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Morphometric Parameters as Correlate of Flooding in River Ajilosun in Ado-Ekiti, Ekiti State, Nigeria

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Abstract
The paper examines the relationship between morphometric parameters and flooding in River Ajilosun in Ado-Ekiti in Ekiti State, Nigeria. Direct field measurement of some morphometric parameters of the river were carried out with the aid of tape measure, ranging pole and tie rod. Some data were also abstracted from the topographical map of the river on scale 1:50, 0000. This was in addition to some data which were generated through the systematic administration of 150 copies of structured questionnaire. The various data generated were subjected to descriptive statistics of the mean, standard deviation, range and percentages. This was also in addition to the use of Student's't' statistic for the testing of the hypotheses raised at 0.05 significant level. The outcome of the statistical analyses and the overall discovery of the study showed that the morphometric properties of the cross-sectional values of the width, depth and hydraulic radius vary spatially across and along the profiles of River Ajilosun. The result of the hypotheses revealed that channel width and channel depth dimensions exhibited spatial variation between the upper concrete-channelized and the lower non-concrete channelized (alluvial) reaches of the river. The result also indicated positive correlation values of channel depth and channel width with flooding in the river at 0.01 level. However, the hydraulic radius exhibit negative correlation with flooding and was significant at 0.05 level. The paper suggests wise modification of River Ajilosun channel, floodplain management and effective implementation of the urban planning regulation as some of the measures for controlling the effects of morphometry on flooding in River Ajilosun.

1.0 Introduction

Morphometry is defined as the measurement and numerical analysis of the configuration of the earth's surface and of the shape and dimensions of its landform (Areola, 1985). When used in respect of river channel, morphometry is concerned with the quantitative indices describing cross-section, long profile and plan geometry of a channel (Goudie et al, 1981). Flooding is a condition of excessive accumulation of storm flow rising to submerge an area of land which is normally dry. When such accumulation takes place in a river channel, it is aptly referred to as channel flooding. River or channel flooding was defined by Ward (1978) as a situation in a river channel were water flow exceeds the confinement of the channel thereby overtopping the banks and spilling on to the adjacent areas of the channel.

Morphometric parameters of a river channel may exercise control and influence on the pattern and characteristic of flooding in the river. Parameters of channel depth, channel width and hydraulic radius are examined in the paper to assess their relationship with, and effect on flooding of River Ajilosun in Ado-Ekiti in Ekiti State.

With the recent global warming scenario and concomitant climatic change more instances of river flooding have been recorded in the last one decade (Tell, 2011). Flooding remains both natural and anthropogenically induced phenomenon with the most ubiquitous environmental hazard militating against human survival. The impact of flooding is particularly more lethal and pathetic in the less economically developed countries like Nigeria. In order to save millions of lives from imperil and protect properties from wanton destruction, role of morphometric properties of river need to be studied in order to assess its effect on the occurrence and control of flooding. This is because specific morphometric relations within a river channel may play determinant role in the distribution of water flow and its evacuation from a river's drainage area.

In line with the foregoing, the paper assesses effect of channel depth, channel width and hydraulic radius of River Ajilosun on characteristics of flooding of the river. The paper also makes suggestions for ensuring sustainable measures for the management of flooding in River Ajilosun in Ado-Ekiti Ekiti State.

2.0 The Study Objectives

The main objective of the paper is to assess the relationship between flooding and the morphometric parameters of River Ajilosun channel such as width, depth and hydraulic radius. The paper also examines the relative contribution of each of the three morphometric parameters to the occurrence of flooding in River Ajilosun. Recommendations for effective control and management of flooding in the river drainage area are put forward.

