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Full Length Research Paper

Change actors' analysis and vegetation loss from remote sensing data in parts of the Niger Delta region

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Studies on land use changes have shown that human activities inevitably result in medium to large scale changes in the ecosystem. These changes can be examined and monitored both in the short or long term using remote sensing data and the right analytical computer packages. Researchers have in the past focused on the land use changes over the years. However, few studies are available on the identification of causative factors to land use changes. Several change actors are responsible for changes in land cover or vegetal cover of an area. Some of these actors may be localized and intensive while others may be global but extensive. The study examined the change actors responsible for major vegetal cover change, in the short run analysis within the Niger Delta region using satellite remote sensing data. The study utilized two-date Landsat satellite images of parts of Niger Delta and other auxiliary data on oil activities to examine the main change actors for the change in vegetation quality. The result showed that settlement development and other similar anthropogenic activities were responsible for major changes in the vegetation cover within the study area. This is contrary to the claims from different quarters that the oil majors are largely responsible for the environmental degradations in the Niger Delta. Oil activities have low correlation (0.38) relationship with the vegetation loss while human settlement developments have high correlation (0.762) with the vegetation loss in the project area. The paper advanced that vegetal changes in the Niger Delta are largely resultant effects of different anthropogenic activities in the informal sector than from the multinationals oil activities.

Key words: Human activities, land use, vegetation quality, change analysis, NDVI, Niger delta.

INTRODUCTION

Human use of land resources gives rise to "land use" which varies with the purposes it serves, whether they be food production, provision of shelter, recreation, extraction and processing of materials, and so on, as well as the bio-physical characteristics of land itself. Hence, land use is being shaped under the influence of two broad sets of forces – human needs and environmental features and processes. Neither of these forces stays still; they are in a constant state of flux. Land use changes occur at different spatial levels and within varying magnitude depending on the dominant human activities at play without the influence of man, certain changes will occur in the geological time as a result of natural processes of landform modifications. However, human actions tend to have indelible imprints on landscape in a short time (Briassoulis, 2000; Goldewijk and Ramankutty, 2004; Fabiyi, 2007). Since civilization human activities have impacted on the natural ecosystem through the aggressive drive for development (Goldewijk and Ramankutty, 2004). It has been estimated that over the last three centuries, more than 1200 million ha of forests and wood lands have been cleared. Grassland and pastures have diminished by about 560 million ha and cropland areas have increased by about 1200 million ha (Richard and Flint, 1994). Human actions especially those involving biomass fuel consumption, land-use change, and agricultural activities have direct interaction with the land surface and negative consequences on vegetation and environmental qualities. These interactions are rather complex and have attracted research interest in the last four decades (Goldewijk and Ramankutty, 2004).

The Niger Delta region in Nigeria had its share of negative influence of human activities on the natural landscape. The primary vegetation of the delta is fast changing to secondary and derived vegetation due to aggressive incursion of human activities into the seemingly undisturbed ecosystem that characterized the region about a century ago. Human activities including oil exploration and urban development are causing imbalances in the ecosystems of the region with resultant negative consequences on environmental quality and livability. The extent of these environmental alterations has prompted different concerns including political agitations with respect to the social, economic and cultural consequences of the changes that are taking place. The oil multinational companies operating in the Niger Delta area have been fingered as the main changed actors especially the activist and environmentalists. The bulk passing from different actors in the region has been responsible for the agitation and militancy in the region for the past two decades. For instance, the Niger Delta Human development report of 2006 reported that. '…..the Niger Delta has an enormously rich natural endowment in the form of land, water, forests and fauna. These assets, however, have been subjected to extreme degradation due to oil prospecting. For many people, this loss has been a direct route into poverty, as natural resources have traditionally been primary sources of sustenance' (UNDP, Niger Delta Human Development Report, 2006).

Change actors and Niger Delta vegetal degradation

Several forces are responsible for the changes in vegetation quality observed in the Niger Delta. Settlement developments, oil prospecting over the years imprint indelibly on the Niger Delta fragile canvas of the ecosystem. The main visible impact is the change in land use and vegetal cover. Human systems is a part of natural ecosystems but the activities that support human enterprises unfortunately damage the natural landscape of the Niger Delta is in the coastal belt of Nigeria, it is characterized by fragile ecosystems including mangrove, nypa palm, fresh water swamp, sheltered tidal flat and large expanse of vegetated bluff. Niger Delta is home to different fauna and flora species (some of which are in endangered list of IUCN) yet with about 31 million populations in an area of about – square kilometers. The Niger Delta combined the presence of oil rich hydrocarbon deposit with the rich alluvium and the abundance of aquatic life to make the place attractive to rapid expansion. The intense urbanization and industrialization that followed the discovery of oil at Oloibiri in the present day Bayelsa state in 1956, have many consequences on the landscape of the Niger Delta, for example enlargement of natural coastal inlets and dredging of waterways for navigation, port facilities, and oil and gas pipelines have direct impact on the fragile coastal ecosystems. The visible manifestations of these anthropogenic activities include loss of biodiversity and essentially deforestation, environmental degradation, loss in vegetal qualities and soil nutrient loss. A number of large scale and cottage industries sprang up in the last thirty years thereby contributing to environmental degradation of the Niger Delta.

Other activities such as sand mining, hydrocarbon production like oil and gas, introduction of invasive species (nypa Palm) and engineering constructions such as jetty, seawalls and channelization are few among numerous activities taking place in the region. The coastal environments are also affected by informal human activities occurring outside the coastal zone or out of the noticeable vicinity of the impacted areas. Such stress causing activities occurring include dam activities – which affects the downstream ecosystem. Two dams were constructed on River Niger within the Nigerian Boundary (Jebba and Kainji) at the lower- middle course of the River Niger and thus, limit deposition of the rich alluvium soil in the delta; this could have negative effects on the quality of the riparian vegetation downstream over time. The land use change such as deforestation in the upper course of the tributaries supplying the River Niger could have negative impact on the downstream ecosystems. Apart from the various human induced changes in the ecosystems of the Niger Delta, the global climatic change is another significant change factor in the Delta. These drivers are responsible for long term modification of the coastal ecosystem including the Niger Delta. Though deforestation and apparent change in vegetal qualities are major land use/ land cover changes occurring in many coastal regions of African countries. The impacts of human activities within the coastal region, and the climate change effects are difficult to separate into different compartments.

