Impact of Global Warming on the Rainfall and Temperature in the Niger Delta of Nigeria

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Abstract

The major aims of this study is to look into the impact of global warming on the rainfall for some selected cities in the Niger Delta of Nigeria, and deduce if urban water supply is sustainable under the prevailing climate condition. The time series of meteorological data (rainfall and temperature) were analysed with the aim of detecting trends in the variables. The non parametric Man-Kendall test was used to detect monotonic trends, and the Sen's slope estimator was used to develop models for the variables. The study revealed that there is evidence of global warming in Owerri, and rainfall has significantly increased in Calabar over the years. Though the trends in rainfall at Owerri and Port-Harcourt were not significant, the slope estimates revealed a positive trend in the rainfall of the stations. Thus it is concluded that water supply is sustainable under the current climate condition.

Keywords

Global warming, Man-Kendall test, Sen's slope estimator.

1. Introduction

There is a growing concern about global warming and the impact it will have on people and the ecosystems on which they depend. Temperatures have already risen 1.4°F since the start of the 20th century—with much of this warming occurring in just the last 30 years—and temperatures will likely rise at least another 2°F, and possibly more than 11°F, over the next 100 years (Wikipedia, 2009).. This has prompted calls for action at every level of government and across many sectors of economy and society. It is therefore pertinent to establish a suite of coordinated activities that will examine the serious and sweeping issues associated with global climate change, including the science and technological challenges involved, and provide advice on actions and strategies nation can take to respond to it (The National Academies, 2008).

Global warming refers to an average increase in the earth's temperature, which in turn causes changes in climate (EPA, 2009). The term "climate change" is often used interchangeably with "global warming." However, given the wide range of impacts beyond temperature variations, the former is generally the preferred in the scientific community because it helps convey that there are other changes in addition to rising temperatures (Climate Institute, 2007). Climate change refers to the variation in the earth's global climate or in regional climates over time. It describes changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the Earth, external forces (e.g. variations in sunlight intensity) or, more recently, human activities (wikipedia, 2009). In recent usage, especially in the context of environmental policy, the term "climate change" often refers only to changes in modern climate, including the rise in average surface temperature known as global warming. In some cases, the term is also used with a presumption of human causation (Climate Institute, 2007).

EPA (2009) has reported that global warming enhances the water cycle by intensifying activities the cycle of water. Global warming causes the earth atmosphere to be warmer. When the atmosphere is warmer, it evaporates more water and it can hold more vapour. More cloud will form and there will be more rain and snow especially in areas closer to water (e.g. Niger Delta in Nigeria). In areas particularly away from water sources, more evaporation and transpiration could dry out soils and vegetation, resulting in fewer clouds and less precipitation. More rain affects other parts of the water cycle by causing more infiltration and runoff, also an increase in ground water and the amount of water in bodies of water that receive runoff. This change in water cycling and storage can cause flooding in this area or water may form new lakes and rivers on ground that was dry before. The environment thus become wetter and affects plants and humans and animals (ecosystem). Places further from water sources gets less precipitation, the ground gets drier due to evapotranspiration. Once it dries out the atmosphere looses an important source of moisture and there are fewer clouds and less rain. Thus less infiltration and runoff, thus the area will probably get more droughts. Rivers and lakes become shallower and the amount of ground water decrease (EPA, 2009). Hence, It is absolutely necessary therefore, to sensitize peoples of all nations about the imminent danger posed by global warming and depletion of fresh water resources.

The Niger Delta in Nigeria, is a densely populated region sometimes called the Oil Rivers because it was once a major producer of palm oil. The area was the British Oil Rivers Protectorate from 1885 until 1893, when it was expanded and became the Niger Coast Protectorate. The Niger Delta, as now defined officially by the Nigerian government, extends over about 70,000 km^2 and makes up 7.5% of Nigeria's land mass. Historically it consists of present day Bayelsa, Delta, and Rivers States. In the year 2000, however, the Federal Government of Nigeria included Abia, Akwa-Ibom, Cross River, Edo, Imo and Ondo States in the region. Some 31 million people of more than 40 ethnic groups including the Efik, Ibibio, Annang, Oron, Ijaw, Itsekiri, Igbo, Urhobo, Yoruba, and Kalabari, are among the inhabitants in the Niger Delta, speaking about 250 different dialects (Wikipedia, 2010). The delta is an oil-rich region, and has been the centre of international controversy over devastating pollution, kleptocracy, and human rights violations.

