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Pipeline right-of-way encroachment in Arepo, Nigeria

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Abstract: Encroachment by host communities on pipeline right-of-way (PROW) constitutes a major problem for the oil and gas sector of the economy. This paper uses remote sensing and geographic information system (GIS) technologies to assess the level of vulnerability of people living along the PROW in Arepo, Ogun State, Nigeria. A satellite imagery of the community was acquired and processed using ArcGIS computer software. A GIS buffering operation was performed on the PROW using 15 m, 30 m, 60 m, and 90 m distances, respectively. Three hundred and forty buildings were identified in the buffered zones, out of which 200 (60%) were randomly selected for the study. A structured questionnaire was administered to household heads in the sampled buildings. Empirical analysis shows that 140 buildings (70%) observed less than a 30 m setback to the pipeline. Also, residents benefit from incidents of oil spillage and see these as an avenue to vandalize the pipeline, making them more vulnerable. GIS analysis shows that more than 30% of respondents are highly vulnerable to the hazard of pipeline explosion incidents. Enforcement of setback regulations by the Town Planning Authority and public education and awareness of risks associated with encroachment on the PROW are canvassed among others.

Keywords: pipeline right-of-way, encroachment, vulnerability, remote sensing, GIS, and Arepo

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1 Introduction

Nigeria is the largest oil producer in Africa and the 11th largest globally, and oil remains the mainstay of the nation's economy. This sector has remarkably brought buoyancy to the country's economy (Okoli & Orinya, 2013).

Refined crude oil products from the central refineries are typically transported to various pump stations and depots by rail, road, coastal waterway, and pipeline systems (Okoli & Orinya, 2013).

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However, the road and pipeline systems are dominant in Nigeria because of a limited rail network and lack of inland waterways.

A pipeline right-of-way (PROW) is a strip of land over, under, and around crude oil pipelines where some of the property owner's legal rights have been granted to a pipeline operator. Usually, a PROW is established about 15 m from each side of a pipeline, excepting special conditions like swamps and coastal areas (Phillips 66 Pipeline, 2012).

Pipeline operation can be compromised by accidental manmade threats such as seismic disturbances caused by legitimate civil engineering works in the area or even by farming activity. Pipeline safety and security, therefore, generally involve federal agencies, oil and gas pipeline associations, and pipeline operators as well as the local communities through which the pipelines pass.

Nigeria has a total pipeline grid of just above 5000 km. This consists of 4315 km of multiproduct pipelines and 666 km of crude oil pipelines (PPMC, 2015). These pipelines traverse the country, forming a network that interconnects the 22 petroleum storage depots and the four refineries (two of which are at Port-Harcourt, one at Kaduna, and one at Warri) and connecting the off-shore terminals at Bonny and Escravos and the jetties at Alas Cove, Calabar, Okirika, and Warri. This system of oil pipelines transports crude oil to the refineries in Port-Harcourt, Warri, and Kaduna, covering a total distance of 719 km. The multiproduct pipelines are used to transport products from the refineries and import-receiving jetties to the 22 petroleum storage depots at various places in the country. The storage infrastructure, consisting of 22 loading depots where the products are stored for distribution, linked by pipelines of 6 to 8 inches diameter range, have combined installed capacities of 1,266,890 metric tons of Premium Motor Spirit (PMS); 676,400 metric tons of Dual Purpose Kerosene (DPK); 1,007,90 metric tons of Automotive Gas Oil (AGO); and 74,000 metric tons of Aviation Turbine Kerosene (ATK).

This paper aims to assess the effect of community encroachment on PROW and its socioeconomic implications on Arepo, Ogun State, Nigeria using remote sensing and GIS techniques. The objectives are to examine the existing pipeline infrastructure in the study area; identify the extent of encroachment on PROW using buffering operations in GIS environment; and assess the security implication due to this encroachment.

The issue of encroachment on PROW by host communities constitutes a major problem to the oil and gas sector of the economy. Encroachment breaches the planning standard set for development, which is often the main reason for infringement and vandalism.

