Assessment of Encroachment on Rumuekpe - Bomu Pipeline Right of Way in Obio/Akpor L.G.A, Rivers State, Nigeria Using Geospatial Techniques

[1] York, F. Newton and [2] Lawrence Hart

[1]Rivers State Boundary Commission, Office of the Deputy Governor, Government House, Port Harcourt.

[2]Department of Surveying and Geomatics, Rivers State University, Nkpolu, Port Harcourt.

atatanewyork@yahoo.com

Abstract

Encroachment on pipeline right-of-way (ROW) constitutes a major problem for the oil and gas sector of the economy. This research work aims at assessing encroachment on Rumuekpe-Bomu pipeline right of way from human activities using data obtained from remote sensing and geographic information system (GIS) techniques. Spatial information from five epochs (2003, 2006, 2009, 2012 and 2015) on Shell Petroleum Development Company (SPDC) pipeline network and associated ROW was extracted from shapefiles and satellite imageries obtained from the Office of the Surveyor General of Rivers State. Ground truthing with GPS observation were carried out to determine the position and coordinates of the pipeline ROW markers. ArcGis 10.1 was used to create buffer zone around a recommended distance of 30m restriction on pipeline ROW and digitize the buildings within the ROW in order to compute the areas encroached upon. GIS technique was used to overlay the polygons of buildings of five epochs (2003, 2006, 2009, 2012 and 2015) on the buffer area. ArcGis software was also used to create a geodatabase to perform some analysis, query and depict areas of encroachment over a periodic interval of 12years. Least squares linear regression model used the results of the query analysis of the total built-up areas to estimate and model the change and possible quantum of encroachment in the future. The study shows that a total of 2709.8m^2, 5651.72m^2, 11990.86m^2, 20702.86m^2, and 33523.18m^2 were encroached in 2003, 2006, 2009, 2012 and 2015 respectively. The least squares model estimated a total of 37919.05m^2 and 45586.84m^2 as encroachments in 2018 and 2021 respectively. The study also shows percentage rate of encroachment as 0.85% in 2003, 1.77% in 2006, 3.76% in 2009, 6.50% in 2012 and 10.52% in 2015. Generally, it was noted that development patterns along the Rumuekpe-Bomu pipeline do not adhere to government and SPDC guidelines and regulations over such activities on pipeline ROW. Therefore, the study recommended proper monitoring of the oil pipelines ROW by pipeline operators, regular maintenance of oil pipeline markers and serious awareness campaign by government agencies and non-governmental organizations.

Key Words: Right-of-Way, Encroachment, Pipeline, Least Squares, Imagery, Georeferencing, Digitizing.

1 INTRODUCTION

The system of transportation of petroleum products by road and rail in the 1960s and 1970s with enormous challenges were replaced by pipeline system of transportation considering its relative safety, efficiency and cost effectiveness. Hence, the rapid construction, expansion and growth of pipeline networks in Nigeria and other parts of the world [2]. To construct a pipeline, it is necessary that an agreement on easement right between the land owner and the pipeline operator is reached before a route survey is carried out to aid proper design and delineation of the pipeline right of way [10] and [8]. In terms of design, The Law of Federal Republic of Nigeria [5] clearly defined the parameters of the pipeline width as 100ft (except for swampy and coastal areas) [1]. These rights-of-way are kept clear to allow the pipeline to be protected, aerially surveyed, and properly maintained. Any further activities on this land after acquisition, is regarded as an encroachment. Encroachment is the unauthorized use of a licensed or permitted right of way by an unauthorized person [11]. This might include building structures, roads or some other form of intrusion upon a contracted easement except the private right of way [3]. Encroachment by host communities on pipeline right-of-way (ROW) constitutes a major problem for the oil and gas sector of the economy

[7]. For example, along Rumuekpe- Bomu pipeline in Rivers State encroachment on Shell Petroleum Development Company (SPDC) pipeline ROW is noticeable and some buildings were marked for demolition. Therefore, it became imperative to carry out a study of this nature to ascertain with GIS technique the level of encroachment on SPDC oil facility.

1.1 **Statement of the Problem**

Networks of oil and gas pipelines carrying petroleum products are significant to our economy. Though most of the pipelines are buried deep enough to prevent accidental contact with land-based activities, they can still pose a threat to the environment [10]. Of concern to the oil and gas industry and the general public are disturbances to the network by accidental spills, encroachment from human activities, and land form changes due to fires, floods and other natural events. Pipeline right-of-way as stipulated by Department of Petroleum Resources (DPR) regulations and Shell Petroleum Development Company (SPDC) guidelines today are being inhabited by people and used for many human activities. Presently, on Rumuekpe- Bomu Trunkline development, construction of buildings and other facilities are very common along the ROW. As noted earlier, these activities are carried out against government and/or Shell Petroleum Development Company guidelines and regulations concerning such activities along the pipeline corridor. As a result there is ongoing demolition of properties on the said pipeline right of way. It was on this ground this research work was considered necessary. However, in this research the standard criteria for pipeline right of way set aside by law will aid the study analyze how much people have encroached on Rumuekpe- Bomu pipeline ROW.

1.2 **Aim of the study**

This study is aimed at assessing encroachment on Rumuekpe- Bomu pipeline right of way (ROW) in five epochs.

