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Effurun, Delta State, Nigeria.



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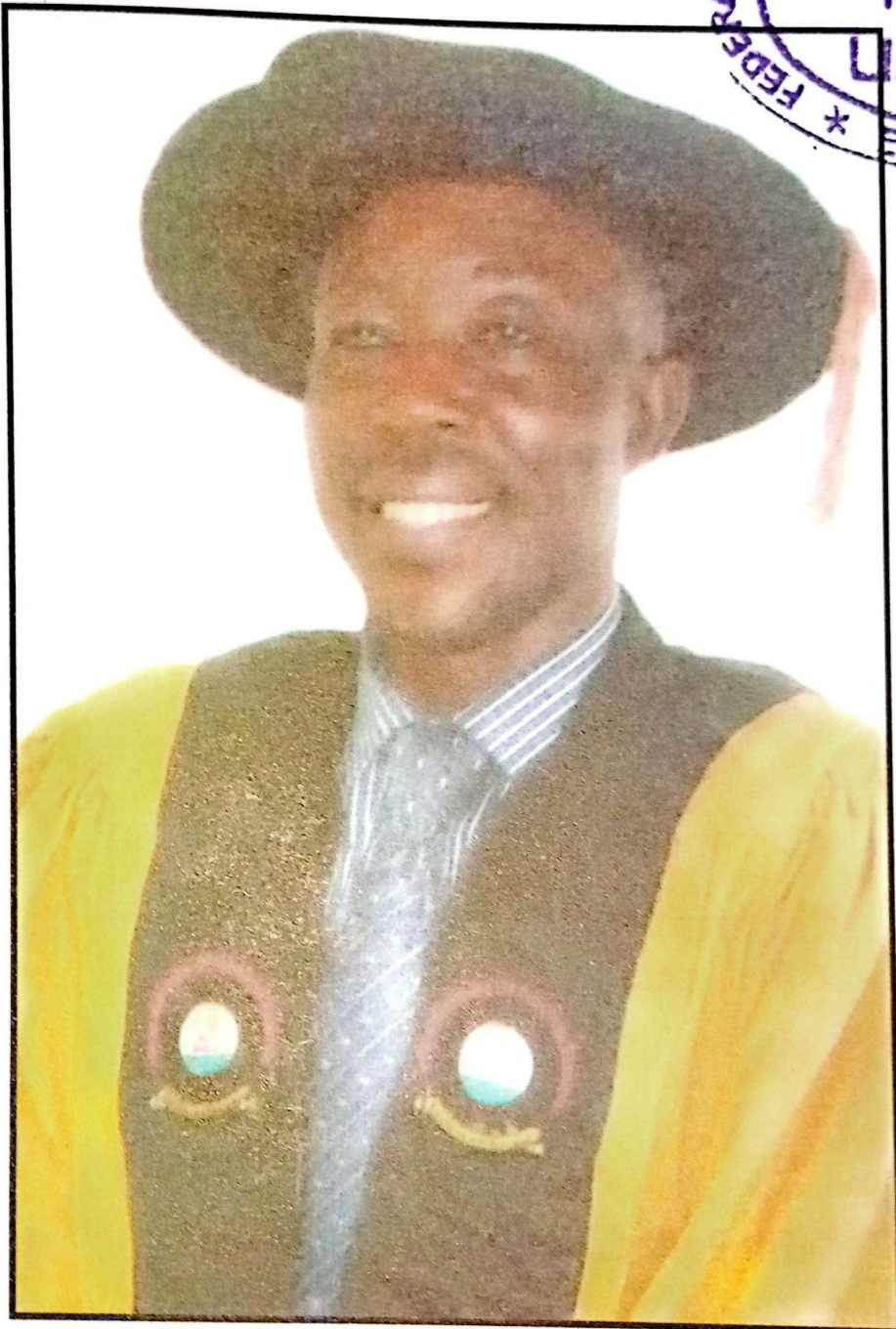
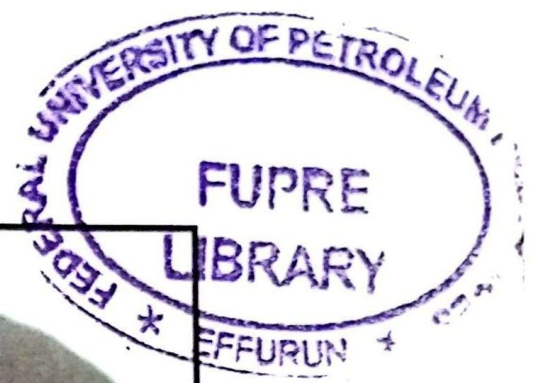
Titled:

**DEPLOYING A
SUSTAINABLE FUTURE THROUGH
THE APPLICATION OF
GEOSPATIAL TECHNOLOGY**

By

Christopher Onosemuode, Ph.D
Professor Of Geoinformatics

18th April, 2019



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GEOSPATIAL TECHNOLOGY**

An inaugural lecture
Delivered at the Federal University of
Petroleum Resources,
Effurun, Delta State, Nigeria
on Thursday 18th April, 2019

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Professor of Geoinformatics

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DEDICATION

This inaugural lecture is dedicated to God Almighty, Tega Lee, Ann Ataikiru and Oghenefejiro Daniel Onosemuode

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DEPLOYING A SUSTAINABLE FUTURE THROUGH THE APPLICATION OF GEOSPATIAL TECHNOLOGY

1.0 INTRODUCTION

The purpose of this inaugural lecture is to document the several ways the authors have used Geospatial technology in solving socio-economic and environmental problems in order to attain sustainable development. To further understand the context of the lecture, the following concepts shall be explained in details:

Geospatial: This pertains to the geographic location and characteristics of natural or constructed features and boundaries on, above, or below the earth's surface; especially referring to data that are geographic and spatial in nature. In simple terms, geospatial information is geography and mapping. It is "place based" or "locational" information. It is data tied to and portrayed on a map.

Spatial perspective: This is a way of identifying, explaining, predicting the human and physical patterns in space and the interconnectedness of various spaces. Spatial perspective therefore, refers to the geographical concept of where things happen on earth in space and in different places, according to National Geographic (Onosemuode and Onosemuode, 2007). Geospatial analytics help move beyond general awareness by looking for trends that provide historical perspective and predictive insight to help foster better decision-making (Onosemuode *et al* 2010). These analytics help detect spatial trends, relationships, and patterns using map-based visualizations.

This lecture is therefore aimed at elucidating Geospatial technology as a panacea for sustainable future.

2.0 GEOSPATIAL PERSPECTIVE OF LANDUSE CHANGE AND URBAN SPRAWL

In response to the challenges of rapid pace of urbanization with its antecedence on environmental and urban planning, the authors in this section tries to evaluate the various changes that have taken place over time.

2.1 Concepts and Models

This section presents and discusses the various concepts and models propounded.

2.1.1 Land Use Model

The study of landuse including its portrayal in map form has long been an important task of the geographer (Mather, 1987). Natural resources managers, environmentalist and researchers working at the landscape level need to understand the spatial dynamics (Turner 1990; Olsen *et al*; 1993; Onosemuode 2004).

Onosemuode (2004) noted that in an attempt to understand the organization of the urban setting, a number of models have been proposed which attempt to describe and account for intra urban landuse pattern, these models according to Ikhuoria (1987) and Onosemuode (2004) are largely derived from the experience of the Western world which were advanced to explain the urban landuse pattern.

Sequel to the assertion that most of the landuse model were derived from the experience of the Western world, Onosemuode (2004) devised a landuse model known as the “**Trellis Model**” (Fig. 1) to explain the landuse pattern of Warri Metropolis which is applicable to landuses with similar structures in southern Nigeria and other parts of the country.

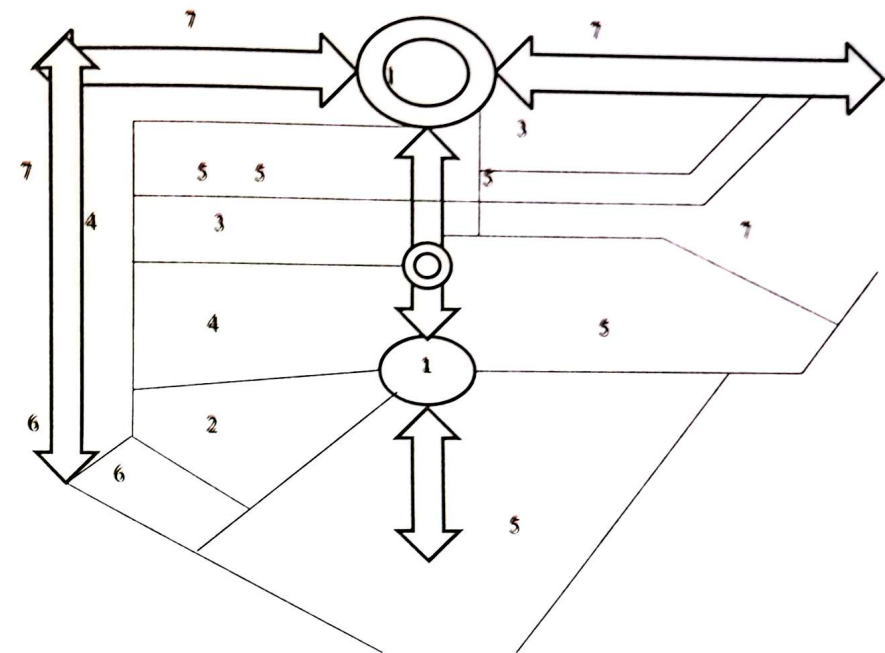


Fig.1: The Trellis Model
Source: Onosemuode(2004)

The representation of the numbers in Fig. 1 above are as explained below:

1. - represents the Central Business District label and can be found at Effurun Round About and at Enerhen junctions. These areas serve as the converging point for most of those people living in the suburb of Warri.
2. - represents the Low Class Residential Areas and are found around the core of the southern part of the study area and it includes the Okere, Agbasa and Ekurede/Itsekiri areas.

3. - represents the Medium Class Residential Areas and are found dispersing from the linear route outwards towards the suburb. The areas considered in this category include Effurun, Enerhen and Okumagba layout.
4. - represents the High Class residential area which could be found at Edjeba housing estate and immediately after this zone, is the commuter zone.
5. - represents the Outlying Business District and are found interspersed within Warri and the industrial suburb.
6. - is the industrial suburb and could be found close to the High Class residential area.
7. - represents the Commuter zone which goes round and terminating at the river banks.

The application of the "Trellis Model" as emphasized in its linear pattern among most towns in southern Nigeria cannot be overemphasized as most of the settlements evolved and grew out of linear settlement pattern.

2.1.2 The Multi-stage Model for Squatter (Slum) Development

Urban centres are the most complex of all human habitats; the level of complexity is a measure of the level of urbanization. Nigerian urban centres are witnessing what Ayeni (1978) described as unprecedented growth rate derived from socio-political and economic factors, rapid population growth rate and rural-urban migration. This growth rate has generated various problems as enumerated by Mabogunje (1974) to include unemployment, lack of adequate social, medical, educational and recreational facilities (problem of serviceability). Others are inability to manage urban facilities effectively (manageability), over-utilization of existing inadequate facilities, retardation in the movement of goods and services and environmental deterioration (liveability). All the

above problems put together give rise to urban dislocation and rural decay (Onosemuode *et al.*, 2007).

Besides, the afore mentioned problems that occur in urban centres due to population explosion, more importantly insufficient shelter (housing) and partly due to exorbitant house rent in most urban centres have led to the development of squatter (slum) settlements. The reasons for the emergence of squatter (slum) settlements as put forward by Onosemuode *et al.*, (2007) include:

- i. uneven spread of job opportunities
- ii. uneven spread of infrastructural facilities
- iii. presence of institution of higher learning, and
- iv. attractions by relatives and friends among others

With the emergence of squatter settlements in most urban centres in Nigeria and how best these squatter (slum) settlements can be improved and developed to a reasonable standard without much distortion to human habitat has led the authors to develop "The Multi-stage Model for Squatter (Slum) Development".

In the multi-stage model (Fig. 2) for squatter (slum) settlement development, the first phase is the documentation of the inventory of existing squatter settlements and land suitable for new residential area. Thereafter, classification of the available land is carried out. The multi-stage model has two alternatives; the "Transformative" and "New Development" alternatives. The transformative alternative does not need to evacuate the inhabitants of the area, but relocates inhabitants within the area after reorganization of the settlement. While the new development alternative has to do with the evacuation of the inhabitants to a new place.

After the organization of the community participation and negotiation, survey of the perimeter boundary of the settlement is carried out at phase 2 of the model. This is closely followed by planning, surveying and cadastral mapping of the area into plots.

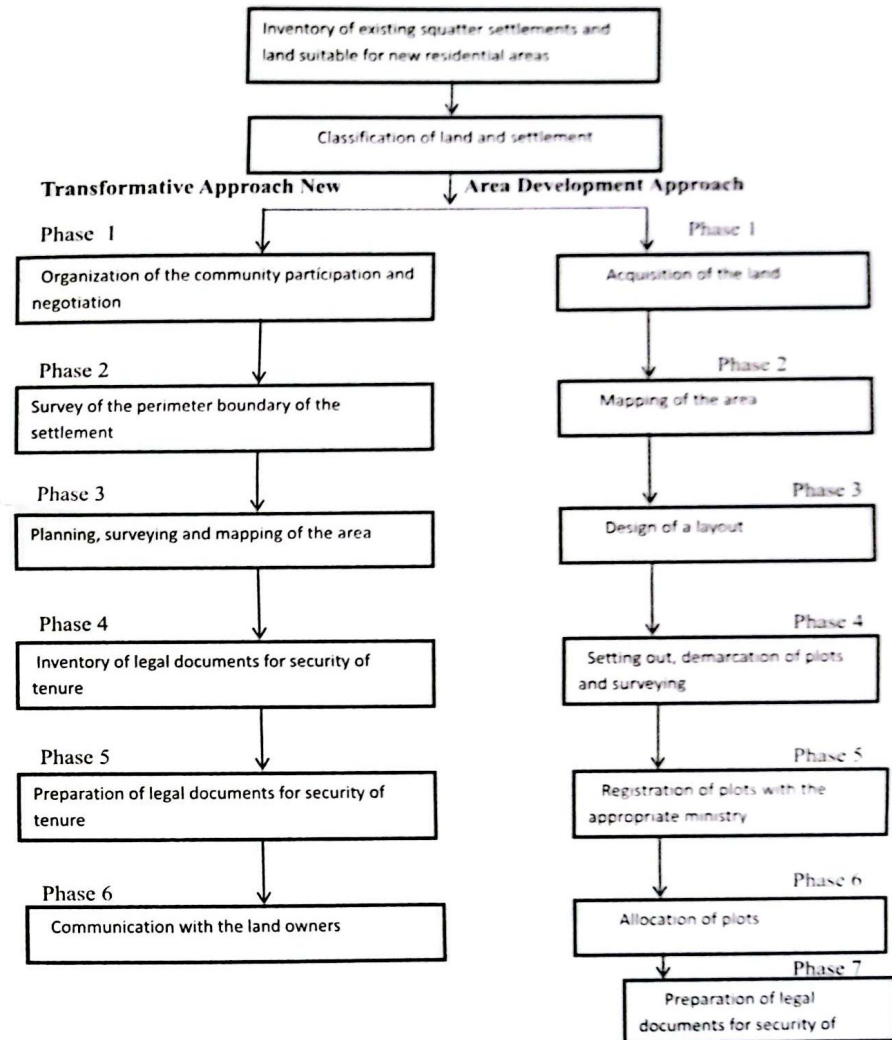


Fig.2: The Multi-stage Model for Squatter (Slum) Development
 Source: Onosemuode *et al.* (2007).

From the onset during the organization of the community participation, detailed data as to the population of the inhabitants should be taken. This should include: names, numbers in household, occupation, place of origin if not an indigene of that community and other information that may be deemed necessary. Those carrying out the transformation should bear in mind that inhabitants with proven documents or evidence of ownership of plots in the community should be noted as this would guide in the allocation of plots without conflict ensuing.

On the basis of these data, plots are allocated and comprehensive inventories of users of the different plots are taken by the appropriate ministry. Potential landowners go for the preparation of legal documents for security of tenure at the Ministry of Lands and Survey or any authorized ministry or commission that could undertake such an assignment of land registration.

To conclude the "Transformative" approach in the upgrading of squatter (slum) settlement, the various land owners are further briefed on the various institutions that will be involved in the day to day running and maintenance of the various infrastructure that would be put in place.

The "New Area Development" approach is the acquisition of land which is based on the data generated from inventory of existing squatter (slum) settlement after classification. Mapping of the acquired land is carried out in phase 2 of the model. Phase 3 is the design of the layout of the various intended utilities (water, gas pipelines, telephone cable, petrol stations, fire service offices etc) to be developed in the area. Phase 4 is the setting out, demarcation of plots and the surveying of the perimeter of the land and each plot.

The various plots demarcated are registered by the Ministry of Lands and Survey or any other authorized body at phase 5 of the model. Individuals that are being relocated who are interested in the "New Area Development" are allocated plots at phase 6 of the model.

Conclusively, those allocated plots go for the preparation of legal documents for security tenure which culminates into the compilation of landowners for such area by the Ministry of Lands and Survey.

For effective and efficient upgrading of squatter (slum) settlement, Onosemuode *et al* (2007) advocated that the following institutions have to be improved, sustained and maintained or put in place if not existing:

- i. legal review,
- ii. organizational review,
- iii. review of financial system,
- iv. community strategy and,
- v. human resource development.

2.2 Landuse Change and Urban Sprawl

This section introduces the various changes that have taken place in the landscape the implications of such changes on the environment.

2.2.1 Dynamics of Landuse Pattern

Onosemuode (2006) in his study on the dynamics of landuse pattern and socio-economic Activities in Warri and environs was able to establish the rate of change in landuse in Warri between 1977 and 1994 as shown in Table 1.

Table 1: Rate of Change and Percentage Change in Landuse from 1977 to 1994

S/N	Landuse Category	1977 (Ha)	1994 (Ha)	Change (Km ²)	Percentage Change
1	Residential	192.25	599.25	407	211.70
2	Commercial	120.05	464.25	334.2	286.71
3	Transportation	6.09	369.22	363.13	5962.73
4	Industrial	104.83	275	170.17	162.33
5	Institutional	147.33	305.36	158.03	107.26
6	Recreation	13.40	7.59	-5.81	43.36
7	Non-urban land	5686.25	4586.05	-1100.2	19.35
8	Vacant land	191.85	62.7	-129.15	67.32
9	Water	504.62	297.25	-207.37	41.09
	Total	6966.67	6966.67	2885.06	6565.05

Source: Onosemuode(2006)

The author observed the obvious growth and changes in landuse during the period under consideration and found out that the residential landuse witnessed positive change of 407km² with the emergent of new residential dwellings. Commercial landuse increased by 334.2km² in 1994 as most streets were then occupied with caravans serving as shops, stores and offices in areas where buildings were not erected. Transportation landuse had an increase of 363.13km² in 1994. This is associated with expansion and construction of roads and notable among the roads as at when the study was carried out were the resurfacing of Fanikayode road linking Okumagba Avenue and Edjeba, Mebire road, Oilfield road, the dualization of Airport road and construction of its bypass to Edjeba housing estate behind the College of Education. Industrial landuse witnessed a growth of 170.17km² in 1994, this growth was recorded as a result of the existing oil producing companies as at then which included Shell Petroleum Development Company (SPDC) CHEVRON and servicing companies to the oil producing

companies. Institutional landuse as used in the study include buildings that were known to perform service functions other than accommodation; these are schools, churches, mosques, hospitals, councils and ministries which made this category of landuse to witness a growth of 158.03km² in 1994. Landuses such as recreation, non-urban land, vacant land and water had reduction in sizes in 1994 to give room for the growth witnessed in the other landuses in 1994.

