Environment and Ecology Research 9(4): 173-185, 2021 http://www.hrpub.org
DOI: 10.13189/eer.2021.090405

Regional Trend in Ambient Air Quality Footprints in Calabar Urban, Nigeria

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Received June 7, 2021; Revised July 13, 2021; Accepted August 22, 2021

Cite This Paper in the following Citation Styles

***(a):** [1] Josiah Nwabueze Obiefuna, Gertrude Nnanjar Njar, Francis Ebuta Bisong , "Regional Trend in Ambient Air Quality Footprints in Calabar Urban, Nigeria," Environment and Ecology Research, Vol. 9, No. 4, pp. 173 - 185, 2021. DOI: 10.13189/eer.2021.090405.*

***(b):** Josiah Nwabueze Obiefuna, Gertrude Nnanjar Njar, Francis Ebuta Bisong (2021). Regional Trend in Ambient Air Quality Footprints in Calabar Urban, Nigeria. Environment and Ecology Research, 9(4), 173 - 185. DOI: 10.13189/eer.2021.090405.*

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Abstract Poor air quality is widely considered as one of the major environmental hazards confronting several urban centres worldwide. This study examined regional trend in ambient air quality footprints in Calabar Metropolis. Data on emission level of CO, NO_2, SO_2, H_2S, and $SPM_{2.5}$ were collected using Crowcon Gasman, while point coordinates were collected using Garmin GPSMap 60CSx device. Interpolation algorithm in Geographic Information Systems infrastructure was used to generate the regional trend maps for the metropolis. Parametric analytical techniques such as Analysis of Variance (ANOVA) were employed to test the hypotheses, while descriptive statistics including tables, maps and standard deviation were also used to present the data based on the objectives of the study. The results of the trend surface analysis for the five (5) measured parameters show that CO and $SPM_{2.5}$ were not significant at $P>0.05$ with F-ratio of 0.99 and 2.45 respectively. Thus, the null hypothesis which states that there is no significant change in the regional trend in air quality across Calabar Metropolis was therefore accepted. Analysis for NO_2, SO_2 and H_2S, were significant at $P < 0.05$ with F-ratio of 3.47, 3.35 and 7.79 respectively, causing the null hypothesis to be rejected. It was therefore recommended that mitigatory measures should be employed for the purpose of ensuring a sustainable, clean and green urban environment.

Keywords Regional Trend, Environmental Hazards, Disasters, Air Quality, Pollution

1. Introduction

Air quality is the condition of air that defines its content level of one or more pollutants such as carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S) and suspended particulate matter of 2.5mm or higher in diameter, etc. The term 'air quality footprints' as used in this research denotes measurement, mathematical and graphical expression or depiction in area or land use based units, a set of green house gasses, pollutants or emissions accumulated within the life cycle of dominant economic activities across various land uses.

However, when land uses are not properly planned and adhered to, air quality would be affected. This condition would arise when large and numerous sources of emission such as industrial, commercial and transportation are located in close proximity to the residential areas or other air pollution-sensitive facilities such as schools. As a result of this, persons, communities and businesses affected would ultimately suffer negatively either in the form of higher costs of public health, higher mortality rate or higher pollution control cost.

The determination of air quality is often achieved by examining air pollutants emitted from anthropogenic activities as well as from nature. In order to improve air quality, control of human activities is very important rather than attempting to remove just air pollutants from the air [1].

Polluted air has been seen as one of the major environmental hazards confronting several urban centres worldwide. It has been proven that as cities grow numerically, physically and functionally, an increase in energy consumption, industrial effluents, and vehicular traffic becomes unavoidable. Ultimately, these would obviously impact negatively on the quality of air [2,3]. The Nigerian environment is continually, progressively and seriously susceptible to myriad of environmental issues such as pollution of water, air, land, erosion, climate change, global warming, biodiversity loss and desertification etc. Notably, air quality concern is principal focus for long term planning. With this, land is engaged and used in a way that minimizes emissions and exposure of the populace to a myriad of air pollutants.

2. The Problematic

Calabar metropolis is dynamic and as a result, varied economic activities are constantly emerging, causing pollution ranging from air and noise. In the metropolis, there appears to be gross inadequacy and lack of coordinated air quality assessment in spatial context. Assessing air quality in spatial context will give a clear picture of the spatial trend, which would be of immense benefit in air pollution attenuation. Several urban centres in Nigeria lack coordinated assessments of local air quality which should be one of the major tasks of the Federal Ministry of Environment or any other government body tasked with pollution control in the city [4]. Therefore, one of the disadvantages of inadequate air quality data is the inability to ascertain and link certain pollutants to a particular land use or to some economic activities within a land use in the metropolis. The ability to identify, predict behavior, map and link certain pollutants to certain land uses would invariably advocate adherence to proper land use planning or zoning regulations. Sule [5] supports the view that land use planning is to ensure that the best land is put to the best use, for the purpose of increasing profit and minimizing incompatibilities and conflicts arising from air and noise pollution.

Another implication of a deficiency of air quality data both on spatial scale is that it would be practically impossible to link certain health threatening and seasonal diseases to poor air quality. When data on air quality regional scale is grossly lacking, it would be impossible to link the prevalence of certain ailments to certain regional development and variability.

Another shortcoming of the inadequacy of air quality trend data is its implication on planning and policy formulation. For example, a leap towards greening of Calabar urban or any other urban area would first depend on available air quality data, which would give information on the most volatile and prevalent sources of air pollutants.

