Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 12 ~ Issue 11 (November 2026) pp: 01-17
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Crude Oil Spill Risk Classification And Management Across Rivers State, Nigeria

[1]M. B. Akan, [2]M. Ogoro and [2]E. I. Elenwo
[1]*Department of Geography and Environmental Science*
University of Calabar
[2]*Department of Geography and Environmental Management*
University of Port Harcourt

Abstract
This study assessed the spatial distribution, risk factors, temporal trends and predictive management of oil pollution in Rivers State using geospatial techniques. an Oil Pollution Risk Prediction and Management Model (OPRPM) by integrating proximity to oil pipelines, oil wells and flow stations, historical spill locations, population density and socio-economic conditions. Major factors associated with oil-pollution risk include proximity to petroleum infrastructure, illegal oil refining and oil theft, population growth and settlement expansion, and socio-economic vulnerability. Sabotage was identified as the dominant source of oil-spill incidents, followed by equipment failure and corrosion. Temporal analysis from 2009 to 2024 showed considerable variations in spill occurrence, with 2015 recording the highest occurrence and 2009 the lowest, while Ogba-Ndoni recorded a peak spill volume of 43,852.49 barrels in 2015. The OPRPM classified Rivers State shows that very-high-risk areas were concentrated around Eleme, Oyigbo, Okrika, Ogu/Bolo, Bonny, Degema, Port Harcourt and parts of Obio/Akpor. The study concludes that GIS-based spatial modelling can be used to provide an effective approach assessing community vulnerability. The study therefore recommends that more actions should be put in place to reduce the incidence of oil sabotage across the study area.

Keywords: *Management, Trend, Prediction, Temporal, Vulnerability, Sabotage*

Received 25 Oct., 2026; Revised 04 Nov., 2026; Accepted 06 Nov., 2026 © The author(s) 2026.
P*ublished with open access at* ***www.questjournals.org***

I. Introduction

Petroleum resources have contributed greatly to global energy demand and to the economic development of oil-producing countries, e.g., Nigeria, over the past fifty–five years. The petroleum industry has a significant global influence, and petroleum hydrocarbons are regarded as an essential commodity underpinning today's global economy (Asghar, Malik, and Javed, 2016). Since the discovery of petroleum resources in commercial quantities in Oloibiri in 1956, Nigeria has been among the group of oil-producing countries and remains one of Africa's largest Oil-producing nations (Ite et al., 2018).

Oil spillage, as a term, refers to the release of liquid petroleum hydrocarbons into the environment due to human activity or malfunctioning equipment, and is a form of pollution. Oil spills include releases of crude oil from tankers, offshore platforms, drilling rigs, pipelines, and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, and heavier fuels used by large ships, such as bunker fuel, or the spill of any oily white substance, refuse, or waste oil. Deliberate acts such as sabotage, oil bunkering, poor maintenance of engineering equipment, and tanker accidents cause oil spills. The Niger Delta region of Nigeria, in which the majority of the petroleum hydrocarbon exploration is carried out in Nigeria, is faced with high oil spill cases and is rated as one of the most oil spills vulnerable areas in the world (United Nations Environment Program, 2011)

The investigation of petroleum hydrocarbons in Nigeria's Niger Delta has led to considerable environmental hazards, mainly due to pollution. Pollution from exploration, development, and production is widespread, with common issues such as facility sabotage, operational failures, accidental discharges, pipeline vandalism and leaks, bunkering, and illegal refining. According to Ite et al. (2018), poor environmental management by the petroleum industry and the lack of effective regulation by Nigeria's agencies have intensified

contamination, adversely affecting local communities' socio-economic conditions, health, and the environment. Oil spills are among Nigeria's most severe environmental challenges, especially in the Niger Delta. Many spills are unreported (Oyinloye & Olamiju, 2013), but the Nigerian National Petroleum Corporation (NNPC) documented over 20,000 spills in the pipeline sector from 2006 to 2013 (NNPC, 2013). An independent analysis estimated that more than 115,000 barrels of oil are spilled annually in the region (Oyinloye & Olamiju, 2013). Twumasi and Merem (2006) reported 4,835 oil spill incidents between 1976 and 1996, which caused serious coastal environmental damage (Nwilo & Badejo, 2006a). The terrain of the Niger Delta is becoming increasingly difficult to access because of militancy and unrest. Previous data collection efforts relied mainly on reports from paid ecotoxicologists or environmental impact assessments. However, GIS technology now enables improved data capture, analysis, and management of oil spill issues. Therefore, this study aims to conduct a comprehensive examination of the history and context of oil spillage in Rivers State, Niger Delta. There is currently limited research on how various land cover types are affected or vulnerable to oil spills, as well as on trends over different years based on spill data. To address these gaps, this research intends to use GIS to identify and evaluate oil spill impacts, revealing patterns and trends in spills within the study area.

Crude oil remains the most significant source of energy in the world, such that the size of an economy is correlated with crude oil consumption (Fantazzini et al., 2011). Crude oil is used in transportation, heating, cooling, and energy generation, and its by-products serve as feedstocks in the petrochemical industry (Hughes & Rudolph, 2011). Therefore, to meet global demand, sophisticated technologies for exploring and extracting crude oil have been developed, and research is still ongoing to improve them. Today, oil reserves are discovered almost daily around the globe, both offshore and onshore. Thus, since the cheapest means of moving bulk crude over long distances is by pipeline (Kandiyoti, 2012), the last couple of years have witnessed increased construction of oil and gas pipelines worldwide (Marcoulaki et al., 2012).

According to Marcoulaki et al. (2012), 193,100 km of international pipelines were planned in December 2011 alone, compared with 28,885 km and 39,059 km for the same period in 2009 and 2010, respectively. In the United States of America (USA), states such as Alaska, California, Louisiana, Michigan, Oklahoma, Texas, and Wyoming are major producers of crude oil (US Energy Information Administration, 2013). On the international scene are countries such as Saudi Arabia, Iran, Iraq, Kuwait, Algeria, Angola, Ghana, Libya, Indonesia, Russia, Mexico, Venezuela, and Canada. Despite known direct and indirect impacts of oil exploration and production on the environment and human health (Finer et al., 2013), the list of oil-producing countries and the quantities produced globally continues to grow. The USA, China, and Japan consume 18.9, 8.9, and 4.5 million barrels per day, respectively, ahead of other consuming nations (US Energy Information Administration, 2013). The significance of oil production in national economic development cannot be overstated; as such, MOCs and governments of producing countries work together to meet demand for crude oil in return for revenue and investment in the socio-economic development of their countries (Kandiyoti, 2012). For instance, Nigeria attracts foreign oil companies to invest in the country because production is cheap; the cost of producing one barrel of crude oil is about $3.5 onshore and $5.0 offshore (Oni and Oyewo, 2011; NAPMS, 2012). The discovery of oil in Nigeria in 1956 led to the influx of companies such as Chevron, Exxon, Gulf, Mobil, Royal Dutch/Shell, and Texaco into the country. The influx of these companies soon translated into more than 45,000 km of multi-product pipelines linking oil fields and flow stations to export terminals and refineries in the country (Ugochukwu and Ertel, 2008; Edino et al., 2009; Sojinu, 2010; Achebe et al., 2011).

Oil pipeline spills can be caused by structural failure, operation error, and third-party damage (TPD) (Achebe et al., 2012; Kandiyoti, 2012). TPD, such as accidental rupture of pipelines, is a common phenomenon, but recently, intentional TPD, such as sabotage and illegal bunkering of hostile and conflict pipelines, is on the increase in places like Mexico, Colombia, the Middle East, Asia, and Africa (Steiner, 2010; Kandiyoti, 2012). The International Tanker Owners Pollution Federation (ITOPF) maintains data on oil spill incidents worldwide; its records indicate that vessel grounding, collision, hull failure, equipment failure, fire, and explosion are the main sources of oil spillage. (ITOPF, 2010).

Despite global awareness of oil spill incidents, little attention is paid to onshore oil spills compared to offshore (Fingas, 2000; Reible, 2010; Chen & Denison, 2011). The Exxon Valdez (1989), Braer (1993), Prestige (2002), and the BP Deep Horizon (2010) oil spill incidents, among others, are common examples. Although evidence shows a decrease in oil spills of more than 7 tonnes at sea from 1970 to 2010 (ITOPF, 2011), there is no record of global oil pipeline spills.

The demand for oil has increased the movement of crude and petroleum products from production platforms to end users. Movement involves transfers from one mode of transport, such as a tanker, pipeline, railcar, or truck, to another (Fingas, 2000). These inter-model transfers increase the risk of accidental discharge during transfer and storage operations. The increase in worldwide energy consumption indicates that more pipelines would be required to transport additional supplies of crude and refined products. For instance, in 2010 global energy consumption increased by 3.8% metric tonnes, with the USA leading (Enerdata, 2011), and in 2012 it dropped to 3.7% metric tonnes, also with the USA still leading (Enerdata, 2013). Records show domestic

consumption of oil products in countries like the USA dropping from 781 metric tonnes in 2010 to 739 in 2012, while China and Japan increased from 406 and 183 metric tonnes in 2010 to 427 and 198 in 2012, respectively

Although some oil spills are caused by equipment failure and operational errors, Royal Dutch Shell, the parent company of SPDC Nigeria, claimed that pipeline interdiction accounts for most of its oil spills in Nigeria (Shell, 2007).

i. Bunkers (thieves): These are experienced and well-connected individuals who work in collaboration with security agents and oil workers to steal crude directly from pipelines. Large oil spills are rare among this group because they possess the skills to regulate flow, usually by installing illegal fittings and control valves to manage pressure and flow rate (Kandiyoti, 2012). They use hoses to load oil onto barges or smaller ships and then transport it through the creeks for onward transfer onto international-class 'mother ships' on the high seas for sale in the international market (Katsouris and Sayne, 2013).

ii. The Amateur Bunkers (thieves): This group uses basic tools like a hacksaw to break or loosen pipe manifolds; they are mostly local unemployed youths without much experience or skills to handle large-scale crude theft. The stolen crude is usually collected in small quantities on canoes and small barges for sale to local refineries or companies that use crude oil to power their furnace. They care little about the spills they cause, as they often leave ruptured pipes discharging crude oil into the environment. According to reports, about 34 cuts were made on the Assa-Rumuekpe trunkline at Egbeda, Emohua LGA in Rivers State over two weeks in December 2004 (Shittu, 2014).

iii. Saboteurs and Vandals: These groups are mainly interested in sabotaging operations of the MOCs. They are generally influenced by their grievances against the government and MOCs regarding how their agitation is ignored. Armed with tools, they go about breaking pipes with tools or explosives. Some of these groups collaborate with community leaders who seek attention or aim to impede oil production in their areas (Shittu). Benedict (2011), who reported the existence of gangs going from one community to another, damaging pipelines, corroborates this claim.

There are two approaches to oil spill contingency plans in Nigeria. The first manages spills in-house within the affected industry, while the second uses the NOSCP. Under the former, spills of less than 100 kg (0.1 ton) are not reported to the DPR but are managed in-house according to tier 1 (Field Interview, 2010). However, spills above 100 kg are reported to the DPR, and a joint investigation team (JIT) is constituted to investigate and appraise the site. The national contingency plan, on the other hand, is divided into tiers, i.e., company (tier one), cooperative (tier two), and government or major (tier three), based on the quantity discharged (NOSCP, 2009).

i. Tier 1 plan (Company). It is mandatory under this tier for producers and marketers to provide response facilities in their areas of operation. The quantity of oil specified for this tier is less than or equal to 7 tonnes (50 bbl), which must be caused by the company's activities.

ii. Tier 2 plan (Cooperative). This category covers oil spills greater than 7 tonnes (50bbl) but less than 700 tonnes (5,000bbl) around the company's vicinity. In this category, other oil industries, government agencies, and the Clean Nigeria Associates are involved.

iii. Tier 3 plan (Government). This stage activates the national contingency plan if the spill surpasses tier 1 and tier 2 conditions. The quantity involved in tier 3 exceeds 700 tonnes (5,000bbl). The government is directly involved in control and issuing directives through the NOSDRA. Spills are not limited to the company's vicinity but extend to all areas where the company conducts its operations.

iv. There are several opportunities for exposure to petroleum hydrocarbons in land use; such exposure may come from hand-to-mouth contact, tracking contaminants back home, etc. (Kimbrough et al., 2010). Despite this, there are "no reliable quantitative data to support Human Health Risk Assessment for activities associated with receptors living in rural areas, or for lifestyles and occupations such as farming, where there is potential for high exposure" (Doyle et al., 2010). It is, in fact, common knowledge that rural lifestyles predispose people to several exposure opportunities, yet there is limited information for detailed risk assessment.

v. Human health risk assessment evaluates the probability and frequency of hazard, and the magnitude of the consequence (Nathanail, 2013).