2.2.2 The Use of Regression Analysis in Landuse Studies

Onosemuode and Olanruwanju(2007) were able to successfully introduce the use of regression analysis into landuse studies which was rare in the literature on landuse studies.

Regression analysis operates on the assumption that the relationship between one variable, the dependent variable Y, and a host of P other variable xi (i= 1,2,-----P), called the independent variables, may be expressed by an equation of the form:

$$Y = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n + E \text{ ----- (1)}$$

In formulation (1), b₀ is called the constant term

While b₁, b₂,....., b_n are the regression coefficient and

E is called the error term, representing the errors that enter the model as a result of some other variables, which could not be specified or are inappropriately measured as well as other random effect errors.

2.2.2.1 Computing the Coefficients

The data used in computing the coefficients are the data derived quantitatively from the landuse maps of 1977 and 1994 as shown in

Table 1. The computed coefficients are shown in Table 2.
To arrive at the coefficients in column (4) of the Table 2, the means of the data in column (2) of same Table were calculated thus:

$$\bar{Y} = \Sigma f/N \text{ ----- (2)}$$

where Σf is the summation of the data in column (2)

N is the number of data in column (2)

Similar procedure was carried out on data in column (3) of Table 2 to arrive at the data in column (5).

Column (6) is the product of columns (4) and (5) while columns (7) and (8) are the squares of columns (5) and (4) respectively.

Table 2: Landuse Data of 1977 and 1994 and Their Computed Regression Coefficients

(1) Landuse category	(2) 1977(y)	(3) 1994(x)	(4) Y(Y- $\bar{Y}$)	(5) X(X- $\bar{X}$)	(6) XY	(7) X ²	(8) Y ²
Residential	192.25	599.25	-581.75	-174.75	101660.8	30537.6	338433.1
Commercial	120.05	464.25	-653.95	-309.75	2022561.0	95945.1	427650.6
Transportation	6.09	369.20	767.91	-404.80	310840.1	163863.0	589685.8
Industrial	104.83	275.00	-669.17	-499.00	333915.8	249001	447788.5
Institutional	147.33	305.37	-626.67	-468.63	293676.4	21914.1	392715.3
Recreation	13.40	7.59	-760.60	-766.41	582931.5	587384.3	578512.4
Non-urban	5686.25	4586.05	4912.25	3812.05	1872572.6	14531725.2	24130200.1
Vacant land	191.85	62.70	-582.15	-711.30	414083.3	505947.7	338898.6
Water	504.62	297.25	-269.38	-476.75	128426.9	227290.6	72565.6
Total	6966.67	6966.67			21093844.4	16611318.6	2731645.0

Source: Onosemuode and Oluwanju(2007).

In the computation of the regression equation, the following equations were adopted thus:

$$Y_c = a + bx \text{ ----- (3)}$$

Where a= Y intercept (The value of Y_c when x = 0)

b = slope of the regression line (The increase or decrease in Y_c for each change of one unit of x)

x= a given value of the independent value,

Y_c = a computed value of the dependent variable

$$b = \Sigma xy / \Sigma x^2 \text{ ----- (4)}$$

Applying equation (4) above;

$$b = 21093844.4 / 16611318.6$$

$$= 1.27$$

$$a = Y - bx \text{ ----- (5)}$$

Applying equation (5) above;

$$a = 774 - (1.27 \times 774)$$

$$= 774 - 982.98$$

$$= -208.99$$

$$a = -209$$

From the above, the regression which describes the relationship between the landuse and the activities into which it is put, is thus:

$$Y_c = -209 + 1.27(x) \text{ ----- (6)}$$

2.2.2.2 Verification of the Predictive Power of the Regression Model

In order to ascertain the predictive power of the regression model, the THEILIS inequality coefficient was used to test the predictive power of the regression model.

The THEILIS inequality coefficient is represented thus:

$$U = \sqrt{\frac{(\sum P_i - A_i)^{2/n}}{A_i^{2/n}}} \text{ ----- (7)}$$

Where P_i is the predicted value of the dependent variable (x),
 A_i is the actual value of the independent variable (Y), while
 n is the sample size.

The inequality coefficient in this regard assumes a value of between zero and infinity. The smaller the value of the coefficient, the better is the predictive performance of the model. However, where the coefficient is 1, it is indeterminate as no change in the value of the variable is predicted. But if the value of the coefficient assumes a value of more than 1, the predictive power of the model is worse than no change prediction.

Table 3 shows the expression of the various components of the THEILIS inequality coefficients. To obtain the predictive values in column (4) of Table 3, the value of X is substituted in the regression equation as follows:

$$Y_c = 209 - 1.27x \text{-----} (6)$$

$$\begin{aligned} Y_c &= 209 - 1.27(599.25) \\ &= 209 - 761.05 \\ &= -552.05; \text{ and so on for the rest values of } X \end{aligned}$$

Applying equation (7), we have:

$$(P_i - A_i)^{2/n} = 129258000.6/9 = 14,362,000.07 = 144$$

$$A_i^{2/n} = 32709191.18/9 = 3,634,354.57 = 363$$

Substituting the values in equation (7), we have:

$$\begin{aligned} U &= \frac{144}{363} = 0.3967 \\ U &= 0.4 \end{aligned}$$

With a THEILIS coefficient of 0.4, the predictive power of the model is of a better performance. With the better performance power of the regression equation, forecasting the change in landuse for a given period of time is highly reliable.

Table 3: Computed Coefficients to Test the Predictive Power of the Regression Model

1 Landuse Category	2 1977 Landuse A_i	3 1994 Landuse (X)	4 Predicted Values (P_i)	5 $(P_i - A_i)^2$	6 A_i^2
Residential	192.25	599.25	-552.05	5539.49	36960.06
Commercial	120.05	464.25	-380.6	50650.42	14412.00
Transportation	6.09	369.20	-259.880	70740.04	37.09
Industrial	104.83	275.00	-140.25	60064.21	10989.33
Institutional	147.33	305.37	-178.81	10637.30	21706.13
Recreation	13.40	7.59	199.36	34581.1	179.56
Non-urban Land	5686.05	4586.05	5615.28	127724580.3	3233349.06
Vacant Land	191.85	62.7	129.37	3903.75	36806.42
Water	504.62	297.25	168.51	453130.92	254661.53
Total				129258000.6	32709191.18

Source: Onosemuode and Olaruwanju (2007)

Having established the reliability power of the regression equation; the change in landuse by the year 2014 from when it was estimated in 1994 was predicted thus:

The period under prediction is 20 years; that is from 1994 to 2014

$$Y_c = 209 - 1.27x$$

$$Y_c = 209 - 1.27(20)$$

$$Y_c = 209 - 25.4$$

$$Y_c = 183.6$$

From the above predictive figure, by the year 2014 from 1994 (20 years) there was an increase by 183.6km^2 (Onosemuode, 2006), by the year 2016 from 1994 (22 years) there was an increase of 193.76km^2 (Onosemuode and Olaruwanju, 2007) and by the year 2020 from the base year 1994 (26 years) there will be an increase of 175.98km^2 .

The increase witnessed from the above predictive figures shall reflect in residential, commercial transportation, industrial and institutional landuses while a corresponding decrease is witnessed in non-urban land, vacant land and water bodies.

It is however worthy of note that the above prediction could not account for the quantity of the portion of landuse that will be taken over by the other. In this regard, the trend of economic activities or development of the area under study had a major role to play in explaining which of the landuse took over the other.

The adoption of quantitative techniques in predicting landuse change which has not been found to be common in literature, would in effect enhance efficient, dynamic and purposeful planning in the management of the environment in the face of limited resources.

2.2.3 The Dynamics of Landuse Change on the Environment

Onosemuode and Habila (2017) carried out a study on the dynamics of landuse change in Lafia, Nasarawa State, Nigeria to ascertain the level of changes in the land between the period 1997 and 2016.

The imageries used were LANDSATETM of 1997 and NIGERSAT -1 of 2016. The various classes of landuse adopted are; cultivated area, bare surface, built-up area, natural vegetation and water bodies. The supervised method of landuse analysis was used in the extraction of the information from the imageries in ArcGis 9.3 environment. The results (Table 4) obtained showed that bare surface accounted for 0.72% in 1997 and increased to 1.91% in 2016, built up area occupy land cover of 2.63% in 1986 and by 2005, it increased to 3.55%, cultivated area covers 27.88% in 1997 and in 2016, it increased to 56.57%. Natural vegetation which include all forested areas and grassland in 1997 decreased in 2016 to 25.43%. Water bodies, including all the surface water found in the study area such as ponds, streams, rivers, marshes and lakes covered 9.43% in 1997 while in 2016, it increased to 12.53%. It can be concluded that despite the adverse effect of the changes on the environment, the study area can be seen as developing as there is increase in the built up areas as well as increase in cultivated area. These increases are reducing the vegetation of the study area, a deliberate attempt should therefore be made to incorporate tree planting as part of the building policy in the study area.

Table 4: Magnitude and Percentage Change in Land use and Land cover Between 1997 and 2016

Classes	A 1997 Area (km ²)	B 2016 Area (km ²)	C Magnitude of change (B - A) km ²	D Annual rate of change C/19 (km ²)	E % change C/A x 100
Bare surface	1.22(0.72%)	3.24(1.91%)	2.02	0.11	165.57
Built up Area	4.45(2.63%)	6.01(3.55%)	1.56	0.08	35.06
Cultivated Area	47.18 (27.88%)	95.72(56.57%)	48.54	2.56	102.88
Natural Vegetation	100.41(59.34%)	24.04 (25.43%)	-67.37	-4.20	-67.10
Water bodies	15.02(9.43%)	21.21(12.53%)	6.19	0.31	41.21
Total	169.22	169.22	-9.06	-1.14	277.62

Source: Onosemuode and Habila (2017).

2.2.3.1 Implication of the changes on the environment

The results of the changes between 1997 and 2016 in Lafia had some adverse effects on the environment which if not looked into critically by planners and environmentalist would degenerate into a state of urban decay. Increase in cultivated area at an annual rate of 2.55 km² between 1997 and 2016 is an indication of an increase in population that need to fend for themselves in the absence of white collar jobs and have resorted to farming. The major farming system practices in the study area as revealed by field observation is intensive continuous cropping as a result of land being competed for by other uses such as residential, commercial, institutional which are subsumed into built up area. The implication of the intensive continuous cropping on the environment is not only

rendering the soil bare and exposed to soil erosion but also reducing the nutrient carrying capacity of the soil for agricultural sustainability (Onosemuode and Akhimien, 2010; Onosemuode *et al.* 2010; Onosemuode and Umunade, 2011).

Besides the implications of increase in cultivated area, the decrease experienced in natural vegetation at an annual rate of 3.49 km², is a pointer that the effects of global warming will be on the increase. The moderating effects of the vegetation on the environment would be greatly reduced exposing the environment to the scorching effects of the heat, which further enhances evapotranspiration reducing photosynthetic activities in plants leading to food shortage. The above observation in the study area is in line with the findings of Dwyer *et al.* (1992) and Xiao and Mcpherson (2002) who concluded that urban trees play important roles in improving landscape aesthetics, reducing pollution and moderating the urban energy budget, water use, reducing storm runoff, and providing other amenities. Many problems facing management of the urban ecosystem are related to these factors. For example, urban heat island effects and increased storm runoff are related to vegetation cover (Gallo and Tarpley, 1996). Air quality and water use are related to crown density and tree density because the total leaf surface area and leaf surface area per unit of land area controls both air pollutant removal and evapotranspiration rates (Peper and Mcpherson, 2003). To this end, with the reduction in the natural vegetation in the study area there is bound to be human discomfort as the air quality, energy exchange, hydrology and microclimate will be adversely affected. The increase in bare surface at an annual rate of 0.11 km² which is made up mainly of outcrop rocks and increased proportion of pavement area during the process of urbanization will strongly influence energy exchange, hydrology

and microclimate in the study area and subsequent increase in global warming and its anticipated effects on the environment.

Increased water bodies were as a result of the presence of gullies, unclear drainages found mostly in the built up area. The presence of these drainages that harbour water all-round the year is attributed to the culture of the inhabitants of the study area that does not allow married women to be seen outside. They are kept in an enclosure known as "Pudah" from the sights of males children and visitors from where all domestic activities are carried out. The presence of these water bodies especially those found close to homes are stagnant and act as breeding ground for mosquitoes and also act as point source through underground seepage for the contamination of wells used as source of drinking water.

3.0 GEOSPATIAL PERSPECTIVE OF ENVIRONMENTAL MANAGEMENT

Environmental management can be reasoned as being concerned with meeting and improving provision for human needs and demands on a sustainable basis with minimal damage to natural habitats and the ecosystems. It is on this basis that this section discusses the studies on waste management with emphasis on collection points, dump site for solid waste and landfill for poultry waste.

3.1 Waste Management

The selection of a dumping site (landfill) is a big question facing local authorities because it represents a point of confluence of science, social science, and planning (Habital, 1987). Urban planners and city managers throughout the world are now confronting this issue within a much broader social development context. "Not in my backyard" may be the mantra facing decision

makers as the volume of solid waste generated in rural and urban areas increases (UNEP, 1996; Nishanth *et al.* 2010).

3.1.1 Determination of Waste Collection Point

For the effective and efficient management of waste in the environment, Onosemuode *et al.*, (2013) carried out the spatial assessment of wastes collection points using GIS approach.

3.1.1.1 Determination of Waste Generated

This is to determine the amount of waste generated in the entire metropolis. This computation takes into consideration, the population of the study area, the rate of waste generated /person/day.

Total number of available waste collection points in the study as determined by fieldwork = 50

Capacity of waste collection bin = 8 metric tones

One tone = 1000 kg therefore, the capacity of a waste collection bin in kg = $8 \times 1000 = 8000\text{kg}$.

Rate of waste generation = 2.6kg/person/day

Projected Population = $P_1 = P_0(1+r)^n$

= 2006 population = 308,621, n = No of years

= $[308621 \times (3.3/100) \times 1] + 308621$

= 10185 + 308621

= 318806 [For 2007 population]

Projected population for 2010 = 351421

Total waste generated = (Projected population) * (Rate of waste generation/person/day)

$351421 \times 2.6 = 913695\text{kg}$

3.1.1.2 Determination of the Spatial Spread of Waste Bins

GIS as a tool has spatial analytical capabilities which are used in solving spatial problems. The following analyses were performed in this study;

- i. Buffering,
- ii. Overlay,
- iii. Network Analysis – [New Route],
- iv. Spatial statistics – [Mean center].

3.1.1.3 Buffering Operation

The criteria that waste collection points should not be more than 300 meters away from the household it services and that the waste collection points should not be less than 30 meters away from water features was adopted. Buffering operation was used to determine places that were within the distance of between 0 and ≤ 300 meters from waste collection points and areas of 30 meters away from water features.

The steps used are;

- Select the arc tool box, click on analysis tool > click on proximity> double click on Buffer

A page will pop up, then select the theme to be buffered and specify the distance > click ok. See result of buffer for both waste collection points and water features in Fig.3 and Fig. 4.

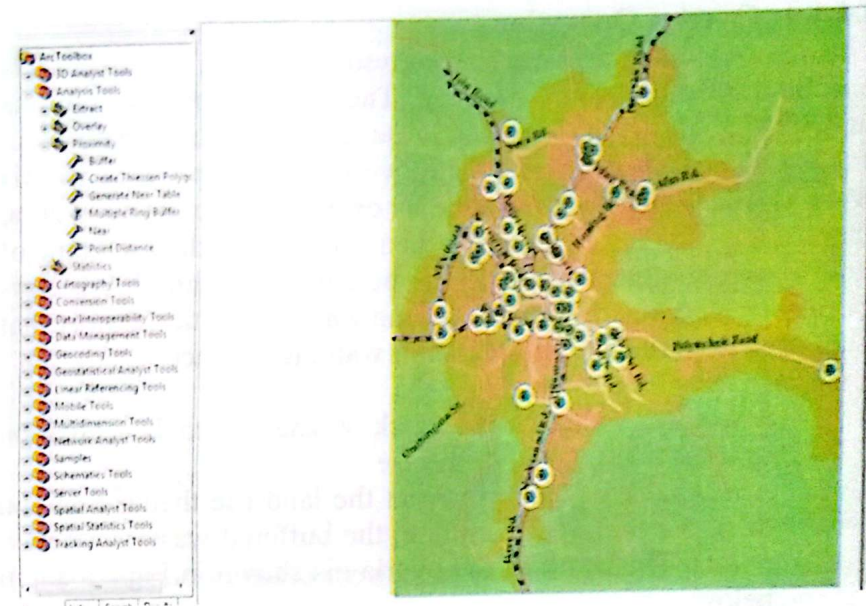


Fig.3: 300 meter buffer around waste collection bins.



Fig.4: 30m buffer around water channels.

3.1.1.4 Overlay Operation

The ability to integrate data from two sources using map overlay is one of the GIS analysis function. The Boolean overlay options include the following; intersect, erase, union, identify, spatial join and symmetrical difference. The overlay operation used in this work is 'ERASE'. This was done by overlaying the buffered zone theme on the land use theme and then erased to produce a theme of map showing areas that could not be covered within 300 meters buffering. The erased area shows the waste collection points that cannot be assessed within 300 meters walking distance.

Steps used are;

- Select the arc tool box > click on analysis tools > click on overlay > double click on erase.
- A dialog box pops up, select the land use theme first and then, the buffered theme i.e, the buffered waste collection points. The result of the overlay is shown in Figs. 5 and 6 below.

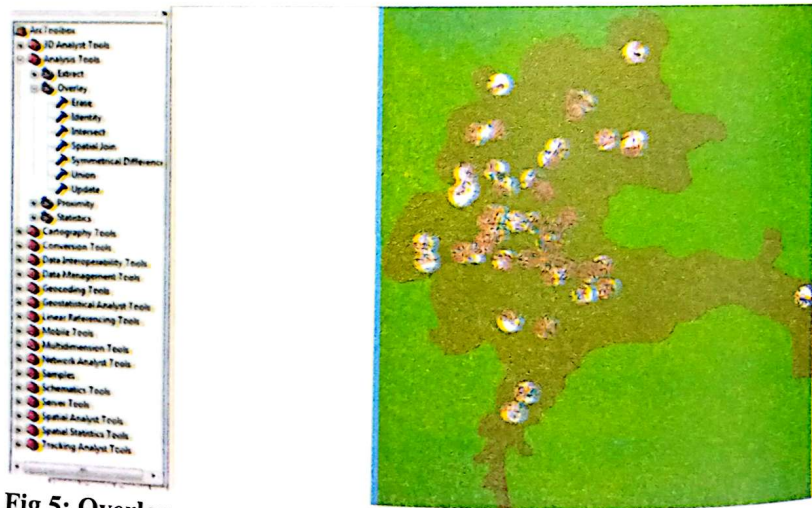


Fig.5: Overlay operation showing areas within 300m buffer.

