

Landscaping of Residential Estates as a Mitigation Measure to Reduce Carbon Dioxide and Temperature Levels in Inner Ibadan City, Nigeria

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To cite this article:

Tejumola Adesoye, Mynepalli Kameswara Chandra Sridhar, Akinwale Oladotun Coker, Mumuni Adejumo. Landscaping of Residential Estates as a Mitigation Measure to Reduce Carbon Dioxide and Temperature Levels in Inner Ibadan City, Nigeria. *International Journal of Environmental Monitoring and Analysis*. Vol. 7, No. 5, 2019, pp. 93-102. doi: 10.11648/j.ijema.20190705.11

Received: June 18, 2019; Accepted: August 12, 2019; Published: September 29, 2019

Abstract: This study assessed the spatial distribution of carbon dioxide emanation in selected residential estates and the impact of landscaping in reducing their levels in Ibadan metropolis. The study was carried out in high, medium and low commercial activity areas characterized by population density and traffic congestion within Ibadan city. CO₂ concentrations and temperature were measured at 4 hourly interval from 9am to 5pm for a period of seven consecutive days while numbers of trees/plants (biomass density) were counted, at 21 different points from seven areas each with high, medium and low commercial activities. Measurements were carried out with the aid of calibrated portable gas meters. The means CO₂ (ppm) were 542±95, 415±11 and 376±14 at 1.00 pm in the high, medium and low commercial activity areas respectively. CO₂ concentrations were generally higher than IPCC value, but highest in the afternoon. Temperature values were generally higher in the afternoon in high and medium commercial activity areas, but lower in the low commercial activity zones. Significantly, density of trees in low commercial activity areas (234.3±6.7) was higher compared to those in medium (22.8±0.5) and high (24.2±0.7) activity areas respectively. An inverse correlation was observed between CO₂ concentration and the density of trees ($r=-0.456$; $p=0.038$). The spatial distribution of CO₂ concentration in relation to landscaping revealed that CO₂ concentration reduces northward away from the urban core areas where there were fewer trees. The areas with low commercial activities had large numbers of trees while temperature and CO₂ flux were lower in these areas. Temperature and density of trees contribute significantly in explaining the CO₂ concentration ($p=0.015$). CO₂ concentrations and temperature were high in high commercial activities areas in Ibadan metropolis, few or no trees were observed in those areas. Increase in density of trees could be attributed to decrease in the CO₂ concentration. Hence, tree planting needs to be encouraged in the urban core of Ibadan metropolis to reduce air pollution.

Keywords: Spatial Distribution, Carbon Dioxide Level, Temperature, Ibadan Metropolis, Landscape

1. Introduction

Pollution can be defined as a disorder within an environment which is a by-product of energy conversion and resources usage [1]. It was defined as a contamination and or reduction in the value of an object, especially by adding harmful or unpleasant substances to it [2, 3]. Air pollution is

any atmospheric condition in which substances are present at concentrations higher than their normal ambient levels and produces a measurable effect on man, animals, vegetation, or materials [4]. Studies have reported that emissions from vehicles and other forms of transportation technologies were responsible for about 22% particulate matter, 77% carbon monoxide, about 80-90% nitrate and 36% volatile organic

compounds [5, 6]. These air pollutants are on the rise in urban areas due to increase in pollution levels from various channels, thereby, posing great risk to the ecosystem health. In Nigeria, apart from industrial pollutants there is increased pollution from mobile sources with per capita increase in vehicle ownership [7].

Carbon dioxide (CO₂) is the most abundant of the minor atmospheric gases, due to its solubility; it is about 98% of the total dissolved carbon in the ocean-atmosphere system. It undergoes a series of reactions depending on the pH of the system for its transformation to bicarbonates and/or carbonic ions [8]. Furthermore, it plays an important greenhouse gas role in the absorption of infrared radiation from the earth, thereby, regulates the earth's climate. The increase in atmospheric CO₂ is brought about by varieties of anthropogenic activities [9, 10]. These activities include, but not limited to, cement production, deforestation, fossil fuels combustion, open burning of refuse, operation of generator sets, and human respiration in congested places [11, 12].

