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An Assessment of Suspended Sediment Decrease in Metropolitan River Ginzo Due To Urbanization Process In Katsina City, Nigeria

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ABSTRACT:

This paper studied the influence of urban development and its accompanied land surface transformation on sediment concentration of a natural flowing Ginzo River across the city of Katsina. An opposite twin river known as Tille River, which flows outskirt, was used to compare the result of the sediment concentration of the Ginzo River in order to ascertain the anthropogenic consequences of the urban area on impacting the sediment concentration. An instrument called USP 61 point integrating cable way sampler described by Gregory and Walling (1976), was used to collect the suspended sediment samples in the wet season months of June, July, August and September. The result obtained shows that data collected along the study river at the city centre are significantly different from the result of Tille River. The disparity ranges from 35% to 45%" having Ginzo River yielding the lesser result. In the general assessment of the difference, the statistical student t-test applied to the sets of data revealed that the suspended sediment concentration obtained in urbanized river Ginzo is significantly different from that of the less urbanized Tille River.

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The study further discovered that the less sediment concentration realized in the urbanized catchment is attributed to concretization of surfaces, tarred roads, reserved Open grassland areas and concretized channeling of segments of the river including the river bed all within the catchment.

The study therefore, concludes that urbanization affects not only the hydrology of an urbanized watershed but also the sediment concentration which is a significant aspect of its geomorphology. This will certainly affect the characteristics of the flood plains downstream areas. It is then recommended that further studies on urbanized watersheds should encompass all elements of geomorphology as it has been focused on hydrology. The Authorities concerned should trigger a proper environmental and land use management policies in order to arrest the menace of urban flood, erosion, land degradation and all related episodic events.

INTRODUCTION :

Geographically the most prominent landmarks of metropolitan Katsina are the two gigantic rivers known as the Ginzo and Tille Rivers. These two rivers drained the entire city and its surroundings areas, forming two distinct basins which are named after the rivers.

Over time these rivers had undergone so many changes as a result of so many processes operating within and outside the catchment. The changes are both hydrologic and geomorphic, and as well they range from small to large scale. This no doubt is resulted from the tremendous expansion of the city which is a continuous process that goes parallel with the rapid population growth of the sub-Saharan

Africa and population inflow to the state capital of Katsina following the creation of Katsina state in 1987 (Ibrahim, 2004).

Rivers are fundamental part of the environment. They are essential agent of erosion and transportation. They form a network which then makes a unit area known as the drainage basin. The drainage basin is an area limited by a drainage divide and occupied by a drainage network wherein the upstream drainage basin supplies water and sediment to the lower parts, reflecting the upstream geologic and hydrologic character of the watershed.

In general, urbanization creates large impervious surfaces which inhibit infiltration and allow a higher percentage of rainfall to become runoff. As such runoff enters urban channels very quickly, leading to the generation of high flow velocities in a dense network of urban gutters. This consequently produces a relatively flashy runoff regime with short lag time and very high peaks. Increase in peak discharge varies with percentage of the basin area urbanized (Jeje, 2007). Also sediment yield, which increase rapidly at the beginning of urbanization during the construction phase, has been estimated at about 200-2000 times the natural yield. This markedly reduced when complete urban development is achieved. Suspended sediment concentrations may then decline far below what was obtained in undisturbed natural catchments.

Channels are assumed to be in equilibrium with present flow levels; i.e. balance between water discharge, sediment transport, erosion and deposition. This equilibrium state may change as a result of human activities; such as the following replacement of natural vegetation by cultivated land or the process of urbanization (Mathew et al, 1999).

The impact of urbanization in the drainage basin depends on the percentage basin urbanized, the pattern and rate of, the urbanization process and the location of urban activities within the basin. The effects are mostly manifested on the river channels, and because of this several attempts have been made to study channel changes in response in response to urbanization (e.g. Walling, 1979; knighton, 1975; Gregory et al, 1992 among others).

In this study area there is also a pressing need to understand the geomorphic changes as much as the hydrologic ones. The need grows from the existing and increasing consequences observed in the basin in term of flooding and sedimentation of Abdallawa river confluence. The study would therefore provide a lead towards development planning.

OBJECTIVES OF THE STUDY

The objective of the study is to assess the changes in suspended sediment concentration in River Ginzo as a result of concretizing its section due to urban development in recent years, and identify the individual influencing factors in an urbanized setting.

THE STUDY AREA

The study area is the catchments of Ginzo and Tille rivers which together drained the urban and peri-urban Katsina, the capital city of Katsina state of Nigeria. The area lies between latitude 12o, 60' and 12o, 75' North of the equator; and between longitudes 07o, 35' and 08o, 10' east of the Greenwich. The area occupies part of the central plain of Hausa land, at the extreme part of Northern Nigeria on a height of about 500 meters above mean sea level. This is a part predominantly underlain by crystalline rocks of the basement complex. But at the Northern and eastern parts of the area, several feet weathered materials cover the solid rock, which has accumulated over drier climatic condition (Maxlock Group, 1977).