1.3 **STUDY AREA**

The study area located within Obio/Akpor LGA, Rivers State lies between latitudes 04˚ 47’ 30” N and 04˚ 55’ 00” N and longitudes 06˚ 55’ 00” E and 07˚ 07’ 30” E [9]. The research area, Rumuekpe- Bomu trunkline is a 28-inch active oil pipeline whose right of way (ROW) was acquired around 1967. The chosen segment of the pipeline for this research work starts from Rukpokwu, passes through Eneka, Rumuewhara, Atali and terminates at Elimgbu community which spans approximately 10.6km. This section of the pipeline has no river channel and other pipeline crossing but traverses many farmlands, forest, settlements and major roads. Pipes along this segment of the pipeline corridor are buried deep into the ground [12].

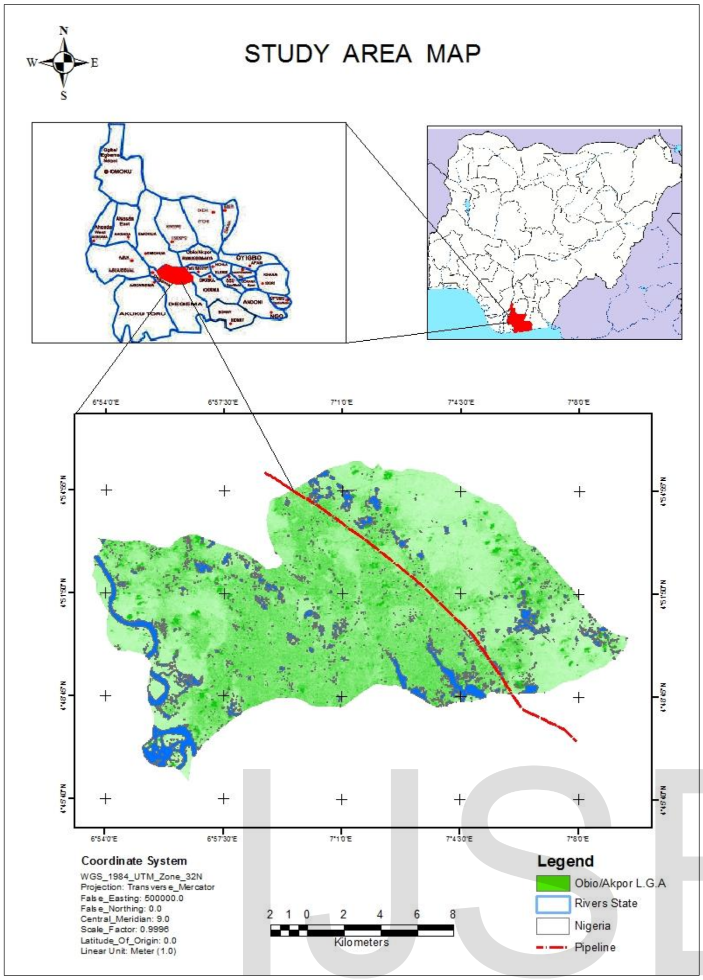


Fig. 1: Study Area (Rumuekpe- Bomu Pipeline ROW).

2 METHODOLOGY

The methodology was subdivided into various steps such as: Planning stage, Data acquisition, Digitization/ Data conversion and coordinate plotting, GIS database design and creation, GIS analysis and results.

2.1 Dataset

Shapefiles for pipelines and roads from SPDC were obtained while imageries from Office of the Surveyor General of Rivers State were equally sourced. Excel spread sheet was used to enter the coordinates of the pipeline markers captured with hand held GPS receiver. The data were processed, converted and plotted as polylines in ArcGIS environment.

2.2 GIS operations

According to [6], in ArcGis a geodatabase is created in order to better manage information for decision making. With the whole data carefully added in ArcMap 10.1, it was easy to create polygons of individual building and a buffer region (30mx1km and less in some cases) using the ROW limit as a reference. These newly created polygons of buildings and the buffers were stored in a well-organized personal geodatabase. Both layers were overlaid in line with the guidelines or criteria of assessing of oil pipelines, thereby revealing the level of compliances or violation on the oil pipeline right-of-way in order to ascertain the extent of encroachment through a geospatial analysis.

2.3 Data Analysis

The processed data obtained were analyzed in order to achieve the set objectives of the study and further make prediction.

Objective 1: To determine the rate of encroachment on ROW.

An overlay operation in ArcGIS software was carried out to achieve this objective. The buffer zone layer created on the ROW was overlaid on the SPOT imageries for each of the years. Specifically, the built up of 2003, 2006, 2009, 2012 and 2015 were overlaid separately on the buffers of pipeline for further analysis and map making. The individual buildings that fall within the buffer zone are those that have encroached on the pipeline ROW. The rate of encroachment was obtained by calculating how much of the ROW was encroached upon by the buildings.

Percentage Rate of Change

Percentage rate of change allows change over the years to be calculated. The area occupied by each buffer was used for the calculation. The simple formula for percentage rate of change that was also employed by this study is as in Mejabi, 2014,

$$\text{Percentage of encroachment} = \frac{E}{\sum(A)} \times \frac{100}{1} \qquad ...1$$

Where E = Area encroached
A = Total Area

Objective 2: To examine the trend of encroachment on the ROW.

The georeferenced SPOT imageries of the study area were digitized onscreen and showed number of buildings within a buffer region in a particular year. This was subsequently repeated for the other years covering the study period. The ROW layer was then overlaid (polygon-on-polygon overlay) on the digitized satellite imageries of the study area for each of the five years to carry out further analysis.

