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A GIS Analysis of Noise Islands in Calabar Metropolis, Nigeria

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Abstract
This study examined noise islands in Calabar Metropolis, using Geographic Information Systems (GIS) infrastructure. Physical measurement of noise levels was made using Barn and Korn (BK) Precision 732 Digital Sound Level Meters. The locations were geo-referenced using a Garmin GPSMAP 60CSx Global Positioning System. Data were manipulated using ESRI ArcGis Software version 9.5, which generated composite noise maps. The point data in the geospatial database were subjected to interpolation, deploying Inverse Distance Weighing (IDW) algorithm for the different temporal periods of morning, afternoon and evening. The results revealed that noise level in the industrial, commercial as well as the transportation land use elements have been found to increase from the morning period, hits the peak in the afternoon and begins to wane in the evening period. Unlike the residential zones, which showed low, as well as moderately high noise level on certain days of the week due to some incompatible activities located there. It was therefore recommended that those activities that generate high noise in the industrial and commercial zones should be discouraged from springing up in the residential landuses in order to maintain their tranquil status. Besides, the source, path, and receiver techniques of noise attenuation have also been recommended as a general antidote to noise menace in the metropolis.
Keywords: Noise Level, Noise Maps, Noise Islands, Spatial Distribution, Temporal Distribution, GIS, Inverse Distance Weighing

1. Introduction

Noise maps have been developed using GIS in most of the European Countries. According to a report by the British Broadcasting Corporation (2008), the residents of 23 towns and cities in England have been given the chance to monitor noise levels in their area using interactive maps achieved through geographic information systems

Environmental noise, particularly in urban areas, has a significant impact on human well-being. Ensuring that noise does not reduce the quality of life needs a precise measurement of its levels using a scientific method. Poor urban planning may give rise to high noise level since industrial and residential buildings constructed side-by-side can result in noise pollution in the residential area. According to Jayant and Stonecypher (2010), poor urban planning results to a rise in noise pollution and measurement of these noise levels has become essential in order that it may be compared with medically safe standard for urban residents.

Noise is derived from the Latin word "nausea" implying unwanted sound or sound that is loud or unexpected (Singh and Joshi, 2010). The term, "island" has been used concertedly with another term, "heat" in several urban heat studies to refer to the distribution and the intensity of heat in a metropolitan area (Baik and Kim, 2000; Voogt, 2002; Arnfield, 2003; Environmental Protection Agency (EPA), 2008; and Weng, 2009). Therefore, Noise Islands as being used in this research are simply noise spurs or distinct noise levels at different spatial locations, caused by varying social, cultural, religious and economic activities.

In Nigeria, cities exude a cacophony of sounds. Daily, Nigerian city dwellers must brave the wail of sirens, the clamour of construction, noise from electric generators, pub closing time banter and the drone of traffic. These noise sources according to Knights (2008), are part and parcel of the urban environment of which Calabar is no exception. Noise is a serious cause of global worry particularly, in the urban areas of the developing and the developed nations (Banerjee, Chakraborty, Bhattacharyya and Gangopadhyay, 2009). Noise causes psychological stress on the living, as well as physical stress on the non-living things exposed to it. Urbanization has led to an increase in infrastructural development and economic activities all of which constitute potential sources of environmental noise problem in Calabar. This research investigates the spatio-temporal distribution of noise islands in Calabar Metropolis.

1.1 The Problematic

Noise is becoming an increasingly prevailing, yet unnoticed form of pollution in Calabar metropolis. In Calabar, population has increased from 99, 352 persons in 1963 to over 371, 022 persons in 2006 (NPC Population Projection, 2007). This population increase apparently resulted to an increase in economic activities and proliferation of many religious houses, which have turned Calabar to a "noise factory", creating many noise islands. As a result, it has now become difficult for one to find peace and tranquility in a place that should be called a home. Again, it has reached a point where someone in search of a housing facility in an area devoid of noise from churches, traffic zones, construction sites, airport, generators, musical equipments and party halls will only be wasting own time.

