FRACTAL ANALYSIS FOR OIL SPILLS CLUSTERING IN AHOADA COMMUNITIES OF THE NIGER DELTA REGION OF NIGERIA

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ABSTRACT:

This study uses fractal analysis to understand how oil spills are clustered at different scales in Ahoada communities of the Niger Delta region of Nigeria. The ArcGIS software was used in designing the hotspot map of the study area using Kernel density estimation. Results of spatial spill distribution from the Kernel density revealed that Bayelsa, Rivers, and Delta states are the hottest spots for oil spill occurrences and distribution and communities within the Rivers state including Ochebeke, Ukperede, Odieke and Akinima has been widely affected by the spills. The box counting method was employed for understanding clustering associated with oil spills in the area using ArcGIS interface. The method uses the conversion tool embedded in ArcGIS to convert oil spills points into raster. A basic analysis of this fractal plot suggest a dual fractal analysis for oil spill occurrences within the study location. This is evident by a low fractal dimension of 0.419 at distances of 1.1 km. At higher distances above 1.1 km, oil spill occurrences are characterised by a fractal dimension of 1.411. According to the fractal plot, regional and local fractal for oil spill occurrences is defined by a threshold distance of 1.2 km. At scales less than 1.2 km, oil spill occurrences exhibit a fractal dimension of 0.063 while at scales above this distance, the occurrences of oil spill are defined by a fractal of 1.249. A general analysis of fractal for both oil spill types suggests a small fractal dimension values and a more discrete scale compared to the regional scale. The relative low fractal dimension values at discrete scale suggest a high clustering of oil spill locations. This study gives a relative idea about the clustering tendency. This would enable proper remediation to be carried out in the area.

1. INTRODUCTION

During their aggressive attacks on pipelines, the Niger Delta militants uses local hacksaw or dynamites to break crude oil pipelines in order to siphon refined or unrefined petroleum products for financial gains. This leaves the pipeline contents to spill and pollute the environment also amounting to huge costs of pipeline repairs. The spilled products cause destruction to the ecosystem and causing huge costs of cleaning up the environment. According to Uwakwe et al (2021), incessant attacks on oil pipelines in the Niger Delta costs Nigeria more than what it is losing from production and clean ups. The different consequences include, damages to farmlands, swamps surface and ground waters, animal diversities, vegetation and health issues are amongst the many consequences of pipeline interdiction in the Niger Delta region. Nnaemeka (2020) revealed that several health issues like diarrhoea, skin irritation and stomach-ache, emanating from consumption of polluted water are common among the people of Tsekelewu and Idu Ekpeye communities of the Niger Delta. According to Yakubu et al. (2017), aside from the loss of means of livelihood of many in Ahoada

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communities of the Niger Delta, there have been exposure to toxic chemicals from environmental pollution which have severe health impacts including cancer, respiratory issues and miscarriage among women. Adekola et al. (2017), suggested toxicity of root crops and other agricultural products through bioaccumulation of toxic components from hydrocarbon pollution in the Niger Delta region of Nigeria as a cause for shortages of farm produced. The destruction caused by oil spill can be devastating, partly due to the mismanagement of land resources. Oil spill have been reported to have negatively impacted crop yield and the general productivity of the land, subsequently affecting the already impoverished poor farmers in the Niger Delta region (Godson-ibeji and Chikaire, 2016). Furthermore, decreases in soil fertility due to the destruction of soil micro-organisms and decreases in agricultural productivity have left farmers with no option than to abandon their farm lands and seek other means of livelihood (Chinedu,and Chukwuemeka, CK, 2018). Chukwuma etal., (2018), collected soil samples from 3 different sites using soil auger to investigate zinc availability in relation to selected soil properties in a crude oil polluted Eutric Tropofluvent in Egbema, South-eastern Nigeria. Results indicated that zinc distribution is more common in an oil polluted site than non-oil impacted sites and its distribution depends on certain soil properties including clay contents, PH and organic matter contents. Edwin-wosu and Nkang AE (2020) studied the physicochemical properties of soil in relation to varying rates of crude oil pollution in Qua-Ibo, Brass River and Bonny area of Niger Delta region. The results showed an increase in the values of some selected physico-chemical properties of the soil with increase in both absorption and adsorption period, concentration of the level of hydrocarbon of different crude samples, as well as the volumes of crude oil used during sorption process. Findings from the study of Akpan EE and Nwadinigwe CA (2021), of clay contaminated with crude revealed a decline on some of its geotechnical properties, such as specific gravity, density index, consistency limits, particle size analysis, compaction, consolidation, permeability and shear strength. This apparent reduction in strength, stiffness and permeability of the clay was partly due to formation of open structure emanating from crude oil contamination. This can have consequences on erected structures in the area.

