To Demonstrate Potential of GIS in Environmental Impact Assessment for Oil Spill Disaster Management

Onojeghuo, A. O.,[1] Billie, H.,[2] Onojeghuo, A. R.[1,3] And Emengini, E. J.[1]
[1]Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Anamabra State, Nigeria, E-mail: lexisgis@yahoo.com
[2]Niger Delta Development Commission, 167 Aba Road, Port Harcourt, Rivers State, Nigeria
[3]Department of Geography, University of Leicester, Lieicester, United Kingdom

Abstract
The overall aim of this study was to evaluate the use of Geographic Information System (GIS) tools for oil spill disaster magement as vital input required for Environmental Impact Assessment (EIA) in the Niger delta. To accomplish the aim, a geospatial database was created using a variety of primary and secondary datasets such as GPS locations of oil spill sites across Bodo community, an oil spill prone location in Rivers state and soil sample contamination data across Ogoniland. The data layers contained in the geodatabase were used to produce map outputs for decision making through the forms of maps and query results. Overall, the study has demonstrated the benefits of utilising GIS tools for managing environmentally related data, particularly oil spill disasters as inputs for effecticient delivery of EIA projects.

1. Introduction

The ecologically fragile Niger delta region is one of the world's largest deltas with vast wetlands, including the third largest mangrove forest in the world and is the hub of oil exploration in Nigeria. Its landscape consists of a patchwork of remnant forest within a matrix of more intensively used and densely populated landscapes (Onojeghuo and Blackburn, 2011). Historic records of oil spill incidents held by the Department of Petroleum Resources (DPR) showed that between 1976 and 1996, a total of 4,647 incidents resulted in the spilling of approximately 2.5 Million barrels of oil into the environment. Of this quantity, an estimated 1.8 Million barrels (approximately 77%) were discharged into the environment and never recovered, affecting land, swamp and offshore environments (Nwilo and Badejo, 2005). The major source of oil spill on the Niger Delta are vandalisation of the oil pipelines by the local inhabitants; ageing of the pipelines; oil blow outs from the flow stations; releases, both accidental and deliberate, from oil tankers on the high sea and the disposal of used oil into the drains by the road side mechanics. The most prominent of these sources of oil spill are through the vandalisation of pipelines either as a result of civil disaffection with the political process or as a criminal activity (Nwilo and Badejo, 2005). These environmental consequences impact greatly the environmement particularly soil, water, vegetation, acquatic / terrestrial wildlife and people (UNEP, 2011). These oil spill diasters often result in fires that cause total or partial destruction of vegetation thereby destroying species diversity. Osuji and Opiah (2007) analysed surface and sub-surface soils for total extractable hydrocarbon contents some physicochemical characteristics in an oil-impacted site at Oshire-2 Niger Delta, Nigeria. The severity of damages caused by hydrocarbons to both acquatic and terrestrial wildlife depended on the type(s) of hydrocarbon involved, quantity spilled, temperature at the time of the incident and the season at time of incident. As a result of the afore-mentioned effects of oil spill incidents along the Nigerian coastline, the Federal Government through an act of the National Assembly created the Niger Delta Development Commission (NDDC) (Nwilo and Badejo, 2005 and Nwilo and Badejo, 2007). In addition to NDDC, the National Oil Spill Detection and Response Agency (NOSDRA) was established in compliance with the International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC90) to which Nigeria is a signatory. Amongst the laws and policies for managing oil spill incidents at the national level is the Environmental Impact Assessment (EIA) decree No 86 of 1992, promulgated to protect and sustain our ecosystem (EIA, 1992). More details of the legistlative frameworks existing in Nigeria are presented further sections of the paper. At present the effective utilisation of geographic information system (GIS) in managing oil spill disasters across the country is limited and under-utilised in tackling this problem. Given the intensity of oil spill related disasters, the