2 Materials and methods

2.1 Research locale

Ogun is one of the 36 states of the Federal Republic of Nigeria, with an estimated population of 3,751,140 people (NPC, 2006), ranking 16th in population. It has a total land area of about 17,000 km^2 and an average density of 220 persons per km^2. Ogun, popularly known as the "Gateway State," is in South Western Nigeria as shown in Figure 1, bounded on the north by Oyo, on the northeast by Osun, on the west by Ondo, and on the south by Lagos.

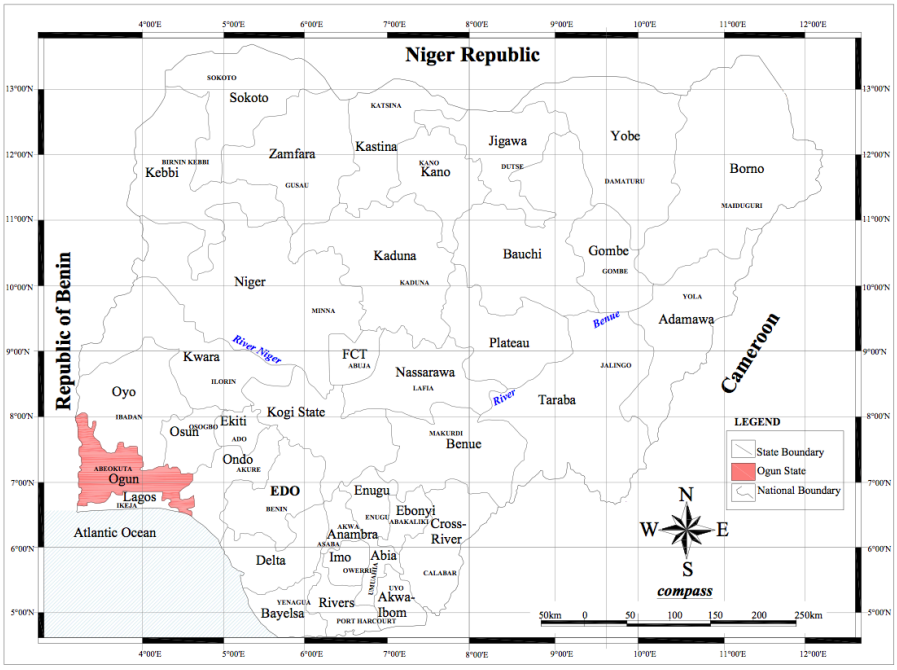

Figure 1: Map of Nigeria showing the study area in its national setting
Source: Survey Department, Ministry of Works, 2016

The study area is located in the Obafemi Owode local government area of the State. Obafemi Owode is one of the 20 local government areas in Ogun. The Arepo community is located along Lagos-Ibadan Express. Figure 2 shows the study area in its regional setting while Figure 3 shows the satellite image of the study area.

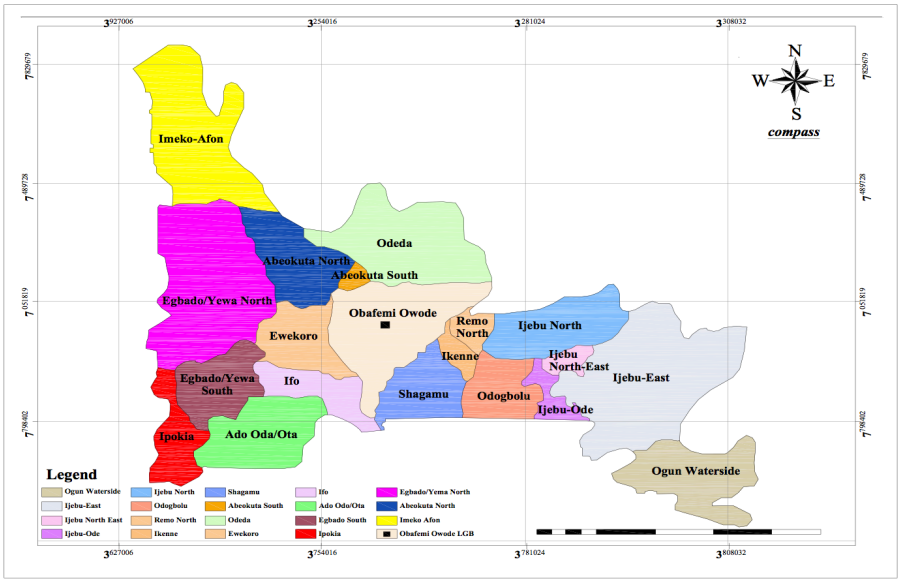

Figure 2: Map of Ogun State showing the study area in its regional setting
Source: Survey Department, Ministry of Works, 2016