On a continental or global level, climatic fluctuations have been linked to the anthropogenic activities through the release of green house gas into the atmosphere, thus depleting the ozone layer. Effects of climate change have been measured in the continental or regional levels through sea level rise, melting of the icecap, increased rainfall and associated flooding in the low lying areas. In the sub local analyses context, the influence of human activities on the landscape can be directly measured through different approaches such as remote sensing and geographic information system (GIS) techniques (Fabiyi, 2011) Recent research discourse focuses on the ways to identify the extent of human influence on the global climate change from the normal perturbation associated with climatic cycle and to what extent will the global warming be reduced with the cutting down of carbon emission by industrialized nations. In the supra local context, it is necessary to separate the impact of the immediate anthropogenic actors on the ecosystems from the changes due to climate changes. It is also of research interest to identify the main actor(s) of land use change of a given landscape in the short run context. While the effects of climate change drivers on the ecosystem or vegetation could take years to be noticed, the effects of human activities could be monitored at the community or district level. It is also possible to delineate the effects of informal change actors from corporate or large scale change actors at the district level. The knowledge of the main actors of land use change will help in identifying the approach to halt deforestation and show policy on the efficient interrelationships between human activities and natural ecosystem.

Deforestation and changes in vegetation cover over time appear to be essential elements being mapped in the land use change analysis, either at the regional or global scale in most past studies. The scientist special interest in deforestation, as compared to other land use/land-cover change issues, may be partly attributable to the stark nature of the transition from forest area to cleared land. Most earth observation satellite data capture data about the earth surface in the visible and the infrared (near, mid and far infrared) bands which discriminates conspicuously the vegetal cover chlorophyll levels. Scientists and authors have used several methods to measure vegetal loss (DeFries et al., 1995). The methods require the definition of the thresholds and classification of the vegetation around the threshold based on some pre-determined schemes. This approach has been fraught with practical inefficiency, especially if there is a need to monitor changes over time. Other methods include the following authors' approaches (Copeland et al., 1996; Bonan, 1999; Houghton, 1999; Postel et al., 1996; Vitousek et al., 1997). Normalized difference of the vegetation index (NDVI) became popular in the last three decades to investigating the quality of vegetal cover. The normalized difference of the vegetation index (NDVI) is a non-linear transformation of the visible (red) and near-infrared bands of satellite information. It is an alternative measure of vegetation amount and condition. It is associated with vegetation canopy characteristics such as biomass, leaf area index and percentage of vegetation cover. NDVI is mathematically defined as:

nir-red/ nir+red (Near infrared band – red band/ near infrared band + red band)

Previous studies have used Channels 1 (0.54 to 0.68 m) and 2 (0.73 to 1.10 mm) which are visible and near infrared of the advanced very high resolution radiometer (AVHRR) data (Groten, 1993; Loveland et al, 1991) other works on the use of NDVI to monitor vegetal changes include. Other studies linked NDVI to plant phenology (Defries et al., 1995; Read and Lam, 2002; Mora and Iverson, 1995). Apart from AVHRR NDVI have been calculated from LANDSAT-TM information using bands 3 (0.63 to 0.69 mm) and 4 (0.76 to 0.90 mm). NDVI values range from -1 to +1 for pixel values ranging between 0 to 255. NDVI is one of the most successful of many attempts to simply and quickly identify vegetated areas and their "condition" and it remains the most well-known and used index to detect live green plant canopies in multispectral remote sensing data. Anthropogenic activities directly affect the photosynthetic capacities of the vegetal covers. When vegetation is removed to give way to urban development, the resulting eco system is in a way degraded and it often take time before re-growth could take place. When oil spill into the environment the plants die and natural restoration may take up to ten years or more. The new species of vegetation and the undergrowth of cleared areas have different reflectance properties from the secondary or primary vegetations. The study attempts an explorative delineation of the effects of major oil corporate industrial activities on the vegetal cover compared to the informal human activities around settlements.

The aim of the study

The aim of the study is to conduct change analysis of vegetal quality in parts of the Niger Delta within a short term transition and identify the change agents contributing to the vegetal loss. Objectives of the study include the following:

1. To conduct change analysis on the vegetation quality in the study area over a 6 year period;
2. To examine the contribution of informal human activities to the observed changes in vegetation quality;
3. To examine the contribution of oil activities on the observed changes in vegetation quality;
4. To indentify policy issues relating to reducing the consequences of human activities on the vegetal cover.

The study area

The geographic Niger Delta stretches for about 240 km from north to south and spreads along the coast for about 320 km. It covers an area of about 36,000 km^2. The River Niger breaks up into an intricate network of channels of creeks draining into the Gulf of Guinea. The major vegetation types include large freshwater swamp, brackish mangrove, nypa palm and vegetated buff. There are also rainfed deltaic vegetation in places with high elevation compared to vast low-lying landforms that dominate the Niger Delta. The study area however covers the western parts of the Niger Delta between longitude: 5° 9′ and 6° 20′ and latitude 5° 32′ and 7° 09′.

The study area covers some major urban settlements such as parts of Benin City, Warri, Asaba, Onitsha, Ughelli, Sapele among others. The areas also cover over 500 settlements/communities. The study area falls in six states including Edo, Delta, Bayelsa, Rivers, Anambra and Imo State (Figure 1).

