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TEMPORAL VARIABILITY IN ATMOSPHERIC TEMPERATURE OF ILORIN, NIGERIA

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ABSTRACT

The Study examined the fluctuations and trend in atmospheric temperature and its possible effect on health of residents in Ilorin. Minimum, maximum and mean temperature data for 35 years obtained from Nigeria Meteorological Agency (NIMET) office located in Ilorin International Airport is used in the study. Reduction analysis aided in assessing percentage changes in temperature, Mann-Kendall test was used in explaining the temperature trends while Sen Model equations that can be used in predicting future minimum, maximum and mean atmospheric temperature in the study area were developed. Result obtained indicates negative percentage changes in both minimum and maximum temperature within the decades 1984 to 1993 and 1994 to 2003. However, within the decade 2004 to 2013, positive percentage changes were observed in both minimum and maximum temperature. Mann-Kendall statistics reveals that even though all the three variables under investigation (i.e. minimum, maximum and mean temperature) exhibits positive trends, only the maximum and mean temperature were found to be significant when their Z values were tested at 95% significant level. This thus means that, the increasing trends in both maximum and mean temperature in the study area did not occur by chance, but results from causative factors. This result does not only reveals evidence of climate change in the study areas but also envision challenges in areas of human health and comfort.

Keywords: Temporal, Variability, Temperature, Climate Change Deforestation

INTRODUCTION

In the last three decades, the earth has warmed up by approximately 6°C with each of the three decades successively warmer than the preceding decade since 1850 (IPCC, 2007). The IPCC (2007) also projected that between 1990 and 2010, the global temperature will rise by between 1.4 and 5.8°C. This increase in global temperature is basically due to factors affecting the amount of solar radiation striking the earth and the rate at which the heat thereby produced escape and influence the temperature of the earth's atmosphere.

Though both natural and anthropogenic factors can be held accountable for the increase in global temperature studies such as Crowley, 2000; Hengeveld et al., 2005; Odjugo 2009; Okafor and Unachukwu (2009); have observed that rise in carbon dioxide emissions and the release of other greenhouse gases from man's activities is the primary cause; especially in the past 40 years. According to Igwebuike et al (2009) mankind, through the burning of fossil fuels, forest clearing and other industrial processes, has increased the amount of carbon dioxide and other greenhouse gases since the eighteenth century.

Apart from the above, characteristics of the built-up environment is another factor which can contribute to increased atmospheric temperature. Impervious surfaces like asphalt and roofs and even pervious surfaces retain more heat than natural surface (Stone and Michael, 2001). Thus in an

environment where the natural surfaces have been replaced with artificial surfaces, temperature in such an area tend to rise because the artificial surfaces usually absorbed heat during the day and release such heat absorbed at sunset to warm the environment. Studies such as Oke, 1982, Bornstein, 1987; Oke and Johnson, 1991 have shown that rapid urbanization which brings about the replacement of natural surface with artificial surfaces, significantly modify both the micro and macro flow fields. According to Oke (1982) the effect of urbanization on local climate, especially on outdoor temperature is alarming. Such changes according to him, alter the radio-active, thermal, moisture and aerodynamic properties of the environment, causing concentration of heat in urban areas.

High atmospheric temperature could have profound effect on the ecosystem, agriculture and the rise in sea level with potentially devastating effects on coastal settlements (Jones, 1994). It is harmful to man as it can cause skin cancer and affect man's vision. Studies such as Sakamoto-Moniyama, 1977; Ellis, 1978; Agyrifo and Otwe, 2012 have associated human mortality and morbidity to hot and cold temperatures. World Health Organization (2014) observed that, every year, heat related disaster results in over 60,000 deaths, mainly in developing countries. Increase in atmospheric temperature could also influence the life cycle of pests and parasites and potentially affect the distribution pattern and incidence of disease across spatio-temporal scales (Agyrifo and Otwe, 2012).

Illnesses associated with hot environment include cerebron-spinal meningitis (CSM), heat stroke, heat exhaustion and syncope. Though some of these illnesses are not fatal, they can interfere with a person's ability to work. However, absence of immediate medical attention during the attack of heat stroke could be fatal. As the earth is getting hotter, disasters like drought, floods and environmental degradation processes such as erosion, siltation and sedimentation are getting more frequent. Scientists predicts that, even a small increase in the average temperature by about 1°C could lead to increase in more extreme weather with consequence effects on frequency and intensity of the aforementioned disasters.

