Use of Remote Sensing Data to Detect Environmental Degradation in the Coastal Region of Southern Nigeria

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ABSTRACT:

Environmental degradation is one of the major issues confronting many governments around the world. This problem is acute in developing countries where the lack of proper regulatory enforcement and ineffective monitoring mechanisms due to weak legislation have led to serious environmental degradation in the form of soil, air, water pollution, degradation of native and planted vegetation and scarring of the land surface. Southern Nigeria, which is the prime focus of this study, is not an exception. The region is home to the industrial heartland sustaining the political economy of the country under the orbit of Global capital. While the region embarks upon a rapid phase of economic expansion, it faces several environmental challenges caused partly by the pressures induced by anthropocentric activities through petroleum activities, economic development and demographic changes. This continued growth has resulted in environmental problems such as coastal wetland loss, habitat degradation, water pollution, gas flaring, destruction of forest vegetation and host of other issues. The gravity of these problems underscores the urgent need to design new approaches for effectively managing these resources. Despite previous efforts, there has not been any major emphasis in the literature focusing on a remote sensing based assessment of the growing incidence of environmental change within the coastal and forest zones environment of the study area. This project explores the applications of remote sensing in the forest and coastal zone environments with emphasis on the environmental impacts of economic development in the coastal regions of Southern Nigeria.

1. INTRODUCTION: BACKGROUND INFORMATION

The current pace of environmental change in Nigeria prompted partly by degradation continues at an alarming proportion (Weller, 2005). The country flares 17.2 billion m^3 of natural gas coupled with incessant oil spillages resulting from the exploitation of crude oil in the Niger Delta region of the South. The rate of gas flaring in the country ranks 15 times more than the Worlds' and 4 times much higher than the entire Petroleum Exporting Countries (OPEC) average. The forest estate of only about 10 million hectares (10 percent of total land area of Nigeria) is declining at a rate of 3.5 percent annually due to encroachments, excisions and outright de-reservations. Although the forestry component of the national agricultural policy prescribes an increase from its present level of 10% of total land area to 20% but this set target remains unattainable. The most important factor contributing to environmental degradation of the country hinges on un-coordinated land use policy. Forestland areas are depleted by other forms of land-use such as agriculture, grazing and water management leading to formation of deserts, bare surfaces and general environmental degradation. Land under agricultural cultivation is increasing at an average rate of 554,657 ha per annum while land under high forest is diminishing at a rate of 105,865 hectares per annum. This land use pattern remains worsened by drought, forest fires, overgrazing and flooding which lead to severe environmental degradation in the form of loss of biodiversity and diminished forest productivity etc.   Southern Nigeria, which is the prime focus of this study, is not an exception. The region is home to the industrial heartland of Lagos and the oil rich Niger Delta sustaining the political economy of the country under the orbit of Global capital. Aside from externalities, the contribution of oil and gas to the Nigerian economy continues to assume greater importance. With over 75 percent of the oil found in coastal areas of the Niger Delta, Nigeria boosts of the largest oil reserve in Africa and the tenth largest in the world (Ambio 1995). Nigeria presently produces 2.2 million barrels of crude oil daily giving it the twelve largest producer spot in global ranking with $17.2 billion from oil proceeds yearly. Petroleum as the base of the economy generates 90 percent of exports by value and 70 percent of the federal government revenue. Judging from the yearly breakdown of the data from the Central Bank of Nigeria, petroleum played a major role in the economy by adding 95 percent in 2002 and 96.7 percent in 2003 of total export proceeds. In other years, existing data indicate that oil revenues grew strongly from about 26 percent in 1970 to more than 81 percent in 1980, to much higher levels of 86 percent in 1992 and 84 percent in 2000. Strangely enough, oil producing states in the Niger Delta have very little to show for the huge oil revenues flowing from their own region (Jike 2004; Worgu 2000). While the Southern region embarks upon a rapid phase of economic expansion, it faces several environmental challenges caused partly by the pressures induced by anthropocentric activities through petroleum activities, economic development and demographic changes. This continued growth has resulted in environmental problems such as coastal wetland loss, habitat degradation, and water pollution, gas flaring, destruction of forest vegetation and host of other issues. More so, land pressure of different kind

transcends the entire region. The problem of population density of the Southeast, the oil and gas pollution of the South and the high degree of urbanization of the South West makes land a major political issue in southern Nigeria

