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Research Article

Atmospheric Visibility and Meteorological Characteristics of the Upper Troposphere Over Selected Cities in Nigeria

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ABSTRACT

The study assessed the trends and characteristics of atmospheric visibility over selected cities in Nigeria. Visibility, rainfall, relative humidity, windspeed and temperature data of 36 years (1982-2017) were obtained from the Nigeria Meteorological Agency Abuja for the selected meteorological stations and computed. Descriptive (mean and standard deviation) and inferential statistics (Analysis of Variance (ANOVA) and multiple regression) were used for the data analysis. Results revealed that visibility decreased over the years in all the selected study locations with the exception of Badagry which recorded an 18.09 m annual increase in visibility. The annual trend of rainfall and temperature showed an increase in temperature and rainfall in all the cities studied except Owerri which witnessed a 5.58 mm decrease in rainfall. The student t-test statistics revealed a statistically significant difference in visibility, rainfall, windspeed and relative humidity between the wet and dry seasons in the selected cities. The study also showed that the relationship between visibility and wind speed, temperature, rainfall and relative humidity was statistically significant ($R=0.904$; $F=75.152$; $p=0.000$) as the p value is less than 0.05. In the light of the increasing deterioration of visibility over the study area, the study recommends an urgent need to develop early warning systems for monitoring, risk assessment, mitigation and response to the vagaries of the ever-fluctuating visibility and weather parametersn.

Keywords: Atmospheric visibility; Trends; Characteristics; Air pollutants; Meteorological parameters

INTRODUCTION

Atmospheric visibility degradation in urban, regional, and nationwide scales in the recent decades caused by particle pollution, motor vehicle emissions and meteorological conditions has been in the front burner of scholarly publications and academic discourse [1-6].

Atmospheric visibility usually demonstrates some distinctive local or regional features since it is influenced by both air pollutants and meteorological parameters [7-10]. The reduction of visibility by air pollutants is mainly due to airborne Particulate Matter (PM), especially fine particles with aerodynamic diameter less than 2.5 µm (PM 2.5) in the air. PM 2.5 µm can absorb or scatter the light away from the path it transferred initially, thereby obscuring the contrast of a target with sky background [11]. In addition, many meteorological parameters such as Relative Humidity (RH), Wind Speed (WS) and Wind Direction (WD), atmospheric temperature, barometric pressure, and precipitation could directly or indirectly contribute to visibility degradation [12-14].

For many decades, urban areas in Nigeria have been facing an atmospheric visibility decline due to rapid industrial development and prevailing meteorological conditions [15]. Poor visibility has adverse effects on human lives, highway crowding and delays of airplane departures, crop damage and land and aerial traffic safety [5]. Millions of pulmonary diseases, respiratory diseases, and premature deaths are caused by poor ambient air quality in developing countries, especially in a country like Nigeria where prevailing atmospheric conditions in addition to rapid urbanization process and economic development have led to a sharp increase in resource consumption and many areas are facing severe atmospheric visibility reduction challenges, which were particularly prominent in coastal and oil producing cities [16,17].

Moreso, the geographic location of Nigeria in sub-Saharan Africa has exacerbated Nigeria's present visibility problems and this has made visibility degradation an urgent environmental problem plaguing Nigeria [18]. The implication of this is that dust aerosols are being transported regularly from Sahara desert worsening the visibility challenges presently witnessed. Poor visibility has adverse

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effects on human lives, highway crowding and delays of airplane departures, crop damage and land and aerial traffic safety. Millions of pulmonary diseases, respiratory diseases, and premature deaths are caused by poor ambient air quality in developing countries [19].

Considering that the deterioration of atmospheric visibility in most urban cities have become an environmental concern, a better understanding of the spatial variability of atmospheric visibility and meteorological parameters have become imperative.

MATERIALS AND METHODS

The study was carried out in selected cities in Nigeria located between longitudes 2°49'E-14°37'E and latitudes 4°16'N-13°52'N (Figure 1). It is bounded on the North by the Republic of Niger, East by Cameroon and West by Benin Republic while the Southern boundary is Gulf of Guinea which is an arm of the Atlantic Ocean.

Primary and secondary data were used for this study. The secondary data include rainfall, visibility, windspeed, relative humidity and surface air temperature values for a period of thirty-six years (1982-2017) obtained from the daily weather register in all the NIMET operated meteorological stations in the selected cities in the study area. The selected cities were purposively selected based on the different ecological regions of Nigeria and the age of the cities and their respective meteorological stations since the data collected are archival in nature. Based on these, the selected cities include Badagry, Calabar, Enugu, Ibadan, Ilorin, Jos, Kaduna, Kano, Maiduguri, Owerri, Port Harcourt and Uyo. In the preliminary treatment of the data, basic statistical techniques like the computation of annual sums and annual means for the rainfall, visibility, relative humidity, wind speed and temperature data for each of the selected cities under study were employed. Statistical Package for Social Sciences (SPSS) version 22 was used in the data analysis. A simple linear regression was employed to explain the time series variation in visibility, temperature, rainfall, relative humidity and windspeed. To model the temporal trend of variation in visibility, temperature, rainfall, relative humidity and windspeed over the 35 years period, the least square regression equation was employed. The student t-test was used to test difference in visibility and meteorological parameters over the wet and dry season while the stepwise multiple regression was employed to determine the relationship between atmospheric visibility and meteorological parameters.

