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ENVIRONMENTAL SENSITIVITY INDEX TO OIL SPILL IN THE NIGER DELTA USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS

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ABSTRACT:

The study assessed oil pollution in Nigeria which are situated between Longitudes 6° 40' 0'' E and 7° 0' 0'' E and Latitudes 4° 20' 0'' N to 4° 40' 0'' N. The aim of the work was environmental sensitivity index to oil spill in the Niger Delta. Sunsequently, the materials contain LandSat ETM 7 + imagery with spatial resolution of 30 metres and dominance soil map of Nigeria. ENVI 4.5 software was utilized to extract shafe file for the various land use and imported to ArcGIS 10.7

for mapping exercise. Remote sensing and GIS techniques were bought in to analysed the soil map and vegetation indices. The result showed 9645.660ha of oil spill from the classification analysis and 98% confident interval.

1. Introduction

According to Opukri and Ibaba (2008), human activities and oil exploration in the Niger Delta region have caused several depletion-related problems. Biodiversity loss, coastal and riverbank erosion, flooding, oil spills, gas burning, noise pollution, sewage and sewage pollution, land degradation, and loss of soil fertility all affect the population of the Niger Delta region. It is a major environmental problem in the region because it is toxic (Gabriel, 2004). Oil spills are perhaps the most significant environmental impact of oil exploration and represent the industry's greatest environmental hazard. Oil spills are the release of liquid petroleum hydrocarbons into the environment (Gunel, 2004). This is a form of pollution from some oil exploration activities. Oil spills have become a topic of global debate, including concerns about how it affects the environment and the people living in that environment.

Some researchers report that the Niger Delta region of Nigeria is Africa's largest wetland and has a highly diverse ecosystem supporting a myriad of terrestrial and aquatic plant and animal species (Kadafa, 2012a). The level of pollutant emissions to the environment in the form of oil spills causes serious environmental problems and has significant and long-term impacts on the environment, ecosystems, and socio-economic livelihoods of the affected areas. (Eregha and Irughe, 2009; Singh and Lynn, 2008a).

Oil spill clean-up has become a critical issue not only for the major oil companies involved in oil production, but also for the federal government and communities in the Niger Delta directly affected by oil spills. Upon this background, this study seeks to investigate the causes and physical impact of oil spill in Asari-Toru Local Government Area of Rivers State, in the Niger Delta Region using Geographic Information System (GIS).

2. Study Area

The study area comprises the three Local Government Areas in Kalabari County, namely Asari-Toru, Degema, and Akuku-Toru, which are situated between Longitudes 6° 40' 0'' E and 7° 0' 0'' E and Latitudes 4° 20' 0'' N to 4° 40' 0'' N (Fig. 1.1).). Degema local government was established on May 27, 1967 and includes all Karabari-speaking communities. According to the census (2006), the population of the region is estimated at 249,773, the definition of land is a parametric measure, and its area is equivalent to 1,011 km². The headquarters of the Degema Local Government Area is Degema Town, which is listed in the Rivers State Government White Paper. Degema is the name of a clan that includes Usokun Degema and Degema City.

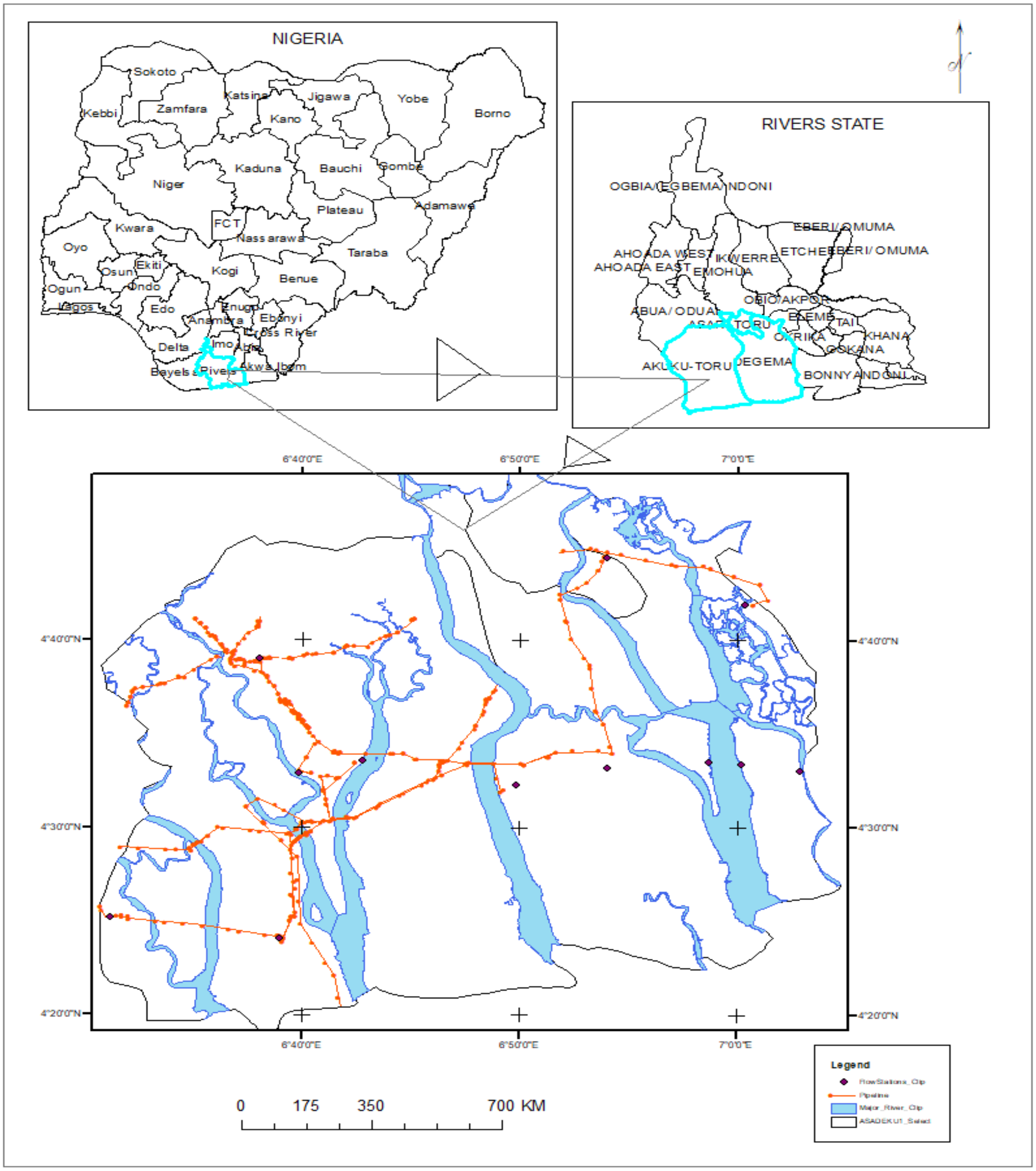

Fig. 1.1: Map of the Study Area

3. Literature Review

Oxford Advanced Learner's Dictionary (2000), defined sensitivity is the ability of an organism to respond to external stimili, that can be seen as a strong influence or effect resulting to a cause.

