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Variation in minimum temperature in South-West Nigeria

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ABSTRACT: Natural climate cycle and human activities have contributed to an increase in the accumulation of heat-trapping "greenhouse" gases in the atmosphere thereby contributing to increase in temperature in the global climate, which results in global warming. This study focuses on the assessment of climatic variation in five locations in south-west Nigeria (Ikeja, Ibadan, Oshogbo, Ondo and Ekiti) based on the variations in minimum temperature within the period 1970-2012. SPSS was used to analyze the trend of average minimum temperature within the period 1970-2007. The 5-Year Moving Average was used to smoothen the time series and to eliminate unwanted fluctuations. Linear Regression was used to estimate the value of variable Y (average minimum temperature) corresponding to a given value of variable X (time), a one way ANOVA was used to determine the degree of variation per year in the climate element across the five locations, while Correlation Analysis was used to determine the relationship between average maximum temperature and average minimum temperature within the study period. Furthermore, the study focused on the spatial variations average minimum temperature in the study area. The result revealed that there is an upward trend in average minimum temperature as well as significant variations ($P < 0.05$) in the climate element across the five locations, the most (70 %) occurring in the year 2000. However, the variations and trends in the mean monthly and average minimum temperature do not conclusively indicate climate change in the regions under study.

Keywords. *5-Year; Climate change; Linear regression; Minimum temperature; Moving average*

INTRODUCTION

Climate change is an environmental life-threatening phenomenon that influences economic development and sustainability of humankind worldwide (Bello et al., 2012). Natural climate cycle and human activities have contributed to an increase in the accumulation of heat-trapping "greenhouse" gases in the atmosphere thereby contributing to increase in temperature in the global climate (global warming) (UNFCCC, 2007). Global warming causes unpredictable and extreme weather events impact and increasingly affect crop growth, availability of soil water, forest fires, soil erosion, droughts, floods, sea level rises with prevalent infection of diseases and pest infestations (Adejuwon, 2006; Zoellick and Robert, 2009). It will cause drought in some parts of the world and flooding in other parts and the poor countries will be hit the most because of their low capacity to cope with change (Uyigue and Agho, 2007). The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP) to provide authoritative information about climate change. Consequently, with the aid of climatic records of over 100 years, the IPCC have shown that there is a strong relationship between the emission of greenhouse gases and climate change and between rise in sea level and global temperature (Egbinola and Amobichukwu, 2013). In Nigeria, the effect of climate change is experienced in various climatic elements especially rainfall and temperature. Recent studies on climate change have focused mainly on long-term variability of temperature and rainfall, which are, however, the most important climate change indicator (Amadi and Chigbu, 2014). Variability of these important resources and their effect on agricultural productivity necessitate detailed analysis of historical rainfall and temperature data for better understanding and efficient planning (Ogedengbe and Olufayo, 2004). The study therefore assesses climatic variation within and across the cities of Ikeja, Ibadan, Oshogbo, Ondo and Ekiti, based on the variations in the temperature patterns. This was done in order to determine the temporal variations in minimum temperature patterns in the study areas by using the mean annual rainfall values for 37 years, evaluate the probability of positive trends in minimum temperature as a function of time in the study areas and also determine the nature of climatic variation in the study area and its possible effects. The hypotheses assumed for this study were that there is an upward trend in minimum temperature within the period under study and there is no significant difference ($p < 0.05$) in the minimum temperature across the five locations within the period under study. Therefore, this study was carried out in South-West Nigeria (Ikeja, Ibadan, Oshogbo, Ondo and Ekiti States) based on the variations in minimum temperature within the period 1970-2012.

MATERIALS AND METHODS

Study area

The study area is the south West geographical zone of Nigeria which lies between longitude $2^{0}31^{1}$ and $6^{0}\ 00^{1}$ East and Latitude $6^{0}\ 21^{1}$ and $8^{0}\ 37^{1}$ N (Adejuwon and Odekunle, 2004) with a total land area of 77,818 km^{2} and a projected population of 28, 767, 752 in 2002. The study area is bounded in the East by Edo and Delta states, in the North by Kwara and Kogi states, in the West by the Republic of Benin and in the south by the Gulf of Guinea. Fig. 1 shows the position of the study area in the map of Nigeria.

