INVESTIGATING CHANGES IN COASTAL ENVIRONMENT USING INTERNET-BASED GEOSPATIAL DATA

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Abstract

The concerns of researchers and policy makers for the deteriorating condition of the coastal environments have increased in recent times. As the threats to the world today, such as, climate change, population pressure, urbanization and disasters are getting worse, it has become needful to give more attention to means of sustaining the human environment, especially the coastal areas. On the basis of this background, access to geospatial data through internet technology has become attractive, for investigating the impacts of dynamic processes on the coastal environment. This paper presents the result of investigation carried out in Okrika coastal areas of Rivers State, Nigeria. In particular, it discusses how internet-based geospatial data (for example; LandSat TM, ETM+ and Google Earth maps) of three epochs, were incorporated into open-source Geographic Information System (GIS), such as, Integrated Land and Water Information System (ILWIS), and applied to the investigation of land use/land cover (LU/LC) changes. The results obtained tend to show that between 1986 – 2007, 10.94% of the coastal areas was modified from water body to residential areas, 1.10% from residential areas to swamps, 0.42% from vegetation to water body and 0.93% from residential areas to water body. With these modifications, the economic mainstay of the people (marine, tourism and fishing activities) has been adversely affected. The research recommends that effective shoreline protection facility be put in place through government regulations in order to minimize further encroachment, particularly with regards to the water bodies. Also, high-resolution geospatial data as well as simple GIS applications should be made available on the internet, to enable more researchers contribute knowledge and solution to coastal crises, as well as improve collaboration within an interactive platform among policy and strategy formulators.

Key Words: *Coastal environment, Geospatial data, Remote Sensing, LandSat TM, ETM+, Internet, Open-source GIS.*

Introduction

Land use/land cover (LU/LC) can be conceptualized as the natural scenery of an area, which gives rise to a range of activities human beings undertake for their survival and well-being. It can also be looked at as the surface and subsurface attributes of the earth, which in a more generic term can refer to biotic and abiotic features, including soil, topography, surface and underground water bodies, and human structures. LU/LC are two terms that mean almost the same, *albeit*, can be applied to refer to different things in the strictest sense. However, they are mentioned interchangeably in literature (for example; DeFries et *al.,* 1995, Loveland *et al.,* 1999), and refer to both natural and human induced scenery of an area, the knowledge and analysis of which can be useful for environmental management.

Concerns about the changes in LU/LC emerged in the research agenda through Global Environmental Change (GEC) literature several decades ago with the realization that land surface processes influence climate (Otterman, 1974; Charney and Stone, 1975 and Sagan *et al.,* 1979). Recent changes and variations in climate, especially in intensity and frequency of rainfall, sea-level rise, are compounded by rapid growth in urbanization and demography to modify urban environments (Barrios *et al.,* 2006; Carter and Parker, 2009) especially the coastal areas. This implies that many coastal areas are losing their natural scenery, and the occupation and economic mainstay of the wider

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population dwelling in such areas are being threatened. Hence the need to investigate and analyze such LU/LC changes cannot be over emphasized. LU/LC change analysis can then be said to be one of the most precise techniques in the fields of Remote Sensing and GIS, directed towards understanding how land resources have been utilized in the past, how estimates of future expectations can be provided with regards to present ongoing inevitable human activities that modify LU/LC, and ways of addressing their accompanying difficulties. LU/LC change analysis also provides researchers with valuable information for assessing the impacts of population pressure, agricultural growth; urban expansion, resettlement program and climate change, on the environmental, and delineates the spatial relationship that exists between different land use activities (Loveland *et al.,* 1999). Such analyses are of significant application to natural resources managers, development agents, fund providers, socio-economic development planners, public administrators, and environmentalists, who apply their findings to define the purposes for which humans beings modify the natural LU/LC. To researchers, such findings promote further studies and enable policy/strategy formulators to plan and execute developmental programmes by means of more realistic data.

