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Monitoring the land-use and vegetation cover changes in the Kainji Lake Basin, Nigeria (1975-2006)

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This paper demonstrates the use of remotely sensed data and geographic information system (GIS) techniques for monitoring the land-use and vegetation cover changes in the Kainji Lake Basin between 1975 and 2006- a period of thirty one (31) years. Since 1968 when Kainji Lake was constructed, various activities such as agriculture, deforestation, irrigation, fishing and construction of roads and bridges have taken place. It is all these activities coupled with other natural factors that cause environmental degradation and the damage of the ecosystem of the lake basin. Landsat TM image of 1975, Landsat MSS image of 1986 and Landsat ETM+ images of 2001 and 2006 were acquired, classified and analysed with the use of Ilwis 3.3 and Idrisi 32 to study the landuse and vegetation changes in the Lake Basin between 1975 and 2006. Area calculations of Idrisi 32 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. Map overlay technique was also used to create a matrix to discuss the location of the changes within the study periods. The study reveals that the Lake Reservoir and settlements around the lake were gradually increasing; intensive agriculture was capturing the basin at alarming rate, while the lake surface itself is recently been occupied by weeds. The woodland vegetation in which the first and the most popular National Park in the country where it is located is also discovered to be changing to other land-use types. Various conservation and control measures were suggested for the sustainable utilization of the Lake Basin.

Key words: Remote sensing, geographic information system (GIS), image classification and land-use and land-cover, change detection.

INTRODUCTION

The Kainji Lake basin is one of the most important inland basins in Nigeria, it is the home of the first and the largest hydro-electricity station in the country, the woodland vegetation of the basin is also the home of the first National Parks in Nigeria. Agboarumi (1997) described the basin as blessed, mighty, great and the central hub upon which the entire social economic activities of the nation depends. It is the realization of this fact that the government of Nigeria in conjunction with the Global Environmental Facility (GEF) financed the sustainable management of the protected areas in the country with the main objective of strengthening the capacity of the relevant institutions at all levels in maintaining the biodiversity of this areas, Kainji Lake basin being among these protected areas (Papka, 2004).

Rivers, lakes, streams and water bodies have complex ecosystem ranging from mountain torrent to quiet, still lowland water which may be deep or shallow, large or small (Haslam 1978). The most important physical variable which affect the land-use and vegetation aquatic

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ecosystem include water movement and the quantity of flow, the soil or substance of the bed of the water course, the width and the depth of the channel, the general position of the channel in the river or lake system, the drainage orders, the slope (gradient of the channel and human intervention). Ikusemoran and Adesina (2009), reported that generally whenever a dam is constructed along a river channel, riparian communities around such locations are often affected directly and indirectly. For instance, the places that are inhabited by man are usually flooded, since the surface area of the river channel increases because of the dam construction. Also, the backward effect of the lake water creates some disturbances to the human population around the river channels. Moreover, human activities are also subjected to changes.

According to Ikusemoran and Adesina (2009), the impoundment of Kainji Lake on River Niger has converted the river to a lake ecosystem and has also changed the land cover around the formed lake. The forest formation has changed overtime, which could be due to the change in the orientation of the riparian communities through temporal displacement that took place after the creation of the lake reservoir. Any nation with sustainable utilization of her resources in mind must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Land-use is only one of such aspects. The knowledge about land-use and land-cover has become increasingly important as every nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of important wetlands, and loss of fish and wildlife habitat. Land-use data analysis 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 land-use patterns and changes in land-use through time. The knowledge on land-use such as agricultural, recreational as well as information on their changing proportions is needed by legislators, state and local government officers in determining better land-use policies, identification of future development on pressure points and areas, and implementation of effective plans for regional development. In this dynamic situation, accurate and meaningful current data on land-use are essential for inventory of water resources, flood control, water supply planning and wastewater treatment. Many federal agencies use current and comprehensive inventories of existing and changing uses of land to improve the management of public lands. Federal agencies also need land-use data to access the environmental impact resulting from the development of energy resources, to manage wildlife resources and minimize man-ecosystem conflicts, to make national summaries of land-use patterns and changes for national policy formulation and to prepare environmental impact statements and assess future impacts on environmental quality.

Remote sensing and/or GIS have been applied to land-use and land-cover changes of Lake Reservoir within and outside Nigeria. 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 study reveals that the construction of the dam contributed to the depletion of the vegetation that could have minimized desertification. Adeniyi and Omojola (1999) also used aerial photographs, Landsat MSS, Spot XS/panchromatic image transparency and topographical maps to study landuse and landcover changes in Sokoto and Guronyo dams, Nigeria between 1962 and 1986. Their studies revealed that settlement covered most part of the area after the construction of the dam.

Therefore, because of the central role of provision of electricity as well as conservation of flora and fauna, by the Kainji Lake, proper monitoring of the Lake Basin becomes important for sustainable utilization and development.

Objectives of the study

1. To create land-use/land-cover maps of the Kainji Lake basin from 1975-2006 using remotely sensed data and GIS techniques and using the maps to assess the trends, magnitudes, nature and locations of the land-use and vegetation cover changes of the lake basin within the study period.
2. To assess the actual land areas which have been lost or gained by the principal features in the lake basin, that is, the lake reservoir, intensive agriculture and the woodlands vegetation within the study period.
3. To evaluate the environmental and social economic implications of the land-use and land-cover changes in the lake basin.

The study area

According to National Electric Power Authority (NEPA) Diary (1995), the genesis of Kainji Lake 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 Nigeria. 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. Nedeco and Balfour (1961) reported that the reason for the choice of Kainji as the best site for the Lake were many among which are; rock foundation which was tested and was found to be capable of