According to the findings of a study, there was about 30% increase in the concentration of atmospheric carbon dioxide after the industrial revolution and an increase of about 1% per year causing a further growth in its concentration [13-15]. Due to the growth of greenhouse gas effect, this increase contributes to global climate change [13, 16]. Observations of CO₂ in ice cores and direct measurements of CO₂ concentrations in the atmosphere demonstrated that CO₂ levels increased from around 280 ppm in 1750 to nearly 380 ppm by 2005 [13, 17]. It has been predicted that by 2100 global temperatures will increase by as much as 3.1°C relative to the 1980-1999 global mean due to increasing levels of atmospheric CO₂ [18].

Urbanization or the social and economic modernization of metropolitan cities has attained unprecedented growth [19]. As an inevitable phase of globalization, it has fuelled society's consumption patterns, alongside incessant technological development. Mass production and industrialization, the primary thrusts of the global market, require consumption of non-renewable resources arising from the increase in energy usage. These centers of production are concentrated in urban, highly populated areas. This phase of progress, however, comes at the expense of environmental quality. High levels of carbon emissions are concentrated in areas with high population density. This hampers the natural flow of the ecosystem and consequently a sustainable environment might not be efficiently maintained. As a result of this trend, increase in the density of carbon emissions might potentially harness catastrophic impacts in the future [20]. The impact could possibly possess direct risks (such as inflammation, reduced higher-level cognitive abilities, bone demineralization, kidney calcification, oxidative stress and endothelial dysfunction) to human health [21]. Also, CO₂ accumulation can progressively displace oxygen in the air, inducing a mild chronic hypoxaemia with untoward health effects [22].

However, tree planting in cities can contribute

significantly to improve human health and environmental quality. In addition, monitoring and quantifying urban vegetative stocks and carbon fluxes have economic, environmental, and social significance, addressing issues of air quality, climate change, and sustainability [23]. Unfortunately, little is known about the urban forest resource and what it contributes to the local and regional society and economy in Nigeria. Poor air quality is ubiquitous in many urban centers, leading to impairment of both human health and landscape, ecosystem damage and impaired visibility [24]. This problem can be alleviated by afforestation. It is with this background that this study therefore is borne out of the need to assess the impact of landscaping on temperature and carbon dioxide in Ibadan urban environment.

2. Methodology

2.1. Study Area

Ibadan is the capital of Oyo State in southwestern Nigeria. It is located approximately on longitude 30°53' E and latitude 7°34' N. Ibadan consists 11 local government areas (LGAs) for governance and administrative purposes. Five of the LGAs are located in the metropolitan core of the city, while the remaining six are either predominantly peri-urban or rural settlements. Ibadan city comprises of five LGAs with an estimated population of about 2,550,593 as of 2006 [25]. With an annual growth rate of 4.14%, the estimated population of Ibadan for 2015 is 3,160,200. A noteworthy feature of the city before 1972 was the absence of high density areas. By 1984, 11.42 km² of the urban area was classified as high-density which had increased to 64.8 km² by 2003. With the current density of approximately 2,889 people per square kilometer, Ibadan has one of the highest population densities in Nigeria [25].

The city is projected to increase to about 5.03 million inhabitants by 2025, considering an average annual growth rate of 4.6% during the period 2010-2020 [26]. The climate is characterized by a rainy season from March through October, while the dry season stretches from November to February. In addition, about 36.25 km² (34.9% of the land area) is devoted to land use (such as residential area, public buildings and facilities, markets, industrial and commercial areas as well as educational institutions), social amenities and open spaces. The remaining 63.75 km² is devoted to non-urban uses such as forest reserves, farm lands and aquatic environment [27]. Despite its size and density, Ibadan grew originally without a clearly defined master plan like many other urban centers in Nigeria [28]. According to population density, the city can be categorized into high, medium and low density areas. Narrow carriageway, closely-packed residential areas, and indigenous people are the characteristics of this density type. However, this situation differs in the low-density area as it is well-planned with paved road and occupied by high income earners and top civil servants.

2.2. Sampling Points and Data Collection

In view of the large size of the study area, and in order to achieve the objectives of the study, a stratified random technique was used. The sample was drawn from residential areas, markets, forest and gardens, and busy roads as shown in Figure 1.