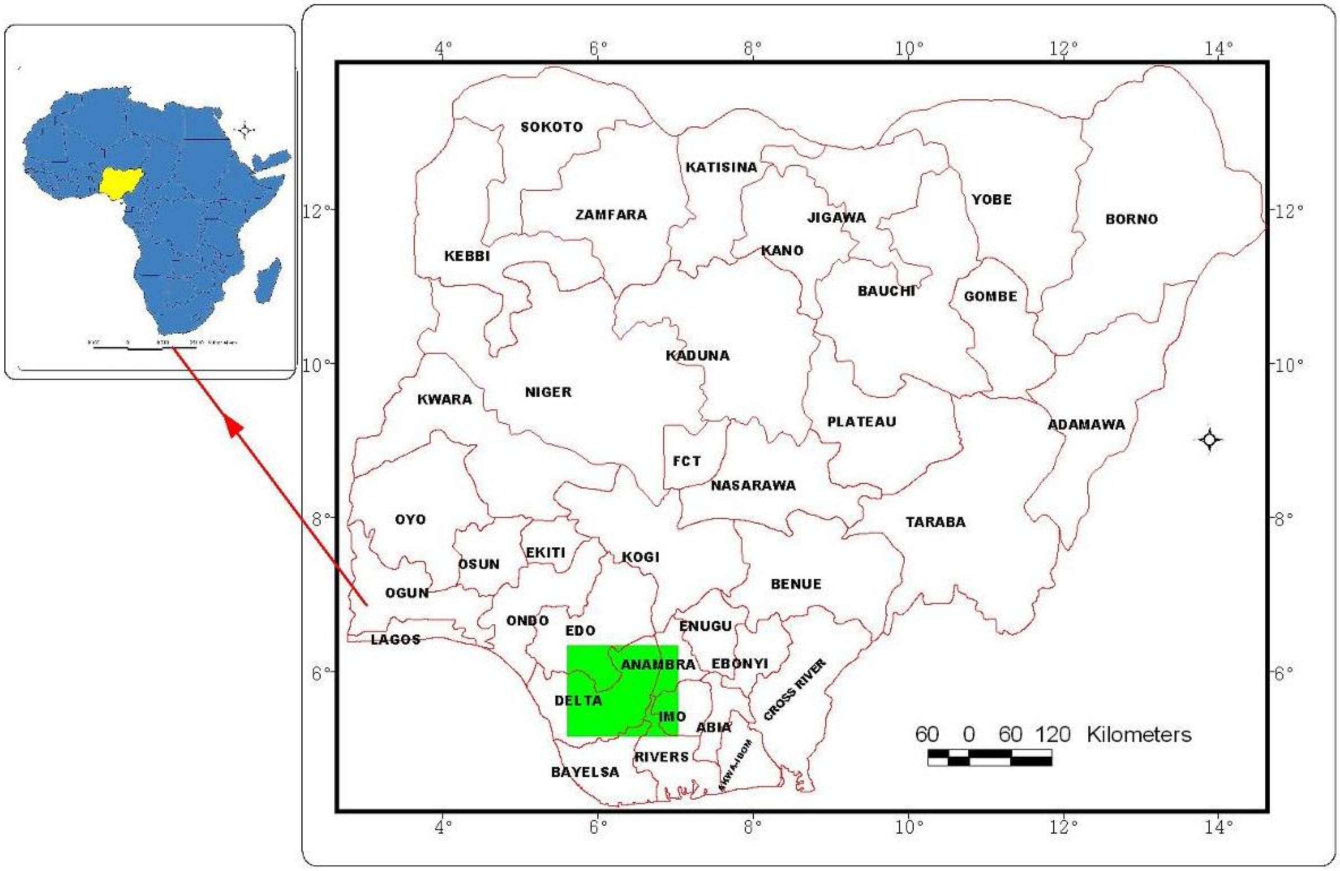


Figure 1. Location of study area.

The dominant economic activity in the study area, especially in the rural and sub urban areas is arable farming and the major food crops being cultivated are cassava, cocoyam, maize, yam and other food crops. There are also cash crop plantation including palm tree plantation, rubber plantation, banana/plantain plantation and pineapple plantation in the area. The women are also actively involved in agricultural activities, and primary food processing such as cassava (garri), palm kernel, rubber tapping and oil palm processing. Fishing activities are confined to some fresh water rivers and creeks. The limit of the selected study site covers a total area of 25,096.166 km^2. The length is 176.20 km and the breadth is 142.43 km as shown in Figure 1.

METHODOLOGY

Image acquisition and pre-processing

Two date Landsat images (Figures 2 and 3) were used for the analysis, with the characteristics in Table 2. The period of acquisition of the images were in the relatively dry period of the year in order to reduce effects of cloud cover, to eliminate the error misclassifying mature seasonal crop land as chlorophyll-rich vegetation. It was however noted that the temporal interval of the two images was very short and any major changes observed could be as a result of variability in the atmospheric condition rather than real change in the land use (Millward, 2011; Jensen, 2004; Lu et al., 2004), in order to reduce errors of misclassifications in this regard, especially in the reflectance values of the images; therefore, image normalization was carried out on the two images according to the techniques suggested by Song et al. (2001). Band 3 and 4 (Red and Infrared) of the two images were used in the normalized difference vegetation index. Ground control points were randomly selected with the aid of hand held GPS to geometrically correct the images and to ensure corresponding pixels are properly aligned.

Regression analysis of the NDVI images

Regression analysis was performed on the two NDVI images primarily to validate the results of the change analysis, to ensure that the result is not due to atmospheric effects on the images. The two NDVI images were regressed using NDVI 2000 as Y and NDVI 2006 as X. It is expected that the r value should be very high showing that very little change took place. If the value of r is very low, it indicates that there is a major difference between the two images within the time interval then atmospheric error would be suspected. The regression value showed 0.91 with the coefficient of determination of 83.1%. This is expected indicating that the change in the vegetal quality between the two dates was marginal. The scatter diagram of the regression analysis is shown in Figure 6.

