



# **Illegal Oil Bunkering Hotspots, Its Implication on Vegetal Depletion in Delta State, Nigeria**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author OM designed the study, performed the statistical analysis and wrote the protocol. Author OOD wrote the first draft of the manuscript. Authors OOD and EAU managed the analyses of the study. Author EAU managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

The study assessed facilities-based activities of illegal oil bunkering and its spatial trend, hotspots across Delta state. Secondary data was obtained from Landsat imageries of 2013 and 2018, National Oil Spill Monitor and National Oil Spill Detection and Response Agency (NOSDRA). The images were classified using supervised classification method, and the coordinates of illegal bunkering sites were overlaid and analyzed using the Differentiate Weighing Technique to express the magnitude of illegal bunkering activities that occurred across space while the coordinate were imported and overlaid on the administrative map of the study area to enable the appreciation and understanding of the trend in facilities-based activities of illegal bunkers across space. Findings revealed that between the years of 2013 through 2018, 162 oil spills was recorded and were spills recorded as a result of illegal bunkering in Delta state. Oil pipeline accounted for over 50 percent of targeted facilities by the operation of the illegal bunkering. Also, there is a noticeable decrease in the area covered by mangrove and fresh water forest in the tune of 68 and 60 percent respectively. This decrease can be attributed to the impact of spill oil on vegetal cover and health. Thus, the study recommends that communities sensitization programs should be encourage educating the host communities on the extent of self-inflicted impacts on the environment by the activities of locals.

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*Keywords: Pipeline; spillage; vegetation; environment; bunkering; hotspots.*

## 1. INTRODUCTION

Oil is the life blood of Nigeria's economy [1], its exploration started in the early 90s and in 1956, it was first discovered at Oloibiri a village in the present day Bayelsa state. Since the discovering of oil in commercial quantity, the lifting of the products using pipes, tanker etc has resulted in reoccurrence of product spill into the environment either intentionally or technically [2,3]. Oil spill is the release of petroleum hydrocarbon into the environment, due to natural or anthropogenic activity, and is a form of pollution of major consequences in Nigeria [4,5,6]. Oil spill either caused by accidents on tankers, barges, pipelines, refineries, drilling rigs, storage facilities and natural oil seeps on the seafloor or well and illegal bunkering as a form of environmental pollution has much effect on the environment [7,8]. When oil is spilled, it affects environmental organism and its functions like respiration, feeding and thermo-regulation. Oil spill has a number of effects on the environment and economy [9,10]. On a basic level, oil spill effects will impact on the water quality, marine life, vegetation and animals. It can also ruin the infrastructure and economy of a particular area with the long-term effect being for decades. See Fig. 1.

This impact on the socio economics of the people has become a major problem complicated by continuous spill of hydrocarbon in the environment as a result of pipeline linkage, poor maintenance and bunkering activities by mostly non-professionals, who pay no value to their environment while embarking on their illegal activities [11,12]. Ending illegal bunkering activities requires urgent action not rhetoric. Countries with such a challenge and huge oil infrastructures have used technology to do the work i.e devices are deployed and mounted on pipelines to detect any form of breach. This action prevents massive spill of hydrocarbon in the environment by a form of early detection and response. The frequency of oil spill within or around an area will affect the level/magnitude of environmental degradation such as depletion of the natural vegetation and animals, causing a significant level of harm to individual organisms and entire populations. Parties responsible for an oil spill may be liable for cleanup cost, natural resource damage, including personal property damage and lost profits or earning capacity. Despite these efforts, some ecological problems

are still persistent as observed and include a brownish vegetation and soil erosion, diminishing resources of the natural ecosystem, fertile land turned barren and adverse effects on the life, health and economy of the people [13,14]. Spill does not just only impact on vegetation, it also reduces the ability of vegetation to hold the soil together, this therefore will result in an increased pressure on the little available land available for other purposes within the locality.

A series of executive orders coupled with memoranda of understanding, have established the various agencies responsibilities to contain the problem of oil spill accruing from oil exploration and production, facility failure and leakage, as well as illegal refining. This study seeks to unveil the trend, pattern and effect of oil spill, its hotspot in the environment.

### 1.1 Study Area

The state lies approximately between longitude 4°30'10" and 6.45'00" east and latitude 4 15' 00" and 6 30' north. Delta State is geographically located in Nigeria's Niger Delta bounded in the North and West by Edo State, the East by Anambra, Imo and Rivers States, Southeast by Bayelsa State and Southern extreme is the Bight of Benin which covers about 160 kilometers of the state's coastline. The State was defined out of the former Bendel State on August 27, 1991, with its capital city at Asaba, located at the Northern end of the state, and an estimated area of 762 square kilometers (294 sq m) (The Niger Delta Budget Monitoring Group [15]. The state has a total land area of 16,842 square kilometers, and is situated in the political region of Nigeria known as the south-south geo-political zone with a population of 4,112,445 (Males; 2,069,309; Females; 2,043,136) [15].

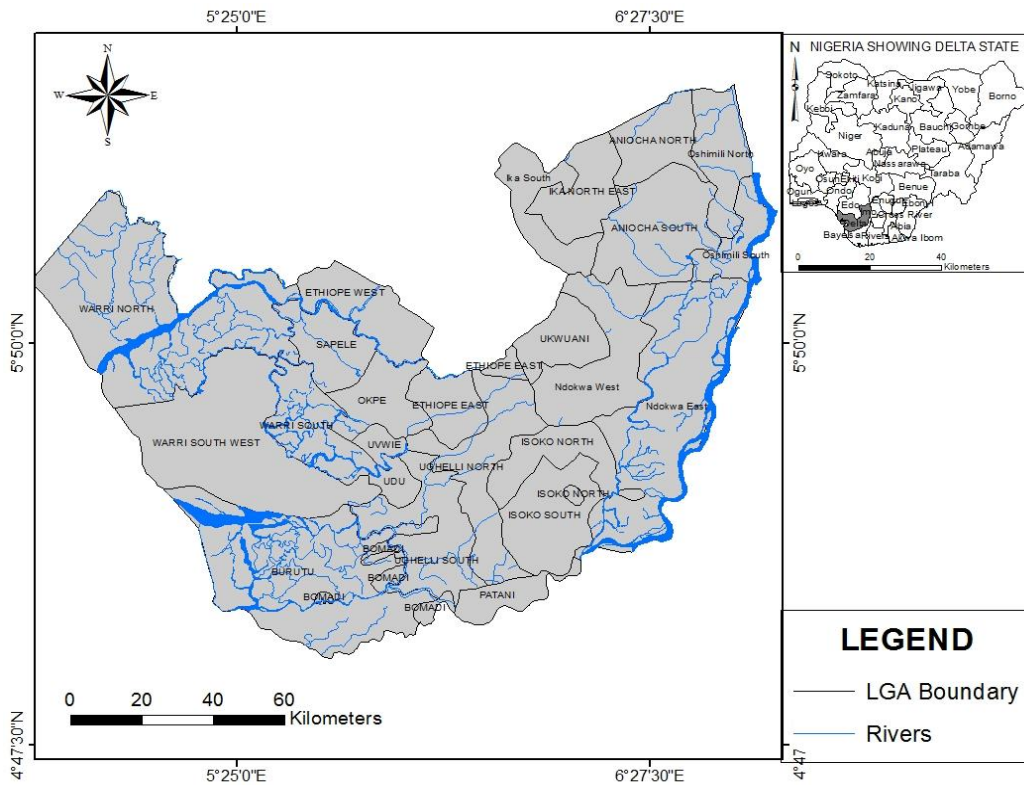
The entire Delta state is a region built up by the sedimentation of the Niger River and consists of four major physiographic units. First is the freshwater swamp which is the most active area, it is located close to the River Niger, where annual flooding and deposition occurs up to 45km from the river's course. Second is the mangrove swamp area described as an intermediate delta stage, invaded by the sea since large amounts of freshwater ceased flowing into it. Third is in the upland and swamp region, which is also called the coastal plain, it

lies between the flood plain and Benin low land [10]. The River Niger drains the state and discharges into the sea through its several

distributaries such as the Forcados, Escravos and Warri rivers and creeks such as the Bomadi creeks amongst others.