II. Methods

Rivers State is an oil-rich state in southern Nigeria, located in the eastern part of the Niger Delta on the oceanward extension of the Benue Trough, with headquarters in the town of Port-Harcourt. Rivers State comprises 23 Local Government Areas, many of which are towns and villages.

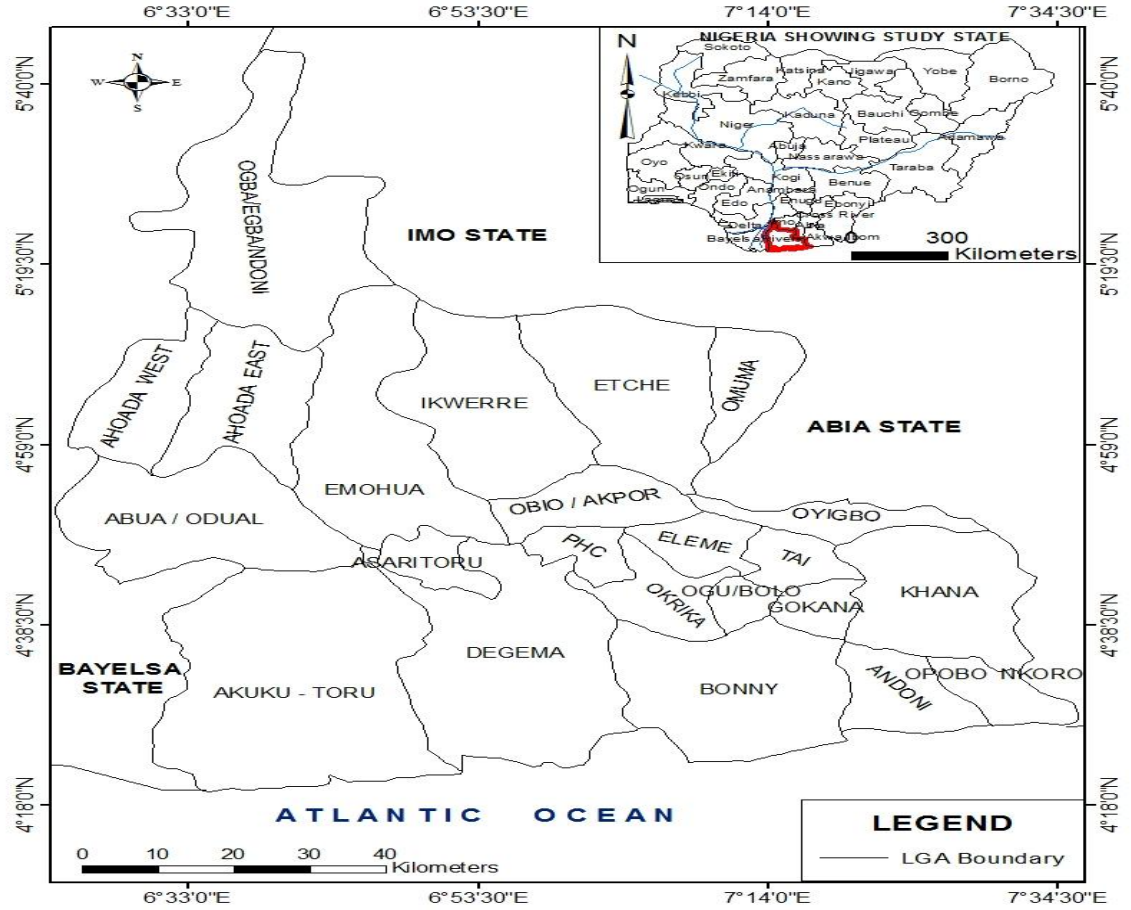


Figure 1Rivers State Showing LGA Area

The inland part of the state consists of tropical rainforest, and towards the coast, the typical Niger Delta environment features many mangrove swamps. Rivers State has a total area of 11,077 km^2 (4,277 sq mi), making it the 26th largest state in Nigeria. Surrounding states are Anambra, Imo, and Abia to the north, Akwa Ibom to the east across the Imo River, and Bayelsa and Delta to the west across the Niger River for about 50 km. On the south, it is bounded by the Atlantic Ocean. Its topography ranges from flat plains to a network of rivers and tributaries.

The area is located between Latitude 5º 10' 0''N and Longitude 6º 54' 0''E. The area within the tropical rainforest is characterized by eight months of the wet season and four months of the dry season. The average temperature of the area is between 22ºC and 29ºC with high humidity and rainfall. The major occupations of the people are fishing and farming, with some individuals also engaged in trading and public service (Odalonu, 2016). The socio-economic life of the rivers people is largely dependent on their geography and environment, and they predominantly are fishermen/fisherwomen, traders, and farmers (Orisakwe, 2021).

The spatial datasets were acquired from secondary sources, and some was generated and updated through supervised classification and on-screen digitization using ArcGIS software. The review of secondary data was very useful for this research. A desk study involved the consultation of official reports, articles, legal documents, and published and unpublished literature. Other information items were derived from journal articles, textbooks, dictionaries, encyclopedias, books, political commentary, biographies, dissertations, newspaper, and opinion pieces.

Data obtained from the field survey was transferred to the ArcGIS environment and this aided the research in the mapping and spatial vulnerability assessment of residents and communities to oil spill.

III. Results

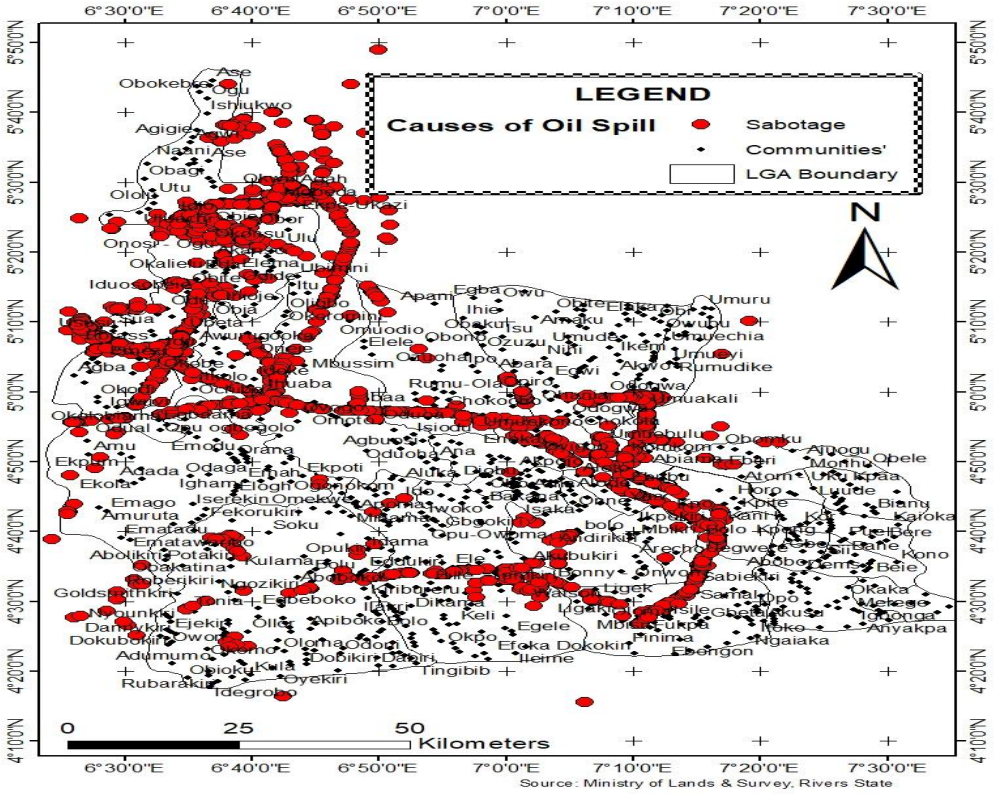


Figure 2 Showing areas affected by illegal crude refining and theft in study area

Oil pollution trend over the ten-year intervals was evaluated using data from the national oil spill monitor and analyzed in the ArcGIS environment. Predicting and manage oil pollution was achieved using the digital elevation model alongside the swat and the OILMAP.

Unauthorized refining and crude-oil bunkering can result in uncontrolled discharge of petroleum products into waterways and surrounding land and also air pollution via burning associated with illegal refining.

Population growth and settlement expansion

Expansion of settlements toward oil-producing areas and pipeline corridors increases the number of people potentially exposed to pollution and also exposes the pipeline to potential impact by the population.

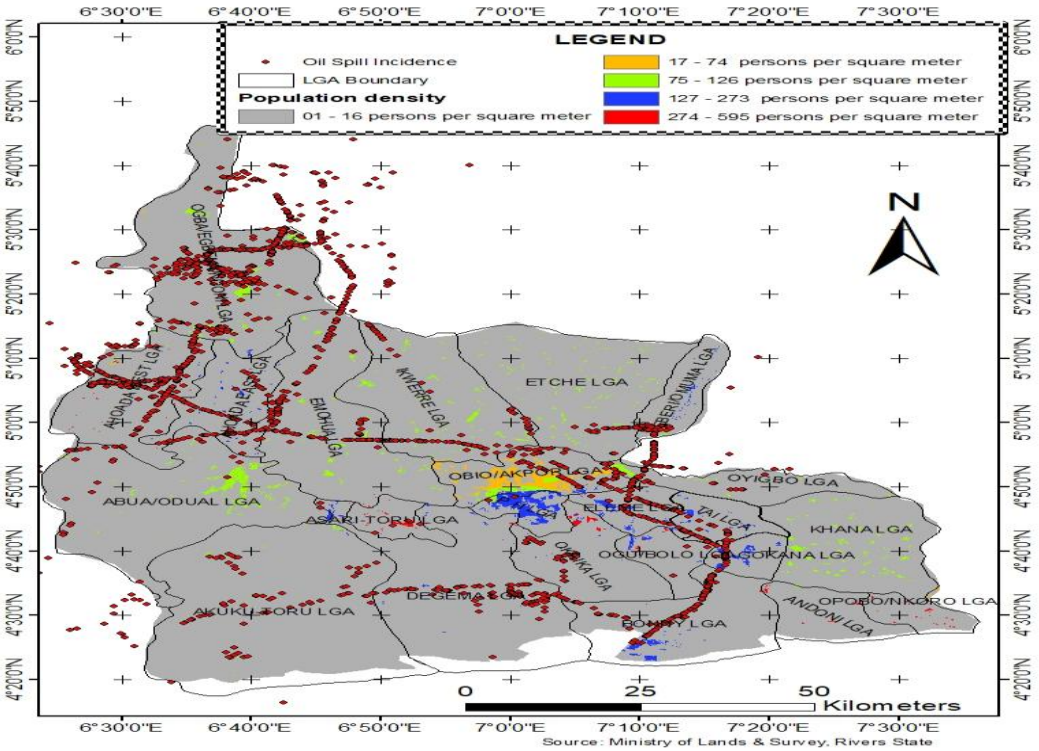


Figure 3Showing population density of the communities in the study area.

Socio-economic vulnerability

Communities economically dependent on fishing and farming may be particularly affected when pollution damages their livelihoods, restriction of access to water where pipelines overlay. Low-income households may have fewer resources to sustain themselves therefore resolving to alternative resource supply from activities of vandalism of pipeline.

