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An Assessment of Changes in Land-Use and Land-Cover within the Kiri Lake, Nigeria (1976-2014)

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***Abstract:** This paper assesses the land-use and land-cover changes within the Kiri lake basin between 1976 and 2014 - a period of 38 years, using remotely sensed data and geographic information systems (GIS). Since 1982 when the Gongola River was impounded and Kiri Lake created, various anthropogenic activities such as agriculture, irrigation, deforestation, fishing, and construction have taken place. The cumulating of these human activities together with natural factors has led to environmental degradation and the damage of the ecosystem of the lake basin. Landsat MSS image of 1976, Landsat TM of 1986 and Landsat ETM+ images of 1991 and 2014 were acquired, classified and analysed between 1976 and 2014. Area calculations of the arc GIS 10.2.2 software were used to derive the trends, rates and magnitudes of changes, while map overlay was employed for assessing the nature and location where the changes have taken place. The study reveals that the rate of deforestation and erosion in the study area is linked to the methods of farming practices as well as the removal of the catchment vegetation as part of land preparation. Uncontrolled human settlement and demand for fuel wood etc., was another issue to contend with. If this issue of land degradation is not appropriately dealt with in the future, it could lead to the decrease in the power generating capacity of the proposed hydropower component due to filling up with silt materials and the ultimate shortening of the life span of the dam. Finally, it is hoped that the findings from the study will provide useful insight into the current state of the environment, and the recommendations proposed in this paper would equally be helpful to mitigate, control and to improve the management of the basin.*

Keywords: Land-Use, Land-Cover, Remote Sensing, GIS and Change detection

1. Introduction

In addition to emissions of heat-trapping greenhouse gases from energy, industrial, agricultural, and other activities, humans also affect climate through changes in land *use* (activities taking place on land, like growing food, cutting trees, or building cities) and land *cover* (the physical characteristics of the land surface, including grain crops, trees, or concrete) Arnfield (2003). For example, cities are warmer than the surrounding countryside because the greater extent of paved areas in cities affects how water and energy are exchanged between the land and the atmosphere. This increases the exposure of urban populations to the effects of extreme heat events. Decisions about land use and land cover can therefore affect, positively or negatively, how much our climate will change and what kind of vulnerabilities humans and natural systems will face as a result.

The pace, magnitude and spatial reach of human alterations of the Earth's land surface are unprecedented. Land use and land cover change directly impacts biotic diversity worldwide, contributes to climate change, is the primary source of soil degradation, and, by altering ecosystem services, affects the ability of biological systems to support human needs. Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations. Lambin and Geist (2006)

According to Tukur and Mubi (2002), changes brought about by the regulation of the flow of the river on the channel geometry and discharge characteristics following the construction of kiri dam in 1978. Result of the assessment revealed that the downstream channel has changed completely and a narrow channel has replaced the large pre-dam channel.

Further findings by Tukur *et al* (2006) revealed that regulation of the Gongola river flow by damming has indeed affected the resilience of the downstream environment, resulting in changes in the wetlands scenario of the pre-dam periods. Assessed against the background for which the kiri dam was constructed, the benefits could not be said to have been fully achieved. The study also revealed that the construction of the dam contributed to the depletion of the vegetation that could have minimized desertification. Ikusemoran *et al* (2013) made similar observation on the Kainji lake basin. Their study revealed that intensive agriculture covered most part of the area after the construction of Kainji dam.

Therefore, because of the imperative role of electricity generation as well as conservation of flora and fauna by the Kiri Lake, proper monitoring of the lake basin becomes important for sustainable utilization and development.

The following were the objectives of the study

1. To create land-use/land-cover maps of the Kiri Lake from 1976-2014 using GIS technique and remote sensing data to assess the trends, magnitudes, nature and locations of the land-use and vegetation cover changes of the lake within the study period.

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2. To assess the actual land areas which have been lost or gained by the principal features around the lake , i.e., the reservoir, flood plain, waterweeds and agriculture/settlement within the study period.
3 To evaluate the environmental implications of the land-use and land-cover changes in the lake basin.

