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RESEARCH ARTICLE

ENVIRONMENTAL SENSITIVITY INDEX MAPPING OF STAINLESS STEEL CORROSION IN NDONI RIVER, AHOADA RIVER, NEW CALABAR RIVER, TOMBIA RIVER, BUGUMA RIVER AND BONNY ESTUARY

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ABSTRACT

Environmental sensitivity index corrosion mapping of Ndoni river, Ahoada river, New Calabar river, Tombia river, Buguma river and Bonny estuary was carried out with the aim of developing an environmental analysis index corrosion map of the shorelines as well as corrosion rates of the different shores comprising of fresh water, brackish water and estuarine environment. Methods developed by National Oceanic and Atmospheric Administration (NOAA) and Nigerian oil Producing Trade Sector (OPTS) was useful in this study.8 ESI types were found in the area which includes 1b, 3a, 4a, 6b, 9b, 9c, 10a and 10b.Animal biodiversities prominent in these shores include Sea turtle, White crab, Shorebirds, Crocodile, Iguana, Snail, Toad, Frog, Millipede, Earthworm, Tilapia and Jellyfish. The relationship between number of socioeconomic features and biological species along the shores using Spearman's correlation coefficient (r) value is 0.93. The corrosion rates of the metal coupons in the various shores of Ndoni river, Ahoada river, New Calabar river, Tombia river, Buguma river and Bonny estuary is 0.053g, 0.059g, 0.109g, 0.125g, 1.630g and 2.680g respectively. The results from this study can serve as a good decision support program for environmental managers because it can provide information on socio-cultural and corrosion rates of the environment.

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INTRODUCTION

Environmental sensitivity index mapping (ESI) is a rapid objective and straight forward method of identifying areas which may be particularly sensitive to development based on environmental and cultural assets present (NOAA, 2008). Environmental sensitivity index mapping is used in land-use planning for minerals and other forms of development. It may be used both to aid and explain decision making in consultation process. It can form part of the strategic environmental assessment process for aggregate provision (Guam, 2006). ESI maps are used to identify sensitive shoreline resources prior to an oil spill event in order to set priorities for protection and plan clean up strategies (ESI map 2010, NOAA 2010). ESI map provides a strategic overview of the environmental and cultural assets in a region. The mapping technique integrates numerous datasets into a simple composite layer in a geographical information system (GIS).
In the event of an oil spill incident, ESI maps contain three types of information. Shoreline habitats; these are classified by rank depending on how easy the garet would be to cleanup, how long the oil would persist, and how sensitive the shoreline is (Gundlach and Hayes, 1978). In 1995, the U.S National Oceanic and Atmospheric Administration extended ESI maps to lakes, rivers and estuary shorelines (NOAA, 2002). The exposure the shoreline has to wave energy and tide, substrate type and slope of the shoreline are also taken into account in addition to biological productivity and sensitivity. The productivity of the shoreline habitat is also taken into account when determining ESI ranking (NOAA, 2008). Mangroves and marshes tend to have higher ESI ranking due to the potentially long lasting and damaging effects of both oil contamination and clean up actions. Impermeable and exposed surfaces with high wave action are ranked lower due to the reflecting waves keeping oil from coming onshore and the speed at which natural processes will remove the oil. Biological resources; habitats of plants and animals that may be at risk from oil spills are referred to as "elements" and are divided by functional groups. Further classification divides each element into species groups with similar life histories and behaviors relative to their vulnerability to oil spill. There are eight element groups: Birds, Reptiles, Amphibians, Fish, Invertebrates, Habitats and Plants, Wetlands, Marine Mammals and Terrestrial Mammals. Element groups are further divided into sub groups for

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example the" marine mammals" element group is divided into Dolphins, Manatees, Pinnipeds (Seals, Sea lions and Walruses), Polar bear, Sea otters and Whales. Problems taken into consideration when ranking biological resources include the observance of a large number of individual in a small area whether special life stages occur ashore (nesting or molting), and whether there are species present that are threatened, endangered or rare (IMO/IPIECA, 1994). Human use resources ; are divided into four classifications; archeological importance or cultural resource site, high use recreational areas or shoreline access points, important protected popular beach sites, Marinas, natural reserves or Marine sanctuaries. The need for environmental sensitivity index corrosion mapping arose due to corrosion of metals used in conveying oil and its products which has led to spillages of various forms in the Niger Delta giving rise to oil pollution affecting the ecosystem of the areas (Odokuma and Williams 2010, Akpabio *et al*., 2011, Belmonte *et al*., 2009). Oil pollution which could be resulting from corroding facilities in these areas has been so unremitting that repeated loss of lives and ecological devastation has been recorded (Oyedepo and Adeofun, 2011). Since environmental/ecological degradation from oil spill results in gradual erosion of biodiversity pools and species, which forms the basis for the survival of the human species, prevention of this kind of disaster via rapid and precise response action is not negotiable (Fabiyi 2002, Gundlach *et al*., 2001).

