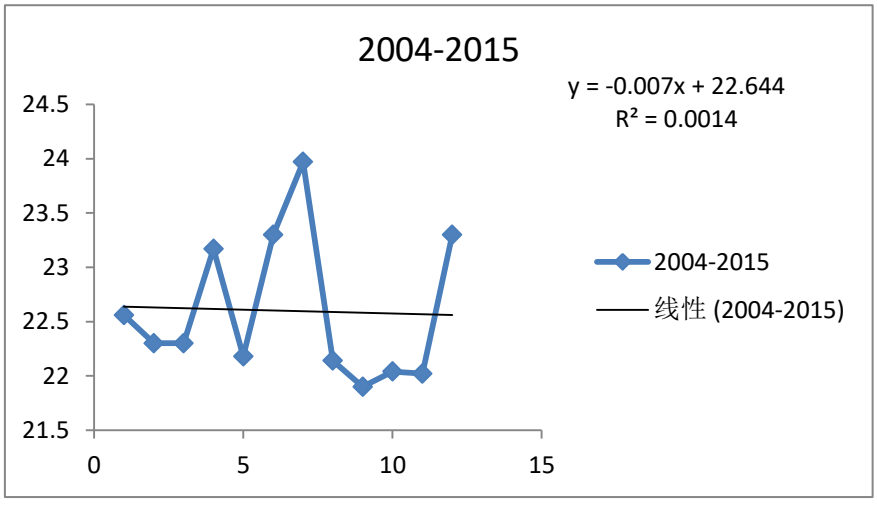

Figure 12. Trend in Minimum Temperature 2004-2015 Decade

4. Discussion

This study examined the trend and variability in annual maximum and minimum temperature over Ebonyi State, Nigeria for the period 1984-2015. Maximum temperature possesses steepness in slope of 0.0046℃ and minimum temperature 0.002℃. The maximum temperature equation shows a positive time trend which suggests that maximum temperature of Ebonyi State of Nigeria tends to increase over time. From the Figures, maximum, minimum, temperature maintained a positive slope with a coefficient of determination that shows considerable explanatory power, although the result did not show evidence of overall significance. Generally, it has been observed that Ebonyi State is experiencing an increase in surface temperature with the implication that the State is prone to global warming with its attendant consequences. Therefore, proactive measure should be applied by all to mitigate these consequences especially with regard to the population whose livelihood depend on economic activity that are affected by high temperature. This study therefore recommends that precise and appropriate weather and climate data should be made readily available for planning in the agricultural sector and water resources that their activities are temperature sensitive.

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