Modelling oil spill trajectory and the Geo - Spatial exposure of Communities in Niger Delta, Nigeria

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Abstract

Digital Elevation Model 30 by 30 meters was analyzed using Arc GIS 9.3 tools to classify the area for the understanding of the terrain dynamics amidst its undulating surface. Potential direction, sinks of spilled oil was modelled using ArcSWAT. Findings revealed that the direction/trend of spill results in the vulnerability of communities with the population density of 1:240 persons per km2. There are more clusters of oil wellhead in the coastal areas of the study area. The horn of the study area enjoys less presence of oil well though there are pockets of oil well in places classified as very highly vulnerable. The vulnerability of the coastal communities is complicated by the clusters of well head increasing the potential of spill induced hazard in the area. This is complicated by the drainage network that crisscrosses the region which makes it difficult to contain the impact of the spill in the region to a particular community. The drainage pattern aids the movement of spilled oil easily across the entire region.
The study recommends an institutional framework for an integrated coastal zone management and future research in areas of species vulnerability to spill to enhance more detailed spatial analysis of vulnerability across the Niger Delta region.

Keywords: Modelling; exposure; vulnerability, undulating; coastal; anthropogenic; spillage

Introduction

Millions of people visit and live in coastal areas which possess a combined spectacular and scientifically significant geomorphologic and cultural feature. Globally, it is estimated that about 60% of human population dwell in coastal environments and depend on these coastal resource in diverse ways. Apart from global climatic change, a major environmental problem in Nigeria is oil spill which for the period between 1976 and 1996 recorded a total of 4,835 oil spill incidents resulting in the loss of 1,896,960 barrels of oil to the environment (Chris, Will, Tastu, and Kelly 2008). The alarming impact of anthropogenic activities on the Niger Delta shoreline and coastal processes however have prompted individuals, environmental scientists, and research institutes to proffer and implement solution to issues that make the region vulnerable to hazard. Oil exploration activities alongside oil spillage have been occurring in the Niger Delta for several decades. This has adversely impacted the Niger Delta region, contaminating the rivers, streams and forest resources which constitute the major socio – economic base of the people. Spill occurrence and flow on land is governed by the undulating nature of the land surface and the degree of slope enhancing its flows (Chris, Will, Tastu, and Kelly 2008). Hence, elevation is identified as one of the most influential factors affecting vulnerability of the coastal landscape to coastal and other industrial perturbations. This is because elevation defines flood pattern, oil spill flow direction, the likelihood of coastal erosion, development constrain and inundation potential. In the wake of today's environmental challenges faced by humanity, everyone has been made vulnerable to environmental impact of some kind. The National Oil Spill Detection and Response Agency (NOSDRA) was created by the Federal Executive Council to contain the problem of oil spill in the region which impacts on the vegetal environment as shown in plate 1 and 2.

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Oil Well Head Located in the Middle of a River in the Ni
Delta

Oil Spilled Site in the Niger Delta

Photo: Researcher's Field Work

Plate 1 Exposure to Spill from Wellhead

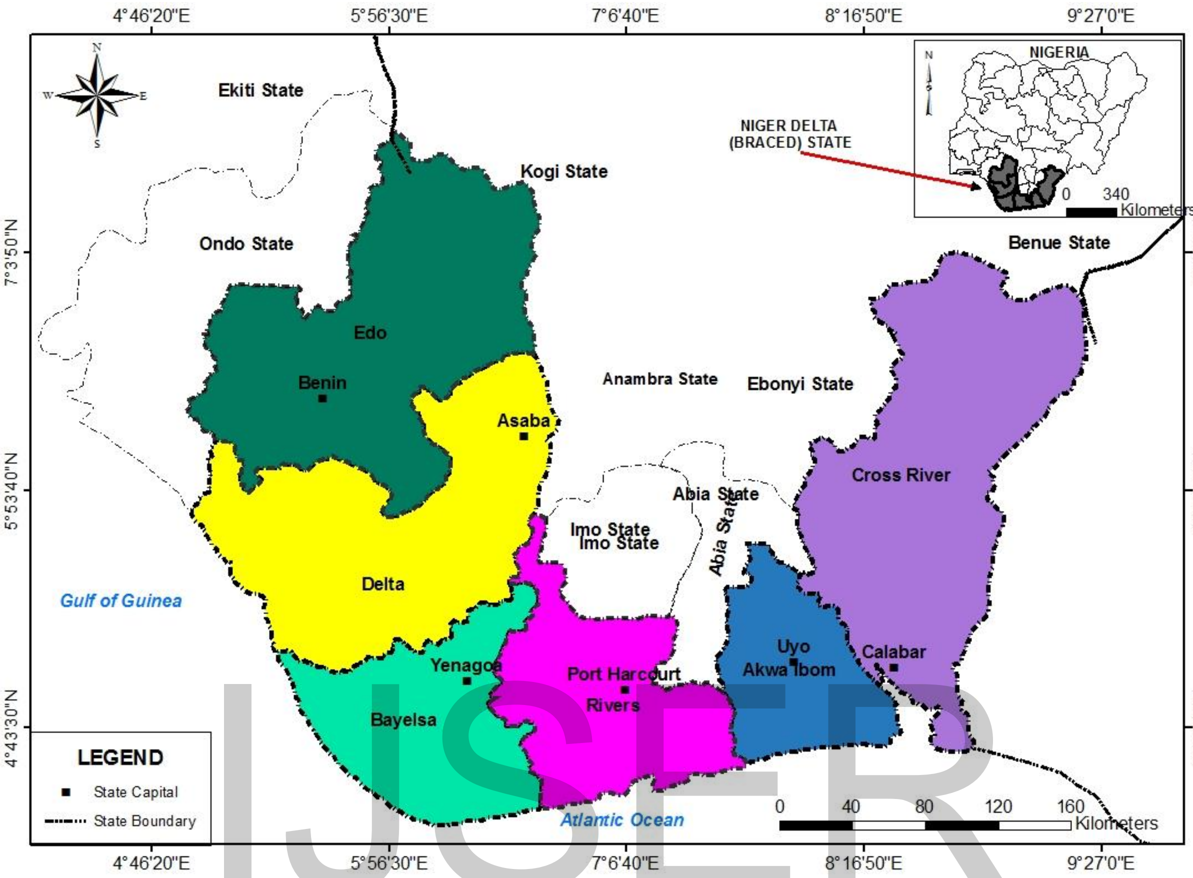
Photo: Author 2013

Plate 2 Oil Spill Polluted Environment from JKT 1

Study Area

The study area is located in the Niger Delta Region of Nigeria which is the Southern – Southern part of Nigeria. The study region stretches within latitude 4^0 12' 30.892'' N and 4^0 50' 10.7'' N through longitude 4^0 56' 15'' E and 9^0 40' 2.654'' E. it comprise five states of Akwa Ibom, Bayelsa, Cross River, Delta, Edo and Rivers State having a total area of 84,643 km^2.

The Federal Government of Nigeria (FGN) (2007) describe the region to be located in the southern part of Nigeria, Neighboured to the south by the Atlantic Ocean, East by the Republic of Cameroon and to the North and West are other federating states of Nigeria. The Niger Delta (BRACED) states comprises six of the nine states in Niger Delta Region namely Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers see figure 1.



Note: Highlighted States Constitute the Niger Delta BRACED States

Source: Adapted from NASRDA, 2010 and Digitized by Researcher

Figure 1. Niger Delta (BRACED) States

Relief and Drainage

The coastal zone of the study area consist of 20 barrier island ridges bordering the Atlantic ocean falling within the classification of a generally low lying terrain consisting of unconsolidated mud and sandy particles resulting in little or no resistance to tidal and wave impact on its shoreline (Oyegun 1993). The morphology of the region can therefore be identified within five geomorphic unit of Strand Coast, Delta Flank, Arcuate Delta, Transgressive mud Coast and

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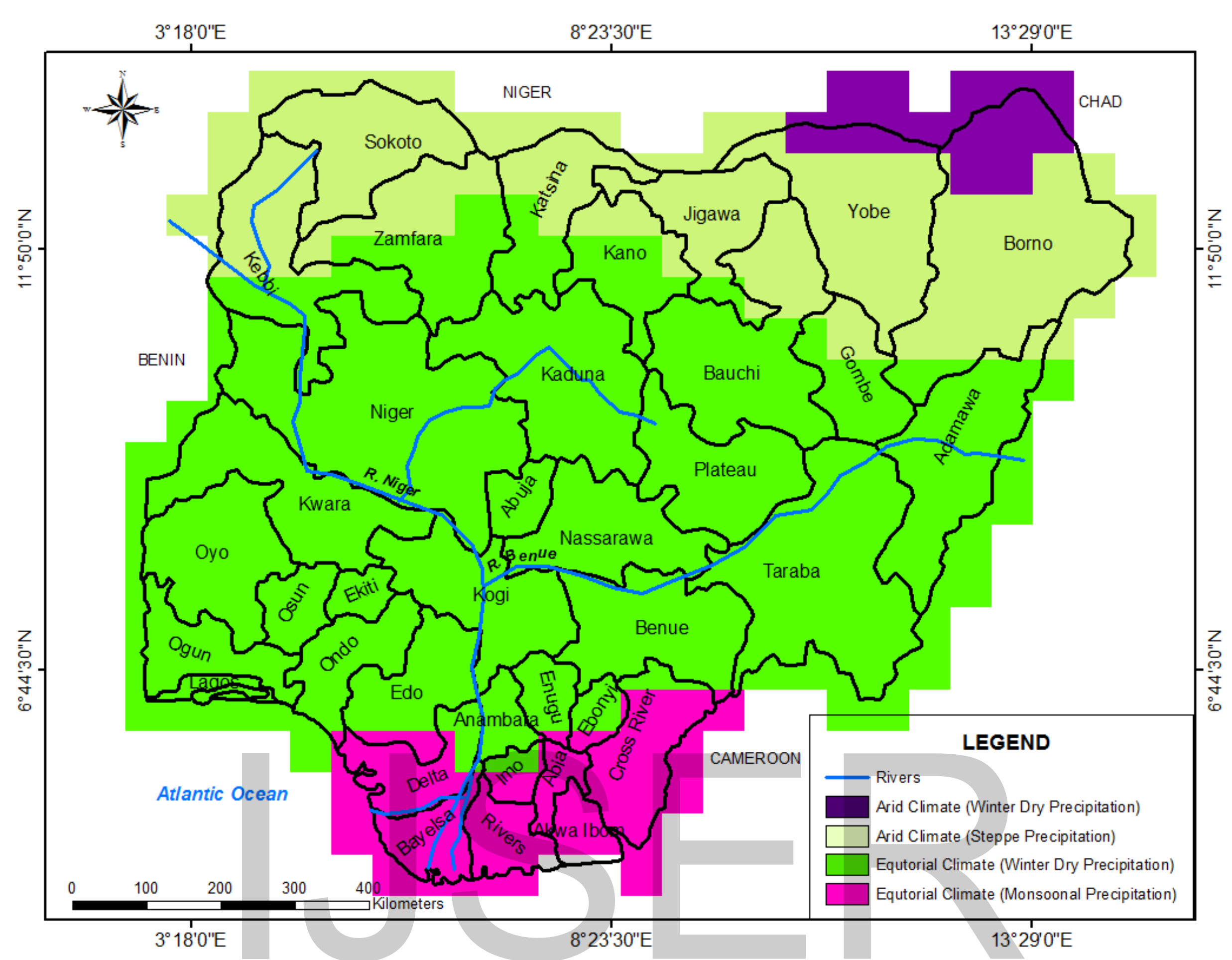
Barrier-Lagoon Coast based on morphological characteristic, nature of beach material/sediments, beach slope and vegetation as identified by Research Planning Institute, (1985) in Oyegun (1993). The Arcute Niger Delta which consist of medium to coarse sand with a shore length of 256km and a Beach Width of 50m is the most dominant morphological feature of the study area shoreline. It protrudes in an arc-like form in to the Atlantic Ocean with distributaries opening in to the Atlantic Ocean through 19 estuaries or tidal/river inlets. The barrier – Lagoon coastline of the Lagos-lekki area of Nigeria Coastline evolves from the coalescence of fossil barrier sand ridges which sandwich lagoons that run parallel to the coastline while the Transgressive mud coast lies between the Benin river entrance and the Lekki Lagoon and stretching for 50 to 70 km in length with pronounced presence of berm cliff of over 1m high, cut in mud and fronted by an inter-tidal off-shore terrace of mud extending 1-2km off-shore in to the Atlantic Ocean. The Niger Delta Flanks is the adjoining area east and west of the arcuate Niger Delta. The relatively unbroken coastline of the eastern margin to include the mouth of Qua Ibo and Cross – River estuary is the strand coastline and it witnesses a relatively stepper inter-tidal slopes in relation to the other stretch of the Niger Delta.