Coincidentally, Nigeria has become Africa's biggest producer of petroleum, including many oil wells in the Oil Rivers. Some 2 million barrels a day are extracted in the Niger Delta. Since 1975, the region has accounted for more than 75% of Nigeria's export earnings. Much of the natural gas extracted in oil wells in the Delta is immediately burned, or flared, into the air at a rate of approximately 70 million m^3per day. This is equivalent to 41% of African natural gas consumption, and forms the largest single source of greenhouse gas emissions on the planet (Wikipedia, 2010). Oil spills is also a key environmental issues in the Niger Delta of Nigeria. Oil spills in Nigeria occur due to a number of causes, including: corrosion of pipelines and tankers (accounting for 50% of all spills), sabotage (28%), and oil production operations (21%), with 1% of the spills being accounted for by inadequate or non-functional production equipment. Due to oil spill, the Niger Delta has witnessed the slow poisoning of surface water, destruction of vegetation and agricultural land, and contamination of wells, soils, and groundwater resources.

From the foregoing, it can be deduced that a main reliable source of freshwater in the Niger Delta is rainfall. The flaring of gas in the Niger Delta has been reported to have increased the concentration of greenhouse gasses, possibly resulting in global warming. Global warming as noted by EPA

(2009) affects the precipitation of an area. Hence this study was conducted to investigate the possibility of global warming in the area, and its effect on rainfall, by using the temperature and rainfall data of three selected cities (Owerri, Calabar, and Port-Harcourt) in the Niger Delta of Nigeria.

2. Materials and Methods

2.1 Data Collection

Monthly rainfall, maximum temperature, and minimum temperature data for the selected cities (Owerri, Calabar, and Port-Harcourt) were obtained from the Nigerian Meteorological Agency (NIMET), Oshodi Lagos, Nigeria. NIMET is the agency responsible for the measurement, control, and storage of the hydro-meteorological data in Nigeria. The nature of data collected are rainfall depth (mm), and maximum and minimum temperatures (^oC) recorded for every month of the year. The rainfall data spanned between 1983 and 2008 (26 years) for all the stations. Temperature data spanned between 1983 to 2007 (25 years) for Owerri, and 1983 to 2008 (26 years) for Calabar and Port-Harcourt. For the analysis, the average of the monthly data were computed to give an average annual value. A summary of statistics for the meteorological variables is presented in Table 1.

Table 1: Statistical summary of meteorological variables

Station	Variable	Statistics				
		Mean	Variance	Std. Deviation	Skew	Kurtosis
Owerri	Rainfall (mm)	201.22	644.42	25.39	-0.530	-0.049
	Minimum Temperature (^oC)	23.42	0.30	0.55	-0.556	-0.115
	Maximum Temperature (^oC)	32.19	0.20	0.45	0.299	-0.943
Calabar	Rainfall (mm)	241.65	971.47	31.17	0.798	0.122
	Minimum Temperature (^oC)	23.09	0.31	0.55	-0.159	-0.309
	Maximum Temperature (^oC)	30.79	0.17	0.42	-0.154	0.148
Port-Harcourt	Rainfall (mm)	187.39	514.25	22.68	-0.289	-0.033
	Minimum Temperature (^oC)	22.66	0.12	0.35	0.253	-0.681
	Maximum Temperature (^oC)	31.38	0.11	0.33	0.523	-0.737

2.2 Trend Analysis

The trend analysis was done in two phases. First the presence of a monotonic increasing or decreasing trend was tested with the nonparametric Mann-Kendall test and secondly the slope of a linear trend is estimated with the nonparametric Sen's slope estimator. Correlation coefficients of the meteorological variables and time were also computed to determine the strength of the linear relationship between the variable.