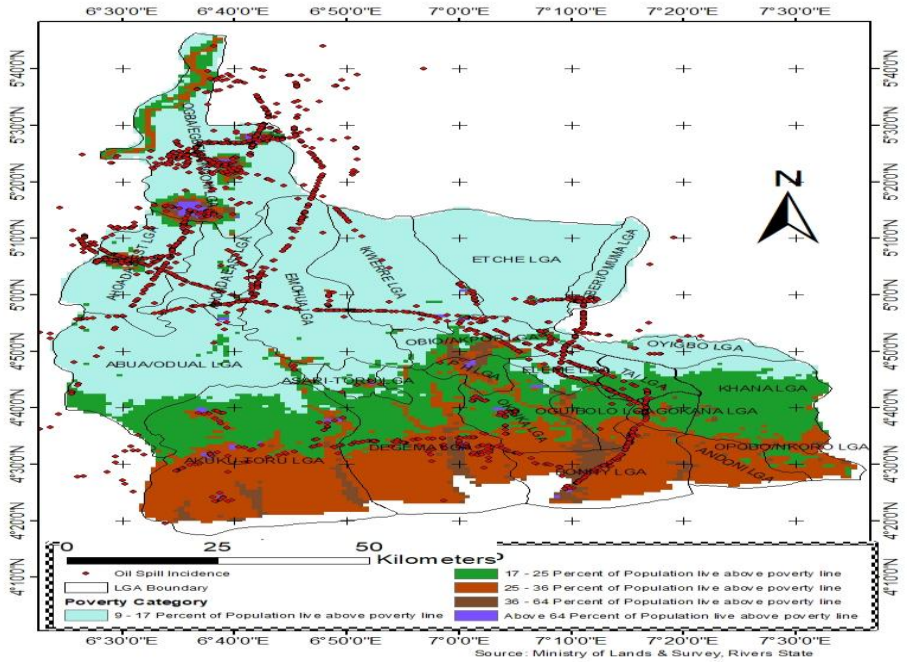


Figure 4 Showing poverty category of people in the communities within the study area

In relation to oil infrastructure proximity, oil facility ranges from well head, pipeline, manifold, flow station, flow line and barge. The pipeline is the most vulnerable to impact by potential vandals. This situation tends to result in the corridor of oil facility impact aimed at extracting crude for the market therefore the presence

of oil infrastructure attracts vandals to such location this increases the risk of oil spill within such locality. The activities of illegal vandals can be seen to have towed a linear path going through same path of facility locations especially pipeline and across spaces of sparse population and very vulnerable population index.

oil pollution trends over the ten-year intervals

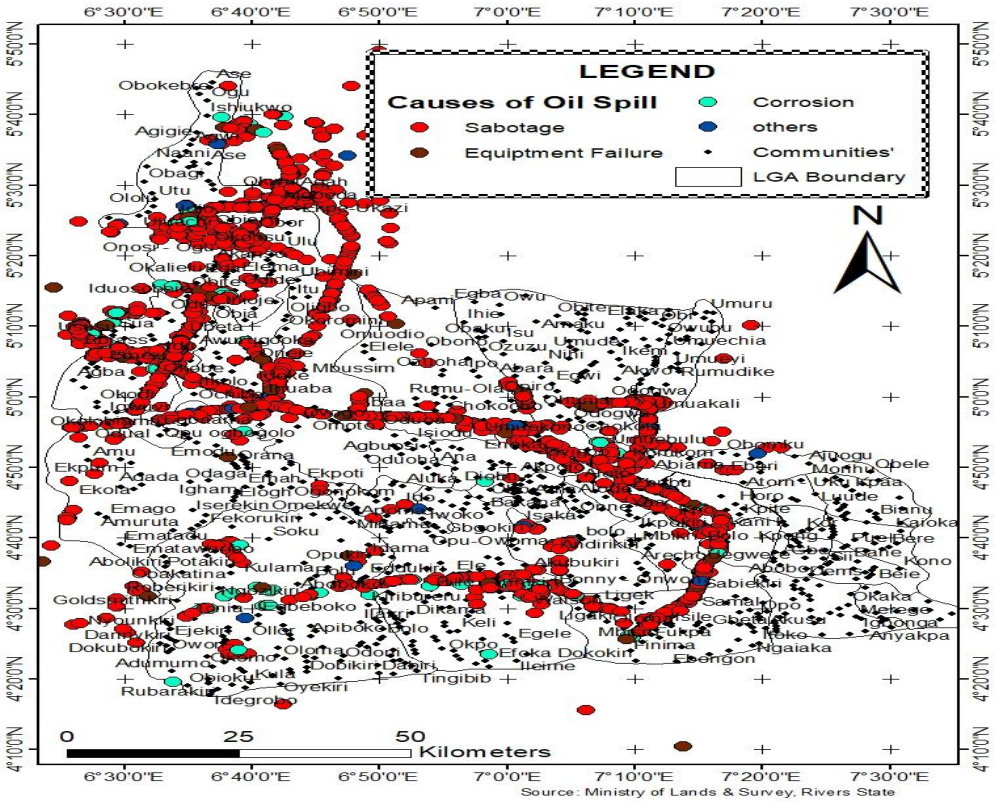


Figure 5 Showing oil pollution trends in study area

The sabotage-related oil spills, represented by the red symbols are widely distributed across the study area but are particularly concentrated in the central, northern and southeastern portions of Rivers State. Several dense clusters can be observed around areas such as Omoku, Egi, Elele, Eneka, Rumuodogo, Bori and the surrounding communities. This pattern implies that oil-spill occurrence is strongly associated with areas where petroleum infrastructure intersects with accessible and populated environments. The geospatial assessment of the spills found that sabotage accounted for the largest proportion of spill incidents.

Equipment failure, represented by the brown symbols, occurs much less frequently than sabotage. Nevertheless, its distribution pattern indicates that technical failures remain an important source of oil spills. Equipment failure may involve malfunctioning valves, damaged pipelines, leaking flowlines, defective joints and other mechanical components. Research on the Niger Delta identifies equipment failure as one of the principal operational causes of oil spills, although its frequency is generally lower than sabotage as shown on the map.

Corrosion-related spills, represented by the green symbols, are also relatively limited compared with sabotage. However, their spatial occurrence across different parts of the state indicates that deterioration of petroleum infrastructure remains a continuing environmental concern. Corrosion is particularly relevant in the Niger Delta because petroleum infrastructure has often been exposed to humid, swampy and chemically aggressive environments for long periods. Aging infrastructure and inadequate maintenance can increase the likelihood of pipeline deterioration and leakage.

The "others" category, shown in blue, has the smallest representation on the map. These incidents include causes that do not fall directly within sabotage, corrosion or equipment failure.

The map further demonstrates that oil spills tend to form linear and clustered patterns rather than a uniform distribution as spill points appear to follow particular corridors, which correspond to petroleum pipelines, flowlines, and other oil-production infrastructure. This is significant because oil-spill risk is often spatially related to the location and density of oil facilities. The northern and central areas show particularly dense concentrations of spill incidents, whereas some areas farther south have fewer incidents. This reflects differences in the distribution of oil infrastructure, accessibility to the facility, settlement patterns, production activities and the nature of the surrounding terrain.

The spatial concentration of oil spills around communities indicates potential of spill impact on rivers, wetlands, forests and other ecosystems within the study area. In Rivers State, where extensive freshwater and wetland environments occur, repeated spills can introduce petroleum hydrocarbons into soils and surface-water systems and consequently affect aquatic organisms, vegetation and human livelihoods. This study therefore demonstrates that oil pollution in Rivers State is not simply an isolated environmental problem. It is a spatially structured problem associated with petroleum infrastructure, human activities and settlements encroachment resulting in uncontrolled access to the oil installations.

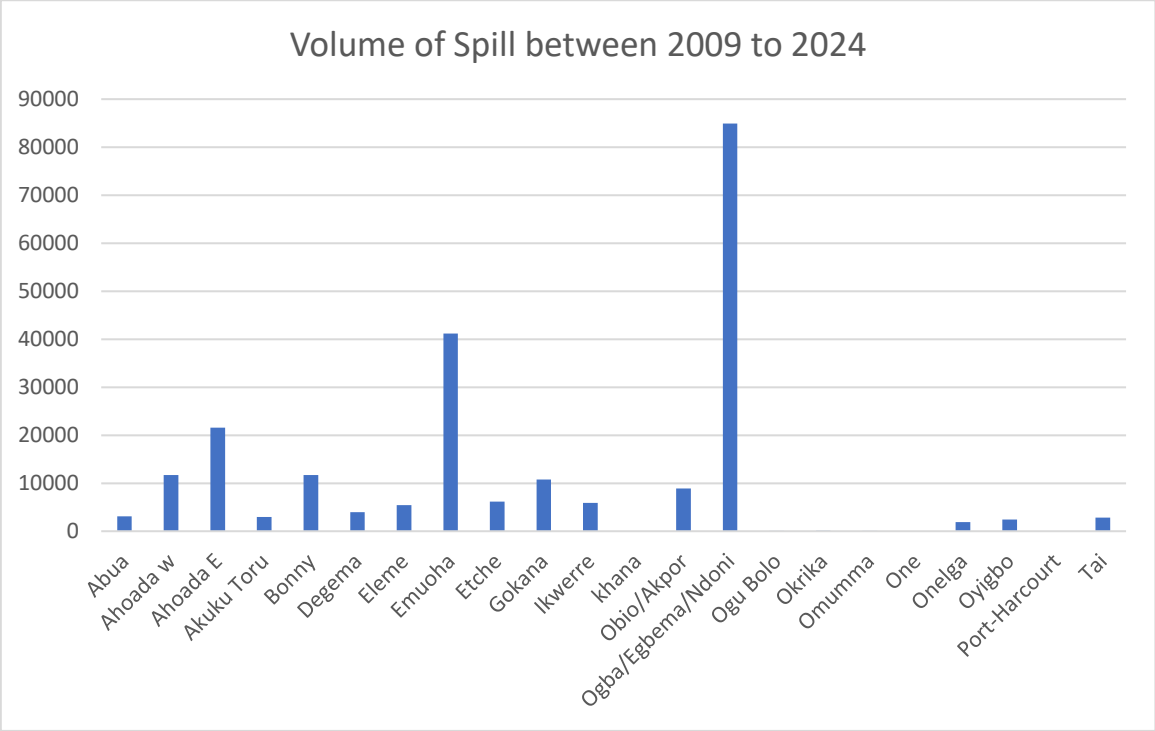


Figure 6Showing Volume of spill between 2009 to 2024

Spill sources across the study area annually were evaluated within the period of 2009 through 2024. the dominant year was pegged at 2014 while the least year was pegged at 2009 as shown in figure with most volume spilled in Ogba-Ndoni local government and a peak volume of spill in 2015 totally 43852.49 barrel of oil spilled into the environment.

The oil pollution risk prediction and management model as applied across the spatial space of the study area.