Concentration of CO₂ and temperature at each of the sample locations were measured at 4 hourly intervals between 9.00 am and 5.00 pm for a period of seven

consecutive days. Carbon dioxide meter was used for measuring CO₂ and temperature level at each sampling points in the study area. In general, CO₂ was quantified by direct sensory measurement and intensity, using the carbon meter sense as the CO₂ detector. The meter took measurements immediately as it was turned on while readings were updated every second. In the event of a rapid change in operating environment (from high to low temperature), it took approximately two minutes for the CO₂ and temperature to adjust and ten minutes for humidity to stabilize.

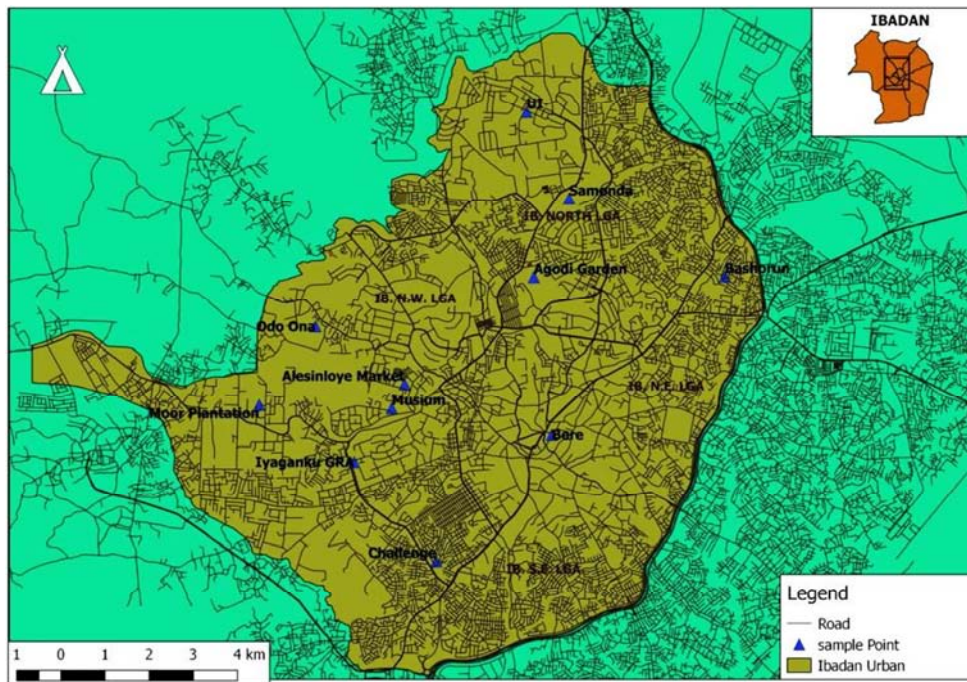


Figure 1. Ibadan Showing Sample Collection Points.

2.3. Spatial Database Description

Spatial information and analysis was carried out for detailed understanding of the spatial variation of CO₂ and temperature. Information collected includes the geographical background of the areas under study and spatial data related to the waste collection procedure used by the state Ministry of Environment. The researcher monitored the samples of air in the study area. The content of the spatial database is summarized in Table 1.

Table 1. The spatial database - type of data and corresponding geometry.

Spatial data	Type	Geometry
Road network	Vector	Line
Land cover/Landscape	Vector	Polygon
Local Government area	Vector	Polygon
Satellite image from Google Earth	Raster	

2.4. GIS Application: Buffer and Spatial Interpolation Analysis

The GIS analysis used in this study is thematic classification and query of feature attributes to examine spatial patterns and relationship between CO₂ concentration

and temperature. This functionality explicitly allowed for exploring spatial relationship at the study site [29]. Furthermore, buffer or proximity analyses mapped the impact zones of vector sampling sites, thereby indicating where control activity needed to be strengthened [30]. This zone was analyzed using the method in which buffer zones of 1000m were created around the sampling sites in order to indicate the spread of CO₂ [31]. In addition, GIS-based CO₂ concentration and temperature mapping-based interpolation techniques such as inverse distance weighting (IDW) and kriging were employed [32]. All the aforementioned GIS applications were adopted in the study.

2.5. Method of Data Analysis

The “Analysis Tool Pak” was used in the analysis of the CO₂ data collected, one-way ANOVA was done to test for significant differences in the levels of CO₂ obtained for different periods at each location while two-way ANOVA was carried out to test the significance of the interaction between period and location. Also, regression model was used to relate CO₂ concentration with temperature and number of trees. Level of significance was set at 0.05.

