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MORPHOLOGICAL RESPONSE OF GINZO RIVER TO URBANIZATION IN KATSINA METROPOLIS, NIGERIA

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Abstract
Ginzo channel like any other small urban streams is predominated by urban induced problems, hence the examination in this study, the extent of urbanization effect on morphological changes of the river channel in Katsina city. For the investigation, bank-full parameters of the study river were measured through direct fieldwork exercise while the river planform parameters and degree of urbanization in each of the three segments of the river channel were computed from satellite imagery of Katsina metropolis (2014) downloaded from glcf.umd.edu/data/Landsat 2014-04with Katsina N.E. Topographical map on scale 1:50,000 serving as a base map. Descriptive and inferential statistics were subsequently used in analyzing the data collected. The study revealed that bankful and planform parameters of the study river were generally lower at the upstream segment when compared with downstream segments. A significant relationship was observed between degree of urbanization and channel cross-sectional area while the result also indicate a general reduction in stream sinuosity index with degree of urbanization. Towards sustainable management of the study river, a number of recommendations were put forward. Amongst such include the use of bio-engineering approach in the river management, a review and enforcement of environment laws to control channel encroachment and relocation of houses erected close to the river channel.

Keywords: Morphology, Urbanisation, Metropolis, Stream, Sinuosity.

Introduction

The world's population is increasingly concentrating in urban areas, and it is predicted that by the year 2030, more than 60% of world's population will be living in urban areas (U.N Population Division, 1999). According to U.S Census Bureau (2001), much of this growth is occurring in developing nations. The extensive and increasing rate of urbanization according to Leopold et al, (1964) represents a threat to streams which hitherto were in state of equilibrium. An equilibrium stream according to Nabegu (2014) is a stream in a state of relative stability within the channel system. Channel of such stream possess the ability to continue its normal activities while maintaining its form under all flow regimes over a period of time. However, when influence within the system alters the channel ability to transport water and sediment efficiently, excess erosion and aggradations occur which is referred to as disequilibrium.

Landscape changes resulting from human activities often cause streams to enter a state of disequilibrium. Prior to urbanization, the ground surface within a given catchment is pervious, allowing infiltration of precipitation. The pavement of such natural surfaces by buildings and other anthropogenic activities causes the infiltration potential of such surfaces to be significantly reduced, hence increase in run-off rates and discharge (Iroye, 2008). Construction activities within a catchment has also been observed by Wolman (1967), Leopold (1968), and Fusillo et al., (1977) to increase sediment yields resulting in aggradation process and subsequent decrease in channel capacity with the resultant effect on flooding and overbank sediment deposition (Booth, 1990).

Another geomorphic change induced by urbanization process according to Douglas (1976) is channel constriction resulting from bridge supports and riverside structures. Such features often reduce the carrying capacity of streams (Nabegu, 2014).

Observations from the field revealed that Ginzo channel like any other small urban streams is predominated by urban induced problems. Such problems include the augmentation of the channel discharge by storm water sewers and gutters from the neighboring quarters. This action which is increasing flow velocity of River Ginzo is reducing its lag time. While building construction which is taking place on the river flood plain is increasing the rate of soil erosion and siltation of the river channel, the sand mining activities within the channel is fast re-grading the channel slope. The high rate of encroachment on the river channel especially at the upstream and mid-stream segments aimed at increasing land acreage is rapidly constricting the channel width consequent effect on flood generation.

Though the degrading impacts of urbanization processes on stream channel have been well explored and documented, most of these studies have focused on streams in the humid tropics. The few studies which have investigated the impacts of urbanization on arid and semiarid streams have only examined perennial streams (Nabegu, 2012; 2013, 2014; Coleman et al., 2005). Ginzo river which is the data collection point in this investigation is an intermittent river. Urbanization effect on such a river is difficult to predict and manage because of the alluvial nature of its river channel; hence its investigation in this study. Specifically however, the study seeks to examine the spatial variation in channel morphology of the study river, assess the relationship between channel morphology and degree of urbanization, analyze the relationship between the river morphological parameters and examine the temporal variation in sinuosity of the study river.