Although it may be too late to completely stop global rise in temperature, making changes now could prevent it from getting worse. Thus, there is the need for a study of this nature which will not only help in explaining the long time trend in temperature, but will also aid in educating people on the dangers that can emanate from increased atmospheric temperature, especially in respect of human health and comfort. Investigation such as this which can either be on regional or local scales will be of particular interest to nations and economic groups (IPCC, 2007; Odjugo, 2010).

THE STUDY AREA

Ilorin, the capital city of Kwara State, Nigeria is the study area for this investigation (Fig. 1). The city which lies between longitudes 8° 24' and 8° 36' north of the equator and between latitudes 4° 10' east of the Greenwich meridian has humid tropical climate which is characterized by wet and dry seasons. Wet season in the town begins towards the end of March when Tropical maritime Airmass is prevalent and ends in October, often abruptly. Dry season in the town begins with onset of Tropical continental Airmass which is predominant between the months of November and February. The mean annual total rainfall for the city is 1200mm (Olaniran, 2002) and temperature in the town is uniformly high between 25°C and 28°C (Oyegun, 1983).

Urbanization process is fast replacing the natural surfaces in the town with artificial surfaces with consequent effect of increased temperature. Oyegun (1987) observed the built up area in Ilorin to have grown from 20.40sqkm in 1963 to about 58.00sqkm in 1982, while the area occupied by grass, fallowland and tall covers decrease from 35.84sqkm to 9.70sq.km within the same period. In this same vain, Aderamo (1990) observed that urban development in the city increased from 1235.8 hectares in 1963 to 4515.8 hectares in 1988 representing almost 400% growth rate within a period of 25 years. This indicates the level at which deforestation activities is taking place in the city.

METHODS

$$\frac{X - X_m}{X_m} \times 100$$

X_m is the annual mean for the period of study.

In a time series, for each element y_i , the number n_i of elements y_j preceding it ($i > j$) is calculated such that $y_i > y_j$.

$$t = \sum n_i$$

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where,

$$\frac{u(t) - (t - E(t))}{\sqrt{\text{var } t}}$$

This principle can be usefully extended to the backward series and $u_i = -u(t_i)$ can be obtained. The intersection of the $u(t)$ and $u'(t)$ curves denotes approximately the beginning of the trend. This is called the sequential version of the Mann Kendall test (Goossens and Berger, 1986).

If the computed Mann-Kendall's test value is higher than 1.96, there is significant trend in the series at 95% confidence level; however, if the value is lower than -1.96, there is no significant trend in the series at 95% confidence level. Also, results between 0.5 and 1.96 indicates increasing trend, between -0.5 and -1.96 indicates decreasing trends, and between 0.5 and -0.5 indicates no trend. The Mann-Kendall statistics was subsequently used in plotting both the significant and non-significant temperature trends while Sen Model equations were generated for predicting future atmospheric temperatures in the study area.

RESULT AND DISCUSSION

Nature of Atmospheric Temperature in the Study Area

Table 1 shows the statistical summary of mean air temperature in Ilorin for the study period. The mean temperature for the 35 year study period range between 25.84°C observed in 1999 and 27.87°C observed in 2010. Maximum temperature in the study period was however highest (30.65°C) in both year 2002 and 2003 while the minimum temperature (23.65°C) was experienced in 1999. Coefficient of variation revealed that year 2007 experienced the highest variability (7.50%) in mean monthly temperature while year 2009 experienced the least variability of 3.97%.

Table 1: Statistical Summary of Mean Temperature (°C) from 1979 to 2013 in the Study Area

Year	Mean	Std. Deviation	Range	Minimum	Maximum	CV (%)
1979	26.84	1.75	5.50	24.40	29.9	6.52
1980	26.90	1.83	5.65	24.20	29.85	6.80
1981	27.58	1.49	4.65	24.35	29.00	5.40
1982	26.41	1.38	4.70	24.30	29.00	5.22
1983	26.98	1.64	4.75	23.80	28.55	6.07
1984	26.78	1.49	4.90	25.10	30.00	5.56
1985	26.92	1.53	5.15	25.10	30.25	5.68
1986	26.54	1.72	4.50	24.60	29.10	6.48
1987	27.59	1.51	4.30	25.80	30.10	5.47
1988	26.86	1.41	4.90	24.35	29.25	5.25
1989	26.60	1.39	4.35	24.65	29.00	5.23
1990	27.21	1.57	5.50	24.30	29.80	5.77
1991	26.75	1.49	4.80	24.60	29.40	5.57
1992	26.69	1.76	5.70	24.50	30.20	6.59
1993	26.35	1.55	4.10	24.75	28.85	5.88
1994	26.56	1.75	5.55	24.50	30.05	6.59
1995	26.74	1.34	4.15	25.20	29.35	5.01
1996	27.09	1.62	4.65	24.95	29.60	5.98

