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Evaluation of Carbon Dioxide Emissions and Temperature Variation in Nigerian Cities

S. I. Efe[1*]

[1]*Department of Geography and Regional Planning, Delta State University, Abraka, Nigeria.*

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The study assesses the effects of CO_2 emissions on temperature in Nigeria. To actualize this, CO_2 and temperature data were generated from field survey of Nigerian cities. Testo 350 flue gas analyzer was used to determine the CO_2 in the urban atmospheric environment, while the Castro 4000 was used to obtain the temperature from same sites where the air samples for the CO_2 were taken from. The data collected were presented with statistical diagram and the simple regression analysis was used to determine the effects of CO_2 on the temperature of these cities. Paired t test was used to compare the mean of CO_2 emissions and temperature in the built up areas and those of the surrounding rural areas. The results showed 31.5℃ mean temperature and 37.88 MMT (Million Metric Tons) mean carbon emissions from 1987-2006 in Nigeria. There is 27% increase in CO_2 emissions in the industrial and traffic congested areas than those of the natural parks and surrounding rural areas, and 7.3℃ rise in temperatur e distribution in the industrial and traffic clogged areas than the natural parks and rural areas respectively, and thus showed that Nigerian cities are 28% warmer than their country sides. It also revealed that a rise in Nigeria temperature is significantly dependent on increase in CO_2 emissions, as such CO_2 emissions accounted for 96% occurrences of urban warming experienced in Nigeria cities. Based on this, the study recommends

**Corresponding author: E-mail: efesundayighovie@gmail.com;*

the adoption of carbon sequestration/carbon capture, green-city green roof approach, extinguish gas flaring, massive afforestation, and environmental impact assessment which will reduce the carbon emissions and lower the urban heat island experienced in Nigerian cities.

Keywords: Carbon emissions; temperature; cities; Nigeria.

1. INTRODUCTION

Over the years, there have been emissions of great volumes of greenhouse gases into the earth's atmospheric environment as a result of anthropogenic activities, and this has being taking place globally since 1800. These gases are chlorofluorocarbons (CFC), carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (NO_x) which absorbs the radiation in the earth atmospheric system, and excess of it often affect the environment and thus leads to the warming of the earth's surface [1]. According to [2] the greenhouse emissions is precipitated from gas flaring, deforestation, bush burning, fumes from generators and vehicular movement, and burning of coal amongst others. Once these gases (CO_2) are airborne, they stay longer and accumulate over time in the atmosphere, and thus have longest life span in the atmospheric environment [3].

Similarly, [4] affirmed that there has been an increased in the concentration of greenhouse gases $CO_{2,}$ CFC, $CH_{4,}$ etc in earth's atmosphere system over the years. Amongst these, the concentration of $CO_{2,}$ has increased significantly in the past century. And over the years there has been controversy on whether changes in CO_2 emissions will produce significant warming as being globally asserted see [5,6]. [7] in his study of greenhouse gases emissions from petroleum products in Nigeria concludes that greenhouses gases have been on the increase in the past ten years. However the study is limited to 1990-2009. [8] adopted the energy efficiency and conservation in light retrofitting as measure to reducing the carbon dioxide emission in the four halls of residence within University of Lagos, which results in 45% on the average of energy conservation. These studies are limited to reducing greenhouses to the neglect of environmental effects of carbon emissions. While [6] asserted that increase in CO_2 do lead to large scale increases in atmospheric temperatures based on climate computer modeling, [5] on the other hand noted that though greenhouse gases may lead to rise in temperature, but it may not be as large as 2℃ as being reported in literatures [3]. They however call for more studies both on a micro scale and over continent to validate this. This call led to Paris climate conference (COP21) agreement held in December 2015, where 195 countries accepted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by reducing global warming to below 2℃. Nigeria government has earlier set national target of 2020 to extinguish gas flaring in the country. To this end the government of Nigeria intends to sign the United Nations Agreement on Zero Routing Gas Flaring by 2030, but till then, the effect of greenhouse in Nigeria remain a quagmire Thus, this study is therefore an off shot of such problems, call and in order to ascertain the extend CO_2 contribute to urban warming in Nigeria.

