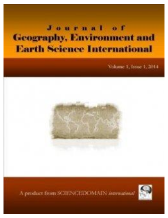

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Assessment of Land Use Changes and Impacts of Dam Construction on the Mbaa River, Ikeduru, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MCI and CPI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KOEU, GTA and SOA managed the analyses of the study. Authors JDN and FIO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This research was conducted in order to ascertain the impact of the earth dam on the physical environment of Mbaa River using Geographic Information System (GIS) and Remote Sensing (RS) techniques. The Specific objective was to use multi-temporal images to assess land use and land cover changes as well as determine the extent of land degradation around the watershed as a result of the dam. Landsat 7 ETM+ of 2000 of path 188 and row 56, and the Nigeria Sat-X image of 2nd December 2011 were classified to identify the changes in the physical features of the

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watershed. The study revealed variations in the land cover of the study area with land degradation and erosion in both the upstream and downstream area and submergence of farm lands in the upstream. The result from the watershed delineation revealed that the shorelines of the upstream increased to an approximate length of 109 m while the downstream shrank to 18 m. There was about 8.05% reduction between the years 2000-2011 in the total area covered by the water body in the area. Urgent action need to be taken to reclaim degraded land especially downstream of the dam through re-afforestation.

Keywords: Geographic information system; land degradation; land use/cover change; remote sensing, watershed.

1. INTRODUCTION

It is known that human activities have a profound effect on the natural environment and are becoming the main agents of environmental degradation. The expansion of dam construction schemes in most countries of the world including Nigeria has gone a long way in assisting the achievement of water sufficiency and poverty reduction [1]. Irrigation agriculture makes production more stable than the rain fed agriculture, it also creates job opportunities for several thousands of people directly or indirectly [2]. Dams are often used for flood control, however, dam construction as well as certain irrigation practices sometimes have adverse impacts on environmental conditions.

A dam is simply a barrier built across a river or stream to confine and utilize the flow of water for human purposes such as irrigation and generation of hydroelectricity. Dams have long been acknowledged for providing electricity, for flood protection, and for making water available for agriculture and human needs. Within recent decades, however, the environmental impacts of dams have been debated. While dams do perform important functions, their effects can be damaging to the environment. The damming of a river usually comes with dramatic consequences on the nature of the environment both upstream and downstream of the dam. This in the words of [3] has had both positive and negative consequences in the area where such dam projects are located. The magnitude of these effects is usually directly related to the size of the dam. Prior to dam construction, most natural rivers have a flow rate that varies widely throughout the year in response to varying climatic conditions. Once constructed the flow rate of the river below a dam is restricted. The dam itself and the need to control water releases for various purposes of the particular dam result in flow rate that occur at times related to need rather than the dictates of nature. In cases where the entire flow has been diverted for other uses, there may no longer be any flow in the original channel below the dam. Dams generally serve the primary purpose of retaining water while other structures such as flood gates or levees (also known as dikes) are used to manage or prevent water flow into specific land regions.

The term land use change refers generally to modification of terrain, usually driven by both anthropogenic and natural factors with the former exacerbating the process through activities such as agriculture, urbanization, settlement expansion, economic development, dam construction, etc. Land use of an area therefore is a product of both natural and socioeconomic factors as well as their utilization in time and space by man.

Studies in the past showed that related environmental effects of dams comprise degradation of the upstream part of the watershed, sedimentation, and changes in water quantity and quality [4,5]. Other environmental effects of dams are the loss of forests, wildlife habitat, loss of vegetation cover, loss of soil quality and the emission of greenhouse gases (from decomposing vegetation). Irrigation dams where improperly constructed can result in the spread of diseases such as malaria and bilharzia through the increase of their vectors as well as create physical problems such as declining soil fertility and soil quality due to water logging, salinization, and hardpan formation [6]. Though dams have advantages; dam construction often brings about adverse social and environmental impacts on the communities as well as people living in such watersheds [4].