Several studies on noise have been carried out in Calabar but they neither took cognizance of the spatial and temporal elements nor did they apply Geographic Information Systems (GIS) as a tool in the study, which this study considered. For example, Menkiti (1990) studied generator noise in Calabar. Besides, Ntui (2009) studied noise sources and levels at the University of Calabar Library, Calabar, Nigeria. In addition, Okoro and Inyang (2010) examined the effect of air traffic noise on residents of Ekpo Abasi street Calabar, Cross River State. In these studies, no form of georeferencing was done and noise maps were not produced. Since noise transmission, as well as its effect on the environment has many spatial components, the use of GIS provides the possibility of optimizing the quality of noise studies. Moreover, in contemporary urban planning process, Geographic Information Systems (GIS) has become an important tool for planners, environmental managers and decision makers. Today, GIS excels at editing, data handling, interpolation and visualization capabilities that are lacking in most models.

Contrary to Calabar situation, there exist some comprehensive data on noise level in some parts of the world. For instance, in the United Kingdom, planners have been creating noise maps in communities around the country for several years. The Department of Environment, Food and Rural Affairs (DEFRA) has launched a noise mapping website so as to make the results available to the public. The Uniform Resource Locator (URL) is http://services.defra.gov.uk/wps/portal/noise. Also, the European Union Noise Observation and Information Service website located at http://noise.eionet.europa.eu/index.html has been developed. It is a dynamic website that graphically shows on a country-wide basis, the number of residents exposed to various levels of road, air and rail noise. These would not have been possible if noise data were not available to them. Finally GIS has been successfully used in various noise-related examinations. The most relevant findings were that GIS application in noise study has proven to be an ideal tool for carrying out noise mapping as well as noise impact assessment in an urban setting, In Calabar, it is certainly a case of "my people perish because of lack of knowledge". Therefore, there is a need for baseline noise data to be acquired while appropriate noise information should be made available to the public.

1.2 The Study Objectives

The main aim of this study is to examine the spatial and temporal distribution of noise islands in Calabar Metropolis. The objectives are as follows:

1) To graphically demarcate all the noise risk zones based on different noise levels.
2) To generate a GIS-based noise-level map of Calabar Metropolis for different temporal periods.

2. Method of Study

2.1 Data sources

Data for this study is made up of noise level reading from line source such as traffic noise and point sources such as commercial sites, loudspeakers, generators, and religious homes. All noise values were expressed in decibel (dB) scale. The geographical coordinates and elevation of the locations were obtained.

Another set of data used for this research is that of secondary origin. Examples of data in this group are landuse maps and high resolution satellite imageries such as Google Earth Satellite Maps.

2.2 Materials used

2.2.1 Global positioning system (GARMIN GPSMAP 60CSx).

A GARMIN GPS was used to geo-reference all the data points. Before operation, the power button was pressed and held to turn on the unit. During operation, the unit was held in front with the top tilted upwards. While the GPS receiver was searching for satellite signals, a "locating satellites" message was replaced by an "acquiring satellites" message until enough signals were acquired to fix its location.

2.2.2 Digital sound level meter (BK Precision 732)

The experimental apparatus used in the recording of noise levels consisted of a BK Precision 732 Digital Sound Level Meters. It is equipped with 4 digits Liquid Crystal Display (LCD), a condenser microphone and an octave filter. During measurements, the microphone was positioned in such a way as not to be in acoustic shadow of any obstacle in the field of the reflected waves. It has a resolution of 0.1 dB and an update cycle 0.5 second.

The system provides 30 to 130dB capability in three convenient measurement ranges. The ranges are Low (30 to 80dB), Medium (50 to 100dB) and High (80 to 130dB), with an accuracy of ±1.5 dB. The meter meets the International Electrotechnical Commission (IEC) 651 Type II standard, and includes frequency weighting of A and C and fast and slow time weighting. The A-weighting was used because of its recommendation for environmental and industrial studies (Peterson and Gross, 1974).

2.5 Site selection and measurement procedure

Site selection for this study was entirely based on observation. A reconnaissance survey of Calabar metropolis by the researcher with a sound level meter revealed 85 noise prone locations, with noise level ranging from 75 to 105dB. There are other locations where noise levels are below, or within the noise exposure limit recommendation of 75dB as stipulated by the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP (1980)).