Pipeline interdiction has remained a major threat to Nigeria's economic prosperity and a nightmare to the oil companies operating in the region. The insidious nature of oil spills in the Niger Delta has deleterious effects on the physical, biological and chemical properties of the soil which negatively affect the growth of farm produce and causes food shortages due to reduction of nutrient contents of the soil (Akpan EE and Nwadinigwe CA (2021). Anejionu et al., (2015) reported oils spills and pipeline explosion amounting to about 10,000 occurrences while more than 350 billion cubic meter of gases were flared within the span of 14 years. Additionally, severe environmental destruction in the region has resulted in to wide range of marine and terrestrial ecosystem degradation, leading to shortages of Agricultural lands and affecting marine lives (Chima etal., 2013; Yakubu, 2017) Cherouat etal (2015) found that a box counting fractal dimension model provided excellent discrimination between oil spills and look-alikes, although the backscatter information, which could allow a first robust localization of the oil spills, had not been considered. Florindo and Bruno (2016) used a multiresolution algorithm which was based on fractal geometry for texture analysis. They found that the sea surface is characterized by an approximately steady value of fractal dimension, while the oil spills have a different average fractal dimension compared to look-alikes. Although. Many studies have noted that the continuous destruction of farmlands and rivers in the Niger Delta emanated from its own people who are supposed to protect them for their uses and for posterity. The security agencies of The Federal Government of Nigeria have been making efforts to end the scourge of pipeline interdictions in the study area. This study therefore uses fractal dimension of box counting to show the destruction caused by oil spills pollution in Ahoada communities of the Niger Delta region of Nigeria.

2. MATERIALS AND METHOD

The study area is Ahoada is located in Rivers State north-west of Porthacourt the capital of Rivers State, and was curved out of old Ahoada in 1996 which hitherto to that was a vast local government area and now split in to Ahoada West and Ahoada East. Ahoada lies at latitude 6o 87.26N and longitude 6o 38'59.9''E. The area comprises several communities including Idu-Ekpeye, Oshie, Akaraolu and Akinima and speaks three distinct languages namely Ekpeye, Engenni and Ogbogolo. Having a high dense rain forest vegetation, the area has a river system that criss-cross over the entire communities known as Orashi and Sombreiro Rivers and thus, makes farming, fishing and hunting the dominants occupation in the area. Furthermore, the area is bounded by Abua/Odua local government and Ogba/Ndoni/Egbema local government areas. Figure 1 shows the map of Ahoada communities.