RESULTS

The trend analysis of atmospheric visibility displayed in Figure 2 reveals that in Badagry, visibility increased by 18.09 m per annum because the least square line shows that visibility is increasing over the year studied. However, in the city of Calabar, the visibility deteriorated by 26.73 m (Figure 3). In Enugu, visibility deteriorated by 88.44 m per annum (Figure 4) while the city of Ibadan experienced a 60.64 m decrease in visibility (Figure 5). In the city of Ilorin, visibility decreased by 130.0 m (Figure 6), while in the city of Jos, visibility decreased by 78.45 m per annum (Figure 7). Kaduna witnessed a 91.11 m decrease in visibility ((Figure 8), while in Kano, visibility deteriorated by 138.8 m (Figure 9). The city of Maiduguri experienced a 103.8 m per annum decrease in visibility

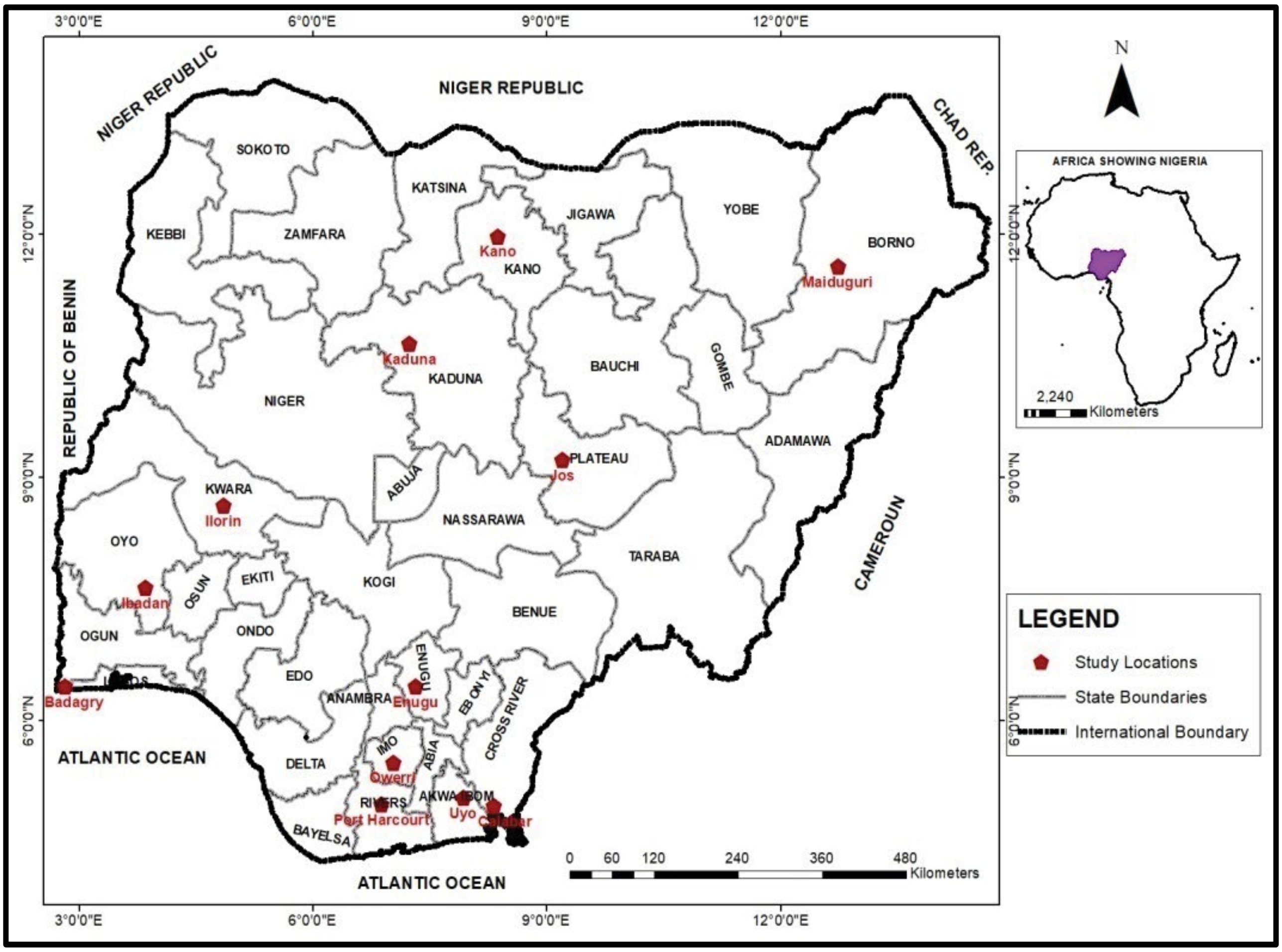

Figure 1: Map of Nigeria depicting the study locations.

(Figure 10), Owerri witnessed an 87.83 m decrease in atmospheric visibility (Figure 11). In Port Harcourt, visibility decreased by 128.6 m (Figure 12) while Uyo experienced a 128.2 m per annum decrease in visibility (Figure 13).

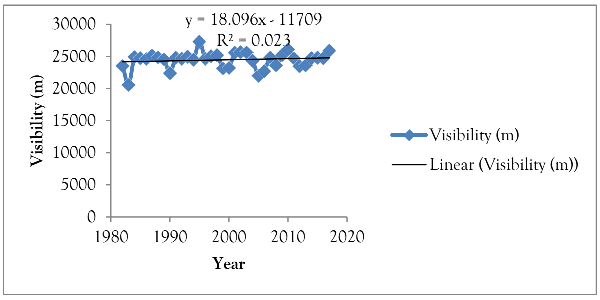

Figure 2: Mean annual visibility over Badagry.

