*Bajopas Volume 2 Number 1 June 2009*

***Bayero Journal of Pure and Applied Sciences, 2(1): 83 - 90***
*Received: October, 2008*
*Accepted: February, 2009*

# LANDUSE AND LANDCOVER CHANGE DETECTION IN THE KAINJI LAKE BASIN NIGERIA USING REMOTE SENSING AND GIS APPROACH

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***ABSTRACT***
***One of the problems associated with dams anywhere in the world, is environmental degradation. On the context of Kainji Lake, the period of over four decades when the dam was constructed has witnessed remarkably, rapid expansion, growth and developmental activities such as agriculture, deforestation, irrigation, fishing, and construction of bridges and roads. In the course of carrying out these activities, the environment is degraded and thereby damaging the ecosystem and the landscape, and offsetting the already fragile ecological balance. Landsat MSS Landuse/landcover map of 1978 and Spot XS landuse/landcover map of 1995 was used to study the landuse/landcover changes of the Lake area between 1978 and 1995 – a period of 17 years. Ilwis for Academic, Arcview 3.0 and Idrisi 32 were used for georeferencing, digitizing and map analysis respectively. The two main methods of change detection that were used were area calculations (trends, rates and proportion), and overlay for the nature and the location of the changes. The study revealed that about 71.92% of the area has been subjected to changes, while, 28.08% had not been subjected to any changes. Within the study period, the lake basin has recorded -239.8842km magnitude of changes, -345.23 percentage change and -57.3% annual rate of changes.***

***Keywords: Landuse, Remote sensing, GIS, Landcover***

## INTRODUCTION

Change detection is the process of identifying differences in landuse and landcover overtime. As human and natural forces continue to alter the landscape, various public agencies are finding it increasingly important to develop monitoring methods to assess these changes. Changes in landuse and landcover often result in the quality or values of the available resources. Methods for monitoring vegetation change at a landscape scale range from the fieldwork inventories to the modern utilization of remotely sensed data which include satellite imageries, using GIS techniques.

Any nation with sustainable utilization of its environment in mind must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Landuse is only one of such aspects. The knowledge about landuse and landcover has become increasingly important as the nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of important wetlands, and loss of fish and wildlife habitat. Landuse data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels.

One of the prime prerequisites for better use of land is information on existing landuse patterns and changes in landuse through time. The knowledge about landuse such as agricultural, recreational, as well as information on their changing proportions, is needed by legislatures, state and local Government officers to determine better landuse policy, to identify future development on pressure points and areas, and to implement effective plans for regional development.

In this dynamic situation, accurate and meaningful current data on landuse are essential. The uses of reliable landuse data are enormous; landuse and landcover data are needed for water resource inventory, flood control, water supply planning and wastewater treatment. Many federal agencies use current and comprehensive inventories of existing and changing uses of lands to improve the management of public lands. Federal agencies also need landuse data to assess the environmental impact resulting from the development of energy resources, to manage wildlife resources and minimize man-ecosystem conflicts, to make national summaries of landuse patterns and changes for national policy formulation, and to prepare environmental impact statements and assess future impacts on environmental quality.

Remote Sensing/Geographic Information System (GIS) have been applied to landuse and landcover change detection all over the world. Mattikalli, (1995), applied Remote Sensing and GIS to the landuse of the River Glen catchments in England by acquiring data from 1931 to 1989. His work revealed that much of the grassland changed to arable land during the study area. Okhimanhe, (1993), used the combination of Spot HRV imagery of 1986 and aerial photographs of 1974 to study the environmental impact assessment of Burumburum/Tiga dam in Kano state, Nigeria. The work revealed that the construction of Tiga dam contributed to the depletion of the vegetation that could have helped still desrtification.

Adeniyi and Omojola, (1999), used aerial photographs, Landsat MSS, Spot XS/Panchromatic Image Transparency and Topographical maps to study landuse/landover changes in Sokoto and Guronyo dams, Nigeria, between 1962 and 1986. Their work revealed that settlement covered most part of the area before and after the construction of the dam. The objectives of this work are to determine the trends, rates, nature, location and magnitudes of landuse and landcover changes of the study area, mapping landuse/landcover changes of Kainji Lake and its environs using Remote Sensing and GIS techniques and to evaluate the environmental and social-economic implications of the changes.