**Fig. 1.** Oil spill impacted vegetal surface at gbaramatu, delta state



**Fig. 2.** Delta state showing local government boundaries  
 Source: Directorate of Lands and Surveys. Governor's Office, Asaba

## 2. MATERIALS AND METHODS

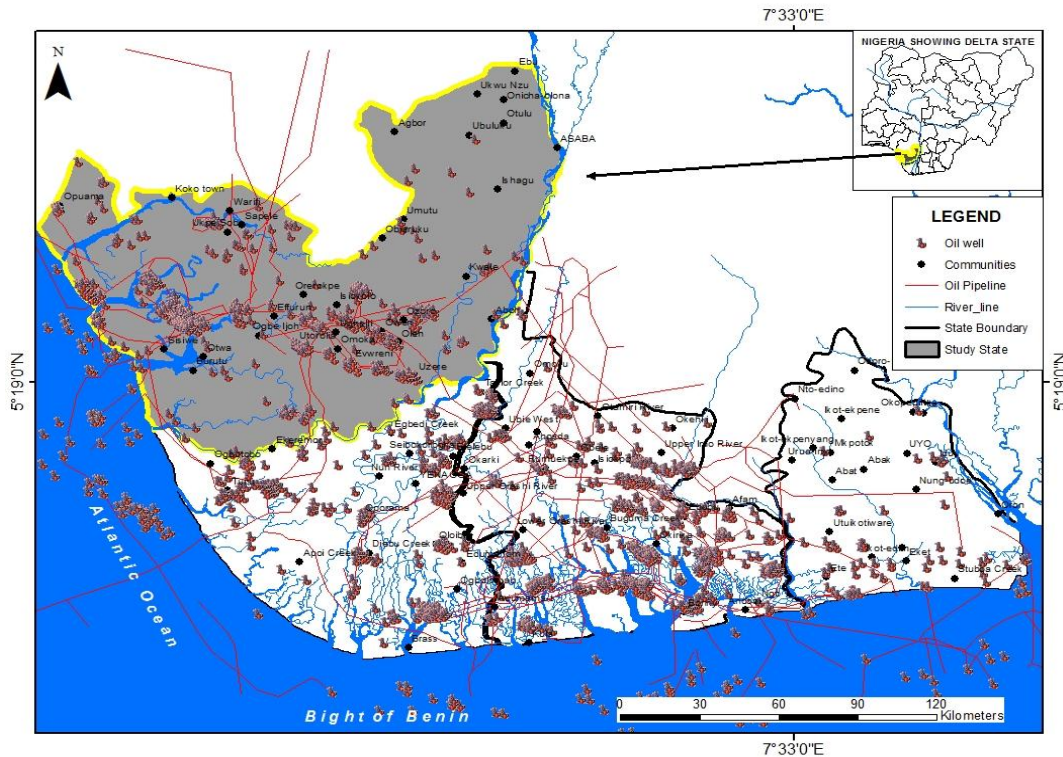
Data was obtained from both primary and secondary sources to give a comprehensive outcome/information. Data were collected via the National Oil Spill Monitor site, images and georeferenced map over the study area. The images over the oil spill sites was clipped and used to measure or extract the extent of vegetal surface depletion over this study area. The images were further classified to allow the extraction of features such as vegetation and other surface cover. The primary data derived was imported into the ArcGIS 10.4 environment and analyzed. The images were further classified using the supervised classification method and the coordinates of the illegal bunkering site were overlaid and analyzed using the differential weighing technique to express the spatial spread of illegal bunkering activities across the study area.

## 3. RESULTS AND DISCUSSION

The result from data derived and analysed shows the spatial trend of oil bunkering hotspots across Delta state.

Fig. 3 shows the study area (Delta State) amidst oil installation and spread across the entire space. From the map, it is obvious that oil well head cuts across the entire study areas and its environment. This stretch does not exclude water bodies around the Atlantic Ocean mostly referred to as offshore wells where oil exploration is favoured by the laying of pipelines, flow lines, and trunk lines to convey these products from the point of production to point of distribution to either local or international market. The trend explains more vividly the spread of illegal bunkering activities across the study area as shown in Fig. 4 where pipelines, flow lines and wellheads accounts of noticeable level of facility impact by illegal bunkers

Table 1 shows oil facilities and the frequency of impact by oil bunkers on each facility across the study across. The table provides the locations of spill points as they occur and are associated to source facilities in the study area. From the table, between the period of 2013 through 2018, 162 spill occurrences was recorded as a result of illegal bunkering.