1997	26.74	1.31	4.75	24.85	29.60	4.90
1998	26.63	1.60	5.05	24.60	29.65	6.01
1999	25.84	1.46	5.40	23.65	29.05	5.65
2000	27.08	2.05	6.10	25.05	29.15	6.57
2001	27.46	1.59	5.55	24.90	30.45	5.79
2002	27.21	1.71	5.55	25.10	30.65	6.28
2003	27.42	1.82	5.40	25.25	30.65	6.64
2004	27.27	1.48	4.90	25.25	30.15	5.42
2005	27.26	1.87	6.00	24.50	30.50	6.86
2006	27.02	1.82	5.65	24.50	30.15	6.74
2007	27.19	2.04	6.10	24.00	30.10	7.50
2008	27.30	1.48	4.75	24.90	29.65	5.42
2009	27.72	1.10	3.30	24.75	28.05	3.97
2010	27.87	1.50	5.05	24.45	29.50	5.38
2011	27.16	1.35	4.75	25.40	30.15	4.97
2012	27.26	1.72	5.45	24.85	30.30	6.31
2013	27.31	1.49	4.76	24.91	29.66	5.43

Source: Author's computation, 2015

Figure 2 shows the mean monthly temperature for the study area. While the highest mean temperature was recorded in the month of March, the lowest mean temperature for the study period was observed in August.

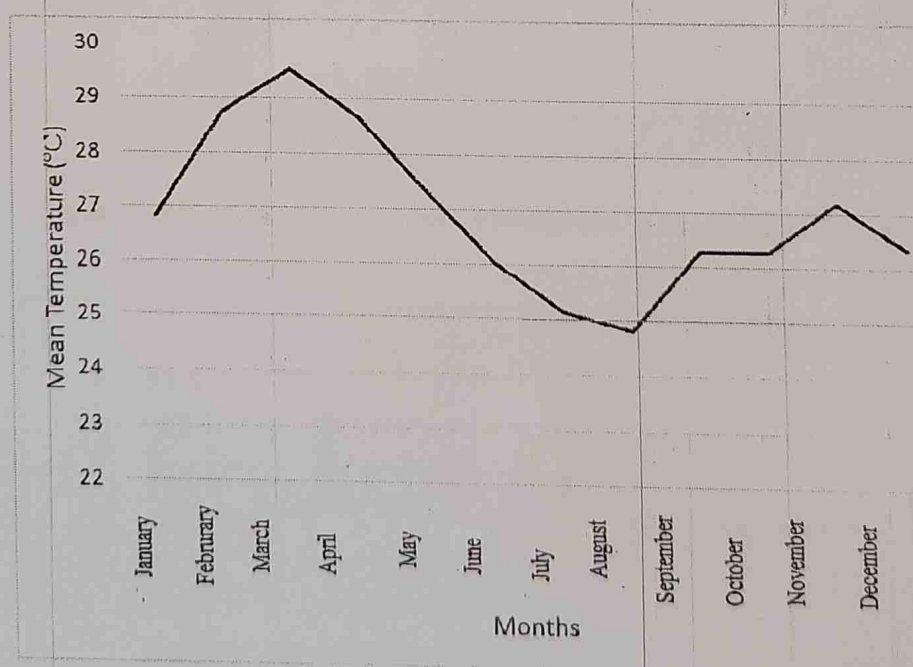


Figure 2: Mean Monthly Temperature in Ilorin (1979-2013)

Source: Author's computation, 2015

Fluctuations in Atmospheric Temperature in the Study Area

The fluctuations in atmospheric temperature in Ilorin are as presented on Figures 3 to 5. The highest and lowest minimum temperature of 23.13°C and 20.34°C were observed in 1981 and 1999 respectively with period 1979 to 1982, 2002 to 2006, 2009 to 2010 and 2012 to 2013 generally warm and period 1987 to 2002 with the exception of years 1990 and 1998 generally cool (Fig. 3). The trend line equation as depicted on the graph shows that the minimum temperature is on the increase at the rate of 0.006°C each year. However, the 0.018 R^2 value obtained shows that this rate of increase is not statistically significant. The highest and lowest maximum temperatures of 33.31°C and 31.32°C were experienced in 2009 and 1993 with decade 2001 to 2011 with the exception of year 2004 to 2006 recording higher temperature than the average value (Fig. 4).