**The Study Area**

The genesis of the Kainji Lake hydro-power station dates back to 1951, when the demand for electricity was rising faster than supply due to the growth of industries and rapid urbanization. In order to meet the increasing demand for electricity, and consequent upon the realization that bulk supply of electricity could be cheaper through the utilization of hydro power technology, the former Electricity Corporation of Nigeria (ECN) began the exploitation of water resources of River Niger, upstream of Jebba. (NEPA Diary, 1995). The reasons for the choice of Kainji as the best site for the Lake were many. According to Nedeco and Balfour (1961) rock foundation, one of the most important factors taken into consideration during the site investigations, was tested and found to be capable of holding the enormous height of the dam; it is the point where the river valley is not too wide; and the physical features upstream of the dam valley allows for a large reservoir. The Kainji dam is today, a pride of nature, providing cheap and abundant means of electricity for the continuously growing population and industries, source of revenue, fishing, irrigation, navigation, cattle crossing, tourism, employment, international recognition, manpower training and many more (Bashil, 1997).

The Lake is located between latitudes 9°50″N to 10°55″N and longitudes (fig.1) 4°23″ to 4° 45″ E. Olokoh (1993), reported that construction work on the Kainji dam began in March 1964 and was completed in December, 1968, and was officially commissioned on 15$^{th}$ February, 1969. The impounding of the Kainji reservoir started exactly on the 2$^{nd}$ August, 1968, and the water level rose steadily to 140.2m on the 19$^{th}$ of October the same year: a period of seventy eight days. The lake that was formed sunk most parts of the Kainji Island on which the dam was constructed. The dam covers an area of 1250km2, with a maximum depth of 54.9m and extends to about 136.8km upstream of Jebba beyond Yelwa. The Lake gets its water from two sources: the River Niger with its headwater in Guinea, and local rivers around the lake basin which flow directly into the lake or into the Niger before entering the lake. The soil depth of the area increases with slope and a gentle undulating topography for the area with red to brown well drained soils differing in texture from sandy loam to clay loam. Most of the basin area have dry seasons of five months starting from early November until mid-March. Rainfall increases from the month of April, reaching the peak in August and starts declining from September. Rainfall decreases with decrease in latitude within the basin and also increases with increasing altitude.

**Scope of the Study**

For this study, due to inadequate data, the study is limited to latitudes 10°02″ to 10°42″ and longitudes 4°22″ and 4°44″, which means that the southern part of the lake, covering latitude 9° 52″ and 10° 02″ are not included in the study.

**MATERIALS AND METHODS**

**Description of Materials**

An HP Laptop with high RAM, An HP Scanner, and a Colour HP Printer as well as three GIS packages: ILWIS Academic 3.0; which was used for georeferencing, ARCVIEW GIS 3.0 for digitizing maps, and IDRISI 32 Release 2 for map overlay and analysis as well as other complimentary non- GIS packages like COREL DRAW 12 were used.

**Description of Data**

The data that were used for this paper include; Landuse and Landcover/vegetation map interpreted from Landsat MSS image of Yelwa region with scale 1:250,000, identified by map index 29, acquired from Forestry Evaluation and Coordinating Unit, (FOMECU) Abuja, and Landuse and landcover/vegetation map interpreted from Spot XS image of Yelwa region with scale 1:250,000, identified by map index 29, also acquired from FOMECU Abuja.

**Methods**

The two methods that were implored for change detection in this paper were:

♦ **Change detection by map overlay.** Change detection by map overlay is done in order to find the nature and the actual locations of the changes that have occurred within the study period. Overlay also enabled accurate calculations of the areas that have or have not changed. The two maps were overlain using Idrisi Reclass module so as to classify areas that have changed from those that were static. The Area sub module was then used to calculate the areas of each of the classes.