Climate

The climatic of the region can be classified into four distinct climatic types which range/stretch from the Equatorial Climate with Monsoonal Precipitation in the south – southern part of Nigeria engulfing study states like Delta, Bayelsa, Rivers, Akwa Ibom part of Cross River and Edo States. The Northern parts of Cross River and Edo States were still Equatorial climatic category though with winter dry precipitation rather than monsoonal precipitation as classified by Koppen – Geiger (2006) see figure 2



Source: Adapted from world map of Koppen – Geiger Climatic Classification, 2006.

Figure 2 Climatic Classification of Nigeria

The wet season in the region is relatively long, lasting between seven and eight months of the year, from the months of March to October. Though, in the northern and north-western parts of the Niger Delta Region, there is noticeable delay in the emergence of the rainy season for as much as four weeks, thereby extending the dry season which, in recent times, tends to last some four to five months. There is usually a short break around August, otherwise termed the "August break". The dry season begins in late November and extends to February or early March, a period of approximately three months. During the dry season, the northeast trade wind blowing over the Sahara Desert extends its dehydrating influence over the region in late December or early January. This period is known as the "Harmattan", which is more noticeable in some years than others. Mean annual rainfall ranges from over 4,000mm in the coastal towns, and decreases inland to 3,000mm in the mid-delta and slightly less than 2,400mm in the northern parts of the region. The north western areas of the region record annual rainfall of 1,500 to 2,000mm. Temperatures are generally high in the region and fairly constant throughout the year as a result, average monthly maximum and minimum temperatures vary from 28^{o}c to 33^{o}c and 21^{o}c to 23^{o}c, respectively, increasing northward and westward. With the warmest months in February, March and early April in most parts of the region. The coolest months are recorded in the month of June through to September which is the peak of the wet season (FGN, 2007).

Geographic Information System (GIS) in Oil Spill Management

Tajadeen & Bager (2014) conducted a research aimed at creating a GIS database of major oil spills in Gokana Local Government Area of Rivers State, characterizing the spills spatially, and finally proposing management approach based on GIS techniques. They used secondary data collected from the literature and media sources for the study. The dataset included oil spill locations, topographic and relief maps. Result of the study revealed three classes of major oil spill which are high volume oil spill 10,000 – 100,000 barrels, very high volume oil spill 100,000 - 200,000 barrel and extremely high volume oil spill more than 200,000 barrel. It was discovered that majority of the spill events are of high volume spill. Buffer zone analysis drawn for oil terminals, fields, pipelines and spill locations located in Gokana LGA in 2014 recommended relocation of residential areas to a minimum of 1km away from oil fields, terminals and pipeline.

Oyinloye & Olamiju (2013) assessed the environmental impact of oil spillage using GIS and Remote Sensing (RS) technologies. Secondary data was secured by the classification of imageries, extractions from books, seminar papers, journals, and other relevant literature. Also used were online data, maps, photographs and direct observation of spilled site. The finding from the land use / land cover map of the study area revealed that oil spill is increasing unabated in the study area.

Kadafa (2012) quantified and modelled oil spill on land and also simulated land based oil spill trends from pipelines and oil storage facilities. The author employed a 30 meter Digital Elevation Model (DEM), surface water network information, to assess flood management stategy and shoreline change. Findings revealed that the oil industries located in the Niger Delta region have caused massive destruction to farmlands, sources of drinking water, mangrove forest, fishing grounds and decline of fish, crabs, periwinkles and birds. Also large areas of mangrove forest have been destroyed by spills. This may have necessitated the complete relocation of some communities, as the spill impacted ancestral homes, fresh water, forest, agricultural land and fishing grounds. The reducing fish population is becoming a problem as it is a major source of income for the Niger Delta people.

Chris, Will, Tastu, and Kelly (2008) modelled oil spill onland and simulated land based oil spills trend from pipeline and oil storage facilities. They employed a 30 meter DEM alongside information on surface water network for the area under consideration. Findings reveal that the predicted overland travel path is only as good as the elevation data.

Udoh & Ekanem (2011) examined the total loss and damages that may result from oil spill in Akwa Ibom State. GIS techniques were used in the study and a combination of hazard and vulnerability data layers constituted a GIS based risk assessment analytical tool. The resulting risk layer was classed into four zones of very high, high, moderate and marginal risk. Findings reveal that Ikom and its environs are in the very high risk zone.

The GIS tool according to Onoja (2012), is ideally suited for various flood plain management activities/analysis such as, base mapping, topographic mapping, and post disaster verification of mapped flood plain extents and depths. For vulnerability assessment, the GIS technique is very essential because it differs from other set of information system as it emphasises location and area/unit, using geographic coordinate in acquisition, storage and analysis of spatial data.

Petroleum Industry and the Niger Delta Environment

Adelana, Adeosun, Adesina, Ojuroye, (2011) examined the environmental pollution and remediation strategy for oil spillage in the Nigerian Coastal areas. Secondary data were obtained and analyzed using qualitative and quantitative methods. Findings reveal that most oil spills were caused by human errors, carelessness and sabotage or bunkering.

Oshwofasa, Anuta, Aiyedogbon, (2012) examined the social and economic implication of environmental degradation as a result of the operation of the petroleum industry in the Niger Delta region. Data obtained was analysed using quantitative and descriptive methods, factoring the abundant resources in the region and the implication on the economy Findings revealed that not much has been done to enhance the development of the area. Therefore, the people of the region have continued to suffer environmental degradation caused by oil and gas related industrial activities.

Spatial Data Model

The process is concerned with the management of the dynamic shaping the physical environment of places. The model is used to make an abstraction of reality with the aim of rendering the problem identified for the study more explorable and understandable. Spatial data models capture the formal expression of the human understanding of space and the spatial objects embedded in it. The major goal of such formalisation is to render the concept of space and spatial objects understandable and amenable to computer implementation (Vossen,1991; Mesgari, 2000). Spatial data models are intended to represent space and the spatial objects along with the relations between them in an abstract fashion. This enhances the creation of spatial database which is a repository of data elements abstracted from the real world. This repository is generally structured in keeping with a designed data model. Such a replica is usually consulted for any analysis or investigation related to the real world.

GIS application in spatial data modelling enhances the efficient handling of geospatial data consisting of geometrical, topological and semantic aspect of real world phenomena. It implies that a spatial data model handled in a GIS environment must satisfy a primary caveat of being properly structured and utilised to identify and represent objects referenced by space relative to the earth surface (Shekhar & Chawla, 2003).

GIS allows for geospatial modelling whose ultimate goal is to structure data in a form that is amenable to computer processing and manipulation.

Oil exploration and the Niger Delta

Nigeria has the largest natural gas reserve in Africa and is the leading African continent primary oil producer. As of the 1980s oil revenue provided 90% of Nigeria foreign exchange earning 85 percent of the government revenue with estimated reserve extending beyond 20 to 30 years (Chris, Will, Tastu, and Kelly 2008).

Despite the oil industries contribution to the growth and development of the national economy via the oil sector which the country depends upon for part of her foreign exchange earnings, unsustainable oil exploration has rendered the region highly degraded with its disastrous impacts on the environment. Oil spill issues in the Niger Delta have been very contentious with the local communities pitching their camp against giant multinationals companies, government and regulators are constantly being accused of double standard and collusion. The local people are of the opinion that the impact of oil spill on their environment has resulted in the contamination of streams, rivers, forest which affects the livelihood of the indigenous people who depend on the ecosystem services for survival leading to increased poverty and displacement of the people.

The magnitude of impact from oil spill on the Niger delta is exacerbated by the terrain and drainage. Spills often enter the stream and are transported through the stream network (Chris, Will, Tastu, and Kelly 2008). Oil has been modelled to travel downstream until all available oil is lost to the shoreline or to evaporation.

As the oil flow down the slope, oil mass is lost through adhesion to surface vegetation, puddle formation on the ground surface and pooling in depression.

