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Regression Analysis of the Climatic Variables over Greater Yola, Adamawa State Northeastern Nigeria

[1]I.M. Abubakar, [2]I. Mohammed, [2]A.C. Abdullahi, [3]S.M. Ade and [4]B.Y. Idi
[1]*Department of Agricultural Education, Federal College of Education Yola, Adamawa State Nigeria*
[2]*Department of Environmental Management Abubakar Tabawa Balewa University, Bauchi, Bauchi State, Nigeria*
[3]*Department of Survey and Geoinformatics Abubakar Tabawa Balewa University, Bauchi, State, Nigeria*
[4]*Department of Physics, Federal University Dutse, Jigawa State, Nigeria*

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Abstract: Climate change has the tendency of negatively affecting the socioeconomic development of a society at both community and national level. The change climate which is manifested as the temporal variability in the climatic elements, varies spatially with location. In this work, attempt is made to analyse the magnitude and direction of the changes of the various climatic elements of greater Yola, Adamawa State Nigeria over a three decade time series. The works involves linear regression analysis of the temporal variability of the mean annual minimum, maximum and meanannual temperatures, mean annual rainfall, mean annual sunshine, mean annual humidity and the mean annual evaporation. The results indicate positive trends for all the variables except for the sunshine and evaporation data which showed negative trends. The model regression equations derived were tested at 0.05 level of significance and the results showed that a p-value of 0.201 (>0.05) for annual mean maximum temperature, 0.000 (<0.05) mean annual minimum temperature, 0.000 (>0.05) for the mean annual maximum temperature, 0.672 (>0.05) mean annual rainfall, 0.7768 (> 0,.5) for the mean annual sunshine hours, 0.129 (>0.05) for the mean annual relative humidity and 0.263 (>0.05) for the mean annual evaporation. Hence, only the mean annual minimum and maximum temperatures are predictable using their respective model equations. The work however showed evidence of local eratic and irregular climate variability relative to global warming.

Corresponding Author:
B.Y. Idi
Department of Physics, Federal University Dutse, Jigawa State, Nigeria

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INTRODUCTION

Climate change is among the toughest challenges facing the entire planet today. The impacts have already been observed all over the globe. It is apparent that, the climate in Africa is already exhibiting significant changes and the incontrovertible evidence of climate change can no longer be ignored[1]. Changes of the natural atmospheric greenhouse are predicted with certain effects and consequences of increase in earth temperature, warmer conditions of the earth leading to more evaporation and precipitation. It is now visible that increasing concentrations of some gases in the atmosphere as a result of human activity over the past hundreds of years are leading to warming of the atmosphere.

The prevailing global concern is focused on climate change that resulted from anthropogenic activities, specifically from the release of carbon dioxide and other greenhouse gases into the atmosphere. These include the burning of fossil fuels, clearing of forests and other human activities that are major sources of greenhouse gas emission. Evidence of climate variability and climate change in various countries include increasing surface air temperature, increasing heat waves which enhance disease vectors, communicable diseases epidemics, sea level rise and associated coastal erosion, flooding, salt water intrusion and mangrove degradation, diminishing food security, pollution of freshwater and acceleration of the extinction of animal and plant species[2]. It also influences increase in evaporation, leading to drying up of streams and river, loss of forest vegetation which promotes soil degradation and desertification as well as changes in seasonal patterns of climatic variables which reduced agricultural productivity[3].

The rising global temperatures has led to many other changes including but not limited to, a rise in atmospheric water vapor, losses of forests and changes in vegetation composition, increase acidification of the oceans, flooding, an increase in extreme weather events and changing ecosystem that will greatly alter biodiversity. Virtually all the states in Nigeria are now experiencing warmer conditions compared to the period thirty five years ago and occurrences of floods. In Adamawa State, empirical evidence of climate change showed delayed onset date of rains, increase in number of dry days during the rainy season and increase in maximum temperature. The communities and people that live in the fragile environments such as dry lands and coastal areas are prone to effects of climate change. Climate change will automatically influence risk of crop producers, livestock keepers, fishers and forest dependent people, particularly in regions that already suffered from soil and water scarcity, high exposure to climatic extremes including floods, droughts, poverty and hunger[4].

