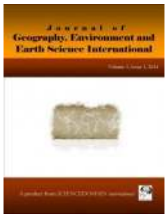

Journal of Geography, Environment and Earth Science International
4(4): 1-8, 2016; Article no.JGEESI.22438
ISSN: 2454-7352

SCIENCEDOMAIN *international*
www.sciencedomain.org

Geo-spatial Analysis and Characterization of Jibwa Basin in Minna (Niger State, Nigeria) for Agricultural Suitability

Paul N. Ojukwu[1*], Ezekiel O. Eguaroje[1], Abayomi T. Alaga[1], John O. Ogbole[1] and Henry U. Okeke[1]

[1]NASRDA, Advanced Space Technology Applications Laboratory (South West), Obafemi Awolowo University Campus, Ile-Ife, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author PNO designed the basis of the study and workflow, wrote the protocol and the first draft of the manuscript. Authors EOE and ATA managed the literature searches and analyses of the study. Authors JOO and HUO managed the experimental process. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2016/22438
Editor(s):
(1) Wael Abdel Kawy, Department of Soil Science, Cairo University, Giza, Egypt.
Reviewers:
(1) Aadil Hamid, University of Kashmir, India.
(2) Joel Efiong, University of Calabar, Calabar, Nigeria.
(3) Edward Ching-Ruey, National Chi-nan University, Taiwan.
(4) Kabi Pokhrel, Tribhuvan University, Nepal.
Complete Peer review History: http://sciencedomain.org/review-history/12748

Original Research Article

Received 1st October 2015
Accepted 9th December 2015
Published 19th December 2015

ABSTRACT

Geo-spatial techniques play a vital role in hydrological investigations that are needed for proper management of drainage basins. This study aimed to determine and characterize tropical river basin for its suitability for diverse use and sustainable agro-economic development using the Jibwa catchment in Minna – Niger State, Nigeria as the region of interest. The data sets used includes: multi-date satellite imagery (Landsat TM 1987, Landsat ETM 2001), and the topographic map covering the study area at a scale of 1:50,000 from which the drainage network and contour were extracted. The hydro-basin was delineated and the output subjected to different hydro-morphometric computations using geo-spatial techniques and automated hydro geo-statistical GIS extensions. The result of this study showed that the Jibwa basin has a fourth-order dendritic stream

**Corresponding author: E-mail: ojukwu213@yahoo.com;*

network with a total of 173 streams and a drainage density of 1.42 per sq. km which indicates the presence of at least 2 streams per square kilometer of the study area. The average bifurcation ratio and slope of the basin is 5.26 and < 2% respectively. The study revealed the area to have adequate surface runoff which makes the area suitable for fishing, irrigation and an all year crop cultivation.

Keywords: Hydro-basin; stream morphometry; geo-spatial; sustainable management; agro-economy.

1. INTRODUCTION

Hydrological investigations form the basis for proper management of drainage basins. Geo-spatial techniques play a vital role in detailed hydrological investigations. A number of investigators have worked on basin morphometry in many parts of the world including [1-3]. In Nigeria, such works have been carried which includes those of [4-8] etc. In the regions of interest, the basins and the basin morphometry have been classified and analyzed. Drainage basin morphometric parameters are used to describe and compare basins of different sizes. Basin morphometry parameters include stream order, stream length, stream number, and basin area. Others are basin shape factor (eg. circularity ratio, elongation ratio, formation factor and compaction ratio), basin perimeter, bifurcation ratios, drainage density, stream frequency and drainage intensity.

Close attention needs to be paid to sustainable management of water resources in order to harmonize management practices with natural conditions and limitations. In agricultural context, finding optimal locations for crops can increase economic benefits, as well as reduce negative environmental consequences. Basin characterization analysis is a prerequisite for sustainable agricultural production. It involves evaluation of the criteria ranging from basin morphometry to agro-economic multi-criteria decision-making techniques for suitability analysis.

