

Geospatial Assessment of Ambient Air Quality Footprints in Relation to Urban Landuses in Nigeria

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Abstract Ambient air pollution is a global concern. It accounts for an estimated 4.2 million deaths yearly as a result of its ability to cause stroke, lung cancer, heart disease and chronic respiratory diseases. It has also been estimated that about 91 percent of the world's population lives in places, mostly urban centres, where air quality levels exceed World Health Organization (WHO) limits. Fortunately, efforts are regularly made in most developed countries to monitor and reduce the level of air pollution and ameliorate its negative consequences. Unfortunately, the case is not the same in most developing countries of which Nigeria is a member, as air pollution status is rarely monitored religiously. This study geospatially assessed ambient air quality footprints vis-à-vis urban land uses in Calabar Metropolis, Nigeria. Data on emission level of CO, NO₂, SO₂, H₂S, and SPM_{2.5} were collected for 6 months in both dry and wet seasons in the year 2020, using Crowcon Gasman, while point coordinates were collected using Garmin GPSMap 60CSx device. Geographic Information Systems (GIS) infrastructure was deployed to generate the ambient air quality maps for the metropolis. Descriptive and parametric analytical techniques were also deployed, based on the objectives of the study. From findings, F-ratio is significant for both season and land use for all the tested parameters (F-ratio for season is $F(1,3224)=574.516$, at $p<0.05$, while for land use, $F(3,3224)=429.946$, at $p<0.05$). The interaction between seasons and land use (season * land use) for all the parameters is also significant. It was

concluded that there is a significant variation in air quality (CO, NO₂, SO₂, H₂S, and SPM_{2.5}) in Calabar Metropolis in relation to either land use types or seasons of the year. It was therefore recommended that there should be protection of residential land uses to avoid encroachment by incompatible uses that cause pollution.

Keywords Geospatial, Air Quality, Footprints, Urban Land Uses, Environmental Pollution

1. Introduction

Every piece of land has a use to which it must be put depending on its natural endowment and profitability. This is termed landuse. Again, land use is the ordered arrangement of socio-economic activities and inputs on a certain land cover type to produce change or maintain it [1]. In a broad perspective, land use is the classification and location of physical structures and conforming activities within a defined region [2]. Land use provides a more livable community to the residents and the work force in a defined urban area. A well organised land use enhances, on a long-term basis, the economic climate as well as green and clean urban areas. It also preserves natural heritage, optimizes recreation and eliminates congestion occasioned by vehicular activities.

Some of the major contaminants of air in urban areas worldwide are the by-products of landuses such as carbon monoxide (CO), carbon dioxide (CO₂), sulphur dioxide (SO₂), oxides of nitrogen (NO_x), volatile organic carbons (VOCs), suspended particulate matters (SPM), etc. Notably, VOCs consist of hydrocarbons. It has been acknowledged that ozone is formed when VOC is mixed with nitrogen oxides and carbon monoxide. Ozone is also a principal pollutant in many urban areas. In most West African cities such as Nigeria, as well as other major cities of the advanced world, outdoor ambient air pollution has been identified as a major threat to human health [3,4,5,6,7,8,9]. Poor ambient air quality is capable of negatively altering the average life span of individuals, communities or even nations that are constantly exposed to it.

According to the global estimates by the United Nations Environment Programme (UNEP), a lot of persons amounting to over one billion breathe unhealthy air [10].

Finally, since economic activities constitute or result to pollution of varying degree, it is pertinent that various land uses in Nigeria, which represent diverse economic activities be scrutinized for various pollutants to ensure that they conform to acceptable standards, otherwise, the people and property would be endangered. Yuvaraj [11] stated that there is a likelihood of impact of man's activity on the natural ecosystem through land use/land cover patterns and changes. In addition, [12] stated that land conflicts in urban areas are usually dynamic in nature and therefore, maintained that it is necessary to consolidate and restructure land use, tenure, and acquisition in order to minimize pollution and improve environmental quality. According to him, land re-adjustment has the potential to improve efficiency, productivity and optimal transformation of urban land use for the purpose of attaining sustainable and just spatial planning.

This research geospatially examined the relationship between urban land uses and ambient air quality footprints in Nigeria urban centres with special emphasis on Calabar Metropolis. Finally, the research was conducted in the year 2020.

2. The Problematic

Generally, it is pertinent to state that there exists thematic and scanty literature on air quality for Calabar Metropolis. Most of these studies focused on air quality micro themes such as air quality status occasioned by transportation activities, or air quality impact from a selected industrial facility, or within a selected processing plant. For instance, [13] examined the Regional Trend in Ambient Air Quality Footprints in Calabar Urban, Nigeria but failed to comprehensively assess and depict air quality

in relation to existing landuses, (spatial) as well as temporal dimension. Besides, studies by [14] as well as [15] were not wide with respect to spatial scope and parameters that were examined. While [15] examined Total Suspended Particulate (TSP) matters, ignoring major or criteria pollutants, [14] concentrated on volumetric transport and air quality relationship. It is worthy to note that a comprehensive air quality study should test for one or more elements from among the criteria pollutants. In addition, [16,17,18] concentrated only on noise level and landslide susceptibility assessment in Cross River State using geospatial techniques.

More importantly, these studies did not assess air quality holistically in relation to all land use types on a city-wide scale. The studies were therefore limited in scope pointing to the fact that there is dearth of relevant air quality data for the metropolis. Moreover, these studies were not captured in spatial context. This means that they are grossly lacking on the aspect of contemporary methodology, since they did not employ environmental visioning tools, and therefore, did not graphically visualize air quality status in the metropolis as it is often said by geographers that "a map speaks more than a thousand words" [19]. Lack of visually projected information on air quality would hamper certain developmental decisions. For example, air quality status taken over a period of time and analyzed graphically would give information on the level of visibility and effluents that are attainable at certain locations and at given time periods. This information would be of immense benefit during transportation planning.

However, there seems to be a sporadic location and ubiquitous distribution of various forms of economic activities as well as other informal enterprises in Calabar Metropolis. All these ultimately give rise to air pollution. Sule [20] states that land use planning is made in order to ensure that the best land is given the best use so that there would be increased profitability as well as minimized incompatibilities and conflicts arising from air and noise pollution.

3. Aim and Objectives of the Study

The aim of this research was to geospatially assess Ambient Air Quality Footprints in Calabar metropolis, Nigeria, in relation to existing dominant landuse elements. The objectives are as follows:

1. Assess the spatial variation of air quality status in relation to land use types in Calabar Metropolis, Nigeria.
2. Assess the seasonality differential in air quality status in Calabar Metropolis.
3. To generate ambient air quality footprint maps of the metropolis, using the GIS infrastructure.

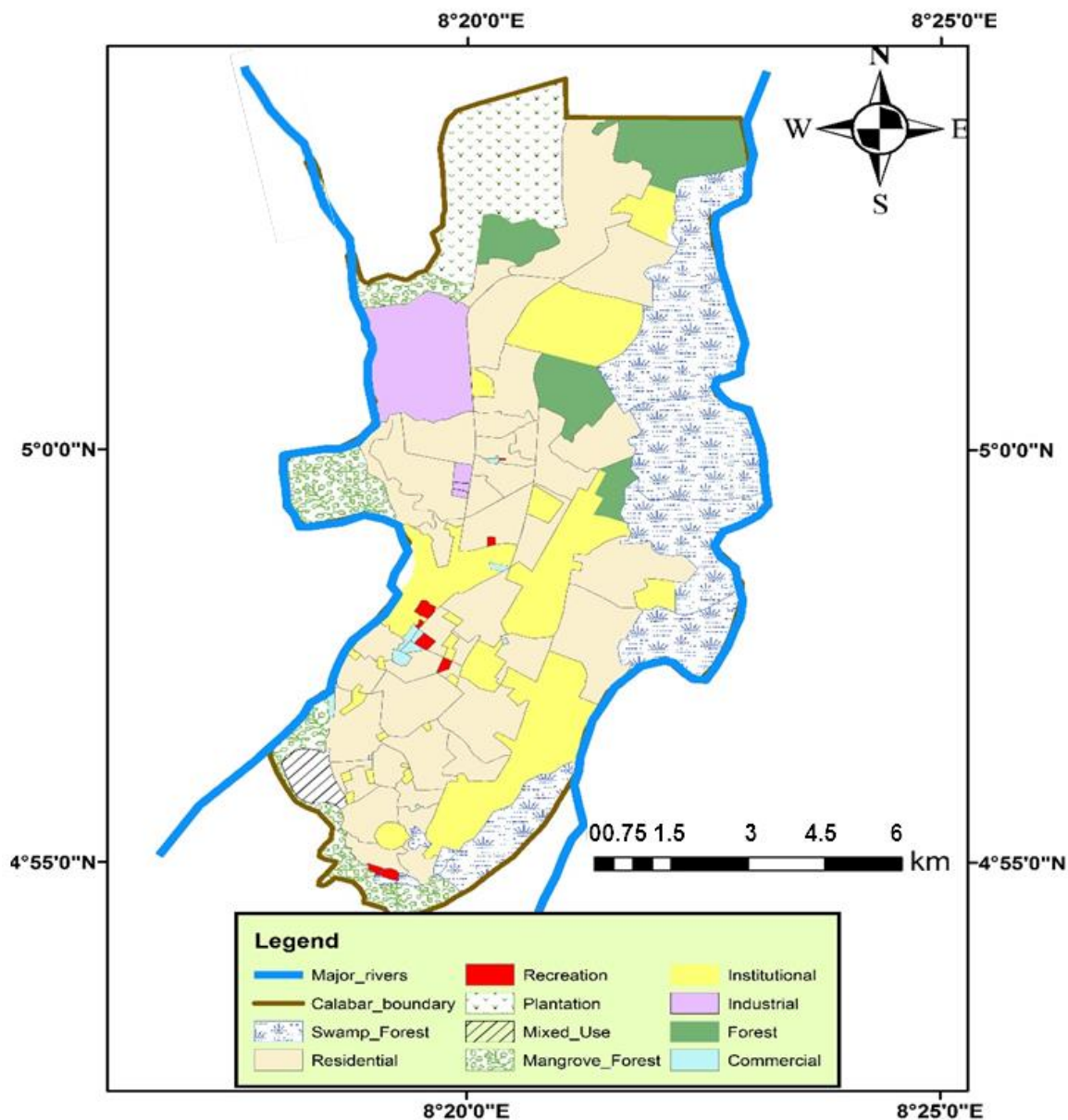
A research hypothesis was set and tested in this research. It states that there is no significant variation in ambient air quality status in relation to either land use types or seasons of the year in the study area being Calabar Metropolis. Calabar is the capital city of Cross River State (FIG.1). Calabar is located between longitudes $8^{\circ} 18'$ and $8^{\circ} 25'$ East of the Greenwich meridian and latitudes $4^{\circ} 55'$ and $5^{\circ} 10'$ North of the Equator. It is sandwiched between the Great Kwa River to the East and the Calabar River to the west. Calabar Metropolis, comprising Calabar Municipality and Calabar South Local Government Areas has a total land area of 1480sq kms. Calabar is bounded to the North by Odukpani Local Government Area, to the East by Akpabuyo Local Government Area.