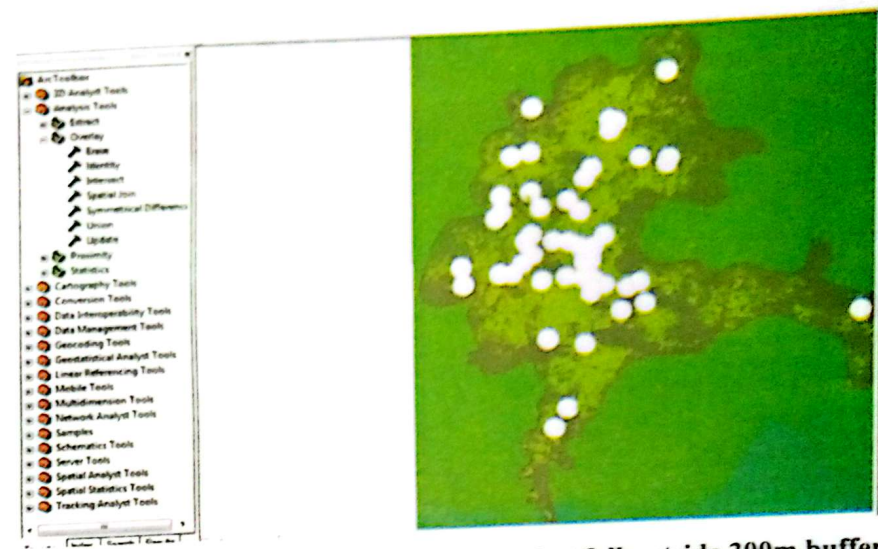


Fig. 6: Overlay operation showing areas that fall outside 300m buffer

3.1.1.5 Network Analysis

The network analysis was modeled in this work to determine the route linking the existing waste collection points in order to show the accessibility to these waste collection points for evacuation. This is very important especially for the Waste Management Board in determining the best route to take in evacuating waste in the study area.

This was done by building a network datasets from the arc catalog for the roads that have been vectorized. The network was built along with the waste collection points. The result of the analysis is shown in Fig.7 below.

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Since the set criterion for a waste collection point is that it should be a maximum distance of 300 meters away from the household it services, it means that an individual should not walk more than 300 meters before getting to a waste collection point. By the virtue of that, the study area was gridded into 500m by 500m. The gridded area was converted into polygons using the data management tools in ArcGIS 9.3. A spatial statistical analysis tool in ArcGIS 9.3 was used to find the Mean Center for each of the gridded polygons (Fig. 8). The mean center is used to find the center point of a polygon feature. The center point will automatically be converted into point feature using spatial statistical tool in ArcGIS 9.3 (Fig. 9). The mean center is the average of x and y coordinate of the gridded polygon features.

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**GRID MAP SHOWING THE MEAN CENTER
FOR THE BUILT UP AREA**

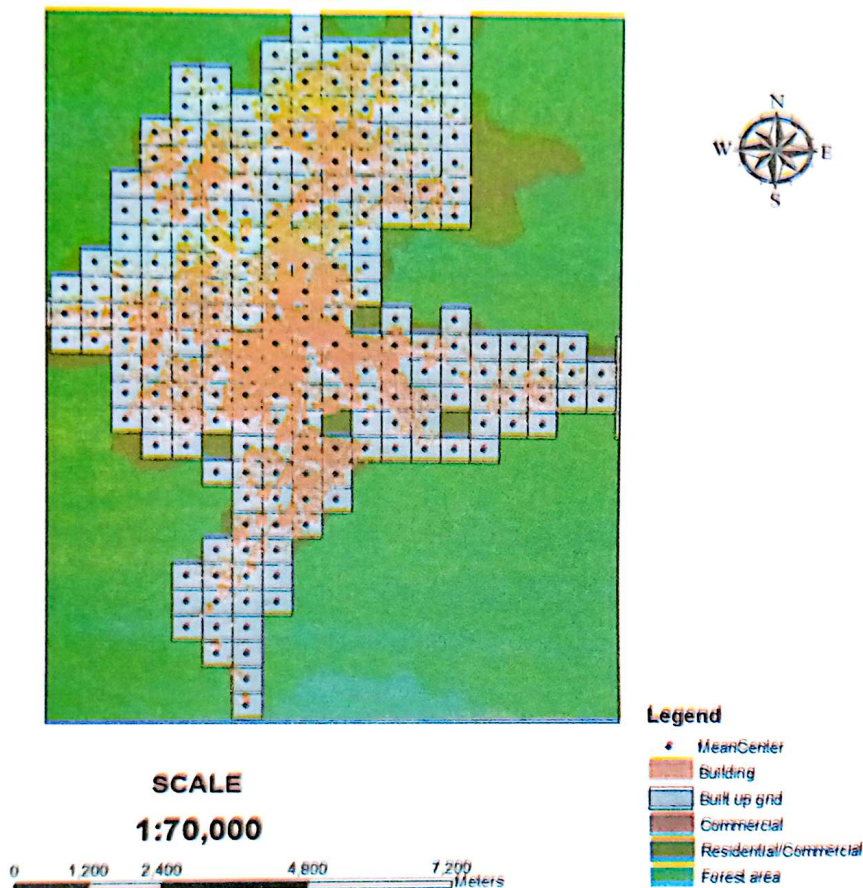


Fig.8: Grid map showing the mean center for the built up area

**GRID MAP SHOWING THE BUILT UP AREA WITH
AND WITHOUT WASTE COLLECTION POINTS**

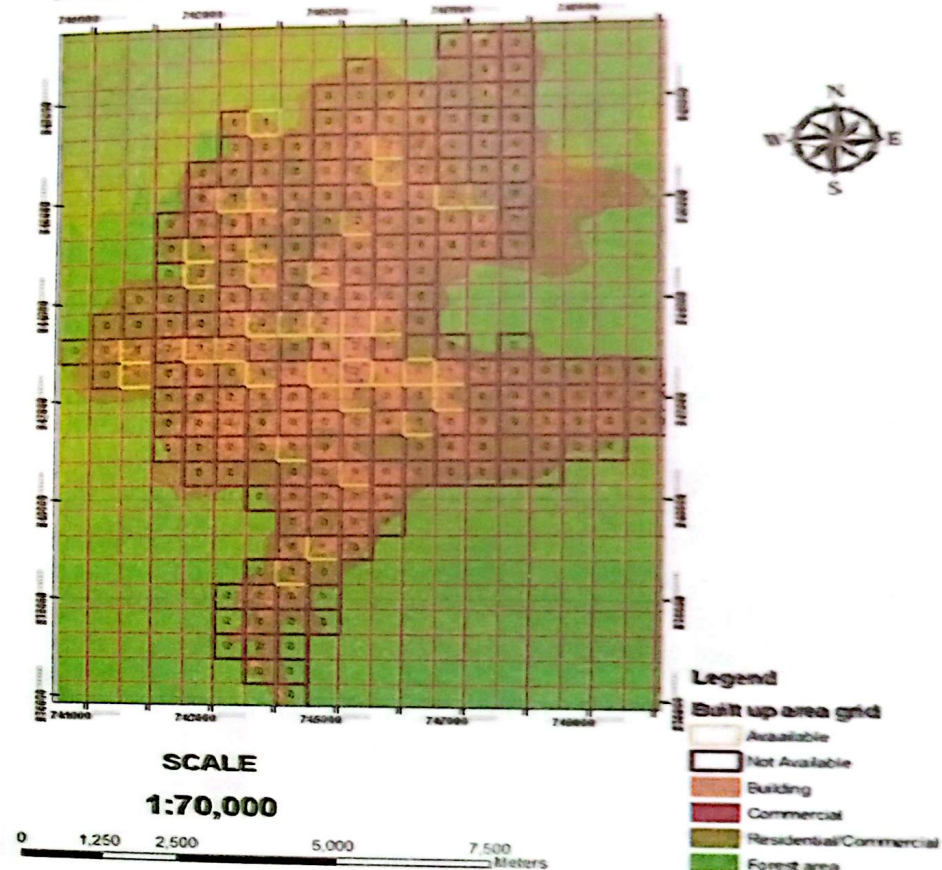


Fig.9: The built up area with and without waste collection points

GRID MAP SHOWING THE BUILT UP AREA

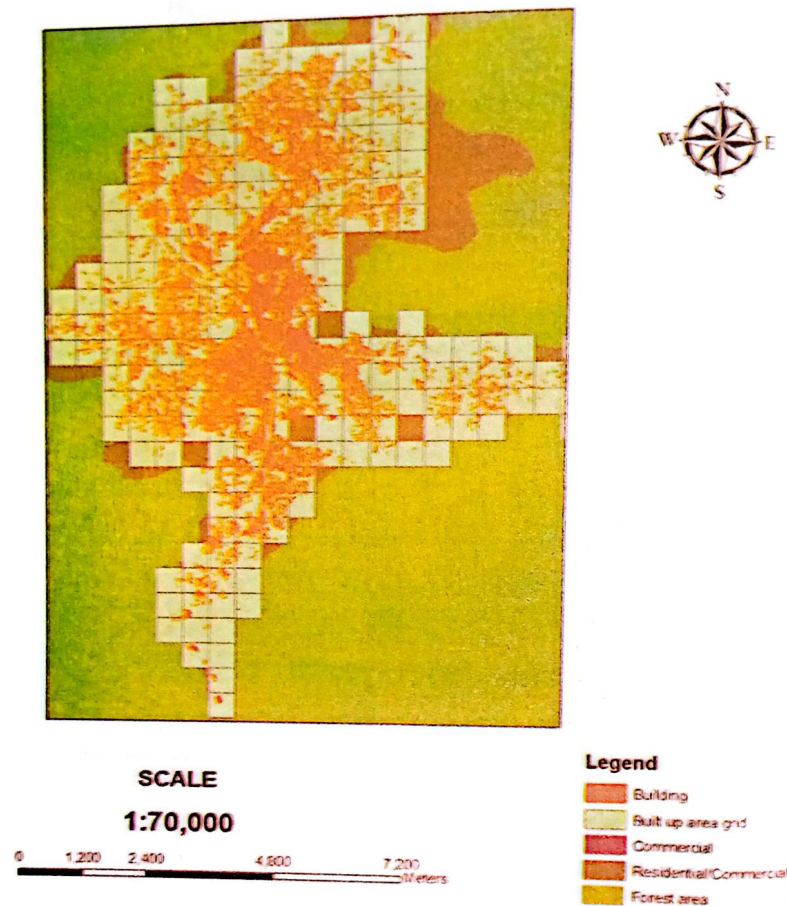


Fig. 10: The built up area

3.1.1.7 Discussion of results

With the classification of the study area into zones of different land use which is built into the database, it eases the identification of

zones that have waste bins and the zones that do not. It also employs the proximity analysis of Arc GIS (buffering) to determine those areas that have waste bins based on the assumption that waste collection points should not be more than 300 meters away from the household it services. From the buffering analysis, it was discovered that the commercial land use zone was completely covered. This is the reason why the erased map could not show the commercial center in the analysis (Fig.5 and Fig.6). Also, it was discovered that two available waste collection points were within 30m buffer around water channel.

The study revealed that only 50 waste collection points which were grossly inadequate and led to the determination of the expected number of waste collection points required to cover the study area.

The method used is the gridding method and a spatial statistical analysis [Mean Center] was used to locate a point feature representing a building in the center of each gridded polygons. The result of the calculation showed that 240 waste collection points would be required to cover the entire study area.

With 351421 projected population in year 2010 generating 913695kg of waste per day and with an increase in population on the average of 10700 per year coupled with the insufficient waste collection points in the study area, there is bound to be more environmental hazards in the near future. The expected environmental hazards anticipated include flooding due to drainage blockage by waste, traffic jam as a result of waste spill over motorable roads, increase in sicknesses and diseases, water and environmental pollution if no adequate measures are taken to facilitate waste management in the study area.

3.1.2 Determination of Solid Waste Dump Site

Onosemuode and Omorogbe (2017) in another study attempted the use of Geoinformatics techniques in determining site selection for solid waste dump in Warri and Environs.

The following were the criteria adopted to determine the best waste collection point in the study area:

- the preferred land use should be an open space,
- the site must be at least 10m from existing road,
- the site must be at least 100m from Residential, Educational and Administrative areas,
- the site should be located on a terrain with a slope less than 20° to prevent erosion and insecure accessibility,
- the waste dump should be greater or equal to 0.5 hectares, and
- the site must be at least 100m from water sources.

The GIS spatial analysis feature used to determine the best waste collection point is the buffer, digital elevation model (DTM), overlay, erase and search operations.

3.1.2.1 Buffer Operations

Buffer operation is a spatial operation that is concerned with the determination of spatial proximity of various spatial features. In this study, application of buffering for analysis of area that are greater than 100m from residential, academic, recreational, religious and administrative areas, 10m from all existing roads, and 100m from existing water sources was carried out.

3.1.2.1.1 Road Buffer

From the resulting map in Fig.11 below, it can be observed that all the open spaces met this criterion (site should be 10m away from existing roads).

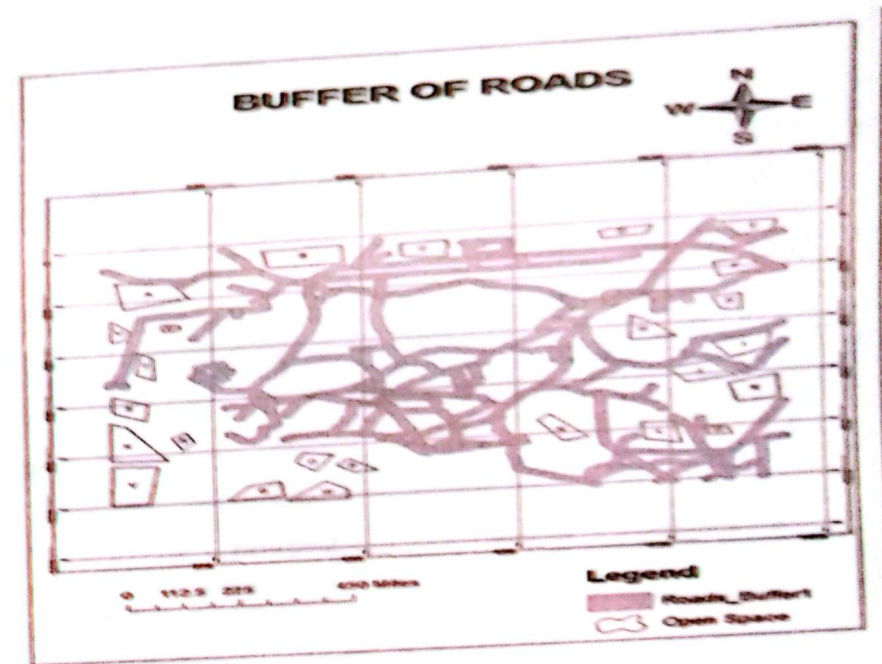


Fig.11: Buffer operation on existing roads at 10m buffer distance.

3.1.2.1.2 Water buffer

From fig.12 below, only open spaces B, C, W, X and Y met the criterion that dump site should be 100m away from existing water bodies.

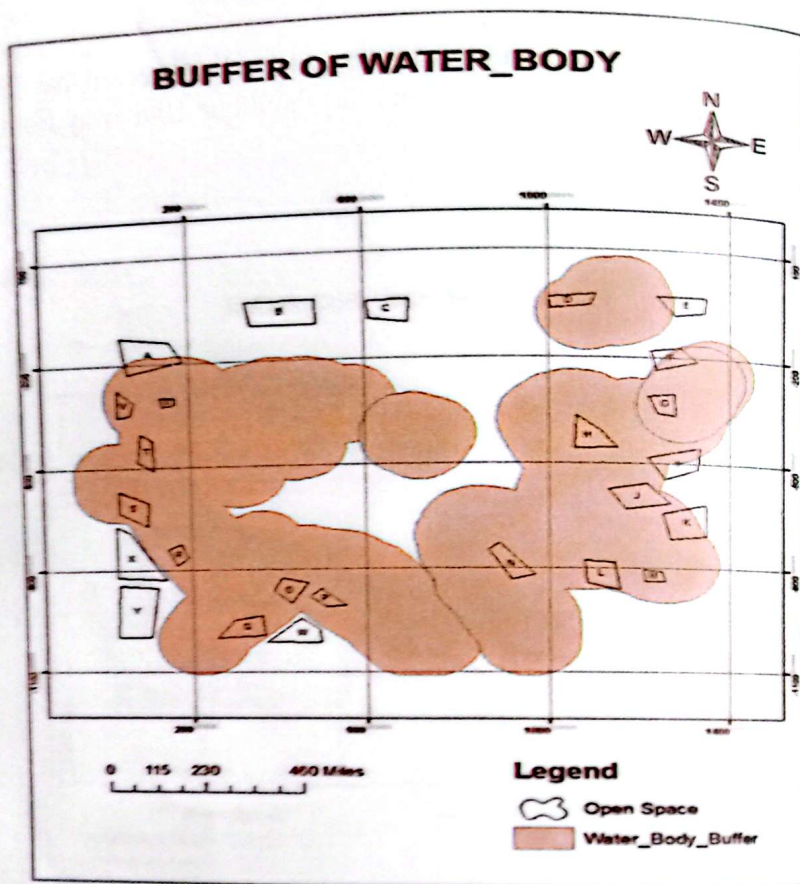


Fig.12:Buffer operation on water body at 100m buffer distance.

3.1.2.1.3 Residential buffer

Figure 13 show that open spaces I, K, W, Q, V, X and Y met the criterion that sites should be 100m away from residential areas.

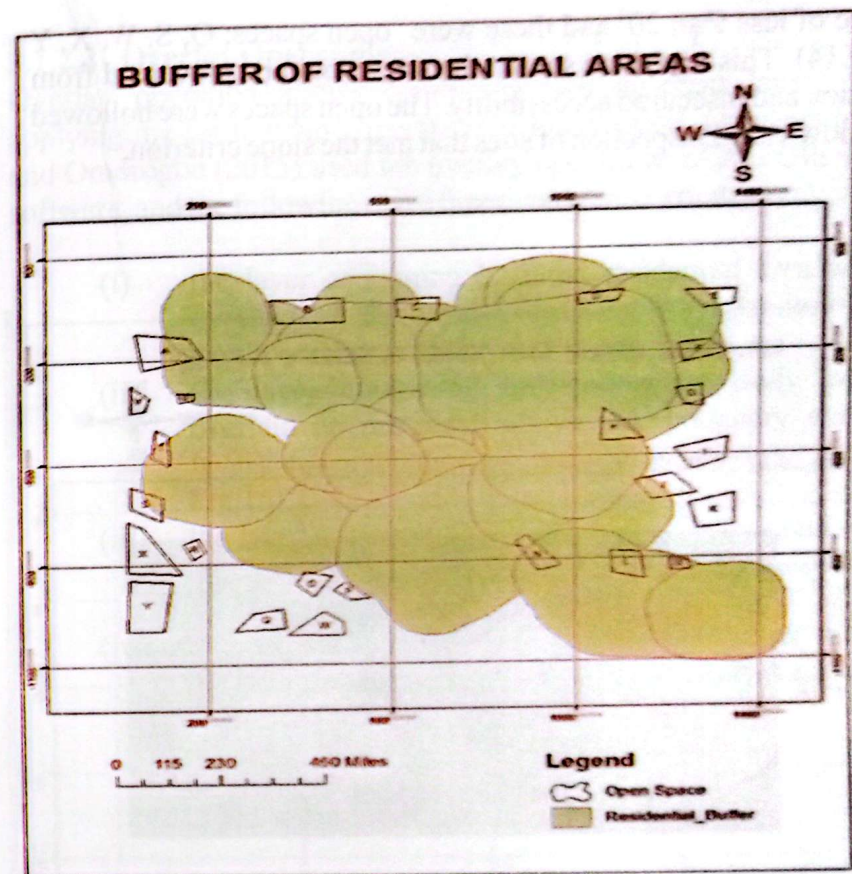


Fig.13:Buffer operation on residential area at 100m buffer distance.

