Journal of Geography, Environment and Earth Science International
4(3): 1-8, 2016; Article no.JGEESI.22223
ISSN: 2454-7352

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Drainage Basin Morphometric Analysis for Flood Potential Mapping in Owu Using Geospatial Techniques

S. A. Samson[1*], A. O. Eludoyin[2], J. Ogbole[1], A. T. Alaga[1], M. Oloko-Oba[1], U. H. Okeke[1] and O. S. Popoola[1]

[1]Cooperative Information Network, National Space Research and Development Agency, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2]Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria.

Authors' contributions

This research work was carried out in collaboration between all authors. Author SAS designed, perform the analysis and wrote the first draft of the manuscript. Author AOE supervised and reviewed the first draft. Authors JO, ATA and UHO reviewed the literature and authors MOO and OSP were involved in field work and production of thematic maps.

Article Information

DOI: 10.9734/JGEESI/2016/22223
Editor(s):
(1) Vijendra K. Boken, Department of Geography and Earth Science University of Nebraska-Kearney, Kearney, NE 68849, USA.
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Reviewers:
(1) Edward Ching-Ruey, LUO, National Chi-nan University, Nantou, Taiwan.
(2) Kabi Prasad Pokhrel, Tribhuvan University, Kathmandu, Nepal.
Complete Peer review History: http://sciencedomain.org/review-history/12520

Original Research Article

Received 23rd September 2015
Accepted 11th November 2015
Published 2nd December 2015

ABSTRACT

This study characterized the Owu drainage basin in southwestern Nigeria using geospatial approach with the objectives of examining the morphometry in relations to flood vulnerability of people in the region. Data used were the topographic maps and satellite imageries of the region. The data were analysed by both hydrological and geographical information techniques for basin delineation, stream ordering and digital elevation modelling. Results showed that the drainage basin is characterized by about 429 stream segments, and mean bifurcation ratio of about 1.9, and that about 23% of the entire basin area is susceptible to severe flooding. The study concluded that livelihoods and people in the flood vulnerable areas are endangered, and recommends preparedness for potential flood hazards in the area.

**Corresponding author: Email: samidoy@yahoo.ca;*

Keywords: Drainage basin; morphometric characteristics; Stream; geospatial; basin.

1. INTRODUCTION

Drainage basin is a unique geographical unit characterized by distinct drainage network and ecosystem. Any study carried out to enhance the understanding of this unit is imperative and provide the needed data and information for it sustainable management. A drainage basin morphometry study involves analyzing area, linear and relief parameters of the basin which help us to understand the natural environment of the basin, and they also summarize spatial characteristics of the basin. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms [1,2].

Studies on drainage basin morphology have been carried out in many parts of Nigeria, this include those of [3-7]. In addition to these is work of the different river basin authorities in Nigeria. These studies provided insights to drainage morphometric system of some selected basins in Nigeria. However, considering the time some of these studies are carried out and method adopted, there is need to improve on the method particularly with the use of geospatial technology and remote sensing derived data.

In recent time, there is increase in different ecological hazard directly or indirectly related to drainage morphometry, this include flooding, erosion, mass movement, soil pollution, deforestation etc. in spite effort provided by government, private individual, ecological funds and different basin authority. The paucity of knowledge and unproved methodological approach has hindered the efficacy of sustainable and optimal management of different hydro-basin.

The study of Owu river basin morphometric will provide a very good alternative to understand the underlying factors controlling the hydrological behavior as well as providing the necessary data and information that will enhance knowledge on the basin potentials and consequent implication of hydro-related disasters. This study attempt to examine the basin morphometry of Owu river basin and evaluate its hydrological implication as relate to flooding. The study used geospatial techniques integrated with achieved analogue data.

1.1 Objective of the Study

The main objective of this research work is to examine the drainage morphometric characteristics of the Owu drainage basin in Oyo State; and evaluate the implication of the morphometric characteristics on basin flood potential in the study area.

2. MATERIALS AND METHODS

2.1 Study Area

The River Owu basin is a sub basin in Oyo State of Ogun-Oshun River Basin Authorities, South-west Nigeria. It originates from Saki West and flows across Saki Eask, Atisbo, Itesiwaju local government area and drains into Ikere Gorge dam. The geographical location of Owu River drainage basin is between 8° 14’11”N, 3° 25’39”E and 8°38’42”N, 3°46’ 13”E (Fig 1).