2. Materials and Methodology

2.1 The Study Area

Kiri Lake is located on the flood plain of lower Gongola river basin, about 25 km upstream of its confluence with river Benue at Numan, while Gongola valley is located within the upper Benue trough. It was formed as a rift phase due to the development of triple junction at a location close to the present Niger delta. The rift was due to lithospheric peak thinning which caused long narrow complex depressions, which develop in some places filled with variety of sedimentary environment (Whiteman, 1982, reported in Mubi, 2001). Specifically, Kiri town is located in Guyuk Local Government Area of Adamawa state and situated on latitude 09^0 39’00” N – 09^0 54’ 00”N and longitude 11^0 57’ 00” E – 12^0 06’ 00” E as shown in Figure 1 below.

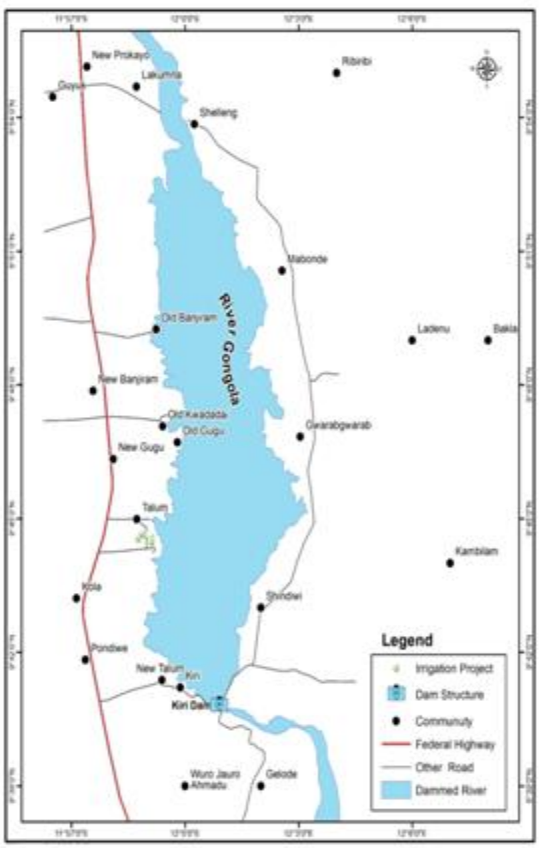

Figure 1: Kiri Dam
Source: Adapted and Modified from Google maps, 2013

2.2 Sources of data
The first four data sets **(Table 1**) which cover a total period of 38 years (1976-2014) were the main images that were acquired for the assessment of the lake basin.

Table 1: Date Type and Sources

S/ No	Date Type	Resolution (m)	Date	Sources
1	Landsat MSS (Multi-Spectral Scanner)	79	12-06-1978	Global Land Cover Facility.
2	Landsat TM (Thematic Mapper)	30	02-07-1986	Global Land Cover Facility.
3	Landsat ETM+ (Enhanced Thematic Mapper Plus)	30	14-08-1991	Global Land Cover Facility.
4	Landsat ETM+ (Enhanced Thematic Mapper Plus)	30	04-09-2014	Global Land Cover Facility.

2.3 Image classification
In classifying the images into various themes, the supervised approach to classification was adopted using Arc GIS 10.2.2 software. The images were classified into three major classes: water body; agricultural, built-up and other land-uses and; floodplain and waterweed seen on Table 2. Maximum likelihood classification method was adopted.

Table 2: Land-Use and Land Cover Classification Scheme
Source: Adapted and modified from Anderson *et al* (1976).
Sources: Global Land Cover Facility, 2014

1	Water Body	Dam reservoir water
2	Agricultural, Built-up& Other land	Agricultural lands, areas containing buildings etc.
3	Floodplain and waterweed	Floodplain and waterweed within the river bed.