4. Research Methodology

4.1. Types and Sources of Data

The study relied on primary data on ambient air quality status across various landuses as well as data on seasonality variation in air quality status in Calabar Metropolis, Nigeria. Data were expressed in parts per million (ppm) scale.

Data were acquired using several automated data loggers named Crowcon Gasman and a Garmin GPSMap. Dataset included logged figures on the level of pollutants and suspended particulate matter from various locations within identified landuses as well as the GPS coordinates for the locations.



Source: Obiefuna, Njar and Bisong (2021)

Figure 1. Land use map of Calabar Metropolis showing the study area

4.2. Selection of Monitoring Sites and Data Collection

Air quality data collection was carried out at each selected location within a land use using a real-time, automated air quality monitor, mounted on a ground-based platform/tripod, or held at a height of a range of between 1.5 and 2.0 meters from the ground.

Data readings were made once in the afternoon between 12 noon and 12.30pm. This represents the peak period when economic activities are at their optimum. The duration of data collection lasted for a period of four months. In the rainy (wet) season, readings were taken between July and August, while in the dry season, readings were taken between November and December.

Harmful pollutants and particulate matters occasioned by economic activities were measured because they have been identified as being very injurious to human health and the environment, while PM_{2.5} is said to be a causal agent for cancer, heart or respiratory disease [21].

4.3. Sampling Procedure

Stratification and randomization were employed to group and randomly select points from each land use for proper representation. Though a total of 24 locations were identified on the transportation land use, 7 were selected. On this landuse, data were acquired along road nodes on major road network, roundabout and parks. For the industrial landuse, data were acquired from both the minor road intersections/junctions within the zone as well as 10 metres from the pollution sources. A total of 18 locations were identified in the industrial landuse, while five (5) locations were selected. For the commercial landuse, data were acquired from the pollution sources after having identified them. 22 locations were identified while 7 locations were selected. With regards to the residential neighbourhood, data were acquired from minor road intersections and from other emission points. A total of 23 locations were identified while seven (7) locations were also selected. Presented below is table 1, which shows a total of 26 sample points representing 30 percent of the total observed points from all land uses. This decision for 30 percent selection was based on [22] which states that a sample fraction of 10 percent is deemed adequate as no serious research can progress with a sample fraction less than 10 percent. This means that the 30 percent sample fraction employed in this research is very adequate and representative. Selection was done using a row by column

digital random number generator. The sample points have been depicted (FIG. 2).

4.4. Techniques for Data Analysis

Sourced data were subjected to geospatial and statistical analytical manipulations using GIS, inferential and descriptive statistics. The output was in averages, tables, charts, graphs and composite maps showing air quality footprints for the study area.

5. Test of Hypothesis

H₀: There is no significant variation in air quality in Calabar Metropolis in relation to either land use type or season of the year.

H₁: There is a significant variation in air quality in Calabar Metropolis in relation to either land use type or season of the year.

A two-way analysis of variance (ANOVA) or factorial analysis of variance was used to test this hypothesis. The mathematical definition of ANOVA is given as:

$$\sum_{ij} \sum_{ij}^n (X_{ij} - \bar{X})^2 = (x + a)^n$$

$$= \sum_{ij} ni(X_1 - \bar{X})^2 + \sum_{ij} (X_{ij})$$

$$TSS = BSS + WSS$$

Where:

TSS = Total Sum of Squares (total mean squares of all locations)

BSS = Between Group Sum of Squares (the sum of square of observations made within each landuse)

WSS = Within Group Sum of Squares (the sum of square of observations made across different landuses)

K = Number of Samples (26 points)

N = Number of Observations (number of all observations in all locations)

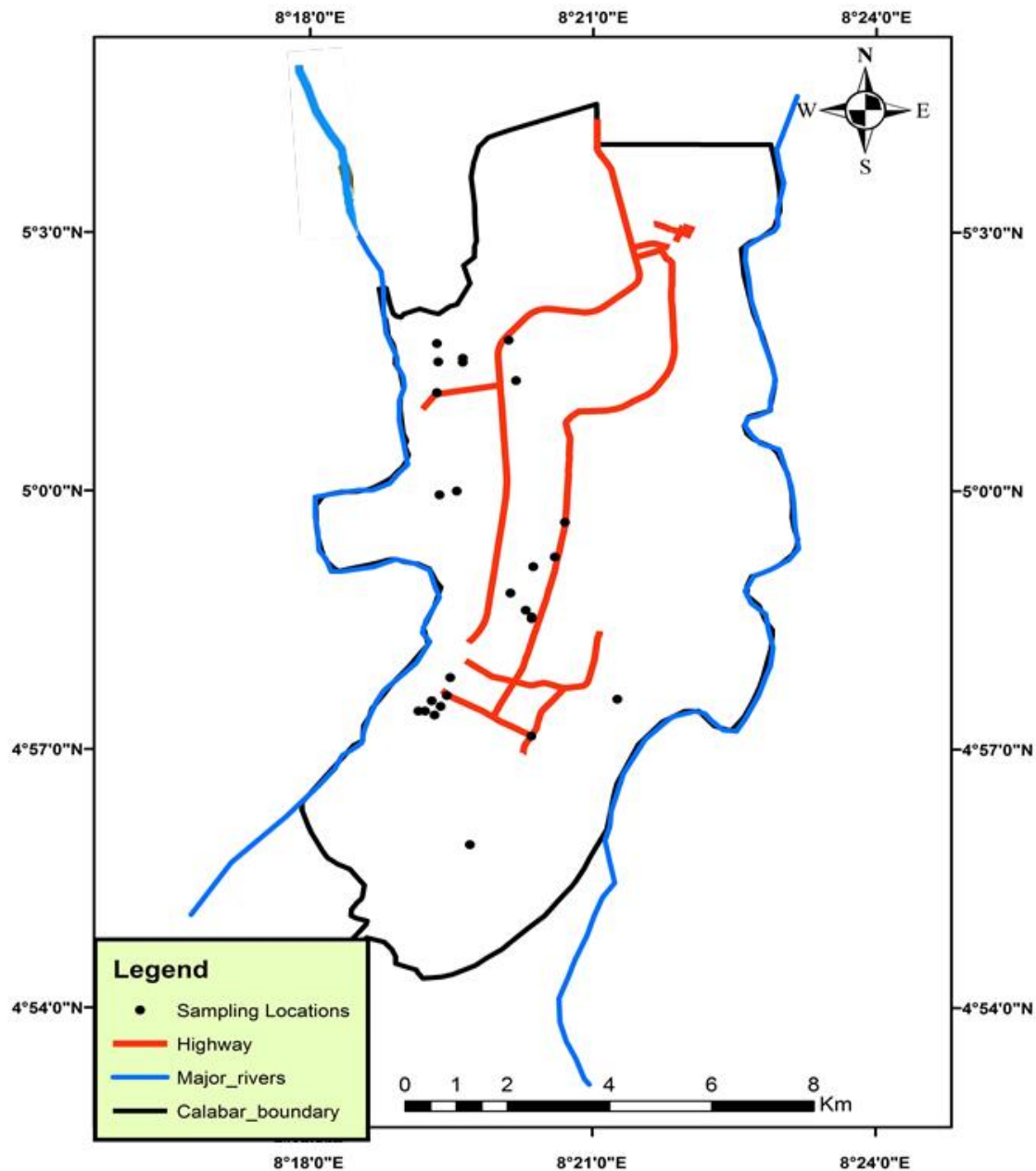
X_{ij} = Value of the ith and jth observation, \bar{X} = Mean, X_i = Mean for the ith sample

$\sum \sum$ = Summation of all items in the matrix i.e. all "k" or "n" (emission level across the days of the week over different time periods in all locations).

