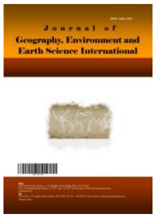

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Geomorphological Parameters as Correlates of Channel Erosion in River Ajilosun in Ado-Ekiti, Ekiti, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author SJA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OOO and AAS managed the literature searches and did the editorials. All authors read and approved the final manuscript.

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ABSTRACT

The paper examined the relationship between geomorphological parameters and channel erosion in River Ajilosun in Ado-Ekiti, Nigeria. Data on geomorphological parameters and channel erosion of the River Ajilosun were generated through direct field measurements using tape measure, ranging pole and a piece of flat board. Some of the variables were also derived through simple linear mathematical relationships. Analysis of the various data was done with both descriptive and inferential techniques. The result of the analysis showed that channel erosion exhibited spatial variation across and along the longitudinal profiles of River Ajilosun and also between the concrete-channelised and the alluvial reaches of the river. The result of the analysis also revealed both positive and negative correlations between the geomorphological parameters and channel erosion in the river. The measures suggested for controlling channel erosion in River Ajilosun included effective channel and slope management, improvement of the channel capacity retention of channel bank vegetation and protection of the valley side vegetation among others.

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1. INTRODUCTION

Channel erosion is the process by which soil is removed from stream banks or is moved in the channel [1]. Channel erosion is also the expansion of river channels through lateral extension and vertical dissection of the channel. Channel erosion, according to Cooke and DoornKamp [2] and Strahler and Strahler (1977) is one of the three geologic activities taking place within a river.

The study on channel erosion is important because of the impact of rivers on the terrains in effecting geomorphological changes through the carving and moulding of the terrains. Since man inhabits the earth's space the specific features and configuration of the earth's surface will play a deterministic role in how he lives and makes a living. In other words, the forms and geometrical relations of the terrains may exercise controls on the degradation of a river channel.

Geomorphological parameters are landform attributes which influences the direction and intensity of surface water distribution and flows. The parameters may also determine the proportion of rainfall reaching the river channel to effect in its erosion. Understanding the basic process of geomorphological parameters will provide the basis for effective management and control of channel erosion.

Ado- Ekiti is a rapidly urbanizing capital city. The various ongoing construction works in the city may alter the geomorphological equilibrium of the city terrains. Particularly, the impact of urban development activities may reflect obviously in the watershed areas. Man occupies watershed and develops it, consequently homeostasis which is the process of adjustment of the natural environment statusquo equilibrium is inevitable. The accelerated channel erosion in watershed is one of the several ways by which our physical environment responds to altered equilibrium of the earth surface.

In the light of the foregoing, the paper looks at the relationship between geomorphological parameters and channel erosion in River Ajilosun in Ado-Ekiti, Nigeria. The paper also includes recommendations on measures to control channel erosion in the river, particularly in relation to its impact on area of human habitation.

2. CONCEPTUAL UNDERPINNING / LITERATURE REVIEW

Erosion can be described generally as the wearing away and gradual lowering of the land surface [3]. It is a geomorphological phenomenon closely linked with flooding. Erosion is a geomorphic process that sculptures the surface morphology of a terrain. The distinctive landform characteristic and features observable in a particular environment is usually a reflection of the erosive imprints on the terrains. The geomorphological process of erosion is also a geophysical event in that it is controlled by climatological and geological characteristics of an environment in which it occurs.

Channel erosion in the content of this paper means a process whereby river channel floods widen the banks of stream channels, through lateral extension and expansion toward the total area of human settlement adjacent to the channel.

Erosion is a contemporary environmental problem ravaging the global environment when it occurs in a River channel it may gradually encroach on the area of human occupance since man occupies and inhabit water sheds. Therefore, understanding of the dynamics of the process of erosion will provide the framework for assessment and control of impacts of channel erosion on the terrains.

Three types of stream channel erosion have been recognized in literature. These are river bed erosion, channel bank erosion and channel bed erosion [2]. River bed erosion and channel bed erosion occur within the river valley geometry. But channel bank erosion occurs through lateral erosion process which may encroach on area of man's occupance when watersheds are developed. The channel bank erosion is the other types of erosion especially in an urbanized watershed.

Climate is a primary control influencing river hydrology and geomorphology as it impacts the precipitation timing and quantity which establishes the hydrologic character of a drainage basin [4,5] as well as the presence of vegetation, which stabilizes channel banks and hillslopes, Bizzi [6]. Geomorphological features of rivers such as bed form, sediment transport, and the relative position of bed and banks, can be altered by changes in flow regime that influence processes of erosion and deposition [7,8]. The rate of sediment transport is greatest during dominant or effective discharge, approximately bankfull flood [9].

