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UTILIZING THE TOOL OF GIS IN OIL SPILL MANAGEMENT - A CASE STUDY OF ETCHE LGA, RIVERS STATE, NIGERIA

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ABSTRACT

This study is concerned with creating an environmental resource database for Etche Local Government Area in the Niger Delta Region of Nigeria. The study reveals the techniques that could be employed in oil spill management. The study was aimed at identifying the different activities and socio-economic component (infrastructures) that can cause oil spill in the study area and attempt at inventorying landuse/landcover that are likely to be affected by any oil spill in the area and build a viable database for oil spill management in the area. Data were collected and imported into GIS environment for analysis using ArcInfo 3.5.1 and ArcView 3.5. Results indicate that about 47.21%, almost half of the study area is cultivated. However, three (3) different buffer zones were created. The waterbodies in the area were identified as the major oil spill distributor. Out of total area of 391.2 km^2 covered by the buffer region, cultivated land occupies the highest areal extent of 35.59%, while rubber plantation has the least areal extent of about 0.64%. This confirms that cultivated land is more affected than any other landuse/landcover class in case of any spill in the area. Moreover, the study ranks waterbody as the most highly sensitive landuse/landcover category with ESI-I, with heavy mangrove forest followed by ESI-2 and ESI-3, respectively. The study has therefore demonstrated the effectiveness of GIS in the creation of a spatial database for monitoring and modeling oil spill in the area. The study also recommends that consistent ESI maps of the area should be prepared, and that such information should be made available when the need arises.

KEYWORDS*:* Geographic Information Systems, oil spill monitoring, oil spill management, environmental sensitivity index, contingency planning.

INTRODUCTION

Nigeria is one the most prolific oil producing countries in the world and the commodity serves as the main source of foreign exchange to the country. It has continued to be a major source of livelihood to a large percentage of the country's work force.

The activities in the oil and gas industry include exploration, refining, distribution, marketing and shipping of the products. There is no gainsaying the fact that oil production and distribution activities are largely responsible for environmental degradation in the oil producing areas of Nigeria.

According to Aina (1996) all the activities of the petroleum industry, be it exploration, exploitation, production, terminal operation, and marketing have the potential of polluting the immediate environment. Environmental Impact Assessment (EIA), Environmental Evaluation Report (EER), Environmental Index (ESI) mapping and the Oil Spill Contingency Plan (OSCP) are some of the techniques used in studying the extent of pollution in Nigeria.

The aim of this study therefore, is to demonstrate the capability of the Geographic Information System (GIS) technology in oil spill management, using Etche L.G.A. in Rivers State, as a case study. GIS is a relatively new technology that is

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viable and quite suitable for detecting, manipulating, analyzing, assessing predicting and managing oil spillage.

Study Area

Etche L.G.A. is located at the North-Eastern part of Rivers State, Nigeria. It lies within latitude $4^0$45'N – $5^0$17'N and longitude $6^0$55'E – $7^0$17'E (Figure 1). The study area covers about 641.28km^2 with some communities including Okehi, Ulakwo, Obite, Obibi, Igbo, Odagwa, Umuechem, Ndashi, Igbodo, Ozuzu, Mba and Afara. It is bounded in the north by Imo State, east-wards by the Imo river, then Omuma L.G.A. while, Obio-Akpor and Oyigbo in the south. Ikwerre L.G.A. is found at the west ward.