Study Area

The study area in this investigation is Katsina city (Figure 1) using data collected from River Ginzo channel. This area lies between latitude $11^0 8^1$ and $13^0 22^1$ north of the equator and between longitudes $6^0 52^1$ and 9^0 20^1 east of Greenwish meridian, covering a landmass of about 3,370sq.km. The climate of this area is characterized by a relatively long dry season which yearly span between the months of November and April. Rainy season in the region is usually experienced between the months of May and October with high rainfall concentration in the month of August and a mean annual rainfall value of 800mm. Maximum daily temperature of about 38^0C is usually experienced in the area between the months of March and May while a minimum temperature of about 22^0C is usually recorded in the months of December and January.

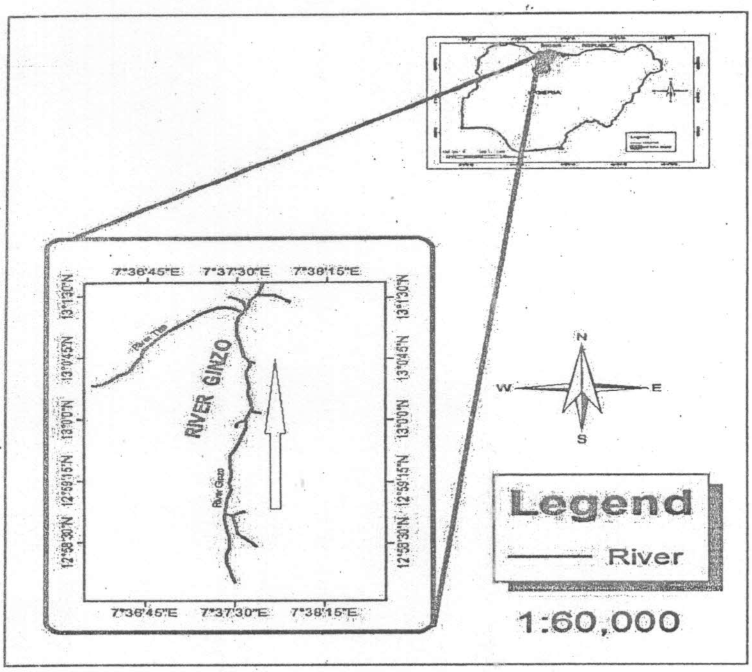

Figure 1: River Ginzo Map with Nigeria as Inset
Source: Geoprocessed Political Map of Nigeria.

The geology of the study area is sedimentary in nature with maximum thickness of about 100 meters and a regional dip to the north-western part of the city. The soils in the area fall under tropical ferruginous type; though weakly developed alluvial soils can be found along the major stream (Zayyana, 2010). The landscape is relatively flat but the city centre is about 510 meters above the sea level (Survey Department, Katsina State 2008). The two main rivers in the study area are Ginzo and Tille Rivers. While River Ginzo drains the northern part of the city, River Tille and its tributaries which exhibit dendtrictic pattern drains the south. All these streams are seasonal with most, like any other semi-arid rivers, experiencing almost zero flow in dry season.

The vegetation of the study area is sudan savanna type where trees such as *Adonsonia Digitata, Cyba Pantandra, Anogessum Leocarpus* among other can be found. Grasses in the area are mostly perennial; they have durable roots which remain underground after stalk have been burnt or witted in dry season. Such grasses re-germinate with the onset of rain. Land use in the area is dominated by residential, commercial, and institutional land uses with small area being use for farming activities.

Materials and Methods

River Ginzo catchment is drained by five streams, three of which are first order streams, one is a second order stream and the fifth which is the main stream is a third order stream. That is being investigated in this study. The stream which measures a total length of 8.2km was divided into three segments in this investigation. While the upper segment falls under rural landscape beginning from Tudun Matawalle to Sabuwar Unguwa quarters, the middle segment falls within urbanized area of the city beginning from Kofar Marusa to Filin Sanji quarters. The downstream segment of the river which is located between Yandadi and Modoji quarters is a region where urban renewal is currently taking place. In each of these three segments, two sampling points located at 1,200 meters away from each other (Figure 2) were chosen for detailed investigation on channel bankful parameters of width, meander length and sinuously index.