Many studies have provided significant evidence regarding the certainty of LU/LC changes on the environment, particularly the coastal areas, both globally and locally. The methodologies applied to investigating them are also addressed. Lo and Yang (2002) presented the investigation of LU/LC changes in Atlanta Georgia metropolitan areas, by means of time series satellite imagery. Other studies are contained in current literature (for example; Brown *et al.,* 2000; Dale *et al.,* 1993; William and Turner*,* 1992; Weng, 2002; Houet *et al.,* 2010; Saikia, *et al.,* 2013): the utilization of freely available geospatial data to investigate these changes is particularly addressed. Although satellite data have contributed meaningfully towards investigating and analyzing LU/LC changes, their availability does appear to favour of the More Developed Countries (MDCs) more than to the Less Developed Countries (LDCs). The major reason for such imbalance being that much funds is invested in acquiring and archiving of such geospatial data in the MDCs (NASA, 2007), where the advantages of geospatial data are also enhanced by information technology (IT). In recent times, significant improvements have been achieved in IT, in respect of processing speed, hardware size and storage capacities of these technologies, and with the internet, researchers and policy makers today have obtained unlimited access, without time or location constraints. The position of geospatial data availability and IT are almost like the other side of the coin in LDCs, while the problem in such places generally ranges from lack of required data to lack of access to the ones available. Many studies regarding coastal regions, for example flooding (Bates and de Roo, 2000), land slide, erosions, oil spillage, require high resolution geospatial data which are not readily available to LDCs. Although there have been several attempts to resolve the difficulty (for example, Google Earth, NASA, EODIS, Global Land Cover Facility (GLCF)), which still have benefited the DCs more than the LDCs, more work is still required.

From the point of view of geospatial data, and considering the prevalence of the various adverse environmental situations, which although, are global phenomena, it is therefore incumbent on researchers, especially in the LDCs to resort to the internet as a source of geospatial data and open source technologies, in order to respond to the ever increasing challenges that confront the environment. It is against such a background that the present study is being carried out, the aim for which is to investigate changes in the coastal environment, with Okrika local government area (LGA) of River state, Nigeria, as a case in point. How the investigation was carried out through a quartet of objectives is presented in this paper. First, a study of the major LU/LC of the study area was undertaken from existing maps, previous literature, and ground survey operations. Then, internet-based geospatial data and open source software were acquired from appropriate sources. Third, the data acquired were processed and analyzed by means of GIS and remote sensing technologies. Finally, the results were interpreted and from their findings, necessary recommendations were made to the government, stake holders, data providers, environmentalists and planners and the human populations inhabiting the Okrika LGA in respect of the present threats to the mainstay and economic activities, and future development of Okrika area. The rest of the paper focuses on a description of the study area, the methodology applied to the study, description of internet-based geospatial data, results and discussions, recommendations and conclusions.

Study Area

Okrika is a coastal environment, as well as a port town located in Rivers State, a part of Niger Delta area of Nigeria (Figure 1). The town, which has a total land area of $222km^2$ is situated on a small island south of Port Harcourt, with geographical coordinates of approximately 4.6^0N to 5.5^0N Latitude and 7.1^0E to 7.6^0E longitudes, and has a total population of 222,026 persons, by the 2006 national population census of Nigeria (NPC, 2007), making it a suburb of the much larger city of Port Harcourt. As Okrika area lies on the north of the Bonny River and on Okrika island, 35 *miles* (56*km*) upstream from the Bight of Biafra, its average elevation is 19.103*m* above the mean sea level.