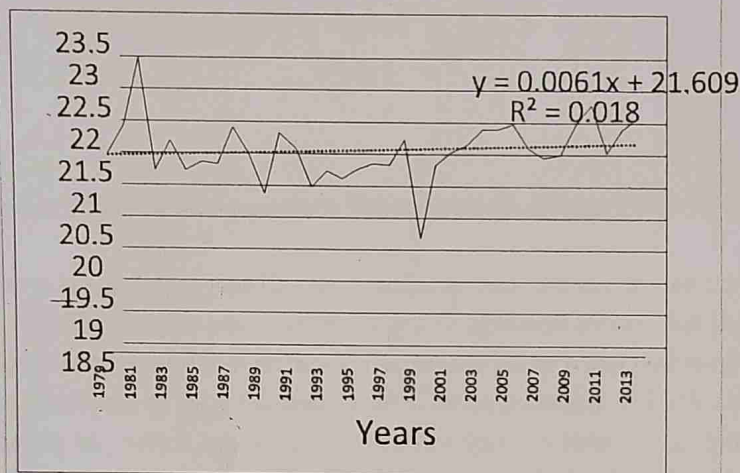


Figure 3: Minimum Temperature Fluctuation in Ilorin (1979-2013)

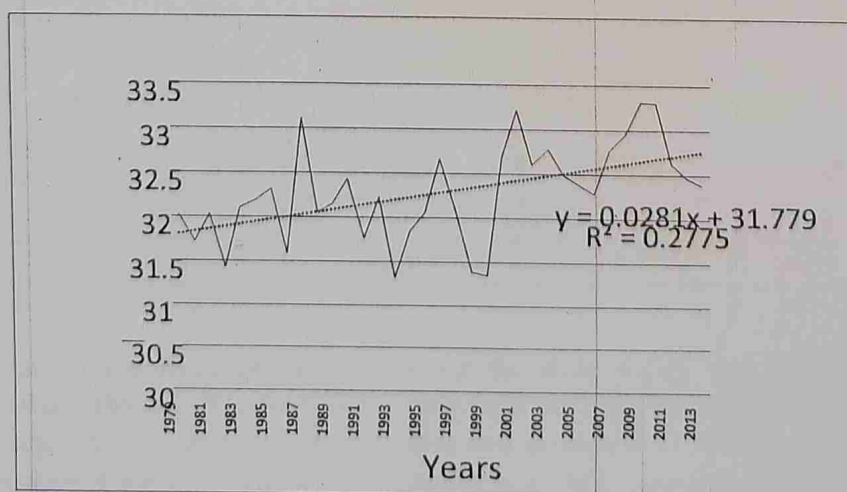


Figure 4: Maximum Temperature Fluctuation in Ilorin (1979-2013)

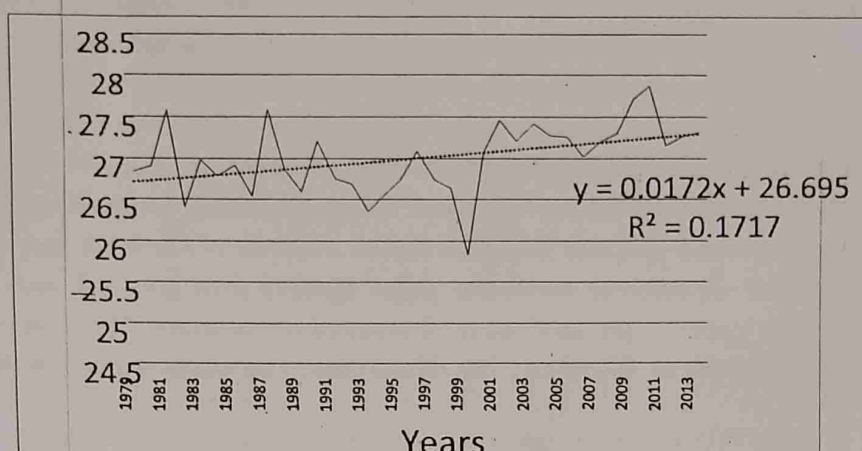


Figure 5: Mean Temperature Fluctuation in Ilorin (1979-2013)