A stratified random sampling was employed in selecting locations or sampling sites for the study. The 85 locations identified as noise prone locations were grouped into 4 different strata representing various land uses. Each stratum was sampled as an independent sub-population. A simple random sample was selected using a digital random number generator shown in figure 3.4. For this study, 30 per cent of the observed data points was selected from each stratum. The 30 percent is very representative as it is supported by Udofia (2006), which states that 30 per cent of sampling population is ideal as a sampling size in any physical study. Enoh (1997) stated that no serious study should admit a sampling fraction that is less than one tenth of the population. Therefore, 30 per cent, which is about one third of the population is very adequate for this study.

(TABLE 1) and depicted (FIG. 1)

Sound Level Meters were simultaneously used to acquire data in all locations. A GPS was used to obtain the coordinates of the sampled locations. Noise data from transportation landuse were acquired from road intersections or nodes. The reason for this is that transport land use is a line source of noise, which is always in continuum. Noise data from other landuses were acquired from the source at a distance of one meter. These sources are point sources and are discrete. Point sources include noise from industrial and commercial landuses. Examples are noise from generators, grinding machines, stereo players, etc.

Table 1.
Sampled points with their coordinates.

SN	Landuse type/ location	Activity Type	GPS value Long.	Latt.	Noise sources
1	Industrial-EPZ	Stone Craft Industry (manufacturing)	5.02563	8.32704	Point source: Cutting and smoothening equipments for Marble production
2	Industrial-EPZ	M-Saleh Industry (manufacturing)	5.02485	8.32704	Point source : Metal cutting, smoothening, welding.
3	Transportation (Eleven-Eleven area)	Round About	4.96384	8.32488	Line Source: Car horn blasting, vehicle engines
4	Transportation (Effio-Ette area)	Road Junction	4.99343	8.3451	Same as 3 above
5	Transportation (MCC)	Road Junction	4.98754	8.33346	Same as above
6.	Transportation(IBB Way)	Round About by Rabana	4.96304	8.33608	Same as above
7	Transportation (Calabar Road)	Road Node by Total filling station	4.95736	8.31927	Same as above
8.	Transportation (Ekpoabasi Rd)	Road Node by CRUTECH	4.93151	8.3284	Same as above
9.	Transportation (Etta-Agbor Road)	Round About (Unical Main Gate)	4.95254	8.33921	Same as above
10.	Transportation (Etta-Agbor Road)	Round About (by IBB Rd)	4.95933	8.32164	Same as above
11.	Transportation (Calabar Road by Atakpa)	Road Node	4.95773	8.32013	Same as above
12.	Residential (Satellite Town)	Church (Demonstration Chapel)	4.96033	8.3569	Point Source: worship activities, generator
13.	Residential (Satellite Town)	worship (Church of God Mission)	4.96189	8.3514	Same as 12 above
14.	Residential (Ekong Bassey Street)	worship centre	4.97071	8.35195	Same as above
15.	Residential (Edem Street)	Worship	4.96269	8.31679	Point source: worship activities, vehicles, electric generator
16.	Residential (Satellite Town)	Worship	4.96085	8.35385	Same as 12 above
17.	Residential (Victor Akan Street)	Worship	4.9533	8.3218	vehicles, worship activities
18	Residential (Palm Street))	worship	4.95075	8.32363	Worship activities, vehicles
19...	Commercial (Marian Market)	Grinding Section	4.97559	8.33927	Point source: Grinding
20.	Commercial(Marian Market)	Music Store	4.9753	8.33922	Point source: loud music.
21..	Commercial (Watt Market Area)	Music Store	4.95653	8.32221	As in 20 above
22..	Commercial (238 Etim Edem Street)	music Store	4.96039	8.3243	As above
23.	Commercial (179 Etim Edem Street)	Music Store	4.95931	8.32309	As above
24.	Commercial (Watt Market area)	Music Store	4.95736	8.31927	As above
25.	Commercial (Watt Market area	Grinding Section	4.9583	8.32143	Point source: Grinding machines,