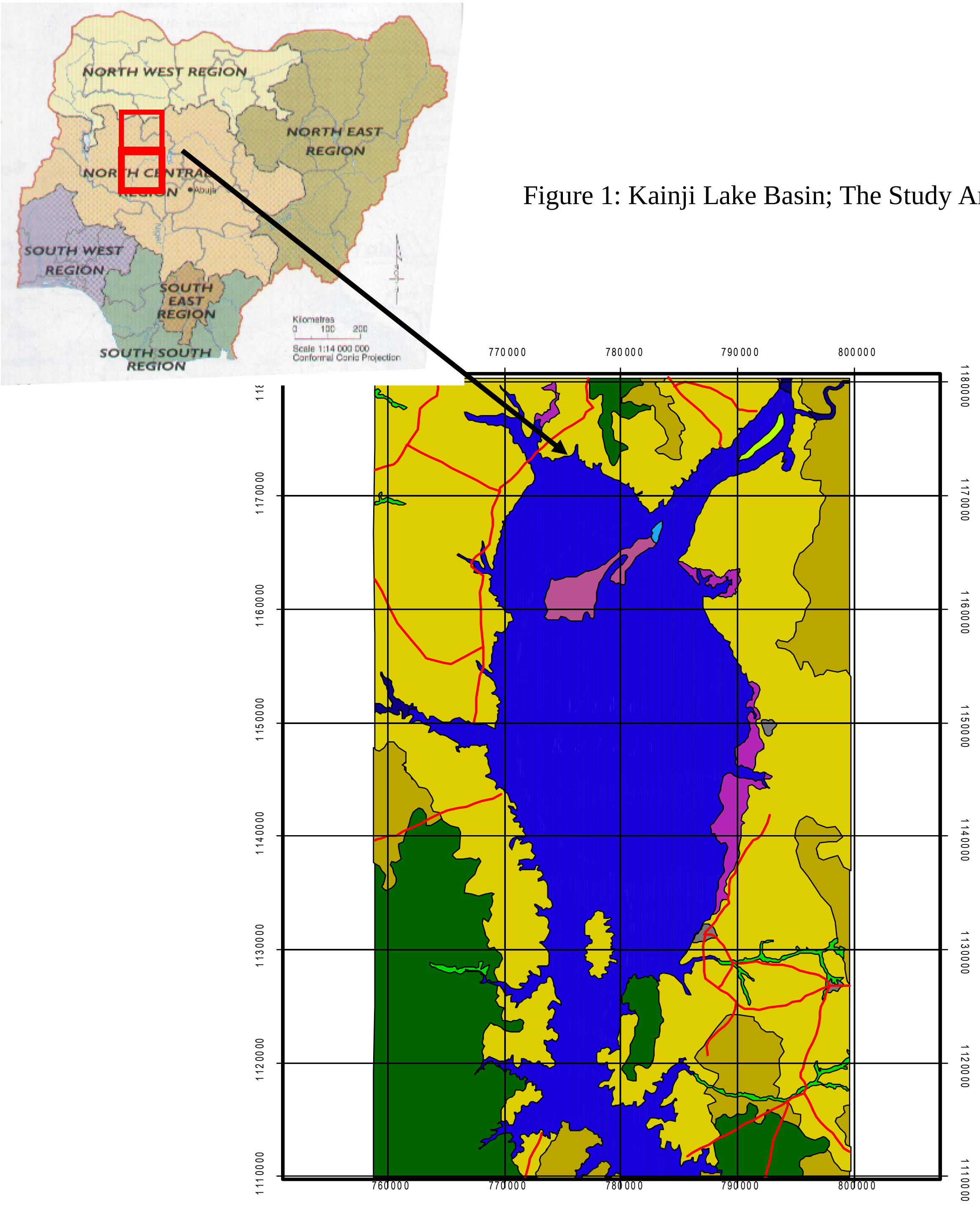


Figure 1: Kainji Lake Basin; The Study Area

♦ **Change Detection by Area Calculation.** The maps that were digitized in Arcview were exported to Idrisi for analysis. The themes of the maps were again digitized, but this time with Idrisi digitizing modules. Values were assigned to each of the themes. Three major steps were involved in change detection by calculation of area.

♦ The first was the calculation of areas of all the themes through the GIS Analysis routine and Area sub-routine of Idrisi software in a tabular form.

♦ The second step was the calculation of the trends, that is, the percentage change of each of the landuse, which was derived by subtracting the percentage of the previous landuse from the recent landuse divided by the previous landuse multiplied by 100 (B-A/A*100)

♦ The final step was the determination of the annual rate of change which was derived by dividing the percentage change by 100 and multiplied by the numbers of the study years, that is, 1978-1995, which is seventeen (17) years.