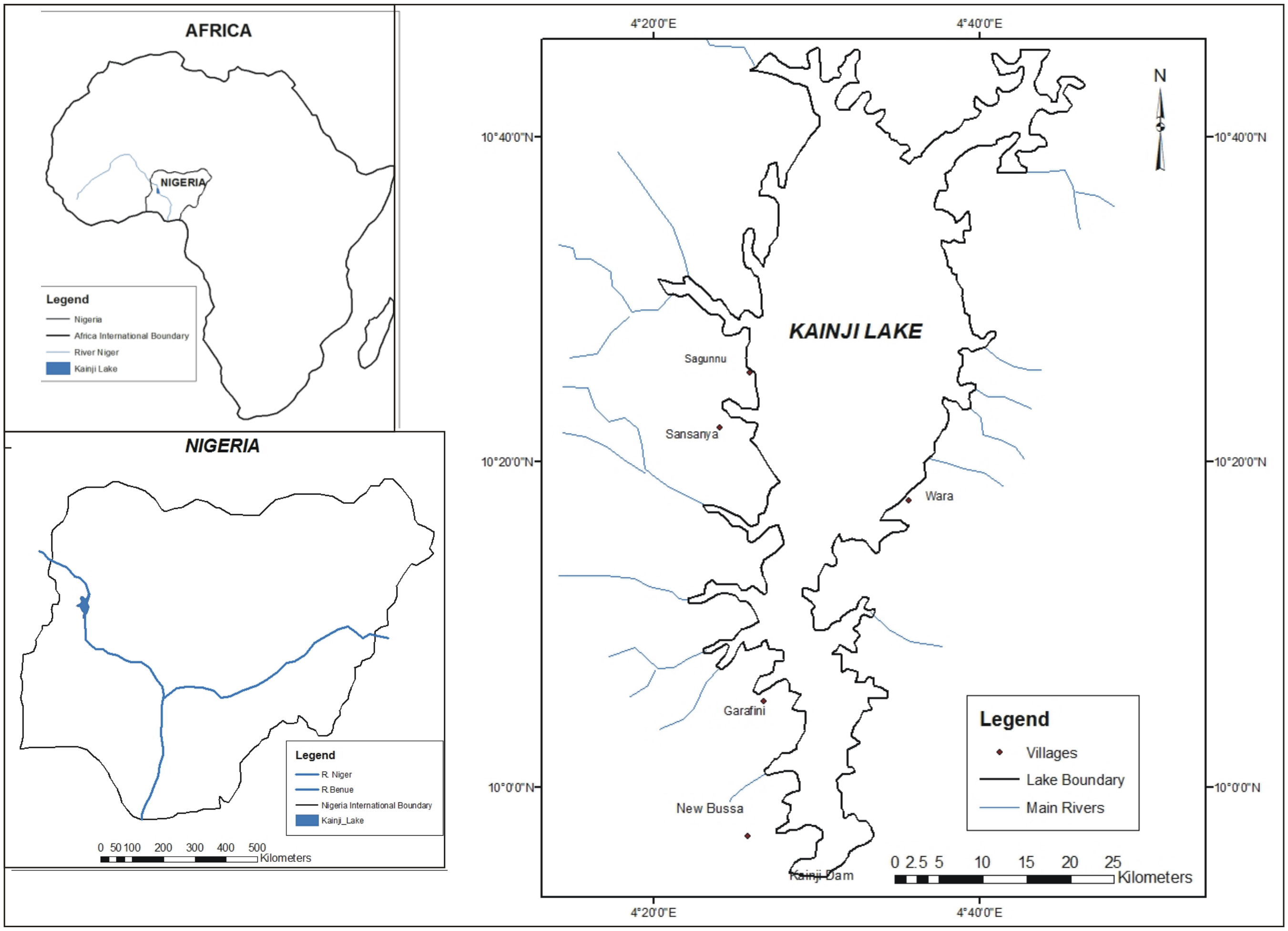


Figure 1. The study area.

holding the enormous height of the dam, it is also the point where the river valley is not too wide, the physical features of upstream of the dam valley also allows for a large reservoir. Agboarumi (1997) observed that the Kainji dam is today a pride of nature, providing cheap and abundant means of electricity for the continuously growing population and industries, sources of revenue, fishing, irrigation, cattle crossing, tourism, employment, international recognition, man-power training and many more.

The lake is located between latitudes 9° 50″ to 10° 42″N and longitudes 4° 20″ to 4° 42″E (Figure 1). Olokoh (1995) reported that construction of the Kainji dam which began in March 1964, was completed in December, 1968 and was officially commissioned on 15th February, 1969. The impounding of the lake started exactly on the 2nd August, 1968 and the water level rose to 140.2 m on the 19th of October the same year - a period of seventy eight days. The lake that was formed sunk most parts of Kainji Island on which the dam was constructed. NEPA Diary (1995) stated that the lake covers an area of 1250 km^2 with a maximum depth of 54.9 m. The lake extends to about 136.8 km upstream of Jebba beyond Yelwa in the North. 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 River Niger before entering into the lake.

According to Nedeco and Balfour (1961), 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 season of five months starting from early November to middle of March. Rainfall increases from the month of April, reaching the peak in August and starts declining in September. Rainfall decreases with decrease in latitudes within the basin and also increases with increasing altitude (Olokoh 1995).

METHODOLOGY

Sources of data

The first four data sets (Table 1) which cover a total period of 31 years (1975-2006) were the main images that were acquired

Table 1. Sources of data

Data type	Source	Date
Landsat TM	http:glcffap.umd.edu:8080/esdi/index.jsp	08/12/1975
Landsat MSS	http:glcffap.umd.edu:8080/esdi/index.jsp	21/10/1986
Landsat ETM+	http:glcffap.umd.edu:8080/esdi/index.jsp	22/10/2001
Landsat ETM+	http:glcffap.umd.edu:8080/esdi/index.jsp	05/11/2006
Landuse/Landcover/ Vegetation Maps	Forestry Monitoring and Evaluation Unit (FOMECU) Abuja	Nov.1978 & Nov. 1995

for the monitoring of the Lake Basin. The first two data sets have large gap of more than ten years each, while the last two have close gaps of five years each. This was designed to reflect the impact of dam in the past years of low population and the recent years when the population of the country has been increasing tremendously. All the four images were acquired between late October and early December which is the transition period between the dry and wet season, the climatic conditions during this period is the same all over the lake basin (Olokor, 1995), hence the vegetation cover and other land-use types appear the same on the image regardless of the year when they were obtained. The fifth data sets (Table 1) were acquired from Forest Monitoring, Evaluation and Coordinating Unit (FOMECU) which was established in 1987 as an organ of the Department of Forestry in the Federal Ministry of Agriculture and Natural Resources with its primary mandate of coordination and monitoring of the implementation of Forestry II programs which contains aforestation, reforestation and desertification control projects (Federal Republic of Nigeria, 1999). The maps were used as complimentary and guide during the classification and ground truthing of the imageries.