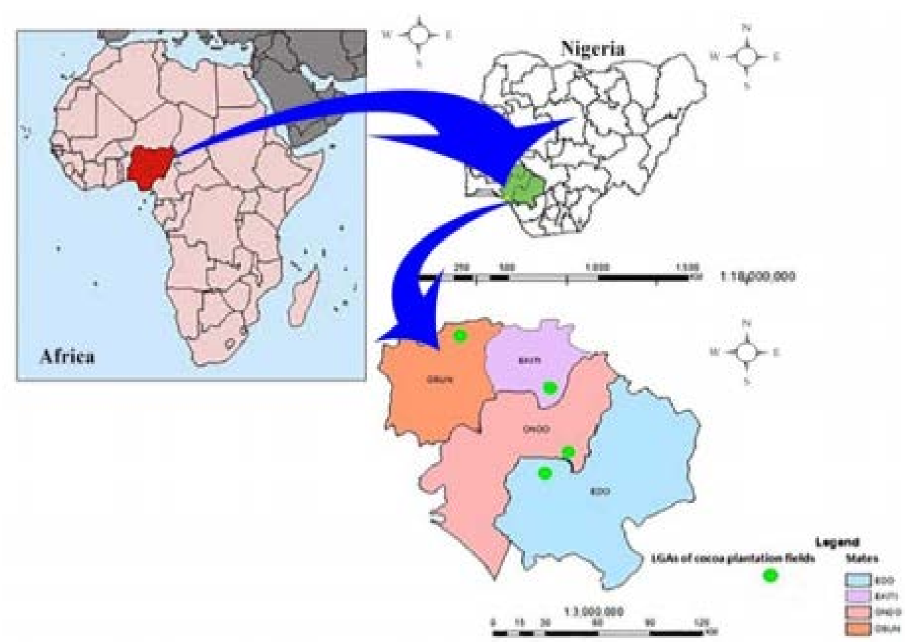

Fig. 1: Locations of the study area

Data collection and analysis

This study employed the use of secondary data obtained from the Nigerian Meteorology Agency (NIMET) weather station. The major climatic parameter used in this study was minimum temperature. In order to understand the nature of minimum temperature variations in each location, as well as the relationship that exists between these variations across the locations. Furthermore, SPSS (windows evaluation version 16.0) was used for the analysis of average minimum temperature trend over time and the Moving Average technique was used in the analyses of the data. This study employed the use of the 5-Year Moving Average, which has the characteristics of reducing the amount of variation and removing fluctuations that are not needed in the set of data. The use of moving average result in the formation of new artificial series in which each of the actual values of the original series are replaced by the mean of itself and some of the values immediately preceding it and directly following it (Ayoade, 2008). To estimate the value of a variable Y (temperature), corresponding to a given value of a variable X (i.e. time), and regression analysis was applied. This was accomplished by estimating the value of Y from a least-squares curve that fits the sample data. The resulting curve is a regression curve. The Curve Fit was used to express the relationship between temperature and rainfall in mathematical form, by determining an equation that connects the variables, after drawing the scatter diagram. From this analysis, the coefficient of determination was obtained, this is given by R^2. This helps to determine how well a linear equation describes or explains the relationship between variables. Correlation analysis was then used to explain the degree of relationship between average maximum temperature and average minimum temperature. Finally, statistical hypotheses were formulated for the purpose of rejecting or accepting them, and the maximum probability of being wrong in rejecting an hypothesis was determined by testing the level of significance (at 0.05) (Ogedengbe and Olufayo, 2004). The proportion of variation (Eta squared; %) per year across the five locations, was derived from a one way ANOVA and t-test was carried out to compare means of annual minimum temperature across the five locations during the period of study (37 years). Eta squared (%) describes the proportion of variation in the means explained by location (across the 5 locations). Abeokuta (Ogun State) was excluded in the analysis because of the limited data available for the location.

RESULTS AND DISCUSSION

Minimum temperature trend

The proportion of variation (Eta squared; %) per year across the five locations was determined with expression in equation 1, which was derived from a one way ANOVA as presented in Table 1. Table 1 also showed the result of t-test with compared means of annual minimum temperature across five locations in a period of 37 years using Eq. 1.

$$\text{Squared (\%)} = \frac{\text{Sum of squares between groups}}{\text{Total sum of squares}} \qquad (1)$$

Analysis of the minimum temperature (T – MIN) revealed that there was no significant difference in the mean minimum temperature between Ondo and Ekiti during the period under study. Conversely, the parameter varied per year across the three other locations. However, the years 1971, 1977, 1978, 1979, 1985, 2006, and 2007 recorded no significant differences in the mean minimum temperature across the five locations under study. Table 1 gave the comparison of mean T-min across five locations in a period of 37 years.

