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Impact of Gurara Dam on Land Cover in the Surrounding Communities of Kaduna State, Nigeria

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Abstract
This research focuses on the impact of Gurara Dam on land cover in the surrounding communities of Kaduna state Nigeria. The aim of the study is to assess changes land cover condition in communities surrounding Gurara Dam as a result of the Dam construction. This was achieved by analysing the land cover changes between pre-dam (2000) and the post-dam (2013) in terms of spatial extent and percentage coverage.To assess the impact, Landsat (ETM, TM and MSS) covering the area for 2000 (pre-dam period) and 2013 (post-dam period) was obtained. To interpret and verify the accuracy of the satellite imagery; ground truth observation was conducted on the land cover of the study area. Using ArcGIS 10.0 and AutoCAD Map 2013 software, different image processing techniques and analysis were undertaken to produce land cover maps of the study area for pre-dam and post dam period. The extent of area coverage of each land use/land cover was calculated in hectares and express in percentages. The study discovers that in the post-dam period (between 2000 and 2013) the impact of Gurara dam has resulted in substantial changes in the land cover, with losses in fadama land. Forestry, arable land and Rock outcrop by 58%, 9%, 7%, and 12% respectively. Whereas gains occurred in bare land (26%), water bodies (42%), circulation (28%). Modern irrigation also witnessed gain by 100% and built up area 26%. It is there recommended that, modern technology (Geographic Information System) be provided as mitigation measure to land cover problems in communities surrounding Gurara Dam.
Keywords: Dam Construction, Geographic Information System, land cover, Upstream and Spatial Extent

INTRODUCTION

Among the different forms of energy, hydropower power is crucial for economic, social and environmental development. The knowledge is proven and obtainable Apart from the high cost of construction and maintenance, the direct cost of dam is insignificant (Evans *et al.,* 2009). It therefore has a low operating cost that provides enough income that replaces the cost of construction. The life span of the dam ranges from 50-100 years, which make it easier to the builders to get back their net profit on time (Yuksel, 2009). It also requires about 60 to 90 seconds attaining full load compare to gas turbine or steam plants which is longer.

Furthermore, the cost of technology is moderately small and it is high in efficacy in relation to other means of power generation. In terms of cost, the energy is affordable compare to other conventional sources of electricity. Because of its moderate cost, most developing nations preferred it to other alternative source (Yuksel, 2009).

Dams provide water supply to arid region, therefore increase their means of support through irrigation, boosting agricultural development. It also makes transportation of people, goods and services possible through navigation (Yuksel, 2009). In areas where there is limited import of fossil fuels or infrastructure, dam generates power to serve as a good substitute. It however, prevents cost changes, enabling a dependable source of power, while petrol and gas prices are constantly changing with time.

The reservoir is sustainable in terms of industrial application, this because some are created to serve specific industrial firm. For instance, the Grand Coulee dam was built to provide electricity needed for Alcoa aluminium in Bellingham. Somewhat, dam is an environmentally low impact form of energy production, when compare to fuels such as natural gas, oil or coal – because carbon emissions are minimal in a cooler region with less biomass decomposition. The technology is known to produce 100 grams per kilowatt hour of photovoltaic solar power, the same as carbon dioxide emissions (Evans *et al.*, 2009). In temperate climate, hydroelectric dams are known no to produce carbon dioxide directly. Therefore have low green house gas impact of electricity.

They are use for water sports, vocations attractions and controlling of floods to people living downstream of the project area. Negative effects of dams can happen downstream, upstream, and in the lake. Apart from destruction of habitat, reservoir blocks the downstream flow of sediment and nutrients therefore, restricting the movement of fish and other water creatures that depend on speed of water level over time. Reservoirs correspondingly impact negatively the aquatic organisms by changing dissolved oxygen and water temperature all inside dams and its outflows (Lessard and Hayes, 2003). Dams also contribute to the release of carbon dioxide and methane gases thereby forming atmospheric greenhouse gases through decomposition of flooded soils and biomass (St. Louis *et al.,* 2000; Ma'kinen and Khan 2010).