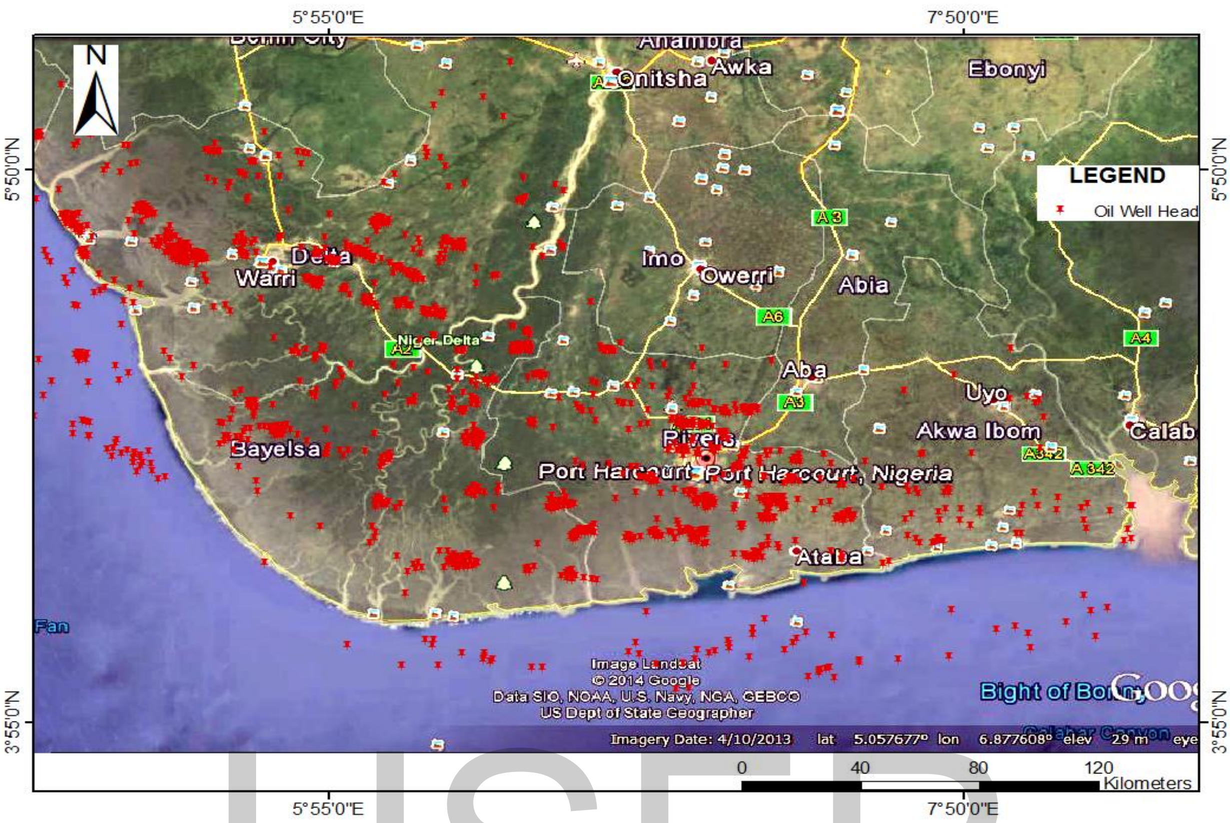
Industrial Perturbation

It is anticipated that the Nigeria Sat 1 satellite for geographical mapping shall help to check the perennial problem of oil pipeline vandalization and also assist in combating and managing oil spill incidents. This is sequel to the estimation by the Nigeria National Petroleum Company (NNPC) that the quantity of petroleum related spill lost to the environment yearly is about 2,300 cubic meters with an average of 300 individual spills yearly. Though, the World Bank argues that the true quantity of petroleum spilled into the environment could be ten times more than the officially claimed amount. Efforts to manage oil spill disaster along the Niger Delta coast line has been made by the Federal Government, oil companies and non – governmental agencies. These efforts include reducing the rate of oil incidents along the Nigeria coast particularly as a result of vandalization. Creation of the Niger Delta Development Commission (NDDC) part of its responsibility is to develop a master plan, infrastructure and create an enabling environment for industrialisation and employment in the region.

There are several other federal and state agencies whose responsibility is to deal with the problem of oil spill in Nigeria. They include Department of Petroleum Resource (DPR), Federal Ministry of Environment, and the State Ministry of Environment, the National Maritime Authority and the National Oil Spill Detection and Response Agency (NOSDRA). They are saddled with the responsibility of executing the national oil spill contingency plan which is in compliance with the International Convention on oil Pollution Preparedness Response and Cooperation. The increasing awareness of the impact and extent of oil spill in Nigeria, the Clean Nigeria Association (CNA) was formed in November 1981. The CNA is a consortium of eleven oil companies operating in Nigeria including the NNPC. The primary purpose of establishing the CNA is to maintain a capacity to combat spill of liquid hydrocarbons or pollutants in general.

The largest global individual spills include the blowout of a Texaco offshore station which in 1980 dumped an estimated 400,000 barrels of crude oil into the Gulf of Guinea and Royal Dutch Shell's Forcados Terminal tank failure which produced a spillage estimated at 580,000 barrels. It was estimated that between 9 million and 13 million barrels of oil has been spilled in the Niger Delta since 1958 (Baird, 2010).

Oil wells in the study area is put at 606 out of which 360 are onshore and 246 offshore hosting a total of 5,284 oil well heads (NCAB, 2005; Lubeck and Ronnie, 2007; GoogleEarth, 2014; Kuenzer, Steffen, Tuan 2014; NOSDRA, 2014).



Source: Shell Map, 2013; NOSDRA, 2014; Google Image, 2014

Figure 3. Niger Delta Showing distributions of Oil wells

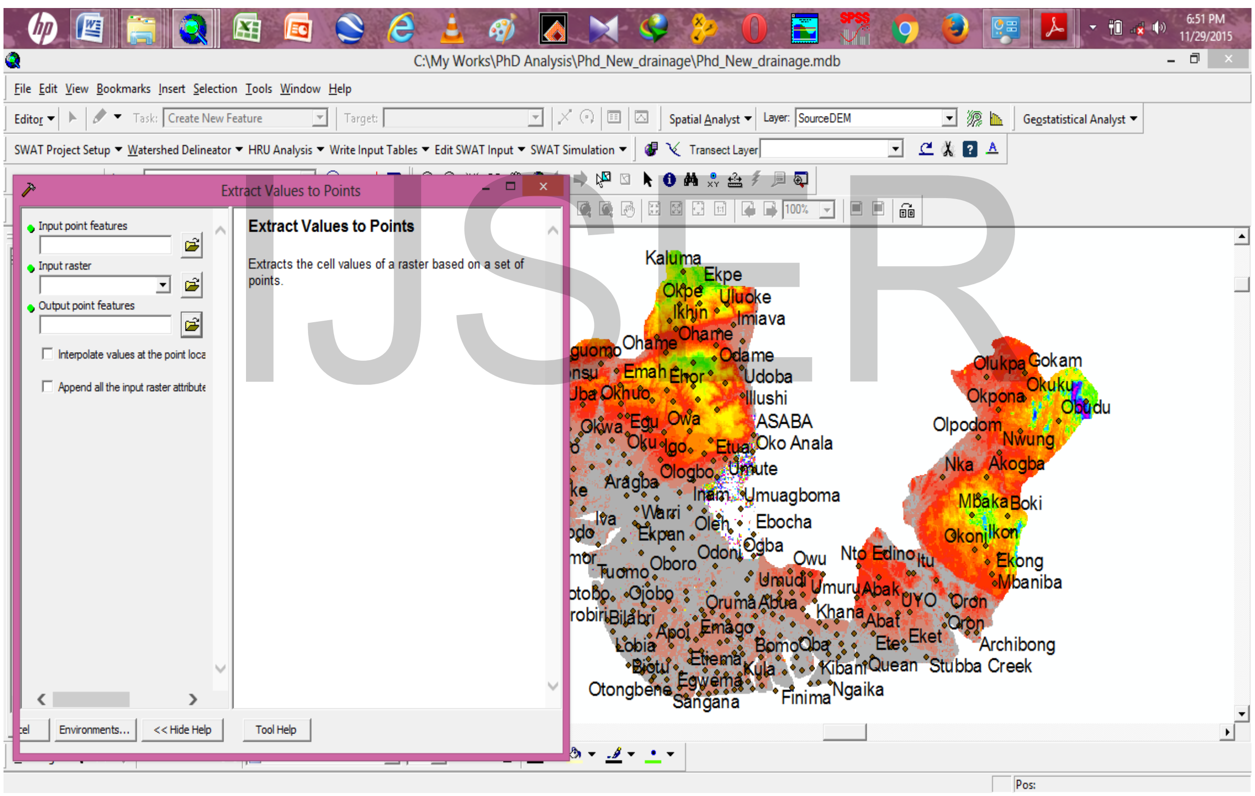
Method

The elevation of communities in the study area was calculated using the Shuttle Radar Topography Mission (SRTM) data which aided in the generation of a digital topographic map of the study area surface at a 30 meter resolution with an absolute horizontal and relative vertical accuracy of 90% confidence level (USGS, 2006).

The print screen shown in figure 4 shows the extraction process of point (Z value) from a raster surface (30 meter resolution DEM). Karwel (2008) specified that STRM data can serve for a better function than their standard specification and hence could be utilised for a variety of geospatial applications, such as coastal vulnerability mapping (Karwel, 2008).

Data on oil spills locations, oil wellheads and pipelines within the study area were sourced from various sources including NOSDRA, oil companies/ agencies, published reports, maps and other sources.

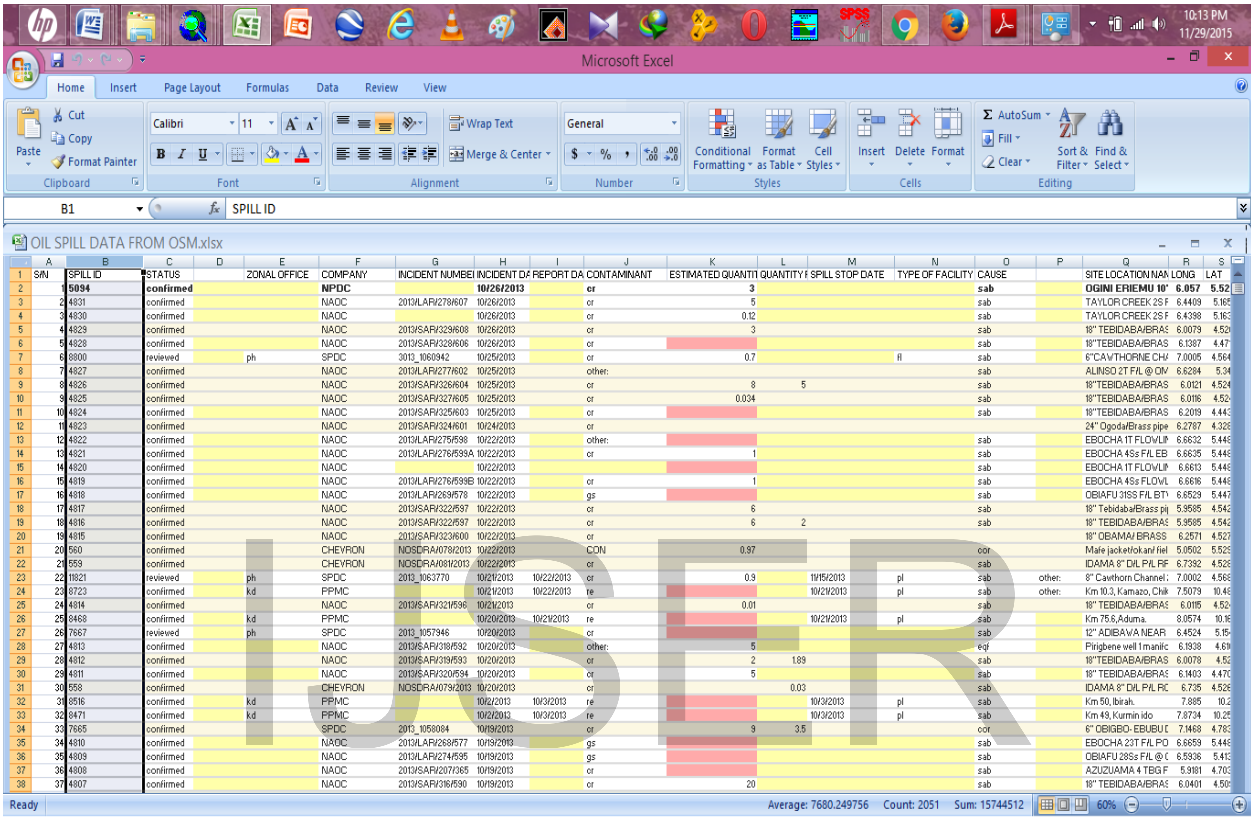
Elevation/Relief: the elevation of each community was extracted using the raster digital terrain model. Community actual location (x and y coordinates) was imported in to the ArcGIS environment where they were labelled and overlain on the terrain model of the region. Using the ArcGIS software, the elevation of each community was then extracted from the raster overlay as shown in figure 4.