Human actions have been a primary responsible for climate change observed today. It might interact negatively to cause desertification and other problems. Population growth for instance in unproductive areas which leads to draining of natural resources for the sake of trading, grazing and horizontal expansion of the population has been at the expense of cultivable areas along with other erosions factors. Climate change is one of the greatest threats encountered by man. Extremes weather and climate events illustrated and experienced across Africa and Nigeria particularly, drought and floods which has significant impact on natural resources, economic sector, ecosystem, livelihood and human health. Adamawa State has many growing urban areas that had its fair share of the growth of these phenomena. As a result of that, there is an increase in population and the attendant infrastructural demand to meet the housing need of the increasing population and other socio-economic and cultural needs of its citizens. This has influenced changes in the land use pattern, in respect of residential, commercial and agricultural practices especially the pastoral system. The changing pattern of rainfall and the increasing temperature combined with low moisture content of the soil and high vapour transpiration as a result of high temperature led to the evolution of deciduous vegetation cover. Thus, the vegetation cover no longer withstands the long dry season with the cutting down of trees and bush burning commencing earlier than known[5].

Livestock husbandry in the study area is predominantly practiced primitively in natural nomadic manner without artificial grassland field. Thus, production of livestock largely depends on the natural grass and water condition thereby over-stretching the vegetation cover[6, 7]. Human activities such as the irrigated agriculture combined with population increase in the region are also factors affecting the vegetation cover[8]. Consequently, greater percentage of the livestock population in the region are migrating to the southern parts of the state like Toungo, Ganye, Jada and neighbouring countries of Cameroun, Central Africa, Chad and Gabon, etc., in search of good postural ground for their livestock. These developments have negatively affected the country's animal protein production rate, foreign exchange earnings, row materials to small scale and large industries and the country's GDP. Studies on the trends and analysis of the driving factors affecting the vegetation cover as a carbon sink is therefore a move towards realizing the goal of Article 2 of the UN Framework Convention on Climate Change meant to avoid dangerous anthropogenic damage to the climate system[9]. It is in realization of this fact that Hassan *et al*.[10] studied the trends of rainfall and temperature over the entire north-eastern Nigeria. The results indicate significant variability of both positive and negative trends across the entire region depending on the time frame and spatial extent. In a similar work, Bibi *et al*.[11] studied the spatio-temporal variation of rainfall in the North-Eastern Nigeria by analyzing 27 year (1980-2006) gridded daily rainfall data using linear regression slopes. Their results indicate temporal variation in agreement between the regression model and the