Huge dam caused inundation of large areas upstream of the dams, thereby destroying riverine valleys, grassland, fadama areas and sites of historical importance. The result is habitat fragmentation of the adjoining areas. Siltation caused by the dam often deposits debris that reduce its capacity to control floods. This action reduces the amount of water that is use for generating power - which results to power shortages. The construction of dam also impact human livelihoods through reduction of fish and other aquatic resources. Reservoir fisheries may be poor replacement for aquatic organisms (fisheries) because of low productivity and the need for constant restocking of fish populations which may not be self-sustaining (Marmula 2001; Baran *et al.,* 2007).

It has the tendency of displacing large number of people. In year 2000, about 40-80 millions of people worldwide were physically relocated by dams (WCD, 2000). Native inhabitants, engaging in subsistence lifestyles are often the most heavily impacted by loss of natural resources from hydropower (McCully, 2001). Additionally, reduction of natural flooding reduces downstream sediment deposition which is important for estoring the fertility of watercourse region (Shoemaker *et al.*, 2001; Lebel *et al.*, 2005). A lot ofinstances exist where reservoir failure during construction or ageing was terrible for local settlements (Baird *et al.,* 2002; Graham, 2009). Dams are known to hold large volume of water which can cause natural disasters due to poor construction or sabotage. About 26,000 people and another 145,000 died due to Banqiao dam failure and epidemic in southern China. Truly, the concern for protection followed by environmental concerns is the major reasons for dams' removal in Wisconsin, USA (Born *et al.,* 1998).

Studies conducted in various regions of the world have indicated that Man's attempts to re-engineer and manage the shrinking and uneven water resources distribution are in direct conflict with natural systems. World Commission on Dams (WCD, 2000) pointed out that dams have significantly contributed to human development and the benefits derived from such have been noteworthy. Notwithstanding, the social, economic and environmental cost has been unacceptably high. Resource regulatory bodies and intellectuals have therefore, begun to think ways to shorten the environmental and socio-economic price of reservoirs. Recently, international initiatives on Sustainable Development (Johannesburg, 2002), World Water Forum (Kyoto, 2003), World Commission on Dams (1997-2002), and the continuing Dams and Development Project of the United Nations Environment Programme—have reaffirmed the commitment of many governments and international agencies (including the World Bank) to dam growth, but in a manner which mirrors modern environmental concerns.

In carrying out studies on Impact Assessment of Dams, Dalil (2007) used Landsat imagery (ETM, TM and MSS) to produce a land cover Map, covering the study area for 1975 (pre-dam period) - 1986, 1999 and 2007 (post-dam period). The essence was to assess the impact of Kiri dam on the Land cover along the lower reaches of Gongola River, due to impact of kiri dam (Adamawa State). To interpret and verify the accuracy of the satellite imagery, ground truth observation was conducted on the land cover of the study area in May, 2005. The classification revealed that in the post-dam period, the impact of Kiri Dam has resulted in substantial changes in the land cover, with losses in shrub and woodland, water bodies and grassland by 14.96%, 15.11% and 35.04% respectively. Whereas gains occurred in farm and grazing land by 37.77%, bare land soil and mud by 27.34%.

Adeniyi and Omojola (1999) demonstrated the application of multi-source archival remote sensing and GIS data for the mapping and evaluation of land cover changes within Sokoto -Rima basin of northern Nigeria. The post-dam period witnessed a total of 7596.2 ha (23.5%) changes in the land use and cover classes with evidence of large-scale conversion of agricultural lands to semi-arid environment. Land degradation resulting from land cover changes of the area was equally mapped. A total of 1042.7 ha (3.2%) of the study area was identified as areas with erosion and over grazing problem; 118.6 ha of land was under land exposure/desiccation while 791.9 ha constitute area with loss of prime (flood plain) agriculture.

In a study carried out in Panthankot and Dharkalan Tensils, Punjab (India) Singh and Khanduri (2006) evaluate the Land cover change detection within the study area. Satellite imageries of IRS-IA, LISS-II, LISS-III, ETM Landsat (1991-2006) and digital SOI topographic maps were used. The GIS was applied to analysed the land use changes and evaluate the socio-economic implications of predicted change. Land cover changes have been detected by image processing method in EDRAS imagine 9.3, ArcGIS 9.3, motoring of land cover changes help to plan development activities such as major land cover changes. Fifteen years period of (1991-2006) shows some major land cover changes. During this period of fifteen years 104.02 Sq/km areas has undergone positive changes into cropped land and built up areas from forest and fallow land. There is a remarkable increase 69.23 Sq/km.