Source: Authors` field work, 2011

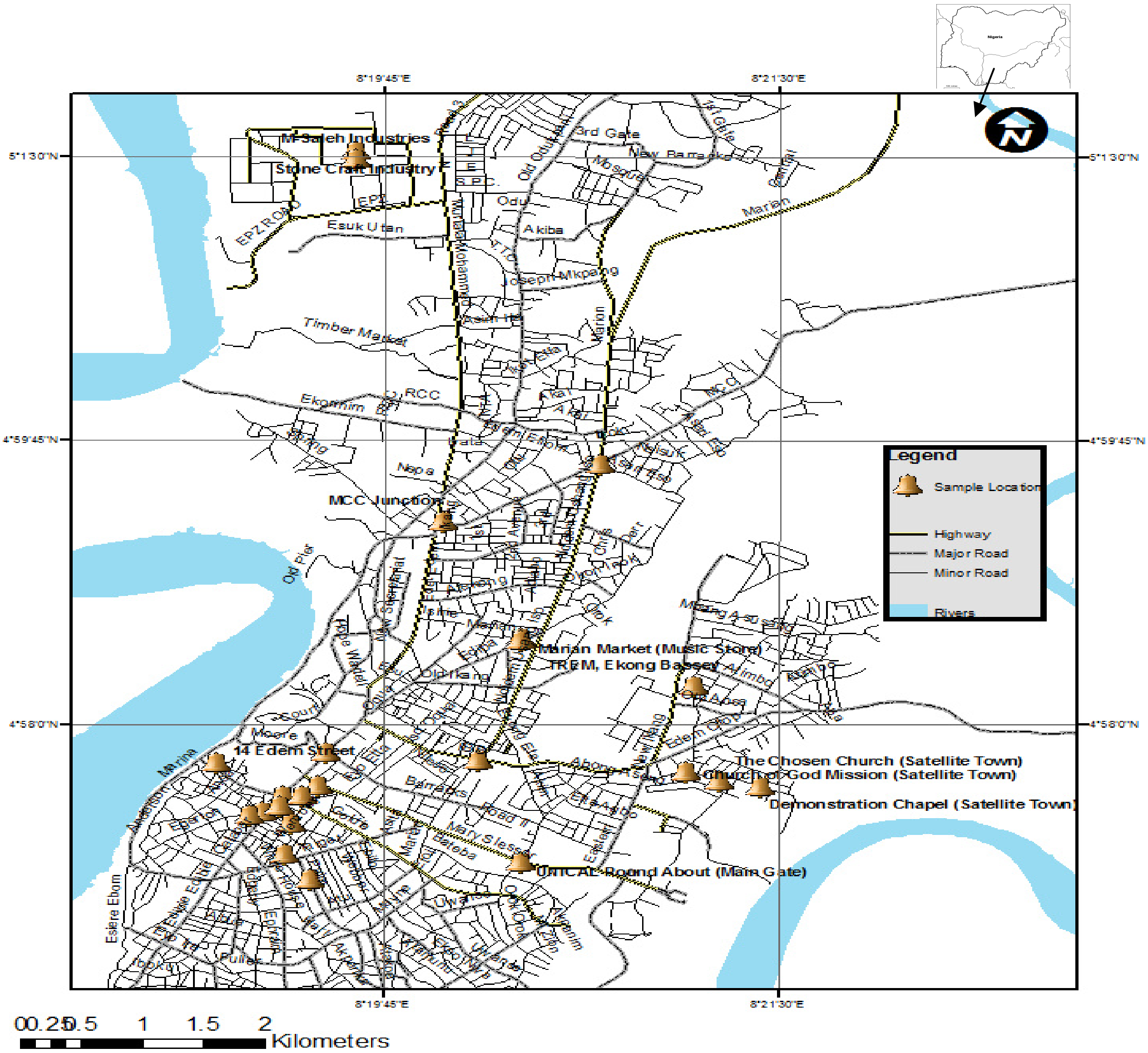

FIG. 1. Sampled points in Calabar Metropolis
Source: Visualization by the authors, 2011.

3. Results

Table 2 shows the mean noise level for all the sampled locations for the three time periods: morning, afternoon and evening. From the tables, nominal labels 1 and 2 represent the industrial landuse; the numbers ranging from 3 to 11 represent the transportation landuse; numbers 12 to 18 represent the residential zone while numbers 19 to 25 represent the commercial landuse. From the tables, it could be revealed that the commercial landuse has the heavier mean decibel values within the range of 68.0dB and 95.8dB. The residential landuse happens to have a lower mean decibel value ranging from 44.9dB to 71.4dB.