Prediction with Least Squares Regression Method

The study used Least squares regression forecasting method to identify the trend or pattern of encroachment on Rumuekpe- Bomu SPDC pipeline right-of-way. The model is appropriate for this research work since there was an assumed pattern in the past information about the variable of interest (built-up) which is also quantifiable. The pattern in time related data include average, trend and other components. The average is simply the mean of the data while trend describes real growth or decline in average demand or other variable of interest, and represents a shift in the average [4]. However, an encroachment predictive analysis was used to estimate (interpolate and extrapolate) encroachments for some other years including 2010, 2014, 2018 and 2021 using the formula for Least Squares Regression;

$$Y = mx + b \qquad ...2$$

Where
Y= amount of encroachment
m= slope or change per unit time
x= independent variable
b= value of the intercept

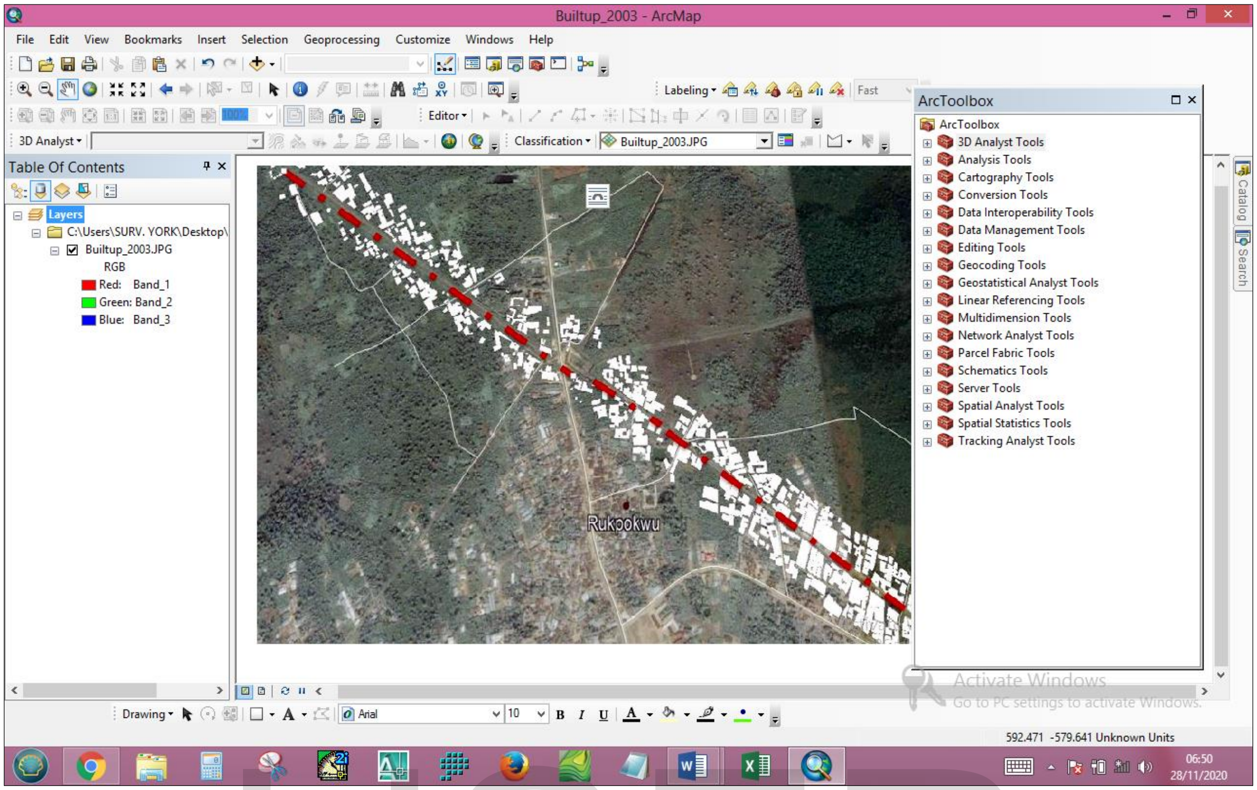


Fig. 2: Imagery of 2003 in ArcGis Environment showing Polygon of Buildings within the ROW.

Table 1: Coordinates from GPS observation at Kilometer one.

STN	COORDINATE		BEARING			DIST	STN
FROM	EASTING	NORTHING	Degree	Minute	Second		TO
P1	276110	544454	121	09	33	50.25	P2
P2	276153	544428	121	09	33	50.25	P3
P3	276196	544402	121	45	34	49.40	P4
P4	276238	544376	121	09	33	50.25	P5
P5	276281	544350	122	44	07	49.93	P6
P6	276323	544323	124	19	49	49.65	P7
P7	276364	544295	125	16	21	50.22	P8
P8	276405	544266	122	44	07	49.93	P9
P9	276447	544239	123	41	24	50.48	P10
P10	276489	544211	124	19	49	49.65	P11
P11	276530	544183	123	41	24	50.48	P12
P12	276572	544155	124	19	49	49.65	P13
P13	276613	544127	122	44	07	49.93	P14
P14	276655	544100	123	41	24	50.48	P15
P15	276697	544072	124	19	49	49.65	P16
P16	276738	544044	123	41	24	50.48	P17
P17	276780	544016	122	44	07	49.93	P18
P18	276822	543989	122	44	07	49.93	P19
P19	276864	543962	124	19	49	49.65	P20
P20	276905	543934	122	44	07	49.93	P21
P21	276947	543907	123	41	24	50.48	P22

3 PRESENTATION AND DISCUSSION OF RESULTS

3.1 Area Computation

On the SPOT imageries of the five epochs, buildings that encroach on the pipeline right of way were manually digitized on screen. With ArcGIS areas of the polygons were calculated and given in square meters according to their kilometers with respect to the buffer area. Using coordinate system of the data source, ArcGIS software was able to compute the area of each polygon with the coordinate method of area calculation.