Image classification

Three bands of infrared, red and green were selected from each of the four imageries to perform colour composition operations using Ilwis 3.3 Academic software. The Imageries were then “submap” individually through the use of the coordinates of the four corners of the lake basin. Colour separation was then performed in order to generate “map lists” while, the sample set module of the Ilwis was also used to create the “domains” which were used for the image classifications. The Maximum Likelihood Classification techniques of the Ilwis 3.3 were used to classify each of the four images. Accuracy assessment was conducted as error matrix commonly referred to as confusion matrix. The following overall accuracy results were obtained for the four images: 90.88% (1975), 87.44% (1986), 82.04% (2001) and 89.63% (2006). Each of the images was filtered through the filtering module of the Ilwis 3.3. The results of the filtered images are shown in Figure 2a-d. The processes of ground-truthing was carried out with the use of Germin 76 Global Positioning System which was used to take the coordinates of settlements, intensive agricultural area, extensive agricultural area around the dam site through Kainji town (see location in Figure 1), as well as some areas within the settlement of Kainji town (Figure 1), the recorded coordinates was linked with the classified image and while other landuse types were found to be correct, the differences between intensive and extensive agriculture on the image was initially difficult until several readings were made to determine the actual positions of each class. The acquired tailor-made map of 1995 processed from satellite images by FOMECU Nigeria, were also used as guide during the ground-truthing. In fact, it was the map in conjunction with the sampled coordinates of freshwater marsh and freshwater swamps taken at the off shore of the Lake at Gaski that was used to ground-truth the two features, that is, freshwater marsh and freshwater swamp. The lake itself was conspicuous on all the images.

Change detection techniques

Three main change detection methods which have been previously applied by several researchers (Adeniyi and Omojola, 1999; Ikusemoran, 2009a) were employed in this paper, they are:

Change detection by area calculation

There are three steps in calculating 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 previous land-use and multiplied by 100 (B-A/Ax100).
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, thirty-one (31) years (1975-2006).

Change detection by nature

The nature of change was derived by map overlay. Each of the four classified images in Figure 2a-d was exported using the TIF. (Geo Tiff) TIFF of Ilwis 3.3 to Idrisi 32 for map overlay and analysis. The output images were overlain to generate the matrix tables (Tables 4a-c) using the addition module of the Idrisi. The area of the features in each image were then calculated through the area module of the Idrsi to generate the magnitude, trends and the percentage change of each of the features in each image.

In generating the matrix table (Table 4a-c) the first image was assigned values from 1 to the maximum class, that is, 10 (as in 2001 and 2006) and nine and eight in 1986 and 1975, respectively. While the second image was assigned 20, 30, 40 and so on until the maximum class of that image (for example 110 in 2001/2006 and 100 in 1986) was reached. (Table 4a-c) The essence of using these figures was that, since the addition of the overlay module was used, when two of these numbers in rows and columns were added, no two additions would produce the same result.

In the matrix tables (Table 4) all the numbers in red colour are the pixel values of each class when the maps were overlain. Those in blue colour were the pixel numbers of each class before they were overlain. The black numbers represents the areas of each of the overlain classes. The purple colour figures are the totals of each

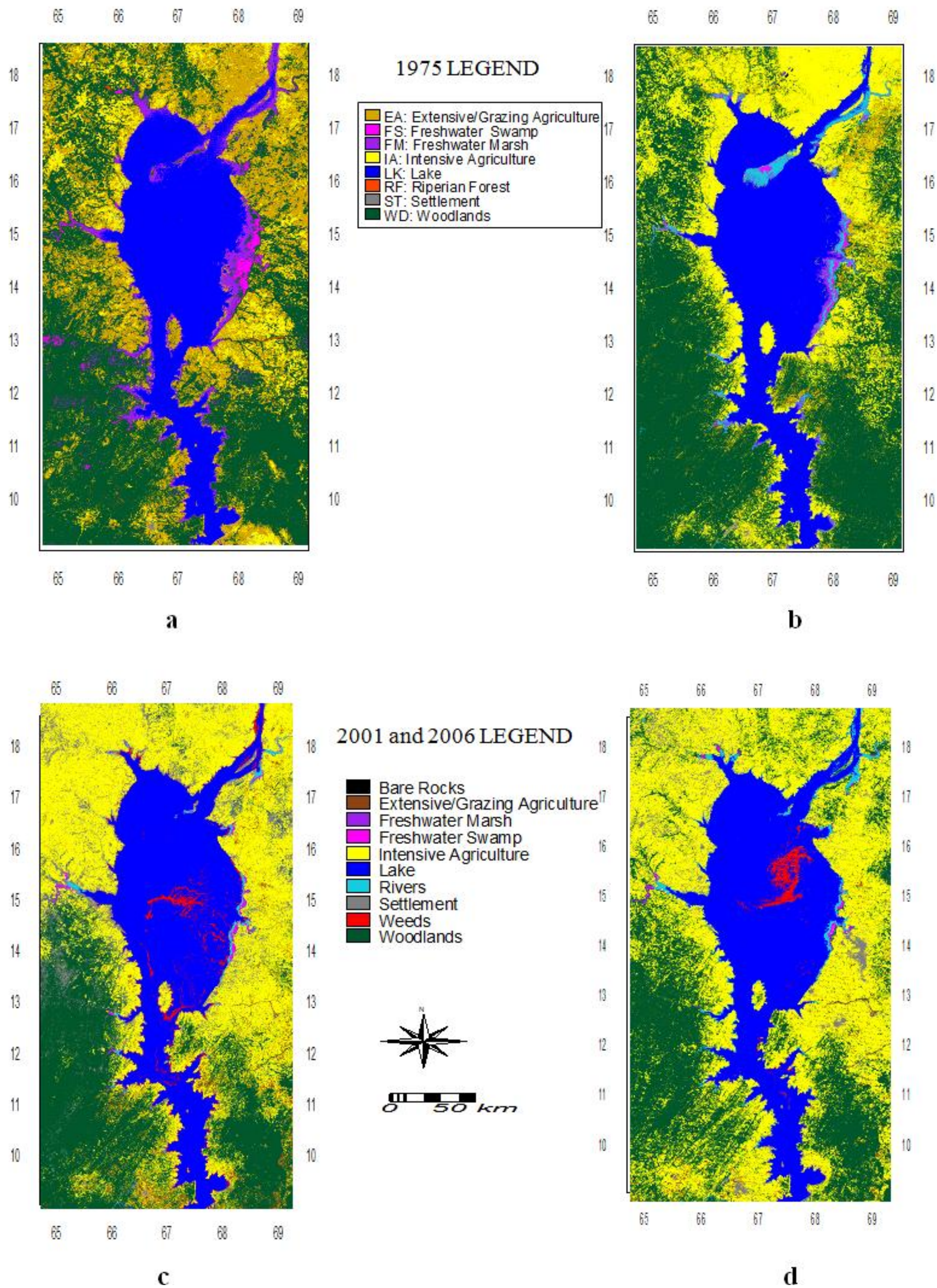


Figure 2. Classified Kainji Lake Basin. **a,**1975; b, 1986; **c,** 2001; **d,** 2006.