**Fig. 3. Study area (delta state) and 'environs' showing oil installations**

Source: The Shell Petroleum Development Company of Nigeria

**Table 1. Facilities and frequency of bunkering related spill in Delta State**

<b>Pipeline</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Pipeline</b>	<b>Latitude</b>	<b>Longitude</b>
Pipeline	5.47375	5.9002222	Pipeline	5.6845556	5.14725
Pipeline	5.4842222	6.1020556	Pipeline	5.5390556	5.5043611
Pipeline	5.3703333	6.0480278	Pipeline	5.6091389	6.2996111
Pipeline	5.5020833	6.0803056	Pipeline	5.5656944	5.6168333
Pipeline	5.43	5.3847222	Pipeline	5.41775	5.3790556
Pipeline	5.4241667	5.3816667	Pipeline	5.6153083	5.1731667
Pipeline	5.4191667	5.3786111	Pipeline	5.5661111	5.6150833
Pipeline	5.49925	5.1975361	Pipeline	5.56625	5.6161389
Pipeline	5.5688611	5.6292778	Pipeline	5.5661389	5.6153056
Pipeline	5.5785278	6.4258056	Pipeline	5.56625	5.616
Pipeline	5.5842222	6.4358333	Pipeline	5.5686389	5.6281389
Pipeline	5.5886944	6.4383611	Pipeline	5.5736111	5.7513889
Pipeline	5.5145556	6.341	Pipeline	5.4448056	5.3964167
Pipeline	5.4306111	5.2736389	Pipeline	5.4190278	5.37975
Pipeline	5.4613333	5.4096389	Pipeline	5.4613056	5.4096111
Pipeline	5.4300278	5.3850278	Pipeline	5.82325	5.1897778
Pipeline	6.0801944	5.5562778	Pipeline	5.8753889	5.7191667
Pipeline	5.5638889	5.5961111	Pipeline	5.2871389	5.3709167
Pipeline	5.4880111	5.2019	Pipeline	5.8891111	5.0733333
Pipeline	5.7821389	5.2633611	Pipeline	5.6271667	5.1631194
Pipeline	5.6106389	5.1766667	Pipeline	5.6323056	5.1588056
Pipeline	5.5616667	6.2322222	Pipeline	5.6991111	5.3060833
Pipeline	5.3246389	6.2626111	Pipeline	5.5699167	5.2051944
Pipeline	5.7544444	5.125	Pipeline	5.6446944	5.1484444
Pipeline	5.6297222	5.1612222	Pipeline	5.8066111	5.1110278
Pipeline	5.5686111	5.6286111	Pipeline	5.6674444	6.47975
Pipeline	5.4205278	5.3061111	Pipeline	5.47525	5.9014722
Pipeline	5.4196111	5.3789444	Pipeline	5.5020556	6.0803056
Pipeline	5.5613056	5.5791389	Pipeline	5.5490556	6.16425
Pipeline	5.6334656	6.0189544	Pipeline	5.7788056	5.27
Pipeline	5.6322989	5.1588239	Pipeline	5.2115556	5.7438611
Pipeline	5.4284444	5.2802222	Pipeline	5.565	6.2541667
Pipeline	5.4286111	5.27975	Pipeline	5.5633333	5.5919444
Pipeline	5.51175	5.4780833	Pipeline	5.91425	5.0560833
Pipeline	5.881	5.1406667	Pipeline	5.4734167	5.8999722
Pipeline	5.4305278	5.2738333	Pipeline	5.3619444	6.1118611
Pipeline	5.4194433	5.30292	Pipeline	5.5288333	6.0665833
Pipeline	5.563	5.8498333	Pipeline	5.5279444	5.9158056
SPM	5.1706944	5.1640833	flare stack area	5.6529722	5.0688889
Saver pit	5.6445833	6.0711667	Floating House	5.1719444	5.1594444
Saver pit	5.5686389	6.3068889	Flowline	5.3604111	6.1525611
St	5.5689167	5.7143333	Flowline	5.4876111	6.2221111
St	5.8151667	5.6651944	Flowline	5.6866667	6.5723611
St	5.8199444	5.6592222	Flowline	5.4360556	5.8576389
Flowline	5.43825	5.8683889	Flowline	5.3603889	6.1525278
Trunkline	5.5414444	5.8866111	Flowline	5.6579167	6.5171111
Trunkline	5.4459167	6.1542778	Flowline	5.8785278	5.0897222
Trunkline	5.4625	6.1297222	Flowline	5.5663056	6.3001389
Trunkline	5.4311111	6.1755556	Flowline	5.4360433	5.860815
Trunkline	5.492	5.9166389	Flowline	5.8698889	5.1334611
Trunkline	5.5607333	5.2026833	Flowline	5.4914722	6.2565833
Bund wall	5.6516667	6.0699444	Flowline	5.4253611	5.8948611
Bund wall	5.3271667	6.2413333	Flowline	5.4322222	5.8830556
Well head	5.8693333	5.1336389	Flowline	5.4419167	5.82125

Pipeline	Latitude	Longitude	Pipeline	Latitude	Longitude
Well head	5.9038889	5.5551389	Flowline	5.4316667	5.8202778
Well head	5.5328056	5.5429722	Flowline	5.8887222	5.6144444
Well head	5.8685833	5.1411111	Flowline	5.9020278	5.5744167
Well head	5.8276389	5.1843611	Flowline	5.4427778	5.8763889
Well head	6.0232222	5.9236944	Flowline	5.3493611	6.0594444
Well head	5.5266667	5.48	Flowline	5.4346978	5.2004806
Well head	5.6557778	6.0590833	Flowline	5.4215278	5.8684167
Well head	5.42975	5.2707222	Flowline	5.7800556	5.4784444
Flowline	5.8938056	5.6079722	Flowline	5.6848278	6.5184028
Delivery line	5.3856	6.2167222	Flowline	5.9016111	5.5748056
Delivery line	5.3636389	6.0908611	Flowline	5.3821389	5.82225
Delivery line	5.3614167	6.1163611	Flowline	5.9016389	5.57475
Delivery line	5.3615833	6.1176944	Flowline	5.4292028	5.8869222
Delivery line	5.3621667	6.11	Flowline	5.8488889	5.1338889
Delivery line	5.5544722	6.1927889	Flowline	5.9027583	5.5747492
Flowline	5.8897222	5.6128056	Flowline	5.4293889	5.8931944
Exportline	6.0797222	5.6997222	Flowline	5.785385	5.4301933
Flowline	5.6659444	6.4865278	Other Sources	5.1696944	5.1636111
Flowline	5.4354444	5.0284167	Other Sources	5.3775556	6.0360556
Flowline	5.9002083	5.5738611	Other Sources	5.8848611	5.6256111
Flowline	5.5276944	5.5463889	Other Sources	5.170611	5.164167
Flowline	5.8897222	5.6128611	Other Sources	4.943056	5.682194
Flowline	5.4758333	6.0377778	Flowline	5.4409722	5.8268333
Flowline	5.9016667	5.5746389	Flowstaion	6.1523333	5.3431167
Flowline	5.8897222	5.6129167	Gasline	5.6613056	6.4965556
Flowline	5.633	5.1583611	Fp	3.6669277	7.3278809
Flowline	5.5736667	6.3125278	Flowline	5.4363056	5.8468056

Source: Nigerian Oil Spill Monitor

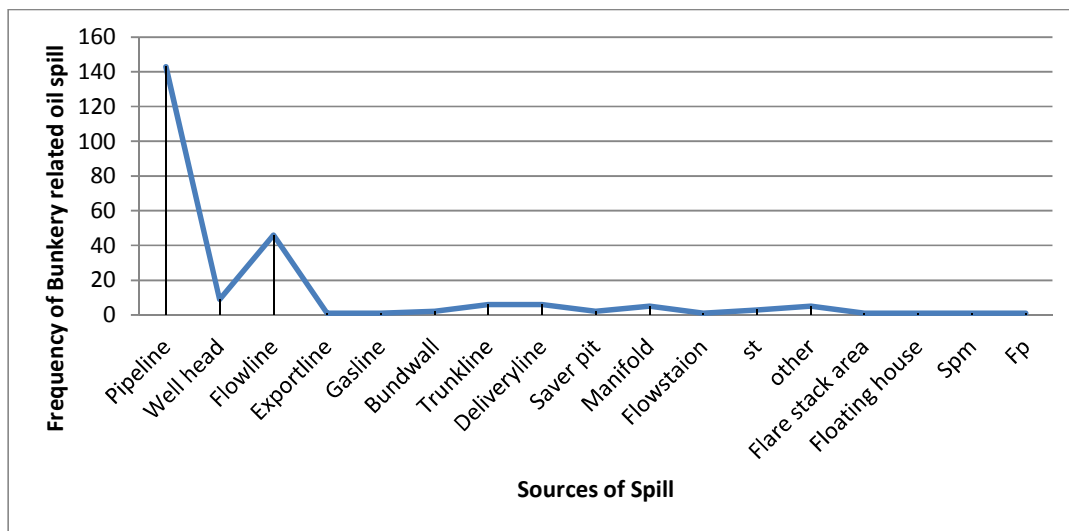


Fig. 4. Frequency of bunkering related oil spill in delta state

Fig. 4 shows the frequency of spill resulting from illegal bunkering as tied to each oil facilities. From the figure, it is observed that pipeline records more of the spill then followed by flow line after which comes well head and others sources.