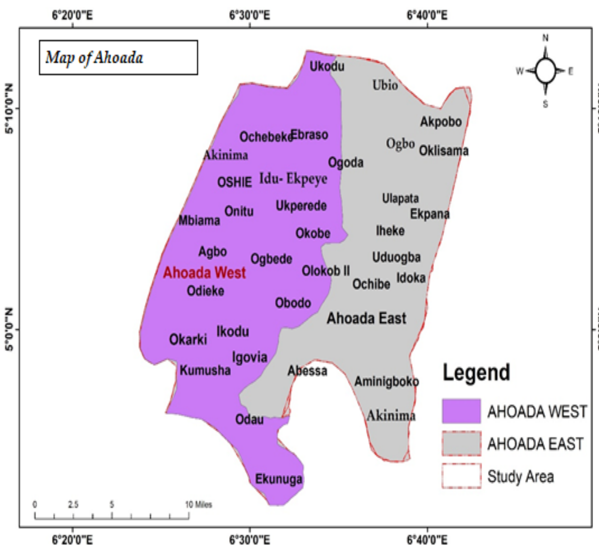

Figure 1. Map of Ahoada communities

2.2 Data Sources and Methodology

2.2.1 Oil Spills Data and Pipeline Map: Pipeline map was georeferenced and digitized to obtained an integrated oil pipeline map of the study area as shown in Figure 2 which was originally obtained from Agip Petroleum Company of Nigeria. The point of leakages around the pipelines was considered as it was overlaid with the pipeline, showing oil spills coming out as a result of interdiction by Niger Delta militants as depicted in Figure 3.

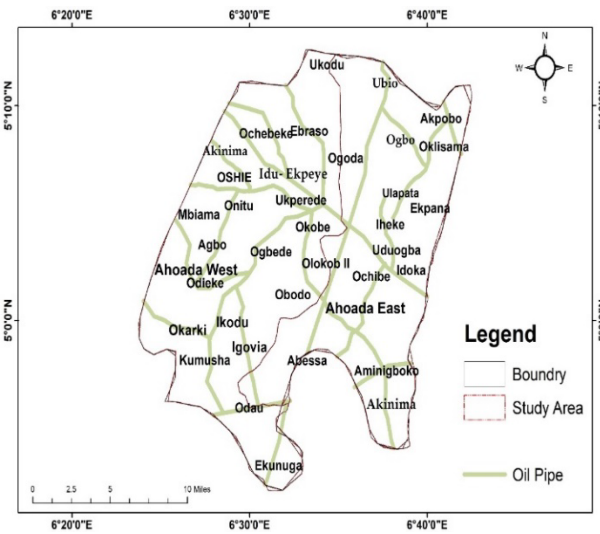

Figure 2. Map of the study area and the oil pipelines criss crossing the communities

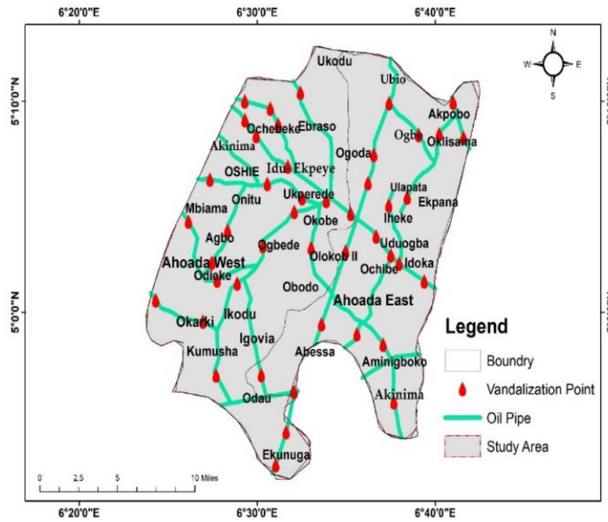

Figure 3. Map of Ahoada with pipelines and vandalization points

Equally, part of this research involves the collection of all available oil spills data of the entire Niger Delta region from NOSDRA which keeps a database of official oil spills and SPDC, a multinational oil company that has operated in Nigeria for several decades. The data have been compiled by both Shell and NOSDRA via a process of joint investigation visits (JIV). Information on the data base which is updated as soon as another incidence occurs, encompasses dates, time, causes, magnitude, and GPS coordinates of spills. Data on Ahoada oil spills, the study area has been extracted. The data is crucial in ascertaining the extent of each oil spill, the frequency of spills at a particular location, and establishing of the rate of risk posed to the closest communities to the various occurrences.