The aim of this study is to assess changes in land cover condition in communities surrounding Gurara dam as a result of the dam construction. This was achieved by analysing the land cover changes between pre-dam (2000) and the post-dam (2013) in terms of spatial extent and percentage coverage.

The study area

The Dam is situated on the Gurara River at 9°05'N, 7°30'E (Figure1. 2). The Gurara River extends to about 570 km from the highland at over 700 m, 530 m through Jere and into the Niger confluence at a height of 40 m. The River flows northeast to southwest and then turns southwards as it flows through FCT to its confluence with the Niger. The study area is bounded to South by Niger state, to the North by Kachia Local Government Area, to the East and West by Kagarko Local Government Area respectively as indicated in Figure 1.

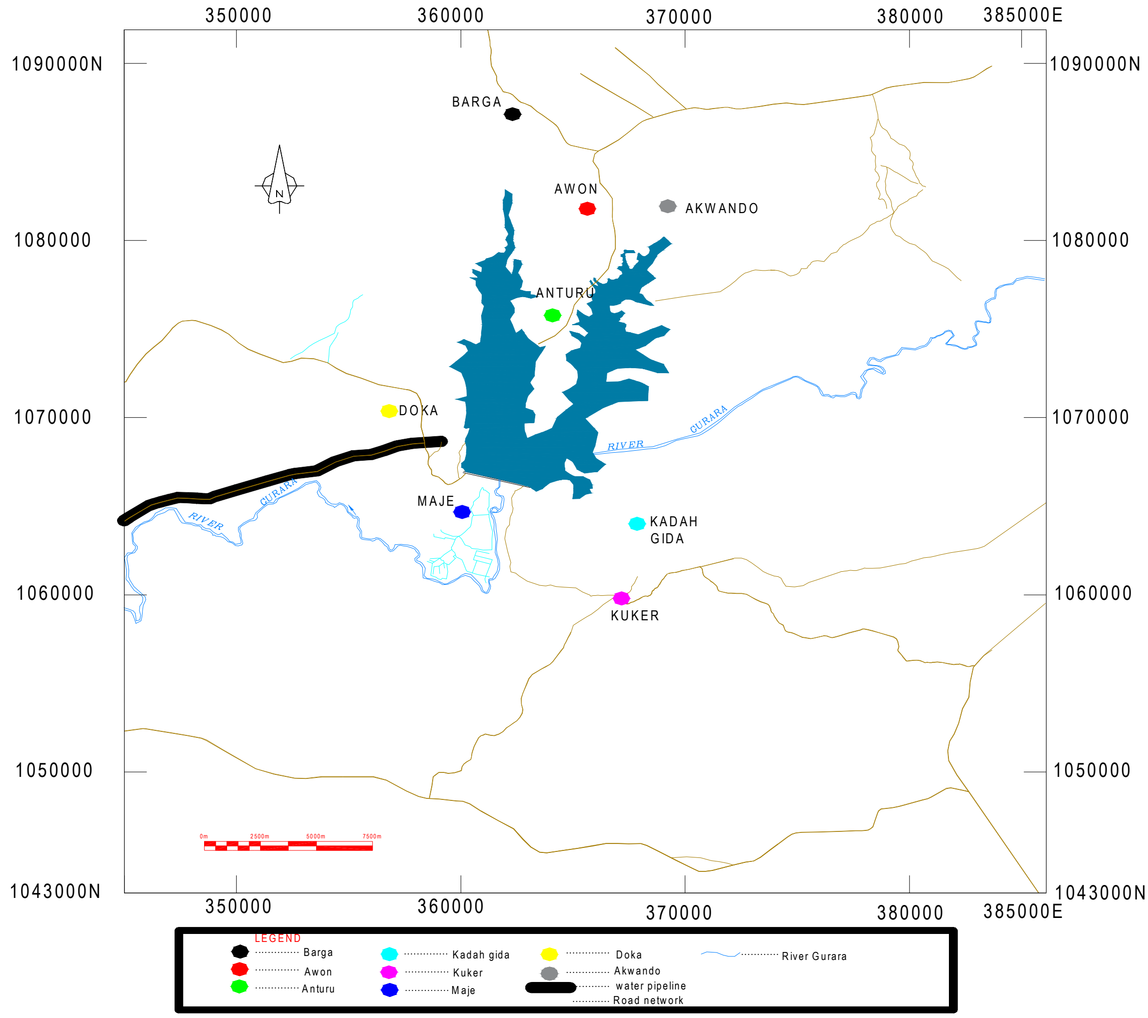

Figure 1: The Study Area

Rainy season begins in May (or April) and lasts till October, with the highest rainfall occurring in September, while dry season lasts between November and March. The mean annual rainfall of some locations in the region is; 1300 mm at Minna, 1500 mm at Abuja, 1600 mm at Kafanchan and 1250mm at Kaduna. Vegetal cover is basically Guinea Savannah grassland interspersed with remnants of tropical forest. The watercourses are distinctly forested with copious trees from the fringing forests, with a few patches of typical natural forest reserve. Mean yearly temperature of the region is nearly 27^{o}c with values that vary over the year from annual minimum of 25^{o}c in July to a maximum temperature of 35^{o}c in March. Mean yearly greatest temperature is 33^{o}c and the mean minimum is 22^{o}c. The maximum diurnal maximum temperature is 41.1^{o}c in March and 18^{o}c in January. The mean monthly minimum and maximum temperatures in the basins are 37.3°C and 19.7°C, respectively, and the hottest months are February, March and April. Mean relative dampness swing with moderate, reaching its peak in the wet season. The mean relative humidity fluctuates from 50 to 60% and has far reaching impact on evaporation and transpiration from large water bodies and adjacent vegetation. The monthly humidity varies from 36% to 46% during the four months of December to March and from 82% to 88% during the five months of June to October around the Kaduna plains.