3.1.2.2 Slope Generation

The map in Fig. 14 shows the different slope area and their values in degrees for the study area. Values ranging from 0° to 20° are those that are acceptable for the location of dump site. Values ranging from 20° to 45° are not suitable for the siting of dump sites. Open space was virtually overlaid on the slope map to see areas having

slope of less than 20° and these were open spaces: Q, S, W, X, Y (Fig.14). This was done so that the sites would be prevented from erosion and insecure accessibility. The open spaces were hollowed to allow visual inspection of sites that met the slope criterion.

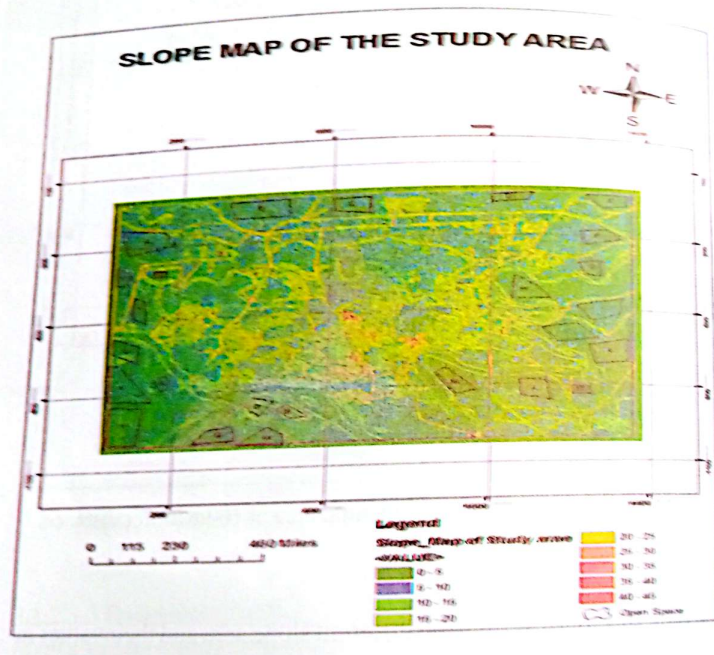


Fig.14: Slope of the study area

3.1.2.3 Overlay Operations

Overlay operation allows combining two different layers by applying the set theoretic operation of intersection. Onosemuode and Omorogbe (2015) used the overlay operations of Arc GIS 9.3 software, and the following erase functions were carried out;

- (i) the layer containing buffered residential area was overlaid on the layer containing the boundary to give boundary_erase layer. (See Fig.15),
- (ii) the layer containing buffered water body was overlaid on the result above (i.e. boundary_erase layer) to give boundary_erase_erase layers. (See Fig.16),
- (iii) the layer containing buffered roads was overlaid on the result from above (i.e. boundary_erase_erase) to give boundary_erase_3. (See Fig.17), and
- (iv) the layer containing buffered boundary was then overlaid on the result above (i.e. boundary_erase_3) to give boundary_erase_4 layer. (See Fig.18).

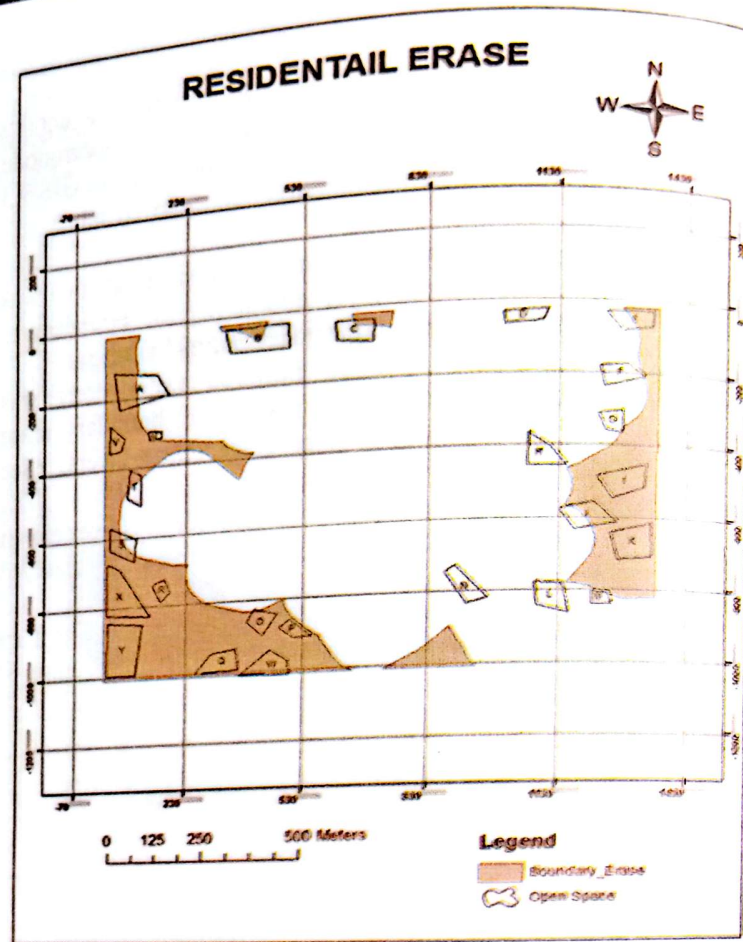


Fig.15:Buffered residential areas overlaid on the layer containing the boundary to give boundary_Erase layer

In Fig.15 above shows the overlay of buffered residential area on the boundary of the map of the study area to give boundary_erase layer. The coloured part of the map i.e the unerased part, shows the part remaining after erasing the buffered residential area from the map. The open space that fell inside the coloured part were areas dump sites can be sited.

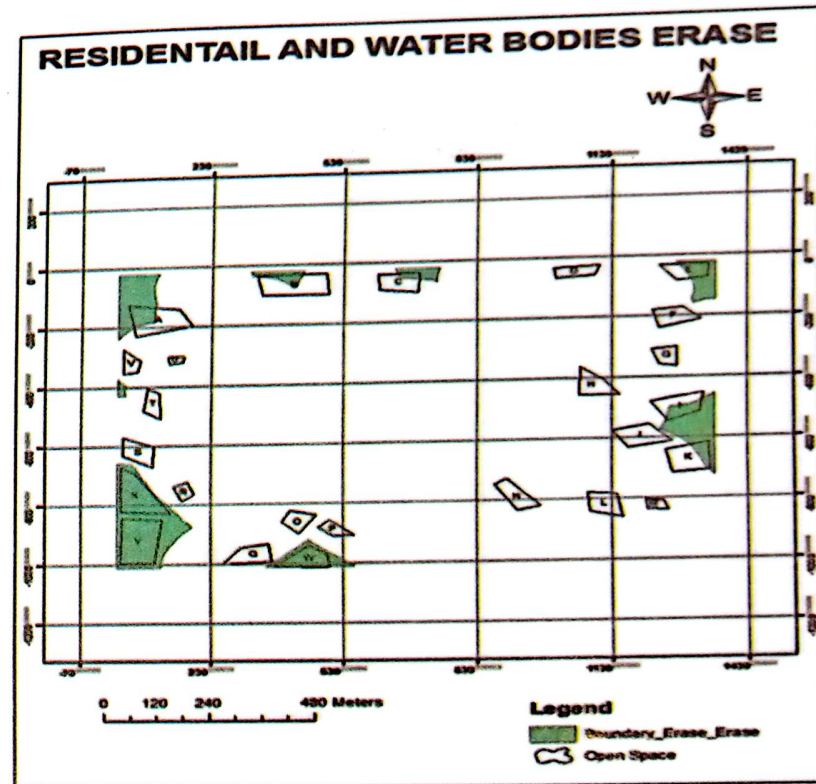


Fig.16:Buffered water bodies overlaid on the result of boundary_erase layerto give Boundary_Erase_Erase.

Figure 16 above shows the overlay of buffered water bodies on boundary_erase layer of the map of the study area to give boundary_erase_erase layer. The coloured part of the map i.e the unerased part, shows the part remaining after erasing the buffered water bodies from the map of boundary_erase. The open space that fell inside the coloured part are areas where dump sites can be sited. The open space outside the coloured part of the map shows areas that are not suitable for dump sites.

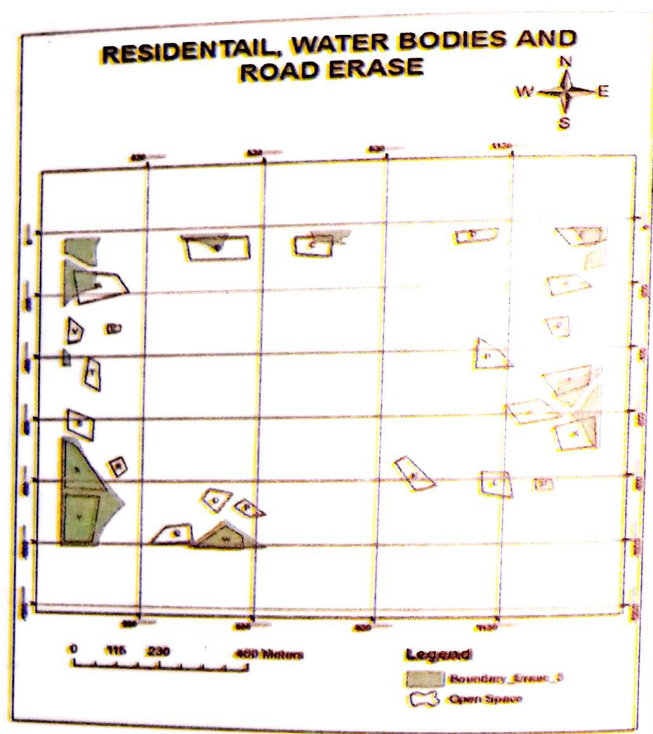


Fig.17:Buffered roads overlaid on Boundary_Erase_Erase layer to give Boundary_Erase_3 layer.

Figure 17 above shows the overlay of buffered roads on boundary_erase_erase layer of the map of the study area to give boundary_erase_erase_3 layer. The coloured part of the map i.e the unerased part, shows the part remaining after erasing the buffered roads from the map of boundary_erase_erase. The open space that fell inside the coloured part were areas where dump sites can be sited. The open space outside the coloured part of the map shows areas that are not suitable for dump sites.

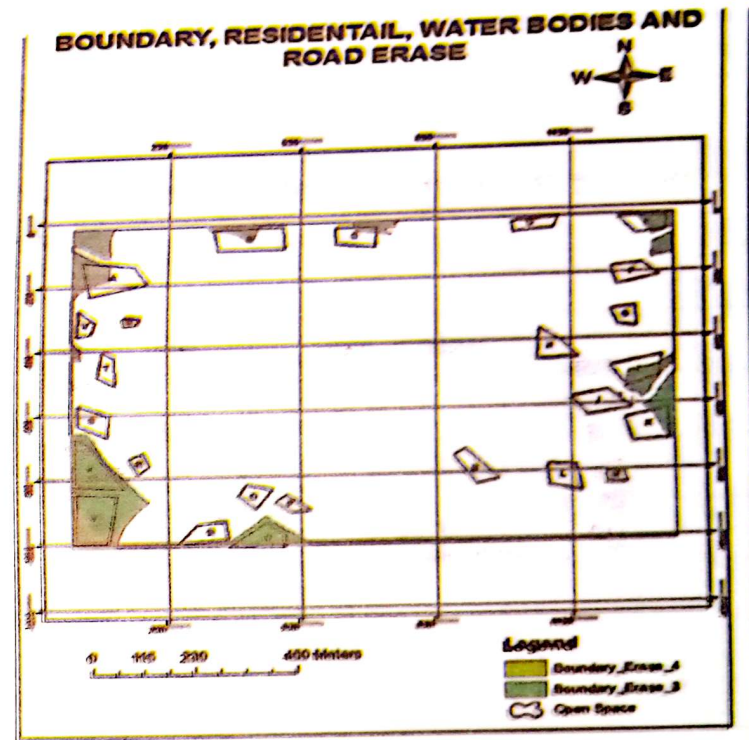


Fig.18:Boundary overlaid on Boundary_Erase_3 layer) give Boundary_Erase_4 layer

Figure 18 above shows the overlay of boundary on boundary_erase_3 layer of the map of the study area to give boundary_erase_4 layer. The coloured part of the map i.e the unerasd part, shows the part remaining after erasing the boundary from the map of boundary_erase_3. The open space inside the coloured part were areas where dump sites can be sited. The open space outside the coloured part of the map shows areas not suitable for dump sites.

3.1.2.4 Spatial Search Query

Spatial search was applied to the attribute data to yield the suitable sites with greater than or equal to 0.5 hectares

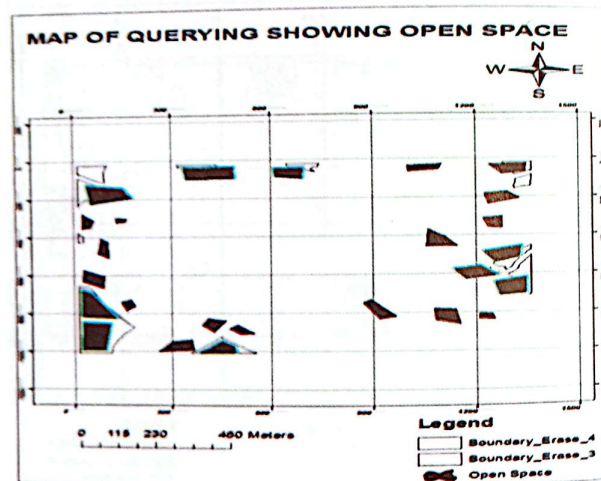


Fig.19: Open space showing query result

Figure 19 shows open spaces that met the criterion that dump sites should be equal or greater than 0.5 hectares. The open spaces; A, B, C, I, J, K, W, X, and Y met the criteria while the other open spaces contravened the criterion. The open spaces that met the criteria are the suitable sites where solid waste dump sites can be located, but some of these open spaces contravened other set of criteria and as such only open spaces W, X, and Y (Fig.20) met this criteria without contravening other set criteria. These open spaces are the most suitable sites that met all the criteria for the sitting of waste dump in the study area.

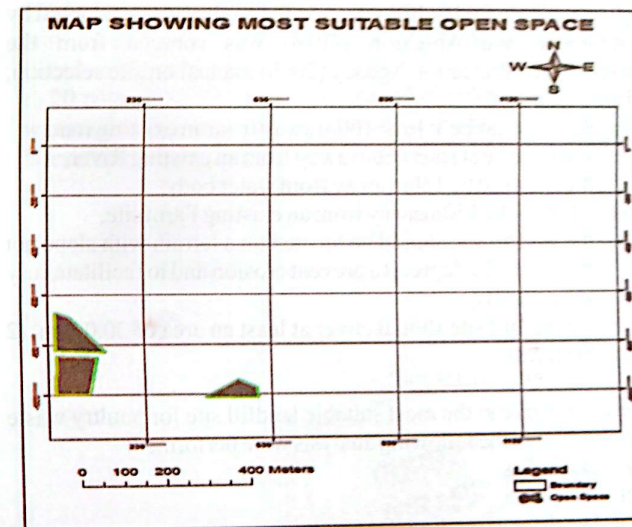


Fig.20: The most suitable open space that met all the set criteria.

Conclusively, Onosemuode and Omorogbe (2015) has been able to show that Geoinformatics technique is a better way of decision making on complex issues related to the environment as the suitable sites selected were in line with the purpose and set criteria for the selection of the most suitable site for solid waste disposal.

3.1.3 Determination of Suitable Landfill for Poultry Waste

In another study by Onosemuode and Abodurin (2016), they were able to determine suitable landfill for poultry waste using Geoinformatics techniques on Amos Farms at Awe Afijio, Oyo State.

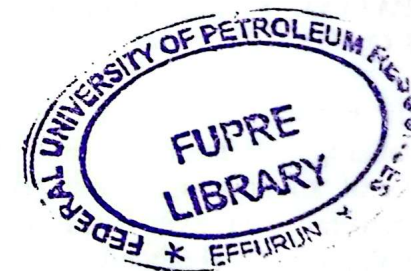
The basic criteria for landfill selection for poultry waste adopted by Onosemuode and Abodurin (2016) was sourced from the Environmental Protection Agency (2006) manual on site selection, and are as follows:

- i. the site must be at least 100m away from an existing road,
- ii. site must be at least 160m away from an existing River,
- iii. the site must be 160m away from water body,
- iv. site must be 150m away from an existing Farm site,
- v. the landfill site should be located on a terrain with slope not more than 20 degree, to prevent erosion and to facilitate easy accessibility,
- vi. the landfill site should cover at least an area of 20,000m² (2 hectares).

In order to arrive at the most suitable landfill site for poultry waste in the study area the following analysis were performed:

- i. Buffering
- ii. Overlay
- iii. Database extraction (Query)

The various layers used for the study were extracted from topographical map and imagery, the river and slope layers were extracted from topographical map and the other layers were extracted from the imagery and included; existing roads, water body, farm site and boundary. They were buffered to satisfy the set criteria. The road buffer was traded off to give the boundary buffer in the first operation and the remaining portion of the area was recognized as 1 (Boundary erase_1). River buffered was also traded off with the first product (Boundary erase_1) and result was tagged 2 (Boundary erase_2). Furthermore, buffered water body was traded off to give 3 (Boundary erase_3), Buffered farm site at the same time was also traded off to give 4 (Boundary Erase_4). Products 1 and 2 were intersected to have E, E was also intersected with 3 which gave F while F was intersected with 4 that resulted to G that was later clipped with slope of the terrain lesser than or equal to 20 degree. At the end of the analytical processes, search query was used to generate the most suitable sites (Fig.21) of an area that is less than or equal to 20,000m² (2 hectares).