3. Results

3.1. Concentration of Carbon Dioxide and Temperature Values

The findings of carbon dioxide and temperature which were collected at four-hour interval between 9 am and 5 pm is presented in Table 2. The mean concentration of CO₂ at a high commercial area was 525±91ppm, 542±95ppm and 535±90ppm at 9am, 1pm and 5pm respectively. At the medium activity area, concentration of CO₂ was 407±12ppm at 9am, 415±11ppm at 1pm and 408±10ppm at 5pm. At low activity area, mean concentrations of CO₂ at 9am, 1pm and 5 pm were 366±12ppm, 376±14ppm and 367±13ppm respectively. All the CO₂ values were higher than the IPCC

values. The mean temperatures at a high commercial area were 30.7±0.6°C, 31.3±1.0°C and 31.5±0.8°C at 9am, 1pm and 5pm respectively. At the medium activity area, hourly temperature was 30.4±0.5°C at 9am, 31.9±1.0°C at 1pm and 31.4±0.8°C at 5pm. At low activity area, mean hourly temperature at 9am, 1pm and 5 pm was 29.3±0.9°C, 30.4±0.9°C and 29.9±0.9°C respectively. Temperature values were higher than the recommended limits by IPCC. Furthermore, CO₂ concentrations were highest in the afternoon when atmospheric temperature is usually highest. The CO₂ concentration reduced with levels of commercial activities from high to low. Temperature values were generally higher in the afternoon in medium and high commercial activity areas, but lower in the low commercial activity zones.

Table 2. Concentration of carbon dioxide and temperature values at different area.

Level of Commercial Activities	CO ₂ concentration (ppm) Mean (SD)			Temperature (°C)		
	9:00 AM	1:00 PM	5:00 PM	9:00 AM	1:00 PM	5:00 PM
High	525±91	542±95	535±90	30.7±0.6	31.3±1.0	31.5±0.8
Medium	407±12	415±11	408±10	30.4±0.5	31.9±1.0	31.4±0.8
Low	366±12	376±14	367±13	29.3±0.9	30.4±0.9	29.9±0.9

IPCC value: CO₂ = 350 ppm.
Temperature = 23.5°C-25.5°C.

3.2. Comparison of Density of Trees, Concentration of CO₂ and Temperature at Different Sampling Locations

Table 3 presents the comparison of density of trees, daily CO₂ and temperature at different sampling points. It was found that mean density of trees in low activity areas (234.3±6.7) was higher compared to those in medium (22.8±0.5) and high (24.2±0.7) activity areas respectively. The difference was statistically significant. Also, a statistically significant difference existed between mean concentration of CO₂ at high activity area (534.3±91.7ppm) compared to medium (410.2±10.6ppm) and low (369.5±13.7ppm) activity areas. The mean temperature (°C) in the high, medium and low activity areas was (31.5±0.6), (31.2±0.7) and (29.5±0.8) respectively. The difference was statistically significant.

Correlation of CO₂, temperature and density of trees was presented in Table 4. It was revealed that a positive correlation existed between CO₂ level and temperature ($r=0.612$, $p=0.003$). This implies that increase in temperature would bring about the increases in CO₂ concentrations. Furthermore, an inverse correlation was observed between CO₂ concentration and the density of trees ($r=-0.456$; $p=0.038$). This indicates that increase in the number of trees could bring about the decrease in the concentration of CO₂ in the same environment. Moreover, an inverse correlation existed between the density of trees and temperature ($r=-0.724$; $p<0.001$). These findings signify that temperature reduces as the density of trees increases. The analysis shows that landscaping has a significant impact on the level of CO₂ concentration and temperature.

Table 3. Comparison of density of trees, daily CO₂ levels and Temperature at different sampling points.

Parameters (Units)	Location	Mean ± SD	F-statistics	p-Value
Density of trees (Number of trees)	High	24.2±0.7	35.365	<0.001
	Medium	22.8±0.5		
	Low	234.3±6.7		
CO ₂ (PPM)	High	534.3±91.7	10.363	0.001
	Medium	410.2±10.6		
	Low	369.5±13.7		
Temperature (°C)	High	31.5±0.6	12.027	<0.001
	Medium	31.2±0.7		
	Low	29.5±0.8		

Table 4. Correlation matrix of CO₂, Temperature and density of trees.