implementation of a GIS driven EIA would significantly impact on how delegated authorities such as NDDC would respond to such environmental disasters. The benefits of such an approach is demonstrated in the ability to perform a variety of spatial analysis (such as proximity analysis to record distances between contaminated sites, buffering of selected locations in relation to contaminated sites locations, queries to extract key information) relevant in making meaniful decisions on how threats could be mitigated. Studies have demonstarted for EIAs, GIS databases can be used to store a variety of information in an interactive and user-friendly interface allowing such data to be asessed quickly and in an efficient manner (Aukett, 2012 and Patil et al., 2002). Using in-built algorithims, contaminant plume contours could be generated to display the extent of contamination levels an approach that was adopted in this study. Data on soil samples of oil spill affected communities were analysed and contamination contour maps genertaed. The overall aim of this paper was to demonstrate the potential utilising GIS tools for oil spill hotspot mapping and generating vital inputs required for EIA in an oil spill prone community within the ecologically fragile Niger delta region. A key component of the study involved building a geospatial database of oil spill hotspots within the study area and utilising spatial analysis techniques to generate map outputs required in decision making and effective management. Based on the results generated, recommendations as to how GIS technology could be used to for EIA related projects in Nigeria were also presented.

1.1 Evolution of EIA and Legislative Framework in Nigeria

In the review of existing literature on evolution of EIA in Nigeria, Ogunba (2004) noted that initial focus of environmental awareness and legislation in Nigeria was on the petroleum industry. It was believed that in Nigeria only the petroleum sector required close environmental monitoring. Hence, environment legislations came in the form of pollution reduction measures that reacted to local problems within the petroleum industry. In the past asides from the petroleum industry, there were neither environmental regulatory institutions nor legislations in Nigeria. However, as a result of participation in international environmental conferences notably the historic United Nations 1972 Stockholm Conference of which Nigeria was one of the 114 governments in attendance, critical issues on the problems of humans' environment were discussed. A direct result of this conference was the creation of an Urban Development and Environment Division in the Federal Ministry of Economic Development in 1975. In May 1982, Nigeria participated in the 10th Anniversary of the Stockholm Conference during which all participants reaffirmed commitment to the protection and enhancement of the quality of human environment. This was followed by the hosting of the 69th Inter-Parliamentary Union Spring Meetings by Nigeria during which the Committee on Education, Culture and Environment adopted a draft resolution on the 'State of the World Environment Ten Years after the UN Conference on the Human Environment' and the steps to be taken for improvement including the fields of national and international legislation. Participation in such international conferences served to build awareness, policy and preliminary institutions (Ogunba, 2004). To this end, the Federal Environmental Protection Agency (FEPA) was created under Decree No. 58 in 1988. FEPA established the National Policy on the Environment in the following year which initiated the creation of a voluntary EIA system. EIA Decree No. 86, 1992, then established a statutory basis for EIA. Under the Decree, FEPA is to carry out an Initial Environmental Examination (IEE) and screen the proposals. FEPA also review documents submitted to them during the process. Proponents must submit terms of reference to FEPA and are responsible for writing the study reports (Donnelly et al., 1998). The EIA Act 86 of 1992 establishes the environmental framework in Nigeria. The National Environmental Standards and Regulations Enforcement Agency (NESREA) is a parastatal of the Federal Ministry of Environment established by the NESREA Act 2007, thus repealing the FEPA Act 2004. NESREA is empowered to enforce all environmental laws, guidelines, policies, standards and regulations in Nigeria as well as enforcing compliance with the provisions of all international agreements, protocols, conventions and treaties on the environment to which Nigeria is a signatory. The National Oil Spill Detection and Response Agency (NOSDRA) was established by Act No. 15 of 2006 as a deliberate and articulate response by the Federal Government to the persistent environmental degradation and devastation of the coastal ecosystem especially, in the oil-producing areas of the Niger-Delta region. NOSDRA is statutorily empowered to co-ordinate oil spill management and ensure the implementation of the National Oil Spill Contingency Plan (NOSCP) for Nigeria in accordance with the International Convention on Oil Pollution Preparedness, Response and Co-Operation (OPRC) 1990, which Nigeria has ratified. The NOSCP is a blueprint for checking oil spill through, containment, recovery

and remediation/restoration. It was drafted in 1981 and first reviewed in 1997, and further reviewed in 2000 and 2006. NOSDRA is essentially mandated to play the lead role in ensuring timely, effective and appropriate response to all oil spills, as well as protect threatened environment and ensure clean-up of all impacted sites to the best practical extent.