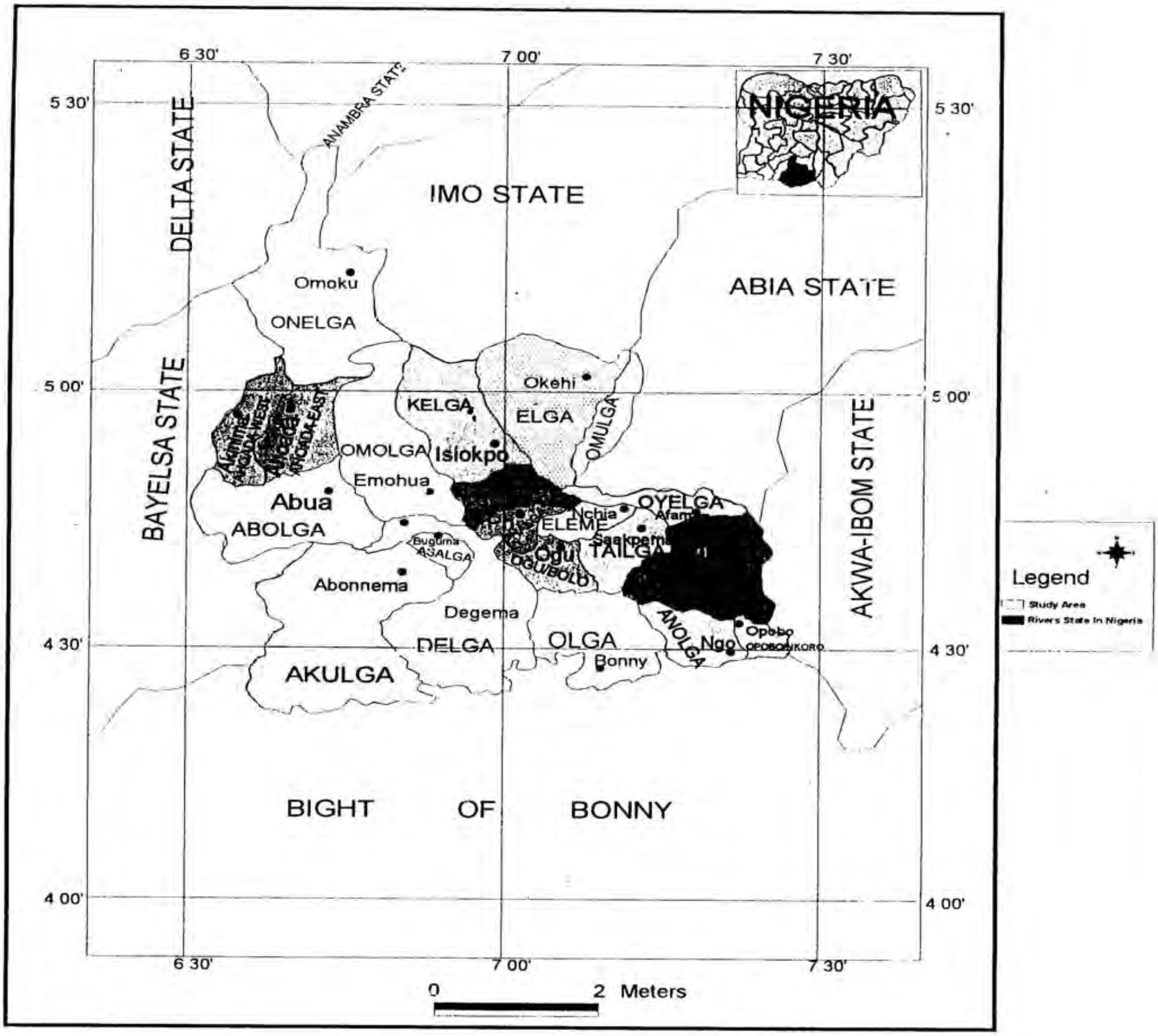

Fig. 1: Map of Rivers State showing the study area-Etche

The Geology of the study area falls under the alluvium type of soil that is a mixture of silt and sands that belong to the Quaternary period. Etche is characterized by two distinct air masses namely, the tropical continental and the tropical maritime air mass. The general rainfall distribution pattern in Etche area exhibits the double maxima phenomenon with the two peaks occurring in June/July and September/ October. The mean annual rainfall of the area is about 3450mm with temperature ranging between 25.4^0C – 29.6^0C. Temperature range modifies the study area with the rainforest vegetative cover predominating (Nwaogu, 2001).

The study area has gently rolling topography (below 200m above sea level) and is drained by the Imo, Otamiri and Ogechie Rivers. Agricutlure is the major economic activity of the populace in addition to farming, fishing, lumbering, hunting and crafts, with only a few working in the oil and gas industry.

Conceptual Framework

According to Nwokedi (1999), oil spill which is the most severe externality of oil exploration activities can be described as the discharge (incidentally or accidentally) of oil on inland, offshore or coastal waters.