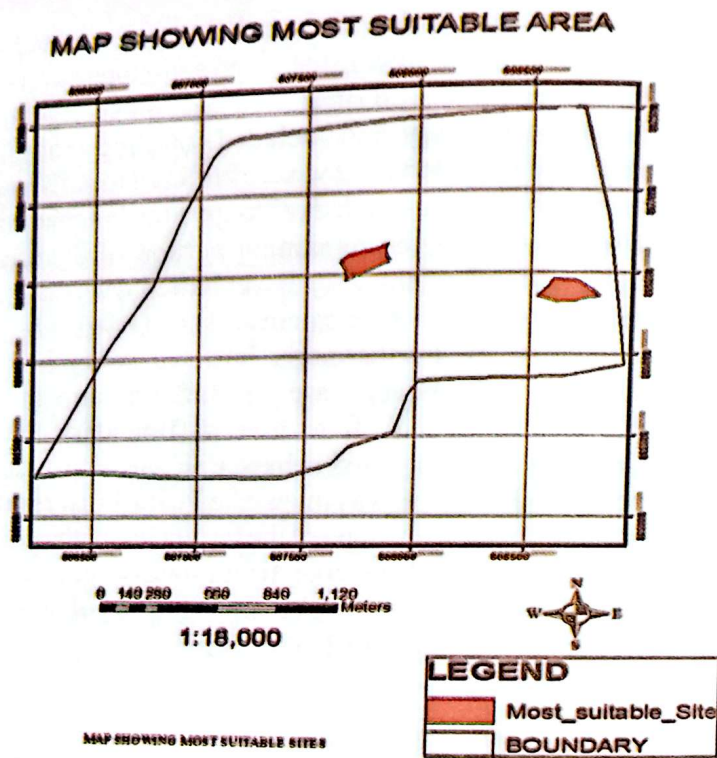


Fig.21: Most suitable landfill sites

4.0 GEOSPATIAL PERSPECTIVE OF RIVER BASIN DEVELOPMENT

A river basin is the portion of land drained by a river and its tributaries. It encompasses the entire land surface dissected and drained by several streams that flow downhill. This section discusses the importance of river basins from the hydrological, economic and ecological points of view.

4.1 The Morphometry of Warri River Basin

The morphometric analysis of drainage geared at validating the Hortonian postulation of Warri River Basin was reported in a study carried out by Onosemuode (2005). The study focused mainly on the geometry with detailed emphasis on the relationship between the morphometrical characteristics such as stream order (U), stream number (Nu) and length (Lu), bifurcation ratio (Rb), drainage density (Dd), channel frequency (F), constant of channel maintenance (CCM) and elongation ratio (Re) (Table 5).

Table 5: Morphometric Parameters of Warri River Basin

Stream Order (U)	Stream No (Nu)	(Rb)	Average (Rb)	Stream Length (Km)		Cumm. Mean Length	Stream Area (Km ²)		(Dd)	(CCM (Km ²))	(F)	(Re)
				Total (Lu)	Mean (Lu)		Total (Au)	Mean (Au)				
1	344	-	-	358.56	1.04	1.04	62.1	0.18	5.77	0.17	5.54	-
2	83	4.15	-	168.72	2.03	3.07	34.1	0.41	5.0	0.2	2.43	-
3	22	3.8	-	109.56	4.98	8.05	22.65	1.03	4.84	0.21	0.97	-
4	6	3.7	-	31.08	5.18	13.23	8.55	1.43	3.64	0.28	0.70	-
5	1	6	-	60	60	73.23	37.75	27.75	2.16	0.46	0.03	-
										6		
Total	465	-	4.41	727.92	-	-	-	-	4.69	0.21	2.94	0.2

Source: Onosemuode, (2005)

The result from the study showed that the drainage density (Dd) of the study area indicates the level of dissection. With a drainage density of 4.69 (Table 5), for every square kilometer of the basin, there is 4.69 kilometer of stream channel. According to the classification of Strahler (1964), values of drainage density fewer than 12 are low density; those with values between 12 and 16 are

medium density basin while basins with values above 16 are high density basin.

From the classification of Strahler (1964), Warri River basin falls in the group of low density, having coarse texture with value between 2mm - 0.02mm. This is favoured by the high impermeable nature of the subsoil.

Bifurcation ratio (Rb) shows the frequency with which streams of a given order enter streams of the next higher order. A mean bifurcation value of 4.41 (Table 5) was obtained and this revealed a significant relationship between stream number and stream order, which has a great tendency for Warri River to develop tributaries.

Constant of channel maintenance (CCM) is the reciprocal of the drainage density. Schumm (1956) used this parameter to show the number of unit area (Km^2) of watershed surface that is required to sustain one linear unit length (km) of stream channel. The constant of channel maintenance for Warri River Basin is 0.21 Km^2 (Table 5). This implies that an average of 0.21 km^2 of the basin area support each kilometer of stream length.

Channel frequency (F) according to Horton (1945), is the number of stream segment per unit area. The value of 2.94 was obtained as the channel frequency and implied that there is an average of 2.94 number of stream segments per square kilometer. Besides, the first order stream contributes about 57.2% of the stream segment per unit area, the second order (25.1%), third order (10.0%), fourth order (7.3%) while the fifth order contributed 0.4% stream segments per unit area.

Elongation ratio (Re) otherwise known as the shape of the watershed is important because it gives the rate at which water is

supplied to the mainstem channel. Strahler (1964) gave possible values of 0 and 0.6, which shows rotundity and low integration within a basin. Values of 0.6 and 1.0 assume pear-shaped characteristics of a well-integrated drainage basin. Values close to 1.0 are typical of regions of low relief whereas values between the range of 0.6 and 0.8 are generally associated with steep ground slopes. The value of the elongation ratio for Warri River drainage basin was 0.2 indicating a low integrated drainage basin which will develop more tributaries.

4.1.1 Implications of the findings

With the low drainage density, the volume of water flow into the basin will be low, which implies that the Warri River would not be able to support all year round navigation most especially during the dry season. This is further supported by the basin's elongation ratio which is 0.2, an indication of low integration of the drainage basin. The implication of which is the development of more tributaries, which will deviate the course of the river. By this deviation, the river as a means of transportation will be misleading, as there will be several stream channels leading to different parts. Seafarers who are not used to the course of the river may miss their way.

With the first order stream contributing the highest volume of about 57.2%, the volume of water received from the discharge of the first order segments is also too low to support an all year round navigation of the Warri river.

However, the volume of water discharge and the tendency of the basin to develop more tributaries is an indication of abundance of swampy flood plains which are good for the cultivation of swamp rice, sugar cane and vegetables besides fishing activity.

4.2. Hydrological Analysis of A Drainage Basin

Onosemuode *et al.* (2010) in another study of the morphometric analysis of Onitsha North East drainage basin focused on the relationship between morphometric characteristics such as stream order (Nu), stream length (Lu), bifurcation ratio forming the linear properties and drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc) form factor ratio (Rf) comprising the area properties of the drainage basin. The result of the analysis (Tables 6 and 7) showed that a total number of 396 streams were identified of which 289 are 1st order streams, 82 are 2nd order, 19 are 3rd order, 5 in 4th order and one is indicating 5th order streams. Drainage patterns of stream network from the basin have been observed as mainly dendritic type which indicates the homogeneity in texture and lack of structural control. The mean bifurcation ratio value of 4.16 (low bifurcation ratio) was obtained from the study area and was within the standard range and shows that the basin conforms to the characteristics of a natural stream which indicates that the geological structures are less disturbing to the drainage pattern. The drainage density (D) of the study area was 1.0 km/sq. km. This value indicates that for every square kilometer of the basin, there is 1.0 kilometer of stream channel. This makes the study area fall into the group of low density basins suggesting that the low drainage density indicates that the basin has a highly permeable subsoil and thick vegetative cover. The elongation ratio (Re) value of the study area was 0.78, the basin in the study area assumes a pear shaped characteristics indicating high degree of integration. The circularity ratio of the study area is 0.01 which indicated that the basin was oval tending towards elongation in shape with high level of integration. The form factor value of the basin is 0.51 indicating lower value of form factor and the basin will

have a flatter peak of flow for longer duration. The texture ratio of the basin was 2.29 and categorized as moderate

Table 6: Linear Characteristics of the Drainage Network of Onitsha East Drainage Basin

Stream Order (U)	Stream Number (Nu)	Stream Length in Km (Lu)	Stream Mean Length in Km (Lu)	Cumulative Stream Length in Km (Lu)	Log Nu	Log Lu
1	289	356.78	1.24	1.24	2.461	2.552
2	82	178.53	2.18	3.42	1.914	2.252
3	19	97.45	5.13	8.55	1.279	1.989
4	5	33.23	6.65	15.2	0.699	1.522
5	1	24.03	24.03	39.23	3.111	1.381
	396	690.02				
Bifurcation Ratio						
1 st order/2 nd order	2 nd order/3 rd order	3 rd order/4 th order	4 th order/5 th order	Mean Bifurcation Ratio		
3.52	4.32	3.80	5.00	4.16		

Source: Onosemuode et al.(2010).

Table 7: Areal Characteristics of Onitsha East Drainage Basin

Morphometric Parameters	Symbols/Formula	Result
Area (sq km)	A	691.35
Perimeter (km)	P	126.30
Drainage density (km/sq km)	$D = \sum L_u / A$	1.0
Stream frequency	$FS = \sum N_u / A$	0.57
Texture ratio	$T = \sum N_u / P$	2.29
Basin length (km)	L_b	36.95
Elongation ratio	$Re = \frac{2\sqrt{A}}{L_b}$	0.78
Circularity ratio	$Rc = \frac{4\pi A}{P^2}$	0.01
Form factor ratio	$R_f = A / L_b^2$	0.51
Where		
$\sum L_u$ = Total stream length of all orders		
$\sum N_u$ = Total number of all orders		
$\sum N_1$ = Total number of 1 st order streams		

Source: Onosemuode et al.(2010).

Onosemuode *et al.* (2010) concluded that the high level of integration of the basin as revealed by the circularity ratio will lead to the steady flow of water which will eventually reduce the rate of flooding.

The low drainage density recorded in the study area is an assertion that the subsoil is highly permeable. This further help to show the reduced rate at which the environment of the study area will be prone to flooding. The moderate texture ratio of the soil in the study area makes it less prone to erosion which has great advantage for farming activities in the area.

Furthermore, the low bifurcation ratio recorded implies that the drainage pattern is not controlled by the geologic structure of the study area giving room for permeable rate of water. The oval basin tending towards elongation with low form factor indicates that the basin will have a flatter peak of flow for longer duration which is easier to manage than of the circular basin.

4.3 Geospatial Assessment of Vulnerable Areas to Flood Hazard and Risk

Onosemuode and Ovririe (2014) in their study of geospatial assessment of vulnerable areas to flood hazard and risk along the Ikpoba River in Benin, Edo State were able, among other objectives produce a vulnerability map to know buildings that are located within the flood risk zones in lines with stipulated setback and other determinant criteria.

4.3.1 Criteria for the analyses that were carried out

The study was divided into three zones using buffer distance as the flood zoning parameter. The river was buffered at 30m to show buildings which falls into high flood vulnerability rate in line with

Town and Country Planning (building plan) Regulation, 1986. The river was buffer at 50m and 70m to indicate those building that are within moderate and low vulnerability rate based on the extent flooding had been experienced in the past. Those building that are < 30m in distance from the river are considered as having high vulnerability rate, while buildings > 30 but < 50m in distance from the river are considered to be moderate in terms of vulnerability and buildings that are > 50m but < 70m in distance from the river are of low vulnerability. A total of 2071 buildings were used in the study as obtained from satellite imagery (Fig. 22).

ANALYSIS 1: BUFFER GENERATION

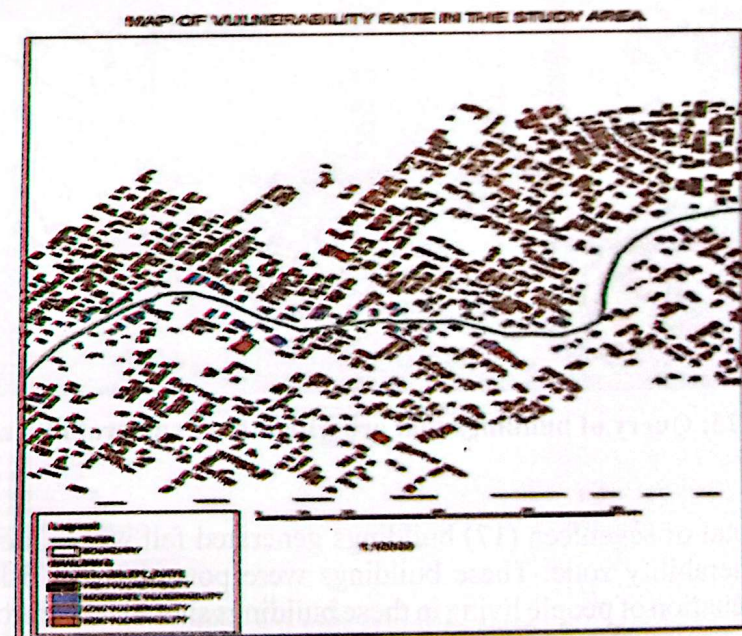


Fig. 22: Vulnerability assessment map of the study area

4.3.2 Determination of buildings that are vulnerable

a. Buildings that are within high vulnerability zone

In the determination of buildings of high vulnerability rate, a single criterion query was used as shown in the syntax below;

SYNTAX[VULNERABILITY_RATE = 1]

The above syntax enables us to assess buildings that are of high vulnerable rate.



Fig.23: Query of buildings that are within high vulnerability zone

A total of seventeen (17) buildings generated fell within the high vulnerability zone. These buildings were potentially at risk and evacuation of people living in these buildings should be enforced so that lives and properties that are risk can be reduced. Figure 23 showed the query result of the buildings that were at high vulnerability rate while Fig. 24 showed the map of the buildings that

were within high vulnerable zone. The buildings in black colour activated in green are the affected ones as shown in Fig.24.

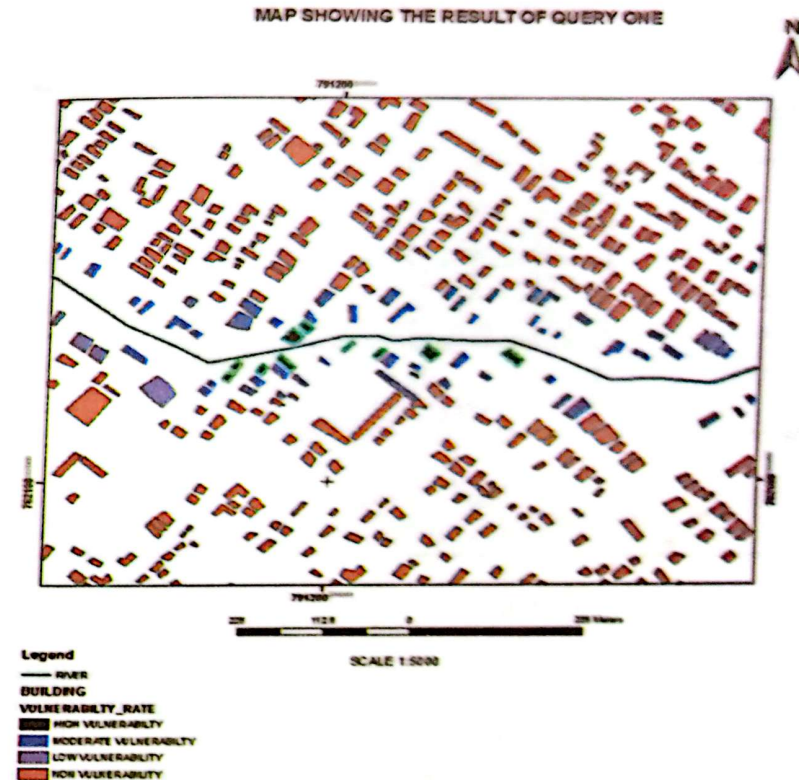


Fig.24: Building within high vulnerability zone.

B. Buildings that are within low vulnerability zone

The buildings with low vulnerability rate were determined using the following syntax:

SYNTAX [BUILDING THAT ARE WITHIN 70m BUFFER DISTANCE]



Fig. 25: Result for buildings within 70m buffer zone

Figure 25 shows the result of the query of those buildings that are of low vulnerability rate. Ninety-six (96) of the buildings are within the low vulnerability zone. These buildings are not potentially at risk but caution needs to be taken as the prediction of the rainfall cannot be fully relied upon. Besides, the extent to which the course of the river is cleared of debris, water weed and refuse that can lead to flooding was not ascertained in the course of this study. Figure 26 is the map of the buildings within low vulnerable zone.

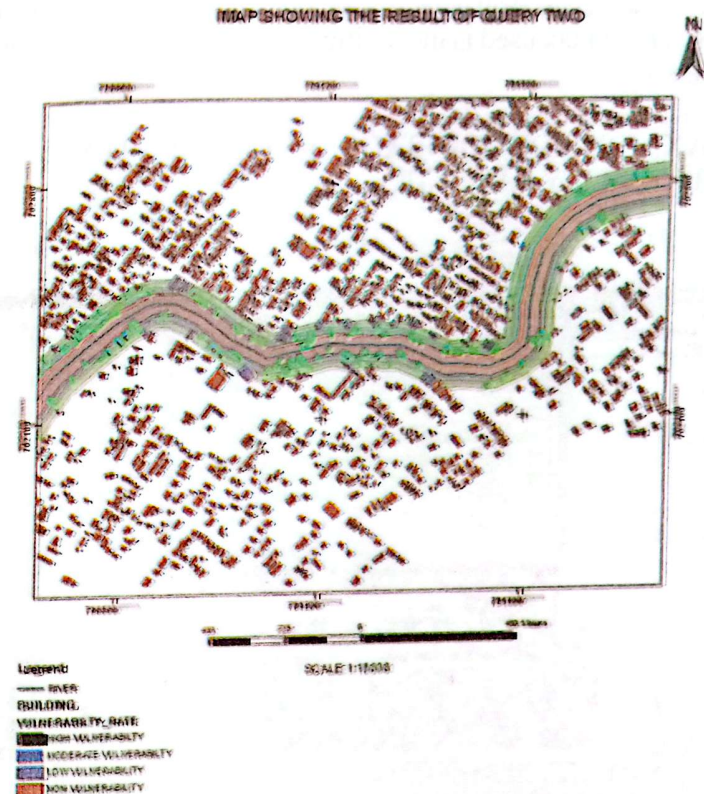


Fig.26: Buildings within 70m buffer distance (Low vulnerability zone)

4.3.3 Determination of the building type that is vulnerable

The query syntax was narrowed down to specify type of building, functionality in terms of usage of the building which could be commercial, residential, industrial etc. This will help in times of rescue operation during flood by providing information on the

affected building based on what is expected to be rescued from such building. The syntax used is the multiple criteria query operation is stated below:

SYNTAX [BUILDING USAGE = RESIDENTIAL AND VULNERABILITY RATE < 4]

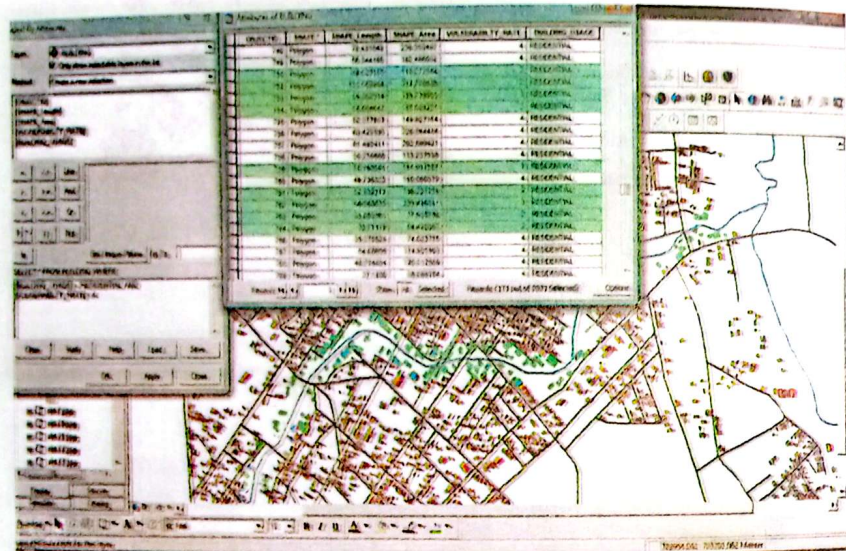


Fig.27: Query for buildings that are residential within vulnerability zones

Figure 27 shows that the result of the query of residential buildings that are within vulnerable zones were eighty-eight (88) while Fig. 28 shows the map of the residential buildings that are within the vulnerable zones.