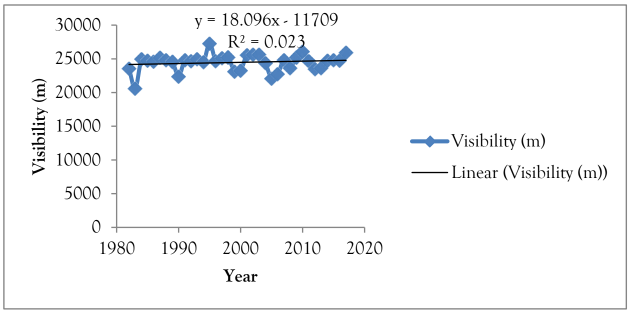

Figure 3: Mean annual visibility over Calabar.

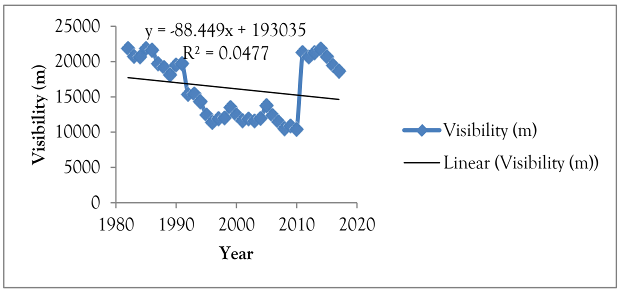

Figure 4: Mean annual visibility for Enugu.

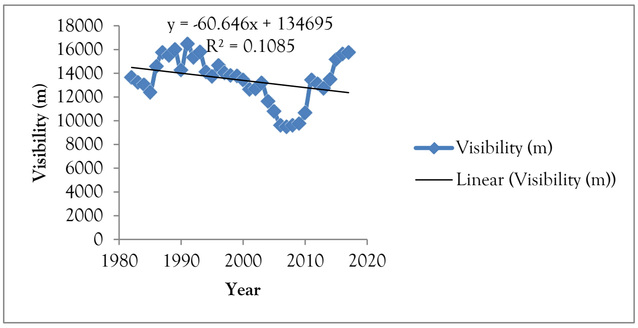

Figure 5: Mean annual visibility for Ibadan.

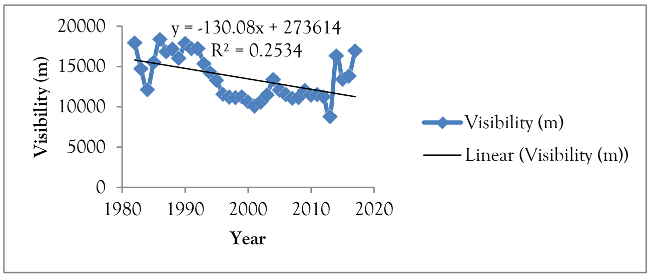

Figure 6: Mean annual visibility for Ilorin.

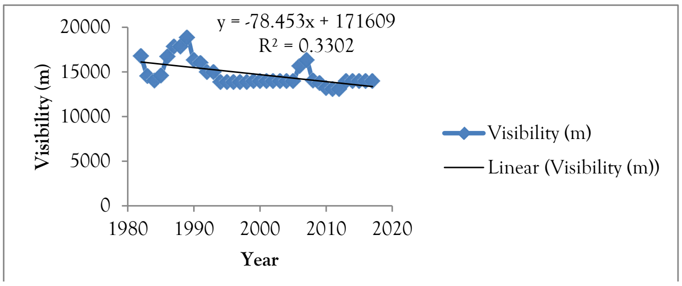

Figure 7: Mean annual visibility for Jos.

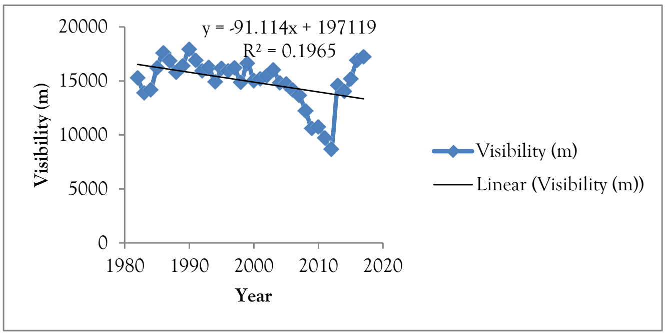

Figure 8: Mean annual visibility for Kaduna.

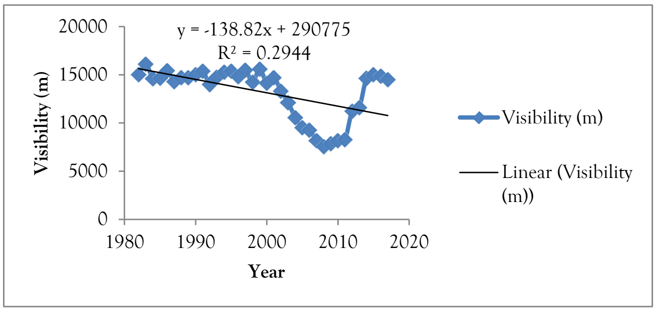

Figure 9: Mean annual visibility in Kano.

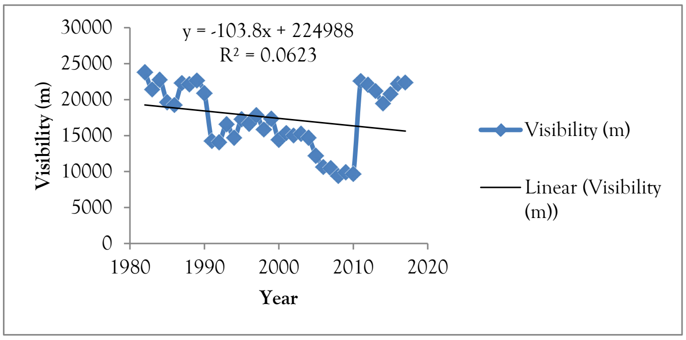

Figure 10: Mean annual visibility for Maiduguri.