The maximum temperature just like the minimum temperature is also on the increase, though with higher value of 0.028°C each year. An R^2 of 0.277 obtained shows that the increasing trend in maximum temperature is statistically significant. The annual mean temperature on Figure 5 shows that the highest and lowest values of 27.87°C and 25.84°C were recorded in 2010 and 1999 respectively. The trend line equation as plotted on the graphic shows that the mean temperature in the study area has been increasing by 0.017°C each year during the period of study. The R^2 of 0.171 obtained shows that this increasing trend in annual mean temperature is statistically significant. This is understandable; as can be seen on the plot, in the last 14 years of period of study, the annual mean temperature in the study area which hitherto fluctuate around 26.5°C has never fallen below 27.02°C .

Percentage Changes in Atmospheric Temperature in Ilorin

Table 2 shows the reduction analysis of minimum temperature in Ilorin for the study period.

Table 2: Percentage Change in Minimum Temperature in Ilorin (1984-2013)

Decade	Annual Mean for 10 years (X)	Annual Mean for the Period of Study (X_m)	Deviation from annual Mean ($X - X_m$)	$\frac{X - X_m}{X_m}$	% Change
1984-1993	21.54°C	21.72°C	-0.18°C	-0.008	-0.83
1994-2003	21.50°C	21.72°C	-0.22°C	-0.010	-1.01
2004-2013	21.92°C	21.72°C	0.2°C	0.009	0.92

Source: Author's computation, 2015

While the average minimum temperature for the study period was 21.72°C , minimum temperature between 1984 and 1993 decreased slightly from this mean value to 21.54°C indicating a negative percentage reduction of -0.83% from the long time average of 21.72°C . From 1994 to 2003, minimum temperature in the study area decreased further to 21.50°C , showing a negative change and a percentage reduction of -1.01%. However, from 2004 to 2013, minimum temperature increased slightly to 21.92°C from 21.72°C ; indicating a percentage change of 0.92%. From this analysis, it can be seen that minimum temperature in the third decade of this investigation (2004-2013) has been on the increase judging by the positive percentage change observed.

Just like the minimum temperature, Table 3 shows the reduction analyses for maximum temperature in the study area. The average maximum temperature for the three decade covered in this study is 32.29°C. Between 1984 and 1993, the maximum temperature in the study area decreased slightly to 31.11°C indicating a negative change and a percentage reduction of -0.56% from the long time average of 32.29°C. From 1994 to 2003, maximum temperature decreased from the average maximum of 32.29°C to 32.26°C, indicating a negative change and a percentage reduction of -0.09%. However, from 2004 to 2013, maximum temperature in the study area increased to 32.69°C indicating a positive change from the preceeding years and a percentage increase of 1.24%. This result clearly shows that though the first two decades in this particular analysis witnessed a decrease in maximum temperature from the long term average value, maximum temperature in the last decade spanning between 2004 and 2012 witnessed an increase from the long term average value. This increase will no doubt have diverse implications on human health and comfort in the study area.

Table 3: Percentage Change in Maximum Temperature in Ilorin (1984-2013)

Period	Annual Mean for 10 years (X)	Annual Mean for the Period of Study (X _m)	Deviation from annual Mean (X-X _m)	$\frac{X - X_m}{X_m}$	% Change
1984-1993	32.11°C	32.29 °C	-0.18 °C	-0.005	-0.56
1994-2003	32.26 °C	32.29 °C	-0.03 °C	-0.0009	-0.09
2004-2013	32.69 °C	32.29 °C	0.4 °C	0.0123	1.24

Source: Author's computation, 2015

Nature of Temperature Fluctuation in the Study Area

For the purpose of determining the nature and significance of temperature trend in the study area, Mann-Kendall analysis was carried out and the result obtained is presented in Table 4, while the Sen Model equations developed are presented in Table 5. The analysis reveals that the nature of minimum temperature trend in Ilorin is not significant. Though the Man-Kendall Statistic ($S = 131.00$) and the Sen Slope estimate ($Q = 0.0122$), indicates a positive trend, the Z value which was tested at 95% level of significance ($Z_{0.025}=1.96$) shows that the trend is not significant. 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 absolute value is greater than the level of significance. However, since the Z value of 1.85 which is obtained is less than the level of significance (1.96), it shows that, though the trend is increasing, the rate of increase is not significant. This implies that the positive trend demonstrated occurred by chance and not by any causative factor. Hence, it cannot be ascertained, based on the evidence at hand (1979-2013) that the minimum temperature in the study area would increase in the future.