3. Research Objectives

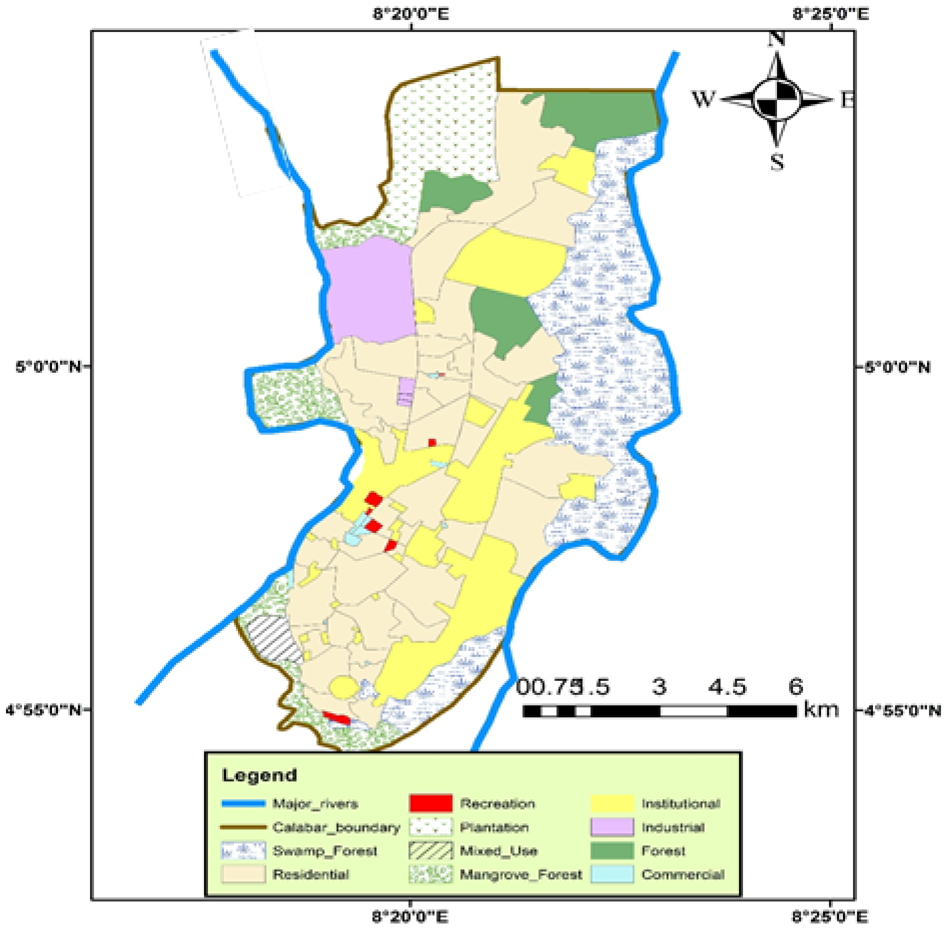
The objective of this research was to examine the regional trend in ambient air quality footprints in Calabar metropolis, Nigeria

4. Research Hypotheses

H_0: There is no significant change in the regional trend in air quality footprints across Calabar Metropolis.

5. The Study Area

This study was carried out in the capital city Cross River State, known as Calabar (Figure 1). Calabar is located between longitudes 8° 18' and 8^0 25" East of the Greenwich meridian and latitudes 4°55' and $5^0$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, which is made up of Calabar Municipality and Calabar South Local Government Area, covers an area of 1480sqkms. Calabar is bounded to the North by Odukpani Local Government Area and to the East by Akpabuyo Local Government Area.



Source: Author`s GIS visualization, 2020.

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

6. Method of Study

Data for this study were made up of continuous variables in the form of air quality readings from various land uses such as industrial, transportation, commercial and residential. In a more specific term, the study relied on data on ambient air quality status in Calabar Metropolis, as well as data on seasonality differential in air quality status. The most commonly existing, harmful pollutants and particulate matters, as defined by the scope of this study, occasioned by predominant economic activities were measured. Data were expressed in parts per million (ppm) scale. Data of primary origin were acquired from various land uses in Calabar Metropolis. Data were acquired using relevant automated real-time data loggers such as Crowcon Gasman and a Garmin GPSMap. Such dataset included logged figures of main pollutants and particulate matter from various selected locations as well as the GPS coordinates for the locations. Another set of data consulted during this research was those of secondary origin. Examples of data in this group are the land use maps of the study area as well as the real-time Google earth imagine data.

During recognizance, GPS data were acquired using a Garmin GPSmap 60CSx. It is digital equipment and consists of large, high resolution coloured liquid crystal display. The device was used to collect point coordinates for all the selected data points for the purpose of geo-referencing. Before operation, the power was activated by pressing and holding the power button. During the process of satellite signal acquisition by the GPS, a real time message “locating satellites” replaced by an “acquiring satellites” message appeared until enough signals were acquired to identify its location. When the receiver has adequate signals from at least three orbiting satellites, the unit’s display changed to indicate position accuracy, elevation and as well, show other information about the location. However, to receive adequate satellite signals, the unit should be used outdoors, and have a clear view of the sky. Although it is small, the GPS is compact and very sensitive.