Several petroleum products that are spilled end up lost to the environment hereby bringing negative consequences, as they are never recovered. Crude oil contains highly dangerous chemicals like Benzene, Toluene, Ethyl-Benzene and Xylene which wreak havoc when released into the environment. Udo (2001) identified causes of oil spillage to include loss of production during dewatering, tank overfill where oil is released into the environment through tank vent on roof; tank failure, seam leakage – corrosive effects due to old age; tank support failure where base of tank is titled thereby causing visible leakage, incomplete closure of bund walls (bund walls are supposed to prevent any discharge from existing tank farm) and on-site disposal of tank sludge. Other cases of spill include improper disposal of drilling mud, shipping and terrestrial traffic accidents, oil well blowout, off shore and onshore production accidents, tank washing and ballast discharges, equipment malfunction, operator maintenance error, natural causes (rain/flood etc) and sabotage.

It is therefore important for proper contingency measures to be put in place so as to effectively combat the spillage when it occurs. This according to Udo and Uluocha (2003) is a more proactive rather than a reactive approach to oil spill management. The need for contingency plan for oil spills to provide a safe, systematic and integrated response to oil pollution incidents that may occur in a sensitive environment like Niger Delta is highly recommended by Adekunle and Forster (1985).

METHODOLOGY

Data Collection

The following data sets, sources and method were adopted for the data collection. The methodology adopted is as presented in the flow chart below (Fig. 2).