Comprehensive information on the sensitivity levels of each category of a susceptible environment is an important requirement for effective oil spill disaster management. Regrettably, the ESI corrosion document that could support the development of good robust oil spill contingency plan for the study areas are not available. In Nigeria ESI mapping began (Gundlach *et a*l., 1981) as attempt by oil and gas operators to characterize the environment in their respective areas of operation by providing detailed and consistent sources of information as a critical tool in oil spill response. Although nuances exist between versions of sensitivity maps from zone to zone, the basic principles of the mapping have remained constant. This paper is a Nigerian example of ESI calculation. The paper adopted a modified Oil Producing Trade Sector Protocol (OPTS, 2001) and National Oceanic Atmospheric Administration (NOAA, 1996) methodology respectively for ESI corrosion mapping of study area. A new technique for validating shoreline sensitivity was added in Margalef's specie richness computation. Metal coupons namely stainless steel was buried in these shoreline study areas susceptible to corrosion and spillage so that we could access how biological and human use resources impact on the pipelines carrying the oil products in the Niger Delta.

MATERIALS AND METHODS

- The field site logistic plan was developed to determine among other things; the primary spatial data which include: a count of plants and animal species, soil/substrate and socioeconomic features during field work. Also types of primary data to be collected, location of data collection and data size.
- The metal coupons namely stainless steel was buried in the various shorelines and corrosion monitored by average weight loss of metal coupons at monthly intervals and the shorelines with the highest corrosion rates per year in each of the locations were used to develop the ESI corrosion map plot.
- Stations were created at intervals of 400 meters along the coastlines namely from left to right Ndoni river, Ahoada river, New Calabar river Tombia river, Buguma river and Bonny estuary respectively. In-situ data such as substrate type, shore slope, exposure to wave energy, number of flora and fauna species present and socio economic features present were collected. Geographical coordinates of all features and points of interest were taken with the aid of a hand held GPS device. The in-situ data gathered were used to build up a data base for the shorelines on the updated Digital Base Map (UDBM) to derive level 1 GIS map modified into ESI map after including biological and socio-economic features as point symbols on the map then copied into Google map.

Results of rapid assessment (field notes and observations) along the shorelines were compared with the standard ESI look up table prepared for Nigerian Shoreline by the OPTS for validation.

Statistical Analysis

The relationship between shoreline biological productivity, human influence via the number of socioeconomic features were measured using Spearman's rank correlation thus

$$r = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)}$$

Where n is the number of observation and d is the difference between the ranked variables.

Rules for Sensitivity Determination

Although there is yet to be a unified yard stick for shoreline categorization in Nigeria, the Oil Producing Trade Sector (OPTS) in Nigeria have adopted some rules which have been adopted in this study for determining the sensitivity rank of particular shoreline. Table1 is the standard ESI validation table with which to compare the results of rapid assessment along the shoreline. In Nigeria what qualifies a shoreline as an ESI type is tabled out clearly.

In this paper, the distributions of biological features encountered along the shoreline were used to ascribe sensitivity values to the shores according to their richness in biodiversity. This was achieved using Margalef's species richness.

$Da = S^{-1}/\log N$.

Where S equals the number of species and N equals total number of individual sampled.

RESULTS

Figure1 below is the map of study area namely from left to right is Ndoni River, Ahoada River, New Calabar River, Tombia River, Buguma River and Bonny Estuary.

Table 1. Standard ESI validation table for shorelines

ESI	Shore Type	Dominant sediment type and slope	Slope	Exposure
1a	Exposed rocky shores or banks	Rocky = boulders (>256mm) Banks = marked by scarping, clay (<0.625mm) are common	Moderate-high	Moderate-High
1b	Exposed sea walls and solid man- Made structures	Vary from Boulders and cobbles (>64 mm) to sand bags, solid concrete, sheet pile or wood	Moderate-high	Moderate-High
2a	Unvegetated/Eroding bank	Silt and Clay (<0.0625 mm)	Very low slope	Moderate
2b	Exposed wave-cut platform	Bedrock or boulders (>256mm)	By bluff or cliff	Moderate-High
2c	Rocky shoals, bedrock ledges	Bedrock or boulders (>256mm)	Low slope	Moderate-High
3a	3a Fine sand beach	Fine sand (0.0625-2.0mm)	Low slope, ($<5^0$)	Low-High
3b	3b Scarps or steep slope in sand	Sand = 0.0625-2.0mm	Marked by scarp Or steep slope	Moderate-High
4a	Medium to coarse sand beach	Grain size =0.25-2.0mm	Low to moderate	Moderate-High
5	Mixed sand and gravel beach, bar or bank	Grain size =1-64mm	Low to moderate	Moderate-High
6a	Gravel beach or bar	Grain size <2mm, moderate	Steep slope ($10-20^0$)	Moderate-High
6b	Riprap	Boulders (<256mm)	Moderate to steep	Moderate-High
7	Exposed tidal flat	Coarse sand-mud (<2mm)	Low slope (3^0)	Low-Moderate
8a	Vegetative steeply sloping bluff	Soil (sand-mud) (<1mm), boulders (>256mm)	Moderate to steep slope ($>15^0$)	Low
8b	Sheltered Riprap	Boulders (>256mm)	Moderate to steep Slope ($>20^0$)	
8c	Sheltered rocky shore or scarp	Bed rock or boulders (>256mm)	Moderate to steep Slope ($>15^0$)	Low
9a	Sheltered tidal flat or sand mud	Medium sand-mud (<0.5mm)	Low slope (3^0)	Low
9b	Vegetated low banks	Soils (sand to mud (1mm)	Low to moderate Slope (20^0)	Low
10a	Mangrove Nympa palm	Mud (0.625mm) vegetation will Indicate shore type	Low slope (3^0)	Low
10b	Brackish/ Fresh water swamp		Low slope (3^0)	Low
10c	Marsh		Low slope (3^0)	Low