The geology is a basement complex with mainly Pre-cambrian metamorphic and plutonic rocks (e.g. granites, granodiorites, gneisses, magmatites, meta-sediments and metaigneous rocks,) assigned to various orogenic events [8]. The soil comprises of lixisols, luvisols and fluvisols.

2.2 Methods

This study used spatial and non-spatial data. The spatial data were locational information (x, y and z) which were obtained by establishing Ground Control Point (GCP) with global positioning systems (GPS). 1:50,000 topographic maps (covering Ikomu NE, Lechilaku NE and NW,Ighoho SW, Shaki SE), soil map, NigeriaSat-X and digital elevation model (DEM) of the study area were used. The maps were scanned, geo-reference, before the region of interest was extracted. The georeferenced map of the area of interest was further processed and required data were digitized using on-screen method in ArcGIS (10.1 version). Line, point and body objects were thematically digitized.

The digitized contour lines were converted to Triangulated Irregular Network (TIN) then, Digital Elevation Model (DEM) using spatial analyst tool in ArcGIS 10.1 environment and subsequently the basin was delineated using ArcSWAT extension tool in ArcGIS environment. The delineated basin was exported as a vector shapefile into a working folder from which it was imported and added into the different software as a layer. Subsequently the basin was used to subset all the participatory thematic geo-referenced data set and images to be used for the project.

The image was imported in Geo-tiff format into ENVI 5.0 software. The generated frame marking the region of interest (RoI) was used to subset the NigeriaSat-X image while False Colour Composite (FCC) band 3, 2, and 1 was generated. Outside the needed thematic feature classes, other surface terrain information needed were generated from the thematic layers. These includes slope generated from the DEM, sub-watersheds, stream order, and other drainage morphometric analysis were generated from the drainage map. The land use/land cover and its class statistics were generated from the classification of the FCC image covering the study area.

In this study, quantitative morphometric analysis of these characteristics, namely, Perimeter, Basin length, number of stream order, mean stream length, stream length, bifurcation ratio, stream length ratio, drainage density, length of overland flow, elongation ratio, relief ratio, infiltration number, form factor, stream frequency and drainage intensity were carried out on the Owu drainage basin and 25 sub basins within the basin were also analyzed using the mathematical formulae given in Table 1.

