



## **Assessment of Oil Spillage Impact on Vegetation in South-Western Niger Delta, Nigeria**

**Umar Wakil Adamu<sup>1</sup>, Emmanuel Yeboah<sup>1\*</sup>, Isaac Sarfo<sup>2</sup>,  
Edward Kweku Nunoo<sup>3</sup>, Clement Kwang<sup>1</sup>, Foster Kofi Addai<sup>1</sup>,  
Collins Oduro<sup>2</sup>, George Darko<sup>4</sup>, Grace Chikomborero Ndafira<sup>5</sup>,  
Michael Batame<sup>1</sup> and Emmanuella Aboagye Appea<sup>1</sup>**

<sup>1</sup>Department of Geography and Resource Development, University of Ghana, Legon, Ghana.

<sup>2</sup>Research Institute for History of Science and Technology, Nanjing University of Information Science and Technology, China.

<sup>3</sup>Institute of Oil and Gas Studies, University of Cape Coast and Department of Environment & Development Studies, Central University, Ghana.

<sup>4</sup>Department of Environment and Biotechnology, Nha Trang University, Vietnam.

<sup>5</sup>School of Business Management, Nanjing University of Information Science and Technology, Nanjing 210044 Jiangsu, China.

### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors UWA, EY, CK, FKA, MB and EAA conceptualized, designed, critically analyzed, wrote the first draft and approved the final draft. The author IS acquired data, analyzed and interpreted the results. The author EKN and remaining authors GD and GCN critically analyzed the results, revised the work (edited) and wrote the final draft. All authors read and approved the final manuscript.*

### **Article Information**

DOI: 10.9734/JGEESI/2021/v25i930307

*Editor(s):*

(1) Dr. Teresa Lopez-Lara, Autonomous University of Queretaro, Mexico.

*Reviewers:*

(1) Deborah Mithya Barros Alexandre, Universidade Federal do Ceará, Brazil.

(2) Yao Marcel Konan, Félix Houphouët-Boigny University, Côte d'Ivoire.

(3) Mukta Jagdish, Jawaharlal Nehru Rajkeeya Mahavidyalaya, India.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/74292>

**Original Research Article**

**Received 20 July 2021  
Accepted 30 September 2021  
Published 05 October 2021**

### **ABSTRACT**

The present study assesses the impact of oil spillage in the Southwestern Niger Delta of Nigeria over the past fifty (50) years. It further sought to find out the driving forces and implications of oil spillage on vegetation, livelihoods and other key parameters. The study employed geospatial

techniques and a secondary source of data to achieve the objectives set out in this study. The Global Moran I statistical tool was used to determine the spatial autocorrelation based on feature locations and attribute values. We observed built-up areas, bare land, and less dense vegetation had an overall increment of 1975.98 km<sup>2</sup>, 1370 km<sup>2</sup> and 23805 km<sup>2</sup>, respectively. Dense vegetation had declension of 22058.33 km<sup>2</sup> over the past five decades. Findings depict a declining trend in Normalized Difference Vegetation Index, attributed to oil spillage as the key contributory factor. Occasioned by anthropogenic activities, the driving forces were traced to attacks on oil pipelines during conflicts and illegal means of creating leakages to siphon crude oil for sale. To achieve sustainability in oil spill management in the Delta, the study recommends further research to ascertain the cost of losses incurred apply geospatial techniques to monitor and predict environmental changes that inform decisions of key actors.

*Keywords: Oil spillage; vegetation; impact; geospatial techniques; Niger Delta.*

## 1. INTRODUCTION

Gaining a comprehensive understanding of oil spillage is essential in risk assessments and evaluation of oil contamination among other impacts on the environment [1]. [2] termed oil spillage as the release of refined petroleum into the environment as a result of several factors. Oil spill normally occurs as result of the extraction, refining, transportation and storage of petroleum product [3]. Other ways through oil spill can occur include through accident, sabotage and lack of equipment maintenance and through natural causes such as earthquakes and hurricanes [4]. Terrestrial spillage in particular are associated with system and production failure, leakages in laid surface and underground pipelines, sabotage, as well as transportation of oil slicks from the ocean to the land [5].

Oil spillage impacts on the environment in diverse ways. The enormity of its impact is linked to the nature of the accident that resulted in the spillage. In some instances, accidents that lead to oil spills emanate from pipeline ruptures, human error, poor maintenance, blow-outs, explosions and so on [6]. The spillage of oil onto the environment has led to the rapid degradation of the environmental [7]. Oil spillage incidents could have negative consequences on vegetation through the ingestion and absorption of harmful petrochemical substances that can affect the growth of plants [8,9]. Oil spillage could also reduce photosynthesis and transpiration in plants [10]. Again, other factors like coating and smothering affect the adaptive capacity of plants to increasing temperature, among other key factors essential for growth [9]. On shore, oil spillage contamination has the potential of increasing erosion and loss of salt marsh due to oil-induced plant mortality [11]. The longer oil resides on land, the greater the consequence

along with sluggish recovery process [11–13]. This results from direct impacts of hydrocarbons on plants' metabolism process. On the other hand, indirect impacts occur through the disturbance of plant-water liaisons, and reduced gas interactions between two components, thus, the soil and the atmosphere [11], [14,15]. Oil spillage has irreparable implications on human health which constitute liver and respiratory damage due to the exposure of harmful hydrocarbons and heavy metals. Continuous accumulation of these heavy metals, commonly known as "*biomagnification*", often result in increased risk of being infected with cancer (carcinogenic nature), declension of one's immune system, physical, psychological and financial stress, death, endocrine toxicity and genotoxicity among others [9,11]. Again, oil spills could impact on socio-economic activities in several ways which entails cost of clean-up and settlement of proponents or people affected (compensation), damage to agricultural lands, fisheries/aquaculture, marine/wildlife as well as the repercussions on the tourism and hospitality industry, local conflicts and so on. Funds used in such clean-up among others could have been channelled to develop other sectors of the economy or improve several livelihoods.

Geographic Information System (GIS) and remote sensing techniques offer the capabilities for detecting and identifying oil spillage incidents on the environment. In the event of an oil spill, explicit communications and precise information are required to minimize risks associated with oil spillage incidents. This in effect protects the natural environment, thereby reducing economic losses [16]. Recently, it has been argued that GIS has gained prominence in the oil exploratory field mainly due to its capability of efficient storage, retrieval, analysis and visualization interface of spatial and tabular data [16]. With the

aid of GIS, it is easier to integrate information of previous incidents among other sources to be presented on one interactive surface [5] [17]. This is quite favourable and workable for manipulating, detecting, assessing, predicting, managing and analyzing oil spillage [18]. The integration of information from previous incidents is essential in mapping, planning, sensitivity analysis and monitoring of similar scenarios. Furthermore, utilization of GIS facilitates the execution of pro-active oil spillage emergency strategies and plans. Besides, it presents a convenient and a dynamic platform to digest several characteristics and physical information generated from such disasters.