The combined use of Remote Sensing with GIS has proven useful for the timely assessment of land use dynamics [7,8]. Many studies have investigated land use dynamics associated with dam construction and reservoir impoundment using Remote and GIS techniques [9,10].

In the year 2003, the Federal Government of Nigeria under the auspices of the Federal Ministry of Agriculture and Water Resources embarked on the construction of an earth dam on Mbaa River, precisely at Inyishi in Ikeduru Local Government Area, as a way of boosting sustainable food production through irrigation. This project was completed about the year 2010. The broad aim of this study therefore is, to assess the impact of dam on the physical environment of Mbaa River by determining and mapping the extent of land degradation and land use change resulting from the dam construction over 2 time steps from 2000 to 2011, representing the epochs before and after the dam construction.

2. DESCRIPTION OF THE STUDY AREA

Mbaa River is the major river that runs from Isiala Mbano through Ikeduru LGA although the individual communities refer to it with specific names. Ikeduru Local Government Area is one of the 27 local government areas of Imo State, Nigeria (see Fig. 1). It is located on longitudes 7°04'E and 7°14'E and latitudes $5^0$29N and 5°39'N.

The study area is located in the humid tropics with over 2,000 mm of rainfall per annum and a mean annual temperature of about 27°c. The rainy season commences in March/April and ends in October/November. The vegetation is typically rainforest, though anthropogenic activities has degraded this useful resource thereby leaving behind mostly secondary regrowths. Inyishi, Ikeduru belongs to the tertiary period of the geological era with coastal plain sands which are centicular, unconsolidated and sandy. This Area is underlain by the Benin Formation of coastal plain sands.