Figure 1 : Map of the Study Area

The climate type of the study area is a hot one because it is located in the dry tropics with mean annual temperature of about 27oC. The temperature is uniformly high throughout the year, but open air condition can be very uncomfortable during the dry season. The mean monthly temperature vary from 24oC to 31oC and reaching about 36oC in March. This shows a wide range of up to 12oC. The month of December and January are usually cold and dry with temperature of about 24oC and 26oC respectively. This condition is due to the influence of the Hamattan wind from the Sahara (Udoh, 1970).

Katsina is within the tropical wet and dry climatic zone which is characterized by wet and dry seasons. The rainy season begins from May and end sometime in October with high variability in intensity and duration. The mean annual rainfall amount for the area is recorded as 879 mm.

The soil type is the Ferruginous tropical Red and Brown soils of the Basement Complex Rocks in the area. The parent materials are composed of unconsolidated sand, the nature which renders the area very porous and susceptible to erosion on the interfluves and upper slopes of the underlying areas, while on the seasonally flooded valley floors a high clay content heavier grey soil occurs. The Lateritic drift soils of the area are coarse and tend to be shallow, less water retentive capacity and of low or medium fertility. This provides the medium for the growth of typical vegetation type of the area characterizes by sparse trees, grasses and shrubs of the Savannah.

DRAINAGE CHARACTERISTICS

The main drainage basin is formed by Abdallawa River which collects the drained water supplied by the Ginzo and Tille Rivers. Abdallawa River has its source in the Southern part of the state comprising Katsina city as one of the major sources. The Ginzo and Tille Rivers are the prominent tributaries of the Abdallawa River. The two river formed the main catchment, dividing the city of Katsina into two. Tille catchment occupying North-western part, while Ginzo catchment occupies the south-eastern part.

The two rivers are seasonal in flow. They nearly dry up during the dry season if not because of the domestic sewages. Their flows varied significantly with time throughout the rainy season.

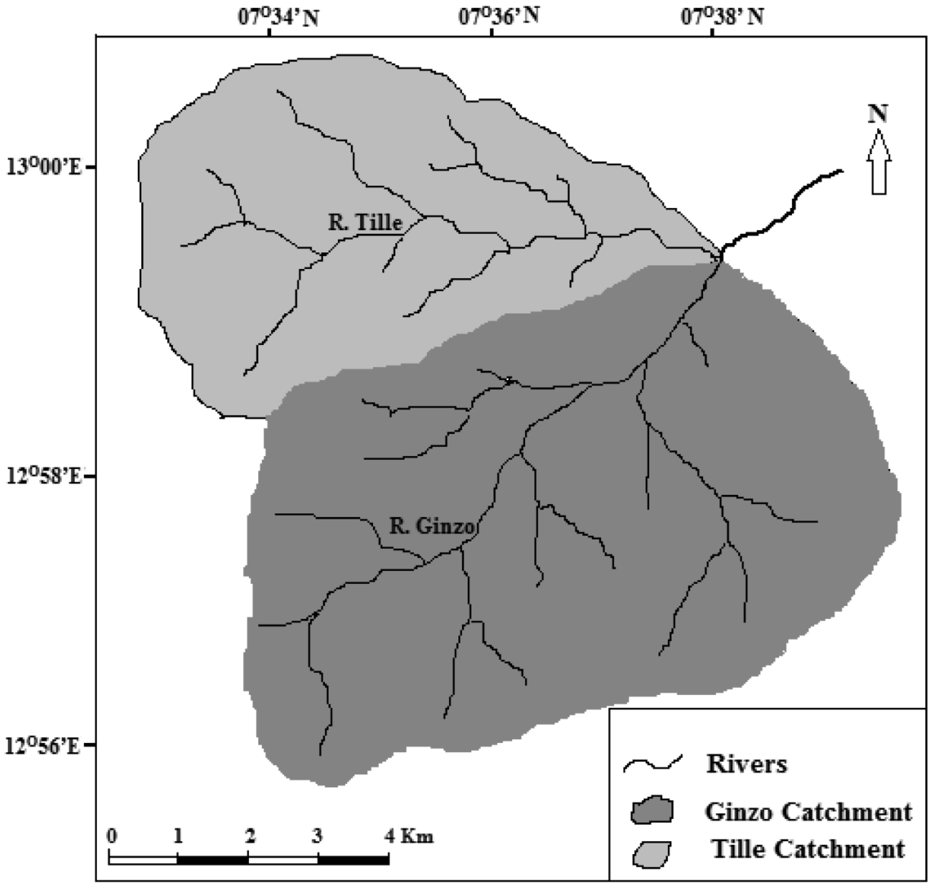

Figure 2: The Two River Catchments Under Study
Source: Sport 4 Imagery, 2008.

