Global Scientific JOURNALS

GSJ: Volume 10, Issue 1, January 2022, online: ISSN 2320-9186
www.globalscientificjournal.com

USING GEOSPATIAL TECHNIQUES IN ANALYZING PIPELINE OIL SPILL IN PART OF NIGER DELTA AREA, NIGERIA

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KeyWords

Digitizing, Georeferencing, Hotspot analysis, Niger Delta, Oil Spillage.

Abstract

This research work was carried out in selected state in Niger Delta area using Agip oil spill data. The research work aimed at analysing the oil spill hotspots using Geographic Information System (GIS) techniques. The data used were collected from two major sources, namely; primary and secondary sources of data. The primary data were collected by using Analogue Map of the study area. The secondary data was the Agip oil spill geospatial database of 2016, 2017 and 2018. Data Processing which includes Scanning, Reprojection, Georeferencing and Digitizing were carried out using GIS software (ArcGIS 10.5). The location of oil spill sites and quantity of oil spill were identified. Hotspot analysis was carried out to identify the area with highest oil spill intensity. The hotspots Analysis shows that the oil spill extended yearly and affects more Area. The results showed that in 2016 only part of Bayelsa State was significantly affected. In 2017 the spill highly affected the whole Bayelsa State and part of Rivers State. The oil spill tends to be highly significant in major Area of Bayelsa and less significant in the remain part. In 2018 the oil spill reduced in Bayelsa and highly extended to River State. This will help to identify the area that will be affected in future which in turn will enhance rapid spill management and effective remediation of the affected areas. This study showed that GIS is an indispensable tool in managing and predicting oil spillage, therefore, it is recommended that oil companies should always apply GIS and remote sensing techniques in identifying, managing and predicting oil spillage. This however may lead to more rapid spill management and effective remediation of impacted areas).

1.0 Introduction

An oil spill involves the discharge of oil or petroleum products into the environment. The term usually refers to oil spills in the ocean or sea leading to marine pollution. However, terrestrial oil spills are also common but are less hazardous than those occurring in the sea. Most of these oil spills occur due to human error. Some occur due to natural phenomenon and some due to environmental factors.

Oil spillage is the major source of environmental pollution in Nigeria, especially the Niger Delta area which is the center of oil exploration, the exploration, production, storage and transportation has some negative impacts on the environment. Nigeria as a nation is blessed with abundant natural resources especially energy resources that are enough to drive the country to a sustainable level of economic growth, but all in all, oil spill a common occurrence in the country (Noko, 2017).

Oil spillage is perhaps, the most significant environmental consequence of oil exploration and constitutes the industry's gravest environmental hazards. It has become a global issue of discourse, as well as how it impacts the environment and also the inhabitants of the host communities. (Joyner, 1985). It has become a recurring problem in most oil producing countries which Nigeria is not an exception. Oil spill which can be caused by natural or human factors has so many effects on both the environment and the inhabitants of the environment where oil pipelines pass through; a lot of people have suffered as a result of oil spillage in many different ways. Particularly, people who live near the banks of the Niger Delta are prone to these risks than any other.

The level of pollutants discharge into the environment in the form of oil spills pose serious environmental problems with significant, long-term impact on the environment, ecology and socio-economic life of local dwellers in affected areas (Eregha, 2009; Singh, 2008a). The Oil Spillage issues has become a significant problem not only for AGIP company and other major oil companies that engage in oil exploitation but also the Federal government as well as inhabitants within the host communities, that are directly impacted by oil spillage.

The high number of spills and their clustering at certain hotspots over a number of years demonstrates a major failure by companies not to put in place all reasonable precautions to prevent them. The fact that so many spills occur along the same stretches of pipeline means that these acts are predictable especially with application of GIS and remote sensing techniques. Companies can identify such location and the quantity of oil spilled for each year. Visualizing and identifying theses sites will enable them to take appropriate measures to protect the pipeline, such as by stepping up surveillance patrols. This work is part of my research on pipelines oil spill hostspots analysis of part of Niger Delta using Remote Sensing and GIS from 2016 to 2018.

GIS is a computer-based tool for mapping and analyzing things that exist and events that occurs on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. Remote sensing on the other hand is the acquisition of data about an object or phenomenon without making physical contact with it, often using electromagnetic radiation.

The combination of GIS and remote sensing (RS) technologies provides an ideal solution for understanding the spatial/temporal distribution of oil spills in the environment (swam and Land area) and is considered as the core of the oil spill monitoring system. Geographic Information system (GIS) and remote sensing can serve as an efficient tool for managing oil resources.

1.2 Materials and Methods

1.2.1 Study Area

The study area is located within the Niger Delta area. Some of the states where Agip Pipelines passed through in Niger Delta include; Bayelsa, Delta, Rivers and Imo state.

The Niger Delta is the delta of the Niger River sitting directly on the Gulf of Guinea on the Atlantic Ocean in Nigeria. It is situated between latitudes 3° and 5° N and longitudes 5° and 8° E. Niger Delta is typically considered to be located within nine coastal southern Nigerian states, which include: all six states from the South-South geopolitical zone, one state (Ondo) from South West geopolitical zone and two states (Abia and Imo) from South East geopolitical zone, of all the states that the region covers, only Cross River is not an oil-producing state. This region, which covers a land mass of over 70,000 km2, cuts across 800 oil-producing communities, and is the worst hit by oil spillage and gas flaring. With an extensive network of more than 900 oil wells, 100 flow stations and gas plants, over 1,500 km of trunk lines, and some 45,000 km of oil and gas flow lines, the Niger Delta has become synonymous with oil pollution

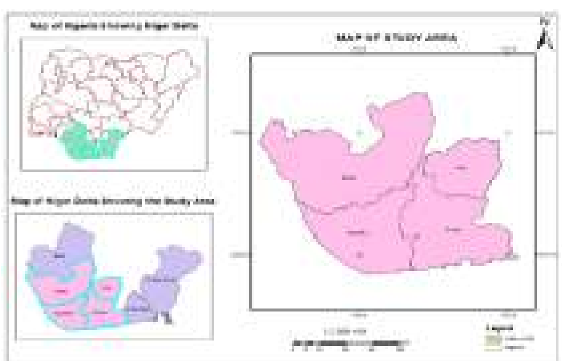


Fig 1: Map of the study area delineated from Nigerian shapefile

1.3 Methods

1.3.1 Data Acquisition

The data for this research were collected from two major sources, namely; primary and secondary sources of data. The primary data were collected by using Analogue Map of the study area. The secondary data was the Agip oil spill geospatial database of 2016, 2017 and 2018.

