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Full Length Research Paper

Suspended sediment yield and sediment concentration in dammed Karadua river in Katsina State, Nigeria

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This study examines the suspended sediment yield in response to dam and its reservoir downstream Karadua river reach in Katsina State, Nigeria. The study river basin is within the tropical savannah of Northern Nigeria. The watershed covers a catchment area of 1838 km^2 and the drainage is mainly formed by a 6-order stream. The approach for this study is the comparison the data obtained above the dam river reach with the data obtained below the dam to mark down the changes in suspended sediment concentration. Results show that suspended sediment yielded a highest value of 8.55g/l above the dam, but only 1.25g/l below the dam. The total sediment yield of the stream above the dam was 24.96 grams per litre and only 4.98 grams per litre below the dam reservoir. This yielded the monthly averages of 4.16g/l at above dam and only 0.83g/l at below dam. The study therefore, concludes that dams reduce the sediment yield of a river by holding the much turbid water after a rainstorm typical of the region, and then letter releases the settled water with clear variation of up to 80%. The study therefore, suggested more studies and action plan on all aspects of river basin ecosystem for proper monitoring and more detailed studies on all aspects of dams and reservoirs effects on the hydro-geomorphology of rivers and the natural environment below the dam, as well as wide coverage investigation across the country.

Keywords: Sediments, Dam, Karadua, River

INTRODUCTION

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. So, river can make good or became harmful to man in human progress. Against this background, therefore, understanding catchment systems should be one of Man's primary concerns, such a concern can only be demonstrated through research efforts (Ibrahim, 2013a).

River channels are assumed to be in equilibrium with present flow levels; that is a balance between water discharge, sediment transport, erosion and deposition. 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 and Adensina, 1996).

Discharge characteristic is one of the most important aspects of the processes in fluvial environment. The fluvial system in rivers holds also to a larger extent the characteristics of sediment yielded by the water discharged. Indentifying the trend of sediment in a river is also very useful in the process of examining the changes which take place through the fluvial system in rivers resulting to morphological changes in rivers valleys. Many research works focused much attention towards monitoring such changes in river regime and morphology especially the anthropogenic changes, giving consideration to sediment and sediment characteristics. This has been given consideration by Petts, (1984), who pointed out that, any change in discharge and/or sediment load bellow a dam would disturb the state of the existing regime and cause an adjustment of the channel form.

In another study by Grimshaw and Lewin, (1980) reported that dam and reservoirs act as sediment sinks, reducing the turbidity of the river downstream. Thus, the potential erosive power of the water has been increased downstream and the debris storage of the river would be devoid of large particles material. As a result, this study intended to examine the sediments characteristics of River Karadua above Zobe dam reservoir and below the dam reservoir. The study is going to be based on suspended sediment yield and sediment particle size distribution.

The study area

The study area lies between 12° 00' and 12° 50' North of the Equator, and between 07°00' and 08°00' east of Greenwich (Figure 1).

Figure 1. Map of Katsina Showing the study River Basin.

The area falls within the Sudan savannah and so experiences a continental wet and dry type of climate, also known as the inter-tropical convergence zone (ITCZ) (Thompson, 1975). The climatic year is divided into a rainy season from mid May to beginning of October and into the dry season, from November to March.

The region experiences relatively cool weather from November to March with a daily maximum of 24 – 33°C and minimum of 10-16°C. Through April and May temperatures increases and the daily maximum are 33 – 38°C and minimum of 16 – 24°C. Rainfall in the area is usually marked with wide gabs of rainy days. The mean annual rainfall is 562mm. All climatic elements in the region of the study area show wide annual and seasonal variability (NIMeT, 2017).

The soil type of Katsina region is ferruginous tropical brown and reddish-brown soils derived from basement complex rock. The Aeolian drift materials are mostly derived from the Cretaceous sandstones lying in the area, and the parent material underlying the study area are composed of unconsolidated sands, the nature of which makes part of the area very porous and susceptible to erosion, (Scott, 1985). The soils of the area have developed under a savannah woodland type of vegetation and in a climate which permits downward percolation of water in wet season. The difference in topography of the study area is found to be very small over vast areas, which makes it less important in soil formation of this area, (WAKUTI, 1978). Over the whole study area, except on eroded and some alluvial soils, top soils are largely influenced by the drift material and are thus similar in properties. They are generally sandy, have little humus and are easily cultivated, (FAO, 1978). Most of the Katsina State according to Maxlock Group, (1977) lies within the so-called Sudan savannah zone. This is where trees and short grass species (less than one meter) predominate. The hydrology of the study area could be depicted from the information on rainfall characteristics of the study area given above. Runoff from arid and semi-arid catchments is often characterized by short and high-peaked hydrographs (Raghunath, 1990). The temporal parameters of the flood hydrographs (time of start, time of concentration) follow each other without delay. This is partly due to the rainfall occurring at short but high-intensity bursts and partly due to the characteristics of soil type. The study here however, assessed the impact of dam reservoir on suspended sediment delivery in this climatic region.