Table 1: Comparison of mean T-min across five locations in a period of 37 years

Year	Locations						
	Ikeja	Ibadan	Oshogbo	Ondo	Ekiti	Eta squared	%
1970	22.79a	22.08a,b	21.37b	22.36a,b	22.36a,b	0.19	19
1971	22.14a	21.61a	20.99a	21.77a	21.77a	0.13	13
1972	22.87a	22.15a	21.26b	22.21a	22.21a	0.37	37
1973	23.19a	22.79a,b	21.70b	22.60a,b	22.60a,b	0.21	21
1974	22.56a	21.93a,b	20.79b	21.94a,b	21.94a,b	0.25	25
1975	22.32a	21.36a,b	20.36b	21.48a,b	21.48a,b	0.16	16
1976	22.59a	21.81a,b	21.02b	21.73a,b	21.73a,b	0.22	22
1977	22.59a	22.23a	21.32a	22.38a	22.38a	0.16	16
1978	22.18a	21.90a	20.94a	21.83a	21.83a	0.11	11
1979	22.18a	22.74a	21.45a	22.07a	22.07a	0.11	11
1980	23.49a	22.60a,b	21.52b,c	21.28c	21.28c	0.46	46
1981	22.69a	22.32a,b	21.33b	22.02a,b	22.02a,b	0.15	15
1982	22.89a	22.31a,b	21.22b	22.24a,b	22.24a,b	0.23	23
1983	23.11a	22.70a	21.55a	22.36a	22.36a	0.10	10
1984	22.86a	22.39a,b	21.19b	22.13a,b	22.13a,b	0.23	23
1985	22.62a	22.56a	21.33a	22.28a	22.28a	0.10	10
1986	22.80a	22.40a,b	21.17b	21.77a,b	21.77a,b	0.20	20
1987	23.79a	23.26a	21.83b	22.77a,b	22.77a,b	0.34	34
1988	23.40a	22.78a,b	21.88b	22.39a,b	22.39a,b	0.22	22
1989	23.02a	22.15a,b	20.63b	22.01a,b	22.01a,b	0.20	20
1990	23.45a	22.88a	21.82b	22.75a,b	22.75a,b	0.30	30
1991	23.66a	22.74a,b	21.69b	22.38b,c	22.38b,c	0.32	32
1992	23.63a	22.26a,b,c	20.43b	21.93b,c	21.93b,c	0.38	38
1993	23.39a	22.28a,c	20.44b	22.13c	22.13c	0.47	47
1994	23.23a	22.61a,b	21.18b	22.13a,b	22.13a,b	0.23	23
1995	23.02a	22.71a	21.12b	22.36a,b	22.36a,b	0.28	28
1996	23.91a	22.87a,c	21.07b	22.52c	22.52c	0.52	52
1997	23.73a	21.91b	19.14c	22.43a,b	22.43a,b	0.65	65
1998	24.42a	23.28a	20.36b	22.92a	22.92a	0.43	43
1999	23.83a	22.54b	20.22c	22.38b	22.38b	0.70	70
2000	24.11a	22.71b	20.70c	22.36b	22.36b	0.57	57
2001	24.02a	22.84a,b	21.69b	22.34b,c	2.34b,c	0.40	40
2002	24.10a	23.27a,b,c	21.58b	22.22b,c	22.22b,c	0.33	33
2003	24.18a	22.90b	22.03b	22.69b	22.69b	0.35	35
2004	23.97a	23.02a,b,c	21.68b	22.76b,c	22.76b,c	0.41	41
2005	24.23a	23.68a,b	21.94b	22.85a,b	22.85a,b	0.22	22
2006	22.42a	21.24a	21.83a	22.85a	22.85a	0.18	18
2007	22.12a	21.37a	22.39a	21.60a	21.60a	0.13	13

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p< 0.05$ in the two-sided test of equality for column means

Analysis of Yearly Variations in the Minimum Temperature (T – MIN)

With the aid of a five-year moving average approach method, Fig. 2 revealed an initial decline in the variance of the mean annual minimum temperature across the locations between 1975 and 1979, followed by a slight increase in variance in 1980 which was uniform until 1984. Another decline in variance was observed in 1985, which was then followed by a sudden peak in variance the following year, which was maintained up to 1999, which showed the maximum proportion of variation (70%) in mean minimum temperature across the five locations. Similarly, the trend was followed by a sudden decline in variance, which lasted till the end of the study period. Table 1 also showed that 2000, 1997 and 1999 had the most significant variation of 57%, 65% and 70% respectively during the study period.

