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# Problems of Suspended Sediment Loads in Asa River Catchment, Ilorin, Nigeria

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**Abstract:** This research is an assessment of the rate of the presence of sediment loads in Asa river catchment. This is with a view to explaining the inherent problems in such sediment compositions in the water body. To achieve this, data sets were primarily sourced, analysed and the following constitutes as the Observations: The properties of basin that facilitates sediment transportation from source to the destination include depth of water, bank full, average velocity, discharge, river competence and capability. Similarly, these parameters along with circularity ratio, bifurcation ratio, relief, basin length, total mean length, basin size, drainage density among others explains the ability of streams to transport sediment materials in suspension. Thus, problems often created by sediment deposits range from river siltation and eventually drying up. Averting this situation will involve water dredging, straightening of water channels to general environmental education with special reference to watershed management.

**Key words:** Problems, suspended, sediment loads, Asa catchment, Nigeria

## INTRODUCTION

The quality of river water is a function of its chemistry and the nature of its sediment characteristics. Thus, suspended sediment loads data and an understanding of the processes of erosion and sediment transport are necessary in a variety of water management tasks (Meyer, 1986). A knowledge of the amount, processes and characteristics of suspended sediment loads in a water source is needed if the sediment is to be removed as economically as possible before the water enters the distribution system.

There are 3 steps in the sedimentation process. The first step is the detachment of materials from the earth's surface. Both rain and sprinkler irrigation water drops can detach solid particles of materials from the soil surface. The overland flow of water also represents an important detachment process. The second step is the transport of detached soil particles. Water movement velocity, depth, volume, frequency, duration and turbulence regulate the extent of detachment and the distance that materials can be transported (Goudie, 1981). And the third step is deposition. Sediment is deposited when water velocity decreases to such an extent that it can no longer support the suspended material, or when the water depth decreases to such an extent that particle movement is impossible (Oyegun, 1980).

Sediment particles vary greatly in size, shape, density and composition (Jimoh, 1997). Light-weight organic materials range in size from microscopic to sub-microscopic colloidal materials. This is also the case with the denser mineral particles. Large-sized minerals particles such as sand and gravel are not likely to present much problems of removal because, they are relatively incoherent and are easily detached from the soil body. Soil aggregates of similar size and less dense than simple particles of sand and gravel, but they tend to react in similar ways.

The global pattern of suspended-sediment loads movement is described by Pritchard (1979) who demonstrated that some $20\times10^9$ tonnes of sediment loads reached the ocean/rivers per year, a quantity equivalent to a denudation rate of 75 mm/1,000 years. In different parts of the world, information on suspended-sediment loads movement and particles size distribution is needed for the design of dams, canals and irrigation works, streams, rivers and reservoirs that are free of suspended-sediment loads offer advantages for domestic consumption, recreation and agricultural purposes.

The nature, extent and location of suspended-sediment loads sources such as relief and slopes characteristic, vegetation cover, landuse, soil texture, drainage pattern and channel conditions are the environmental and geomorphological factors affecting the suspended-sediment loads generation and yields (Gregory and Walling, 1973; Jimoh, 1997).

Suspended-sediment loads yield is depended not only on erosion, climate, landuse but also on deposition on the channels, reservoirs and flood plains and the ability of the stream to transport the materials

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(Strahler and Strahler, 1977). Since, there is spatio-temporal variation of these factors hence the need to study the problems of suspended-sediment loads in Asa River Catchment, Ilorin-Nigeria. This will not only reveal the problems associated with the suspended-sediment loads but also its effects on the socio-economic activities of the people.

The prime focus of this research premised basically on the assessments of suspended sediment loads in river catchment. To achieve this, the following specific objectives are being pursued as follows:

- To examine the hydrometeorological data, hydraulic characteristics and basin morphometric properties of Asa River Catchment
- Finally, to examine the sediment yield regimes, the associated problems and the management techniques

## MATERIALS AND METHODS

**The study area:** Ilorin City is the study area. It is the capital of Kwara State, Nigeria. It lies on latitude 8°35'East and longitude 4°35'North. It is located within the 4 urbanized drainage basins of Aluko, Agba, Alalubosa and Okun and occupying a total land area of about 43.0 km (Jimoh, 1997) (Fig. 1).

The climate of Ilorin is the humid tropic type and characterized by both the wet and dry seasons with a mean annual temperature that ranges from 25-28.9°C. In addition, the annual mean rainfall is about 1,150 mm, exhibiting the double maximal pattern between April and October of every year. Days are very hot during the dry season from November to February temperature typically ranges from 33-34°C while the February to April, values are frequently between 34.6 and 37°C.