**Map Georeferencing/Data Capture**

The two maps were scanned, using Corel Draw 11 and then exported to Ilwis environment through tagged Image File format (TIFF) for georeferencing. The need for map georeferencing is to enable all the maps to have the same rows, columns, pixel numbers and other reference parameters. An ungeoreferenced map cannot overlay. Each of the two maps (1978 and 1995) was georeferenced. The Latitude and Longitude coordinates of the four corners of the study area, that is Latitude 10°02″ to 10°42″ and Longitudes 4°22″ and 4°44″ were transformed to Universal Transverse Mercado (UTM) through the transform module of Ilwis 3.1, to create the georeference corner. The Transformation gave the minimum "X' and "Y" values as 758903.865 and 1109924.365 respectively, and also 799643.865 and 1180344.365 as the maximum "X" and "Y" respectively. Nine (9) points were selected on the 1978 maps which were used as tiepoints for the 1995 map. The tiepoints were then used to georeference the two maps individually. The referenced maps were resampled, using map-to-map registration with 1978 map as the master map and 1995 as the slave map into the earlier created Georeference corner map. Each of the resampled maps was imported into Arcview, at where the maps were digitized. All the area features such as the landuse classes were digitized as polygon, line features such as roads as line, and locations such as settlement as points.

**RESULTS AND DISCUSSION**

**Landuse/Landcover Changes: Nature**

The 1978 and 1995 images of the Kainji lake basin (fig 2a & 2b) are overlain in order to derive the nature of landuse and landcover changes in the Lake basin. (Fig. 3) The three main information that were generated from the nature of landuse/landcover changes were; areas in the Landuse/landcover with no changes, areas that were gained by other classes, and areas that were lost to other classes. The nature of the landuse/landcover of the area within the study period is illustrated in Fig 2a & 2b, while the derived matrix Table from the map overlay is shown in Table 1.

Table 1 shows the matrix table for the landuse and landcover changes between 1978 and 1995. All the red numbers are the pixel values of each of the classes. Those in Blue are the values of each class when the maps were overlain using addition sub routine. The black figures represent the areas of each of the overlain classes. The dark brown colour represents the total of each class.

The dark green figure represents the total square kilometer of the study area. All the bold black figures along the diagonals are the areas with no change throughout the study period. All the figures along the rows, except those bold black numbers at the diagonals, represent the areas that were gained to other classes.