2. METHODS OF DATA COLLECTION

To generate the data used for the study, a survey of twelve Nigerian cities was carried out. These cities from south to north are: Lagos, Benin, Warri, Port Harcourt, Calabar, Lokoja, Abuja, Ilorin, Jos, Kano, Sokoto and Maiduguri etc. The choice of these towns in Nigeria is based on where instruments are available and they are amongst the most populous cities in Nigeria with large urban morphology. Similarly, these cities in terms of population are densely populated with over 50,000 inhabitants in each. The southern cities of Warri, Benin and Port Harcourt house the oil and gas province of Nigeria where continuous gas flaring is carried out. They also features high industrial and anthropogenic activity that has led to rapid urban expansion and development in recent years, and thus serves as economic nerve centers of Nigerian. These characteristics have also led to increase greenhouse gas emissions and urban warming in these cities [3].

Testo 350 flue gas analyzer was the instrument used to determine the CO_2 in the urban atmospheric environment. The Testo 350 flue gas analyzer carried out automatic analysis of sample of ambient air with the use of the physical properties that gives continuous output signal to the analyzer which returns the values of the CO_2, were read from the screen of the digitized Testo 350 in 2015. CO_2 data for some countries (USA, Iran, Iraq, Nigeria, Libya, and Algeria) were obtained from the archive of [9] and [10] from 1987-2006. The choice of these countries and years is based on data availability, consistency and continuity of records.

The Castro 4000 which is held at arm length is used to obtain the temperature from same sites where the air samples for the CO_2 were taken from. With the aid of field assistants both instruments were read at the hours of 0600, 1200 and 1800 GMT for three time daily for six months. These hours were chosen based on the fact that they are meteorological hours recommended for weather observation by world meteorological organization. Temperature and CO_2 measurement in six land uses and the surrounding rural area were also carried to ascertain urban effects on them; the data were summarized with the mean and presented with statistical diagram. Simple regression analysis was used to ascertain the effects of CO_2 on the temperature of these cities, and paired t test was used to compare the mean of CO_2 emissions and temperature in the built up areas and those of the surrounding rural areas.

3. RESULTS AND DISCUSSION

This section presents and discussed the data obtained from the field. Globally there have being huge volume of CO_2 emissions into the atmosphere, this span an average of 163.49 MMT in 1987 to 248.33 MMT in 1991 see [10] and [11]. with Nigeria and USA having a general increase in carbon emissions than others countries, with the highest carbon emissions recorded in Nigeria (49.74 MMT), and the lowest emissions 0.09MMT in Iraq [10]. In fact Iraq almost had zero CO_2 emissions from 1993 to 1996 (0.09 MMT), however 2005 to 2006 had abnormal rise in CO_2 emissions of above 14 MMT. In Africa, Libya has reduced their CO_2 emissions from 9.13 MMT in 1990 to between 1.64 and 1.36 MMT [9] and [10]. The high rate of carbon emissions recorded in these countries could be attributed to high gas flares, and increased anthropogenic activities, since these countries are oil producing nations. Also Nigeria had higher carbon emissions than other countries because of higher gas flaring which is more than those emitted by USA and the others countries [10].

Nigeria carbon emissions shows two epochs of CO_2 emissions could be identified; these are 1992-1996, and 2005 to 2006, as well two recessions 1987-1988, and 1998 to 2000. Over the years, there have being gradual increase in CO_2 emissions from 1987 (21.5 MMT) to 1996 (49.74 MMT), and from 2001 (31.32 MMT) to 2006 (41.69 MMT). According to [10] these epochs and recession in CO_2 emissions over the years corroborated the period of high/low gas flared in Nigeria. This corroborated the work of [7] in his study of greenhouse gases emissions from petroleum products in Nigeria where he concludes that greenhouses gases have been on the increase in the past ten years. However the study is limited to 1990-2009.