This paper attempts is to characterize the suitability tropical river basin for sustainable agro-economic development using the Jibwa catchment in Minna – Niger State, Nigeria as the region of interest.

1.1 Aim

The aim of this research is to characterize and assess the potential of Jibwa hydro-basin for agricultural suitability using Geospatial techniques.

1.2 Objectives

1. To delineate the drainage basin and obtain the basin parameters.
2. To generate vegetation index of the basin.
3. To ascertain the suitability of the basin for crop production.

1.3 Study Area

For this study, the Jibwa basin in Minna, Niger State was delineated using topographical maps bounded by 9° 30' 00" N to 10° 00' 00"N latitude and 6° 30' 00" E to 7° 00' 00" E longitude. Jibwa basin covers about 225.98 km^2 area. It is located in the central part of Nigeria. Meanwhile, River Jibwa is located along the north-west zone of Minna.

The climate of the area is essentially the same as that of the central part of Nigeria with moderate temperature and humidity during the greater part of the year. The normal annual rainfall ranges between 1687 mm maximum and 1038 mm minimum. The peak water level occurs within the months of July, August and September with lowest water level recorded in the months of January, February and March.

From the available records of temperature, the highest mean monthly temperatures are in March at 30℃ and lowest in August at about 25℃. The project area is underlain by un-differentiated basement rock mainly quarto-feldspathic rocks: granites, gneises and migmatites. Fig. 1 shows the administrative map of the study area.

Livestock, Hunting, farming, stock raising, hunting and fishing; the manufacture, use and discard of objects made from materials such as wood (carvings), day (pottery), stone (beads and other domestic utensils made of stone), glass (beads), and metal (smelting); livestock and animal husbandry.