1.2 GIS and EIA Application

In comparison to computerised databases, GIS takes into consideration the inclusion of spatial datasets to existing databases (attribute tables). GIS can be viewed as spatially referenced databases with the facility of displaying information as maps and performing spatial analysis such as extraction, intersection, overlaying, appending etc. Studies have demonstrated the potential use of GIS as a tool for oil spill preparedness and response (Aukett, 2012), oil spill disaster management (Smara et al., 2005) and oil spill monitoring and mapping (Ivanov and Zatyagalova, 2013 and Morovic and Ivanov, 2011), thereby making it a vital component in EIA projects. The concept of environmental assessment is based on evidence that is clearly spatial in nature, one which supports plan-making and project implementation (Campo, 2012). Aukett (2012) states that GIS provides a dynamic and user-friendly interface capable of managing different attributes and physical information gathered from a spill, thereby making it a valuable tool in decision making and useful for accurately quantifying offshore spill size and trajectory. Also, hazards and risks can be pre-determined and strategies developed to mitigate the impacts of potential oil spills. This can be achieved using geographic layers and parameters overlaid and interrogated to illustrate a range of information such as sensitive areas, pre-defined Net Environmental and Economic Benefit Analysis (NEEBA) studies, habitat mapping, booming plans, logistic routes, response times, and waste sites (Ivanov and Zatyagalova, 2013). This paper reviews studies that demonstrate the benefits of GIS in both preparedness activities and actual responses of oil spill disasters. In the study by Miller and Onwuteaka (2006) utilised GIS to develop a resource for vulnerable landscape prone to oil spills. The paper discusses the use of GIS based tools as a means of providing rapid response and information in the event of an oil spill disaster. The study utilised GIS based tools and remotely sensed imageries supplied by Earth Satellite Corporation (EarthSat) (i.e. Landsat TM imagery) to model the potential risk of oil spills from existing oil facilities and hydrocarbon shipping lanes offshore East Central Nigeria. The Landsat TM imagery was used to generate the land-cover classification maps, which were integrated with other digitised maps to model the sensitivity of the region to oil spills. The results were integrated in the GIS for display, query and analysis by emergency response planners (Miller and Onwuteaka, 2006). A number of map outputs were generated, such as the derived risk surface for wellheads offshore and environmental sensitivity maps of the region. These maps were combined to generate an overall sensitivity map of the study area and further analysis. Aukett (2012) utilised spatial analysis tools and techniques for the placement of booming points on GIS layers thereby providing important information key stakeholders for decision making. The products were updated continuously and provided as requested. During the response, all the products produced were made available to the public via interactive web sites specifically set-up for the project. This tool proved to be an effective means of making information available to the public and all stakeholders.

2. Study Area

The key study area for this project, Bodo community, is located in Gokana LGA of Rivers state with an estimated population of 69,000 people making it the largest community in the state (Environmental Rights Action and Friends of the Earth Nigeria, 2009). It is situated in the upper reaches of the Andoni-Bonny estuarine system at latitude 4°36′ N and longitude 7°21′E (Scott and Nenibarini, 2013). The community is dominated by a network of brackish water creeks, mangrove swamps and pockets of island forests which are collectively known as the Bodo Creek (Onwugbuta-Enyi et al., 2008) (Figure 1). The people of Bodo community are predominantly farmers and fishermen.

3. Methodology

This section outlines the methodology adopted in the development of a geospatial database for environmentally related issues for the study area. For the purpose of this study, adequate hardware with sufficient processing capacity was used. The software used were ESRI ArcGIS 10.2.2 (ESRI, 2014) for GIS analysis and SURFER 12 Golden software for production of soil contamination maps.

3.1 Data Sources

The primary datasets used included GPS positions and soil contamination readings of oil spill affected sites across the study area. Relevant spatial and non-spatial attribute data for the EIA geospatial database included: GPS data of oil spill location along oil pipelines in the study area; and GPS locations and pictures of oil contaminated sites within the study

area. Google Earth facilities were complemented with available satellite data to obtain relevant background information for verification and historic snap-shots of the study area. Other vital sources of secondary datasets included: existing background literature from journal publications, reports (such as the United Nations Environment Protection report on the Environmental Assessment of Ogoniland), the Department of Environment (Nigeria), NDDC and SPDC. Data on samples of soil, groundwater and community well sites for total petroleum hydrocarbon contents, soil depths and GPS coordinates of sites were compiled for the four local government areas making up the Ogoniland by the UNDP team in 2011. This data formed one of the key layers created in the GIS database of this study.