From Fig. 1, mean temperature showed 31.5℃ and 37.88 MMT for mean carbon emissions from 1987-2006. However both showed same pattern of gradual increase, two epochs and recessions at 1996 and 2005 rise; and 1987 and 2000 for reduced CO_2 emissions and temperature distribution in Nigeria. Thus a rise in CO_2 emissions leads to corresponding rise in temperature distribution in Nigeria. This is confirmed by the correlation value of 0.98 and t value of 57.62 which indicate that the effects of CO_2 emissions on temperature distribution is significant at $P>0.05$. Thus CO_2 emissions are 96% responsible for the urban heat island experienced in Nigeria cities. This corroborated [12-14] who opined that emissions from power generation and energy consumption has influenced greenhouse gas increase which influences source of global warming and therefore suggest the need for increase renewable energy consumption which will help in reducing the problems of energy security, energy control and health related problems. [15] asserted that rise in ambient temperature and changes in related processes are connected directly to increasing greenhouse gas (GHG) emissions in the atmosphere. And specifically, the temperature rise is said to be triggered by carbon emission from fossil fuels consumption for power generation.

Fig. 2 showed the relationship between carbon emissions and temperature distribution in Nigeria. Generally, it revealed that an increase in CO_2 emissions leads to corresponding rise in temperature distribution in Nigeria. For instance at 21.5 MMT, temperature showed 29℃ and at 48.99 MMT temperature rose to 34℃. An R^2 value of 0.58 was recorded indicating that carbon emissions contributed 58% to rise in temperature. This confirmed the earlier result in Fig. 1.

Figs. 3 and 4 showed the spatial CO_2 emissions and temperature distribution in Nigerian cities. Generally, CO_2 emissions and temperature distribution increases from the south to northern cities. For instance CO_2 emissions span 5.70 MMT in Calabar to 12.88 MMT in Sokoto. Similarly, temperature varies from 28.4℃ in Port Harcourt to 35.1℃ in Sokoto as such both followed the same pattern. The higher carbon emissions and temperature in the northern cities is attributed to the low vegetal covers and tress to absorb the excess CO_2 emissions. This is at variance with the policy of carbon capture and tree planting as mitigating options to global warming. However cities within the oil producing Niger Delta (Warri and Port Harcourt) were gases are flared had higher CO_2 emissions and invariably higher temperature than their neighboring towns.

From Table 1, the hourly CO_2 concentration and temperature distribution showed a gradual rise in CO_2 and temperature from the morning hours to afternoon hours and gradual decrease to the evening hours in all the cities. For example the mean CO_2 span 5.36 MMT at 0600 Hours to 10.72 MMT at 1200 Hours and 6.70 MMT at 1800 Hours, temperature follow similar pattern and it varies 27℃ at 0600 Hours, 33℃ at 1200 Hours and 30℃ at 1800 Hours (see Fig. 5). However the northern cities (Sokoto, Kano and Maiduguri, etc) had higher CO_2 and temperature than the southern cities (Warri and Port Harcourt, etc) (see Table 1).