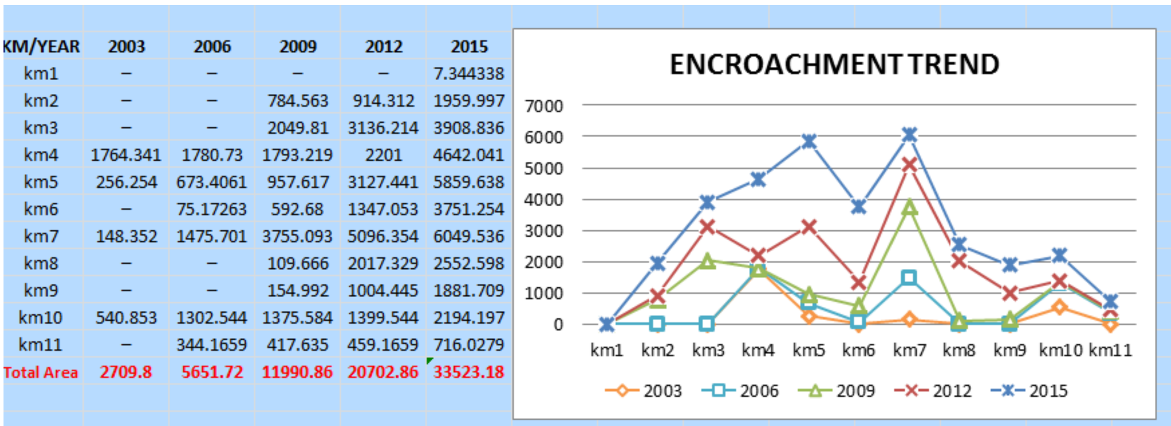
Table 2: Size (area) and Shape of the Encroached Building at Kilometer one

S/N	Object_Id	Class_Name	Shape_Length(m)	Shape_Area(Sq.m)
1	Polygon	buitup_471 points	22.391405	30.050631
2	Polygon	buitup_471 points	24.989453	37.988276
3	Polygon	buitup_471 points	44.945080	104.251468
4	Polygon	buitup_471 points	39.170422	93.738457
5	Polygon	buitup_471 points	28.853837	50.599653
6	Polygon	buitup_471 points	27.336696	45.885478
7	Polygon	buitup_471 points	54.217222	124.149681
8	Polygon	buitup_471 points	64.140450	180.883669
9	Polygon	buitup_471 points	17.181336	17.558108
10	Polygon	buitup_471 points	21.459329	30.401565
11	Polygon	buitup_471 points	24.264948	35.004548
12	Polygon	buitup_471 points	21.894635	28.241499
13	Polygon	buitup_471 points	21.796413	28.208148
14	Polygon	buitup_471 points	55.450513	118.526602
15	Polygon	buitup_471 points	25.553116	40.223796
16	Polygon	buitup_471 points	20.978627	24.258832
17	Polygon	buitup_471 points	40.172504	91.032999
18	Polygon	buitup_471 points	21.711463	23.559030
19	Polygon	buitup_471 points	36.185332	77.882104
20	Polygon	buitup_471 points	33.616752	52.095312

Table 3: Total Encroachments in square meters with respect to each epoch.

KM/YR	2003	2006	2009	2012	2015
km1	–	–	–	–	7.344338
km2	–	–	784.563	914.312	1959.997
km3	–	–	2049.81	3136.214	3908.836
km4	1764.341	1780.73	1793.219	2201.000	4642.041
km5	256.254	673.4061	957.617	3127.441	5859.638
km6	–	75.17263	592.68	1347.053	3751.254
km7	148.352	1475.701	3755.093	5096.354	6049.536
km8	–	–	109.666	2017.329	2552.598
km9	–	–	154.992	1004.445	1881.709

km10	540.853	1302.544	1375.584	1399.544	2194.197
km11	–	344.1659	417.635	459.1659	716.0279
Total	2709.8	5651.72	11990.86	20702.86	33523.18



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km6	–	75.17263	592.68	1347.053	3751.254
km7	148.352	1475.701	3755.093	5096.354	6049.536
km8	–	–	109.666	2017.329	2552.598
km9	–	–	154.992	1004.445	1881.709
km10	540.853	1302.544	1375.584	1399.544	2194.197
km11	–	344.1659	417.635	459.1659	716.0279
Total Area	2709.8	5651.72	11990.86	20702.86	33523.18

Figure 3: Builtup in 30m buffer of 2003, 2006, 2009, 2012 and 2015.

Table 4: Summary of encroachment in percentage.

Year	Encroachment (m^2)	Encroachment (%)
2003	2709.8	0.85
2006	5651.72	1.77
2009	11990.86	3.76
2012	20702.86	6.50
2015	33523.18	10.52

3.2. **Overlay Operations using ArcGIS**

The built-up of 2003, 2006, 2009, 2012 and 2015 were overlaid one after the other on the buffer zone created. At every one kilometer, encroachment is analyzed according to the degree of its density with deeper color assigned to the year with greater development (Figure 4, 5, 6 and 7).