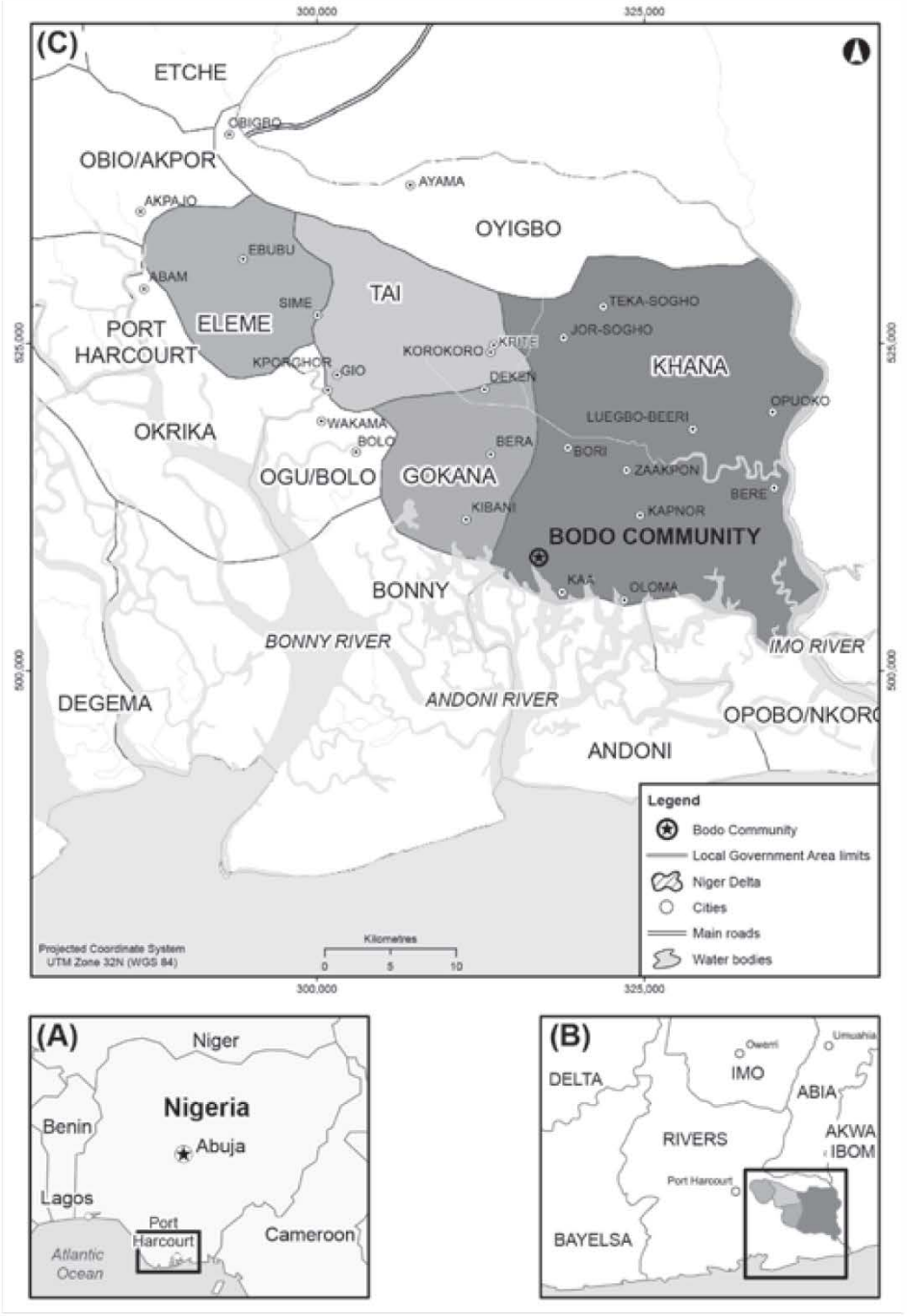

Figure 1: Map of Ogoniland showing the four local government areas and study area, Bodo community (A); insert maps of Nigeria showing study area (B) and the local government areas comprising Ogoniland in Rivers State

3.2 Design and Creation of Geospatial Database

The geospatial database comprising of spatial entities such as oil spill sample points, administrative information of the Niger delta states and LGAs, existing pipeline networks, roads networks and water bodies were created using ArcGIS software. The methodology for geodatabase creation was categorised into three key components: data capture, GIS database design and generation of final output (Figure 2). During the data acquisition process it was vital that the correct map coordinate system having precise projection parameters were utilised. The coordinate system used in the study was Universal Transverse Mercator (UTM) Zone 32 north, with datum World Geodetic System (WGS) 1984.