Source: Researcher’s Analysis, 2015

Figure 4. Extraction of Communities Elevation in the ArcGIS using 30meter DEM

Oil Spill Locations: the location (x and y) coordinate of oil spill points from pipeline or wellhead was derived from the National Oil Spill Monitor.



OIL SPILL DATA FROM OSM.xlsx

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	S/N	SPILL ID	STATUS		ZONAL OFFICE	COMPANY	INCIDENT NUMBEI	INCIDENT DA	REPORT DA	CONTAMINANT	ESTIMATED QUANTI	QUANTITY F	SPILL STOP DATE	TYPE OF FACILITY	CAUSE		SITE LOCATION NAN	LONG	LAT
2	1	**5094**	**confirmed**			**NPDC**		**10/26/2013**		**cr**	**3**				**sab**		**OGINI ERIEMU 10'**	**6.057**	**5.52**
3	2	4831	confirmed			NAOC	2013/LAR/278/607	10/26/2013		cr	5				sab		TAYLOR CREEK 2S F	6.4409	5.165
4	3	4830	confirmed			NAOC		10/26/2013		cr	0.12				sab		TAYLOR CREEK 2S F	6.4398	5.163
5	4	4829	confirmed			NAOC	2013/SAR/329/608	10/26/2013		cr	3				sab		18" TEBIDABA/BRAS	6.0079	4.520
6	5	4828	confirmed			NAOC	2013/SAR/328/606	10/26/2013		cr					sab		18"TEBIDABA/BRAS	6.1387	4.47
7	6	8800	reviewed		ph	SPDC	3013_1060942	10/25/2013		cr	0.7			fl	sab		6"CAWTHORNE CH/	7.0005	4.564
8	7	4827	confirmed			NAOC	2013/LAR/277/602	10/25/2013		other:					sab		ALINSO 2T F/L @ OM	6.6284	5.34
9	8	4826	confirmed			NAOC	2013/SAR/326/604	10/25/2013		cr	8	5			sab		18"TEBIDABA/BRAS	6.0121	4.524
10	9	4825	confirmed			NAOC	2013/SAR/327/605	10/25/2013		cr	0.034				sab		18"TEBIDABA/BRAS	6.0116	4.52
11	10	4824	confirmed			NAOC	2013/SAR/325/603	10/25/2013		cr					sab		18"TEBIDABA/BRAS	6.2019	4.443
12	11	4823	confirmed			NAOC	2013/SAR/324/601	10/24/2013		cr							24" Ogoda/Brass pipe	6.2787	4.328
13	12	4822	confirmed			NAOC	2013/LAR/275/598	10/22/2013		other:					sab		EBOCHA 1T FLOWLI	6.6632	5.448
14	13	4821	confirmed			NAOC	2013/LAR/276/599A	10/22/2013		cr	1				sab		EBOCHA 4Ss F/L EB	6.6635	5.448
15	14	4820	confirmed			NAOC		10/22/2013							sab		EBOCHA 1T FLOWLI	6.6613	5.448
16	15	4819	confirmed			NAOC	2013/LAR/276/599B	10/22/2013		cr	1				sab		EBOCHA 4Ss FLOWL	6.6616	5.448
17	16	4818	confirmed			NAOC	2013/LAR/269/578	10/22/2013		gs					sab		OBIAFU 31SS F/L BT	6.6529	5.447
18	17	4817	confirmed			NAOC	2013/SAR/322/597	10/22/2013		cr	6				sab		18" Tebidaba/Brass pi	5.9585	4.542
19	18	4816	confirmed			NAOC	2013/SAR/322/597	10/22/2013		cr	6	2			sab		18" TEBIDABA/BRAS	5.9585	4.542
20	19	4815	confirmed			NAOC	2013/SAR/323/600	10/22/2013		cr							18" OBAMA/ BRASS	6.2571	4.527
21	20	560	confirmed			CHEVRON	NOSDRA/078/2013	10/22/2013		CON	0.97				cor		Mafe jacket/okan/ fiel	5.0502	5.529
22	21	559	confirmed			CHEVRON	NOSDRA/081/2013	10/22/2013		cr					sab		IDAMA 8" D/L P/L RF	6.7392	4.528
23	22	11821	reviewed		ph	SPDC	2013_1063770	10/21/2013	10/22/2013	cr	0.9		11/15/2013	pl	sab	other:	8" Cawthorn Channel	7.0002	4.568
24	23	8723	confirmed		kd	PPMC		10/21/2013	10/22/2013	re			10/21/2013	pl	sab	other:	Km 10.3, Kamazo, Chik	7.5079	10.48
25	24	4814	confirmed			NAOC	2013/SAR/321/596	10/21/2013		cr	0.01				sab		18" TEBIDABA/BRAS	6.0115	4.52
26	25	8468	confirmed		kd	PPMC		10/20/2013	10/21/2013	re			10/21/2013	pl	sab		Km 75.6,Aduma.	8.0574	10.16
27	26	7667	reviewed		ph	SPDC	2013_1057946	10/20/2013		cr					sab		12" ADIBAWA NEAR	6.4524	5.15
28	27	4813	confirmed			NAOC	2013/SAR/318/592	10/20/2013		other:	5				eqf		Pirigbene well 1 manifc	6.1938	4.61
29	28	4812	confirmed			NAOC	2013/SAR/319/593	10/20/2013		cr	2	1.89			sab		18"TEBIDABA/BRAS	6.0078	4.52
30	29	4811	confirmed			NAOC	2013/SAR/320/594	10/20/2013		cr	5				sab		18" TEBIDABA/BRAS	6.1403	4.470
31	30	558	confirmed			CHEVRON	NOSDRA/079/2013	10/20/2013		cr		0.03			sab		IDAMA 8" D/L P/L RC	6.735	4.526
32	31	8516	confirmed		kd	PPMC		10/2/2013	10/3/2013	re			10/3/2013	pl	sab		Km 50, Ibirah.	7.885	10.2
33	32	8471	confirmed		kd	PPMC		10/2/2013	10/3/2013	re			10/3/2013	pl	sab		Km 49, Kurmin ido	7.8734	10.25
34	33	7665	confirmed			SPDC	2013_1058084	10/19/2013		cr	9	3.5			cor		6" OBIGBO- EBUBU [	7.1468	4.783
35	34	4810	confirmed			NAOC	2013/LAR/268/577	10/19/2013		gs					sab		EBOCHA 23T F/L PO	6.6659	5.448
36	35	4809	confirmed			NAOC	2013/LAR/274/595	10/19/2013		gs					sab		OBIAFU 28Ss F/L @ (	6.5936	5.413
37	36	4808	confirmed			NAOC	2013/SAR/207/365	10/19/2013		cr					sab		AZUZUAMA 4 TBG F	5.9181	4.703
38	37	4807	confirmed			NAOC	2013/SAR/316/590	10/19/2013		cr	20				sab		18" TEBIDABA/BRAS	6.0401	4.50

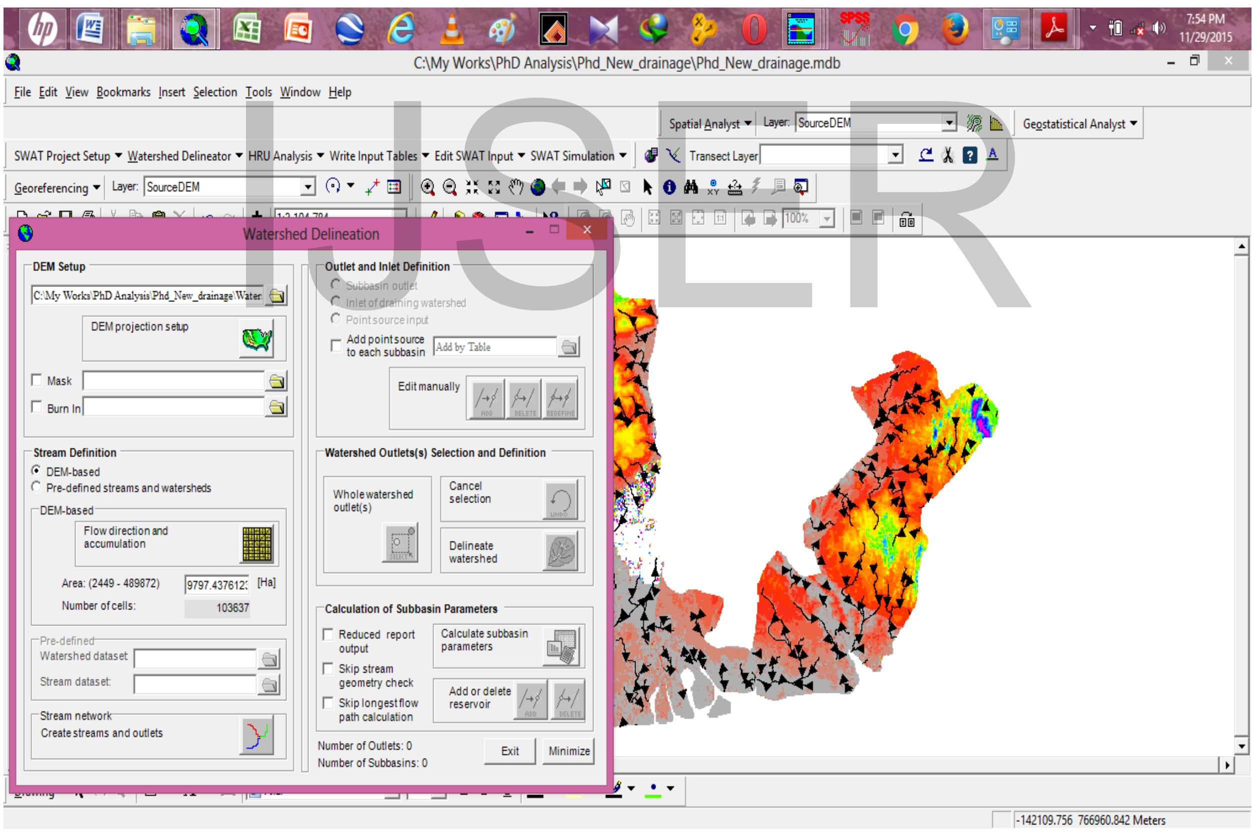
Average: 7680.249756 Count: 2051 Sum: 15744512

Source: Researcher's Analysis, 2015

Figure 5. Extracting Spill Coordinates from National Oil Spill Monitor

The data on oil spill from infrastructures as shown in figure 5 was imported in to the ArcGIS environment and utilized in the spatial analysis of vulnerability to oil spill from oil installations in the study area.

