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Research Article

Resultant Land Use and Land Cover Change from Oil Spillage using Remote Sensing and GIS

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Abstract: The spill of oil into the environment threatens the existence of vegetation. This study identified the coastal area of Lagos impacted by oil spill, explosion and fire; using Landsat ETM+2005 and Ikonos 2007 and evaluated the effect. Subsequently, geo-spatial database was created for monitoring of oil pipelines Right of Way (ROW) in the area. The biggest land use land cover changes were the high forest and the light forest classes of mangrove vegetation by 22.2 and 15.5% respectively. The control quadrat sampled had the highest species diversity index of 0.6758 compared to the others. The study concluded that oil spill had affected the land use land cover as well as provided oil spill emergency response centres sites as a Spatial Decision Support System (SDSS) for oil pipeline management.

Keywords: Oil pipeline, proximity, settlement, vegetation, quadrant

INTRODUCTION

Oil spills can happen on land or water when oil is incorrectly handled and the toxic substances from oil spills can remain in the land and water for years (Burger, 1997). Oil spill can affect vegetation, water and fish and the impacts of even small spills can send ripples into surrounding ecosystems and affect communities beyond the immediate spill area (Hess and Kerr, 1979). Mangrove is the common vegetation type of the Nigerian coast. Nigeria has the largest mangrove forest in Africa. It covers an area of about 9,723 km² forming a vegetative band of 15-45 km wide above the barrier islands and running parallel to the coastline. About 305 km² of the mangrove forest are in reserves. Lagos state has an area of mangrove 42.20 Km² and mangrove in forest reserve of 3.13 Km² (NEST, 1991). The Nigerian mangrove resource is dominated by the red mangroves (*Rhizophoraceae*), covering over 90% of the area and can grow to a height of 45 m under favourable conditions in association with white mangroves (*Avicenneaceae*) (Keay, 1949). The death of a large portion of a mangrove system from oil spill can threaten the organisms which depend upon it for survival (Briggs *et al*., 1996). The objective therefore is to identify the land use land cover and the changes that have taken place as a result of oil spill; and to provide a geo-spatial database for oil Pipeline management.

Study area: The study area (Fig. 1) is in Lagos and it falls within the coastal areas along the shore of the Atlantic in the Gulf of Guinea, west of the Niger River delta. The land use land cover types identified in this area consist of water bodies, bare ground and mangrove vegetation. These land use are scattered over the coastal settlement. Lagos is an environment characterized by a tropical savanna climate with the rainy season from April to November and the dry season from December to March. Monthly rainfall between May and July averages over 400 mm, while in August and September it is down to 200 mm and in December as low as 25 mm. The main dry season is accompanied by harmattan winds from the Sahara Desert, which between December and early February can be quite strong. The average temperature in January is 27°C and for July it is 25°C. On average the hottest month is March; with a mean temperature of 29°C; while July is the coolest month (British Broadcasting Corporation, 2010).

METHODOLOGY

Remote Sensing (RS) and Geographical Information System (GIS) techniques provide the only reasonable means for timely and accurate data for vegetation mapping over large geographical areas (Salami, 1999). This technique was used to assess and analyze the changes in the land cover characteristics as well as develop a geo-spatial database for monitoring of oil pipelines right of way in the study area.

Sampling design, collection and field observations: Landsat ETM+2005 and Ikonos 2007 images acquired.