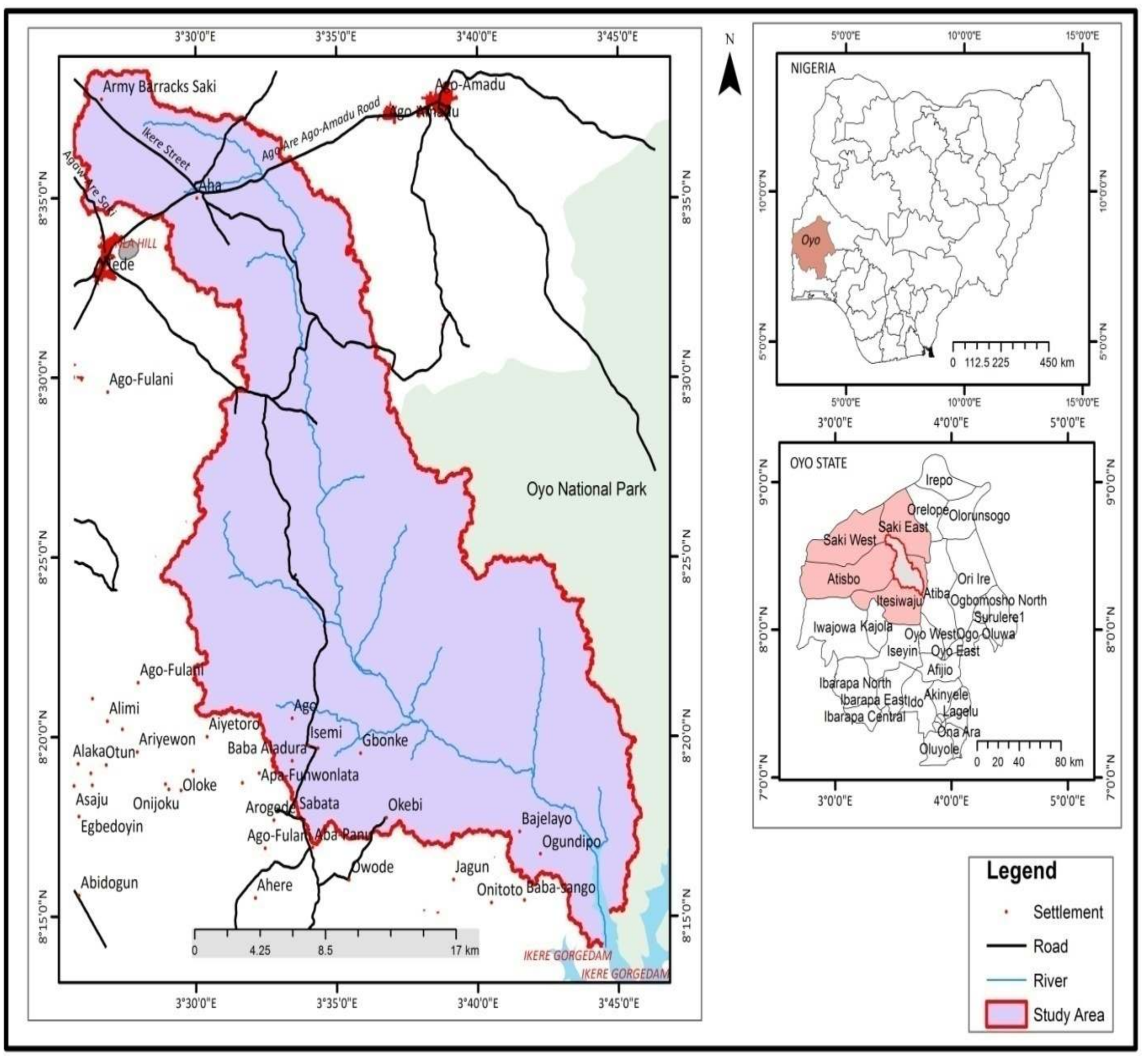


Fig. 1. Owu drainage basin in Oyo State, Nigeria

Furthermore, multiple spatial criteria were used to map the basin flood potential area whereby each layer was classified into a number of classes with each having its own specific weight. The layer of interest for building the model includes: Rainfall, slope, soil, drainage density, stream frequency, landuse and relief ratio. These layers were assigned a weight in accordance to their contribution to flooding which must sum up to one hundred percent (100%) and/or one (1). The assigned weight was multiplied by its constant class which is also assigned an index value, after which, the critical index for each cell of the overlaid grid was obtained by the addition of all the computation results of the cell for each layer (Table 2). The assignment of layers and class weight were achieved through pairwise computation techniques, field work evaluation, literature review guide [9,10] and expert judgment. Using specific query and geo-statistics operation, the critical index value of each cell was' analyzed in a GIS supported weighted overlay in ArcGIS (10.1) and also interpolated to produce the vulnerability assessment.

Table 1. Summary of morphometric characteristics determined in the study area and their methods

Category	Parameter	Derivation procedure	Reference
Area	Basin area	Area = Map scale x counted squares	[11]
	Drainage density	Dd = ΣL/A; where Dd = Drainage density, ΣL = Sum of all stream lengths and A = Basin area.	[12]
	Number of streams	ΣNu; where Nu is the stream number and Σ = Sum	[13]
	Stream frequency	$F_s = N_u/A$. F_s= stream frequency, N_u = total length of stream, A=basin Area.	[12]
	Basin length	This is the straight line from the mouth of the basin to the farthest point on the basin perimeter.	[14]
Linear	Total stream length	This is the total length of all the tributaries and the principal drainage	[15]
	Average stream length	Total stream length divide by total number of streams.	[15]
	Main stream length	This is the length of the principal drainage line	
	Bifurcation ratio	$R_b = \frac{N_u}{N_u+1}$ where R_b= Bifurcation ratio, N_u= Number of streams in the order U and $N_u + 1$= Number of streams in the next higher order $R_b = \frac{N_u}{N_u+1}$	[11]
Relief	Basin slope	$B_s = \frac{VI}{HE}$ where B_s= Basin slope, VI= Vertical Interval and HE = Horizontal equivalent	[15]
	Relief ratio	$R_h = \frac{H}{L}$ Where R_h = 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.	[14]