Modelling Potential Oil Spill Path: modelling potential spill path for spilled oil will give an understanding on the direction, trend and sinks of spilled oil in the study area. This was analysed in the ArcGIS and ArcSWAT environment where the location of spill in the study area is imported in the geospatial environment and overlaid on the DEM of the study area. This was therefore analysed in the ArcSWAT environment to determine the spill flow path and sink accumulation within the study area as shown in figure 6



Source: Researcher's Analysis, 2015

Figure 6 Calculating Flow Direction and Accumulation

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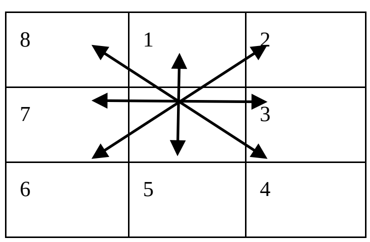
Figure 6shows the calculation process of potential flow direction sinks, and accumulation in the study area using the ArcSWAT software in the ArcGIS environment. The DEM is loaded, project of analysis to be done created and the analysis of the DEM is carried out using the ArcSWAT tools.

Spill Pathway/Flow Modelling

Land based spill is known to travel over land and most often end up in a stream or other local base level of erosion. Hence, modelling approach was used to simulate movement and path of oil spill on land and water. This determined the path spilled oil travels and flows. The queens case flow direction was employed alongside the DEM in the ArcGIS environment to determine the steepest direction due to gravity for oil spill path in the eight adjacent cells of the elevation grid. The oil moves to the neighbouring cell with the lowest elevation this process repeats itself successively until a flat area or depression is reached. In the ArcSWAT model, the minimum distance path to a next lowest cell is determined. Spatial modelling in ArcSWAT was used to determine oil spill path, sink and accumulations.



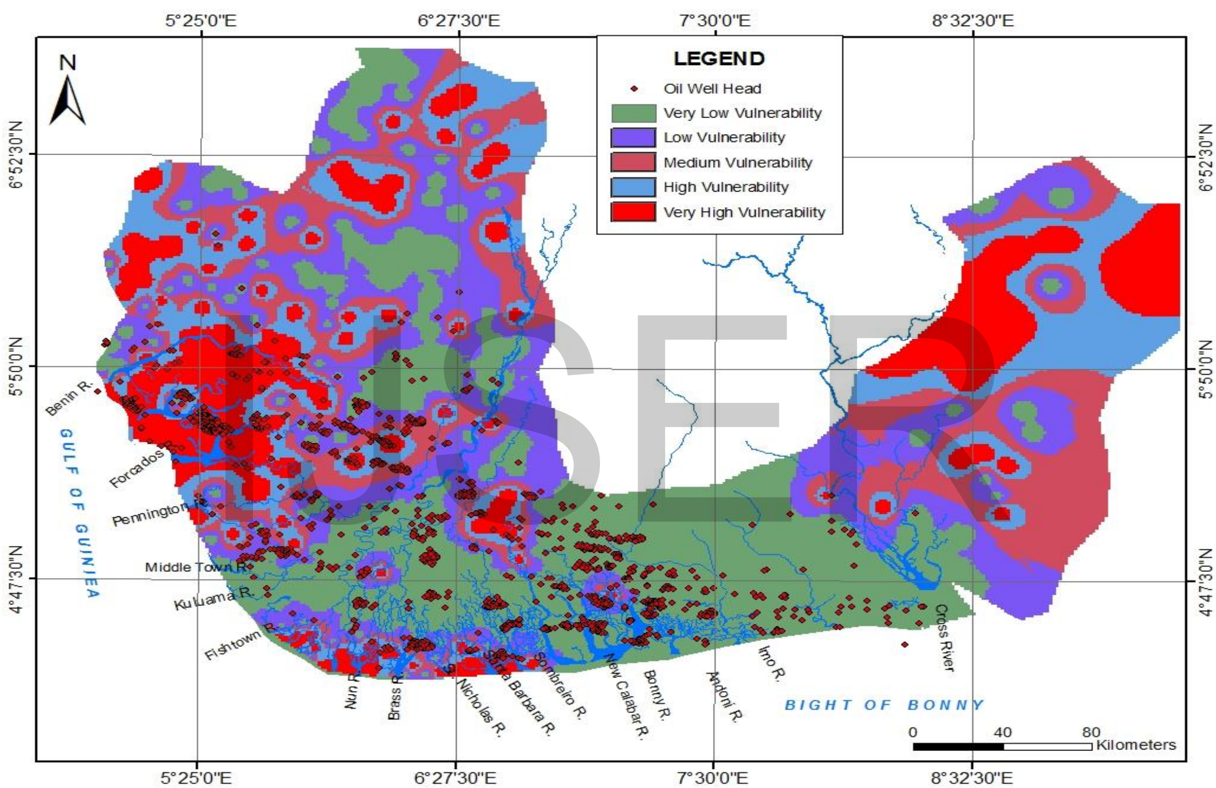
Source: Adapted from (Chris, Will, Tastu, and Kelly 2008)

Figure 7. Queens case flow direction

In the queens' case flow, the oil continues until the path reaches a stream or other surface water feature. The model determines the steepest descent direction in the eight adjacent cells of the elevation grid (Chris, Will, Tastu, and Kelly 2008). Since the rate of movement of oil spill over land surface is a function of the nature of the surface, the characteristic of these surfaces act on the moving oil either impeding or assisting the movement (Miller 1999). When the spilled oil reaches a stream, it is transported through the stream network.

Results and discussion

The impact of oil spill in the study area is of concern to environmental professionals.



Oil Well Data : NOSDRA (2014) and analyzed by Researcher

Figure 8. Clusters of Oil Well in Vulnerability Classes

From figure 8 there are more clusters of oil well head in the coastal areas of the study area. The horn of the study area enjoys less presence of oil well though there are pockets of oil well in places classified as very high vulnerable. Vulnerability of the coastal communities is complicated by the clusters of well head increasing the potential of spill induced hazard in the area.

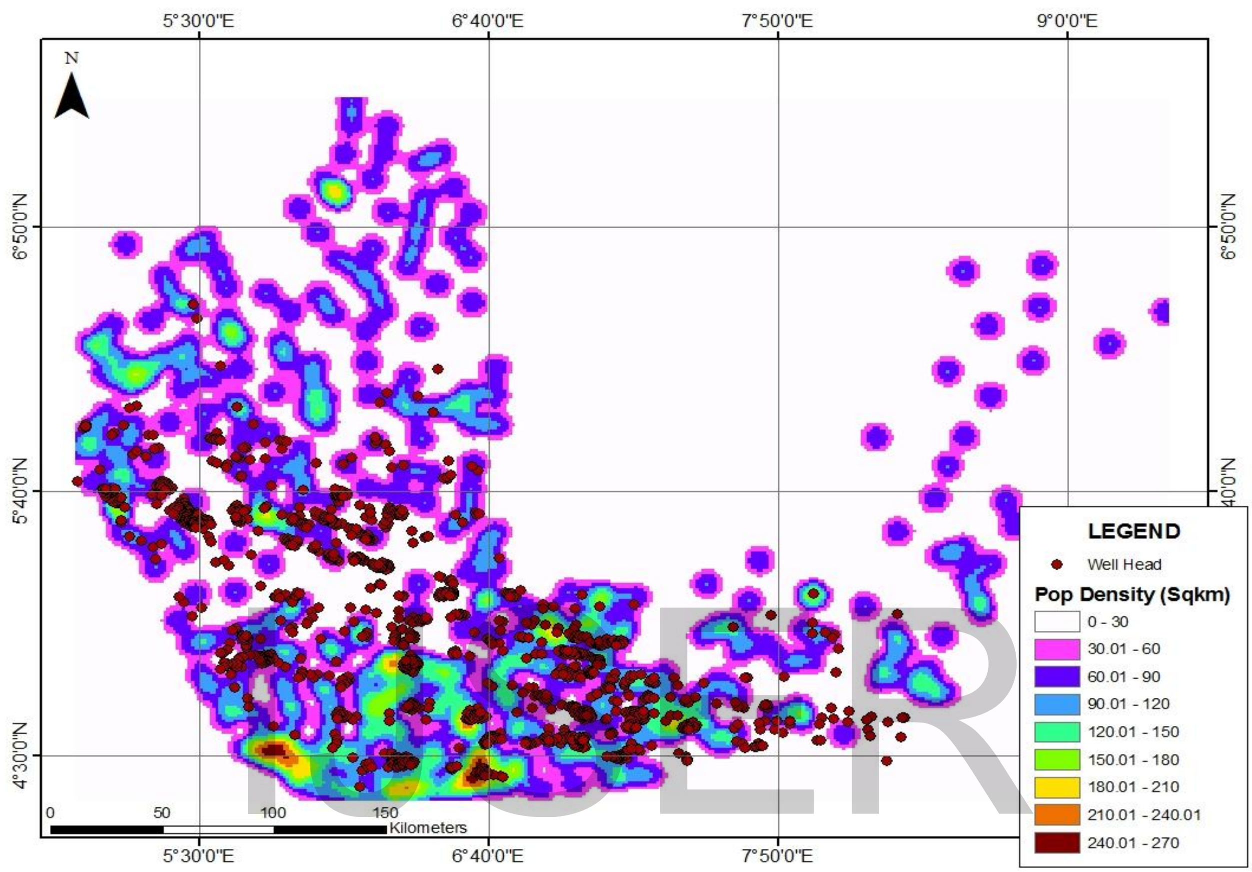


Figure 9 Wellhead and Population

The population density maps as shown in the figure 9 shows the density of population as spread over the study area. The total population of the study area was put at 23,055,176 comprising more male than female at 11,710,516 and 11,344,659 respectively.

In relation to population of the study region, most of the well head are located within population density area of 100 persons per square kilometre making residents in the study region to be highly vulnerable to oil spill in the event of a contingency event.

From the analysis done using the Soil and Water Assessment Tool (SWAT) model potential spill is modelled to have moved to the lowest elevation and repeat the determination of lower elevation from each point. The model predicts the impacts anthropogenic practices of oil exploration on the land has on the study area and calculated the flow direction and accumulation grids. The red line derived from the analysis indicates the direction of flow until a flat area or depression is reached. These areas of accumulations are majorly depression where the spill oil may accumulate and remain. The accumulated spill either percolates to the subsurface overflow or continues until the spill path reaches a stream after it had filled the flat surface or depression as shown in figures 10 to 15, which shows pockets of depressions/flat area within the study area where spill oil could accumulate in accordance to the Queens case model.

