An Assessment of the Physical and Environmental Aspects of a Tropical Lake: A Case Study of the Oguta Lake Watershed, Niger Delta Basin, Nigeria

Ahiarakwem, C. A.
Nwankwor, G.I.
Onyekuru, S.O.

Department of Geosciences
Federal University of Technology
Nigeria

Idoko, M. A.
Department of Geography and Regional Planning
University of Calabar
Calabar, Nigeria

Abstract

The assessment of very important physical and environmental aspects of Oguta Lake and its watershed, Niger Delta Basin was carried out using data obtained from satellite imagery (Landsat Tm 2000) and the Global Positioning System (GPS). The data were analysed and interpreted using the Integrated Land and Water Information System (ILWIS) and AutoCAD Land developer. False Colour Composite (FCC) map generated from the satellite imagery displayed the study area into portions covered by vegetation as red; built-up areas around the lake as cyan; areas covered by sediments as blue/cyan and eutrophication, pale red. Digitalization/processing of the FCC map indicated that areas covered by the Oguta Lake water body is about 1,870.4m^2 (68.2%) while degraded portions of the lake occupied an area of 1152.25m^2 (38.8%). The degraded portions of the lake is comprised of areas under intense environmental stress arising from anthropogenic activities (degradable portion) with a total area of 1099.97m (36.91%), areas covered by sediments and eutrophication with total areas of 41.3 m^2 (1.39%) and 14.9m^2 (0.5%), respectively. The study also showed that built-up areas outside the vicinity of the lake with an area of about 4,983.3m^2 have very strong positive correlation (R^2=1) with the degradable portions (areas characterized by human activities such as washing, bathing and sand mining) of the lake. Since the areas covered by degraded portions (including sediments and eutrophication) is relatively high (about 38.8%), there is thus an urgent need to ensure proper management of the lake and its ecosystem. This can be achieved through constant monitoring of the status of Oguta Lake's environment and good government policies. Such steps would help in maintaining the resource status and usefulness of the Lake.

Keywords: False Colour Composite, Satellite Imagery, Eutrophication, Sediments and Ecosystem

Introduction

Background Information

Lakes are very important aspects of surface water resources of the earth (surface water resources cover about 71% of the land areas of the earth). In Nigeria, Oguta Lake is one of the natural water resources of non-marine habitat located in a low-lying (elevation < 50m) platform. The lake precisely lies between latitudes 5^0 41^1 and 5^0 44^1 North and longitudes 6^0 45^1 and 6^0 50^1 East in the equatorial rainforest belt of Nigeria (Figure 1). Although, it is a very small lake compared to man-made and natural lakes in Nigeria like Lake Chad, Kainji and Tiga, it is, however, the largest freshwater system in southeastern Nigeria.

Oguta Lake is of strategic importance to both the local population and the Imo State government of Nigeria. To the former, the lake is the main source of domestic water supply and also used for recreation, fishing, transportation and sand mining activities.

To the later, it constitutes a focal point for sporting, research and tourism development. Unfortunately, the lake also acts as outlet for sewage disposal (Ahiarakwem and Onyekuru, 2011). Although some studies (Nwadiaro and Umeham, 1985; Odigi and Nwadiaro, 1988; Odigi and Nwadiaro, 1993; Ahiarakwem, 2006) have been carried out on some aspects of the lake using bio-chemical techniques, the use of Geographic Information System (GIS) is yet to be employed in the study of the lake and its watershed.

GIS is a computer-based system used to store and manipulate geographic information (Stan, 2005). The technology has developed so rapidly in the past two decades that it has now been accepted as an essential tool for the study of natural resources (minerals, soil and water), municipal facilities and forestry to mention but a few. The use of GIS in the study of natural resources has been successfully employed by a lot of scholars (Ahmadi, 1999; Kang, 2002). The Geographic Information System (GIS) is associated with remote sensing technique as it makes use of satellite data imagery at times.

In this study, the GIS approach was employed to assess some physical and environmental aspects of Oguta Lake with a view to providing baseline information of the lake and its environs for future development. The study aims to quantitatively delineate the Oguta Lake and its watershed in terms of areas covered by the water body, sediments, eutrophication and built-up areas around the lake as well as areas degraded by anthropogenic activities.

Geology and Hydrology

The regional geology of the Tertiary Niger Delta Basin of Nigeria in which the study area is a part, has been studied extensively (Short and Stauble, 1967; Akaegbobi, 2000; Umeji, 2003; Olabanyi and Owoyemi, 2004). These studies covered different aspects including but not limited to the basin's petroleum potential, lithostratigraphic units and structural configuration.