Primitive of this study is to outline the insight of all literature concerning the resultant effects of oil spillage. Studies on crude oil spillage have been carried out on small-scale farming and subsistence scale in the nine (9) Niger Delta States. Cropping patterns identified were mainly sole, mixed and intercropping. Low agricultural output was noticed within the environs of the Delta. This is mainly due to humongous oil pollution which reduced the quality of the soil fertility whereby rendering productive agricultural lands to wastelands. On the other side, peasants are cascading to abandon their land and looking for alternative means of self-sustainability. Hunger and poverty became the order of the day as a result of aquatic life and fishing grounds destructibility of spill. Traditionally, rural dwellers are fishermen who depend totally on the marine sector for virtually everything in life possession (Odjuvwuerhie et al., 2006; Olayemi, 1998). In a related study, researchers reported that oil spills have done massive destruction to the host of the plant kingdom because of greater retention time and reduced flow rate. The process by which air is circulated through or mixed with a substance such as soil or water is blocked by oil spillage. Nevertheless, it also alters the physio-chemistry of the soil reactivity namely temperature, structure, nutrients, acidity and alkalinity of the soil. Crops like pepper and tomatoes die off immediately, it was noticed to be lack photosynthesis, transpiration and respiration (Chindah & Braide, 2000; Anoliefo & Vwioko, 1994).

Okoli and Orinya (2013) further conducted oil spillage incidence in Nigeria within some specified years. Reports show that oil spills increase daily in Nigeria and these activities put the nascent economy at risks thereby creating environmental degradation, unusual pressure on the land, vegetation and habitation within the circle of influence. In analysing the impact factors, shorelines of Barrow Island Terminal were a direct victim of an oil spill, where a vessel carrying a condensate Crude oil spilt the water body by the accidental grounding of a tanker by an adjacent coral reef. The spill was measured at 1.97 x 10-4 per year, triggering simulation in the atmosphere resulting in the release of volatile aromatic compounds including the subsea. The situation also noticed dissolved high remnants of hydrocarbon in the sea intertwined with wave energy at Gorgon lasted for three days without proportionate evaporation. The study presented stochastic modelling to indicate the types of hydrocarbon from Barrow Island, Lowendal Islands and Montebello Islands were within the range of 2.5 x 10^{-1} and 9.9 x 10^{-1} incident of occurrence and forecasted the risks of the shoreline (French, 2000a; EPA, 2001; French et al., 2001).

Spill incidence could also be traced back to August 1983, Crude oil spilt at Oshika Community in Rivers State to a tone of 5,000 barrels from Ebocha –Brass official is known as Ogada-Brass 24 inches pipeline vegetated with swamp forest and lake, in her previous experienced, 500 barrels of spills in 1979 killed crabs, fish, shrimp and after a good number of Months, the fetus of the shrimp impair to their developmental stages (Gabriel, 2004; Anochie & Onyinye, 2015). Makinde and Tologbonse (2017) in a bit to conclude the state of the study of the spill and its impact within the limited space of the Ijeododo region of Lagos State visualized the presence of spilling heavy metals. The impacts of the spill were not only felt by the environment but the canopy coverage of the area, human beings, and the animal was seen dead during field investigation and called for urgent, effective recovery management team process that will reposition the country. Theory of assessment exposed that if the spill is not vigorously checked, it may jeopardize the ecosystem in Nigeria.

Subsequently, while estimating the impacts from land, water and soil, the conclusive part of the study revealed devaluation of land use land cover, loss of ancestral home, religious and cultural edifice which are evidence of displacement of the affected persons and family (Niger Delta Environmental Survey, 1997). The threat of oil spill is incomplete without mentioning the socioeconomic impact of the dreaded spill ravaging the economy of the State, and the following institutions were affected such as market and non-market values. Ecological damage is also extended to commercial fishing, loss of revenues from recreational centres which boost the economy of the State. Wetland, natural habitat, wildlife and natural resources experienced set back during the state of the spill and related issues are loss of oil and drinking water consumption (United State Environmental Protection Agency, 2009). Following (Francisco et al., 2010), quoted (Gill & Picou, 1998) observed the strong influence of the spill on populaces and societal disturbance.

Carvalho and Gherardi (2008) mapped the Environmental Sensitivity to Oil Spill and Land Use/Land Cover using Spectrally Transformed Landsat 7 ETM data. The methods used were segmentation, unsupervised classification and principal components to map shoreline information, biological and human-use resources in Potiguar sedimentary basin, Northeast Brazil. Environmental Sensitivity Index (ESI) maps are critical components of oil spill contingency planning because they identify substrates that necessitate specialized clean-up activities and response alternatives while taking ecological, recreational, and commercial issues into account (Halls et al., 1997). These critical areas require remote sensing data to generate sensitivity index mapping for decision making with the aid of computer based supervised classification for proper habitats identification (Green et al., 2000; Jensen et al., 1990; Abdel-Kader et al., 1998).

Gomal et al., (2021) finding a panacea to an oil spill, endorsed Sentinel-1 (S-1) C-band Synthetic Aperture Radar (SAR) data and K-means clustering algorithm methodology in assessing the spatial distribution and impacts of the oil spill along the western coast of Karachi, Pakistan, that kills the local ecology. Researchers in geosciences have a wider scope of sensitivity of the spill, measured, dependability have all been created and used to monitor and identify oil spills (Amir-Heidari et al., 2019; Fingas & Brown, 2018; Marghany, 2019a; Topouzelis, 2008; Vincent & Philip, 2015). In photogrammetry, visual surveys and aerial photography are examples of traditional procedures across a vast region. In addition, using standard ways to monitor oil spills, daily weather conditions provide a significant problem. Remotely sensed data can be utilized as an option to solve these challenges (Marghany, 2019b).

Similarly, Harahsheh et al., (2003) researched the topic “Operational Satellite Monitoring and Detection for Oil Spill in Offshore of United Arab Emirates”. The study is aimed at monitoring an offshore oil spill in the United Arab Emirates (Japan) towards its adjacent waters and it’s impact level. Remote Sensing change detection method was applied in the study to identify the changes in the environment and the materials used conformed with remote sensing.