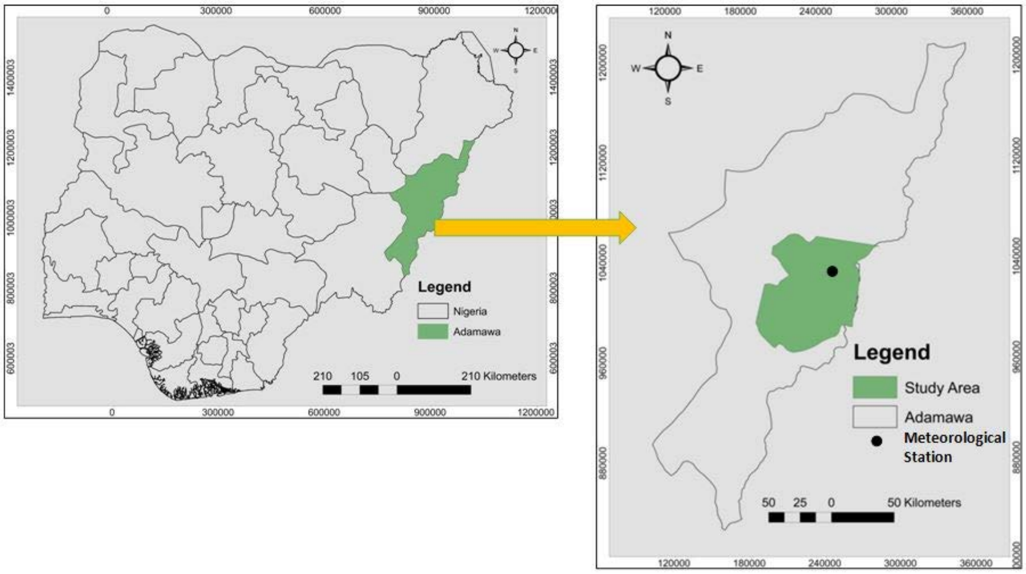

Fig. 1: Map of Nigeria shown Adamawa State and the study area. Location of the meteorological station is indicated with black dot

observed data in which insignificant agreement between the two during wet season were recorded between May to October.

In this work, we scale down the spatial extent of the area by narrowing the scope to cover Yola and its environs (greater Yola) for detail and précised analysis. The weather condition of the area is covered and recorded by a reliable meteorological station of the Upper Benue River Basing Development Authority. The work is aimed at analyzing the time-series trends of Climatic elements in the forover three decades (1988-2017). The work involves time-series analysis of the magnitude of the climatic variables with the aim of observing the magnitudes of the rate at which climate of the area change over time. Linear regression analysis was used to observed the fitting and trends of the regression model curve with the observed data. The overall goal of the work is to assess the significance of climate change relative to the study area and develop a model for extrapolating the climatic elements. The work involves acquisition and regression analysis of climate data for the period between 1988 to 2017. The climatic data which includes maximum and minimum mean temperatures, rainfall, sunshine hours and relative humidity were obtained for the study period from the meteorological station.

The study area: The study area is located at the central area of Adamawa state, North Eastern part of Nigeria. It lies between latitude 9º20'00"N of the equator and between longitude 12º30'00"E of the Greenwich meridian. Adamawa State shares political boundaries with Taraba State in the South and West Gombe, in the North West and Borno to the North. Adamawa State has an international boundary with the Cameroon Republic along its eastern border (Fig. 1). The State covers a land area of about 38,741km with a population of about 3,176,950. Adamawa State is divided into 21 local government areas.

Topographically, Adamawa State is a mountainous land crossed by large river valleys, The Benue, Gongola and Yedsarem. The valleys of the Cameroon, Mandara and Adamawa mountains form parts of the landscape. In line with the vegetation zones of the Sub-Sudan and Northern Guinea Savannah, the major occupations of the people in the study area are arable farming, Fishing and livestock rearing. The Village Communities that lives on the bank of the River engage in fishing while the Fulanis are cattle rearers. The >1000 fishermen in the study area live around the shores of the River. As a result of environmental changes since the 1980s including fluctuations in the Water level, there have been considerable changes in the fish fauna. These include high mortality, the disappearance of some open water species and the appearance of species adapted to swamp conditions in areas where they were previously unknown. Increased economic activities associated with increase in population and human mobility has resulted in over-fishing, over-grazing, poor farming practices and deforestation in the River Benue valley. This also leads to increase in the demand for fresh drinking water which is mainly extracted from ground water.

The climatic condition of the study area is conducive for agricultural practices. The mean sunshine hours in the area is adequate throughout the year to provide the drying power of the air required by the field crops and vegetation. The rate of evaporation is generally high in the area due to high insulation. The air temperature of the area is typical of West African Savannah climate. The maximum temperature can reach up to 40°C around April and minimum can be as low as 18°C in December and January. The mean temperature of the entire Adamawa State ranges from 26.7°C in Southern part to 27.8°C in the North-Eastern part of the state[12]. The sunshine hours or period has seasonal variation in number of hours from April. It tends to increase around October and December. The mean hour is 207 and increase to 255, respectively. The relative humidity in Adamawa State is extremely low to about 20-30%. It increases gradually to 80% and reaches its peak from April through to September. Because of the influence on maritime air mass which cover the whole state during this period it reduces from October following the cessation of rains. The rainfall in Adamawa State starts in April with scanty rains with 10-80 mm from North to Southern part of the state. The state experiences a strong and devastating wind storm that accompanies scanty rains. The months of May-September constitute the wet season in the state with a record above 60mm of rains and increases steadily from May-June all over the state. In August, the rainfall amount range from 180 mm in the Northern part to 250 mm in the Southern part of the state. In September, the rainfall is relatively high in Southern part with 350 mm and low amount of 150 mm in the Northern part could be experienced[12].