The project area covers part of Kachia and Kagorko Local Government Areas of Kaduna State. The affected towns and villages in Kachia Local Government Area are found principally within the upper Gurara dam reservoir area, while the pipeline passes through Kagarko local Government Area to Bwari Area council.

MATERIALS AND METHODS

Reconnaissance Surveys

The study commenced with several reconnaissance surveys of the study area in 44 communities that are in close proximity to the dam, order to familiarise with the area and to acquire first-hand information on the land cover.

Digital camera was used to capture images of the dam and the surrounding settlements, Hand held Global Positioning System (GPS) was used to take readings of the coordinates around the dam for geo-referencing. Observations of interest that were relevant to the study were documented in a hand book.

Processing and Analysing of Satellite Imageries

The Topographic map of the study area (Abuja, Sheet 43) of the year 1967 with scale of 1:250,000 was scanned and imported to the GIS environment as raster data. This was used to complement the satellite images. After making ground verifications, these boundaries were digitized into AutoCAD Map and polygonised.

The boundaries of the study area were delineated as sub map from the scene of the satellite image. The satellite images obtained for the study were processed and classified into 11 classes comprising built-up area, tarred roads, minor roads, footpath, forest, arable land, bare surface, fadama land, rivers, water body and rock outcrops. The classes were broad in order to account for as many land use/land cover classes as possible. This was complemented by information collected during the field work.

ArcGIS 10.0 was used to carry out vector and raster analysis based on the research objectives, however, map overlay operation and area analysis are some of the analyses undertaken. The extent of the various classes for the pre-dam and post-dam era was quantified using the available statistical attribute Table function in ArcGIS 10.0 environment. The extent of the land cover for the 13 year period was ascertained using percentages. The results were presented in form of maps. The steps adapted in processing and analysing the satellite imageries is illustrated in Figure 2.