Table 3 shows the mean noise level for all the identified landuses. From the table, the industrial landuse has the highest noise values in the morning, which spans from 88.5dB at 8am, 89.1dB at 8.30am and 89.5dB at 9am. The least is the residential landuse, with value ranging from 55dB to 57dB at the same time period. In the afternoon, the commercial zone emerged the first in terms of noise level with the following figures: 84.8dB at 12 noon, 85.6dB at 12.30pm, and 86.5dB at 1pm. In the evening, the commercial zone also emerged the first with the following figures: 86.5dB at 4.pm, 86.6dB at 4.30pm, and 86.9dB at 5pm.

Table 2: Mean noise level (in dB).

Location/ Landuse	1 Ind	2 Ind	3 Tran	4 Tran	5 Tran	6 Tran	7 Tran	8 Tran	9 Tran	10 Tran	11 Tran	12 Res	13 Res	14 Res	15 Res	16 Res	17 Res	18 Res	19 Com	20 Com	21 Com	22 Com	23 Com	24 Com	25 Com
Morning (8-9am)	90.4	85.7	71.9	**72.2**	**75.6**	**61.8**	**66.4**	**75.8**	**69.3**	64.0	71.5	56.5	53.0	50.2	66.1	54.9	67.5	50.3	90.4	75.4	74.8	92.5	81.8	70.7	88.5
Afternoon (12-1pm)	80.3	79.0	**77.4**	**76.0**	**77.6**	**73.5**	**72.7**	81.0	76.5	71.6	76.7	53.1	53.5	49.5	70.3	49.9	68.7	46.6	93.4	81.5	78.1	93.1	85.8	76.1	91.4
Evening (4-5pm)	84.8	79.8	83.3	84.7	85.2	72.7	70.9	72.0	77.2	74.6	79.7	52.8	53.8	47.2	67.4	47.8	63.2	45.7	94.3	83.2	83.2	95.5	87.9	77.2	86.3

Ind = Industrial, Tran = Transportation, Res = Residential, Com = Commercial

Source: Author's field work, 2011.

Table 3: Mean noise level for the identified landuses expressed in dB.

		Industrial	Transportation	Residential	Commercial
Morning	8.00am	88.5	65.6	55.4	79.0
	8.30am	89.1	70.9	57.7	83.2
	9.00am	89.5	73.0	57.6	83.8
Afternoon	12.00pm	77.8	75.0	56.9	84.8
	12.30pm	71.4	76.0	55.7	85.6
	1.00pm	90.1	76.7	55.2	86.5
Evening	4.00pm	83.7	79.3	54.7	86.8
	4.30pm	81.0	78.5	54.7	86.6
	5.00pm	82.4	75.7	52.4	86.9

Source: Author's field work, 2011.

In the digital framework, the point data in the geospatial database were subjected to interpolation, deploying Inverse Distance Weighing (IDW) algorithm for the different temporal periods (morning, afternoon and evening). The results of the operation are presented (FIGs. 2, 3 and 4).