The Oil Pollution Risk Prediction and Management Model (OPRPM) was developed to spatial show the trend in oil spill risk across the study area. The model combined environmental, anthropogenic, spatial, and socio-economic factors to identify areas that are most vulnerable to oil pollution. the major risk factors or variables identified that influence the occurrence and spread of oil pollution in the study area; Distance from oil pipelines, Distance from oil wells and flow stations, Historical oil-spill locations, Proximity to rivers, streams and wetlands, socio – economic category and population density

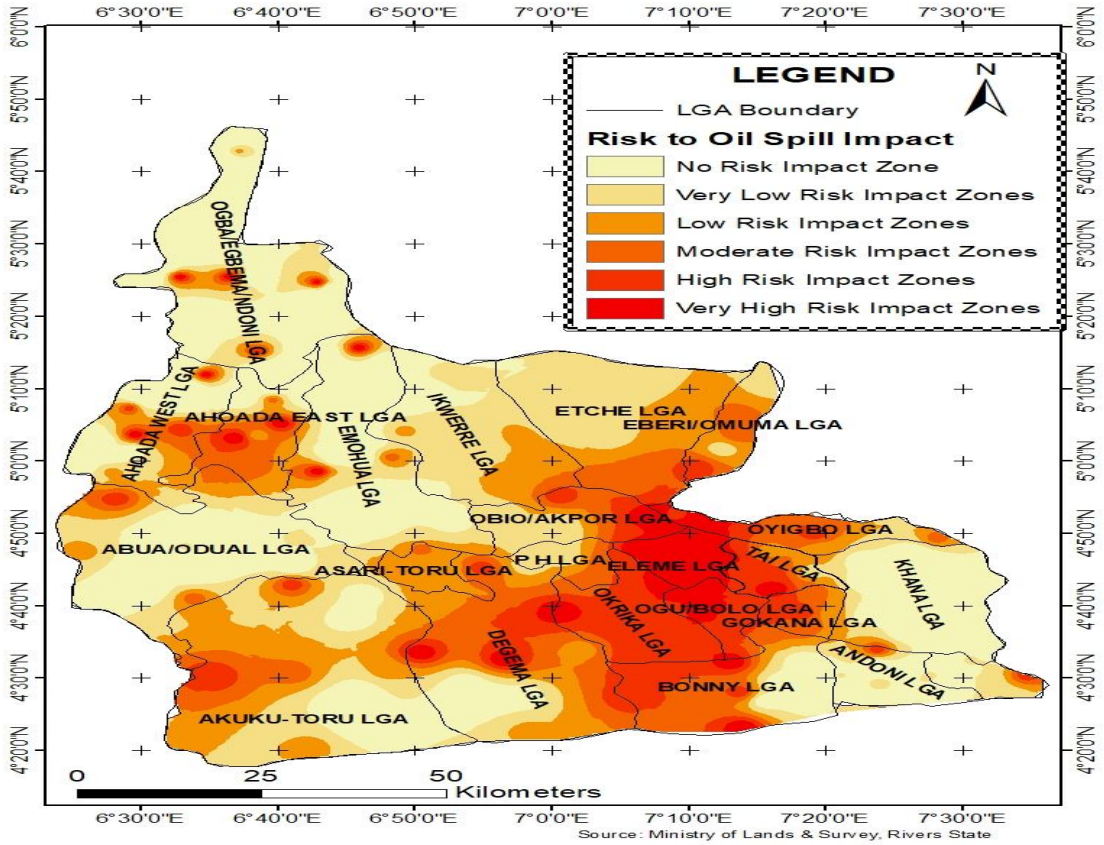


Figure 7 Showing spatial distribution of risk to oil-spill impacts across the study area

The map presents the spatial distribution of risk to oil-spill impacts across Rivers State, Nigeria. The risk classes range from No Risk Impact Zone to Very High-Risk Impact Zones, represented by progressively darker shades from pale yellow to red.

The spatial pattern indicates that the risk of oil-spill impact is not uniformly distributed across Rivers State. Rather, areas of moderate, high, and very high risk are concentrated mainly in the central, southern, and southeastern parts of the state, while large portions of the northern and southwestern areas exhibit low or very low risk.

The very high-risk zones, shown in dark red, are particularly concentrated around Eleme, Oyigbo, Okrika, Ogu/Bolo, Bonny, Degema, and parts of Port Harcourt and Obio/Akpor. This concentration suggests that these areas are more vulnerable to the consequences of oil spills. The pattern is particularly pronounced around the Port Harcourt–Eleme–Okrika–Bonny corridor, which is associated with intensive petroleum-related activities, industrial development, pipelines, terminals, and waterways. Oil spills occurring within or close to these areas could therefore have substantial environmental and socioeconomic consequences.

The high-risk zones, represented by red, extend around the central and southern portions of the state as observed around Obio/Akpor, Port Harcourt, Eleme, Okrika, Ogu/Bolo, and Bonny, with some extensions toward Degema and Oyigbo. The broad spatial extent of these zones indicates that oil-spill vulnerability is not restricted to individual oil-producing locations but may extend across neighbouring LGAs because of the interconnected nature of rivers, wetlands, drainage networks, and coastal environments.

The moderate-risk zones, represented by orange-red colours, occur extensively around the central part of the state, including areas around Ikwerre, Etche, Emohua, Asari-Toru, Degema, and Akuku-Toru. These areas may have a combination of relatively lower direct exposure to petroleum infrastructure and environmental conditions that can still facilitate the movement or effects of spilled oil. In particular, the presence of river channels, wetlands, and low-lying terrain can increase the potential for pollutants to spread from their original point of release.

The low and very-low risk zones are more widespread in the northern and western parts of the state. Areas such as Abua/Odual, Khana, parts of Gokana, Tai, Andoni, and parts of Etche contain substantial areas within the lower-risk categories. The northernmost areas, including Ogba/Egbema/Ndoni, are predominantly characterized by the no-risk or very-low-risk classes, although isolated hotspots of higher risk can be observed. This indicates that the overall risk is spatially heterogeneous rather than completely absent in these areas.

The southern and central portions contain numerous petroleum-related facilities and transportation networks, making them more susceptible to oil-spill occurrence and associated impacts. The analysis therefore

demonstrates the importance of considering both oil-spill sources and the environmental characteristics of receiving areas when assessing oil-spill risk.

IV. Discussion

The study identified proximity to oil infrastructure, illegal oil refining and oil theft, population growth and settlement expansion, and socio-economic vulnerability as major factors associated with oil-pollution risk.

The proximity of communities to petroleum infrastructure represents an important risk factor because infrastructure such as pipelines, oil wells, flow stations, manifolds, flowlines and barges provides potential pathways through which crude oil can enter the surrounding environment. The study particularly identifies pipelines as vulnerable to vandalism and other forms of human interference. The linear distribution of some spill incidents corresponds with the locations of petroleum facilities, suggesting a strong spatial relationship between infrastructure corridors and oil-spill occurrence.

Illegal oil refining and oil theft constitute another important risk factor. The findings indicate that unauthorized refining and crude-oil bunkering can result in uncontrolled releases of petroleum products into waterways and surrounding land. In addition to contamination of land and water, illegal refining may produce air pollution through the burning associated with the process. The spatial relationship between oil infrastructure and illegal activities is important because the presence of oil facilities can attract unauthorized access to locations where crude oil can be extracted for economic purposes.

Population growth and settlement expansion further increase the vulnerability of communities. As settlements expand toward oil-producing areas and pipeline corridors, more people become exposed to potential pollution incidents. At the same time, increasing human presence around petroleum infrastructure may increase the likelihood of interference with infrastructure.

The socio-economic condition of communities also influences their vulnerability to oil pollution. Communities that depend substantially on fishing and farming can experience considerable livelihood consequences when oil pollution affects water bodies, agricultural land and other natural resources. The findings indicate that low-income households may have fewer resources to cope with pollution-related impacts, potentially increasing their dependence on alternative and sometimes environmentally harmful activities. This demonstrates that oil pollution is not solely an environmental issue but also has important socio-economic dimensions.

The analysis of oil-pollution trends shows that sabotage-related spills constitute the dominant category of oil-spill incidents within the study area. Dense clusters were observed around locations such as Omoku, Egi, Elele, Eneka, Rumuodogo and Bori and their surrounding communities. This distribution suggests that sabotage is strongly associated with locations where petroleum infrastructure intersects with accessible and populated environments. The dominance of sabotage indicates that a substantial proportion of oil-spill risk is associated with human activities rather than being exclusively attributable to technical or natural deterioration of infrastructure. The spatial pattern of sabotage-related spills also follows petroleum infrastructure corridors, particularly pipelines and flowlines. This suggests that areas containing extensive petroleum infrastructure may require stronger surveillance and security measures. Although equipment failure occurs less frequently than sabotage, the study demonstrates that it remains an important source of pollution. Equipment failures may arise from malfunctioning valves, damaged pipelines, leaking flowlines, defective joints and other mechanical components. The occurrence of equipment-related spills across the study area indicates that operational and maintenance-related risks cannot be ignored in oil-pollution management.

Similarly, corrosion-related spills are less prominent than sabotage but are spatially dispersed across the study area. The persistence of corrosion-related spills indicates that the deterioration of petroleum infrastructure remains an environmental concern, particularly where infrastructure has been exposed to humid and swampy environmental conditions over long periods. Aging infrastructure and inadequate maintenance can therefore contribute to continued leakage and contamination.

The study also reveals that oil spills exhibit linear and clustered spatial patterns rather than a uniform distribution. These patterns correspond with pipelines, flowlines and other petroleum infrastructure. The northern and central areas contain particularly dense concentrations of spill incidents, whereas some southern areas show comparatively fewer incidents. These differences are associated with variations in infrastructure distribution, accessibility, settlement patterns, petroleum activities and terrain characteristics.

The study identifies the extensive network of rivers and creeks as a pathway through which contaminants can be transferred from areas of initial pollution toward downstream environments. The trajectory of drainage and surface flow creates a situation in which pollution originating in upland areas may ultimately affect riverine communities and coastal environments, including areas within Akuku-Toru, Degema, Bonny, Andoni and Opobo-Nkoro. The temporal analysis covering 2009–2024 further indicates variations in annual spill occurrence and volume. The study identifies 2015 as the dominant year in terms of spill occurrence, while 2009 recorded the least occurrence. Ogba-Ndoni recorded the largest volume in the analysis, with a reported peak spill volume of 43,852.49 barrels in 2015. This temporal variation demonstrates that oil-pollution risk changes over time and reinforces the need for continuous monitoring rather than relying solely on a single-period assessment.

The development of the Oil Pollution Risk Prediction and Management Model (OPRPM) integrates multiple factors influencing oil-pollution risk into a spatial framework. The model incorporates distance from oil pipelines, distance from oil wells and flow stations, historical oil-spill locations, proximity to rivers, streams and wetlands, socio-economic category and population density.

The model demonstrates that oil-pollution risk is spatially heterogeneous across Rivers State. The resulting risk map classified areas into no-risk, very-low, low, moderate, high and very-high risk zones. Moderate, high and very-high risk areas were concentrated mainly in the central, southern and southeastern portions of the state, while extensive areas in the northern and southwestern portions were characterized by lower levels of risk.

The very-high-risk zones were particularly concentrated around Eleme, Oyigbo, Okrika, Ogu/Bolo, Bonny, Degema and parts of Port Harcourt and Obio/Akpor. The concentration of very-high-risk areas around the Port Harcourt–Eleme–Okrika–Bonny corridor indicates the combined influence of petroleum activities, industrial development, pipelines, terminals and waterways. Consequently, a spill occurring within these areas could potentially produce substantial environmental and socio-economic impacts.

The high-risk zones extend across parts of Obio/Akpor, Port Harcourt, Eleme, Okrika, Ogu/Bolo, Bonny, Degema and Oyigbo. The relatively broad distribution of these zones demonstrates that oil-pollution vulnerability is not necessarily confined to the immediate locations of oil-producing facilities. Because Rivers State has interconnected rivers, wetlands, drainage systems and coastal environments, pollutants can potentially spread beyond their initial point of release.

Moderate-risk areas were extensively distributed across the central part of the state, including parts of Ikwerre, Etche, Emohua, Asari-Toru, Degema and Akuku-Toru. The occurrence of moderate-risk areas in locations with comparatively lower direct exposure to petroleum infrastructure suggests that environmental characteristics also contribute to vulnerability. In particular, river channels, wetlands and low-lying terrain can facilitate the movement and persistence of pollutants after an oil-spill event.

Conversely, low and very-low risk areas were more widespread in the northern and western portions of the state. However, the presence of isolated higher-risk hotspots within some generally low-risk areas indicates that low overall risk does not necessarily imply complete absence of oil-pollution vulnerability.

Overall, the OPRPM demonstrates the usefulness of integrating source-related, environmental and socio-economic variables in assessing oil-pollution vulnerability. The results show that areas with high concentrations of petroleum facilities become particularly vulnerable when they are also associated with dense settlements, waterways, wetlands and other environmental pathways. Thus, effective oil-pollution management requires consideration of both the location of pollution sources and the characteristics of the receiving environment.

V. Conclusion

The study established that proximity to oil infrastructure, illegal oil refining and oil theft, population growth and settlement expansion, and socio-economic vulnerability are important factors contributing to oil-pollution risk. Petroleum infrastructure, particularly pipelines, provides a major spatial pathway for spill occurrence, while sabotage and illegal activities increase the likelihood of uncontrolled releases of crude oil. At the same time, the expansion of settlements toward oil-producing areas increases the number of people exposed to potential pollution events.