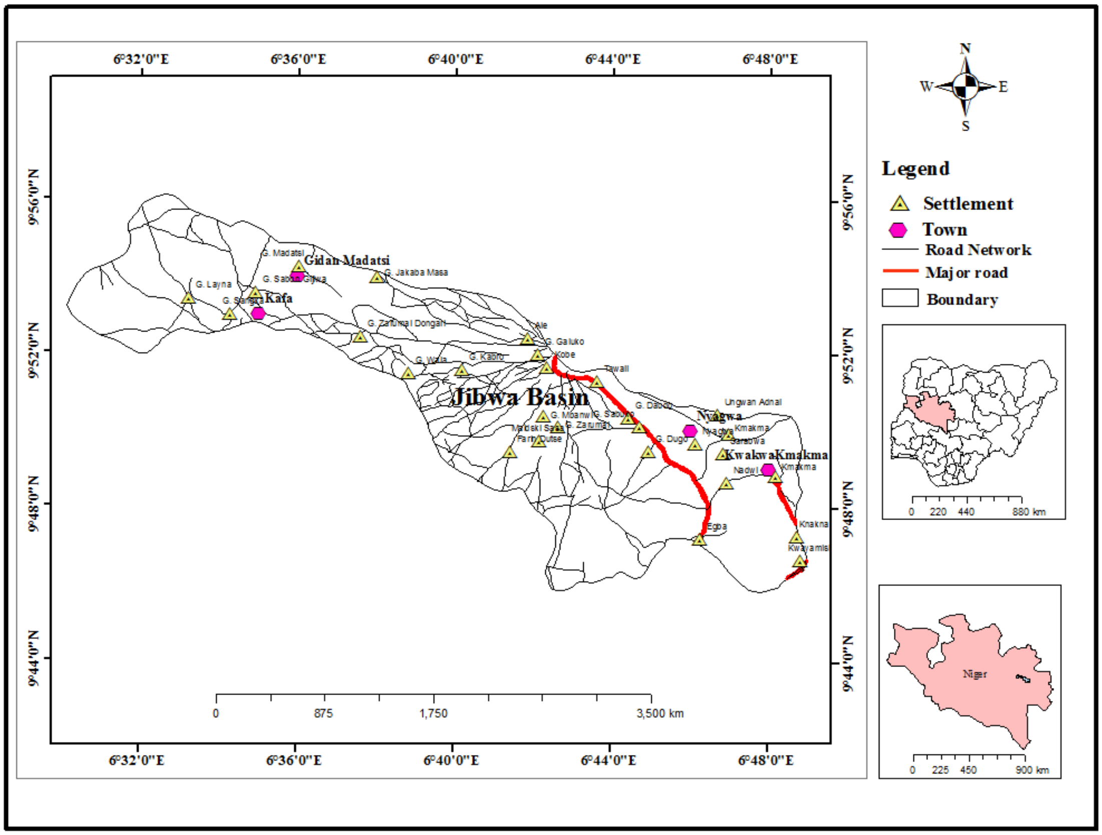

Fig. 1. Administrative map of the study area

2. MATERIALS AND METHODS

2.1 Data

The data used for the study were: topographic sheet of Minna (1:50,000), drainage map of the area, digital Elevation model of the area, soil map of the area, satellite image of the area (Landsat TM 1987, Landsat ETM 2001), and 10 years rainfall data showing daily rainfall in Minna from 1998 – 2007 (Niger State River Basin).

2.2 Work Flow

In this study, different space-temporal multi-date satellite imagery was adopted. These includes; Landsat Thematic Mapper (TM) 1987 and Landsat Enhanced Thematic Mapper ETM 2001. The satellite images were analysed in .TIFF format. The next step was visualization of the images and stacking of the bands of interest (Band 4 NIR,3 RED & 2 GREEN, 1 BLUE). From the stacked band, a false-color composite (FCC) of band 4, 3 and 2 was generated and visualized. The FCC image was subset using the area of interest (AoI) vector frame. After the image preparation and classification, the normalized difference vegetation index (NDVI) for the years 1987 and 2001 were generated. The initial date was first input followed by the latter date image.

For the stream analysis the first step in studying and quantitatively analyzing a watershed and its basin morphometry is a proper delineation of the watershed (stream network limits). There are different methods to achieve this procedure, example of this include: the blue line method [9] on a topographic map drawn perpendicular across the elevation contour lines for land that drains to the point of interest. However; for this study, Geospatial technique i.e. remote sensing (RS), Geographical Information System (GIS), and Global Positioning System (GPS) was adapted to delineate the area of interest.

As reference and base map preparation four topo-sheets of Minna on 1: 50,000 scale (SHEETS 164 NW, NE, SW and SE published by Federal Surveys, Nigeria 1968) in paper format were used. The topo-sheets were scanned using *colortracsmartlf* Ci140 A0 scanner, saved in .tiff format and were geometrically rectified and geo-referenced to UTM coordinate system. The assigned projection system was WGS Minna zone 32 Minna datum Clark 1880. The root mean square error achieved was less than a pixel. Afterward the topo-sheets were trimmed and mosaicked, the feature class of interest such as contour lines, streams and settlement were extracted through on-screen digitizing into a personal geo-database created for the study. The delineated area parameter of the drainage basin was used to subset the settlement image and other spatial data of interest.

From the database, the 3D analyzing tool was used to generate the triangulated irregular network (TIN) from the digitized contour and subsequently the digital elevation model (DEM) was generated from the TIN via its conversion to raster. The overlay of the stream network on the DEM gave a clear visualization of the entire landscape. The drainage area was delineated by determining the ridge separating water flowing in opposite directions to the point of interest where the stream drains into another basin.

To complement the drainage network from the topo-sheet (scale 1:50,000) automatic digital