6.1. Selection of Monitoring Sites and Data Collection

During reconnaissance, decision for selecting monitoring sites within a land use considered parameters such as predominant economic activities, chemicals or physical interference, locality, terrain, services and local activities. Air quality test was carried out at each sample location within a land use using an automated, real-time air quality meter mounted on a ground-based platform, or held at a height of a range of between 1.5 and 2.0 meters from the ground. The choice of the height was based on the fact that the study was particularly interested in the ambience level of the pollutants. Data readings were made once between 12 noon and 12.30pm in the afternoon. The time period of choice represents peak period for most economic activities. Besides, the research is not focused on micro level but seasonal and land use based variation. Recording of data was done after 5 minutes delay for the equipment to fully adjust or internally calibrate to the new environment. Data collection lasted for a period of four months in two seasons. In the rainy (wet) season, readings were taken in the month of July and August. In the dry season, readings were taken in the month of November and December.

The most commonly existing, harmful pollutants and particulate matters occasioned by economic activities as stated in the scope were measured. Carbon monoxide has 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 [6].

6.2 Sampling Procedure

Stratification was employed to group and randomly select points from each land use for proper representation. On the transportation land use, 24 locations were identified. However, 7 locations were selected. Data were acquired from the road nodes or roundabouts along the major road networks and parks. In the industrial zone, data were acquired from both the minor road intersections within the zone as well as 10 metres from the pollution sources. A total of 18 locations were identified while five (5) locations were selected. In the commercial zones, data were acquired from the pollution sources after having identified them. A total of 22 locations were identified while 7 locations were selected. In the residential neighbourhood, data were acquired from minor road intersections as well as from other direct emission points. A total of 23 locations were identified while seven (7) locations were also selected. Table 1 shows a total of 26 representative samples representing 30 percent selected from all land uses using a row by column digital random number generator. This has been depicted (Figure 2).

6.3. Urban Land use/Land Cover Classification Scheme

In this research, a system of land use/land cover classification adapted from [7, 8] was adopted. For this study, attention was only be given to area occupied by settlements, companies, and infrastructures, otherwise known as the urban or built up area, as well as its sub classes such as the residential neighborhood (estates, housing quarters), commercial/services (market areas, buying and selling points within the urban area), transportation routes (road networks, airport, motor parks, bus terminals), and the industrial area (processing, fabrication, etc.).

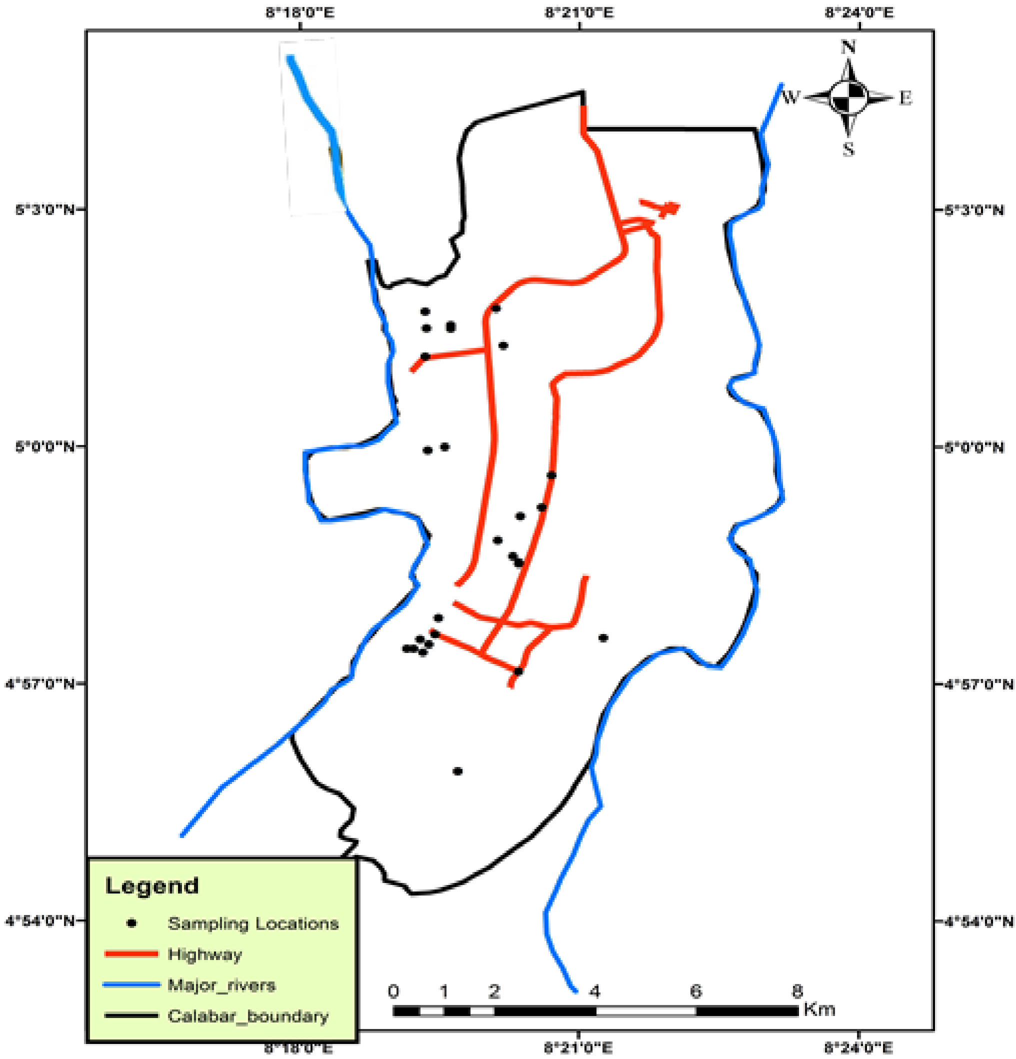
6.4. Techniques for Data Analysis

Sourced data were subjected to analytical manipulations using GIS, as well as descriptive and inferential statistics. The output was in form of composite trend maps, averages, tables, charts and graphs. Besides, inferential statistics was also used to test the hypotheses.