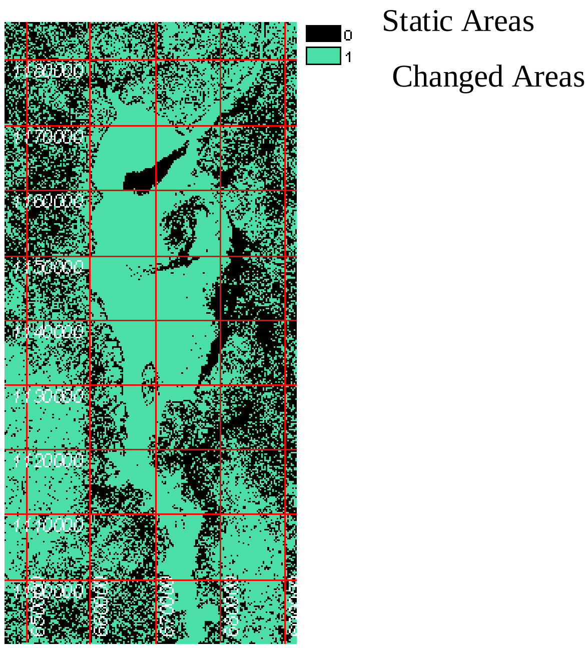


Figure 3. Changed and static areas (1975-2006).

of the classes. Finally, the green colour represents the total area of the study area in square kilometres.

There are three important classes of information that could be generated from the change detection by nature through the matrix table; the first information is that it shows the areas that have not recorded any change at all throughout the study period. This is represented by all the figures (bold) in the diagonals, that is, all the classes with the values in the diagonal have not recorded any change.

The second information that could be extracted were the areas or classes that have changed from their initial land-use or land-cover to another land-use or land-cover type, that is, the areas that have lost to other land-use/land-cover type. These areas were represented by all the classes with values along the columns in the matrix tables. The third was the areas that have gained from other land-use/land-cover type, that is, the areas with all the values along the rows of the matrix tables.

Change detection by location

The reclass module of the idrisi software was used to create the map that shows the areas that have experienced changes (changed areas) and the areas that have not (static areas) within the study periods. All the classes with the values in the diagonals, (the static areas) were assigned "1" while the values of the other classes, that is, those at the rows and columns were assigned "0" (changed areas). The output map shows the static (1) and the changed areas (0) (Figure 3). The area of the output map was also automatically calculated in Idrisi environment.

Mapping and calculations of the extent of changes of each class

The logic expression of the image calculator and the area module of the Idrisi were used to map and calculate the extent to which each of the features in the basin has changed respectively.

However, only three features of major concern were selected for this purpose: the lake reservoir, the woodland vegetation and the intensive agriculture areas. The result was to produce the following:

1. Areas that were not Lake Reservoir in 1775 but have changed to lake reservoir in 2006 so as to know whether the lake is expanding or not as has been the fear of Nigerians.
2. Areas that were of woodland vegetation type in 1975 but have changed to other land-use types in 2006. This was done to determine the land areas of the woodlands (home of National Park) that have been lost within the study periods to other landuse types.
3. Areas that were not intensive agriculture in 1975 but have changed to intensive agriculture in 2006 so as to assess the rate of land captured by intensive agriculture within the study periods.

RESULTS

The result of the trends of changes of the landuse and landcover of Kainji Lake is presented in Table 2, while the magnitudes, percentage changes and annual rate of changes are presented in Table 3a-c. The spatial locations of the changes in the lake area between 1975 and 2006 are presented in Table 4a-c, while Table 5 shows the extent of changes in the Lake area within the study period. Moreover, Figure 2a-d represents each of the four classified images of 1975, 1986, 2001 and 2006, respectively, while Figure 3 shows the parts of the lake that have not been subjected to changes (static) between 1975 and 2006. Figure 4a represents the total areas captured by the reserviour between 1975 and 2006, Figure 4b shows the area that was captured by intensive agriculture within the study period, while Figure 4c shows the areas that have been lost by woodland vegetation between the same period.

DISCUSSION

Trends, magnitudes, percentage changes and annual rate of changes

Table 2 shows the trends in terms of the area coverage and the percentage of each class of the basin area from 1975 to 2006. It was revealed that the Lake Reservoir that covered 910.6224 km^2 in 1975 has increased to 1094.2302 km^2 (addition of 1053.3750 km^2 lake reservoir and 40.8602 km^2 weed coverage) in 2006. The woodland vegetation of the Basin area which is the home of the first National Park in the country has also reduced in size from 41.41% in 1975 to 24.38% in 2006. Moreover, intensive agriculture that covered only 5.59% in 1975 has increased to 40.95% in 2006. There was the presence of riparian forest in 1975 which had disappeared in the lake basin before 1986. Human settlement area that covered only about 12 km^2 in 1975 has risen to 175 km^2 in 2006. Finally, between 1975 and 1986, there were no weeds on the lake, but the weeds has not only appeared on the lake but was rapidly capturing the lake surface which has been a great concern to the country as noted by Ayeni et

Table 2. The trends of the landuse/landcover changes of the lake basin (1975-2006).