The Davisian Geographical Cycle of Erosion provides a useful theoretical framework for our understanding of the processes of erosion across a landscape and particularly in a channel. Cycle of erosion posits that landform evolution and development over time follow a specific cyclical evolutionary trend. The cycle mimics the biological trend of evolution of species. The basic tenets of the cycle recognizes the landscape, a river's profile or watershed as developing from the youth stage, through the mature stage with an evolutionary conclusion reflecting an almost plainland called peneplain. Every stage of landform development entails mass wasting and degradation of the landscape. Such processes could also impact negatively on cultural environment. Wohl [10] asserted that geomorphic response dictates modifications to the floodplain, channel pattern and channel geometry.

2.1 The Study Area

River Ajilosun is located in Ado-Ekiti, Nigeria within Latitudes 7°35^1 and 7°38^1 North of the Equator and Longitudes 5°10^1 and 5°5^1 East of the Greenwich Meridian. River Ajilosun is a 4th order basin having a drainage area of 18.125 km^2. The river runs in the North West-South East directions of the city of Ado-Ekiti. River Ajilosun drainage basin forms part of the upper Ogbesse drainage basin. River Ajilosun has its head waters at the Central Business District and the core traditional area of the city where the high density of physical development is concentrated.

River Ajilosun experiences tropical climate characterized by the dry and rainy seasons. The two seasons are determined by the interaction of two principal airmasses called the Tropical Maritime and Tropical Continental air mass. Total annual rainfall in the drainage basin varies between 1200 and 1400mm. The drainage basin has a relative relief of 150 m. Most slopes of the terrains falls in the range of 5°-15° indicating an undulating relief. Except on the Ayoba hill, where the mean gradient is about 31°, all other relief segments within the daring basin generally have gentle slopes of about 3°. The river flows is an almost saucer shape morphology with the western interfluves having 540 metres as the highest relief while on the eastern segment the relief stood at 447metres at its peak.

The population of Ado-Ekiti city was 308,626 in 2006 according to the National Population Commission Census fallouts. The city has a projected population of 1,111,953 in 2030 [11]. Using the 2006 population figure, Ado-Ekiti has an annual growth rate of 2.23%. With this rate the city has a population doubling period of 31years. This may have implication on urban physical growth, deforestation, extent of imperviousness and susceptibility to erosion in River Ajilosun.

Landuses in the drainage basin consists mainly of the residential, commercial, institutional, recreational, water resources (bodies) and open spaces or undeveloped plots of land.

2.2 Method of Investigation

Data were collected on geomorphological parameters such as channel width, channel depth and channel capacity. Other variables on which data were also generated are channel slope, valley slope and ground slope and number of channel obstructions. The channel depth and channel width were measured with tape and a piece of tie rod graduated in centimeters. However data on slopes were measured with the abney level. The numbers of channel obstructions were counted directly on the field by taking inventory of the rock outcrops in the channel and unofficial refuse dumpsites in and along the River Ajilosun channel.

2.3 Procedure for Data Collection

2.3.1 Cross-sectional channel width

Channel width is the dependent variable (Y). It is an index of the degradation and lateral extension of the channel banks. Channel width was measured with the aid of a tape measure, a ranging pole. One end of the tape measure was held at a determined and fixed point on one flank of the river. Sagging of the tape was prevented as much as possible by holding the tape taut. The measurement was taken at different points across a section of the river. The average width was then calculated from such measurements. Measurements were taken at every 10metres along River Ajilosun channel.

2.3.2 Channel depth

Channel depth measurements were done cross-sectionally at different points along the channel. At each transect across the channel corridor,