Fig. 5 shows spilled areas as a result of illegal oil bunkering activities and the host facilities that results to recorded oil spill into the environment across the study area. According to the study, pipeline oil spill as a result of illegal oil bunkering activities occurs mostly in the South-West of

Buturu, where the frequency of occurrence is more pronounced and stretches from Warri South-West to Warri - South, while illegal oil spill from flow lines occurs in places like North-West area of Warri South-West and the North-West of Okpe. Illegal oil spill on delivery line occurs randomly in the South-Eastern parts of Ugehelli North, Isoko South, and Patani. Wellhead spills as a result of illegal oil bunkering occurs in places like Patani and North-East of Ndokwa East Local Government. Places like the Ethiope East and the North-East of Ethiope West Local Government witnesses oil spill from Saver pit sequel to illegal oil bunkering activities in the area.

Fig. 6 shows the pattern of illegal bunkering induced oil spill in the study area. From the analysis in Fig. 6, it is obvious that oil spill occurrence is dispersed throughout the Local Government areas except the Northern horns of the study area which reveals some form of facilities and environmental peculiarities that favours the activities of bunkering in the study area. Pipeline is the most noticeable and disturbed facility by illegal bunkers across space followed by flow lines. This indicates that linear features or oil installations across the study area are the most impacted by the activities of illegal oil bunkers (thieves).

Fig. 7 shows the spatial occurrence of oil spill as a result of illegal oil bunkering on pipeline in the study area. From the analysis, the spill data available reveals that, pipeline bunkering are peculiar to certain environments and regions hence, occurring in almost all the local government areas, which exposes the gaps in anti-bunkering methods deployed across the study area. From the analysis, almost all the Local Government areas under study have witnessed some levels of impact on her pipelines conveying crude oil product at one time or the other.

Fig. 8 shows tampered bund wall oil facilities as noticed within Isoko South and Ughelli North Local Government Areas. From the figure, the spatial occurrence of oil spill from illegal bunkering on bund wall facilities does not show spread across space. Therefore, the analysis reveals that, the activities of bunkers on the bund wall is specific at targeted facilities and does not cut across the entire region/space hence, illegal bunkers pay specific attention to this facility. It can be deduced that the bunkers have some level of knowledge which gives accurate target plan for the bund wall locations exposing them to vandalism.

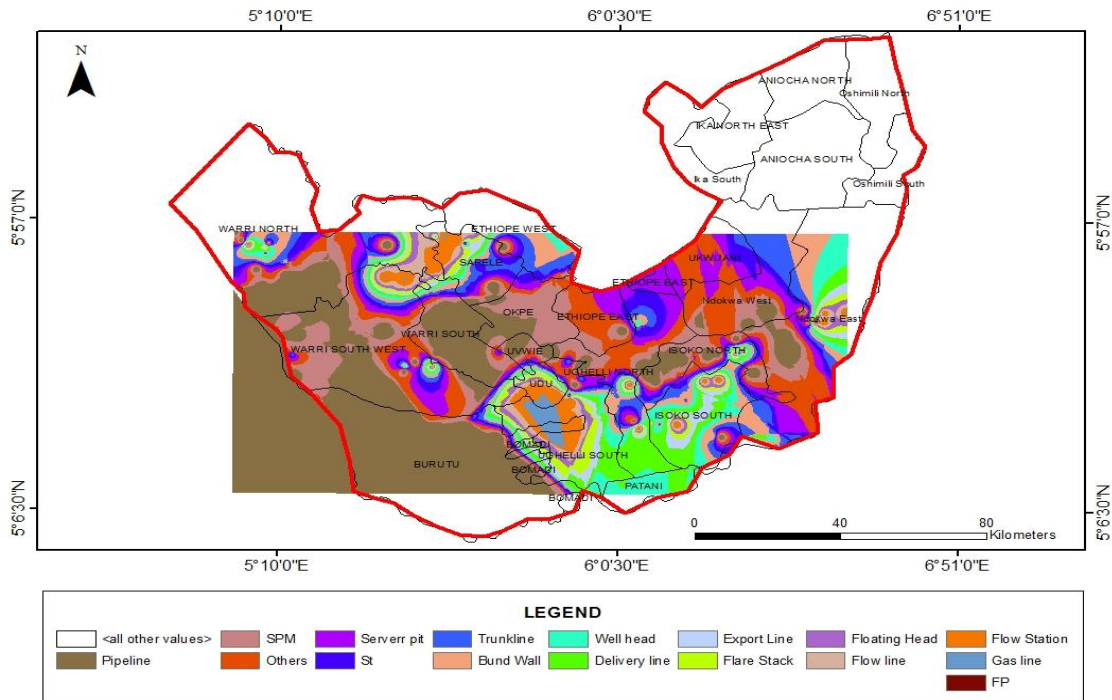


Fig. 5. Spatial trend of illegal bunkering activities across delta state

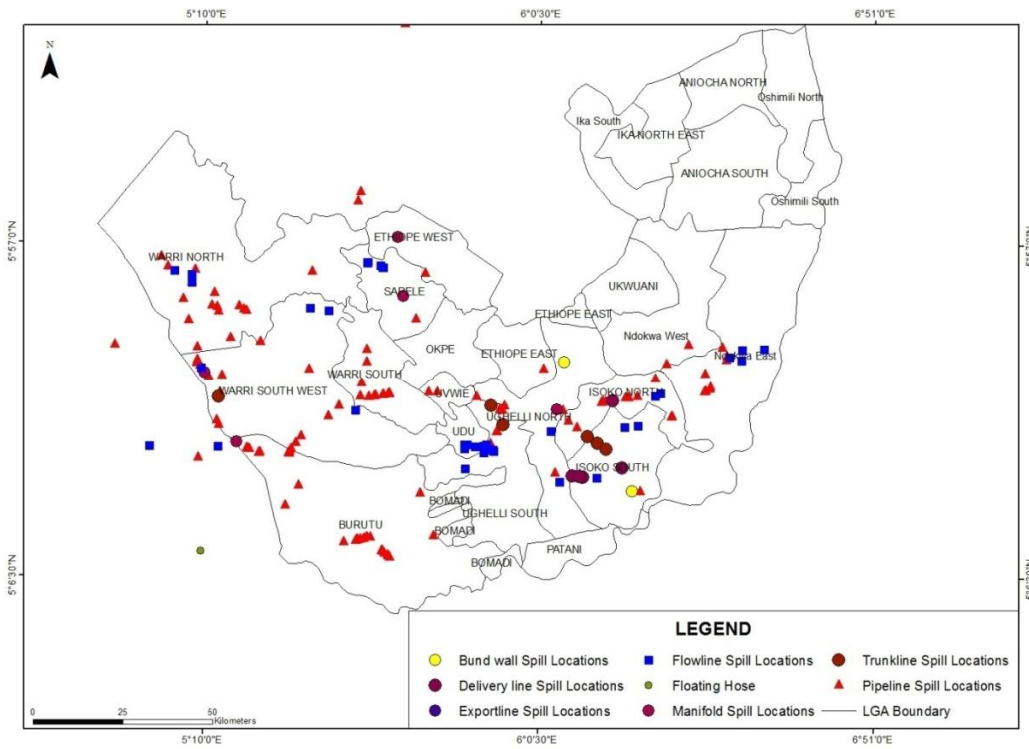


Fig. 6. Spatial occurrence of facilities based illegal oil bunkering induced spill