Table 1. Sampled points with their GPS coordinates

S/N	Land use Type/ Location	Activity Type	GPS Lat.	Value Long.	Prevailing Activities/pollutants
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: Author's fieldwork, 2020



Source: Author`s GIS visualization, 2020.

Figure 2. Sampled locations across land uses in Calabar Metropolis

7. Test of Hypothesis

H_0: There is no significant change in the regional trend in air quality across Calabar Metropolis.

H_1: There is a significant change in the regional trend in air quality across Calabar Metropolis.

The linear trend surface analysis was used in testing the hypothesis. The trend surface analysis is important in geospatial studies as it enables the researcher to segregate any spatially distributed variables into a broad system pattern of variation (regional trend) and random nonsystematic variables (local component). By adopting the linear trend in this work, it was assumed that the gradient between any two points on the map of the distribution approximates a straight line. The regional trend which is of interest to the researcher in the present study is expressed by the following equations:

$$Z=a+b(x) + c(y) \quad (1)$$

Where Z is the value of the variable being mapped (CO, NO_2, SO_2, H_2S, and SPM 2.5), X is the Eastings, while Y is the Northings. Actually, this is a multiple regressing equation of the independent variables. The normal equation can be expressed as follows:

$$aN + b\sum X + c\sum y = \sum Z \quad (2)$$

$$a\sum X + b\sum X^2 + c\sum XY = \sum ZX \quad (3)$$

$$a\sum y + b\sum XY + c\sum Y^2 = \sum ZY \quad (4)$$

The results of the regional trend are shown in graphs, while the f-ratio was used to test the significance of the trend for each of the variables.

7.1. Assessment of Regional Trend Surface Analysis of Ambient Air Quality Footprints in Calabar Metropolis

H_0: There is no significant change in the regional trend in air quality across Calabar Metropolis.

H_1: There is a significant change in the regional trend in air quality across Calabar Metropolis.

The result of the trend surface analysis for the five measured parameters is shown both in graphical and statistical forms. The differential data has been presented (Appendix 1). Table 2 presents the result of the analysis, while figures 3, 4, 5, 6 and 7 show the regional trends of the air quality footprints in Calabar Metropolis. For example, figure 3 shows the direction of distribution of CO level. The concentration of CO is high in the North East area (red) but low in the South West direction of the chart (green). Same interpretation is applicable to the rest of the trend maps. The regional trend model for each of the parameters is given as follows:

$$CO: Z = 32.27 + 0.12x + 0.08y \quad (5)$$

$$NO_2: Z = 41.12 + 0.25x + 0.10y \quad (6)$$

$$SO_2: Z = 33.70 + 0.27x + 0.05y \quad (7)$$

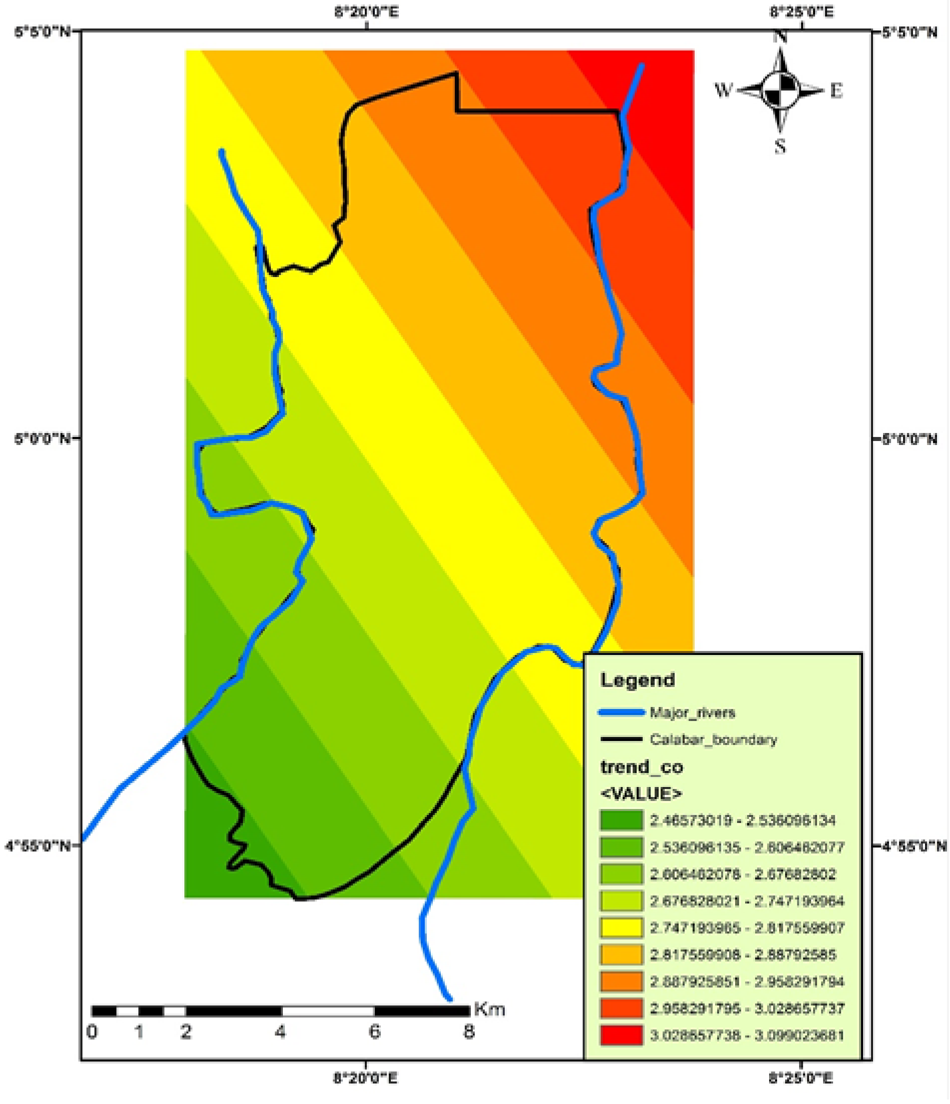
$$H_2S: Z = 5.55 + 0.44x + 0.14y \quad (8)$$