MAP SHOWING THE RESULT OF MULTIPLE CRITERIA QUERY



Fig.28: Residential buildings within vulnerable zones

4.3.4 Classification of vulnerable buildings

In the classification of vulnerable buildings, the “classify” in ArcGIS spatial analysis function was used to classify the buildings in the study area into four zones. This was done to enable at a glance assessment of the buildings that are of high, moderate, low

vulnerability and those that are not vulnerable to flooding as shown in Table 8.

Table 8: Classification of buildings according to vulnerability rate.

Building	Number of buildings within each category	Vulnerability rate
Categories 1	17	High
Categories 2	73	Moderate
Categories 3	96	Low
Categories 4	1885	Non

Source: Onosemuode and Ovirie (2014)

Buildings that are of high vulnerability rate are 17, buildings that are of moderate vulnerability are 73, those that are of low vulnerability and non-vulnerable are 96 and 188,5 respectively.

Onosemuode (2015), assessed the spatio dynamics of surface water characteristics of some rivers in Delta State and found out that most rivers which serves as source of drinking water to most people living in communities situated along the banks of these rivers are vulnerable to water borne diseases. These diseases were traceable to source of domestic, agricultural, industrial wastes and sewage disposal, storm run-off from urban landscape and other forms of waste that find their way from unidentified sources into the rivers. These various sources of wastes made it difficult for the rivers to maintain high level of hygienic water through self-purification. The need for the provision of portable water supply for communities along affected rivers formed the highlights of the recommendation of the study.

5.0 Geospatial Perspective of Environmental Development and Monitoring

Environmental development is the outcome of investment in infrastructure, scenic surroundings, green areas, and public spaces. For this to be sustainable, there has to be monitoring designed to help us understand the natural and man-made environment and protect it from any negative outcomes of human activity. This section presents the studies of development and monitoring of infrastructure, landscape and environmental sensitivity index map for oil spill clean up

5.1 Infrastructural Planning and Monitoring

Onosemuode and Abidogun (2014), in their study of the use of Geoinformatics for the planning and monitoring of maintenance of infrastructural facilities are of the view that an organization (institution) can only survive if there are enough and well maintained infrastructural facilities. When these facilities are available, lack of maintenance culture may affect the life span hence, the need for provision of new ones, and fund for which may not be readily available. How can this maintenance be planned for and monitored? In order to answer this question or any other related ones prompted this study. The infrastructural emphasis in this study includes buildings, roads network, and electric poles. The composite map of the study area is shown in Fig. 29.

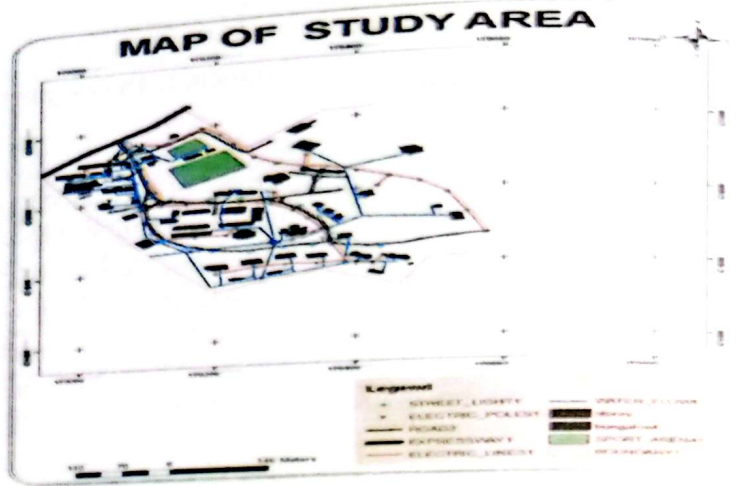


Fig.29: Composite map of Study Area.

5.1.1 Determination of Buildings that needed Minor Repairs

In the determination of buildings that needed minor repairs, the Single Criterion Query was used adopting the following syntax:

From the Menu bar of ArcMap of ArcGIS 9.3 click on “Selection”
From the drop down menu, click on “Select by Attribute”
Using the query operations the attributes to query was selected as follows:

SELECT*FROM BUILDING

WHERE [Maint_stat]="Minor Repair"

Click on **Apply** and **Ok** to generate the output in Figure 30

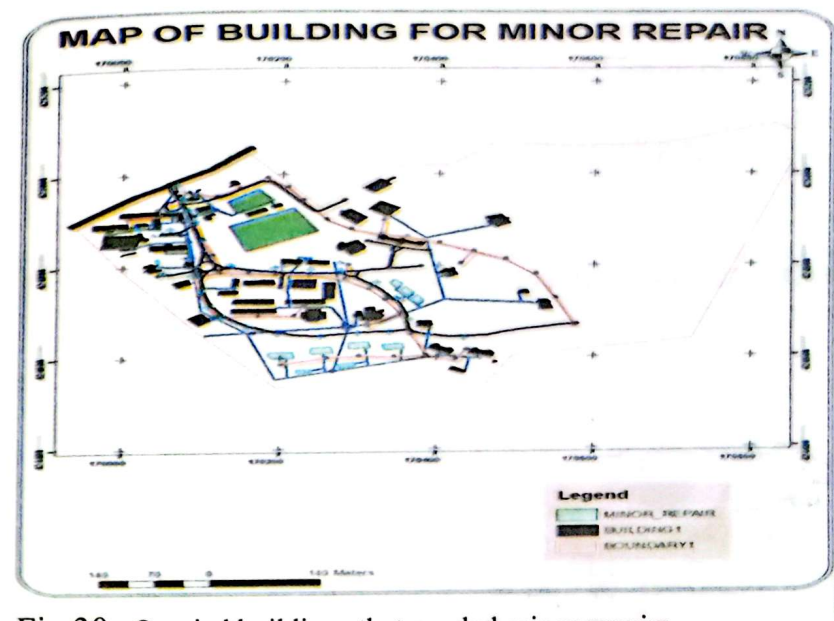


Fig.30: Queried buildings that needed minor repairs

Figure 30 above shows buildings needing minor repairs highlighted. Mostly affected are the staff quarters. It has been a long time repair work was done on any of the quarters; this may be due to Government Policy on Monetization. From the result of the query, sixteen (16) buildings needed minor repairs.

5.1.2 Determination of Roads that Needed Drainages

In the determination of roads that needed drainages, the Single Criterion Query was used adopting the following syntax:

From the Menu bar click on “Selection”

From the drop down menu, click on “Select by Attribute”

Using the query operations select the attributes you want to query as follows:

**SELECT*FROM ROAD
WHERE [DRAIN_STAT]="NEED REPAIR"**
The outcome of the output generated is shown in Fig. 31.

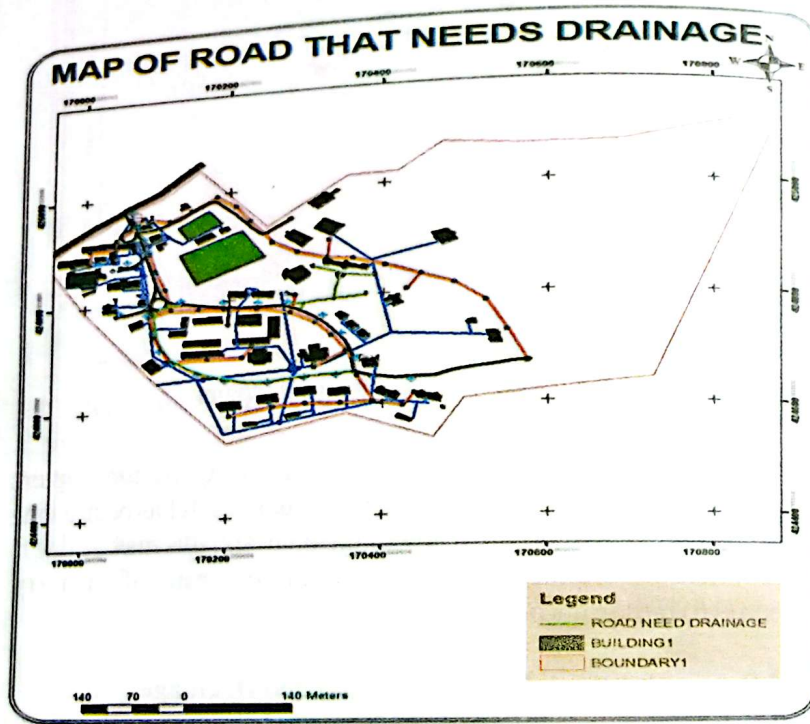


Fig.31: Queried Road Drainages needing Repair.

From Fig. 31 above, the roads from student union building passing through the staff quarters and that leading to the office complex ("Abuja") need drainage. This is important as the roads are being eroded due to the effect of erosion when rain falls.

5.1.3 Determination of Pipelines that Need Repairs

In the determination of pipelines that need repairs, the Single Criterion Query was used adopting the following syntax:

From the Menu bar click on "Selection"

From the drop down menu, click on "Select by Attribute"

Using the query operations select the attributes you want to query as follows

SELECT*WATER_FLOW

WHERE [Maint_stat]="Fair"

The outcome of the output generated is shown in Figure 32.

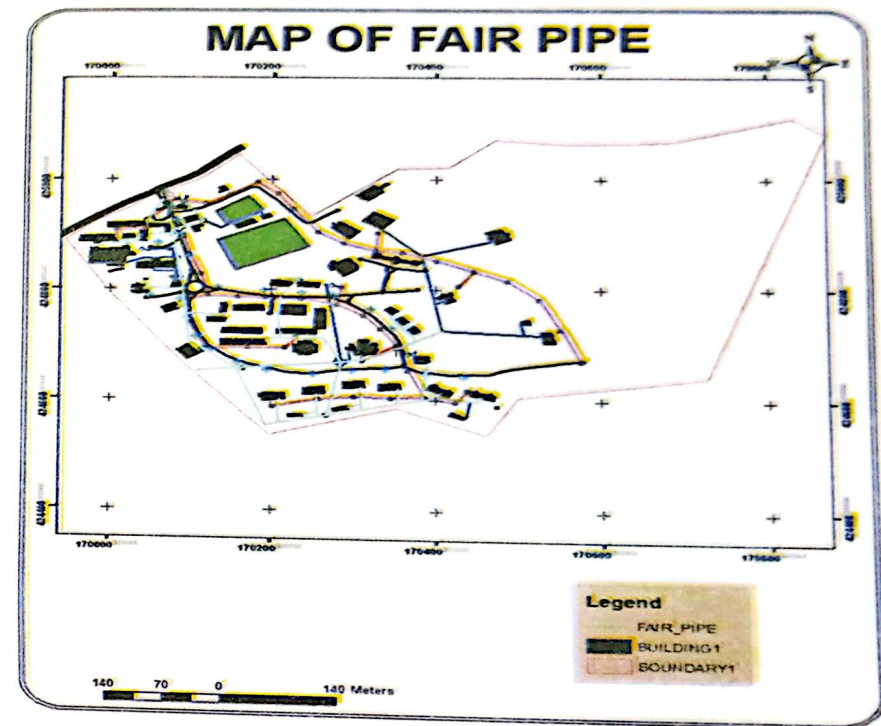


Fig.32: Query Result of Pipelines that are Fair/needing repair.

More than half of the pipelines were aged and needed to be repaired; some are even due for total replacement (Fig. 32). The only exceptions are the ones laid in the last 10 years, connecting new buildings to the mains. Some of the pipelines are as old as the school itself, which celebrated its Centenary in 2009.

5.1.4 Determination of Electric Poles that Needed Maintenance

In the determination of electric poles that needed maintenance, the Single Criterion Query was used adopting the following syntax:

From the Menu bar click on "Selection"

From the drop down menu, click on "Select by Attribute"

Using the query operations select the attributes you want to query as follows

```
SELECT * FROM ELECTRIC_POLES
```

```
WHERE [Maint_st]=FAIR.
```

The outcome of the output generated is shown in Fig. 33.

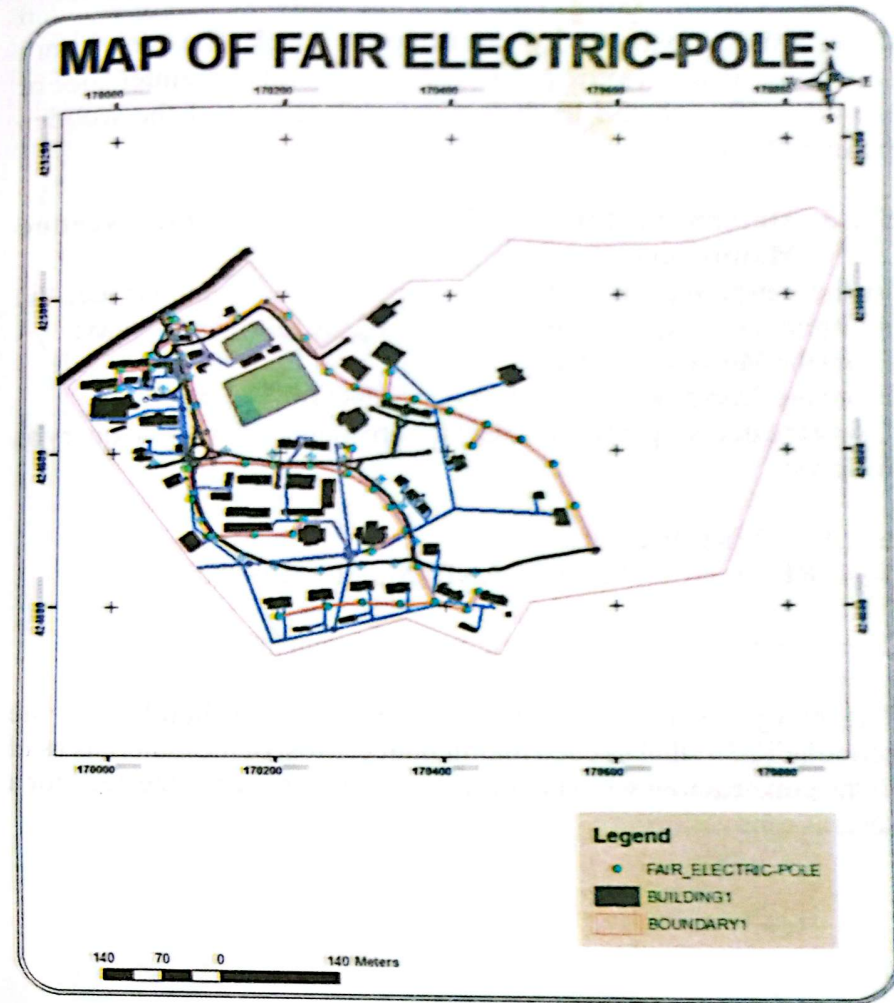


Fig.33: Query result of electric poles that needed maintenance.

All the 53 electric poles (Fig. 33) in the study area were wooden poles. This has made them prone to termite attack. The query result shows that all the electric poles needed one form of maintenance or the other. This should be in form of replacement of the wooden poles with concrete poles.

5.1.5 Determination of Building Type That Needed Maintenance

In the determination of building type needing maintenance, the multiple criteria query was used adopting the following syntax:

From the Menu bar click on **"Selection"**

From the drop down menu, click on **"Select by Attribute"**

Using the query operations select the attributes you want to query as follows:

```
SELECT * FROM BUILDING  
WHERE [B_type]="Storey" AND [Maint_stat]="Fair"
```

The outcome of the output generated is shown in Fig. 34.

The query result is one of the oldest and only building in the school (Fig. 34) that needed maintenance. Most of the materials used in the construction were no longer in use again, hence the need for a serious renovation.

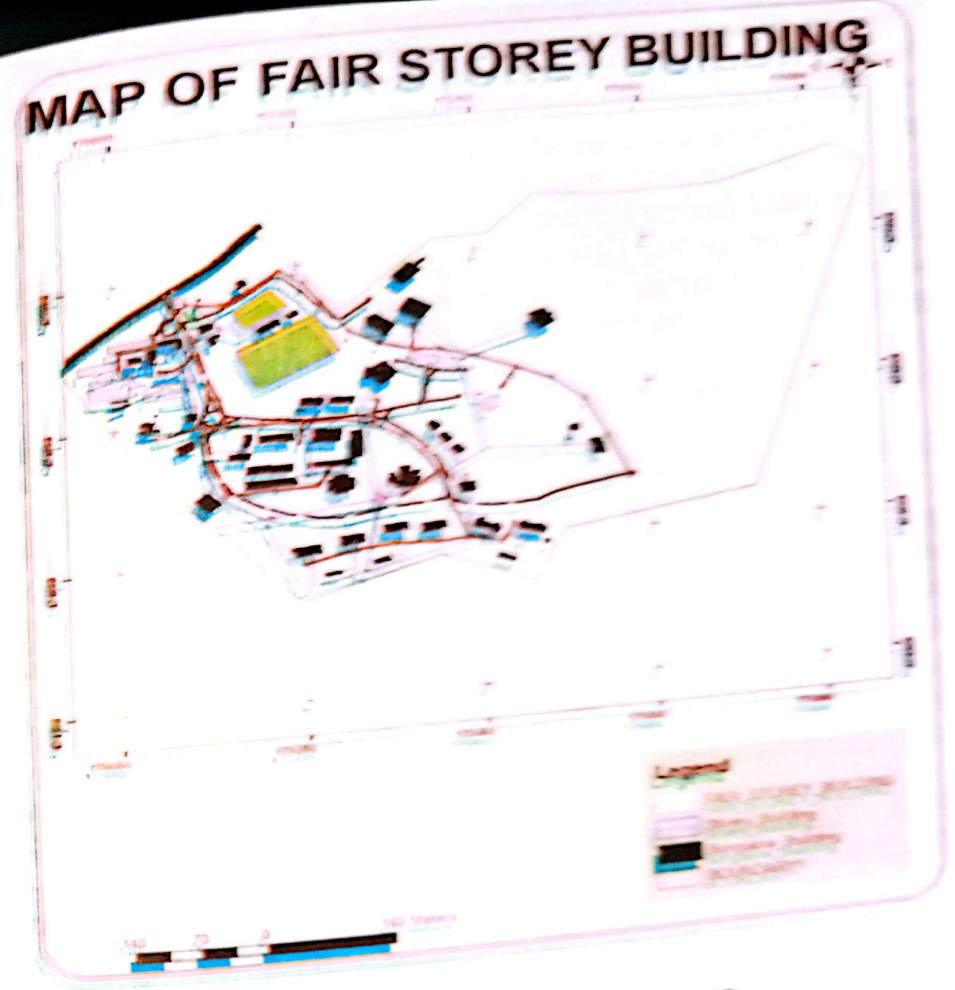


Fig. 34: Query of buildings that needed maintenance.

5.1.6 Conclusion

Onosemuode and Abidogun (2014) concluded that when digital database for all entities and their attributes have been created, spatial information can be retrieved at any point in time for the purpose of planning and monitoring the maintenance of infrastructural facilities. Having the inventory of the facilities and how they are spatially related is very relevant and are good information for taking decision on the issue of maintenance as demonstrated from the results of the study.