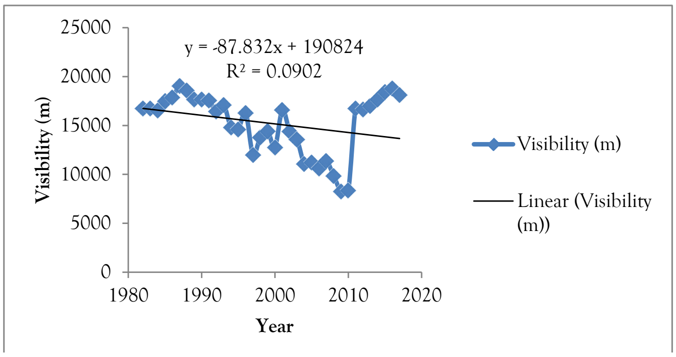

Figure 11: Mean annual visibility for Owerri.

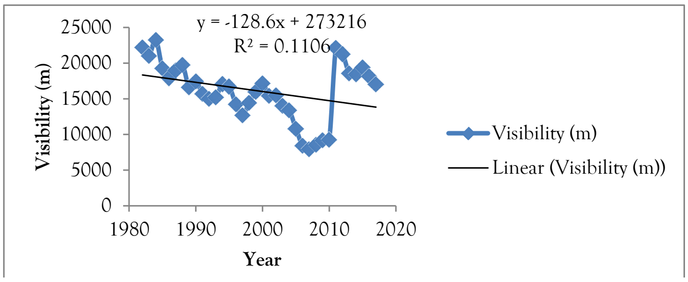

Figure 12: Mean annual visibility for Port Harcourt.

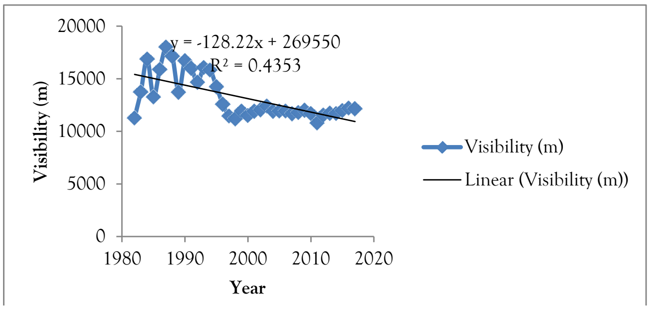

Figure 13: Mean annual visibility for Uyo.

The analysis of rainfall reveals that in Badagry, rainfall increased by 11.03 mm per annum. As displayed in figure 14 the least square line shows that rainfall was increasing in the city of Badagry in the duration studied. Similarly, in the city of Calabar, rainfall increased by 16.23 mm (Figure 15). In Enugu, rainfall increased by 11.81 mm per annum (Figure 16) while the city of Ibadan experienced a 6.83 mm increase in rainfall (Figure 17). The city of Ilorin witnessed an increase in rainfall by 14.51 mm (Figure 18). In the city of Jos, rainfall increased by 2.16 mm per annum (Figure 19). Kaduna witnessed a 10.47 mm increase in rainfall (Figure 20), while in Kano, rainfall increased by 18.03 mm per annum (Figure 21). The city of Maiduguri experienced a 10.73 mm per annum increase in rainfall (Figure 22), Owerri witnessed a 5.58 m decrease in rainfall (Figure 23). In Port Harcourt, rainfall increased by 3.76 mm (Figure 24) while Uyo experienced a 37.31 mm per annum increase in rainfall (Figure 25).

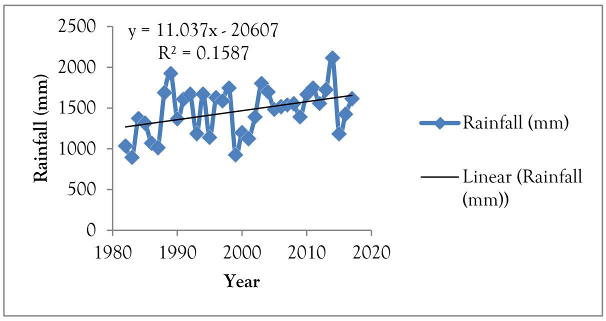

Figure 14: Total annual rainfall for Badagry.

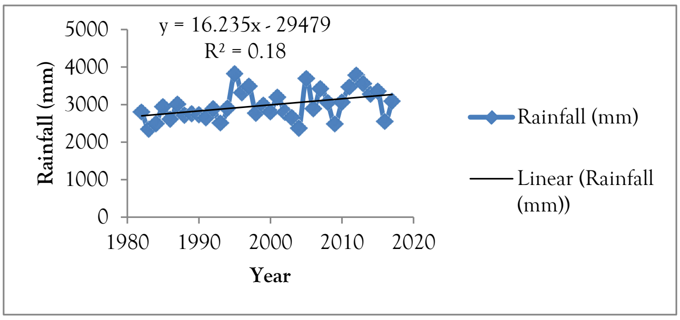

Figure 15: Total annual rainfall for Calabar.

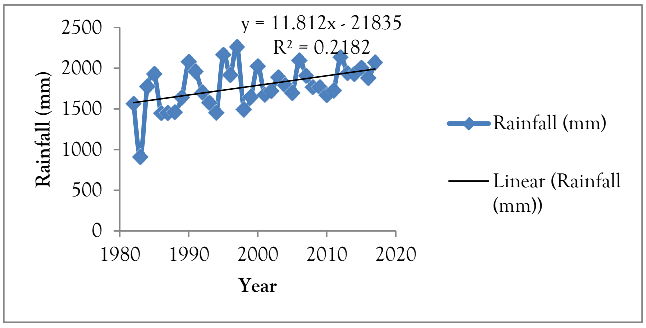

Figure 16: Total annual rainfall for Enugu.