1.3.2 Sources and Method of Data Collection

Table 1: Detail Data Acquisition for Research (Okeke and Asogwo, 2019)

S /N	***DESCRIPTION OF DATA***	***YEAR***	***SOURCE***
1	**Analogue Map of Nigerian Agip Oil**		**National Oil Spill Detection and Response**

	Company pipe line		**Agency (NOSDRA) web site.**
2	**The Longitudinal profile and Horizontal and vertical control station of Agip Oil Major Pipeline**		**Nigerian Agip Oil Company (NAOC) and National Hydrocarbon Authority (ENI)**
3	**The geospatial Database of the oil spill record**	**2016, 2017, 2018**	**Nigerian Agip Oil Company (NAOC) and National Hydrocarbon Authority (ENI).**

1.4 Data Pre-Processing

Data pre-processing functions are house cleaning tasks that make GIS input data usable for data analysis. The objective is to get all of the GIS datasets into the same projection, and then to make each layer spatially in tune with each other. Many data pre-processing tasks include Map Scanning, reprojection and georeferencing.

1.4.1 Data Scanning

The Analogue map of the study area and longitudinal profile sheet of pipeline were scanned. The reason for scanning data is to transform the analogue data into digital. Digital data are very easy to use as input in GIS software for data processing. Scanning coverts paper maps into digital format by capturing features as individual cells, or pixels, producing an automated image (figure 3). Different methods were adopted in data processing to achieve each objective. This is a process of converting data into information or knowledge. The processing is usually assumed to be automated and running on a computer because data are most useful when well-presented and actually informative. These paper maps have to be first converted into a digital format usable by the computer. This is a critical step as the quality of the analogue document must be preserved in the transition to the computer domain. The technology used for this kind of conversions is known as scanning and the instrument used for this kind of operation is known as a scanner.

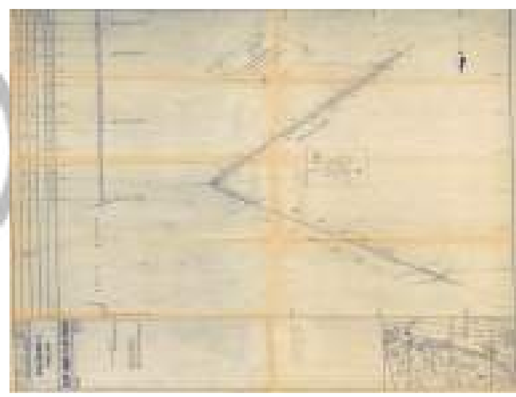


Figure 3: Analogue Map of A section of Agip Pipeline in the study Area (Source: Nigerian Agip Oil Company (NAOC)).

1.4.2 Data Reprojection

All the data used in this research work were projection into the same reference system, the reference system chosen for this projection was WGS 84 UTM zone 32N (figure 4). The ArcCatalogue of ArcGIS 10.5 was used for reference system transformation. The reference system was assigned to the scanned map. ArcCatalogue application enables conversion of data set from one projection, coordinate system, and datum to another. In Importing the Oil spill excel data sheet to Shapefile the same reference system was also selected.

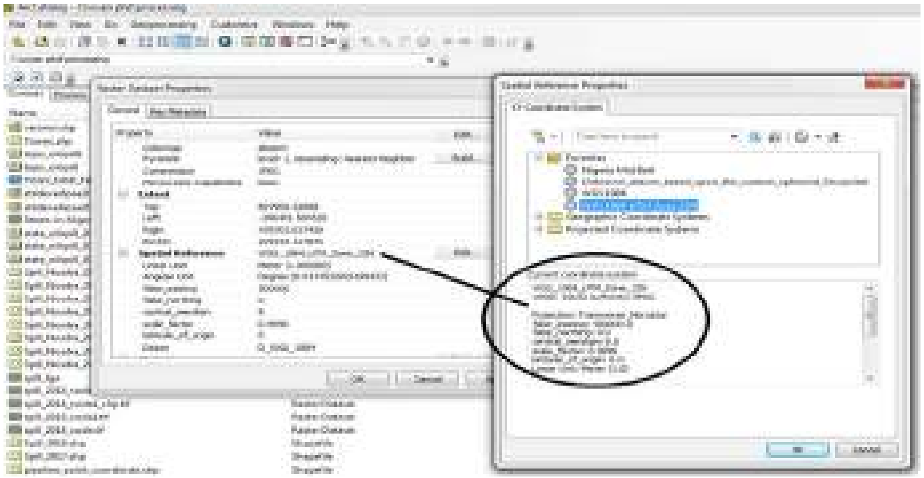


Figure 4: Definition of reference system of analogue Map of the study area (Screenshot of ArcCatalogue)

1.4.3 Georeferencing

There is a great deal of geographic data available in formats that cannot be immediately integrated with other GIS data. In order to use these types of data in GIS it is necessary to align it with existing geographically referenced data, called georeferencing. The process of georeferencing relies on the coordination of points on the scanned image (data to be georeferenced) with points on a geographically referenced data (data to which the image will be georeferenced). By" linking" points on the image with those same locations in the geographically referenced data to create a polynomial transformation that converts the location of the entire image to the correct geographic location. The linked points on each data layer are called control points. The selection of control points is important.

The analogue map of the study area was Scanned and imported into ArcMap 10.1, environment. The reference system was defined as ellipsod WGS 84, UTM zone 32 Hemisphere North. It is needed to register the analogue Map with Shapefile of Administrative map of Nigeria. Four points were recognized from both data and were used as control point for georeferencing. The georefencing toolbar in ArcGIS 10.5 were turn on. The add point control was used to register the point using 1st order polynomial transformation (see figure 5)

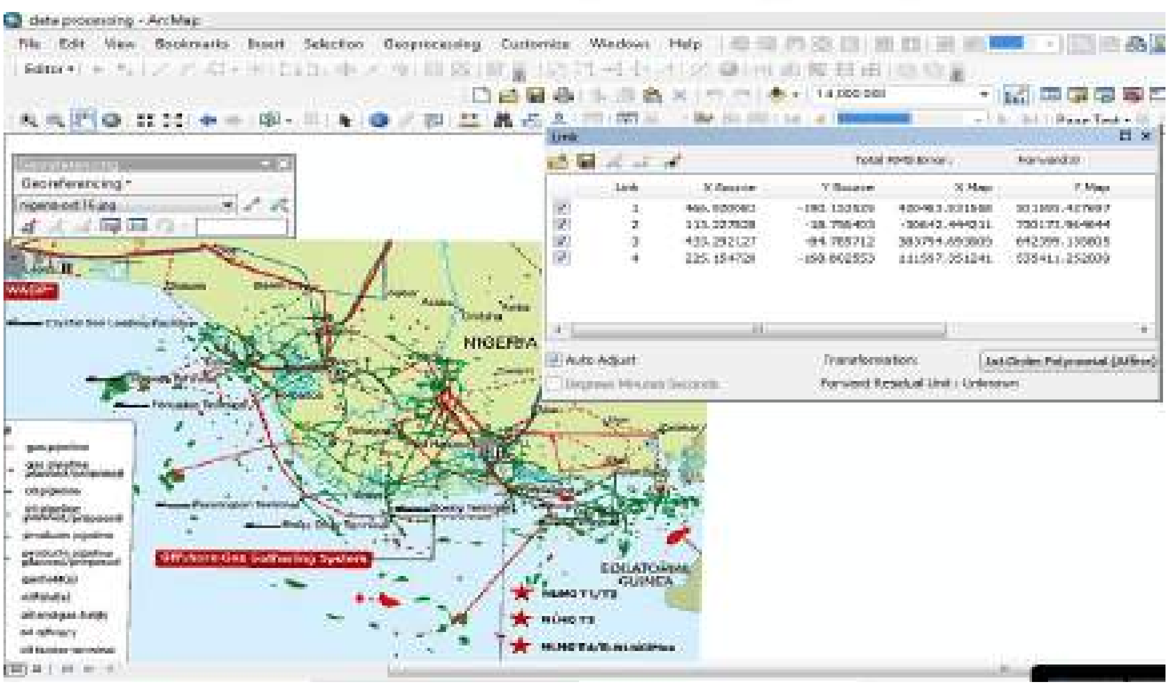


Figure 5: Process of Georeference of Agip pipeline (Source: From ArcMap)