METHODOLOGY

A simple comparison of the historical hydrological data and current hydrological information as well the differences derived between the two river reaches, above and below the dam reservoir, would definitely bring out the hydrologic and geomorphic impact expected to have taken place. This is the simple design and approach adopted in this research work. The sites selected for discharge characteristics used in this work are the gauge stations used prior to the dam construction which provided the historic data obtained at that time.

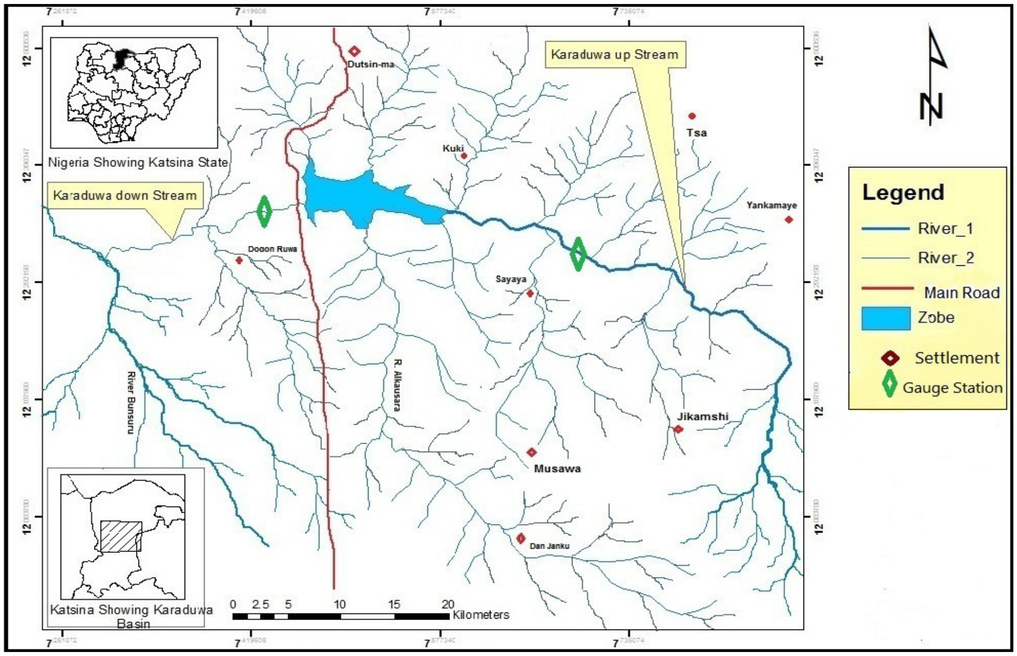

Figure 2. Study Area showing Gauge Stations above and Below the Dam
Source: Sheet 9, Sport 4 Imagery, 2008 (Hamisu and Aziza 2015).

The gauge stations were constructed and installed at that same time. They provided a point where all the water in the river passed through without side spills and diversions, allowing all discharge to flow pass the gauge station. These two sites are located both at above Zobe dam reach and at below the dam reach. At above the dam, the gauge station is located along a straight portion of the river course approximately 4km away from the dam. The other one is at a straight portion roughly 400m below the dam reservoir (Figure 2). Sediment yield data was derived from water samples collected weekly from the main River Karadua at the gauge station. Sampling was done with the aid of an improvised water sampling frame. The frame consists of a thin iron bar 1.5m long, fitted with adjustable clamps. One litter bottle fitted with cork stoppers, were positioned on the frame with the aid of the clamps at regular intervals above the stream bed. The three samples were collected at the basal, middle and upper positions (at least 10cm below water surface). Two holes on the cock (stopper) enabled water intake and expulsion of air. Samples were then taken to the lad and sediment analysis was obtained.

RESULTS AND DISCUSSION

The amount of sediments delivered by the Karadua stream obtained during the rainy season considered for this study is shown in (Table 1 and Figure 3). The table shows the suspended sediment transported by the stream above the dam into the Zobe reservoir. As well as the sediment amount measured at the other stretch of the stream below the dam reservoir.

Table 1 and Figure 3 show that highest sediment yield is in received in July and August at the river reach above the dam reservoir. This period marks the arrival of the peak murky waters of the Karadua River. After mid August, the volume of sediment transport drops towards the end of August before rising to September peak. This condition is quite variable with the patterns of sediment load in the river reach below the dam reservoir. Below the Dam river reach suspended sediment peak discharge was recorded in the month of August and September. Another interesting situation can be observed in these two sets of data in the month of October where the sediment yield is found greater below the dam reservoir with an average of 1.13g/l, than above the reservoir with only 14g/l as the average. This is because stream flow occurs in October for only few days above the dam because the period marks the end of the rainy season. But on the contrary, the flow covers the whole of October below the dam reservoir due to persistent released of water from the reservoir throughout the month. Another interesting aspect of the sediment yield is the sharp rise from the beginning of the sediment discharge in May. This can be depicted in the graph at the river reach above the dam. And on reaching the peak in July; the curve dropped steeply to its lowest in October (Figure 4). In contrast there is a gentle and steady rise in the sediment yield at the river reach below the dam. This gentle rise continued right from the beginning in May all through to the end in October.