Table 4: Summary of the Mann-Kendall Statistical Analysis

Variables	S	Z (normalized test statistic)	Q (Sen slope estimate)	Trend Significance	Nature of Trend
Minimum Temperature	131.00	1.85	0.0122	Not Significant	Positive
Maximum Temperature	234.00	3.31	0.0281	Significant	Positive
Mean Temperature	186.00	2.63	0.0176	Significant	Positive

Source: Author's computation, 2015

The analysis also reveals that the nature of maximum temperature trend in Ilorin is significant. The Man-Kendall Statistic ($S = 234.00$) and the Sen Slope estimate ($Q = 0.0281$), indicates a positive trend. The Z value was also tested at 95% for level of significance ($Z_{0.025}=1.96$). Since the obtained Z value (3.31) is greater than the level of significance (1.96), its shows that the increasing trend in maximum temperature is significant. This implies that the positive trend demonstrated did not occur by chance but results from a causative factor. Hence, it can be ascertained, based on the evidence at hand (1979-2013) that the maximum temperature would increase in the future. This rise in temperature can be attributed to the increase in the rate of urbanization in the city. Olarewaju (2009) has earlier obtained similar result for the city.

Table 5: Developed Sen Model equations

Variables	Model equations
Minimum Temperature	$Y = 0.0122X + 21.4463$
Maximum Temperature	$Y = 0.0281X + 31.8636$
Mean Temperature	$Y = 0.0176X + 26.7084$

X represents time, and Y represents the meteorological variable

Source: Author's computation, 2015

The Mann-Kendall Statistic and Sen Model equations reveals that the nature of mean temperature trend in Ilorin is significant. The Man-Kendall Statistic ($S = 186.00$) and the Sen Slope estimate ($Q = 0.0176$), indicates a positive trend. The Z value was also tested at 95% level of significance ($Z_{0.025}=1.96$). The obtained Z value of 2.63 which is greater than the level of significance (1.96) shows that the increasing trend in mean temperature is significant. This implies that the positive trend demonstrated did not occur by chance but by a causative factor. Hence, it can be ascertained, based on the evidence at hand (1979-2013) that the mean temperature would increase in the future. The plots showing the time trend of variables examined in this study are as presented on Figures 3, 4 and 5. These figures can be used in making future projection on atmospheric temperature in Ilorin.

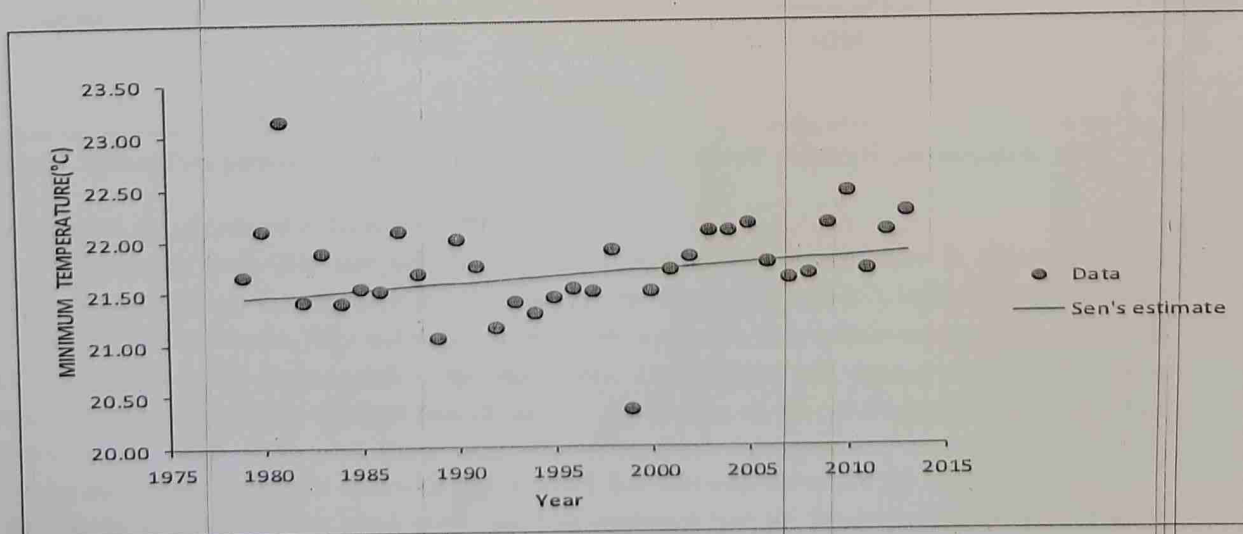


Figure 3: Ilorin Minimum Temperature Trend in Ilorin (1979-2013)