1.4.5 Map Digitization

The digitizing process was done by creating new layers in ArcCatalog, and then adding features in ArcMap. The created feature was added to ArcMap and editor was started to digitize the pipeline feature. The polygone shapefile of State boundary were extracted from Nigerian administrative geospatial data.

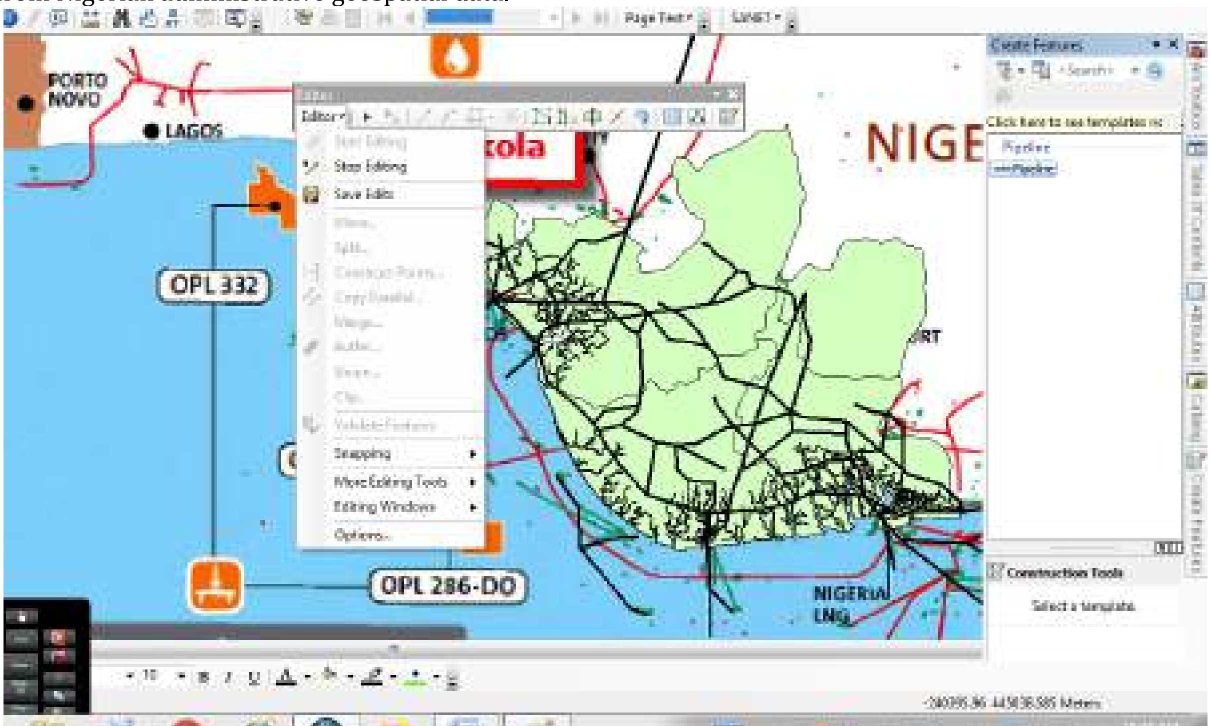


Figure 6: Process of digitization of Pipeline feature of the study area in ArcMap environment

1.5 Data Processing

The data processing involves the method used to achieve the objective of the research. Data processing systems are often referred to as information systems to emphasize their practicality, nevertheless, both terms are roughly synonymous performing similar conversions; data processing system typically manipulate raw data into information and likewise information system typically take raw data as input to produce information as output. In context of data processing, data are defined as numbers or characters that represent measurements from observable phenomena. A single entity is a single measurement from observable phenomena. Measured information is then algorithmically derived and or logically deduced and/or statistically calculated from multiple data. Information is defined as either a meaningful answer to query or a meaningful stimulus that are moved on into further queries. From this perspective; data processing becomes the process of converting information into data and also the converting of data back into information.

1.5.1 Identification of the Location of Oil Spill within the Study Area.

The oil spill geospatial database in excel sheet format was imported to ArcGis 10.5. The process of conversion of the spill excel sheet was done in Arc Catalogue environment. The sheet1 containing the database was right click and the create feature class from X,Y was selected to execute the task. In Dialogue box the parameters were set accordingly. In ArcMap environ, the attribute data of oil spill was sorted in alphabetical order using the Site Name of the oil spill column. The summary statistics in attribute tool was applied on the Estimated Spill quantity (figure7). The result of the query was used to produce the oil spill map and also was exported to excel sheet to produce the histogram.