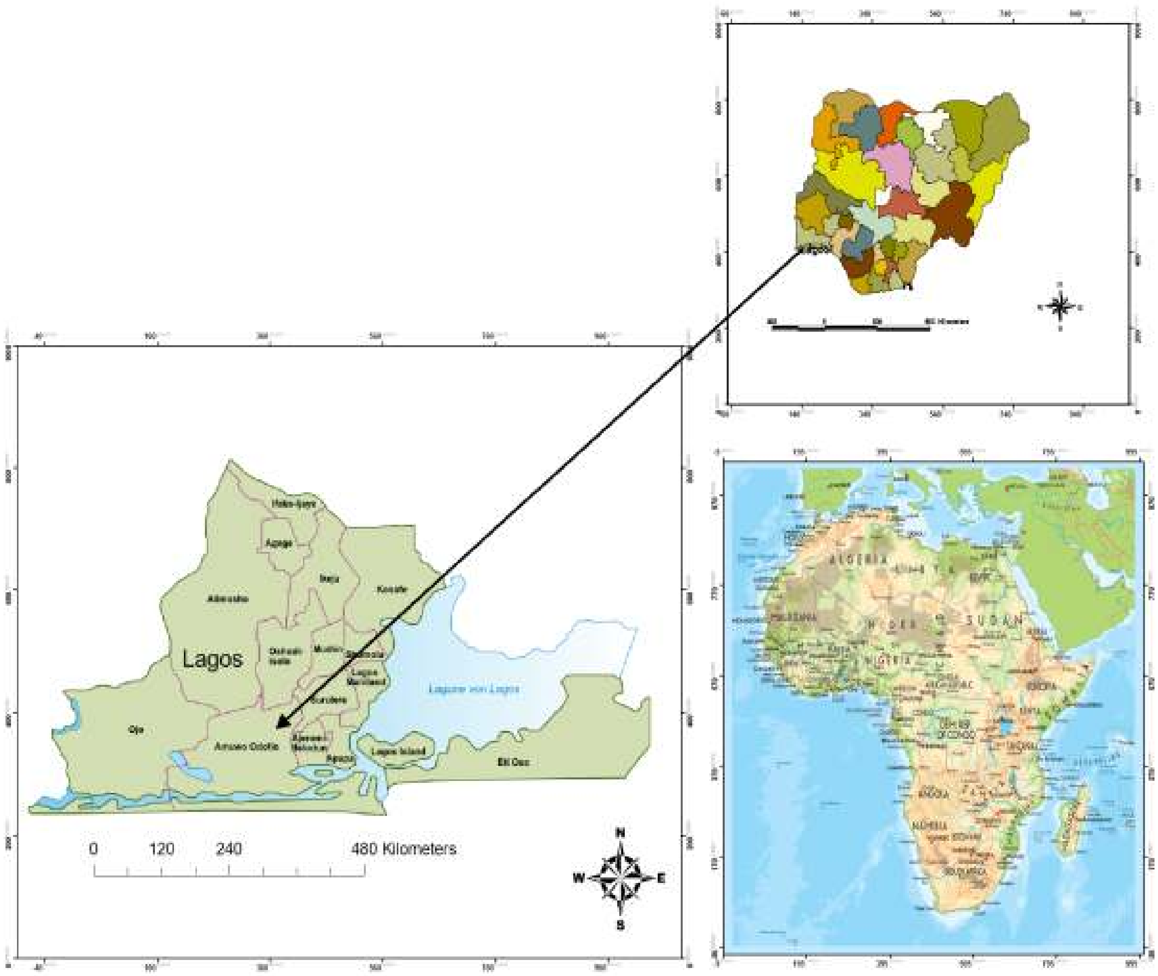


Fig. 1: The study area

where subjected to post-processing in ERDAS IMAGINE 9.2 image processing software. Ikonos image (2007) used for this study was rectified by the selection of distinguishable Ground Control Points (GCP's) in the image, such as road intersections, in order for it to be used in conjunction with other data sets. Training samples were obtained using a combination of field observation and visual interpretation. Image signature editor was used to facilitate the delineation of training samples and the extraction of imagine signatures. These points were then assigned the appropriate reference information of latitude/longitude coordinates obtained from the ortho-photo map, Landsat ETM+ (2005) and from fieldwork utilizing Global Positioning Systems (GPS). After a certain number of GPS's were entered and referenced, the computer program resamples the original pixels into the desired projection of UTM, Zone 31 North (0E-6E) and Datum WGS 84. Subset of the area of interest was extracted from the images before they were then classified using the supervised classification technique of maximum likelihood algorithm. This algorithm assumes that the histograms of the bands of data have normal distributions and the probability that a pixel belongs to a particular landcover/landuse class. The parametric method was used as a decision rule where it operates in a continuous decisions space which allows the entire pixel on an image to be identified. This is because of a prior knowledge that the probabilities are not equal for all classes and that weight factors can be specified for particular classes. The basic equation assumes that these probabilities are equal for all classes and that the input bands have normal distributions.