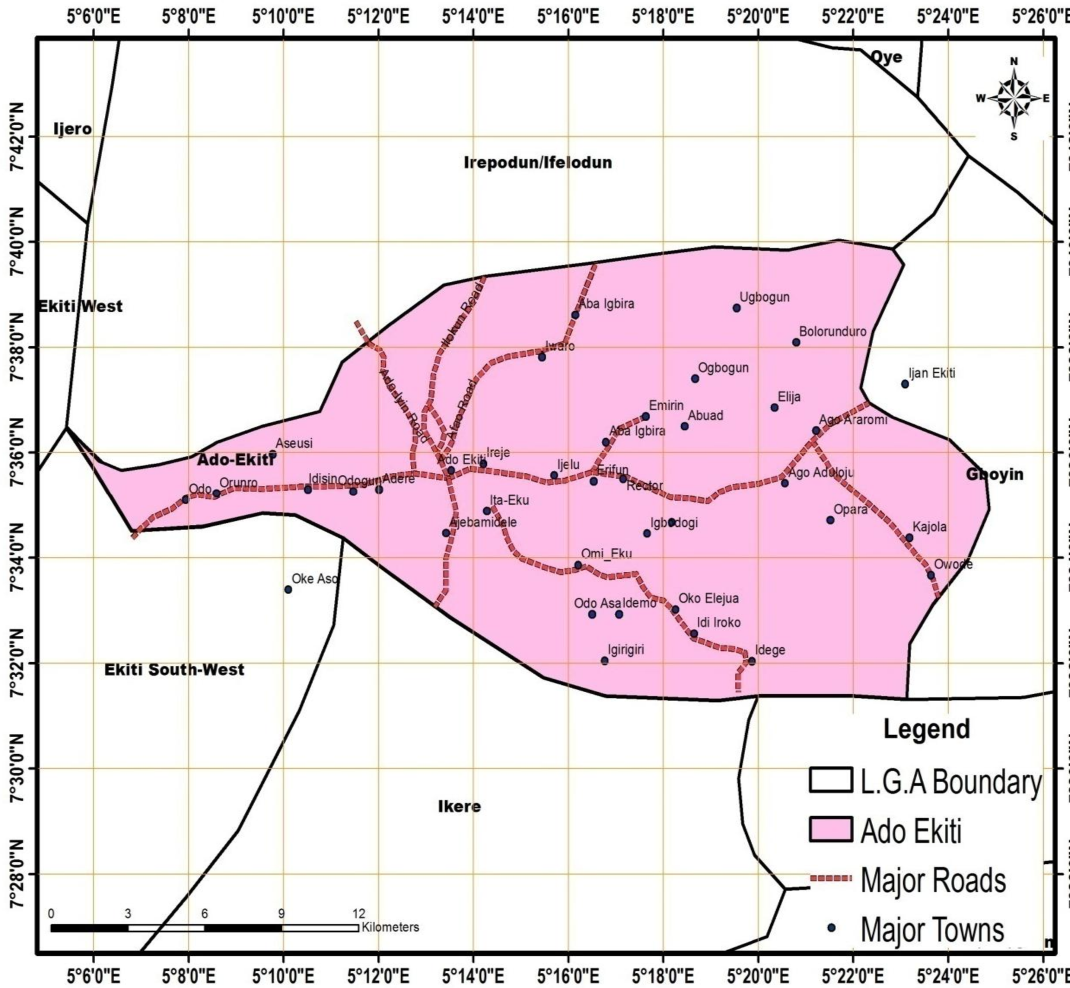

Fig. 1. Map of Ado Ekiti

Source: Ekiti State Ministry of Physical, Urban and Regional Planning/Department of Geography and Planning Science, Cartographic Unit, EKSU, Ado Ekiti 2019

calibrated flat board was used to determine the depth by placing the pole vertically at each determined and marked point. The average of the cross-sectional depth was then calculated as seen below in equation 1

Cross-sectional channel depth (d) = (d1+d2---------dn)/N (1)

Where, d_1+d_2---------d_n are individual measurements of channel depth and N is the total number of measurements.

2.3.3 Channel capacity

The channel capacity was computed as the production of the channel depth and channel width. The formulae used are of the form;

$$C = W \times D\ (M^2) \quad (2)$$

Where C is channel capacity in metres square;

W is channel width in metres;
D is channel depth in metres.

The mean channel depth (c) is

$$C = (\Sigma\ C_1 + C_2 \text{------} + Cn)/N \quad (3)$$

Where, C is mean channel capacity measurements at sampled points,

ΣC_1--------+Cn is summation of all channel capacity measurements at sampled points; And, N is the number of sampled points.

2.3.4 Channel efficiency

Channel efficiency is defined by the hydraulic radius of a river channel. Hydraulic radius ® is derived as follows

$$R = A/Pw \quad (4)$$

$$\text{But } A = w \times d \quad (5)$$

$$\text{And } Pw = 2d + w \quad (6)$$

Where, A is channel area; Pw is wetted perimeter of the channel; W is channel width and d is channel depth.