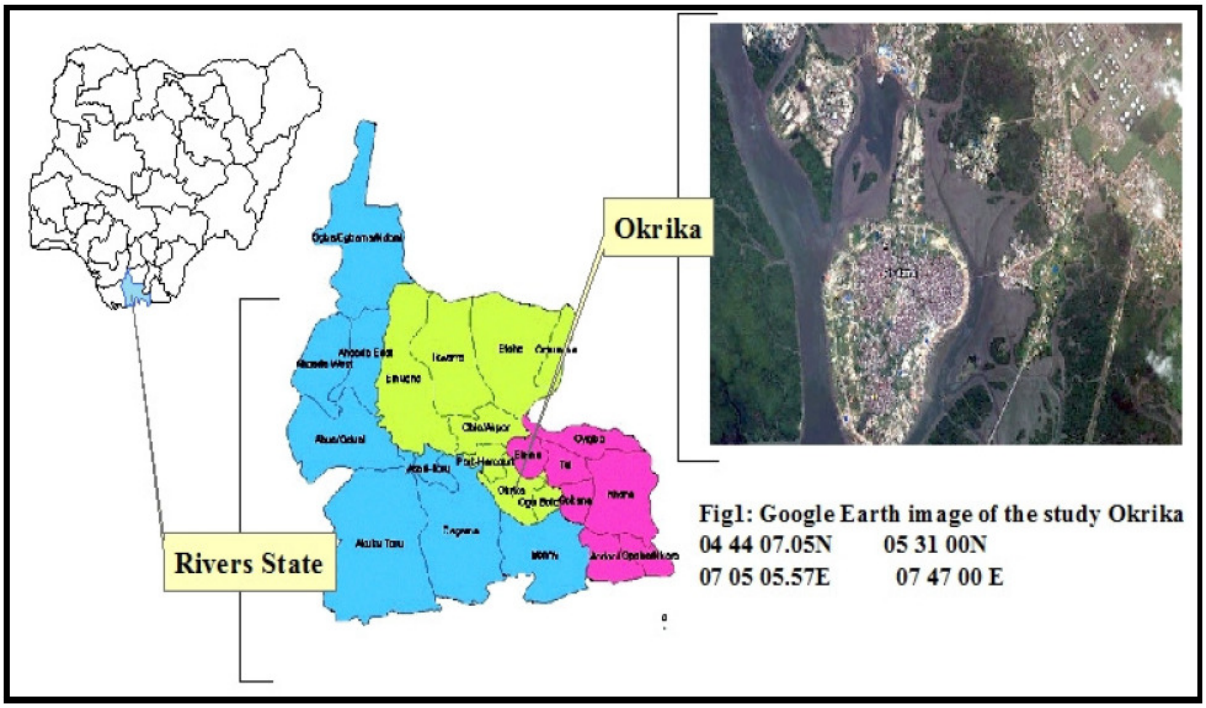

Fig1: Google Earth image of the study Okrika
04 44 07.05N 05 31 00N
07 05 05.57E 07 47 00 E

Figure 1 Okrika Coastal Area of Rivers State, Nigeria

From antiquity, the town of Okrika was formerly a small fishing village of the (Ijaw) people in the mangrove swamps of the eastern Niger River delta, but became the capital of the Okrika kingdom in the early 17th century and actively dealt in slave trading. It served as a port for the exportation of palm oil after the abolition of the slave trade in the 1830s, but was a less significant port facility than either Bonny (18 *miles* [46*km*] south) or Opobo (32*miles* [81*km*] east-southeast). By 1912, Okrika had been completely eclipsed by Port Harcourt, and was not revived as a commercial port until 1965, when the nearby Port Harcourt oil refinery was completed and pipelines were built to a jetty on Okrika Island. It also has a major gas plant facility (Alakiri gas plant) that supplies the refinery. Refined petroleum products are only significant exports of Okrika, although it has considerable local trade in fish, oil palm produce, locally processed salt, cassava (manioc), plantains, and yams.

Of recent, expansion of residential area is noticed to have encroached into the farm lands, water body, swamp/mangrove and vegetation. Many residential areas are being converted into water bodies as a result of the back and swath of the ocean current along the shoreline. These recent characteristics of the land, which is swift environmental conversions and modifications attributed to a range of human activities, environmental, climatic, and socio-economic conditions have been adverse to the economic development of the area, and therefore call for immediate attention.

Methodology

The LU/LC of the study area, the knowledge of which is fundamental to the investigation of the changes that have occurred over a period of 20 *years*, was first studied from existing maps, and previous literature, in order to understand the major socioeconomic and environmental themes of the area. The findings of the preliminary investigation are shown in table 1.