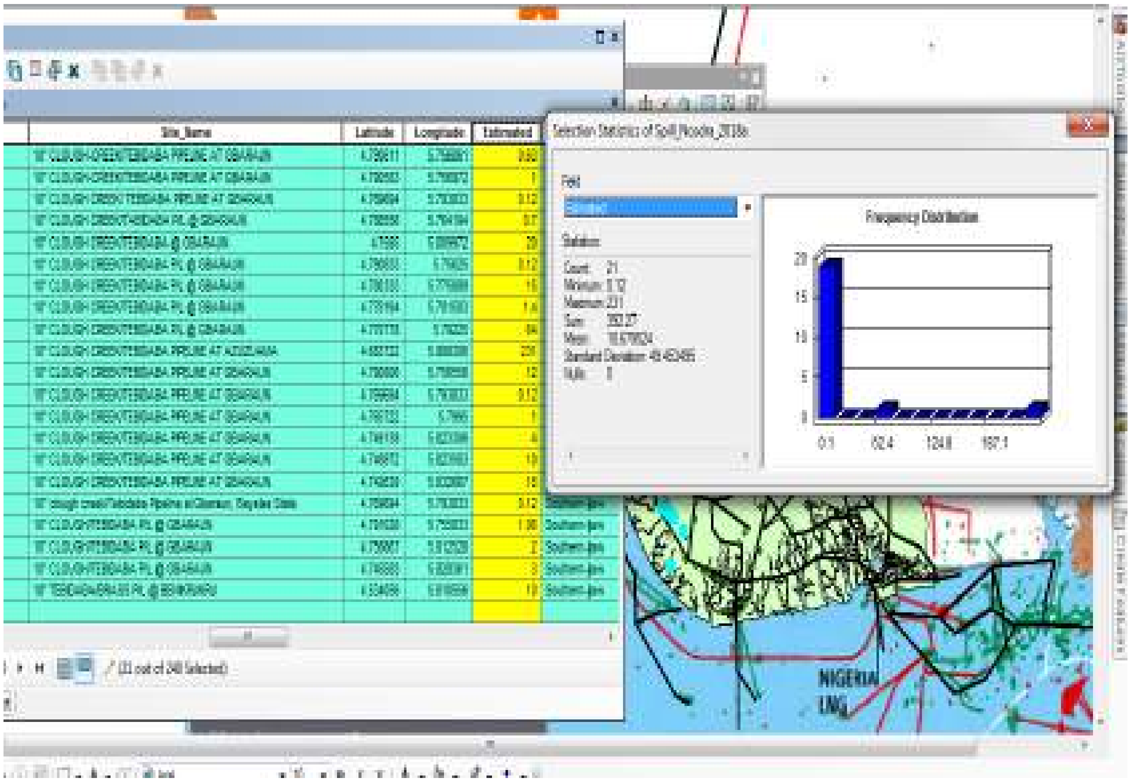


Figure 7: Process of spatial query to identify the oil spill in the study area (Source Author).

1.6. Data Analysis and Presentation

1.6.1 Inventory of spatial Distribution of Oil Spill within the study Area in 2016

The table 1.1 below revealed that 46 spots of oil spill occurred along 10" cloud –creek / Tebidara pipeline and the quantity of spill was about 397.002 bbl.

Along 10" Ogoda _Ohie delivery Line, 2 spots of oil spill were found at 199.35 bbl quantity estimated.

Along 14" Ogboimbiri/Tebidara Pipeline, 14 spots of oil spill were discovered at estimated quantity of 1780.57bbl.

Along 18" Obama / Brass pipeline 4 spots of oil spill were found at 81.1bbl quantity estimated. 132 spots of oil spill occurred along 18" Tebidara/Brass Pipeline at estimated quantity of 810.026bbl.

Along 24" Ogada –Brass Pipeline 3 spots of oil spill were found and the estimated quantity is 306.4bbl.

Along 4" Oshie 15Ss flowline, 24 spots of oil spill were counted at quantity estimation of 280.831bbl.

At Umoru 6T well head 2 spots of oil spill were recorded at about 388.9618bbl estimation. The other minor spills along other pipeline were counted to be 109 spot and the estimated quantity was 388.9618bbl. The spatial distribution of the oil spill along Agip Pipeline is illustrated in the map (figure 4.1.1b) below. The total oil spill quantity in 2016 along Agip Pipeline is recorded to be 4433.7408 bbl at total of 336spill spot.

The histogram (figure 4.1.1a) shows that the highest oil spill spot was found to be along 18" Tebidaba/Brass pipeline with about132 spots and 810.026 bbl oil spills. However, the highest oil spill quantity occurred along 14'' Ogboinbiri/Tebidaba pipeline with estimated quantity of 1780.57bbl at 14 different spots.

Table 1.1: Oil Spil along Agip pipeline 2016 (Source: researcher Field work)

S/N	AFFECTED PIPELINE	No. OF SPILL	ESTIMATED QUANTTITY (BBL)
1	10'' Cloudh-Creek/Tebidaba Pipeline	46	397.002
2	10'' Ogoda -Oshie Delivery Line	2	199.35
3	14'' Ogboinbiri/Tebidaba Pipeline	14	1780.57
4	18'' Obama/Brass Pipeline	4	81.1
5	18" Tebidaba/Brass Pipeline	132	810.026
6	24'' Ogoda-Brass Pipeline	3	306.4
7	4'' Oshie 15ss Flowline	24	280.831

8	Umoru 6t Well Head	2	189.5
9	Other	109	388.9618
TOTAL		**336**	**4433.7408**

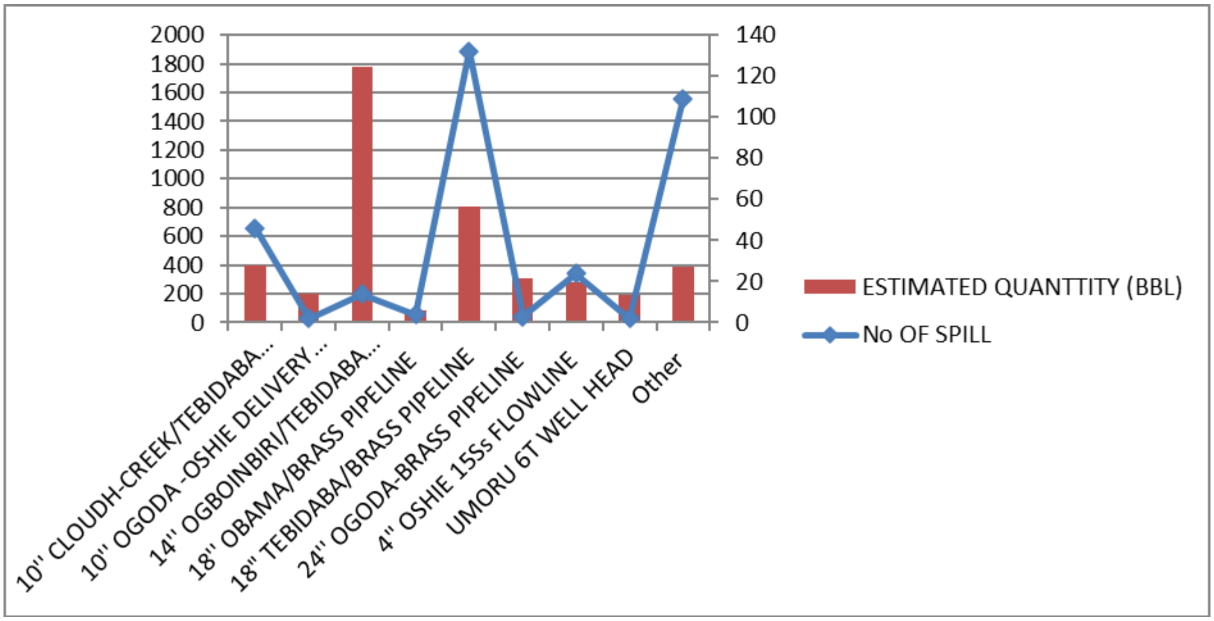


Figure 1.3: Histogram of oil Spill along Agip pipeline 2016 (Source: Vivian and Okeke, 2019)