Table 1. Sampled points with their GPS coordinates

S/ N	Land use Type/ Location	Activity Type	GPS		Prevailing Activities/pollutants
			Lat.	Long.	
1.	Industrial-EPZ	Administrative Block	5.024907	8.322707	Administrative Block
2.	Industrial-EPZ	By Dangote Flour Mills, Haulage, processing	5.018985	8.322473	Processing, Haulage, vehicles, trucks
3.	Industrial-EPZ	M-Saleh Industry: Fabrication, welding	5.02485	8.32704	Point source: fabrication, welding, metal cutting, smoothening, welding.
4.	Industrial-EPZ	Stone Craft Industry: Processing	5.02563	8.32704	Point source: Cutting and polishing of stones, marble production
5.	Industrial-EPZ	Rosa Mystica Tank farm, Combination Industries: processing	5.028472	8.32248	Tank farm, storage, processing
6.	Transportation: Muritala Muhammed highway	Road Node: Mobil by MCC	4.98720	8.343341	Line sources: vehicles, dust particles
7.	Transportation (Eleven-Eleven area)	Round About	4.96384	8.32488	Line sources: vehicles, dust particles
8.	Transportation (Effio-Ette area)	Round About	4.993898	8.345098	Line sources: vehicles, dust particles
9.	Transportation (Etta-Agbor Road)	Round About (Unical Main Gate)	4.95254	8.33921	Line sources: vehicles, dust particles
10.	Transportation (Etta-Agbor Road)	Round About (by IBB Rd	4.95933	8.32164	Line sources: vehicles, dust particles
11.	Transportation (Ekpoabasi Road)	Road Node by CRUTECH	4.93151	8.3284	Line sources: vehicles, dust particles
12.	Transportation (park)	Etim Edem park	4.96039	8.3243	Line sources: vehicles, dust particles
13.	Commercial: Calabar Road by Watt Market	By Atakpa Police Station	4.95736	8.31927	Buying and selling, vehicles
14.	Commercial (Watt Market Area)	By Nelson Mandela	4.956593	8.32212	Buying and selling, vehicles
15.	Commercial (Watt Market area)	By Goldie	4.958283	8.32317	Buying and selling, vehicles
16.	Commercial (Watt Market area)	By Calabar road round about	4.957348	8.320463	Buying and selling, vehicles
17.	Commercial (Marian Market)	Point source pollution	4.9753	8.33922	Buying and selling, grinding, vehicles
18.	Commercial (Marian Market)	Point source of pollution	4.97559	8.33927	Buying and selling, vehicles, grinding
19.	Commercial: Marian Market area	Commercial activities, waste dump	4.976893	8.338185	Buying and selling, vehicles,
20.	Residential: Ekorinim	Residential: by Redeemed Church	4.99921	8.32295	Residential, mobility
21.	Residential: Ekorinim II	Residential: By NPA	4.999927	8.325983	Residential, mobility
22.	Residential: Satellite town	Residential: By Children of Promise School	4.959683	8.354402	Residential, mobility
23.	Residential (State Housing)	Residential: State Housing by Atekon Drive	4.980188	8.33551	Residential, mobility
24.	Residential (State Housing)	By the police Station	4.98532	8.33952	Residential, mobility
25.	Residential (Federal Housing)	Residential: By Esien Kooffreh/Police Station	5.021298	8.336463	Residential, mobility
26.	Residential (Federal Housing)	Residential	5.029147	8.335152	Residential, mobility

Source: Obiefuna, Njar and Bisong (2021)



Source: Obiefuna, Njar and Bisong (2021)

Figure 2. Sampled locations across land uses in Calabar Metropolis

6. Results/Findings

6.1. Spatial Analysis of Land Use Based and Seasonality Differential in Air Quality Footprints in Calabar Metropolis

The hypothesis was tested using a two-way analysis of variance (ANOVA). Table 2 shows the descriptive statistics for CO in terms of the mean and standard deviation for the wet season, dry season and total over the various land uses. For example, the mean value of CO for industrial land use is 2.3433 in the wet season and 3.4587

in the dry season. These values have corresponding standard deviations of ± 0.73000 and ± 1.12405 respectively. This shows that CO concentration was higher in the dry season than in the wet season. Similarly, observations can be made on CO for other land uses.

Table 3 shows the test of between subject effects with CO as the variable of interest over the various land uses and seasons of the year. It was hypothesized as follows:

H_0 : There is no significant variation in air quality (CO) in Calabar Metropolis in relation to either land use type or season of the year.

H_1 : There is a significant variation in air quality (CO) in

Calabar Metropolis in relation to either land use type or season of the year. From the result in table 3, the F-ratio for season is $F(1, 3198) = 574.516$, $p < 0.05$ is significant. Similarly, for land use, $F(3, 3198) = 429.946$, $p < 0.05$ is significant. For the interaction between seasons and land use (season * landuse), $F(3, 3198) = 58.189$, $p < 0.05$ is

also significant. Hence, we do not have enough evidence to retain the null hypothesis. Therefore, it was concluded that there is a significant variation in air quality (CO) in Calabar Metropolis in relation to either land use type or season of the year.

Table 2. Descriptive statistics for the analysis of CO across land uses

Season	Land use	Mean	Std. Deviation	N
Wet season	Industrial	2.3433	.73001	310
	Transportation	2.8467	.67254	434
	Commercial	2.7493	.67084	434
	Residential	1.4429	.39254	434
	Total	2.3457	.84688	1612
Dry season	Industrial	3.4587	1.12405	305
	Transportation	2.9144	1.40331	427
	Commercial	3.5877	.64288	427
	Residential	2.2422	.59354	427
	Total	3.0194	1.12572	1586
Total	Industrial	2.9010	1.09923	615
	Transportation	2.8805	1.10024	861
	Commercial	3.1685	.77916	861
	Residential	1.8426	.64248	861
	Total	2.6826	1.05139	3198

Dependent Variable: CO

Source: Analysis by the Author, 2020.

Table 3. Tests of Between-Subjects Effects for CO

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1366.034 ^a	7	195.148	285.698	.000	.383
Intercept	22978.640	1	22978.640	33640.982	.000	.913
Season	392.426	1	392.426	574.516	.000	.152
Land use	881.031	3	293.677	429.946	.000	.286
Season * Landuse	119.239	3	39.746	58.189	.000	.051
Error	2196.705	3216	.683			
Total	26763.091	3198				
Corrected Total	3562.738	3197				

a. R Squared = .383 (Adjusted R Squared = .382). Dependent Variable: CO

Source: Analysis by the Author, 2020.

The result of the post hoc test indicates a significant difference in most comparisons except between industrial and transportation land uses. The land uses that cause significant variation are the commercial and residential. This has been graphically depicted (FIG.3).

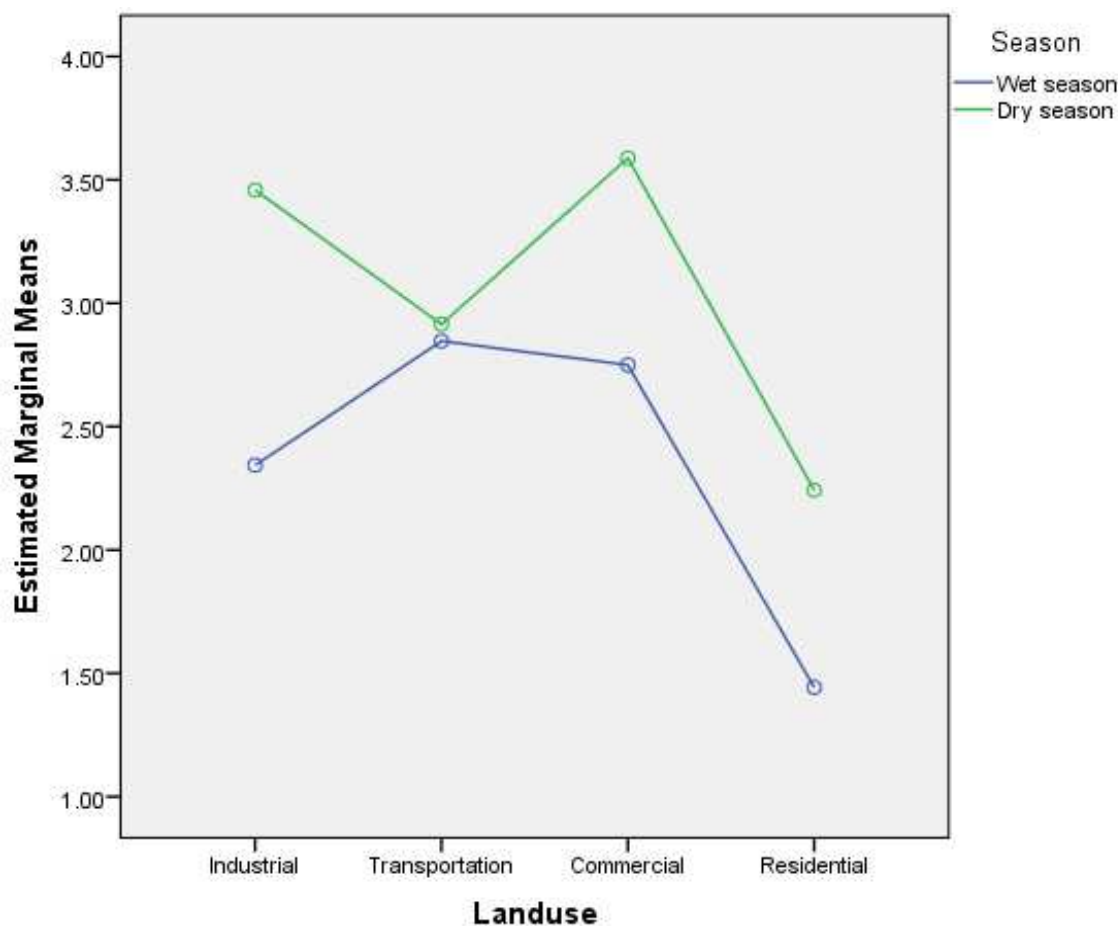
Table 4 shows the descriptive statistics for NO_2 in terms of the mean and standard deviation for the wet season, dry season and total over the various land uses. For example, the mean value of NO_2 for industrial land use is 0.3265 in the wet season and 0.7586 in the dry season. These values have corresponding standard deviations of ± 0.36859 and ± 0.72436 respectively. This shows that NO_2 concentration is higher in the dry season than in the wet season. Similarly, observations can be made on NO_2 for other land uses.