Adamawa State has Sub-Sudan Savanna vegetation and Guinea savannah vegetation, the northern part of Adamawa State has the sub Sudan vegetation zone marked by short grasses interspersed short trees, while in its Southern part, the northern Guinea Savannah vegetation exists. The Guinea Savannah vegetation type is a bye product of centuries of tree devastation due to human activity and fire incidences and the continuous attempts by the plants to adapt themselves to the climatic environment. The true vegetation of the area has for years been modified by human activities and hence, traces of the climatic climax are difficult to come by Adebayo and Tukur[2]. The evolution of Agriculture from bush fallowing to mixed farming near settlements is paralleled by massive changes in the structure and composition of the vegetation. At each successive clearing, unwanted trees are cut to near ground level but those valued for their oil, edible green leaf, fiber and fruit or merely for shade, are carefully preserved. Among the preserved species are *Butyrospermum paradoxum* (shea butter or oil), *Parkiabighibosa*, *Tamarindus indica* and *Vitax doniana* (all valued for their edible fruit) *Adansonia digitata* (a multipurpose producer of edible green leaf, fibre and edible fruit). The study area, being the corridor of the River Benue (the flood plain) is largely dominated by an extension of grassland and few scattered trees which are mainly used as rangelands. The gallery that existed which is mainly a woody vegetation has been cleared by intensive human activities going on within the flood plain. It is replaced by grasses which increasingly attracts large stock of livestock thereby causing overgrazing in the area[13].

MATERIALS AND METHODS

This study involves time-series multi temporal analysis of climatic elements recorded with respect to the study area. Descriptive statistics of the climatic variables were conducted leading to the annual mean values of all the variables used as dependant variable in the regression analysis. The climatic data were obtained from the meteorological station of the Upper Benue River Basin Development Authority located at Yola (Fig. 1). The 30 year time series data of the meanannual maximum and minimum and mean annual temperatures, mean annual rainfall, mean annual sunshine hours, mean annual relative humidity and mean annual evaporation were obtained from the station. Standard deviation was used to check the validity of the data obtained. Missing data were completed using interpolation techniques from close (difference of 5 years) as described by Turkes *et al*.[14] modified and adopted by Elodoyin[15].

Linear Regression statistical model was used to fit the observed data into a trendline linear for each of the variable covering the entire study period. The modelling is based on the Ordinary Least-Square (OLS) regression which is useful in testing the relationship between variables over time. The time is considered as independent variable (x) while the climatic elements are dependent variable (Y). OLS trends were qualified by the slope of the regression line and significance was tested at 0.05, significant level (α) on the bases of null hypothesis. The OLS model is illustrated by the equation

$$Y = \alpha + \beta X + \varepsilon \tag{1}$$

Where:

- Y = The dependent variable (NDVI, rainfall, temperature etc.)
- X = The independent variable (time)
- α = The is the intercept
- β = The slope coefficient for independent variable (relationship between X & Y variables)
- ε = The random error

Trends of climatic elements from 1988-2017 were analyzed using excel software. Missing climatic data were completed using interpolation techniques and data cleaning processes. The significant difference of each climatic element was analyzed using SPSS software. Regression analysis was also used to develop a model for the prediction and extrapolation of the climatic elements values.

