Morphometric Analysis of Ogunpa and Ogbere Drainage Basins, Ibadan, Nigeria.

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Abstract

The paper analysed the morphometric parameters of Ogbere and Ogunpa drainage basins located on basement complex rock in Southwestern Nigeria. Data used were generated from topographical map of Ibadan North-east on scale 1:25,000 published by Federal Survey of Nigeria (1975). Result obtained indicated that studied basins exhibits high spatial variation in their morphometric properties. The study further revealed that morphometric properties of Ogunpa drainage basin are likely to induce high magnitude flood compared to morphometric properties of Ogbere drainage basin. The study thus suggested a number of management practices that can be used in reducing rates of environmental degradation in the basins.

Introduction

Morphometry represents the topographical expression of land by way of area, slope, shape, length, etc. These parameters affect catchment streamflow pattern through their influence on concentration time (Jones, 1999). The significance of these landscape parameters was earlier pointed out by Morisawa (1959), who observed that stream flow can be expressed as a general function of geomorphology of a watershed. The assertion still stand valid following Jain and Sinha (2003), Okoko and Olujimi (2003) and Ifabiyi (2004) who reported that the geomorphic characteristics of a drainage basins play a key-role in controlling the basins hydrology. Morphometric analysis of drainage basins thus provides not only an elegant description of the landscape, but also serve as a powerful means of comparing the form and process of drainage basins that may be widely separated in space and time (Easterbrook, 1993).

In the early days, most basins were described as well-drained or poorly drained or they were connoted descriptively in the Davisian scheme as being youthful, mature or old (Gregory and Walling, 1973). The mechanics of how river channels actually form within a basin and how water gets into the channels was only understood in vague terms by both geologist and hydrologists. Measurement and quantitative expression of drainage basin began with the work of James Hutton in 1775. Subsequently, a great step forward was made by Horton (1932) when he crystallized previous works added new measures and proposed general methods for the description of drainage basins characteristic (Gregory and Walling, 1973). Since then, mathematical analysis of drainage basin has been a subject of considerable analysis, both in temperate region (Schumm, 1954; Morisawa, 1959; Sokolov, 1969; Gregory and Walling, 1973; Gardiner, 1975) and in humid tropics (Hewlett and Hibbert, 1967; Ebisemiju, 1976; 1979; Nwa, 1979; Adejuwon et. al 1983; Ayandike and Phil-Eze, 1989; Ifabiyi, 2004).

However, morphometric characteristics of drainage basin exhibit spatio temporal variation, hence the need for detail investigation of basin characteristics, not only from one area to another, but also from time to time. This is because, the form of a basin in terms of its morphometric characteristics determine the processes operating in such a basin. This form-process relationship according to Gregory and Walling (1973) produced a temporary dilemma in geomorphological investigation either in the study of form or process.

In this work, forms of basins were investigated with a view to understanding the processes operating within them. These kinds of efforts are expected, not only to provide understanding for the past, but also to help in estimating the future and for application to hydro-geomorphic phenomena currently operating in the basins (Carlson and Krikby, 1971). Thus, the result from this investigation will aid in suggesting management techniques that can be adopted in ameliorating land degradation problems being caused by processes operating in the studied basins.

Study Area

The study area in this investigation is Ibadan, the capital city of Oyo State in south-western Nigeria, using Ogunpa and Ogbere river basins as data collecting points (Fig. 1). Ogunpa drainage basin is located at the south-eastern corner of Ibadan city between longitudes $3^0 52'$E and $3^0 36'$E and between latitudes $7^0 22'$N and $7^0 26'$E while Ogbere

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drainage basins is located in the south-western part of Ogunpa drainage basin between longitude $3^0 55'$E and $3^0 58'$E and between latitude $7^0 19'$N and $7^0 27'$N. The two basins are situated on a rugged relief (Fig. 2) in the tropical rain forest of Nigeria occupying an area of 40.75sqkm and 52.88sqkm respectively. The basins are covered mainly by ferruginous tropical soil on basement complex rock (Areola, 1978). The two basins are built-up as a result of urbanization process, which is fast replacing the natural vegetation in the basins with artificial paved surfaces with consequent effects on runoff production and sediment generation. (Akinola, 1966, Akintola, 1974; Faniran, 1991).

