INDICATORS OF CLIMATE CHANGE IN OYO NIGERIA

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Abstract: This work identified, analyzed and interpreted some statistical indicators of climate change in Oyo, Nigeria. Data on daily rainfall amount (mm), maximum air temperature (^oC) and maximum relative humidity (%) for Oyo metropolis was sourced from the International Institute of Tropical Agriculture (IITA), Ibadan and used in the study. The data span a period of 34 years (1977-2010). The statistical indicators indentified include; significant difference in the distribution of wet and dry days for each month over the period, increasing number of dry days and decreasing number of wet days over the period. Additional indicators identified include; significant difference in the distribution of warmer and colder maximum air temperature for each month over the period, increasing number of warmer days and decreasing number of colder days over the period. The last set of indicators include significant difference in the distribution of high and low relative humidity for each month over the period, increasing number of high relative humidity days and decreasing number of low relative humidity days over the period. One of the statistical methods employed in analyzing the indicators include; Kruskal-Wallis one-way analysis of variance test for ascertaining significant differences in the distribution of wet and dry days, distribution of warmer and colder maximum air temperature and the distribution of high and low relative humidity for each month over the period. The linear trend analysis was another method used in identifying the presence of increasing or decreasing trend in the distribution of the number dry and wet days, the number of warmer and colder maximum air temperature days and in the distribution of high and low relative humidity days. The study concludes that with these indicators, climate change is fast setting into Oyo metropolis, Nigeria and finally recommends that the best way to communicate the presence of climate change is through the use of indicators.

Keywords: Indicators, rainfall, maximum air temperature & relative humidity, climate change

Introduction

The Variation of Solar radiation and exchange of radiation between the ocean and atmosphere of a place affect the climate system, resulting to fluctuations in the climatic variables. Climate variability has great effect on the society, future generations, the economy, biological community and agriculture (Capparelli *et al.*, 2015). Hence, the need for studying the data generated by the climatic system in order to assess climate change. Research as shown that human activities such as the burning of coal formed from the remains of animals and plants, clearing of forest and production of cement, have greatly intensified nature's green house effect, causing global warming (Le Treut, 2007). This green house effect refers to increase in the concentration of green house gases; Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O) which is responsible for the depletion of the ozone layer causing global warming.

Two major green house gases, Methane (CH_4) and Nitrous oxide (N_2O) have been on the increase since 1970 (Steele *et al.*, 1996). Increasing parallel trends of CO_2 isotope in the atmosphere has also been observed (Francey and Farquhar, 1982). In addition, Carbon dioxide (CO_2) has been on exponential increase since the industrial era (Neftel *et al.*, 1985; Etheridge *et al*., 1996; IPCC, 2001a). Furthermore, the equations connecting greenhouse gases and climate change revealed an increase in the average global temperature of 2°C whenever the concentration of atmospheric CO_2 is doubled (Callendar, 1938). From the foregoing, it can be inferred that increase in the concentration of greenhouse gases in an area can be used as warning signals of the increased chances of climate change while increase in air temperature, changes in the distribution pattern of snow and rainfall, increase and decrease in the frequency and magnitude of river flood, drought, and unusual climate events – like heavy rainstorms are strong indicators that establish the fact that climate change is fast setting in (US Environmental Protection Agency, 2016).

Our argument is that, while it will not be environmentally safe to use some of these indicators namely; magnitude of river flood, drought, and heavy rainstorms besides the outbreak of epidemics as either warning signals or strong indicators of climate change, neither would the measurements of the concentration of green house gases in the atmosphere be always available for use in this regard. We emphasize that, the use of climatic variable based – indicators such as those used in this research will minimize the aforementioned risks. This is because measurements of climatic variables are readily available and easily analyzed for use as warning signals of climate change.

In this research, the indicators of climate change indentified include; significant difference in the distribution of wet and dry days for each month over the period, increasing number of dry days and decreasing number of wet days over the period. Additional indicators include; significant difference in the distribution of warmer and colder air temperature for each month over the period, increasing number of warmer days and decreasing number of colder days over the period. The last set of indicators include significant difference in the distribution of high and low relative humidity for each month over the period, increasing number of high relative humidity days and decreasing number of low relative humidity days over the period.

Materials and Methods

This section focuses on the data description and transformation made as well as the statistical methods employed.

Data description and transformation

The data employed in this work is a 34 year data (1977-2010) of daily rainfall (mm), maximum relative – humidity (%) and maximum air temperature (^oC) for Oyo, Nigeria. The data is sourced from the International Institution for Tropical Agriculture (IITA) in Ibadan, Nigeria. We want to note in this work that for ease in communication, maximum air temperature and maximum relative humidity are simply referred to as air temperature and relative humidity, respectively.