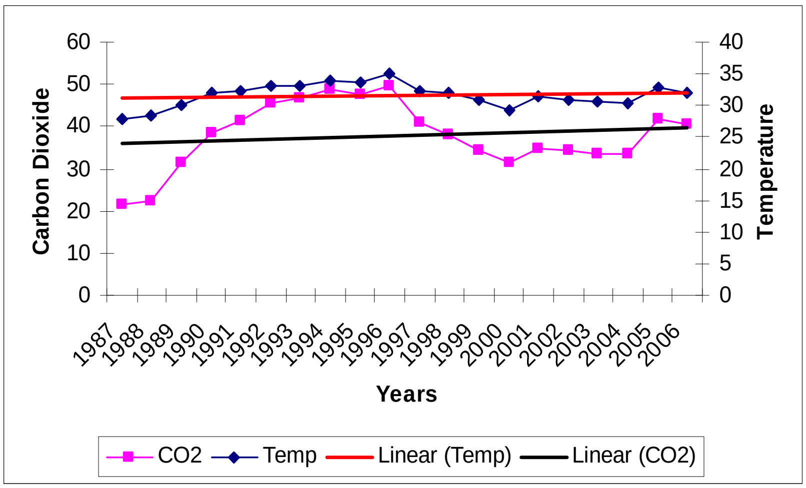

Fig. 1. CO_2 emissions (MMT) and temperature (℃) trend over th e years

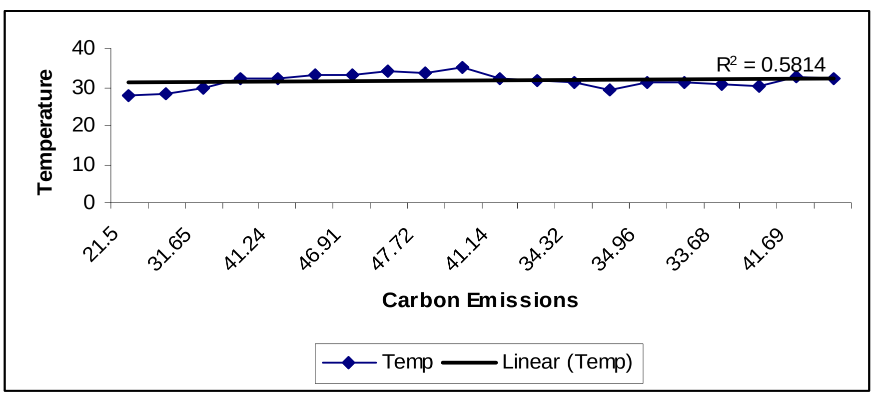

Fig. 2. CO_2 emissions (MMT) and temperature (℃)