Runghen et al., (2003) remarkably conducted a study, aimed at conservation and monitoring the state of oil pollution in Mauritius (Southern Africa). The materials and method used include a digital topographic map of Mauritius as a base map for the thematic layer, a handheld Global Positioning System (GPS) receiver with 3m accuracies, ArcGIS TM 9.0, and multi-criteria methodology provided a visual aid to enhance the study. Environmental Sensitivity Index (ESI) was also developed to assist ranking shoreline in GIS environment. Cost distance analysis was carried out in relevance to Shoreline sensitivity. The sensitivity was to map out and present in ascending order with regards to the oil spill in the study area. The results show that exposes cliff had a sensitivity index (SI) of 1 with 2.25%, basalt, beach rock and seawall, (SI) of 2 with 7.38%, expose boulder and cobble beaches, (SI) of 3 with 2.30%, sand beaches, (SI) of 4 with 16.78%, mixed sand and gravel, (SI) of 5 with 5.33%, expose sand flat, (SI) of 6 with 1.43%, sheltered rocky shores, (SI) of 7 with 50.06%, coral reefs, (SI) of 8 with 150km, sheltered tidal flats, (SI) of 9 with 1.31% and marshes and mangroves, (SI) of 10 with 13.08%.

Victor (2010) researched the title “Tracking and predicting oil slicks using remote sensors and models: Sea Princess and Deepwater Horizon Oil Spill case studies”. The study is aimed at identifying oil slicks and their predictions in the Gulf of Mexico (United Kingdom) using Remote Sensing technology. Ships and buoys also provide valuable data, including oil chemical analysis samples, oil concentration versus depth, and local meteorological information, shore-based radars, and other secondary data to fix spill scenarios. Remote sensors on satellites and aircraft also provide some of these data. The study employed a combination of methodologies ranging from Autonomous Underwater Vehicles (AUV), side-scan sonar for the ocean and underwater features including oil plume, remote sensing imageries, aircraft were fully equipped with Side-Looking Airborne Radar (SLAR) and visible, infrared, and ultraviolet sensors deployed flying over the tanker and the oil spill. Result entails dark oil slicks off the coast of Wales near Saint Ann's Head on the Satellite imageries as a backscatter radar energy to the receiver and oil spill areas backscatter recorded less energy to the radar receiver station.

Adesinda et al., (2011) used Remote Sensing and Geographical Information Science (GIS) technologies to solve challenging oil spill in Apapa harbour, Lagos State for proper contingency planning which will be served as a timely and effective response to emergencies. Materials for the study includes GPS coordinates of tank farms and jetties are collected, satellite images, topographic information, administrative map of Apapa Local Government Area, environmental sensitivity map (ESI), street network map and ship route lane. This information imports into ArcGIS 9.3 environment for the creation of environmental sensitivity maps and hazardous analysis. The study resulted in to spill model, which showed risks zonation very high (11.703 %), high (10.773%), moderate (8.140%), and marginal (1.436%).

Tiana et al., (2015) re-evaluated the oil spill scenario within the coastal locale of Fujian Territory of China. The duty of the work centred on the point of perceptibility of oil spill between HJ-1C and Envisat ASAR pictures. The strategy utilized to explore or extricate the spill is called Damping Coefficient is base on SAR escalated picture, and polarization calculation. The result appears a damping proportion of spilt ocean surface shifted from -4.12dB to 7.20dB in L band, C band and X band SAR pictures concurring to the computation in a re-enacted oil spill in SAR picture. The picture moreover uncovers common characteristics like ocean state, shape, area of discharged oil, and separate from the spill occurrence to the coast. This result demonstrates commendable utilizing SAR pictures and HJ-1C SAR information.

Ali et al., (2016) worked on oil spill occurrence in Modern York, the capital City of commercial centre within the marine division. They explored an oil spill and anticipate long run mishaps likely to come across around the Cove. Whereas finding an arrangement to the waiting issue, they considered numerical displaying as a strategy to address contamination things inside the limits of marine transportation. The numerical displaying includes two-direction models, and NOAA operational displaying environment is utilized for surface spread re-enactment, vanishing, and common dissemination. The by-product clearly distinguish wind, current, and discuss temperature, as natural calculate, whereas pronouncing consistency, bubbling point, and specific gravity is the solid weathering poisons rate of loss.

Haiyan et al., (2019) balanced on Recovery of Oil–water blend proportion at Sea Surface utilizing compact Polarimetry Engineered Gap Radar in Beijing, China. The aim at blend proportion of spills on the sea and remediation arranging impacts on natural life. Satellite imagries and vita engineering components were involved.The outcome appears positive to watched in situ information of the blend ratios.

Selvakumar et al., (2017) piloted an oil spill on the biota off Chennai, Southeast coast of India with emphasis on crab using the survey method and laboratory analysis to define the impact level, Peterson et al., (2017) also mentioned the calamity in the Oil and Gas sectors in a global perspective. The impacts of oil spills on benthic living beings may be particularly vital on account of the different biological prepare and environmental capacities that these living beings back. The work, moreover serve as nourishment for living things, air circulation incorporated by human (Mendelssohn et al., 2011).

Schvoerer et al., (2000) displayed examination, questionnaires and telephone interview methods in expounding spill situation in France. Their outcome demonstrated that 7.5% of the people experienced a few sort of wound and 53% a few wellbeing issues of hazard. Oil slicks are produced from the spill and their association with the water surface to form sheen which appears rainbow like in colour. Highly toxic to heavy oil, light oils are less harmful and quickly evaporate. Heavy oil remains too long for years when mixed with pebbles and sandy beaches (Anderson et al., 1993). Oil spills as a result of pipeline vandalism have economic losses which can be measured in a monetary term to Nigeria Government. Nigeria National Petroleum lost one hundred and sixty-five thousand nairas to oil theft and repairs of vandalized pipelines. Ugwuanyi (2013) in his literature reports, mentioned that more than 1.011 trillion nairas have dashed to oil theft which would have been using to better the country.

Baars (2002) assessed the wellbeing hazard for individuals included within the cleaning exercises after the Erika oil spill in France, using the determination method (16 Polyaromatic Hydrocarbon-PAH), additionally for sightseers, with an accentuation on the carcinogenic properties of the oil, on the premise of the known toxicological properties of the oil components and presumptions on the levels of presentation amid the execution of different exercises. In evaluating harmful dangers the genuine presentation levels were compared with restraining values taken from the written composition. Carcinogenic chance of the genuine exposure level was compared with the 1:104 lifetime overabundance hazard of creating tumours. The result has shown that the dangers for the common populace were restricted. For individuals who had been in bare-handed contact with the oil, there was an expanded hazard of creating skin bothering and dermatitis, but these effects were in common reversible, additionally that of creating skin tumours, which was exceptionally restricted due to the brief contact time with the oil.

4. Materials and Method

The Soil data was also acquired from the Office of the Surveyor of Nigeria at the scale of 1:1000, 000 and was used to obtained soil type and composition of the same place. Geometrically rectified medium resolution LandSat imageries covering Asalga, Delga and Akulga environs were acquired from Global Land Cover Facility (GLCF) as part of remote sensing data. The multi-temporal Landsat imagery which has spatial resolution of 30m for 2013 was used for estimating land use and land cover dynamics of the area. Also, the models for Normalized Difference Vegetation indices were used to estimate the influence of oil spill on the vegetal cover using minimum distance algorithm, and the soil map was scanned and georeferenced to WGS 84 projection.