Parameters (Units)	CO ₂	Temperature	Density of trees
Carbon dioxide (PPM)	1		
Temperature (°C)	0.612**	1	
Density of trees	-0.456*	-0.724**	1

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

* . Correlation is significant at the 0.05 level (2-tailed).

3.3. Spatial Distribution of CO₂, Temperature and Density of Trees Within the Sampling Locations

The spatial distribution of CO₂ concentration in relation to temperature and landscaping is depicted in Figures 2, 3 and 4. It was observed that CO₂ concentration reduces northward away from the urban core area where there were fewer trees. The areas with low commercial activities had large number of trees while temperature and CO₂ flux were lower in these areas. It was observed that few or no trees were found in the

high commercial activities zones which could have contributed to the surge in concentration of CO₂ and temperature values in the areas. It was found that areas with landscape of trees had lower temperature and CO₂, which was as a result of photosynthesis of the trees which sequestered the CO₂ present during the day. The ten most common species, including unidentified dead trees, account for 45.7% of all trees; while in total, 43 tree species were sampled in Ibadan.

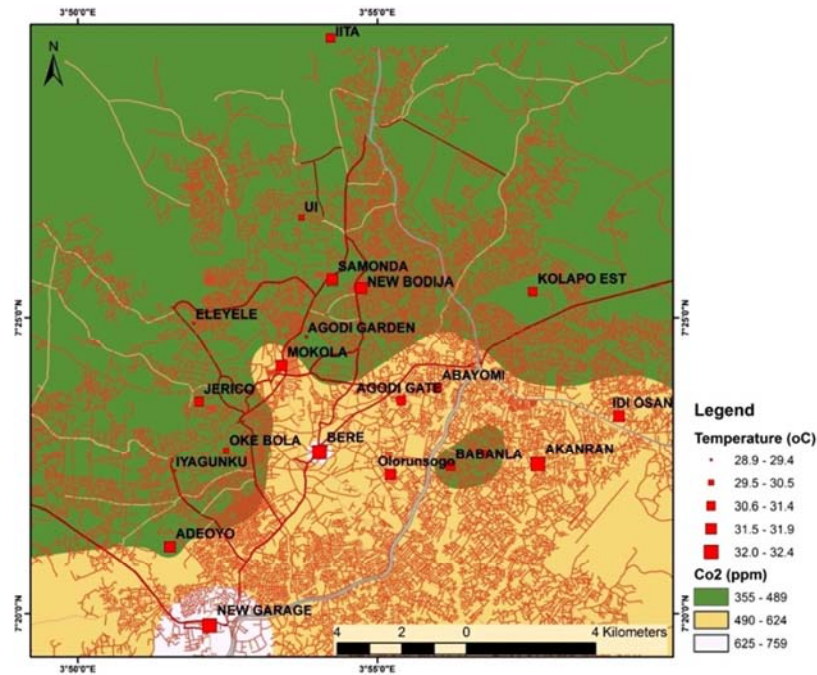


Figure 2. Spatial distribution of CO₂ in relation to temperature.