3.0 Conceptual Considerations

River's morphometric parameters of channel depth and channel width exert important influence on flooding potentials of a river (Adebayo, 1987; Ebisemiju, 1993; Arohunsoro, 2011). Many researchers amongst whom some have just been sited have demonstrated the impact of morphometric variables on river channel flooding. For instance, Olaniran (1983) demonstrated that the length of a stream segment determines the geometric relations of the channel to flooding of the stream. Adebayo (1987) also described a positive relationship between channel depth and width of flooding in some streams in Ado-Ekiti, in Ekiti State. Similarly, positive regression coefficient was found between flooding and width of channel in River Ajilosun in Ado-Ekiti (Arohunsoro, 2011). Both the depth and channel of a river determines the hydraulic radius and hence, efficiency of channel in transporting flows and debris out of the entire fluvial system (Knapp, 1979; Pritchard, 1979). However, the effect of these parameters and their relative contribution to flooding has not been specifically considered in River Ajilosun in Ado-Ekiti. Besides, the application of the advance statistical technique to such a study has not been done for the river. It has been empirically established that channel depth which are twice the width are more particularly efficient in evacuating water out of the river system (Sparks, 1975; Pritchard, 1979; Adebayo, 1987).

The hydraulic radius of a river channel determines the efficiency of the channel in the transportation and evacuation of runoff from the entire fluvial system. The hydraulic radius is related with the channel depth and channel width through a linear mathematical model. The model links these two variables with the wetted perimeter of the channel; the wetted perimeter is defined as the section of a river channel which is in constant contact with water.

Thus in symbolic terms;

$$R = \frac{A}{Pw} \quad \ldots\ldots (1)$$

Where R is hydraulic efficiency;

$$A = w \times d \quad \ldots\ldots (2)$$

$$Pw = 2d + w \quad \ldots\ldots (3)$$

Where A = Channel Area;
Pw = Wetted perimeter of the channel;
W = Channel width;
D = Depth of channel.

It follows therefore, that the hydraulic efficiency of a river may vary in line with the variability of the depth and width of a channel. This paper therefore considers river channel forms or geometry as germane to our understanding of the occurrence of floods in River Ajilosun. Besides, the present study also recognizes morphometry factors as crucial in comprehending the dynamics of river flooding.

4.0 The Study Area

River Ajilosun is located in Ado-Ekiti in Ekiti State within Latitudes $7^{0}35^{1}$ and $7^{0}38^{1}$ North of the Equator and Longitudes $5^{0}10^{1}$ and $5^{0}15^{1}$ East of the Greenwich Meridian (Fig 1). The river runs in North-East and South-West directions of the city. It is the river with the largest drainage basin among the ones that originate within the settlement. The river forms part of the upper catchment of the larger Ogbese drainage basin. The river has total channel length of 40.11km, a drainage density of 1.90km/km^2 and a stream frequency of 1.26 streams/per km (Arohunsoro, 2011). River Ajilosun drains an area of 18.125km^2. Some other morphometric properties of River Ajilosun drainage basin are shown in Table 1.

Table: 1 Morphometric Parameters of River Ajilosun Drainage Basin

Morphometric Parameter	**Value**
Area	18.125km^2
Perimeter	16.05k
Basin length	4.70km
Relief ratio	0.72km
Elongation ratio	0.19
Circulation ratio	0.88
Basin form	0.82
Total channels length	40.11km
Number of 1st order channels	22
Number of 2nd order channels	5
Number of 3rd order channels	2
Number of 4th order channels	1
Drainage density	1.90km/km^2
Mean bifurcation ratio	3.0

Source: Author's calculations from the topographical map of the drainage basin.

Due to Rapid spate of urbanization, the longitudinal and cross-sectional profiles of River Ajilosun have undergone series of alterations and modifications in their geometric relations in the recent time. The population of Ado-Ekiti grew by as much as 83% between 1963 and 2006 (Table 2).

Table 2: Ado-Ekiti Population Growth 1963-2030

Year	Population	Land Area
1963	261,465	2.5km^2
1966	120,855	6.9km^2
1991	149,472	Not Available
2006	308,621	36.7km^2
2030	1,111,953*	134.7km^2

Source: Oriye, 2008 *Projected Figure

The rapid growth in the population of the city has brought about an upsurge in the spate of human interactions with the fluvial system of the river's basin. Within the river basin, area of imperviousness has increased as typified by about 64.8% physical growth in urbanization of the (Arohunsoro, 2011).