2.3.5 Valley side slope

The slope of River Ajilosun was measured with the abney level and a piece of tie rod 1.5 metres long. The abney level was placed on the flat board and reading was subsequently taken. The slope angle at its maximum point along selected profile lines was taken from the drainage divide to the adjacent stream bank. Measurements were repeated at the intervals of 10metres in the two segments of the drainage basin.

2.3.6 Ground slope

The procedures used for the measurement of valley side slope were repeated for the measurement of the ground slope using the abney level.

2.3.7 Stream channel slope

Channel slopes measurement was carried out along River Ajilosun using the abney level and the tie rod. Channel slope was measured at successively and systematically determined points along the channel. The flat board was placed at the edge of the channel bank in an inclined angle to the middle of the channel. The procedure was repeated at the opposite end of the bank. The two measurements, on both flanks of the river, formed a transect or profile line.

2.3.8 Number of channel obstructions

The number of channel obstructions was determined by making an inventory of the number of refuse dumpsites in the drainage basin and the number of instances of occurrence of rock outcrops in channel corridor. This was done by physically counting the spatial location of such obstructions.

3. RESULTS AND DISCUSSION

Descriptive Characteristics of Geomorphological Parameters of Channel Erosion in River Ajilosun.

The descriptive statistics of the variables of channel erosion in River Ajilosun in Table 1 show that the width of channel erosion had a mean value of 5.88 ± 3.250metres. The value varies along the longitudinal profile of the river and there were also variations in the width of erosion between the concrete channelised segments of the river in the upper reaches (3.39±1.92metres) and the corresponding dimension in the lower reaches of the river (8.37±2.26metres). The width of the channel determines or predicts the extent of lateral degradation of the channel. Channel depth indicates the vertical dissection of the channel. This variable also exhibited differences in value across and along the River Ajilosun profiles. For instance, channel depth had a mean value of 1.51 ± 0.641metres in the river. However, there were variations in values of channel depth between the upper concrete channelised (1.35 ± 0.22metres) and the lower

Table 1. Descriptive statistics of geomorphological parameters of channel erosion in River Ajilosun

Parameter	N	Mean	Std. deviation	Range	SE
Channel width(Y)	150	5.88	3.250	5.36-6.41	0.261
Channel depthX1	150	1.51	0.641	0.59-1.78	1.063
Channel capacityX2	150	11.61	25.750	6.27-246.0	6.562
Channel efficiencyX3	150	2.20	3.235	1.88-4.23	1.035
Channel slopeX4	150	13.12	5.340	7.77-19.26	1.614
Ground slopeX5	150	5.50	2.320	0.05-12.0	0.630
Valley slopeX6 channel	150	4.37	3.124	3.86-4.87	0.255
Obstruction X7	14	12.0	4.200	10.0-14.0	0.314

Source: The Author, 2019

alluvial reaches of the river (1.66 ± 1.06metres). Similarly, the channel hydraulic capacity showed differences in its dimensions along the river's profile. While the mean channel capacity for the river was 11.612 ± 25.750 metres it ranged in value from 6.7 m^2 in the upper segment to 246.0 metres in the lower reaches.

The efficiency of the River Ajilosun which is indexed by the hydraulic radius had a mean of 2.20 ± 3.235metres in the river's profile. But the values ranged from 1.88metres in the upper reaches to 4.23metres in lower segment. This indicates a progressive increase in the river's hydraulic capacity from the upstream segment to the lower reaches. Channel slope also follows an increasing trend from the upper channel segment to the lower channel segment. The variable had of mean of 13.12^0 and varied between 7.77° and 19.26° from the upper and the lower segment. The ground slope had an average of 5.50° ± 2.320° but had a range of value between 0.50° and 12.0°. The average valley side slope is 4.37° ± 3.124°. The valley slope ranged from 3.86^0 to 4.87° between the upper segment and the lower segment of the river.

Channel obstructions are taken as number of refuse dumpsites and the number of instances of occurrence of rock outcrops in channel corridor. In the upper concrete channelised segment of the river, there were six (6) refuse dumpsites and eight (8) bridges totaling fourteen(14) obstructions. In the lower reaches there were channel obstructions in the form of four (4) quartzite outcrops, two (2) granite outcrops and four (4) bridges along the river channel. Thus the river channel had an average of twelve (12) channel obstructions with a range of such obstructions varying from ten (10) to fourteen (14) in the river channel.

