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MORPHOMETRIC ANALYSIS OF URBANIZED SUB-DRAINAGE BASINS OF ASA RIVER CATCHMENT IN ILORIN, NIGERIA

*Iroye, K.A. and Sodipo O.A.

ABSTRACT

This research work analysed morphometric properties of four urbanized sub-drainage basins of Asa river catchment in Ilorin. Data for the study were generated from Ilorin North West topographical sheet. The extracted data were subsequently subjected to various statistical analyses. Results obtained indicate that the studied basins exhibit high variability in values of morphometric parameters. Correlation matrix generated reveals that basin area exercises a tremendous influence on other morphometric parameters. The study thereafter recommended a number of ways towards reducing environmental disaster of flooding induced by basin characteristics.

INTRODUCTION

There are different ways by which the physical characteristics of drainage basins can be expressed and an equal variety of methods that can be used to explain the processes operating within the basins (Gregory and Walling 1973). Relationship between these two according to Morisawa (1959) is required to assist in the explanation and prediction of processes within the basins, and to indicate changes over time past and future.

Measurements of basin characteristics can be traced back to mankind's early history; for example, measurements by the Egyptians appeared and developed from the necessity to reconstitute the boundaries separating estates which were wiped away by each flood of the Nile (Zavoianu, 1985). These measurements were encouraged by a desire to manage water resources. Detailed study of drainage basin morphology was however given its impetus by the work of an hydrologist, Robert E. Horton whose 1945 paper has since become a classic. In the study, Horton (1945) demonstrated that drainage basin and its network could be dissected and its component studied on a stream ordering basis. Horton (1945) stream ordering system has benefited considerably the genetic explanation of hydrological phenomena and the establishment of laws of development for river networks (Zavoianu, 1985). The main purpose of Horton's work was to discover holistic stream properties from the measure of various stream attributes (Pidwimy, 2006). Horton (1945) work was later modified by Strahler (1964) who classified the morphometric features of the erosional drainage basin into linear, areal, relief and gradient attributes (Chorley et. al., 1985).

Basin characteristics to a great exercise a profound influence on basin processes. Rates of catchment runoff, erosion, siltation, sedimentation etc have been linked to the geomorphic characteristics of drainage basins (Jain and Sinha, 2003; Ogar and Anyorah, 2003; Adeniji and Jeje, 2004; Nabegu, 2005; Iroye, 2008). For example, basin area has been discovered to influence, greatly a river's discharge pattern (Pitlick, 1994). The larger the basin the greater the

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basin the greater the volume of rainfall it intercepts, and the higher the peak discharge that results (Kirkby, 1976). Other catchment parameters which affect basin hydrology include stream length, basin slope, drainage density etc. These parameters affect catchment stream flow through varying effects on lag time.

For efficient basin management therefore, forms of basins needs to be investigated. This will only aid in the understanding of processes which operates with the basin, but will also assist in developing appropriate management techniques which can be adopted in reducing environmental and land degradation problems such as flooding, desertification and erosion being witnessed in different parts of the globe.

STUDY AREA

Ilorin, the capital city of Kwara State, Nigeria is the study area for this investigation (Fig. 1) Ilorin lies on latitude $8^{\circ}30'N$ and longitude $4^{\circ}35'E$. The city has humid tropical climate and it is characterized by wet and dry seasons (Ilorin Atlas, 1981).

