APPRAISAL OF THE HYDROLOGICAL POTENTIAL OF UNGAUGED BASIN USING MORPHOMETRIC PARAMETERS

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Abstract

Discharge data for most basins in developing countries are lacking or inadequate where available. An alternative is to find other ways of appraising the natural water potential of basins without stream discharge records. This study attempts an appraisal of the water resource potential of the Eze-Aku basin in Ebonyi State of Nigeria using morphometric indices alone. From its morphometry the basin is essentially a low land and erosional surface. This affects both the quantity and quality of water for use by inhabitants of the basin. The analysis of results show the Eze-Aku basin is not suitable for water resources development projects demanding large monthly and annual discharge volume such as hydropower and navigation. Other morphometric parameters investigated in the study include bifurcation, shape, stream and drainage densities. Analyses of these parameters provide the basis for demonstrating the effects of environmental controls on both the basin stream network system and for predicting the basin's output variables. Such information are essential and provide framework for improving agricultural activities, flood control and management measures and potable water supply in the study area for increased standard of living in the agricultural dominated area.

Key words: *Discharge, Morphometry, Water Resources Management and Planning.*

INTRODUCTION

Water resource planning and management activity involves not only steps towards having the right amount of water as well as in the right quality for a particular purpose but understanding the character of streams/rivers for prevention, avoidance and minimization of the effects of having too much or too little water. Thus, in planning for the water resources of a drainage basin, information on the stream discharge of such basin is fundamental for understanding the basins' hydrological characteristics such as discharge volume, duration and variability etc. Unfortunately, studies have shown that data on stream discharge for most basins in developing countries are either lacking or grossly inadequate where they exist (Abiodun 1973, Ayoade 1998).

In Nigeria, one of the major problems of hydrological studies and water resources planning and management is that of generating adequate hydrological data for use by water resource managers and researchers. Many stream discharge gauging stations which were established in the early 1970's are no longer functional and where the function they are poorly maintained. This development is even worsened following the fact that no serious attempts have been undertaken by government agencies responsible for hydrological statistics in the country to coordinate let alone harmonize hydrological data collection and according to Ayoade (1998), this is making pure hydrological research almost impossible. Consequently, most hydrological studies in the country are often abandoned in favor of other aspects of the study.

Consequently, it often becomes necessary to resort to alternative measures of appraising and evaluating the natural water resources potential of basins without stream gauge records, using series of generalized regional relationship based on morphometric parameters. Morphometric analysis of drainage basin attempts to quantify and mathematically analysis of the drainage basin topography, stream network arrangement and areal characteristics.

Unlike the areal inspection technique, morphometric analysis defines more clearly and precisely the general form of the basin landform as represented on a map and serve as a basis for demonstrating the effects of the environment control on fluvial system and for predicting the basin output variables such as discharge. In this study, a comprehensive analysis of the morphometric parameters of the Eze-Aku drainage basin in Ebonyi State of Nigeria was undertaken in order to generate information needed to explain the hydrology of the basin as well as how some aspects of the basin's

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morphometric parameters will affect water resources development in the basin.

The Study Area

The Eze-Aku drainage basin lies between latitude 5° 45N and 5° 55N and longitude 7° 30'E and 7° 45'E. The basin is located within Afikpo Local Government Area of Ebonyi State, Nigeria. The basin is a fifth order basin and covers an area approximately of 256.8km^2 .The Eze-Aku River flows in a south-easterly direction across the flooded Shales of the Cross River plain and joins the Asu river in the North-easterly direction, before emptying into the Asu basin river (Figure. 1). The southernmost part of the basin which forms its headwaters has an extensive stream network

Geologically, the basin is composed of sedimentary rocks which are essentially of low permeability. A greater part of the basin lies between 50 meters to 100 meters above sea level. The Eze-Aku drainage basin has a tropical wet and dry climate.