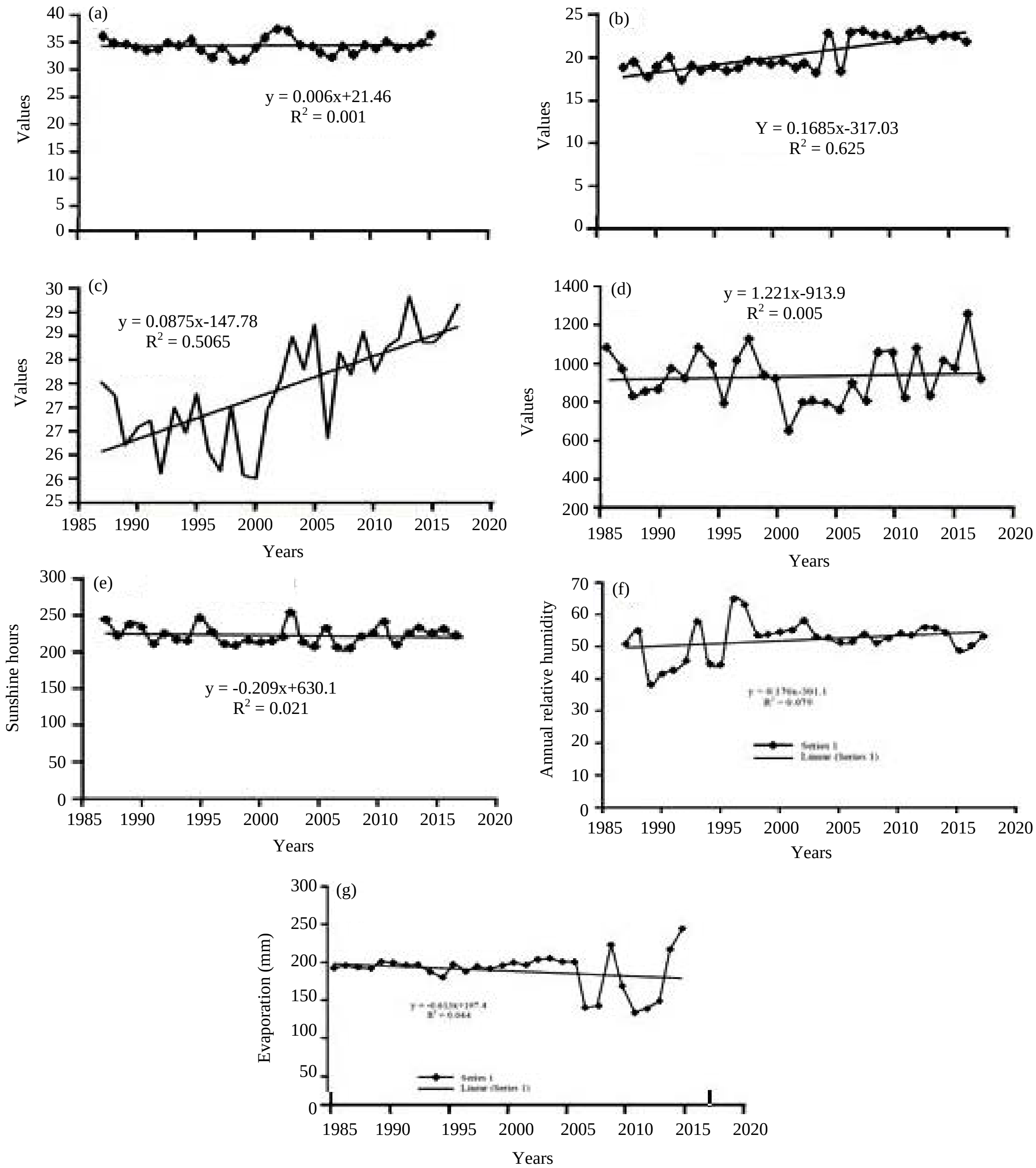

Fig. 2(a-g): Plots of the records of the climatic elements for the study area over time in years, (a) Mean annual maximum temperature, (b) Mean annual minimum temperature, (c) Mean annual temperature, (d) Mean annual rainfall, (e) Mean annual sunshine hours, (f) Mean annual relative humidity and (g) Mean annual evaporation

RESULTS

The results of the trends of the climatic elements considered in this study mostly indicates positive trend with time except for the annual sunshine hours and evaporation which exhibit negative trends. Figure 2a-g are the plots of the annual maximum, minimum and mean temperatures, rainfall, sunshine hours, relative humidity and evaporations as recorded from the station.