5.2 Geospatial Perspective of Developmental Control

Onosemuode *et al.* (2015), in a study of the use of geoinformatics in landscape development control, focused on the adherence of inhabitants of the studied area to set-back and land use of the existing buildings based on the development control guidelines and standards. The analytical capabilities of ArcGIS 9.3 were explored by using it to process the attribute data and the spatial data. The results obtained from queries, buffering, and overlay analysis performed demonstrated the effectiveness of the application of GIS in development control.

5.2.1 The Existing Features in the Study Area

Temidire estate is a residential estate located in Ogbomosho North Local Government Area along Ikoyi road, Oyo State. It covers an area of about 800m by 550m, the estate currently housed about 61 buildings. The Fig.35 below shows the details of the estate.

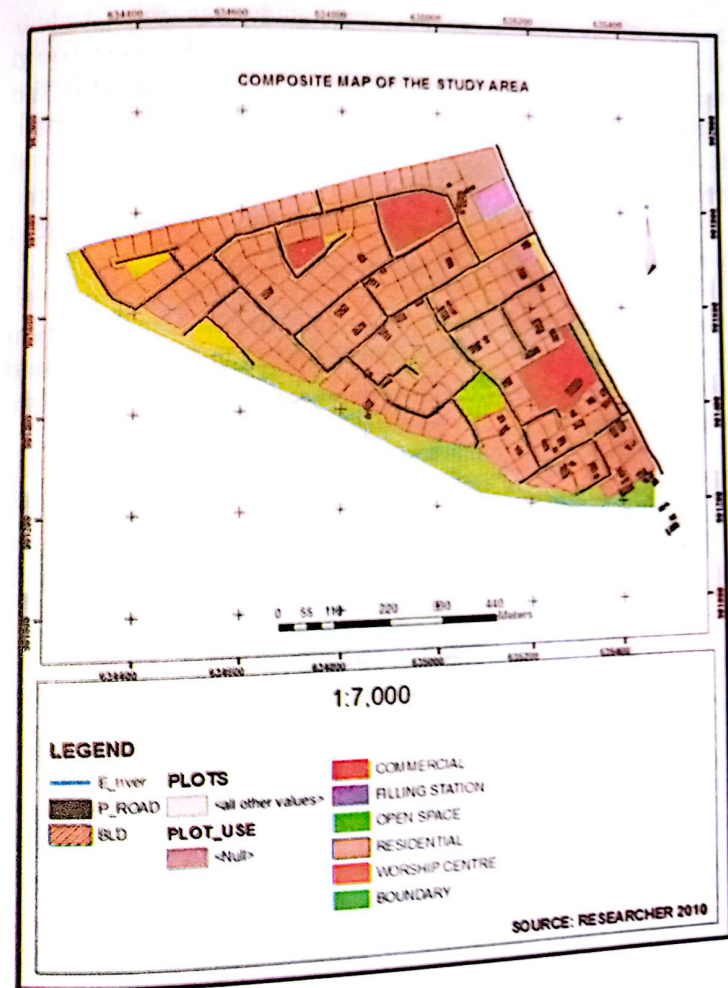


Fig.35: Existing features in the study area

The map of the existing features in the study area gives a clear picture of how every informal settlement looks like. One could observe from Fig.35 above that not all the buildings found in the existing situation of the study area were served with access road. This could be as a result of the non-implementation of the layout plan developed for this estate by Local Planning Authority or the non-compliance of the inhabitants of the study area to the said layout plan.

Also, another defect that one could observe in this existing situation is the way and manner roads were created. In neighbourhood designs, "Y" junctions are always prohibited and town planners are always encouraged to do away with them.

5.2.2 Determination of 6 Meter Setback From Roads

The 6 meter setback as required by the Town Planning Rules and Regulations for buildings built along roads was adopted to ascertain buildings that contravene this set criterion.



Fig. 36 Queried buildings at 6m setback from roads

Carrying out querying operation in the existing road would enable on discovery of the buildings of the study area that do not meet the setback rule of 6 meters. The result of the query operation carried out in Fig. 36 above revealed that 12 buildings contravened the setback rule. The implication of this is that some parts of these

buildings would have to give way for right of way during roads construction.

5.2.3 Determination of 20 Meter Setback From River Bank

The 20 meter setback as required by the Town Planning Rules and Regulations for buildings built along river bank was adopted to ascertain buildings that contravene this set criterion.

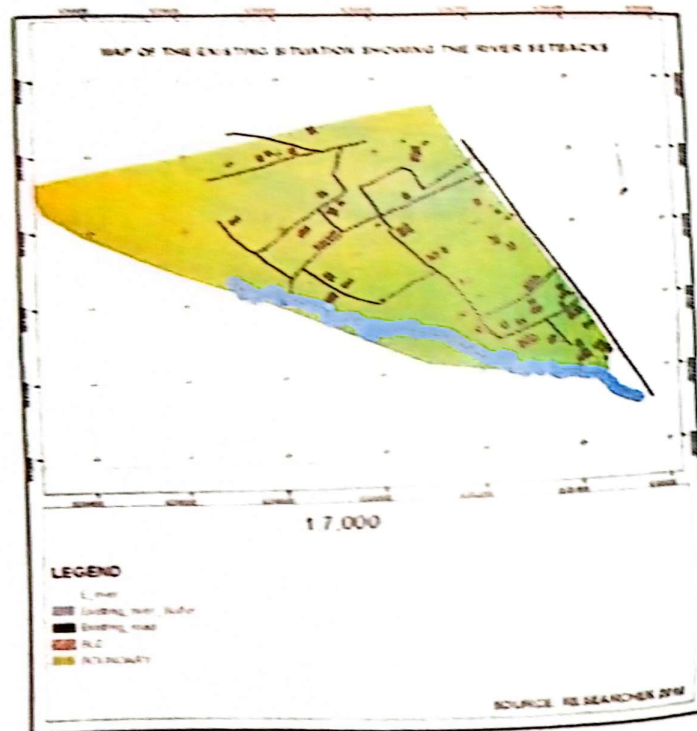


Fig.37:Existing features showing river setback at 20m

Figure 37 above shows that buffering operation was carried out on the river to provide the setbacks of 20meters to the river's edge and the result revealed that one building was affected which means that the affected building will give way to the setback or may likely be affected by flooding from the river.

5.2.4 Detecting Buildings Contravening Structures Using Overlay and Query Operations

Overlay operation involves bringing different datasets (themes) which are available in the database together for meaningful analysis to be carried out overlay of existing buildings on the layout plan was performed.

The plots (plan) and buildings layers were brought over each other to depict the structures that contravene in terms of the use of plots as designed by the Planning Authority and through the use of intersect and query, the results were generated from the database. Figure 38 shows buildings structures that were built on land meant for circulation while Fig. 6 shows the result of the query to determine the number of contravening buildings structures.

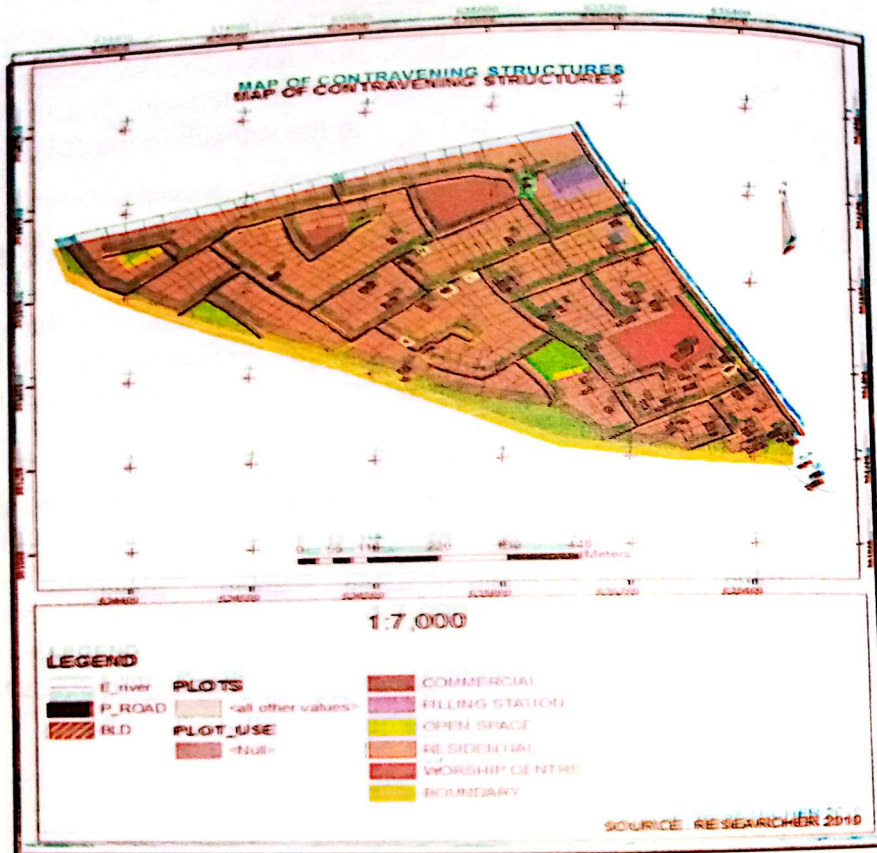


Fig 38: Contravening buildings/structures

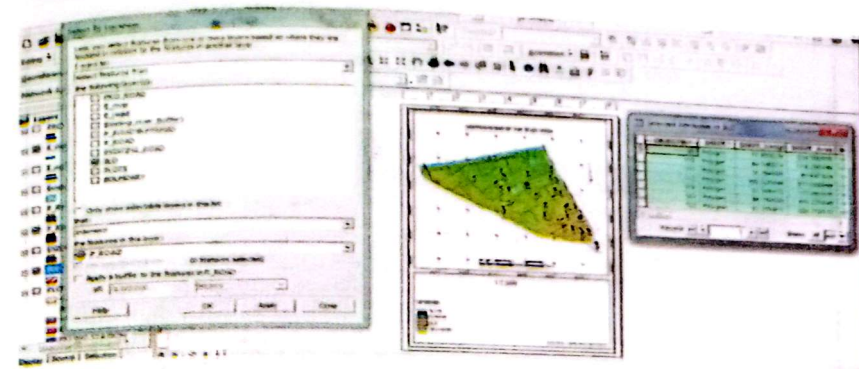


Fig. 39: Query of contravening building/structures

Figure 39, shows the result of the query indicating the number of buildings/structures that were built on the wrong land use. The generated query showed that out of the 61 buildings/structure in the study area, 16 buildings/structures were built on land meant for circulation, this amounts to about 9.8% of the whole buildings/structures in the study area. The implication of the result is that the buildings that were found located on the land meant for circulation use will give way for road as time goes on.

5.2.5 Determining Adherence of Building to 6 Meter Road Set Back Using Buffering and Overlay Operations

Buffering is an act of creating zones of influence at specified distance around features in such a way that the features will be contained in a frame or window.

With the aid of buffering analysis, a buffer of 6 meters was created for the roads within the layout. On the buffered roads, the building map layer was overlaid to depict the buildings that contravened the road setback standards.

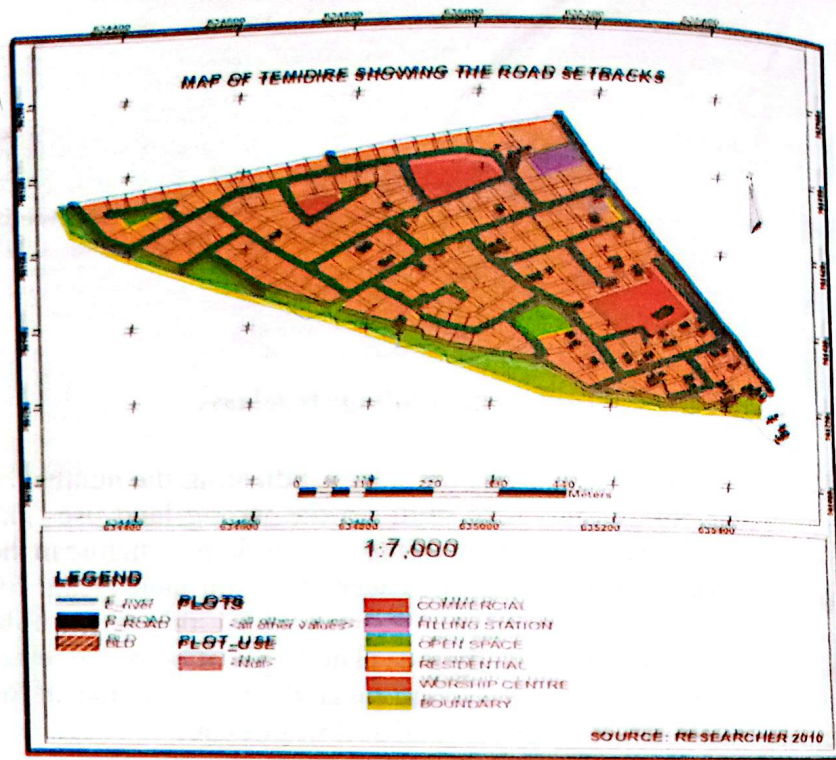


Fig. 40: Setback of 6m from roads

From Fig. 40, buffering operation was performed using 6 meters to create buffer zones on both sides of the road. It was discovered that 16 buildings did not observe the road setbacks rule and this may be due to the fact that the monitoring of development was not carried out as at the time of building neither was building plan approval done for such buildings.

5.2.6 Determining Buildings with Adequate Clearance (Air Space)

Buffering operation was carried out to determine the building/structures that observed the 3-meters airspace rule. This was done in such a way that 3 meters zone of influence was created around the buildings. This makes the buildings buffered to overlap each other and after this operation, a spatial search was carried out to determine buildings that were within the plots after being buffered.

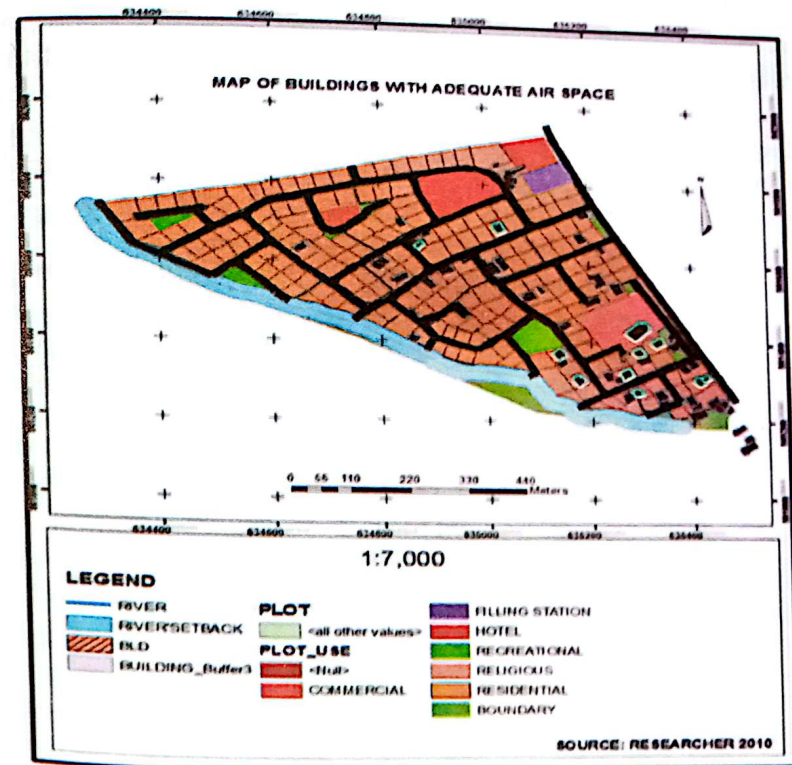


Fig. 41: Buildings with adequate airspace

Figure 41 above showed buildings that would survive the aftermath of development control in Temidire Estate. The buffer operation shows that eleven (11) buildings observed the 3 meters clearance airspace (Fig. 41). This implies that only the selected buildings in Fig. 41 above would survive the test of development control using adequate clearance airspace.

5.2.7 Detecting Plots Affected by the 20 Meter Rivers' Setback Using Query

Query involves the logical statements or commands issued in order to retrieve certain vital information either in graphical or non-graphical formats to serve the purpose of the user. In view of this, information about plots affected by the rivers' set back, the changes in the designed use of land and the present use of land in the study area would be retrieved using query. In detecting plots affected by the 20m rivers' setback, the following steps were adopted:

- From the Menu bar click on “Selection”,
- From the drop down menu, click on “Select by Location”,
- Click on select features from “plots”,
- Then choose condition that **intersect rivers' setback**, click **apply** and **ok**.

The query operation helps in bringing out the plots that were affected by the setback to the river. In the Fig. 42 below, the details of the affected plots were brought forth.

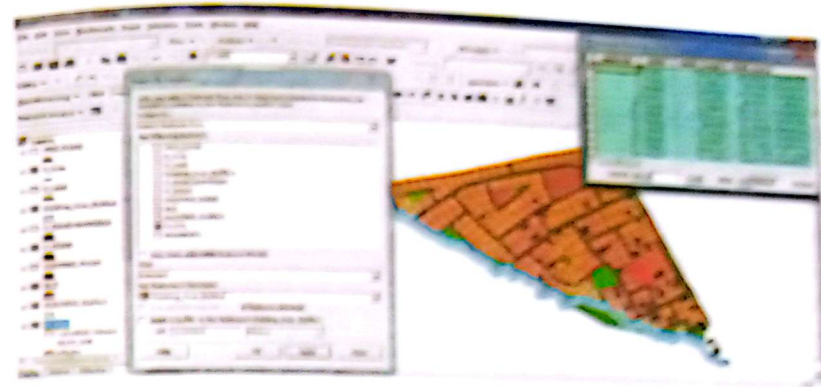


Fig.42: Plots affected by 20m river setback

From Fig. 42, eleven (11) plots were selected as been affected by the setback to the river at 20m and the implication of this is that those plots selected are not to be considered for residential purpose.

5.2.8 Conclusion

Onosemuode *et al*, (2015) concluded that the contributions and importance of GIS in landscape development control cannot be overemphasized. Given its spatial and analytical functions of building databases, update and retrieval of the same is a worthwhile development.

The demonstration of this is shown in this study, where spatial database was created with the object to carry out spatial analysis and spatial search aimed at checking contravention to Development Control Regulations. This is to serve as an instrument of spatial decision support System (Onosemuode and Dare, 2010) to the relevant bodies.

5.3 Environmental Sensitivity Index Mapping For Oil Spill Clean up

Onosemuode *et al.* (2019) in a recent study carried out an environmental sensitivity index (ESI) mapping of the Petroleum Product Marketing Company (PPMC) pipeline along Ugbomro community, Delta State. The study is to provide information on the coastal and inland resources that would be at risk at the event of an oil spill. To this end, the study attempts to establish the inland habitats and their sensitivity to oil spill along the 4.95km of the PPMC pipeline passing through Ugbomro community and as it relates to its environs.

5.3.1 Buffer Zones of the Land use/cover along PPMC Pipeline Corridor

The inland habitat classes were identified and represented in the land cover/use feature within the established buffer of 75m, 250m and 500m according to local and international standards (Fig. 43).