Table 1. Suspended sediment yield above and below dam reservoir.

	May	June	July	Aug	Sep	Oct	Total	Average
Above dam reservoir (Grams/liter)	2.89	5.57	8.55	5.97	1.84	0.14	24.96	4.16
Below dam reservoir (Grams/liter)	0.02	0.46	0.52	0.60	1.25	1.13	4.98	0.83

Source: Author's Field work

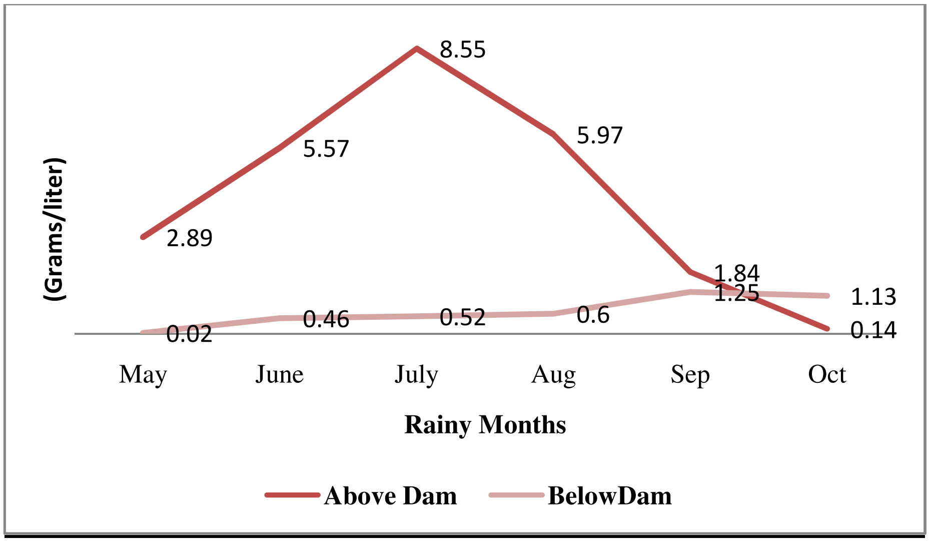

Figure 3. Suspended sediment yield above and below dam reservoir
Source: Author's Field work.

Table 2. Above dam suspended sediment (Pre-and post Dam).

	May	June	July	Aug	Sep	Oct	Total	mean	max	mini
Pre-Dam (Grams/Liter)	3.20	4.30	7.45	6.07	1.45	0.45	22.93	3.82	7.45	0.46
Post Dam (Grams/Liter)	2.89	5.57	8.55	5.97	1.84	0.14	24.96	4.16	8.55	0.14

Source: S.R.R.B.D.A./Author's Field work.

Table 3. Below dam suspended sediment (Pre-and post Dam).

	May	June	July	Aug	Sep	Oct	Total	mean	max	min
Pre-Dam (Grams/Litre)	3.20	4.30	7.45	6.07	1.45	0.46	22.93	3.82	7.45	0.46
Post-Dam (Grams/Litre)	0.02	0.46	0.52	1.60	1.25	1.13	4.98	0.83	1.60	0.02

Source: S.R.R.B.D.A./Author's Field work

The total sediment yield of the Karadua stream above the dam was found to be 24.96 grams per litre and only 4.98 grams per litre below the dam reservoir. This yielded the monthly averages of 4.16g/l at above dam and only 0.83g/l at below dam (Table 3). This shows clear variation between the two results which is as high as 80%.

In order to increase the level of confidence on the above findings, the primary sourced data was compared with pre-existing data and is presented in (Tables 2 and 3). The information in the tables is also demonstrated in (Figures 3 and 4). This is based on comparing the two set of data at above dam and below the dam with pre-existing. Figures 4 and 5 show that the amount of sediment conveyed by the Karadua stream during pre-Dam period varies slightly with the current primary data at above the Zobe dam reservoir. The relationship in the two set of data reflects in their minimum, maximum and