Source OPTS (2001).

Table 2. Rules for assigning sensitivity values to habitats based on species Richness and Species Diversity

Score Range	Points to be Assigned	Remarks on Value
If score is 0	Assign no point	No sensitivity
If score is > 0 - 0.5	Assign 1 point	Very low sensitivity
If score is 0.51 - 1.0	Assign 3 points	Very low sensitivity
If score is 1.1-2.0	Assign 4 points	Low sensitivity
If score is 2.1-4.0	Assign 6 points	Moderate sensitive
If score is 4.1-6	Assign 7 points	High sensitivity
If score is 6.1-8.0	Assign8 points	High sensitivity
If score is 8.0->10	Assign 10 points	Very high sensitivity

Table 3.

Shore location	Dominant substrate type (mm)	Shore description	Slope	Exposure to wave energy
Ndoni (Imonita)	Solid concrete	Sea wall/Structures	0.83	Moderate
" (Utuechi)	Grain size 0.25-2.0	Mangrove	0.22	Low
" (Aseazaga)	"	Medium to coarse sand beach	0.17	High
" (Ogbegene)	Fine sand beach	Fine sand beach	0.14	Moderate
" (Onuiku)	Sandy loam soil (0.0625-0.25)	Sheltered vegetative low bank	0.24	Low
Ahoada F (East)	Sandy loam soil (0.0625-0.25)	sheltered vegetative low banks	0.18	Moderate
" F (West)	Fine sand (0.0625-0.25)	Fine sandy beach	0.13	High
" F (North)	Grain size 0.25-2.0	Mangrove	0.14	Low
" F (South)	Sandy loam soil (0.0625-0.25)	Sheltered vegetative low banks	0.18	Moderate
" (Central)	Solid concrete	Seawall/Structures	-	Moderate
NCR F (Choba)	Sand mud (< 0.0625)	Brackish/Freshwater	-	-
" (Emuoha)	" "	-	-	
" (Aluu)	Grain size 0.25-2.0	Mangrove	0.15	Low
" (Ogbogoro)	Sandy loamy soil (0.0625-0.25)	Sheltered vegetative low bank	0.20	Low
" (Ahia oha)	"	"	0.17	Low
Tombia F (East)	Sand mud (< 0.0625)	Brackish/Freshwater	-	-
" " (West)	"	"	-	-
" " (North)	"	"	-	-
" " (South)	Grain size 0.25-2.0	Mangrove	0.18	Moderate
" (Central)	Sandy loam soil (0.0625-0.25)	Huts along shore line	0.18	Low
Buguma (Northeast)	Sand mud (< 0.0625)	Brackish/Freshwater	-	-
" (Horse fall Ama)	"	"	-	-
" F (West)	Boulders	Riprap	0.85	Very High
" F (South)	"	"		" "
" (Central)	"	"	"	"
Bonny F (Enyamba)	Boulders	Riprap	0.92	Very High
" " (Oputambi)	"	"	0.88	"
" " (Peterside)	"	"	0.92	"
" " (South)	"	"	0.92	"
" (Central)	Solid concretes	Seawall/Structures	0.88	"

Source: Gundlach *et al*., 2001. NCR: New Calabar River. F: facing.