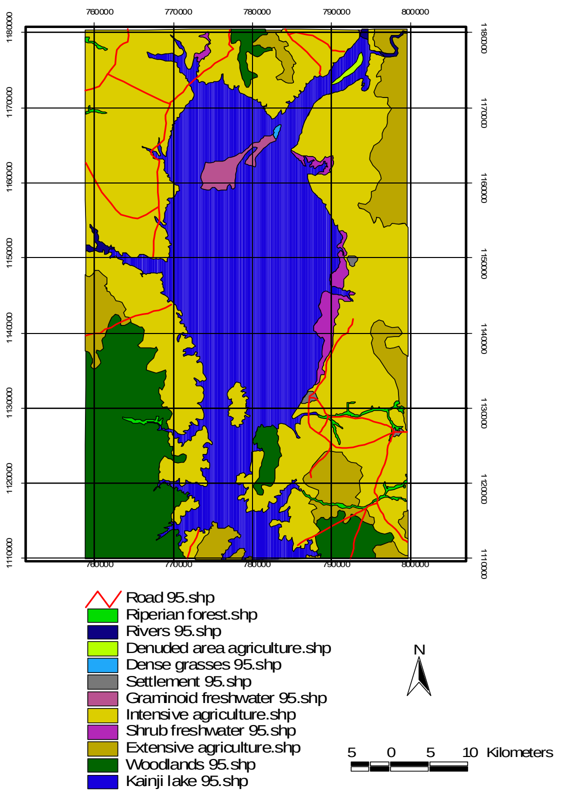


Fig.2a 1978 image of Kainji Lake Basin

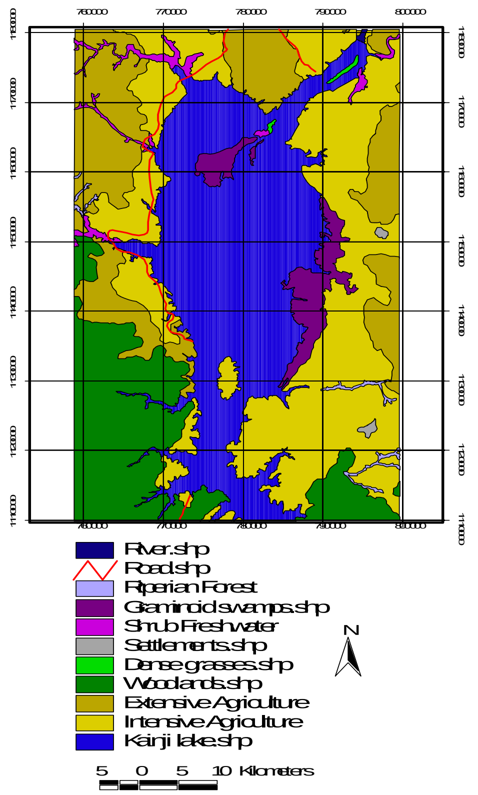


Fig.2b 1995 Image of Kainji Lake Basin

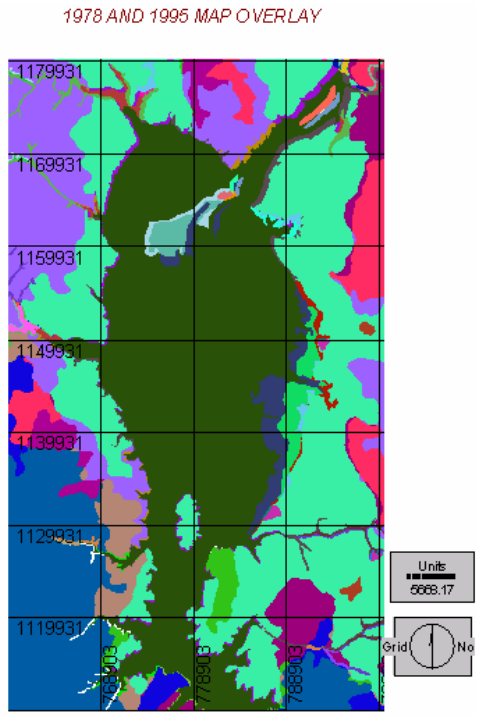


Fig 2c 1978 and 1995 overlay of Kainji Lake

The figures along the columns, excluding the bold black numbers at the diagonals represent the loss by the landuse and landcover.

**Landuse/Landcover Changes: Location.**
The landuse/landcover changes by location enables management decisions to be made on the spatial locations of the specific places where the changes had occurred within the time period of the study. The location which is generated by map overlay is presented in Fig. 3.

The reclass module of the Idrisi software was used to classify the study area into static and changed areas. The green colour areas show the areas that have not been subjected to any form of changes within the period of the years of study, while the red areas represent the areas that have changed. 2063.2336 $km^2$ out of the total area of 2868.5478 $km^2$, representing 28.08%, had not been subjected to changes within the seventeen years, while the remaining 2063.2336$km^2$, representing 71.92% had been subjected to changes.

Table 2 shows the trends and rates of landuse and landcover of Kainji lake basin between 1978 and 1995. It shows the landuse/landcover classes, the area coverage and the percentage area of each of the classes. Roads which are linear features were measured in kilometers.

**Social Economic Effects:**
♦ **Communal Crises;** The loss of land for extensive agriculture and grazing from 16.60% in 1978 to 8.9% in 1995 (Table 2) may lead to communal crises among the farmers and the hardsmen as has been recorded in most part of the country such as Song and Dumne (Adamawa state) crisis (2002), Yelwa/Shedam/Wase (Plateau state) crisis (2003), Okeogun (Oyo State) crisis (2003) and Demsa (Adamawa state) crisis (2005). (Mayowa and Omojola 2005).
♦ **Flooding;** The continual expansion of the lake reservoir, if unchecked, may lead to excessive flooding especially around and at the downstream of the lake.
♦ **Erosion;** The increase in the total area for agriculture (intensive, extensive and agriculture in denuded areas) from 48.89% in 1978 to 50.62% in 1995 (table 2) may expose the lands to land degradation and soil erosion.
♦ **Dam failure;** Following the gradual expansion of the reservoir, the lifespan of the lake may be put into danger especially if or when the dam cannot hold the lake water which may result into dam failure.

**The Magnitudes and Annual Rate of Landuse and Landcover Changes**
The magnitudes, the percentage change and the annual rate of change are illustrated in Table 3. Table 3 shows that the lake basin recorded -57.3% annual rate of change, -345.23 percentage changes and a total of -239.8842 magnitude of changes.