The equation for the maximum likelihood/Bayesian classifier is as follows (ERDAS, 2006):

$$D = \ln (ac) - [0.5 \ln (|Covc|)] - [0.5 (X\text{-}Mc)\ T\ (Covc\text{-}1)\ (X\text{-}Mc)]$$

where,

D = Weighted distance (likelihood)

c = A particular class

X	=	The measurement vector of the candidate pixel
Mc	=	The mean vector of the sample of class c
ac	=	Percent probability that any candidate pixel is a member of class c (defaults to 1.0, or is entered from a priori knowledge)
Covc	=	The covariance matrix of the pixels in the sample of class c
|*Covc*|	=	Determinant of Covc (matrix algebra)
Covc-1	=	Inverse of Covc (matrix algebra)
ln	=	Natural logarithm function
T	=	Transposition function (matrix algebra)

The inverse and determinant of a matrix, along with the difference and transposition of vectors, would be explained in a textbook of matrix algebra. The pixel is assigned to the class, c, for which D is the lowest.

Based on the prior knowledge and a brief reconnaissance survey of the study area with additional information from previous research area, a classification scheme was developed for the study area after Anderson *et al.* (1976). This classification scheme is a modification of Anderson *et al*. (1976). These are:

- High forests includes secondary re-growth and tree crops
- Light forests includes farmlands and agro-forestry
- Built-up areas class involves bare ground and utilities
- Water bodies

The comparison of the land use land cover statistics assisted in identifying the percentage change and rate of change between 2005 and 2007. This was achieved by developing a table that shows the area in hectares change for 2005 and 2007 measured against each land use land cover type (Table 1). Percentage change to determine the trend of change was calculated by:

$$P = \{(A-B)/B\}*100$$

where,

P	:	Percentage change of land use/land cover for a particular purpose within a specified time interval
A	:	Area under that particular purpose of land use/land covers after the time interval
B	:	Area under that particular purpose of land use/land covers before the time interval

In addition, field survey was carried out to measure the species density of some woody vegetation species within ten quadrants measuring 10m x 10m were selected, of which a quadrat, 2 km away from and perpendicular to the pipeline was established in control area where oil spill did not occur (Williams and Lambert, 1959).

Also, a geo-spatial database was created for the study area using information such as settlements, vegetation and oil pipeline acquired from the satellite images of the study area. This was done to facilitate location information, integration, mapping and further analysis within the study area. This environmental application used geographical locations to explore the relationship factor that may influence the location of coastal communities and oil spill from oil pipeline vandalization. Buffering operation of 50 m and 500 m was performed to spatially analyse the land use land cover within its proximity. Buffer operation is a spatial analysis tool that creates a new polygon data set, where a specified distance is drawn around specific features within a layer. It is used to determine if the coastal settlements at their present location are in the best proximity to the oil pipeline. ArcView 3.2 and ArcGIS 9.2 software were used to perform these procedures including generating the outputs (maps).

RESULTS AND DISCUSSION

Digital image processing and analysis: The vegetation cover change between 2005 and 2007 is shown in Fig. 2a, b and Table 1.

The biggest decline was the high forest (deep green colour) and light forest (light green colour) of mangrove vegetation by 22.2% and 15.5% respectively from 2005 to 2007. By 2007, the built up area had increase by a rate of 5.7% and the water body by 0.03%. Vegetation had undergone some formed of changes between 2005 and 2007. Vegetation land cover was high in 2005 but has been replaced by light forest by 2007 at the locations under study.

Field observations and interaction with the locals revealed that these changes in the land use land cover could be as a result of the oil spill and explosion that had occurred in the study area and had decimated the mangrove vegetation (Fig. 3, 4 and 5). The study also revealed that the proximity of the mangrove vegetation to oil spill increased the rate at which the vegetation decayed and dies. Oil bunkering seems to be a form business venture carried out in the study area. It seems

Table 1: Land use land covers distribution from supervised classification

Land cover classes	2005Area (Ha)	2007Area (%)	Area (Ha)	Area (%)	Rate of Change (%)
High forest	1052.440	7.819	818.420	6.080	-22.2359
Light forest	1427.610	10.607	1206.680	8.965	-15.4755
Built-up area	7600.150	56.467	8045.680	59.780	5.862121
Water body	3379.290	25.107	3388.710	25.177	0.278757
Total	13459.490	100	13459.490	100	