To fully understand changes that have already occurred in Nigeria, land cover data are needed to generate scenarios of future modification of the environmental system. Land use and land cover data can be obtained using in situ field measurements or remote sensing technology. To extract useful thematic information such as land cover maps from the raw imagery decision-makers must rely on intermediate steps involving scientific expertise, use of calibration data, and image-processing resources. Different applications of land use and land cover information normally require that remotely sensed data be obtained at different spatial resolutions. Nigerian society can also benefit from the capabilities of Geographic Information Systems (GIS). GIS as conceptualized in the literature are used for mapping and analyzing geographic data (Danka and Klein, 2002). They are versatile tools for studying many types of information and for managing different kinds of resources with the potentials of contributing to regional sustainability in Southern Nigeria. GIS have the potential to play a role in conservation planning and monitoring of degradation convulsing southern Nigeria at a time when environmental assessments by the oil sector negate the existence of externalities. This is because the country currently lacks any major geospatial scientific work that would offer an impartial evaluation of the destruction caused by oil and gas activities in the Delta area of the South (Human Rights Watch, 1999).

This paper uses GIS and remote sensing in detecting the extent of environmental degradation caused by human activities in the Southern region of Nigeria. Emphasis is on the issues and the environmental impacts of economic development and remedies In terms of methodology the paper draws from a mix scale approach based upon the existing literature, access to census databases of Nigeria and spatial information systems. This information is analyzed using GIS and remote sensing techniques.

2. METHODS AND MATERIALS

2.1 The Study Area: Southern Nigeria

The study area is located in the Federal Republic of Nigeria between latitudes 4^o15'N (the Southern tip of the Niger delta on the Atlantic Ocean) and 13^o55'N (the North-Western frontier with Niger) and between longitudes 2^o45'E (the Southern frontier with Benin) and 14^o40'E (the Northern frontier with Cameroon) (Arufor, 2005). It occupies a total area of 923,768 km^2. The population trends in Nigeria shows a rapid growth at the countryside and the major urban centers. The nearness of Nigeria to the south of the Atlantic Ocean together with the existing wind patterns and soil classes, bestows on Southern Nigeria diverse ecological habitats ranging from pure coconut sands near Lagos and Badagry to semi-liquid mud on which a number of fresh and salt water organisms thrive in the Niger Delta. With a large portion of the coastal part of Southern Nigeria covered by mangrove swamp forests and seven forest species, the ecosystem contains a number of wild and cultivated plant species and animals important in agriculture, fisheries and forestry (Ossom and Rhykerd, 1985)
The region has several significant wetlands that have been recognized by the government of Nigeria as ecological features

of international importance. The Southern region with a population of almost 71 million and an area of 192,793 square kilometers has 17 states divided into three zones, the South East, the South and the South West. The Lagos area of the region appears physically smaller, but it is ranked as the most highly populated state in the country and the region with an estimated population of about 10 million inhabitants representing 10 % of the total population of Nigeria. The population is expected to hit 22 million by the year 2015. The more built up mainland and Lagos Island, which make up what is referred to as the Metropolitan Lagos is inhabited by about 80% of the population of the state. Major developments on the area in the middle of last century show that the area not only experienced a rapid expansion, but it engulfed adjacent towns and villages (Abiodun, 1997; Iwugo, 2003; Ogunleye, 2001).