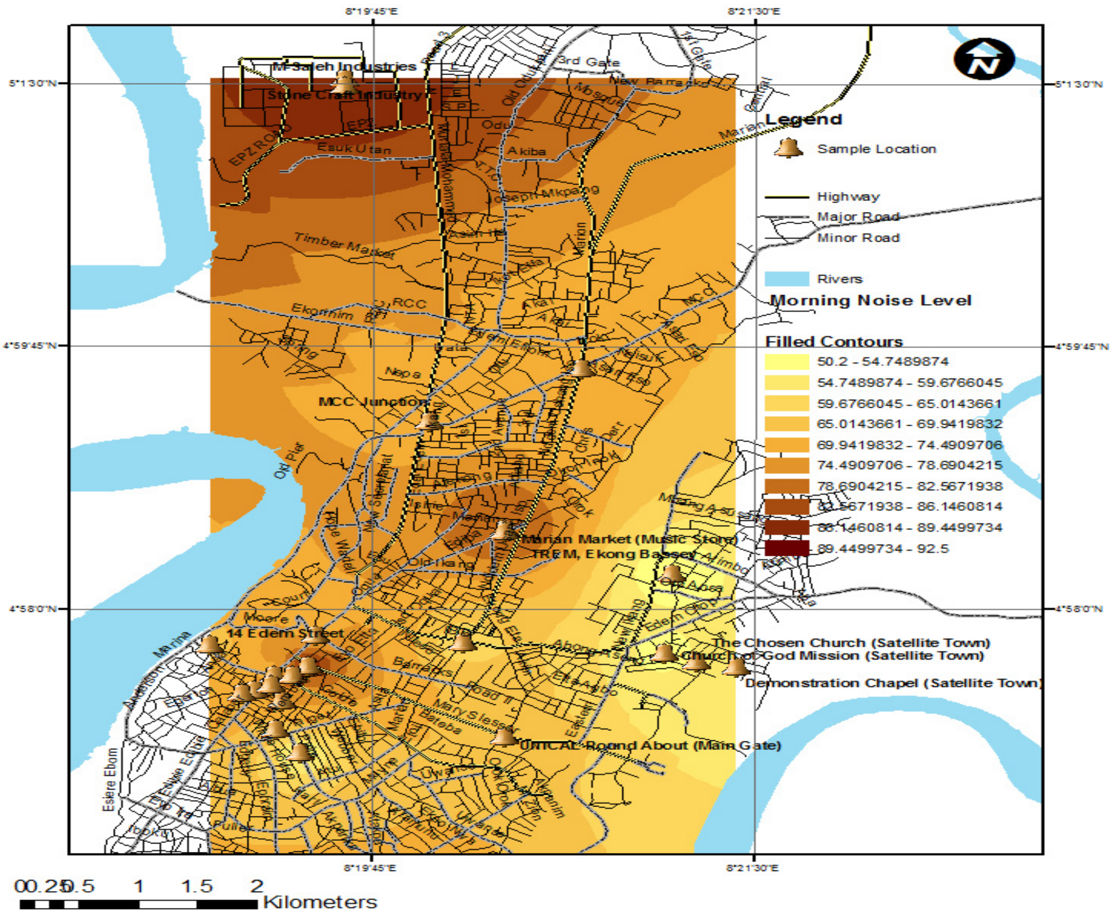

FIG 2. Noise island map of Calabar Metropolis highlighting the noise prone zones (morning).
Source: Visualization by the authors, 2011**.**

As the figures have succinctly depicted, noise level at the industrial (EPZ) and commercial (Marian and Watt Market) zones range between 78dB and 93dB as indicated by the colour tones. The colour tones have been defined at the filled contour section of the map legend. From figure 2, the industrial area has a wide distribution of noise bandwidth in the morning, while the commercial zone has a low noise bandwidth due to sparse noise emission points. In the afternoon, there is a huge variation as the commercial zones and traffic congestion points are dark coloured signifying higher noise level than the morning period (FIG. 3). Besides, the area covered by noise is much larger than observed in the morning. In the evening, the commercial and the transportation landuses are dark coloured, indicating higher noise level from the landuses. At this period, noise intensity at the industrial zone has diminished (FIG. 4).