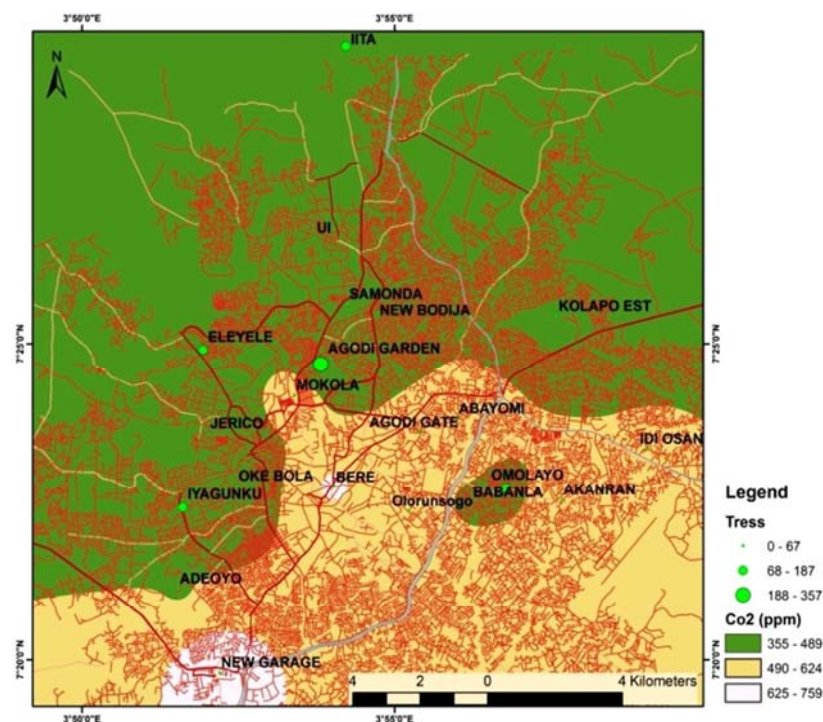


Figure 3. Spatial distribution of CO₂ in relation to density of trees.

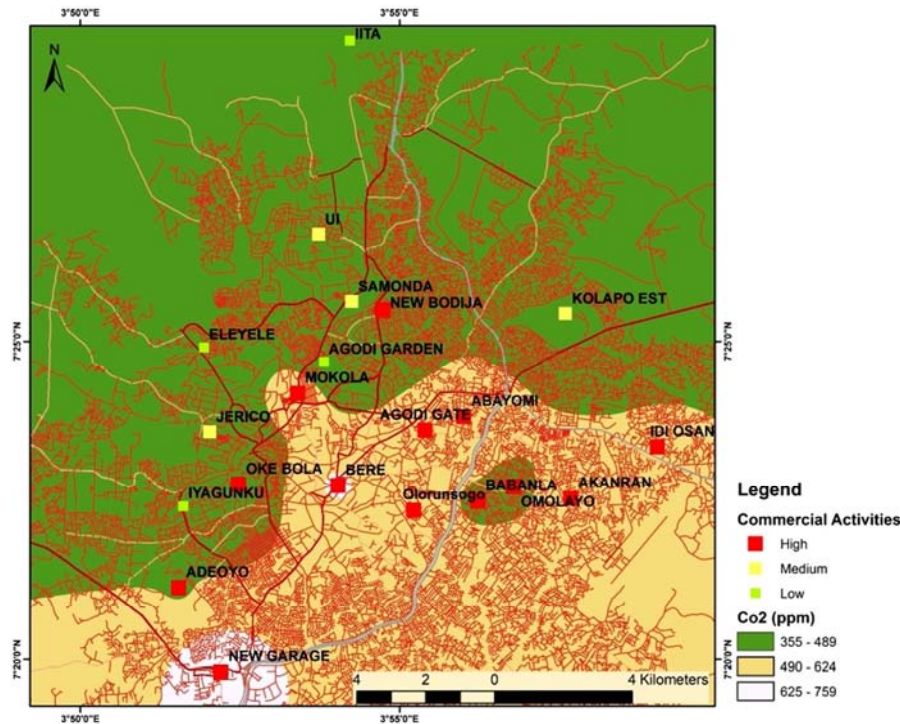


Figure 4. Spatial distribution of CO₂ in relation to commercial activities.

3.4. Regression Model of CO₂ Concentration with Temperature and Density of Trees

Modelling of temperature of the sampling area, density of trees and CO₂ concentration was carried out using multiple regression analysis (Table 5). This was done to ascertain the predictors of CO₂ concentration in the study area. The predictor, only density of trees, has a negative regression coefficient (-0.029). This shows a negative regression relation with CO₂ concentration which is an indicator of increase in CO₂ concentration. However, density of trees has the lowest β -value (0.592), which goes to show that change in the number of trees or biomass density may not be the only major factor responsible for change in the concentration CO₂ in Ibadan. Temperature has the highest β -value (0.592), indicating that temperature makes the strongest unique contribution to explaining the dependent variable

(Concentration of CO₂) when the variance explained by all other variables in the model is controlled. Temperature and density of trees contribute significantly in explaining the CO₂ concentration ($p = 0.015$). The fitted model is significant. Therefore, the regression equation is represented as:

$$Q_c = 57.9T - 0.029Q_t - 1322.238$$

Where Q_c = concentration of carbon dioxide, T = Temperature, Q_t = Number of trees.

Furthermore, a positive relationship was observed between CO₂ and temperature as depicted in Figure 5, although the relationship was not significant. Also, Figure 6 revealed that there was an inverse relationship between CO₂ and number of trees (biomass density). This indicates that an increase in the density of trees could bring about decrease in the CO₂ concentration.