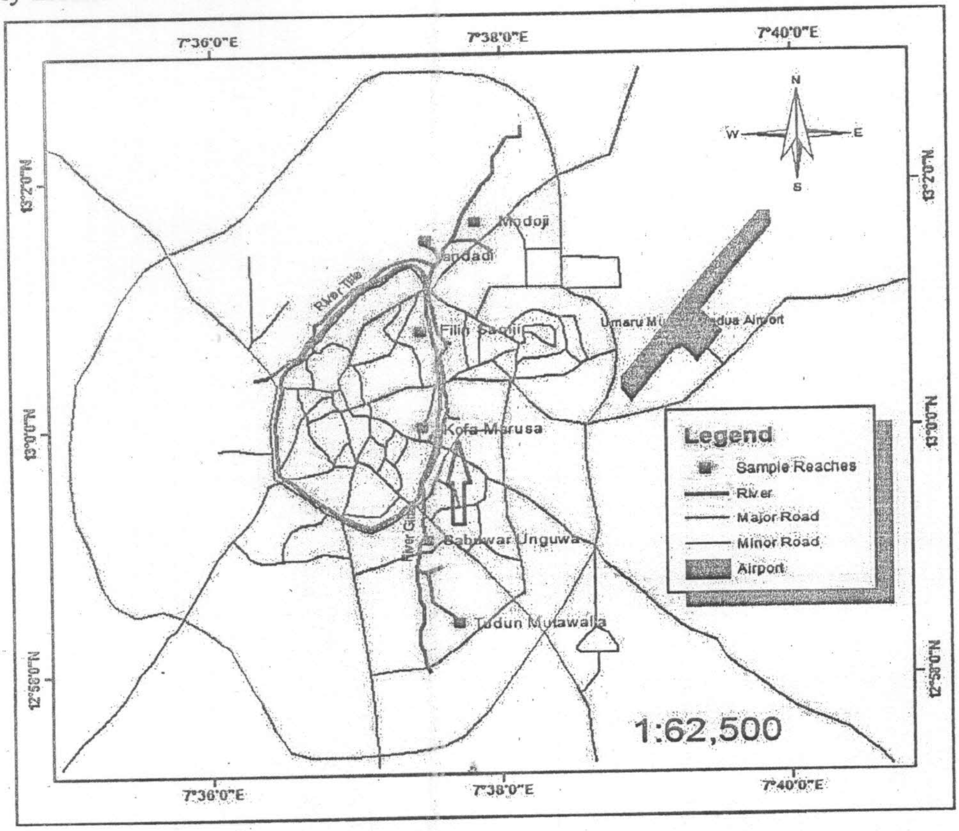

Figure 2: Map of Katsina Metropolis Showing Selected Sampling Points along River Ginzo
Source: Geo-processed Landsat Image 2014

Channel bankful parameters were measured using measuring tape, ranging pole and abney level while platform parameters were computed from satellite imagery obtained from glcf.umd.edu/data/landsat 2014-04 with Katsina North-East Topographical map of scale 1:50,000 serving as base map. Sinuosity index was computed from Leopold et al (1964) formula given as:

SI = CL/DL

Where

SI = Sinuosity Index

CL = Average Channel Length

DL = Average Direct Length

Data collected from both fieldwork and map computations were subsequently analyzed using both descriptive and inferential statistical methods.

Results and Discussion

Table 1 shows the bankful characteristics of the study river.

Table 1: Dimension of Bankful Parameters of River Ginzo

Sampled Reaches	Segment of River Channel	Distance from River Source (m)	Width (m)	Depth(m)	Cross sectional Area (m^2)	Wetted Perimeters
A	Upstream	600	3.2	1.2	2.7	3.4
B		1800	19.2	0.7	27.4	5.2.
C	Midstream	3200	25.5	0.44	57.9	12.2
D		4400	15.0	0.23	65.2	15.6
E	Downstream	6200	10.8	2.2	4.9	4.1
F		7400	47.0	0.77	61.0	21.5
Mean			20.1	0.92	36.5	2.10
S.D			15.2	0.71	28.7	7.4
Range			43.8	1.97	62.50	18.10
C.V			75%	77%	79%	35%

Source: Fieldwork, 2015.