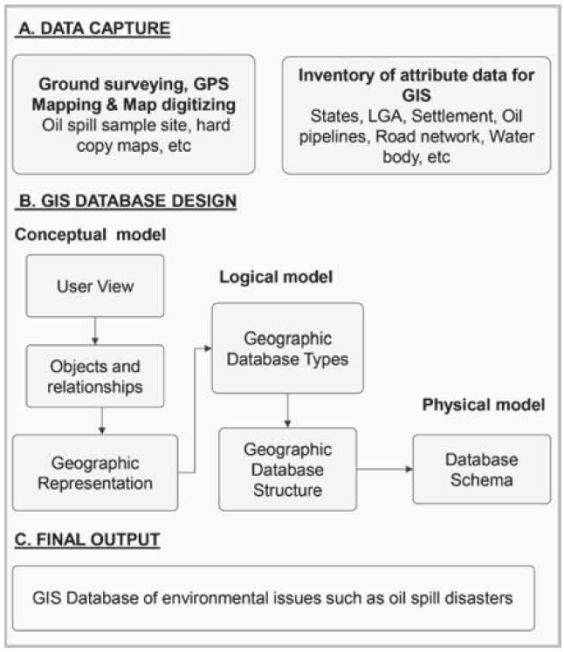

Figure 2: Methodology for geospatial database creation

4. Results and Discussion

4.1 Creation of Map Outputs

GIS provides a dynamic, user-friendly interface to explore a variety of attribute and physical information gathered from a spill, thereby facilitating in the means by which decision making is done more rapidly and with better precision (Aukett, 2012). Using available information compiled in the geodatabase maps were generated and queries to extract vital information needed for decision making performed using a number of spatial analysis tools in the GIS. Using different geographic layers of spatially and non-spatial data, a number of response maps of the study area were created.

4.2 Utilising Identity and Hyperlink Tools for Information Extraction

The hyperlinks tool was used in the study to interrogate a number of photographs of oil spill sites across Bodo creek and its environs inputted in the geodatabase. The photographs, acquired using a digital camera with an integrated GPS device, were integrated in the attribute tables of each oil spill site location visited as a path to the saved images (latter converted to Adobe pdf files). This tool proved to be most beneficial during this study as it allowed for geocoding the pictures and importing such information into the GIS database. Figure 3a shows a display of attribute information obtained using the identify tool and picture hyperlinks of oil spill sites in Bodo creeks and environs. This demonstrates the potential of GIS in collating such events and presenting the data in a proper and effective manner for decision making. This would assist policy makers and stakeholders in decision making thereby enabling the implementation of necessary policies that would assist in alleviating the burden of devastated ecosystem in the Ogoniland.

4.3 Spatial Analysis using Queries and Buffering Analysis

By utilising information contained in the geodatabase, vital data such as oil spill sites within different local government areas and other vital records stored within the database could be extracted. In this study simple and complex queries (combining a number of criteria) were tested and successfully used to derive information. For example, in this study queries to identify all oil spill sites within Gokana LGA was performed. The result indicated that there were two oil spill sites situated recorded in Gokana. These sites were along the 28 inch Bomu-Bonny trunk line and on-land. Such information retrieved at such short time shows the potential of utilising the GIS in managing oil related activities. Using the Proximity analysis tool it was possible to select objects at specific distances relative to another (Figure 3b). Buffer analysis was used to locate communities within radius coverages of 10 – 30 km with reference from an identified oil spill hotspot situated along a pipeline in the swampy region of Bodo West field. Results of the buffer analysis indicated that within a radii distance of 10 km, two settlements namely – Kibani and Bolo were discovered. For the buffer distances of 20 km and 30km a total of 23 and 8 communities would be prone to oil spill disaters from the affected site.