Landuse/Landcover	1975		1986		2001		2006	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Lake Reservior	910.6224	21.07	955.8086	22.12	1010.4105	23.38	1053.3760	24.38
Woodlands	1789.2332	41.41	1925.3175	44.55	1366.9067	31.63	1146.5369	26.53
Intensive Agriculture	241.4720	5.59	1031.4233	23.87	1549.6968	35.86	1769.5118	40.95
Extensive/ Grazing	1131.4632	26.18	200.4712	4.64	119.1034	2.76	59.8514	1.39
Settlement	12.3040	0.28	69.9070	1.62	140.7425	3.26	175.5531	4.06
Freshwater Swamp	187.6231	4.34	40.9016	0.95	9.0850	0.21	7.4500	0.17
Freshwater Marsh	41.8048	0.97	12.0611	0.28	8.3117	0.19	6.1934	0.14
Riparian Forest	6.6992	0.15	-	-	-	-	-	-
Rivers	-	-	84.4552	1.95	51.5014	1.19	61.4718	1.42
Bare Surface	-	-	0.8732	0.02	0.3219	0.01	0.4142	0.01
Weeds	-	-	-	-	62.1358	1.51	40.8602	0.95

Table 3a. The magnitudes, percentage and annual rate of changes of the lake basin (1975-1986).

Landuse/Landcover	1975	1986	Magnitude of change	Percentage change	Annual rate of change	Remark
LakeReservoir	910.6224	955.8086	45.1862	2.03	+4.97	Increase
Woodlands Vegetation	1789.2332	1925.3175	136.0343	6.11	+7.61	Increase
Intensive Agriculture	241.4720	1031.4233	789.9513	35.45	+327.14.	Increase
Extensive/Grazing	1131.4632	200.4712	930.992	41.78	-82.28	Decrease
Settlement	12.3042	69.9070	57.603	2.59	+468.16	Increase
Freshwater Marsh	187.6231	40.9016	146.7215	6.58	-78.20	Decrease
Freshwater Swamp	41.8084	12.0611	29.7437	1.33	-71.15	Decrease
Riparian Forest	6.6962	-	6.6962	0.30	-100	Decrease
Rivers/Freshwater	-	84.4552	84.4552	3.79	+8445.52	Increase
Bare Surface	-	0.8732	0.8732	0.04	+87.32	Increase
Total	4321.2189	4321.2187	2228.3066	100	9009.09	

Table 3b. The magnitudes, percentage and annual rate of changes of the lake basin (1986-2001).

Landuse/Landcover	1986	2001	Magnitude of change	Percentage change	Annual rate of change	Remarks
LakeReservoir	955.8086	1010.4105	54.6019	3.85	+5.71	Increase
Woodlands Vegetation	1925.3175	1366.9067	558.4108	39.39	-29.00	Decrease
Intensive Agriculture	1031.4233	1549.6968	518.2735	36.55	+50.25	Increase
Extensive/Grazing	200.4712	119.1034	81.3678	5.74	-40.59	Decrease
Settlement	69.9070	140.7425	70.8355	5.00	+101.33	Increase
Freshwater Marsh	40.9016	9.0850	31.8166	2.24	-77.79	Decrease
Freshwater Swamp	12.0611	8.3117	3.7494	0.26	-31.09	Decrease
Rivers/Freshwater	84.4552	51.5015	32.9538	2.32	-39.02	Decrease
Bare Surface	0.8732	0.3249	0.5513	0.04	-63.14	Decrease
Weeds	-	65.1359	65.1358	4.59	+651.36	Increase
Total	**4321.2187**	**4321.2189**	**1419.6964**	**99.98**	**528.02**	

al. (1994), Obot et al. (1995) Adesina et al. (1998) and Mbagwu et al. (2002).

In Tables 3a-c, the total land area that was subjected to changes (magnitude) in the lake basin was revealed to

Table 3c. The magnitudes, percentage and annual rate of changes of the lake basin (2001-2006).

Landuse/Landcover	2001	2006	Magnitude of change	Percentage change	Annual rate of change	Remark
LakeReservoir	1010.4105	1053.3760	42.9655	6.98	+4.25	Increase
Woodlands Vegetation	1366.9067	1146.5369	220.3698	35.81	-16.12	Decrease
Intensive Agriculture	1509.6969	1769.5118	219.8149	35.72	+14.18	Increase
Extensive/Grazing	119.1034	59.8514	59.252	9.63	-49.75	Decrease
Settlement	140.7425	175.5531	34.8106	5.66	+24.74	Increase
Freshwater Marsh	9.0850	7.4500	1.635	0.27	-18.00	Decrease
Freshwater Swamp	8.3117	6.1934	2.1183	0.34	-25.49	Decrease
Rivers/Freshwater	51.5015	61.4718	9.9703	1.62	+19.36	Increase
Bare Surface	0.3219	0.4142	0.0928	0.02	+28.67	Increase
Weeds	65.1359	40.8602	24.2757	3.95	-37.27	Decrease
Total	4321.2189	4321.2188	615.3044	100	-55.45	

Table 4a. The matrix table created from the 1975 and 1986 overlay.

	1986									
Landuse/ Landcover 1975 ↓	Lake 20	Woodlands 30	Intensive Agric. 40	Extensive/ Grazing 50	Settlement 60	Freshwater Marsh 70	Freshwater Swamp 80	Rivers 90	Bare Surface 100	Total
Lake 1	21 **860.0672**	31 1.6351	41 12.9424	51 0.5239	61 8.6951	71 6.0439	81 1.5352	91 19.1756	101 0.0041	910.6225
Woodlands 2	22 8.2687	32 **1338.4333**	42 296.5595	52 95.1436	62 8.6927	72 8.5479	82 3.5479	92 21.1956	102 0.4240	1789.2332
Intensive Agric 3	23 0.1316	33 83.2523	43 **136.7763**	53 16.0322	63 4.7008	73 0.1218	83 0.0097	93 0.3095	103 0.1381	241.472
Extensive/ Grazing 4	24 19.7831	34 457.7723	44 539.6454	54 **78.1327**	64 24.9840	74 4.2408	84 0.1852	94 6.4411	104 0.2786	1131.4632
Settlement 5	25 0.3891	35 1.8113	45 8.5847	55 0.3696	65 **1.0803**	75 0.0268	85 -	95 0.0162	105 0.0260	12.304
Freshwater Marsh 6	26 67.0398	36 18.8986	46 31.9482	56 3.5179	66 12.7686	76 20.1308	86 2.1308	96 30..5991	106 0.0016	187.6232

Table 4a. Contd.