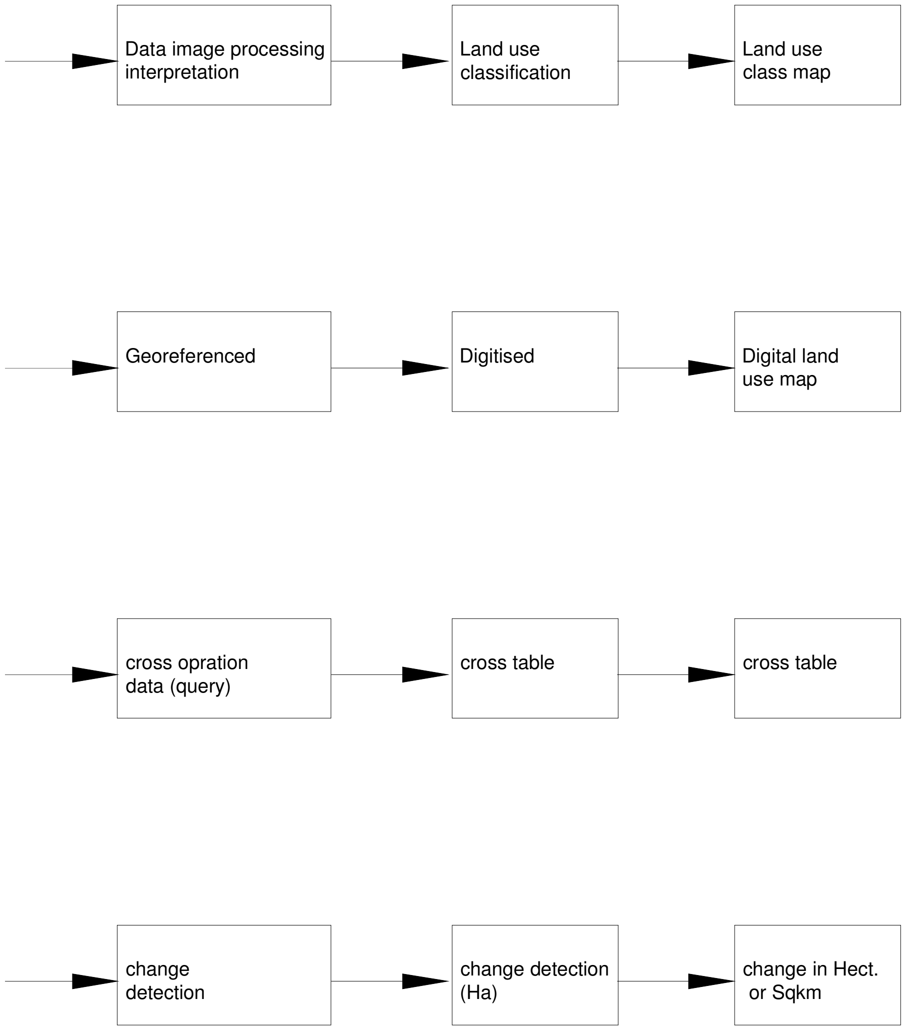

Figure 2: Procedure adopted for image analysis/Research flowchart

Two sets of quick bird high resolution and LANDSAT TM satellite images were obtained for the study for pre – dam construction (2000) and post dam construction (2013). This is necessary for the determination of the land use changes that have occurred over the years.

Secondary Data

The secondary source of data for this research includes publications from Institutions and Governmental Organizations relevant to the study such as publications from the Federal Ministry of Water Resources, the website of Gurara Multi-purpose Project, Federal ministry of Water Resources, Local Government Area of Kagarko and Kachia, and Federal Surveys Kaduna were consulted. Secondary data was also collected from the authorities of Salini Nigeria Limited and SCC Nigeria Limited (The main Contractors to the project). A review of existing literature was conducted to enhance the study as a whole. These include published materials such as journals, textbooks, conference papers, unpublished thesis, and other relevant articles from internet source.

RESULTS

Classified Land use/Land cover Map for 2000 and 2013

Classified land use /land cover maps presented in Figures 3 and 4 show the land cover conditions for 2000 and 2013. Table 1 shows the spatial extent of each class of land cover expressed in percentage.

Magnitude of Change in Land cover between 2000 and 2013

Changes in the Land cover condition between 2000 and 2013 are identified. Table 2 shows the changes in terms of aerial losses and gains expressed in percentages. Photographs are produced and presented in plates I to VI showing the situation of the land cover in 2013. Figure 5 shows the change map during the study period.