3.1 Spatial Pattern of Channel Erosion in River Ajilosun

Channel erosion exhibit spatial variation along the longitudinal profile and between the concrete and non-concrete channelised segments of River Ajilosun. The descriptive statistical analysis of channel width erosion demonstrated obviously that channel width erosion varied along the entire drainage basin of the river. The upper segment of the river had a mean channel width of 3.39±1.92 metres while the lower segment of the river had a mean value of 8.37±2.26 metres Table 2.

The facts in Table 2 depicted disparities in the channel erosion within each segment of the drainage basin as well as between the two segments of the basin.

For instance, while the sum of square for the channel erosion between the upper and lower segments of River Ajilosun was 906.786, the corresponding sum of squares for the differences within each of the two segments was 656.850. Implication of this is that channel erosion varies more between the two segments of the river's profile than within each of the segments. The differences may be

Table 2. Analysis of variance of channel erosion in River Ajilosun

Variables		Sum of squares	D_f	Mean square	F	Sig.
Channel width	Between Groups	906.786	1	906.786		^{XXX}.000
Erosion	Within Groups	656.850	147	4.468		
	Total	1563.636	148			

Source: Author's Analysis, 2019
Note ^{XXX} significant at 0.05

Table 3. Paired samples correlation of channel erosion in the upper and lower segments of River Ajilosun

Variable		N	Correlation	Sig.
Pair 1	Channel Erosion (upper segment and Channel erosion (lower segment)	150	0.017	0.886

Source: Author's Analysis, 2019
This signified wide spatial variation in channel erosion between the upper and the lower segments of River Ajilosun

Table 4. Correlation coefficient of channel erosion and geomorphological parameters of River Ajilosun

Mcw	1.000						
Mcd	.421**	1.000					
Cc	.972**	.565**	1.000				
Ce	-.285*	-.091	-.270*	1.000			
Mcs	.383**	.129	.377**	.169	1.000		
Mgs	-.087	.103	-.063	-.206	-.032	1.000	
Vss	-.230*	-.324**	-.232*	-.232*	-.063	0.106	1.000
	Mcw	**Mcd**	**Cc**	**Ce**	**Mcs**	**Mgs**	**Vss**

*Source: Author's Analysis, 2019; Significant level ** = .01, *=.05*

Note: Mcw is Mean channel width of erosion; Mcd is Mean channel depth; Cc is Channel capacity; Ce is Channel efficiency; Mes is Mean channel slope; Mgs is Mean ground slope; Vss is Valley side slope

as a result of the variation in the intensity of urban development between and within each segment of the river. Also, the paired correlation coefficient (r = 0.017, fig = 0.886) of channel erosion between the two segments of the river (Table 2) indicated incomparable dimensions of the width of channel erosion in the river which further attests to the variation in the extent of channel erosion along and across the river's profiles.

3.2 Inter-relationship of Channel Erosion and Geomorphological Parameters of River Ajilosun

The Pearson Product Moment Correlation Analysis gives the correlation coefficients between the channel erosion and the geomorphological parameters of River Ajilosun Table 4 shows wide variations of association between the two groups of variables.

Mean channel width (Mcw) and channel capacity (Cc) exhibited very strong positive correlation (r = .972^{xxx}) with the channel erosion. Moderate positive correlation existed between mean channel depth (Mcd) and mean channel slope (Mcs) (r = .383^{xx}). Other positive correlations included between mean channel depth and mean channel width (Mcd/Mcw), mean channel width and mean channel capacity (Mcw/Cc), mean channel depth and channel capacity (Mcw/Mcd), mean channel depth and channel capacity (Mcd/Cc), valley side slope and mean ground slope (Vss/Mgs). The implication of the positive correlations is that positive improvement in either of the pair of parameters depicting positive relationship will bring about increase in the effect of one on the other.

Conversely, the pair of geomorphological parameters having negative relationship included valley side slope and channel efficiency (Vss/Ce), mean channel width and mean ground slope (Mcw/Mgs), mean channel width and valley side slope (Mcw/Vss), channel capacity and channel efficiency (Cc/Ce). Negative correlations also existed between mean ground slope and channel capacity (Mgs/Cc), mean ground slope and channel capacity (Mgs/Cc), mean ground slope and channel efficiency (Mgs/Ce), valley side slope and channel efficiency (Vss/Ce), mean ground slope and mean channel slope (Mgs/Mcs) and also between valley side slope and mean channel slope (Vss/Mcs).All the parameters had negative correlations with the valley slope except with the mean ground slope (Mgs).