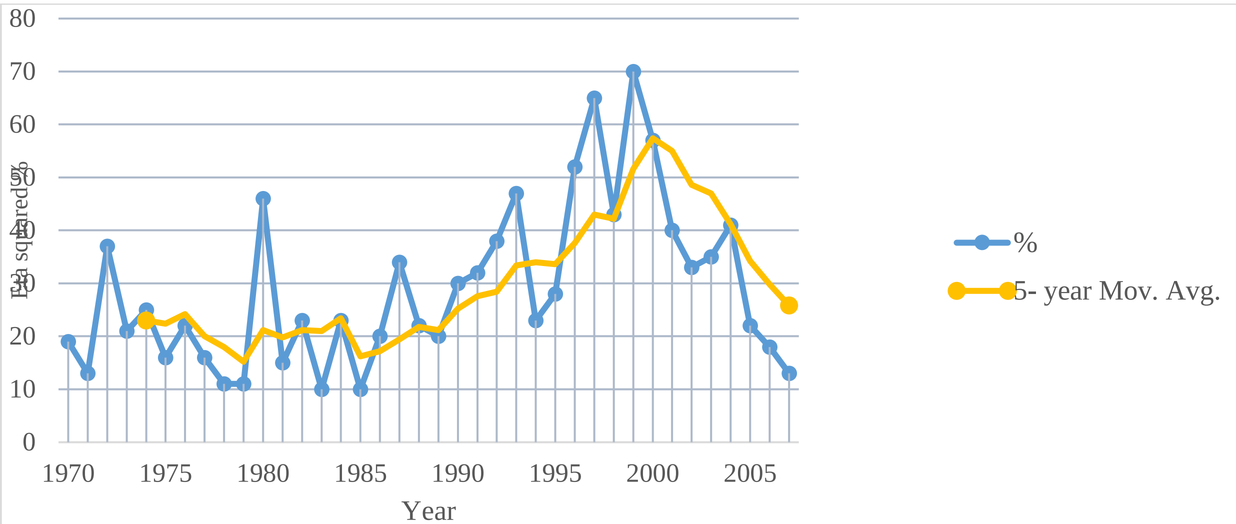

Fig. 2: Proportion of variation in the T – MIN during the study period

Minimum Temperature Trend in each Location for the study period

The relationship between mean annual minimum temperature (X) and the period under study (38 years) (Y) was expressed with a curve fit. Linear regression analysis was carried out on the variables in order to determine the predicting power of the independent variable (Y), using Eq. 2.

$$Y = b_0 + b_1 X \qquad (2)$$

Where, X = mean annual minimum temperature

Y = Years;

b_0= Intercept/Constant; which is part of the rainfall not due to time;

b_1 = Slope; which is a magnitude of change in T-MIN due to a unit change in time; and

R^2= Correlation coefficient; it describes how well the equation describes the data

Minimum Temperature Trend in Ikeja (Lagos State) for the study period

Similarly, a 5-year moving average was employed in order to smooth out short-term fluctuations and highlight longer-term trends. Fig. 3 showed the T-Min distribution in Ikeja (Lagos State) for the study period. There was a decline in the T-MIN between 1974 and 1978, which was followed by an unsteady rise between 1979 and 2005, with declines in the years 1991, 2000, 2002 and 2005. The lowest value for T-MIN was recorded in 2007 while the highest was in 1998.