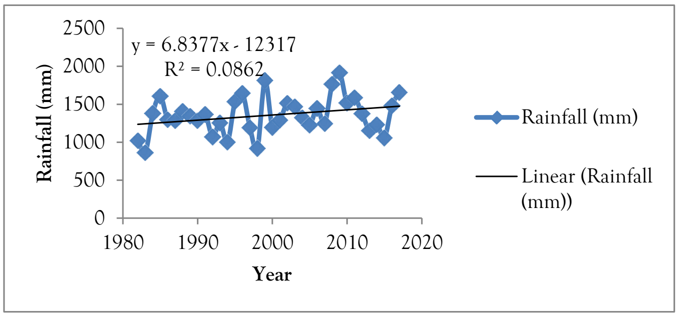

Figure 17: Total annual rainfall for Ibadan.

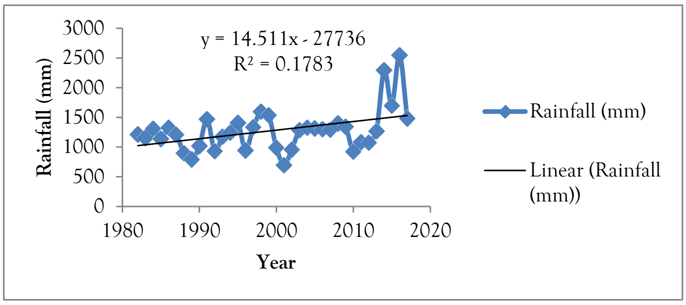

Figure 18: Total annual rainfall for Ilorin.

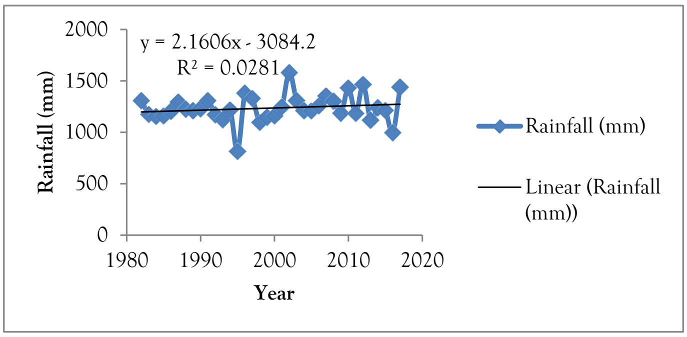

Figure 19: Total annual rainfall for Jos.

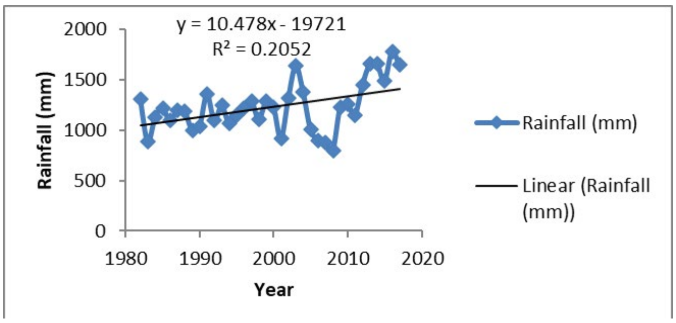

Figure 20: Total annual rainfall for Kaduna.

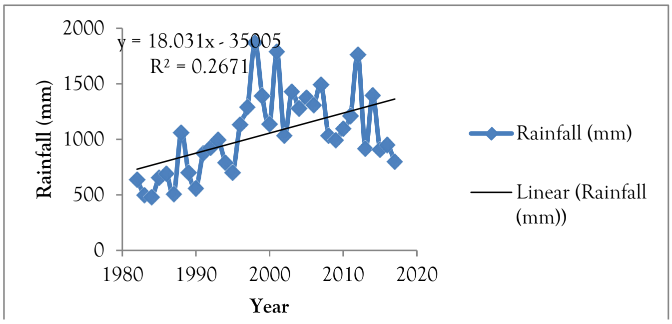

Figure 21: Total annual rainfall in Kano.

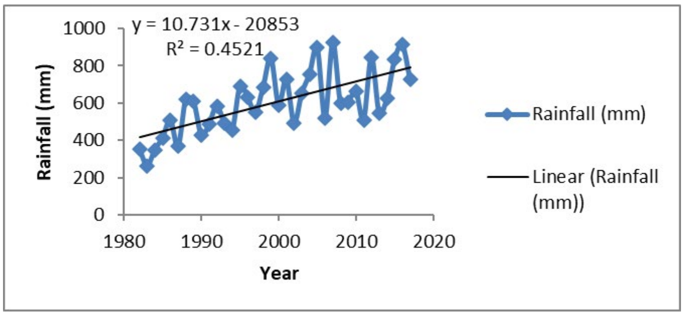

Figure 22: Total annual rainfall for Maiduguri.

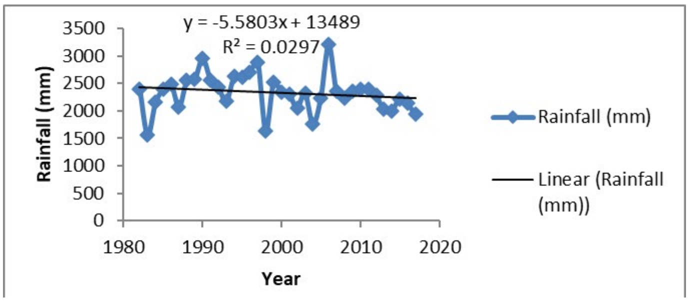

Figure 23: Total annual rainfall for Owerri.