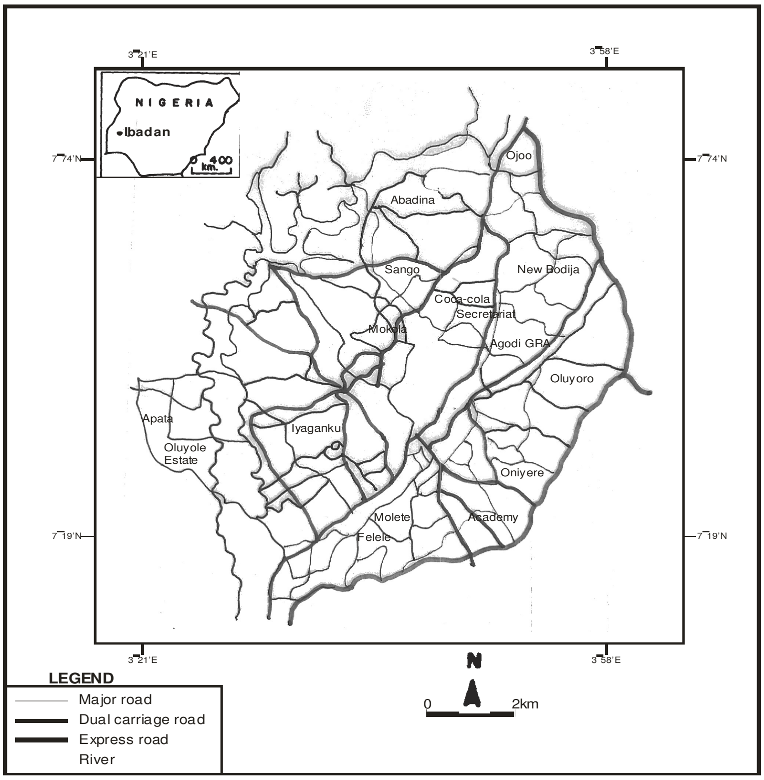

Fig. 1: Map of Ibadan Metropolis
Source: Oyo State Ministry of Land and Environment (1992)

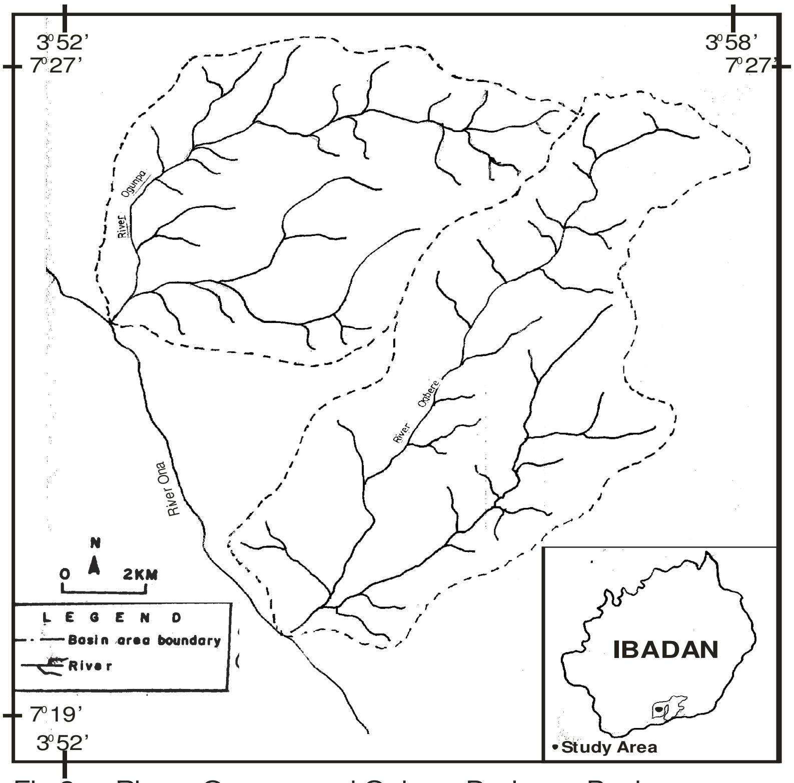

Fig.2: Rivers Ogunpa and Ogbere Drainage Basins
Source: Prepared from Federal Surveys (1967)

Methodology

This work was based on map analysis carried out on morphometric parameter on topographical map of Ibadan North East on scale 1:25,000 published by Federal Survey of Nigeria in 1965. This is a large scale map which is highly recommended for a study of this nature (Ebisemiju, 1976; Adejuwon, et. al. 1984; Ifabiyi, 2004). The topographical map was earlier corrected following the method suggested by Morisawa (1959) and Morgan (1971). Thereafter, the studied basins were demarcated through the insertion of watershed lines.