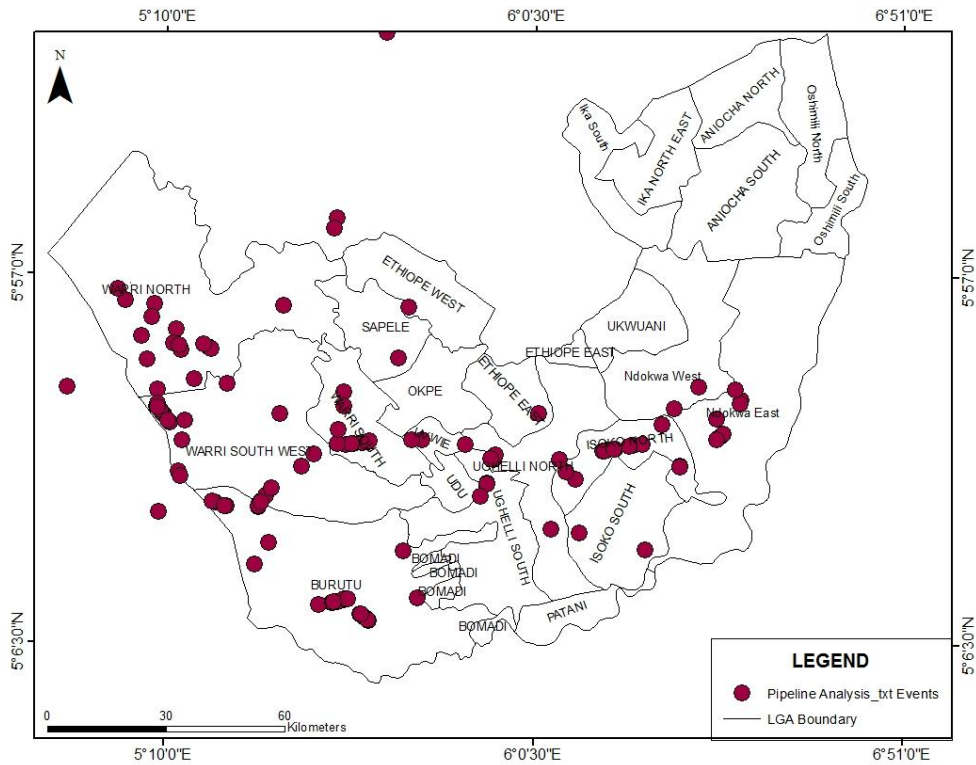
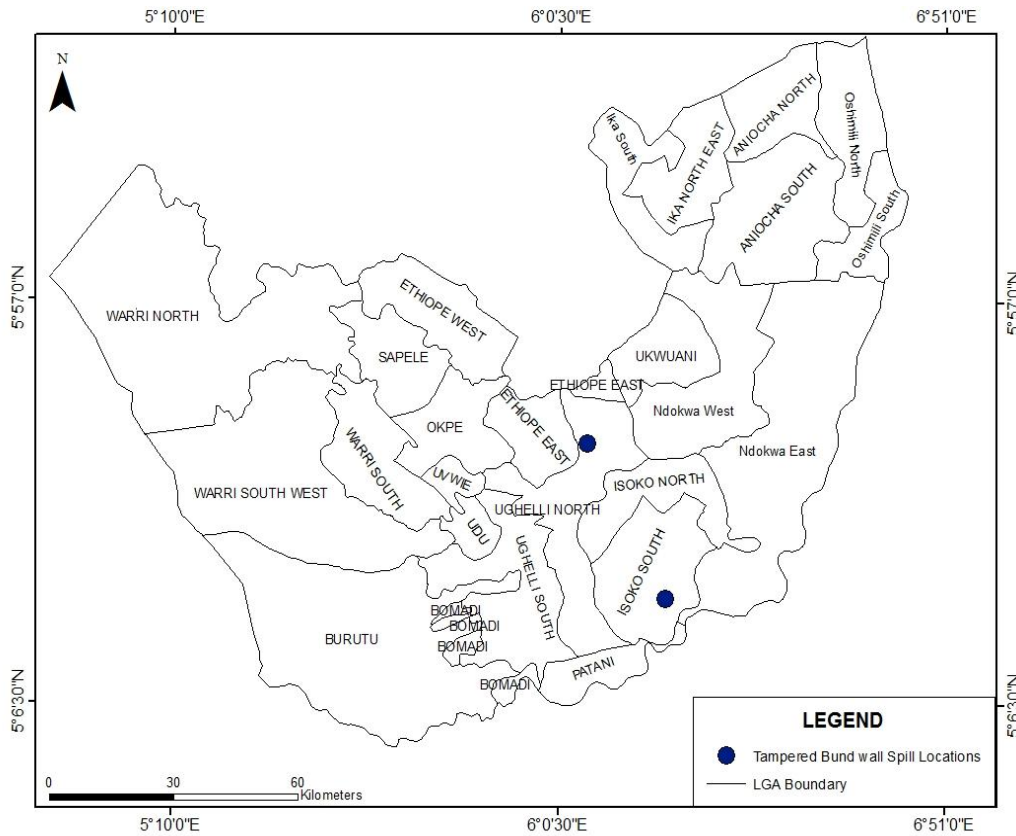


Fig. 7. Oil pipeline spill locations induced by illegal bunkering





**Fig. 8. Oil bund wall spill locations induced by illegal bunkering**

Fig. 9 shows the pattern of spill occurrence from flow lines due to the activities of illegal bunkers across the study area. In this figure, it is observed that oil spill from tampered flow line is dominantly noticed within favoured environment and facilities. Hence, flow line associated illegal bunkering are specifically and strategically carried out in favourable environment and regions, clustering in Udu, Ughelli, Isoko, Warri, and Ndokwa regions of the study area. Though, these spills as a result of illegal bunkering on the flow line are not noticed in the Northern, Central and Burutu Local Government areas.

Fig. 10 show the spatial pattern of oil spill into the environment from manifold as a result of illegal oil bunkering in the study area. The figure, indicates that, the trend of oil spill from manifold is dispersed across the study area signifying a form of scattered spill points in the study area. Illegal bunkering on Manifolds are noticed in ughelli North, Warri South-West, Burutu, Sapele and Ethiope West Local Government areas of the State.

Fig. 11, shows the spatial pattern of illegal oil bunkering induced spill from delivery line in the study area. From the figure, it is obvious that spill from delivery line as a result of illegal bunkering occurs in clusters, focusing on the Isoko Local Government axis of the state.

Fig. 12, shows the spatial occurrence of oil spill from trunk line across the study area. From the figure, oil spill from trunk line induced by bunkering activities is clustered within the central Local Governments of Isoko, Ughelli and other coastal Local Governments of the state with an exception of Warri South.

Fig. 13, shows the spatial spread of oil spill as a result of illegal bunkering activities across the study area. The coordinate of spill locations across oil facilities were overlaid on the classified image in the study area. The analysis reveals that, most of the spills resulting from tampered facilities are located in the forest belt of the study area. This situation has created some level of impact on the forest cover altering a tune of 2,213.2 km<sup>2</sup> vegetal surfaces across the study area.