The climate of River Ajilosun is the microcosm of the climatic regime of Ado-Ekiti. The city enjoys the tropical climate characterizes by the rainy and dry seasons. The location has an annual rainfall totals varying between 1200mm and 1400mm. The period of rainfall maxima are in June and September. Rainfall is highly intensive and intensely localized. Eighty (80) percent of the rainfall in the settlement is concentrated between June and October.

Geologically, River Ajilosun drainage basin consists of the ancient granite and metasedimentary formations. About 86.21% of the area drained by River Ajilosun is underlain by the coarse-grained-charnockite rocks. Interspersed within the predominant rock suite is the quartz forming 4.14%. The medium-grained-biotite-hornblende-granite constitutes about 2.07% while the recent alluvial deposits made up 7.58% of the basin area.

Along the river are found riparian bushes dominated by rhizomes, canna plant and the elephant grasses. These bushes occasionally obscure the river channel at intermittent sections along its course. The soils are ferruginous and they are derived from the basement complex rocks. However, the chemical weathering of the predominant rock suite produces silty-sand texture. This soil is non-plastic, non-coherent and highly erodible (Adeduro, 1993; Arohunsoro, 2011). Hydromorphic soils showing greyish to whitish appearance are found along the part of the river channel which is constantly in touch with water.

Landuses within River Ajilosun drainage basin consist predominantly of the residential, commercial, transportational and institutional types. However, relatively few patches of land are devoted to recreational and sporting uses while wet points and fish cultivation are aspects of agricultural landuse in the drainage basin.

5.0 Method of Investigation

Data were derived from both the primary and secondary sources. The data on channel width and channel depth were obtained from direct field work by carrying out systematic measurements of these variables at every 10metres along longitudinal profile of River Ajilosun. The data on flooding were also generated through direct field measurement. The third variable hydraulic radius was derived mathematically from the channel width and channel depth.

The data on channel width was collected by using a tape measure and ranging pole. Measurements were taken with the help of two researcher assistants, one holding one end of the tape at one end and the other taking charge of the other end. The Tape was a held against the ranging pole in order to prevent the sagging of the tape (see figure 2).

Measurement of channel depth was also done with the tape measure and the ranging poles. The depth was taken at different points along the cross-sectional profile of the river. The average value of the measurements was then taken to arrive at the mean channel depth (Fig 3). The hydraulic radius was mathematically derived from the relationship between channel depth and channel width as in equations 1, 2 and 3. Width of flooding was measured with the tape measure. It was defined as the length over which floodwater travels from the river bank to respective houses along River Ajilosun. Occupants of the houses sampled were asked about the extent to which flood travels during rains, and such distances were then measured in other to obtain the length covered by the floods.

The data generated on the drainage basin indices were obtained from the topographical map of the basin, sheet 244NE on scale 1:50,000. Calculations of the percentage composition of the basin underlain by different rock types were carried out on the geological survey map of Ado-Ekiti region carried out by Adeduro (1993).

Analysis of the various data was done using the descriptive and inferential statistical techniques. The descriptive techniques used include the mean, range, standard deviation and percentages of the data sets while the Pearson's correlation coefficient was employed in the computation of the relationship between flooding and the morphometric parameters of River Ajilosun. The linear regression was also performed of the morphometric parameters of the river's channel and spatial extent of flooding. This was done in order to determine the relative contribution of the parameters to flooding of the river.

6.0 RESULTS AND DISCUSSION

6.1 Questionnaire Analysis

Out of the 150 respondents (landlords) interviewed, 43.33% were males while 56.67% were females. 60.0% were married while 40.0% were single. The ages of the respondents varied between 20 and 80years. 26.0% of the respondents had either National Certificate of Educational or National Diploma qualification, 43.3% held professional certificates while 31.7% had higher certificates of either Masters or Doctorate. The occupational distribution of the respondents revealed that 12.0% of them were into farming while 19.3% were also engaged in more than on type of job at a time. With the higher percentage of the respondents having higher education one expects a better understanding of the environment by the inhabitants of the Ajilosun drainage basin.