$$SPM\ 2.5: Z = 86.3 + 0.05x + 0.23y. \quad (9)$$

Table 2. Summary result of the trend surface statistics

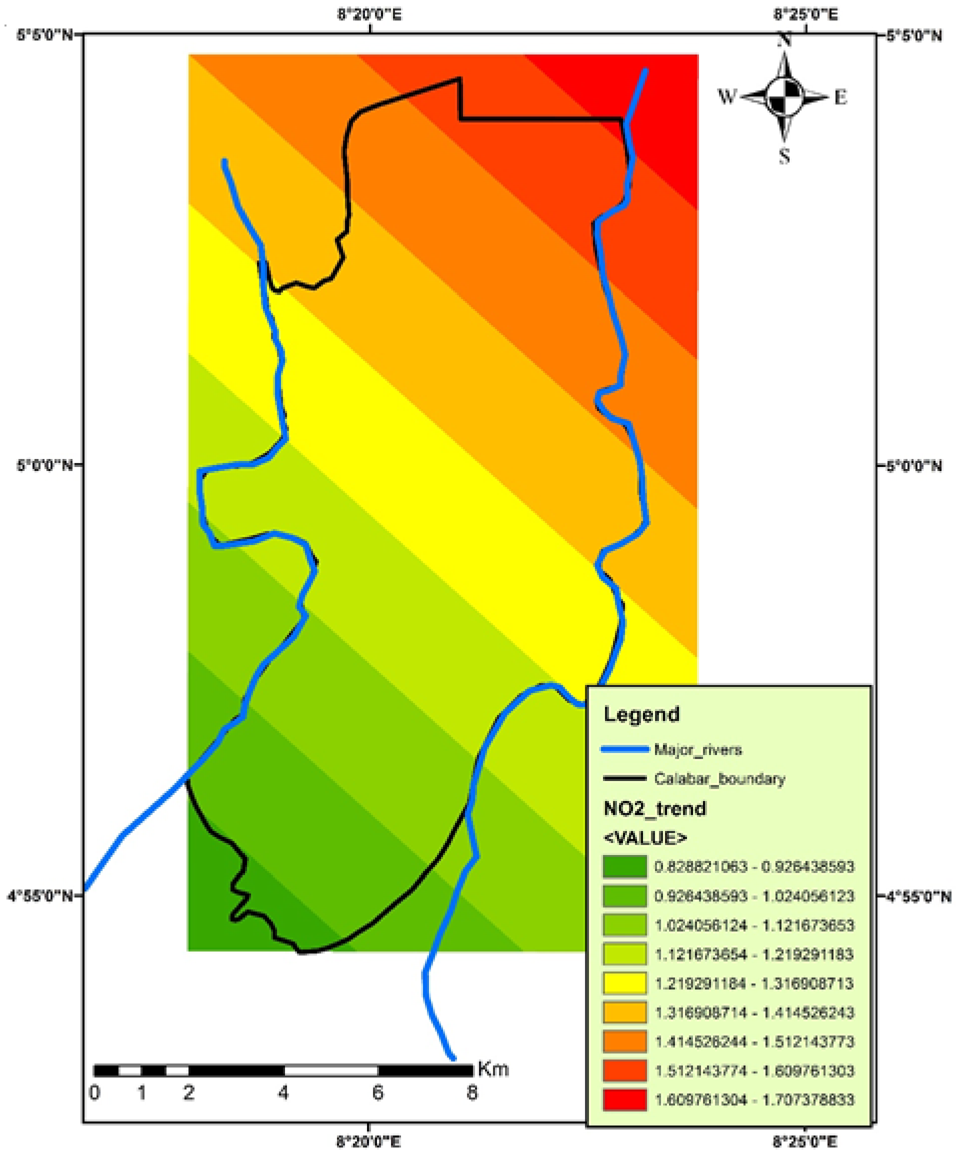
Parameters	R^2 (%)	d.f	F-ratio	P	Remarks
CO	3	2, 75	0.99	>0.05	Not significant, accept H_0
NO_2	9	2, 75	3.47	<0.05	Significant, reject H_0
SO_2	8	2, 75	3.35	<0.05	Significant, reject H_0
H_2S	17.6	2, 75	7.79	<0.05	Significant, reject H_0
SPM 2.5	6.3	2, 75	2.45	>0.05	Not significant, accept H_0

. Source: Author's analysis, 2020.