Short and Stauble (1967) recognized three main lithostratigraphic units in the basin namely (from top to bottom), Benin, Agbada and Akata Formations. The Oguta Lake lies within the Benin Formation (Figure 2). The Benin Formation consists of continental sands with lenses of clay/shale and some isolated units of gravel, conglomerate and sandstones (Ananaba et al., 1993). The formation is Pliocene to Miocene in age and overlies the Agbada Formation which consists of sands and shale units. Odigi and Nwadiaro (1988) studied the surface geology of Oguta Lake area using road cuts and low hills and observed that it consists of ferruginized sands which are occasionally massively bedded and pebbly.

Four rivers (Njaba, Awbana, Utu and Orashi) are associated with Oguta Lake (Ahiarakwem and Onyekuru, 2011). The Njaba and Awbana discharge into the lake all the year round while Utu Stream flows in during the rainy season. The Orashi River flows past the lake in its southwestern portion. The total annual inflow from the rivers and stream is about 25,801.60m^3 (Ahiarakwem, 2006). The annual return and overland flow into the lake is estimated to be about 69.000 and 138,000m^3, respectively while the annual recharge of the lake from precipitation is about 693,000m^3. The annual groundwater inflow into the lake is estimated at about 2,750,400m^3. The total annual water inflow greatly outweighs the total annual outflow (Ahiarakwem, 2006). These statistics show that Oguta Lake is adequately recharged all the year round.

Materials and Methods

The approach employed in this study involved the application of remote sensing/Geographic Information System (GIS) and detailed field study to compliment satellite data imagery interpretation.

The materials used include satellite imagery (Landsat Tm 2000), ILWIS (Integrated Land and Water Information System) - a Remote sensing/GIS application software, hand-held Global Positioning System (GPS) and AutoCAD land developer.

The systematic steps employed in the study included image acquisition and enhancement, image interpretation and delineation.

The satellite imagery Landsat Tm 2000 data covering the study area was acquired and subjected to image preparation. Subsequently, the data was enhanced using filtering and stretching operations in the ILWIS window. The enhanced landsat imagery was then processed into foreign collection' which represents non-spatial environment.

The product was then processed to a geo-referenced spatial ILWIS format to create a False Colour Composite (FCC) map using bands (RGB) 1, 2 and 3 of the electromagnetic spectrum (Figure 3). Unwanted signals like associated rivers and vegetation components in the FCC map were filtered out through further processing and digitalization to obtain the model of the area, which shows the spatial distribution of the physical aspects and environmental status of Oguta Lake and its watershed (Figure 4)**.**

The ILWIS was also used to delineate and digitalize the identified features into closed segments linked to the close domain. The closed segments were polygonised to delimit the different physical components of the lake, including the water body, degradable areas, areas covered by sediments and eutrophication (Figure 5).

Ground truthing of the identified features involved a detailed field survey using handheld Global Positioning System (GPS) which was used to acquire co-ordinates (Latitudes and Longitudes) at various points around the lake (Table 1). The geographic co-ordinates were later converted to Nigerian National (NN) using the Geographical calculator (Geocal) software. AutoCAD was then used to plot and letter the generated profile of the lake (Figure 6). The ground truthing operation was also used to confirm areas characterized by human activities such as the sites for sand mining activities.

Results and Discussion

False Colour Composite (FCC) map generated from the acquired satellite Tm 2000 imagery (Figure 3) was interpreted as follows: vegetation was described with red colour; built-up areas, cyan; sediments, cyan; eutrophication, pale red and water body, blue. Apart from the above features, the FCC map also indicated associated river systems and adjoining marshy surroundings. However, vegetation, associated rivers and marshy surroundings were treated as unwanted signals in this study, and filtered off through to produce a model of Oguta Lake and adjoining areas (Figure 4). This model indicated the limits of the Oguta Lake water body, built-up areas, degradable portions and areas covered by sediments and eutrophication (degraded portions of the lake).
Quantification of the spatial distribution of the major physical and environmental components of Oguta Lake and its watershed showed that the water body covers an area of 1,870.36m^2 (61.2%) and the degraded portions, an area of 1152.25m^2 (38.8%) (Figure 5). The degraded portion is comprised of the areas covered by degradable portion with a total area of 1,099.97m^2 (36.91%), sediments and eutrophication covering an area of 41.33 (1.39%) and 14.95m^2 (0.5%), respectively (Figure 7).