Source: Author's computation, 2015

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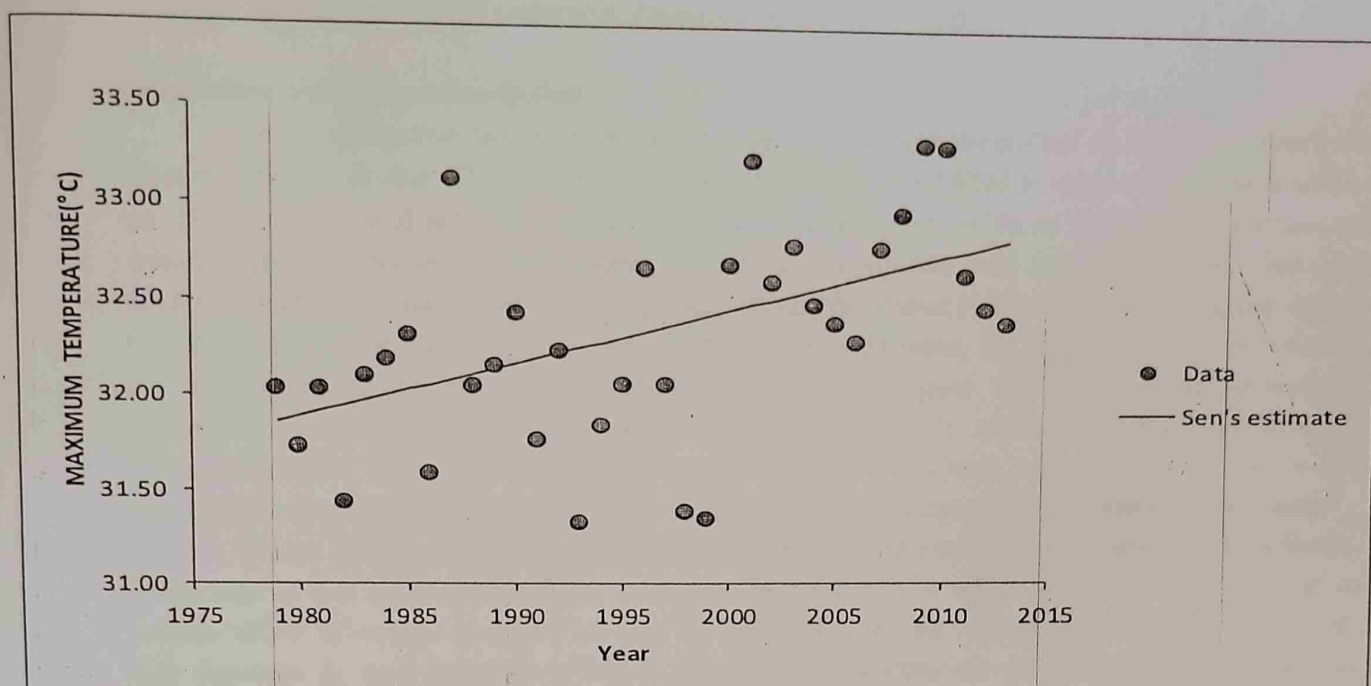


Figure 4: Maximum Temperature Trend in Ilorin (1979-2013)