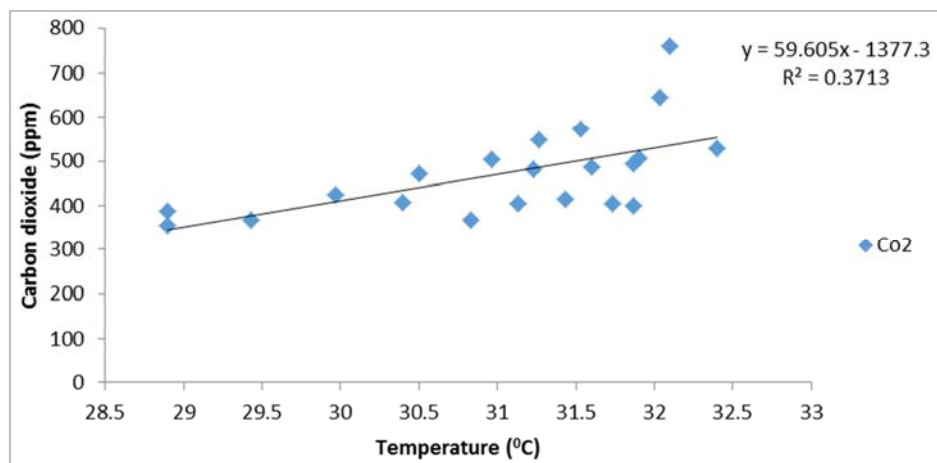


Figure 5. Regression analysis of carbon dioxide and temperature.

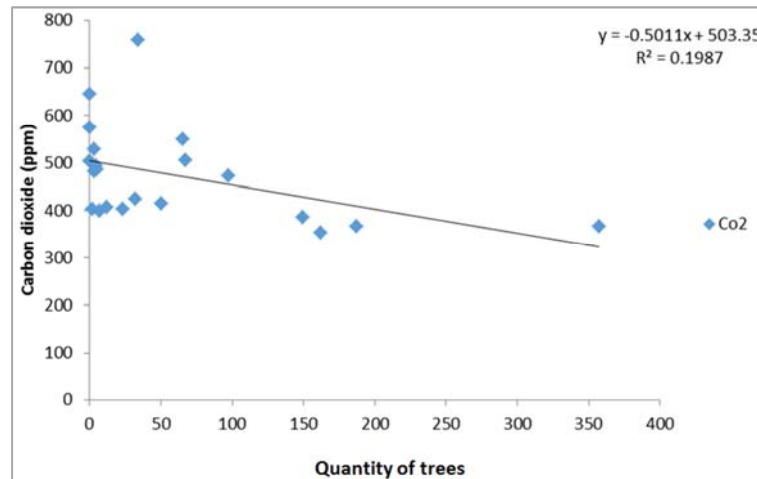


Figure 6. Regression Analysis of Carbon dioxide and Quantity of Trees.

Table 5. Modeling temperature and density of trees as predictors of CO₂ concentration.

Variables	R square	a (coefficient)	B	F/t (p Value)
Concentration of CO ₂ (Non adjusted)				
Model	0.612			5.384 (0.015)
Temperature		57.9	0.592	2.188 (0.042)
Density of trees		-0.029	-0.027	0.101 (0.921)
Constant		1322.23		

4. Discussion

The study assessed the spatial distribution of carbon dioxide and temperature flux at different landscapes in Ibadan metropolis. The study found that CO₂ concentration was higher in the afternoon compared to concentrations in the morning and late evening. Concentration of CO₂ among the high, medium and low commercial activity areas exceeded Intergovernmental Panel on Climate Change (IPCC) limit of 350ppm [33]. This is similar to the findings of previous studies [34, 35]. However, CO₂ concentration was higher in high commercial activity areas compared to the medium and low commercial activity areas. This probably could have been due to decreases in CO₂ emissions convective mixing when anthropogenic activities were minimal in the study area. It could also be as a result of high density of trees in low commercial activity areas as revealed in this study. These results agree with the assertion of a study that large and periodic variations indicate the stronger daily dependence of the CO₂ [36]. During the study period, the average CO₂ concentrations varied between 355 and 759 ppm, with 19% of data lying below 400 ppm, 28.6% lying in the range 400 – 500 ppm, and 33% of the data lying above 600 ppm. Maximum frequency of CO₂ was observed at 402.5 ppm during the study period. The study also revealed that temperature was highest during the day at all sampling sites. Also, it was observed that temperature was lower in areas with low to medium commercial activities and landscapes with sufficient density of trees. This corroborates the findings of a study in which lower air temperatures in landscaped areas compared to surrounding un-landscaped areas were