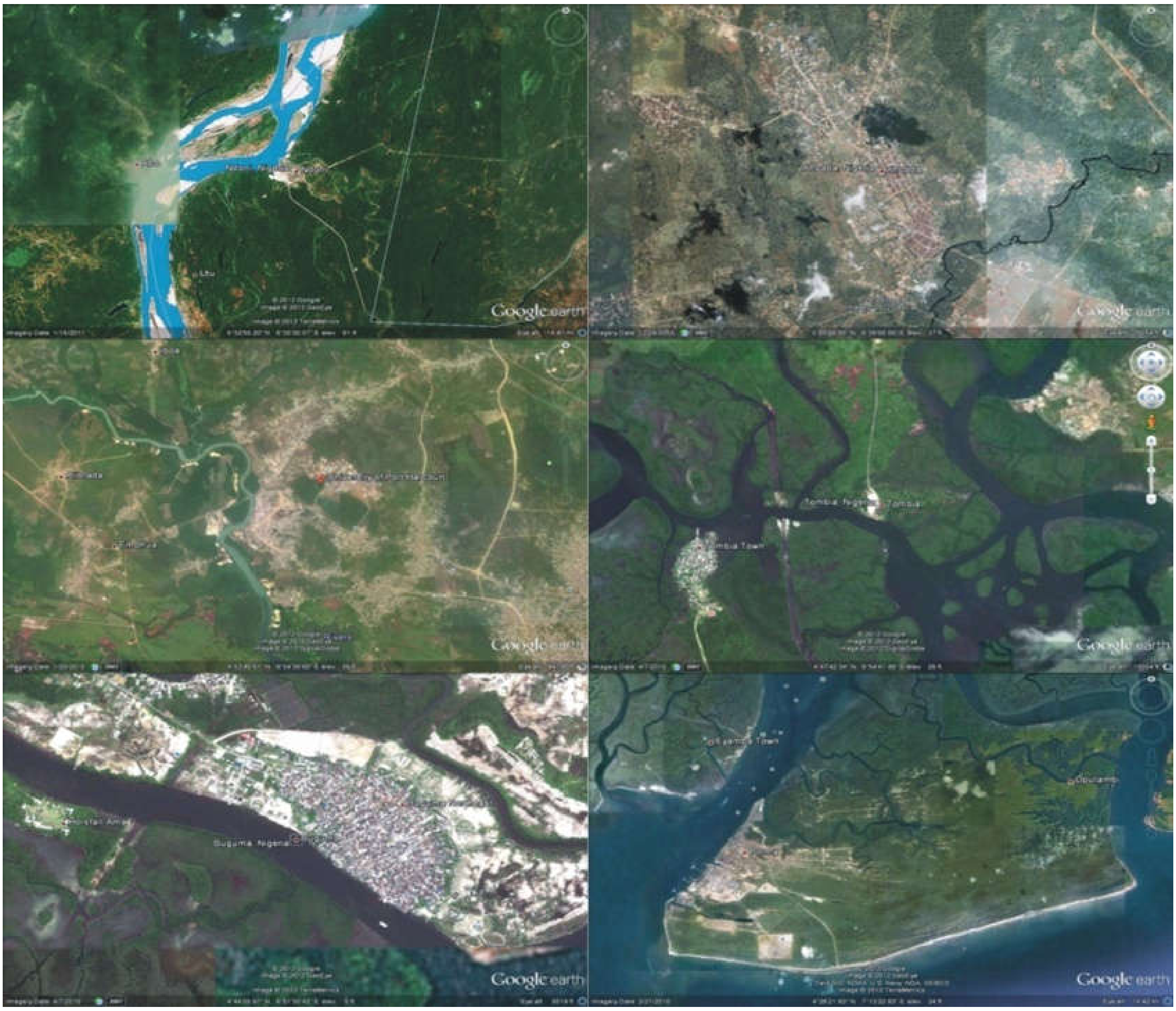

Figure 1. is the result of physiographic characteristics of the shorelines in Ndoni River, Ahoada River, New Calabar River, Tombia River, Buguma River and Bonny Estuary

Table 4. below represents the shoreline by category

ESI type	Shore types	Location
1b	Sea walls/Solid manmade structures	Ahoada (Central), Ndoni (Imonita), and Bonny (Central)
3a	Fine Sand beach	Ndoni (Ogbogene), Ahoada (West)
4a	Medium to coarse sand beach	Ndoni (Ogbogene)
6b	Riprap	Buguma (West, Central & South), Bonny (South, Enyamba, Oputambi & Peterside)
9b	Sheltered vegetative low banks	Ndoni (Onuiku), Ahoada F (East, South), NCR F (Ogbogoro, Ahiaoha) Tombia (Central)
9c	Huts or settlements along shoreline	Ndoni (Utuechi), Ahoada F (North), NCR, F (Aluu) & Tombia F (South)
10a	Mangrove/Swamp	NCR F (Choba), Tombia F (East, West, North), Buguma (North East), Horse fall Ama
10b	Brackish/Freshwater swamps	NCR F (Choba), Tombia F (East, West, North), Buguma (North East), Horse fall Ama

NCR: New Calabar River, F: Facing

It shows the potential behavior of oil slick along shores and the ESI types each shoreline belongs. From Ogbogene (Ndoni) to Ahoada (West) the grain size are finer (0.0625-0.25mm) than those of Aseazaga in Ndoni (medium size grain 0.25-2.0mm). Along Imonita (Ndoni) to Buguma (West, Central and South) to Bonny (Enyamba, Oputambi, Peterside and South), heavy quarry rocks were used for shoreline protection and fortification. This is the largest in terms of substrate size (>256mm).With respect to slope and exposure to wave energy, they have the highest. The deepest slope 0.92% was observed in Bonny (Enyamba, Peterside and South). The flattest slope (0.13%) was observed in Ahoada facing (West) with finer substrate size. This trend is typical of the geomorphology Nigerian coastline (Gundlach *et al*., 2001, Nosakhare *et al*., 2004). Note that the shore types in Nigeria are quite different from the ones found in some temperate countries; therefore a slight difference can be seen in the ESI classification in this paper. Table5 shows the distribution of Socio-economic and biological features along the shorelines the richness of each shoreline with respect to biodiversity is shown here. To ascertain this statement, Spearman's rank correlation was used to test the level of association. Figure 2 below is the result of Environmental Sensitivity Index Map of Stainless Steel Corrosion in Ndoni River, Ahoada River, New Calabar River, Tombia River, Buguma River and Bonny Estuary.