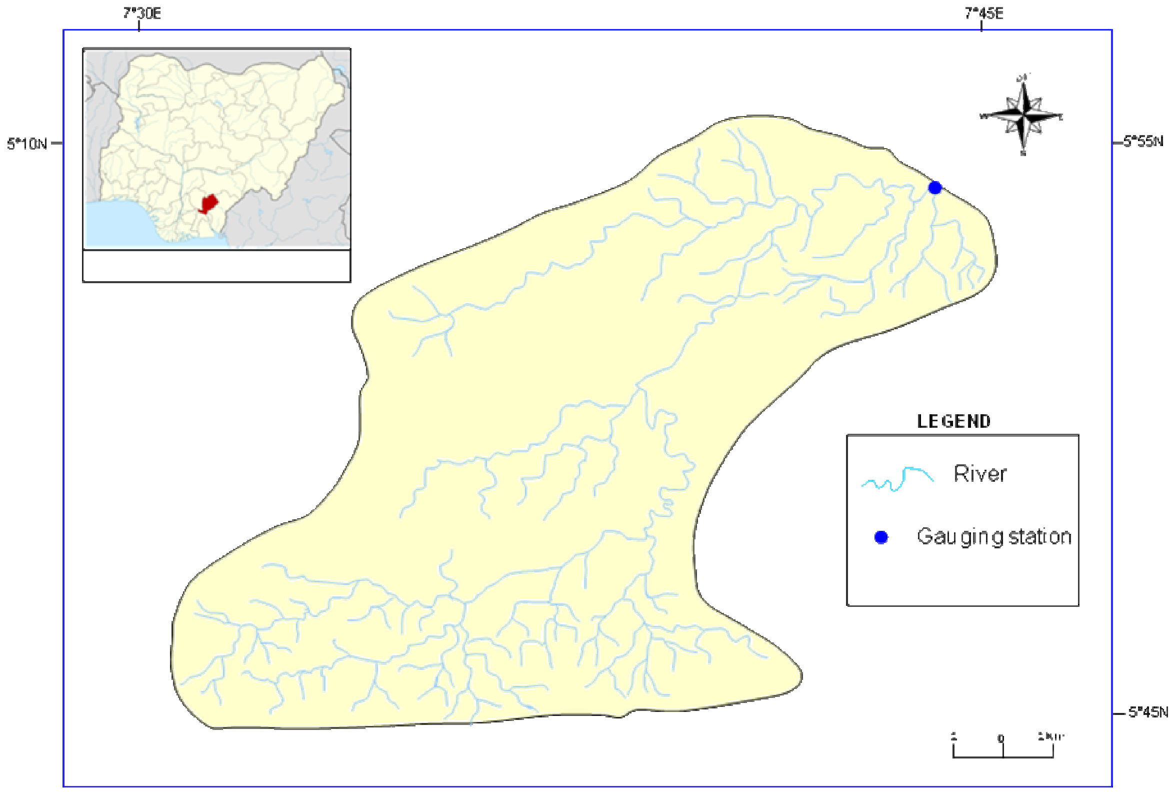

FIG. 1 THE EZE-AKU DRAINAGE BASIN
Source: Fieldwork,2011

The rainfall of the basin essentially depends on the interaction of two major air masses viz; the Tropical Continental (cT) and Tropical Maritime (mT), and both meet at the Inter-Tropical Discontinuity (ITD). Annual rainfall of the basin ranges from 1450-1900mm with the rainiest month being September. Occasionally, rainfall season spans from April to September while the dry season lasts from December to March. Temperature values in the basin are relatively high, with mean annual temperature ranging from 27°C to 28°C. The soils of the basin are deeply weathered red and yellowish-brown soil with abundant free iron oxides. According to Areola (1982) classification system, the vegetation of the Eze-Aku drainage basin is rainforest – savanna ecotone and subsistence agriculture is the major landuse.

Methodology

Materials used for the study include topographic maps on a scale 1:50,000 covering the entire drainage basin. These topographic maps include the Afikpo north-west and south-west scaled 1: 50,000 and were obtained from the Cartography Laboratory of the Department of Geography University of Nigeria, Nsukka. Morphometry from topographic maps was the major method by which data were generated on the configuration of the study area. Identified geomorphological units in the basin were supported by field observations and checks at selected points. Although the use of topographic maps for drainage basins studies has been criticized on the ground of map accuracy (Morisawa, 1958) as well as accuracy of scale and stream representation, studies have shown that these problems can be minimized when topographic maps on a scale1:50,000 is used. At best, the topographic map represents an "average" stream network (Zavoianu, 1985). Streams shown on topographic maps (The blue lines) are often very selective and this may affect the morphometric data by introducing some amount of bias Ebsemeju (1979). A method suggested to combat this problem is the contour crenulations which utilizes all the valleys instead of blue lines for measurement. This method was adopted in this study.