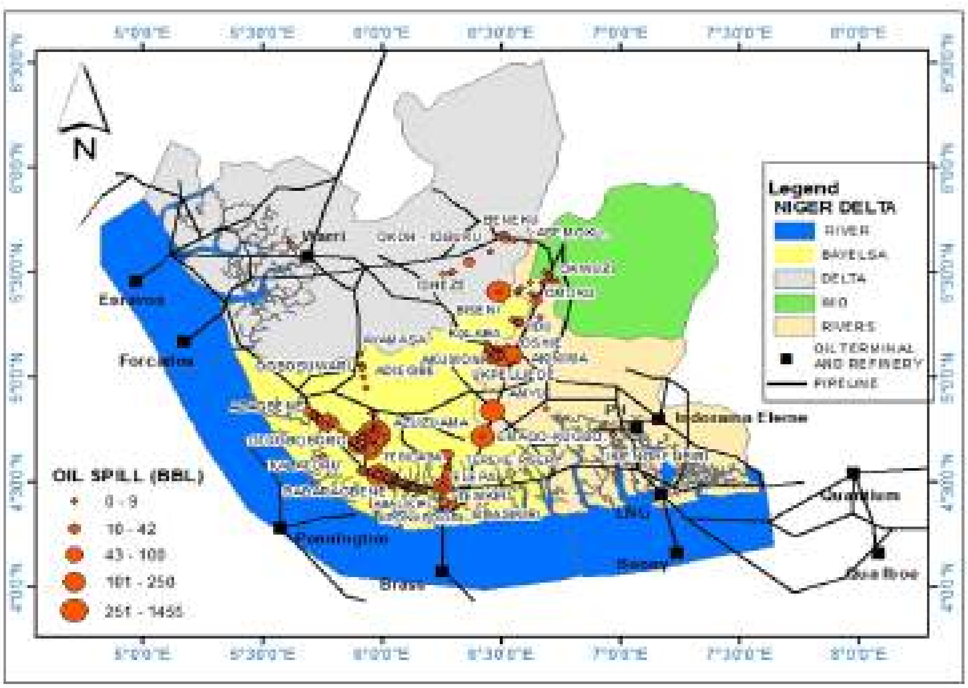


Figure 1.4: Map of oil Spill along Agippipeline 2016 (Source: Vivian and Okeke, 2019).

1.6.2 Inventory of Spatial Distribution of Oil Spill within the Study Area in 2017

The table.1.2 below shows that the total oil spill in the study area is about 3566.959bbl at about 262 spots. Along 10” Clough Creek/Tebidara Pipeline 29 spot of oil spill were recorded at about 502.39bbl quantity estimation. Along 10” Oshie-Ogoda Pipeline six (6) spots were found and about 1145.707bbl quantities of oil were spilled out. 63.4 bbl oil spills were estimated along 14” Akri_Ebocha pipeline at five (5) spot locations. Along 14” Ogbainbiri / Tebidara Pipeline seven (7) spot were found

and were estimated at 181.45bbl. At three (3) different locations along 24" Ogoda - Brass pipeline 839.176bbl quantities were spilled out. Along 6" Ogboinbiri/ Tebidara Pipeline Five (5) spots were found at quantities of 197.1bbl. Along Ebegoro 12Ls Flowline eighteen (18) spots were recorded at estimated quantity of 62.7bbl. The Estimated quantities of 100 bbl oil spill were found in only one (1) spot at Kwale 2 well Head. Along ObiafuFlowline 51 spots were found and 79.613 bbl oil spill quantities were estimated. Along UmuoruFlowLine, three (3) spot of oil spill were found and were estimated at 112 bbl. The other minor spills were estimated to be 283.423 along 134 spots (see detail in appendix 2). The spatial distribution of the oil spill along Agip Pipeline is illustrated in the map (figure 1.6) below. The total oil spill quantity in 2017 along Agip Pipeline is recorded to be 4433.7408 bbl at total of 336 spill spots estimated at 3566.959bbl.
The histogram (figure 1.5) shows that the highest oil spill spot was found to be along Obiafuflowline with about51spots and 79.613 bbl oil spill, whoever the highest oil spill quantity occurred along 10'' Oshie-Ogoda pipeline with estimated quantity of 1145.707bbl at 5 different spots.

Table 1.2: Oil Spill along Agip pipeline 2017 (Source: researcher Field work)

S/N	AFFECTED PIPELINE	NO OF SPILL	ESTIMATED QUANTTITY (BBL)
1	10'' Clough Creek/Tebidaba P/L	29	502.39
2	10'' Oshie-Ogoda Pipeline	6	1145.707
3	14'' Akri-Ebocha Pipeline	5	63.4
4	14'' Ogbainbiri/Tebidaba P/L	7	181.45
5	24'' Ogoda - Brass Pipeline	3	839.176
6	6'' Ogboinbiri/Tebidaba F/L	5	197.1
7	Ebegoro 12ls Flowline	18	62.7
8	Kwale 2 Well Head	1	100
9	ObiafuFlowline	51	79.613
10	UmuoruFlowline	3	112
11	Other	134	283.423
Total		**262**	**3566.959**

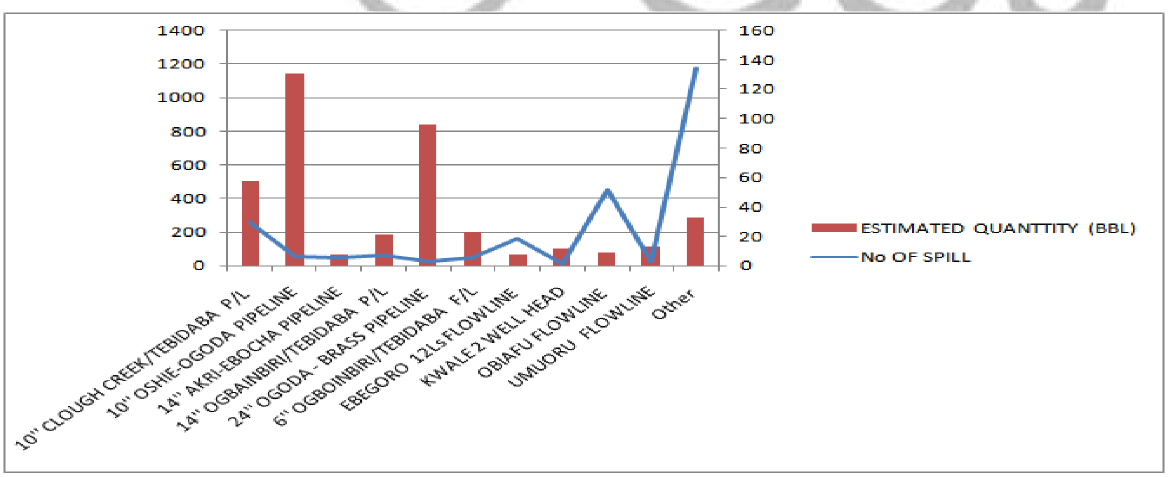


Figure 1.5: Histogram of oil Spill along Agip pipeline 2017 (Source: researcher Laboratory)