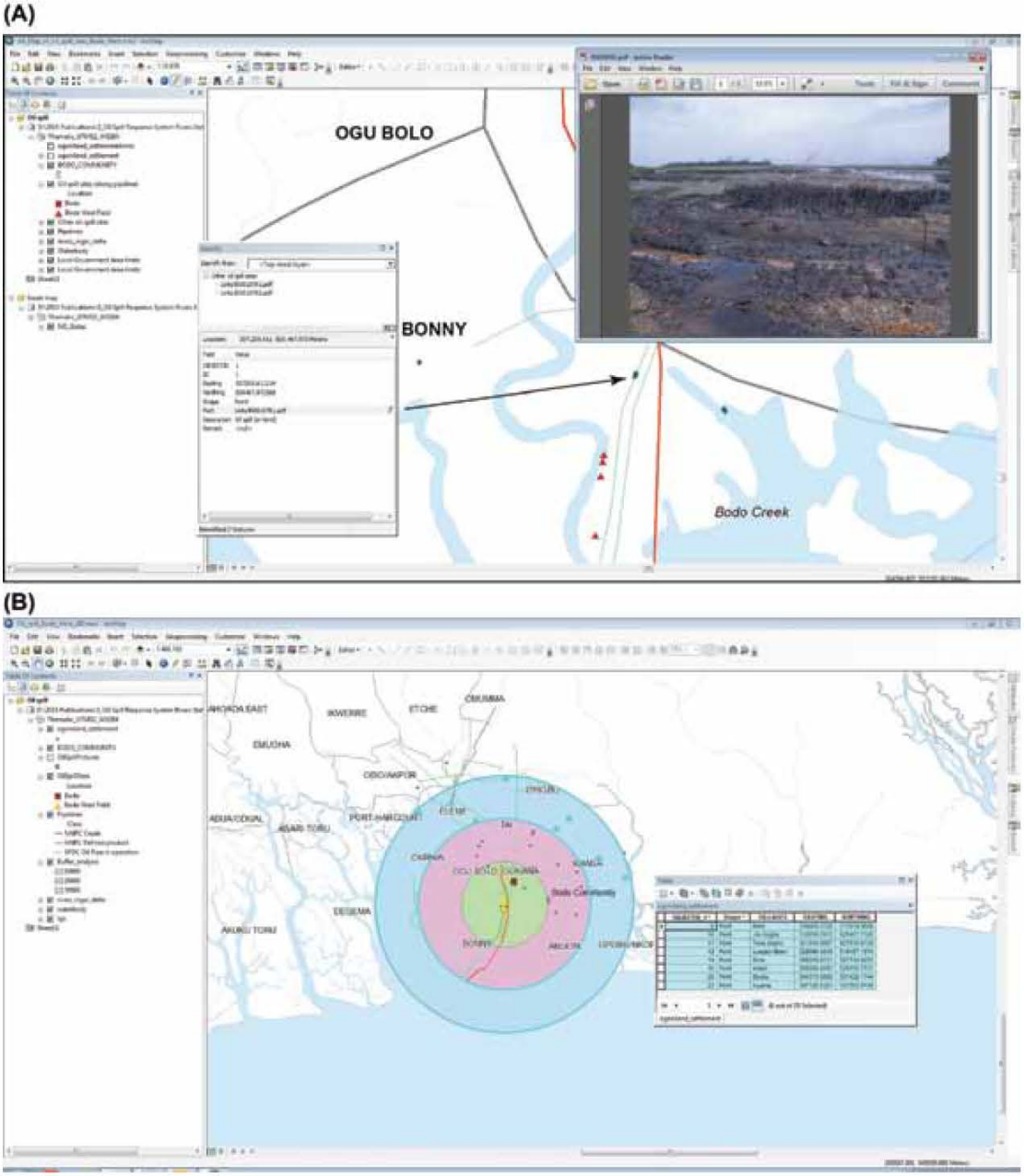

Figure 3: Results of geospatial database showing: (A) attribute information using the "identify" tool and hyperlinks for oil spill sites within Bodo creek and environs and (B) Attribute display of selected oil spill site in Bodo community