Incidents of oil spill occur in different ways, it can be due to refining, operations of petroleum industries such as extraction and utilization of petroleum which invariably result in the formation of oil slicks of distinct thickness on the surface of the ocean [19]. One of the best available sensors for detecting oil spillage is laser fluorosensors. The machinery has dual working periods, thus, during the day and night. It has the capacity to categorize and identify spillage incidents on all surfaces including shoreline and glacial surface [20]. On the other hand, measuring the composition and texture of oil slick thickness can be conducted with the aid of a passive microwave radiometer. Though these sensors are valuable for such scenarios, they however, need require further advancements and extensive commercialization in order to be used effectively in studies related to detecting oil spillage [21]. In relation to offshore incidents, satellite radar data has rapidly expanded, with Synthetic Aperture Radar (SAR) proven to be useful in detecting and monitoring oil spillage. SAR can operate regardless of prevailing climatic conditions, be it light wind to high wind of 12-14 m/s [22].

Contemporarily, the availability of aerospace remote sensors with repetitive and wide coverage at low costs gives Remote Sensing the merit in monitoring and detecting environmental changes on Earth [23]. Remote sensors have the ability to control and detect hydrocarbon spillage on both lithosphere and hydrosphere. Also, multispectral Remote Sensing images can provide important information that will be required for modelling the spread of oil spillage. GIS oil spill models can aid in assisting clean-up operations and controlling oil spillage [20].

The Niger Delta region was primarily chosen due to the increasing rate of oil spillage incidents in the area. According to the Nigerian National Petroleum Cooperation (NNPC), there were 20,000 incidents of oil spillage recorded between 2006 and 2013 [24]. The region is known to be mostly affected by oil spill in Nigeria and Africa at large [24]. The Department of Petroleum Resources (DPR) in Nigeria reported that only 23% of such incidents that occurred between 1976 to 1996, had been recovered [25]. Additionally, an independent assessment conducted by an external or independent unit revealed an estimated 115,000 barrels of oil are spilled annually in the study area [26]. Here, the problems associated with this menace keep increasing, which in turn, compounds existing issues. The colossal amount of oil spills in the Niger Delta region propelled the use of geospatial techniques to assess the impact of oil spillage in Southwestern Niger Delta, Nigeria. This could partly influence land cover conversions in the region. We therefore attempted to answer the following research questions: (i) What factors drive oil spillage incidents among the key actors in the Niger Delta? (ii) In what way can Remote Sensing and GIS be used to assess the impact of this phenomenon on vegetation? (iii) How can these resultant impacts be managed? Using Remote Sensing to analyse the consequences of such disasters on vegetation is key towards identifying, monitoring and understanding areas of risk and ultimately mitigating human exposure in the Niger Delta. The present study through its findings intends to provide useful reference to the citizenry, policy makers and other developmental agencies within the sub region. Some propositions associated with oil spillage and its impact on vegetation in the Niger Delta Region, Nigeria are:

- Oil spillage in Niger Delta Region is caused by pipe-line vandalism, ruptures and blow outs.
- The negative consequences of oil spillage on vegetation influences the natural vegetation spaces (infertile), thereby making farming activities very difficult.
- Oil spillage on vegetation tends to destroy the green spaces.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The Southwestern Niger Delta region is located in the Niger Delta region of Nigeria. It lies

between latitudes 4° and 6° N of the equator and also 8° E of the Greenwich meridian. The Niger Delta region constitutes nine states, namely: Cross River, Akwa Ibom, Edo, Rivers, Bayelsa, Delta, Ondo, Imo and Abia state. In Nigeria, the states in the Niger Delta are the major oil exploratory areas [27]. The Niger Delta area stretches over 70,000 km<sup>2</sup> of swamp land, covered by tropical rainforest and mangrove swamp. It is touted globally as the second largest delta, with about 450km stretch of coastline [28]. The region consists of distinct ecosystems, freshwater swamps, mangroves and rain forest. It has a population of about 31 million people with Ijaw, Itsekiri, Ikwere, Urhobo, Kalabari, Yoruba, Igbo and Andoni Efik ethnic groups, dominating the area. The area hosts colossal oil deposits, extracted by multinational companies and the Nigerian government worth over \$600 billion revenue [29].

## 2.2 Methodology

Geospatial technologies such as laser fluorosensors and passive microwave radiometer, synthetic aperture radar and optical sensors have been used in studying, identifying spillage incidents in both hydrosphere and biosphere. The spatial dataset used for Land Use/Land Cover (LULC) and Normalized Difference Vegetative Index (NDVI) in the study area were obtained from United States Geological Survey's (USGS) website. Data for oil

spillage were obtained from Nigerian AGIP Oil Company's (NAOC) website which was used for spatial auto-correlation to determine hotspot and cold spot areas in the study area.

## 2.3 Image Classification

Supervised classification was employed to extract detailed LULC classes constituting; dense vegetation, less dense vegetation, bare lands, water bodies and built-up areas. The classification scheme was based on the USGS LULC classification system. Furthermore, a maximum likelihood classifier was used for preliminary classifications based on the outcome of the supervised classification. In order to improve the preciseness of interpretation, Google Earth Pro software (version 7.3.4, 2021) was used to differentiate areas which were difficult to understand.

## 2.4 Change Detection Analysis

The analysis was used to ascertain the extent of change over the given study period. The statistics were calculated using square kilometres, pixel counts and area in percentage. This facilitated the generation of statistical data of how the land cover had changed across time in relation to features like dense vegetation, waterbodies, bare-land, built-up areas and less dense vegetation.