Special characteristics of the South include a high degree of urbanization, especially the petroleum industry and economically higher levels of pollutions and environmental degradation. Agriculture is still a major component of the Southern economy and contributes to environmental problem partly triggered by pressures from urbanization. In a regional environmental assessment conducted by the USAID, the agency ranked the use of renewable of natural resources, especially forests as the prime issue, while the region's second environmental concerns were grouped as unplanned urban development with water shortages and pollution, waste disposal problems and regulated construction. The proliferation of petroleum operations emerged as the third major ecological issue in the area. In terms of the zonal distribution of environmental problems, the most important environmental problem in the South East is massive soil erosion, while in the South it is primarily soil deforestation, the loss of biodiversity and problems of spills and gas flaring that are specific to oil exploitation. The core ecological issue in the South West is coastal erosion (USAID, 2003). On a generic scale, the entire region suffers from ineffective solid waste management system, the loss of ground cover and land degradation and poor soil fertility.
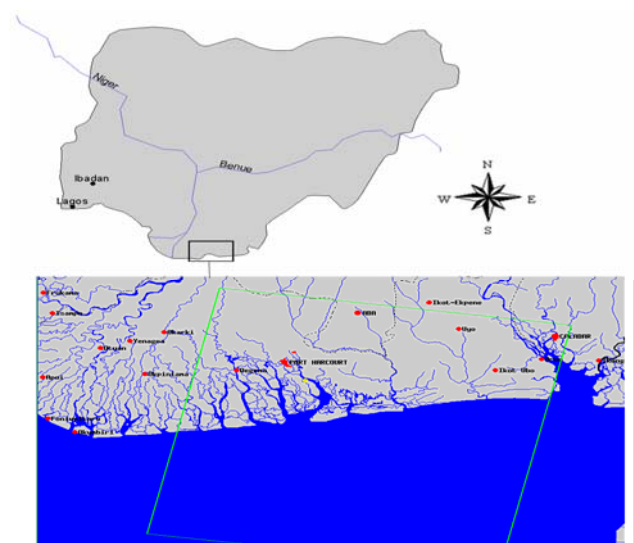

Figure 1. Map of the Study Area

2.2 Methods Used

This paper stresses a mix scale approach involving the integration of primary and secondary data provided through government sources and data bases from other organizations. The raw spatial data and satellite images used in the research were procured through the United States National Aeronautical and Space Administration NASA, the United States Geological Survey and the University of Maryland.

2.2.1 Data Acquisition: The first step involves the identification of the variables needed to assess environmental change at regional level. The variables consist of socioeconomic and environmental information, including amount of cropland, human settlement (population), water bodies and forest types, (See Tables 1 and 3). This process continued with the design of data matrices for the variables covering the various periods from 1984 and 2000. In addition, to the design stage, access to databases and abstracts that are presently available within the Federal archives in Nigeria, The United States National Aeronautical and Space Agency (NASA), the University of Maryland free Online Data Services and host of other organizations helped facilitate the search process. The spatial data acquired from NASA consists of two Satellite images for the separate periods of 1986 and 2000 while the information from the University of Maryland covered the 1984 and 2000 period.

2.2.2 Geo Spatial Data Processing and Analysis: Four Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) multi-seasonal images of 20 May 1986 and 19 June, 2000 for the Niger Delta and data pair of December 18, 1984 and February 6, 2000 covering Lagos ,were obtained for this study. The Landsat TM and ETM+ satellite data were processed using ERDAS IMAGINE 8.7 image processing software. The images were imported into ERDAS using ERDAS native file format GEOTIFF. Since the images were in single bands, they were stacked together using ERDAS layer stack module to form a floating scene and to group the bands together. Path 188 and 189 were mosaicked to form seamless image. The 1986 image was co-registered with the 2000 image and later geo-linked to allow for the subset of the both images to the study area. This was followed by performing further Geometric corrections of the 1984 and 2000 images to remove few scattered clouds in the image. Both images were projected to the Universal Traverse Mercator (UTM) coordinates zone 31. The spheroid and datum was also referenced to WSG84. Enhancement of the images using histogram equalization techniques was later performed on all the images and subset to an area of approximately 2,383.994 km^2 to cover Lagos and its vicinity. The Lagos images were later displayed as false-color composites with band combination of red as band 7, green as band 4, and blue as band 2. All the images were later categorized using unsupervised classification technique to identify land cover features within the study area. The remaining procedure involves spatial analysis and output (maps-tables-text) covering the study period, using ARCVIEW GIS. The spatial units of analysis consist of the states located in the Delta region. Outputs for the region were mapped and compared cross time. This process helped show the extent of temporal-spatial evolution of ecological change induced by human activities in the selected areas of Southern Nigeria.