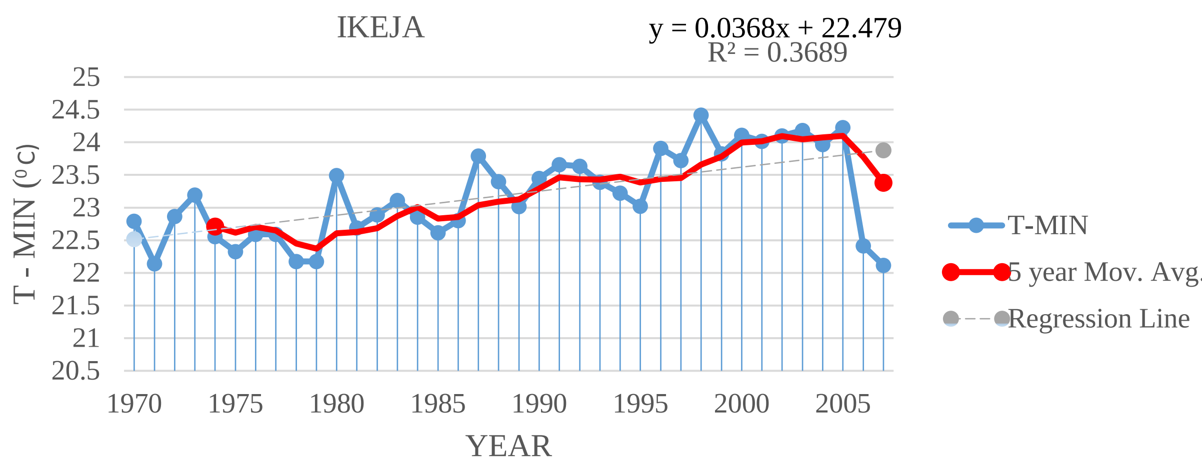

Fig. 3: T-Min distribution in Ikeja (Lagos State) for the study period

Minimum temperature trend in Ibadan (Oyo State) for the study period

Fig. 4 depicts the T-Min distribution in Ibadan (Oyo State) for the study period. An initial decline in the T-MIN was observed between 1974 and 1978, which was followed by a steady rise between 1978 and 1991. Another decline was observed between 1991 and 199 followed by a steady rise to 2005 where it declines until the end of the study period. The least mean annual minimum temperature was recorded in 2006 while the highest was recorded in 2005.

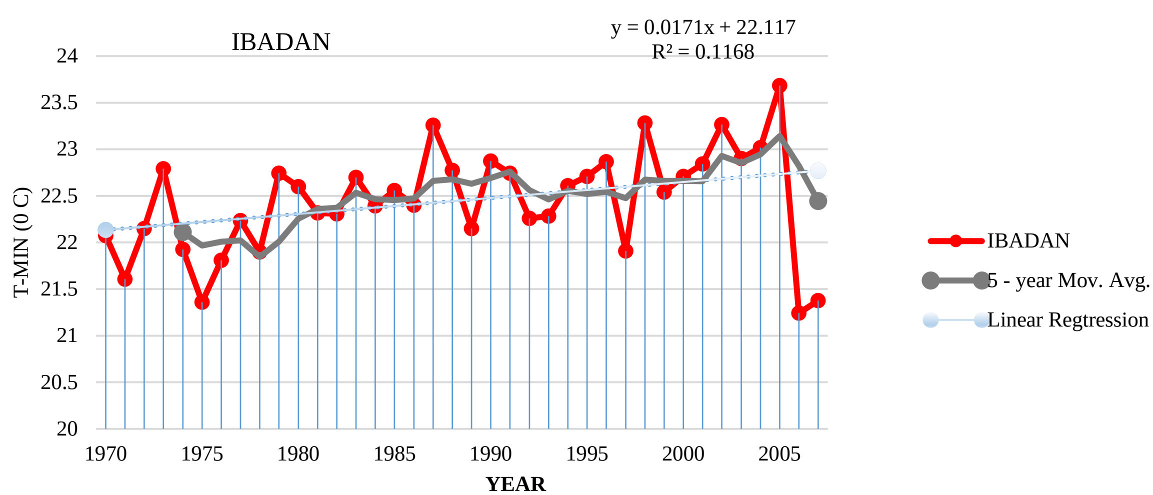

Fig. 4: T-Min distribution in Ibadan (Oyo State) for the study period

Minimum Temperature Trend in Oshogbo (Osun State) for the study period

Similarly, an initial decline in the T-MIN was observed between 1974 and 1978, which was followed by an unsteady rise between 1978 and 1991 because of a significant decline in T-MIN in 1986. This was followed by another decline in T-MIN between 1991 and 2000 and a subsequent rise in T-MIN from 2000 until the end of the study period. The least mean annual minimum temperature was recorded in 1997 while the highest was recorded in 2005 as displayed in Fig. 5.