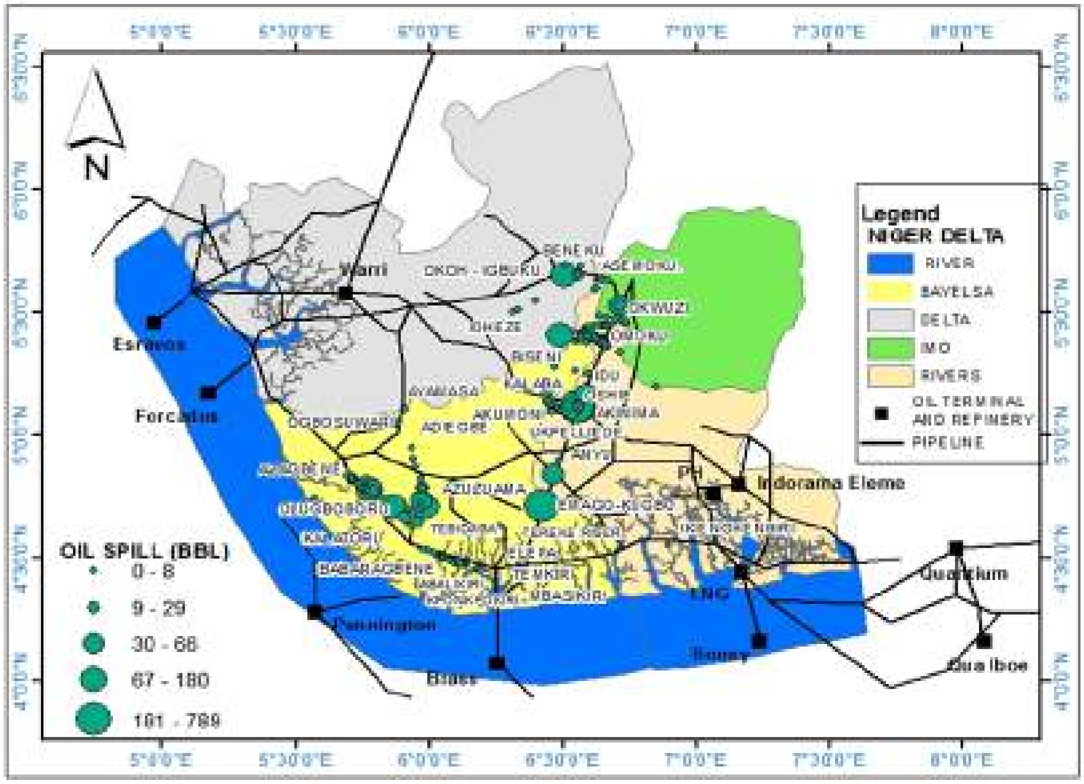


Figure 1.6 Map of oil Spill along Agippipeline 2017 (Source: researcher GIS Laboratory).

1.6.3 Inventory of spatial Distribution of Oil Spill within the study Area in 2018

The table 1.3 below shows that the total of 228 oil spill spot were found along Nigerian Agip Oil Company (NAOC) and pipeline and the spill was estimated at 3672.791bbl quantities. The spatial distribution of the spill was illustrated in figure 1.7. The study revealed that 20 spots were found along 10” Clough Creek/Tebidaba pipeline with estimated quantity of 382.270bbl. Along 10” Oshie-Ogoda pipeline 4 oil spill spots were discovered and were estimated at 366.370bbl. Six (6) spots were recorded at 14” Ebocha-Akri pipeline with 186.538bbl quantity. Spill also occurred at 18 spots along 18” Tebidaba/Brass pipeline and was estimated as 185.957bbl. Along 24 Ogoda Brass Pipeline 17 spots were found and were estimated at 1507.362bbl. Along 6” Azuzuama/Tebidaba Pipeline nine (9) spill spot were found with estimation of 88 bbl. Along Ebegoroflowline 18 oil spill spots were recorded with estimation of 292.899bbl. Also, along ObiafuFlowline 43 spot were found with small estimation of 49.743bbl. The estimation of 48.430bbl at 15 different spots was recorded along OshieFlowline while 48.430 bbl spills across 2 oil spill spots were found along Tebidaba well Flowline. The other minor spills were estimated at 150.174bbl across 75 spots distributed along other Agip pipeline.

The histogram (figure 1.6) shows that the highest spill spot number was along Obiafuflowline with 43 spots, but the spill quantity was not significant (49.743bbl). However, the highest spill quantities were estimated at 1507.362bbl and was found at only 17 spot along Ogoda Brass pipeline.

Table 1.3: Oil Spill along Agip pipeline 2018 (Source: researcher Field work)

	AFFECTED PIPELINE	No OF SPILL	ESTIMATED QUANTTITY (BBL)
1	10'' Clough Creek/Tebidaba P/L	20	382.270
2	10'' Oshie-Ogoda Pipeline	4	366.370
3	14" Ebocha-Akri	6	186.438
4	18'' Tebidaba/Brass	18	185.957
5	24' Ogoda Brass Pipeline	17	1507.362
6	6'' Azuzuama/Tebidaba	9	366.430

7	6" Nembe South 5t Flowline	1	88.000
8	EbegoroFlowline	18	292.899
9	Obiafu 26l Flowline	43	49.743
10	Oshie 15 L Flowline	15	48.719
11	Tebidaba Well 10tbg 4'' Flowline	2	48.430
12	Other	75	150.174
Total		**228**	**3672.791**

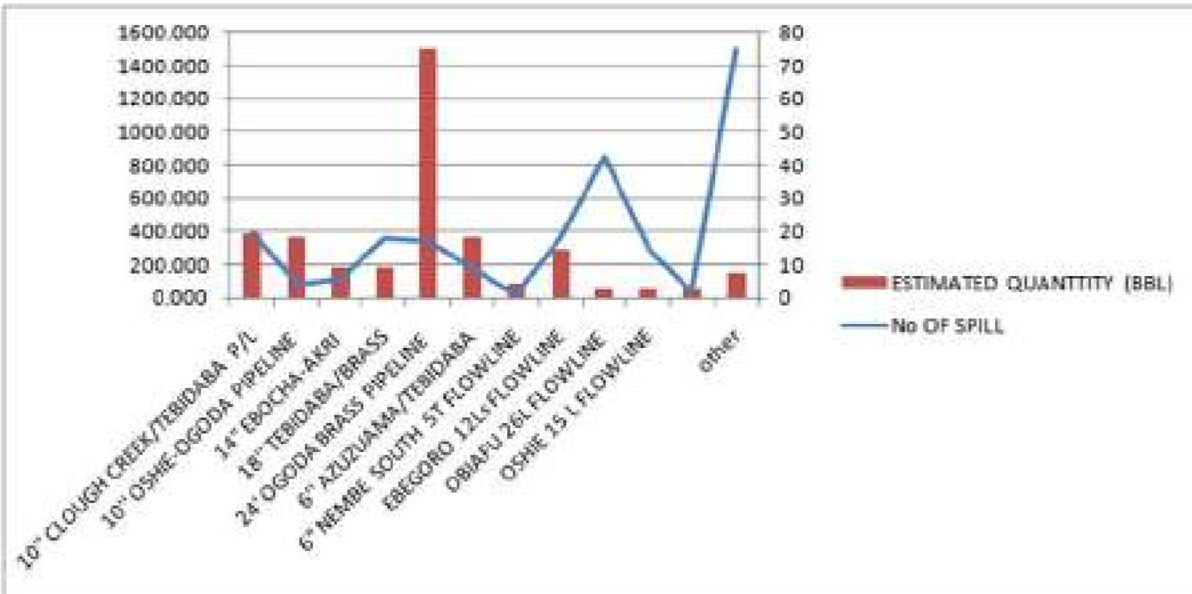


Figure 1.6: Histogram of oil Spill along Agip pipeline 2018 (Source: Researcher Laboratory)