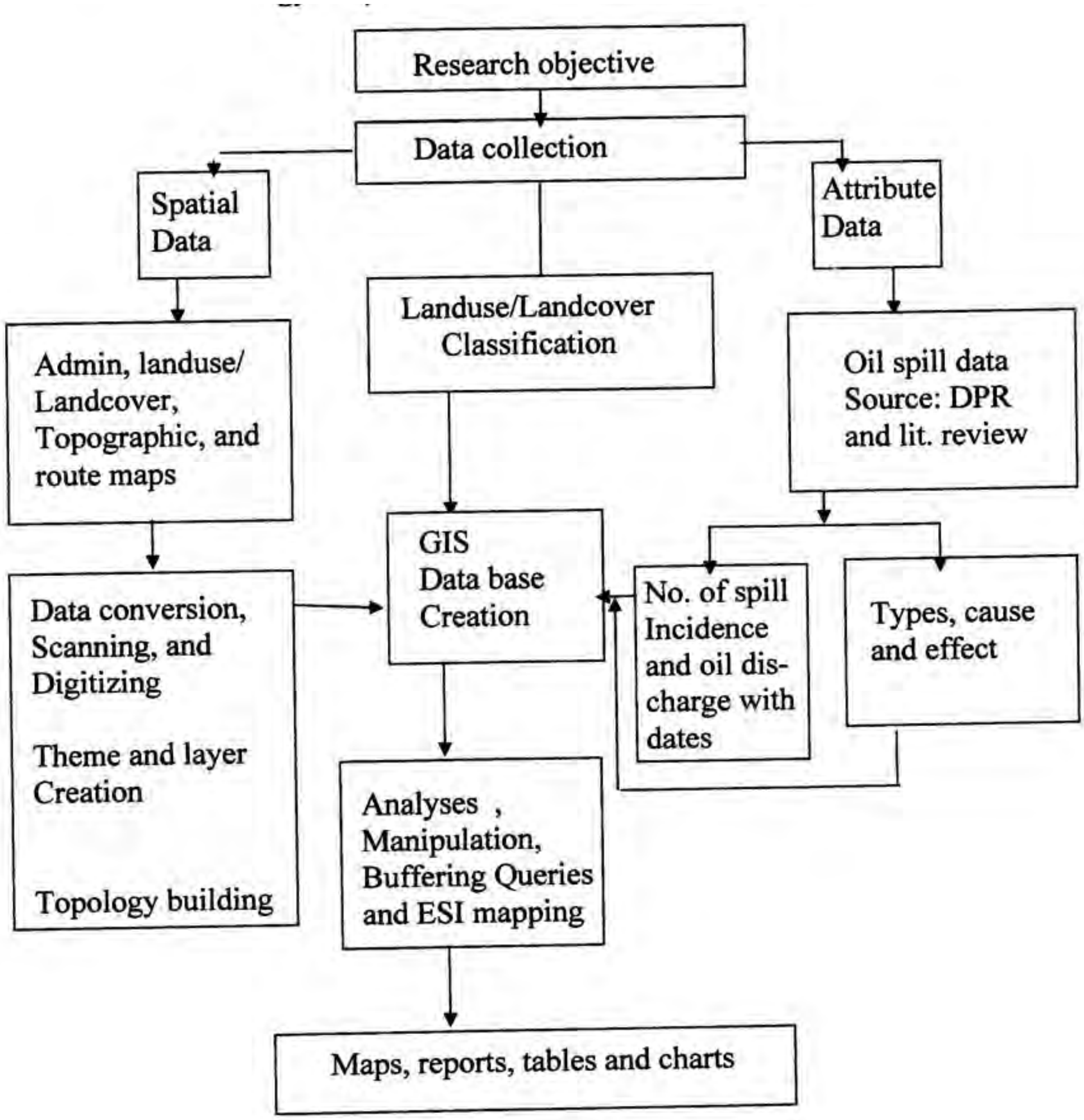

Fig. 2: Schematic Diagram of Research Methodology (Source: Federal Surveys, Lagos).

The Ikwerre/Etche Topographic map on a scale of 1:125,000 from the Lands, Housing and Surveying Division of Rivers State helped in providing vital data such as real geographical locations, roads, place names, rivers and pipeline positions.

Administrative Maps

Administrative map of Rivers State serves as a master map in the extraction of current information on recent road network, local government boundaries, changes in place names and others. This is because, it was a current map produced in the late 1990s. This map was obtained from the Rivers State Planning Office.

Data Input, Manipulation and Analysis

The base data of the study were scanned and imported to the GIS environment for on-screen digitizing using Arc-view 3.1. The Arc-view and

ArcInfo facilities such as the editing and view menu, the theme or add field menus enhanced the digitizing of the land-use/land-cover classes as polygons, rivers, roads, and the pipeline networks as linear features, and the major communities and villages and some important infrastructural facilities as point features. It also enables in the topological building, cleaning and geo-rectifications. Attribute tables were created during digitizing on-screen using Arcview GIS. These include attributes of point **data** such as communities and village identification numbers and names while, **line data** - include roads, paths, and pipeline identification numbers. **Polygons** – landuse/land cover types, classes, identification number.

Buffering Operations

The buffer zones are built to determine proximity of the area to the water body which has contact with the pipeline. To carry out this successfully, a command was given to the system to create buffer of 500m away from the water body/pipeline.

Buffering was carried out at distances of 0.5km, 1km and 1.5km away from the waterbody/pipeline. The three different region buffers were used to find the effects of oil spill with respect to the existing land use/land cover as well as ascertain the area of each land use/land cover classes in each buffer zone.

Environmental Sensitivity Index (ESI) Mapping

This is done by ranking the land use/land cover types in order of their sensitivity to oil spill. It is usually designed based on various observations of oil spills and their influence on different coastal types, including marine and fresh water environment. As stated by Nwokedi (1999), such ranking was carried out based on the following guideline or criteria: (i) possibility or difficulty of cleaning after spill (ii) the socio-economic importance of the ecological class (iii) Ecology (iv) shoreline and oil interaction (v) sensitivity of biological community (v) exposure to slope, and physical settings (vii), substrate type grain size and permeability, etc.

RESULTS AND DISCUSSIONS

Land use/Land cover

Through a field survey of the area, and by the use of the topographic map of the area, nine (9) landuse/land cover classes were identified in the area. Such ecological classes are shown in Table 1 and Figure 2. The ecological classes are built-up area 4.47km^2 (0.70%), heavy forest 124.93km^2 (19.50%), mangrove forest 67.97km^2 (10.61%), and light forest 43.06km^2 (6.72%). Others are cultivated land (302.75km^2 (47.21%), Shrubs/open grass land area 56.88km^2 (8.81%), the plantation (oil palm and rubber) which are 17.23km^2 (2.69%) and 0.62km^2 (0.10%) respectively. The water-body covers 23.36km^2 (3.64%).