**Table 1: Matrix Table for Landuse/Landcover for 1978 and 1995**

1978

| 1995 | Lake 1 | Extensive Agric 2 | Woodland 3 | Intensive Agrice 4 | Settlement 5 | Rivers 6 | Shrub Freshwater 7 | Graminoid Freshwater 8 | Grasses 9 | Denuded Agric 10 | Riperian Forest 120 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake 10 | 11 **842.9844** | 12 5.8016 | 13 2.9417 | 14 26.8548 | 15 - | 16 0.0608 | 17 9.1476 | 18 46.8188 | 19 3.5196 | 20 0.5048 | 130 - | **938.6340** |
| Extensive Agric 20 | 21 1.4876 | 22 **120.0896** | 23 43.4463 | 24 86.06496 | 25 - | 26 0.0444 | 27 2.1656 | 28 - | 29 - | 30 0.4888 | 140 1.4712 | **255.3376** |
| Woodland 30 | 31 4.0380 | 32 39.2404 | 33 **314.6516** | 34 27.5089 | 35 - | 36 - | 37 - | 38 - | 39 - | 40 0.4888 | 150 0.0104 | **385.9381** |
| Intensive Agrice 40 | 41 22.9088 | 42 307.4336 | 43 58.4896 | 44 **764.0952** | 45 4.5836 | 46 1.1332 | 47 18.6228 | 48 8.6004 | 49 - | 50 - | 160 6.8284 | **1192.7156** |
| Settlement 50 | 51 - | 52 - | 53 - | 54 3.6032 | 55 - | 56 - | 57 - | 58 0.5076 | 59 - | 60 0.0104 | 170 0.2872 | **4.4084** |
| Rivers 60 | 61 - | 62 2.3304 | 63 0.0044 | 64 1.0368 | 65 - | 66 **0.1372** | 67 3.5464 | 68 - | 69 - | 70 - | 180 0.1624 | **7.2176** |
| Shrub F/water 70 | 71 3.3896 | 72 - | 73 - | 74 8.3404 | 75 - | 76 - | 77 **0.4356** | 78 27.0676 | 79 - | 80 - | 190 - | **39.4332** |
| Graminoid 80 | 81 7.4420 | 82 - | 83 - | 84 - | 85 - | 86 - | 87 - | 88 **15.6420** | 89 - | 90 1.0456 | 200 - | **24.1296** |
| Dense Grasse 90 | 91 0.8752 | 92 - | 93 - | 94 - | 95 - | 96 - | 97 - | 98 - | 99 **0.1832** | 100 0.0732 | 210 - | **1.1316** |
| Denuded Agri 100 | 101 3.6672 | 102 - | 103 - | 104 - | 105 - | 106 - | 107 - | 108 - | 109 0.0604 | 110 **0.0040** | 220 - | **3.7316** |
| Riperian 110 | 111 0.7400 | 112 1.1296 | 113 2.1620 | 114 6.2876 | 115 - | 116 - | 117 0.7724 | 118 - | 119 - | 200 - | 230 **5.0108** | **16.1024** |
| **TOTAL** | **887.5328** | **476.0452** | **421.6960** | **924.5765** | **4.5836** | **1.3756** | **34.6904** | **98.6364** | **3.7632** | **2.1496** | **13.7704** | **2868.5478** |