Source: Author's computation, 2015

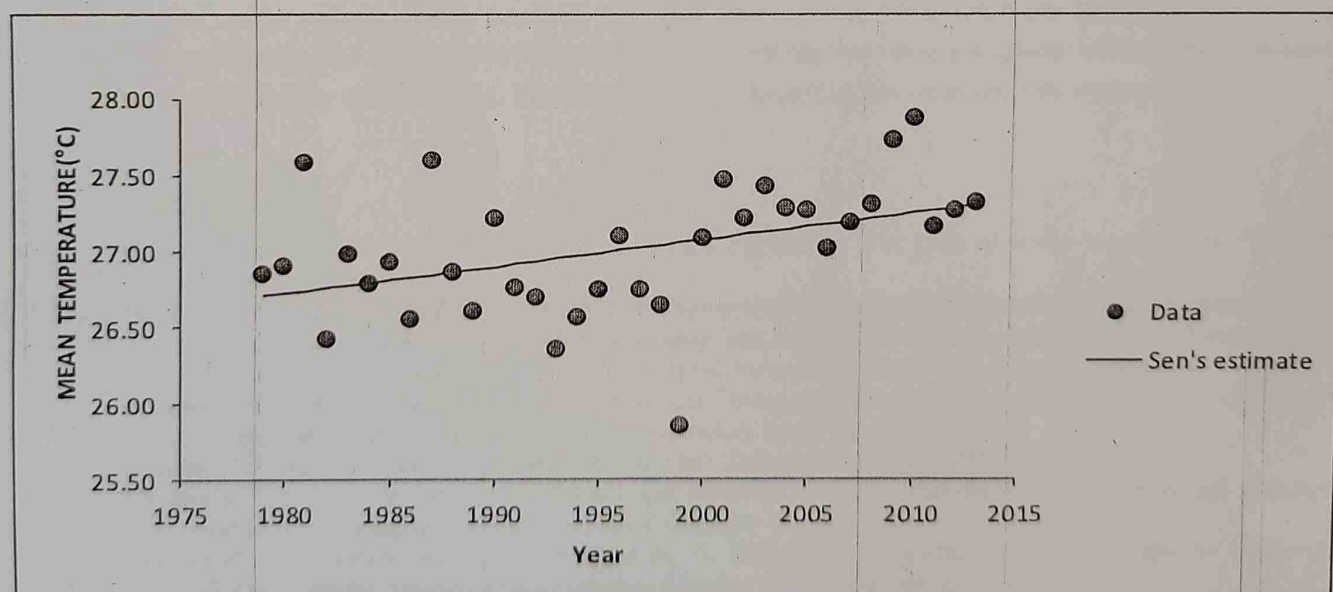


Figure 5: Mean Temperature Trend in Ilorin (1979-2013)Source: Author's computation, 2015

Management Implications of Research Findings

The results from this analysis shows that the atmospheric temperature in Ilorin is on the increase. And based on the evidence from the study, the increasing trend in maximum temperature will continue into the future. This increase will no doubt have serious implications on socio-economic activities, human health and comfort in the study area. The increase will expose residents of city to greater risk of heat disorders and heat related medical consequences such as fatigue, heat cramps, heat exhaustion and heat stroke. All these heat related medical disorders will not only have great implications on resident's level of health and comfort, but will also influence the level of productivity of the people. If the increasing trend in temperature continues into the future as predicted by models generated in the study, the demand for electricity to power such gadget as fan, air conditioner and fridge will also increase. This increase in demand will however affect the purse of the poor more especially now that the economy is moving into recession.

Conclusion and Recommendation

This investigation has revealed the evidence of rising temperature in Ilorin, the result which support global warming. This increase in temperature could be linked to rapid urbanization which has resulted in high rate of deforestation, coupled with increasing use of fossil fuels for energy generation, industrial production and transportation. Increased temperature will have both direct and indirect health impacts on residents of the study area. While the direct health impacts can come inform of heat-related mortality, dehydration, spread of infectious diseases, the indirect health impacts can be manifested inform of changes in weather, pattern ecological disturbance, and environmental degradation induce by flooding, erosion and sedimentation. In addition, increase in atmospheric temperature will influence increasing demand for cooling which will lead to a rise in energy consumption thereby aggravating the already bad situation in respect of greenhouse gas emission.

Effects of increased temperature will however be felt more in urban areas such as Ilorin, the study area in this investigation. This is because, problems induced by temperature increase in urban centers which is brought about by burning of fossil fuels will be further aggravated by "heat islands" that develops in such settlements due to the presence of concrete constructions, paved and tarred roads.

In order to ameliorate the aforementioned problems, especially in the study area, afforestation programme should be vigorously pursued. This can be carried out by dedicating some areas within the city as forest reserve. Deforestation activities and burning of fossil fuels increases the amount of carbon dioxide and other greenhouse gases thus altering the energy balance of the earth. Presence of trees will remove substantially, the amount of heat trapping gas from the atmosphere.

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