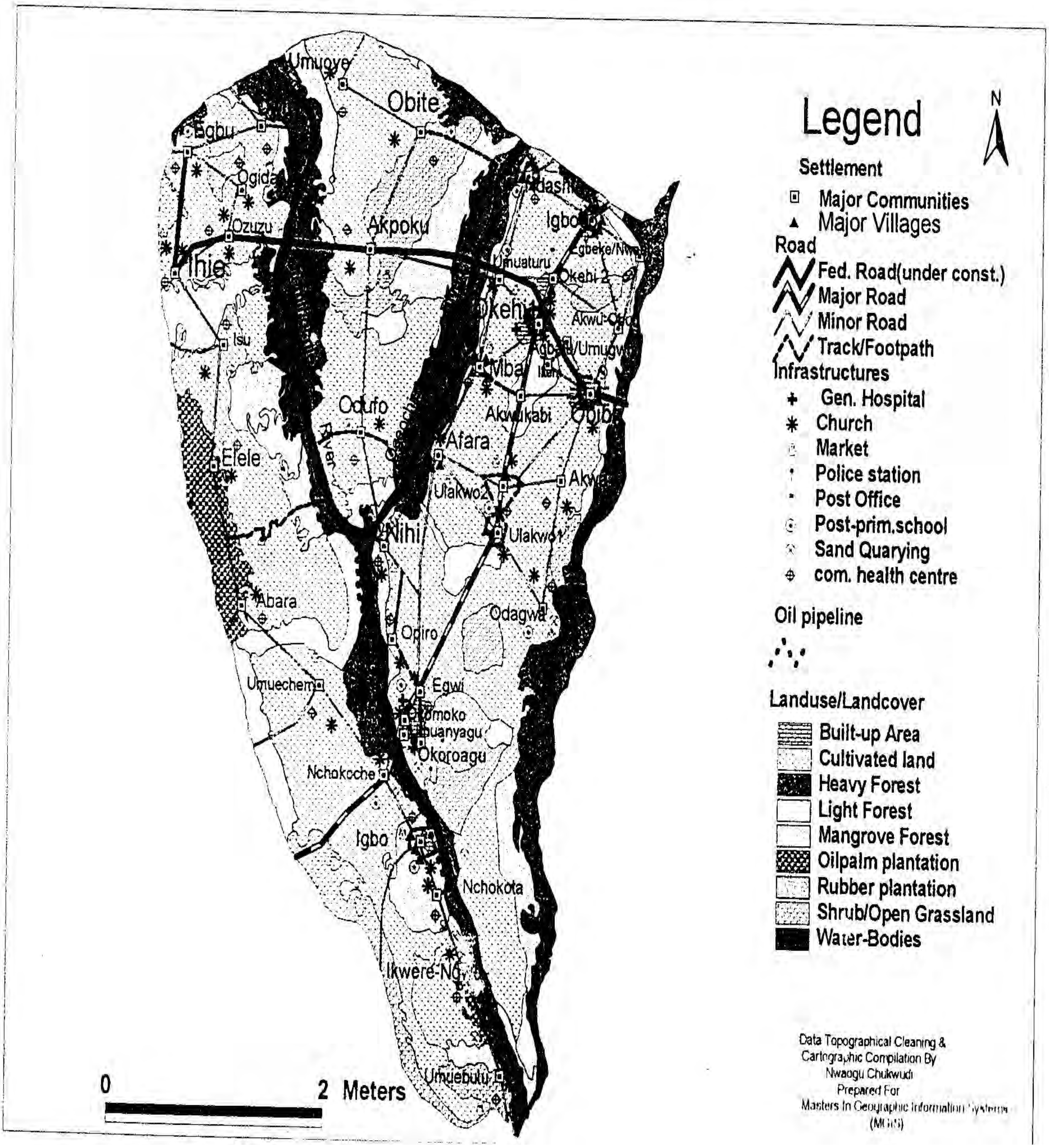

Fig. 3: Landuse/Landcover of Etche – The Study Area

Table 1: Landuse/cover classification of the study area

Code/I.D.	Class of Landuse/Landcover	Area (Km^2)	%
1.	Built-up area	4.47	0.70
2.	Heavy Forest	124.93	19.50
3.	Mangrove Forest	67.97	10.61
4.	Light Forest	43.06	6.72
5.	Cultivated land	302.76	47.21
6.	Shrubs/open grassland	56.88	8.81
7.	Oil palm plantation	17.23	2.69
8.	Rubber plantation	0.62	0.10
9.	Water body	23.36	3.64
	Total	**641.28**	**100.00**