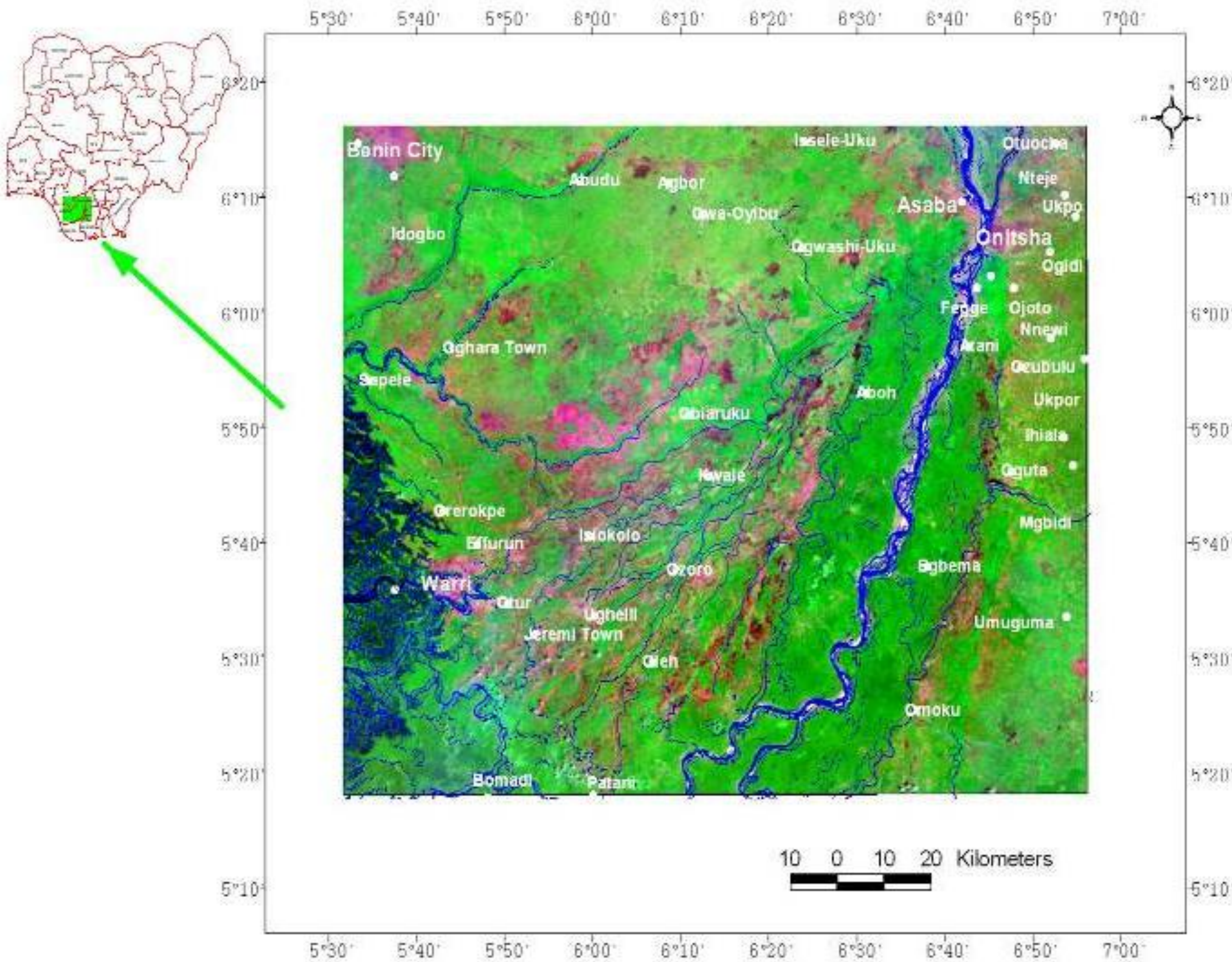


Figure 2. Satellite image 2000.

Table 1. Pearson correlation analysis of change and distance to oil facilities and settlements.

Parameter	Change value in vegetal quality	Distance to nearest settlement (km^2)	Distance to nearest oil facility
Change value in vegetal quality	1.00	0.762**	0.380**
Distance to nearest settlement	0.762**	1.00	0.033
Distance to nearest oil facility	0.380**	0.033	1.00

** Significant and one tailed test.

Table 2. Landsat image characteristics.

Acquisition date	Sensor	Band used	Spectral range	Spatial resolution
Dec 31 2000	Landsat 7 ETM+	3,4	0.63 - 0.69, 0.76- - 0.90	28
Dec 22 2006	Landsat 7 ETM+	3, 4	0.63 - 0.69, 0.76- - 0.90	28

Image differencing

Image difference analysis was performed on the two resulting NDVI of 2000 and 2006 to extract changes in the vegetation qualities during the interval periods using the methods advanced by Millward (2011) and Jensen (2004). The values obtained from each

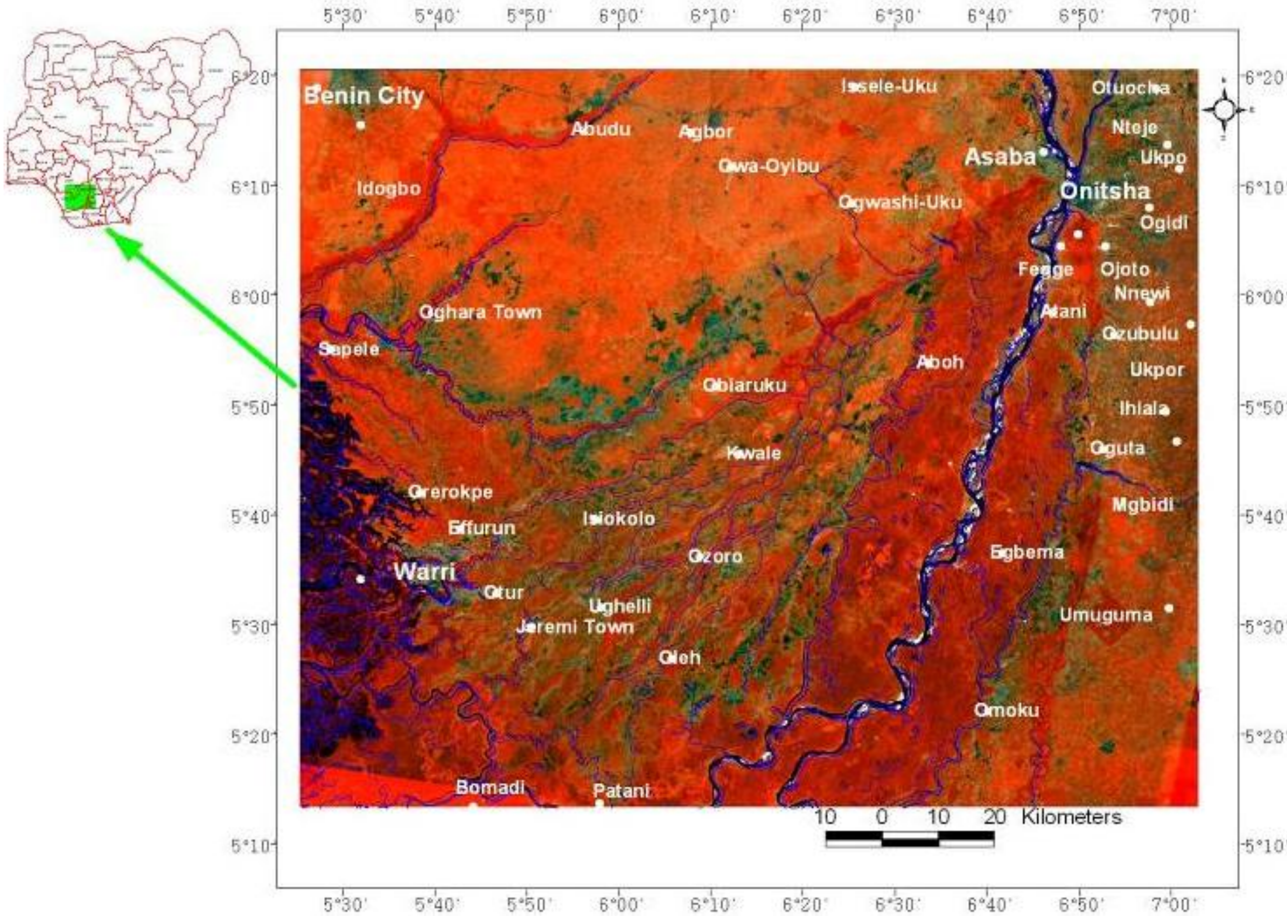


Figure 3. Satellite image 2006.