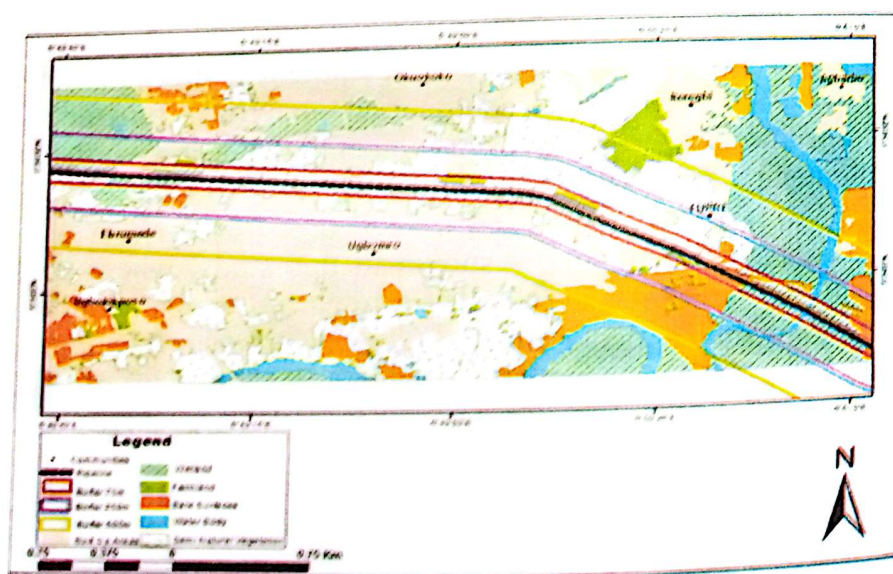


Fig.43: Buffer zone standards along PPMC pipeline corridor

Using the established buffer standards to determine the buffer zones (Fig.43), Table 9 shows that bare surfaces occupy 6.56%, 6.83% and 8.32% of the land area, respectively, built up areas occupy 11.36%, 26.68% and 35.08%, respectively, farmlands is apportioned 2.42%, 1.73% and 1.67% respectively, semi natural vegetation has 53.81%, 39.68% and 29.57%, respectively. Water body within the specified buffer zones occupied 0.58%, 0.68% and 1.13%, respectively and wetland has 25.26%, 24.48% and 24.22%, respectively. The habitat that would be of most concern within the 75m buffer is the built up area with the presence of socio-economic and cultural activities that have direct relationship with the people and the impact increases for buffer zones of 250m and 500m, while this is closely followed by farmland that have direct impact on the people of the study area but with a decreasing impact as the buffer zone increases.

Table 9 Statistics of the Land Use/Cover for the Different Buffer Standards

Buffer Standards	Local Buffer (75m)		International Buffer (250m)		International Buffer (500m)	
	Area (ha)	100%	Area (ha)	100%	Area (ha)	100%
Bare Surfaces	4.87	6.56	16.64	6.83	39.41	8.32
Built up Areas	8.44	11.36	64.96	26.68	166.1	35.08
Farmland	1.8	2.42	4.02	1.73	7.93	1.67
Semi Natural Vegetation	39.97	53.81	96.6	39.68	140.04	29.57
Water Body	0.43	0.58	1.66	0.68	5.35	1.13
Wetland	18.76	25.26	59.59	24.48	114.68	24.22
TOTAL	74.28	100	243.46	100	473.52	100

Source: Onosemuode *et al.* (2019).

5.3.2 Sensitivity Index Ranking and Classifications of the Landuse/Cover

The environmental sensitivity index (ESI) map of the study area is shown in Fig.44, while Table 10 shows the landuse/cover sensitivity ranking and classification with built up area, water body and wetland having ESI ranking very high and having ESI classification of 5A, 5B and 5C respectively. Farmland ESI ranks high with ESI classification of 4, semi natural vegetation has ESI ranking of medium with ESI classification of 2 and bare surfaces had ESI ranking to be Low and ESI classified as 1 (Table 10). The details of each landuse/cover are discussed in subsections below.



Fig.44: Environmental Sensitivity Index Map of the Study Area

Table 10: Landuse/Cover Sensitivity Ranking and Classification

Landuse/cover Classes	Environmental Sensitivity Index(ESI) Rank	ESI Class
Built Up Area	VH	5A
Water Body	VH	5B
Wetland	VH	5C
Farmland	H	4D
Semi Natural Vegetation	M	2E
Bare Surfaces	L	1F

Source: Onosemuode et al. (2019).

5.3.2.1 Built-Up Areas ESI Classification and Ranking for the Buffer Zones

The built-up area within the study area generally comprise of pockets of communities and other settlements within Uvwie Local Government Area. The Built up area has environmental sensitivity index classification of 5A and ranks very high (VH) for ESI (Table 9 and Fig. 45). The very high SI is as a result of the presence of the socio-economic and socio-cultural activities due to the presence of the Federal University of Petroleum Resources that is centred in the study area. When built up areas are impacted by oil it poses direct or indirect impact on the people, the flora and fauna. Oily sheens are formed on the soil surface and the oil can stick to the walls of built up structures if the spill is heavy. Oil may come in contact with domestic material such as paper, broom and domestic waste generating oily waste which must be properly managed to minimize pollution. When pipeline cuts across the communities they are at risk of accident that may lead to fire disaster and destroy lives,

properties and means of livelihood. This very high SI ranking would therefore call for urgent attention and priority response in times of oil spill incident.

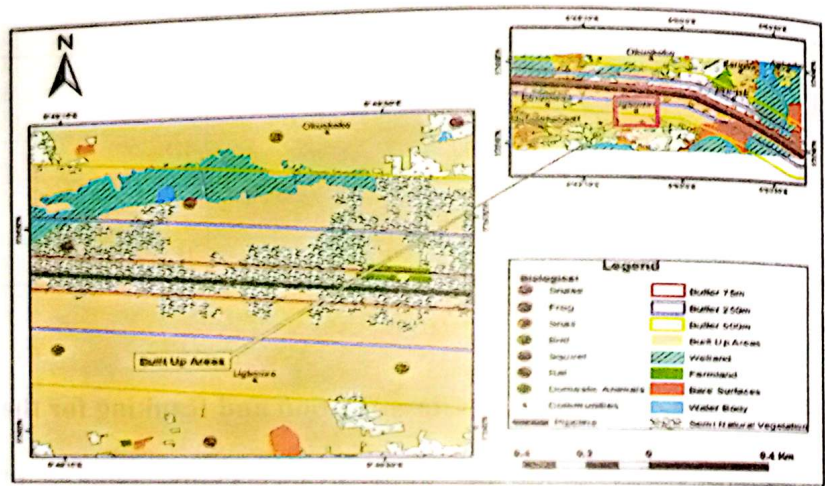


Fig.45: Built-Up Area along the Pipeline Corridor

5.3.2.2 Water Body ESI Classification and Ranking for the Buffer Zones

The environmental sensitivity index classification of water body is 5B ranking very high (VH) next to built-up area (Table 10 and Fig.46); this is because marine environment is very sensitive to oil. Marine spill maybe difficult to contain, recover and remediate. It contains flora and fauna that include aquatic plants, fishes, water birds (either breeding or migratory ones), and reptiles. Other varieties of species are water snail, frog, toad and water hyacinth. Oil tends to float and spreads on water because it is lighter. Depending on the nature of the oil spill and type of water body it is

spilled on; when the spilled oil is acted upon by factors such as specific gravity, wind action and direction it may result in processes such as dispersion, weathering, evaporation, oxidation, biodegradation and emulsification.

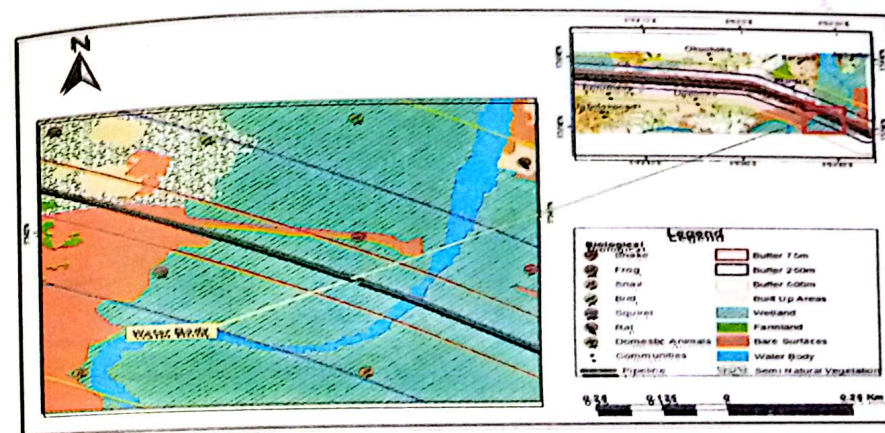


Fig. 46: Water body along the Pipeline Corridor

5.3.2.3 Wetland ESI Classification and Ranking for the Buffer Zones

Wetland in this study has environmental sensitivity index class of 5C and ranks very high (VH) next to water body (Table 10 and Fig.47). The wetland is generally characterized by swampy and marsh/grass surfaces. Also comprise of biological lives such as crustacean, fishes, snapping shrimp, water snail, mudskipper and reptiles. Birds can be found here seasonally as they migrate for breeding and mating purpose supporting other habitat around them. Oil spilled in this habitat usually persists for long as underlying wet soil below marsh and grasses restrict oil from flowing; leading to percolation of oil and seepage into the subsoil. As a result hydrocarbons are deposited in the ground water aquifer. Grass

covered with oil get sticky and soggy leaving residue over the surface when spillage is heavy.

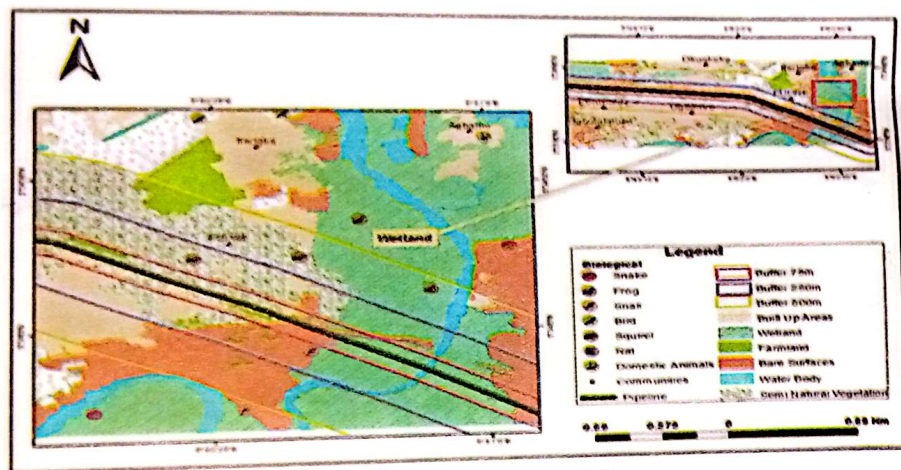


Fig. 47: Wetland along the Pipeline Corridor

5.3.2.4 Farmland ESI Classification and Ranking for the Buffer Zones

Farmland has ESI classification of 4D with high as ranking of its ESI (Table 10 and Fig.48). Farmland as used in this study describes area where agricultural activities are carried out for subsistence purposes. The biological lives found here are different flora species and fauna like snakes, ground squirrel, monitor lizard, and agama lizard. When farmland is polluted by oil the flora and fauna are affected as well as the ground water as oil seeps through soil. Plants may bioaccumulate residue of hydrocarbon in the soil; if they are ingested by human or animal it can have adverse health implications.

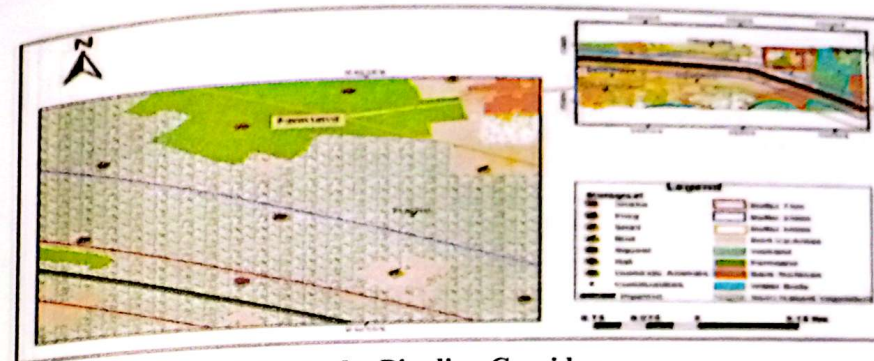


Fig.48: Farmland along the Pipeline Corridor

5.3.2.5 Semi Natural Vegetation ESI Classification and Ranking for the Buffer Zones

The feature semi natural vegetation is found mostly along the pipeline route south of Ugbomro, sparsely distributed between Ebrumede and Ugbolokposo communities and largely in FUPRE. The semi natural vegetation has ESI classification of 2E and is ranked medium (Table 10 and Fig.49). Some flora found here include varieties of shrubs and grass species and faunas like rodents, *Xerus sp* (ground squirrel) and *Rattus sp.* (giant rat). Generally spilled oil travels slowly in this environment. Oil penetrates the topsoil and seep into the ground to infiltrate the soil leaving a slippery surface on the topmost soil layer.

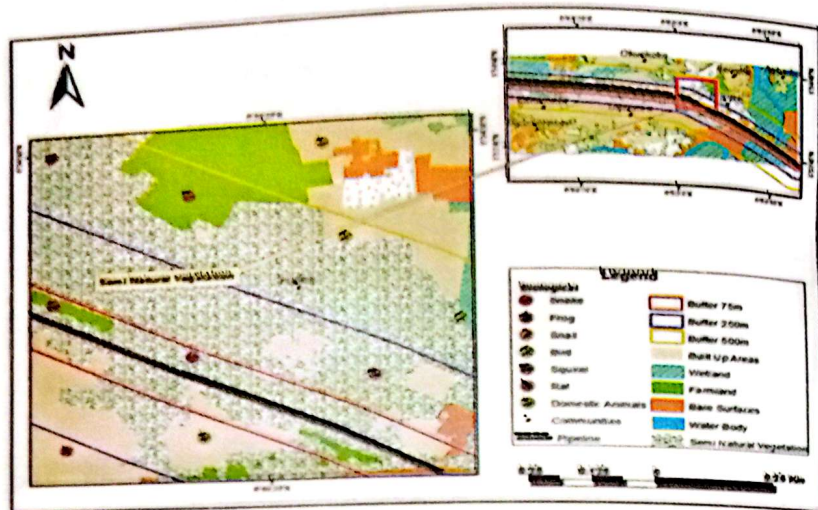


Fig.49: Semi Natural Vegetation along the Pipeline Corridor

5.3.2.6 Bare Surfaces ESI Classification and Ranking for the Buffer Zones

They are found at different section of the habitat. They have been exposed to human activities mostly in bid to reclaim land portions while some sections of it have been impacted by various natural components. Its ESI is ranked low (L) and its ESI classification is 1F (Table 10 and Fig.50). It would suffer the least impact in case of an oil spill. Generally, very few animals exist in this habitat some of them are lizard, cricket, small rodents and some other creeping insects. Oil tends to accumulate on topsoil and slowly seeps into the ground. Oil spill leaves stain on the soil surface as oil seeps into the soil and pollute microbiological species and ground water aquifer.

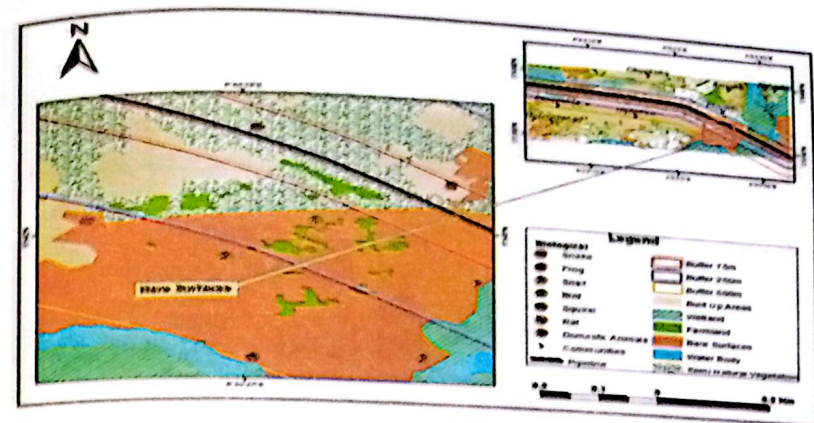


Fig. 50: Bare Surfaces along the Pipeline Corridor

5.3.2.7 Emergency Response Zone (ERZ-1)

Emergency response zones (ERZ) is usually strategically positioned at areas considered to be easily accessible; between area that the inland habitat features are likely to suffer great harm and where responders and equipment such as hard booms, skimmers, storages and vehicles can easily be deployed within a short time after oil spill incident has been reported.

The emergency response zone (ERZ-1) has been proposed to be established along the PPMC pipeline corridor around the point at which the pipeline pass through the Federal University of Petroleum Resources, Delta which falls within the 500m buffer zone (Fig. 51). The rationale being that the agency responsible for emergency response to oil spill and PPMC are some distance with the pipeline passing through the University, there is the danger of sabotage from student unrest anytime. To this end the institution can serve as ERZ to cater for emergency spills.

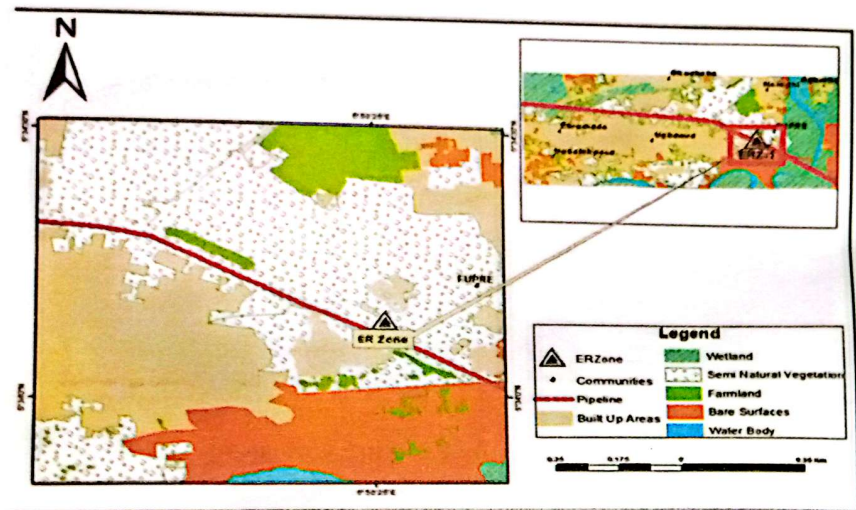


Fig. 51 Emergency Response Zone along the Pipeline Corridor

5.3.2.8 Conclusion

In conclusion, Onosemuode et al. (2019), reported that the PPMC pipeline safety can be evaluated as an individual risk, where the safety zone is set as the right-of-way. Thus the surrounding ecosystem features that are endangered by oil spill can be pre-determined. The generation of buffer zone based on the standards encapsulates the endemic ecological resources that are susceptible to contaminants from pipeline oil spill, vandalism and ruptures due to mechanical or human errors along the study area. These ESI maps will aid involved authorities and agencies responsible in managing oil spill disaster in understanding what and where to respond to and the required equipment to use in managing oil spill.

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