Channel width ranged between 3.2m observed at 600m away from the river source to 47m observed at 7.4km away from river source. Though channel width increased significantly over a distance of 3.2km from 3.2m at the first sampling point to 25.5m at the third sampling point, the value dropped from the 25.5m observed at the third sampling point to 10.8m observed at the fifth sampling point which is located 6.2km away from the river source. The mean channel width for the channel is 20.1m while coefficient of variation (75%) shows that the study river exhibits high variability in width.

The depth of the study river just like the width also exhibits high (77%) variability with depth ranging between 0.23m observed at the fourth sampling point which is 4.4km distance away from river source to 2.2m observed at the fifth sampling point which is located at 6.2km away from the river source. While the mean depth of the study river is highest (1.45m) at the downstream segment, the mean depth is lowest (0.34m) at the midstream segment. The cross section area of the study river ranged between 2.7m^2 observed at 600m away from river source to 65.2m^2 observed at 4.4 km away from river source. The mean cross sectional area of the study river is highest (61.55m^2) at the midstream-segment while the value of this parameter is lowest (15.40m^2) at the upstream segment. And just like the channel width and depth, the cross sectional area of the study river also exhibits high (79%) variability.

The wetted perimeter exhibits the lowest (35%) variability among the studied parameters with values ranging between 3.4 observed at the first sampling point which is 600m distance away from river source to 21.5 observed at 7.4km away from the river source. The variation in the mean values of this parameter exhibits direct relationship with the mean values of cross sectional area. Thus, just like cross sectional area, mean wetted perimeter of the study river is highest (13.90m) at the midstream segment while the mean value is lowest (4.3m) at the upstream segment. Figure 3 shows the spatial variability in channel morphology of the study river.

While the width observed at the upstream segment of the study river could be due to the structural reinforcement of the channel banks carried out to prevent lateral and vertical erosion as can be seen on Plate 1, the high values observed in mean width, depth, and cross sectional area at the downstream section is basically due to the fact that the downstream section is still in its natural state as can been on Plate 2. The channel segment in this section is thus able to adjust to a semi equilibrium state. However, the general low values recorded in all the four parameters of river morphology at Yandadi (E) could be attributed to the presence of riparian vegetation as depicted on Plate 3. Vegetation provides stabilizing force against channel bank erosion.