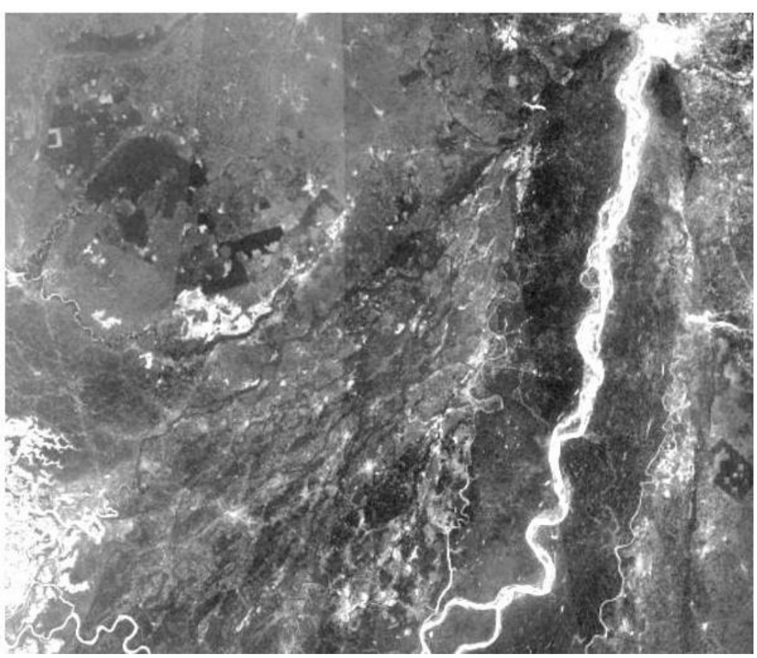


Figure 4. NDVI band 3 and 4 (2006).

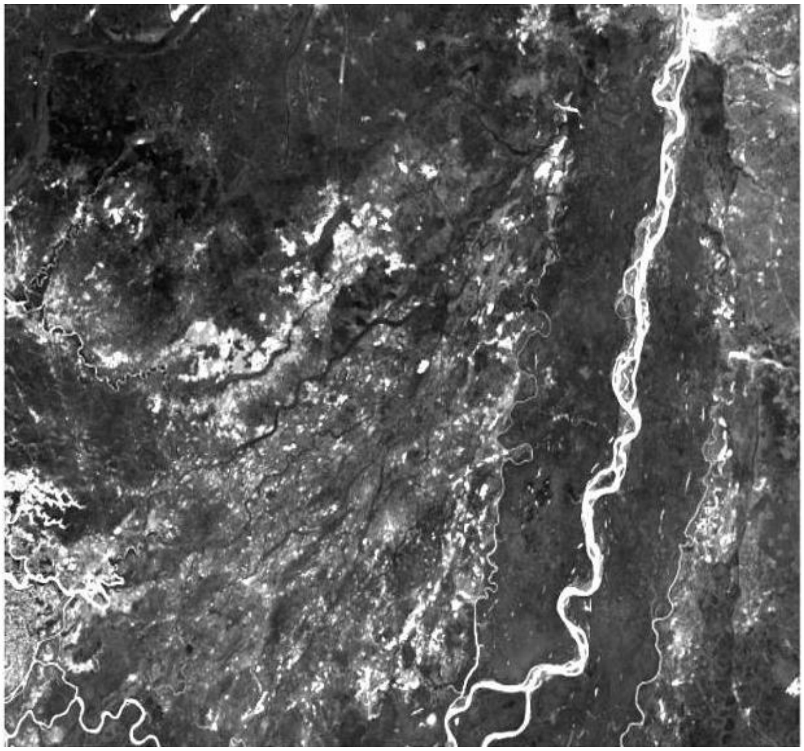


Figure 5. NDVI band 3 and 4 (2006).

of the NDVI were used as surrogate for the vegetation quality for each image. The values of the image differencing of the two NDVI images were used as a measure of change in the interval period. The values in the image differencing analysis showed some positive and negative areas (Figure 5). The negative areas were extracted as areas were noticeable degradation were recorded within the interval. The negative values were used without the sign since they were just measures of quality degradation. Figure 7 shows the result of image difference analysis of the two NDVI images. Figure 7 shows the image difference analysis of the two images. The places with bright tone areas are those significant changes as indicated by the legend. The major changes were noted in the eastern part of the study areas. The communities where vegetation degradation were noted include Onitsha, Asaba, Aboh, Fede, Egbema, Obiaruku, Kwale, Atani and Omoku communities. On the western section of the study areas are Abudu and Oghara towns. Figure 8 further shows that the changes in vegetation were around major settlements. The locations of all oil activities including oil wells, terminals, and flow stations, gas points within the study area were extracted from the map obtained from the Department of Petroleum Resources (DPR) -Nigeria, while the locations of major settlements were also extracted and overlaid (Figure 9).