The choice of morphometric variables that were examined in this study was based on the result obtained from previous studies, which have been found to correlate highly with peak discharge, runoff volumes and sediment delivery (Morisawa, 1962; Gregory and Walling, 1973; Oyegun, 1980; Pitlick, 1994; Jeje, 1999; Ifabiyi, 2004; Nebegu, 2005)

In all, fifteen (15) morphometric variables (broadly categorized into three (3) vis; area, linear and relief morphometrics) were examined (Table 1). The procedure used in deriving each of the variables is equally shown. Analysis of variance (ANOVA) was used in examining the difference in morphometric parameters, both between and within the studied basins.

Observations and Discussions

Hydrological response of a drainage basin is defined by the production of runoff against a given rainfall, which in turn is characterized by basin morphometric properties, soil characteristics and landuse pattern. While the soil characteristics and landuse pattern control the infiltration loss, the distribution of the remaining excess rainfall is governed by basin morphometric properties. Table 2 shows the computed values of the morphometric parameters of the studied basins.

Table 2 shows that disparity exists, both within and between all the variables measured in the two basins. Degree of disparity is however strongest in the area dimension. This is of high significance in this study. Basin area has been identified as the most important of all the morphometric parameters controlling catchment runoff pattern. This is because, the larger the basin, the greater the volume of rainfall it intercepts, and the higher the peak discharge that result (Morisawa, 1959; Faniran and Ojo, 1980; Pitlick, 1994; Jain and Sinha, 2003; Okoko and Olujinmi, 2003; Nabegu, 2005). Another reason for the high positive correlation between basin area and discharge is the fact that basin area is also highly correlated with some of the other catchment morphometric characteristics which influence runoff, such as, basin length and stream length (Gregory and Walling, 1973; Ebisemiju, 1976; Jain and Sinha, 2003; Ifabiyi, 2004).

However, other catchment morphometric parameters such as relief, shape and length also influence basin discharge pattern strongly. This is through their varying effects on lagtime (Gregory and Walling, 1973). These morphometric factors have proved very important when rates of flooding is being compared between the two basins being investigated in this study. Though, Ogunpa is smaller in size, the basins has recorded more flood events in the city than Ogbere drainage basin, which is larger in size. Table 3 shows the records of major floods events in Ogunpa between 1960 and 1988.

Reasons for more frequent flood in Ogunpa when compared with Ogbere drainage basin is not far fetched. Ogbere drainage basin is larger in size, a factor which affect its length (the larger the basin, the longer its length). The longer the length of a basins, the lower the chances that such a basin will be flooded when compared with a more compact basin like Ogunpa. This is because, the longer the basin, the lower its slope (Table 2). Not only this, time of concentration (lag time) in such a basin will be higher than a more compact basin which produces sharp hydrographic peak due to high bifurcation ratio. This led to rapid withdrawal of water from such a basin (Knapp, 1979). High concentration time thus exposes the water intercepted by Ogbere drainage basin to longer duration of infiltration and evaporation process, hence reduction in runoff volume.

Other reasons which might have promoted higher incidences of flooding in Ogunpa when compared with Ogbere includes higher drainage density, higher relief and circulatory ratio. Relief ratio is an indicator of rates of erosion operating along the slope of a basin (Schumm, 1954). Ogunpa river basin has higher relief ratio when compared with Ogbere river basin hence, the higher erosive capacity and sediment yields which disposes the basin to higher flood peaks (Okoko and Olujimi, 2003). Higher circulatory ratio recorded by Ogunpa drainage basin is in conformity with Miller (1953) proposition. The shorter the basin length, the closer to one (1), the circulatory ratio. The implication of this is that, Ogunpa river will have shorter time lag, shorter time of rise and higher hydrographic peak; hence the frequency of flood in the basin.