Figure 3: Google Earth imagery of the study area
Source: Google Earth, 2016

Figure 4 shows the buffer distances from the PROW. The figure shows 26 buildings housing an estimated 728 persons within the 15 m buffer, violating the statutory standard setback for the PROW.

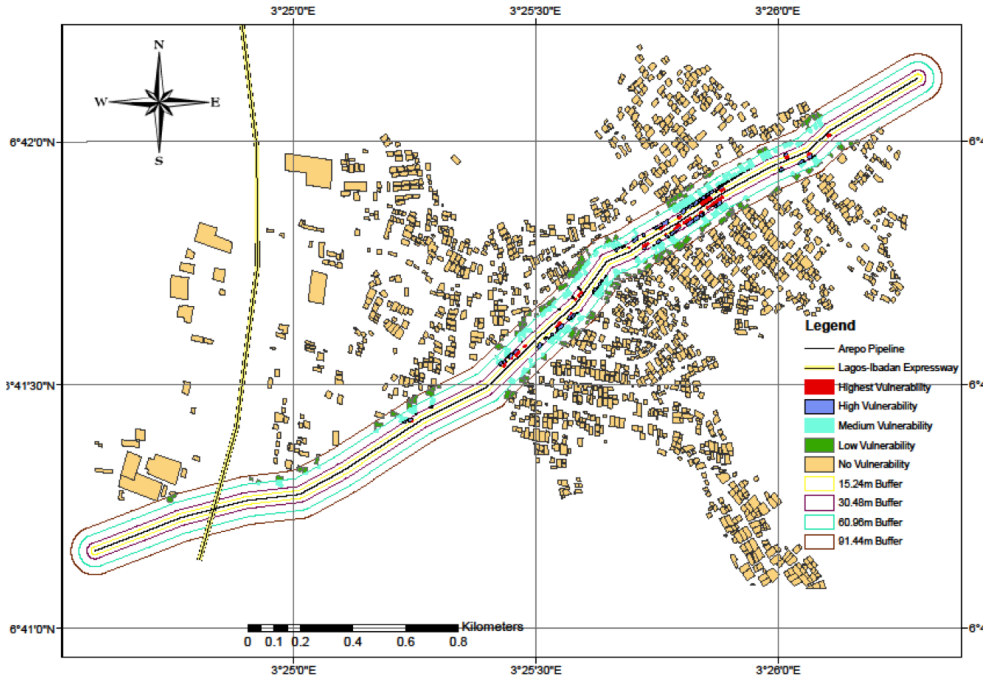

Figure 4: Vulnerability zones/buffer along the PROW in Arepo, Nigeria
Source: Authors' fieldwork, 2016

The vulnerability levels indicate the impact of incidents of pipeline explosion that could occur from incessant oil bunkering, sabotage, or domestic fire accidents. This could further result in causalities and property loss due to the impact of the pipeline incident.

2.2 Database description

A shapefile of the pipeline network passing through the community was created and digitized through the use of ArcMap GIS software. This provides a clear overview of the existing pipeline infrastructure in the study area. The study area was divided into 4 zones using buffers of 15 m, 30 m, 60 m, and 90 m, respectively. The total number of encroaching buildings and the estimated total number of persons affected in the study area were determined by the buffering operation.

The total number of buildings constitutes the population for this study. Table 1 shows sampling in the study area. A structured questionnaire was used to generate the attribute data. Using the building population, a 60% sample was purposively taken due to homogeneity characterizing the study area. In this way, a total of 204 structured questionnaires were administered to household heads in the community, out of which 200 were found fit for analysis. The simple random sampling technique was used to administer the selected sample.