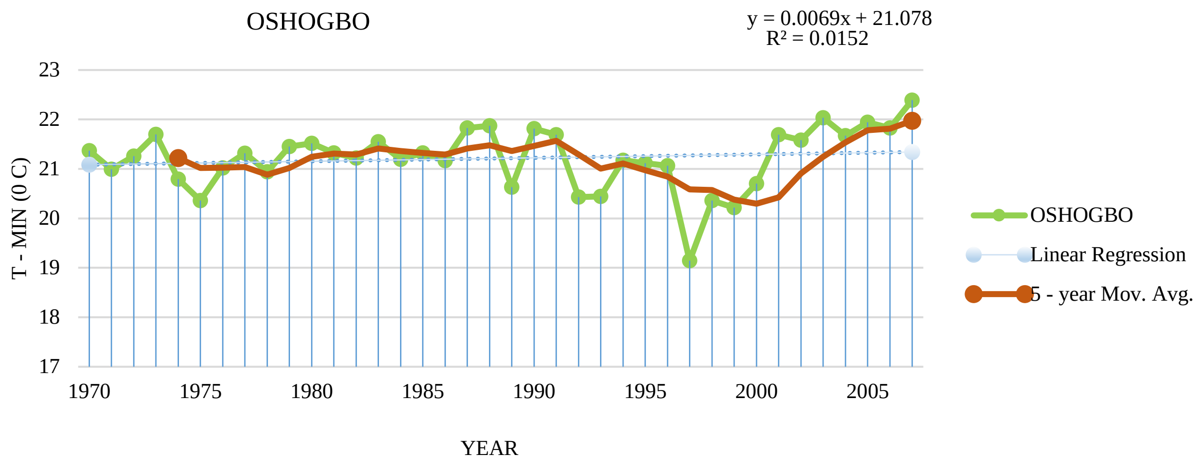

Fig. 5: T-Min distribution in Oshogbo (Osun State) for the study period

Minimum temperature trend in Akure (Ondo State) and Ado-Ekiti (Ekiti State) for the study period

The results of the analyses of the mean annual minimum temperature (T-MIN) data for Ado-Ekiti and Akure were the same. Figs 6 and 7 showed the T-Min distribution in Akure (Ondo State) and Ado- Ekiti (Ekiti State) for the study period. This is attributable to the perfect correlation ($p < 0.05$) between them (Table 2). It is characterized by an unsteady rise in T-MIN between three peaks; 1974, 1991 and 2006. The unsteadiness is because of significant declines between; 1974-1980, 1991-1995 and 1999-2003. The least mean annual minimum temperature was recorded in 1980 while the highest was recorded in 1998.