Table 5 shows the test of between subject effects with NO_2 as the variable of interest over the various land uses

and seasons of the year. It was hypothesized as follows:

H_0 : There is no significant variation in air quality (NO_2) in Calabar Metropolis in relation to either land use type or season of the year.

H_1 : There is a significant variation in air quality (NO_2) in Calabar Metropolis in relation to either land use type or season of the year. From the result in table 5 the F-ratio for season is $F(1, 3198) = 1113.49$, $p < 0.05$ is significant. Similarly, for land use, $F(3, 3198) = 792.457$, $p < 0.05$ is significant. For the interaction between seasons and land use (season * landuse), $F(3, 3198) = 236.546$, $p < 0.05$ is also significant. Hence, we do not have enough evidence to retain the null hypothesis. Therefore, it was concluded that there is a significant variation in air quality (NO_2) in Calabar Metropolis in relation to either land use type or season of the year.



Source: Analysis by the Author, 2020.

Figure 3. Mean plot of CO over land use

Table 4. Descriptive statistics for the analysis of NO₂ across land uses

Season	Land use	Mean	Std. Deviation	N
Wet season	Industrial	.3265	.36859	310
	Transportation	1.0506	.26289	434
	Commercial	.8037	.50439	434
	Residential	.3267	.16754	434
	Total	.6500	.46739	1612
Dry season	Industrial	.7586	.72436	305
	Transportation	2.9324	1.42421	427
	Commercial	1.1599	.60121	427
	Residential	.8904	.47664	427
	Total	1.4874	1.26240	1586
Total	Industrial	.5425	.61359	615
	Transportation	1.9915	1.39063	861
	Commercial	.9818	.58251	861
	Residential	.6086	.45499	861
	Total	1.0687	1.03977	3198

Dependent Variable: NO₂

Source: Analysis by the Author, 2020.

Table 5. Tests of between -subjects effects for NO₂

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1994.947 ^a	7	284.992	615.325	.000	.573
Intercept	3355.684	1	3355.684	7245.227	.000	.693
Season	515.722	1	515.722	1113.490	.000	.257
Land use	1101.098	3	367.033	792.457	.000	.425
Season * Landuse	328.675	3	109.558	236.546	.000	.181
Error	1489.516	3216	.463			
Total	7166.467	3198				
Corrected Total	3484.463	3197				

a. R Squared = .573 (Adjusted R Squared = .572). Dependent Variable: NO₂

Source: Analysis by the Author, 2020.

In order to account for the variation in NO₂ across the land uses, a post hoc test was carried out and the result indicates a significant difference in most comparisons except between industrial and residential land uses. The land uses that cause significant variation are the commercial and transportation, as graphically depicted (FIG.4).

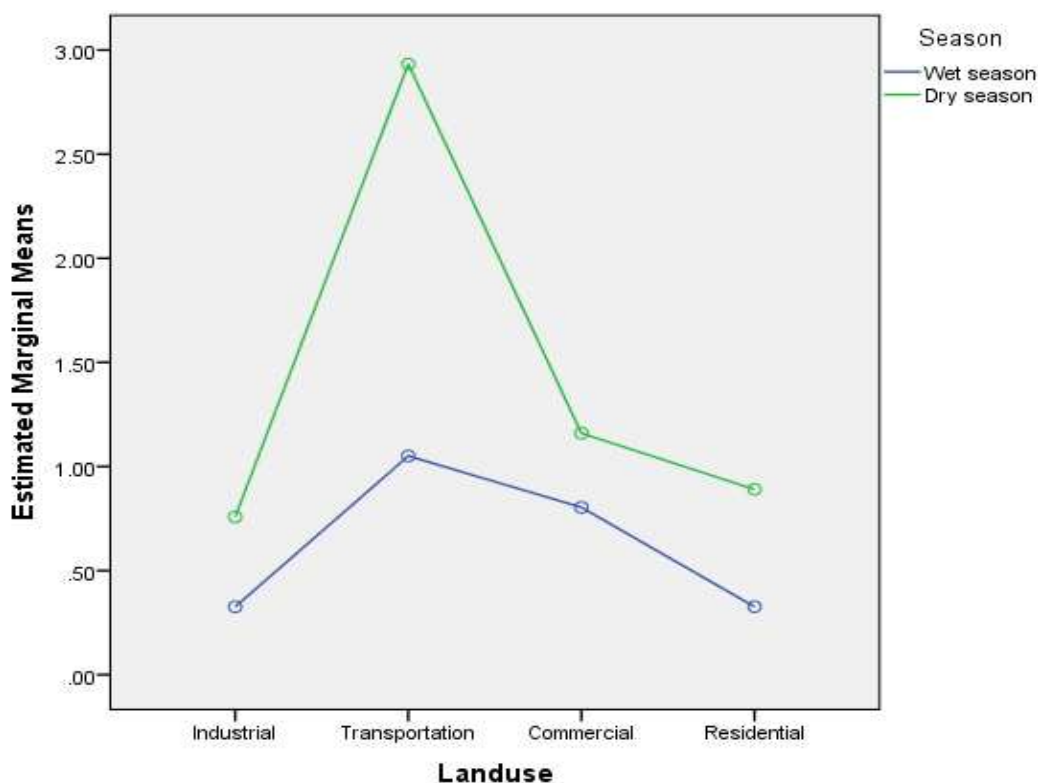
Table 6 shows the descriptive statistics for SO₂ in terms of the mean and standard deviation for the wet season, dry season and total over the various land uses. For example, the mean value of NO₂ for industrial land use is 1.5381 in the wet season and 1.6538 in the dry season. These values have corresponding standard deviations of ± 0.63464 and ± 0.46832 respectively. This shows that SO₂ concentration is higher in the dry season than in the wet season. Similarly, observations can be made on SO₂ for other land uses.

Table 7 shows the test of between subject effects with

SO₂ as the variable of interest over the various land uses and seasons of the year. It was hypothesized as follows:

H₀: There is no significant variation in air quality (SO₂) in Calabar Metropolis in relation to either land use type or season of the year.

H₁: There is a significant variation in air quality (SO₂) in Calabar Metropolis in relation to either land use type or season of the year. From the result in table 7, the F-ratio for season is $F(1, 3198) = 271.213$, $p < 0.05$ is significant. Similarly, for land use, $F(3, 3198) = 875.421$, $p < 0.05$ is significant. For the interaction between seasons and land use (season * landuse), $F(3, 3198) = 30.004$, $p < 0.05$ is also significant. Hence, we do not have enough evidence to retain the null hypothesis. Therefore, it was concluded that there is a significant variation in air quality (SO₂) in Calabar Metropolis in relation to either land use type or season of the year.



Source: Analysis by the Author, 2020.

Figure 4. Estimated marginal means of NO₂ over land use

Table 6. Descriptive statistics for the analysis of SO₂ across land uses

Season	Land use	Mean	Std. Deviation	N
Wet season	Industrial	1.5381	.63464	310
	Transportation	2.0356	1.32927	434
	Commercial	.7609	.63466	434
	Residential	.2409	.20770	434
	Total	1.1136	1.08369	1612
dry season	Industrial	1.6538	.46832	305
	Transportation	2.9281	1.41756	427
	Commercial	1.1109	.48160	427
	Residential	.8539	.59108	427
	Total	1.6354	1.19471	1586
Total	Industrial	1.5960	.56026	615
	Transportation	2.4819	1.44410	861
	Commercial	.9359	.58962	861
	Residential	.5474	.53858	861
	Total	1.3745	1.16985	3198

Dependent Variable: SO₂

Source: Analysis by the Author, 2020.

Table 7. Tests of between-subjects effects for SO₂

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2138.598 ^a	7	305.514	432.411	.000	.485
Intercept	6100.973	1	6100.973	8635.039	.000	.729
Season	191.622	1	191.622	271.213	.000	.078
Land use	1855.552	3	618.517	875.421	.000	.450
Season * Landuse	63.597	3	21.199	30.004	.000	.027
Error	2272.222	3216	.707			
Total	10501.493	3198				
Corrected Total	4410.820	3197				

a. R Squared = .485 (Adjusted R Squared = .484). Dependent Variable: SO₂

Source: Analysis by the Author, 2020.