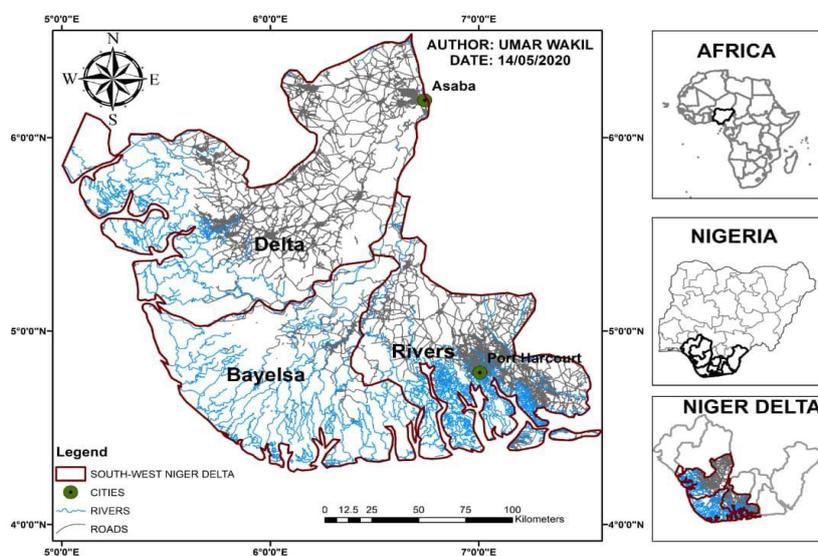


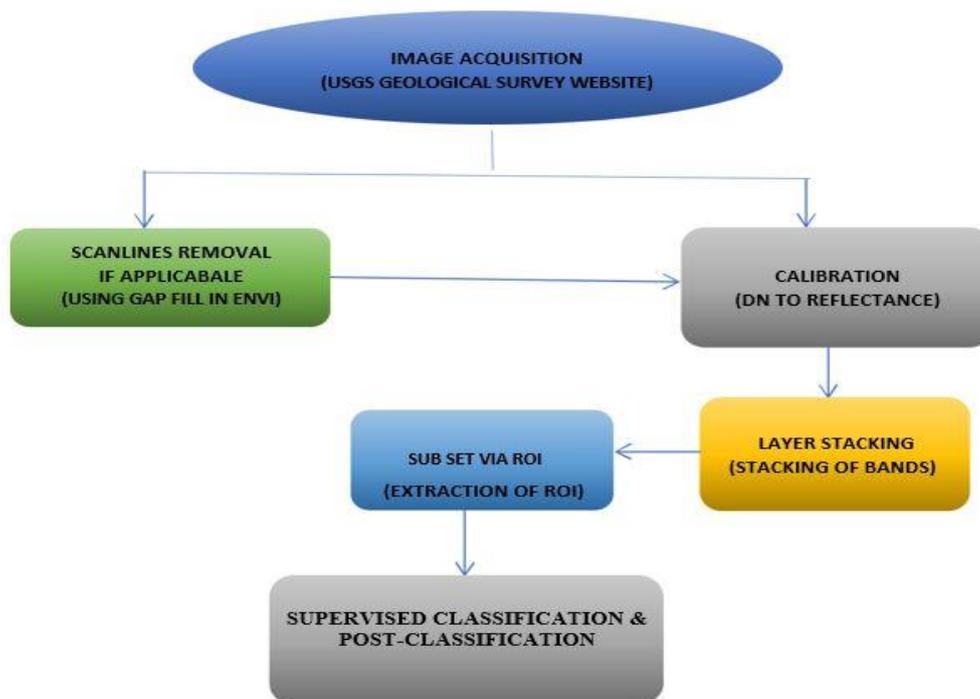
Fig. 1. Map of the study area: Southwestern Niger Delta, Nigeria

**Table 1. Description of satellite imageries used for the study**

Remote Sensing Data	Year Acquired	Resolution	Source	Path	Row
Landsat 5 MSS	1970s	30m	USGS	188/189	156/057
Landsat 4 TM	1980s	30m	USGS	188/189	156/057
Landsat 5 TM	1990s	30m	USGS	188/189	156/057
Landsat 7 ETM+	2000s	30m	USGS	188/189	156/057
Landsat 7 ETM+	2010	30m	USGS	188/189	156/057
Landsat 8 OLI/TIRS	2020	30m	USGS	188/189	156/057

**Table 2. Description of land use cover classes for Southwestern Niger Delta**

Classes	Description
<b>Dense Vegetation</b>	Areas covered by closely knit trees and luxurious vegetative cover. It encompasses all vegetated areas that expose no bare soil and vegetation reserved areas
<b>Built-up areas</b>	Entails residential areas, commercial and industrial areas classified as built-up areas. Parks, gardens, playgrounds and roads within communities are classified as built-up.
<b>Bare land</b>	Patching land or rocks which are not covered by vegetation. Bare lands are common in and near built-up areas. Lands that have been cleared in readiness for construction, mining or farming fall within this category.
<b>Less dense vegetation</b>	Describes areas that portray sparsely located trees, grasslands, shrubs, isolated thickets, farms and areas with non-tree crops
<b>Waterbodies</b>	Comprise rivers, lagoons, lakes and others.



**Fig. 2. Flow diagram of image pre-processing and post-classification (change detection) analysis**

## 2.5 Normalized Difference Vegetation Index (NDVI)

Basically, the function of NDVI is the quantification of vegetation, measuring the distinction between near infrared and red light [30]. NDVI was determined using the expression:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \dots eqn. 1$$

NDVI values often range between +1 and -1. The degree of positivity or negativity depicts the healthiness or presence of vegetation in the area. It is worthy to note that healthy vegetation absorbs more red and blue light.

## 2.6 Data Analysis

To achieve clearer results and identifying oil spills hotspot areas, the symbology and classification tools were also used to group the results into 50 points. Colours were given to the grid output file. Interpolation (Inverse Distance Weighted (IDW) using ArcMap 10.7 was used to identify highly impacted oil spill areas in the South Western region of the Niger Delta. For the purpose of this study, a hotspot was defined as an area which has a greater number of oil spillage compared to the surrounding states. This method is useful in defining areas of high occurrence of a phenomenon versus areas of low occurrence. An interpolated surface is created by analyzing point data which shows the density of occurrence.

Results of the study were subjected to content analysis to validate findings. ENVI 5.3 and ArcGIS 10.7 were used in the processing of spatial datasets. Accuracy assessment was conducted for the six periods (1970's, 1980's, 1990's, 2000's, 2010 and 2020) using ground truth sample points and the above listed software. The sampled points were overlaid on Google Earth-Pro for verification. One hundred (100) samples were generated from each class in the classified images for the accuracy assessment, making a total of five hundred (500) samples in all.

Number of Total Sample Points generated (TSP) =500

Number of Sample Points that accurately fell on each required feature (ASP) =453

Therefore;

$$\begin{aligned} \text{Accuracy Assessment (A.A)} \\ = \frac{ASP}{TSP} \times 100 \dots eqn. 2 \end{aligned}$$

Source: Sarfo et al. 2021

### 2.6.1 Global moran's i index

Global Moran I index was employed to calculate the spatial autocorrelation (in ArcMap) based on feature locations and attribute values. This function was used to evaluate spillage incidents, their spatial distribution and to test how the spills were clustered, randomized or dispersed in space. The null hypothesis used here states that the attribute being analyzed is randomly distributed among the classes in the region. The 'Inverse Distance' was chosen as the conceptualization of spatial relationship parameter. Hence, any point that coincides with another was given a weight of one to avoid zero division. This in effect, ensured that appropriate classes were not excluded from the analysis. Calculations for Moran's I are based on a weighted matrix, with units  $i$  and  $j$ . Similarities between units are calculated as the product of the differences between  $y_i$  and  $y_j$  with the overall mean. The tool calculates the Moran's I Index value and both the z-score and p-value to analyse the significance of that Index.

The Moran's I statistic for spatial autocorrelation is given as:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} z_i z_j}{S_0 \sum_{i=1}^n z_i^2} \dots eqn. 3$$

Where  $z_i$  is the deviation of an attribute for feature  $i$  from its mean ( $x_i - X$ ),  $w_{i,j}$  is the spatial weight between feature  $i$  and  $j$ ,  $n$  is equal to the total number of features, and  $S_0$  is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^n \sum_{j=1}^n w_{i,j} \dots eqn. 4$$

The  $z_i$  score for the statistic is computed as:

$$z_i = \frac{I - E[I]}{\sqrt{V[I]}} \dots eqn. 5$$

Where:

$$E[I] = -1/(n - 1) \dots eqn. 6$$

$$V[I] = E[I^2] - E[I]^2 \dots \text{eqn. 7}$$

Source: Mitchell (2005) and Griffith (1987).