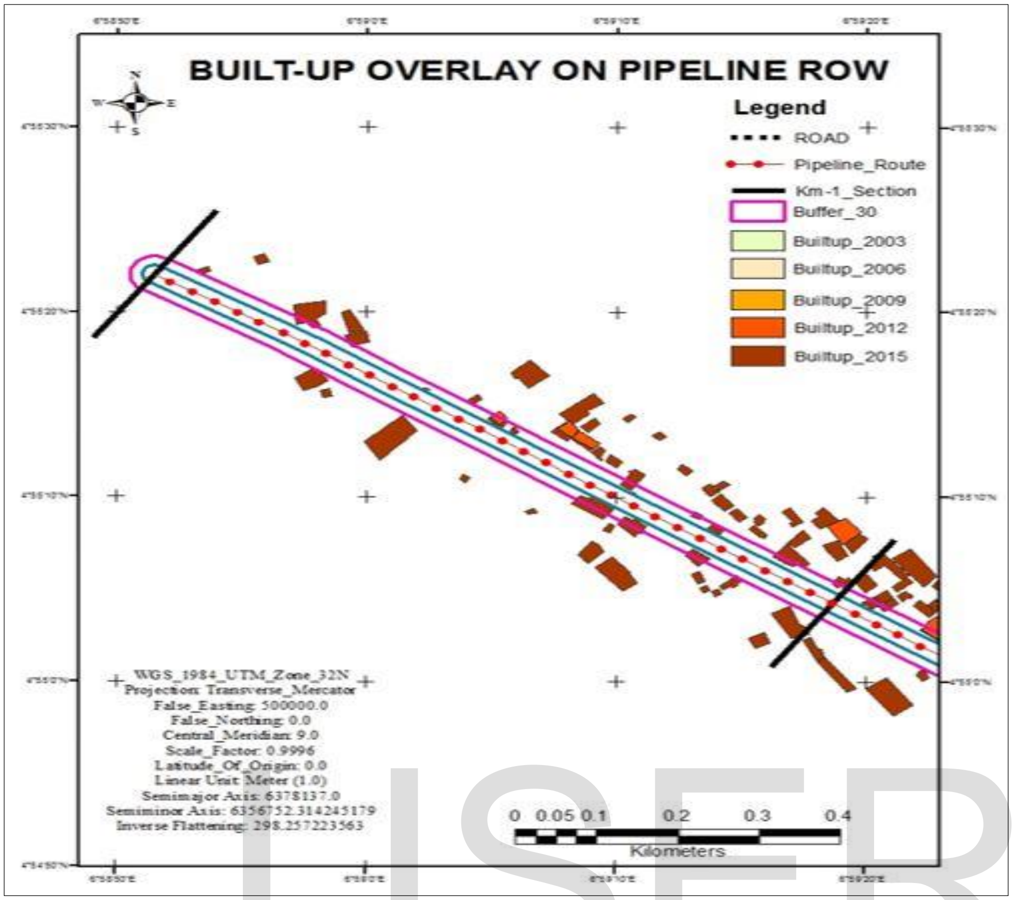

Figure 4: Overlay of built-up at first kilometer.