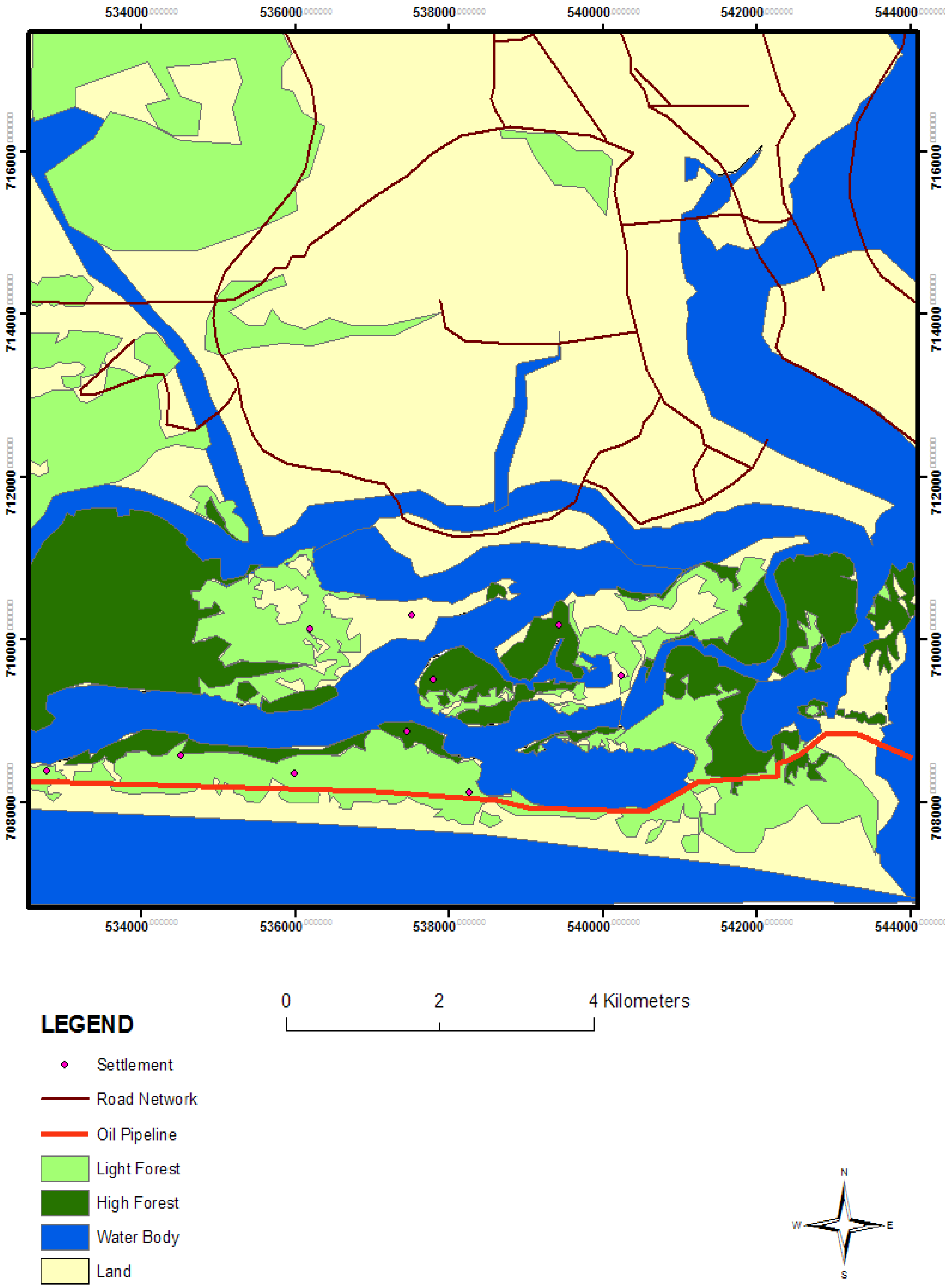


Fig. 2a: Vegetation map of the study area in 2005

that jerry-cans with names written on them were discovered in hide-outs during the clean-up exercise, where stolen oil was stored for onward transportation and distribution (Fig. 5). This agrees with Egberongbe *et al*. (2006) that thousands of barrels of oil have been spilt into the environment through our oil. Imevbore and Odu (1985), Fagbemi *et al*., (1988) and Fakpor *et al*. (2006) have shown that oil pollution can lead to the death of mangrove plant.