### 3. RESULTS

#### 3.1 LULCC Statistics From 1970 to 2020

Based on the classifications in the 1970s, built-up lands occupied an area of 3,044.83 km<sup>2</sup> (6.82%); Dense vegetation occupied an area of 30,563.53 km<sup>2</sup> (76.10%); Less dense vegetation occupied an area of 9,409.63 km<sup>2</sup> (11.83%); bare land occupied an area of 728.82 km<sup>2</sup> (1.54%); while water bodies occupied an area of 1,358.70 km<sup>2</sup> (2.86%). However, in 1990's, built-up areas occupied an area of 4,240.87 km<sup>2</sup> (9.46%); dense vegetation occupied an area of 23,889.24 Km<sup>2</sup> (53.29%); less dense vegetation occupied an area of 14,409.63 km<sup>2</sup> (32.14%); bare land occupied an area of 858.82 km<sup>2</sup> (1.92%); while water bodies occupied an area of 1,428.65 km<sup>2</sup> (3.19%).

In the 1980s, built-up areas occupied an area of 3,333.17 km<sup>2</sup> (7.02%); dense vegetation occupied an area of 32,633.79 km<sup>2</sup> (76.75%); less dense vegetation occupied an area of 9,409.63 km<sup>2</sup> (11.83%); bare land occupied an area of 728.82 km<sup>2</sup> (1.54%); while water bodies occupied an area of 1,358.70 km<sup>2</sup> (2.86%). However, in 1990's, built-up areas occupied an area of 4,240.87 km<sup>2</sup> (9.46%); dense vegetation occupied an area of 23,889.24 Km<sup>2</sup> (53.29%); less dense vegetation occupied an area of 14,409.63 km<sup>2</sup> (32.14%); bare land occupied an area of 858.82 km<sup>2</sup> (1.92%); while water bodies occupied an area of 1,428.65 km<sup>2</sup> (3.19%).

In 2000s, built-up areas occupied an area of 5,430.71 km<sup>2</sup> (11.67%); dense vegetation occupied an area of 21,486.72 km<sup>2</sup> (46.16%); less dense vegetation occupied an area of 15,119.19 km<sup>2</sup> (32.48%); bare land occupied an area of 3,010.71 km<sup>2</sup> (6.47%); and water bodies occupying an area of 1,505.24 km<sup>2</sup> (3.23%). The 2010 classification statistics shows built-up areas occupied an area of 6,207.48 km<sup>2</sup> (11.20%); dense vegetation occupied an area of 20,067.35 km<sup>2</sup> (44.92%); less dense vegetation occupied an area of 16,998.43km<sup>2</sup> (36.31%); bare land occupied an area of 2,010.71 km<sup>2</sup> (4.29%), Water bodies occupied an area of 1,536.60 km<sup>2</sup> (3.28%). As at 2020 January, dense vegetation had immensely decreased with current coverage occupying an area of 9,005.20 km<sup>2</sup> (14.77%) in the Southwestern Niger Delta region. This could be attributed to the expansion in oil exploration fields along with high oil spillage incidences, affecting the forest belt. Built-up areas occupied an area of 7,138.89 km<sup>2</sup> (12.26%); less dense vegetation on the other hand, occupied an area of 32,900.15 km<sup>2</sup> (64.59%); bare land occupied an area of 3,068.85 km<sup>2</sup> (4.81%); water bodies occupied an area of 1,631.45 km<sup>2</sup> (4.16%). Having analyzed the classifications of LULC from 1970s to 2020, further details of the statistics have been presented in Table 3 and Table 4. The confusion matrix developed for the accuracy assessment resulted in a 90.6% accuracy for the study over the given period [31].

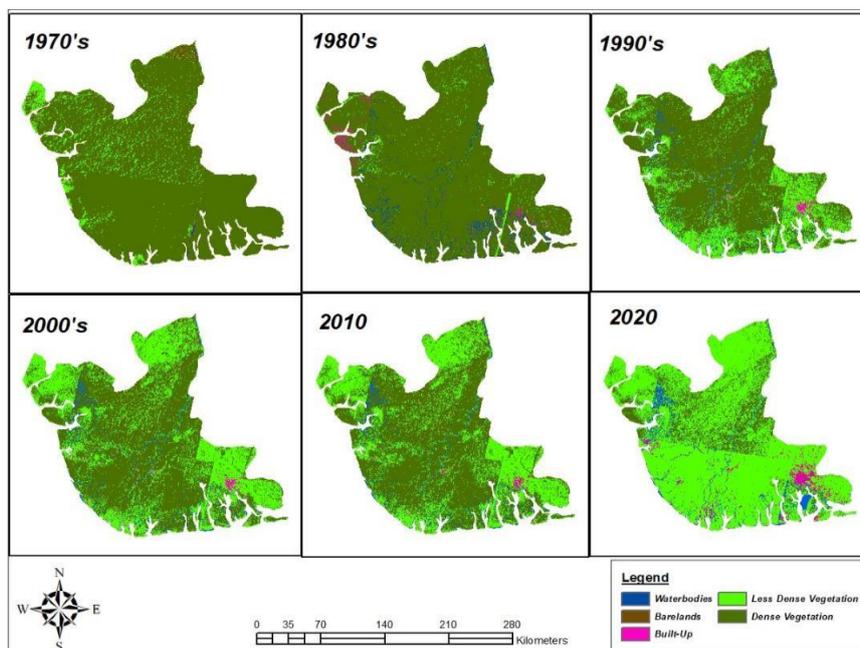


Fig. 3. LULCC classification statistics for Southwestern Niger Delta for the given period (1970-2020)

**Table 3. Classification statistics in square kilometres (%)**

Class	1970s sq.km (%)	1980s sq.km (%)	1990s sq.km (%)	2000s sq.km (%)	2010 sq.km (%)	2020 sq.km (%)
Built-up	3,044.83 (6.82%)	3,333.17 (7.02%)	4,240.87 (9.46%)	5,430.71 (11.67%)	6,207.48 (11.20%)	7,138.89 (12.26%)
Dense Vegetation	30,563.53 (76.10%)	32,633.79 (76.75%)	23,889.24 (53.29%)	21,486.72 (46.16%)	20,067.35 (44.92%)	9,005.20 (14.77%)
Less Dense Vegetation	9,493.40 (13.58%)	9,409.63 (11.83%)	14,409.63 (32.14%)	15,119.19 (32.48%)	16,998.43 (36.31%)	32,900.15 (64.59%)
Bare land	1,509.30 (3.38%)	728.82 (1.54%)	858.82 (1.92%)	3,010.71 (6.47%)	2,010.71 (4.29%)	3,068.85 (4.81%)
Water bodies	53.59 (0.12%)	1,358.70 (2.86%)	1,428.65 (3.19%)	1,505.24 (3.23%)	1,536.60 (3.28%)	1,631.45 (4.16%)
Total	44664.65 (100%)	47464.11 (100%)	44827.21 (100%)	46552.57 (100%)	46820.57 (100%)	53744.54 (100%)