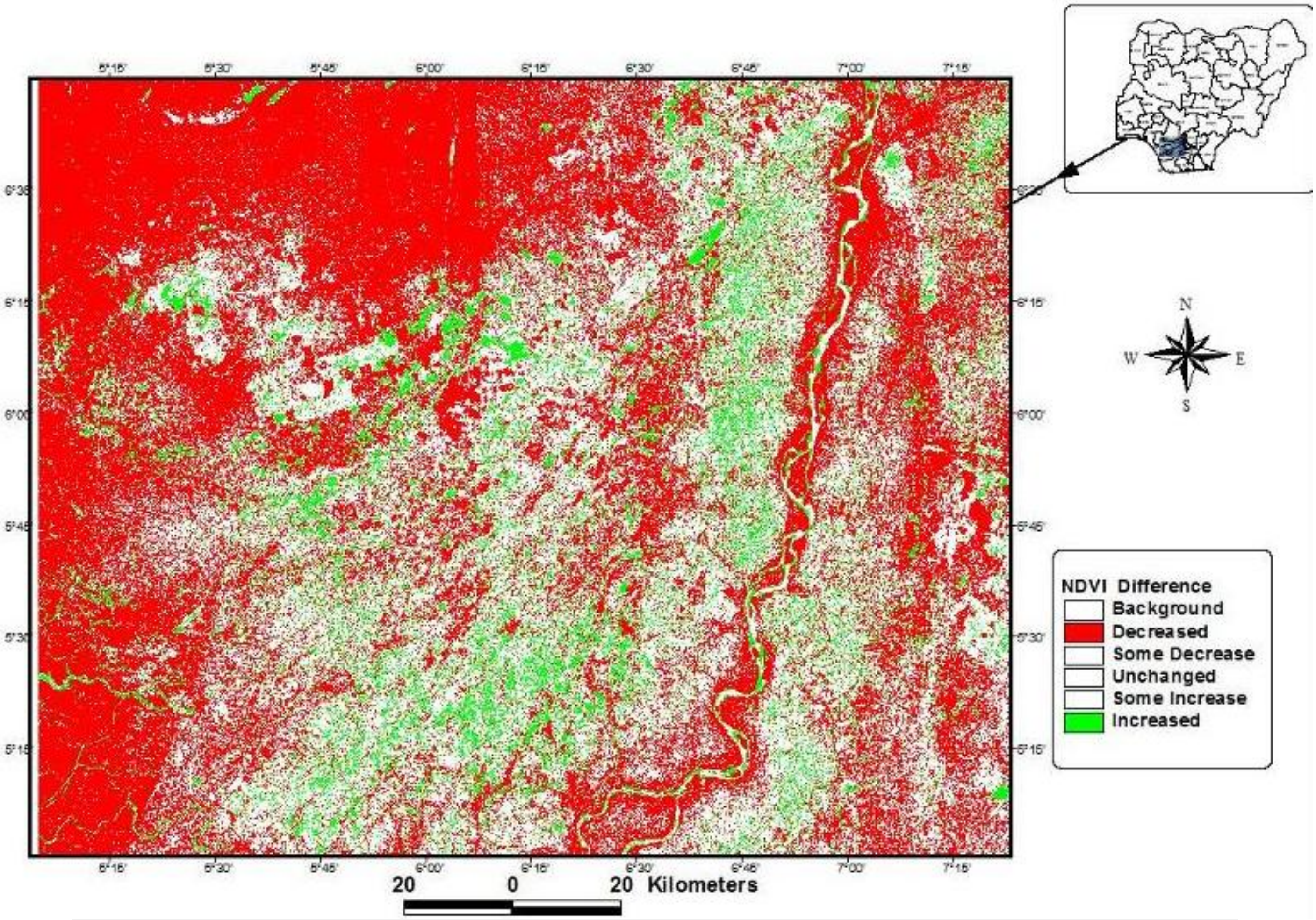
A grid of 5.8 by 4.2 km were laid over the entire study area and a 20% sample was randomly selected among the 900 grids making a total of 169 grids (Figure 9). The mode of the negative image difference values in each selected grid was used as representative vegetation degradation value for each selected grid (Appendix 1). The centroid of each of the selected grids were captured as point data and used to measure distances between the grids and location of major settlements and grid and location of oil activities. The resulting data generated were the vegetation degradation value of grid, the distance of grid-cell to nearest major settlement, and distance of grid cell to nearest oil facility. The tree attribute data were used in a person moment correlation analysis. “Pearson product” moment correlation analyses were conducted on the distance measurement and the degradation values of the grid cells are as follows:

Y (reduction in vegetation quality) α × (distance to the nearest oil facility)

Y (reduction in vegetation quality) α × (distance to the nearest settlement)

RESULTS OF ANALYSIS

The analysis shows that changes in vegetation quality were not evenly distributed in the study areas. The degraded values was high above the threshold (-0.4) in fact some areas returned r value of (-0.2) while in some areas a positive value were returned showing there were minor difference in the vegetation quality during the period of study. The areas where significant negative change values in the vegetation quality were recorded were areas around Sapele, Obiaruku, Asaba, Onitsha areas, other areas where high vegetal quality reduction was observed include Warri, Ughelli, Ozoro and kwale, Jeremi, Otuocha, Nteje and Ukpo and Ozubulu. Though the short term changes were observed to be minimal the spatial pattern of the major changed area shows that the pattern is not random. Further analysis using nearest neighborhood analysis to examine if the changed pattern is random or systematic returned R value of 1.506. This R value shows that pattern tends toward regularity, which



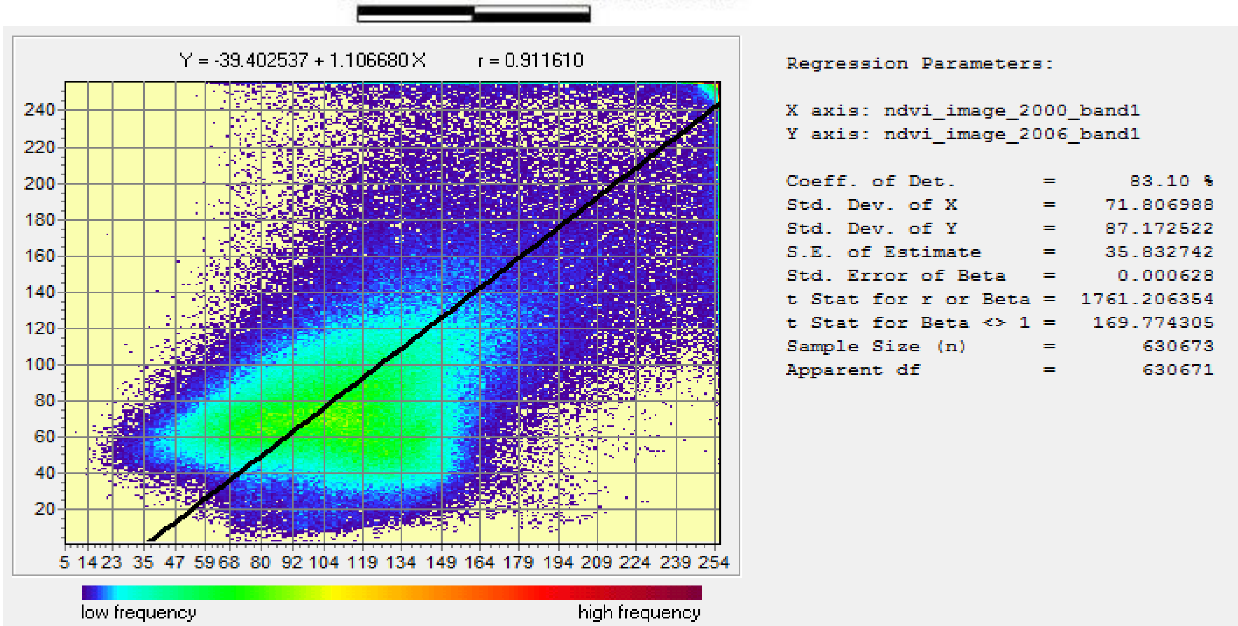


Figure 6. Scatter diagram of the regression analysis of two NDVI images.