2.2.1 Mann-Kendal analysis

The non-parametric Mann-Kendall test, which is commonly used for hydrologic data analysis, can be used to detect trends that are monotonic but not necessarily linear. The null hypothesis in the Mann-Kendall test is that the data are independent and randomly ordered. The Mann-Kendall test does not require the assumption of normality, and only indicates the direction but not the magnitude of significant trends (McBean and Motiee, 2008). The Mann-Kendall test statistic *S* is calculated using the formula

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k), \qquad (1)$$

where x_j and x_k are the annual values in years *j* and *k*, $j > k$, respectively, and

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases} \qquad (2)$$

A very high positive value of S is an indicator of an increasing trend, while a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend (Khambhammettu, 2005). The variance of S is computed as

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5) \right] \qquad (3)$$

Here q is the number of tied groups and t_p is the number of data values in the p^{th} group. The values of *S* and *VAR(S)* are used to compute the test statistic *Z* as follows

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \tag{4}$$

Z follows a normal distribution. The Z value is tested at 95% level of significance ($Z_{0.025}$=1.96). The trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance, while it is increasing if Z is positive and greater than the level of significance. If the absolute value of Z is less than the level of significance, there is no trend (Khambhammettu, 2005).

2.2.2 Sen's Slope Estimator

One of the most useful parametric models to detect trend is the "Simple Linear Regression" model. However the method of linear regression requires the assumptions of normality of residuals (McBean and Motiee, 2008). Viessman et. al., (1989) has noted that many hydrologic variables exhibit a marked right skewness partly due to the influence of natural phenomena, and do not follow a normal distribution. It is also evident from the skew and kurtosis of the variable presented in Table 1 that the variables do not follow a normal distribution. Hence the Sen's slope estimator, which is a non parametric method was used to develop the linear models in this study. This methods offer many advantages that have made them useful in analyzing atmospheric chemistry data. Missing values are allowed and the data need not conform to any particular distribution. Besides, the Sen's method is not greatly affected by single data errors or outliers (Salmi et.al, 2002). To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear i.e.

$$f(t) = Qt + B \tag{5}$$

where Q is the slope, B is a constant and *t* is time. To get the slope estimate *Q* in equation (5) the slopes of all data value pairs is first calculated using the equation

$$Q_i = \frac{x_j - x_k}{j - k} \qquad (6)$$

where $j>k$. If there are *n* values x_j in the time series there will be as many as $N = n(n-1)/2$ slope estimates Q_i. The Sen's estimator of slope is the median of these *N* values of Q_i. To obtain an estimate of B in equation (5) the *n* values of differences $x_i - Qt_i$ are calculated. The median of these values gives an estimate of B (Salmi et.al, 2002). In this study a program was written in Visual Basic for Applications to facilitate the computation of the Man-Kendall statistics S, Sen's slope Q, and intercept B.

2.3 Correlation Coefficient

The correlation coefficient determines the strength of linear relationship between two variables. It always takes a value between –1 and +1, with 1 or –1 indicating a perfect correlation (all points would lie along a straight line, having a residual of zero). A correlation coefficient close to or equal to zero indicates no relationship between the variables. A positive correlation coefficient indicates a positive (upward) relationship and a negative correlation coefficient indicates a negative (downward) relationship between the variables (Rahman, 2008). The correlation coefficients between temperature, rainfall, and time were calculated using Microsoft Excel software application.

3. Results and Discussion

The correlation coefficients between temperature, rainfall, and time for the stations are presented in Table 2. The result of the Mann-Kendal analysis is presented in Table 3, while the developed Sen model equations are presented in Table 4. The plots showing the time trend of the variable are presented in Figures 1 to 9.