**Table 4. Change Detection Statistics for the study area over the given period (1970-2020)**

Classes	Initial State 1970s (Km <sup>2</sup> )					Row Total
	Water bodies	Bare land	Built- up	Less Dense Vegetat ion	Dense Vegetatio n	
Water bodies	20.76	41.0 7	3.53	110.85	1452.96	1629. 16
Bare land	5.2	15.2 1	2.47	16.1	105.1	145.0 9
Built-up	0.64	7.53	556.87	21.17	481.98	1068. 18
Less Dense Vegetation	29.86	1113 .76	2378.2 6	1830.4	20942.91	26295 .19
Dense Vegetation	2.26	330. 23	102.83	509.66	4559.69	5504. 66
Class Total	53.59	1509 .3	3044.8 3	2493.4	27563.53	
Class Changes	32.83	1494 .09	2487.9 6	663	23003.84	
Image Difference	1577.85	1370 .42	1975.9 8	23805.7 4	-22058.33	

**3.2 Change Detection Statistics**

The analysis was to ascertain the extent of change in the study domain over the study period (1970- 2020). Overall, the change detection statistics from 1970 to 2020 indicated areas, occupied by bare land had an overall area increment of 1370.42 km<sup>2</sup>; Less Dense Vegetation had an overall area increment of 23805.74 km<sup>2</sup>; built-up had an overall area increment of 1975.98 km<sup>2</sup>; Dense vegetation had an overall area decrement of 22058.33 km<sup>2</sup> whilst water bodies had an overall area increment of 1577.85 km<sup>2</sup> over the past fifty (50) years (Table 4).

**3.3 NDVI Variations over the Study Period**

The NDVI value for the 1970s ranged between 0.987 and -0.327 which connotes a healthy vegetation due to limited mining or oil exploration around that period. However, the NDVI value for the 1980s was between 0.824 and -0.476 which signifies a healthy vegetation despite the decline in comparison to the NDVI value range for the 1970s. Subsequently, the health of vegetation further decreased in 1990s with NDVI range value between 0.721 and -0.573. The NDVI range for the 2000s was between 0.605 and 0.693, showing a further decline in the health of the vegetation. NDVI range further decreased to

between 0.551 and -0.727 in 2010 as a result of extreme increase in oil spillage in the Southwestern Region of the Niger Delta. However, the NDVI ranged between 0.713 and -0.424, indicating a significant increase in the health of vegetation (Fig. 4).

### 3.4 Oil spillage point locations in Southwestern Niger Delta

Fig.5 depicts the oil spill point locations in the study area based on available data on AGIP's website. From the illustration, it could be observed that Bayelsa state explicitly has more oil spillage points, followed by River state and lastly, Delta state with very few oil-spillage points.

### 3.5 Hotspot Analysis

Fig. 6 presents results of hot and cold spot areas of oil spillage in the study area which is been presented as a raster grid output.

The diagram below shows that in 2015, the oil spill hotspot (high oil spillage magnitude) was between the South-Eastern part of Bayelsa state and the South-Western part of the River state. However, 2016 witnessed hotspot in some areas within all the three states, same applied for 2018 and 2019. In 2020 high oil spillage magnitude (hotspot) was witnessed in the Bayelsa state, with River state having few hotspots and Delta state having cold hotspot across its areas.

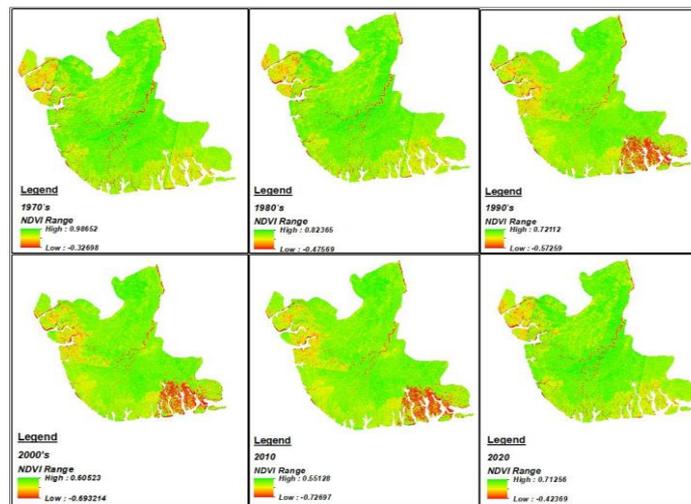


Fig. 4. Changes in NDVI over the study period in Southwestern Niger Delta

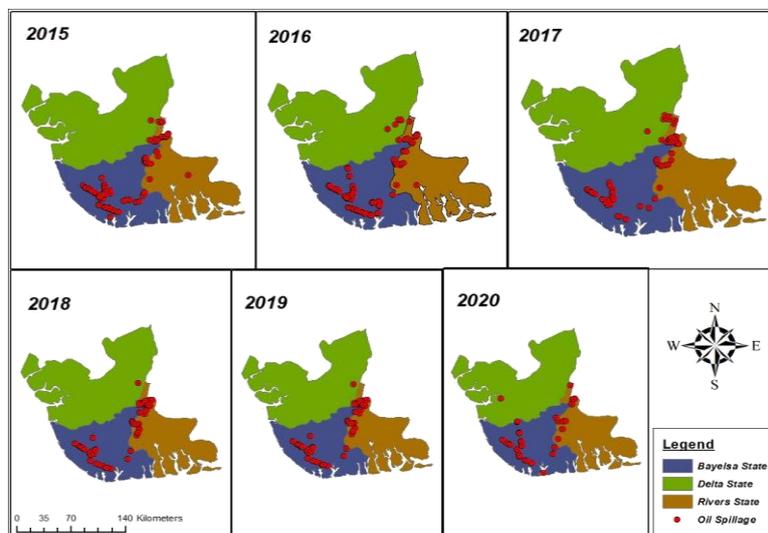
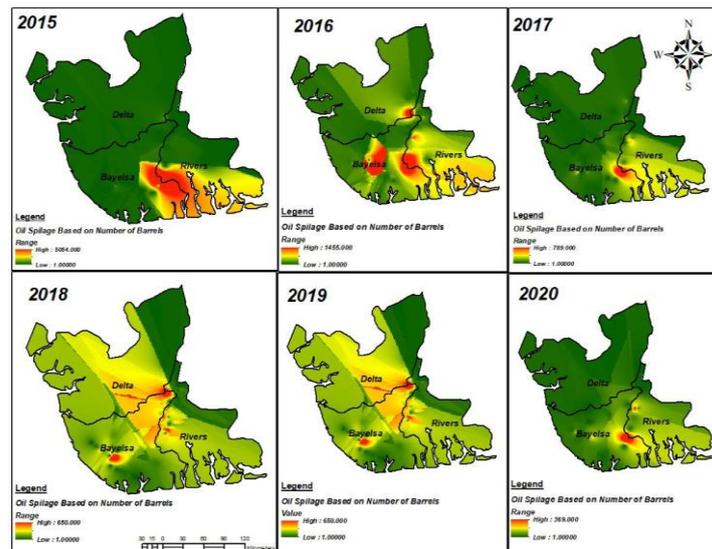