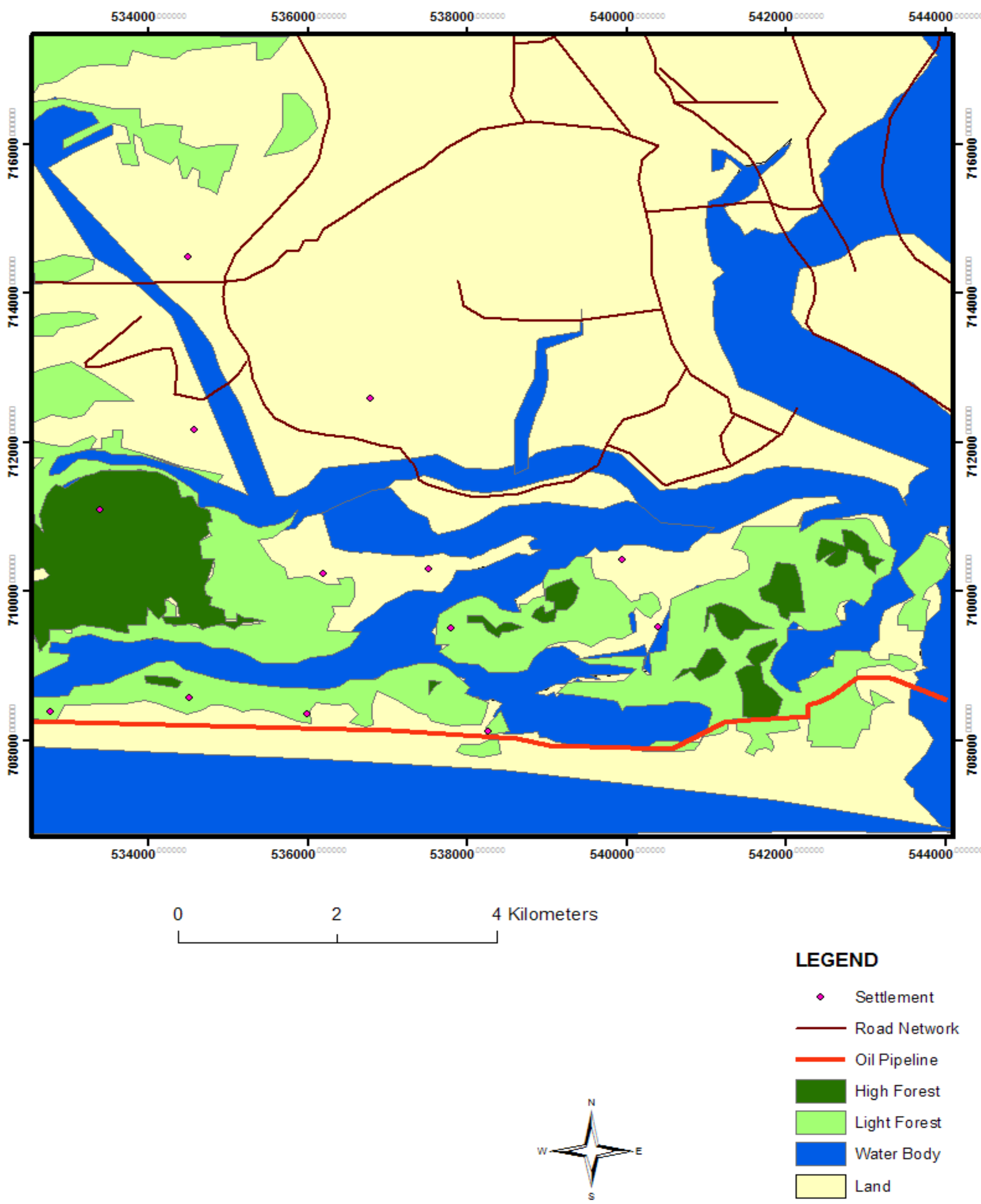


Fig. 2b: Vegetation map of the study area in 2007

Fig. 3: Portion of the mangrove vegetation not affected by the oil spill

Therefore, the increase in the built up area may be as a result of an increase in the bare surfaces due to vegetation loss. This is evident in the fast decay and dying of the mangrove vegetation in the areas impacted by oil spill. Similarly, Ewa-Oboho (1988, 1994) and Levell (1975) noted that impacted vegetation usually respond to oiling stress, the extent of which depends on the severity of the oiling.