5. Results and Discusion

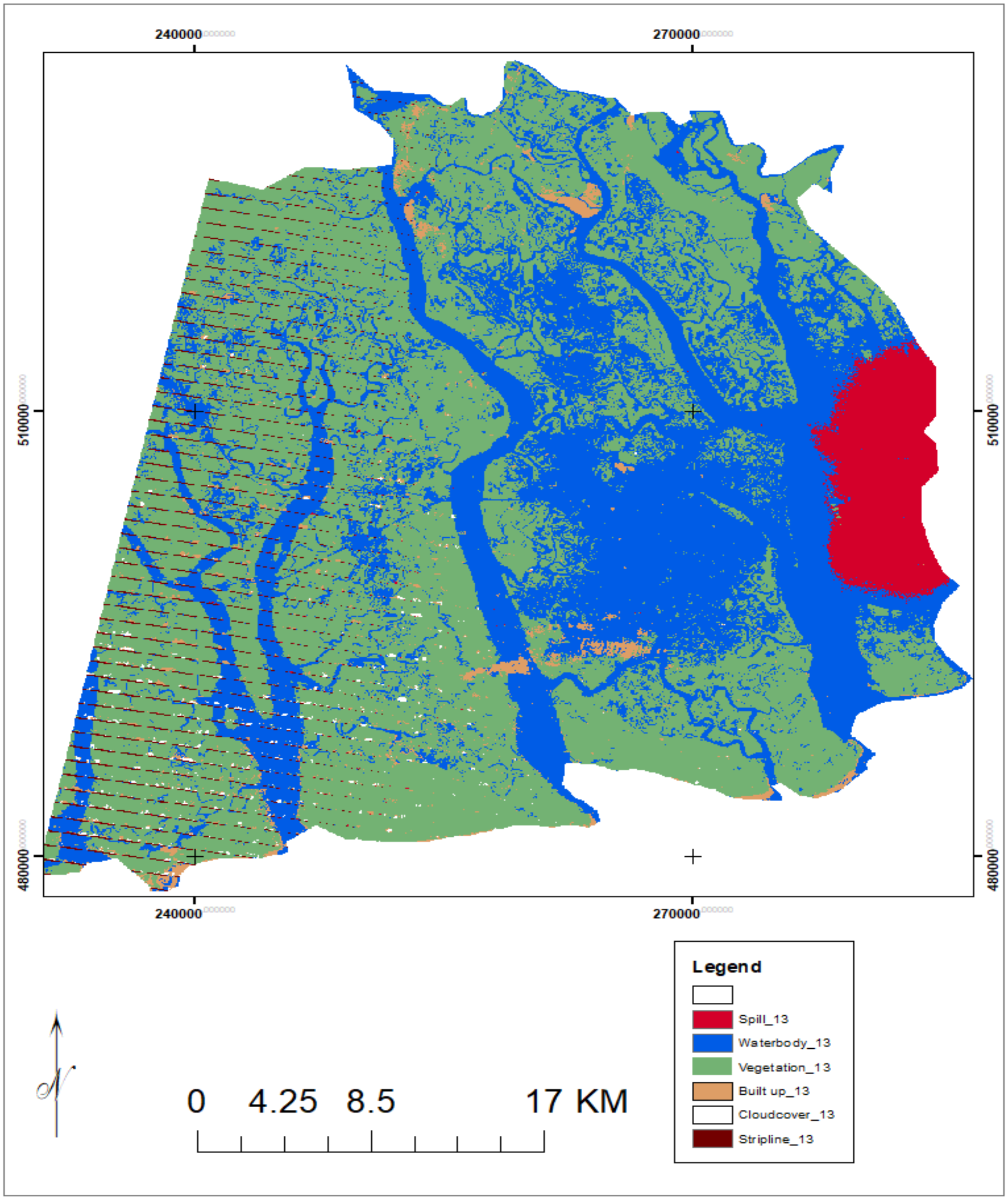

Fig. 5.1: Classified Map of 2013

The classification above is a land use and land cover for 2013 which comprise six categories and are measured in hectares. Spill recorded 9645.660 hectares to produce 3.07% in the land cover division. The spill in 2013 is caused as a result of offshore damage to transportation line in the aquatic environment. The spill which produces oil sheen on the surface of the water in the Degema Local Government of Rivers State flows along the tidal water called Sombrero and affect some communities in the Local Government. Waterbody in the land use and land cover contains 25% with an area value of 78415.290 hectares. Vegetation and built-up also have a significant role to play, 13.14% goes to vegetation while built-up show 0.55% in the classification hierarchy.

5.1 Confusion Matrix for 2013 Classification

The confusion matrix is additionally referred to as error matrix analysis or accurate assessment. The confusion matrix compares two pictures for the aim of accuracy assessment. It's most significantly employed in the post-classification assessment of land cowl classifications derived from remotely perceived knowledge. One image contains the understood land cowl map whereas the second image contains the results of ground truth investigation. From these, the error matrix creates a miscalculation matrix that tabulates the various land cowl categories to that ground truth cells are appointed. In essence, the error matrix is a clone of cross-tabulation with the exception that no tabulations are created for cells marked with a zero on the bottom truth map. Output conjointly includes column and row marginal totals, errors of omission and commission, associate overall error live, confidence intervals for that figure, and an alphabetic Kappa Index of Agreement (KIA), each for all categories and on a per-class basis.

Table 5.1 is the error matrix analysis for 2013 classification for six land use and land cover in the study area. The rows correspond to classes in the ground truth map (or test set) while the columns correspond to classes in the classification result. The diagonal elements in the matrix represent the number of correctly classified pixels of each class, that is to say, the number of ground truth pixels with a certain class name that obtained the same class name during classification. The results show that the spill contains 47380 pixels, waterbody (39944 pixels), vegetation (9234 pixels), built-up (3202 pixels), cloud cover (502 pixels) and strip line (0.0000 pixels) were correctly classified in the classified image. Thus, there are two off-diagonal elements namely upper right and lower left, and row elements represent ground truth pixels of a certain class that were excluded from that class during classification. Such errors are also known as errors of omission or exclusion and the confidence intervals for the land use ranges from 90% to 99% in the classification scheme. The values of omission for the various land use and land cover are given below:

1. Spill = 0.0011
2. Waterbody = 0.0004
3. Vegetation = 0.0120
4. Built- up = 0.1128

Moreover, off-diagonal column elements represent ground truth pixels of other classes that were included in a certain classification class. Such errors are also known as errors of commission or inclusion and are given in Tables 5.1 and 5.2 the values are:

1. Spill = 0.0001
2. Waterbody = 0.0026
3. Vegetation = 0.0431
4. Built-up = 0.0350

However, KIA mapping accuracy is the overall accuracy that correctly classified pixels (sum of major diagonal cells in the error matrix) divided by a total number of pixels checked. Though, overall accuracy is a measure of accuracy for the entire image across all classes. It is archived by the use of classified image and that of the training site information (ground truth). Table 5.1 and Table 5.2 illustrate the uniqueness of the overall kappa value to be **= 0.9896** which symbolize 98.96% while the numbers 1 to 6 represent different land use and land cover as discussed before.