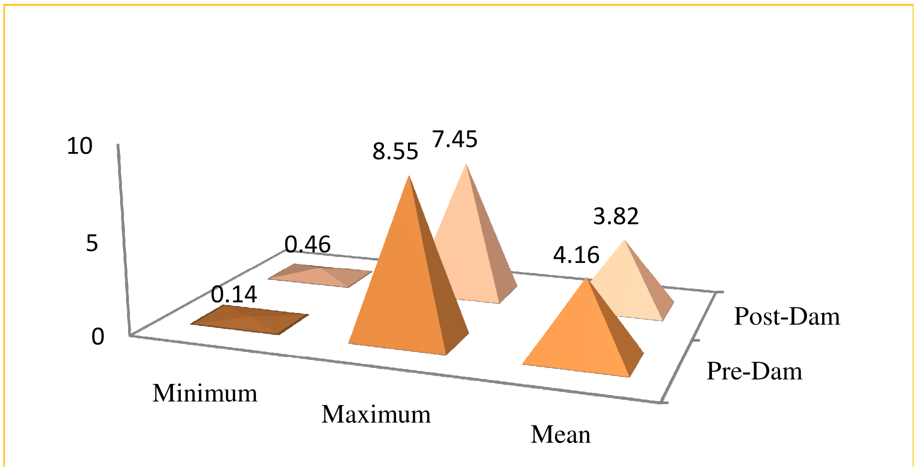

Figure 4. Above Dam Minimum, Maximum and Average.

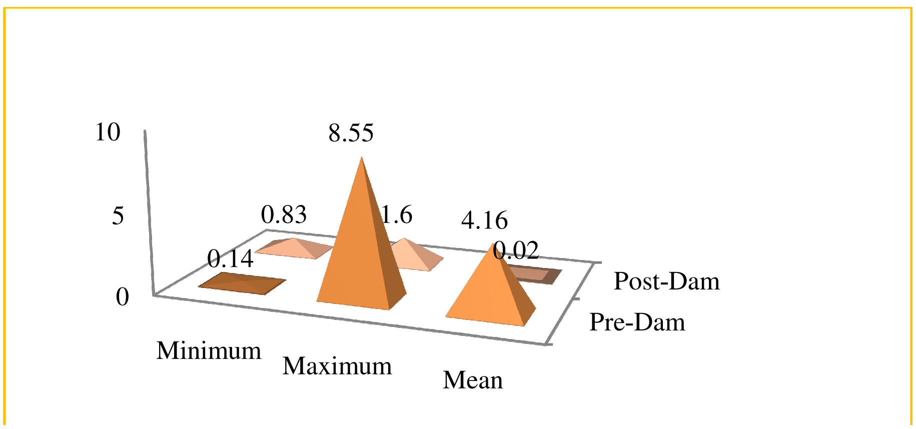

Figure 5. Below Dam Minimum, Maximum and Average Sediment Yield against Pre-existing Data.

mean values. The average sediment yield varies slightly with only 8%. Their average maximum yield also slightly differs with 8.55g/l in the pre-existing and 7.45g/l at the current data above the dam. The average minimum values are also alike, given the value of the pre-existing data as 0.45g/l, a bit higher than the current data (0.14g/l) at above dam g. The result signifies that the sediment yield of the Karadua stream does not change significantly with time, going by the results obtained at two different periods and on the natural flowing and unregulated stream.

On the other hand (Table 2 and Figure 3) show that the average sediment yield in the pre-existing data is grater to about 78% than the sediment yield at the below dam river reach. On the current data below the dam, there is only a maximum sediment yield of 1.60g/l and minimum yield of 0.02g/l, whereas there are up to a maximum sediment yield of 3.82g/l in the pre-existing data and a maximum value of 0.46g/l. This significant difference shows that at the time before the dam was constructed, the river was free of the effect of the reservoir. This high percentage difference of 78% is a very wide disparity worthy of note.

Conclusion

The amount of suspended sediments delivered by the Karadua stream however, displayed a variant pattern. There is significant difference between sediment delivered at the river reaches below and above the dam reservoir, whereby the amount obtained at the above dam is by far higher than the sediment at below the dam. This signifies the action of the reservoir which collects the sediment from the onset of run-off and discharge which later releases it through the spill ways on reaching its maximum capacity. Sediment delivery above the dam rise in a sharp manner and at a certain time drops drastically, whereas at below the dam river reach, it behaves in a steady and moderate way. This coincides with the ascertaining of Patrick and Wayne, (1994). In this study, information on sediment discharge above the dam reservoir yielded almost similar with the old pre-existing data of the Karadua River, while on the other hand, the data obtained below the dam reservoir is much less than the pre-existing data. This offers reliable bases to logically conclude that there is a significant difference between the two sets of data between below dam and pre-dam existing data on sediment yield. Owing to the fact that this is the first study of its kind in this study river basin, it has revealed the rate at which Zobe dam reservoir trap the sediments generated before reaching downstream of the Karadua river. This is so because decrease in turbidity increases the erosive power of the water and thereby impacting on the morphology of the river downstream. Such changes eventually translate to impact on agriculture and livelihood.

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