6.2 Descriptive Statistic of the Morphometric Parameters of River Ajilosun

Table 3 shows that the mean values of the morphometric parameters vary between the upper and the lower reaches of River Ajilosun. While the mean value of channel depth in the upper reaches was 1.35±0.22 meters, in the lower reaches it was 1.66metres. Channel width dimensions varied between 2.95metres and 3.84 meters in the upper segment with a mean value of 3.39metres, while the mean in the lower segment was 8.37±2.26metres.

Table3: Descriptive Statistics of the Morphometric Parameters of River Ajilosun

Variable SE			N	Mean	SD	**95% confidence interval for mean** Lower limit	 Upper limit
Channel depth	Upper segment		1.35	0.22	0.03	1.30	1.40
	Lower segment	150	1.66	1.06	0.12	1.42	1.91
Channel width	Upper segment		3.39	1.92	0.22	2.95	3.84
	Lower segment	150	8.37	2.26	0.26	7.85	8.89
Hydraulic radius	Upper segment		2.15	1.25	0.14	1.86	2.44
	Lower segment	150	1.16	0.47	0.05	1.05	1.27

Source: Output of Computer Analysis of Data
Table at 0.05 level of significance.

The hydraulic radius also exhibited disparities in their values between the upper and the lower segments of the river. The parameter ranged from 1.8metres and 2.44metres in the upper segment with an average value of 2.15metres. However, in the lower segment of the river, it was 1.16±0.47 metres. The implication of this is that the morphometric parameters of River Ajilosun varied spatially along and across the profile of the river. The variation in the morphometric parameters may have reflected in the differences of the spatial extent of flooding along the longitudinal profile of River Ajilosun.

6.3 Relationship of Flooding and Morphometric Parameters in River Ajilosun
The result of analysis in Table 4 showed that the flooding established positive correlation with the mean channel depth (.421**) which is significant at 0.01 level. The implication of this is that positive improvement in channel will cause an improvement in the flooding situation in River Ajilosun. Improvement in flooding signifies reduction in the spatial extent of flood inundation in the drainage basin. For instance, with greater dimension of channel depth relative to the dimension of the width, more flood water can be accommodated thereby reducing the lateral migration of flood water. The coefficient of determination (R^2) of the mean channel depth showed that about 18.0% of the variances in flooding is explained by the variation in the mean channel in River Ajilosun.

Table 4: Correlation and R^2 Values between Morphometric Parameters and Channel Flooding in River Ajilosun

	M_{cw}	M_{cd}	H_r
M_{cw} 'r'	1.000	.421**	-.285*
r^2	1.000	0.177	0.081

Source: Output of Computer Analysis of Data
Significant level **.10, *.05
Note: M_{cw} is Mean channel width
M_{cd} is Mean channel depth
H_r is Hydraulic radius (efficiency)

The hydraulic efficiency is negatively correlated with flooding (r = -.285) which is significant at 0.05 level. The negative correlation of hydraulic radius with flooding indicates greater efficiency of the channel to transport and evacuate flood water. The coefficient of determination showed that 8.10% of the variation in flooding in the drainage basin can be explained by the variances in the hydraulic radius and hence, the hydraulic efficiency of the channel.

6.4 Relative Contribution of Morphometric Parameters in River Ajilosun.
The result of the analyses in Table 5 revealed that the channel width (t=2.263, p<0.05) and hydraulic radius (t=-2.237, p<0.05) were significant factor for explaining the variation in flooding on River Ajilosun; but channel depth (t=6.131, p<0.05) was not. There was a direct relationship between channel width and the spatial extent of flooding which suggest the greater dimension of width of flooding would associate with greater dimension of channel width. Meanwhile, channel width contributed about 6.0% (b=6.3) of the total variances in the width of flooding in River Ajilosun. However, channel depth and width and hydraulic radius made -1.0% (b= -1) contribution each to the explanation of the variance in channel flooding in the river. However, channel depth and hydraulic radius exhibited inverse relationship with the width of flooding in River Ajilosun. The implication of this is that improvement in channel depth and hydraulic radius will attenuate the extent of flooding of River Ajilosun. This is quite reasonable since greater depth of channel will provide more space for accommodating flood water.

