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Changes in River Channel form and Geometry below Dam Reservoir in Karadua Catchment, Katsina State, Nigeria

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ABSTRACT

This paper studied the effects of dam on the downstream changes in river channel form and geometry below dam reservoir in karadua catchment, katsina state, Nigeria.

The objective of the study includes assessing the changes in river form and geomorphic characteristics of the downstream River Karadua as a result of dam and reservoir operations following the construction of Zobe Dam. The method used for computing cross-sectional area was simply by obtaining Bankfull width and depth of the stream by dividing the width into 10 equal intervals based on the technique outlined by Gregory and Wailings (1973).Using Topographical maps alongside the remotely sensed images, Global Land Cover Facility (GLCF) MSS+1978/79 and spot-4 Imagery 2008 were used to study changes on stream length, sinuosity and channel shifting which was undertaken mainly by comparing the old and new imageries of the study area. The result shows a slight variation in cross-sectional area because the greater value of the mean width at above dam reach was counterbalance by the greater value of mean depth at below dam reach. The significant variation was only obtained between mean width and average mean depth of the channel reaches. Channel morphology from the cross-sectional information indicates two main morphological changes. The first is the narrowing of the channel below the Dam, abandoning the former storm channel and creating an incised channel. The second is vertical cutting and deepening of the channel. These all together bring about lateral displacement of the active channel and flood plains. Alteration of the river morphology will therefore, hinder the much dependence of the populace on the river for sustenance in the study area.

Keywords: *River, Geometry, Reservoir, Catchment, Karadua Katsina*

INTRODUCTION

Rivers are well organized agents of landscape transformation and landforms creation. They are therefore significant physical features to reckon with in any physical environment. They erode, transport and deposit; activities which are of great concern to man. Rivers use transported materials to create spectacular features which are either useful or harmful to Man in the catchment. From centre or side, rivers are very essential components of man's physical environment because it is one of his daily needs as all his activities are closely related to water. A drainage basin is an area drained by a river and its tributaries. It is also refers to an area of land that drains all the streams and rainfall to a common outlet or mouth. The mouth is the end point of drainage system which may end in a lake, but more normally in the sea. Drainage basin is sometimes used interchangeably with watershed or catchment.

Smith and Stop, (1978) defined catchment as an area drained by a single river. Natural drainage area which may coincide with a river basin, in which divides direct water derived from rainfall and percolation into a river, while Gregory and Walling, (1973) conceived the drainage basin as a unit area over which water collects, concentrates and promotes the movement of water and sediment on the landscape. The catchment or drainage basin is therefore a basic land unit in terms of area that is convenient enough to organize the study of landscape development based on fluvial processes.

However, in a recent review of over 50 years worth of literature, Petts and Gurnell (2005) identified three main factors as the driving forces behind ecological changes in flow and sediment transfer that lead in turn to changes in the form of the channel downstream: (1) channel dynamics, (2) the role of Riparian vegetation, and (3) channel change. They note that such changes can be rapid in semi-arid regions but may also take longer to manifest.

Despite the value of dams in river regulation for water resources management, they create artificial flow regimes downstream and interrupt the transfer of sediments from headwater source areas. These changes of the primary fluvial processes below dams cause adjustments of channel form, (Hathaway, 1948).

These adjustments are assumed to be change in the river channel equilibrium. This equilibrium state may change as a result of human activities; such as replacement of natural vegetation; urban development; reservoir construction etc. The construction of Dam and reservoir behind it, for example, tends to alter the magnitude of flood event for a given rainfall event. The construction and operation of a dam and the associated reservoir for irrigation facilities represent a major and common developmental project in Nigeria, particularly the northern part (Jeje, 2007).