Essentially, Ilorin is located in the transition zone between the deciduous forest (rainforest) of the southwest and the savannah grasslands of the north (Oyegun, 1982). The vegetation of the Ilorin composed of species of plants such as locust bean trees, shear butter trees, acacia trees, baoba trees, elephant grasses, shrubs and herbaceous plants among others are common in this area.

Further, from the research of Jimoh (1997), Ilorin city is underlain by basement complex rocks which composed largely of metamorphic rocks especially gnesis and resistant quartzite. The soil of Ilorin is formed from the Precambrian basement complex rocks and it is under the grassland savannah forest cover and belong to the soil group called ferruginous soil.

This research utilized data from direct fieldwork investigations and such data have been categorized into 4, namely:

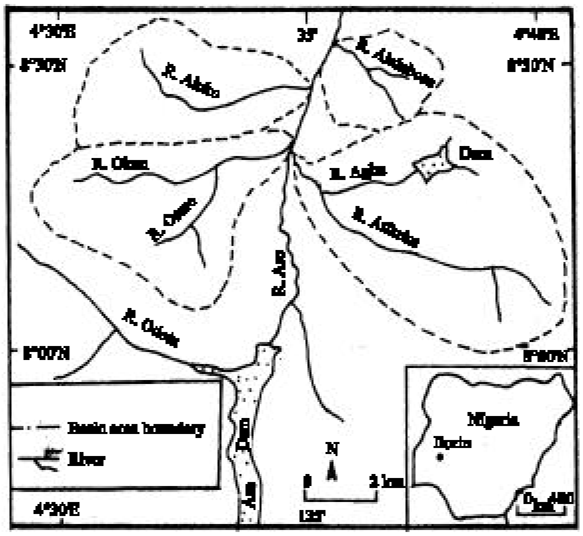


Fig. 1: Ilorin, showing the four drainage basins as the study area. Source: Oyegun (1982)

- Hydrometeorological data of suspended-sediment loads
- Morphometric data of suspended-sediment loads
- Hydraulic data of suspended-sediment loads
- Sediment yield data

Data collected and analysed in this study emanated from 4 sources such as field observation and measurements, questionnaire administration, map interpretation, laboratory analysis to determine the magnitude of sediment yield and estimated sediment yield was generated from rainfall data collected from meteorological station.

The topographical map of Ilorin drawn on a scale of 1:25,000 in 1966 by Federal Survey of Nigeria was used in collecting data on morphometric properties of the river. Data on hydraulic was generated from field observation and measurements. The hydrometeorological data was collected from Lower Niger River Basin Development Authority, Ilorin. In addition, three days sediment yield data was collected with the use of locally made sediment sampler. Also, seven years sediment yield data was also generated from hydrometeorological station.

**Sampling selection procedure:** These categories of data have been generated as stated below.

**Hydrometeorological data:**

- Rainfall in wettest month-this is the highest monthly amount of rainfall in each year of record
- Monthly rainfall-this is the total amount of rainfall in each month of the year

- Mean annual rainfall-this is the total monthly rainfall in each year divided by number of month in the year of record (usually 12)

**Morphometric properties**

**Basin area:** Area was calculated here based on graphical method. This is expressed mathematically as:

$$\text{Area (km}^2) = \frac{\text{NCS} + (\text{NIS}) \times \text{SF}}{2}$$

where:
NCS = Number of Complete Squares in the graph
NIS = Number of Incomplete Squares in the graph
SF = Scale Factor

**Basin length:** This is measured as the longest basin diameter between the mouth of the basin and the most distant point.

**Total stream length:** It is measured as the summation of all the lengths of the tributaries and the main stream length. The final result is expressed in kilometer.