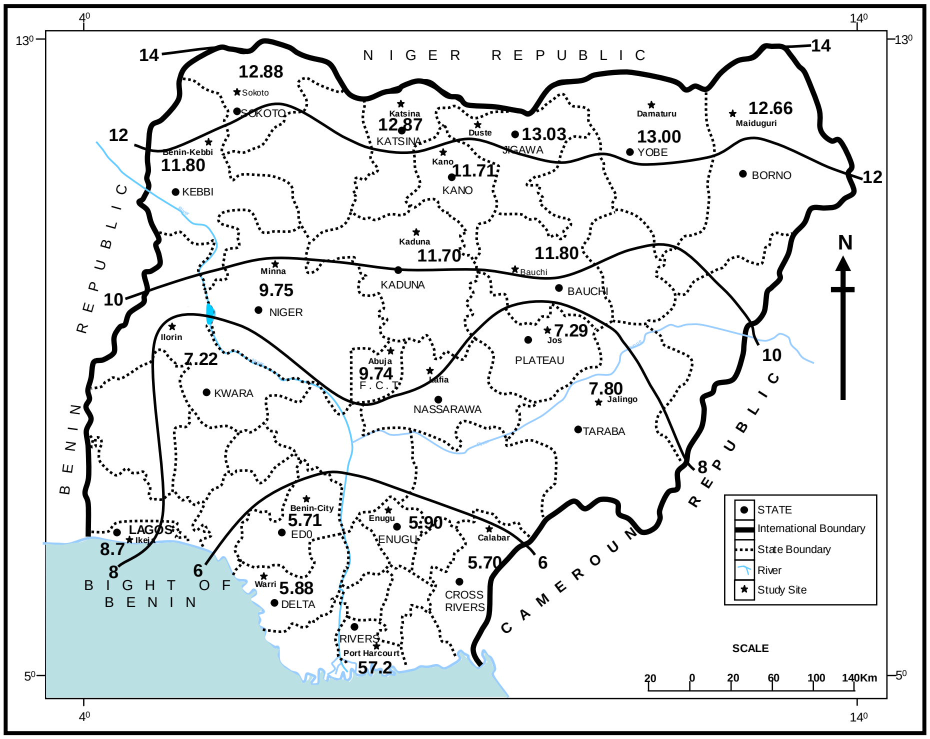

Fig. 3. Co_2 emission (MMT) in Nigeria cities

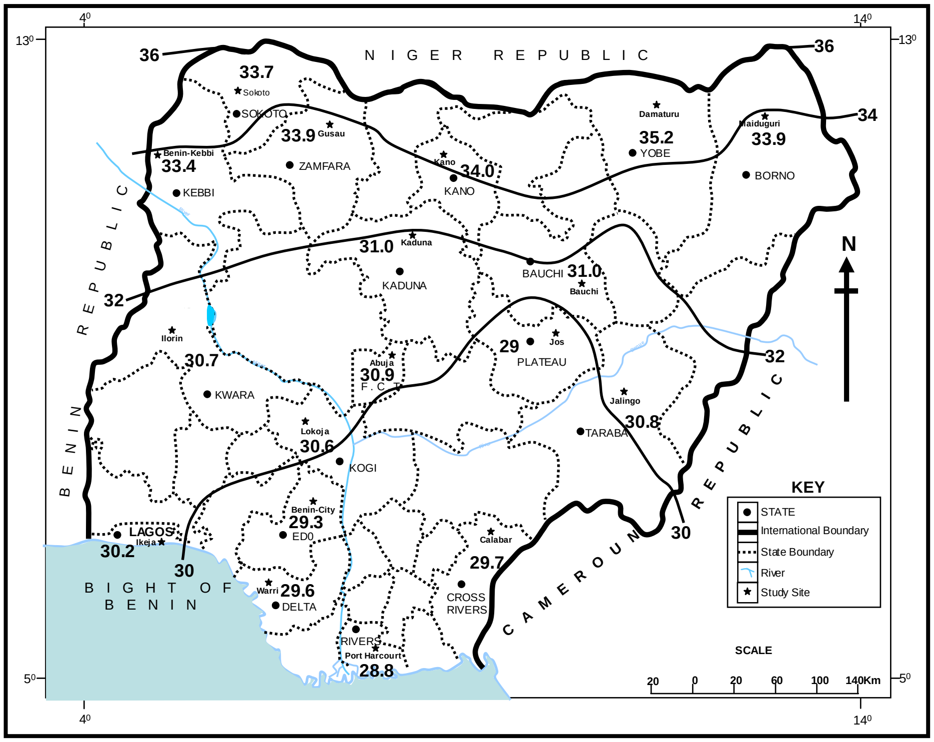

Fig. 4. Mean temperature (℃) distribution in Niger ia cities

Table 1. Mean CO_2 (MMT) emissions and temperature (℃) in the variou s cities

Cities	0600H		1200H		1800H	
	CO_2	Temp	CO_2	Temp	CO_2	Temp
Lagos	5.26	27	9.09	31	7.00	29.3
Warri	4.10	26.5	7.32	30	5.55	28.5
Benin	4.18	26.7	7.57	30	5.72	28.3
Port Harcourt	4.06	25	7.46	29	5.02	28
Calabar	4.56	26.9	7.54	30	5.20	28.2
Abuja	5.45	27	13.87	32	5.47	28.6
Lokoja	5.89	27.3	11.11	31.3	7.65	29.7
Ilorin	5.34	27.2	9.56	31	6.13	29.8
Jos	5.76	27.3	9.81	30	6.15	29.6
Kano	6.03	28	14.65	38	8.73	30.5
Maiduguri	6.30	28.6	15.63	38.7	8.83	31
Sokoto	6.28	28.8	15.56	38.5	8.90	31
Mean	5.36	27.2	10.72	32.5	6.7	29.5