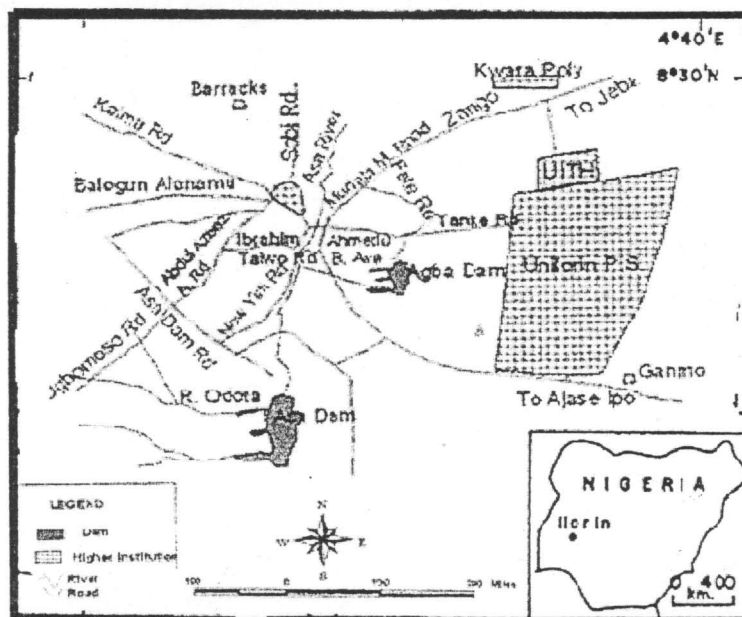


Fig. 1 Map of Ilorin, showing the study area

Wet season in the town begins towards the end of March when Tropical maritime airmass is prevalent and ends in October, often abruptly. Dry season in the town begins with the onset of Tropical continental airmass which is predominant between the months of November and February. The mean annual total rainfall for Ilorin is 1200mm (Olaniran, 2002). Analysis of rainfall values for the town shows that rainfall scarcely occur in the months of January, February, November and December (Oyegun, 1983). Rainfall concentration is usually between the months of March and October, exhibiting double maxima rainfall pattern with peak periods in the months of June and September and a period of dry spell in July. Temperature in the town is uniformly high ($25^{\circ}C - 28^{\circ}C$) and open-air

insolation can be very uncomfortable during the dry season (Oyegun, 1983). Evaporation values in Ilorin range between 3.1mm and 7.8mm while potential evapotranspiration is usually highest in January. Ilorin is covered mainly by ferruginous tropical soil on crystalline acidic rock (Areola, 1978). The soil type has both sandy and clayey deposits lying on each other. The city is drained mainly by River Asa, tributaries of which form the four sub-drainage basins under this investigation (Fig. 2)

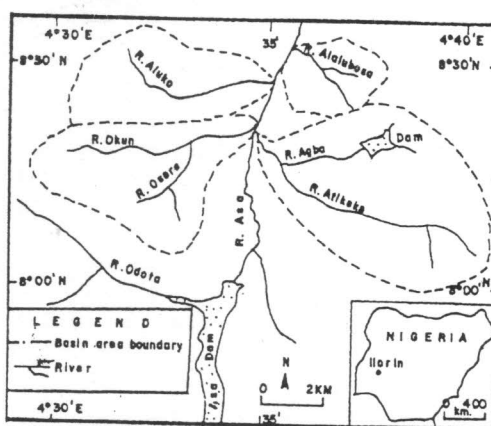


Fig. 2. Map of Ilorin, showing the four drainage basins as the study area
Source: Oyegun (1986)

METHODOLOGY

Data used in this study are basically secondary in nature. These were data on morphometric parameters of the studied basins computed from topographical map. Though Morgan (1971) suggests the use of large scale topographical map such as 1:25,000 for a study of this nature, the computations in this study were carried out on Ilorin North West topographical map, sheet number 223 of scale 1:50,000. This is the only map available for the study area. The computations were however, carried out only after the necessary corrections were made on the map following the methods suggested by Morisawa (1959). Adeniji and Jeje (2004); Ifabiyi (2004) and Iroye (2008) have used maps of similar scale with high degree of success.

In all, eleven morphometric parameters categorised into three broad groups of area, linear and relief were studied. The choice of these parameters was based on findings from previous studies which have found them to be highly correlated with peak discharge, runoff volume and sediment yield (see Doornkamp and King 1971; Gregory and Walling, 1973). Procedure adopted in computation of the variables is as presented on Table 1.

Table 1: Computed Morphometric Variables and Derivation Procedures

Category	Parameter	Derivation procedure
Area	Basin area	Area = map scale x counted squares (Gregory and Walling, 1973).
	Circulatory ratios	$R_c = 4 \pi A/2$ where R_c = circulatory ratio, A = basin area and π = constant (Miller, 1953)
	Bifurcation ratio	$R_b = N_u/N_{u+1}$ R_b = bifurcation ratio, N_u = Number of stream in the order u and N_{u+1} = Number of stream in the next higher order (Gregory and Walling, 1973)
	Drainage density	$DD = \sum L/A$; where DD – Drainage density, $\sum L$ = sum of all stream lengths and A = Basin area (Horton, 1932)
	Number of stream	$\sum N_u$; where N_u is the stream number and $\sum$ = sum (Strahler, 1952)
	Leminiscate ratio	$K = L^2/4A$ where L = length of the basin and A = Area of the basin (Schumm, 1956)
	Stream frequency	$S_f = \frac{N_u + N_{u+1} + N_{u+2}}{A}$ where S_f = Stream frequency, N_u = Number of stream in order 1, N_{u+1} = Number of streams in order 2 and N_{u+2} = Number of streams in order 2 (Strahler, 1952)
Linear	Basin length	This is the straight line from the mouth of the basin to the farthest point on the basin perimeter. (Schumm, 1956)
	Total stream length	This is the total length of all the tributaries and the principal drainage (Schumm, 1963)
	Main stream length	This is the length of the principal drainage line (Schumm, 1963)
Relief	Basin slope	$B_s = VI/HE$ where B_s = basin slope, VI = vertical interval and HE = horizontal equivalent (Schumm, 1963)