Table 5. Biological & Socio-economic features per shore location

Location	ESI type	Number of socio-economic features	Number of species of biota observed
Ndoni (Imonita)	1b	1	10
" (Utuechi)	10a	1	12
" (Aseazaga)	4a	3	11
" (Ogbogene)	3a	1	12
" (Onuiku)	9b	3	10
Ahoada F (East)	9b	2	10
" " (West)	3a	2	11
" " (North)	10a	2	12
" " (South)	9b	3	12
" (Central)	1b	1	10
NCR F (Choba)	10b	-	13
" " (Emuoha)	10b	-	13
" " (Aluu)	10a	1	14
" " (ogbogoro)	9b	2	13
" " (Ahia oha)	9b	1	13
Tombia F (East)	10b	1	13
" " (West)	10b	2	14
" " (North)	10b	2	19
" " (South)	10a	1	17
" (Central)	9c	-	19
Buguma (North East)	10b	2	24
" (Horse fall Ama)	10b	2	22
" F (West)	6b	1	24
" F (South)	6b	-	24
" (Central)	6b	-	21
Bonny F (Enyamba)	6b	1	25
" " (Oputuambi)	6b	1	25
" " (Peterside)	6b	-	29
" " (South)	6b	-	27
" (Central)	1b	-	25

NCR: New Calabar River; F: Facing

Table 6. Sensitivity of shoreline with respect to specie richness

Location	Number of biota	($Da = S^{-1}/\log N$)	Score	Sensitivity
Ndoni (Imonita)	10	2.000000000	4	Low sensitivity
" (Utuechi)	12	2.073371592	4	"
" (Aseazaga)	11	2.039747432	4	"
" (Ogbogene)	12	2.073371592	4	"
" (Onuiku)	10	2.000000000	4	"
Ahoada F (East)	10	2.000000000	4	"
" " (West)	11	2.039747432	4	"
" " (North)	12	2.073371592	4	"
" " (South)	12	2.073371592	4	"
" (Central)	10	2.000000000	4	"
NCR F (Choba)	13	3.102288282	6	Moderate sensitive
" " (Emuoha)	13	3.102288282	6	"
" " (Aluu)	14	3.12749713	6	"
" " (ogbogoro)	13	3.102288282	6	"
" " (Ahia oha)	13	3.102288282	6	"
Tombia F (East)	13	3.102288282	6	"
" " (West)	14	3.12749713	6	"
" " (North)	19	3.217988517	6	"
" " (South)	17	3.187288491	6	"
" (Central)	19	3.217988517	6	"
Buguma (North East)	24	3.275473225	6	"
" (Horse fall Ama)	22	3.25507814	6	"
" F (West)	24	3.275473225	6	"
" F (South)	24	3.275473225	6	"
" (Central)	22	3.25507814	6	"
Bonny F (Enyamba)	25	4.284661721	7	"
" " (Oputuambi)	25	4.284661721	7	"
" " (Peterside)	29	4.316191624	7	"
" " (South)	27	4.301365575	7	"
" (Central)	25	4.284661721	7	"

NCR: New Calabar River F: Facing

Figure 3 below is the Stainless Steel section corrosion rate. Here we can see that corrosion rates increased from Ndoni River to Bonny estuary. We can say that the corrosion rates were higher in Bonny estuary than the brackish water Rivers namely New Calabar, Tombia and Buguma respectively. Corrosion rates were least in the fresh water Rivers namely Ndoni and Ahoada. Figure4 below is the Environmental Sensitivity Index Map of the study areas.