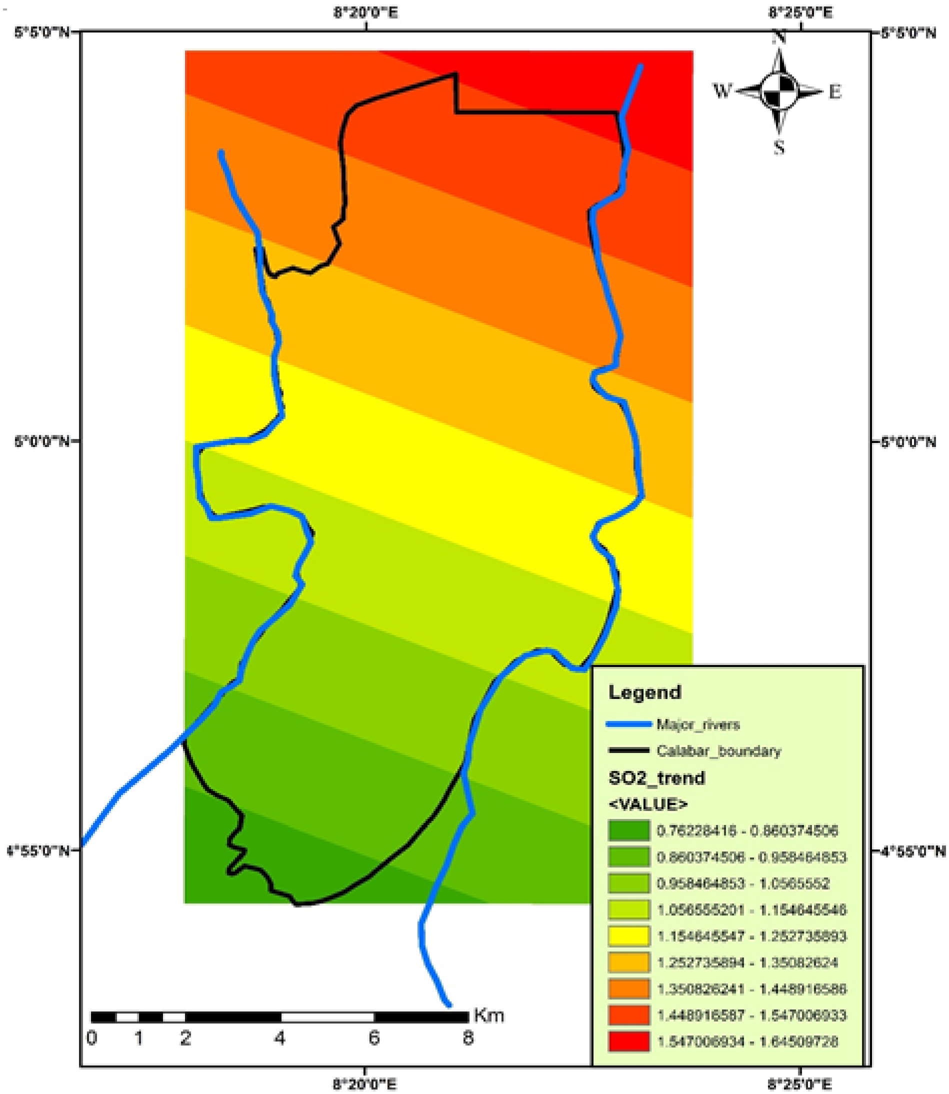
Source: Author`s GIS visualization, 2020.

Figure 3. Regional trend in CO across Calabar Metropolis



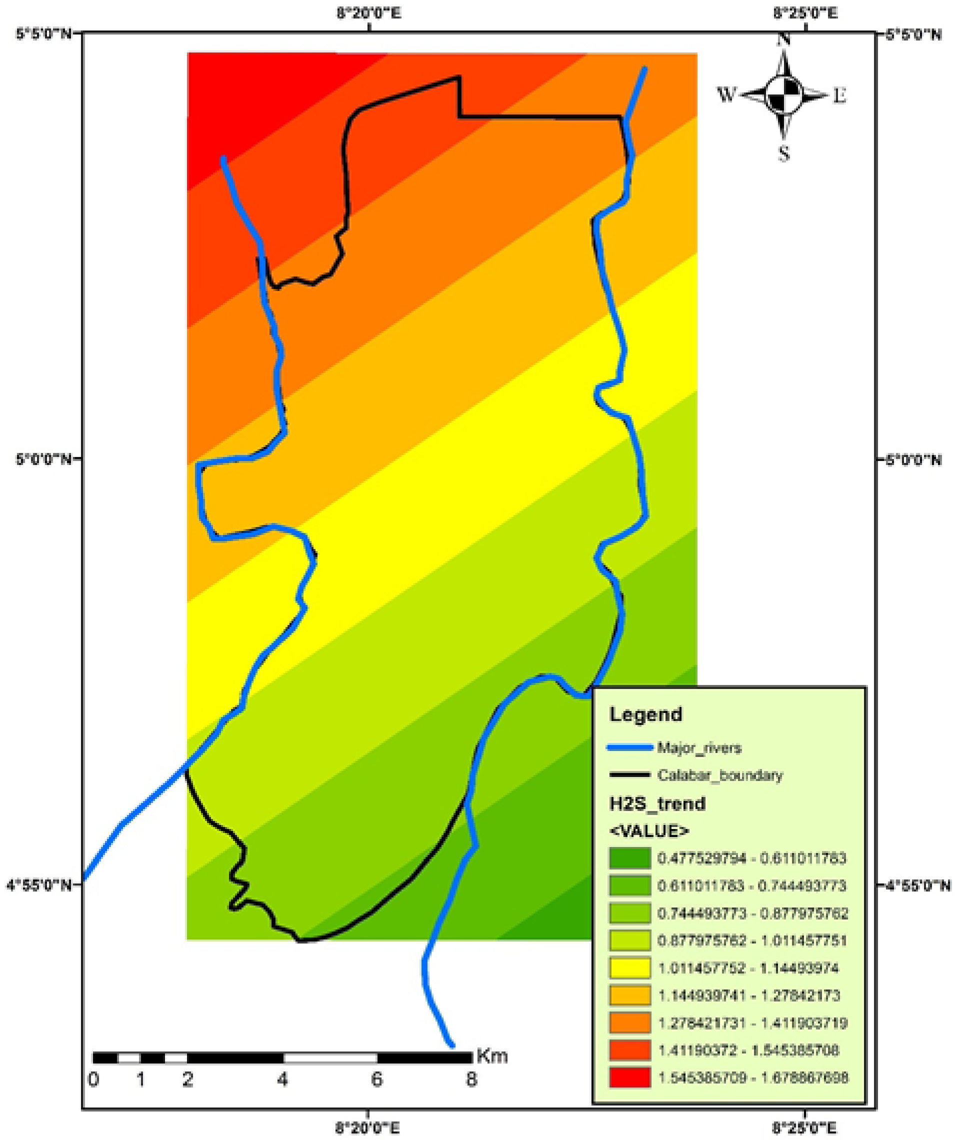
Source: Author`s GIS visualization, 2020.