Fig. 5. Points location of oil-spillage in the study area



**Fig. 6. Hotspot and cold spot analysis of oil-spillage**

### 3.6 Spatial Autocorrelation Analysis

The result usually returns five values: the Moran's I Index, Expected Index, Variance, z-score, and p-value. The z-score or p-value indicates statistical significance when positive Moran's I index value connotes a probability toward clustering while a negative Moran's I index value represents a probability toward dispersion (ArcGIS Pro). The results produced z-scores of (0.24 (2015), 0.16(2016), 0.11(2017), -0.4(2018 and 2019) and -0.22 (2020) which are all much lesser than 1.96 for a 95% confidence interval. This means the results are statistically not significant at the 0.01 level (99% confidence interval) which reveals that there is no strong relationship (that is, they are random and not clustered or dispersed). Based on these results, null hypothesis could be rejected which states that the attribute being analyzed is randomly distributed.

## 4. DISCUSSION

### 4.1 Causes of oil-spillage in the Niger Delta region

It is worthy to note that in Nigeria, early surveys have revealed the amplification of recorded spillage incidents, leading to a destruction in the Niger Delta region where oil activities are dominant. Oil spillage have devastating impacts on the livelihoods of the locals in the study domain. There are a host of driving forces to spillage incidents in the Niger Delta. The causes of this phenomenon were grouped by [34] under

eight thematic areas. According to [34], the causes of oil spillage in the Niger Delta area are as a result of sabotage, corrosion, blow outs, accident from third party, natural causes, operations or maintenance error, malfunctioning equipment's and unknown causes. Sabotage was revealed as the dominant or major cause of oil spill highlighted by [34]. This cause of spill is often mischievously deliberate, not accidental and intentional. The next known cause after sabotage is attributed to corrosion; this outflow of oil is due to rusty equipment's. Then followed by malfunctioned equipment, operational, accident and unknown causes. Blow-out and bio-physical factors are the least causes of oil spillage in the study area.

To gain a thorough insight into oil spillage incidents in the region, we resorted to secondary data from NNPC and existing literature [29], [34] – [35] to ascertain the factors responsible. Findings proved poverty, competency, technology, policy, orientation and negligence. Previous studies [29], [34] – [35] revealed poverty as a major and an underlying driver to other drivers. This is mainly as a result of spillage incidents negatively impacting on water resources and farmlands which the local folks rely on, as their source of livelihood. When this phenomenon occurs, means of income will minimize and, in some instances, no means of income at all. Hence, people get frustrated and resort to other means for survival such as pipeline sabotage in order to extort [29], [35] and illegal trading of oil for income. After poverty, then comes policy, technology, orientation and

then negligence and competency as the least factors responsible for oil spillage in the study area.

## 4.2 Implications of the Spillage

Over the years, numerous researchers have examined the impact of oil spillage on the environment in general. The complexity of this phenomenon, reflects on its encompassing and interdisciplinary nature. Findings based on existing literature highlighted contamination of water bodies, deterioration in vegetation and land, as well as the health implications on locals and other ecosystems.

### 4.2.1 Effects on vegetation

Results revealed agricultural activities as the predominant activity in the Niger Delta region. Inhabitants, mainly farmers had constantly expressed their dissatisfaction in relation to how the activities of oil companies in the study area impacted on their farming activities/productivity as well as vegetation. [25] in their study entitled "Impacts and management of Oil Spillage along the coast of Nigeria", argued the vegetation of South Western Niger Delta constitute rainforests, extensive mangroves and swamp forests. Petroleum activities, anthropogenic and ineffective land management practices had resulted in the decline of about 5-10% of vegetation in the region. They further asserted that oil spillage that occurred close to drainage basins, caused the hydrologic force of rivers and tides to move the spilled oil into vegetated areas. This affected the healthiness of biodiversity and other ecological functions organisms in vegetation zones. It has been proven that whenever there is an oil spillage incidence in vegetative zones, specifically along the coast, mainly swampy and mangrove areas, the soils of the affected area become acidic which in turn, starves the roots from obtaining oxygen which eventually affects plant life. Also, these grounds serve as breeding or nursing grounds for some aquatic species, hence, such grounds cause extinction of such species which affects spawning or species population and stock density.

The decrease in the 1990s indicate oil exploration was on ascendancy. Recovery or significant increase in NDVI (Fig.4) over the past 3 years could be partly attributed to the influence of the pandemic (COVID-19) which halted exploration for some time, coupled with external

factors like drop in the prices/demand of crude oil on the international market as well as some Nigerian and multinational forest restoration initiatives. Decreasing rate of spillage over the past 2-3 years, along with the other factors stated above have somewhat reverted the decreasing trend of a healthy vegetation in the region.

In Southwestern Niger Delta, there is an aesthetic mangrove specie known as *Rhizophora racemose*. These unique ecological features have been adversely impacted on by spillage incidences among other agents through the introduction and colonization of non-native invasive species of palm called "*Nypa fruticans*". The implication of *Nypa fruticans* when it takes over the vegetation lies in its nature of having shallow roots. The shallow roots destabilize the banks along the waterways. Consequently, it impacts sediment distribution in the delta system which also hinders navigation. Apart from affecting flora and fauna, the loss of mangroves also affects the humans as well. It affects the inhabitants as they serve as nursing grounds as well as break against any extreme climatic event. Furthermore, the mangrove forests also provide habitats for some rare species such as pygmy hippopotamus and manatee [26]. Oil-spillage in these mangrove areas or zones poses threat to these rare species when they undergo depletion.

### 4.2.2 Effects on land and other resources

Oil-spillage on land is associated with several consequences. Limited efforts in managing incidences after spillage expose land to contamination or pollution through percolation. The contaminated lands upon exposure to other agents like fire and other chemical elements could exacerbate events, resulting to wildfires which influences vegetation, food security, water resources, soil fertility, biodiversity and livelihoods. Such incidences incur high cost for rehabilitation or afforestation as stipulated by [36]. Furthermore, oil spillage which contaminates land may percolate or seep down to affect ground water or water tables in low-lying areas. The spread of oil that seeps into land is amplified by precipitation which allows the oil to run off into nearby swamps, ponds, creeks or farms. If the spill reaches the root parts of plants, they begin to experience extrinsic cases and stress, which eventually leads to plants dying off. These may eventually affect productivity or crop yield. Pollution of ground water levels or wetlands could impact on the health of

inhabitants who uses these through bio-magnification or accumulation of heavy metals and other chemical elements, that could cause severe respiratory problems over time. Oil spillage may cause the soil to lose its fertility, which may in a long run result in the conversion of land from one class to another. For instance: conversion of a less dense vegetation to bare land and so on.