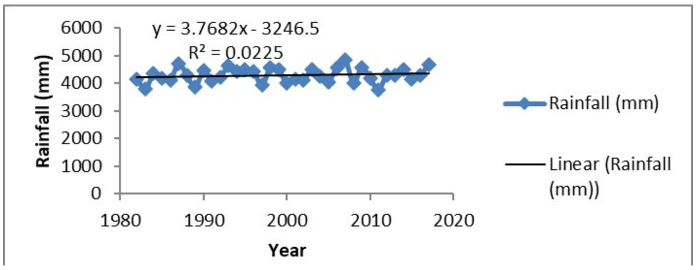

Figure 24: Total annual rainfall for Port Harcourt.

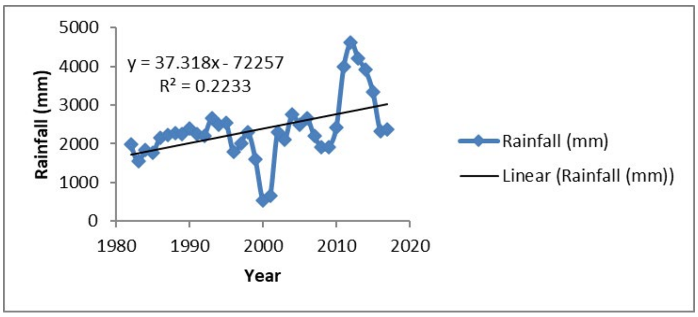

Figure 25: Total annual rainfall for Uyo.

The trend analysis of temperature across the cities under study shows that temperature was increasing in Badagry by 0.029°C per annum (Figure 26). In Calabar, temperature increased slightly by 0.010°C per annum (Figure 27) while it was also increasing over time in Enugu airport by 0.008°C per annum (Figure 28). Similarly, there was an increase in temperature over the time of study in Ibadan and Ilorin by 0.008°C (Figure 29) and 0.027°C (Figure 30) respectively. In Jos, temperature increased by 0.02°C (Figure 31). Kaduna experienced a 0.041°C increase in temperature (Figure 32) while Kano also experienced a 0.011°C increase in temperature (Figure 33). In Maiduguri, a 0.021°C increase in temperature was recorded (Figure 34) while Owerri recorded a 0.003°C increase in temperature (Figure 35). In Port Harcourt, there was an increase in temperature per annum by 0.043°C (Figure 36) and Uyo also recorded 0.018°C increase in temperature decrease as shown in figure 37.

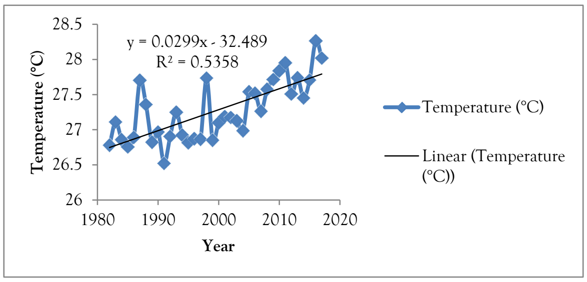

Figure 26: Mean annual temperature for Badagry.

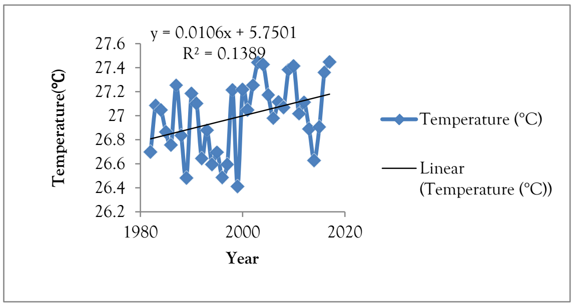

Figure 27: Mean annual temperature for Calabar.

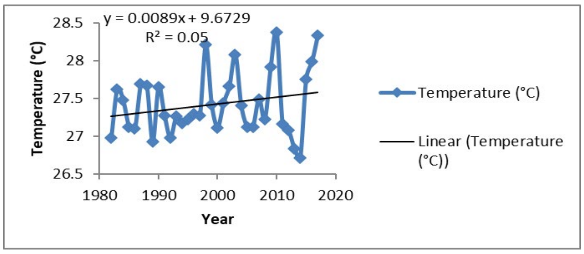

Figure 28: Mean annual temperature for Enugu.

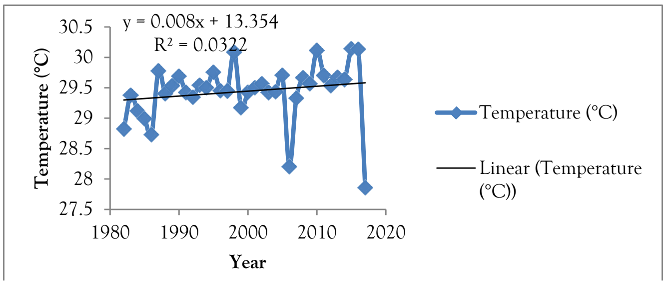

Figure 29: Mean annual temperature for Ibadan.

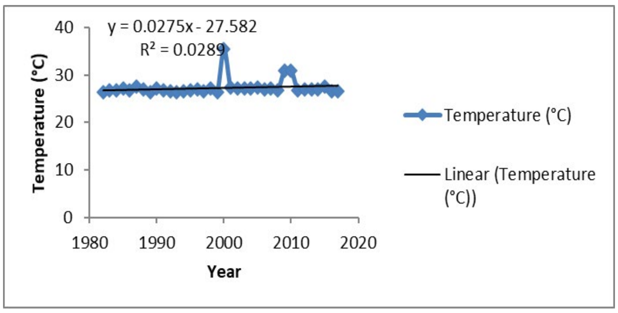

Figure 30: Mean annual temperature for Ilorin.