The whole stream network was ordered using the Strahler system of stream classification (Strahler, 1952). This system is more objective and has a genetic basis unlike other ordering systems such as the methods by Shreve (1967) Scheidegger (1965), Woldenberg (1966) etc. Adapting the universal morphometric equations in the work such as Stream Density ($Fs = \frac{\sum N}{A}$) *and* Drainage Density ($Dd = \frac{\sum L}{A}$) equations (Horton, 1932); Circularity ratio equation ($Rc = \frac{A}{Ti(p/2Ti)^2}$) (Miller, 1953), the morphometric values of the study area were determined. Some selected morphometric parameters analyzed include; Drainage basin area (Ab), Drainage basin shape (Rf); Basin Order (Bo), Stream Numbers (Nu); Basin Bifurcation ratio (Rb); Stream density (Fs); Drainage density (Dd). The choice of the selected parameters does not amount to the loss of information on other morphometric parameters influencing the discharge of the basin. This is because virtually all the basin parameters are inter-dependent on each other. For example, the analysis of basin shape also provides information on the basin geology and relief characteristics whereas stream density and drainage density give insight into the basin physical configuration.

Results and Discussion

Stream Order (U) and Number (Nu)s

Results of stream numbers and Orders as presented below in Table 1 show, the study area is a 5th order basin with the 1st order basin numbering 107 and variations exist between the bifurcation ratios. The sum of all the bifurcation ratios in the basin was divided by the number of bifurcation ratios to give the mean bifurcation ratio of the basin. Research has shown that generally, basin mean bifurcation ratio tends to vary from 2.0 for flat basins to 4.0 for mountainous areas. The calculated mean bifurcation ratio for the study area is 2.08; an indication the study is a flat surface. Besides, this suggests that the study area has little potentials for discharge compare to those of mountainous areas with bifurcation ratio of 4.0 (Strahler, 1952).

Table 1 Eze-Aku stream order, area and bifurcation ratio

Order	Number	Bifurcation ratio	Total Area Km^2	Average Area Km^2
1	107	3.3	48	0.45
2	31	2.8	75.6	2.44
3	10	3.3	95.00	9.50
4	2	1	101.6	50.8
5	1	0	114.8	114.8
	ΣNu = 151	**Rb 2.08**		

Bifurcation ratios are controlled by basin physiographic factors especially basin relief and drainage density (Milton, 1966). However, in regions where the network geometry of streams develops without pronounced lithological or structural control, bifurcation ratios between basins of different orders are stable showing little variation from one order basin to another (Strahler, 1957; Chorley et al., 1957). From Table 1, values of bifurcation ratio calculated for the different order basins in the study area show variations. This suggests that relief characteristic is a major factor in the stream network development in the study area.

The Eze-Aku basin area was determined as $256.8km^{2.}$. The area of the basin of each order (from first to fifth order basin) was also calculated in such a way that the area of a higher order basin will include area(s) of the next lower order basins. It is observable form table 1 that average basin areas increases geometrically with increasing order.

The fifth order basin had the highest area value; however the value decreases with decreasing order. This geometric arrangement conforms well to the universal law of stream composition. Furthermore, the calculated area of individual basin provides information on the organization of surface runoff by each order stream and hence the threshold from which denudation processes had began under the impact of linear erosion.

The analysis of stream and drainage densities is both significant in appraising the potential water resources of drainage basin, in that the two morphometric parameters play important roles in runoff generation processes, as well as influences the intensities of torrential floods, sediment load and even the water balance in a drainage basin. From the field work, stream density (*Fs*) of the Eze-Aku basin was determined as 0.6 stream segments per square km while drainage density was obtained as 0.91km. Both values of stream density and drainage density show that Eze-Aku basin has a low relief and by implication has a low response to surface runoff. This also points to the fact that there will hardly be enough water supplies to support large scale water resources development projects particularly hydropower project in the region except with intensive development of the land and water resources of the region

The Miller circularity ratio for Eze-Aku was computed as 0.42. The ratio expresses the relationship between the perimeters of basin with the circumference of a circle having the same area as the basin. The ratio has unit value for a circular basin and thus the closer the value to unit (1), the more circular the basin is said to be. Since our study area has a circularity value far from unit, the Eze-Aku drainage basin is said to be elongated and this suggests that the basin will produce little discharge since runoff travels more rapidly in circular shaped basin where overland flow has an equidistant travel to the main discharge channel than in elongated basin.

Conclusion and Recommendations

This study evaluated the hydrological potential of the EzeAku basin in Ebonye State using morphometric parameters. From the results of our analyses, the Eze-Aku basin has a low relief with elongated shape and is liable to stream flow drought due to low response to surface runoff. Consequently, the region may not be suitable for a large water resources project especially those requiring large monthly and annual discharge quantities. However, taking into consideration the standard of living of the rural populace in the study area, it is recommended that Low Energy Precision Application (LEPA) irrigation system be practiced. This would be affordable and beneficiary to all farmers as the LEPA will increase the efficiency of water use and its availability especially as the basin is liable to seasonal stream flow drought in dry season. It is also recommended that efforts should be made to gauge the un-gauge streams in the study area.

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