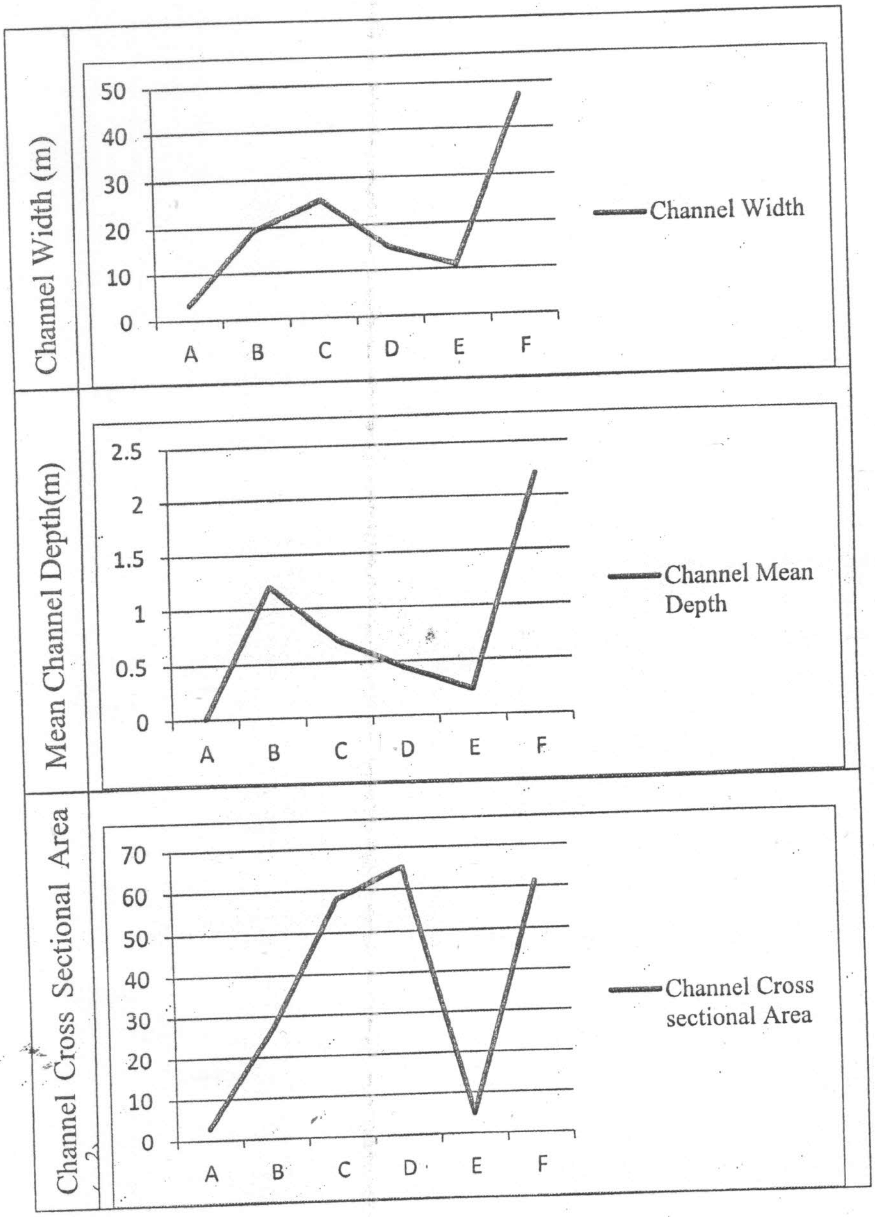

Figure 3: Spatial Variation of Channel Width, Depth and Cross Sectional Area
Source: Authors Computation, 2015

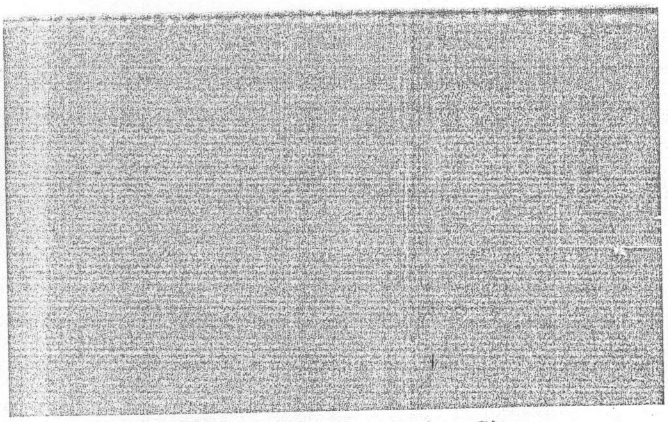

Plate 1: Reinforced Upstream Section of River Ginzo
Source: Fieldwork, 2015.

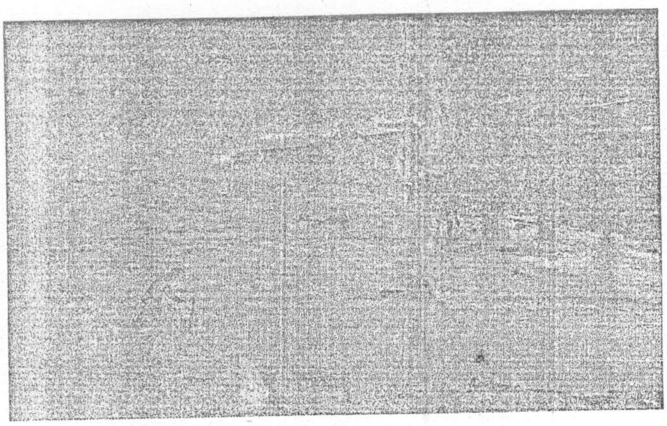

Plate 2: Unmodified Downstream Section of River Ginzo
Source: Fieldwork, 2015.