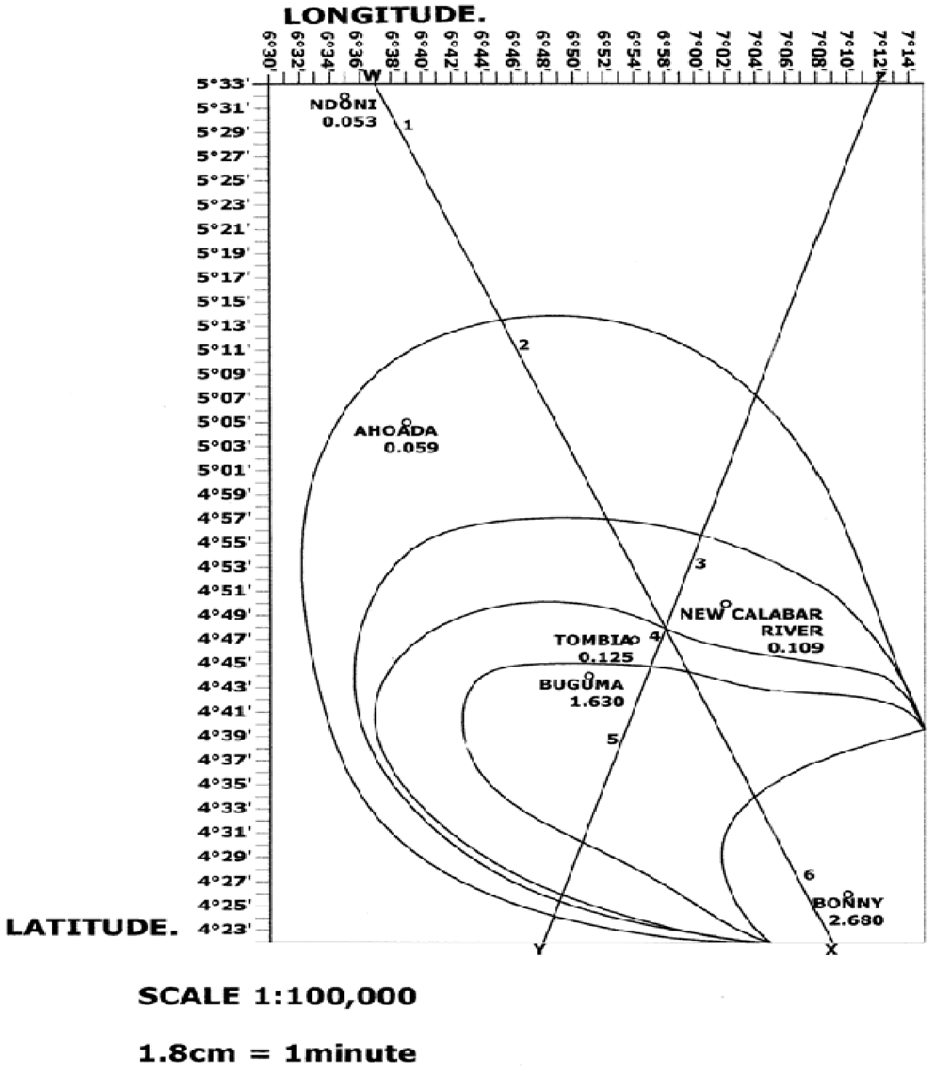

Figure 2. Environmental Sensitivity Index Map of Stainless Steel Corrosion in Study Area