**Average stream length:** This is mathematically defined as:

$$\text{ASL (Km)} = \frac{\text{TSL}}{\text{NT} + 1}$$

where:
TSL = Total Stream Length
NT = Number of Tributaries
I = Constant (the main stream)
ASL = Average Stream Length

**Circulating ratio:** This is an important away of expressing the basin shape. It is one of the most elusive morphometric properties to measure unambiguously with accuracy, significance and precision. It is expressed as:

$$\text{RC} = \text{A/AC}$$

where:
RC = Circulating Index
A = The Area of the Basin
AC = Circular Area with the same circumference with the basin

**Relief ratio:** This is measured as the ratio of the minimum basin relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line. It is expressed as:

$$\text{Rh} = \text{H/L}$$

where:
Rh = Relief Ratio
H = Maximum Relief
L = Length along the channel in straight line

The final result is expressed in meters

**Bifurcation ratio:** This was defined as the ratio of stream of order 'n' to the number of streams of next higher order 'n+1'. It is given as:

$$\frac{\text{N}}{\text{N+1}}$$

where:
N = Number of First order Stream
N + 1 = Number of Second Order Stream

**Drainage density:** This is one of the morphometric factors that can be viewed as a feature which affects amount and rate of output (sediment) from the drainage basin. The density is calculated as:

$$\text{Dd} = \frac{\Sigma \text{L}}{\text{A}}$$

where:
Dd = Drainage density
L = Length of Channel (stream total length)
A = Area of the basin

The final result is expressed in km/hr.

**Hydraulic data**

**Average water depth:** This data was collected through the use of ranging pole sank into the river at various distance from the bank of the river. This is mathematically defined as:

$$\text{AWD} = \frac{\Sigma \text{d}}{\text{N}}$$

where:
Σd = Summation of depth at various point
N = Number of points
AWD = Average Water Depth and the final answer is expressed in meter

**Bankful width:** This is done by measuring the distance between the banks of the river. The final answer is expressed in meters.

**Velocity:** This is usually expressed as distance over time. It is measured here by surface floats method. This is done by considering the time and length of travel. It is mathematically expressed as:

$$\frac{\text{D}}{\text{T}}$$

where:
D = Distance
T = Time

The final answer is expressed in (m $sec^{-1}$)

- Bankful discharge can be expressed in the form of:

$$W \times V \times d = \text{Discharge}$$

where:
W = Width
V = Velocity
d = Depth

The method is employed here and the final answer is expressed in ($m^3$/sec)

- Competence-it is expressed as:

$$(Vb)^6 = \text{Competence}$$

where:
V = Velocity
b = bed (depth)

- Capability-it is expressed as:

$$Vb^3 = \text{Capability}$$

where:
V = Velocity
b = bed (depth)

**Data on sediment yields**

**Total sediment yield:** This is summation of dissolved and suspended-sediment loads/yields in a given river catchment. Here, depth was used to obtain the sedimentary yield data lasting for three days. In addition, the hydrometeorological data was employed to get the yearly sediment yields/loads of seven years, using the Fournier's precipitation index II. This index was expressed as;

$$\text{Log Ds} = 2.65 \log P^2 + \frac{0.46}{P} \text{Log } H^2 - \frac{1.56}{S}$$

where:
Ds = Suspended-sediment yields/loads (tones $km^{-2}$ year)
H = Mean relief of the basin or the difference between the mean altitude and minimum altitude (m)
S = Catchment area $Km^2$
$P^2$ = Rainfall in wettest month in mm
P = Mean annual rainfall in mm

This method was employed to estimate the yearly sediment yields for 7 years.

## RESULTS AND DISCUSSION

Interesting issues of relevance have been unveiled following the data analysis of the data sets collected to address this research work.

**Precipation and sediment yields:** Rainfall has been found to be foundamental relevant to sediment generations on all land use types. The effects are indded the concern in this recent work (Table 1).

The precipitation and sediment yield data in the table above were represented visually on a bargraph below to show sediment yield variation over some period of time. It is obvious from the graph that Asa River catchment has higher sediment yield through out the year. Inspite of the fact that higher sediment yield is observed in the yearly processed data, there are variations in the amount of sediment yield between the years. In short, Fig. 2 shows the variation in sediment yield between and within the years too.

The implication of the Fig. 2 shown above is that, since the amount of sediment yield is related to the amount, duration and intensity of rainfall, therefore, water resource management and the environmentalist must prepare against this occurrence for it often increases the water level and finally causes flooding in the basin area especially as observed in 1992 in Ilorin. This preparation can be in form of proper waste disposal management, reduction in the agricultural activities around the basin area, avoiding building of houses on the river courses, etc, so as to reduce the sediment available to the river. Further, accentuating the sediment yields mechanisms is the issue of basin properties (Table 2).