Table 5: Relative Contribution of the Morphometric Parameters to Flooding in River Ajilosun

Variable	B	STD ERROR	BETA	T	SIG
Channel width	6.3E-015	0.046	.146	2.263	*** . 000
Channel depth	-1E-014	0.050	- .272	-6.131	. 286
Hydraulic radius	-1E-015	0.313	- .084	-2.237	*** . 003

Source: Output of Computer Analysis of Data
*** Significant at P < 0.05

In addition to this, higher values of hydraulic radius portend greater hydraulic efficiency of channel in the evacuation of floodwater out of the fluvial system. This is in line with the theoretical proposition that channels having depth more than the dimension of their width exhibit greater efficiency of water transportation. (Gregory and Walling, 1976; Pritchard, 1979; Knapp, 1981).

The hydraulic (efficiency) of River Ajilosun accounted for about 18..0% explanation of the variances in the width of flooding. The negative sign of the regression co-efficient confirms the negative correlation coefficient between the two variables. The inverse relationship implies that positive improvements in the hydraulic radius and hence, the hydraulic efficiency of River Ajilosun channel will reduce the occurrence of flooding in the drainage basin. Such improvement could be in terms of dredging (widening and deepening) of the channel. As part of efforts to enhance floodwater transportation through enhanced efficiency of channel, any avenue for indiscriminate disposal of refuse inside river channels must be discouraged illegal disposal of wastes in river channels will only obstruct free flow of floodwater, causes braiding of water in streams and resultantly increase spatial extent of flooding. This finding was in line with the findings of some reseachers (Akintola, 1981; Rashid, 1982; Adebayo, 1987; Adebayo and Jegede, 2010; Arohunsoro, 2011).

7.0 Summary and Conclusion

This paper has shown that morphometric parameters of channel width, channel depth and hydraulic radius exhibited spatial variation along the longitudinal profile of River Ajilosun. The dimensional values of the parameters increase progressively from the upper reaches towards the lower reaches of the river. Channel depth established positive correlation with flooding. The hydraulic efficiency is indirectly correlated with flooding and this is significant at 0.05 levels.

The relative contribution analysis of the morphometric parameters revealed that channel width and channel depth are the two morphometric factors making most significant contribution to spatial variation in the flooding of River Ajilosun. Thus effective control of flooding in River Ajilosun required proper management of the channel depth and channel width.

8.0 Recommendations

In order to effectively control effect of channel morphometry on flooding in River Ajilosun there is need to put up the following measures.

(i) Further concrete-channelization of River Ajilosun should be carried out. An extension of the project is desirable beyond the where it presently terminates behind the cross of salvation church at Ajilosun street. Subsequently concrete channelization of the river must put the natural sinuosity of the channel into consideration. When channelization follows the natural winding course of a river, runoff flow, flooding and its erosive effect are substantially attenuated. The riparian bushes along the river banks must be conserved and protected against degradation. This is because they provide stabilizing effect on the channel bank soils; this will help to keep erosion and channel in-caving in check.

(ii) Construction of concrete embankments should be carried out to keep floods out of the area of human habitation along the River Ajilosun valley. The measure will also keep indiscriminate degradation unnecessary expansion of the channel width in check.

(iii) There is the need to control the parting of urban development in River Ajilosun drainage basin, particular in the floodplains in Atikankan, Odo Aremu, Odo Ugbehin, Odo Otu etc. when the floodplains are kept out of construction works, the natural role of the floodplains in storing excess surface and channel flow during storm will be sustained. Prohibition of construction of buildings in the floodplains will also improve the hydraulic efficiency of River Ajilosun channel. Also, controlled urban development through enforcement of the building codes on every developer will prevent unnecessary interference with the hydrological and fluvial equilibrium of the channel.

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