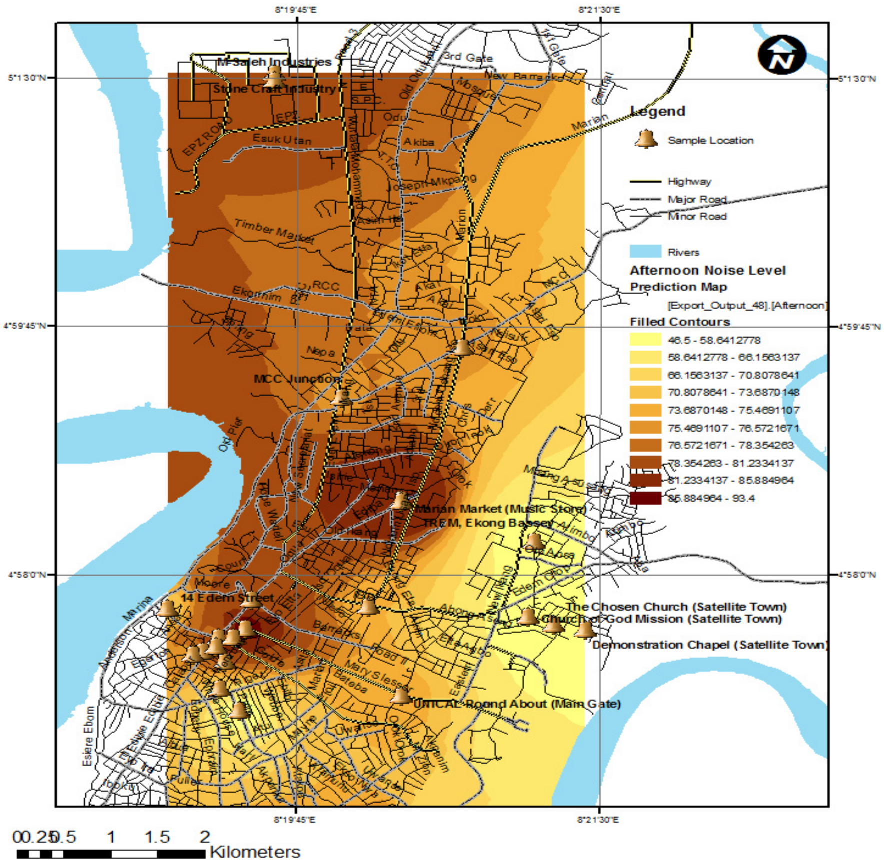

FIG 3. Noise island map of Calabar Metropolis highlighting the noise risk zones (afternoon). Source: Visualization by the authors, 2011.

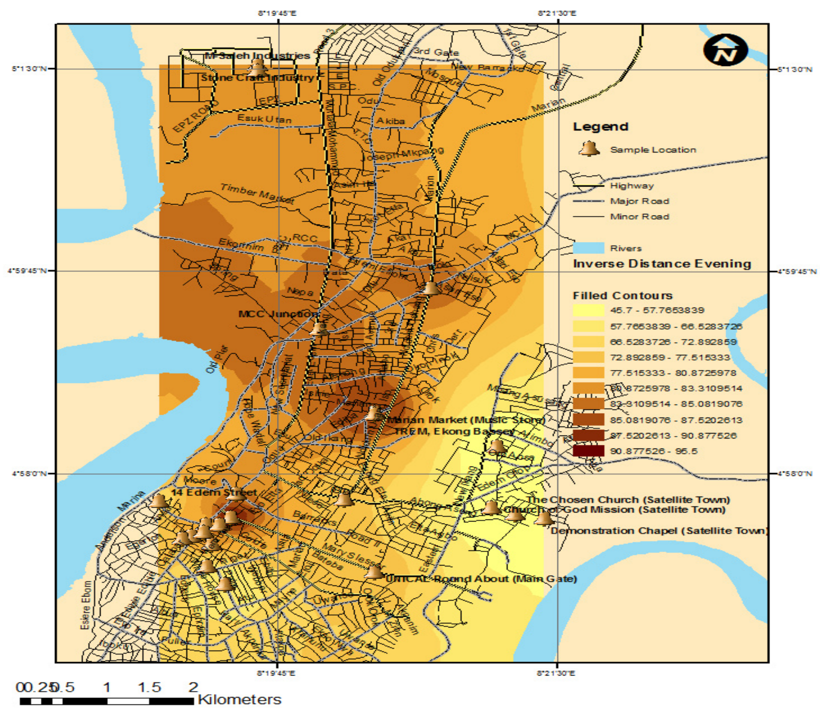

FIG 4. Noise island map of Calabar Metropolis highlighting the noise risk zones (Evening).

4. Conclusion and Recommendations

This study examined noise islands in Calabar Metropolis. In order to develop noise island maps, an automated, GIS-based approach was used to manipulate geospatial data. The outputs are three composite noise island maps showing noise levels at various locations for different time periods of the day: the morning, afternoon and the evening. Undoubtedly, there is a need for harmonized research such as this, in order to constantly acquire, validate and update noise level information in Calabar Metropolis, and other urban areas in Nigeria, as well as generate a map that could be used for planning of facilities. It is therefore recommended that those activities that generate high noise in the industrial and commercial zones should be discouraged from springing up in the residential landuses in order to maintain the tranquil status of the zones. Besides, the `source-path-receiver` technique of noise attenuation is also recommended as a general remedy to noise menace in the metropolis.

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