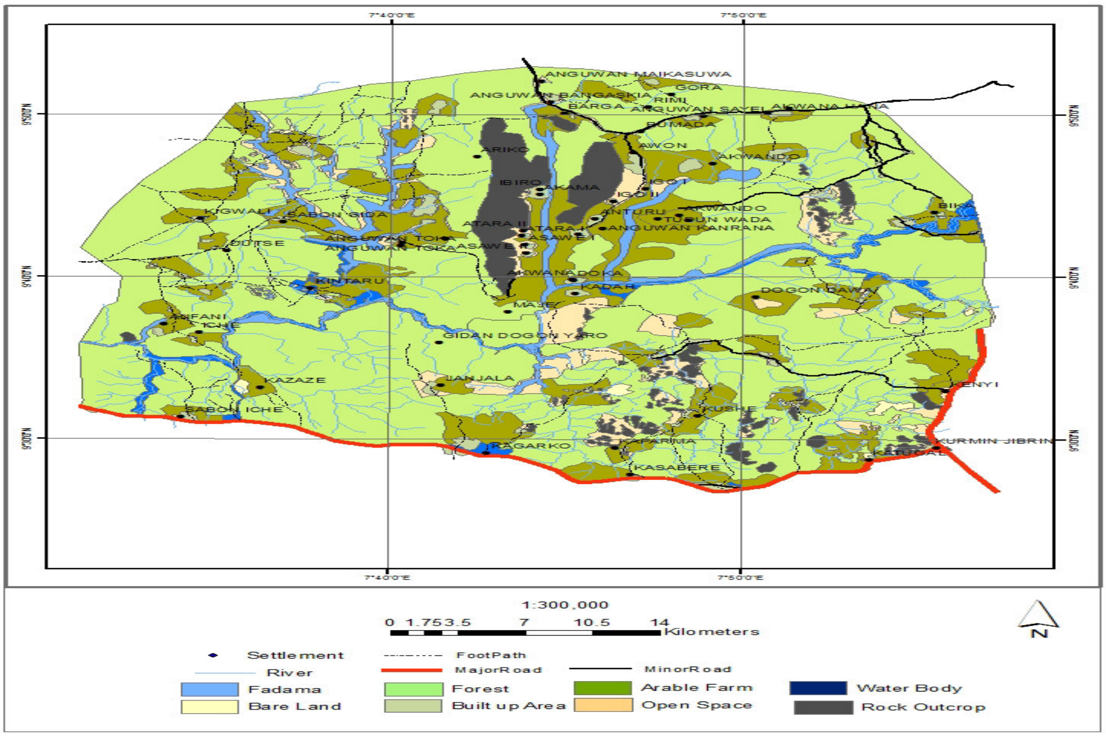

Figure 3: The Land cover pattern of the pre-dam period
Source: obtained from Landsat MSS, 200

These changes are numerically presented in Table 1 showing spatial extent of the land covers for the two periods.

Table 1: Spatial extent of coverage of Land cover in 2000 and 2013

Landcover/land cover categories	2000 Area (Ha.)	2000 Area (%)	2013 Area (Ha.)	2013 Area (%)
Arable land	46548.18	25.09	43449.99	23.42
Forest	106324.29	57.31	97734.49	52.68
Bare land	4675.23	2.52	6326.39	3.41
Fadama land	5769.82	3.11	3654.84	1.97
Water bodies	7420.99	4.00	12745.55	7.73
Rock outcrop	4953.51	2.67	4415.49	2.38
Tarred road	1391.43	0.75	2077.88	1.12
Minor road	2875.63	1.55	3970.23	2.14
Footpath	1057.49	0.57	1743.93	0.94
Modern irrigation	0.00	0.00	3302.34	1.78
Built-up area	4508.25	2.43	6103.77	3.29
Total	**185524.86**	**100**	**185524.86**	**100**