Table 1 Distributions/Identified land use/ land change category at different epochs (1986-2007) in Okrika River State Nigeria

Land Use Category	*1986*		*1996*		*2007*	
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
Farmland	171	1.57	2.7	0.03	0	0.00
Residential	2794.5	25.88	3833.1	35.49	4723.2	43.73
Swamp	3862.8	35.77	2573.1	23.83	1802.7	16.69
Vegetation	272.7	2.53	292.5	2.71	2088	19.33
Water body	3699	34.25	4098.6	37.95	2186.1	20.24
TOTAL	10800	100.00	10800	100.00	10800	100.00

Following the existing LU/LC, which included residential area, water body, vegetation, farmland and swamp, a design data matrix was constructed for the existing LU/LC themes, covering the periods from 1986 to 2007, as shown in table 1 above, for easier identification and further operations. A topographic map of Okrika, which served as a basis for delineating the topography of the area, was acquired from Google Earth database. Landsat Thematic Mapper (*TM*), and Enhanced Thematic Mapper plus (*ETM+*) which were the primary data for the change detection study, were acquired orthorectified from GLCF – data distribution center of NASA. The *TM* imagery, acquired by Landsat 5 satellite in a low sun-synchronous orbit is made up of seven bands, including a panchromatic band, with spatial characteristics of 30*m* and 15*m* resolution respectively. The study datasets are shown in table 2 below.

Table 2 Geospatial data requirements and Sources

S/No.	DATA	SOURCES
1.	Landsat TM of 1986 & 1996 bands 2,4&7	NASA GLCF
2.	Landsat ETM+ of 2007 bands 2,4&7	NASA GLCF
3.	Topographic Map of Okrika (1m Resolution)	Google Earth

There were three tiles of Landsat images each representing epochs 1986, 1996 and 2007, while the false colour bands 1-7 images were combined and sharpened with the panchromatic band. This operation enhanced the spatial resolution, as well as the pictorial quality of the images, and assisted in feature recognition and extraction during image classification. Unsupervised maximum likelihood classifier was applied to extract features and to group pixels into different LU/LC classes. The LU/LC classes extracted included; residential area, water body, swamp/mangrove, vegetation and farmland, consistent with Anderson *et al*., (1976) classification scheme.

For investigating the changes in LU/LC themes, the total area for each theme in the three epochs was calculated and the results compared. Field verification and accuracy assessments were carried out for all the three images after classification, to verify and validate the classification results. The overall accuracy level for the Landsat TM (1986), Landsat TM (1996), and Landsat TM (2007) was found to be 82.23%, 86.12%, and 94.33% respectively. Then, the final output of LU/LC change investigation was mapped, according to the three epochs – 1986, 1996, and 2007. While image processing and classification was carried out in ILIWIS 3.6, open source remote sensing software, the final mapping of the change detection output was implemented in ESRI ArcGIS 9.3 software. The trends of modifications in LU/LC in the study area are given in table 3.

Table 3 Trends in changes investigated in Okrika Land Use distribution between 1986-1996 and 1996-2007

LAND USE CHANGE CATEGORY	1986-1996			1996-2007		
	Change (km2)	% Change	% Change km2/yr.	Change (km2)	% Change	% Change km2/yr.
Farmland	-168.3	-98.42	-9.84	-2.7	-100	-10.0
Residential	1038.6	37.17	3.72	890.1	23.22	2.32
Swamp/mangrove	-1289.7	-33.39	-3.34	-770.40	-29.94	-2.99
Vegetation	19.8	7.26	0.73	1795.5	613.85	61.38
Water body	399.6	10.80	1.08	-1912.5	-46.66	-4.67

Internet-based Geospatial Data

Geospatial data can be referred to as data that represents the geographic location of natural and man-made features on the surface of the earth. It is usually stored as coordinates and topology, and can be mapped. Geospatial data can be accessed, manipulated or analyzed through Geographic Information System. Groot and McLaughlin, (2000) linked geospatial data to geospatial data infrastructure needed to integrate networked databases, and data handling facilities, along with institutional, organizational, technological, human and economic resources that interact with one another. Such interactions also underpin the design, implementation and maintenance mechanisms that facilitate the standardization, access and sharing, and responsible utilization of geospatial data at affordable costs within specific application domains or enterprise. In support of this, Van Loenen and Kok, (2004) revealed that geospatial data are becoming increasingly important as a component in decision making processes and planning efforts across a broad range of industries and information sectors. Researchers, policy makers and the government depend so much on geospatial data to provide solutions to a plethora of environmental and institution-based problems. Acquisition of geospatial data and making them easily accessible to those in need of them should be a general concern (Groot and McLaughlin, 2000).