It is imperative to note that the areas covered by sediments and eutrophication lie within the portions occupied by the water body (Figure 4). To this end, the FCC map was further processed to obtain a model that delimited the lake area into two segments (Figure 8) showing the water body (61.2%) and degraded portions (including degradable areas and areas covered by sediments and eutrophication) representing 38.8% of the Oguta Lake area and its watershed.

The ground truthing operation carried out in the area generated the profile of the lake and showed that the lake flows in the east-west direction (Figure 6). This is the direction in which Suspended Particulate Matter (SPM) introduced into the lake from associated rivers and anthropogenic activities will predominate. The study of suspended matter is essential in water quality models. First, when sediment is stirred up, nutrients, trace metals and organic contaminants are released into the water column. In turn, as suspended sediment settles out the dissolved chemicals may be scavenged, thus promoting organic activity. Secondly, since the light intensity at depth depends inversely on suspended sediment load in the water column above, suspended matter impacts on primary productivity (Morris and Howarth, 1998).

It also confirmed that the areas adjoining the lake (degradable portions) are characterized by pronounced anthropogenic activities such as washing/bathing, fishing, sand mining activities, etc. it also indicated that the portions covered by eutrophication were not navigable because of luxuriant growths of aquatic plants.

The degraded portion, which occupies an alarming 38.8% of the lake area and its watershed, calls for proper management strategies of the lake and adjoining areas through constant bio-chemical investigations and constant assessments of the environmental status of the area. Government should also enact and implement laws to urgently prohibit improper land use activities in a tourist centre like Oguta Lake.

The present low level of eutrophication (0.50%) observed in Oguta Lake compared to many other surface water bodies in the area is attributed to low concentrations of nutrients (example, dissolved silica, nitrate and phosphate) in the lake. The observed mean concentrations of dissolved silica, nitrate and phosphate are 18.13, 1.49 and 0.19mg/l respectively, while the loading rates of these constituents (evaluated between 1985 and 2006) are 0.26, 0.03 and 0.004, respectively (Ahiarakwem, 2006). These figures confirm the present low eutrophication level in the lake. The observed low concentrations of nutrients have actually been adduced to the moderately high nutrients flushing rate of the lake. A change (increase) in nutrients input into the lake due to a reduction in the flushing rate of the lake would definitely alter the present level of eutrophication in Oguta Lake. It could also arise as a result of increased loading of contaminants, especially the use of chemicals during fishing activities, e.t.c.

The built-up areas around the lake which cover an area of about 4,983.28m^2 show strong positive correlation (R^2=1) with the degraded portions of the lake (Figure 9). This implies that the built-up areas have serious impact on the degradation of the lake area and its water body. The effluents arising from human activities in the upland areas constantly alter the chemistry and silting of the lake. Overdependence on resources from the lake by the residents has also added some environmental stress on the study area. This situation calls for proper land use management around the lake and its environs to ensure its usefulness as one of the foremost tourist centers in Nigeria.

Conclusion

The result of evaluation of some physical and environmental aspects of Oguta Lake using remote sensing/GIS techniques indicates that the water body covers an area of 61.2% while the degraded portions cover 38.8% of the surface area of Oguta Lake and its watershed.

The degraded portion includes areas under intense human activities (36.91%), areas covered by sediments (1.39%) and eutrophication (0.5%).

The present low level of eutrophication is in conformity with recent chemical analysis of the lake which indicated low mean concentrations of nutrients (dissolved silica, nitrate and phosphate).

There is a strong positive relationship (R^2=1) between built-up areas and degraded portions of the lake.

There is need for constant monitoring of the Oguta lake ecosystem using both bio-chemical as well as remote sensing/GIS approach.

Government should set up machineries for proper land use and utilization in order to check the adverse effects of anthropogenic activities on the lake and its ecosystem.

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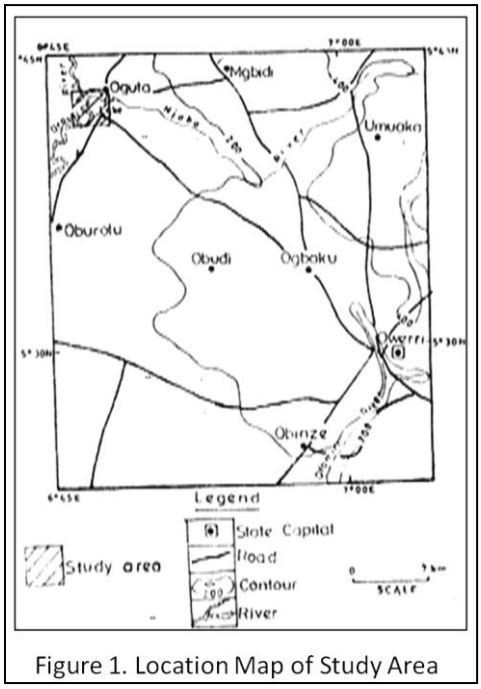