The implication of the negative correlation between these pairs of parameters is that positive improvement in either of them will cause a decrease in the other. For instance, improvement in valley side slope will lead to reduction in the rate of channel erosion in the river's drainage basin. This is because much of the flood water in transit would have infiltrated and evaporated in the process of its movement over the space of the basin when the slopes have been properly managed. The negative correlation coefficient of channel efficiency with channel erosion implies reduction in channel erosion with increasing value of channel hydraulic efficiency. This is because water will be transported efficiently and this may reduce erosion of the channel.

The facts in Table 3 also show that Ajilosun basin's slope parameters correlate negatively with channel erosion in the basin. The interpretation of this is that as the terrain slopes reduce, the width of channel erosion in Ajilosun drainage basin may be expected to increase channel width erosion in River Ajilosun has therefore been characterized by variation across the space of the basin as a result of the influence of the geomorphological parameters of the basin on the channels.

However, it is important to note that channel capacity ($r=.972^{xx}$), channel depth ($r = .421^{xx}$) and mean channel slope ($r = .383^{xx}$) were the geomorphological parameters which established the highest and significant correlations with the channel width erosion in the drainage basin. Therefore, effective and sustainable management of channel capacity channel depth and the channel slope in the basin will go a long way in curtailing their negative impacts on channel erosion in the basin; and in lessening the various geomorphological problems they may generate.

4. SUMMARY AND CONCLUSION

The pattern of channel erosion in River Ajilosun in Ado-Ekiti, Nigeria exhibit variation both across and along the profiles of the river. There were both direct and inverse relationship between channel and geomorphological parameters of River Ajilosun. Mean channel width and channel capacity established the highest positive correlations with channel erosion in the river. Conversely, valley side slope and channel efficiency are the two geomorphological parameters which had the highest negative relationships with channel erosion in the river. Besides, there are also both positive and negative inter correlations among individual geomorphological variables. In conclusion, public enlightenment campaigns and environmental education are other necessary measures which could also play positive role in effective management of channel erosion in River Ajilosun.

5. RECOMMENDATIONS

Curtailing channel erosion in River Ajilosun in Ado-Ekiti requires proper management and improvement of the channel capacity. The capacity of the channel can be improved through dredging and concrete channelization of River osun. However, concrete channelization must embrace the natural sinuosity of the river channel. Improvement in the channel depth can also be achieved through deepening of the river course. Effective management of the slopes in River Ajilosun drainage basin will require prohibition of unlawful and indiscriminate destruction of the vegetal cover and particularly riparian bushes. In place of concrete surfacing of the surroundings of the residential units, short growing and creeping grasses can be grown to protect the ground surface from erosion.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Payne R. Sustainable Resources in Water Erosion Information Sheet; 1997. Available: www.soilpir.sa.gov.a
2. Cooke RV, Doorn Kamp JC. Geomorphology in Environmental Management: An introduction. Oxford University Press, Oxford. 1974;22-44.
3. Adebayo WO. The menace of erosion on the landscape of Ekiti State and the Necessary Remedial Measures. Journal of Contemporary Studies and Research. 2005;2(1):131-143.
4. Humphries P, Keckeis H, Finlayson B. The river wave concept: Integrating river ecosystem models. BioScience. 2014;64: 870–882.
5. Shen XH, Zou LJ, Zhang GF, Su N, Wu WY, Yang SF. Fractal characteristics of the main channel of Yellow River and its relation to regional tectonic evolution. Geomorphology. 2011; 127:64–70.
6. Bizzi S, Lerner DN. Characterizing physical habitats in rivers using map-derived drivers of fluvial geomorphic processes. Geomorphology. 2012;169(170):64–73.
7. Church M, Ferguson RI. Morphodynamics: Rivers beyond steady state. Water Resour. Res. 2015;51:1883–1897.
8. Lindenschmidt KE, Long JA. GIS approach to define the hydro-geomorphological regime for instream flow requirements using geomorphic response units (GRU). River Syst. 2013;20:261–275.
9. Carbonneau PE, Piégay H. Fluvial remote sensing for science and management; John Wiley & Sons, Ltd.: Hoboken, NJ, USA; 2012.

10. Wohl E. Rivers in the landscape: Science and management; Wiley-Blackwell: Hoboken, NJ, USA; 2014.
11. Oriye O. The impact of urban expansion on the landuses types of Ado-Ekiti, Nigeria. In Aribisala JO, Jemiriye TF, Adewole SO (eds.) University of Ado-Ekiti School of Post Graduate Studies PhD and Masters Thesis Abstracts. 2008;1997-2010: 50-51.

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