2.2.2 Fractal analysis of oil spills clustering: In this study, the box counting method was employed for understanding clustering associated with oil spills. According to Akhlaq etal (2022), the box counting method can be implemented by placing a rigid grid with specific length over a given set of points and counting the number of boxes containing one or more points. The sizes of these grids are increased while the number of boxes with points are noted. A log- log plot of grid size versus number of points is plotted and a straight line drawn through these plots satisfy the power law defined by the equation

$$N(r)=Cr^{(-Db)} \quad (1)$$

Here, Db is the box counting fractal and C is the constant of proportionality between N(r) and r (Carranza et al., 2009). The box counting method was initially developed using ArcGIS interface. The method was initiated by using conversion tool embedded in ArcGIS, to convert oil spills points into raster. Feature to raster was equally used and subsequently spatial analyst tool were used for the extraction of multi values to points, where 1000 to 24000 box sizes were used. The processing of box count dimension was carried out using excel sheets, after it was exported from ArcGIS environment. The method has been applied successful in many fields, as fractal dimensions (FD) plays an important role in shape classification, texture partitioning (segmentation) and graphic analysis in different fields. The box-counting approach is one of the frequently used techniques to estimate the FD of an image.

3. RESULTS AND DISCUSSION

3.0 Oil spills mapping, pipeline proximity to human settlements

Kernel density hotspots map depicted in Figure 4 is a result of 13 years' oil spills that polluted many part of the Niger Delta, the map shows areas that are more clustered, moderately clustered and less clustered, indicating highly impacted areas, moderately impacted areas and less impacted areas respectively. Areas mostly affected are Rivers, Bayelsa and Delta states. Out of these states.

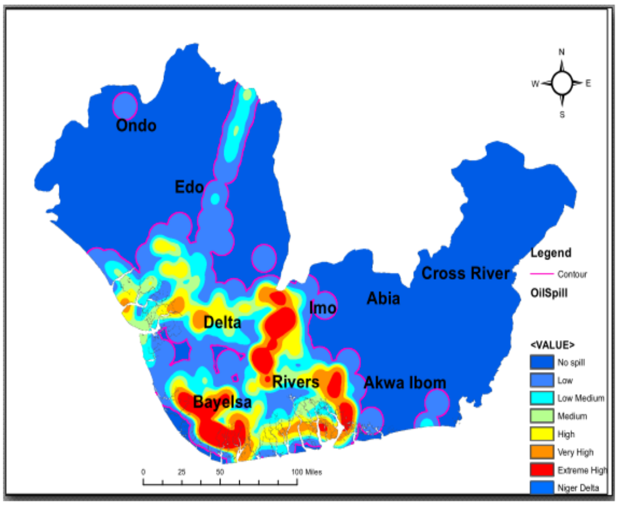

Figure 4. Oil spill hotspot map of KDE of the Niger Delta Region

Ahoada communities is the study area and the map of oil spills hot spots were drive from the hotspot map of the Niger Delta. The map of Ahoada shows areas that are more affected, moderately affected and less affected as shown in Figure 5 and 6 respectively. The hotspots vandalization areas include, Ochebeke, Idu-Ekpeye, Ukperede, Okobe, Odieke in Ahoada west, while areas like Iheke, Uduogba and Akpobo in Ahoada west, east are highly impacted. Communities falling within the moderately affected includes Akinima, Oshie and Onitu in Ahoada while places like Okobe, Ogbo, Oklisame, Obulubulu and Abessa in Ahoada east are moderately affected. With regards to the general spills which consist of accidental, natural and interdiction, the hotspots areas are Ochebeke, Oshie, Idu-Ekpeye and Ebraso in the west while Ochebe and Obulubulu from the east respectively. This has been demonstrated in Figure 6.