Species diversity index: The species diversity index was calculated using Shannon-Weiner's index for each

Fig. 4: Withering of the affected mangrove vegetation decay seems to start from the top of the trees further inland and from the base of trees on water banks

(a) (b)

(c) (d)

(e)

Fig. 5: (a, b) polluted environment from oil spill explosion, (c), tools used by vandals, (d) vandalized pipeline, (e) jerry cans used to siphon oil

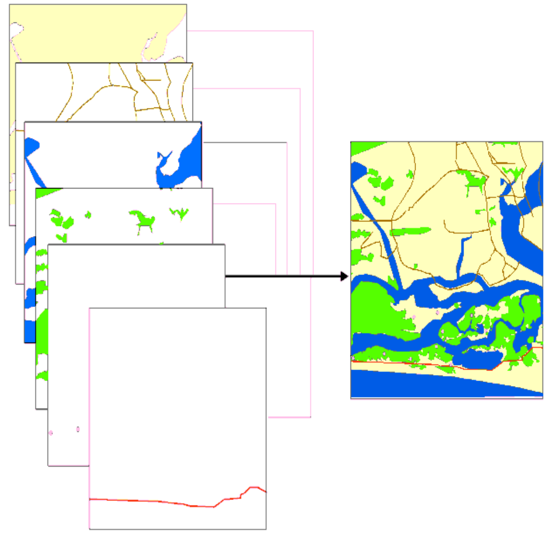


Fig. 6: Ploygonize image of the study area

of the quadrat. Comparing the entire nine quadrats with the control, it is seen that the control quadrat has a highest diversity of 0.6758 (Table 2). It means the control quadrat is richer (number of species present) and more even (abundance of each species) and more diverse than the entire nine quadrats.

Shannon-Weiner's index of species diversity used to calculate the diversity of some woody vegetation species revealed that the nine quadrats were not significantly different from one another which is an indication that all the quadrats are impacted by oil pollution to a similar extent. This is also an indication that the original vegetation has been degraded. This have far reaching negative consequences on the floristic composition as well as in the immediate environment. These are in agreement with the findings of Adesina (1989), Salami (1995) and Ekanade *et al*. (1996).

Spatial analysis: Figure 6 shows the database created used for the spatial analysis.