Figure 4. Regional trend in NO_2 across Calabar Metropolis



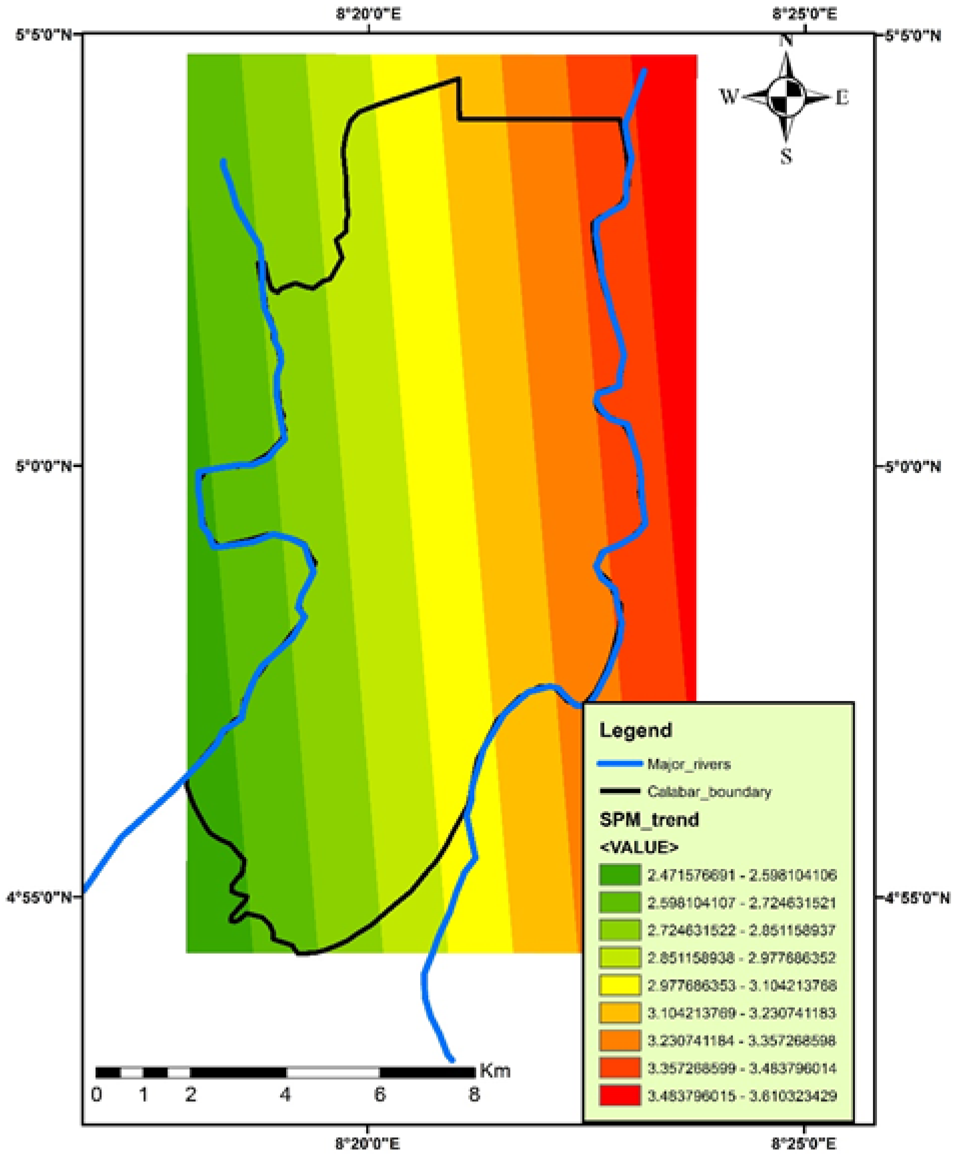
Source: Author`s GIS visualization, 2020.

Figure 5. Regional trend in SO_2 across Calabar Metropolis



Source: Author`s GIS visualization, 2020.

Figure 6. Regional trend in H_2S across Calabar Metropolis



Source: Author`s GIS visualization, 2020.