The temporal and spatial assessment of oil-spill sources showed that sabotage is the dominant source of oil-spill incidents within the study area, followed by equipment failure and corrosion, while other causes constitute the least represented category. The linear distribution of several spill locations corresponds closely with pipeline and flowline corridors, further confirming the important relationship between petroleum infrastructure and oil-spill occurrence. The analysis of spill records from 2009 to 2024 also demonstrated temporal variations in spill occurrence and volume, with 2015 recording the highest occurrence and 2009 the lowest, while Ogba-Ndoni recorded the largest volume and a peak spill volume of 43,852.49 barrels in 2015.

The development of the Oil Pollution Risk Prediction and Management Model (OPRPM) provides a significant outcome of the study. By integrating proximity from oil pipelines, oil wells and flow stations, historical oil-spill locations, proximity to rivers, streams and wetlands, socio-economic conditions and population density, the model demonstrated that oil-pollution risk is spatially heterogeneous across Rivers State. The resulting classification into no-risk, very-low, low, moderate, high and very-high-risk zones provides a spatial basis for identifying areas requiring different levels of intervention.

The model particularly identified Eleme, Oyigbo, Okrika, Ogu/Bolo, Bonny, Degema, Port Harcourt and parts of Obio/Akpor as areas containing substantial high and very-high-risk zones. The concentration of these zones around the Port Harcourt–Eleme–Okrika–Bonny corridor reflects the combined influence of petroleum infrastructure, industrial activities, settlements, transportation networks and interconnected waterways. Conversely, extensive portions of the northern and southwestern parts of the state were classified within low or very-low-risk categories, although isolated areas of higher risk occur within some of these zones.

This study examined the spatial distribution, risk factors, trends and predictive management of oil pollution in Rivers State using geospatial techniques. The study has demonstrated that oil pollution is a widespread

and spatially structured environmental problem whose occurrence and potential impacts are influenced by the interaction of petroleum infrastructure, human activities, settlement expansion, environmental characteristics and socio-economic vulnerability.

VI. Recommendations

Based on the findings of this study, is recommended that Prioritization of high and very-high-risk areas: Government agencies, oil companies and environmental regulatory bodies should prioritize communities identified as high and very-high-risk zones for preventive interventions. Particular attention should be given to Eleme, Oyigbo, Okrika, Ogu/Bolo, Bonny, Degema, Port Harcourt and parts of Obio/Akpor, where the model identified substantial concentrations of oil-pollution risk. Integration of the OPRPM into environmental management: The Oil Pollution Risk Prediction and Management Model (OPRPM) developed in this study should be adopted as a decision-support tool for identifying vulnerable areas and prioritizing intervention strategies. Relevant agencies should regularly update the model with new information on oil spills, petroleum infrastructure, population distribution, land-use changes and environmental conditions.

BIBLIOGRAPHY

[1]. Abam, T.K.S. (1999). Impact Of Dams 0n the Hydrology of the Niger Delta.*Bulletin of Engineering Geology and Environment*, 57(3),239-251.

[2]. Abam, T.K.S. (2001). Regional Hydrological Research Perspectives in the Niger Delta. Hydrological Sciences -*Journal-Des Sciences Hydrologiques*, 46(1),13-25.

[3]. Abenan, A.T., Jean, K.K., Bachir, S.M., Armand, A.K., Serge, D.K., Tanoh, K.J.J., Adiow, S.H.K., Jean-Patrice, J.J. and Jean, B. (2012). Contribution Of Multicriteria Analysis and GIS For the Specific vulnerability Mapping to Agricultural inputs of Groundwaters InBonoua Area (Southeast Of Cote D'ivoire). *Journal Of Engineering Studies and Research*, 18(3),11-18.

[4]. Abosede, A.T. (2010). Phytoplankton Dynamics of River Oli in Kainji Lake National Park, Nigeria During Dry Season. *Journal Of American Science*, 6(5),72-76.

[5]. Abowei, J.F.N. (2010). Some Population Parameters of distchodus Rostratus (Gunther,1864) From the Fresh Water Reaches of Lower Nun River, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology,* 2(2),84-90.

[6]. Abowei, J.F.N., Davies, O.A. and Eli, A.A. (2010). Physico-Chemistry, Morphology and Abundance of Finfish of Nkoro River, Niger Delta, Nigeria. *International Journal of Pharma and Bio Sciences*, 1(2),1-11.

[7]. Abu, S.T. and Malgwi, W.B. (2011). Effects Of Deficit Irrigation Regime and Interval on Chemical Properties and Paddy Rice Yield in Sudan Savanna of Nigeria. *Journal Of Agronomy*, 10(2),48-55.

[8]. Achebe, C.H., Nneke, U.C. and Ansiji, O.E. (2012). Analysis of oil pipeline failure in the oil and gas industries in the Niger Delta area of Nigeria. Hong Kong, Proceeding of the International MultiConference of Engineers and Computer Sciences. Vol. II IMECS.

[9]. Achudume, A.C. (2009). The Effect of Petrochemical Effluent on The Water Quality of Ubeji Creek in Niger Delta of Nigeria. *Bulletin of Environmental Contamination Toxicology*, **38**,410-415.

[10]. Achudume, A.C. (2009). Environmental Health, Development and Economic Empowerment of Rural Women in Nigeria. *Environment Development and Sustainability*, **11**,459-469.

[11]. Adebayo, A.G., Oyun, M.B. and Kadeba, O. (2010). Access Of Rural Women to Forest Resources and Its Impact on Rural Household Welfare in North Central Nigeria. *Forest Policy And Economics*, **12,** 439-450.

[12]. Adekalu, K.O., Osunbitan, J.A. and Ojo, O.E. (2002). Water Sources and Demand in South Western Nigeria: Implications for Water Development Planners and Scientists. *Technovation*, **22**, 799-805.

[13]. Adekola, O., Shittu, W. and Ogwu, F. (2012). Assessment Of Policies and Legislation That Affect Management of Wetlands in Nigeria. *Wetland*, **32**, 665-677.

[14]. Adeoti, O., Idowu, D.O.O. and Falegan, T. (2001). Could fuelwood use contribute to household poverty in Nigeria. Biomass and Bioenergy, 21, pp. 205-210.

[15]. Ajayi, J.O. and Owumi, B. (2013). Ethnic pluralism and internal cohesion in Nigeria. *International Journal of Development and Sustainability*, 2(2),45-57.

[16]. Akpan, N. (2005). Between the sectional and the national: oil grassroots discontent and civic discourse in Nigeria. [Art] (PhD Thesis submitted to the Rhodes University).

[17]. Akpokodje, E. (1987). The Engineering-Geological Characteristics and Classification of The Major Superficial Soils of The Niger Delta. *Journal Of Engineering Geology*, **23**, 193-211.

[18]. Alegria, A.C., Sahli, H. and Zimanyi, E. (2011). Application Of Density Analysis ForLandmine Risk Mapping. Spatial Data Mining and Geographical Knowledge Servises (Icsdm). Fuzhou China, Ieee International Conference Held On 29th June – 1st July, 2011.

[19]. Alencar, M.H. and de Almeida, A.T. (2010). Assigning priorities to actions in a pipeline transporting hydrogen based on a multicriteria decision model. *International Journal of Hydrogen Energy*, **35**,3610-3619.

[20]. Allaby, M., Coenraads, R.R., Hutchinson, S., Mcghee, K., O'byrne, J. and Rubin, K. (2008). The Encyclopedia of Earth: A Complete Visual Guide. Australia: Weldon Owen Pty Ltd.

[21]. Allen, W.A. (2011). GIS Tutorial: Spatial Analysis Workbook. ESRI Press, New York Street, Redlands, California.

[22]. Al-Shalabi, M.A., Bin Mansor, S., Bin Ahmed, N. and Shiriff, R. (2006). GIS Based Multicriteria Approaches to Housing Site Suitability Assessment. Paper Presented. [Online] Available at: http://www.fig.net/pub/fig2006/papers/ts72/ts72_05_alshalabi_etal%20_0702. pdf [Accessed 08/01/2010].

[23]. American Petroleum Institute (API). (2001). Managing System Integrity for Hazardous Liquid Pipelines, API Standard 1160, 1st Edition, Nov. 2001.

[24]. Amnesty International. (2013). Bad Information: Oil spill investigations in the Niger Delta, Amnesty International Publications, London.

[25]. Anifowose, B., Chapman, L., Lawler, D. and Van der Horst, D. (2011). Pipeline interdiction and bridging in Nigeria: is a modification to the spatial connectivity matrix model required, *Journal of Transport Geography*, **19**,179 184.

[26]. Anifowose, B., Lawler, D.M., Van Der Horst, D. and Chapman, L. (2012). Attacks on oil transport pipelines in Noigeria: a quantitative exploration and possible explanation of observed pattern. Applied Geography, Issue 32, pp. 636-651.

[27]. Anozie, O. I. and Onwurah, I. N. E. (2001). Toxic Effects of Bonny Light Crude Oil in Rats after Ingestion of Contaminated Diet. *Nigerian Journal Of Biochemistry and Molecular Biology* (Proceeding Supplement), 16(3), 1035-1085.

[28]. Aroh, K.N., Ubong, I.U., Eze, C.L., Harry, I.M., Umo-Otong, J.C. and Gobo, A.E. (2010). Oil spill incidents and pipeline vandalisation in Nigeria Impact on public health and negation to attainment of Millennium development goal: the Ishiagu example. *Disaster Prevention and Management*, 19(1), 70-87.

[29]. ASME (2012). Gas transmission and distribution piping systems: ASME Code for Pressure Piping, B31, New York USA: The American Society of Mechanocal Engineers.

[30]. ASME, 2004. Managing System Integrity of Gas Pipelines: ASME Code for Pressure Piping, B31 Supplement to ASME B31.8, New York: The American Society of Mechanical Engineers.

[31]. Ayoola, O., Ebersole, K., Omotade, O.O., Tayo, B.O., Brieger, W.R., Salami, K., Dugas, L.R., Cooper, R.S. and Luke, A. (2010). Relative height and weight among children and adolescents of rural southwestern Nigeria. *Ann Hum Biol*. 34(4), 388-399.

[32]. Badejo, O. T. and Nwilo, P. C. (2004). Management Of Oil Spill Dispersal Along The Nigerian Coastal Areas. Proceedings From The 2005 International Oil Spill. [Online] Available at: http://www.oceandocs.org/bitstream/1834/267/1/241.pdf [Accessed 26/05/2009].

[33]. Baiphethi, M. N and Jacobs, P. T. (2009). The contribution of subsistence farming to food security in South Africa. *Agrekon*, 48(4),456-482.

[34]. Bamat, T., Chassy, A. and Warne, R. (2011). Extractives and Equity An overview and case studies from Peru, Angola and Nigeria. Baltimore, USA: Catholic Relief Services.

[35]. Banks, C.M. And Sokolowski, J.A. (2010). Modeling The Niger Delta Insurgency. *The Social Science Journal*, **47**, 271-293.

[36]. Barron, M.G., Carls, M.G., Short, J.W., Rice, S.D., Heintz, R.A., Rau, M. and Giulio, R.D. (2005). Assessment of the phototoxicity of weathered Alaska North Slope crude oil to juvenile pink salmon. *Chemosphere*, 60(1), 105–110.

[37]. Batzias, F.A., Siontorou, C.G. and Spanidis, P.M.P. (2011). Designing a realiable leak bio-detection system for natural gas pipeline. *Journal of Hazardous Materials,***186**, 35-58.

[38]. Bayoumi, R.A. and El-Nager, A.Y. (2009). Safe Control Methods of Petroleum Crude Oil Pollution in the Mangrove Forests of the Egyptian Red Sea Coast. *Journal Of Applied Sciences Research*, 5(12), 2435-2447.

[39]. Bellas, J., Saco-Alvarez, L., Nieto, O., Bayona, J.M., Abaiges, J. and Beiras, R. (2013). Evaluation of artificailly-weathered standard fuel oil toxicity by marine invertebrate embryogenesis bioassays. *Chemosphere*, **90,** 1103 1108.

[40]. Belore, R., Trudel, K. and Morrison, J. (2011). Weathering, Emulsification and Chemical Dispersibility of Mississippi Canyon 252 Crude Oil: Field and Laboratory Studies. Proceedings of International Oil Spill Conference 2011Held On February 10, 2011In Portugal. [Online] Available at: http://ioscproceedings.org/doi/pdf/10.7901/2169-3358-2011-1-247 [Accessed 05/12/2013].