General Analysis of the Three Buffer Zones

Buffering was carried out to determine the proximity of the area to the water body which has contact with the pipeline. Moreso, it was used to find the effect of oil spill with respect to the existing land use/land cover as well as ascertain the area of each land use/land cover classes in the area. Table 2 and Figure 4 depict the details of the buffering around the oil pipeline/ water-body. Table 2 indicates that cultivated area covers the highest areal extent of $281.41km^2$ (35.59%) of the buffer area. Heavy forest follows by $244.91km^2$ (30.98%) Rubber plantation ranks the lowest by $5.04km^2$ (0.64%) of the total area within buffer zones.

In summary, the 0.5km buffer zone covers an area of about $134.73km^2$. 1km (1000m) buffer covers $264.71km^2$ whereas the 1.5km (1500m) buffer covers about $391.20km^2$.

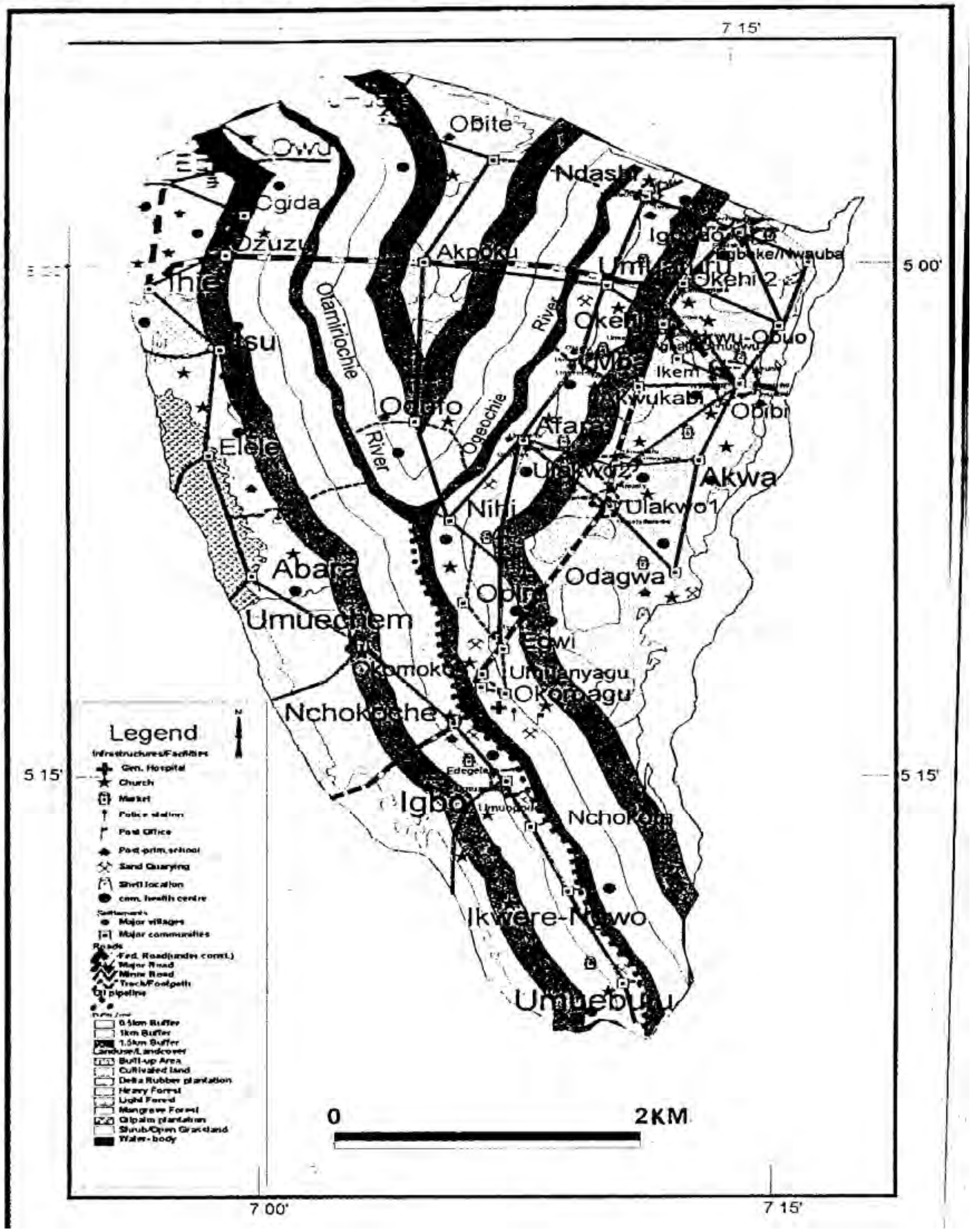

Fig. 4: Buffer around the Oil pipeline/waterbody in the study area

Table 2: Landuse/landcover area covered (in Km^2 and %) per buffer distance in the study area

Landuse/ landcover	**Buffer distance**			**Total**	
Class	0.5km	1 km	1.5km	Km^2	%
Built-up area	1.77km^2 (1.31%)	3.36 km^2 (1.27%)	4.30 km^2 (1.19%)	9.43	1.19
Heavy Forest	79.2 km^2 (58.78%)	80.15 km^2 (21.87%)	85.56 km^2 (13.25%)	244.91	30.98
Mangrove Forest	20.84 km^2 (15.47%)	50.93 km^2 (19.24%)	51.82 km^2 (13.25%)	123.59	15.63
Light Forest	km^2 (7.27%)	21.13 km^2 (7.98%)	23.44 km^2 (5.99%)	54.36	6.88
Cultivated land	17.60 km^2 (13.06%)	87.25 km^2 (32.96%)	176.56 km^2 (45.13%)	281.41	35.59
Shrubs/open grassland	1.17 km^2 (1.27%)	17.17 km^2 (6.49%)	44.80 km^2 (11.45%)	63.68	8.05