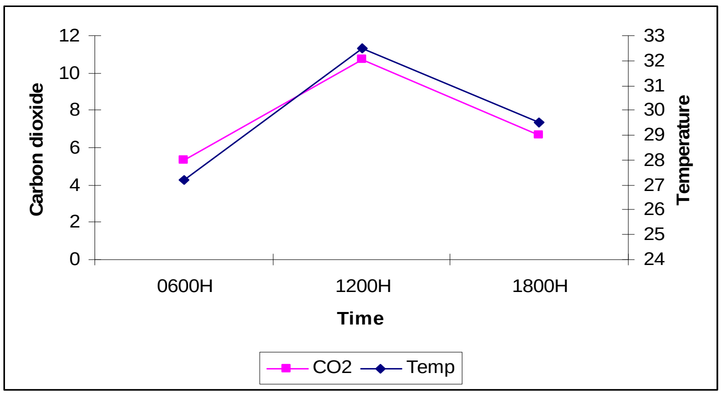

Fig. 5. MEAN hourly CO_2 MMT concentration and temperature (℃) distribution

Tables 2 and 3 showed the CO_2 concentration and temperature distribution in the Various Land use in Nigeria Cities. Generally, CO_2 and temperature were higher at the industrial and traffic clogged areas than the rural and the natural parks areas. CO_2 emissions varies from 11.27 MMT and 11.26 MMT at the industrial and traffic clogged areas to 5.04 MMT and 3.08 MMT at the natural parks and rural areas respectively. This behaviour could be attributed to the temporal distribution of traffic emissions for a specific day that could affect the carbon dioxide emissions of that day. This showed 27% increase in CO_2 emissions in the industrial and traffic congested areas than those of the natural parks and surrounding rural areas. Temperature distribution span 33.4℃ and 33.5℃ in the industrial and traffic clogged areas to 27.2℃ and 26.4℃ at natural parks and rural areas respectively (see Fig. 6). This revealed a rise of 7.3℃ and indicate 28% urban warming differential from the surrounding rural areas.

From Tables 4 and 5, CO_2 emissions and temperature distribution showed that significant difference exist in the CO_2 emissions and temperature distribution observed within the built up areas and the surrounding rural areas of the various cities in Nigeria. This is evident when we calculated t value, that measures the difference between an observed sample statistic and its hypothesized population parameter in units of standard error and obtain 9.99 and 10.92, and a correlation value of 0.936 and 0.838 for CO_2 and temperature respectively that are significant at $P<0.05$ confidence level. This corroborated those of [3] in same cities.

Table 2. Mean concentration of CO_2 (MMT) in the various land use in Nigeria cities

Cities	Industrial area	Traffic Clog area	High density area	Low density area	Commercial area	Natural Park/ Recreation sites	Rural area	Mean
Lagos	12.10	11.9	9.00	5.65	11.3	3.67	2.85	8.7
Warri	8.21	7.89	7.65	4.85	7.82	2.55	2.16	5.88
Benin	8.13	7.77	7.12	4.67	7.57	2.53	2.16	5.71
PH	8.20	7.86	7.02	4.44	7.98	2.43	2.13	5.72
Calabar	8.60	7.49	7.22	4.52	7.44	2.50	2.15	5.70
Abuja	13.5	14.2	10.32	6.45	14.00	6.05	3.67	9.74
Lokoja	9.00	10.12	8.78	5.76	9.00	4.78	3.00	7.21
Ilorin	9.24	9.20	8.96	5.84	9.10	4.84	3.34	7.22
Jos	8.76	8.56	8.13	5..62	8.06	3..92	2.97	7.29
Kano	15.30	15.45	12.7	10.64	15.12	8.45	4.34	11.71
Maiduguri	16.90	17.10	13.8	10.89	17.00	8.86	4.09	12.66
Sokoto	17.30	17.60	13.9	10.92	17.6	8.78	4.05	12.88
Mean	11.27	11.26	9.55	6.78	11	5.04	3.08	8.28

Table 3. Distribution of temperature (℃) in the va rious land use in Nigeria cities