Table 1: Sampling in the Arepo community (the study area)

Buffer distance from Pipeline	Zone	Total no. of buildings	60% of buildings
15m	A	26	16
30m	B	78	47
60m	C	89	53
90m	D	147	88
Total		**340**	**204**

Source: Authors' fieldwork, 2016

3 Results and discussion

The data acquired from the administered questionnaire (see appendix) based on implications of community encroachment on PROW are as described below.

3.1 Planning implications of encroachment on the PROW

Table 2 shows the relationship between respondents' length of stay in the study area and the distance of their respective buildings to the pipeline. From the Table, it is evident that 140 buildings (70%) observed less than a 30 m setback to the pipeline. Those nearest the pipeline have the least tenure of residence, indicating people prefer to live farther from the pipeline, as locations near the pipeline have higher residential turnover. In addition, 55.7% of respondents have stayed in the PROW for more than 10 years.

The final row of the table shows the number of buildings in the study area by distance from the pipeline. It is evident that the farther one moves away from the pipeline, the more buildings there are. This implies that the pipeline affects the location of buildings in the study area and a willingness to encroach. In other words, residents are reluctant to build too close to the pipeline, probably due to well-understood impacts on building and human health.

Table 2: Length of stay of respondents vs. distance to pipeline

Length of stay	Distance of Respondent's Residence from				Total Freq	Total %
	< 15 m	15 -29 m	30-59 m	60 – 90 m		
below 5yrs	33	16	0	0	49	24.5
5-10yrs	0	15	14	11	40	20.0
11-15yrs	27	16	0	0	43	21.5
above 15yrs	0	33	21	14	68	34.0
Total	**60**	**80**	**35**	**25**	**200**	**100.0**

Source: Authors' fieldwork, 2016

Table 3 shows reasons residents moved to the community. The largest number of people (57%) moved to the area to engage in retail trading rather than being employed by another organization. Only 43% of respondents migrated to the community for employment purposes by other organizations. This shows that the community is a center for commercial and employment opportunities.

Table 3: Attraction factor to community vs. distance to pipeline

Attraction Factor	Distance of Respondent's Residence from Pipeline				Total Freq	Total %
	< 15 m	15 -29 m	30-59 m	60 – 90 m		
Lumbering	0	0	0	0	0	0
Trading	43	46	14	11	114	57
Employment	17	34	21	14	86	43
Grand Total	60	80	35	25	200	100
Total	**60**	**80**	**35**	**25**	**200**	**100.0**

Source: Authors' fieldwork, 2016

Table 4 shows the response of the community to cases of oil spills; 22% of the respondents claimed the community reported oil spill cases to security agencies, 25.5% claimed they evacuated the area whenever there is an oil spill, and 44.5% agreed that the community took advantage of oil spills to scoop petroleum because of their closeness to the area.

Table 4: Community response to oil spillage vs. distance to pipeline

Response	Distance of Respondent's Residence from Pipeline				Total Freq	Total %
	< 15 m	15 -29 m	30-59 m	60 – 90 m		
Report to security agency	20	17	4	3	44	22.0
Evacuate from area of spill	22	18	7	4	51	25.5
Vandalize the pipeline	42	21	19	7	89	44.5
Do nothing	10	6	0	0	16	8.0
Grand Total	**94**	**62**	**30**	**14**	**200**	**100.0**

Source: Authors' fieldwork, 2016

However, Plate 1 illustrates people scooping petroleum during oil spillage in the study area. This indicates that whenever there was oil spillage, at least some residents saw it as an avenue to vandalize the pipeline to gain from black-market sales (see Plate 1).

Plate 1: Residents scooping petroleum after an explosion
Source: Yusuf, A., 2015.

Table 5 shows possible safety measures. Of the sample, 45% opined that the use of "No Trespass" signs was the best measure, 1% suggested aerial surveillance of the PROW was the best safety technique, 19% believed security personnel should patrol the PROW periodically, 14% opted for enforcement of regulations by the town planning authority against houses located on the PROW, and 21% strongly believed that the use of all the available techniques will serve the best purpose in ensuring a safer PROW. This implies a majority support for relocation of encroaching residents.