Freshwater Swamp 7	27 0.1291	37 18.8344	47 3.7298	57 6.2600	67 0.6141	77 1.6245	87 **4.0335**	97 6.5743	107 -	41.8047
Riparian Vegetation 8	28 -	38 4.6802	48 1.2371	58 0.4914	68 0.0967	78 0.0203	88 0.0260	98 **0.1438**	108 0.0008	6.6963
Total	955.8036	1925.3175	1031.4235	200.4113	69.9074	40.9016	12.0611	84.4552	1.2732	4321.22

Table 4c. The matrix table created from the 2001 and 2006 overlay.

	2006										
Landuse/ Landcover 2001 ↓	**Lake 20**	**Woodlands 30**	**Intensive Agriculture 40**	**Extensive/ Grazing 50**	**Settlement 60**	**Freshwater Marsh 70**	**Freshwater Swamp 80**	**Rivers 90**	**Bare Surface 100**	**Weeds 110**	Total
Lake 1	21 **964.4217**	31 0.1129	41 1.3394	51 0.0227	61 5.2975	71 0.0008	81 0.0812	91 6.8546	101 0.0008	111 32.2788	1010.4104
Woodlands 2	22 1.2444	32 **867.8331**	42 453.8906	52 16.1589	62 18.9546	72 1.9039	82 1.2874	92 5.4015	102 0.0252	112 0.2071	1365.9147
Intensive Agric 3	23 4.4503	33 235.0917	43 **1146.0406**	53 32.2625	63 115.9486	73 2.2954	83 0.8878	93 11.6915	103 0.2729	113 0.7554	1550.0967
Extensive/ Grazing 4	24 0.2087	34 21.8463	44 80.8440	54 **10.0093**	64 5.2309	74 0.1340	84 0.1470	94 0.5515	104 0.0536	114 0.0780	119.1033
Settlement 5	25 7.6693	35 16.7632	45 80.0991	55 1.2070	65 **24.1368**	75 0.8090	85 0.3736	95 9.1102	105 0.0487	115 0.5255	141.2872
Freshwater Marsh 6	26 0.3078	36 2.5781	46 1.0194	56 0.0439	66 0.2372	76 **1.1469**	86 1.3118	96 2.4254	106 -	116 0.0146	9.0852
Freshwater Swamp 7	27 1.2371	37 0.4776	47 0.1949	57 0.0114	67 0.0796	77 0.6100	87 **1.5287**	97 4.1668	107 -	117 0.0057	8.3119
Rivers 8	28 24.6737	38 1.5985	48 3.1328	58 0.0707	68 1.9267	78 0.5483	88 0.5491	98 18.4202	108 0.0008	118 0.5808	50.5022

Table 4c. Contd.

Bare Surface 9	29	39	49	59	69	79	89	99	109	119	0.3211
	0.0016	0.0065	0.1746	0.0089	0.1178	-	-	0.0041	**0.0106**	0.0008	
Weeds	30	40	50	60	70	80	90	100	110	120	65.1358
10	49.1614	0.2291	2.7763	0.0560	3.6234	0.0016	0.0268	2.8461	0.0016	**6.4135**	
Total	1053.376	1146.537	1769.5117	59.8513	175.5531	7.4499	6.1934	61.4719	0.4142	40.8602	4321.22

Table 5. The extent of changes of the lake reservoir, woodlands and intensive agriculture (1975-2006).

	Land-use/ Land-cover class	Area (km^2)	Area (%)
1	LakeReservoir in 2006 but notLake Reservoir in 1975	205.2586	4.75
2	Intensive Agriculture in 2006 but not Intensive Agriculture in 1975	1587.7759	36.75
3	Woodlands in 1975 but not woodland in 2006	943.2975	21.83

be 2228.3066 km^2 between 1975 and 1986 which decreased to 1419.6964 km^2 before 2001 and reduced drastically to 615.3044 km^2 in 2006. This means that some parts of the lake have been subjected to changes. This was also revealed in Figure 3.

Extensive agriculture/grazing land and intensive agriculture had the highest percentage changes of 41.78 and 35.45%, respectively, between 1975 and 1986, though, while extensive agriculture changes positively, intensive agriculture recorded negative changes.

From 1986 through 2001 to 2006, extensive agriculture/grazing land reduced drastically which is a result of the policy of the Federal Government against grazing in the basin area in order to protect the National Park.

This policy has always resulted in communal classes between the communities, the park rangers and the nomads (Mayowa and Omojola, 2005; Ikusemoran, 2009b; Henry et al., 2013; Wahab and Adewumi, 2013).

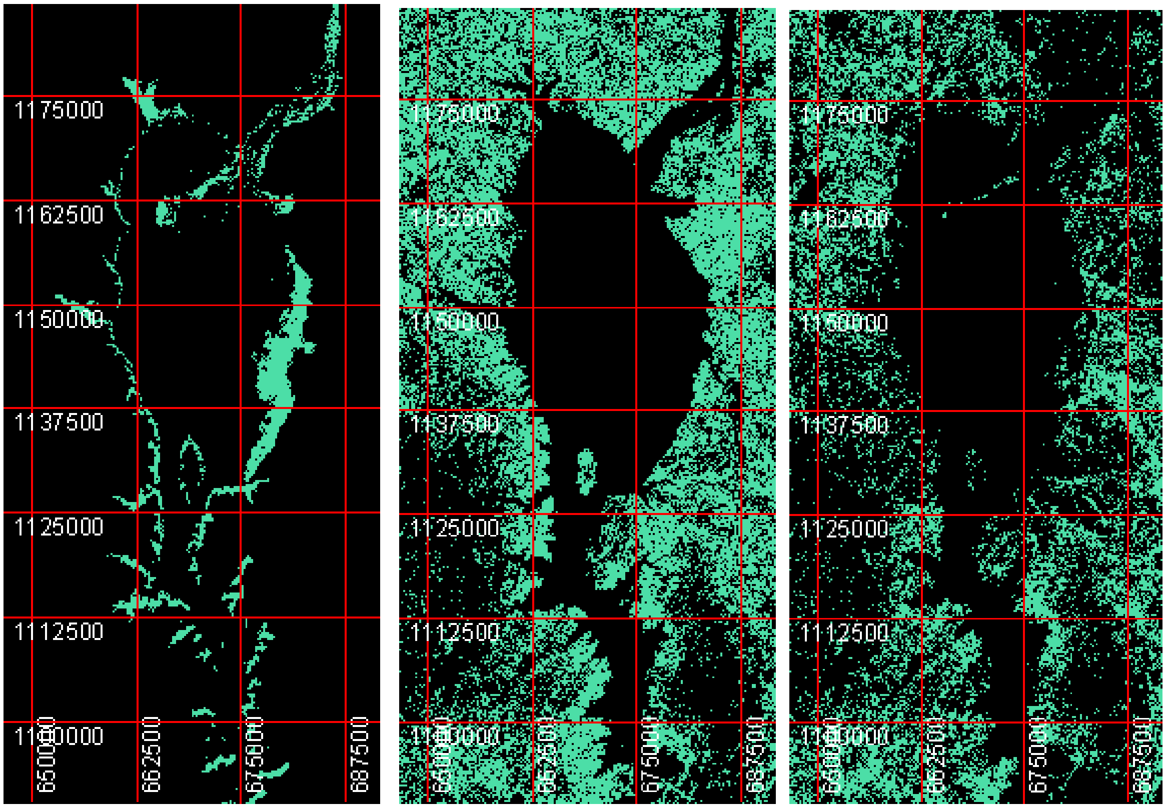
The nature of the changes of the lake basin