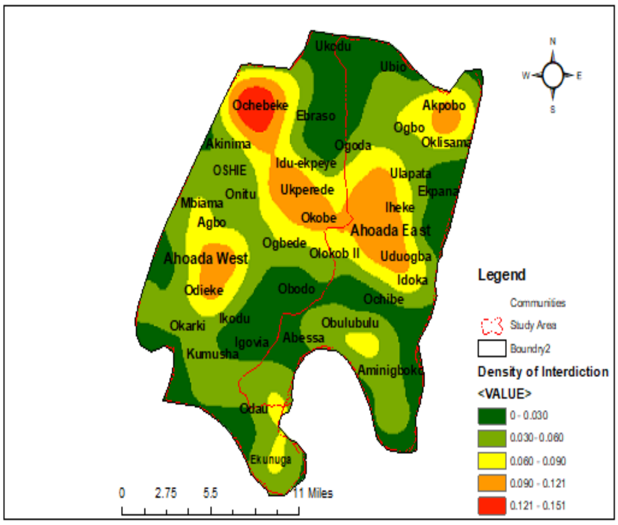

Figure 5. Oil spill hotspot map by interdictions using KDE

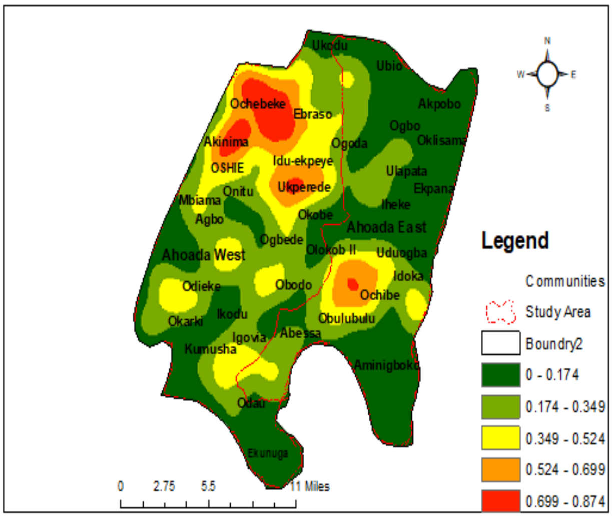

Figure 6. Oil spill hotspot map of KDE of the Niger Delta

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3.1 Fractal analysis for oil spills clustering

The results of the fractal analysis are presented in this section. A basic analysis of this fractal plot suggests a dual fractal analysis for oil spill occurrences within the study location. This is evidence by a low fractal dimension of 0.419 at distances of 1.1 km. At higher distances above 1.1 km, oil spill occurrences are characterised by a fractal dimension of 1.411 as presented in Figure 7. Also, the fractal dimension for oil spill occurrences associated with sabotage is presented on Figure 8. According to this plot, regional and local fractal for oil spill occurrences is defined by a threshold distance of 1.2 km. At scales less than 1.2 km, oil spill occurrences exhibit a fractal dimension of 0.063 while at scales above this distance, the occurrences of oil spill are defined by a fractal of 1.249. A general analysis of fractal for both oil spill types suggest a small fractal dimension values and a more discrete scale compared to the regional scale. The relative low fractal dimension values at discrete scale suggest a high clustering of oil spill locations.