Table 2 Correlation coefficients between meteorological variables and time

Station	Variable	Correlation Coefficient
Owerri	Rainfall (mm)	0.200
	Minimum Temperature (^oC)	0.401
	Maximum Temperature (^oC)	0.544
Calabar	Rainfall (mm)	0.425
	Minimum Temperature (^oC)	0.103
	Maximum Temperature (^oC)	0.106
Port-Harcourt	Rainfall (mm)	0.174
	Minimum Temperature (^oC)	0.241
	Maximum Temperature (^oC)	0.392

Table 3: Summary of the Mann-Kendall analysis

Station	Variable	S	Variance	Z	Trend Significance
Owerri	Rainfall (mm)	45	2058.3333	0.9698	Not Significant
	Minimum Temperature (^oC)	118	1833.3333	2.7325	Significant
	Maximum Temperature (^oC)	129	1832.3333	2.9903	Significant
Calabar	Rainfall (mm)	93	2058.3333	2.0278	Significant
	Minimum Temperature (^oC)	55	2058.3333	1.1902	Not Significant
	Maximum Temperature (^oC)	19	2056.3333	0.3969	Not Significant
Port-Harcourt	Rainfall (mm)	23	2058.3333	0.4849	Not Significant
	Minimum Temperature (^oC)	54	2057.3333	1.1685	Not Significant
	Maximum Temperature (^oC)	59	2053.6667	1.2799	Not Significant

Table 4. Developed Sen Model equations

Station	Variable	Model Equation
Owerri	Rainfall (mm)	y = 0.8236x - 1438.1319
	Minimum Temperature (^oC)	y = 0.0359x - 48.1062
	Maximum Temperature (^oC)	y = 0.0383x - 44.3355
Calabar	Rainfall (mm)	y = 1.6129x - 2982.8030
	Minimum Temperature (^oC)	y = 0.0208x - 18.4479
	Maximum Temperature (^oC)	y = 0.0042x + 22.4313
Port-Harcourt	Rainfall (mm)	y = 0.3903x - 587.5125
	Minimum Temperature (^oC)	y = 0.0130x - 3.3891
	Maximum Temperature (^oC)	y = 0.0157x + 0.0287

x= time, and y represents the meteorological variable

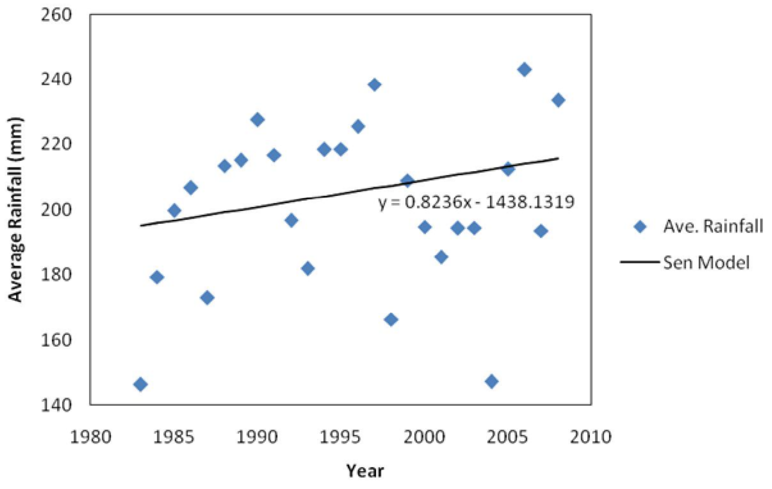

Figure 1: Owerri Rainfall Trend (1983 - 2008)

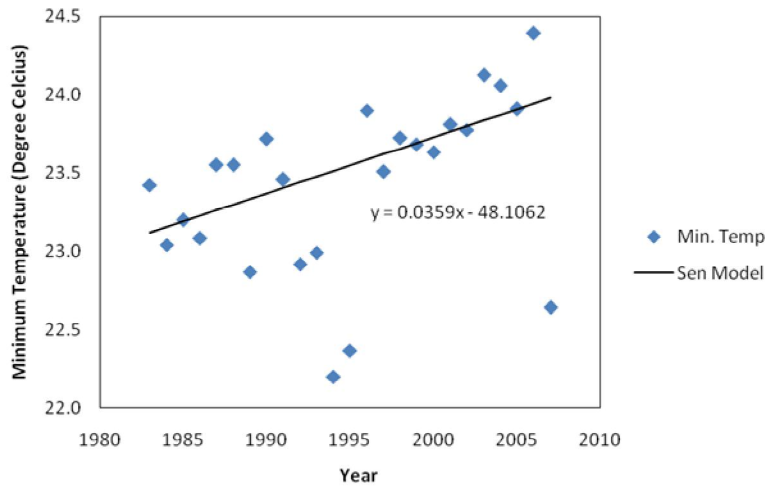

Figure 2: Owerri Minimum Temperature Trend (1983 - 2007)