4.4 Analysis of Soil Contamination Data

During the data screening stage of the project a number of assessment criteria were set to serve as guides during analysis and interpretation of the data. The Soil, Groundwater and Sediment contamination levels were set according to the Nigerian standards EGASPIN (Environmental Guidelines and Standards for Petroleum Industries in Nigeria) (available on www.drp.gov.ng). Based on pre-defined guidelines by EGASPIN the intervention values for soil, groundwater and sediment contamination were set as 5000 mg/kg (target value of 50 mg/kg), 600 µg/l (target value 50 µg/l) and 5000 mg/kg (target value 50 mg/kg) respectively. The drinking water contamination threshold was set using both the World Health Organisation (WHO) guidelines and Nigerian drinking water standards, with values of benzene of 10 µg/l and mineral oils of 3µg/l (UNEP, 2011).

The soil contamination data formed the basis for creating soil contamination maps of the study communities within Ogoniland local government areas. For example in Kwawa community, surrounded by Wiikue Kwawa and Yorla communities, a total of 85 soil samples were collected with the deepest investigation done at 5.2m. Results of the analysis indicated that the maximum soil TPH (total petroleum hydrocarbons) was 8,820 mg/kg (exceeding the EGASPIN intervention value). The number of soil measurements greater than EGASPIN intervention value was 2 in total for Kwawa community. The deepest sample greater than the EGASPIN intervention was at 0.4m. The results further showed that no soil measurements below 1m were greater than the EGASPIN intervention.

The records indicated that for Kwawa community SPDC had recorded 4 spill incidents (23 October 1993, 9 December 1992, 14 October 1993 and 6 May 1993) all of which were reported by the community. Figure 4 shows soil contamination map of the sample site in Kwawa community.

4.5 Policy Implementation and Social Responsibility

The Niger delta region is one of the worst affected ecological zones across the world most affected by oil spill disasters resulting in environmental degradation. Studies have highlighted the in detail the implication of non-effective national policies aimed at protecting inhabitants the Niger delta from devastating magnitude of environmental degradation (Jike, 2004 and Osaghae, 1995) and Ogoniland in particular.