From this Table 2, the river has an average water depth of 2.8 m with bankful width of 42.6 m. The average velocity is 1.8 m $sec^{-1}$, the bankful discharge is 88.9 $m^3$ $sec^{-1}$. It has a competence value of about 6,500 and it must be able to transport enough sediment loads and the value of its capability is also high. The implication of these is that the operational processes of Asa River will be very high especially in sediment yields and the subsequent loads available to the stream. This picture becomes clearer from Table 3 and Fig. 3.

The sediment yield rating curve above shows the relationships between discharge and suspended sediment yield in Asa River Catchment, Ilorin. This directly reflect the intensity of soil erosion. The sediment yield curve is a measure of catchment sediment conditions. The graph above shows that Asa River produces large amount of

Table 1: Precipitation and sediment yields of Asa River Catchment

| Years | Rainfall in wettest month (mm) | Mean annual rainfall (mm) | Sediment yield (10%) |
|---|---|---|---|
| 1990 | 238.7 | 123.6 | 14.5 |
| 1991 | 338.8 | 137.0 | 27.5 |
| 1992 | 327.6 | 106.1 | 45.7 |
| 1993 | 272.6 | 117.5 | 13.1 |
| 1994 | 238.0 | 104.4 | 8.9 |
| 1995 | 278.4 | 124.5 | 12.9 |
| 1996 | 281.0 | 105.6 | 20.9 |

Table 2: Hydraulic characteristics of Asa River Catchment

| Properties | Asa River (m) |
|---|---|
| Average water depth | 2.8 |
| Bankful width | 42.6 |
| Average velocity | 1.8 m $sec^{-1}$ |
| Bankful discharge | 88.9 $m^3$/sec |
| Competence | 6,500 |
| Capability | 31.5 |

Table 3: Sediment yield rating curve

| Water depth (mm) | Bankful width (m) | Average velocity (m $sec^{-1}$) | Bankful discharge (m $sec^{-1}$) |
|---|---|---|---|
| 2.88 | 43.0 | 1.80 | 222.9 |
| 2.05 | 42.5 | 1.72 | 149.9 |
| 2.92 | 42.6 | 1.71 | 212.7 |
| 2.95 | 42.9 | 1.76 | 222.7 |
| 2.89 | 42.1 | 1.81 | 220.2 |
| 3.01 | 42.1 | 1.80 | 228.1 |
| 2.82 | 42.2 | 1.76 | 209.5 |
| 2.90 | 42.8 | 1.75 | 214.7 |
| 2.96 | 42.8 | 1.77 | 224.2 |
| Mean (x) 2.8 | 42.6 | 1.77 | 21.31 |

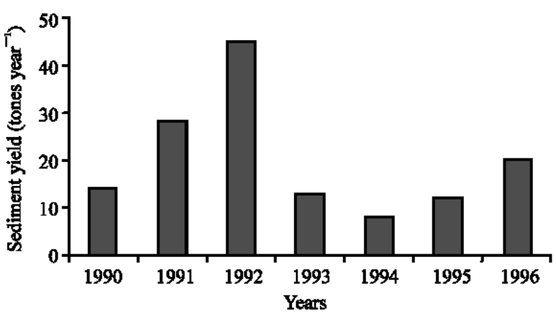


Fig. 2: Rates of sediment yields between 1990-1996

sediment yield because of its relatively high stream discharge. The implication of these is that the aquatic animals of Asa River will have more food available to them because sediment yield is an important source of food for the aquatic animals.

But this sediment yield (food source) can be a problem to them because it disturbs their visibility especially from seeing the food. It is also harmful to their metabolic processes and likely to increase chemical and biological activities which are harmful to them. That is why Asa River catchment has not been used as fishing pond, etc.

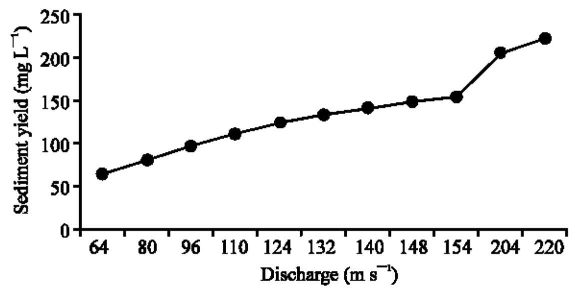


Fig. 3: Sediment rating curve (1990-1996)