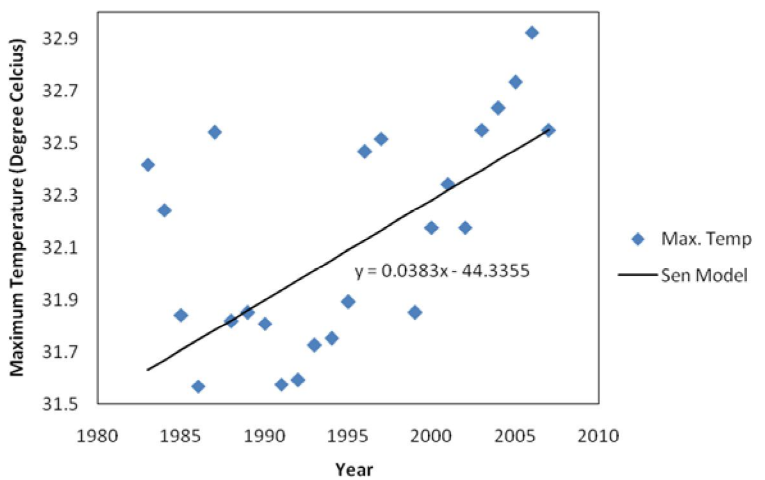

Figure 3: Owerri Maximum Temperature Trend (1983 - 2007)

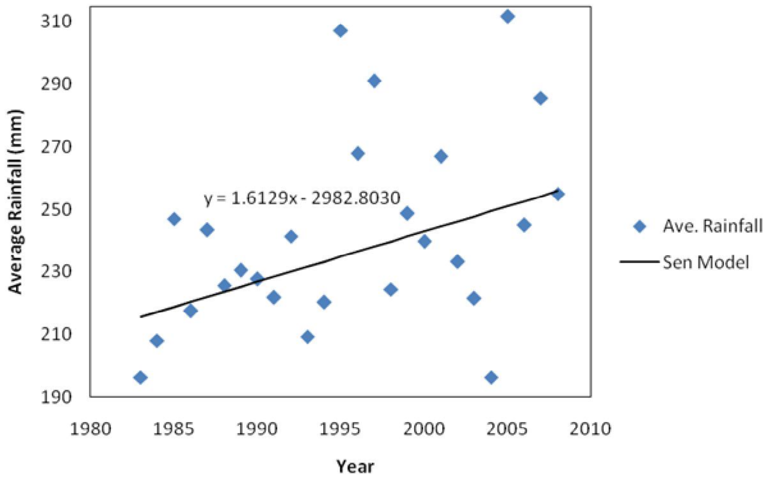

Figure 4: Calabar Rainfall Trend (1983 - 2008)

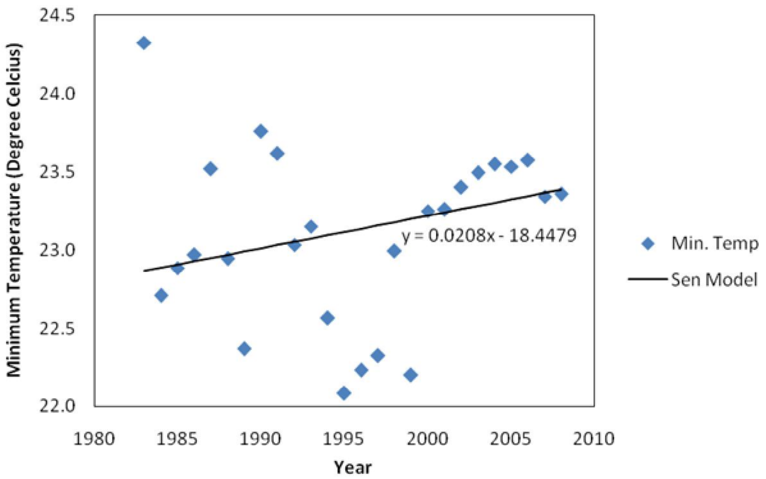

Figure 5: Calabar Minimum Temperature Trend (1983 - 2008)