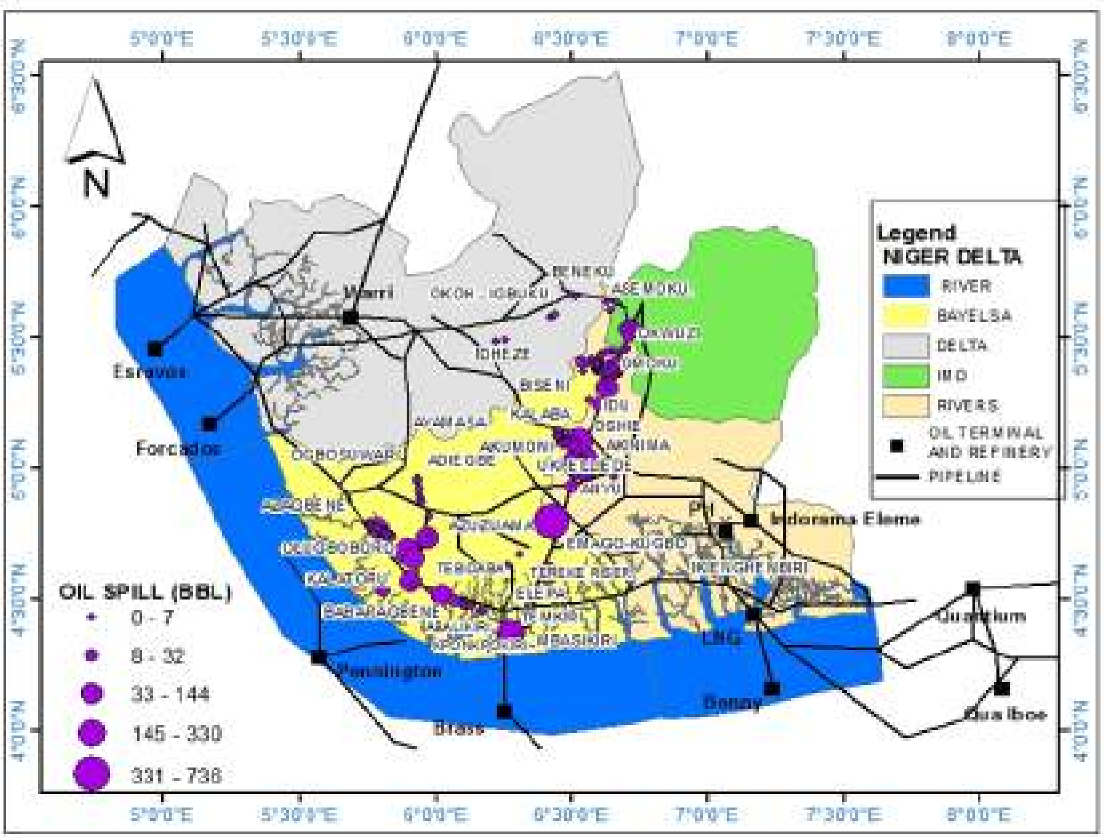


Figure 1.7: Map of oil Spill along Agip pipeline 2018 (Source: researcher GIS Laboratory)

1.7 Hot Spot Analysis

The administrative Local Government Area (LGA) boundary the study area was use to summarize the sum of the quantity of oil spill estimation using zonal statistical as table in zonal analysis tool. The join attribute tool was used to join the output table to the LGA feature using LGA name as a key. The Hot spot analysis (Getis Ord Gi*) of spatial statistic in ArcGIS 10.5 was used to carry out the hotspot analysis. The Fixed_Distance Band was chosen for conceptualization of spatial relationship and the Euclidean Distance was chosen as Distance method.

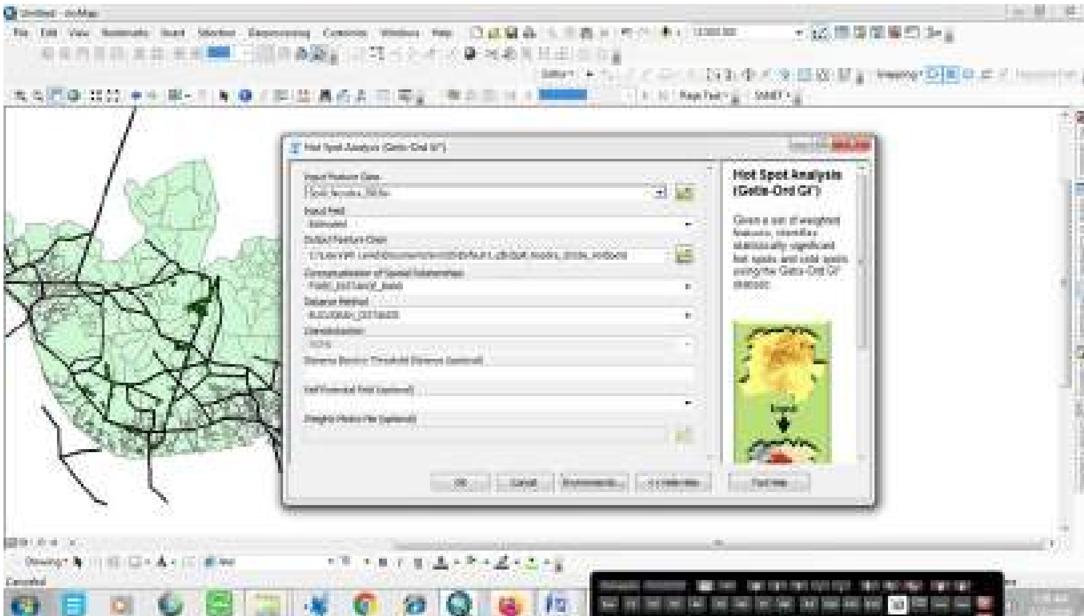
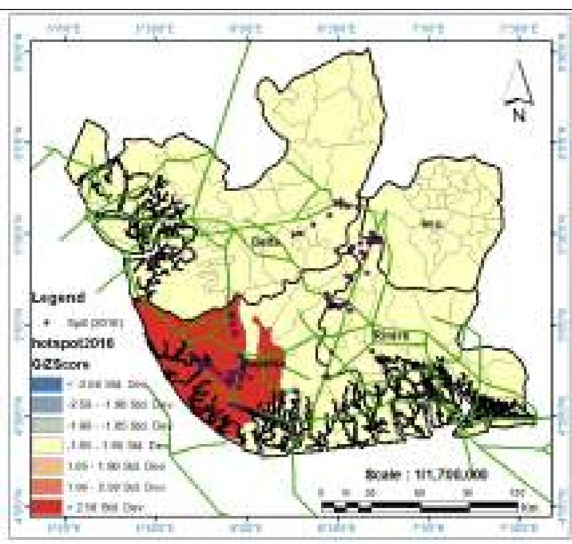
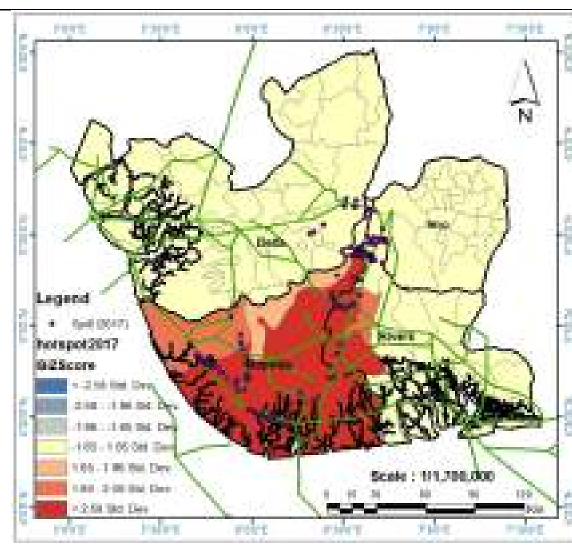
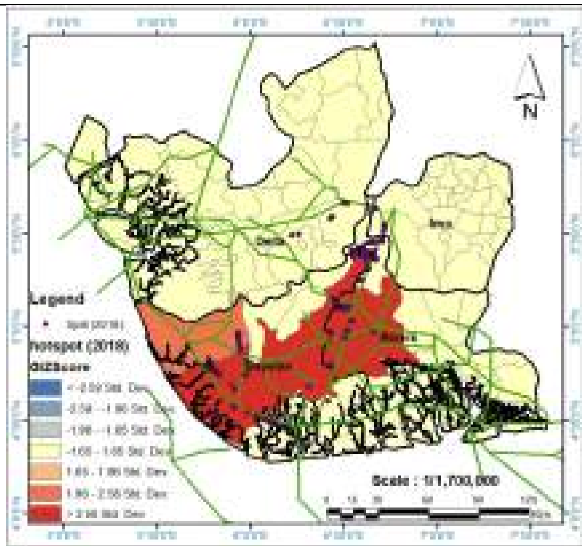