LandSat *TM* and *ETM+* applied to this study were both acquired from Global Land Cover Facility (GLCF). GLCF is a geospatial data and research agency, sponsored by National Aeronautics and Space Administration (NASA) and other governmental agencies, non-profit organization and private corporations, and universities, in particular, university of Maryland (NASA, 2007). Through GLCF, NASA makes earth-related data available to the public at no cost through their main of data provision arm, the Erath Science Data Interface (ESDI).

Results and Discussion

The five major LU/LC types of the study area were also identified and detected, as the

Landsat images of 1986, 1996 and 2007 were classified. The detected pixels represented farmland, vegetation, residential area, water body and swamp/mangrove in discrete proportions. On the image, the sum of features detected as residential area, farmland and vegetation for the epochs 1986, 1996 and 2007, was found to be, 3,038.0km^2, 4,128.2km^2 and 6,811.2 km^2 respectively. Also, the sum of features detected as swamp/mangrove and water body for the same epochs, gave 7561.8 km^2, 6671.7 km^2 and 3988.8 km^2 respectively. Residential areas appeared to be the predominant type of LU/LC theme within the epochs under review, and covered significant part of the study area (See Table 1). From the investigation, residential areas showed an increase at the rate of 3.72 % between1986-1996 and 2.32% between1996-2007. Such increase can be attributed to excessive human activities, such as demographic growth, industrialization, urbanization, which *albeit,* strongly correlates negatively with water body and swamp/mangrove in the area, has been found to depend on it, and thus, results to a sharp decline in the distribution of water resources and swamp/mangrove in the study area. The percentage change for water body is 10.80% for 1986-1996 and -29.94% for 1996-2007 while that of swamp/mangrove was -33.39% for 1986-1996 and -46.66% for 1996-2007. The negative change may be attributed to impact of human actions such as population pressure; socio-economic and climatic change.

Moreover, the results tends to show that farmland has almost been totally lost within the period under investigation (see tables 4 and 5), a matter that calls for serious and urgent intervention from administrators/land planners and land policy formulators since the inhabitants of the area are predominantly peasant farmers.

Table 4 Land use category at different epochs (1986-1996) with their respective amounts of modifications

S/No.	CHANGE 1986-1996	AREA (Hectares)	% CHANGE
1.	Water body to Water body	326.61	30.24
2.	Water body to Residential Area	38.43	3.56
3.	Water body to Vegetation	0.45	0.04
4.	Water body to Swamp	4.41	0.41
5.	Residential Area to Water body	6.75	0.63
6.	Residential Area to Residential Area	263.97	24.44
7.	Residential Area to Vegetation	3.33	0.31
8.	Residential Area to Swamp	5.13	0.48
9.	Residential Area to Farmland	0.27	0.03
10.	Vegetation to Water body	1.71	0.16
11.	Vegetation to Residential Area	14.94	1.38
12.	Vegetation to Vegetation	6.66	0.62
13.	Vegetation to Swamp	3.96	0.37
14.	Swamp to Water body	73.98	6.85
15.	Swamp to Residential Area	60.48	5.60
16.	Swamp to Vegetation	13.05	1.21
17.	Swamp to Swamp	238.77	22.11
18.	Farmland to Water body	0.81	0.08
19.	Farmland to Residential Area	5.49	0.51
20.	Farmland to Vegetation	5.76	0.53
21.	Farmland to Swamp	5.04	0.47
		1080	100.00

The results also tends to show that the coastal environment of the study area has undergone changes in pattern and utilization, *viz:* between 1986-1996, 3.56%, much of the area was modified from water body to residential area, 0.48% was changed from residential to swamp, 0.16% was modified from vegetation to water body and 0.63% was converted from residential area to water body. Besides, between 1996 -2007, 7.38% of the study area was changed from water body to residential area, 0.62% was changed from residential to swamp, 0.26% was changed from vegetation to water body and 0.30% was converted from residential area to water body, etc. The results are maps shown in figures 2, 3 and 4.