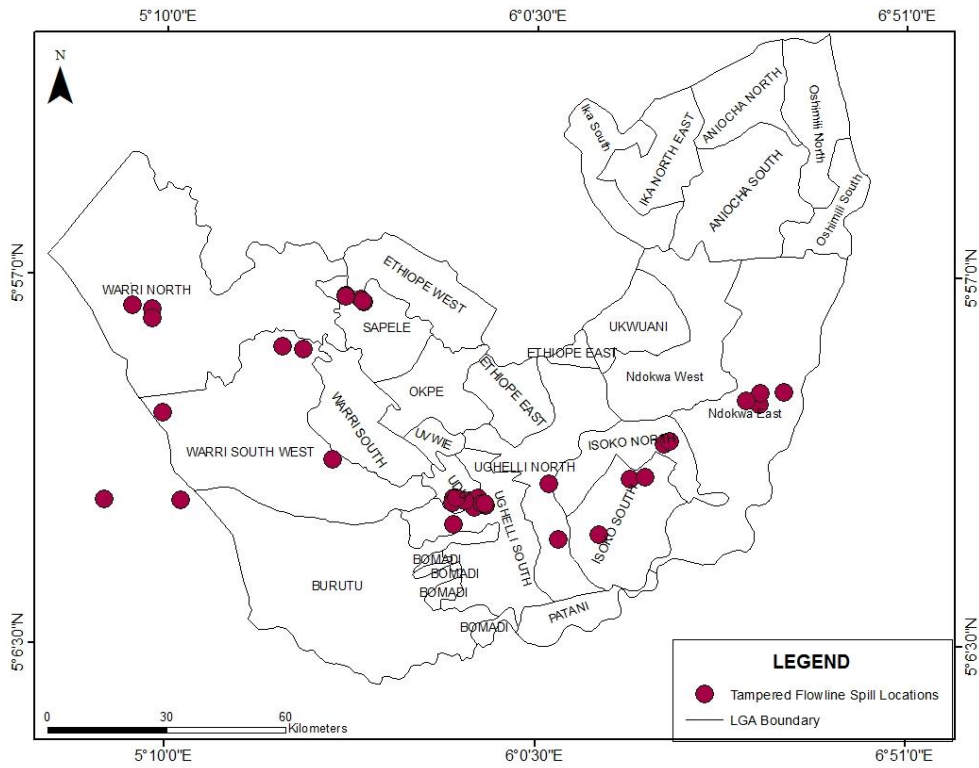


Fig. 9. Oil flow line spill locations induced by illegal bunkering

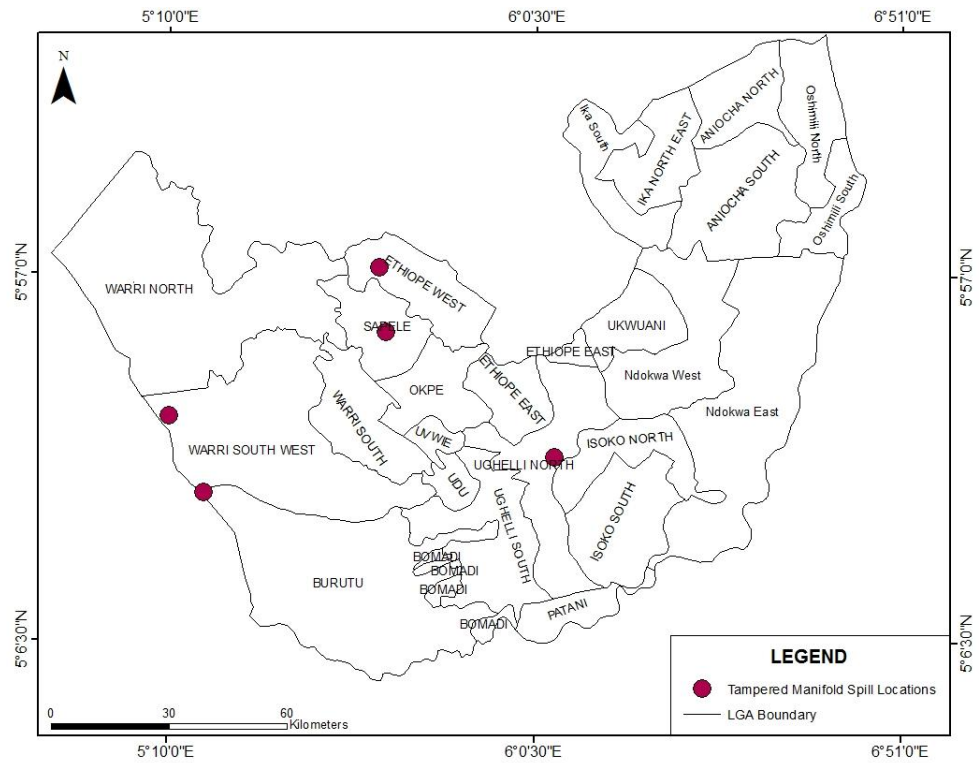
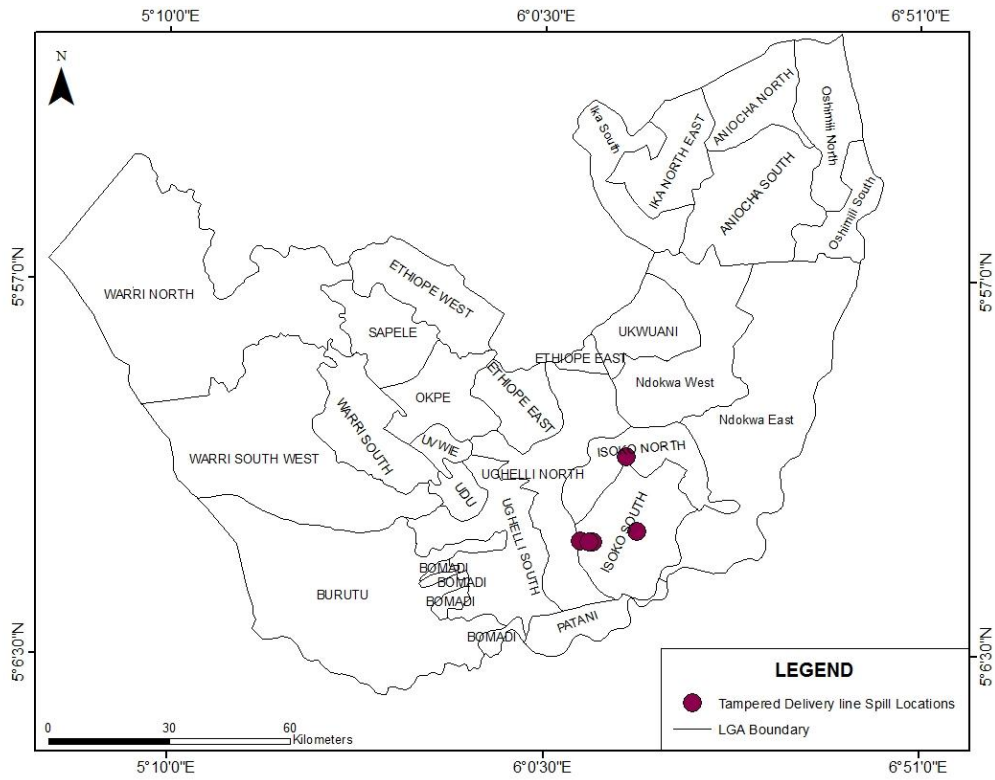
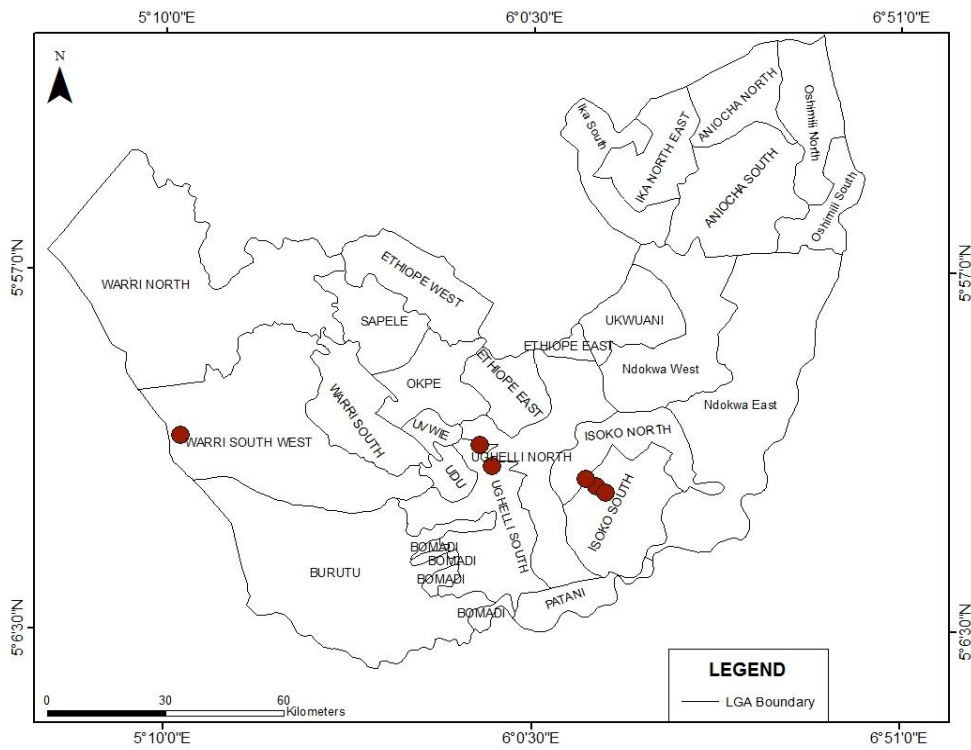