[41]. Benedict, A. (2011). Tragedy of Commons: Analysis of oil spillage, gas flaring and sustainable development of the Niger Delta of Nigeria. *Journal of Sustainable Development*, 4(2),1-12.

[42]. Bernard, H. (2002). Research methods in anthropology. 3rd ed. Walnut Creek: AltaMira Press. Boroushaki, S. and Malczewski, J. (2008). Implementing And Extension Of Analytical Hierarchy Process Using Ordered Weighted Averaging Operators With Fuzzy Quantifiers In Arcgis. *Computers And Geosciences*, **34**, 399-410.

[43]. Brito, A.J. and de Almeida, A.T. (2009). multi-attribute risk assessment for risk ranking of natural gas pipelines. *Reliability Engineering and System Safety*, **94**, 187-198.

[44]. Brito, A.J., de Almeida, A.T. and Mota, C.M.M. (2010). A multicriteria model for risk sorting of natural gas pipelines based on ELECTRE TRI integrating uitility theory. European Journal of Operational Research, Issue 200, pp. 812-821.

[45]. Brody, S.D., Grover, H., Bernhardt, S., Tang, Z., Whitaker. B. and Spence, C. (2006). Identifying Potential Conflicts Associated with Oil and Gas Exploration in Texas State Coastal Waters: A Multicriteria Spatial Analysis. Environmental Management, **38**, 597-617.

[46]. Brown, D. G., Knightes, C. D. and Peters, C.A. (1999). Risk Assessment for Polycyclic Aromatic Hydrocarbon Napls Using Component Fractions. *Environmental Science & Technology*, 33(24), 4357-4363.

[47]. Brown, G., Patterson, T. and Cain, N. (2011). The Devil in The Details: Non-Convexities in Ecosystem Service Provision. *Resource And Energy Economics*, **33**, 355-365.

[48]. Bruce, B. (1998). Ethnicity, patronage and the African state: the politics of uncivil nationalism. *African Affairs*, 97(388), 305-341.

[49]. Bryman, A. (2008). Social Research Methods. 3rd ed. Oxford: Oxford University Press.

[50]. Cadenasso, M.L. and Pickett, S.T.A. (2002). The Ecosystem AsA Multidimensional Concept: Meaning, Model and Metaphor. Ecosystems, 5, 1-10.

[51]. Canadian Council of Ministers of the Environment. (2006). A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines, Manitoba:

[52]. Canadian Council of Ministers of the Environment. Canadian Council of Ministers of the Environment. (2010). Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Polycylic Aromatic Hydrocarbons, Gatineau: Canadian Council of Ministers of the Environment.

[53]. Carver, S. (1991). Integrating Multi-Criteria Evaluation with Geographical Information System. *International Journal of Geographical Science*, 5(3),321-339.

[54]. Chakhar, S. and Mousseau, V. (2008). Gis-Based Multicriteria Spatial Modelling Generic Framework. *International Journal of Geographical Information Science*, 22(11-12), 1159-1196.

[55]. Chang, K. (2010). Introduction To Geographic Information System. 5 ed. Asia: Mcgrew-Hill Education.

[56]. Chang, N., Parvathinathan, G. and Breeden, J.B. (2008). Combining GIS with fuzzy multicriteria decision–making for landfill sitting in a fast-growing urban region. *Journal of Environmental Management*, **87**, 139-153.

[57]. Chen, J. and Denison, M.S. (2011). The Deepwater Horizon Oil Spill: Environmental Fate of the Oil and the Toxicological Effects on Marine Organisation. *The Journal of Young Investigators*, 21(6),84-95.

[58]. Chen, K., Blong, R. and Jacobson, C. (2001). Mce-Risk: Integrating Multicriteria Evaluation and GISfor Risk Decision-Making in Natural Hazards. Environmental Modelling and Software, **16**, 387-397.

[59]. Cheng, Y. (2009). Generic Assessment Criteria for Human Health Risk Assessment of China's Contaminated Land Management. A PhD Thesis Submitted to The School of Geography, University of Nottingham. United Kingdom.

[60]. Cheng, Y. and Nathanail, C.P. (2009). Generic Assessment Criteria for human health risk assessment of potentially contaminated land in China. Science of the Total Environment, **408**, 324-339.

[61]. Church, R. L., Scaparra, M. P. and Middleton, R. S. (2004). Identifying critical infrastructure: the median and covering facility interdiction problems. *Annals of the Association of American Geographers*, 94(3), 491-502.

[62]. Cohen Hubal, E.A., Sheldon, L.S., Burke, J.M., Mccurdy, T.R., Berry, M.R., Rigas, M.L. and Zartarian, V.G. (2000). Exposure Assessment for Children: A Review of The Factors Influencing Exposure of Children, and the Data Available to Characterize and Assess That Exposure. *Environmental Health Perspectives*, 108(6), 475-486.

[63]. Coulon, F., Whelan, M.J., Paton, G.I., Semple, K.T., Villa, R. and Pollard, S.J.T. (2010). Multimedia fate of petroleum hydrocarbons in the soil: oil matrix of constructed biopiles. *Chemosphere*, 81(11), 1454-1462.

[64]. Dai, F.C., Lee, C.F. and Zhange, X.H. (2001). Gis-Based Geo-Environmental Evaluation For Urban Land-Use Planning: A Case Study. Engineering Geology, Volume 61, pp. 257-271. Dalton, G. (1962). Traditional Production in Primitive African Economies. *The Quarterly Journal of Economics*, 76(3), 360-378.

[65]. David, S. & Mirick, D.K. (2006). Soil ingestion in children and adults in the same family. *Journal of Exposure Science and Environmental Epidemiology*. **16**, 63-75.

[66]. Dawotola, A.W., Van Gelder, P.H.A.J.M. and Vrijling, J.K. (2010). Multi Criteria decision analysis framework for risk management of oil and gas pipelines. In: Reliability, Risk and Safety. London: Taylor and Francis Group, 307-314.

[67]. Di Toro, D.M., McGrath, J.A. and Stubblefield, W.A. (2007). Predicting the toxicity of neat and weathered crude oil: Toxic potential and the toxicity of saturated mixtures. *Environmental Toxicology and Chemistry*, 26(1), 24-36.

[68]. Diamond, J.T. and Wright, J.R. (1988). Design of an Integrated Spatial Information System for Multi-objective Land-Use Planning. *Environment And Planning B: Planning and Design*.**15**, 205-214.

[69]. Doyle, J.R., Blais, J.M. and White, P.A. (2010). Mass Balance Soil Ingestion Estimation Methods and their Application to Inhabitants of Rural and Wilderness Areas: *A Critical Review. Science Of the Total Environment,***408**, 2181-2188.

[70]. DurgaRao, K. (2005). Multi-Criteria Decision Analysis for Forecasting Urban Water Requirements: A Case Study of Dehraduncuty, India. Landscape And Urban Planning., **71**, 163-174.

[71]. Eastman, J.R., Jin, W., Kyem, P.A.K. and Toledano, T. (1995). Raster procedures for multicriteria/multi-objective decisions. *Photogrammetric Engineering and Remote Sensing*, 61(5), 539-547.

[72]. Ebdon, D. (1985). Statistics in Geography. 2nd Edition. Blackwell Publishing USA, UK, Australia.

[73]. Edino, M.O., Nsofor, G.N. and Bombom, L.S. (2010). Perceptions And Attitudes Towards Gas Flaring in The Niger Delta, Nigeria. *Environmentalist*, **30**, 67-75.

[74]. Edwards, D.A., Andriot, M.D., Amoruso, M.A., Tummey, A.C., Bevan, C.J., Tveit, A., Hayes, L.A., Youngren, S.H. and Nakles, D.V. (1997). Total Petroleum Hydrocarbon Criteria Working Group Series Volume 4: Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH), Massachusetts: Amherst Scientific Publishers.

[75]. Efiong, J. (2011). Changing pattern of land use in the Calabar river catchment Southern Nigeria. *Journal of Sustainable Development*. **4**, 92-102.

[76]. EGASPIN (2002). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria. Revised Edition ed. Lagos: Department of Petroleum Resources.

[77]. Environment Agency. (2009). Science Report SC050021/SR3: Updated Technical Background to the CLEA Model, Bristol: Environment Agency.

[78]. Faksness, L.G., Brandvik, P. J. and Sydnes, L.K. (2008). Composition of the water accommodate fractions as a function of exposure times and temperatures. Marine Pollution Bulletin, 56(10), 1746–1754.

[79]. Fantazzini, D., Hook, M. and Angelatoni, A. (2011). Global oil risk in the early 21st century. *Energy Policy*, **39**, 7865-7873.

[80]. Farwell, C., Reddy, C.M., Peacock, E., Nelson, R.K., Washburn, L. and Valentine, D.L. (2009). Weathering and the Fallout Plume of Heavy Oil from Strong Petroleum Seeps Near Coal Oil Point, Ca. *Environmental Science and Technology*, **43**, 3542-3548.

[81]. Fielding, N. (2012). Triangulation and Mixed Methods Designs: Data Integration with New Research Technologies. *Journal of Mixed Methods Research*, 20(10), 113.

[82]. Finer, C., Jemkins, C.N and Power, B. (2013). Potential of best practiceto reduce impact from oil and gas project in the Amazon. *Plos One*, 8(5),1-14.

[83]. Finer, M., Jenkins, C.N., Pimm, L.S., Keana, B. and Ross, C. (2008). Oil And Gas Projects InThe Western Amazon: Threats to Wilderness, Biodiversity and Indigenous Peoples. *Plos One*, 3(8), 1-9.

[84]. Fingas, M. (2000). The Basics of Oil Spill Cleanup. 2nd ed. London, New York Washington Dc: Lewis Publishers.

[85]. Fingas, M. and Fieldhouse, B. (2009). Studies On Crude Oil and Petroleum Product Emulsion: Water Resolution and Rheology. Colloids And Surfaces A: Physicochem Eng. Aspect, **333**, 67-81.

[86]. Gay, J.R. and Korre, A. (2006). A Spatially-Evaluated Methodology for Assessing Risk to a Population from Contaminated Land. *Environmental Pollution*, **142**, 227-234.

[87]. Geneletti, D. (2008). Incorporating Biodiversity Assets in Spatial Planning: Methodological Proposal and Development of a Planning Support System.*Landscape And Urban Planning,* **80**, 252-265.

[88]. Girard, L.F. and De Toro, P. (2007). Integrated Spatial Assessment: A Multicriteria Approach to Sustainable Development of Cultural and Environmental Heritage in San Marco Dei Cavoti, Italy. Central European Journal of Operations Research, **15**, 281-299.

[89]. Gomez, E.G. and Lins, M.P. (2002). Integrating Geographical Information Systems and Multi-Criteria Methods: A Case Study. *Annals of Operations Research*, **116**, 243-269.

[90]. Gomez-Delgado, M. and Tarantola, S. (2006). Global Sensitivity Analysis, GIS And Multi-Criteria Evaluation for a Sustainable Planning of a Hazardous Waste Disposal Site in Spain. *International Journal of Geographical Information Science*, 20(4), 449-466.

[91]. Haines-Young, R. (2011). Exploring Ecosystem Service Issues Across Diverse Knowledge Domains Using Bayesian Belief Network. *Progress In Physical Geography,* 35(5), 681-699.

[92]. Heywood, I., Cornelius, S. and Carver, S. (2006). An Introduction to Geographical Information Systems. 3 ed. England: Pearson Education Limited.

[93]. Heywood, I., Oliver, J. and Tomlinson, S. (1993). Building An Exploratory Multicriteria Modelling Environment for Spatial Decision Support. *International Journal of Geographical Information Science*, 7(4)1-15.

[94]. Holdway, D. (2002). The acute and chronic effects of wastes associated with offshore oil and gas production on temperature and tropical marine ecological process. Marine Pollution Bulletin, 44(3), 185-203.

[95]. Hooper, R.J., Fitzsimmons, R.J., Grant, N. and Vendeville, B.C. (2002). The Role of Deformation in Controlling Depositional Patterns in the South-Central Niger Delta, West Africa. Journal Of Structural Geology, 24, 847-859.