Table 5 Land use category at different epochs (1996-2007) with their respective amounts of modifications

S/No.	CHANGE 1996 - 2007	AREA (Hectares)	% CHANGE
1.	Water body to Water body	145.71	13.49
2.	Water body to Residential Area	79.74	7.38
3.	Water body to Vegetation	73.17	6.78
4.	Water body to Swamp	111.24	10.30
5.	Residential Area to Water body	3.24	0.30
6.	Residential Area to Residential Area	360.99	33.43
7.	Residential Area to Vegetation	12.42	1.15
8.	Residential Area to Swamp	6.66	0.62
9.	Vegetation to Water body	2.79	0.26
10.	Vegetation to Residential Area	8.55	0.79
11.	Vegetation to Vegetation	14.31	1.32
12.	Vegetation to Swamp	3.60	0.33
13.	Swamp to Water body	66.87	6.19
14.	Swamp to Residential Area	22.95	2.12
15.	Swamp to Vegetation	108.72	10.07
16.	Swamp to Swamp	58.77	5.44
17.	Farmland to Residential Area	0.09	0.01
18.	Farmland to Vegetation	0.18	0.02
		1080	100.00

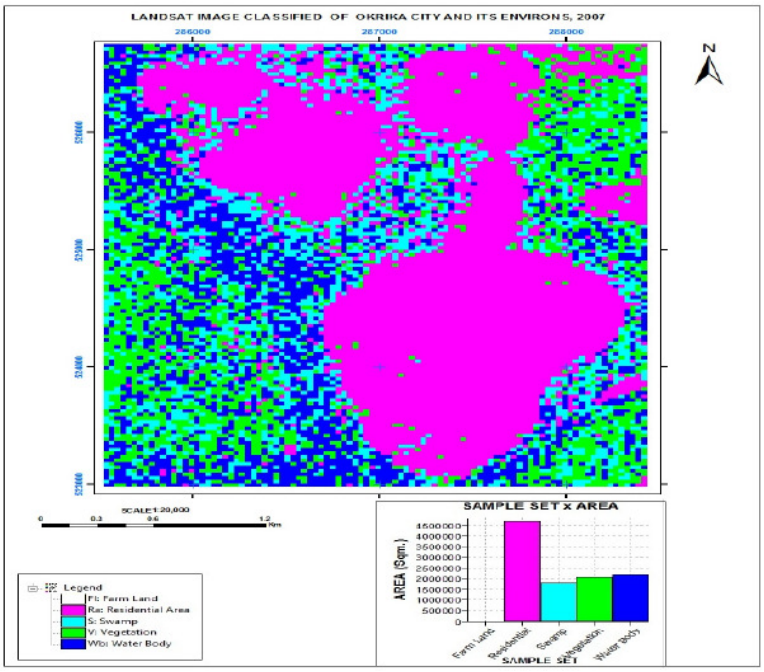

Figure 1 Classified Image of Landsat of 1986. Dark blue color for water body, Pink for Residential areas, Green for vegetation, and light blue for Swamps