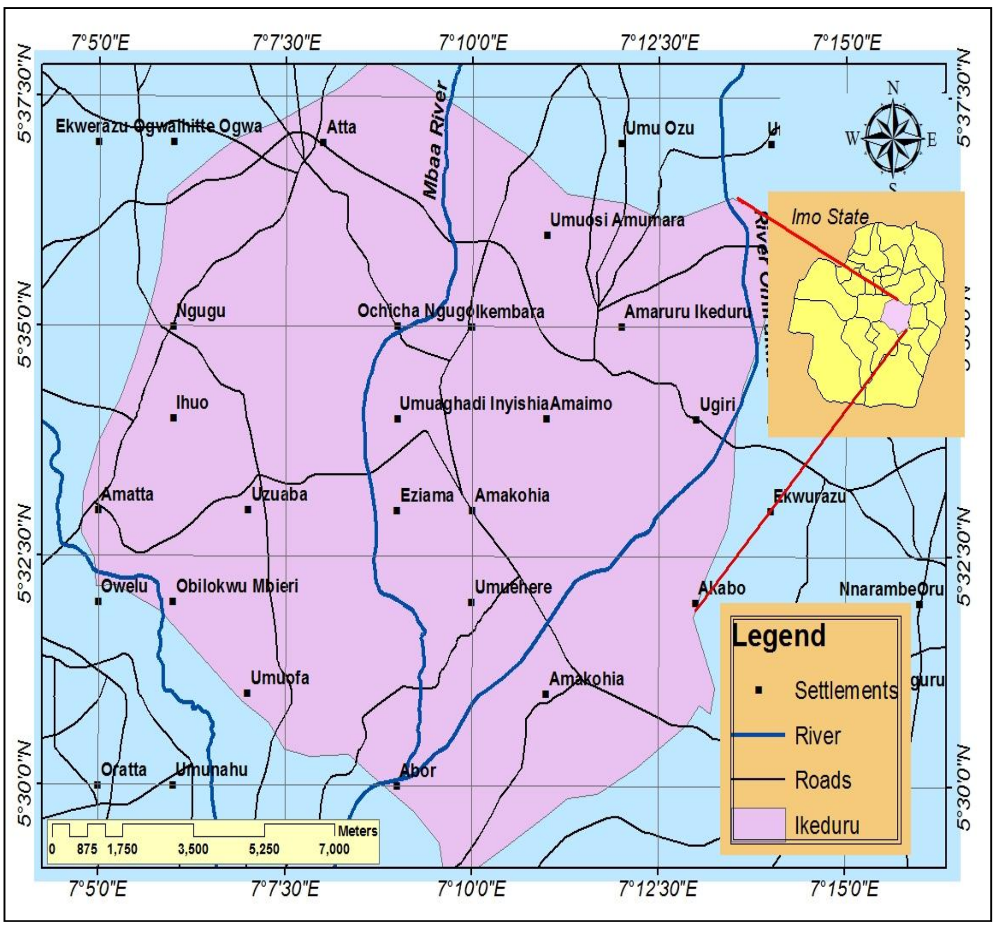

Fig. 1. Location Map of the Study Area-Mbaa River

This high forest largely coincides with the coastal belt of sedimentary rocks where the sandy loam and sandy–clay loam aid good drainage. The forests as a result have tall-buttressed trees. The area has a high fertile soil suitable for agricultural practices. In some areas around the study area, the soil consists of lateritic material under a superficial layer of fine grained sand. The soil would naturally be fertile but excessive leaching has removed much of the required plant food.

Ikeduru is densely populated with about 199,316 people according to the 2006 National Population Census figures and has an annual growth rate of about 3 percent. The economic activities here include farming, trading, few banking services and civil services at Iho which is the L.G.A. headquarters.

3. MATERIALS AND METHODS

Data Used for this research include primary data consisting of GPS coordinates and elevation data of the study area which were collected using GPS (Extrex Garmin Version 16.0). There was also secondary data which include Landsat 7 ETM+ of 2000, Nigeria Sat-X image of 2011 and base map of the study area which was extracted from Arc GIS Explorer and further processed during analysis.

3.1 Method of Data Collection

Primary data was collected via field work where a hand held GPS was used to obtain coordinates of some locations in the study area.

Landsat 7 ETM+ of 17th December 2000 with resolution of 30m was obtained from the online archive of Global Land Cover Facility (GLCF) and U.S Geological Survey (USGS). Band 432 (false color composition) of this imagery were combined and subjected to re-sampling analysis of 22m in order to match the resolution of Nigeria Sat-X. While Nigeria Sat-X data of 2nd December 2011 with band combination 123 and a 22 m resolution, was acquired from Geo-Apps Plus, a commercial arm of National Space Research and Development Agency.

3.2 Methods of Data Analysis

Geographic Information Systems (GIS) and Remote Sensing techniques were used in modeling land use and land cover change with respect to spatial parameters such as built-up area, bare soil, vegetation, water body and other human induced parameters and socio-economic variability. In this respect the Landsat image of 2000 was subjected to re-sampling analysis and further enhanced to 22 m resolution, the study area was sub-mapped using the same distance and Conner values. Areas mapped out for analysis were subjected to a supervised classification analysis and at this stage the domain of those spatial parameters mentioned above were adopted and further subjected to maximum likelihood classifier of ILWIS software.

a. Arc GIS 10.0: Arc Map was used for vectorization and digitizing of the images to generate the study area map. Arc Catalogue was used in creating a personal geodatabase and shape file used in performing the overlay.
b. Erdas Imagine 9.1 was used for spatial, spectral and radiometric enhancement. Spatial enhancement was carried out using a resolution merge model.
c. Other ancillary software include Microsoft office word and excel 2013.

4. RESULTS PRESENTATION AND DISCUSSION

Results of spatial analysis are presented in maps, tables and histogram for discussion. They include the changes in LULC of each classified map adopted from the basic classification scheme by [11]. Fig. 2 and Fig. 3 are land use maps of the area for two time steps of 2000 and 2011 showing four classes of land use type namely; water body, settlements, bare soil and vegetation. Tables 1 and 2 also show the raster attributes of the land use classification for the stated time. Table 4 portrays change detection witnessed in the area over the said time, while Fig. 4 depicts comparative change in land use classes for the two time steps. Equally Fig. 5 indicates delineation of watershed within the area of interest.