The matrix tables (Table 4a-c) show the nature of the land-use and land-cover changes in the basin area. Between 1975 and 1986 (Table 4a), the reservoir had static area of 860.0672 km^2 but gained heavily from freshwater marsh (67. 0398 km^2), extensive agriculture (19.7831 km^2) and woodlands (8.2687 km^2). Within this period, parts of the lake were also lost to other classes especially 19.1756 and 12.9424 km^2 to rivers/-freshwater and intensive agriculture, respectively. Woodland vegetation, though gained 457.7723 km^2 from extensive agriculture and a sizeable areas from other classes but also lost 296.5595 km^2 to intensive agriculture, 95.1436 km^2 to extensive agriculture and little losses to other classes.

However, the gain was more than the losses which might be due to the then few population in the basin area coupled with the strict protection of the Kainji Lake National Park that was just established and shouldered the responsibility of the protection of the basin.

Riparian forest that was found especially along the main rivers had disappeared before 1986 as it was mostly captured by woodlands. In Table 4b, the Lake basin, though, was still capturing much of the freshwater marsh (29.8412 km^2) but the rivers/freshwater class was the worst victim as the lake gained a total land area of 48.2208 km^2 from the class.

Weeds that suddenly appeared on the lake after 1986 as reported by Daddy et al. (1995) and water hyacinth *(Eichhorinia crassipes)* was first reported in 1989 on Kainji Lake and since then the plant continued to increase and spread to every part of the lake. Hence the dominance of the weeds on the lake as 42.7381 km^2 of the surface of the lake was captured by the weeds between 1986 and 2001. Intensive agriculture gained much from woodlands, and extensive agriculture during this period (644.2672 and 132.0717km^2 respectively) but also lost some parts to other land-use



a b c

Figure 4. a. Area captured by the reservoir between 1975 and 2006; **b.** Area captured by intensive agriculture between 1975 and 2006; **c.** Area loss by woodlands between 1975 and 2006.

types as 155.4621, 78.0515 and 31.1660km^2 to woodlands, settlement and extensive agriculture, respectively.

Table 4c shows the nature of the changes of the lake basin between 2001 and 2006. Due to the control measures especially by the National Institute of Freshwater Fisheries Research (formerly Kainji Lake Research Institute). Daddy et al. (1995) reported that the institute evolved mechanical, biological and manual control measures in controlling the water hyacinth on the lake. They reported that 45% of the estimated coverage by the weeds has been effectively removed. It was these efforts that made the lake to regain 49.1614 km^2 from the weed coverage area within this period

The spatial location of the changes in the lake basin

Spatial location procedures show the actual points or areas where changes have really taken place within the study period. The spatial locations of changes between 1975 and 2006 were derived by the overlay of 1975 and 2006 images and creating a matrix table from them in the same way it is shown in Figure 4a-c. The result of the reclass processes using the figures in the diagonal as 1 and other figures in the rows and columns as 0 gives an output map as shown in Figure 3.

The area module of the Idrisi was used to calculate the area of the output map. Out of the total basin area of 4321.22 km^2, it was revealed that 1638.9273 km^2 representing 37.93% has been subjected to changes, while 2682.2915 km^2 (62.07%) of the lake area has not been subjected to any change (Figure 3). The large static area is due to the large area coverage of the lake and the protected woodland area by the National Parks of Nigeria.

The extent of changes of each land-use/land-cover

It is important to know the extent of changes of each land-use type so as to assess the area coverage of the areas in any desired unit and percentages for proper land-use planning. The image calculator of the Idrisi software was used to determine the extent of the changes on the Lake Reservoir, woodland vegetation and intensive agriculture. These three classes are of great concern to the country as the lake has been a subject of discussion as having the possibility of dam collapse, some environmentalists (Ikusemoran, 2009a; Mbagwu et al., 2002) have also been emphasizing the loss of the woodland vegetation in the basin area which may affect the ecosystem of the lake basin, no wonder Wahab and Adewumi (2013) noted the presence of 14 sawmills within 40 km buffer around the park boundary between Wuromakoto and Gidan Aboki. Finally, human activities especially intensive agriculture was singled out to be the main activity responsible for the degradation of the lake basin (Ikusemoran, 2009a). The result of the image calculator on the different images as used is presented in Figure 4a to c. The values of the area of each class were also used to create Table 5.

A total area of 205.2558 km^2 representing 4.75% (Table 5) of the lake basin has been captured by the reservoir between 1975 and 2006. This means that the lake is actually expanding as has earlier been reported by Abiodun (2009) and Ikusemoran (2009a). The woodland vegetation has also lost a total area of 943.2975 km^2 (21.83%) between 1975 and 2006. Intensive agriculture is the degrading factor of the basin as 1587.7759 km^2 (36.75%) of the basin area have been lost to intensive agriculture between 1975 and 2006 (Table 5). This conforms to the earlier reports of Henry et al. (2013) that increased human and cattle population is continuously putting more pressure on the Kainji Lake Area and has ultimately cause fragmentation and degradation of wildlife habitats.