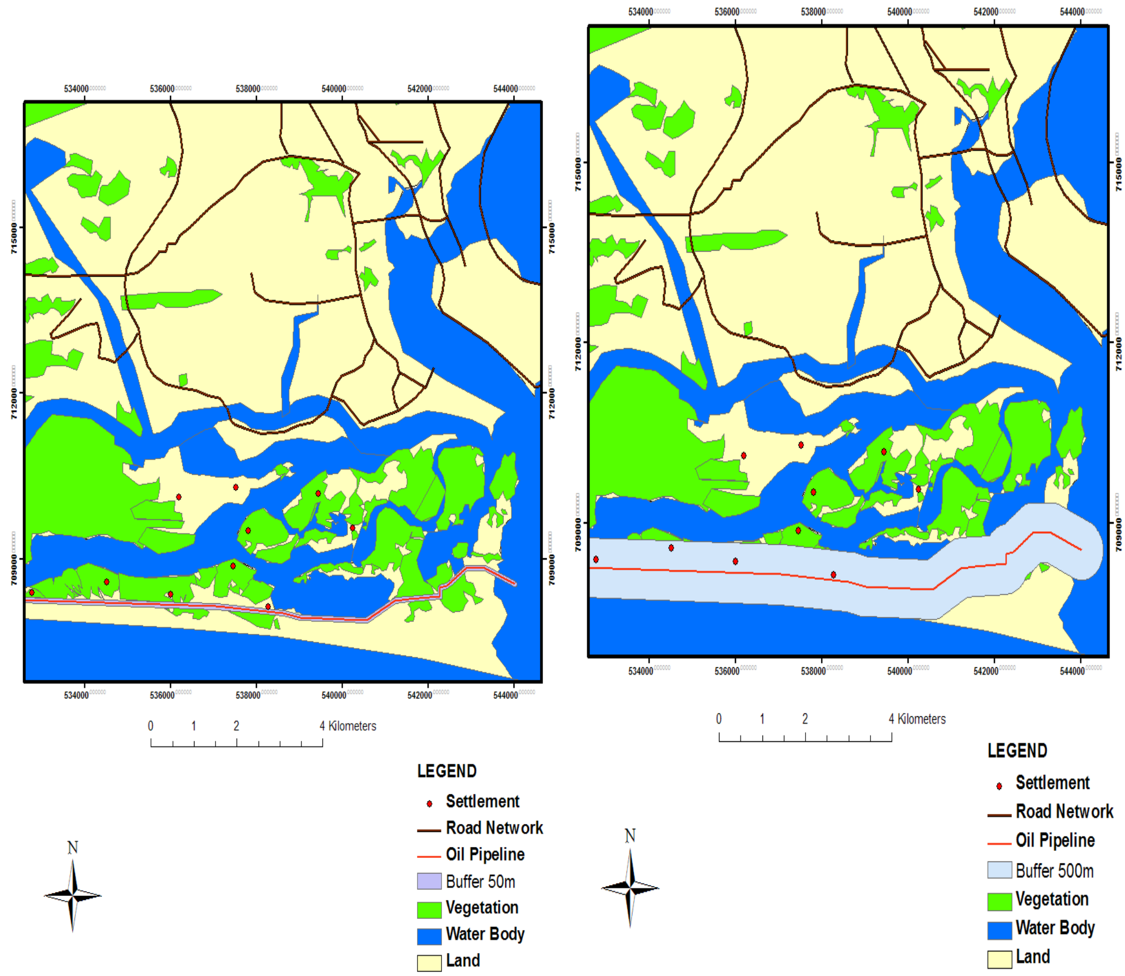
The spatial analysis used to identify the land cover features within the Oil Pipeline Corridor by 'buffering' operation revealed the proximity of coastal settlements to the vandalized oil pipeline. At 50 m, it was observed that Inuegbe settlement was the closest community to the pipeline while three additional communities (Okun Glass, Akaraba and Sanke) are enclosed within 500 m. The field study confirmed that these settlements were the most impacted with oil spill. Inuegbe settlement was the closest to the pipeline corridor (Fig. 7a) and was the most impacted than settlements further away (Fig. 7b). From field observations, these settlements, the mangrove vegetation as well as the water body were polluted from the oil spill that had occurred in the area and had led to a drastic decline in the agricultural and fishing activities of the settlers.