[96]. Howard, P., Meylan, W., Aronson, D., Stiteler, W., Tunkei, J., Comber, M. and Parkerton, T.F. (2005). A new biodegradation prediction model specific to petroleum hydrocarbons. *Environmental Toxicology and Chemistry*, 24(8), 1847-1860.

[97]. Hughes, J. and Rudolph, J. (2011). Future world oil production: growth, plateau, or peak? Current Opinion in Environmental Sustainability, **3**, 225-234.

[98]. Ikeji, C. (2011). Politics Of Revenue Allocation in Nigeria: A Reconsideration of Some Contending Issues. Sacha *Journal of Policy and Strategic Studies*, 1(1), 121 136.

[99]. Ikelegbe, A. (2001). Civil Society, Oil and Conflict in the Niger Delta Region of Nigeria: Ramifications of Civil Society for a Regional Resource Struggle. *Journal Of Modern African Studies,* 39(3), 437-469.

[100]. Imoobe, T. O. T. and Iroro, T. (2009). Ecological Restoration 0f Oil Spill Sites in the Niger Delta, Nigeria. *Journal Of Sustainable Development in Africa*, 11(1), 54-65.

[101]. International Programme on Chemical Safety (IPCS, 2000). Human Exposure Assessment. Environmental Health Criteria; 214. Geneva, World Health Organisation.

[102]. International Programme on Chemical Safety (IPCS, 2004). Report of the First Meeting of the IPCS Working Group on Uncertainty in Exposure Assessment in conjunction with a Scoping Discussion on Exposure data Quality. 19-20 August 2004. Geneva, World Health Organisation.

[103]. International Programme on Chemical Safety (IPCS, 2005). Principles of Characterising and Applying Human Exposure Models. Harmonisation Project Document No.3 Geneva, World Health Organisation.

[104]. Isreal, M. and Hay, L. (2006). Research ethics for social scientists. Newbury: Pine Forge Press.

[105]. Jankwoski, P. (1995). Integrating Geographic Information Systems and MultipleCriteria Decision-making Methods. *International Journal of Geographical Information System*, 9(3), 251-273.

[106]. Jiang, H. and Eastman, J.R. (2000). Application Of Fuzzy Measures inn Multi-Criteria Evaluation in GIS. *International Journal of Geographical Information Science*, 14(2), 173-184.

[107]. Joerin, F., Theriault, M. and Musy, A. (2001). Using Gis and Outranking Multicriteria Analysis for Land-Use Suitability Assessment. *International Journal of Analysis for Land-Use Suitability Assessment*, 15(2), 153-174.

[108]. John, V. (2013). DIY illegal oil refinery in the Niger Delt, video recording The Guardian. P 16/october/2013. [Online] Available at: http://www.theguardian.com/global development/video/2013/oct/16/illegal-oil-refinery-niger-delta-video [Accessed 31/10/2013].

[109]. Jooa, C., Shima, W., Kimb, G., Haa, S., Kima, M., Ana, J., Kima, E., Kima, B., Jungc, S., Kimd, Y. and Yima, U. (2013). Mesocosm study on weathering characteristics of Iranian Heavy crude oil with and without dispersants. *Journal of Hazardous Materials*, **248**-249,37-46.

[110]. Kamnikar, B. (2001). Managing Petroleum Contaminated Soil: Department Of Transportation Perspective. *Journal Of Environmental Engineering*12(127), 1080-1088.

[111]. Kandiyoti, R. (2012). Pipelines Flowing oil and crude politics. London: I.B.Tauris& Co Ltd.

[112]. Kassali, R., Ayanwale, A.B. and Williams, S.B. (2009). Farm location and determinants of agricultural productivity in the Oke-Ogun area of Oyo state, Nigeria. *Journal of Sustainable Development in Africa*. 11(2):1-18.

[113]. Katsouris, C. and Sayne, A. (2013). Nigeria's Criminal Crude: International Options to Combat the Export of Stolen Oil, London. Chatham House.

[114]. Kemp, M. (2009). Vilfredo Pareto's principle of compensation. International Trade and Economic Dynamics, **5**, 525-532.

[115]. Kennedy, M. (2009). Introducing Geographic Information Systems with ArcGIS: A Workbook Approach to Learning GIS. John Wiley & Sons, Inc, Hoboken, New Jersey.

[116]. Kimbrough, R.D., Krouskas, C.A., Carson, M.L., Long, T.F., Bevan, C. and Tardiff, R.G. (2010). Human Uptake of Persistent Chemicals from Contaminated Soil: Pcdd/Fs and Pcbs.. Regulatory *Toxicology and Pharmacology*, **57**, 43-54.

[117]. Koshland, C.P. and Connelly, L. (2001). Energy And Industrial Ecology-Part 1: An Energy-Based Definition of Consumption of Ecosystem Evolution. *Energy International Journal*, 1(3), 146-165.

[118]. Kraak, M. and Ormeling, F. (2010). Cartography: Visualization Of Spatial Data. 3 ed. England: Pearson Education Limited.

[119]. Kramer, B., 2013. North American Oil and Gas Pipelines: Saving the pipe. [Online] Available at: http://www.napipelines.com/saving-the-pipe-pipeline-securit/ [Accessed 28/09/2013].

[120]. Lamberts, F.R., Johnsen, A.R., Andersen, O. and Christensen, J.H. (2008). Univariate and Multivariate Characterization of Heavy Fuel Oil Weathering and Biodegradation in Soil. *Environmental Pollution*, **156**, 267-305.

[121]. Land Use Act. (1990). Laws of the Federation of Nigeria 1990 Land Use Act 1978, Part II: Principles of Land Tenure, Powers of Governor and Local Governments, and Rights of Occupiers. [Online] Available at: http://www.nigeria law.org/Land%20Use%20Act.htm [Accessed 04/12/2013].

[122]. Langley, A. (2011). Hazard Assessment and Contaminated Sites. In: F. Swartjes, ed. Dealing with Contaminated Site. pp. 517–570.

[123]. Lawler, D. (2003). Safeguarding water resources in the FSU in an era of transition: establishing WIA within the EIA process. European Water, 3(4), pp. 28-35.

[124]. LFN (1999). Constitution of the Federal Republic of Nigeria. [Online] Available at: http://www.nigerstate.gov.ng/epubl/Niger_constitution_1999.pdf [Accessed 19/11/2013].

[125]. Licari, L., Nemer, L. and Tamburlini, G. (2005). Children's Health and Environment Developing Action Plans, Denmark: World Health Organization Europe.

[126]. Lins, P.H.C. and de Almeida, A.T. (2012). Multidimensional risk analysis of hydrogen pipelines. International Journal of Hydrogen Energy, Issue 37, pp. 13545-13554.

[127]. Lodwick, W.A,. Monson, W. and Svoboda, L. (1990). Attribute Error and Sensitivity Analysis of Map Operations in Geographical Information System: Suitability Analysis. International *Journal of Geographical Information Science,* 4(4), 413-428.

[128]. Longley, P.A., Goodchild, M.F., Maguire, D.J. and Rhind, D.W. (2011). Geographic Information System and Science. 3 ed. United States of America: John Wiley and Sons.

[129]. Makropoulos, C.K. and Butler, D. (2006). Spatial Ordered Weighted Averaging Incorporating Spatially Variable Attitude Towards Risk in Spatial Multi-Criteria Decision-Making. *Environmental Modelling and Software*, **21**, 69-84.

[130]. Malczewski, J. (1999). GIS and Multi-Criteria Decision Analysis. New York: John Wiley & Sons, Inc.

[131]. Malczewski, J. (2006). GIS-Based Multi-criteria Decision Analysis: A Survey of the Literature. International Journal of Geographical Information Science, 20(7), pp. 703-726.

[132]. Mamdani, M. (1996). Citizen and Subject. Contemporary Africa and the Legacy of Late Colonialism. Princeton: Princeton University Press.

[133]. Manoharan, T.R. Muralidharan, C. and Deshmukh, S.G. (2011). An Integrated Fuzzy Multi-Attribute Decision-Making Model for Employees' Performance Appraisal. The International Journal of Human Resource Management., 22(33), pp. 722 745.

[134]. Mcintosh, S., King, T., Wu, D. and Hodson, P. (2010). Toxicity Of Dispersed Weathered Crude Oil to Early Life Stages of Atlantic Herring (Clupea Harengus). *Environmental Toxicology and Chemistry,* 29(5), 1160-1167.

[135]. Meyer, B.C. and Grabaum, R. (2008). Mulbo: Model Framework for Multicriteria Landscape Assessment and Optimization. A Support System for Spatial Land Use Decisions. *Landscape Research*, 33(2), 155-179.

[136]. Meyer, V. and Haase, D. (2009). A Multicriteria Flood Risk Assessment and Mapping Approach. In: Samuels et al, ed. Flood Risk Management: Research and Practice. London: Taylor And Francis Group.

[137]. Mitchell, A. (2009). The ESRI Guide to GIS Analysis Vol 2: Spatial Measurement and Statistics. ESRI Press California.

[138]. Mitchell, A. (2012). The Esri Guide to GIS Analysis Vol. 3: Modelling Suitability, Movement, and Interaction. ESRI Press California.

[139]. Molins, S., Mayer, K.U., Amos, R.T. and Bekins, B.A. (2010). Vadose Zone Attenuation of Organic Compounds at a Crude Oil Spill Site–Interactions Between Biogeochemical Reactions and Multicomponent Gas Transport. *Journal Of Contaminated Hydrology*, **112**, 15-29.

[140]. Monprapussorn, S., Thaitakoo, D., Banomyong, R. and Watts, D.J. (2009). The Application of Geographic Information System and Multi Criteria Decision Analysis; Towards Waste Transport Sustainability. *Journal of Applied Science*, 9(2),268-277.

[141]. Montevecchi, W. Fifield, D. Burke, C., Garthe, S., Hedd, A., Rail, J. and Robertson, G. (2011). Tracking long-distance migration to assess marine pollution impact. Biol Letters, pp. 1-4.

[142]. Morra, P., Bagli, C. and Spadoni, G. (2006). The Analysis of Human Health Risk with A Detailed Procedure Operating in A GIS Environment. Environment International, Volume 32, pp. 444-454.

[143]. Nathanail, C. P. (2013). Engineering geology of sustainable risk-based contaminated land management. Quarterly Journal of Engineering Geology and Hydrogeology, Volume 46, pp. 6-29.

[144]. Nathanail, C. P., Mccaffrey, C., Ashmore, M., Cheng, Y., Gillett, A., Hooker, P. and Ogden, R.C. (2007). Generic Assessment Criteria for Human Health Risk Assessment. Land Quality Press, Nottingham.

[145]. Nathanail, C.P., McCaffery, C., Asmore, M. H., Cheng, Y. Y., Gillett, A., Ogdem, R. and Scott, D. (2009). The LQM/CIEH Generic Assessement Criteria for Human Health Risk Assessment (2nd Edition). Nottingham: Land Quality Press.

[146]. Nathanail, P. and Bardos, P. (2004). Reclamation of Contaminated Land. John Wiley & Sons Ltd, Chichester, England.

[147]. Nnubia, C. (2008). Clean Nigeria Associates Limited: Development, Challenges and Future of an African Oil Spill Co-Operative. International Oil Spill Conference Proceedings, 2008(1), 1123-1129.

[148]. Nobre, A., Pacheco, M., Jorge, R., Lopes, M.F.P. and Gato, L.M.C. (2009). Geo-Spatial Multi-Criteria Analysis for Wave Energy Conversion System Deployment. *Renewable Energy*, **34**, 79-111.

[149]. Nobrega, R.A.A., O'hara, C.G., Sadasivuni, R. and Dumas, J. (2009). Bridging Decision-Making Process and Environmental Needs in Corridor Planning. Management Of Environmental Quality: *An International Journal*, 20(6), 622 637.

[150]. Nwabughhuogu, A.I. (1981). The role of propaganda in the development of indirect rule in Nigeria, 1980-1929. *International Journal of African Historical Studies*, 14(1), 65-92.