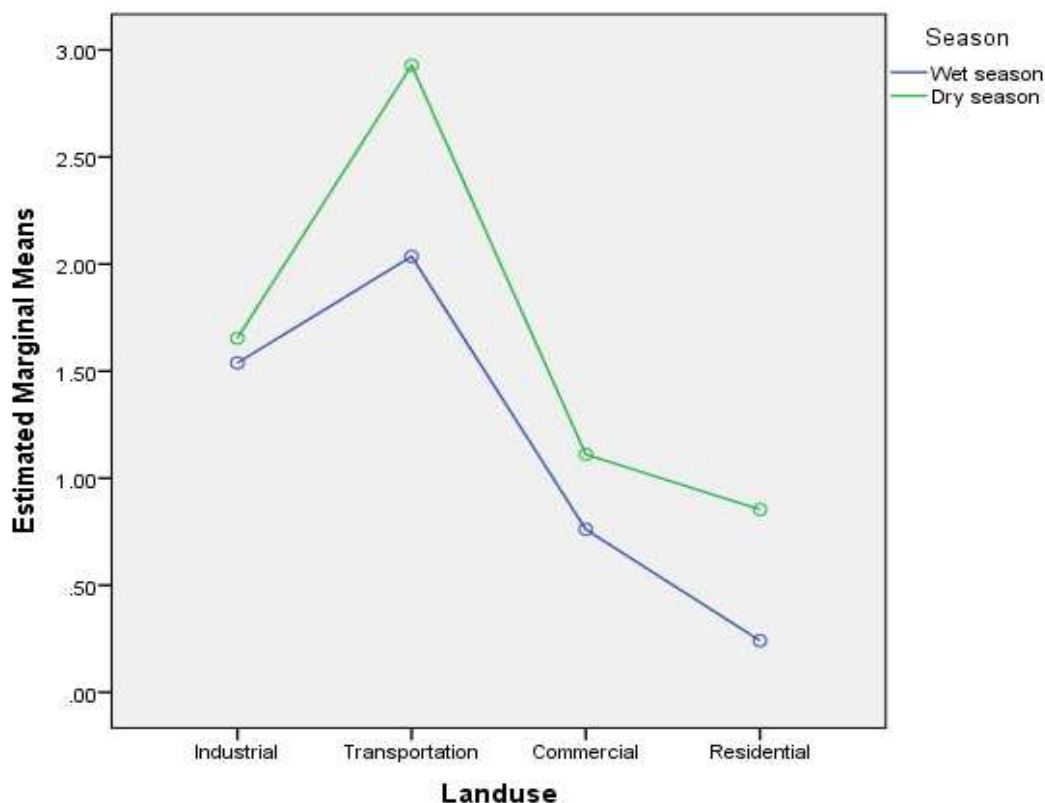
In order to account for the variation in SO_2 across the land uses, a post hoc test was carried out and the result indicates a significant difference in all between the land uses. This has been graphically depicted (FIG.5).

Table 8 depicts the descriptive statistics for H_2S in terms of the mean and standard deviation for the wet season, dry season and total. They are reported over the various land uses. For the industrial land use, table 4.31 indicates that the mean is 0.2989 for the wet season and 0.8966 for the dry season. Hence, the mean concentration of H_2S is higher

for the dry season than for the wet season. Table 9 shows the test of between subject effects with H_2S as the variable of interest over the various land uses and season of the year. It was hypothesized as follows:

H_0 : There is no significant variation in air quality (H_2S) in Calabar Metropolis in relation to either land use type or season of the year.

H_1 : There is a significant variation in air quality (H_2S) in Calabar Metropolis in relation to either land use type or season of the year.



Source: Analysis by the Author, 2020.

Figure 5. Estimated marginal means of SO_2 over land use

Table 8. Descriptive statistics for the analysis for H_2S across land uses

Season	Land use	Mean	Std. Deviation	N
Wet season	Industrial	.2989	.34922	310
	Transportation	1.0947	.26352	434
	Commercial	1.2078	.50844	434
	Residential	.2450	.28479	434
	Total	.7433	.57414	1612
dry season	Industrial	.8966	.85249	305
	Transportation	2.8967	1.40732	427
	Commercial	1.8932	.86328	427
	Residential	.7931	.27878	427
	Total	1.6755	1.27826	1586
Total	Industrial	.5978	.71633	615
	Transportation	1.9957	1.35518	861
	Commercial	1.5505	.78669	861
	Residential	.5190	.39308	861
	Total	1.2094	1.09490	3198

Dependent Variable: H_2S

Source: Analysis by the Author, 2020.

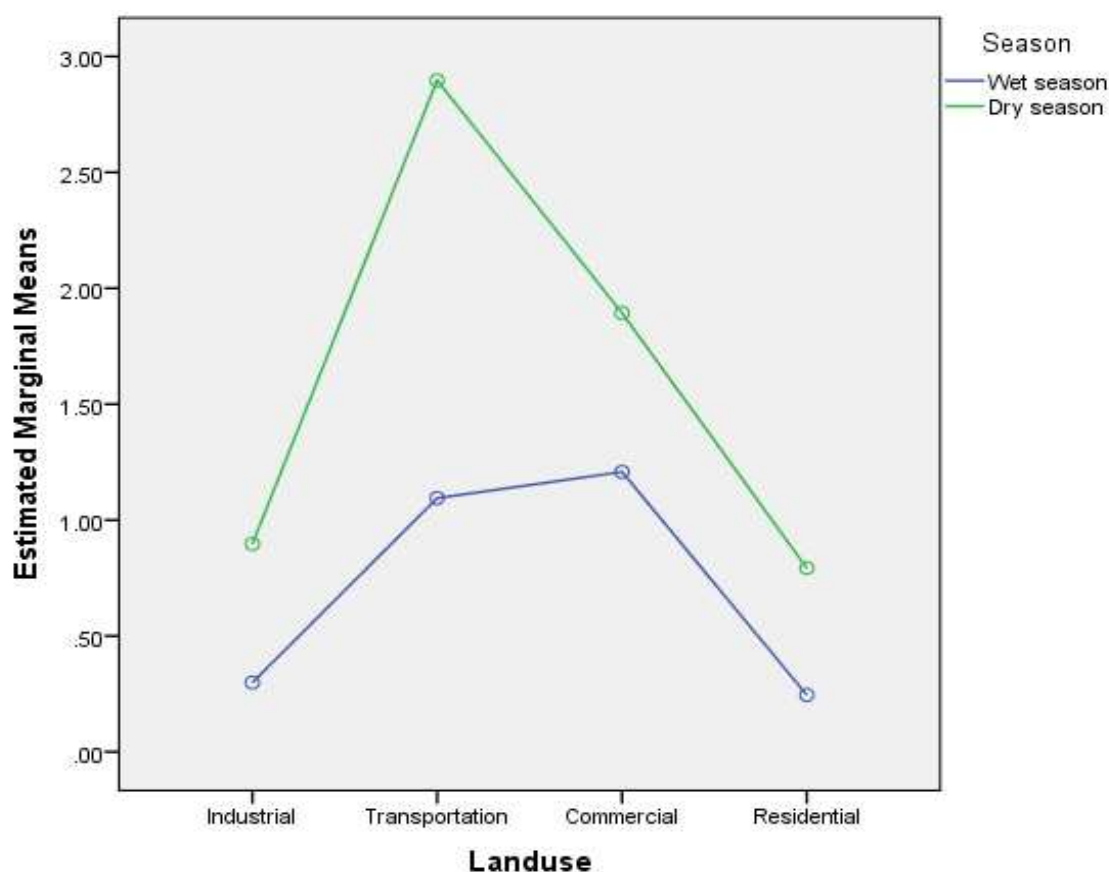
Table 9. Tests of Between-Subjects Effects for H₂S

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2210.432 ^a	7	315.776	614.252	.000	.572
Intercept	4289.408	1	4289.408	8343.818	.000	.722
Season	650.999	1	650.999	1266.332	.000	.283
Land use	1283.315	3	427.772	832.108	.000	.437
Season * Landuse	226.729	3	75.576	147.012	.000	.121
Error	1653.288	3216	.514			
Total	8579.621	3198				
Corrected Total	3863.720	3197				

a. R Squared = .572 (Adjusted R Squared = .571).

Dependent Variable: H₂S

Source: Analysis by the Author, 2020.



Source: Analysis by the Author, 2020.

Figure 6. Estimated marginal means of H₂S over land use

From the result in table 9 the F-ratio for season, $F(1,3198) = 1266.332$, $P < 0.05$ is significant. Similarly, the F-ratio for land use $F(3, 3198) = 832.108$, $P < 0.05$ is also significant. The interaction between season and land use is again significant since $F(3, 3198) = 147.012$, $P < 0.05$. Hence, the evidence provided by the data is not enough to retain the null hypothesis. Therefore, it was concluded that there is a significant variation in air quality in Calabar Metropolis in relation to either land use type or season of the year.

The land uses that cause significant variation are the transportation and residential, as visualized (FIG.6).

Table 11 shows the descriptive statistics for SPM_{2.5} in terms of the mean and standard deviation for the wet season, dry season and total over the various land uses. For example, the mean value of SPM_{2.5} for industrial land use is 2.6471 in the wet season and 3.9073 in the dry season. This shows that SPM_{2.5} is higher in the dry season than in the wet season. Similarly, observations can be made on SPM_{2.5} for other land uses. Table 12 shows the test of

between subject effects with $SPM_{2.5}$ as the variable of interest over the various land uses and seasons of the year. It was hypothesized as follows:

H_0 : There is no significant variation in air quality ($SPM_{2.5}$) in Calabar Metropolis in relation to either land use type or season of the year.

H_1 : There is a significant variation in air quality ($SPM_{2.5}$) in Calabar Metropolis in relation to either land use type or season of the year.

From the result in table 12, the F-ratio for season is

$F(1,3224) = 511.669$, $P < 0.05$ is significant. Similarly, for land use, $F(3,3224) = 299.015$, $P < 0.05$ is significant. For the interaction between seasons and land use (season * landuse), $F(3, 3224) = 211.488$, $P < 0.05$ is also significant. Therefore, it was concluded that there is a significant variation in air quality ($SPM_{2.5}$) in Calabar Metropolis in relation to either land use type or season of the year.. The land uses that cause significant variation are the commercial and residential. This has been depicted (FIG.7).