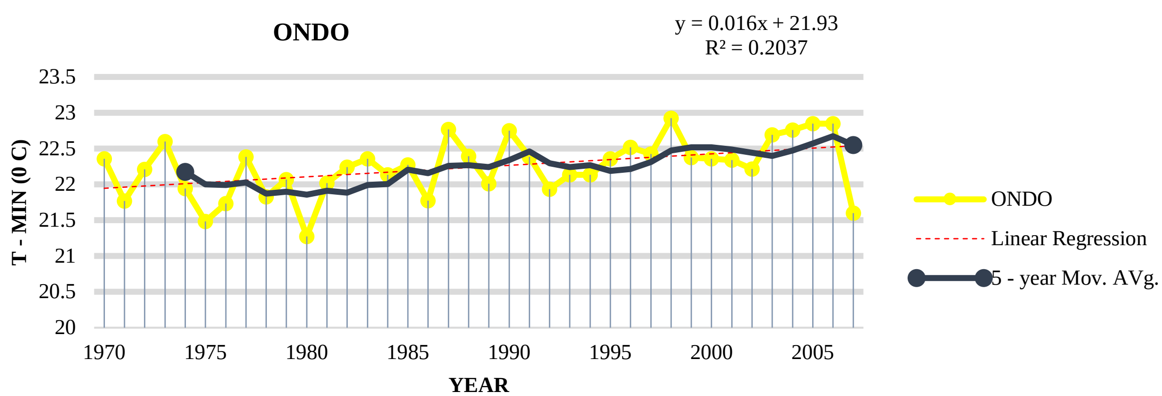

Fig. 6: T-Min distribution in Akure (Ondo State) for the study period

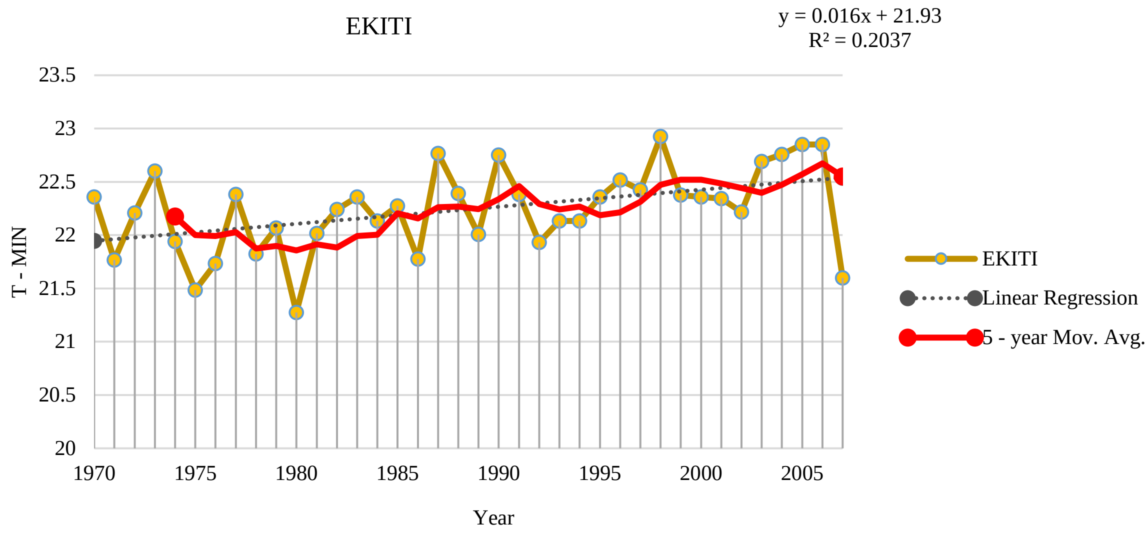

Fig. 7: T-Min distribution in Ado- Ekiti (Ekiti State) for the study period

Correlation Analysis of T-MIN and T-MAX across the Five Locations under Study

The result of the correlation analysis revealed that Ondo and Ekiti were perfectly correlated ($p < 0.01$) for both T-MIN and T-MAX. Ikeja showed a positive significant ($p < 0.01$) correlation ($r = 0.77$) with Ibadan, Ondo and Ekiti ($r = 0.57$) for T-MIN. While for T-MAX, it showed a positive significant ($p < 0.01$) correlation ($r = 0.67$) with Ibadan, Oshogbo ($r = 0.68$), Ondo and Ekiti ($r = 0.82$). Similarly, Ibadan showed a positive significant ($p < 0.01$) correlation ($r = 0.77$) with Ikeja, Ondo and Ekiti ($r = 0.57$) for T-MIN. While for T-MAX, it showed a positive significant ($p < 0.01$) correlation ($r = 0.67$) with Ikeja, Oshogbo ($r = 0.63$), Ondo and Ekiti ($r = 0.85$). Oshogbo showed a positive significant ($p < 0.01$) correlation with Ondo and Ekiti ($r = 0.79$) for T-MAX only.

Table 2: Correlation analysis of T-MIN and T-MAX

		IKEJA	IBADAN	OSHOGBO	ONDO	EKITI
T-MIN	IKEJA	1				
	IBADAN	.77**	1			
	OSHOGBO	-0.046	0.276	1		
	ONDO	.57**	.570**	0.193	1	
	EKITI	.57**	.570**	0.193	1.000**	1
T-MAX	IKEJA	1				
	IBADAN	.67**	1			
	OSHOGBO	.68**	.63**	1		
	ONDO	.82**	.85**	.79**	1	
	EKITI	.82**	.85**	.79**	1.000**	1

**Correlation is significant at the 0.01 level (2-tailed).

Monthly minimum temperature pattern

The monthly minimum temperature pattern (Fig. 8) indicates a rise in the average minimum temperature from January to March (highest); 24.5^0 C, 23.8^0 C, 22.7^0 C, 23.4^0 C and 23.4^0 C in Ikeja, Ibadan, Oshogbo, Ondo and Ekiti respectively. This was followed by a decline in the average minimum temperature from March to August (lowest); 22.3^0 C, 21.5^0 C, 21.1^0 C, 21.5^0 C and 21.5^0 C across the five locations and a slight rise till November followed by a final decline in the average minimum temperature in December. Fig. 9 depicts the geo-spatial variation of minimum temperature in the study area for 2007.