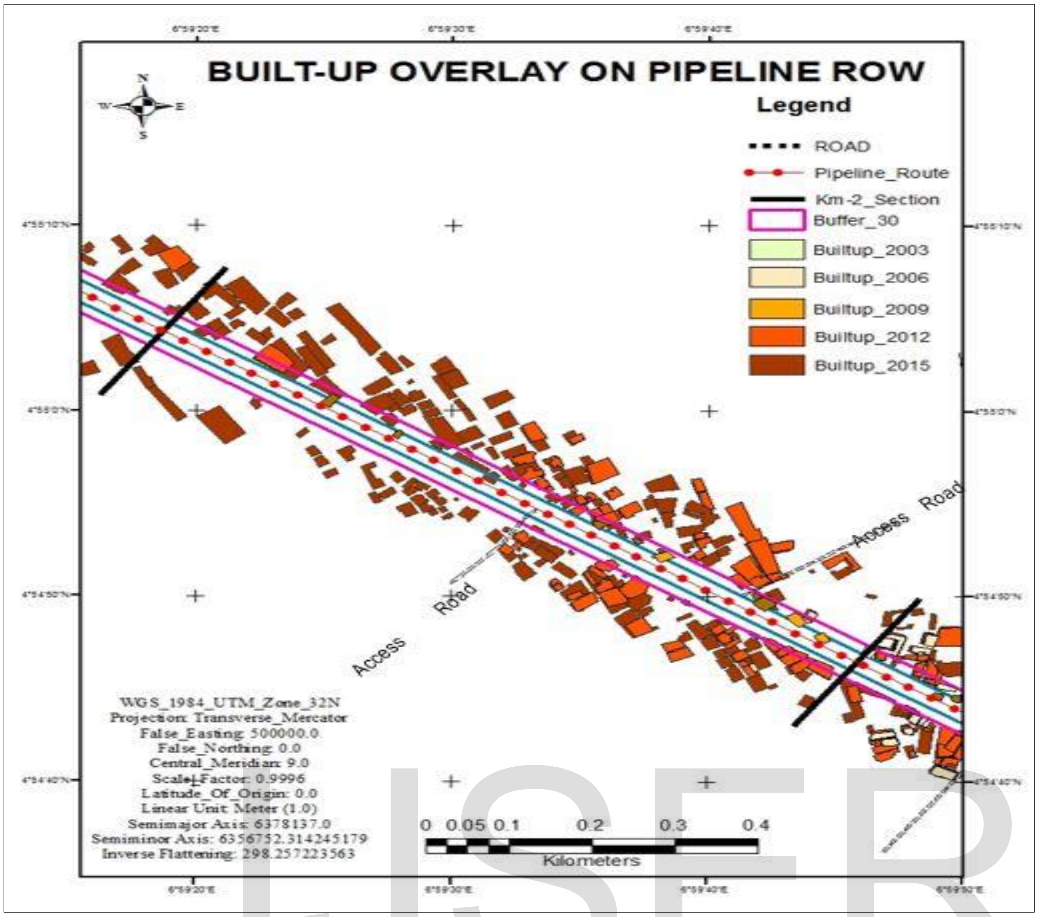

Figure 5: Overlay of builtup at second kilometer.

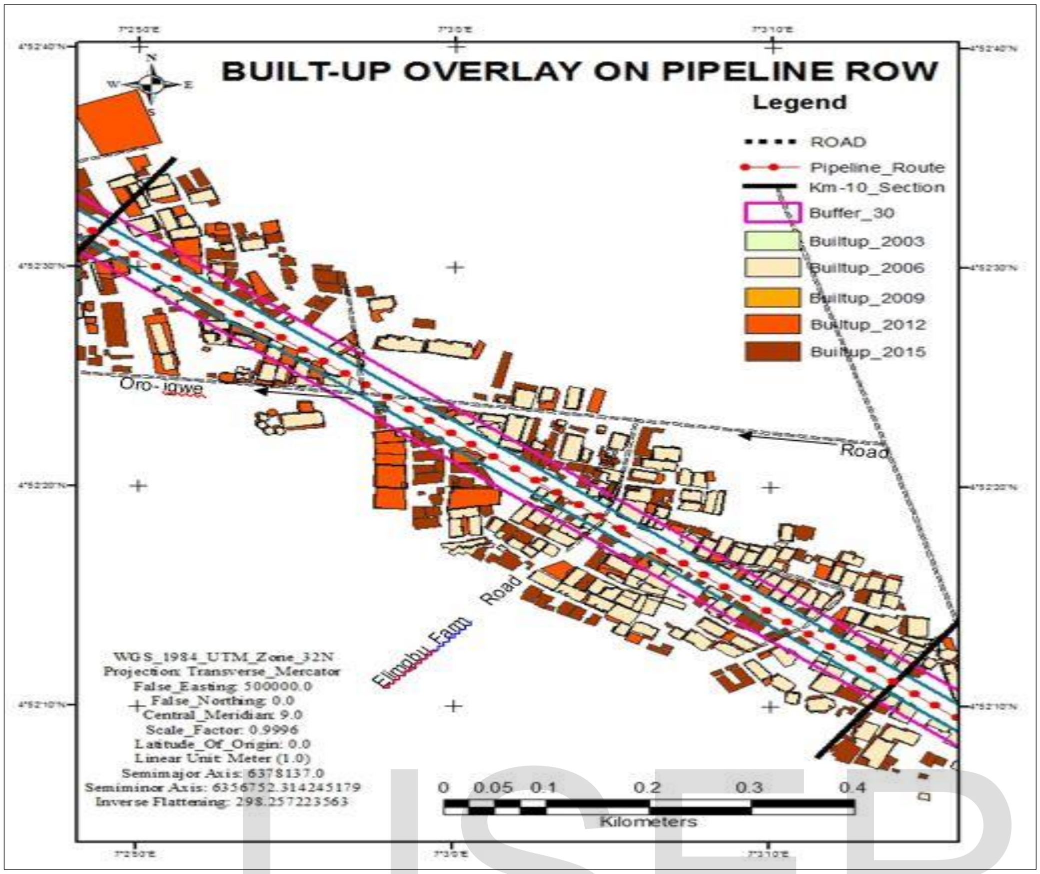

Figure 6: Overlay of builtup at tenth kilometer.