Table 1. Basin morphometric parameters

Category	Parameter	Symbols	Derivation procedure	References
Area	Basin Area	A	Entire area covered by all draining streams	[10]
	Bifurcation ratio	Rb	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	[11]
	Mean Bifurcation Ratio	Rbm	Rbm = Average bifurcation ratio of all orders	[12]
	Number of streams	∑NU	∑ NU ; where NU is the number of streams in the order U and ∑ = Sum	[12]
	Drainage density	DD	DD = (∑L) / A; where DD = Drainage density, ∑L = Sum of all stream lengths and A = Basin area	[13]
	Stream Order	u	Hierarchical rank	[14]
	Stream frequency	Sf	Sf = Total number of streams / Basin area	[15]
Linear	Total stream length	TL	This is the total length of all the tributaries and the principal drainage	[16]
	Mean stream length	ML	Total stream length divide by total number of streams	[16]
	Basin length	BL	This is the length of the straight line from the mouth of the basin to the farthest point on the basin perimeter.	[16]
Relief	Basin slope	Bs	Bs = VI / HE where Bs = Basin slope, VI = Vertical Interval HE = Horizontal equivalent	[16]

techniques of edge detection and linear enhancement, filters were applied to extract the drainage layer from FCC for better interpolation of the stream order. Order was given to each stream by following [13] stream ordering technique. The attribute table was populated to create the digital database for the delineated drainage area. The final map showing drainage pattern of the study area (Fig. 5) was verified after detailed ground check with GPS survey on channel network and the database was subjected to specific topology rule meant to eliminate network connectivity error.

Various morphometric parameters such as linear aspects of the drainage network: Stream order (Nu), bifurcation ratio (Rb), stream length (Lu) and Ariel aspects of the drainage basin: drainage density (D), stream frequency (Fs) etc. of the basin were computed. The equations for these parameters are shown in Table 1.

3. RESULTS AND DISCUSSION

The various morphometric parameters of the Jibwa river basin were determined and are summarized in Tables 2 and Table 3 showing the analytical results of the linear aspect of drainage network such as stream order, mean stream length ratio, bifurcation ratio e.tc. The DEM of the study area generated is displayed in Fig. 2, Fig. 3 and Fig. 4 displays the NDVI of the area obtained for the years 1987 and 2001 respectively. The Basin morphometry of Jibwa basin with Strahler ordering is displayed in Fig. 5.

Table 2. Summary of drainage basin parameters for the study area

Drainage basin parameter	Value
Basin area	225.98 km2
Bifurcation ratio	15.8
Mean bifurcation ratio	5.26
Numbers of streams	173
Drainage density	1.42 km/km2
Stream order	4
Stream frequency	0.77 km-2
Total stream length	319.784 km
Mean stream length	1.85 km
Basin length	35.652 km
Basin slope	0.0048

Source: Authors' research

Table 3. Number of streams and bifurcation ratio against stream order in Jibwa basin

Stream order	No. of streams	Bifurcation ratio
1	135	-
2	30	4.5
3	7	4.3
4	1	7
Total	173	15.8
Mean		5.26