Source: Landsat satellite imagery, 2000 and 2013

The table shows that between 2000 and 2013, the built up area increased from 2.43% (4508.25 hectares) to 3.29% (6903.77 hectares) of the total area. Other land covers also showed appreciable changes within the period. These include: arable land which decreased from 25.09% (46548.18 hectares) to 23.42% (43449.99 hectares); forest landcover also decreased from 57.31% (106324.29 hectares) to 52.68% (97734.49 hectares). Bare land landcover also changed from 2.52% (4675.23hectares) to 3.41% (6326.39hectares). In the same vein, Table 3 shows an increase in water bodies from 4% (7420.99 hectares) to 7.73% (293 hectares). Rock outcrop decreased from 2.67% (6953.51hectares) to 2.38% (4415.49 hectares); circulation (comprising of tarred/untarred roads, and footpaths) increased from 2.87% (5324.55 hectares) to 4.2% (7792.04 hectares). Modern irrigation also changed from 0% (38.hectares) to 1.78% (3302.77 hectares).

Table 2: Magnitude of changes in land cover between 2000 and 2013

Land use/ Land cover class	2000 Area (Ha.)	2000 (%)	2013 Area (Ha.)	2013 (%)	Magnitude of Change (2000-2013) Area Change (Ha.)	%	Average rate of change Ha/yr	Remarks
Arable land	46548.18	25.09	43449.99	23.42	-3098.19	-7	-23.71	Loss
Forest	106324.29	57.31	97734.49	52.68	-8589.80	-9	-660.75	Loss
Bare land	4675.23	2.52	6326.39	3.41	1651.16	26	127.01	Gain
Fadama land	5769.82	3.11	3654.84	1.97	-2114.98	58	-162.69	Loss
Water bodies	7420.99	4.00	12745.55	7.73	5324.56	42	409.58	Gain
Rock outcrop	4953.51	2.67	4415.49	2.38	-538.02	-12	-41.39	Loss
Tarred road	1391.43	0.75	2077.88	1.12	686.45	33	52.80	Gain
Minor road	2875.63	1.55	3970.23	2.14	1094.6	28	84.2	Gain
Footpath	1057.49	0.57	1743.93	0.94	686.44	39	52.8	Gain
Modern Irrigation	0.00	0.00	3302.34	1.78	3302.34	100	254.03	Gain
Built-up area	4508.25	2.43	6103.77	3.29	1595.52	26	122.73	Gain
Total	**185524.86**	**100**	**185524.86**	**100**				

Source: Landsat satellite imagery, 2000 and 2013

The First and the second columns show that between 2000 and 2013, the Arable land reduces from 25.09% (46548.18 hectares) to 23.42% (43449.99 hectares). Other land covers also expressed appreciable changes within the period. These include: water bodies which increased from 4% (7420.99 hectares) to 7.73% (12754.55 hectares); rock outcrop decreasing from 2.67% (4415.49 hectares) to 2.38% (415.49 hectares). Bare surface changed from 2.52% (4675.23hectares) to 3.1% (1651.16hectares).

The information in Figure 5 shows land cover change from pre –dam period (2000) and post-dam period (2013). The green colour indicates those classes that have considerable increase, while the red colour depicts the classes that experienced reduction as a result of dam construction.

Plates i to iv depict different conditions of the land cover due to the Gurara Dam activities.