The first two and last two data sets have large gap of at least ten years while the middle two have close gaps of five years. This was designed to reflect the impact of the dam in the past years of low population and the recent years when the population of the country has been increasing tremendously. All four images were acquired between June and September, which is the peaking periods of the wet season, climatic conditions during this period, is the same all over the lake basin (Olokor, 1995), hence the vegetation cover and land-use types appear the same on the images regardless of the year they were obtained.
Three features of major concern were selected for this purpose: the lake reservoir, the flood plains and the agriculture/settlement areas. The result was to produce the following:
1. Areas that were not Lake Reservoir in 1976 but have changed to Lake Reservoir in 2014 so as to know whether the lake is expanding or not as has been the fear of Nigerians.
2. Areas that were flood plains in 1976 but have changed to other land-use types in 2014. This was done to determine the

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land areas of the flood plains that have been lost within the study periods to other land use types.

3. Areas that were not intensive agriculture/settlement in 1976 but have changed to intensive agriculture in 2014 so as to assess the rate of land captured by intensive agriculture/settlement within the study periods.

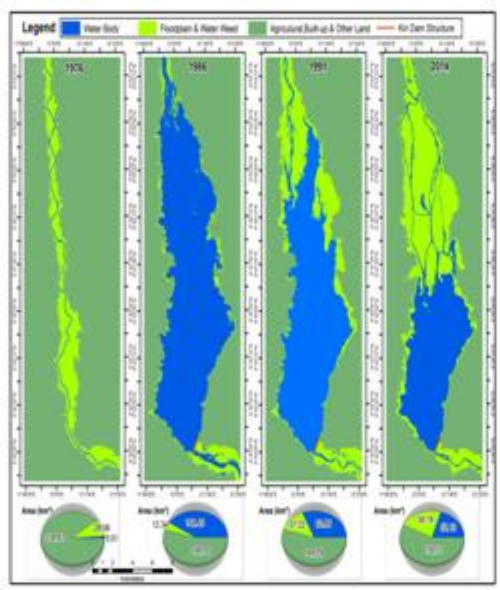

Figure 2: Spatial location of changes in the lake area between 1976 and 2014

2.4 Change detection techniques

Three main change detection methods which have been previously applied by (Ikusemoran *et al*, 2013) were employed in this paper, they are:

2.4.1 Change detection by area calculation

1. The first step is the calculation of the magnitude of change, which is derived by subtracting observed change of each period of years from the previous period of years.
2. The second step was the calculation of the trends, that is, the percentage change of each of the land-use, by subtracting the percentage of the previous land-use from the recent land- use divided by the total land-use and multiplied by 100 (B-A/Tx100).
3. The last is the calculation of the annual rate of change by dividing the percentage change by 100 and multiplied by the number of the study years, that is 38 years (1976-2014)

3. Results

The result of the trends of the land-use and land-cover of Kiri Lake is presented in **Table 3,** while the magnitudes, percentage changes and annual rate of change are presented in Tables' 4a-c. The spatial location of changes in the lake area between 1976 and 2014 are presented in Figure 2.

Table 3: The trends of the land-use/land cover of the river basin (1976-2014)

Land-use/ Land cover	1976 Area (km^2)	1976 Area (%)	1986 Area (km^2)	1986 Area (%)	2001 Area (km^2)	2001 Area (%)	2006 Area (km^2)	2006 Area (%)
Lake/ Reservoir	3.01	1.11	148.84	55.15	82.96	30.79	55.19	20.48
Flood Plan/ Water weeds	28.06	10.41	12.34	4.57	37.22	13.81	58.18	21.59
Agriculture, Settlement and others	238.41	88.47	108.70	40.28	149.29	55.40	156.11	57.93
Total	**269.48**	**99.99**	**269.49**	**100**	**269.47**	**100**	**269.48**	**100**

4. Discussion

4.1 Trends, magnitudes, percentage change and annual rate of changes.

Table 3 shows the trends in terms of the area coverage and the percentage of each class of the basin area from 1976 to 2014. It was revealed that the lake reservoir which covered 3.01 km^2 in 1976 has increased to 55.19 km^2 in 2014 (addition of 52.18 km^2) and 30.12 km^2 increase in flood plain/waterweed coverage. The agriculture/settlement of the basin area has also reduced in size from 88.47% in 1976 to 57.93% in 2014 as noted by Mubi (2001), Tukur *et al* (2006) and Ikusemoran *et al* (2013).