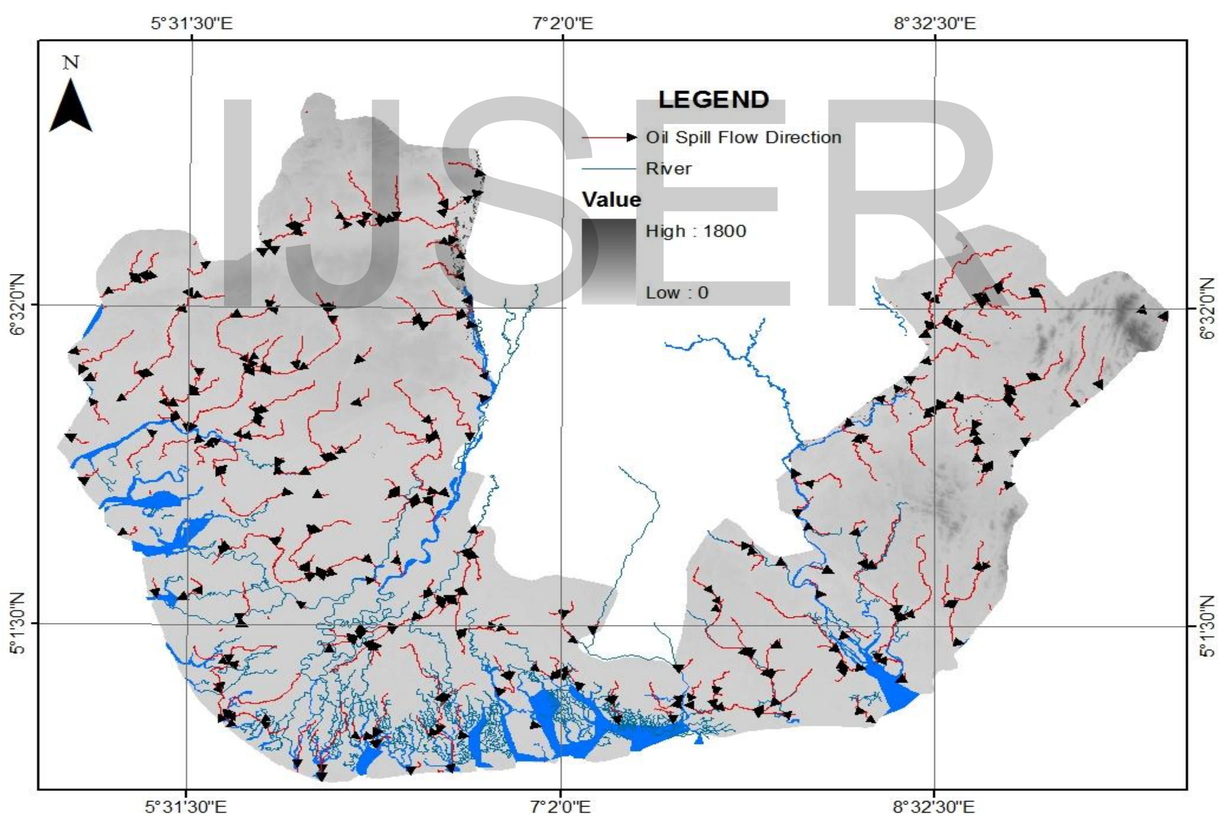


Figure 10 Potential Spill Network Path

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The figure 10 shows the path of flow of oil spilled in the region. The coordinate of subsequent spill locations can be derived using the Global Positioning System (GPS) and imported in to the GIS environment, overlaid on the flow path to show and monitor the trend and direction of flow over the study area. The flow map shows area s that is more vulnerable to the impact of spill in the study area alongside the contributions of the drainage networks. The drainage network that crisscrosses the region makes it difficult to contain the impact of spill in the region to a particular community. The drainage pattern aids the movement of spilled oil easily across the entire region.

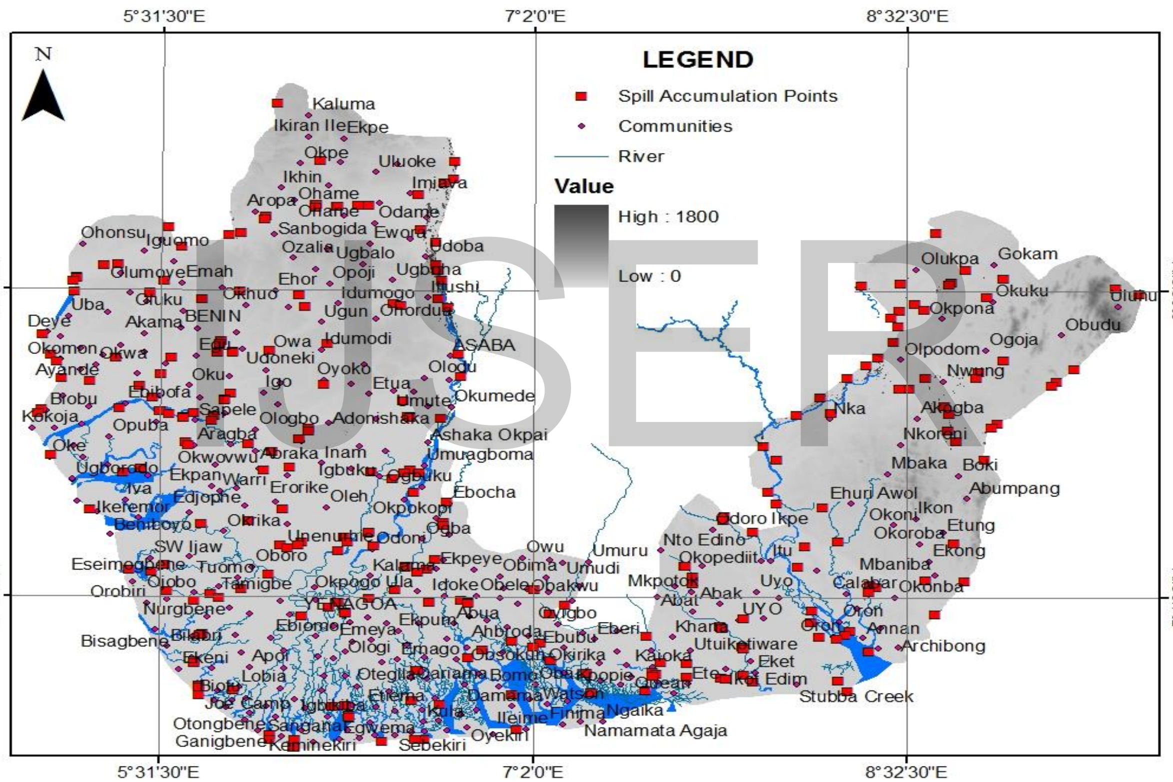

Figure 11 Spill Accumulation/Concentration Point

The topographic parameters of the flow direction map show the sinks along the flow direction path where there could be potential accumulation of spilled oil in the study area. This location of sinks enhances the accumulation of spilled oil which would allow infiltration/percolation of spilled oil into the ground with a potential of contaminating ground water within the study area.

This development makes the people ground water source for drinking very vulnerable to contamination by oil spill alongside the already contaminated network of surface water.

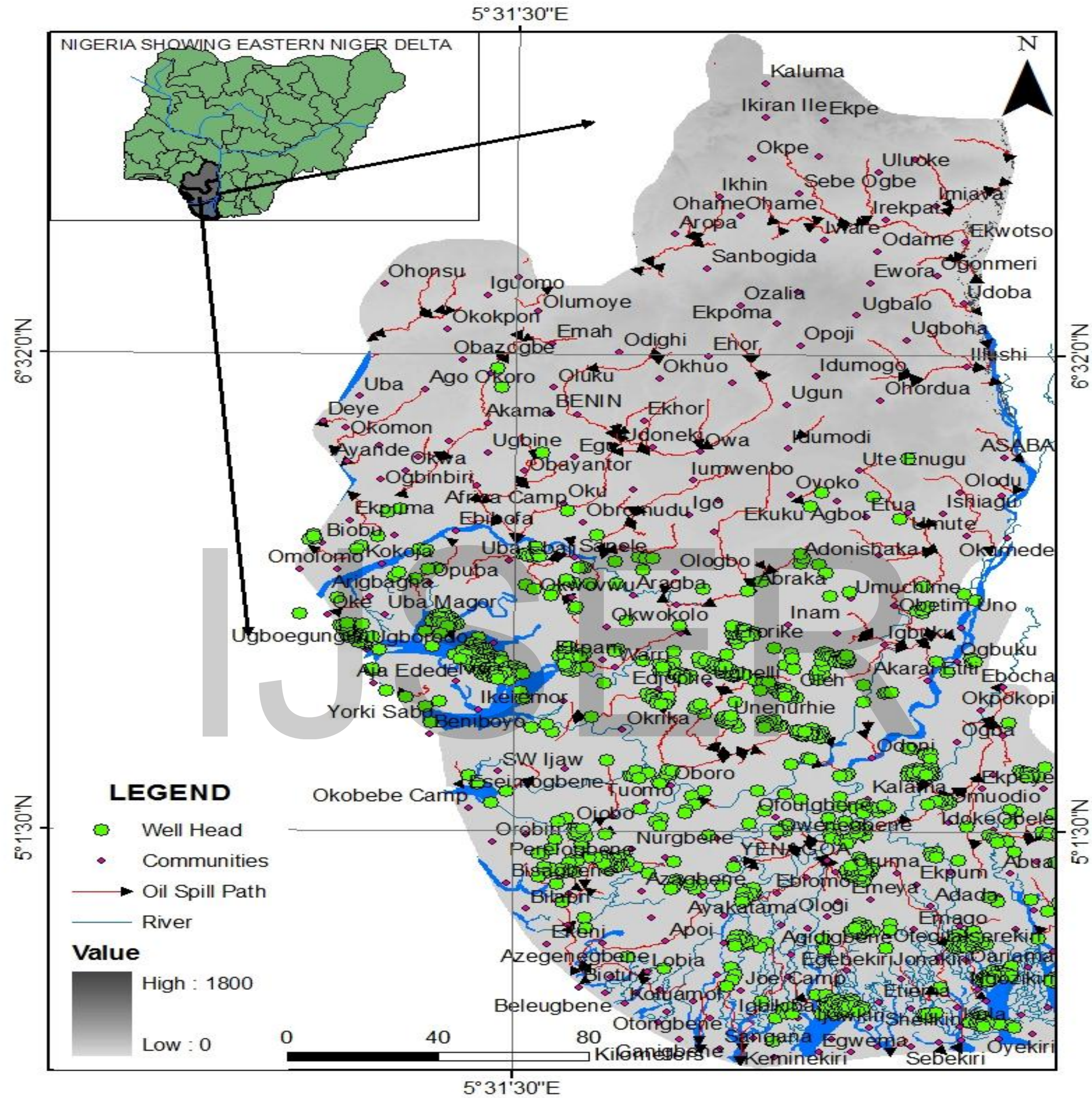

Figure 12 Western Study Area Potential Spill Network Path

The figure 12 shows the western Niger Delta divided by the Nun River and the location of oil well head for clarity. The flow direction of potential oil spill from oil infrastructure and well head in the study area is indicated by the red line and arrow. Communities overlay shows the possible impact such event would have on the communities in the region. Oil well head is dominantly present in the coastal part of the region dominated by intense drainage network than the upland part.