4.1 Dam Construction and Land Cover Change

Fig. 4 and Table 4 shows that water bodies, bare soil and vegetation cover had negative change trends between 2000 and 2011 with -8.06%, -1.75% and -12.81% respectively indicating a decrease or loss in their area coverage.Whereas settlements had a positive trend with 22.62% indicating an increase or gain in its area coverage. The loss of farmland and vegetation as well as increase in built-up area witnessed in this research agrees with the findings of [12] who reported a loss of 58%, 9% and 7% in fadama, arable land and forestry respectively, while there was an increase of 26% in built-up area in communities in Kaduna, Nigeria, following the construction of the Gurara Dam. Vegetation loss which was also reported is in line with the submission of [13], who reported a decline of 9.27% in vegetation cover of riparian forest in inundated zones below 175 metres elevation of the Three Gorges Dam in China. In 2000, the area was covered mostly by vegetation while in 2011, built up became a prominent land cover in the area.This implies that, large proportion of vegetation and water bodies including areas of bare soil were lost within the 11 years period covered by this study. It was also observed that the total built up areas increased with high percentage value. This increase could be atttributable to percieved gains that may accrue from the utilization of the dam including increased agricultural and economic activities that may boost population and increase demand for housing.

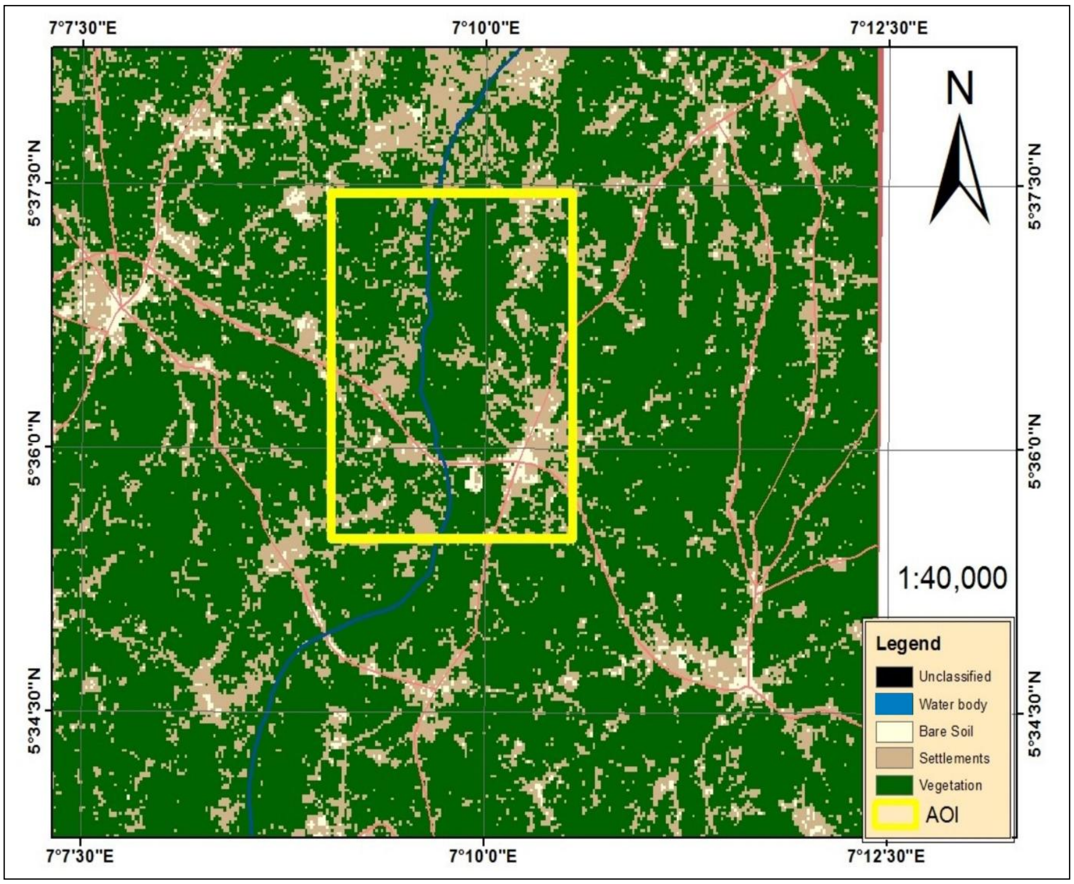

Fig. 2. Land Use Map 2000

Table 1. Spatial pattern and areal extent of land cover/land use in 2000

The raster attributes for 2000 results			
Class name	**Count**	**Area (Ha)**	**Area (%)**
Unclassified	2246	0	0
Water body	11549	989.51	10.0
Bare Soil	2232	190.38	2.0
Settlements	22703	2243.27	23.0
Vegetation	69367	6430.03	65.0
Total	**108097**	**9853.19**	**100**

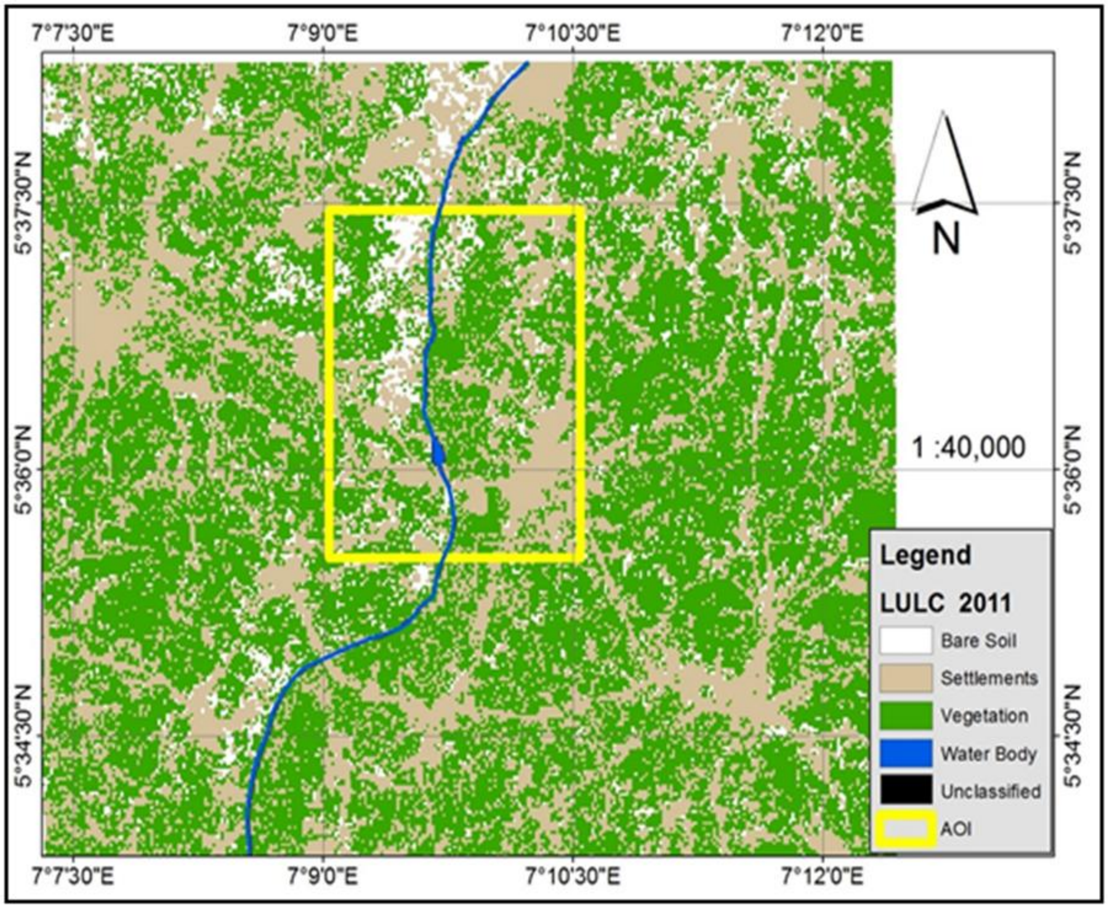

Fig. 3. Land Use Map for 2011

Table 2. Spatial pattern and areal extent of land cover/land use in 2000

The raster attributes for 2011 results			
Class name	**Count**	**Area (Ha)**	**Area (%)**
Unclassified	0	0	0
Water Body	4045	195.778	1.986934
Bare soil	364	17.6176	0.178799
Settlements	92392	4471.773	45.38363
Vegetation	106779	5168.104	52.45063
Total	**203580**	**9853.272**	**100**