It is worthy of note that farming in the soil which is contaminated by oil spill exposes the community to dermal contact with hydrocarbons. Lastly, fire outbreaks associated with oil-spillage may leave behind thick burnt crust of substances on top of the soil. This eventually makes the affected area unsuitable for vegetational growth. Such instances as observed and reported by the [24] aligns with the findings of [37]. Smoke from such fire outbreaks could travel lengthy distances which may impact on the health of local folks (inhaled) and plants when the deposits of substances from the resultant smoke settle on some plants or the top soil.

### 4.3 Recommendations

To prevent or regulate oil-spillage incidences in the study area, the present study proffers some valuable recommendations based on study findings:

Relevant stakeholders must prioritize local agenda 21 initiative which advocates for public consultation and stakeholder involvement. Various stakeholders having inputs coupled with ironing out the competing interests of all stakeholders would minimize conflicts and set out clear zones or road map for effective and sustainable resource use.

The public and key actors within the study area must be sensitized on the health implications of oil-spillage on the lives of humans and other ecosystems. Again, oil spillage could tickle both direct and indirect effects on key sectors of growth and welfare of the people in general. Such engagements could be carried out at all stages during the formulation and implementation of policies, plans, programs and projects in the area through organized conferences, seminars, communal meetings and workshops.

Furthermore, human resource development in relation to managing oil spillage should be prioritized. It is advised that the training of

personnel should meet up contemporary standards. In addition to this, it is encouraged that the organization (Department of petroleum resources) responsible for petroleum activities should be staffed properly in order to efficiently and effectively play its role and achieve its desired objectives. Synergy between local and scientific knowledge could be merged in managing resources and oil spillage.

More so, since agriculture is the main source of livelihood as majority of inhabitants do not having other alternative livelihood sources. Hence, the traditional authorities and Nigerian government could draw up a plan with oil companies to employ and train local folks, which in effect, would foster sense of ownership and minimize or prevent cases of sabotage. In addition, locals employed in these oil companies could trickle down economic growth and development as improvement in their welfare in this scope would affect their families and other relatives.

Also, it is recommended that the Nigeria government should invest adequate resources in the rehabilitation of decayed infrastructures. Oil facilities in the oil producing states should be well maintained to avoid rusting or deterioration when over used or become obsolete. This can be achieved by implementing proactive measures of managing facilities by using contemporary technologies. There should be stringent or stern penalties for perpetrators of vandalism. The stiff penalties meted out on offenders will serve as a deterrent to prospective pipeline vandals. Finally, it is recommended that the Nigerian government should be proactive in controlling oil spillage that has bedevilled the oil producing region. This can be achieved by putting forth policies and regulations. Political and public support is required in order to effectively control the rate of oil spillage in the region.

### 5. CONCLUSION

The present study assessed the impact of oil-spillage on vegetation and how to sustainably manage it. Findings depict a drastic change in the LULC of Southwestern Niger Delta, Nigeria. Image classifications illustrated prior to the exploration of oil in the study area, vegetation coverage was high with a representation of 30, 563.53km<sup>2</sup>. Subsequent periods revealed increased in socio-economic activities drove significantly impacted on vegetation coverage in the area. Change detection analysis over the study period revealed built-up areas, bare land,

and less dense vegetation had an overall increment of 1975.98km<sup>2</sup>, 1370km<sup>2</sup> and 23805km<sup>2</sup>, respectively. Besides, dense vegetation had an overall decrement of 22058.33km<sup>2</sup> whereas water bodies coverage increased by 1577.85km<sup>2</sup> during the last fifty years. Study findings depicted a dynamic ebb in NDVI from a range of 0.987/-0.33 in the 1970s to a range of 0.55/-0.73 in 2020. This could be attributed to oil-spillage along with other socio-economic activities in the study area.

Results revealed the main driving factor of oil spillage in the region could be attributed to vandalization of oil pipelines during conflicts between inhabitants and oil companies, sabotage and illegal means of creating leakages to store crude oil for sale. Agricultural activities remain the main source of livelihood for the local folks, hence, most inhabitants believe their livelihoods are threatened by the activities of the oil companies. This eventually make inhabitants resort to deeds that would create loss of production and revenue for the oil industries. These factors in turn results in unintended consequences which adversely impacts on the vegetation, livelihoods and other ecosystem functions and end points in the area. To achieve sustainability in oil spill management in the Delta, the study recommends for further research to ascertain cost of losses incurred apply geospatial techniques to monitor and predict environmental changes that inform decisions of key actors. Application of GIS and remote sensing tools present an appropriate platform to enhance the understanding complex environmental issues. Contextually, using satellite imagery among other quantitative tools to monitor changes in the environment as presented in this study informs the decisions of policy-makers and aligns with our quest to achieve Millennium Sustainable Development Goals that seeks to alleviate poverty, protect and sustain the natural environment.

## DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Seitinger P, Baumgarbner A, Schindlbauer H. The behaviour of oil spills in soils and groundwater. *National Resources and Development*. 1994;40:69-84.
2. Osuji LC, Onojake CM. Trace Metals Associated with Crude Oil: A case study of Ebocha-8 Oil Polluted Site in Niger Delta, Nigeria. *Chemistry and Biodiversity*. 2004;1708-1715. DOI:10.1002/cbdv.200490129
3. Ukhurebor KE, Athar H, Adetunji CO, Aigbe UO, Onyancha RB, Abifarin O. Environmental implications of petroleum spillages in the Niger Delta region of Nigeria: A review. *Journal of Environmental Management*. 2021;293:112-872. DOI: 10.1016/j.jenvman.2021.112872
4. Adebayo M. Oil Spills and Their Impact on the Niger Delta. Bachelor of Engineering Thesis. Helsinki Metropolia University of Applied Sciences; 2018. Available: <http://urn.fi/URN:NBN:fi:amk-201903143109>
5. Taheri R. Oil slicks and coastal zones post-Gulf War: a 20-years assessment, employing high-resolution satellite imagery, *International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production*. Society of Petroleum Engineers; 2012. Available:<https://doi.org/10.2118/156053-MS>
6. Fisher JB, Sublette KL. Environmental releases from exploration and production operations in Oklahoma: Type, volume, causes and prevention. *Environmental Geosciences*. 2005;12(2):89-99. DOI: 10.1306/eg.11160404039
7. Opukri CO, Ibaba IS. Oil induced environmental degradation and internal population displacement in the Nigeria's Niger Delta. *J. Sustain. Dev. Africa*. 2008;10:173-193.
8. Joel OF, Amajuoyi CA. Determination of Selected Physicochemical Parameters and Heavy Metals in a Drilling Cutting Dump Site at Ezeogwu-Owaza, Nigeria. *Journal of Applied Sciences & Environmental Management*. 2009;13(2):27-31.