Source: Author's compilation (2011)

OBSERVATIONS AND DISCUSSION

Morphometric characteristics of the studied basins

Table 2 shows the computed morphometric properties of the studied basins.

Table 2: Basin Morphometric Properties

Morphometric variables	Agba	Alalubosa	Aluko	Okun	Total	X	SD	CV
Basin area (sq/km)	22.68	6.83	11.33	14.98	55.82	13.95	5.81	41.65
Circulatory ratio	0.85	1.14	0.68	0.66	3.33	0.83	0.192	23.13
Drainage density	0.59	0.43	0.38	0.54	1.94	0.49	0.114	25.27
Total number of streams	7	3	1	4	15	3.75	2.16	57.6
Leminiscate ratio	0.547	0.27	0.54	0.63	2.01	0.5	0.136	27.2
Stream frequency	0.31	0.42	0.09	0.25	1.07	0.26	0.119	45.76
Basin length (km)	7.38	2.79	5.23	6.31	21.71	5.43	1.7	31.31
Total stream length (km)	13.33	3.2	4.46	8.2	29.19	7.29	3.938	54.02
Main stream length (km)	6.82	2.37	4.46	5.7	19.35	4.84	1.662	34.34
Basin slope (0°)	0.46	0.48	0.45	0.35	1.74	0.44	0.05	11.36

Source: Author's finding (2011)

Key: $\bar{x}$ = Mean, CV = Coefficient of variation, SD = Standard Deviation

As evident from this table, there are wide disparities in the basin's physiographic properties. The four studied ranged in size between 6.83 and 22.68sq.km, while the basin length ranges between 2.79 and 7.38km. The total stream length for the smallest basin is 3.2km, while that for the largest basin is 13.33km. The four studied basins have a total stream length of 29.19km and occupies a total land area of 55.82sq.km. Drainage density in the studied basins range from 0.38 to 0.59, with a mean value of 0.49. This variable is of high significance in this study. Drainage density reflects the topographic, lithographical, pedological and vegetational controls. Drainage density determines the speed of catchment runoff with its consequence effects on flooding sedimentation erosion. Basin slope which controls the vertical movement of water by infiltration and lateral movement of water by interflow range from 0.35 to 0.48. The standard deviation of the morphometric properties of the studied basins range between 0.114 and 5.81, while the coefficient of variation of the morphometric properties range from 11.36 to 57.6. Total number of stream segments exhibits the highest variability while basin slope exhibit the least variability.

Interrelationship Between the Studied Morphometric Parameters

Table 3 shows the correlation matrix generated between the studied parameters. The matrix enabled an understanding of the relationship existing between the studied variables and the type and extent of their relationship.

Table 3: Correlation matrix of the studied parameters

	Basin slope	Circulatory ratio	Drainage density	Total number of stream	Leminiscate ratio	Stream frequency	Basin length	Total stream length	Main stream length	Basin slope
Basin slope	1									
Circulatory ratio	-0.41	1								
Drainage density	0.84	-0.13	1							
Total number of stream	0.82	0.12	0.94	1						
Leminiscate ratio	0.71	-0.92	0.50	0.27	1					
Stream frequency	-0.10	0.85	0.34	0.49	-0.63	1				
Basin length	0.94	-0.69	0.74	0.62	0.90	-0.37	1			
Total stream length	0.98	-0.29	0.91	0.90	0.63	0.06	0.89	1		
Main stream length	0.95	-0.64	0.78	0.67	0.88	-0.31	0.99	0.92	1	
Basin slope	-0.20	0.69	-0.36	-0.03	-0.69	0.28	-0.43	0.19	-0.42	1

Source: Author's finding (2011)

The varieties of relationship and the results obtained from the matrix can be summarized as follows:

- i. Only total number of streams does not exhibit negative relationship with any of the studied parameters
- ii. The highest positive correlation coefficient observed is between mainstream length and basin length ($r = 0.99$), followed by that between total stream length and basin area ($r = 0.98$)
- iii. Other high positive correlation ($r \geq 0.90$), apart from the highest two quoted above, are those observed between mainstream length and basin area ($r = 0.95$), total number of stream and drainage density ($r = 0.94$), basin length and basin area ($r = 0.94$), mainstream length and total stream length ($r = 0.92$), total stream length and drainage density ($r = 0.91$), total stream length and total number of streams ($r = 0.90$), and basin length and lemniscate ratio ($r = 0.90$).
- iv. The lowest positive correlation ($r = 0.06$) as between total stream length and stream frequency
- v. The matrix also shows that more than seventy percent ($>70\%$) of the total parameters investigated exhibits positive relationship
- vi. Basin slope exhibits the highest number of negative relationship with other parameters: with the two lowest negative correlative observed with total stream length (-0.19) and basin area (-0.20).

The above observations can be explained thus:

- i. The highest positive correlation coefficient observed between basin length and basin area is expected. This is because, the bigger the basin, the longer its length; previous studies such as Gregory and Walling (1973), Pilgrim et. al., (1982) and Jain and Sinha (2003), have observed similar result. This relationship is what influenced other results such as high correlation between mainstream length and total number of stream and between basin length and lemniscate ratio.
- ii. The lowest positive relationship observed in the matrix between total stream length and stream frequency is due to the fact that the study area is poorly drained. This fact can be supported with the case of Aluko drainage basin which covers a land area of 11.33sq.km and the basin is only drained by a single river. The entire study area covers a total area of 55.82sq.km is drained by only fifteen (15) streams; ten (10) in the first order, four (4) in the second order and one (1) in the third order.
- iii. The negative correlations between basin slope and basin area, drainage density, lemniscate ratio, basin length, total stream length and mainstream length are understandable. The bigger the basin the longer its length; and the longer the basin length, the lower its slope. Thus this relationship exists because most of those parameters hitherto mentioned are in one way or the other related to basin area.

Implication of Research Findings for Environmental Management in the Study Area

Though, most of the studied parameters do not on their own cause degradation activities within the basins, they do to a very large extent influence other catchment characteristics such as climate, soil, vegetation and even land use pattern, to influence basin processes which can emanate in form of flooding, sedimentation and erosion. While basin slope can influence the rate of stream discharge within a catchment, drainage density and shape of a basin do exercise tremendous control on the amount and rate of runoff from a catchment area. Gregory and Walling (1978) observed that basin area has an outstanding dominance on the explanation of catchment response pattern. This variable has been described as "devils variables". This is because, the larger the basin, the higher the volume of runoff that is generated since the area contributing to runoff will be large. The implication of this in this research is that runoff in large basins such as Agba and Okun should be put under control and management to prevent flooding. This action can be carried out through the construction of micro dams on Rivers Agba and Okun to regulate the speed and volume of runoff in the basins.

Another way to go about controlling runoff volume is through afforestation programme. Trees can be planted in these basins. When this is done, infiltration activities will be promoted and volume of runoff from such catchments will be drastically reduced. Previous studies such as Atoyebi (1995), Jimoh (1997) and Ifabiyi (2000) have demonstrated the important role different vegetation types play in influencing infiltration process. Runoff discharge in a basin such as Alalubosa with high slope can also be managed through afforestation programme and micro-dam construction.

CONCLUSION

The destructive effects of extreme meteorological events and human induced environmental hazards are increasingly affecting numerous watersheds globally. As drainage basins become urbanized, rates of environmental hazards such as flooding, soil erosion, river siltation etc increases. While most of the hazards results from human activities, especially the replacement of natural vegetation with artificial surfaces; others are caused by natural factors of extreme hydro-climatic events encouraged by nature of basin physiographic properties. These actions usually result in basin degradation process. While attempts are being currently made globally to control human negative influence on the environment; man's ingenuity should also be applied in controlling these natural factors such as nature of basin physiography which negatively encourage degradation process.

Effective and efficient basin management however calls for not only the understanding of the relationship between morphometric parameters but also the roles of other catchment controlling variables such as landuse, soil, geology, climate etc. This effort will not only aid in controlling basin runoff discharge but will also assist in reducing rates of natural disaster induced by erosion and sedimentation in the basins.

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