Figure 7. Regional trend in $SPM_{2.5}$ across Calabar Metropolis

8. Summary

The study examined regional trend in ambient air quality across Calabar Metropolis. The analytical techniques took both geospatial and statistical dimensions. The outputs are in the form of 5 composite maps out of which five depicts regional trends for the measures parameters; as well as the results of the tests of hypotheses.

The hypothesis examined the nature of significance in spatial trend in air quality across Calabar Metropolis. The result of the trend surface analysis for the five (5) measured parameters show that CO and $SPM_{2.5}$ were not significant at $P>0.05$ with F-ratio of 0.99 and 2.45 respectively. Thus, the null hypothesis which states that there is no significant change in the regional trend in air quality across Calabar Metropolis was therefore accepted. Analysis for NO_2, SO_2 and H_2S, were significant at $P < 0.05$ with F-ratio of 3.47, 3.35 and 7.79 respectively, causing the null hypothesis to be rejected.

9. Conclusions

The spatial trend in ambient air quality footprint in Calabar urban has been examined. The study has been able to unearth serious deterioration of ambient air quality status in the area as air pollution has been found to be a prevalent issue associated with anthropogenic activities being undertaken in the metropolis. Thematic composite maps were generated, while hypothesis was also tested. The hypothesis proved that test of CO and $SPM_{2.5}$ were not significant at P>0.05 with F-ratio of 0.99 and 2.45 respectively causing the null hypothesis to be accepted. Analysis for NO_2, SO_2 and H_2S, were significant at $P < 0.05$ with F-ratio of 3.47, 3.35 and 7.79 respectively, causing the null hypothesis to be rejected.

10. 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. Green areas, open spaces and gardens should be well maintained, preserved and protected due to their potentials in sanitizing the air by acting as green lungs.
2. Finally, a more comprehensive research which would cut across the 12 calendar months should be undertaken on this theme.

APPENDIX 1

Seasonal Differential in air pollutants

DAY	WET SEASON					DRY SEASON				
	CO	NO_2	SO_2	H_2S	SPM2.5	CO	NO_2	SO_2	H_2S	SPM2.5
1	2.42	0.70	1.24	0.80	3.02	3.07	1.08	1.29	1.23	3.76
2	2.44	0.70	1.27	0.78	3.02	3.07	1.08	1.28	1.22	3.77
3	2.45	0.69	1.26	0.79	3.01	3.18	1.16	1.30	1.22	3.82
4	2.44	0.71	1.24	0.79	3.00	3.14	1.16	1.29	1.25	3.82
5	2.42	0.71	1.23	0.78	2.99	3.12	1.17	1.31	1.25	3.83
6	2.41	0.71	1.21	0.78	3.02	3.18	1.19	1.34	1.25	3.88
7	2.42	0.68	1.13	0.77	2.97	3.17	1.21	1.35	1.27	3.84
8	2.37	0.68	1.14	0.76	2.96	3.17	1.21	1.36	1.29	3.83
9	2.41	0.68	1.27	0.76	2.98	3.24	1.21	1.37	1.30	3.87
10	2.40	0.68	1.21	0.74	2.99	3.24	1.23	1.40	1.31	3.91
11	2.42	0.68	1.21	0.76	2.99	3.25	1.24	1.41	1.32	3.93
12	2.42	0.67	1.20	0.75	2.97	3.24	1.27	1.42	1.34	3.95
13	2.40	0.65	1.23	0.73	3.06	3.25	1.28	1.43	1.35	3.94
14	2.32	0.65	1.16	0.72	2.93	3.30	1.29	1.45	1.36	3.95
15	2.31	0.64	1.20	0.71	2.91	3.32	1.29	1.46	1.37	3.95
16	2.36	0.64	1.18	0.71	2.92	3.41	1.31	1.47	1.38	4.00
17	2.37	0.64	1.11	0.70	2.90	3.36	1.32	1.48	1.38	4.02
18	2.35	0.63	1.15	0.70	2.87	3.37	1.32	1.49	1.44	4.05
19	2.33	0.64	1.12	0.70	2.86	3.39	1.34	1.50	1.46	4.05
20	2.33	0.62	1.11	0.70	2.83	3.34	1.34	1.51	1.48	4.05
21	2.28	0.60	1.08	0.68	2.81	3.33	1.36	1.52	1.48	4.05
22	2.26	0.60	1.07	0.68	2.83	3.43	1.36	1.55	1.45	4.09
23	2.32	0.60	1.08	0.68	2.82	3.43	1.39	1.56	1.46	4.11
24	2.30	0.59	1.09	0.68	2.81	3.46	1.35	1.57	1.47	4.13
23	2.28	0.59	1.07	0.67	2.78	3.47	1.36	1.58	1.48	4.14
26	2.26	0.57	1.12	0.65	2.82	3.56	1.36	1.59	1.49	4.16
27	2.28	0.56	1.05	0.65	2.74	3.51	1.36	1.60	1.54	4.16
28	2.23	0.55	1.06	0.65	2.73	3.51	1.38	1.61	1.51	4.15
29	2.21	0.53	1.07	0.64	2.73	3.53	1.40	1.62	1.52	4.25
30	2.18	0.52	1.04	0.64	2.73	3.56	1.40	1.63	1.50	4.22
31	*2.17	*0.52	*1.05	*0.63	*2.70	*1.93	*0.79	*0.92	*0.86	*2.32

*Values were not considered during analysis

Source: Author's fieldwork, 2020.

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