Road
Farm

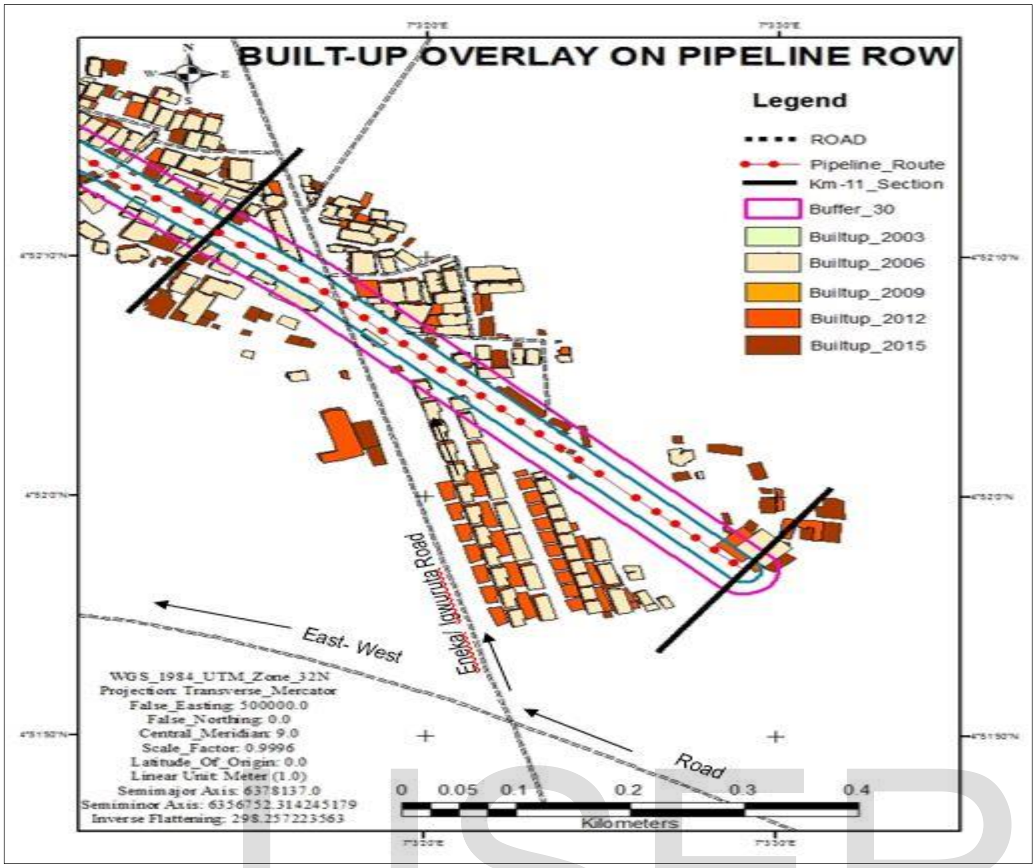

Figure 7: Overlay of builtup at eleventh kilometer.

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3.3 **Discussion of Results**

There are visible encroachments along this pipeline ROW at one point or the other. However, there are no buildings on the pipeline ROW on the first, second, third, eighth and ninth kilometers in 2003 and 2006 (Table 3 and Figure 3). From the analysis other areas that are free from encroachment in 2003 but are encroached in 2006 are kilometer sixth and eleventh. In other words in 2003, 2006, 2009, and 2012 the pipeline right of way was encroached within 4km, 6km, and 10km respectively. In 2015 buildings were scattered all over the entire length though not heavily built upon in the first kilometer.

It was also noticed that more buildings keep encroaching on the pipeline right of way as the year goes by. This research work shows in its results that encroachment has practically increased almost two times within the space of three (3) years. Precisely, encroachment has moved from 2709.8 m^2 (0.27ha) to 5651.72m^2 (0.57ha) between 2003 and 2006. Also, between 2006 and 2009, encroachment has risen from 5651.72m^2 (0.57ha) to 11990.86 m^2 (1.199ha) and again moved to 20702.86m^2 (2.07ha) and 33523.18 m^2 in 2012 and 2015 respectively.

Similarly, encroachment percentage from 0.85% in 2003 has moved up consistently to 10.52% in the space of 12 years (2003- 2015).

Table 5: Total encroachments in square meters with respect to each epoch.

Year	2003	2006	2009	2012	2015
Encroachment	2709.8	5651.72	11990.86	20702.86	33523.18

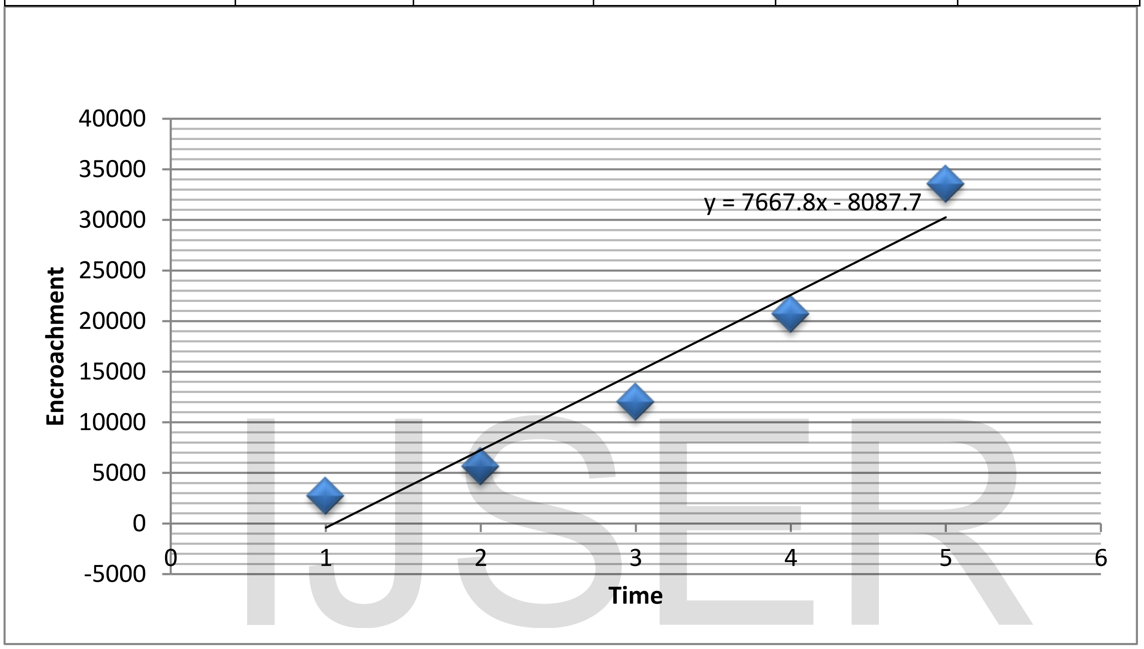

Figure 8: Builtup for five epochs (2003- 2015).