Oil palm plantation	2.14 km^2 (1.59%)	3.04 km^2 (1.15%)	3.04 km^2 (0.43%)	8.22	1.04
Rubber plantation	1.68 km^2 (1.25%)	1.68 km^2 (0.63%)	1.68 km^2 (0.43%)	5.04	0.64
Total	134.73 km^2 (100.00%)	264.71 km^2 (100.00%)	391.20 km^2 (100.00%)	790.64	100.00

Landuse/Landcover and Environmental Sensitivity Index (ESI) Ranking (Mapping) of the Study Area.

Following the criteria earlier established by Nwokedi (1999), the land use/land cover of the study area was ranked into nine (9) different classes of sensitivity to oil pollution based on the socio-economic importance of each land use/land cover. ESI-1 is the most sensitive to oil pollution, while ESI-9 is considered to be the least sensitive to any oil pollution. Other land use/land cover classes fall in between (see Table 3 and Fig. 5).

Table 3: Landuse/Landcover and ESI Ranking of the Study Area.

Sensitivity Ranking	Landuse/Landcover class	
ESI – 1	Waterbody	most sensitive
ESI – 2	Heavy Forest	
ESI – 3	Mangrove Forest	
ESI – 4	Light Forest	
ESI – 5	Oil palm plantation	
ESI – 6	Cultivated land	
ESI – 7	Built-up area	
ESI – 8	Shrubs/open grassland	
ESI – 9	Rubber plantation	least sensitive

Water body ranks highest not only because the pipeline follows along side it and also terminates into it, but as a major carrier of oil in the study area. The ESI ranking of the land use/landcover resources of the study area as shown in Figure 5, reveals the level of sensitivity of specific ecological classes during oil spill (s). Because the landuse/landcover varies in character, component, shape and location, their levels of vulnerability and clean-up during any spill also differs.