Implications of the land-use changes on the lake basin

1. Communal classes: Communal classes among the farmers, communities and the nomadic have recently become a problem especially in the savanna belt of Nigeria because of classes on land for their desired interests. For instance, extensive/grazing land has reduced drastically from 1131.4632 km^2 in 1975 to 200.4712 km^2 in 2006 and yet more animals are being reared in this belt since it is the main occupation of the people in the area, hence there is much pressure on the land and government efforts in controlling the parks have been faced with stiff opposition by the nomads who have no other occupation and no other home than the savanna where pastures are available for their animals. Henry et al. (2013) have reported on this syndrome that the effects of all these pressure on land culminate in increased man and animal conflicts lead to revenge killings and poaching.

2. Dam collapse: The area coverage of the lake reservoir has been increasing. The lake that covered 910.6224 km^2 in 1975 has increased to 1075.5464 km^2 (weed area coverage inclusive) a difference of 164.924 km^2. Many individuals, organizations and NGOs have been reporting that if the lake is actually increasing in size, then dam failure is inevitable unless solid maintenance is put in place, but how effective the maintenance will be in a country where maintenance culture is not valued remains a great question that calls for immediate answer.

3. Loss of Agricultural Land: With the increasing settlement area (12.3040 to 175.5531 km^2 between 1975 and 2006), and with the high rate of increase of intensive agriculture, (241.4720 km^2 in 1975 to 1769.5118 km^2 in 2006) (Table 2), if unchecked, there would soon be no land to use for agriculture. At present from Figure 4b, the only places that are yet to be utilized for agriculture are the lake reservoir and some parts of the preserved woodland areas.

4. Reduction or loss of park land: The reduction of the size of the woodland vegetation area as reflected in Table 3a-c coupled with the increasing capturing of the woodland area especially by intensive agriculture (Table 4a-c). According to Amusa et al. (2010), reduction of the park land could be attributed to the fact that the primary occupation of the Kainji Lake area is agriculture, which in effects reduced the park land area. This means that sooner or later the woodland vegetation which is the home of the first national park in Nigeria will become a history. Moreover, due to poaching and other human interference, many animals, plants and other micro organisms in the basin may become extinct.

5. Land exposure/desiccation: Continuous usage of land for agriculture may lead to agricultural land been converted to open, non-cultivated type such as open grassland or sandy bare surfaces as noted in Table 3a-c where bare surface that was not present in the basin in 1975 has been appearing though at a slow rate since 1986. Adeniyi and Omojola (1997) asserted that land exposure and desiccation are noted for increasing the local rainfall run-off and reducing infiltration. This factor affects the total water balance of a drainage basin, reduce soil matter by exposure to agents of erosion and consequently hamper land cultivation. Ogunwusi (2012) also reported that over 90% of the natural vegetation in Nigeria had been cleared and over 350,000 ha of forest and natural vegetation are lost annually.

6. Flooding: The expansion of the lake water has resulted into serious flooding especially at the western bank (where much land has been captured by the lake (Figure 4a) and the downstream which is the receiving end (Abiodun, 2009). The sudden appearance of weeds on the lake has also been attributed to another possible cause of flood of the lake (Olokor et al., 1998; Mbagwu, 2002).

In the work of Okhimanhe (1993) highest susceptibility of the flood in the Kainji Lake occurs within the first 3 km from the reservoirs including the river channels and surface waterbody lying between 69 and 162 m above sea level, while the lowest is at 15 km away from the reservoir and greater than 193 m above sea level. The serious flood at the downstream of this lake in this year (2012) has caused many displaced settlements, destructions of farmlands and properties (Adedeji et al., 2012; Nkeki et al., 2013).

7. Reduction in fish catch: The degradation of the lake area coupled with other factors such as excessive water (floods) and weed encroachment no doubt have collectively impart negatively on the annual fish catch in the lake area as Omojowo et al. (2010) reported that total fish catch reduced from 38,346 mt in 1996 to 13, 361 mt in 2001.

Conclusion

In this paper, the use of remotely sensed data and GIS techniques for environmental monitoring has been demonstrated. The Kainji Lake basin which is the home of the Kainji dam (the first and the largest hydro-electricity dam in Nigeria which provides electricity to the entire country and other neighbouring countries such as Niger Republic), the home of the first National Parks in Nigeria, and the base of various research institutions such as National Institute of Freshwater Fisheries Research, College of Wildlife, Fisheries College and many more is so important to the country that all hands must be on deck to see to its sustainable utilization. The lake water has been revealed to be expanding- causing fear of dam collapse, the woodland vegetation is rapidly decreasing-putting the existence of the National Park in suspense, water hyacinth has recently captured some parts of the lake, and despite numerous efforts by the government and research institute, the weeds as at 2006, still covered more than 40 km^2 of the lake surface, intensive agriculture that was very minimal in 1975 was discovered to have captured more than 40% of the lake basin. The lake basin therefore, needs nothing but proper monitoring if only the survival of the lake is in the interest of the country. Human interventions especially agricultural practices was discovered to be the major cause of the changes in the basin, this calls for further studies in the preservation of the basin from human interference. Dam collapse, communal classes, flooding, land desiccation and reduction in park and agricultural lands have also all been discussed as the possible implications of the changes on the lake basin. Remote sensing and GIS techniques can be used to monitor land-use and land-cover changes to guarantee quality environment which would provide for future needs of the nation.

Recommendations

The Kainji Lake basin is so much important to Nigeria that its sustainable utilization should not be compromised. The basin which is the central hob of Nigeria's economy should be well protected from environmental degradation. The lake water is rapidly expanding which may cause serious problems to the inhabitants especially at the downstream, hence, the government should do all they can to resettle the people at the sides and the downstream of the lake. Furthermore, government should discourage new settlement in the basin area so as to reduce pressure on the land area. To complement the efforts of the National Parks in the protection of the basin, Kainji Lake Basin Management Authority should be established to be solely responsible for the protection of the Lake Basin. The protection of the woodland vegetation of the basin should be of primary concern to the country as the depletion of the vegetation may lead to the end of the first and the most popular national park in the country. There should be proper land-use and land-cover planning of the basin area to reduce land degradation or loss of wetlands, provision of modern irrigation facilities for efficient utilization of the lake water instead of bastardizing the basin land surface, provision of improved seedlings that would yield better output from minimal land area, extensive training on lake basin, wetlands and general environmental management and finally ensuring public awareness and action to guarantee quality environment and making the lake basin a recreation and eco-tourism site. Remote Sensing and GIS techniques, though, still very new in most parts of Nigeria, is second to none in environmental monitoring, hence, the techniques is recommended for use in environmental monitoring and management of our already fragile environment.

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