Table 5.1: Error Matrix Analysis for 2013 Classification

Category	Spill	Waterbody	Vegetation	Built-up	Cloud Cover	
Spill	47380	1	0	0	0	0.0001
Waterbody	32	39944	26	43	0	0.0026
Vegetation	13	8	9234	364	31	0.0431
Built -up	5	7	86	3202	17	0.0350
Cloud Cover	0	0	0	0	501	0.0000
Strip Line	0	0	0	0	0	0.0000
Total	47430	39960	9346	3609		

Error of omission(O)	0.0011	0.0004	0.0120	0.1128		

Table 5.2: Error of Omission and Commission 2013

Category	LULC (6)	Total	Error of Commission (C)
Spill	3	47384	0.0001
Waterbody	4	40049	0.0026
Vegetation	0	9650	0.0431
Built- up	1	3318	0.0350
Cloud Cover	0	501	0.0000
Strip Line	27	27	0.0000
Total	35	100929	
Error (O)	0.2286		0.0064

5.2 Agricultural Stress

The soil is defined as the unconsolidated mineral of the earth's composition that serves the basis for plant growth. This includes living organisms, soil organic matter, gas and water. The dominant soil of Nigeria (1997) entails that there are many soil structures in Nigeria but for sake of this study, the areas in view show six types namely Gleysols (deep blue in colour by representation), Nitisols (red), Fluvisols (sky-blue), Aritisols (yellow), Ferralsols (pink) and Ocean (block- blue). The outbreak of spill at George –Ama affects the six layers of the soil to the detriment of the various organic matters present in the soil components. The impact of the spill is more dominant in nitisols, followed by fluvisols, and ocean soil (Figure 5.2). Eventually, the result indicates that Gleysols is 21.6473%, 21.555% goes to ocean, Fluvisols incorporate 20.8073% and Nitisols enclose 20.3053% (Table 5.3) which is opted for decision making in the study as heavy metals in the soil will be an enemy to the host of organic matters in the comity of state. This means that any crop planted in the area of spill will be undergoing agricultural stress by this simple definition and will take enormous time for any plant input to grow as expected. Dry or dying crops do not use nitrogen and light, indicating an agricultural stress, whereas a crop that is showing healthy, productive vegetation indicates low stress.

Table 5.3: Soil Composition

S/N	Area (Hectares)	Percentage (%)
Gleysols	6,174.462	21.6473
Nitisols	5,791.663	20.3053
Ferralsols	2,939.663	10.3063
Fluvisols	5,934.847	20.8073
Ocean	6,148.163	21.555
Arenosols	1,534.119	5.3785
Total	**28,522.917**	

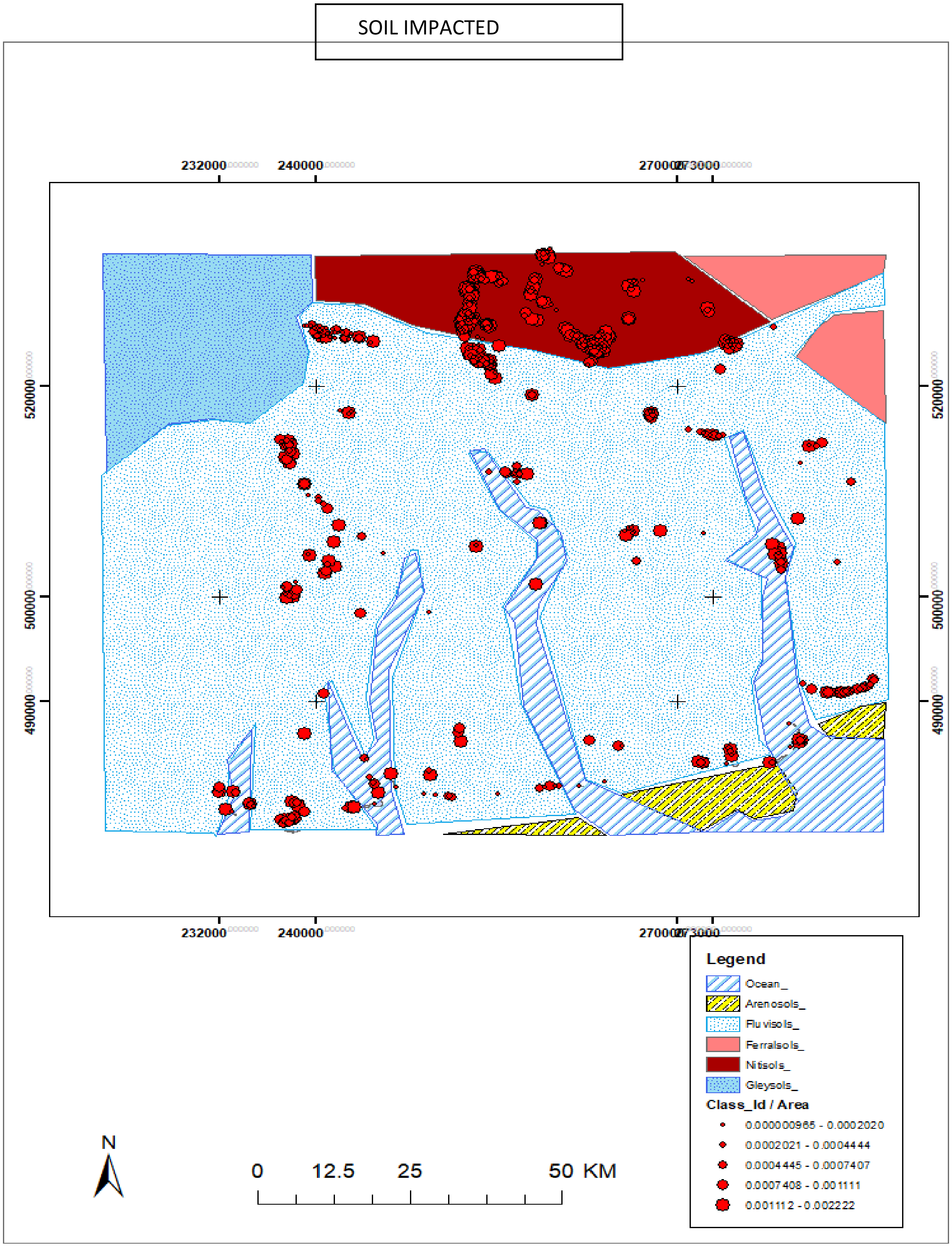

Figure 5.2: Soil Impacted Map

5.3 Normalized Difference Vegetation Index (NDVI)

NDVI is an instrument design to indicate the presence and condition of green vegetation. It was first used in 1973 to monitor and distinguish vegetated areas from other land cover types (Lunnetta et al., 2006). The NDVI instrument is used to calculate the effect of the spill with respect to the waterbody, vegetation and the built-up. The water course and spill area share the same light green in colour which reflect -0.0401 to -0.0188. Figure 5.3 contains a dark green which represent vegetation from -0.5651 to -0.4010 while the yellow patches inside the map represent built-up with value range of -0.0188 to -0.0053. While interpreting the results obtained, waterbody signify high rate of emission, vegetation equally noted to be high with a loss of pixels' value in vegetation. The rate at which this emissivity show high value is the deposition of spill particle on the waterbody and that of the vegetation from the analytical results. Built is normally high because of loss of canopy, it is believed there are no grassland within the built environment.