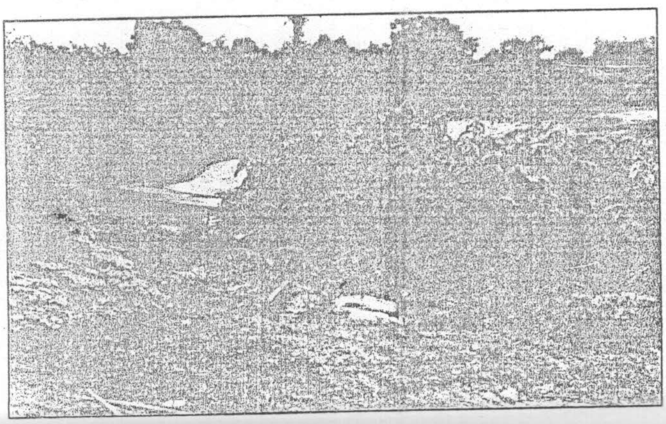

Plate 3: Channel Constriction Resulting from Vegetation Cohesion at the Downstream Section of River Ginzo
Source: Fieldwork, 2015.

The planform parameter of the study river (Table 2) reveals that the width of the meander belt at the upstream segment (3.3m) is lower than that at the downstream segment (16.6m), while the meander wavelength at the upstream segment (0.8m) is lower than that at the downstream segment (2.45m). The table also shows that the low channel slope (0.6^0) observed at the first sampling site which is 600m away from the river source in the upstream segment falls steadily to 0.4^0 over a distance of 4,400km before plunging to its lowest constant value of -0.5^0 from a distance of 6.2km away from the river source. While the observed variation in meander width and length could be attributed to the fact that upstream segment of the river has undergone artificial channel straightening unlike the downstream section which is still in its natural state, the reduction is slope gradient observed could be due to the increasing rate of construction and building activities along the channel.

Table 2: Planform Parameters of the Study River

Planform Parameters	Sampling Point					
	A (600m)	B (1800m)	C (3200m)	D (4400m)	E (6200m)	F (7400m)
Meander Width (m)	1.7	4.9	8.1	8.7	15.9	17.3
Meander Length (m)	0.9	0.7	1.5	0.7	2.6	2.3
Slope	0.6^0	0.5^0	0.5^0	0.4^0	-0.5^0	-0.5^0

Source: Fieldwork, 2015.

To further understand the relationship between channel morphological variables, a correlation matrix (Table 3) was generated. The result of the correlation shows that 65.7% of the studies variables exhibit positive relationship with each other while 34.3% exhibits negative relationship. The high positive correlation (r=0.897) observed between channel cross sectional area and wetted perimeter is basically due to the fact that river channel always adjust to accommodate increase in flows.

Table 3: Interrelationships between Channel Morphology and Degree of Urbanization

	CHANNEL MORPHOLOGY PARAMETERS							
	CW	CD	CS	WP	MW	ML	CS	DU
CW	1							
CD	-.365	1						
CS	.691	-.807	1					
WP	.832*	-.579	.897*	1				
MW	.610	.328	.276	.527	1			
ML	.415	.628	-.088	.200	.875*	1		
CS	-.485	-.584	.063	-.268	-.923**	-.913*	1	
DU	.293	.082	.376	.484	.750	.398	-.594	1

Source: Authors Computation, 2015.
ABBREVIATIONS: CW = Channel Width, CD =Mean Channel Depth, CS = Channel Cross sectional Area, WT= Wetted Perimeter, MW = Meander Width, ML = Meander Length, CS = Channel Slope, DU = Degree of Urbanization.

Nabegu (2012) has earlier observed that urban channels adjust their width to maintain increasing velocity of higher flows. The high positive correlation (r= 0.875) between meander width and meander length is expected. This is due to the nature of the river being examined in this study. The river is an alluvial stream and alluvial channel according to Vermont Agency for Natural Resources (2014) are characterized by high sediment load which results in larger channel width and thus, shorter meander wave length. The positive correlation (r=0.691) between channel width and cross sectional area can be explained with the theory of hydraulic geometry.