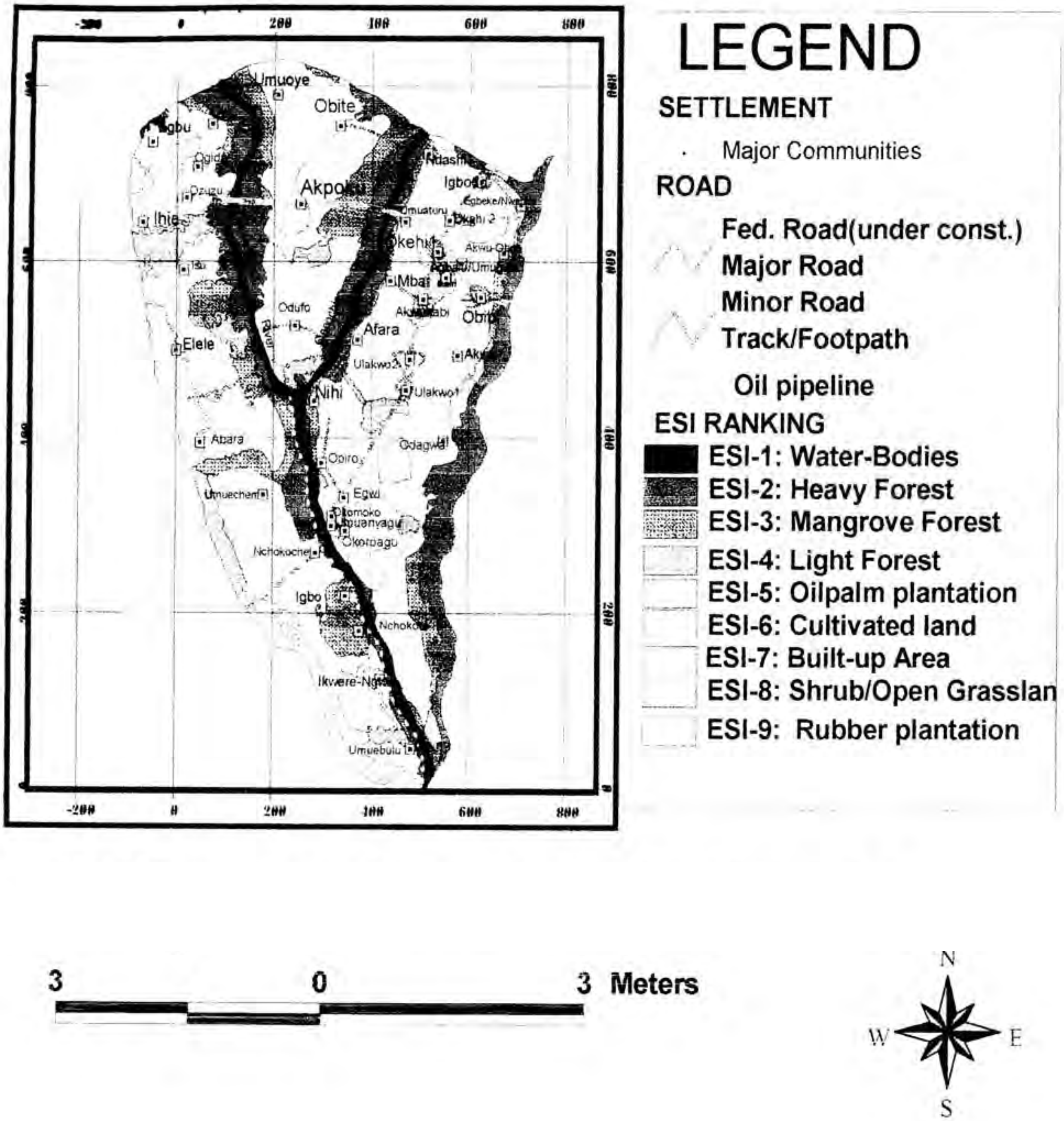

Fig. 5: Environmental Sensitivity Index (ESI) of Etche L.G.A

CONCLUSION

This study has shown the need for proper spill contingency planning in the society (especially Etche). In the even of a spill, the use of a more efficient and effective clean-up operation data is also demonstrated. This is justified in the use of ESI mapping. It is important to note that the challenge of oil spillage management lies in the fact that spillage is a by- product of development efforts. In the light of this, it is quite expedient and necessary for scientific and technological innovations (like the use of GIS) to be incorporated in oil spill management.

Meanwhile, the need and vital role of GIS in oil spill monitoring and management as discussed in this study can not be underestimated. Following this, it is pertinent that a level of interest should be shown by the government, multinational companies, oil operators (both indigenous and foreign), oil stakeholders, environmental regulatory agencies (such as the DPR, Federal, State and Local Ministries of Environment, NGOs, CBOs and host communities) in ensuring that GIS is fully embraced in oil spill monitoring.

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