The study area is surrounded by small settlements that entirely depend on the river for their socio-economic sustainability being it subsistence economy mostly Fadama cultivation and fishing both at upper and downstream. It has been the practice before and after the Zobe Dam construction. Even after the construction of the dam, the local settlers continue to depend on the river and practice irrigation side by side with the government's large scale irrigation project below the Zobe dam reservoir which has now stopped as a result of poor management and system policy. This is because certain activities were observed which has to do with physical transformations of the river valley and responsive actions of the local inhabitants towards utilization of the river and its floodplain. More spectacular is the lengthy duration of flow discharge below the dam after the last rainfall of the season was received and narrowing of the channel and abandonment of vast flood plains below the dam. On the other hand, the flood plains irrigation has disappeared along the stretch of the Karadua River below the dam. Another aspect is that unlike most of the rivers within the Karadua basin, sand mining is no longer taking place while it also support the economy.

Hence, understanding the pattern of changes in the river process and response are significant to the growing dependence on the river because the information gained will aid effective planning and efficient management of the use of the basin under study.

The conceptual framework on Dams and Reservoirs and the changes they imposed on the environment at large, to the downstream river reach in particular have received so many attentions by so many researchers. Yet not very much was compiled in the region of this study and virtually non in this study area particularly. However, individual areas need to be given individual attention so as to explore their peculiarities which will obviously fill in certain gab in the literature.

Objectives of the Study

The objective of the study is to assess the changes in river form and geomorphic characteristics of downstream River Karadua as a result of dam and reservoir operations following the construction of Zobe Dam.

The Study Area

The study Catchment is the Karadua basin located in Katsina State in northern part of Nigeria. It lies between 12o 00' and 12o 50' north of the Equator, and between 07o00' and 08o00' east of Greenwich (figure 1). The area is found within the southern margin of the Mesozoic and tertiary lullameden basin of the South Sahara. The crystalline base portion of this area, predominantly consist of granite-magmatite and gneiss rock, (Kogbe, 1976).

Figure1. *Map of the Study area showing the Karadua River*

The unconsolidated quaternary deposits of the region cover the basement rocks and the cretaceous sandstones to a large extent. The area is generally known as the savannah plain of Nigeria with quite insignificant difference in elevation, forming as high as 600 metres above

Mean Sea Level around the central area sloping North-West direction toward Sokoto, with an average height of 300 metres above sea level, (Buckle, 1978). The area is in the Sudan savannah zone experiencing a continental wet and dry type of climate with a maximum monthly temperature of 24 - 38 and a mean annual rainfall of 562mm (NIMet, 2011). The vegetation is the savannah type dominated by grasses and scattered threes (Maxlock Group, 1977). The soil type of the region is ferruginous tropical brown and reddish – brown soils of the basement complex rock.

The Karadua catchment is a dendritic type, draining an area approximately 1838 km2. As a 6-oreder stream, the Karadua River is a major tributary of River Bunsuru within the main Sokoto River Basin. The stretch of the Karadua is 38km Downstream and 26km upstream of Zobe Dam. The Watershed has a drainage density of 1.06 and a slope angle of 1.5o. The average monthly discharge in the rainy months is 356m3/sec above the dam and 253m3/sec below the dam. Suspended sediment for the river is given as 4.16 grams/litre and 0.83 grams/litre for the above and below the dam reservoir respectively (Ibrahim, 2013).

Methodology

The objective of this study is designed to be achieved by examining the differences in morphological characteristics of two river reaches resulted from reservoir operation. The methodology therefore, involved identification of the river reaches above and below the dam reservoir and selection of suitable locations for taking cross-sectional information. The second part involves the acquisition of information on the river linear metamorphosis before and after the construction of the dam and reservoir.

Sites for Measuring Cross-Sectional Area

For taking cross-sectional area, the main trunk of the Karadua river valley was considered for obtaining the geometrical variables. These gulley positions were selected along the river reach at a suitable intervals base on the target goals and easy access. Generally, two (2) gulley positions were considered at each of the two study reaches. These sites were selected at a certain distances away from the reservoir where natural shape could be observed without artificial modifications typical of the locations near the dam.