Table 11. Descriptive statistics for the analysis of $SPM_{2.5}$ across land uses

Season	Land use	Mean	Std. Deviation	N
Wet season	Industrial	2.6471	.57872	310
	Transportation	3.4923	.67118	434
	Commercial	3.3060	.62331	434
	Residential	2.1045	.50544	434
	Total	2.9060	.82468	1612
dry season	Industrial	3.9073	1.14172	305
	Transportation	2.9024	1.40953	427
	Commercial	4.3394	.76751	427
	Residential	3.1191	.67090	427
	Total	3.5409	1.19109	1586
Total	Industrial	3.2772	1.10252	615
	Transportation	3.1974	1.14207	861
	Commercial	3.8227	.86920	861
	Residential	2.6118	.78103	861
	Total	3.2234	1.07232	3198

Dependent Variable: $SPM_{2.5}$

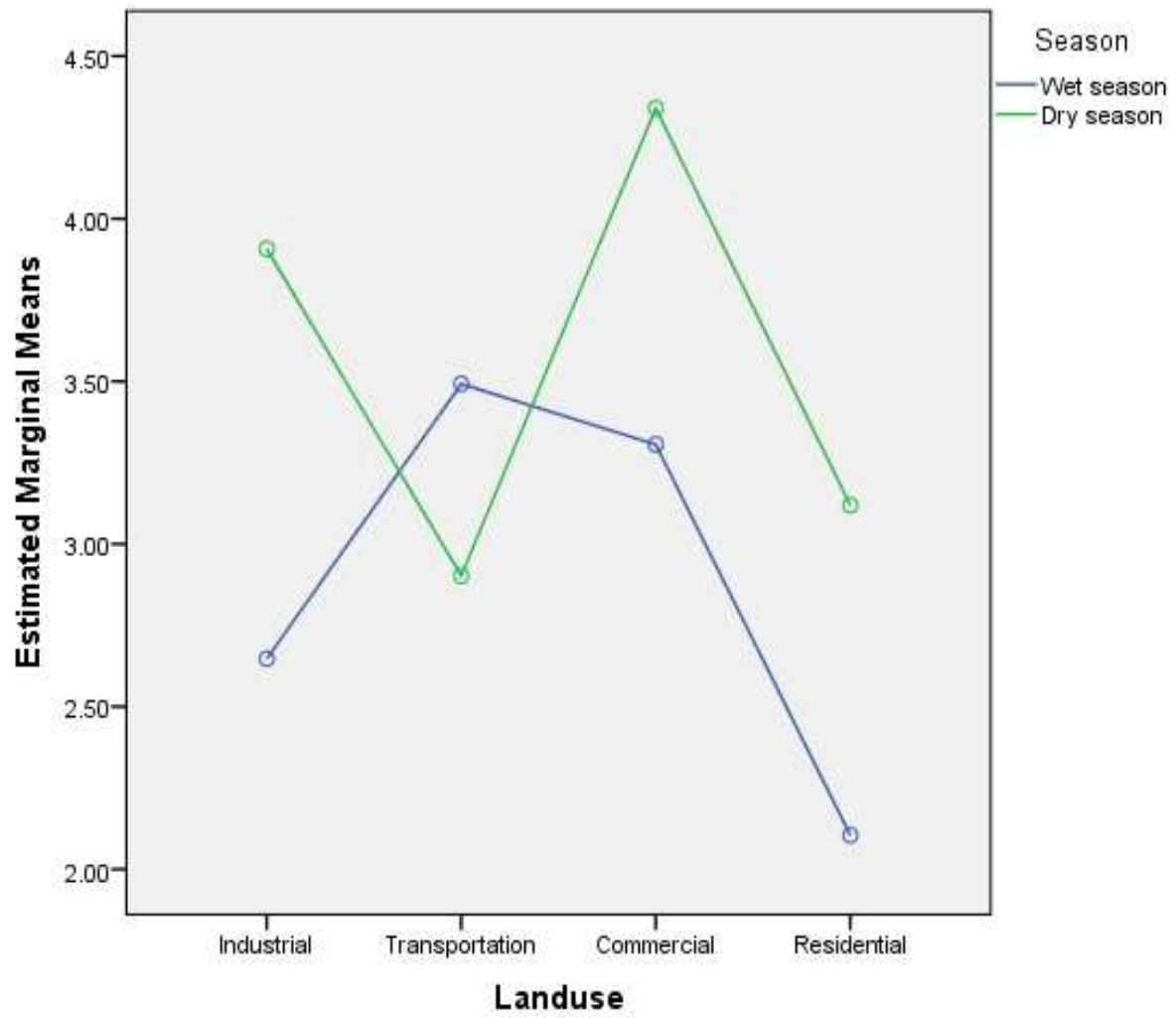
Source: Analysis by the Author, 2020.

Table 12. Tests of Between-Subjects Effects for $SPM_{2.5}$

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1415.630 ^a	7	202.233	283.957	.000	.382
Intercept	32874.118	1	32874.118	46158.854	.000	.935
Season	364.408	1	364.408	511.669	.000	.137
Land use	638.870	3	212.957	299.015	.000	.218
Season * Landuse	451.862	3	150.621	211.488	.000	.165
Error	2290.420	3216	.712			
Total	37204.778	3198				
Corrected Total	3706.050	3197				

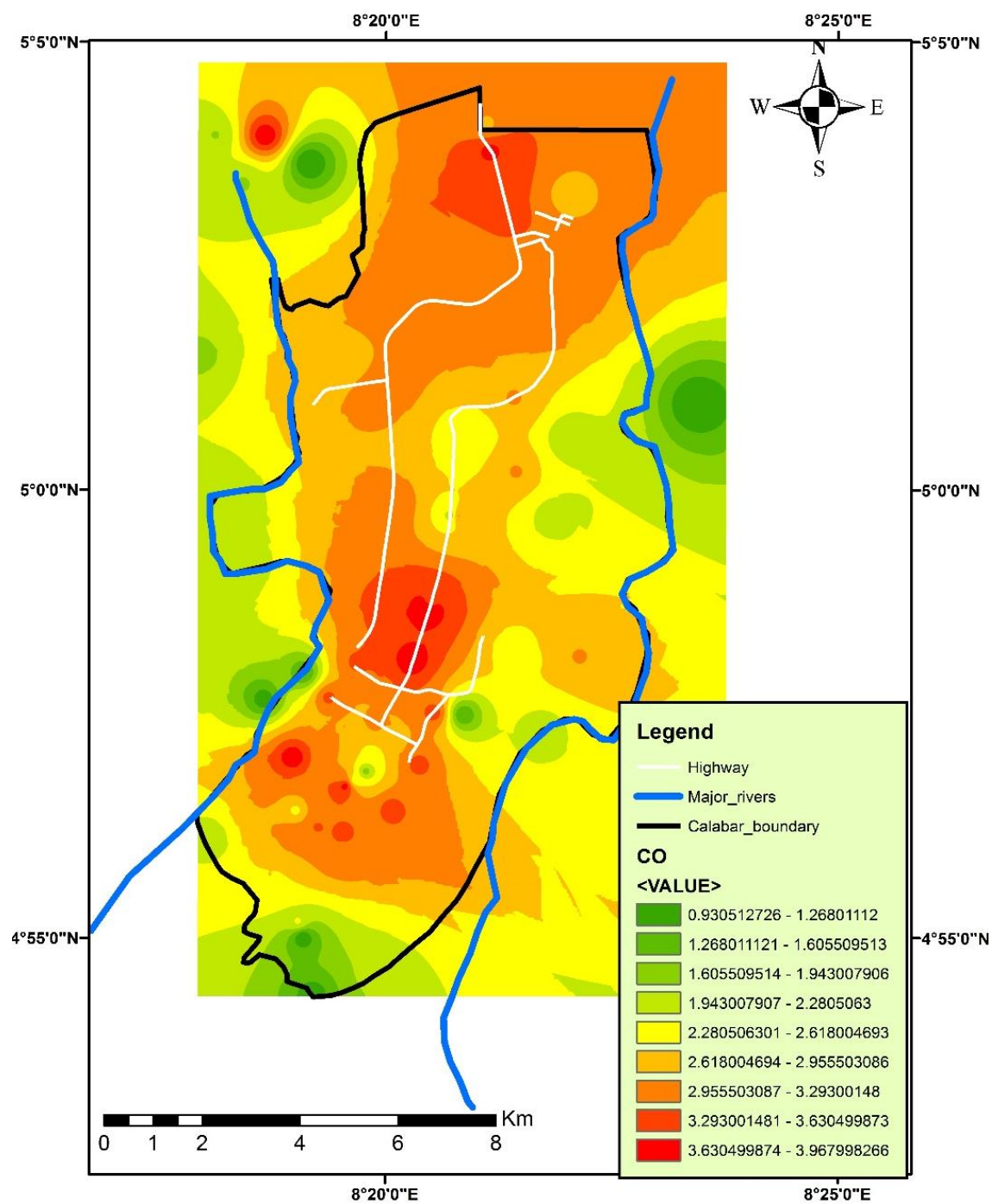
a. R Squared = .382 (Adjusted R Squared = .381). Dependent Variable: $SPM_{2.5}$

Source: Analysis by the Author, 2020.