Management Implications of Research Findings

The study has demonstrated the influence of catchment morphometric parameters on hydro-geomorphic process of drainage basin. This influence is however encouraged by other basin characteristics such as climate, soil characteristics and landuse pattern which acts as contributory factors to flooding in the drainage basins. Efficient basin management techniques therefore calls for understanding of the combined roles played by all the catchment controlling variables; as this action represent the best option towards reducing rates of catchment degradation in the basins.

Specific management practices that can however be adopted in the basins includes:

i. Controlled urban development by government agencies such as town planning authority through promulgation of edicts and laws. This is to reduce both the magnitude and frequency of flood being experienced in the basins. In this light, buildings already erected on floodplains can be pulled down while areas yet to be built-up can be zoned for future development.

ii. Engineering construction such as building of micro dams, stream channelization and construction of embankments along main river channels to reduce flooding.

iii. Afforestation programme to reduce flood incidents during rainy season by promoting infiltration process. This management effort will also aid in conserving water supply for dry season usage.

iv. Efficient waste management techniques to reduce flooding due to channel blockage and debris is pile-up.

These management techniques will not only aid in the improvement of river regime by retaining greater volume of rainfall intercepted by the basins on the land, but will also help in solving problems of soil erosion, sediment generation and water supply.

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Table 1: Basin Morphometrics Parameter

Category	**Parameter**	**Derivation procedure**
Area	Basin area	Area = Map scale x counted squares (Gregory and Walling, 1973)
	Circulatory ratio	Rc = 4πA/2 where Rc = Circulatory ratio, A = Basin area and π = Constant (Miller, 1953)
	Bifurcation ratio	Rb = Nu/Nu + 1 where Rb = Bifurcation ratio, Nu = Number of streams in the order U and Nu + 1 = Number of streams in the next higher order (Gregory and Walling, 1973)
	Drainage density	DD = ∑L/A; where DD = Drainage density, ∑L = Sum of all stream lengths and A = Basin area (Horton, 1932)
	Number of streams	∑Nu; where Nu is the stream number and ∑ = Sum (Strahler, 1952)
	Elongation ratio	El= $2\pi\sqrt{A/L}$ where El = Elongation ratio, A = Basin area L = Basin length and π = Constant (Schumm, 1956)
	Form factor	F = A/L^2 where F = Form factor, A = Area of the basin and L = Length of the basin (Boyce and Clark, 1964)
	Leminiscate ratio	K = $L^2/4A$ where L = Length of the basin and A = Area of the basin (Schumm, 1956)
	Stream frequency	Sf = $\frac{Nu + Nu+1 + Nu + 2}{A}$ where Sf = Stream frequency, Nu = Number of stream in order 1, Nu + 1 = Number of streams in order 2 and Nu + 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)
	Average stream length	Total stream length divide by total number of streams (Schumm, 1963)
	Main stream length	This is the length of the principal drainage line (Schumm, 1963)
Relief	Basin slope	Bs = VI/HE where Bs = Basin slope, VI = Vertical Interval and HE = Horizontal equivalent (Schumm, 1963)
	Relief ratio	Rh = H/L where Rh = Relief ratio, H = Horizontal distance along the longest dimension parallel to the principal drainage line and L = Length of the basin along the principal drainage line (Schumm, 1956)

Table 2: Basin morphometric parameters

Parameters	Computed values	
	Ogunpa Drainage Basin	**Ogbere Drainage Basin**
Basins area	40.75sq. km	52.99 sq. km
Circulatory ratio	0.64	0.49
Bifurcation ratio	4.67	4.57
Drainage density	1.22km/sqkm	1.02km/sq km
Number of streams	28	30
Elongation ratio	0.12	0.14
Form factor	0.65	0.26
Stream frequency	0.56	0.59
Basin length	7.9km	14.25km
Total stream length	49.85km	53.95km
Average stream length	1.78km	1.80km
Mainstream length	8.1km	13.1km
Basin slope	0.32	0.41
Relief ratio	0.22	0.014
Leminiscate ratio	0.41	0.49

Source: Authors fieldwork (2009)

Table 3: Major flood events in Ogunpa (1960-1980)

Year	Properties damaged in Naira	Lives lost
1960	Several	No record
1963	Several	Not less than 2
1969	Several	Not less than 2
1973	More than N100,000	3
1978	Several	Not less than 2
1980	More than N300,000	More than 500 with over 50,000 displaced

Sources: Faniran (1991) and Adam Environmental Consultant (1985)