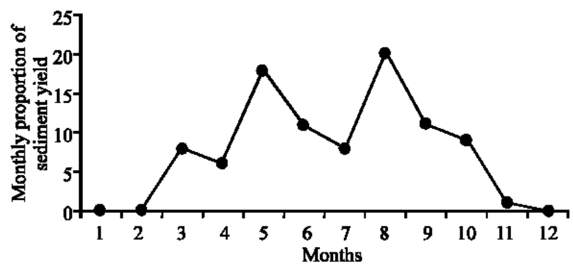


Fig. 4: Sediment yield regimes for 1990

**Sediment yield regime:** Monthly sediment yield regime as a proportion of annual sediment yield and precipitation. The formula is:

$$X \times 100/Y$$

where:

X = Monthly Sediment Yield. This is derived by dividing the annual sediment yield by annual total rainfall; then the result is multiply by monthly rainfall

Y = Annual Sediment Yield

From the Fig. 4, sediment yield started from March 1990 and increased in magnitude and reached it first peak in May, then declined in June and July and its second peak in August. In 1991, the same trend of maximal peak was experienced but occurred at different months, that is, July and September. In 1992, the yield reached first maximum in July and a very low yield in September, while its 2nd maximum peak was recorded in October in 1992. the trend differs from 1993-1994 to what was observed. Sediment started to increase from January and reaches its maximum in the month of June and July and started top decline again to its lowest yield in the month of December. In 1995 and 1996, the patterns of sediment yield also revealed a monthly variation.

The graphs below show the sediment yield regimes for the 1990-1996 periods (Fig. 4-10).

The co-efficient of determination result (50.4%) also shows that 50.41% in the precipitation is explained by the

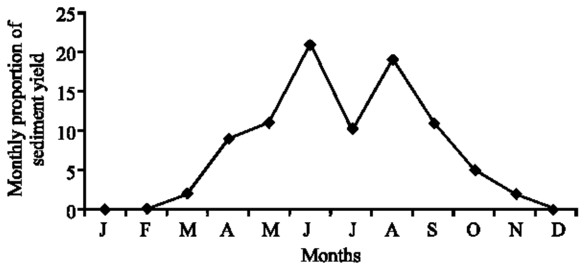


Fig. 5: Sediment yield regimes for 1991

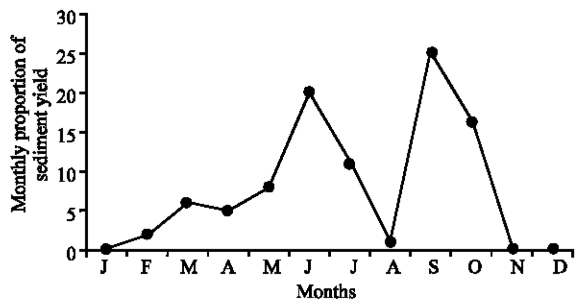


Fig. 6: Sediment yield regimes for 1992

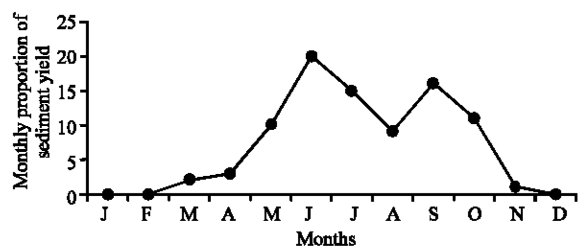


Fig. 7: Sediment yield regimes for 1993

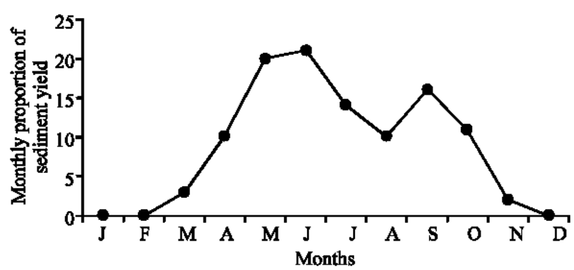


Fig. 8: Sediment yield regimes for 1994

sediment yield generated per year in Asa River catchment, Ilorin. This simply means that during the raining season more sediment yields are generated more than during the dry season.