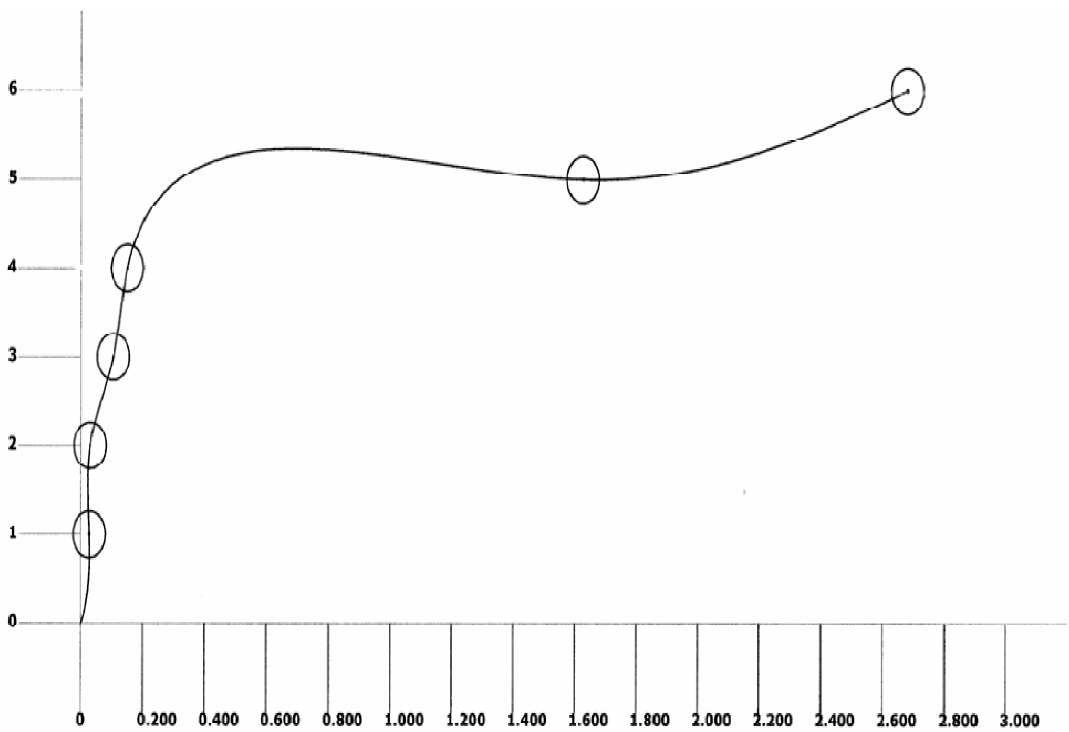

Figure 3. Stainless Steel Section Corrosion Rate

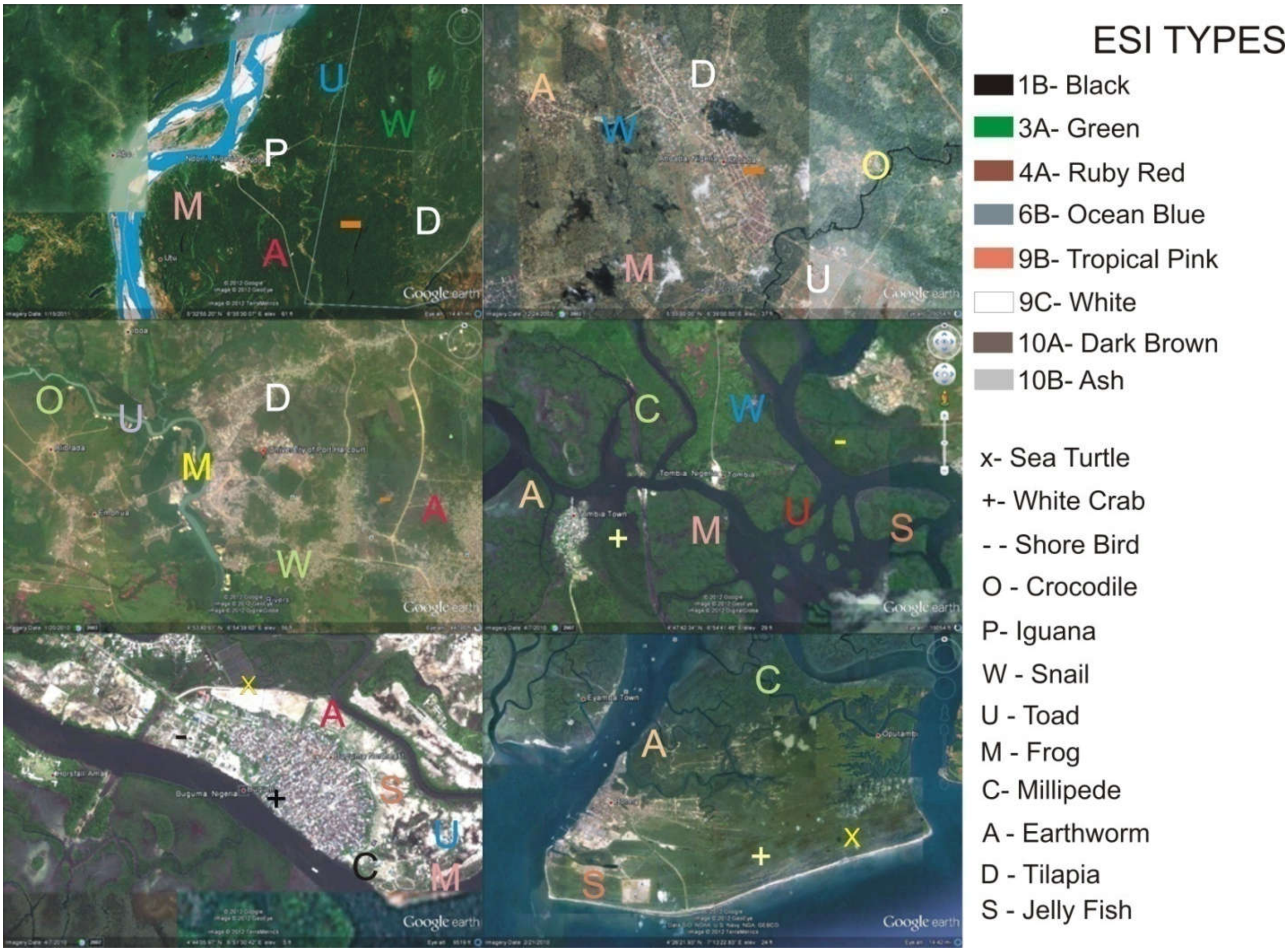

Figure 4.

DISCUSSION

Simplifying the ambiguous nature of shorelines into biodiversity distribution pattern and shore types alone will generate a simple trend and the underlying assessment becomes very proactive. A lot of importance is always attached to individual issues in ESI mapping, the need to look at physical attributes of each shoreline and the metal coupon namely stainless steel buried on the study area. This will guide in prediction of behavior of oil and best clean-up method as well as areas more prone to corrosion which could lead to oil spill in these Niger Delta shoreline. The mangrove and brackish water swamp ranked highest with score of 10a and 10b respectively. Studies by Gundlach et al., (2001) in the Niger Delta agree that mangrove and wetlands are the most sensitive in terms of oil spill on biodiversity in shoreline. Several life forms will be affected since oiling impact heavily on these areas and pose difficulty in cleaning. From the study the mangrove and the wetlands have low exposure to wave energy similar to the study by Oyedepo and Adeofun, (2011). Since the slopes are not steep, oil will get onto them with slight increase in tidal wave. Most pipes carrying oil pass through these mangroves and are exposed to bio-corrosion as well as vandals breaking these pipes for economic and financial gains at the detriment of the ecosystem and the economy .It will be an understatement to say that this will be a threat to the ecosystem because the vegetation will stick and trap oil and if not immediately removed, may smoother and kill the animals.