3. RESULTS AND DISCUSSIONS

3.1 Environmental Change: The Niger Delta

Overall land cover change for the duration of 14 years between 1986 and 2000 is given in Table 1 and Figures 2 .1 and 2..2 The accuracy of the results was compared to government statistics and available information on the area. From Figures 2.1 and 2.2, and Table 1, water bodies experienced slight decline from 399,346 to 305,207 hectares. Mangrove also posted an overall decline of 11 percent. The biggest decline in the area was the closed forest. It declined from an initial estimate of 357,657hectares in 1986 to 108,759 hectares representing an overall decrease of 70 percent. While mangrove, water bodies and closed forest were decreasing, settlement, agricultural and economic activities were increasing as well. Agricultural and economic activities increased from 17,810 hectares to 116,092 hectares representing a change of 552 percent. Settlement also shows an overall change of 190 percent from 10,968 hectares in 1986 to 31,839 hectares in 2000. A number of forest areas that were degraded also increased during the 14 years' period. For example, from the initial estimate of 73,097 hectares in 1986, it increased to 309,921 hectares in 2000 representing an overall increase of 324 percent.

Classes	Area (ha) in 1986	Area (ha) in 2000	% change
Water	399,346	305,207	-24
Agriculture/economic activities	17,810	16,092	552
Settlement/bare areas	10,968	31,839	190
Mangrove	114,266	101,326	-11
Closed Forest	357,657	108,759	-70
Degraded Forest	73,097	309,921	324

Table1. Results of the classified 1986 and 2000 images of the Niger delta.

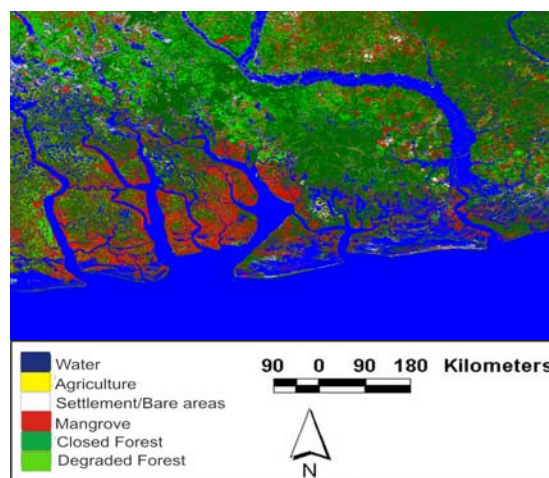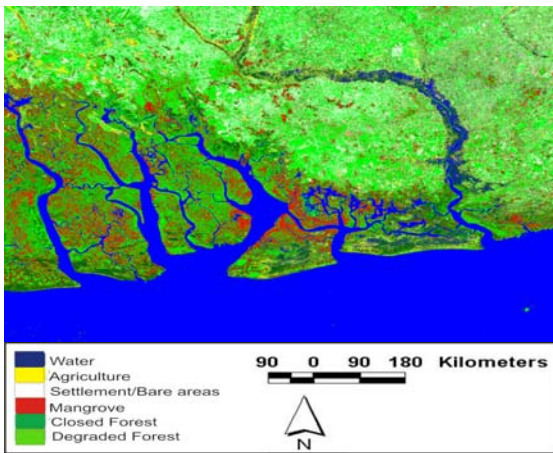Figure 2.1. May 20, 1986 Classified Landsat TM image Of the Niger delta