Table 3. Summary of overall classification accuracy and kappa coefficient

Year	Overall classification accuracy	Overall kappa coefficient
2000	85.6%	0.7991
2011	88.8%	.8290

Changes to channel morphology, physical degradation/aggradations of land cover and high loss of riparian vegetation were revealed to be evident from the GIS delineation of Mbaa river watershed shown in Fig. 5 and the width of the river upstream was observed to have increased to approximately 109 meters while its downstream width shrank down to 18meters.

Table 4. Land use percentage distribution for 2011

Class name	Area 2000 (Ha)	Area 2000 (%)	Area 2011 (Ha)	Area 2011 (%)	Change detection
Unclassified	0	0	0	0	0
Water body	989.51	10.04253	195.778	1.986934	-8.0556
Bare Soil	190.38	1.932166	17.6176	0.178799	-1.75337
Settlements	2243.27	22.76694	4471.773	45.38363	22.61669
Vegetation	6430.03	65.25836	5168.104	52.45063	-12.8077
Total	**9853.19**	**100**	**9853.272**	**100**	**0**

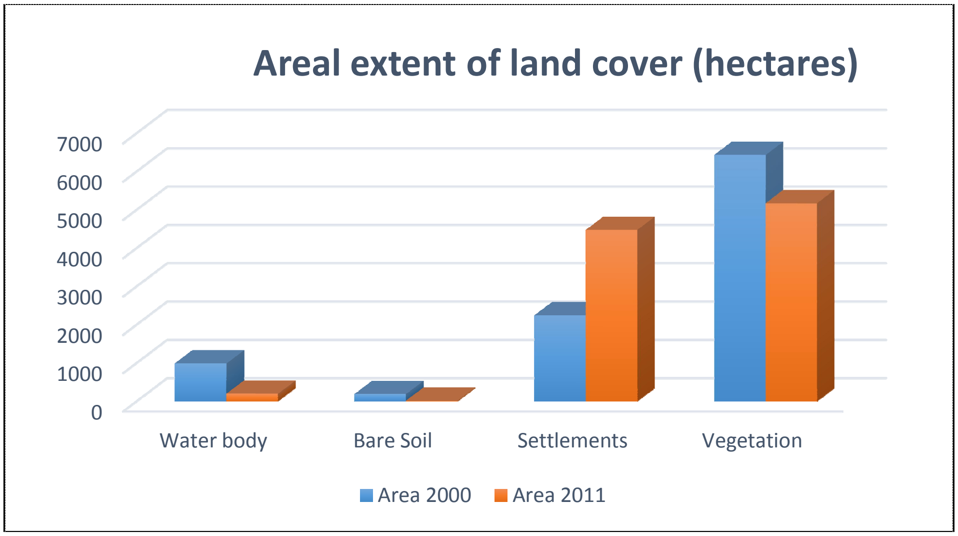

Fig. 4. Areal extent of land cover in hectares.