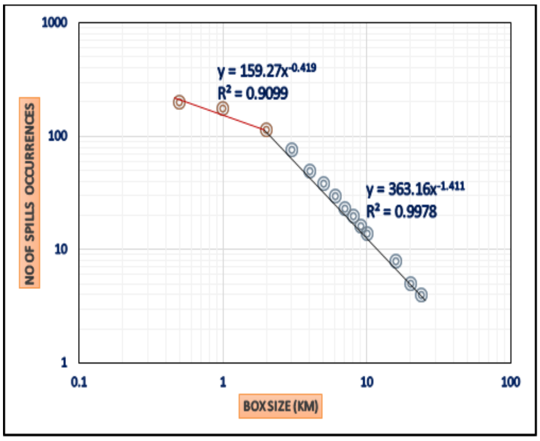

Figure 7. Box count dimension of general oil spills

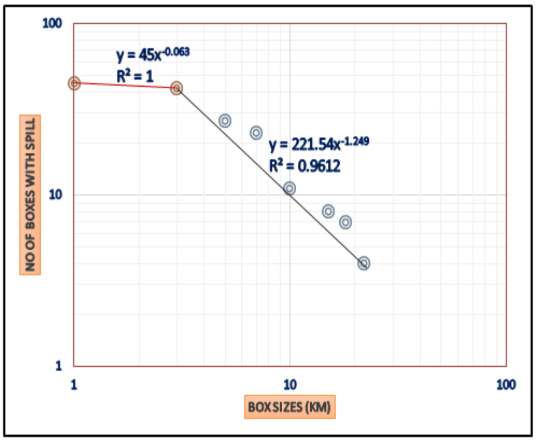

Figure 8. Box count dimension of oil spill vandalization

3.1.1 Relationship between spills and settlement:

The analysis of the relationship between spills and settlements was conducted in order to find out if there is any positive or negative relationship between them. This gives an idea about the proximity between the spills location and settlements so that proper monitoring and evaluation on the impacts of the spills on human health and the environment can be executed. Based on the result depicted in Figure 9, there is an average (nearly positive) relationship between the former and the later, this is simply because most of the oil installations are not very far away from the settlements, some are even adjacent to the settlements. This and many more have led to the spread of oil spills in and around human environments which actively exposes residents to oil pollution of varying scales near their homes, farms and fishing grounds. The spills curves been on top of the settlements curved is an indication of positivity in the relationship.

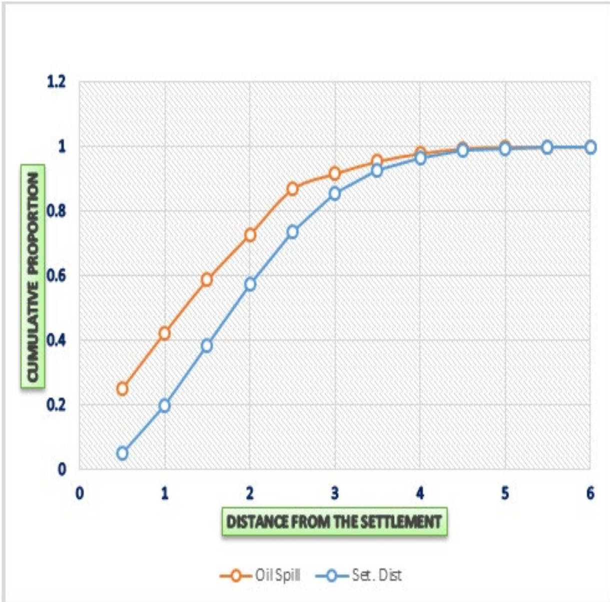

Figure 9. Proximity of spills to the settlements

However, when correlating between the settlements and the vandalization points it was found out that there is negative relationship between the vandals and the settlements as can be seen in Figure 10. This is due to the fact that oil spills by interdiction normally occur at a far distance, where the vandals hide in order to avoid been caught up by the security agencies. They normally interdict inside the creeks and locations where it is very difficult for police and other sister security agencies to have a glimpse of their operations. Technically spills curves are above that of the settlements showing no relationship exist between the two. Most of the artisanal refineries in the Niger Delta are located far away from the settlements and the location of point of interdiction and where it is locally refined are always hidden.

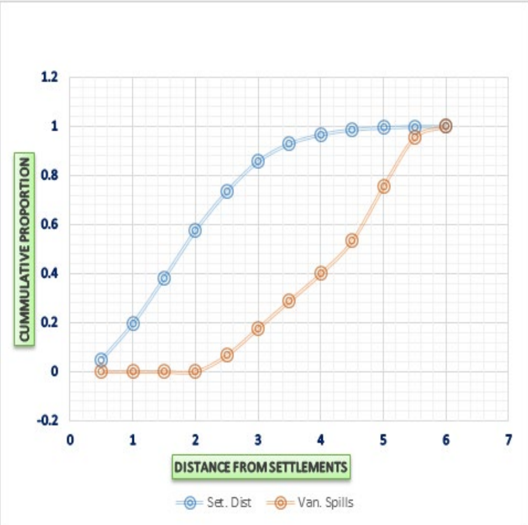

Figure 10. Proximity of settlements to the vandalization points

3.1.2 Proximity between the roads and spills locations: The result of the distance correlation between roads and spill locations are presented here. The analysis shows slightly higher proximity to the road network, signaling positive relationships as shown in Figure 11. The curved of oil spills been above that of the road is an indication that both the two share close proximity to each other and this is due to the fact that there are many other sources of oil spills around the area including spills from tankers during transportations, pipelines crisscrossing the communities' been raptured and other mystery sources of oil spills that occurred.