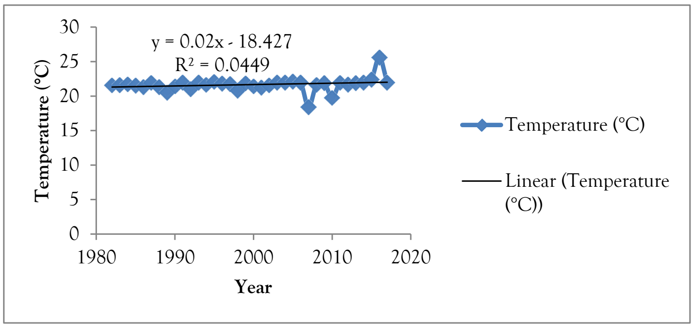

Figure 31: Mean annual temperature for Jos.

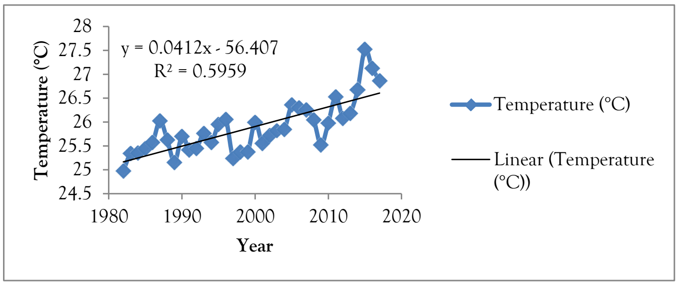

Figure 32: Mean annual temperature of Kaduna.

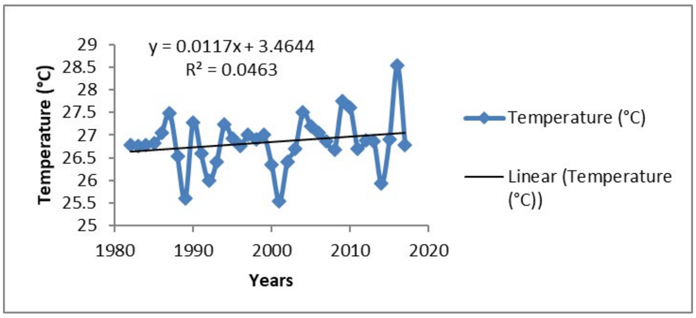

Figure 33: Mean annual temperature of Kano.

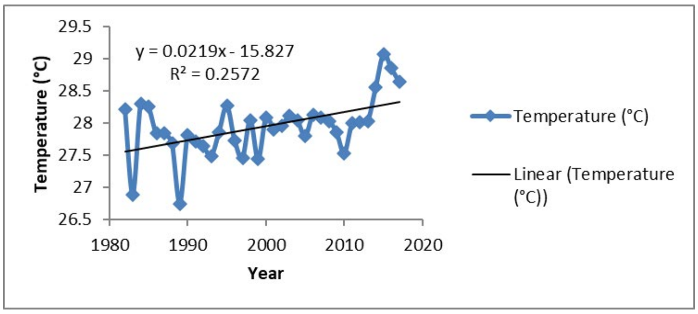

Figure 34: Mean annual temperature for Maiduguri.

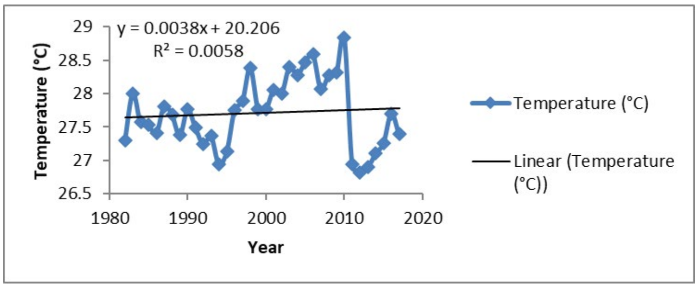

Figure 35: Mean annual temperature for Owerri.

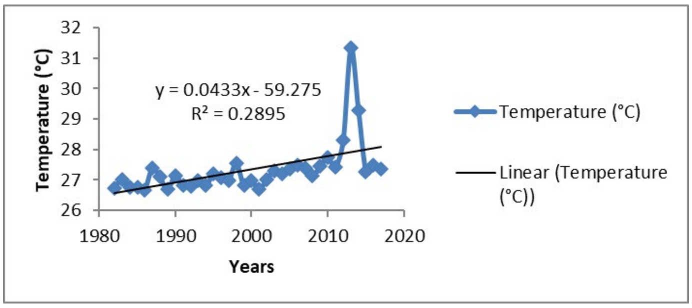

Figure 36: Mean annual temperature for Port Harcourt.

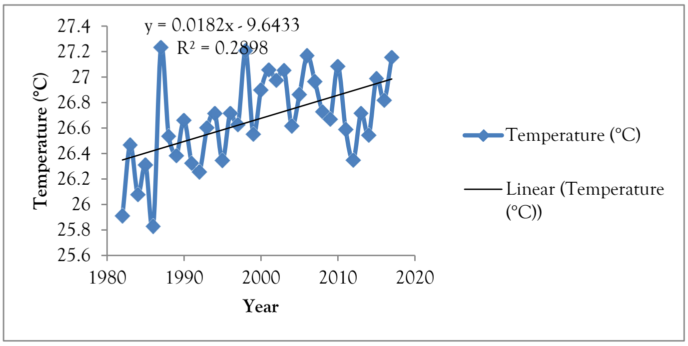

Figure 37: Mean annual temperature for Uyo.