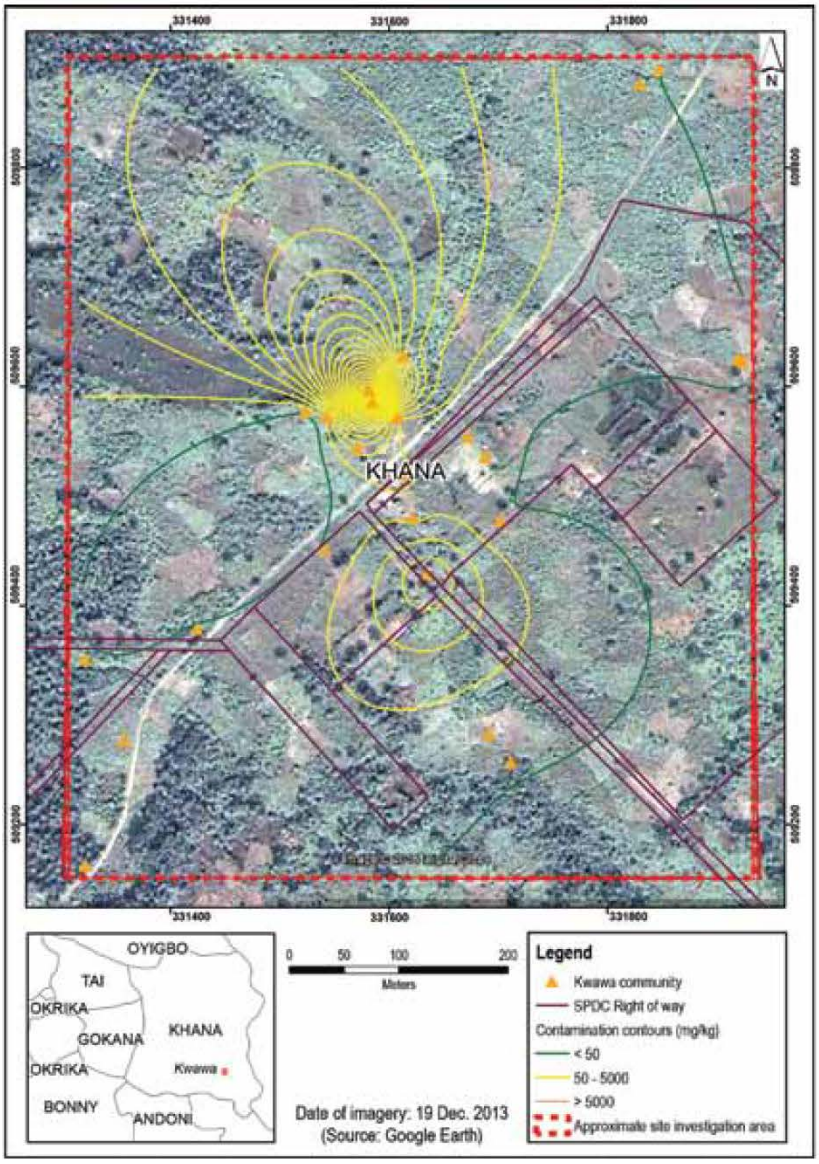

Figure 4: Soil contamination map of Kwawa community in Khana LGA in Rivers state

Jike (2004) takes a look at the level of environmental degradation in the Niger delta and links this to social disequilibrium resulting in unsustainable development in the region. The rate of development in the Niger delta is skewed in disfavor of the region because of public policies that have consistently failed to improve the welfare of the people (Jike, 2004). Hence, the Federal Government of Nigeria is encouraged to provide for the region policies aimed at protecting her environment and mandating exploration companies operating in the region to be socially responsible to the inhabitants, an approach that would positively impact on the social well-being of its inhabitants. Rhuks (2012) suggest that the role of oil-multinationals in delivering corporate social responsibility to host communities in the Niger delta can be re-invented through effective and peaceful dialogue between both parties, thereby optimising their business potentials. An approach that's beneficial to both parties and the national at large. Also, adherence to safe and environmentally friendly approaches during oil exploration and other related activities should be a priority.

5. Conclusion

This study has demonstrated the benefits of utilising GIS tools for managing environmentally related data, particularly oil spill disasters for proper and effective delivery of EIA projects. Using a variety of primary and secondary data sources a geospatial database for oil spill related sites in the study area was generated. Based on the compiled information, GIS maps of mapped oil spill locations were generated, attribute tables containing important information created and queries performed using a number of spatial analysis tools. Queries were performed using attribute information contained in the geodatabase and proper maps presenting vital information created. The following results demonstrate the benefits of utilising GIS tools to manage environmental datasets. Based on these the following recommendations as to how GIS can be utilised in EIA projects within the oil and gas sector of Nigeria are listed below.

1. Having the information on the nature of oil spill disasters, both marine and on-land, it's recommended that a GIS system is set up in organisations charged with the responsibility of overseeing oil and gas exploration activities in the region. This would prove to an efficient tool for collating such events and presenting the data in a proper and effective manner (such as the use of maps and reports) to decision makers. This would assist policy makers and stakeholders in decision making thereby enabling the implementation of necessary policies that would assist in alleviating the burden of devastated ecosystem in the Ogoniland.

2. Studies have noted that an accurate knowledge of the spatial extent and distribution of oil spill is vital to a successful implementation of an efficient response system. Given the nature of the study area, which is dominated by a network of brackish water creeks, mangrove swamps and pockets of island forests, marine oil spills is a major concern. Over the years, remotely sensed data and ground verification data have been used for estimating the extent of oil spills in marine environments (Topouzelis, 2008). Hence, there is need to have satellite or airborne imagery of the affected sites under short notice. With this in mind, it's recommended that collaboration between monitoring agencies such as NDDC and image providers such as the National Space Agency of Nigeria (NASDRA) be made. With the availability of medium and high resoluton satellite data provided by the Nigeria Space Agency – NASRDA (National Space Research and Development Agency - www.nasrda.gov.ng) a proper monitoring system for oil spill detection and response can become a reality. This component shall form part of a further reaserch.

3. Atmospheric remote sensing provides data to analyse the air quality over large areas simultaniously per time (Duncan et al., 2014) and may serve as a tool to estimate atmospheric impacts of spill. This information may be incorporated into the GIS thus creating a total EIA which could account for atmospheric pollution resulting from oil spills.

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