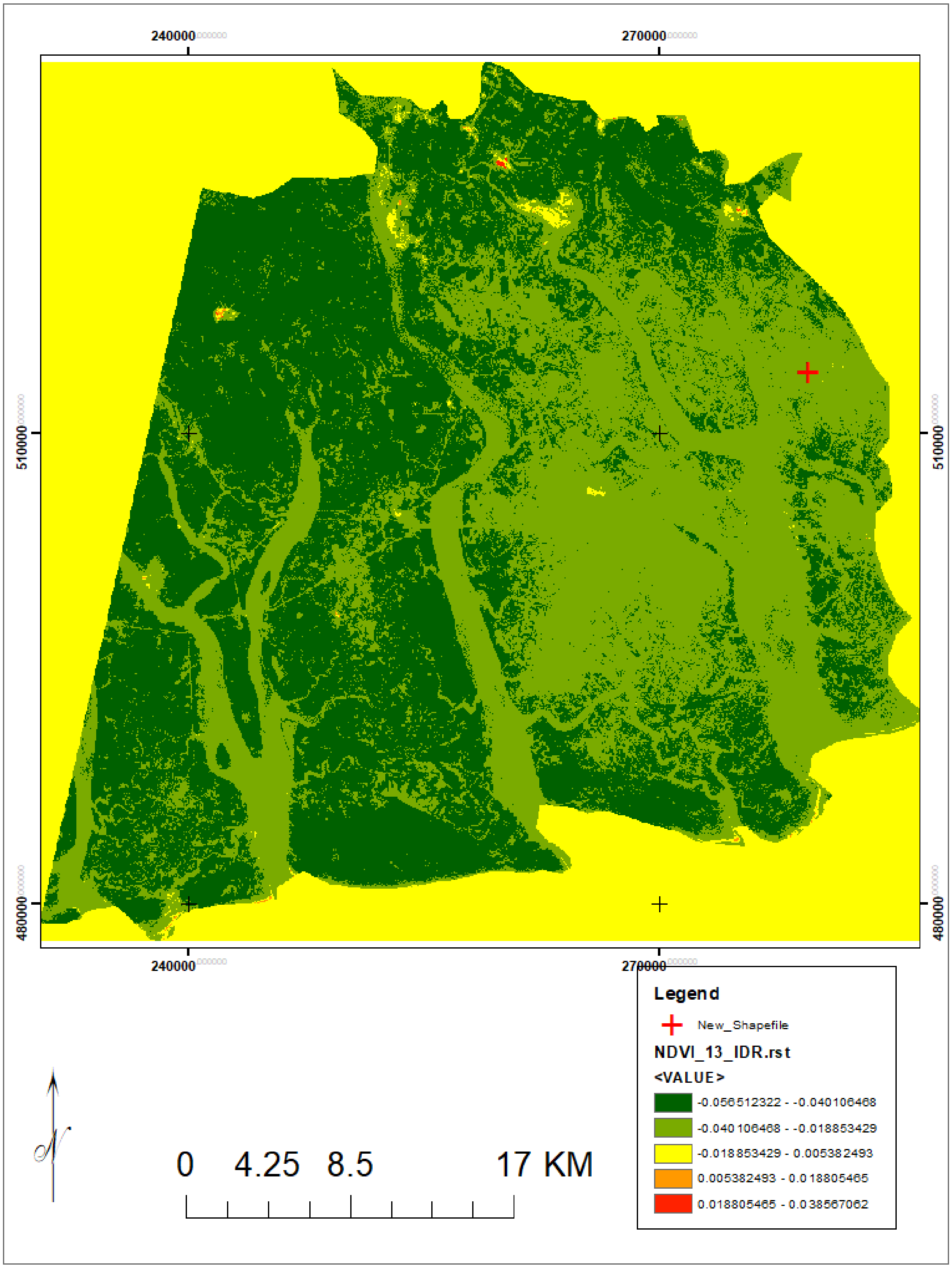

Figure 5.3: Normalized Difference Vegetation Index for 2013

5.4 Simple Ratio Index (SRI)

Simplest ratio-based index is termed the straightforward quantitative relation (SR) or quantitative relation Vegetation Index (RVI). This index is just the reflection factor within the close to infrared band divided by the reflection factor within the red band (Equation 5.1). A bigger SR price indicates healthy vegetation, whereas lower values indicate soil, water or ice. The band five (5) is used as near infrared band while band four (4) is the red band used in Landsat eight (8) for vegetative index calculation. The red cross on the eastern part of the map (Figure 5.4) shows the spill domain and the colour of the waterbody is the same. The reflection of the spill and waterbody ranges from 0.9231 to 0.9642. Consequently, the light green represents the built-up which show an interval of 0.9642 to 1.010 and vegetation is coloured dark brown with a value of 0.8930 to 0.9231. Results of the study is comparatively analyzed with standard interpretation (Table 5.4), for waterbody and vegetation, the reflection is high due the presence of oil spill, and loss of vegetation in the spilled environment. The result of the built –up value is also high due to lack of green pigment in the neigbourhood.

$$\text{Simple Ratio Index} = \frac{PNIR}{PRED} \qquad 5.1$$

where,

NIR = Near Infrared Band

Red = Red Band

Table 5.4: Standard NDVI Values and Observed Results

Range	Standard interpretation		Observed	Interpretation
-0.1 to 1.0	Sand, Barren, Snow, Route		0.9642 to 1.0	High
0.2 to 0.5	Grassland, Shrub		0.89 to 0.92	High
0.6 to 0.8	Temperature, Rain Forest		0.8930 to 0.9231	High
-1 to 0	Waterbody		0.9642	High