The raw data on rainfall which gives the daily precipitation amount over the period was first transformed into a sequence of binary events: wet day or dry day as follows. For any K^{th} day, a random variable X_k is defined to represent this event with the realization; 1 if the daily precipitation amount is greater than or equal to 0.85 mm or with realization 0 if the daily precipitation amount is less than 0.85 mm (Garbutt *et al.*, 1981). The raw data which gives the daily air temperature over the period was also transformed into a sequence of binary events: the positive and negative anomaly as follows. For any K^{th} day, a random variable X_k is defined to represent this event with the realization; 0 if the daily air temperature (T) is less than the monthly average ($\bar{T}$) or with realization 1 if the air daily temperature (T) is greater than the monthly average ($\bar{T}$). This is done for the maximum air temperature data sets for each month of the year. The random variable X_k is therefore defined as;

$$X_k = \begin{cases} 0, if\ T < \bar{T} (\text{negative anomaly or colder air temperature}). \\ 1, if\ T > \bar{T} (\text{positive anomaly or warmer air temperature}). \end{cases}$$

Where $k = 1, 2, \ldots, n$ (days) and air temperature anomaly $= T - \bar{T}$ (Joseph and Rufus, 2003)

The raw data on daily maximum relative humidity was transformed in the same manner as that of the maximum air temperature with the random variable X_k defined to represent event with the realization; 0 if the daily relative humidity is less than the monthly average or with realization 1 if the daily relative humidity is greater than the monthly average. This is done for the maximum relative humidity data sets for each month of the year. The Microsoft Excel Package (2007) was used to implement these transformations for accuracy and computational ease.

Methods of analysis

Kruskal-Wallis (H) test

The Kruskal-Wallis (H) test for One-Way Analysis of Variance was employed in comparing each of the distribution of wet and dry days, high and low relative humidity and that of warmer and colder air temperature for each month of the year in order to ascertain whether there is a significant difference over the period (1977-2010). The rationale is that all things being equal (such as no effect of climate change), the distribution should not differ significantly.

Kruskal-Wallis test is a non-parametric test based on the statistic computed from ranks determined for pooled sample observations. It is an alternative to the parametric one-way analysis of variance test with independent sample. It was considered appropriate for use in this study because it supports the use of ordinal data (see data transformation in section 2.1) and does not require the assumptions underlying the use of the parametric one-way analysis of variance test. The test rank all the observations in the entire sample from smallest to largest, and then calculate the sum of the rank of the observations in each sample. It compares three or more ranks (mean rank). In this test, each sample size must be 5 or more and the distribution of H can be approximated by the chi-square distribution with k-1 degree of freedom and for a given level of significance.

Mathematically;

The Kruskal-Wallis test statistic is defined by:

$$H = \frac{12}{n(n+1)} \left[\sum_{i=0}^{n} \frac{R_i^2}{n_i} \right] - 3(n+1) \quad \ldots\ldots\ldots 1$$

Where: H = Kruskal-Wallis test statistic

n = total number of observation in all groups combined

k = number of groups

n_i = number of observation in the i^{th} group

R_i = sums of ranks in the i^{th} group (Oladugba *et al.*, 2014)

The Statistical Package for Social Science (SPSS) version 21 was used to implement the Kruskal-Wallis test.

Linear trend analysis

Linear trend lines were fitted into data extracts of number of wet days, number of high relative humidity and number of warmer air temperature days. Furthermore, linear trend lines were also fitted into data extracts of number of dry days, number of low relative humidity and number of colder air temperature days. This is to help ascertain whether there is an increasing or decreasing trend, as well as the rate of the increase or decrease using the sign and magnitude of the gradient (slope), respectively.

The general equation of the linear trend line is given as:

$$Y = MX + C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where, $Y =$ the number wet or dry days, number high or low relative humidity or number of number of warmer or colder air temperature days. $M =$ gradient or slope and $C =$ the intercept on the Y-axis.

Result and Discussion

This section presents the result of the study and the discussion.

The distribution of wet and dry days show significant difference in the months of February, March, July August, September, October, November and December, p_values < 0.05. January, April, May and June do not show significant difference, P_values > 0.05. The distributions of high and low relative humidity days as well as that of warmer and colder air temperature days show significant difference in all the months of the year, p_values < 0.05 (Tables 1 and 2). We argue that if there is no effect of climate change, there should be no significant difference in these distributions for the same months over the period. From the stated result above, we can infer that climate change has set into Oyo Metropolis and it should be checked.