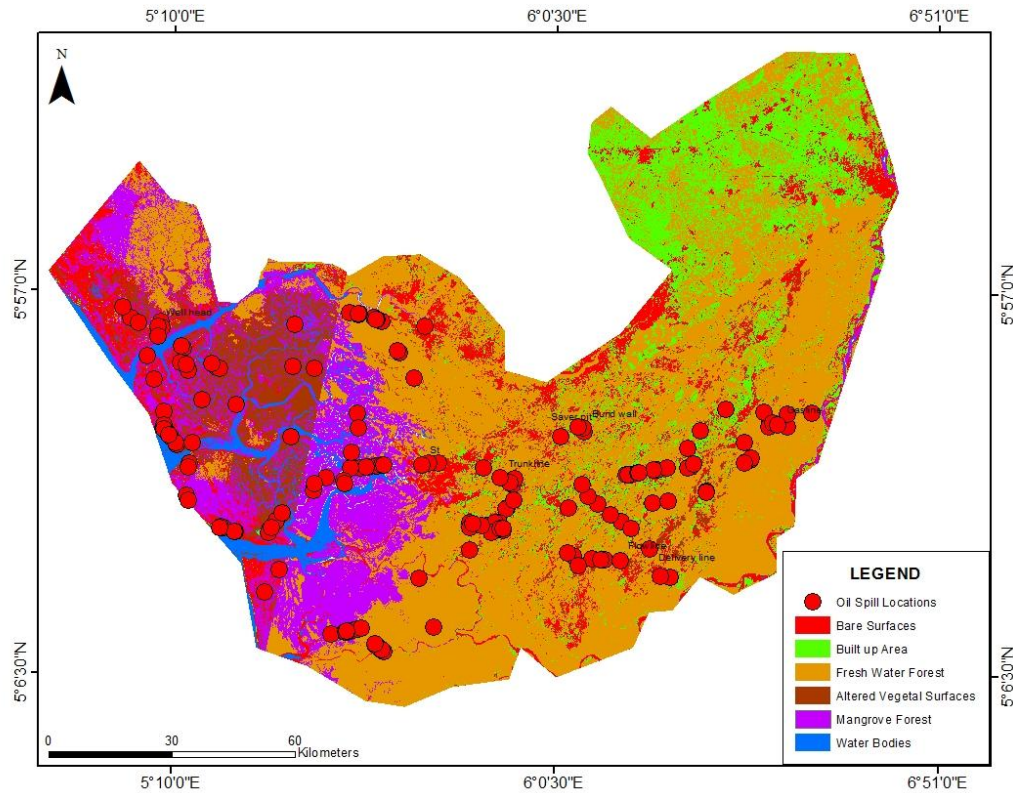
Fig. 10. Oil manifold spill locations induced by illegal bunkering



**Fig. 11. Oil delivery line spill locations induced by illegal bunkering**



**Fig. 12. Oil trunk line spill locations induced by illegal bunkering**



**Fig. 13. Delta state showing extent of land cover change in 2013**

**Table 2. Land cover changes in the study area as at 2013**

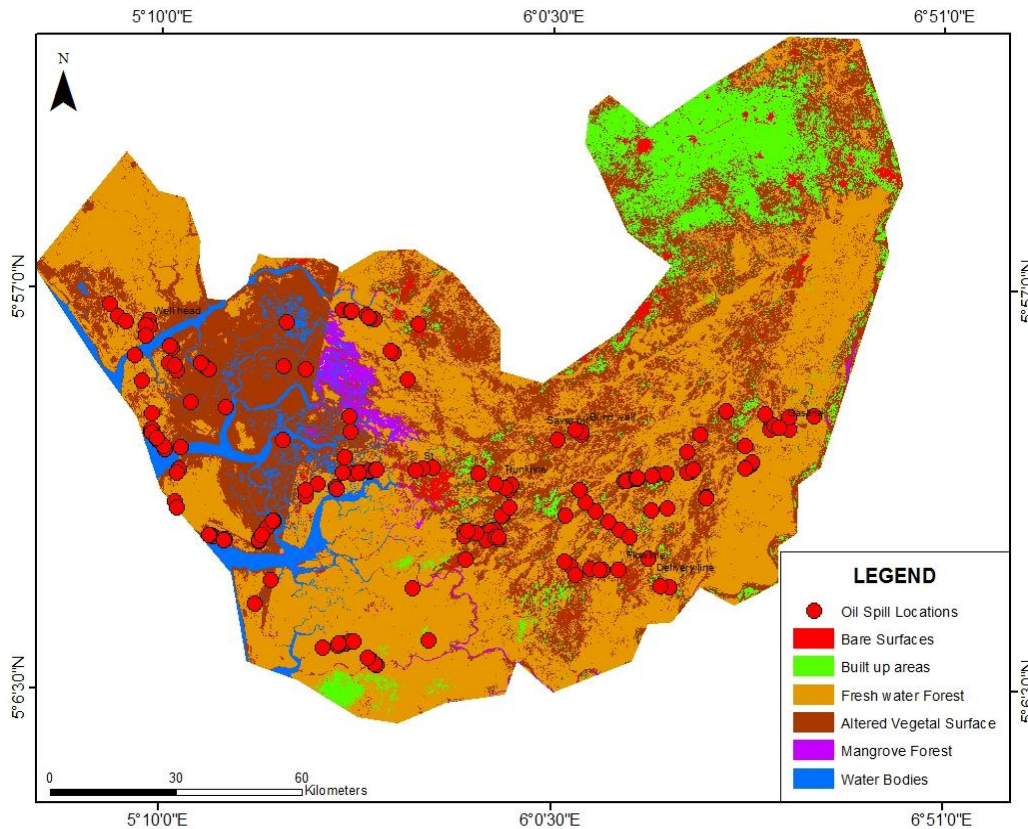
Variables	2013 Area in Square km
Built up	1,946.22
Bare Surfaces	40.2
Fresh water forest	3,421.53
Water Bodies	3,267.2
Altered Vegetal Surfaces	2,213.2
Mangrove Vegetation	6,598
	17486.35

Source: Author's Analysis

From the analysis as shown in Table 2, mangrove forested area is the largest, occupying 6,598 km<sup>2</sup>, next is fresh water forest with a tune of 3,421.53 km<sup>2</sup> land area followed by water bodies occupying a tune of 3,267.2 km<sup>2</sup>, then altered vegetal surfaces in the tune of 2,213.2 km<sup>2</sup>. Other features such as built up areas ranked fourth in land cover features enveloping 1,946.22 km<sup>2</sup> of land across the study area and the least are bare surface covering 40.2 km<sup>2</sup> of land surface.