[151]. Nwilo, P.C. and Badejo O.T. (2005). Oil Spill Problems and Management in the Niger Delta. International Oil Spill Conference Miami, Florida.

[152]. Nzeadibe, C.T. and Ajaero, C.K. (2010). Assessment of Socio-Economic Characteristics and Quality of Life Expectations of Rural Communities in Enugu State, Nigeria. *Applied Research Quality Life,* **5**, 353-371.

[153]. O'Rourke, D. and Connolly, S. (2003). Just Oil? The Distribution of Environmental and Social Impacts of Oil Production and Consumption. Annual Review Environmental Resources, **28**, 587-617.

[154]. Ogbondah, C. (1994). Press Freedom in West Africa: An Analysis of One Ramification of Human Rights. *Journal Of Opinion*, 22(2), 21-26.

[155]. Okereke, J.N., Obiekezie, S.O. and Obasi, K.O. (2007). Microbial flora of oil-spilled sites in Egbema, Imo Stata, Nigeria. *African Journal of Biotechnology,* 6(8), 991-993.

[156]. Okoli, C.G. (2006). Rural household perception of the impact of crude oil exploration in Ogba/Egbema/Ndoni local government area of Rivers state, Nigeria. *Journal of Agriculture and Social Research (JASR)*. 6(2), 86-91.

[157]. Olokesusi, F. (2005). Environmental Impact Analysis and the Challenge of Sustainable development in the Oil Producing Communities. Nigeria Institute of Town Planning Abuja. Omofonmwan, S. I. and Osa-Edoh, G. I. (2008). The Challenges of Environmental Problems in Nigeria. *Journal Of Human Ecology*, 23(1),53-57.

[158]. Omo-Irabor, O.O., Olobaniyi, S.B., Akunna, J. Venus, V., Maina, J.M. and Paradzayi, C. (2011). Mangrove Vulnerability Modelling in Parts Of Western Niger Delta, Nigeria Using Satellite Images, Gis Techniques and Spatial Multi-Criteria Analysis (Smca). *Environ Monit Assess,***178**, 9-51.

[159]. Oni, S.I. and Oyewo, M.A. (2011). Gas Flaring, Transportation and Sustainable Energy Development in the Niger-Delta, Nigeria. *Journal Of Human Ecology,* 33(1), 21-28.

[160]. Onojeghuo, A.O and Blackburn, G.A. (2011). Forest Transition in an Ecologically Important Region: Patterns and Causes for Landscape Dynamics in the Niger Delta. Ecological Indicators, **11,**1437-1446.

[161]. Onuoha, S.C., Olugbue, V.U., Uraku, J.A. and Uchendu, D.O. (2011). Biodegradation potentials of hydrocarbon degraders from waste-lubricating oil-spilled soils in Ebonyi State, Nigeria. *International Journal of Agriculture & Biology*, 13(4), 586-590.

[162]. Onwe, O.J. (2012). Economic Implications of Petroleum Policies in Nigeria: An Overview. *American International Journal of Contemporary Research*, 2(5), 60-71.

[163]. Onwurah, I. N. E., Ogugua, V. N., Onyike, N. B., Ochonogor, A. E. and Otitoju, O. F. (2007). Crude Oil Spills in The Environment, Effects and Some Innovative Clean Up Biotechnologies. *International Journal of Environmental Research*, 1(4),307-320.

[164]. Osha, S. (2006). Birth of the Ogoni Protest Movement. *Journal of Asian and African Studies*, 14(1/2), 13-38.

[165]. Osuji, L. C., Egbuson, E. J. and Ojinnaka, C. M. (2006). Assessment And Treatment of Hydrocarbon Inundated Soils Using Inorganic Nutrient (N-P-K) Supplements. A Case Study of Eneka Oil Spill in Niger Delta, Nigeria. *Journal of Environmental Monitoring and Assessment,* **115**, 265-278.

[166]. Ozkaynak, H., Xue, J., Zartarian, V.G., Glen, G. and Smith, L. (2010). Modeled Estimates Of Soil and Dust Ingestion Rates for Children. Society For Risk Asssessment, 1-17.

[167]. Park, C. (2008). Oxford Dictionary of Environment and Conservation. Oxford University Press. United Kingdom.

[168]. Perkins, R.A., Rhoton, S.and Behr-Andres, C. (2003). Toxicity of dispersed and undispersed, fresh and weathered oil to larvae of a cold-water species Tanner crab (C. bairdi), and standard warm-water test species. *Cold Regions Science Technolology,* 36(1-3), 129–140.

[169]. Prince, R.C. and Lessard, R.R. (2004). Crude Oil Releases to The Environment: Natural Fate and Remediation Options. Encyclopedia Of Energy, **1**, 727-736.

[170]. Pulido, L. (1996). Environmentalism and Economic Justice. University of Arizona Press USA. Qimin, M.N., Zhanglin, N.I. and Zhiganga, Y.U. (2009). The Biomarker Changes of a Heavy Fuel Oil After Different Weathering Times. *Journal Of Ocean Univ. ChinaOceanic and Coastal Sea Research*,**8**, 51-56.

[171]. Ramseur, J.L. (2010). Deepwater Horizon Oil Spill: the fate of the oil. Congressional Research Service. 7-5700.

[172]. Ratcliffe, J.H & Taniguchi, T.A. (2008) "Is crime higher around drug-gang street corners? Two spatial approaches to the relationship between gang set spaces and local crime levels". *Crime Patterns and Analysis,* 1(1) 17-39.

[173]. Reible, D. (2010). After the oil is no longer leaking. Environmental Science and Technology, Issue 44, pp. 5685-5686.

[174]. Rial, D., Radovic, J., Bayona, J. and Macrae, K. (2013). Effects of simulated weathering on the toxicity of selected crude oils and their components to sea urchin embryos. *Journal of Hazardous Materials,* 260, 67-73.

[175]. Saaty, R. (1987). The analytic hierarchy process- what it is and how it is used. *Math. Modelling*, 9(3-5), 161-176.

[176]. Saaty, T. (1980). Analytic Hierarchy Process, McGrawHill, New York.

[177]. Saaty, T. (2008). Decision making with the analytical hierarchy process. *Int. J. Services Sciences*, 1(1), 83-98.

[178]. Salanitro, J.P., Dorn, P.B., Huesemann, M.H., Moore, K.O., Rhodes, I.A., Rice Jackson, L.M., Vipond, T.E., Western, M.M. and Wisniewski, H.L. (2009). Crude oil hydrocarbon bioremediation and soil ecotoxicity assessment. Environ*mental Science & Technology*, 31(6), 1769-1776.

[179]. Shell Nigeria. (2013d). Oil Spills in the Niger Delta-Monthly Data. [Online] Available at: http://www.shell.com.ng/environment-society/environment-tpkg/oil spills/monthly-data.html [Accessed 05/12/2012].
[180]. Shell Petroleum Development Company (2007). Environmental performance: oil spills and managing our facilities. Published by Shell Companies in Nigeria: Shell Petroleum Development Company, Shell Nigeria Exploration and Production Company, Shell Nigeria Oil Products and Shell Nigeria Gas Ltd.
[181]. Short, J. (2003). Long-term effects of crude oil on developing fish: lessons from the Exxon Valdez oil spill. Energy Sources, 25(6), 509-517.
[182]. Sojinu, O.S.S., Wang, J., Sonibare, O.O. and Zeng, E.Y. (2010). Polycyclic Aromatic Hydrocarbons in Sediments and Soils from Oil Exploration Areas of the Niger Delta, Nigeria. *Journal Of Hazardous Materails*, **174**, 641-647.
[183]. Steiner, R. (2010). Double standard Shell practices in Nigeria compared with international standards to prevent and control pipeline oil spills and the Deepwater Horizon oil spills, Amsterdams: Milieu DefensieThe Netherlands.
[184]. Store, R. and Kangas, J. (2001). Integrating Spatial Multi-Criteria Evaluation and Expert Knowledge For Gis-Based Habitat Suitability Modelling. *Landscape And Urban Planning*, **55**, 79-93.
[185]. Teerarojanarat, S. and Tingsabadh, K. (2011). A GIS Based Approach for Dialect Boundary Studies. *Dialectologia,***6**, 55-75.
[186]. The Petroleum Economist. (2005). Energy Map of Nigeria. South Africa, Produced by the Petroleum Economist Ltd, London, in association with the Nigerian National Petroleum Corporation, for the 18th World Petroleum Congress.
[187]. U.S. Energy Information Administration. (2013). Independent statistics and analysis: petroleum and other liquids data. [Online] Available at: http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm [Accessed 15/11/2013].
[188]. Ugochukwu, C.N.C. and Ertel, J. (2008). Negative Impact Of Oil Exploration on Biodiversity Management InThe Niger Delta Area Of Nigeria. Impact Assessment and Project Appraisal, 26(2), 139-147.
[189]. Uluocha, N. (2007). Elements of Geographic Information Systems, Sam Iroanusi Publications, Lagos.
[190]. United Nations Environmental Programme. (2011). Environmental assessment of Ogoniland, Nairobi, Kenya: UNEP. DEP/1337/GE.
[191]. United Nations Treaty Series. (1977). Convention on The Prevention of Marine Pollution by Dumping of Wastes and Other Matter. [Online] Available at http://treaties.un.org/doc/Publication/UNTS/Volume%201046/volume-1046-I 15749-English.pdf [Accessed 14/11/2013].
[192]. United Nations Treaty Series. (1978). International Convention for the prevention of Pollution from ships. [Online] Available at: http://treaties.un.org/doc/Publication/UNTS/Volume%201340/volume-1340-A 22484-English.pdf [Accessed 14/11/2013].
[193]. Urhobo Historical Society. (no date). Niger Delta: Rivers, States, Vegetation. [Online] Available at: http://www.waado.org/nigerdelta/maps/NigerDelta_Rivers.html [Accessed 03/11/2013].
[194]. Von Kemedi, D. (2003). The Changing Predatory Styles of International Oil Companies in Nigeria. *Review Of African Political Economy*, 30(95),134-139.
[195]. Wang, S., Shen, Y., Guo, Y. and Tang, J. (2008). Three-Dimensional Numerical Simulation for Transport of Oil Spills in Seas. *Ocean Engineering*, **35,**503-510.
[196]. Wang, Z., Stout, S.A. and Fingas, M. (2006). Forensic Fingerprinting of Biomarkers for Oil Spill Characterization and Source Identification. Environmental Forensics, Volume 7, pp. 105–146. Watts, M.J. and Ibaba, I.S. (2011). Turbulent Oil: Conflict And Insecurity in the Niger Delta. *African Security*, **4**, 1-9.
[197]. William, A.B. and Benson, N.U. (2010). Interseasonal Hydrological Characteristics and Variability in Surface Water of Tropical Estuarine Ecosystems Within Niger Delta. *Journal Of Environmental Monitoring and Assessment,* 165(1-4), 399-406.
[198]. Wise, S. (2002). Gis Basics. Taylor and Francis, London. Wong, K. M., Strecker, E.W. & Stenstrom, M. K. (1995). GIS to estimate storm-water pollutant mass loading. *Journal of Environmental Engineering.* 123(8):737-745.
[199]. Wood, L.J. and Dragicevic, S. (2007). GIS-Based Multicriteria Evaluation and Fuzzy Sets to Identify Priority Sites for Marine Protection. *BiodiversConserv*, **16**, 2539-2558.
[200]. Yalcin, G. and Akyurek, Z. (2004). Analysing Flood Vulnerable Areas with Multicriteria Evaluation. Proceedings of the Commission. Istanbul, Turkey, 20th International Society ForPhotogrametryAnd Remote Sensing (ISPRS) Congress, 12-23 July 2004.
[201]. Zemo, D.A. and Foote, G.R. (2003). The technocal case for eliminating the use of the TPH analysis in assessing and regulating dissolved petroleum hydrocarbons in ground water. *Ground Water Monitoring and Remediation*, 23(3), 95-104.
[202]. Zhibing, J., Yijun, H., Xiaoqun, X., Yibo, L., Lu, S., Jingjing, L., Quanzhen, C. and Jiangning, Z. (2010). Advance in the toxic effects of petroleum water accommodated fraction on marine plankton. *Acta Ecologica Sinica*, **30**, 8-15.s