The frequency of wet days and high relative humidity days over the period is decreasing with slope values of -0.136 and -0.614, respectively while the frequency of warmer days is increasing with a slope of 2.724 as shown in Fig. 1. The frequency of colder days is decreasing with a slope value of -2.724 while the frequency of dry days and low relative humidity is on the increase with slope values of 0.136 and 0.614, respectively (Fig. 2). Observe in this work that the slope values for the number of wet days and number of dry days are the same but opposite in sign. That of the number of high relative humidity and low relative humidity days is also the same and opposite in sign. In the same vein, that of warmer and colder air temperature days is the same and opposite in sign. These indicate equal rates of change but in reverse direction (increase or decrease). From the stated result, it can be inferred that climate change is fast setting into Oyo metropolis with evidence of environmental dryness and heat.

Table 1: Summary of KrusKal-Wallis (H) one way analysis of variance test

Months	Rainfall			Maximum Air Temperature			Maximum Relative Humidity		
	Kruskal-Wallis Chi-square Statistic	P_Value	Remark	Kruskal-Wallis Chi-square Statistic	P_Value	Remark	Kruskal-Wallis Chi-square Statistic	P_Value	Remark
January	37.108	0.285	Not significant	112.21	0.000	Significant	340.213	0.000	Significant
February	59.881	0.003	Significant	191.912	0.000	Significant	242.384	0.000	Significant
March	57.217	0.006	Significant	307.06	0.000	Significant	483.321	0.000	Significant
April	39.249	0.210	Not Significant	173.81	0.000	Significant	426.098	0.000	Significant
May	36.149	0.324	Not Significant	126.111	0.000	Significant	546.222	0.000	Significant
June	28.307	0.700	Not Significant	111.391	0.000	Significant	604.233	0.000	Significant
July	56.197	0.007	Significant	134.871	0.000	Significant	575.382	0.000	Significant
August	83.072	0.000	Significant	153.736	0.000	Significant	612.983	0.000	Significant
September	61.214	0.002	Significant	151.51	0.000	Significant	512.527	0.000	Significant
October	61.362	0.002	Significant	122.14	0.000	Significant	527.814	0.000	Significant
November	91.326	0.000	Significant	308.033	0.000	Significant	486.193	0.000	Significant
December	48.44	0.040	Significant	331.153	0.000	Significant	339.006	0.000	Significant

$\alpha = 0.05$

Table 2: Frequency of dry, wet, colder, warmer, low relative humidity and high relative humidity days

	Rainfall		Temperature		Relative Humidity	
Year	Dry Days	Wet Days	colder Days	warmer Days	LowRel.Hum. Days	High Rel.Hum. Days
1977	279	86	215	150	122	243
1978	253	112	275	90	87	278
1979	255	110	215	150	108	257
1980	250	115	248	117	123	242
1981	274	91	204	161	233	132
1982	261	104	193	172	93	272
1983	297	68	161	204	108	257
1984	269	96	136	229	136	229
1985	266	99	240	125	240	125
1986	281	84	251	114	213	152
1987	267	98	126	239	162	203
1988	275	90	224	141	141	224
1989	271	94	212	153	105	260
1990	256	109	147	218	87	278
1991	268	97	145	220	71	294
1992	274	91	156	209	181	184
1993	239	126	120	245	201	164
1994	272	93	139	226	268	97
1995	268	97	108	257	153	212
1996	266	99	136	229	39	326
1997	270	95	146	219	29	336
1998	287	78	84	281	38	327
1999	242	123	130	235	11	354
2000	281	84	95	270	21	344
2001	282	83	106	259	12	353
2002	266	99	145	220	117	248
2003	270	95	155	210	146	219
2004	280	85	166	199	82	283
2005	276	89	173	192	94	271
2006	281	84	176	189	103	262
2007	272	93	140	225	44	321
2008	269	96	160	205	316	49
2009	272	93	192	173	320	45
2010	250	115	109	256	305	60