The use of vacuum low pressure flushing and containment should be considered. Sheltered vegetative low banks were found along the banks of Ndoni River, Ahoada River and New Calabar River. These were predominantly filled with terrestrial trees. Oil spillage occurring due to corrosion of the pipe lines conveying oil or any other cause, will lead to oil sticking to vegetation along the waterlines. They may be very high level of accumulation along shore lines. In case of oil spillage occurring, all free oil must be removed by vacuum or low pressure flushing. If the vegetation is heavily accumulated with oil, it may be necessary to remove them. Ripraps as seen in Buguma River and Bonny Estuary are highly exposed to wave energy. In the case of Bonny Estuary the influence of Atlantic Ocean makes the wave energy very high. Oil can sip between the boulders especially where the riprap is located along the waterline. Asphalt deposits resulting from serious leaching caused by oil sticking to surfaces of boulders may occur. If there is spillage and the oil is fresh and liquid, high pressure spraying and or water flooding can be used, making sure that all the released oil is recovered. Hot water spraying and or scraping may be used where the oil has weathered and seems heavy. Replacement of densely oiled Riprap becomes necessary if the oiling has gone out of control. The fine sand beach and medium to coarse sand beach found in Ndoni and Ahoada Rivers could be accreting in nature. In case of oil spillage due to corroding pipes or other factors, Oyedepo and Adeofun (2011), noted that oil will most likely concentrate in bands along sandy beaches.

Maximum penetration of oil into fine grain sand will be less than 15cm while penetration into coarse grain sand can reach 25cm and burial of oiled layers by clean sand within the first few weeks after the spill will be limited usually to less than 30cm whereas burial up to 60cm on coarse grain is possible. If the oil is stranded on shore at the beginning of an accretion period, such as wave, the deepest burial will occur but much of the oil will be removed during the next wave. Heavy accumulation of residual oil can form tar mats. Impact on biota will likely be low unless the beaches are used for foraging and nesting. The beaches are always in use by people living in the mainland; cleanup must be done with care. Use of heavy equipment for oil removal could impact on the shores and sand removal could lead to erosion. Preferably, manual cleanup is recommended. Corrosion of metal used to transport oil especially stainless steel leading to spillages across the Niger Delta cannot be over emphasized. Lots of work done by different people including Jaganathan *et al*., (2011), Rybalka *et al*., (2006), Sidorin *et al*., (2005) showed that stainless steel is more resistant to corrosion than other metals. In this study from the sensitivity of shoreline with respect to specie richness, we can see that the score and sensitivity of Margalef's specie richness increased in accordance with corrosion rate of stainless steel coupons buried from Ndoni River via Ahoada River, New Calabar River, Tombia River, Buguma River and Bonny Estuary respectively.

From corrosion rates of stainless steel, Ndoni and Ahoada Rivers had values of 0.053g and 0.059g respectively being fresh water. New Calabar River, Tombia River and Buguma River had values of 0.109g, 0.125g, 1.630g respectively being brackish water. Bonny Estuary had value of 2.680g. From these data, we can see that Ndoni and Ahoada Rivers had lower corrosion rates as well as score of 4 and low sensitivity from Margalef's specie richness in table4 while New Calabar River, Tombia River and Buguma River had moderate corrosion and score of 6 as well as moderate sensitivity from Margalef's specie richness. Bonny Estuary had the highest corrosion rate as well as score of 7 with the highest sensitivity from Margalef's species richness. This could imply that corrosion rates of the stainless steel coupons are proportional to the Margalef's specie richness in score and sensitivity. This also implies that corrosion rates and specie richness in score and sensitivity were lowest in the freshwater followed by the brackish water areas and highest in the estuarine. This may be attributed to the higher proliferation of Sulfur Reducing Bacteria especially in estuarine and brackish water environments than in the freshwater areas in respect to bio-corrosion. This gives an insight that more spillages are likely to occur in these areas with higher corrosion rates. According to Moller *et al*., (2003), West Africa where Nigeria is a big coastal nation, has a very low level of preparedness in combating oil pollution. The score Nigeria (-1) showing that the level of risk outweighs that of preparedness.

Conclusion

The environmental sensitivity index mapping of stainless steel corrosion will provide more information to managers or agencies whose duties is to protect Nigeria shorelines especially that of the Niger Delta areas. This can also serve as a guide when venturing into the Niger Delta shorelines. From the finding of this study, response agencies like National oil Spill Detection and Response Agency (NOSDRA), National Emergency Management Agency (NEMA), Nigeria Environmental Study Team (NEST) and Department of Petroleum Resources in conjunction with the Federal government as a matter of urgency undertake research that will develop very high profile potent biocides that can be used to contain biofilms without necessarily endangering the environment thereby minimizing corrosion rates of pipes used to in conveying oil in these regions so that spillages can be curtailed to the barest minimum. The ESI map when looked into very well could be used in areas such as coastal resource inventory / assessment, Environmental risk assessment, Coastal and Recreational Planning, Environmental Impact Assessment and Base Environmental Studies.

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