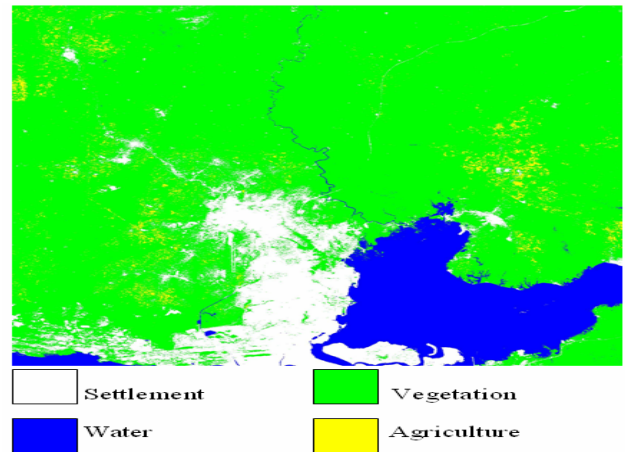Figure 2.2: June 19, 2000 Classified Landsat
TM image of the Niger delta

3.2 Environmental Change: The Lagos Area

Table 2 and Figures 3.1 and 3.2 show the results of the classification for 1984 and 2000 images of the Southwest area of Lagos. From Table 2, the land area under water declined from the initial estimate of 29,040 hectares (ha) in 1984 to 24,708 in 2000 representing an overall decrease of 14.91 percent. The size of area covered by vegetation, which include coastal mangrove, forest and grassland areas experienced a significant decline from 180,384 ha in 1984 to 140,568 ha in 2000. While the area of Lagos containing water and vegetation were experiencing a decline, agriculture and settlement was increasing. For example, between 1984 and 2000, agricultural activities increased from 4,615 ha to 9,806 representing an overall change of 112.48 percent. The size of land designated as settlement also showed a change of 159.02 percent in the same time.

Figures 4.1 and 4.2 also show the results of the false-color composites for 1984 and 2000 images. In these images, the relatively dark-brown areas represent the built up and heavily populated area, whereas greenish areas are vegetation. The deep blue regions are the water bodies. While these figures show the tremendous rate of urban expansion between 1984 and 2000, it is safe to say also based on figures 4.1-4.2 that the population of the Lagos area seems to have doubled between 1984 and 2000. This not only puts a tremendous pressure on the resources of the city, but it has the potentials to aggravate flooding of the Lagos area due to its location on the floodplain.
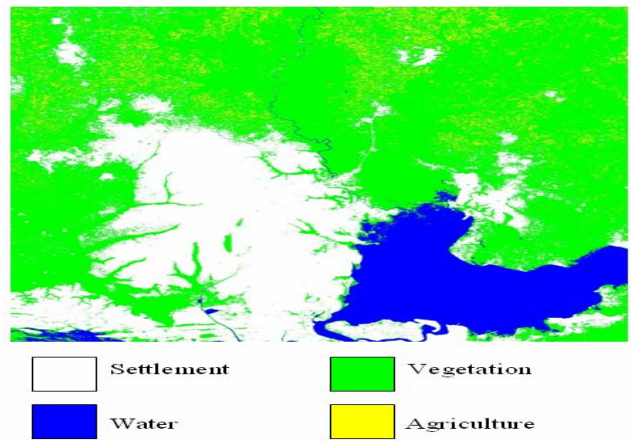

Figure 3.1: 1984 Classified Landsat Image of Lagos and its vicinity

Figure 3.2: 2000 Classified Landsat ETM+ Image of Lagos and its vicinity

Figure 4.1: 1984 False-Color Composite (742) Landsat Image of Lagos and its Vicinity

Classes	Area (ha) In 1986	Area (ha) In 2000	% change (1986-2000)
Water	399,346	305,207	-24
Agriculture/economic activities	17,810	16,092	552
Settlement/bare areas	10,968	31,839	190
Mangrove	114,266	101,326	-11
Closed Forest	357,657	108,759	-70
Degraded forest	73,097	309,921	324