Rel. Hum. = Relative humidity

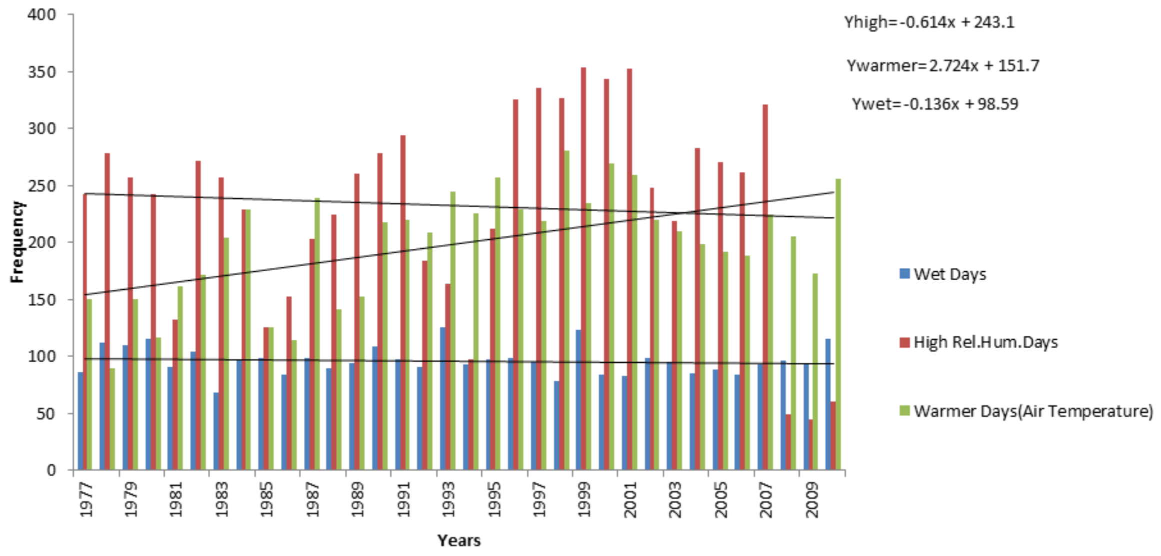

Fig. 1: Distribution of wet, high relative humidity and warmer days over the years

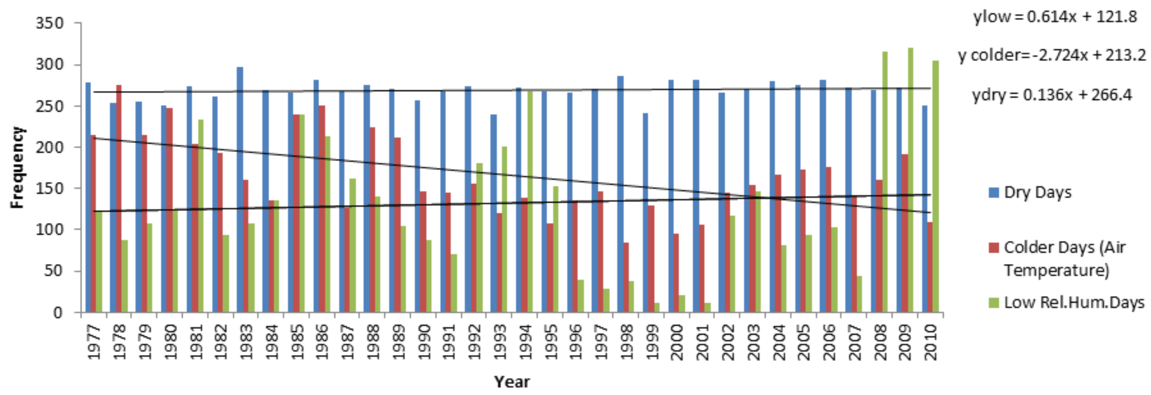

Fig. 2: Distribution of dry, low relative humidity and colder days over the years

Study implications

The number of wets days and high relative humidity days is reducing in Oyo metropolis which could eventually lead to drought. Drought affect crops, animals, supply of water, production of energy, and the ecosystem negatively. Stream flow is also affected due to changes in rainfall pattern and many plants and animals depend on it for survival. The fact that the number of warmer days is ascertained to be on the increase is a good ground for the outbreak of certain high temperature related epidemics and increased death rate on the long run (US Environmental Protection Agency, 2016). Beard *et al.* (2016) affirmed this by stating that mosquito development, bite rates and disease incubation increases as temperatures gets warmer. Oyo metropolis is under the threat of these risks if the climate is left unchecked.

Conclusion

The following conclusions were drawn from the study;

(1) The distribution of wet and dry days differs significantly in most months of the year.

(2) The number of wet days is decreasing while the number of dry days is increasing at the same rate over the period.

(3) The distribution of warmer and colder air temperature days differ significantly in all the months of the year.

(4) The number of warmer days is increasing while the number of colder days is decreasing at the same rate over the period.

(5) The distribution of low relative humidity and high relative humidity days differ significantly in all the months of the year.

(6) The number of low relative humidity days is increasing while the number of high relative humidity days is decreasing at the same rate over the period.

(7) An effective way of communicating the presence of climate change is through the use of indicators such as those identified in this study.

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