Source: Authors' research

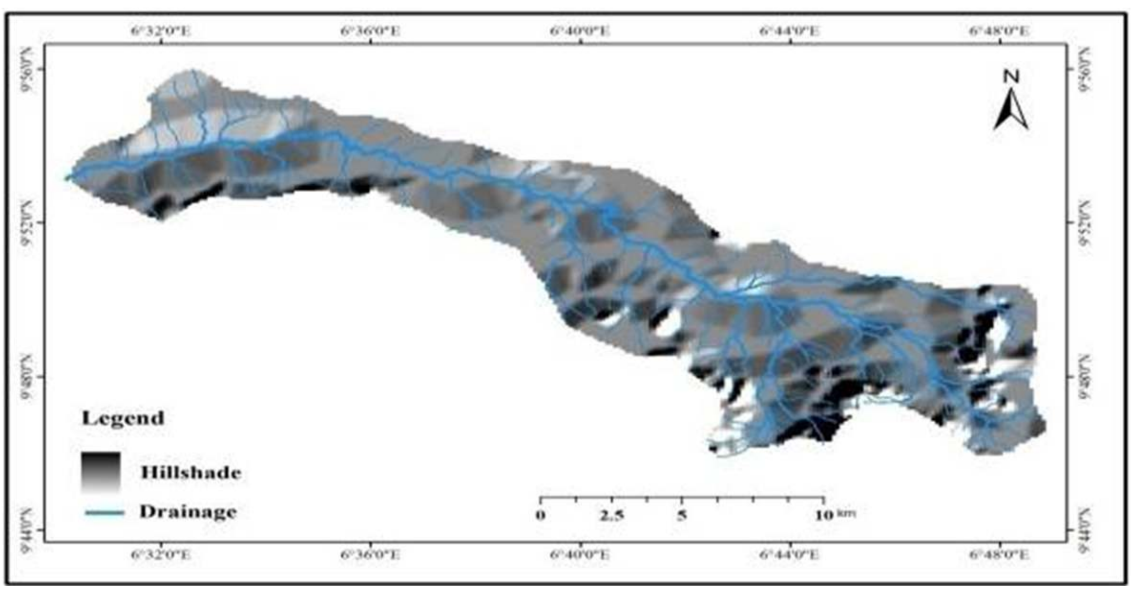

Fig. 2. Digital elevation model of the study area

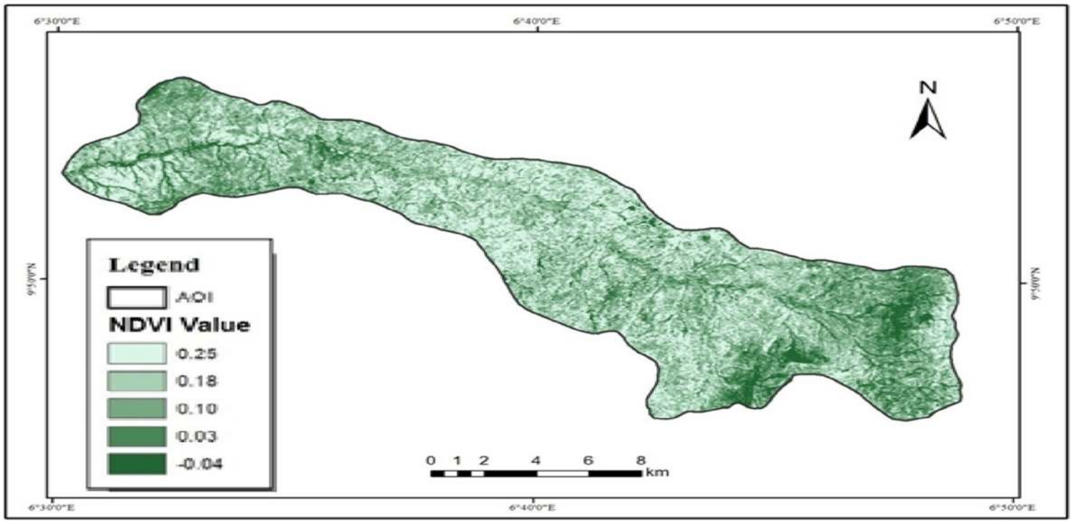

Fig. 3. Normalized difference vegetation index in 1987 for the study area

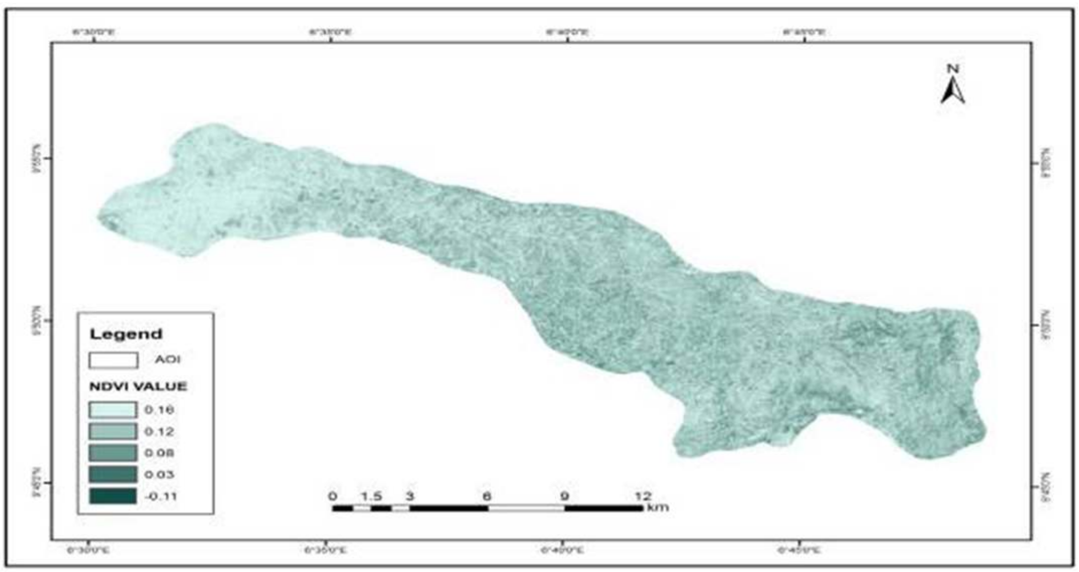

Fig. 4. Normalized difference vegetation index in 2001 for the study area

More positive NDVI values obtained indicated presence of rich vegetation which showed that the area supports agriculture. The trend shows the ability of the study to sustain agriculture. The drainage density of 1.42 km/sq. km is low which suggests that the basin has a highly permeable subsoil and thick vegetative cover. Similar observation was made by [17].

The value of stream frequency (Fs) for the basin exhibit positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density. Similar observation was made by [18]. The stream