Table 6: Predicted encroachment values in square meters.

2003	2006	2009	2010	2012	2014	2015	2018	2021
2709.8	5651.7	11990.8	17446	20702.8	27644	33523.2	37919	45587

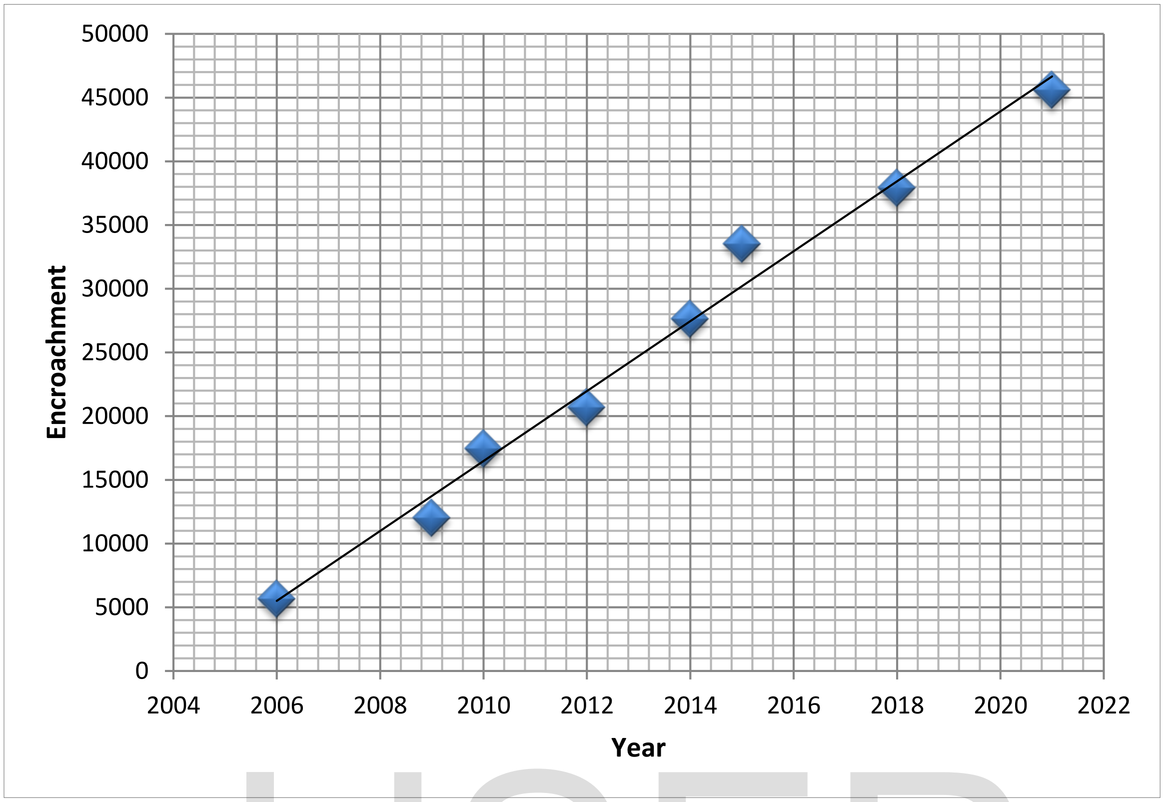

Figure 9: Builtup estimation for 2010, 2014, 2018 and 2021.

4 CONCLUSION & RECOMMENDATION

4.1 Conclusion

This study used remote sensing and GIS techniques to map encroachment in the study area. The study has demonstrated the use of a geospatial technology to provide a decision support system for land management. It has also shown that some of the buildings and infrastructures have encroached into the pipeline corridor, making them vulnerable. The mapping of oil pipelines right of way carried out in this research work makes it possible to identify the built-up areas within and nearest to the Right of Way (ROW). Hence, it was possible to identify where more security should be concentrated.

This research also used a statistical predictive method (the least squares method) to predict what the future encroachment in the study area would be like up till the year 2021. The least squares method is a very sound prediction method capable of deducing the most probable value of a measured quantity made with equal care and skill from a series of direct observations. Therefore, its usefulness in this study cannot be overemphasized. It was with the aid of least squares linear regression model that possible future quantum of encroachments were estimated from the acquired data assuming the present trend is unchecked and the rate of encroachment continues to be the same.

4.2 Recommendations

It was based on the findings of this study that the following recommendations were made to aid Stakeholders and Government in monitoring and enforcing compliance to the regulations guiding the SPDC pipelines right-of-way in the study area.

Proper monitoring of the oil pipelines in the area since most of them are accessible to minimize encroachment, sabotage, vandalism and theft.
Regular maintenance of oil pipeline markers throughout the pipeline corridor to clearly show the limit of pipeline right-of-way.

More awareness campaign by relevant government agencies and concerned non-governmental organizations to educate the general public to resist from building on pipeline and also enlighten them on the associated risk if they continue to encroach on pipeline right of way.

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