suggests that the process producing the pattern is deterministic and resulted from artificial forces. The Pearson moment correlation analysis of the distances to oil facilities and major settlements is as presented in

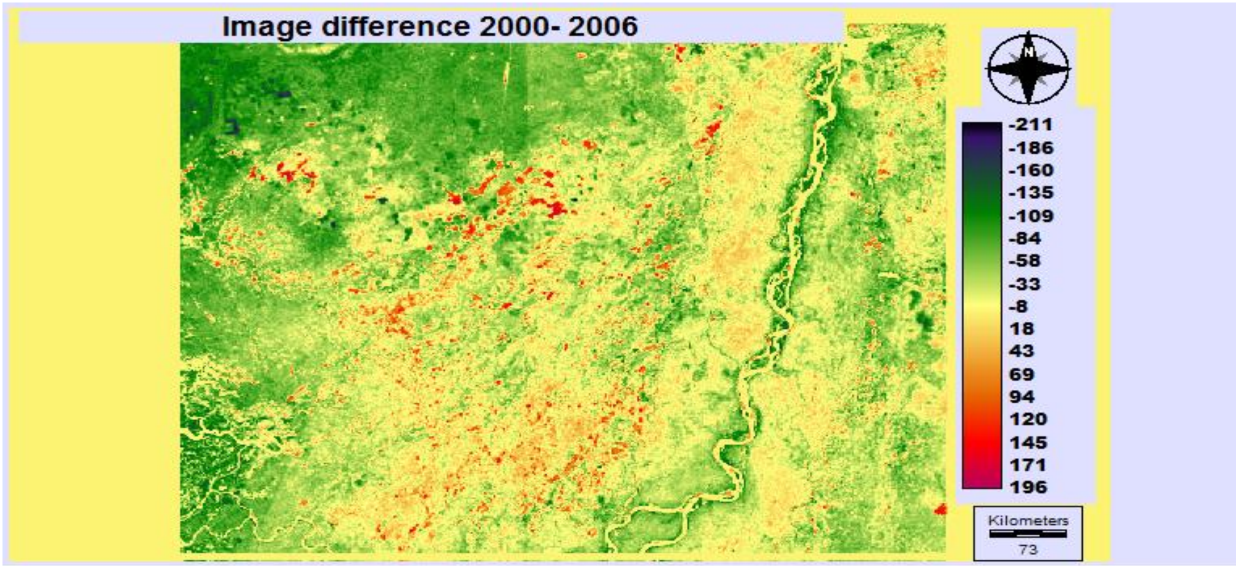


Figure 7. Image difference analysis of the two NDVI scenes.

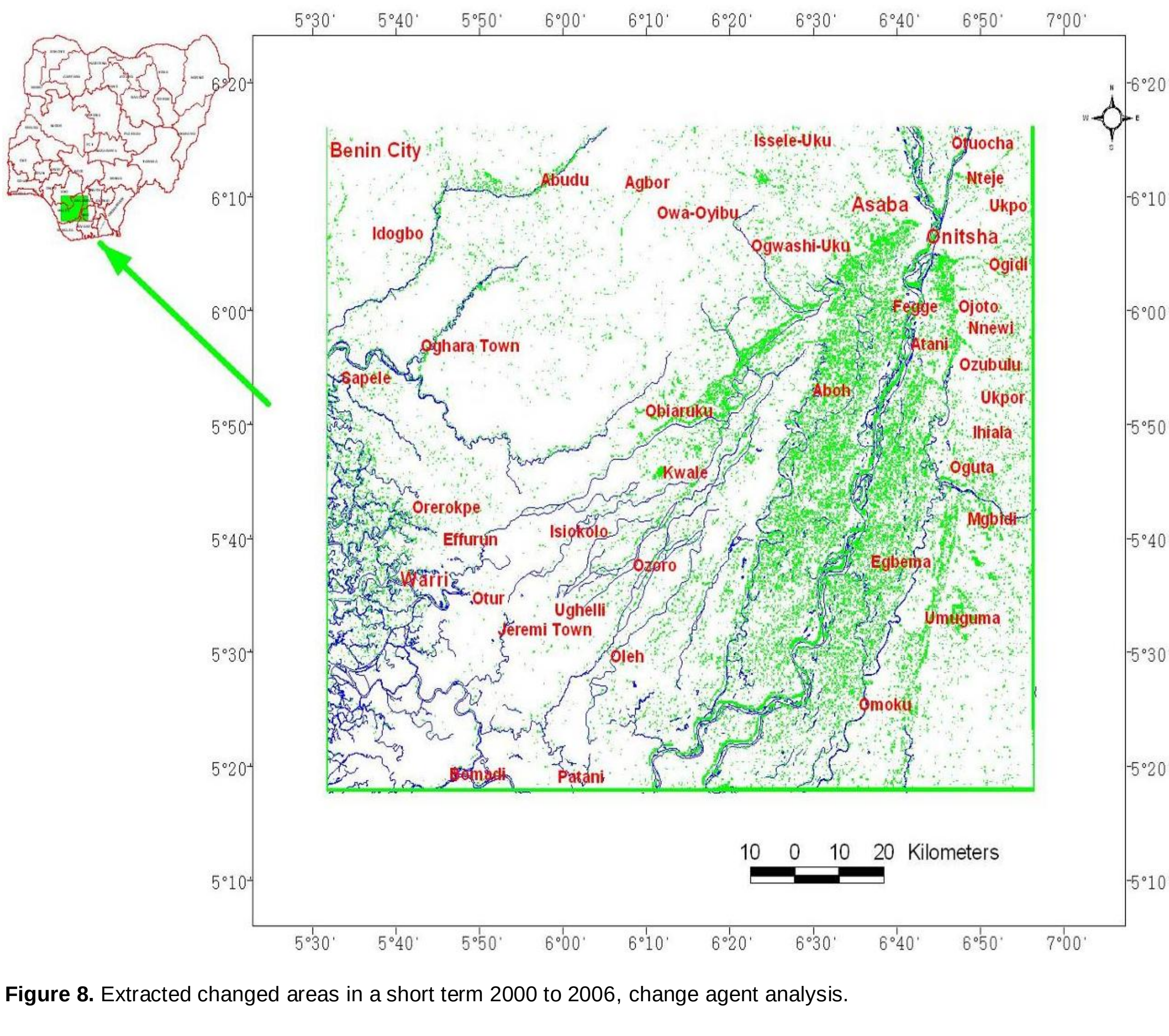


Figure 8. Extracted changed areas in a short term 2000 to 2006, change agent analysis.