MORPHOMETRIC PROPERTIES OF THE TWO CATCHMENTS

In a drainage basin study, it is important to highlight on the Morphometric properties of the catchment under study. This is because such properties are known to affect its hydrologic and geomorphic dynamics. For example, the shape of the basin influences the peak flow and eventually the shape of the basin is simply characterized by reference to its maximum Axial Length (L), its Perimeter (P), and its area (A) (Gregory, 1973). Table 1 below presents the summary of few Morphometric variables of the two basins.

Table1: Morphometric Properties of the Two Study Watersheds

S/N	Parameters	Ginzo Catchment	Tille Catchment
1	Basin Slope (0^o)	5.7	5.2
2	Basin Area (km^2)	48	26
3	Total Length of Streams (km)	12.2	6.4
4	Drainage Density Ratio	0.25	0.24
5	Basin Shape	Almost Rectangular In Shape	Almost Triangular In Shape

Source: Ibrahim (2004)

From figure 2 above it is possible to have an impression of the shapes of the basins which are reliably interpreted in table 1 above. From the same table 1, Ginzo River is said to be almost rectangular in shape, whereas Tille River is said to be Triangular in shape. Other variables of the basins were also shown in the same table 1. It shows that the Ginzo basin has a slope angle of 5.7o which is slightly greater than that of Tille basin with 5.2o. The entire basin area of Ginzo is measured as 48 km2, almost twice of Tille basin with 26 km2. The total length of the entire streams that formed the drainages was computed as 12.2 km for Ginzo and 6.4 km for Tille. The Drainage

Density which is the ratio between the total length of streams of a basin and the total area covered by the basin is also presented in the table. The computed densities are 0.25 for Ginzo basin and 0.24 for Tille, which is considerably a slight different between the two.

The above description of the study area coupled with the Morphometric analysis of the basin presented in table 1 shows interesting bases for this field of research. It is indicated that all the two bases are similar in climate, vegetation and other physiographic properties. With this therefore, the hydrologic and geomorphic variables are suppose to portray similar trend in a normal situation. Secondly, the Morphometric information shows that Ginzo basin should be characterized by higher and speedy generation of runoff (e.g. Smith et al, 1978) and consequently greater erosive potency and Sediment transport potentiality. Does this presumed tendency about the sediment concentration happen to be the situation in the Urbanized Ginzo River? This is the single most important question to be answered in this work by field investigation and statistical proves.

METHODOLOGY

The objective of this study is designed to be achieved by examining the differences in sediment concentration of full pledged urbanized Ginzo River and a partially urbanized Tille River all within a rapidly growing Katsina metropolitan area. The methodology therefore, involved identification and mapping out of the two river basins. This was achieved by the use of topographic map sheet, land use map of the area on a scale of 1:50, 000 and Satellite Imagery (ETM). These procedures were supported by field observations and use of Google map for obtaining actual referenced locations and topographical information using Geographical Positioning System (GPS).

Using the same mentioned Satellite Image, the Morphometric information of the watersheds was depicted with the aid of GIS software known as Global Mapper-11.

Sampling sites for data collection were selected based on suitability and appropriateness along each of the two river courses. As the degree of concretization varies in a along streams, systematic sampling was required to provide a representative samples of the concretized reaches. In this regard, four sample sites were selected along each of the two rivers for the collection of water sample. The respective locations of these sample sites and the relative positions are shown in figure 3 below.

The data collection for the suspended sediment was carried out in the rainy season of 2012, in the months of June, July, August and September. The available instrument used is the USP 61 Point Integrating Cable Way Sampler described by Gregory et al, (1973).

The samples collected were analyzed in the laboratory to determine the suspended sediment concentration in mg/l. This has been achieved following the procedure developed by Douglas (1971).

A simple type of statistical analyses illuminate the suspended sediment concentration between the Ginzo River basin of the highly urbanized basin and Tille River basin that is less urbanized. This was achieved by using non-parametric test of the differences of means. A difference of mean test, using mean and standard deviation, reveals whether or not the observed differences between the two rivers are statistically significant.