From the Table 4, it is obvious, that the basin area is 40.75 $km^2$ and this will encourage a relatively high water and higher amount of sediment yield. Also, the basin length is 7.9 km. This is an indication that sediment yield

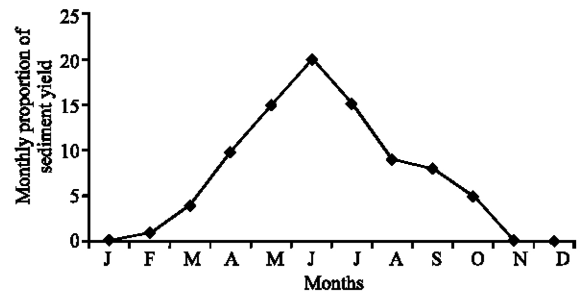


Fig. 9: Sediment yield regimes for 1995

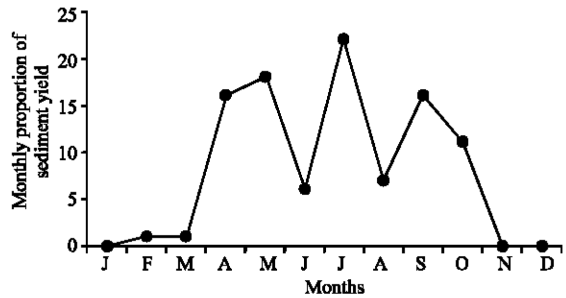


Fig. 10: Sediment yield regimes for 1996

Table 4: Basin morphometric properties of Asa River Catchment

| Properties | Computed values |
|---|---|
| Basin area | 40.75 $km^2$ |
| Basin length | 7.9 km |
| Total stream length | 49.85 km |
| Average stream length | 1.33 km |
| Circularity index | 0.64 |
| Relief ratio | 0.22 |
| Bifurcation ratio | 4.67 |
| Drainage density | 1.22 km $km^{-2}$ |

will travel from the source to the area of deposition. It also determines the length of the time in which abrasion, cavitation, corrosion, eversion and erosional activities of water can affect the river channel morphologies.

The total stream length of the basin is 49.85 km. This determines the drainage density which in turn affects the rate of water yield and tendency for sediment availability. Also, the average stream length of the river is 1.33 km. The higher the average stream length the lesser will be the hydraulic radius as related to threshold concept. This is because the capacity of the river which is not more than moving some sediment loads by rolling, sliding or saltation will change stream length.

The circularity index is 0.64, (i.e., maximum circularity ratio $\leq 1$), the closer the circularity ratio to 1, the shorter the basin length.

The implication of this is that Asa river will have shorter lag time, the time of rise and hydrograph peak, little wonder the frequent flood along the Asa river. The relief ratio is 0.22. This is the degree of ruggedness of the basin. The lower the relief ratio the more rugged the relief. The relief ratio is an indicator of rates of erosion operating along the slope of the basin. The bifurcation ratio is 4.67 and this simply means that Asa river is in the fourth order basin. Also, the bifurcation ratio measures the rates at which a stream of lower order enters into a subsequent order. The drainage density stood at 1.22 km. Essentially, classifications of this basin are areas of steep impervious areas with medium to high precipitation. Therefore, the higher the drainage density, the steeper the catchment; the lower the drainage density the lower the undulating structure of the basin.

## IMPLICATIONS

The basic issues observed in this research include the measurement and determination of the total amount of suspended-sediment yield from Asa River Catchment, Ilorin Nigeria. Thus, the following constitutes as the basic observations as follows:

- The hydrometerological data showed precipitation in the wettest month and the mean annual rainfall and the sediment yields that was generated on yearly basis
- The hydraulic data shows the average water depth, the bankful width, average velocity, discharge, the competence and capability of the Asa River to transport sediment loads from the source areas to the areas of deposition
- The relationship between the discharge and the sediment loads in Asa River Catchment has being explained by the sediment yield rating curves
- The sediment yield regimes shows the variations in the sediment yield and precipitation (1990-1992) while, the sediment yield regimes showed the frequency and distribution of the precipitation vis-à-vis the monthly proportion of sediment yields
- The morphometric data revealed the Asa River basin properties such as basin length, total stream length, average stream length and basin size. It also shows the circularity ratio, relief ratio, bifurcation ratio and drainage density. All these characteristics determined to a large extent the magnitude of suspended-sediment yield generated in Asa river catchment, Ilorin

## CONCLUSION

This research has attempted the examination and measurements of various precipitation, hydraulic, hydrological, morphometrical and sediment yield data in analyzing the suspended-sediment loads in Asa River catchment, Ilorin. Thus, the city of Ilorin has witnessed some flood events most especially as it was experienced in 1992 and most recently in 2007 raining season. These flood events were associated with higher sediment loads available to the basin following the waste disposals through various anthropogenic activities, higher delivery ratio, competence and capability of the stream. However, this situation can be remedied through the dredging of rivers and general environmental education with emphasis on watershed management.

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