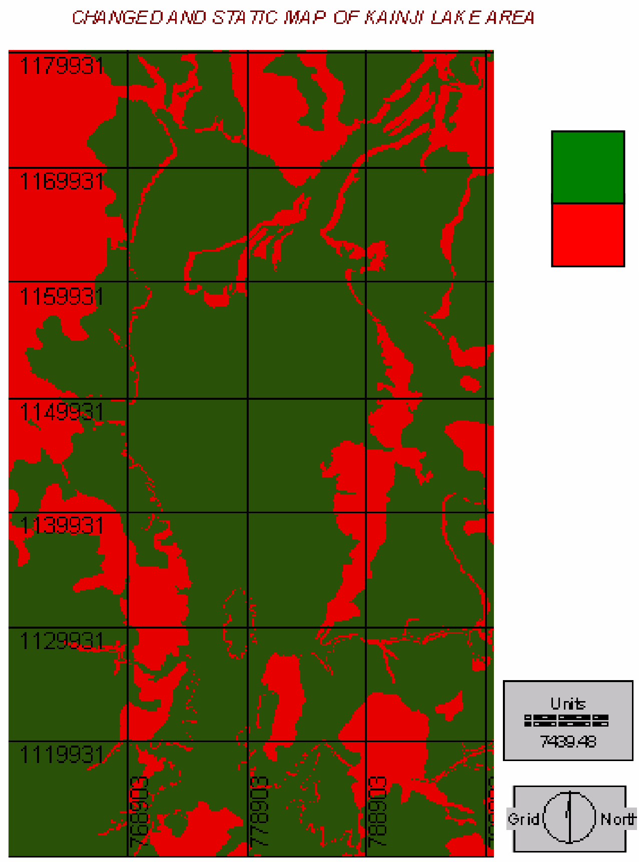


Fig 3; Changed and static Map of Kainji Lake basin; 1978/1995

**Table 2: Trends and Rates of Landuse/Landcover Distribution for 1978/1995 in Kainji Lake Basin**

| | **Landuse/landcover** | **1978** | | **1995** | |
|---|---|---|---|---|---|
| | | **Area (km$^2$)** | **Area (%)** | **Area (km$^2$)** | **Area (%)** |
| 1 | Lake Reserviour | 887.4776 | 30.94 | 938.2212 | 32.72 |
| 2 | Ext./Grazing Agric | 476.0452 | 16.60 | 254.9836 | 8.90 |
| 3 | Woodlands | 421.6960 | 14.70 | 385.4720 | 13.44 |
| 4 | Intensive Agric. | 924.5764 | 32.24 | 1193.0268 | 41.60 |
| 5 | Settlements | 4.5836 | 0.16 | 4.3980 | 0.15 |
| 6 | Rivers | 1.3756 | 0.05 | 7.2280 | 0.25 |
| 7 | Shrub Freshwater Swamp | 34.6904 | 1.21 | 39.4332 | 1.38 |
| 8 | Graminoid Freshwater | 98.6364 | 3.44 | 24.1296 | 0.84 |
| 9 | Dense Grasses | 3.7632 | 0.13 | 1.1316 | 0.04 |
| 10 | Agriculture in Deduded | 1.4576 | 0.05 | 3.7276 | 0.12 |
| 11 | Riparian Forest | 13.7704 | 0.48 | 16.1064 | 0.56 |
| | **Total** | **2868.0348** | **100** | **2867.835** | 100 |
| | Road | **74.33km** | | **166.91km** | |

**Table 3: The Magnitudes, Percentage & Annual rate of changes: 1978 to 1995.**

| | | | Magnitude and the proportion of changes | | | |
|---|---|---|---|---|---|---|
| **LU/LC** | **1978 ($km^2$)** | **1995 ($km^2$)** | **Mag. of Change** | **Percentage Change** | **Annual Rate of change** | **Remark** |
| Lake Reserviour | 887.4776 | 938.2212 | +50.7436 | +5.72 | 0.97 | Increase |
| Extensive/Grazing | 476.0452 | 254.9836 | -221.0616 | - 46.44 | -7.89 | Decrease |
| Woodlands | 421.6960 | 385.4750 | -36.2210 | - 8.52 | -1.45 | Decrease |
| Intensive Agric. | 924.5764 | 1193.0276 | +268.4512 | +29.06 | 4.94 | Increase |
| Settlements | 4.5876 | 4.3980 | -0.1896 | - 4.13 | 0.70 | Decrease |
| Rivers | 1.3756 | 7.2280 | +5.8524 | +425.44 | 72.32 | Increase |
| Shrub Freshwater Swamp | 34.6904 | 39.4332 | +4.7428 | 13.67 | 2.32 | Increase |
| Graminoid Freshwater | 98.6364 | 24.1296 | -74.5068 | - 862.92 | -146.70 | Decrease |
| Dense Grasses | 3.7632 | 1.1316 | -2.6316 | - 69.81 | -11.87 | Decrease |
| Agriculture in Deduded | 1.4576 | 3.7276 | 2.2700 | 155.74 | 26.48 | Increase |
| Riparian Forest | 13.7704 | 16.1064 | 2.3360 | 16.96 | 2.88 | Increase |
| **Total** | **2868.0764** | **2867.8618** | **-239.8842** | **-345.23** | **-57.3** | |

**CONCLUSION**

This paper has demonstrated the potential use of the integration of remotely sensed data with GIS techniques in the study of landuse and landcover changes within specific periods of time. Remarkable changes were observed between 1978 and 1995 which were mainly due to human interventions, especially agricultural practices, this however calls for the necessity of further research on human impacts on the landuse and vegetation cover changes of the basin area, assessment of the social-economic impacts of the landuse and landcover changes on the basin areas well as the post-dam environmental impact assessment.

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