Table 2. Multi- criteria decision analysis modeling table

Factor	Criteria	Index	Weightage
Mean Annual Rainfall	< 157 mm/hr	0.1111	0.3244
(MAR)	157 mm/hr – 159 mm/hr	0.3333	
	>159 mm/hr	0.5556	
Land use	Forest	0.0625	0.1602
LU	Cultivation	0.1875	
	Builtup	0.3125	
	Wetland & Water	0.4375	
Soil type	Fluvisols	0.1111	0.0352
(ST)	Lixosols	0.3333	
	Luvisols	0.5556	
Slope	< 2%	0.5556	0.3238
(SLP)	2% - 20%	0.3333	
	>20%	0.1111	
Stream frequency	0.04 - 0.24	0.0625	0.0515
(Fs)	0.24 – 0.6	0.1875	
	0.6 – 01.08	0.3125	

Factor	Criteria	Index	Weightage
	1.08 – 1.88	0.4375	
Drainage density (Dd)	0.05 – 0.35	0.0625	0.0534
	0.35 – 0.81	0.1875	
	0.81 – 1.26	0.3125	
	1.26 – 2.1	0.4375	
Relief Ratio Rr	0.40 – 0.50	0.4375	0.0515
	0.50 – 0.70	0.3125	
	0.75 – 0.91	0.1875	
	0.91 – 1.07	0.0625	

*CI= (MAR*W1 + Lu*w2 + ST*W3 + SLP*W4 + Fs*W5 + Dd*W6 + Rr*W7)*

Where CI = Critical Index, MAR = Mean Annual Rainfall, Lu = Land Use, SLP = Slope, Fs = Stream Frequency, Dd = Drainage Density, and Rr = Relief Ratio [16,17]

3. RESULTS AND DISCUSSION

3.1 Morphometric Characteristics of the Owu River Basin

The Linear morphometric characteristics of Owu river basin are given in Table 3. The linear aspect of the Owu basin is characterized on the basin topography and the drainage network. The Owu basin is 5th order drainage basin as shown in Fig. 2a. The 5th order drainage segment has the highest amount of water and sediment flow. The study shows that Stream order one has the highest number of stream segments of 201 and the total number of stream order in the basin is 429. Stream order one has the highest number of stream segments and a sum stream length of 281.209 km for 1st order stream. Owu drainage basin has a total stream length of 508.705 km. The highest Rb (3.03) is found between the 2nd and 3rd order stream in the basin. The basin mean bifurcation ratio is 1.93, which is relatively low. This indicates that the basin is less vulnerable to flooding.