Determination of Cross-Sectional Area

The collection of the geometric data of the two designated river reaches was conducted in the dry season of 2017 at the time fluvial condition was never a hindrance. For convenience during the exercise a straight clean sections of river, where the Bank full level of the river may be easily identified, were located.

At each and every locations selected, the width and depth of the valley was measured. This was done by fixing a measuring tape at one banks of the river, using a survey arrow, and stretched across the stream to the other end. The Bank full width of the stream was measured by dividing the width into 10 equal intervals. At each interval a Staff was used to measure the depth of the channel and the results were recorded. Using the readings obtained from the measurements, the cross-sectional area was computed based on the technique outlined by Gregory and Wailings (1973).

Remote Sensing

The remote sensing materials used were mainly satellite imageries. The various GIS soft-wares used for analysing the images are Arc GIS and Global Mapper 11. The specific satellite images used are Global Land Cover Facility, ETM+ 2008, Global Land Cover Facility (GLCF) MSS+ 1978/79 and spot-4 Imagery 2008. Google Earth was also used for identification of certain features as well as representation of some areas in this work. The GLCF - MSS+1978/79 and GLCF – ETM+2008 were used to study changes on stream length, sinuosity and channel shifting which was undertaken mainly by comparing the old and new imageries of the study area which shows the resultant effects of the Zobe dam on the study river and the entire basin.

Topographical maps were also used alongside the remotely sensed images. These are the North-western Nigerian on the scales 1: 50,000 and 1:100,000; large scaled contour maps of the area prepared by WAKUTI, (1973 and 1977), on the scale of 1:2,000 and 1: 4000.

The study on the impact of Zobe dam on stream length, sinuosity and channel shifting was undertaken mainly using pre-existing satellite image (Global Land Cover Facility, MSS), for the pre dam structure and spot imagery for the current post-dam structure.

RESULTS

Variation in River Channel Cross-sectional Area

To examine the degree at which the operation of the reservoir changes the geometry of the river under study, the cross-sectional variables were obtained at two different river reaches. These are the reach above and that of below the dammed reservoir. A summary of the measured variables was summarized in table 1 below. The table also shows other geomorphic variables that as well described and compare conveniently the two river reaches above and below the Dam.

Table1. *Above Dam (Unregulated reach) and Below Dam (Regulated reach) Karadua River Cross sectional Characteristics*

	Average Width (m)	Average Mean Dept (m)	Average Cross sectional Area (m^3)	Incised Channel	Braided Channel
Above Dam River Reach	243.3	1.38	325.7	No Incision	Well Braided Channel
Below Dam River Reach	100	3.65	368	Well pronounced Incision	No Braiding within this stretch
Variance	143.3	- 2.27	- 42.3	-	-
Percentage Variance	59%	62%	11.5%	-	-

Source: *Author's Field Work 2018*

The summary of data in the table also shows variations in the mean width of the unregulated channel reach and regulated channel reach. The difference obtained in their mean width is 143.3m. Mean depth was also significantly different between the two river reaches. The difference from the table is as high as –2.27 meters from above dam reach to below Dam River reach. The rate at which these variations occur yielded as high as 59 percent in the mean width and 62 percent in the average mean depth. It should be pointed out that the observation of the Karadua basin on the Global Land Cover Facility (GLCF) MSS+1978/79, shows that Bankfull width of the regulated channel increased gradually downstream along the 11.65km during the pre-Dam period. This is because new tributaries joined the main river and increase the drainage area downstream. However, this situation reversed after reservoir operation; Bankfull width consistently decreased downstream and at nearly 2.5 times the rate it was increasing during the pre-Dam period. Figure 3 below shows a clear picture of that morphology. Decreasing channel width likely leads to increase in channel depth, which is in line with the Harvey and Schumm (1987) findings that the channel bed near the dam was armoured one year after dam construction and operation. This also reflects the prediction that channel bed would continue to erode downstream and become increasingly armoured in following years (Williams and Wolman, 1984).