Table 2. Results of the classified 1984 and 2000 images of Lagos and its vicinity
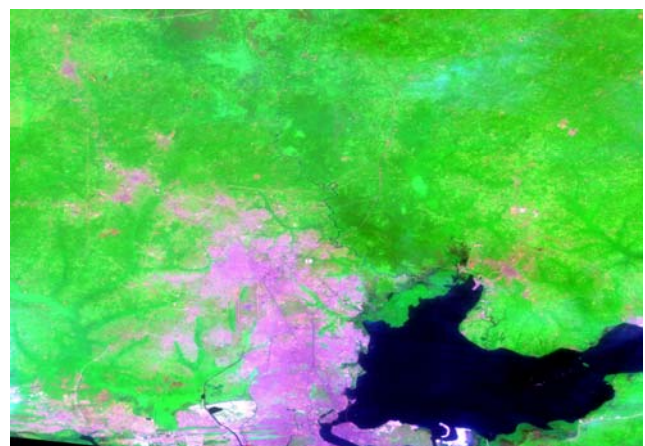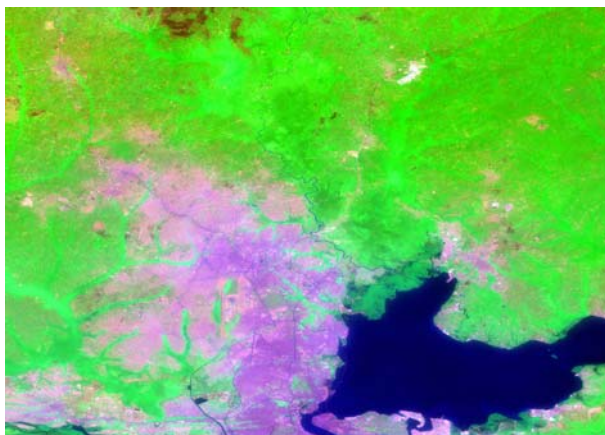
Figure 4.2: 2000 False-Color Composite (742) ETM+ Image of Lagos and its Vicinity

4. CONCLUSIONS

This paper has presented the applications of GIS and remote sensing tools in detecting the degradation of the environment from development activities along the coastal region of Southern Nigeria. The paper outlined the issues based upon the global environment, the incidence of environmental degradation in Nigeria and its Southern region, the essence of GIS and remote sensing approach, the analysis of environmental change and the effects as well as series of suggestions to mitigate the problems. Notwithstanding the gravity of the trends in the region, there has not been any major effort aimed at analyzing these issues in the Southern region with the latest advances in geospatial technologies. Considering the growing pressures mounted by development activities in the region most notably the Lagos and Niger Delta area, the results from the data analysis reveal that the study area experienced some significant variability in its coastal environments especially on the surrounding ecology of the Lagos area and the Niger Delta. This involves a decline in the land area covered with vegetation and water, pressure from agriculture and human settlement on available land base, the loss of forested areas and land cover. These changes are attributed to socio-economic and environmental variables and host of other factors linked with decades of intense development activities. The results point to a decline in water bodies , mangrove forests, and increase in human settlement, mixed forests, erosion, cropland and agricultural intensification as well as several cases of oil spillages and gas flaring ravaging both the natural and human environment. Other interesting findings touch on the potentials for population growth in the Lagos and Port Harcourt area and the anticipated stress on the environment. This will not only threaten the carrying capacity of an already fragile ecosystem, but it poses enormous challenges for environmental and resource managers and policy makers in the region if taken lightly.

The practical applications of a mix scale approach involving GIS and remote sensing as analytical tools in detecting change and degradation prompted by development activities showed some interesting results in the Southern coastal region of Nigeria. It is evident that using remotely sensed satellite imagery and GIS facilitated the detection of the geographic diffusion of ecological change involving land use, land cover classification, forest cover and the coastal hydrological issues confronting the Southern region. We believe that successful implementation of some of the strategies outlined herein could lead to effective management in the Southern region.

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