3.2 Basin Morphometric Characteristics

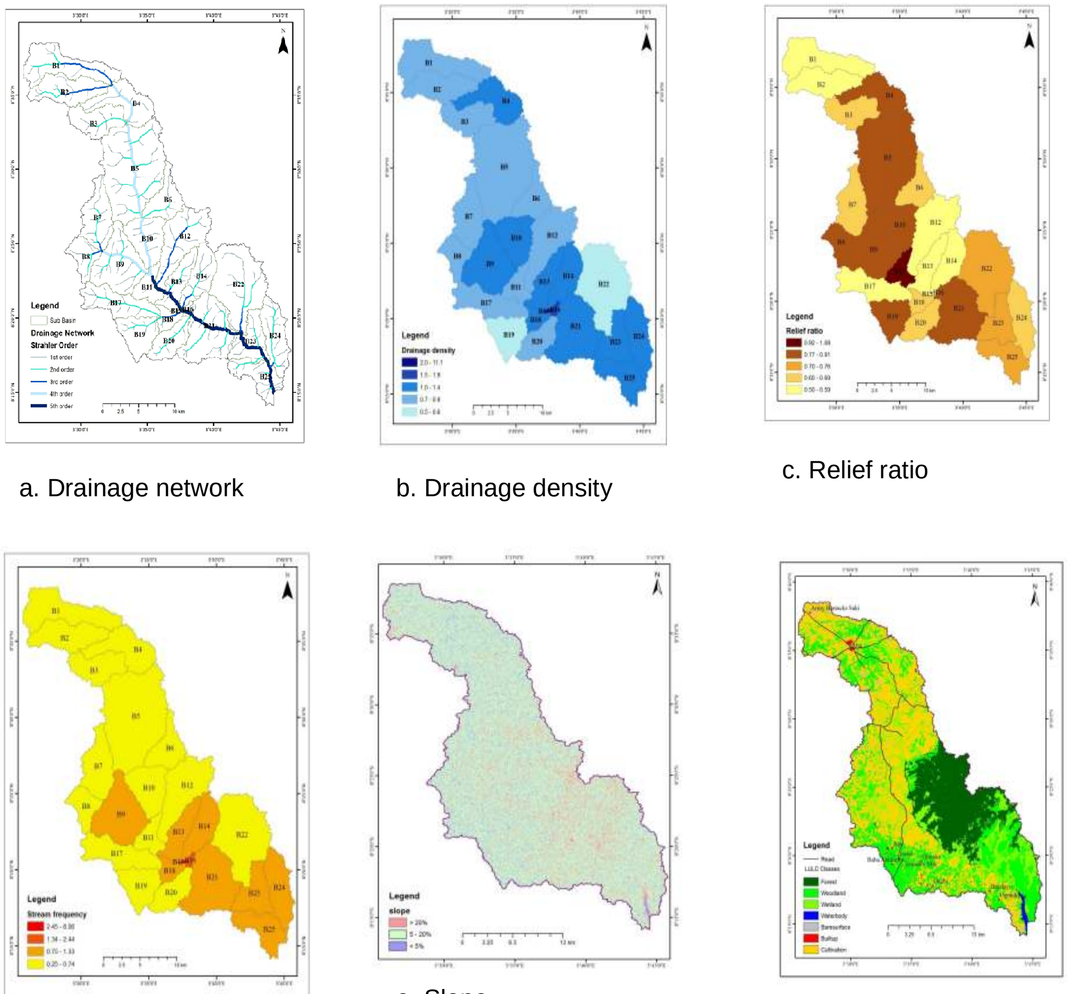
The area of Owu basin as at the time of study was 668.97 km^2 and the perimeter was 273.04 km. Drainage density is 0.76 km/km^2. The basin Dd value is moderate, this suggests indicates sufficient vegetation cover, and moderate relief [18,19]. The Basin's stream frequency is 0.64 per km (Table 3). According to [19], Stream frequency has been related to permeability, infiltration capacity and relief of watersheds. Relief ratio gives the average drop in elevation per unit length of river. The Basin relief ratio is 0.0074 (Table 3). The basin relief ratio value is relatively small thus indicating that there is less erosion processes and makes the basin less susceptible to erosion. Results of the slope analysis were classified on the range of less than 5%, 5% - 20% and greater than 20% (Fig. 2e). Slope can be evaluated as quantitative parameter and it has been identified as the most important and specific feature of the earth's surface form. Furthermore, the landuse/ landcover analysis of Owu basin indicates that the basin is more dominated by cultivation (Fig. 2f, Table 4).

3.3 Basin Flood Potential Areas

The Owu River Basin final product for flood potential area is shown in Fig. 3. Potential areas were classified into four classes based on their vulnerability to flooding; highly vulnerable,

Table 3. Result of morphometric characteristics of the Owu river basin

	Order I	Order II	Order III	Order IV	Order V	ORB
Area A (sq. km)						668.97
Perimeter P (km)						273.04
Basin length Lb(km)						55.90
Stream order Nu	210	109	30	40	40	429
Mean stream length Lu (km)	1.339	1.097	1.299	0.992	0.731	5.46
Stream length LT (km)	281.20	119.60	38.97	39.69	29.24	508.71
Bifurcation ratio Rb		I/II	II/III	III/IV	IV/V	
		2.35	3.07	0.98	1.36	1.94
Stream length ratio RI		II/I	III/II	IV/III	V/IV	
		0.43	0.33	1.02	0.74	0.63
Drainage density Dd						0.76
Relief Ratio Rr						0.0074
Stream Frequency Fs						0.64