Figure2. *Zobe Dam, Above Dam and Below Dam Karadua River Mophology*

In the same table 1, other characteristics of the two river-reaches are also shown. The river-reach above the dam reservoir appeared very vast, yielding an average width of 243.3meters. This makes it a favourable condition for the flowing water to wind-up as it moves; forming spectacular pattern known as braiding. Figures 4 and 5 below show the braided channel at the above Zobe Dam river reach. The channel braided spectacularly at a stretch, winding through the wide sandy alluvium of the storm channel.

Figure3. *Above Dam Karadua Braided Channel*

Source: *Google Earth – http://www.google.com.eg/imgres*

Figure4. *A Braided Channel above the Dam reservoir*

Information on incise-channel is also presented in table 1. The incise channel is the feature observed within the river reach below the Dam, although the feature is not well pronounced to dominate the overall structure of the river reach. The feature developed mostly towards the end of the wet season during which the flow deceases to a certain extent. The outcome reveals that the river reach above the dam which is characterized by braided channel, possessed no incision. While the river reach below the dam, there is a well pronounced incision but has no braiding of channel. The result therefore, suggested that during pre-Dam period, the river reach below the dam also exhibits similar feature as the unregulated channel above the Dam, but at present has changed from braided channel to incised channel. This is depicted from the fact that the river reach above the dam (unregulated) maintained the braiding nature rather than incision.

Impact of Dam on Karadua River Stream Length and Sinuosity

The result of the satellite image analysis shows that during the pre-Dam period, stream length varies in a similar magnitude both at below and below the Zobe dam river channels. Up till now the above dam stream maintained the same level of variation, while below dam reach experienced a 47% reduction in stream length. Table 2 and figure 6 below shows clearly the outcome. The analysis of the rate of stream length changes indicates that along the main Karadua channel, stream length changes were not significantly different. But when the braided channels are added up to the main channel, the reverse is the case.

Table2. *Pre and Post-Dam Karadua Stream length and Sinuosity*

Time Reference	Main Channel (km)	Braided Channel (km)	Total (km)
Before Dam Construction	13.30	16.30	29.60
After Dam Construction	14.80	0.95	15.75
Difference	-1.50	15.35	13.85
Percentage (%)	11.30	94.17	46.80

Source: *Author, 2018*

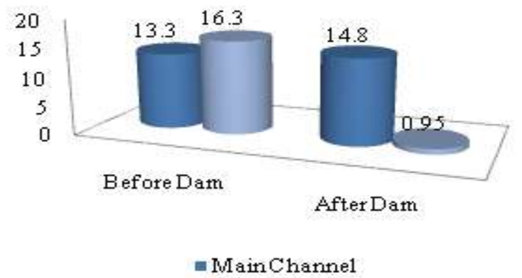

Figure5. *Pre and Post Dam Karadua Stream Length Characteristics*

The fact that Regulated stream length varied 47% less during the post-Dam period supports the idea that flow regulated by dams reduces the frequency of overbank flows and episodic channel migration within the entrenched channel. This is further supported by the findings of this work that the stream used as control varied in length consistently during both periods. The variability exhibits same character with the regulated stream at pre-Dam period. Once the regulated channel became vertically and horizontally contained, it likely becomes unable to migrate regularly as it does during pre-dam flood events. Figure 7 and 8 shows a clear picture of this situation. Looking at the figures closely, it is clear to see that braided channel (figure. 7) before Dam construction has changed in to a single channel flowing with only slight channel shifting in (figure 8). However, an examination of the entire regulated study reach revealed that along the entire stream length, only at the largest curve of the meander, about 5.2km away from the reservoir, shows a clear channel shifting. This alone yielded a difference of about -11.6%.