Cities	Industrial area	Traffic Clog area	High density area	Low density area	Commercial area	Natural Park/ Recreation sites	Rural area	Mean
Lagos	33	32.4	31.3	30	32	26.5	26	30.2
Warri	32.1	31.7	31	30.4	31	26.3	25	29.6
Benin	31.3	30.8	30.2	30	30.7	26.6	25.5	29.3
PH	30.3	30.3	29.2	28.1	30.1	25.6	25	28.4
Calabar	31.5	31.3	30.3	30	31.5	26.8	26.5	29.7
Abuja	33.8	33	32.5	31.5	32	27.2	26.5	30.9
Lokoja	33.3	33	31.3	30.4	32.7	27.4	26	30.6
Ilorin	33.4.	33.2.	31.	30.2.	32.6.	27.7	27.3	28.7
Jos	31.8	30.4	30	28.4	30	26.3	25.8	29
Kano	39.7	38.8	38	32.6	37	28.3	28	34.6
Maiduguru	39..8	38.5	37.5	33.3	38	28.5	27.6	33.9
Sokoto	39.7	38.5	37.5	35.5	38	28.7	27.6	35.1
Mean	33.7	33.5	32.5	30.9	33	27.2	26.4	31

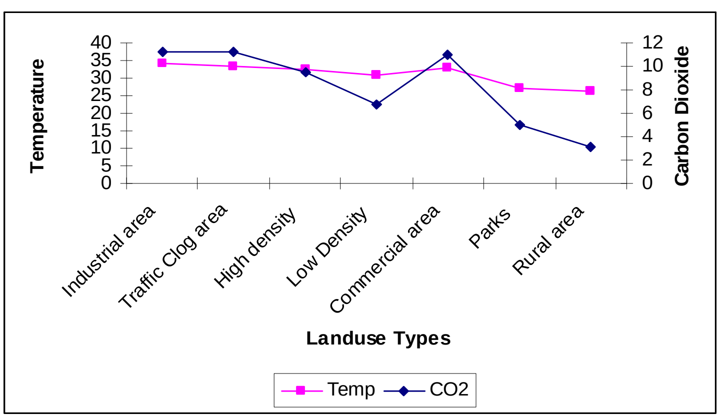

Fig. 6. Mean concentration of CO_2 (MMT) and temperature distribution (℃) in the dif ferent land use

Table 4. Paired t test summary of CO_2 emissions in the urban and rural area in Nigerian cities

	Paired difference								
				95% Confidence Interval Diff					
	Mean	**Sd**	**Sd Error Mean**	**Lower**	**Upper**	**t**	**Df**	**R**	**Remark**
Urban –rural	6.14	22.2	.61	4.80	7.48	9.99	12	.936	Sign. Diff Exist

Table 5. Paired t test summary of temperature distribution in the urban and rural area in Nigerian cities

	Paired difference								
				95% confidence interval diff					
	Mean	**Sd**	**Sd error mean**	**Lower**	**Upper**	**t**	**Df**	**R**	**Remark**
Urban - Rural	5.40	1.78	.50	4.33	6.48	10.92	12	.838	Sign. Diff Exist

4. CONCLUSION

The study showed 31.5℃ mean temperature and 37.88 MMT mean carbon emissions from 1987-2006 in Nigerian cities, This also indicate 27% increase in CO_2 emissions in the industrial and traffic congested areas than those of the natural parks and surrounding rural areas, and 7.3℃ rise in temperature distribution in the industrial and traffic clogged areas than the natural parks and rural areas respectively, and showed that Nigerian cities are 28% warmer than their country sides. It also showed that a rise in temperature is significantly dependent on an increase in CO_2 emissions in Nigeria, and CO_2 emissions accounted for 96% occurrences of urban warming experienced in Nigeria cities. Arising from this, the study therefore recommends the adoption of green city green roof approach; extinguish gas flaring carbon sequestration/carbon capture, massive afforestation, and the implementation of environmental impact assessment. This will lead to an increase of carbon sinks, an increase of the air buoyancy and fresh air, and reduces the surface temperature of Nigerian cities.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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