Table 4a: The magnitudes, percentage and annual rate of change of the lake (1976-1986)

Land-use/ Land cover	1976 (km^2)	1986 (km^2)	Magnitude of change (km^2)	Percentage change (%)	Annual rate of change	Remark
Lake/ Reservoir	3.01	148.85	145.84	50.07	+19.02	Increase
Flood Plan/ Water weeds	28.06	12.34	15.72	5.39	- 2.05	Decrease
Agriculture, Settlement and others	238.41	108.7	129.71	44.53	-16.92	Decrease
Total	**269.48**	**269.49**	**291.27**	**99.99**	**0.049**	

Table 4b: The magnitudes, percentage and annual rate of change of the lake (1986-1991)

Land-use/ Land cover	1986 (km^2)	1991 (km^2)	Magnitude of change (km^2)	% Change (%)	Annual rate of change	Remark
Lake/ Reservoir	148.85	82.96	65.89	50.16	-19.06	Decrease
Flood Plan/ Water weeds	12.34	37.22	24.88	18.94	7.2	Increase
Agriculture, Settlement and others	108.7	149.29	40.59	30.9	11.74	Increase
Total	**269.49**	**269.47**	**131.36**	**100**	**0.118**	

Table 4c: The magnitudes, percentage and annual rate of change of the lake (1991- 2014)

Land-use/ Land cover	1991 (km^2)	1914 (km^2)	Magnitude of change (km^2)	% Change (%)	Annual rate of Change	Remark
Lake/ Reservoir	82.96	55.19	27.77	49.99	-18.9	Decrease
Flood Plan/ Water weeds	37.22	58.18	20.96	37.73	14.34	Increase
Agriculture, Settlement and others	149.29	156.11	6.82	12.28	4.66	Increase
Total	**269.47**	**269.48**	**55.55**	**100**	**0.106**	

4.2 Implications of the land-use changes on the lake basin

1. Dam safety concerns: increase in lake area from $3.01km^2$ to $55.19km^2$ since the inception of the dam in 1982 raises a lot of potential dam safety concerns, considering the fact that hydropower component is to be added to irrigation purpose. This could lead to inevitable dam collapse if unchecked and unless articulated and effective maintenance is put in place having it in mind the maintenance culture issue in Africa at large.

2. loss of agricultural land: with the alarming rate of settlement, grazing and the likes, it can been seen that between 1976 and 2014, land meant for agriculture/settlement and other purposes is gradually disappearing ($238.41km^2$ to $156.11km^2$). This is an indication that flood waters are taking over these land surfaces. If unchecked, there might be no more land available for agriculture in the area.

3. Flooding: the expansion of the lake has resulted into dire flooding within the catchments area, especially on the upstream of the dam where much land was captured by the lake. The continuous forest depletion by the inhabitants of the local communities in quest for cooking fuel has been attributed to another possible enhancement of flooding by the lake (Mubi, 2001).

5. Conclusions and Recommendations

This paper found that the rate of deforestation and erosion in the study area is linked to the methods of farming practices as well as the removal of the catchment vegetation as part of land preparation. Uncontrolled human settlement and demand for fuel wood etc., was another issue to contend with. If this issue of land degradation is not appropriately dealt with in the future, it could lead to the decrease in the power generating capacity and irrigation purposes of the dam due to filling up with silt materials and the ultimate shortening of the life span of the dam. It is very important to emphasize that by working together, it is possible for the responsible authorities, government and the host communities to tackle the major environmental problems facing the fragile environment of the dams. Finally, it is hoped that the findings from the study area will provide useful insight into the current state of the environment, and the recommendations proposed in this paper would equally be helpful to mitigate, control and to improve the management of the dams.

The following recommendation were made

i. The author strongly suggests that the main solution to deforestation has to start from local action. In other words a bottom-up approach between the responsible authorities and local people to work together in partnership to check deforestation is highly recommended.

ii. Tree planting and protection of existing vegetation from fire and land clearing should be also encouraged, as the restoration of degraded lands.

iii. Remote Sensing and GIS techniques are recommended for use in environmental monitoring and management of our already fragile environment.

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