The annual mean maximum temperature of Yola for the period of the study shown in Fig. 2a indicates a slight temporal variation with peak of 37°C in 2004 and 2005. The lowest value of 30°C was in 1998 and 2009. The trend indicated increase with a positive slope value of 0.0064/year while the value of fitting coefficient is R^2 = 0.0017. This is an indication of relatively low linear fitting but generally slight increment with time. The p-value of 0.201 (>0.05). This indicates the acceptance of the null hypothesis. Hence, it could be concluded that the linear model cannotbe accurately used to predict the temporal changes in the maximum ambient temperature within the study area. The mean annual minimum for the study period is depicted in Fig. 2b. The figure indicates that the mean annual minimum temperature of Yola has the highest temperature value of 23°C in 2007 and a decrease to the lowest value of 17°C in 1993. The trend showed an increase with slope value of 0.165/year with a linear fitting coefficient R^2 = 0.625 and the p-value of 0.000. The p<0.05 indicates rejection of the null hypothesis. Hence there is a significant association of linear regression model with the observed data.

Figure 2c is the plot of the mean annual maximum and minimum temperature of Yola from 1988-2017. The trend showed highest variation in temperature value of 29.1°C in 2017 and a minimum value of 25.5°C in 2000. The mean annual maximum and minimum temperature indicated a high significant increase with a value of fitting coefficient of determination of R^2 = 0.506. With a p-value of 0.000 (<0.05), the null hypothesis is here also rejected. Hence the data also agreed with the linear model despite high residual values.

The average annual rainfall recorded in Yola from 1988-2017 is depicted in Fig. 2d. The plot indicates highest rainfall distribution of 1280 mm in 2016 and lowest of 640 mm in 2002. The trend of annual average rainfall changes over time showed a slope value of 1.221/year and fitting coefficient value of R^2 = 0.006. The p = 0.672 (>0.05) indicates that the null hypothesis is accepted. Hence, there is no significant relationship between the regression model and the observed data.

The average sunshine hours on the other hand, exhibits negative trend as depicted in Fig. 2e. The data indicates increase in sunshine hours to a maximum value of 251 h in 2004 and a decrease to a minimum value of 200 h in 2009. The Trend of changes in the annual average sunshine hours over the period of time indicate a significant decrease in the slope with the negative value of -0.2094/year and fitting coefficient of R^2 = 0.021. The p = 0.768 (>0.05) indicates acceptance of the null hypothesis which indicate that there is no significant relationship between the model and the observed data. Hence the model cannot accurately be used to predict the data. Figure 2f shows the plot of the observed annual average relative humidity of Yola from 1988-2017. The resultsindicate that the highest relative humidity value of 65 mm is recorded in 1997 and lowest value of 38 mm occurs in 1990. A positive slope of 0.176/year is observed with a fitting coefficient value of R^2 = 0.0793. The p-value of 0.129 (>0.05) is also an indication of the acceptance of the null hypothesis. Hence there is insignificant relationship between the regression model and the observed data. Thus, the model could also not be a good predictor of relative humidity within the study area. The annual average evaporation data however gives a negative trend with a slope of -0.613/year (Fig. 2g). The data indicates that highest evaporation value of 149% is recorded in 2017 and the lowest of 14% is recorded in 2014. The annual average evaporation has a fitting coefficients value of R^2 = 0.044. The p-value of 0.263 (>0.05) also indicates acceptance of the null hypothesis. Hence, there is insignificant relationship between the regression model and the observed data. Table 1 shows the results of regression analysis on the trend of all the climatic variables in the study area.