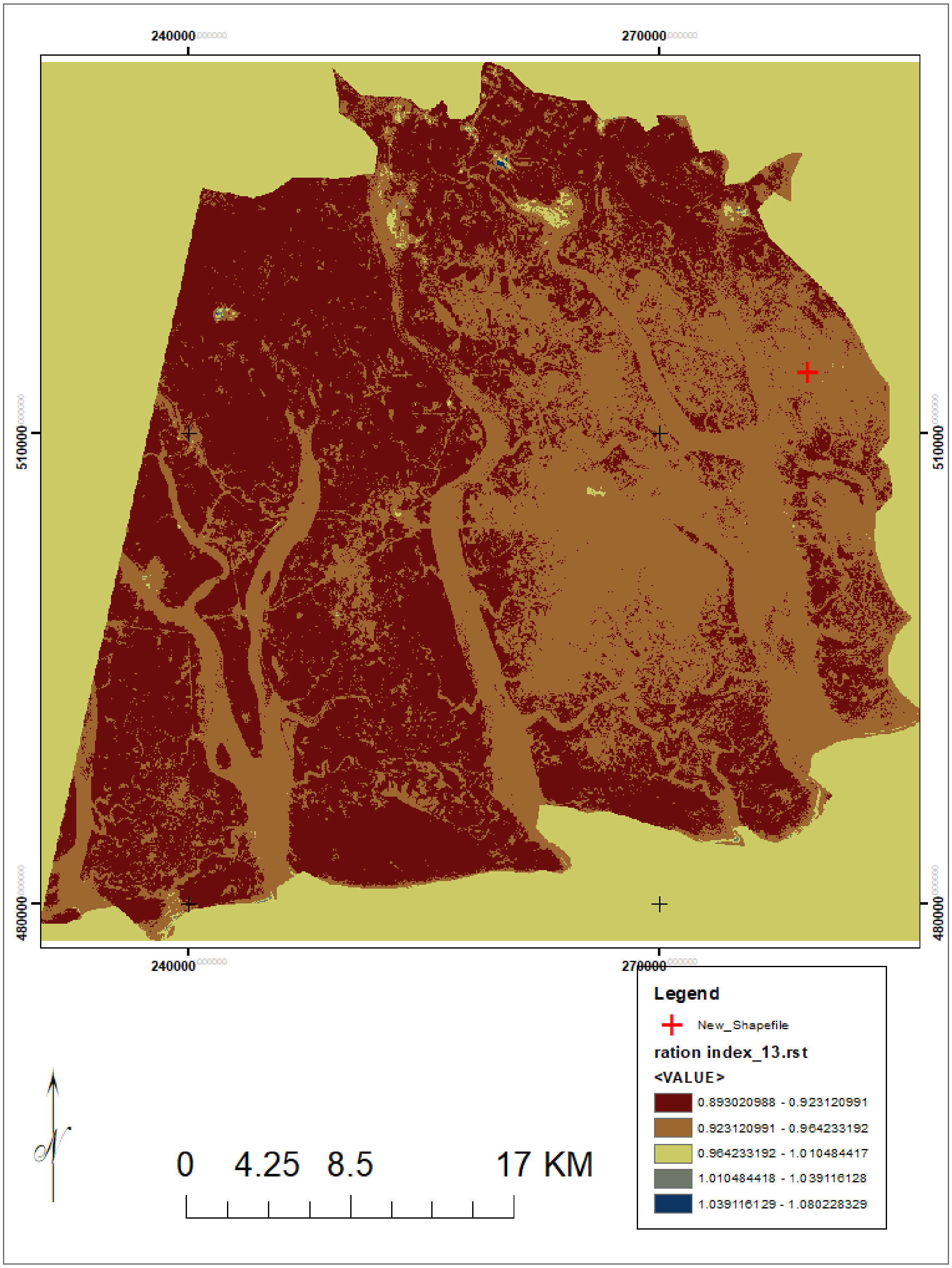

Figure 5.4: Ratio Index for 2013

5.5 Advanced Vegetation Index (AVI)

Advanced Vegetation Index (AVI) is a numerical indicator, similar to NDVI, that uses the red and near-infrared spectral bands (Equation 5.2). Like NDVI, AVI is used in vegetation studies to monitor crop and forest variations over time. Figure 5.5 is a typical index that show waterbody in red colour which falls from 1.0262 to 1.1254, vegetation is in two categories, light vegetation is from (0.7192-0.8094) and dark vegetation covers (0.4860-0.7192). The yellow background stands for the oil spill environment which stretches from 0.8094 to 0.9248. The findings show that oil spill reflectance is very high, waterbody is high, vegetal cover also depicts high. This result is illuminating to demonstrate the impact of oil spill over the land cover. Judging from the above analytical results, the environmental sensitivity index of the land cover to oil spill is based on count probability with ranking order listed below according to the level of spill influence (Table 5.5 and Figure 5.6). The associated letters for the tabular interpretation are stated below:

1. VH is for very high influence
2. H is for high influence
3. M is for the medium influence
4. L is for the least influence

Based on the influence level of spill on the land cover, soil is ranked number one (1), water body is two (2), vegetation apparently occupies the third position and built-up the fourth (4) in the order of ranking which is least sensitive to oil spills.

$$\text{Advanced Vegetation Index} = \frac{[(NIR \times (1 - Red) \times (NIR - Red)]}{3} \qquad 5.2$$

where,

NIR = Near Infrared Band

Red = Red Band

Table 5.5: Sensitivity Index of the Land Use and Land Cover to Oil Spill

Category	2013 count	2019 count	2021 count	Sum	ESI-Ranking	Interpretation
Soil	Nil	21400	Nil	21400	1	VH
Water body	1332	70	962,27	2364.27	2	H
Vegetation	311.53	103.2	203.06	617.79	3	M
Built-up	120.3	107	188.9	416.2	4	L