Figure 1. Location Map of Study Area

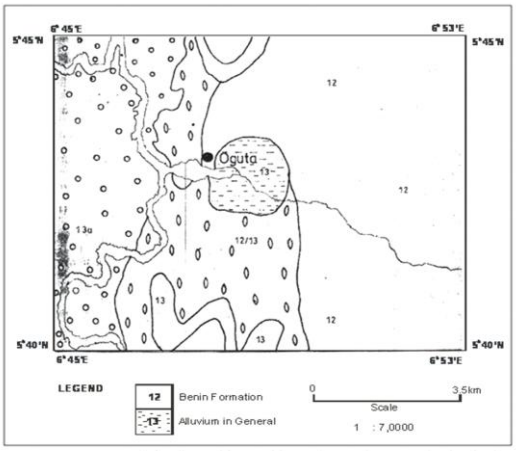

Figure 2. Geological Map of Imo State, showing the Study Area

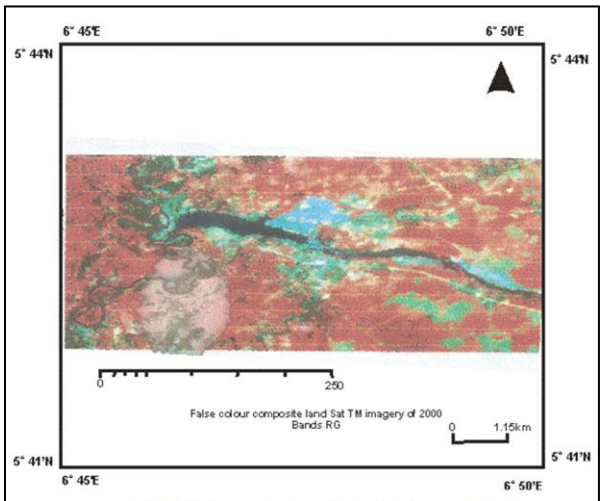

Figure 3. False Colour Composite of Map the Study Area

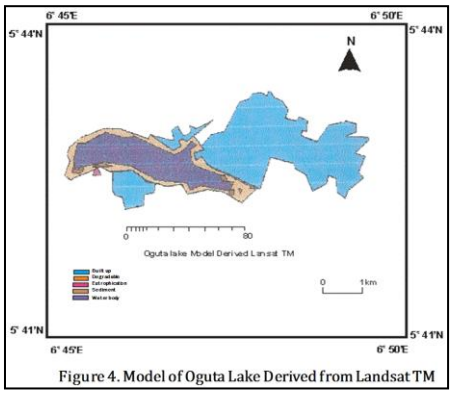

Figure 4. Model of Oguta Lake Derived from Landsat TM

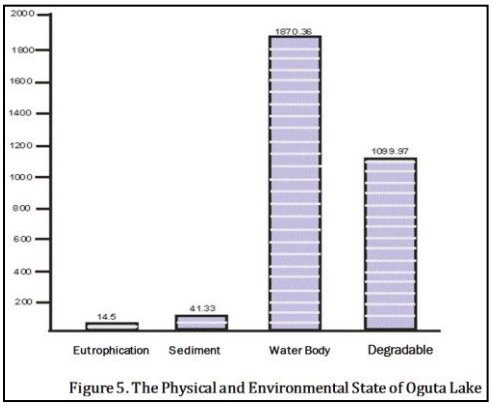

Figure 5. The Physical and Environmental State of Oguta Lake

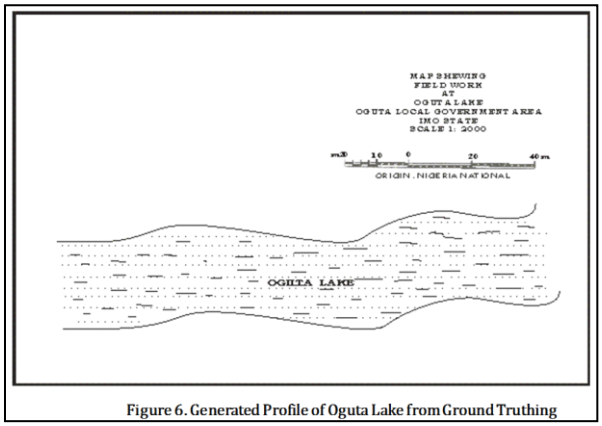

Figure 6. Generated Profile of Oguta Lake from Ground Truthing

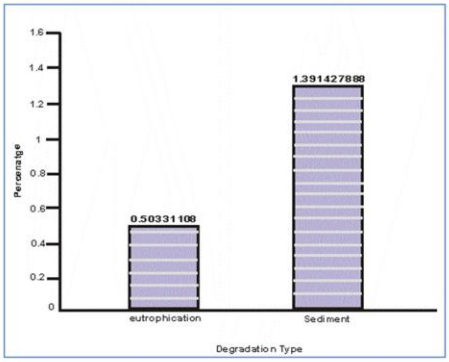

Figure 7. Relative Percentage of Areas occupied by two Degradable Portion Types in the Study Area

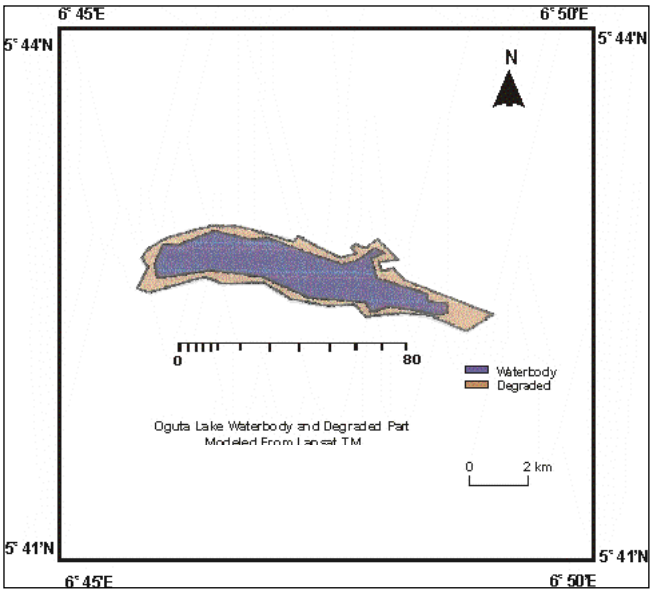