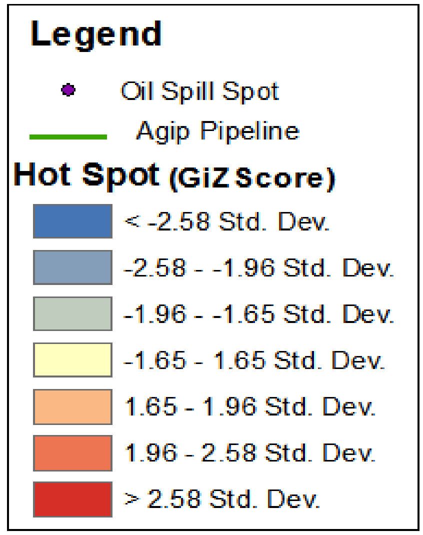
Figure 8: Process of Hot spot Analysis of Agip Pipeline Network

The figure 9 below shows the spatial distribution of oil spill hot spot in Niger Delta from 2016, 2017 and 2018. The Hot spot analysis (Getis Ord Gi*) carried out in this study shows that the Z score in High for whole the year of study and closer to 2.58 Standard Deviation (figure 9d), this is implied that the oil spill is more concentrated and highly clustered. It has also revealed that the oil spills extended yearly and affect more Area. In 2016 only part of Bayelsa State was significantly affected (figure 9a). In 2017 the spill highly affected the whole Bayelsa State and part of Rivers state. The oil spill tends to be highly significant in major Area of Bayelsa and less significant in the remain part (figure 9b). In 2018 the oil spill reduced in Bayelsa and highly extended to River's state. The River State oil spill is significantly increased (figure 9c).

	
a: Oil spill Hot spot in 2016	b: a: Oil spill Hot spot in 2017



c: a: Oil spill Hot spot in 2018



d: Legend

Figure 9: Map of Hot spot Analysis (Getis Ord Gi*) of the study area

1.8 Result Discussion

The study revealed that spatial distribution of oil spill along Agip pipeline varied from location and time. In 2016 the result shows that the highest oil spill spot was found to be along 18"Tebidaba/Brass pipeline with about132 spots and 810.026 bbl oil spills. However, the highest oil spill quantity occurred along 14''Ogboinbiri/Tebidaba pipeline with estimated quantity of 1780.57bbl at 14 different spots. In 2017 the highest oil spill spot was found to be along Obiafuflowline with about 51 spots and 79.613 bbl oil spills and the highest oil spill quantity occurred along 10''Oshie-Ogoda pipeline with estimated quantity of 1145.707bbl at 5 different spots.

In 2018 the highest spill spot number was along Obiafuflowline with 43 spots, but the spill quantity was not significant (49.743bbl). However, the highest spill quantities were estimated at 1507.362bbl and was found at only 17 spot along Ogoda Brass pipeline.

Hotspots Analysis also shows that the oil spill extended yearly and affects more Area. In 2016 only part of Bayelsa State was significantly affected. In 2017 the spill highly affected the whole Bayelsa State and part of Rivers state. The oil spill tends to be highly significant in major Area of Bayelsa and less significant in the remaining part. In 2018 the oil spill reduced in Bayelsa and highly extended to River's state. The river state oil spill is significantly increased.

1.9 Conclusion

The prevalence of oil spills in the Nigeria has led to severe environmental degradation which has caused much tension in Niger Delta area. Geographical Information Systems (GIS) offer a means to understand the situation in the study area as a result of a spill from facilities. GIS can analyze spill data to enhance understanding spillage spatial distribution, thereby contributing to oil spill management.

The results of the analysis have shown that GIS approach offers a means to understand the situation in the study area as a result of a spill. It was used to map the locations of oil spill; the quantity spilled each year and also to identify the oil spill hotspots. This can enable the oil company to predict the area prone to oil spill, in order to take appropriate measures to protect the oil pipelines, such as by stepping up surveillance patrols.

It also revealed that GIS is an indispensable tool in managing and predicting oil spillage; therefore, it is recommended that oil companies should always apply GIS techniques in identifying, managing and predicting oil spillage. This may lead to more rapid spill management and effective remediation of impacted areas.

Acknowledgment

This paper is part of my PhD research work titled: Pipeline Oil Spill Hotspots Analysis of Part of Niger Delta Area, Nigeria Using Remote Sensing and GIS From 2016 to 2018, it was written for the award of a PhD at the GeoInformatics and Surveying Department, University of Nigeria, Nsukka, Enugu Campus.

The author wishes to thank the Nigerian Agip Oil Company for providing free of charge the oil spill data used for the research work. The author would also like to sincerely thank the supervisor, reviewers and everyone who contributed in one way or the other for the success of this research.

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