Table 2: Species diversity index

Quadrat	Name of species	Total	Pi	Log (Pi)	-Pi Log (Pi)	
1	Mangifera indica	3	0.1304	-0.8847	-0.1153	
	Cocos nucifera	5	0.2173	-0.6629	-0.1440	
	Rhizophora mangle	15	0.6521	-0.1856	-0.1210	
	Sum					-0.3803
	Hs					0.3803
2	Mangifera indica	2	0.25	-0.6020	0.1505	
	Ananas comosus	2	0.25	-0.6020	0.1505	
	Cocos nucifera	4	0.5	-0.3010	-0.1505	
	Sum					-0.4515
	Hs					0.4515
3	Rhizophora mangle	7	0.35	-0.4559	-0.1595	
	Mangifera indica	4	0.2	-0.6989	-0.1397	
	Phoenix spp	6	0.3	-0.5228	-0.1568	
	Ananas comosus	3	0.15	-0.8239	-0.1235	
	Sum					-0.5795
	Hs					0.5795
4.	Rhizophora mangle	6	0.3333	-0.4777	-0.1590	
	Phoenix spp	5	0.2777	-0.5564	-0.1545	
	Mangifera indica	2	0.1111	-0.9542	-0.1060	
	Sum					-0.4195
	Hs					0.4195
5	Phoenix spp	6	0.6666	-0.1761	-0.1173	
	Cocos nucifera	3	0.3333	-0.4771	0.1570	
	Sum					-0.2743
	Hs					0.2743
6	Ananas comosus	3	0.25	-0.6020	-0.1505	
	Mangifera indica	3	0.25	-0.6020	-0.1505	
	Phoenix spp	6	0.5	-0.3010	-0.1505	
	Sum					-0.4515
	Hs					0.4515
7.	Rhizophora mangle	9	-0.4090	-0.3882	-0.1587	
	Cocos nucifera	10	-0.4545	-0.3424	-0.1556	
	Phoenix spp	3	-0.1364	-0.8651	-0.1179	
	Sum					-0.4322
	Hs					0.4322
8	Mangifera indica	3	0.1304	-0.8847	-0.1153	
	Cocos nucifera	5	0.2173	-0.6629	-0.1440	
	Rhizophora mangle	15	0.6521	-0.1856	-0.1210	
	Sum					-0.3803
	Hs					0.3803
9.	Phoenix spp	4	1	0	0	
	Total	134				
	Mean	14.89				
	Steam	1488.9				
Control quadrat						
	Mangifera indica	15	0.1079	-0.9669	-0.1043	
	Ananas comosus	20	0.1438	-0.8422	-0.1211	
	Cocos nucifera	35	0.2517	-0.5991	-0.1507	
	Phoenix spp	37	0.2662	-0.5747	-0.1529	
	R. mangle	32	0.2302	-0.6378	0.1468	
	Sum					-0.6758
	Hs					0.6758
	Total	139				

With the database, the proximity of settlements to the pipeline was used to suggest and locate six oil spill response centre (Fig. 8) 20 m away from the settlements and 50 m away from the oil pipeline. Three of these centers are suggested within the most vulnerable settlement, Inuegbe while the other three centres are suggested and located in the other settlements that are also along the pipeline Right of Way (ROW).

RS and GIS was used to create a geo-spatial database which involved information on the location of the oil pipeline, existing settlement and their proximity to the pipeline as well as the vegetation type and other land cover types was used to identify oil spill response centers. This agrees with Smith and Loza (1994), who stated that the creation of regional spill response centres along coastlines, will help in managing oil spill



(a) (b)

Fig. 7: (a) 50 m, (b) 500 m buffer around the pipeline

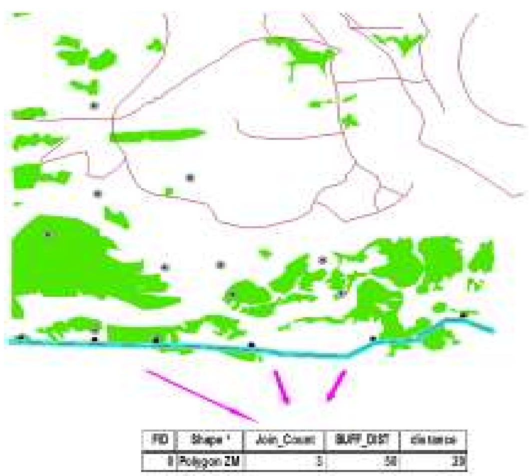


Fig. 8: Six sites along the pipeline for locating oil spill response centre

problems. WWF (2007) observed that the quick mobilization and deployment of response equipment and trained personnel is important to the overall response to oil spill. This is because oil when spilled and begin to spread, evaporate and emulsify and as time passes, generally becomes more difficult to track, contain and recover or treat spilled oil.

CONCLUSION

It can be concluded that the findings from this study revealed that the initial land use and land cover of the coastal communities has been changed by human activities through the oil spill that had occurred and polluted the vegetated land cover. The spatial analysis revealed that some settlements were situated in close proximity to the pipeline thereby exposing it to human encroachment which poses great danger to the environment. Hence, this study has chosen to demonstrate the use of a geospatial technology to provide a decision support system for oil pipeline management. It has also shown that remote sensing as well as field study is useful in assessing the effect of oil spill from oil pipeline vandalization on land use land cover in coastal settlements.

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