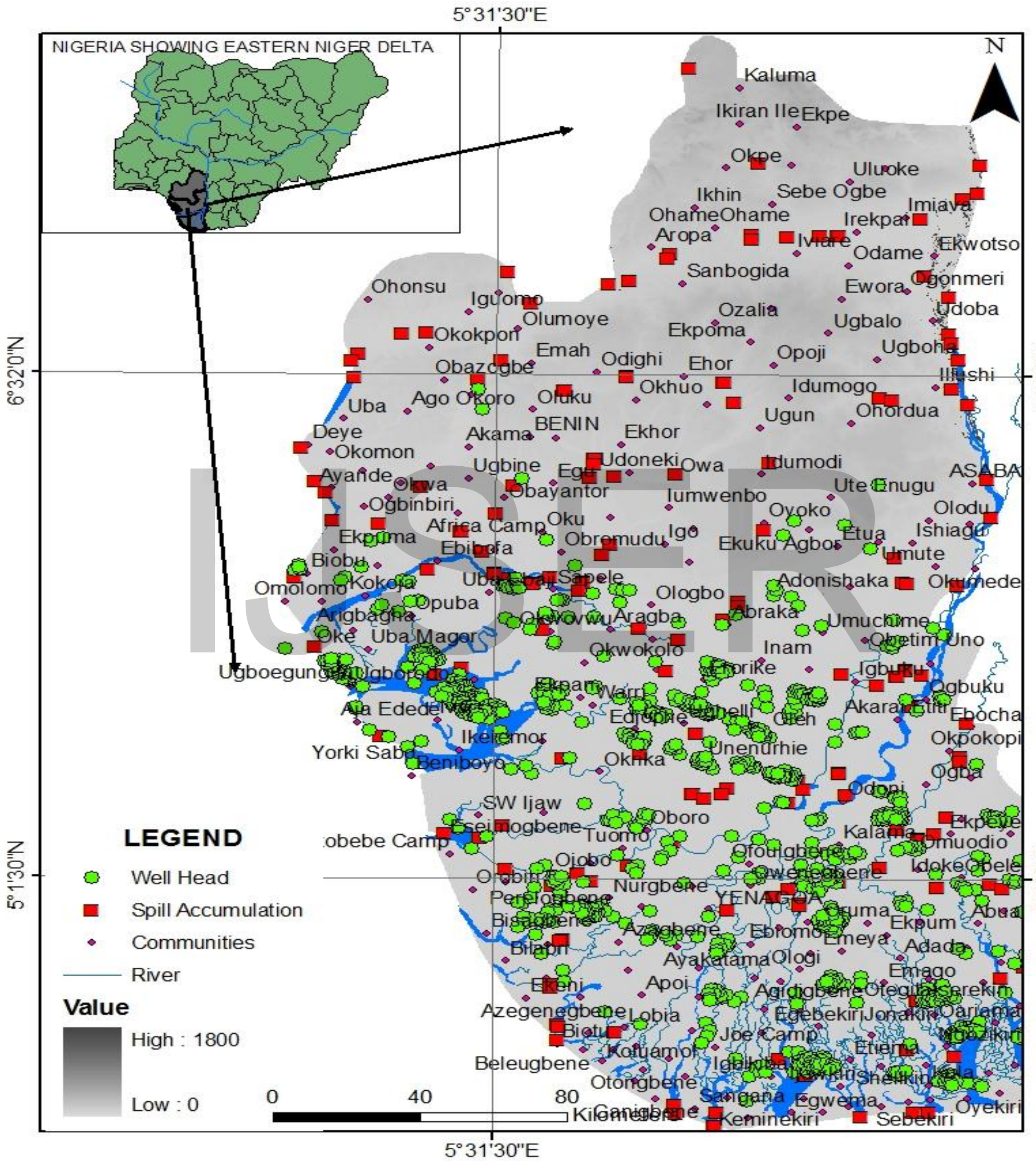

Figure 13 Spill Accumulation/Concentration Point

The figure 13 shows the western Niger Delta divided by the Nun River and the location of oil well head for clarity. The sinks/accumulation of oil during flow of potential oil spill from oil infrastructure and well head in the study area is indicated by the red cube/box. Communities overlay shows communities within the path that could be possibly impacted in the region. Oil well head is dominantly present in the coastal part of the region dominated by intense drainage network than the upland part.

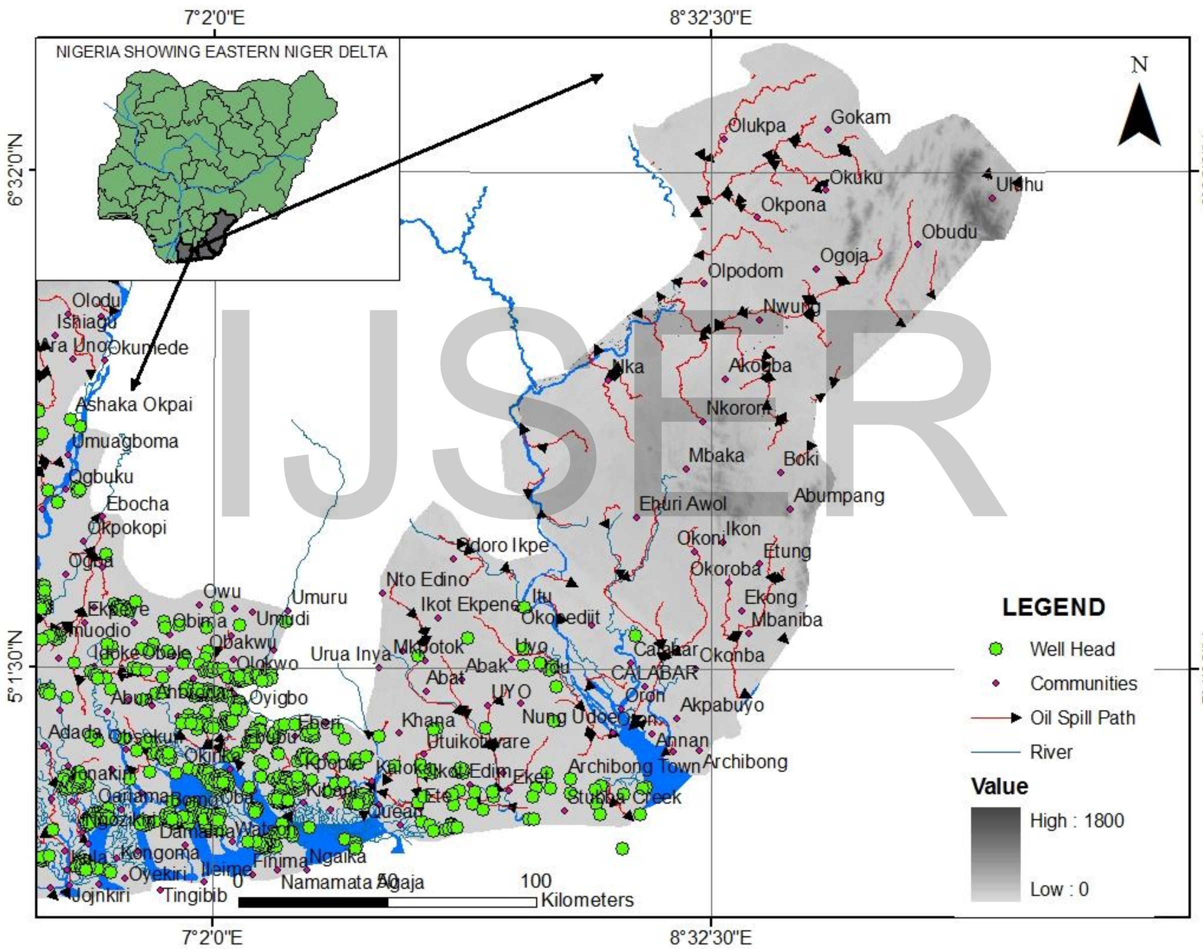

Figure 14 Eastern Study Area Potential Spill Network

The figure 14 shows the eastern Niger Delta divided by the Nun River and the location of oil well head for clarity. The flow direction of potential oil spill from oil infrastructure and well head in the study area is indicated by the red line and arrow. Communities overlay shows communities within the path that could be possibly impacted in the region. Oil well head is dominantly present in the coastal part of the region dominated by intense drainage network than the upland part.

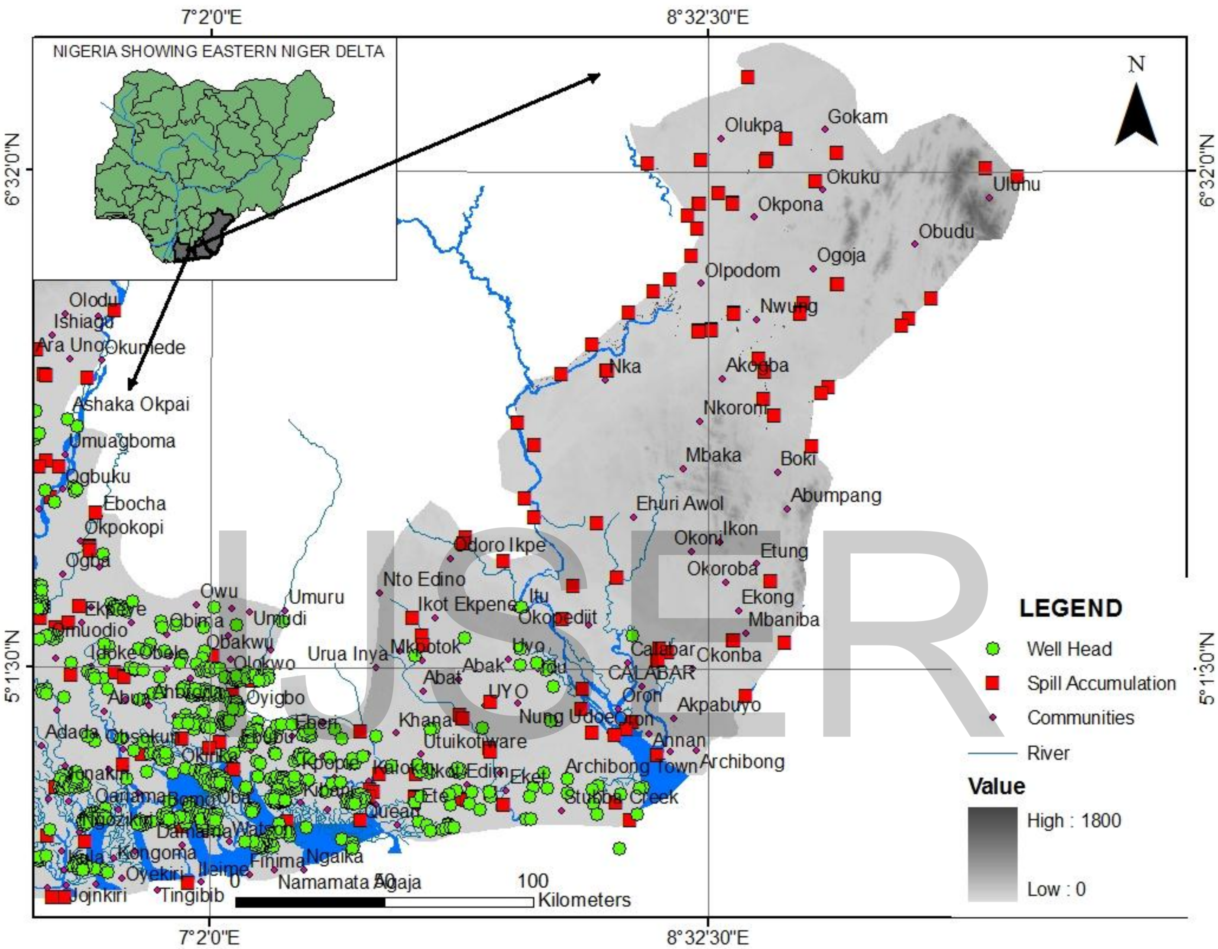

Figure 15 Spill Accumulation/Concentration Point

The figure 15 shows the eastern Niger Delta divided by the Nun River and the location of oil well head for clarity. The sinks/accumulation of oil during flow of potential oil spill from oil infrastructure and well head in the study area is indicated by the red cube/box. Communities overlay shows communities within the path that could be possibly impacted in the region. Oil well head is dominantly present in the coastal part of the region dominated by intense drainage network than the upland part.