Table 1 reveals the student t-test values of visibility, temperature, rainfall, relative humidity and windspeed between wet and dry seasons. The values revealed statistically significant difference in visibility, rainfall and relative humidity between the wet and dry seasons as the p values of 0.000 and 0.002 were less than the critical value of 0.05. However, the analysis on Table 1 revealed no statistically significant difference in temperature between the wet and dry seasons as the p value of 0.306 was higher than the critical value of 0.05.

The analysis in Table 2 indicates the model summary of the stepwise regression analysis between visibility (dependent variable) and wind speed, temperature, rainfall and relative humidity of

Table 1: Student t-test values of visibility and weather parameters over seasons.

Meteorological Parameters	Mean	Standard Deviation	Standard Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Temperature	0.28306	1.63523	0.27254	-0.27022	0.83635	1.039	35	0.306
Rainfall	3185.006	513.2708	85.54513	3011.34	3358.671	37.232	35	0
Windspeed	-0.32377	0.5783	0.09638	-0.51944	-0.1281	-3.359	35	0.002
Visibility	6885.709	2708.432	451.40536	5969.307	7802.11	15.254	35	0
Relative humidity	33.70745	4.18533	0.69756	32.29134	35.12357	48.322	35	0

Table 2: Stepwise regression showing relationship between visibility and weather parameters.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			Sig. F Change
						F Change	df1	df2	
1	.820[a]	0.673	0.668	2352.15606	0.673	143.925	1	70	0
2	.869[b]	0.755	0.748	2049.00671	0.082	23.245	1	69	0
3	.892[c]	0.796	0.787	1885.95665	0.04	13.447	1	68	0

a: Predictors: (Constant), rainfall, b: Predictors: (Constant), rainfall, relative humidity, c: Predictors: (Constant), rainfall, relative humidity, wind speed

the entire study area (predictors). The regression coefficient (R) is 0.820 while the regression coefficient of determination is 0.673 for model 1. This shows that rainfall only can explain the can explain 67.3% of the variation in the visibility of the study area. Thus, the relationship between visibility and rainfall is significant (R=0.0.820; F=143.825; p=0.000) as the p value is less than 0.05. For the model 2, the R is 0.869 and the R square is 0.755. This signifies that the combination of rainfall and relative humidity can explain 75.5% of the variation in the visibility of the study area. Also, the combination of rainfall and relative humidity significantly related with visibility (R=0.869; F=23.245; p=0.000). For the model 3, the combination of rainfall, relative humidity and wind speed had regression coefficient of 0.892 with visibility and R square of 0.796. This implies that the 79.6% of the combination of rainfall, relative humidity and wind speed can explain the variation in the visibility of the entire study area (R=0.892; F=13.447; p=0.000) Therefore, the analysis revealed a statistically significant relationship between visibility and meteorological parameters.

DISCUSSION OF FINDINGS

The finding of this research revealed that visibility deteriorated in all the selected study locations with the exception of Badagry which recorded an 18.09 m annual increase in visibility. The finding of this research is in agreement to the findings of Ochei and Adenola, who studied the variability and trend of Harmattan dust haze over Northern Nigeria revealing decreasing visibility trends [20].

The finding of this research analysis revealed an increase in temperature and rainfall in all the cities studied except Owerri which witnessed a 5.58 mm decrease in rainfall. The finding of this research agrees with the previous researches of Balarabe whose study revealed increasing rainfall and temperature trends over a 30-year period [18].

The research findings indicated that the study revealed a statistically significant difference in visibility, rainfall, windspeed and relative humidity between the wet and dry season which is in tandem with the findings of Nwokocha and Okujagu who estimated the seasonal indices and seasonal effect of visibility, relative humidity and wind direction over selected locations in the Niger Delta and revealed that the difference in visibility, rainfall, temperature, windspeed and relative humidity between the wet and dry seasons was statistically significant [16].

The study also revealed that the relationship between visibility and wind speed, temperature, rainfall and relative humidity was statistically significant. The finding of this study agrees with the findings of Weli and Ifediba who revealed in their study that thunderstorms in conjunction with other meteorological parameters have been known to lead to a deterioration of visibility [5].

CONCLUSION

The study affirms that visibility is deteriorating in most cities in Nigeria which is attributed to the contributory roles of rainfall, temperature, relative humidity and windspeed. The study further revealed seasonal and annual variation in visibility, temperature rainfall, relative humidity and windspeed in the study area. It was also established that the relationship between visibility and wind speed, temperature, rainfall and relative humidity was significant. Therefore, the observed variability is expected to intensify in the future given the current climate change projections.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations were necessary such as:

- The study recommends the development of early warning systems for monitoring, risk assessment, mitigation and response to the vagaries of the ever-fluctuating visibility and weather parameters.
- This study has successfully revealed the threat of deteriorating visibility in the study area. There is therefore the need for seasonal monitoring of visibility and weather parameters on a yearly basis
- Remote sensing technology needs to be developed and adequately funded to enable the adequate monitoring of sensitive climatic parameters such as visibility, rainfall, temperature, windspeed and relative humidity
- There is a need for the development of satellite imageries that will enhance the capability to map areas vulnerable to the deteriorating visibility. This will help in the formulation of management plans
- Timely seasonal enlightenment programs should be conducted by various meteorological authorities and other relevant government agencies with the aim of reaching out to members of the public on the need to adhere strictly to weather alerts and warning systems as a means for mitigating and management in the case of a disaster

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