a. Drainage network

b. Drainage density

c. Relief ratio

d. Stream frequency

e. Slope

f. Land use

Fig. 2a-f. Morphometric and landuse characteristics of the Owu drainage basin

moderately vulnerable, less vulnerable and least vulnerable. It was observed that areas with highest elevation such as Army barracks Saki and around Iyanla Hill, Tede areas are least vulnerable to flooding. Aha region down southern part of the basin areas are less and moderately vulnerable to flooding. Highly vulnerable areas to flooding are Temidire settlement and environs, southern part of Oyo National Park and upstream of Ikere Gorge Dam area. Fig. 3 shows vulnerability map of the Owu River Basin draped on a terrain model to geographically visualized areas that are susceptible to flooding. Table 4 shows a further classification of vulnerable regions, in terms of area covered in square kilometer and percentage, the analysis shows that more than half the basin is less vulnerable to flooding and about 23% of the study area is highly vulnerable.

Table 4. Land use classification of the study area

LULC	Area (km2)	%
Forest	124.93	18.67
Woodland	167.53	25.04
Cultivation	263.28	39.36
Builtup	1.18	0.18
Baresurface	6.74	1
Waterbody	2.31	0.35
Wetland	103.01	15.4
Total	668.98	100

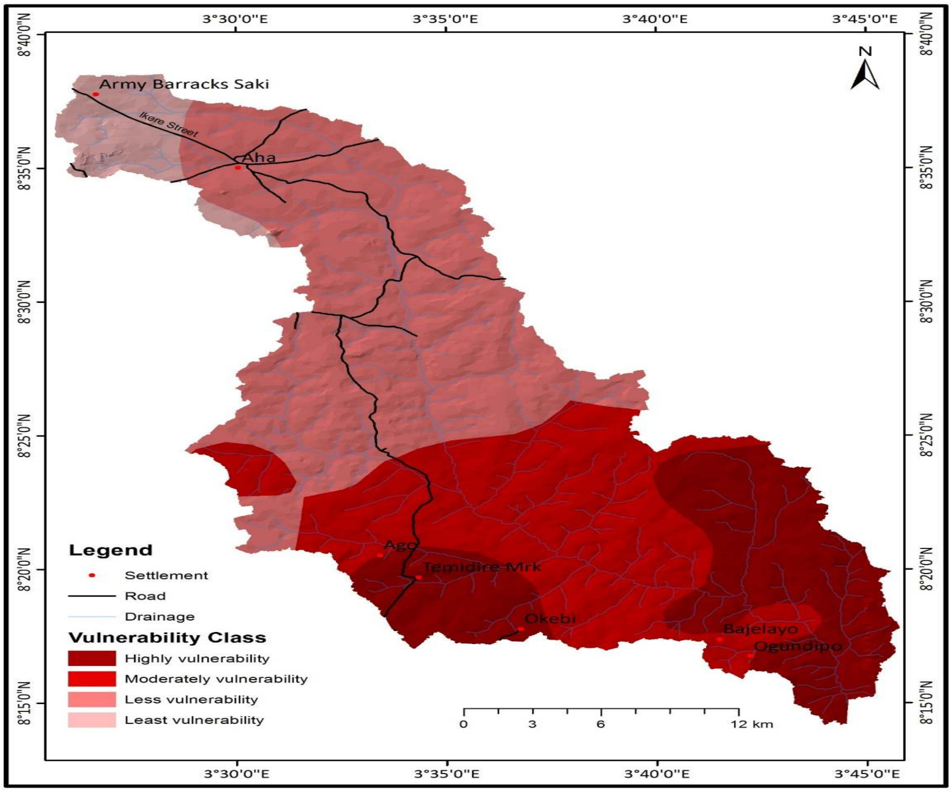


Fig. 3. Basin flood potential model

Table 5. Basin flood potential class statistical report

Vulnerability class	Area (km^2)	% Area
Highly Vulnerable	155.25	23
Moderately Vulnerable	187.95	28
Less Vulnerable	286.40	43
Least Vulnerable	39.37	6
	668.98	100

4. CONCLUSION

The use of geospatial techniques, remote sensing derived data and integrated analogue archived topographic map for mapping and measurement of morphometric characteristics of Owu drainage basin, a sub basin of Oshun-Ogun River Basin, Nigeria have proven to be competent with reliable accuracy in morphometric studies.