Discussion

Oil well heads are mostly located at the Southern part of the study area which coincidentally is the most vulnerable part of the region to inundation. The North Eastern and Western part of Edo and Cross River state witness little to no presence of oil well heads.

Digital elevation model at a 30 meter resolution for the study area served as the land elevation data which defines the land surface over which oil moves. Oil flows over land is governed mostly by the degree of slope over which it flows, therefore the SWAT Geospatial tools was used to model the flow path for oil spill in the study area. The DEM of the study area was imported and topographic parameters were calculated. The DEM was then processed, filling the sinks and calculating the flow direction and accumulation/concentration points for potential oil spill from well heads and pipelines.

The locations of oil well in the southern part of the study area endowed with tributaries of rivers inter connected draining most communities made the entire communities in the southern part of the study area vulnerable. Spills from wellhead could seep to nearby communities via horizontal movement of liquids beneath soil surface in the southern Niger Delta. This direction or trend will result in vulnerability of communities with population density of 1:240 persons per km^2.

Conclusion

The Geo – spatial modelling of oil spill path reveals that oil spill over land is governed mostly by the degree of slope over which it flows. Therefore, terrain contributes to great extents the flow pattern of oil spill in the study area. Also the undulating nature of the surface determines the number of sinks in the region which enhance percolation and seepage. Hence, oil spill in the study area travel over land in the study area is governed by slope of the region and the drainage network dominance in the region.

Recommendations

It is therefore recommended that

- Observation systems and geographic data base should be put in place to create adequate database for analysis.
- activities and trends that promotes spill of oil in the environment should be reversed.
- Federal and state Emergency service should pay attention to risk management in areas identifies in the study.

REFERENCES

Adelana, S. O., Adeosun, T. A., Adesina, A. O., & Ojuroye, M. U. (2011). Environmental Pollution and Remediation: Challenges and Management of Oil Spill in the Nigeria Coastal Area. *Journal of Scientific and Industrial Research 2*(6).

Ayeni, B. (1988). *Rural Spatial Structure and Geographical Information System for Planning Rural Areas.* . Paper presented at the Nigeria Geography Association, University of Port Harcourt.

Baird. (2010). Annual Report.

Bapalu, G. V., and Sinha, R., 2005. GIS in Flood Hazard Mapping: A Case Study of Kosi River Basin, India. GIS Development Weekly, 1(13)

Bohle, H. G. (2001). Vulnerability and Criticality; Perspectives from social Geography In JornBirkman (Ed.). Tokyo: United Nation University Press.

Cardona, (2040 The need for rethinking the concepts of Vulnerability and Risk from a Holistic Perceptive: A necessary Review and Criticism for effective Risk Management, Washinton D C

Chava, F., David N. (2009) Research Methods inthe Social Sciences, Fifth Edition, Hodder Educational, London

Chris G., Will, F., Tastu, I., and Kelly, K. (2008). [GIS Technology Applied to Modelling Oil Spill on Land].

Coburn, (1994). Vulnerability and Risk Assessment, Disaster Management Training Programme module, *United Nations Development Programme*, Cambridge, United Kingdom

Downing, T. (2004). *What have we learned Regarding a vulnerablity Science? In science support of adaptation to climate change.* . Paper presented at the Framework Convention on Climate Change, Buenos Aires.

Ebisemiju F. S. (1987). An Evaluation of factors controlling present rate of shoreline retrogradation in the Western Niger Delta Nigeria, catena, Volume 14 Issue 1-3.

Emiliano R, Andrew H, Andrea B, Anipe D, Ana G, Mikeel H, pasi L (2011). Climate Change Impact Vulnerability and Adaptation, Viale Aldo Moro44, Italy

ERML, 2005 Environmental and Socio – Economic Characteristic of the Niger delta, E-International Publication

FGN. (2007). *Niger Delta Regional Development Master Plan* Abuja.

GoogleEarth (2014). Niger Delta Imagery.

Harrilik, R. M. (1980). *A Spatial Data Structure for Geographic Information System*. New York: Academic Press Inc.

Isaac, B. (2010). *Spatial Planning in Coastal Region.* . Paper presented at the Facing the Impact of Change International Federation of Surveyors, Denmark.

Jimmy, O. A., Timi Ologunorisa E. (2010). An Assessment of Recent Changes in Niger Delta Coastline Using Satellite Imagery. *Journal of Sustainable Development, 3*(4).

Jorn, B. (2006). *Measuring Vulnerability to Natural Hazard*. Japan: United Nations University Press

Kadafa, A. A. (2012). Environmental Impacts of Oil Exploration in Niger Delta of Nigeria. *Global Journal of Science Frontier Research Environmental and Earth Science, 12*(3).

Kadafa, A. A. (2012). Oil Exploration and the Niger delta of Nigeria, *Civil and Environmental Research Journal*.

Karwel, K. a. E. I. (2008). *Estimation of the Accuracy of the SRTM terrain Model on the Area of Poland.* Paper presented at the The XXI ISPRS Congress.

Koppen – Geiger (2006) World Map of Climatic Classification Updated

Kuenzer C., A. B., Steffen G., Tuan V. G., and Stefan D. . (2014). Remote Sensing of mangrove Ecosystem. *A Review Remote Sensing, 3*(5).

Kuenzer C, Sybrand V B, Ursula G, and Stefan D, (2014). Land Surface Dynamics and Environmental Challenge of the Niger Delta Africa, Remote Sensing Based Analysis Spanning there Decade (1986 – 2013), Applied Geography 53.

Kumar, T. and Kunte, P.(2010): Coastal Vulnerability Assessment for Chennai, East coast of India using Geospatial Techniques, J. Natural Hazards, 64.

Lubeck, P. M. M., Ronnie, L. (2007). *Convergent Interest: United State Energy Security and Their Securing of Nigeria Democracy*. Washinton: Centre for International Policy.

Maiti, S., & Bhatta, A. (2009). A three Unit based Approach in Coastal Change Studies Using Landsat Images. *International Journal of Remote Sensing, 32*(1).

Mathew, J. C., Michael, D. B., & Michael, O. (2005). *Future Sea Level Rise and the New Jersey Coast.* Paper presented at the Assessing Potential Impacts and Opportunities. Science, Technology and Environmental Policy Programme.

McKnight, T. L. (1992). *Essentials of Physical eography*. New Jersey: Pretice-Hall, inc.

Mesgari, M. S. (2000). *Topological Cell-tuple strucres for three- dimensional Spatial data.*, Netherlands.

Miller J. B., O. J. (1999). *Oil Spill Emergency Response GIS: Using GIS to Model Environmental Vulnerability in Coastal Oil Fields.* Paper presented at the ESRI Users Conference, East Central Nigeria.

Murali M. R., A. M., Amrita S., and Vethamony P. (2013). Coastal Vulnerability Assessment of Puducheriy Coast, Indian using Analytical Hierarchical Process. *Natural Hazard Earth System Science, 13*.

National Space Research And Development Agency (2010)

NEDECO (1961) The Waters of the Niger Delta, The hague

NIOMR: Marine Geology/Geophysics, available at: http://www.niomr.gov.ng.

N.P.C. (2006). *Population Census of Nigeria*. Abuja: N P C.

NCAB. (2005). Nigeria Country Report.

NJDEP. (1981). *Future Sea Level Rise and New Jersey Coast*. New jersey: New Jersey Digital Library.

NOSDRA. (2014). Nigeria Oil Spill Monitor. Abuja.

Olorunlana, F. A. (2013). *State of the Environment in the Niger Delta Area of Ondo State.* Paper presented at the 1st Annual International Interdisciplinary Conference Proceeding.

Oshwofasa, B. O., Anuta, D. E., and Aiyedogbon, J. O. (2012). Environmental Degradation and Oil Industry activities in the Niger Delta region. . *Africsa Journal of Scientific Research, 9*(1).

Oyegun, 2003: Essentials of Social and Environmental Research, University of Port harcourt Press Linited, Port Harcourt, Nigeria

Oyegun, C. U. (1993). Land Degradation and the Coastal Environment of Nigeria, The Hague

Oyegun, C. U. (1991). Spatial and Seasonal Aspects of Shoreline Changes at Forcados Beach, Nigeria, Earth Surface Processes and Landforms, Vol 16

Oyinloye, M. A., & Olamiju, O. I. (2013). An Assessment of the Physical Impact of Oil Spillage using GIS and Remote Sensing Technologies empirical evidence from Jesse town, Delta State, Nigeria. *British Journal of Arts and Social Sciences, 12*(2).

Pilouk, M. (1996). *Integrated Modelling for 3D GIS Analysis.* ITC, Netherlands.

Robert E. G. James F. P. Michael T L. Dorothy S. (2009) *Physical Geography* ninth edition Brooks/Cole cengage learning, USA

Shekhar, S., & Chawla, S. (2003). *Spatial Databases a Tour*. New Jersey: Prentice hall.

SPDC Map, (2013) Shell Petroleum Development Company

Stefan S and Daniele E (2006) *Social Level and Hazard (in) dependence in defining Vulnerability.* United Nations University, Tokyo.

Tajadeen, A. O., & Bager, M. A. (2014). *A GIS Approach to the Management of Oil Spill in Nigeria.* Paper presented at the 9th National GIS Symposium, Dammam, Saudi Arabia.

Twigg, J. (2004). Disaster Deelopment and Vulnerability in Benfield Hazard Research Centre.

Udoh, I. C., & Ekanem, E. M. (2011). GIS Based Risk Assessment of Oil Spill in the Coastal Areas of Akwa Ibom State, Nigeria. *Journal of Environmental Science and Technology 5*(3).

UNDP (1996) Human Development Index Nigeria, New York Oxford, Oxford University Press

UN/ISDR. (2002). *Living with Risk: A Global Review of Disaster Reduction Intiative*. Geneva.

USGS (2000). World Petroleum Assessment, Description and Results, World Energy Assessment Team, Digital Data Series 60

USGS (2006). Shuttle Radar Topography Mission (SRTM) 3Arc Second (30 meter).

Vossen, G. (1991). *Data Models, database Languages and Database management Systems*. Wokingham, England: Addison - Wesley.

Winter (2009) Institute for Work & Health, Toronto At Work, Issue 55.

Wisner, B. B., P.; Cannon, T.; and Davis, I.; . (2003). *Natural Hazard, People Vulnerability and Risk*. London: Rout eye.

Yaw, A. T., & Edmund, C. M. (2006). GIS and Remote Sensing Application in the Assessment of Change within a Coastal Environment in the Niger Delta region *International Journal of Environmental Research and Public Health.*

ISSN 2229-5518

Zhang, K. Bruce C., Stephen L,. (2004). Global Warming and Coastal Erosion Kluwer Academic Publication, Netherland.