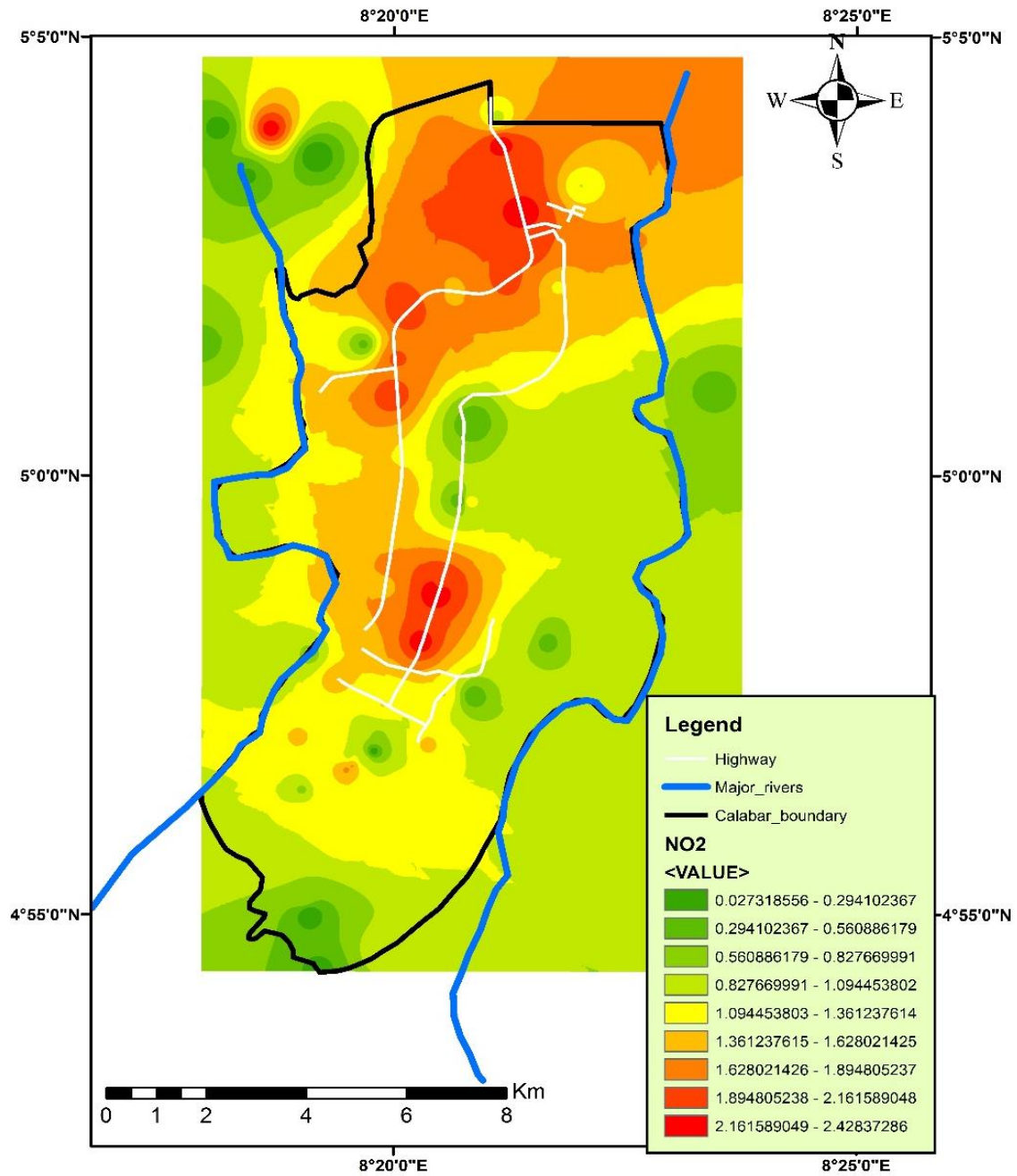
Source: Analysis by the Author, 2020.

Figure 7. Mean of SPM_{2.5} across the various land uses.



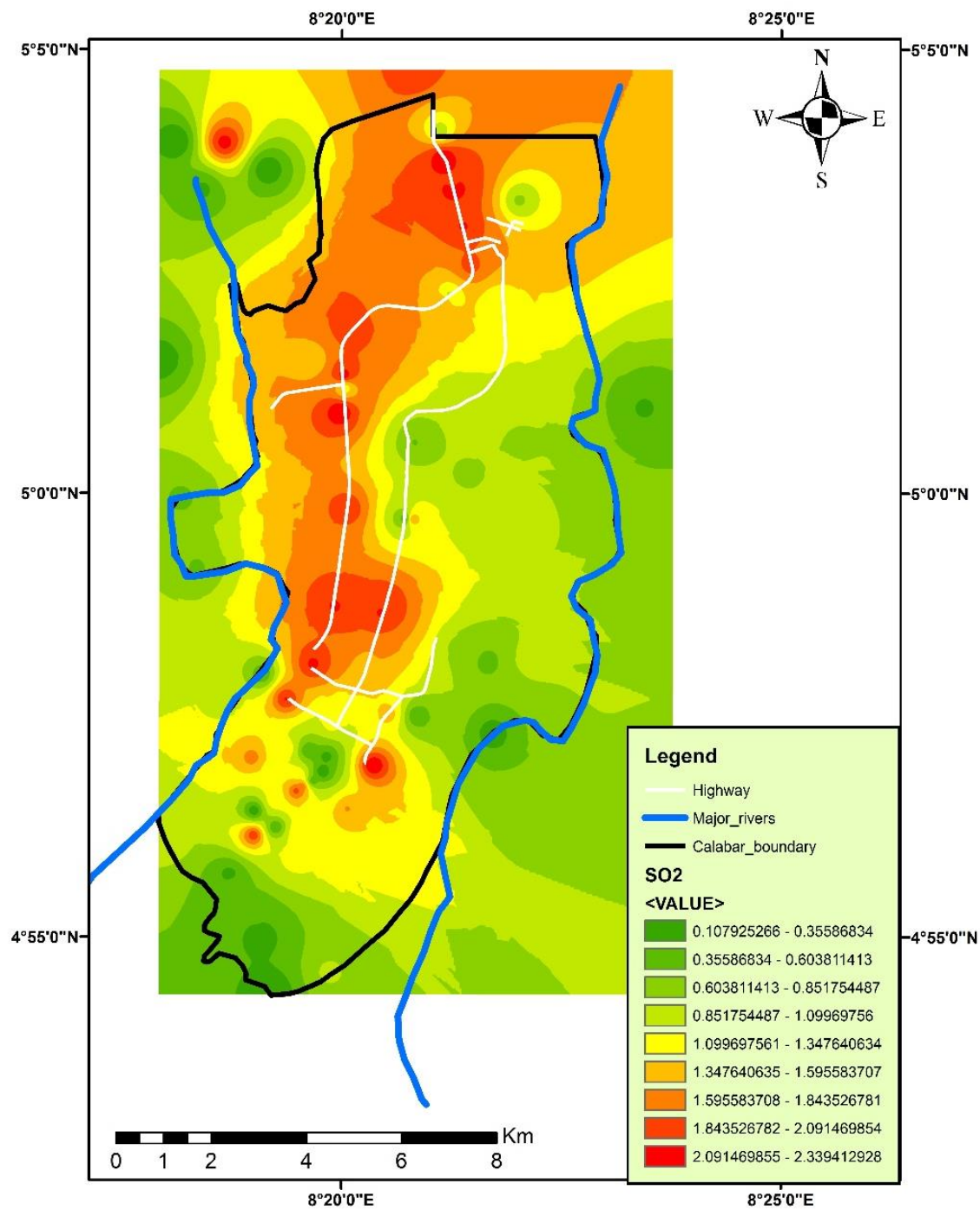
Source: Author's GIS visualization, 2020.

Figure 8. CO footprints for Calabar Metropolis



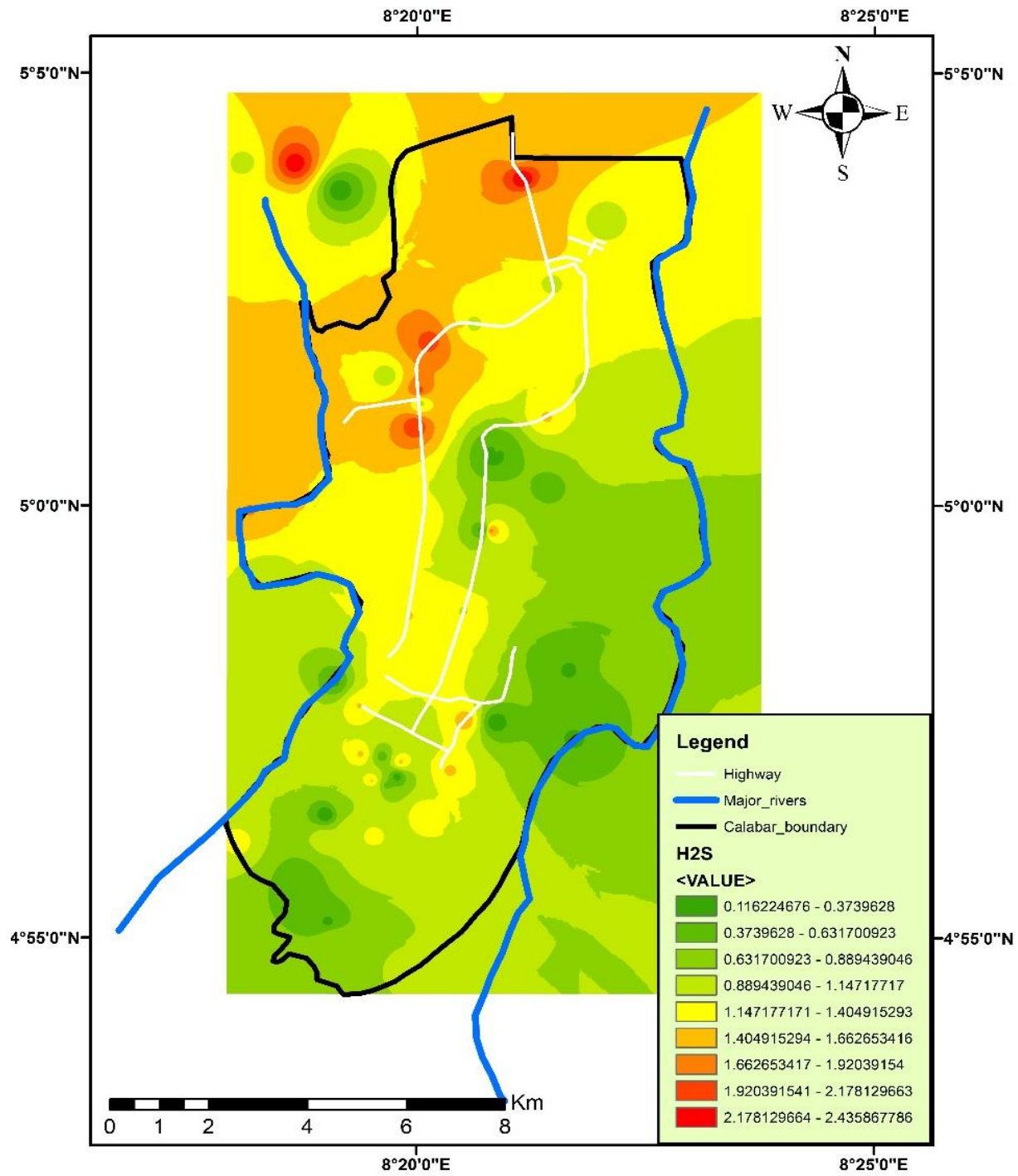
Source: Author's GIS visualization, 2020.