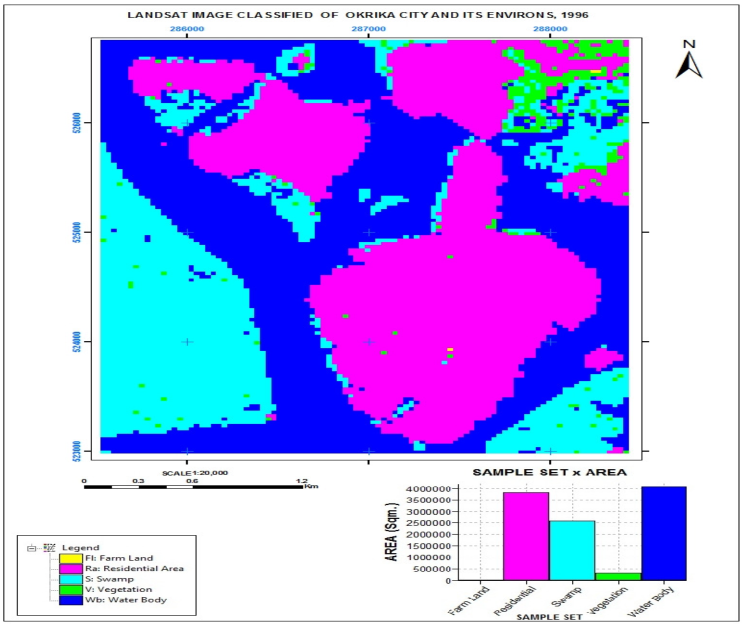

Figure 2 Classified Image of 1996. Dark blue color for water body, Pink for Residential areas, Green for vegetation, and light blue for Swamps

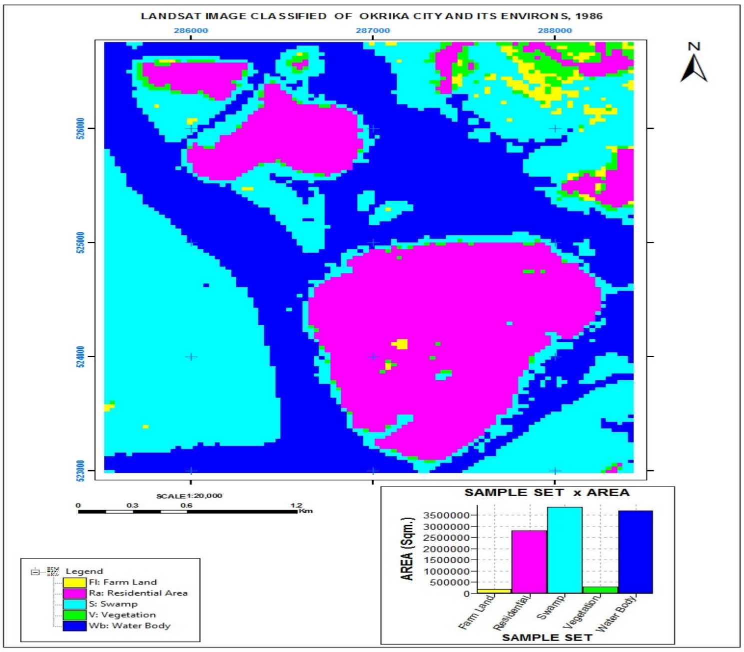

Figure 3 Classified Image of 2007. Dark blue color for water body, Pink for Residential areas, Green for vegetation, and light blue for Swamps

Conclusion

Internet-based geospatial data and open source GIS applications, in combination with field observations, have been applied to investigate the LU/LC changes in Okrika LGA of River state, Nigeria. The study revealed significant LU/LC conversion and modification in land resources pattern and utilization. The present high population density, which can be attributed to increasing rate of birth, and migration/resettlement, exerts immense pressure is land resources in the study area. The overall consequences of these alteration and modification of the LU/LC, is the severe degradation of the natural scenery of the environment in the study area. This, coupled with the current threats of global warming, would lead to severe flooding, soil loss and deterioration of its nutrients, micro-climatic change, destruction of wildlife resources, and the much difficulty for the human population in the area. Hence, it is imperative to take all the necessary measures available to the local and state government and other concerned bodies to arrest the present destruction of farmland and swamp/mangrove and depletion of water body due to increased demands for residential space in the area.

Recommendations

The increased human activities which have led to depletion of the water bodies and swamp/mangrove in the Okrika LGA need to be checked in a concerted manner, and by a coordinated and integrated approach that examines the dynamics of the study area as a watershed area of the Niger Delta. The deforestation of the area as a result of utilizing of firewood, as source of energy for cooking – a situation which has resulted to its high cost, almost unaffordable by the local populace – should be checked. This could be achieved through intervention by government departments such as ministry of water resources, forestry, agriculture and environment. Dredging of rivers around the study area should be discontinued, as a matter of necessity. However, where it is not possible, strategic measures should be adopted, in order to reduce the environmental impact, such as flooding, which will likely affect both the coastal and urban areas.

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