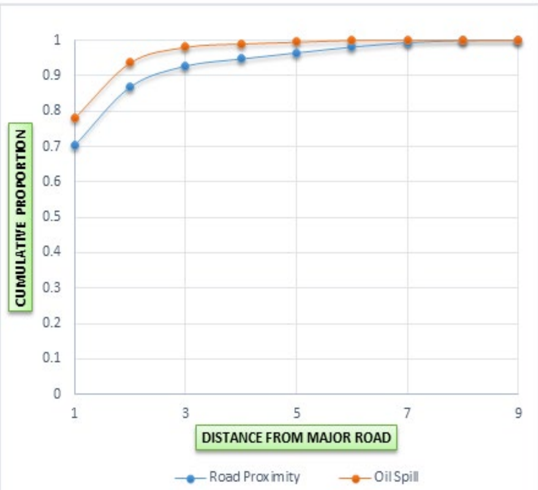

Figure 11. Proximity of roads to spills locations

However, taking into consideration, the proximity between the oil spills vandalization sites and that of roads, it is evident that the two does not share any form of relationship. Just like in the case of vandal versus settlements, the vandals hide themselves and went as far away as possible before cutting the pipe manifolds and siphoned as much oil they needed for fear of been apprehended by security personnel. The distance correlation curved depicted in 12 shows negative relationship between the two and by observation the closer the curves the more apart they are to each other and vice-versa.

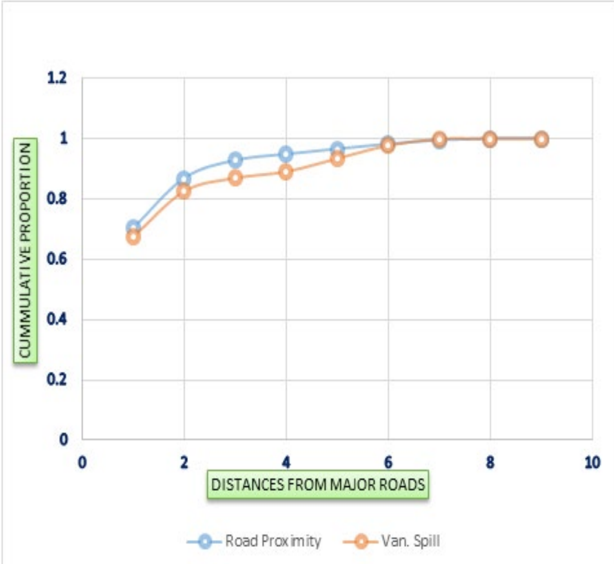

Figure 12. Proximity from vandalization points to the roads

4. CONCLUSION

Third party damage (interdiction) have negatively impacted the daily operations of both government and oil companies in the Niger Delta. The oil spill data examined in this study revealed that third party damage remains the major causes of oil spills pollution in the region. The statistics has always been that the multinational oil companies were solely responsible for pollution incidences in the region. Even though, interdiction claimed most of the spill incidences, operational failure by multinational oil companies has also contributed significantly to environmental degradation in the region. Failure to adhere strictly to the standards of maintenance and slow responses to spill incidences are responsible for operational failures. The fractal analysis applied in this study indicates that most of the destruction of Niger Deltas ecosystem is through the activities of vandals. It also shows that most of the operations of this militants are within the areas that are mostly inaccessible by the security agencies. Successive government has putting a lot of measures to ends the operations of Niger Delta militants. The report of 2013 prepared by the multinational joint task force indicated that about 3,778 artisanal refineries were destroyed, eight vessels fully loaded with 120 barges, 178 pumps, 878 boats, 5238 surface tanks, 606 pumping machines and 626 outbound engines were confiscated (Franklin et al., 2018).

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