Table 1: Regression analysis of climatic variables of the study areas (1988-2017)

Variables	Equation: y =	R^2	p-values
Temperature max	0.0064x+21.468	0.001	0.201
Temperature min	0.1685x-317.03	0.625	0.000
Temperature mean	0.0875x-147.78	0.507	0.000
Rainfall	1.221x+913.9	0.006	0.672
Sunshine	-0.209x+640.16	0.021	0.768
Rel. Humidity	0.1763x-301.16	0.079	0.129
Evaporation	-0.613x+197.4	0.044	0.263

DISCUSSION

The results obtained from this work indicates that the climatic variables within the study area change slightly in varying magnitude and direction within the 30 year study period. Positive slopes obtained relative to the minimum, maximum and mean temperatures are good indicators of increase in global warming which has significant impact on the climate. Furthermore, the findings indicate increase in rainfall data over time at a rate of 1.22/year. This fact can be justified by the frequent occurrence of floods, erosion and changes in the landscape of the riverine areas close to the study area. It can be inferred from this finding that, there is a relationship between climatic factors namely; Temperature, Sun shine, Rain fall, Relative humidity and Evaporation over the study area during the study period. It was also found out that, increase in rainfall, relative humidity and temperature had the strongest impact among other climatic factors observed in this work.

In the same vein, the increase in temperature and sunshine came in conjunction with increasing evaporation which indicated an expectable result considering the weather condition of North East Region. Although, variations occur on the sunshine hour in the study area, the result indicated that Yola axis recorded decrease in sunshine hours. This variation may not be unconnected with the altitude and landscape of the area. Temperature normally affects and regulates plant growth and development in a variety of ways. The most important of all is the primary productivity, canopy development and leaf adjustment in terrestrial communities as well as species stratification in aquatic habitat. When rainfall began to decrease between the years 2000-2008 the vegetation started to deteriorate.

Based on these findings, it can be argued that there is increase in temperature which appeared to be significant enough to show evidence of climate change on the area. This finding is in line with that of Hassan *et al*.[10] whose results on the study of the trends of Rainfall and Temperature over North-Eastern Nigeria (1949-2014) show positive trends ranging from 0.04°C/decade to about 0.001°C/decade. Although, they recorded negative trend on the rainfall data for the long time period of 1949-2014, a positive trend was recorded for the short time period of 1982-2014 which corresponds to the period of this study.

The result of trend analysis for all the climatic elements within the study area shows a strong evidence of increased temperature and rainfall which correspondingly lead to increase in humidity. It also indicates decrease in sunshine hours and evaporation in Yola arm of the North-Eastern Nigeria. According to IPCC[16], the global time-series trends of ambient temperature over 15 year period between 1998-2012 ranges between °C per decade, indicate global warming within the study period. This is also in line with the findings of this work. The study is therefore in consistent with several similar studies that observed an increase in temperature within the area and its surroundings[17-20]. The increased humidity in association with increased temperature could lead to rise in regional precipitation. This is also an indication of the fact that the region has been drier for the past few decades.

CONCLUSION

In this research, we used linear regression analysis to study the time series variability of climatic elements for the period between 1984-2017. Positive trends were recorded with respect to the atmospheric temperature, rainfall and relative humidity with time while negative trends were recorded with respect to sunshine hours and annual evaporation. This implies increases in atmospheric temperature, rainfall and relative humidity and decreases in sunshine hours and annual evaporation with time. The study provide evidences for significant shift in the climatic condition of the study area within the last three decades indicating the preponderance of climate change on the study area. Two climatic elements, the annual mean minimum temperature and the annual maximum and minimum temperature are predictable by extrapolation based on the linear regression equations obtained while statistical analysis of the regression equations obtained from the remaining elements indicate low fitting with the linear model due complexity in the time-series variation. The study therefore provide a baseline tool for simulating ambient temperature of the environment.

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