RESULT AND DISCUSSION

Table 2: Ginzo River Summary of Suspended Sediment Concentration in (mg/l)

Sample Site	June	July	August	Sept	Total
G1	660	895	573	410	2538
G2	380	400	380	216	1376
G3	440	456	396	220	1512
G4	372	612	480	240	1704
Total	1850	2363	1829	1086	7130
Average	463	596	457	272	-

Source : Author's Fieldwork

The result obtained from the laboratory analysis on suspended sediment concentration of the two rivers are summarized and presented in tables two and three below. The results show a considerable variance between the two river basins based on their monthly records. In Ginzo catchment there is as high as 895 mg/l recorded in the month of July and a value as low as 186 mg/l in the month of September. From this result, a highest average value of 553 mg/l and a lowest average value of 249 mg/l were computed also in the months of July and September respectively. Considering the suspended sediment yield from individual sampled site, site G1 yielded an outstanding total value of 2538 mg/l, whereas, sample site G2 yielded the least value which amounted to only 249mg/l. It is also apparent to see that the values in G2, G3 and G4 shows a marginal difference between one another, but when the three sites are compared with site G1, the disparity becomes a wide one. Another interesting phenomenon in this result worthy of note is the drastic fall in value which occurs from G1 to G2. The result then rises through G3 to G4 with a kind of low and consistent increase rate.

Table 3: Tille River Summary of Suspended Sediment Concentration in (mg/l)

Sample Site	June	July	August	Sept	Total
G1	815	930	610	420	2775
G2	760	865	388	392	2405
G3	952	858	680	416	2906
G4	665	692	532	352	2241
Total	3192	2805	2210	1580	10327
Average	798	701	553	395	-

Source : Author's Fieldwork

In the case of Tille catchment, there was no such wide gab encountered in the behavior of the sediment amount obtained among all the four sampled sites. There is also no specific trend in the values regarding their increase or decrease from one point to another. The differences among the various sites are generally low. This is presented in the table 3, which shows that the highest value of 2906 mg/l was obtained at site T3, whereas the lowest value of 2241 mg/l was obtained at site T4. The monthly mean values revealed that the month of June yielded the highest value of 811 mg/l, while September yielded the lowest of 417 mg/l.

Inter Basin variation in suspended sediment concentration.

The comparison of the mean values of the suspended sediment concentration between the two Study Rivers is presented in table 4 below. The table shows that sediment concentrations are generally higher in Tille River considering each of the rainy months taken into account for the investigation. The mean values and standard deviation displayed in the table revealed that there is a significant difference between the values obtained at Ginzo and Tille Rivers. A difference of 227 mg/l was computed between the mean value (412 mg/l) of Ginzo and that of Tille (639 mg/l). in addition to this, Ginzo resulted a standard deviation of 124.7, while the Tille resulted up to 174.4.

Table 4 : Comparison between River Ginzo and River Tille In Suspended Sediment Concentration.

Months	Ginzo River (mg/l)	Tille River (mg/l)	Variance (mg/l)
June	430	932	502
July	423	627	204
August	385	533	148
September	225	353	128
Total	1463	2445	
Average	365.75	611.25	

Source : Author's Fieldwork

The statistical result shows a significant difference in the values of two out of the four months presented in the table and as well in the overall total result of the suspended sediment concentration between the two rivers. In the month of June, the urbanized Ginzo basin was found to be 48% less than the Tille basin which is a significant difference at the 0.05 confidence level. Another significant difference is also found in September with -40% negative variations for the Ginzo basin to the less urbanized Tille basin. The overall totals for the Ginzo and Tille also shows a significant difference between them. This resulted to -36% less in the urbanized Ginzo from the total values of the less urbanized Tille catchment.

CONCLUSION

The result obtained in the above analysis and presentation have provided the ground for making a logical conclusion that; urban development within a river basin have statistically significant effect on suspended sediments concentration in the river discharge. These effects were made very clear from the fact that the amount of suspended sediment obtained at a river section before the urban center is significantly higher than that obtained within the city. And the decrease in suspended sediment amplifies with increase in distance into the urbanized area. The result of the investigation on the trend of suspended sediment in the urbanized and partially urbanized basins revealed three important events operation in the urbanization process. These are the concretization of surfaces in the urban settings, which hinders runoff to generate substantial sediment after rain event; the channelization and alteration of the river dimension that involve cementing the section and bed of the river; the development of open grassland surfaces within the urban areas which also reduces runoff, increases infiltration and consequently decreases the chances of sediment generation.

This study therefore, revealed so much on the impact of land surfaces on sediment generation other than those factors such as slope angle, rainfall intensity and Soil type among others as in the previous works of Hammer, (1972); Graf (1977); Douglas, (1995); Gregory et al (1992) and so on, touching all elements impacting on fluvial geomorphology of urbanized river basin.

The study at this point suggests that further researches should focus attention on the impacts of low sediment concentration in highly urbanized watersheds and as well the impact of high sediment concentration on such less urbanized watersheds at the suburb, which to some extent can translate to high rate of erosion. It is also recommended that the Authorities concern should carry out their urban development plans and monitoring along with advisory blue-prints designed by Geotechnical experts. This should be coupled with proper land use and urban design which will not conflict with the Hydrologic and Geologic settings of the urbanized watershed.

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