Plate i: Water run-off due to dam impoundment at the upstream, August, 2013

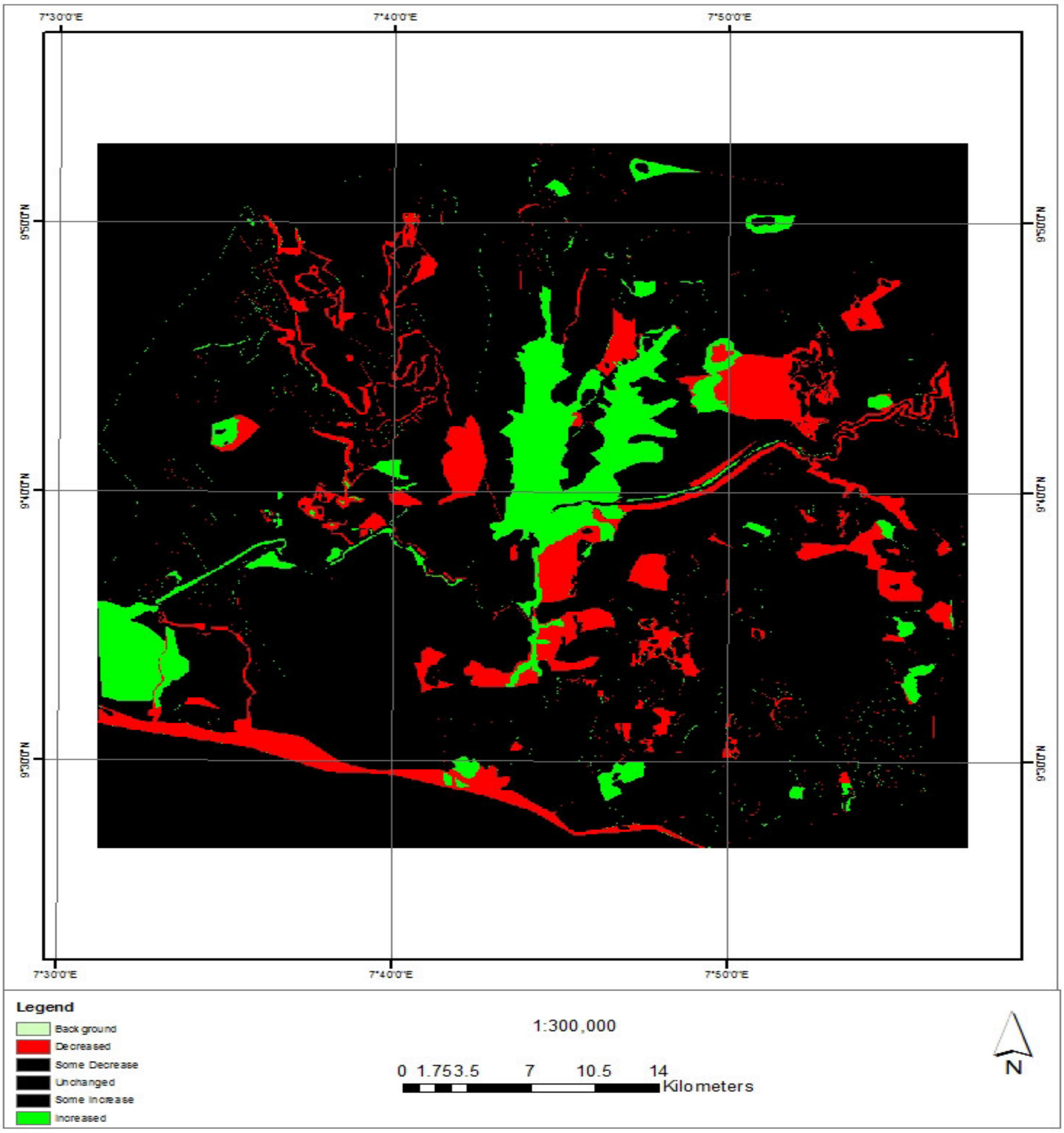

Figure 5: Land cover change from 2000 -2013, Landsat MSS, 2000 and 2013

Plate ii: Bare surfaces resulting from construction activities in Chinka, May, 2013

Plate iii: Canalisation pattern of River Gurara at Anfani, June, 2013

Plate iv: Irrigation farm at the flood plain near Anfani, March, 2013


Plate v: Impact on rock outcrop at Maje Plate vi: Condition of marshy land at Doka, March, 2013

CONCLUSION

This study has revealed a tremendous transformation of the land covers in the surrounding communities of Gurara dam between 2000 and 2013. The physical changes have happened in an unplanned manner. The major land cover types in the study area include forest, arable land, built up area, water bodies, Rock outcrop, Roads and bare land. These have witnessed significant changes in the various land covers in the study area over the period of 13years studied.

RECOMMENDATIONS

To ensure periodic monitoring and evaluation of the land cover conditions in the study area, technologies like Geographical Information System (GIS) and remote sensing can be used to address arising environmental problems especially as it relates Environmental Impact Assessment.

High resolution imagery such as IKONOS and Quick Bird are required for a clearer view of the land use/land cover condition. This is with the view to provide a robust platform for understanding the nature of environmental impact of gigantic projects such as Gurara Dam.

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