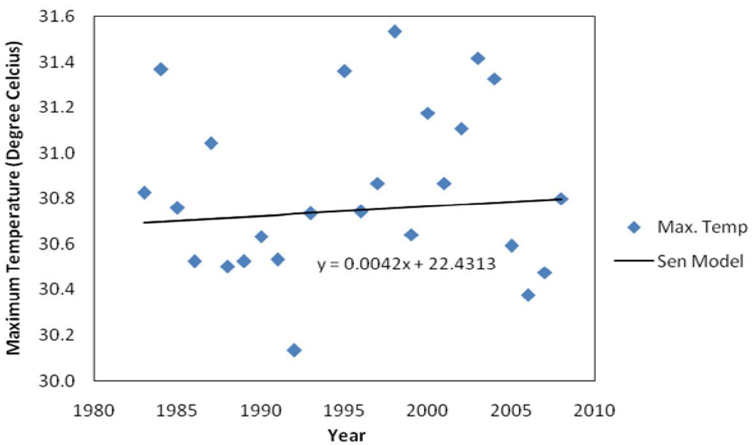

Figure 6: Calabar Maximum Temperature Trend (1983 - 2008)

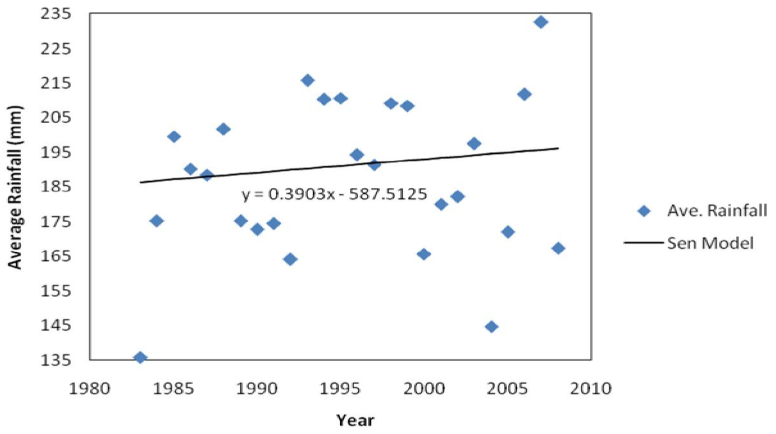

Figure 7: Port Harcourt Rainfall Trend (1983 - 2008)

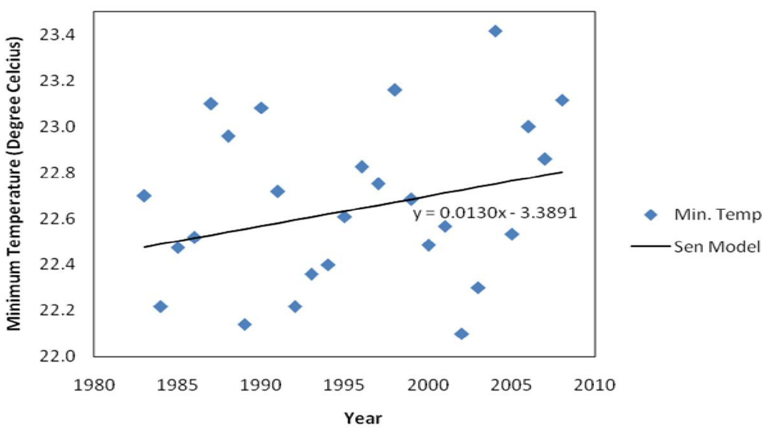

Figure 8: Port Harcourt Minimum Temperature Trend (1983 - 2008)