Channel cross sectional area of an alluvial stream, just as the one being investigated in the study usually increases with increasing width. The positive but low correlation (r=0.376) between rate of urbanization and channel cross sectional area may be due to the fact that the channel of the study river adjust to accommodate increase in flows from upstream impervious surfaces. The rate of adjustment has been handicapped by both bank vegetation and bank reinforcement as earlier shown on Plates 1 and 3.

High negative correlations were observed between meander length and channel slope (r=-0.913), and between channel cross sectional area and channel depth (r=-0.807). While the high negative correlation between meander width and channel slope could due to the fact that in alluvial channel that is characterized by high sediment load, meandering reaches usually adjust to accommodate braided bars and thus results in the formation of relatively gentle channel slope, the observed negative correlation between channel cross sectional area and mean channel depth could be due to the fact that in alluvial channel that are characterized by rapid lateral erosion, width increases more rapidly than depth. The eroded materials which are removed are subsequently deposited on the river bed thus decreasing the depth. Ebisemiju (1989) and Odemerho (1992) have earlier indicated that channel reduction in Nigeria rivers is mostly manifested in depth dimension which indicates stream bed aggradation.

The stream sinuosity index as can be seen on Figure 4 has decreased from 3.1 in year 2000 to 1.07 in 2014. This decrease which represent almost 35% reduction in 14 years is due to the fact that, rapid urbanization process which is taking place in the study area has made substantial length of the study stream to be stripped of its riparian vegetation which thus allows the river to increase its rate of meandering. This finding corroborates Pizzuto et al (2000) earlier observation which indicates that urban streams in southeast Pennysylvania are 8% less sinuous than their rural counterparts. Another reason that can be adduced for the reduction in sinuosity of the studied channel is the engineering construction as shown on Plate 1 which has been used to straighten the channel in order to prevent further lateral and vertical erosion. Artificial channel modification as also been observed by Moslay (1975) to be responsible for the decrease in sinuosity index of River Bollin in Cheshire from 2.34 to 1.37.

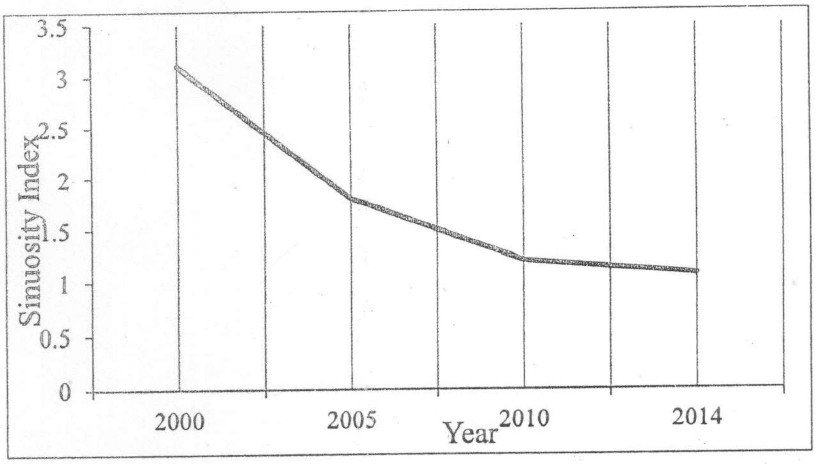

Figure 4: Temporal Variations in Stream Sinuosity Index
Source: Authors Computation, 2015.

Conclusion and Recommendations

Though man's role in channel modification has been exercised over a number of decades, it is only of recent that the effect of his action has begun to attract significant attention from researchers. The cause of this recent attention may not be unconnected with the magnitude of ecological problems being witnessed in urbanized catchments in different parts of the world, especially in developing countries. Anthropogenic activities induced by urbanization process is not only rapidly changing the riparian environment of river systems, but also taking place within the river corridors.

Result of such action is daily manifesting through channel widening which is displacing inhabitants of riverine area and flooding which has led to loss of lives and destruction of properties.

As a way of managing the study river to avoid negative incidents of flooding, erosion and displacement of people, this study is thus recommending bio-engineering approach in the river management, review and enforcement of environmental laws to control illegal channel encroachment and evacuation of residents along the channel segments.

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