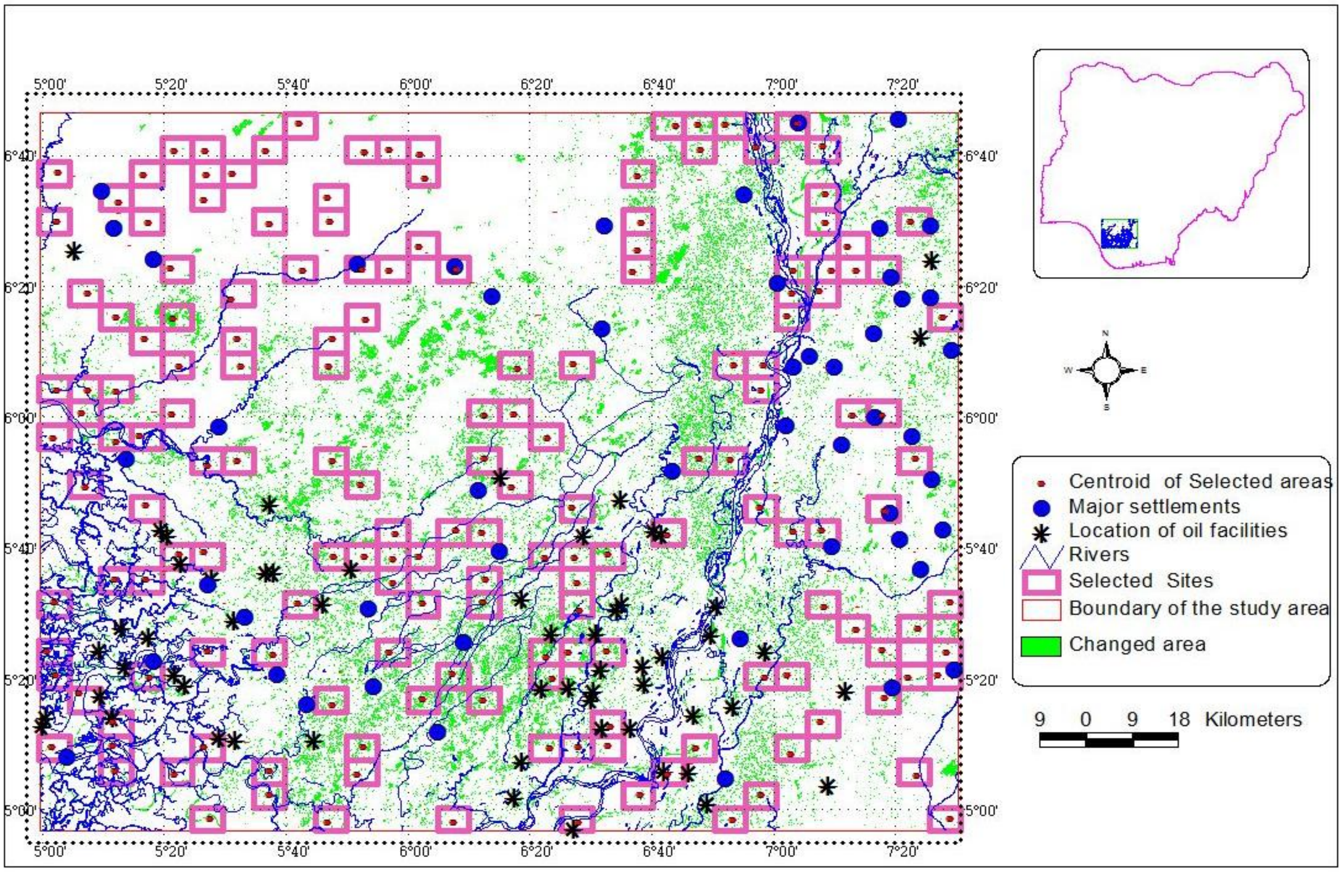


Figure 9. Selected sites and the change areas.

Table 1, which shows that distances to settlements has higher correlation coefficients 0.762 than the distances of degraded area to oil facilities (0.38). The informal human activities and large scale industrial activities may be more critical in the vegetation degradation in the Niger Delta, that the activities of the oil multinationals.

However, it is necessary to note that some of the activities of these oil companies have been captured again in the settlements measurement, especially those activities that are not directly related to oil exploitation (Figures 4 and 9). Oil facilities are not large space users therefore their influence on the landscape may be local compare to other human activities such as logging, farming, sand mining and building developments that compete with oil company in the use of land in the study area. The two values; r_{xy} = 0.762, and r_{xy} = 0.380 are significant at two tailed test. The results suggest that in short terms, the vegetation degradation can be attributed to informal anthropogenic activities especially those mentioned earlier rather than the activities in the oil industry. This was corroborated with ground reconnaissance conducted in the study area which shows that the major land users and change factors in the study area include logging, farming, building sand mining, cottage industries and middle scale industrial activities. This observation was observable in Figure 8; though there were a number of oil facilities in the south eastern parts of the study areas, the change in vegetal qualities were less in these areas. The areas where there are most noticeable changes in the vegetal quality are those in the north western parts and the central parts of the study areas including areas around Abraka, Sapele, Obiaruku, among others which have high urban presence. This study therefore posited that it cannot be established that the activities of the multinationals affect vegetal quality in the Niger Delta, than the urban development and other anthropogenic activities that were part of human development of the Niger Delta people.

Conclusion

The study showed the discrimination of the effects of oil multinationals as change agent in vegetation quality compared to human activities through urban development's and farming in the Niger Delta, Nigeria. It represents a methodological approach to resolving change agents of vegetation degradation in the short run. It shows that even in the short term analysis, changes in vegetation could be observed and the process causing the major changes succinctly identified. This study however, could not be used to delineate the contributory impact of climate change on the vegetation, although it could be explored. The wide ranging effects of the oil activities in the Niger Delta could also not be captured by the methods because the effects of oil activities are largely global while the effects of human activities is in the first instance local. While the world today focused on major industries to cut down the carbon emission, this study posited that contribution of informal anthropogenic activities to environmental degradation should not be ignored. Efforts should be directed toward efficient living in terms of activities causing major imbalances in the ecosystem.

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