Figure 9. NO₂ footprints for Calabar Metropolis



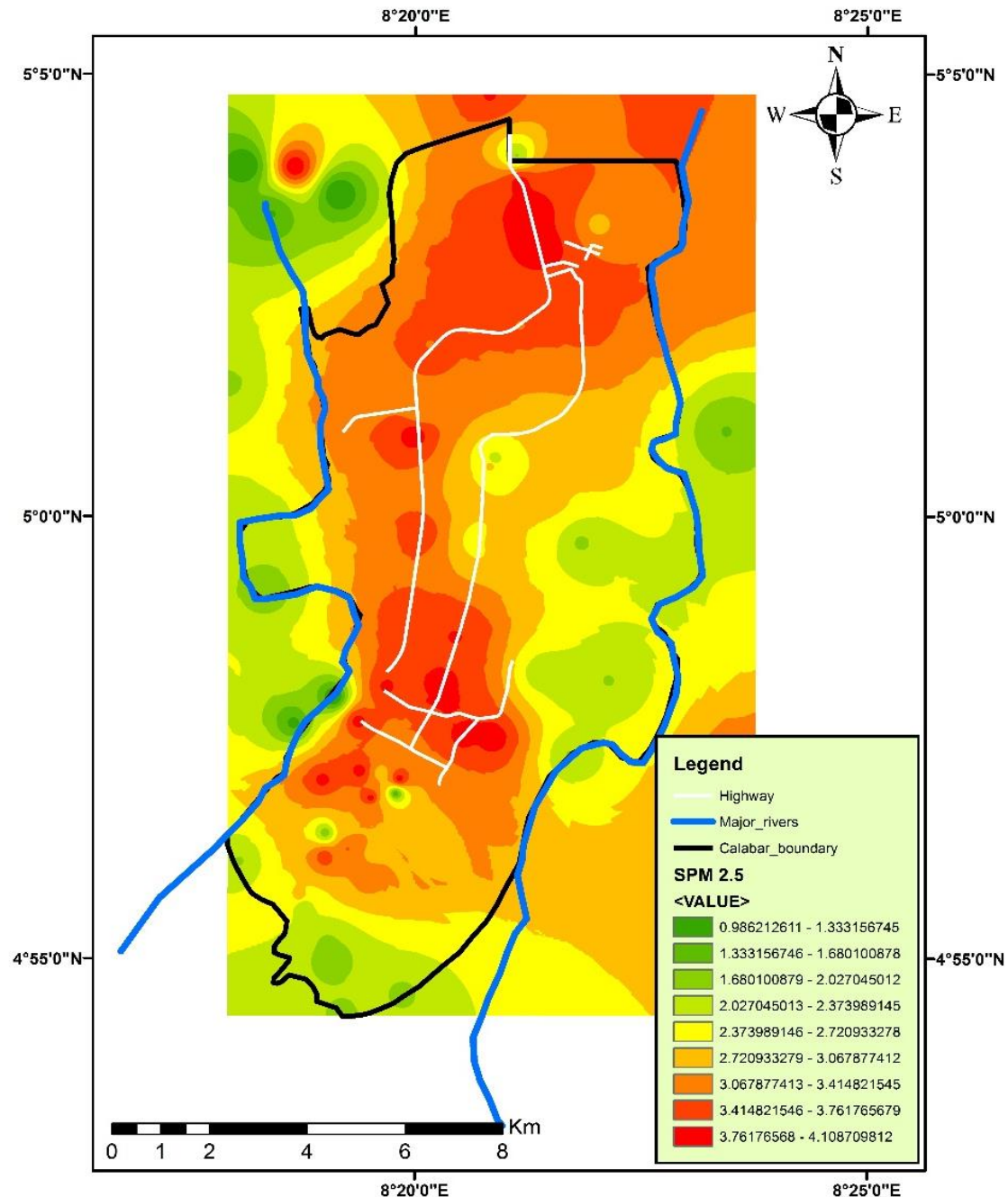
Source: Author`s GIS visualization, 2020.

Figure 10. SO₂ footprints for Calabar Metropolis



Source: Author's GIS visualization, 2020.

Figure 11. H₂S footprints for Calabar Metropolis



Source: Author's GIS visualization, 2020

Figure 12. SPM_{2.5} footprints for Calabar Metropolis

In addition, figures 8, 9, 10, 11 and 12 show the air quality footprints for Calabar Metropolis. The red portion on figure 8 shows the level of CO concentration over the metropolis. From the footprint map, concentration of CO is dense in most parts of the built up area particularly along the transportation, commercial and industrial land uses. The peripheral zones in green shades have been identified to be low in CO. This interpretation is applicable to the rest of the footprints maps.

7. Summary

The study geospatially assessed Ambient Air Quality Footprints in Calabar Metropolis, Nigeria, in relation to existing dominant landuse elements. The major objectives were to assess the spatial variation in air quality status in relation to land use types in Calabar Metropolis, Nigeria as well as to assess the seasonality differential in air quality status in Calabar Metropolis.

The analytical techniques took both geospatial and statistical dimensions. The outputs are in the form of 5 composite maps which depict air quality footprints for the measures parameters; as well as the results of the tests of hypotheses.

The hypothesis tested the level of significance in the variation of air quality (CO , NO_2 , SO_2 , H_2S , and $\text{SPM}_{2.5}$) in Calabar Metropolis in relation to either land use type or season of the year. Descriptive statistics for CO , NO_2 , SO_2 , H_2S , and $\text{SPM}_{2.5}$ shows that their concentration is higher in the dry season than in the wet season. From further analysis, the F-ratio for season and land use for all parameters were significant at $p < 0.05$. For the interaction between seasons and land use (season * landuse), there was significance at $p < 0.05$. Therefore, the alternate hypothesis which states that there is a significant variation in air quality (CO , NO_2 , SO_2 , H_2S , and $\text{SPM}_{2.5}$) in Calabar Metropolis in relation to either land use type or season of the year.

8. Conclusion

This study has been able to geospatially establish the relationship between urban land uses and ambient air quality footprints in Calabar Metropolis, Nigeria. Currently, urban centres worldwide now sing the new song of green urbanism. This cannot be attained and sustained if proper data and information on prevailing air quality status were not known. No doubt, urban planning which is geared towards allocating the right activities at the right location for the right people and at the right time cannot be achieved if information on the effects of urban land use related activities is not taken very seriously for making informed decision. For instance, the location of the residential neighbourhood of state housing estate is presently grossly inadequate as it is sandwiched almost at the hub of the city, between two areas of volumetric economic activities. Ultimately, in an event of any form of blockage of the major highway, state housing is seen as an alternative route to other destinations. This results to CO , SPM , noise and other pollution sources caused by vehicles, unlike satellite town and Ekorinim, which are off the city centre.

Therefore, based on the findings of this research, it was deduced that though within the acceptable limits, the commercial, transportation and industrial activity are the major sources of high concentration of air pollutants which would have significant implications on the integrity of the urban area if not checked or controlled. It was also discovered that seasonality has great implications on air quality. Therefore, a research of this nature should be sustained, and regularly depicted so that a sustainable, green, clean and livable urban environment would be created.

Finally, this research was limited in scope with regards to the study area, as only 2 local government areas making up Calabar metropolis were studied. Besides, data collection period covered only 6 months of the year (3

months in the rainy season and 3 months in the dry season).

9. Recommendations

Based on the findings of this research, certain mitigatory measures are therefore recommended for the purpose of ensuring a sustainable, clean and green Calabar Metropolis.

1. Residential zones should be exclusively maintained so as to avoid encroachment of incompatible uses which could lead to pollution and blight. Residential zones that have already been encroached, depending on the form of encroachment, should be reclaimed. For example, multiple exit routes should be closed to discourage motorists from using such as alternative routes to other destinations thereby causing heavy traffic and pollution.
2. Open spaces and gardens should be well maintained, preserved and protected due to their potentials in sanitizing the air by acting as green lungs.
3. There is need for a periodic and real-time monitoring and envisioning of air quality status to ensure adequate and strict compliance with standards. This would help in the enforcement of related codes once violated. It would be very helpful in the continuous acquisition of more robust datasets that could be used in pre-emptive planning of the metropolis in favour of clean air act. Finally, a more comprehensive research which would cut across the 12 calendar months should be undertaken on this theme.

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