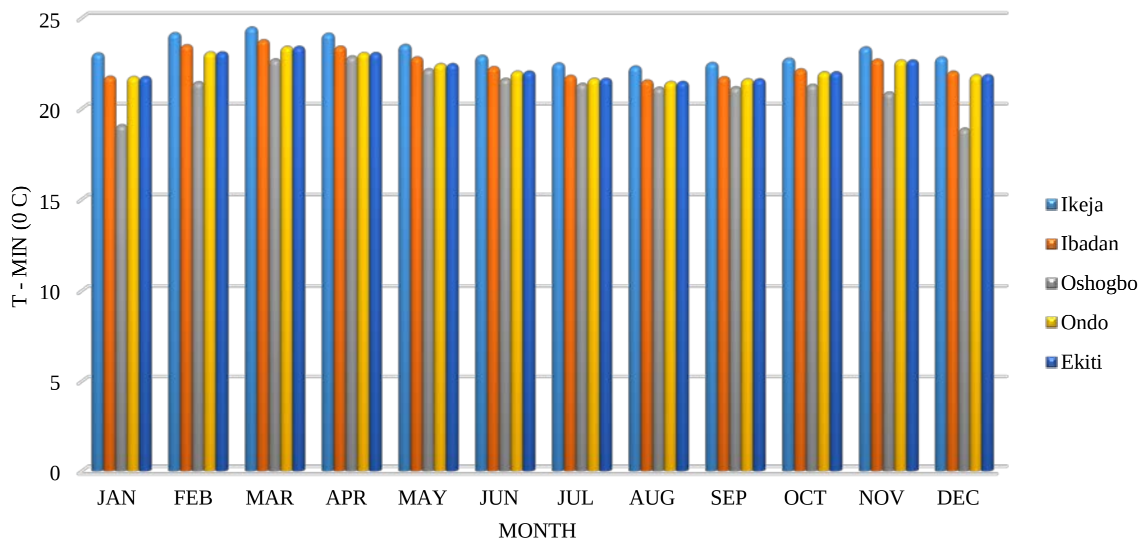

Fig. 8: Average monthly minimum temperature over the study period

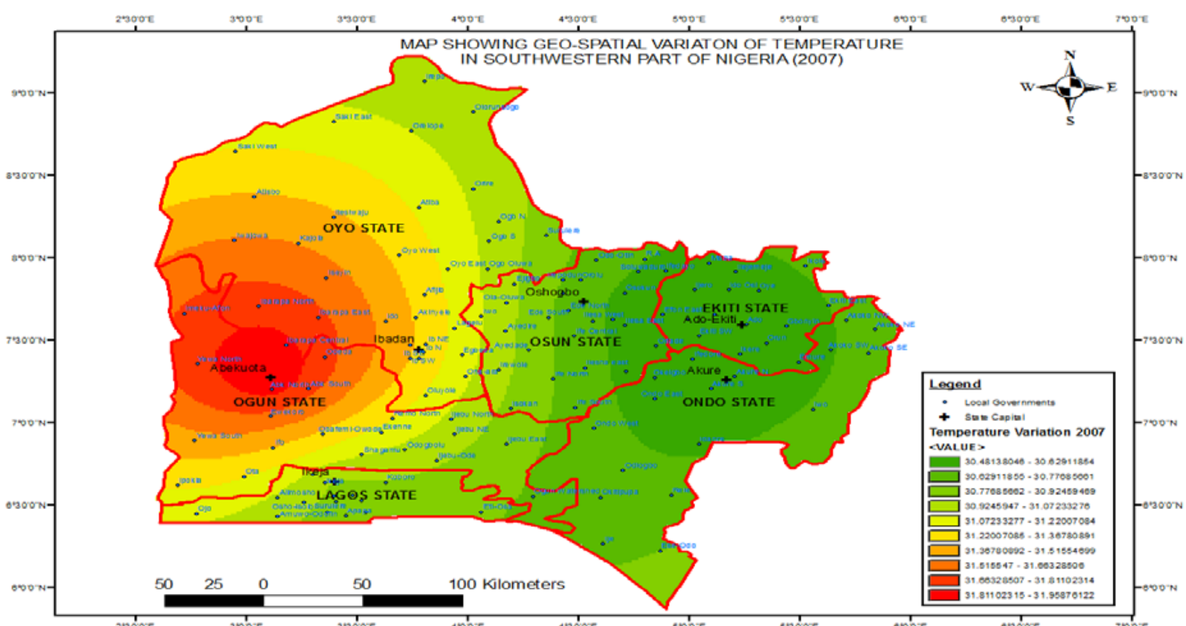

Fig. 9: Geo-spatial variation of minimum temperature in the study area for 2007

CONCLUSION

The results of this study showed that the variations and trends in the mean monthly and average minimum temperature do not conclusively indicate climate change in the regions under study. However, one cannot underestimate the possibility of climate change in the study area and possible human impact on the 'local' climate. In addition, the use of other climate elements such as rainfall, relative humidity data of a much longer period or duration (e.g. 100 years, which is not available in the region) and spatial data should be used to provide more accurate information on climatic change in the areas. However, it will be correct to state that the average minimum temperature within and across the five regions under study was characterized by considerable variations.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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