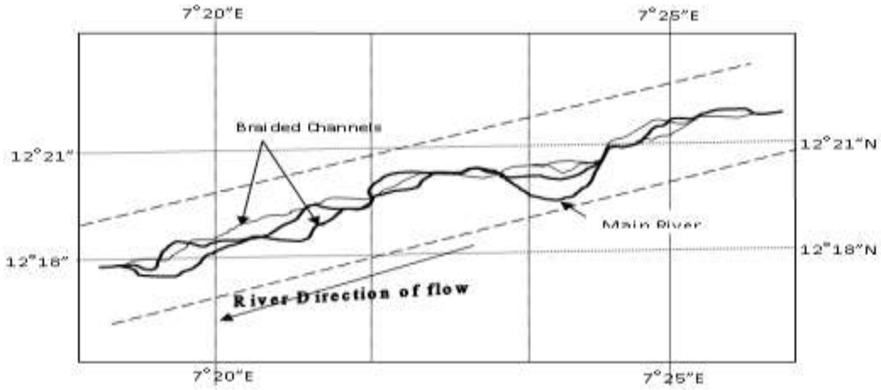

Figure6. *Below Dam Karadua River Section before the Dan Construction (1978) Evidence of river sinuosity and Braided Channels*

Source: *GLCF Multi Spectral Scanner (MSS), Land sat 7, http://gmcf.umiacs.umd.edu*

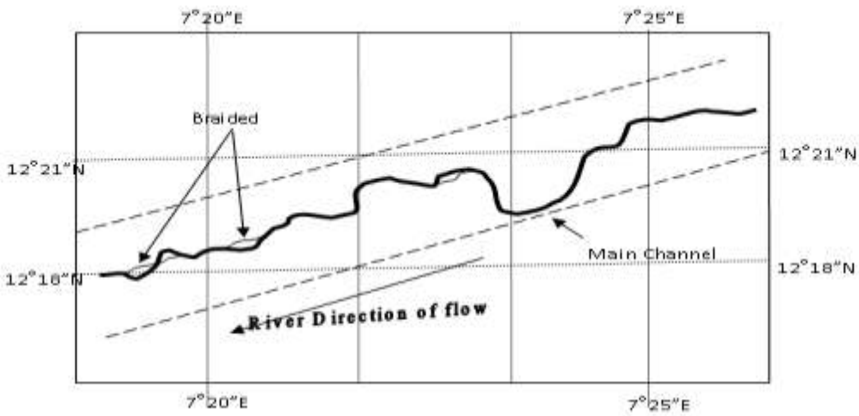

Figure6. *Below Dam Karadua River Section after the Dan Construction (2008) Evidence of single Channel and absence of Braided Channels*

Source: *Spot 4 Imagery*

Conclusion

This activities initiated by decrease in flow as a result of the trap impact of the reservoir, also reduces the amount and character of sediment below the upstream. Subsequently, this variation in the temporal pattern of sediment characteristics is reflected in the increase erosive potential of the less turbid water; actual channel deepening, lithology and morphology of floodplains upstream.

The analysis of the channel morphology from the cross-sectional information indicates two main morphological changes between the shape of the Karadua River reach before Dam and after to the Dam construction. The first instance is the narrowing of the channel below the Dam, abandoning the former storm channel and creating an incised channel. The second issue is vertical cutting and deepening of the channel. These all together bring about lateral displacement of the active channel and flood plains.

The analysis of the cross-sectional area shows a slight variation generally. Looking closely at the outcome of the field analysis, it is easy to derive an understanding of the geomorphic patterns of the two channel reaches under consideration. There is a kind of balance, because the greater value of the mean width at above dam reach was counterbalance by the greater value of mean depth at below dam reach. The disparity in the actual cross-sectional area does not portray a significant difference. As such, the most important point is on the differences obtained between mean width and average mean depth of the channel reaches.

The resultant morphological effects of the dam on the study river can be translated to change in floodplains characteristics, on which means of sustenance relied on and thereby affects the livelihood of the populace

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