- DOI: 10.4314/jasem.v13i2.55297
9. Mendelssohn IA, Andersen GL, Baltz DM, Caffey RH, Carman KR, Fleeger JW, Overton EB. Oil impacts on coastal wetlands: implications for the Mississippi River Delta ecosystem after the Deepwater Horizon oil spill. *Bio Science*. 2012;62(6):562–574. Available: <http://dx.doi.org/10.1525/bio.2012.62.6.7>
  10. Obida CB, Blackburn GA, Whyatt JD, Semple KT. Counting the cost of the Niger Delta's largest oil spills: Satellite remote sensing reveals extensive environmental damage with >1million people in the impact zone. *Science of the Total Environment*. 2021;775:145-854. Available: <https://doi.org/10.1016/j.scitotenv.2021.145854>
  11. Khanna S, Santos MJ, Ustin SL, Koltunov A, Kokaly RF, Roberts DA. Detection of salt marsh vegetation stress and recovery after the Deepwater Horizon Oil Spill in Barataria Bay, Gulf of Mexico using AVIRIS data. *PLoS One*. 2013;8(11): e78989. DOI: 10.1371/journal.pone.0078989
  12. Gundlach ER, Hayes MO. Vulnerability of Coastal Environments to Oil Spill Impacts. *Marine Technology Society Journal*. 1978;12:18-27.
  13. Jackson SE, Randall S, Schuler, Kaifeng J. An Aspirational Framework for Strategic Human Resource Management, *The Academy of Management Annals*. 2014;8(1):1-56. DOI: 10.1080/19416520.2014.872335
  14. Pezeshki S, Hester M, Lin Q, Nyman J. The effects of oil spill and clean-up on dominant US Gulf coast marsh macrophytes: a review. *Environ Pollut*;108 (2):129–139. DOI: 10.1016/s0269-7491(99)00244-4
  15. Hester MW, Mendelssohn IA. Long-term recovery of a Louisiana brackish marsh plant community from oil spill impact: Vegetation response and mitigating effects of marsh surface elevation. *Marine Environmental Research*. 2000;49: 233–254. DOI: 10.1016/s0141-1136(99)00071-9
  16. Ivanov AY, Zatyagalova VV. A GIS approach to mapping oil spills in a marine environment. *International Journal of Remote Sensing*. 2008;29(21):6297-6313. DOI:10.1080/01431160802175587
  17. Aukett L. The Use of Geographical Information System (GIS) in Oil Spill Preparedness and Response. *International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production*, Perth, Australia. 2012;11-13. Available: <https://doi.org/10.2118/157384-MS>
  18. Nwankwoala HO, Nwaogu C. Utilizing the tool of GIS in oil spill management: a case-study of Etche LGA, Rivers State, Nigeria. *Global Journal of Environmental Sciences*. 2009;8(1). DOI: 10.4314/gjes.v8i1.50820
  19. Lu Y, Tian Q, Li X. The remote sensing inversion theory of offshore oil slick thickness based on a two-beam interference model, *Sci. China Earth Sciences*. 2011;54:678-685. Available: <https://doi.org/10.1007/s11430-010-4154-1>
  20. Jha MN, Levy J, Gao Y. Advances in remote sensing for oil spill disaster management: state of the art sensors technology for oil spill surveillance. *Sensors*. 2008;8(1):236-255. DOI:10.3390/S8010236
  21. Fingas M, Brown C. Review of Oil Spill Remote Sensing. *Marine Pollution Bulletin*. 2014;83(1):9-23. Available: <https://doi.org/10.1016/j.marpolbul.2014.03.059>
  22. Fustes D, Cantorna D, Dafonte C, Arcay B, Iglesias A, Manteiga M. A cloud-integrated web platform from marine monitoring using GIS and remote sensing: Application to oil spill detection through SAR images. *Future Generation Computer Systems*. 2014;34:155-160. DOI:10.1007/978-3-642-35377-2\_62
  23. Uchebulam O, Ayolabi EA. Satellite image analysis using remote sensing data in parts of Western Niger Delta, Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences*. 2013;4(4):612-617.
  24. NNPC. 2013 Annual Statistical Bulletin Nigerian National Petroleum. NNPC; 2014. Available: <https://www.nnpcgroup.com/Public-Relations/Oil-and-Gas-Statistics/Pages/Annual-Statistics-Bulletin.aspx>
  25. Nwilo P, Badejo O. Oil Spill problems and management in the Niger Delta. *International Oil Spill Conference*; 2006. Available: <https://cpb-us-w2.wpmucdn.com>

26. Ajide OM, Isaac OO. 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 & Social Sciences*. 2013;12(2).
27. Afintotan LA, Ojatorotu V. The Niger Delta Crisis: Issues, Challenges and Prospects. *African Journal of Political Science and International Relations*. 2009;3(5):191-198.
28. Awosika LF. Impacts of Global Climate and Sea Level Rise on Coastal Resources and Energy Development in Nigeria. (ed. J.C Umolu) *Global Climate Change: Impact on Energy Development DAM TECH Nigeria Limited, Nigeria*; 1995.
29. Amnesty-International. Nigeria: Hundreds of oil spills continue to blight Niger Delta. Amnesty International; 2015. Available:<https://www.amnesty.org/en/latest/news/2015/03/hundreds-of-oil-spills-continue-to-blight-niger-delta/>.
30. Zaituna A, Samsuri AG, Ahmad, Safitri RA. Normalized difference vegetation index (NDVI) analysis for land cover types using Landsat 8 OLI in Besitang watershed, Indonesia. *Iop Conf. Ser.: Earth Environ.Sci*. 2018;126:012-112. DOI: 10.1088/1755-1315/126/1/012112
31. Sarfo I, Bi S, Beibei L, Amankwah OYS, Yeboah E, Koku JE, Kwang C. Spatiotemporal development of land use systems, influences and climate variability in Southwestern Ghana (1970-2020). *Environ Dev Sustain* (2021); 2021. DOI: 10.1007/s10668-021-01848-5
32. Mitchell A. *The ESRI Guide to GIS Analysis* (2), ESRI Press; 2005.
33. Griffith D. *Spatial Autocorrelation: A Primer*. Resource Publications in Geography Association American Geographers; 1987.
34. Egbe RE, Thompson D. Environmental challenges of oil spillage for families in oil producing communities of the Niger Delta region. *JHER* 2010;13:24-34.
35. Mba IC, Mba, EI, Ogbuabor JE. and Arazu, W. O. Causes and Terrain of Oil Spillage in Niger Delta Region of Nigeria: The Analysis of Variance Approach. *International Journal of Energy Economics and Policy*. 2019;9(2):283-287. Available: <https://doi.org/10.32479/ijeep.7332>
36. UNEP. Environmental Assessment of Ogoniland. United Nations Environmental Program. Job No.: DEP/1337/GE; 2011. Available: [www.unep.org/nigeria](http://www.unep.org/nigeria).
37. Akpomuvie O. Tragedy of Commons: Analysis of Oil Spillage, Gas Flaring and Sustainable Development of the Niger Delta of Nigeria. *Journal of Sustainable Development*. 2011;4(2):200. DOI:10.5539/jsd.v4n2p200

© 2021 Adamu et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*

*The peer review history for this paper can be accessed here:*  
<https://www.sdiarticle4.com/review-history/74292>