found out [37, 38]. Also, in landscaped areas, temperatures are observed to be usually cooler towards the center than around its edges. One of the previous studies opined that cooler air temperatures achieved from urban landscape can have significant impacts on human health [37]. The concentration of population in urban cities has remained one of the robust contributors of carbon emissions, which may be because of the lack of opportunities in rural areas.

The study found that, in spatial distribution, CO₂ concentration reduced northward away from the urban core area where there were fewer trees. Furthermore, the areas with low commercial activities had large number of trees while temperature and CO₂ flux were lower in these areas. This indicates that existence of trees in an area has a role to play in the reduction of CO₂ concentration and temperature of that particular location. The study found that there is a significant negative relationship between quantity of trees with CO₂ concentration and temperature. In areas where there was large quantity of trees such as Agodi Garden, both temperature and CO₂ were minimal, while areas characterized with high commercial activities and traffic congestion having minimum trees around (Agodi Gate) had high concentration of CO₂. The spatial analysis of the results revealed that CO₂ flux increases with urbanization in the study area. More so, the findings of this study agree with a previous report that there were higher values of CO₂ concentration, 1780-1840 ppm, in heavily congested areas in Kaduna and 1160-530 ppm in Abuja, Nigeria [39]. The benefit of landscaping in pollution removal cannot be overemphasized in the study area. The study has shown that areas where there were minimal number of trees had highest concentration of CO₂. A major risk, low number of trees in

the study area, is health related hazards from poor air quality. Poor air quality has been confirmed to be a common problem in many urban areas [40-42]. It can lead to human health problems, damage to landscape materials and ecosystem processes, and reduced visibility.

Urban landscape plays a major role in reducing the effect of climate change, by sequestering atmospheric carbon (from carbon dioxide) in tissues and by reducing energy use in buildings, and consequently reducing carbon dioxide emissions from fossil-fuel based power plants [43]. This study has found that temperature positively correlates with the CO₂ concentration. This shows that increase in temperature could contribute to the increased CO₂ concentration. Also, density of trees inversely correlates with the CO₂ concentration. This is an indication that increase in density of trees could be attributed to decrease in CO₂ concentration. This is similar to the report of a study that CO₂ concentration could be reduced to a certain extent through decreasing impervious surface cover and increasing vegetation coverage [44]. The prediction model established in this study relates CO₂ concentration with temperature and number or density of trees. This study found that temperature and density of trees predicts change in CO₂ concentration in the study area. The findings revealed that each of the above stated variables contributes significantly as independent variables in explaining CO₂ concentration. A study had shown that urban landscaping in form of afforestation improves air quality through reduction in air temperature and direct pollutants removal from air [42]. Also, integrative studies on trees planting have revealed that an increase in tree cover leads to reduced ozone formation [24].

5. Conclusion

Human exposure to air pollutants poses severe health problems especially in urban areas where pollution levels are on the increase. The study revealed that daily CO₂ concentrations and temperature were higher than IPCC recommended value, but higher in the afternoon compared to the value obtained in the morning and evening periods. The prediction model established in this study relates CO₂ concentration with temperature and quantity/number of trees. This study found that temperature and density of trees predicted change in CO₂ concentration in the study area. Each of temperature and density of trees contributes significantly as independent variables in explaining CO₂ concentration. Majority of the areas with high commercial activities in Ibadan metropolis had little or no parks where trees are planted. Temperature was positively correlated with the CO₂ concentration while density of trees was inversely correlated with the CO₂ concentration. These findings indicate that increase in density of trees could be attributed to decrease in the CO₂ concentration. Hence, tree planting as an important component of landscaping to reduce air pollutants at source needs to be encouraged in an urban center, particularly in the urban core of Ibadan metropolis.

Acknowledgements

The authors wish to acknowledge the contributions of community heads in all the sampling locations and the field staff.

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