The basin flood potential area map reveals levels of vulnerability within the basin, which were categorized into highly, moderately, less and least vulnerable. Despite the uniform distribution of rainfall, the basin area have varied vulnerability level, this is due to the difference in geomorphology and morphometry characteristics within the basin as revealed via the multi criteria analysis. Areas within the least vulnerable class tend to have higher elevation and slope and characterize with first order stream network. While areas with high vulnerability are in the southern part characterised with gentle slope, higher stream order and excessive water accumulation. This implies that, with uniform rainfall, settlement within the southern part of the basin will be severely affected if no mitigation measures are not quickly done.

High rainfall intensity, landuse and slopes, as well as morphometric characteristics have been found to influence flood potential in the study area. Areas with steep slopes with dendritic elongated basin tend to have severe flooding in the lower course of the drainage basin due to excessive accumulation of runoff discharge via a single outlet. In addition, inappropriate land-use coupled with anthropogenic activities (particularly vegetation degradation and poor land-use management) were leading cause of flooding within the basin. This study has emphasized on the application of geospatial techniques and mutli-criteria analysis that give consideration to phenomenon that influences the magnitude, intensity, duration and spatial distribution of flood in order to produce a base information on the vulnerability of an area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Agarwal CS. Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P. Jour. Indian Soc. Remote Sensing. 1998;26:169-175.
2. Obi Reddy GE, Maji AK, Gajbhiye KS. GIS for morphometric analysis of drainage basins. GIS lndia. 2002;11(4):9-14.
3. Anyadike RNC, Phil-Eze PO. Runoff response to basin parameters in southeastern Nigeria. Geografiska Annaler. Series A, Physical Geography. 1989;71(1/2):75–84.
4. Ebisemiju SF. The structure of the interrelationships of drainage basin characteristics. Unpub. Ph.D Thesis, Department of Geography, University of Ibadan, Nigeria; 1976.
5. Faniran A, Ojo O. Man's physical environment: An intermediate physical geography. London: Heinemann, (Chapter 8); 1980.
6. Ogunkoya OO. All rivers run into the sea; yet the sea is not full. Inaugural lecture series 256, Obafemi Awolowo University, Ile-Ife, Nigeria; 2013.
7. Okechukwu GC. Fluvial-geomorphic interrelationships in some river catchments in the Nigerian precambrian basement complex. Unpub. Ph. D Thesis, Department of Geography, University of Ibadan, Nigeria; 1974.
8. Anon. Ogun –Oshun River Basin Feasibility Study, vol. 4. Ogun-Oshun River Basin Authority, Abeokuta; 1982.
9. Kelvin M, Siddique M, Julian S. Using multi-criteria evaluation and GIS for flood risk analysis in informal settlements of Cape Town: The case of graveyard pond. South African Journal of Geomatics. 2012;1:1.
10. Nasim Yeganeh, Soheil Sabri. Flood vulnerability assessment in Iskandar Malaysia using multi-criteria evaluation and fuzzy logic. Research Journal of Applied Sciences, Engineering and Technology. 2014;8(16):1794-1806.
11. Gregory KJ, Walling DE. The variation of drainage density within a catchment. International Association of Scientific Hydrology – Bulletin. 1968;13:61-68.
12. Horton RE. Drainage basin characteristics. Am. Geophysic. Union, Trans. 1932;13: 348–352.
13. Strahler AN. Hypsometric analysis of erosional topography. Bulletin of the Geological Society of America. 1952;63: 1117–1142.
14. Schumm SA. Evolution of drainage system and slope in badlands of Perth Amboy, New Jersey. Bull. Geol. Soc. Am. 1956;67: 597-46.
15. Schumm SA. Sinuosity of alluvial rivers on the great plains. Bulletin of the Geological Society of America. 1963;74:1089-1100.
16. Fishburn PC. Methods of estimating additive utilities. Management Science. 1967;13:7.
17. Triantaphyllou E. Multi-criteria decision making methods: A comparative study. Kluwer Academic Publishers; 2000.
18. Mmon PC, Fre-Nwagwu WF. Analysis of landuse and landcover change around the City of Port Harcourt, Nigeria. Global Advanced Research Journal of Geography and Regional Planning (ISSN: 2315-5018). 2013;2(5):076-086.
19. Montgomery DR, Dietrich WE. Source areas, drainage density, and channel initiation. Water Resources Research. 1989;25(8):1907–1918.

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