Table 5: Suggested safety measure on the PROW vs. distance to pipeline

Recommended Measure	**Distance of Respondent's Residence from Pipeline**				**Total Freq**	**Total %**
	< 15 m	**15-29m**	**30-59 m**	**60- 90 m**		
Erection of "No Trespass" signs	10	20	30	30	90	45.0
Aerial surveillance	2	0	0	0	02	1.0
Security patrol along pipeline right-of-way	10	12	9	7	38	19
Enforcement of Town Planning Regulations	20	8	0	0	0	14
All of the above	10	10	10	12	12	21
Total	**60**	**80**	**35**	**35**	**24**	**100**

Source: Authors' fieldwork, 2016

Table 6 shows dominant building uses along the PROW. Of the sample 70% believed that residential buildings are most dominant in the community, 22% opted for commercial buildings as most prevailing, and 4% and 3.5% suggested industrial and mixed uses, respectively. Interestingly, more residential buildings (53/141) are found within a less-than-15 m statutory setback to the pipeline. This implies lack of adequate town planning regulations and enforcement operations in the community.

Table 6: Dominant building uses along the PROW vs. distance to pipeline

Dominant Building Use	Distance of Respondent's Residence from Pipeline				Total Freq	Total %
	< 15 m	15-29m	30-59 m	60- 90 m		
Commercial	0	33	11	0	44	22.0
Residential	53	39	24	25	141	70.5
Industrial	3	5	0	0	8	4.0
Mixed	4	3	0	0	7	3.5
Total	60	80	35	25	200	100.0
Total	**60**	**80**	**35**	**35**	**24**	**100**

Source: Authors' fieldwork, 2016

3.2 Remote sensing and GIS results

Figure 4 shows the buffer distances from the PROW at 15 m, 30 m, 60 m, and 90 m representing the zones of vulnerability, respectively. At the 15 m buffer distance (Zone A), the total number of encroached buildings on the PROW is 26 and the estimated total number of persons within this zone is 728. This indicates that the number of residents is very highly vulnerable to incidents of pipeline explosion in the community. The figure shows it as the area of highest vulnerability, depicted with the color red.

At the 30 m buffer zone (Zone B), 78 buildings with an estimated population of 2184 persons fall within this zone. The buildings and persons in this buffer zone are considered to be under high vulnerability in the incidence of an explosion from the oil pipeline. Buildings that fall within this zone are depicted with the color blue as shown also in Figure 4.

Also at the 60 m and 90 m buffer zones (Zones C and D), the total number of buildings is 89 and 147, with an estimated population of 2492 persons and 4116 persons, respectively. The buildings in these zones are considered to be under medium and low vulnerability levels in the incidence of an oil pipeline explosion. These vulnerability levels are depicted by turquoise blue and green colors, respectively; buildings with no vulnerability are shown with pink (Figure 4).

The vulnerability levels indicate the impact of a potential pipeline explosion, which could occur as a result of human activities such as incessant oil bunkering or sabotage as well as domestic fire accidents. The implication of these findings for planning is that buildings that fall in zones A and B should be marked for contravening town planning regulations and consequent removal or demolition. Only buildings in Zone D (area of no vulnerability) are expected to remain.

4 Conclusion and recommendations

This study has revealed the degree of encroachment on the PROW in the study area. The study also demonstrated the use of remote sensing and GIS technologies in infrastructure management. This paper therefore recommends that:

1. Aerial surveillance of the pipeline using remote sensing and GIS technologies should be employed for effective development control operations in the study area.
2. Enforcement of setback regulations by the town planning authority will ensure more orderly development of infrastructure and promote safety of both the residents and the pipeline.
3. Removal of structures on the PROW should also be carried out for public safety. However, this requires finding adequate replacement housing for the displaced residents. The pipeline company should engage in community development for the displaced residents, including creating replacement communities with the project such as construction of good roads and boreholes

and provision of electricity and schools. This is to foster a good relationship between the pipeline companies and the community and mitigate the negative outcomes from displacement.

4. Public sensitization and awareness on the level of vulnerability and risks associated with encroachment on the PROW should be carried out by the pipeline company. This should be done while recognizing the need for peaceful oil company–community relationships for an enduring business environment.

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