4.2 The Physical Impacts on Mbaa River

A number of physical impacts on the watershed which resulted to observable environmental degradation that has drastically reduced the aesthetics of the river include:

1) **Desiccation of Soil:** This may have resulted from the use of heavy duty trucks and other equipment during construction activities leading to compaction of soil and formation of hardpan as shown in Plate 1. It is in line with the submission of [6] that improper dam construction among other problems leads to decline in soil quality and fertility arising from water logging, salinization and hardpan formation.
2) **Gully erosion:** Removal of vegetation cover as a result of dam construction was observed to result in the systematic removal of top layers of the soil and this has resulted in development of gully erosion within the watershed as shown in Plate 2 and agrees with the argument of [4] that dam construction leads to problems such as vegetation loss and soil erosion.
3) **Landslide:** There has been expansion of the upstream reservoir which has led to collapse of adjoining riverbank sand into the river, thus leading to further loss of agricultural land as evident in Plate 3.
4) **Submergence of Agricultural Land:** There has been steady overflow of the reservoir upstream of the dam which has resulted in submergence of nearby farms leading to loss of agricultural land and decomposition of flooded vegetation as shown in Plate 4. This agrees with the submission of [14] vegetation in flooded areas. A situation that will cause soil deterioration and increase greenhouse gases emission while reducing stream flow and channel size downstream.

This situation could also have been largely responsible for the loss in area coverage of waterbody as area gained upstream may not be commensurate with area lost downstream and agrees with the submission of [15] that one of the consequences of dam construction is the narrowing of stream channel downstream of the dam and subsequent invasion of the channel by vegetation.

Plate 1. Section of soil where a hardpan has been formed

Plate 2. Gully erosion site at Mbaa River

Plate 3. Section of landslide at the river bank

Plate 4. Section of submerged agricultural land

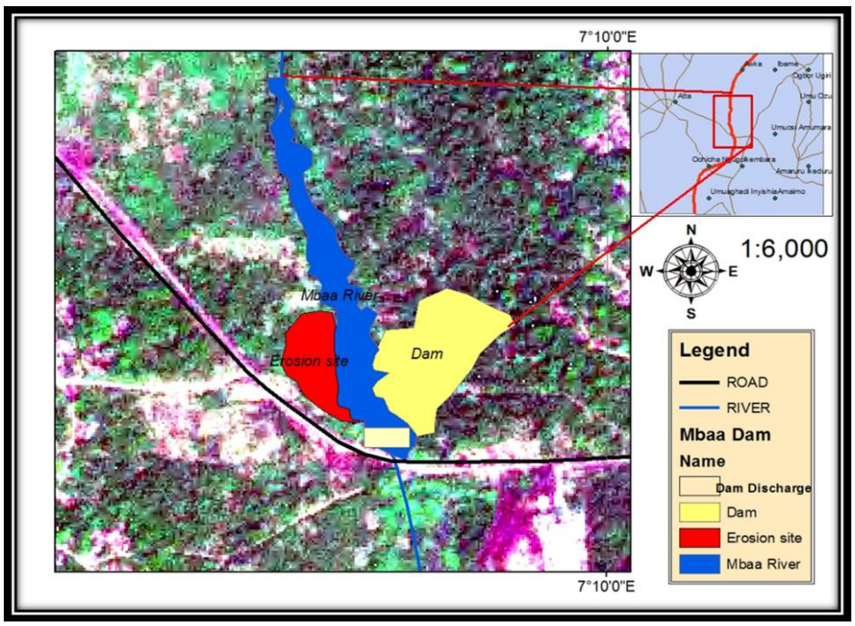

Fig. 5. Watershed delineation
Source: Author's fieldwork 2016

5. CONCLUSION

It is evident from this study that Mbaa River which is a very vital surface water resource for adjoining communities has been modified by the construction of a dam. This modification has been accompanied by large scale consequences including environmental modification, inundation of farmlands upstream, landslide, soil erosion, etc. There has been accelerated erosion as a result of increased built-up surfaces that has created more impervious areas and increased surface run-off. This phenomenon no doubt will increase reservoir sedimentation which has been identified as an endemic problem of dams all over the tropics [16,17]. These changes have had far reaching consequences on the socio-economic life of the people thereby portending grave danger for food security as well as sustainable development. It becomes imperative therefore that relevant stakeholders in the constructed dam put up mechanisms and measures in place to mitigate the negative impacts of this dam. Such efforts should include land reclamation at the downstream sector, as well as proper utilization of impounded water for irrigation to boost dry season farming thereby compensating for lost farmland.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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