Figure 8. Oguta Lake Water body and Degraded Portions modeled from Landsat TM

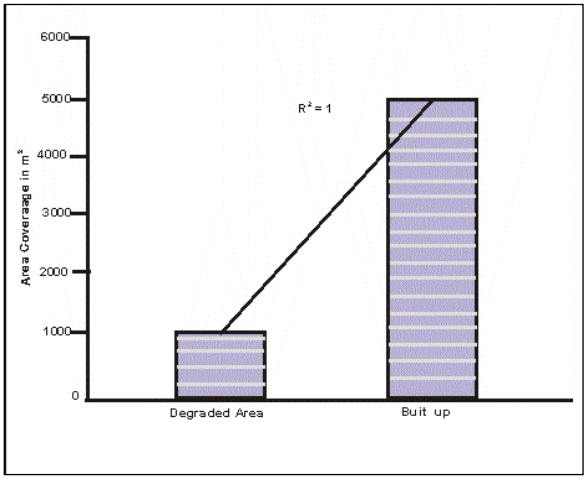

Figure 9. Relationship between Degraded Area and Built up Area in the study Area

Table 1. Handheld GPS Data Set

S/No	Latitude, N	Longitude, E
1	5 42 20.86	6 46 37.56
2	5 42 28.43	6 46 37.56
3	5 42 34.38	6 46 37.11
4	5 42 38.94	6 46 39.91
5	5 42 41.86	6 46 46.42
6	5 42 44.74	6 46 46.42
7	5 42 45.65	6 47 01.22
8	5 42 45.65	6 47 11.12
9	5 42 40.36	6 47 20.31
10	5 42 34.54	6 47 48.12
11	5 42 36.06	6 47 32.25
12	5 42 30.76	6 47 38.70
13	5 41 59.31	6 46 27.11
14	5 42 25.32	6 48 16.70
15	5 41 59.34	6 47 55.96
16	5 46 13.03	6 47 26.93
17	5 42 18.73	6 47 19.57
18	5 42 22.87	6 47 44.05
19	5 42 23.30	6 47 11.52
20	5 42 23.12	6 46 52.86