Fig. 14, shows the locations of illegal bunkering induced spills recorded for the periods of 2013 through 2018. The activities of illegal bunkers as

viewed in Fig. 14, is more pronounced in the vegetal belt of the study area therefore, creating much impact and burden on the vegetation cover with an increase in altered vegetal surfaces accounting to 2,213.2 km<sup>2</sup> in 2013 to 4,894 km<sup>2</sup> in 2018 giving an increase of 49 percent across the years of investigation as obtained in the Fig. 14. Also, there is a noticeable decrease in fresh water forest and mangrove vegetation accounting to 60 percent and 68 percent decrease respectively. This situation can be attributed to the extent of tidal inundation, ecological nature of the region categorised as flood plain and frequent flood occurrence in the region aiding pollutant transfer inland.



**Fig. 14. Delta state showing extent of altered vegetation in 2018**

**Table 3. Land cover changes in the study area as at 2018**

<b>Variables</b>	<b>2018 Area in Square km</b>
Built up	2,472.35
Bare Surfaces	36.55
Fresh water forest	2,085.9
Water Bodies	3,529.55
Altered Vegetal Surfaces	4,894
Mangrove Vegetation	4,468
	17,486.35

Table 3 shows land cover changes in the study area as at 2018. From the analysis, altered vegetal surfaces occupied most of the land cover in a tune of 4,468 km<sup>2</sup>, followed by mangrove vegetation occupying 4,468 km<sup>2</sup> then water bodies. This trend took a swift change with an increase in areas of noticeable altered vegetal depletions in the mangrove and fresh water forest belts as observed in 2013, Fig. 13.

Fig. 15, shows the ecological belt of the study area revealing the subsequent flow of vegetal cover. From the figure, the coastal boundary of

the region is separated from the mainland by a stretch of Beach Island with pocket of river estuaries which allows the inflow of ocean water and the outlet of materials from the Niger River. This situation has made for a depositional land form creating a plain in the region which supports/allows material transfer between the upland and the ocean, hence, the free flow of materials not excluding pollutants from crude oil in the event of spill. This situation enhances vast movement of crude oil and materials over beyond terrestrial, aquatic boundaries making an observable pocket of altered vegetal surfaces across the study area.

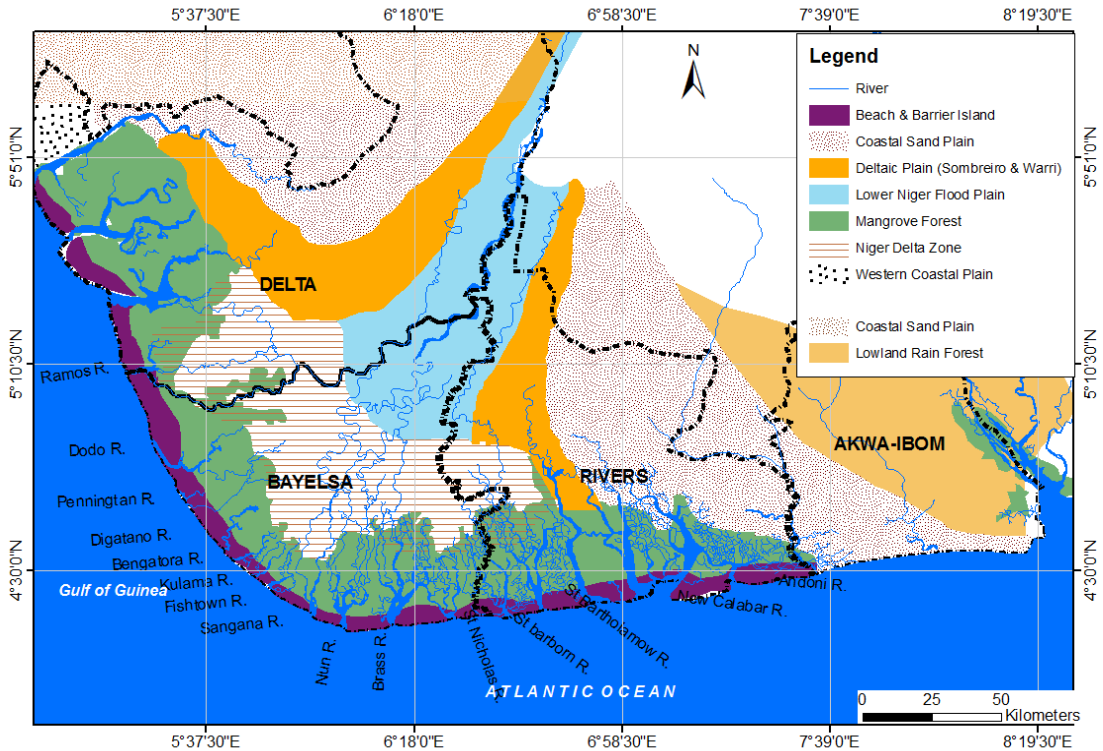


Fig. 15. Ecological belt of study area (delta state) and ‘environs’

Table 4. Summary of land cover changes between 2013 and 2018 in the study area

Variables	2013 Area in Square km	2018 Area in Square km	Percentage change
Built up	1,946.22	2,472.35	78 increase
Bare Surfaces	40.2	36.55	90 decrease
Fresh water forest	3,421.53	2,085.9	60 decrease
Water Bodies	3,267.2	3,529.55	92 increase
Altered Vegetal Surfaces	2,213.2	4,894	49 increase
Mangrove Vegetation	6,598	4,468	68 decrease

#### 4. CONCLUSION

The analysis, examined the spatial spread of facilities-based illegal bunkering induced oil spill across Delta state. From the analysis conducted, there is a noticeable wide spread of illegal bunkering induced oil spill across the study area with more emphasis on pipelines and flow lines. It is obvious that oil facilities cuts across the entire study areas and its environment. This stretch does not exclude water bodies around the Atlantic Ocean mostly referred to as offshore wells where oil exploration is favoured by the laying of pipelines, flow lines, and trunk lines to convey these products from the point of production to point of distribution to either local or

international market. This trend shows and validates the reason why pipeline and flow lines which serves as the conveyor of the product across the study area and stretches beyond local governments, is the most impacted as a result of its accessibility and proximity to the local. To this end, it is therefore recommended that community education is necessary to discourage the locals form self-inflected impact of oil spill as a result of their activities thereby impacting on their socio-economies and livelihood.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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