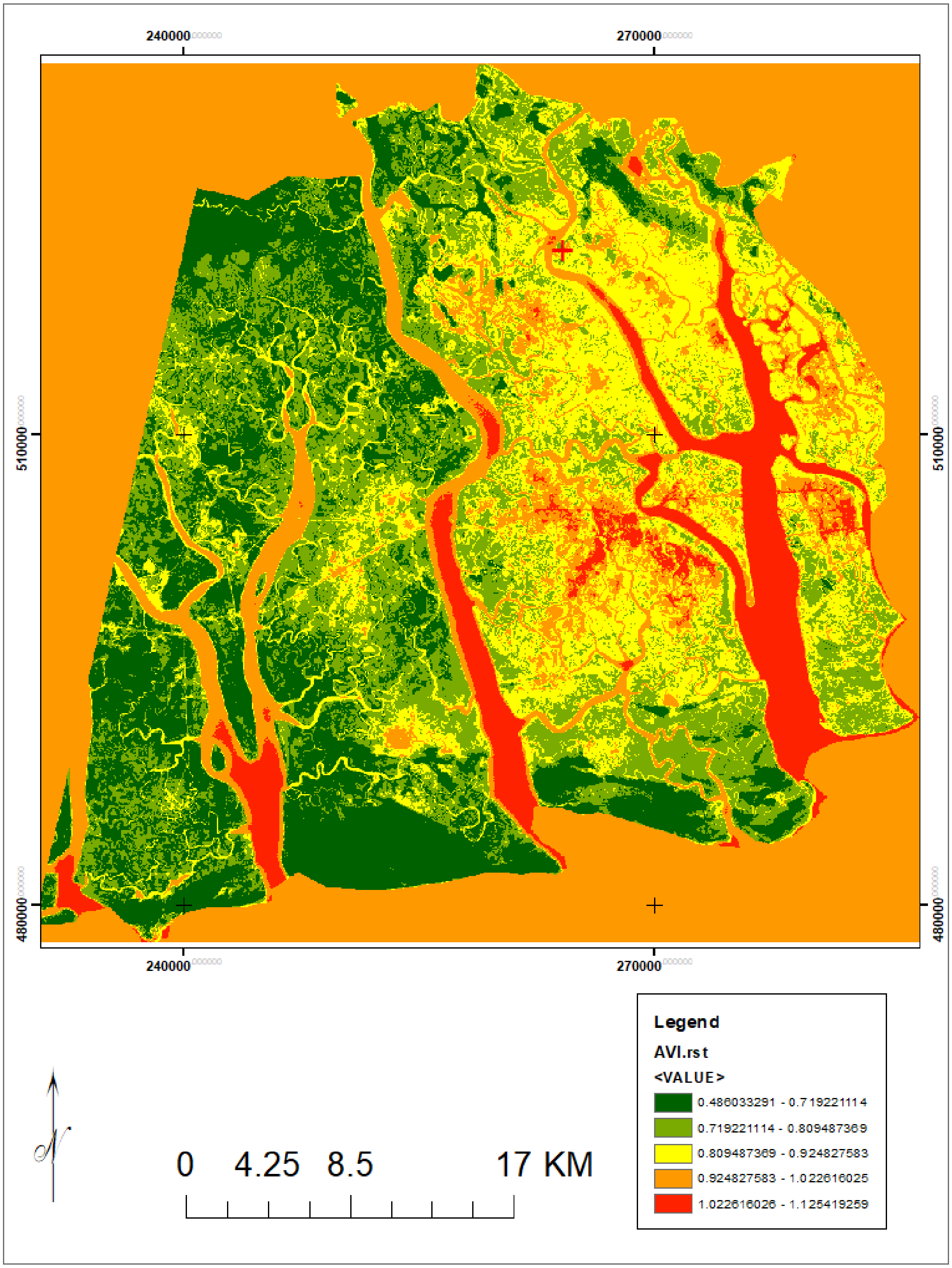

Figure 5.5: Advanced Vegetation Index for 2021

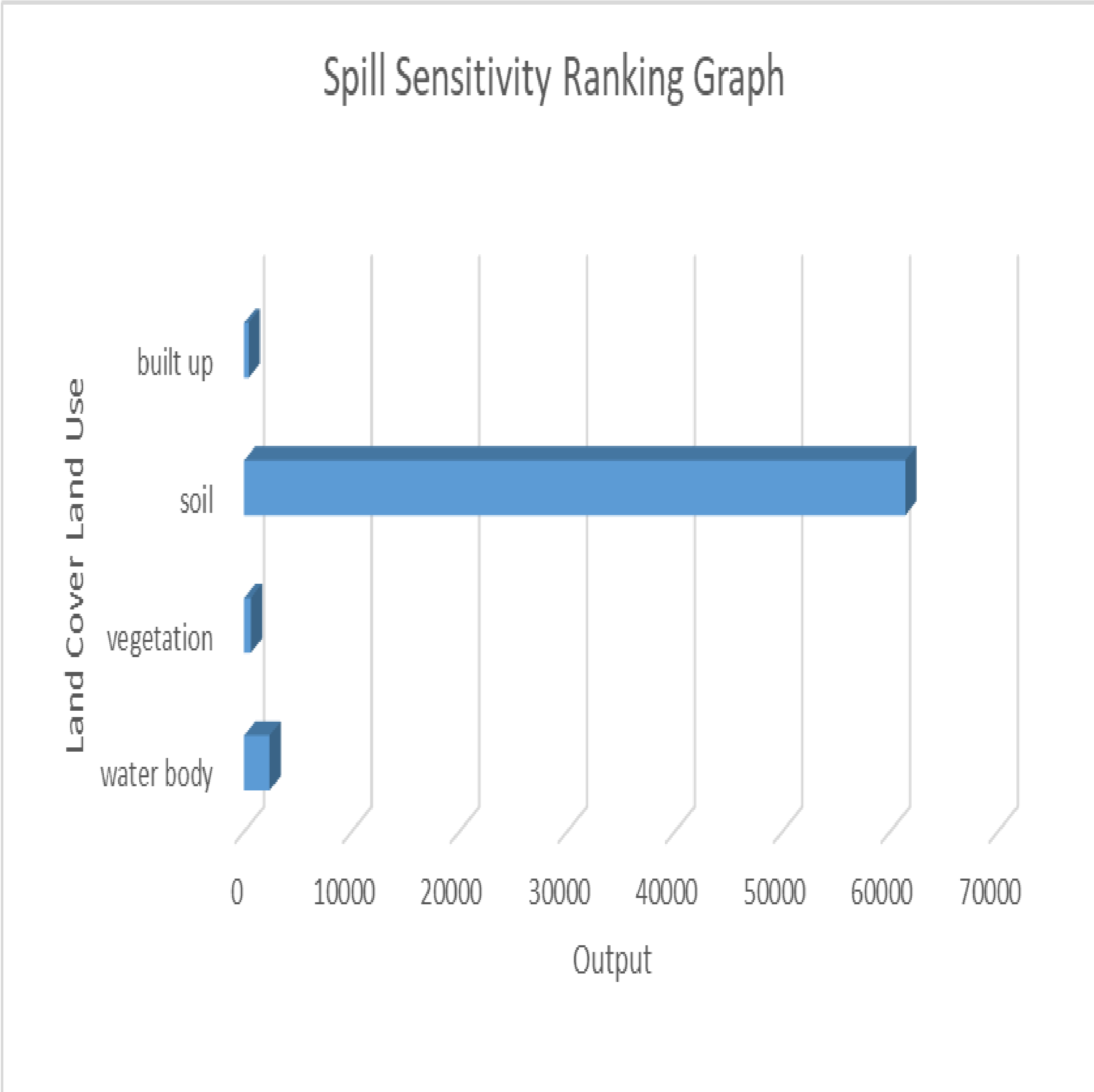

Figure 5. 6: Spill Sensitivity Ranking Graph

Conclusions

The research conducted centred on the geospatial revelation of the oil spill, operationally used was Landsat 7 to define the particles of the spill. The satellite observation supported the dominance of spill in 2013 to the tone of (9645.660ha). The impact of the spill is further experienced in the vegetal trend line from 2013 to date along with Communities in the shore areas. Nevertheless, the state of agriculture is also suffering same magnitude of spill in the study area, thereby affecting crop yield.

Recommendations

Based on the findings of the results, the following recommendations are factual for the effective management of spill in the region.

1. Periodic checks of pipeline route should be carried out to forestall future reoccurrence.
2. Ageing pipes should be replaced to avert spillage.

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