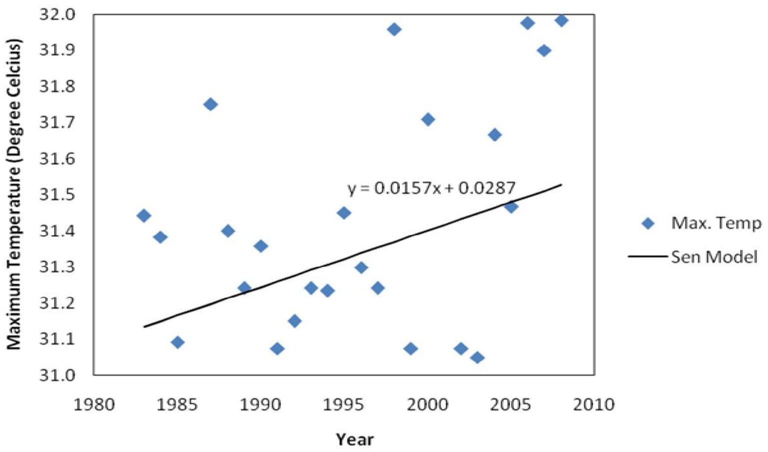

Figure 9: Port Harcourt Maximum Temperature Trend (1983 - 2008)

The analysis reveals that the rainfall trend at Owerri is not significant. The Man-kendall Statistic S = 45 and the Sen slope estimate Q = 0.8236, indicating a positive trend. However a correlation coefficient = 0.2 reveals a weak relationship, and the Z value of 0.9699 shows that the trend is not significant. For the rainfall of Calabar, the Man-kendall Statistic S = 93 and the Sen slope estimate Q = 1.6129, which is indicative of a positive trend. However the correlation coefficient is 0.425, and the Z value of 2.0278 establishes that the trend is not significant. In Port-Harcourt, the Man-kendall Statistic S = 54 and the Sen slope estimate Q = 0.3903, reveal a positive trend in rainfall. However a correlation coefficient of 0.174, and a Z value of 0.4849 show that the trend is not significant.

For the minimum temperature at Owerri, the Man-kendall Statistic S = 118 and Sen slope estimate Q = 0.0359 indicate a positive trend. The correlation coefficient is 0.401, and a Z value of 2.7325 reveal that the trend is significant. Likewise the Man-kendall Statistic S = 129 and Sen slope estimate Q = 0.0383 indicate a positive trend in the maximum temprature at Owerri. A correlation coefficient of 0.544 and a Z value of 2.9903 indicate that the trend is significant.

At Calabar, the Man-kendall Statistic S = 55 and Sen slope estimate Q = 0.0208 indicate a positive trend in the minimum temperature. The correlation coefficient is 0.103, and a Z value of 1.1902 reveal that the trend is not significant. Similarly, the Man-kendall Statistic S = 19 and Sen slope estimate Q = 0.0042 indicate a positive trend in the maximum temprature. The correlation coefficient is 0.106 and a Z value of 0.3969 reveals that the trend is not significant.

The Man-kendall Statistic S = 54 and Sen slope estimate Q = 0.0130 indicate a positive trend in the minimum temperature at Port-Harcourt. The correlation coefficient is 0.241, and a Z value of 1.1685 reveals that the trend is not significant. Also, the Man-kendall Statistic S = 59 and Sen slope estimate Q = 0.0157 indicate a positive trend in the maximum temprature. The correlation coefficient is 0.392 and a Z value of 1.2799 reveals that the trend is not significant.

4. Conclusion

From the results of the analyses, the temperature at Owerri demonstrates a significantly increasing trend. Thus it may be concluded that there is sufficient evidence of global warming in Owerri. The rainfall at Calabar also demonstrates a significantly increasing trend. Although the temperature trends at Calabar and Port-Harcourt are not significant, the positive values of slope estimates areindicative of a positive trend. The Sen slope estimates of the rainfall trends in the three stations are positive, and the plots of rainfall against year reveals an upward rise over the years (1983 – 2008). Thus it may be concluded that since global warming is not having a significant negative effect on the rainfall of the selected cities, urban water supply is still sustainable under the present climate condition of the Niger Delta.

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