frequency of 0.77 indicated the presence of at least 2 streams per square kilometer within the drainage basin which makes the study area suitable for irrigation farming. The average bifurcation ratio and slope of 5.26 and < 2% respectively cutting across rich hydromorphic soils indicated good water retaining capacity of the area that encourages cultivation of tree crops such as coffee, coconuts, palm oil, citrus fruits, cocoa, timber etc. The study revealed the drainage area to have adequate surface runoff which makes it suitable for fishing, irrigation and all year crop production. Therefore if the area is properly harnessed, sustainable agriculture will be successful within the area.

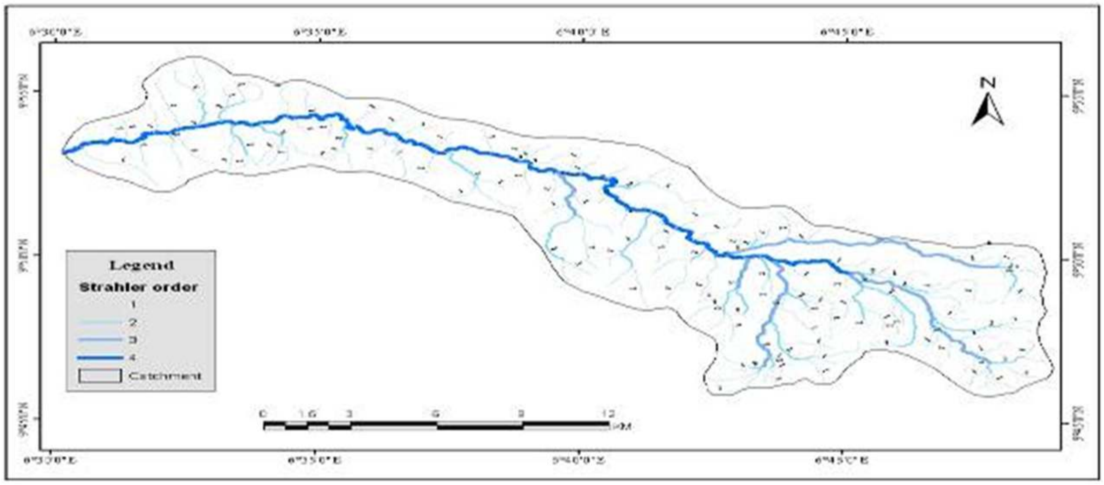

Fig. 5. Drainage basin morphometry with strahler ordering

4. CONCLUSION

This study has shown that the Jibwa River basin has the potential to support fishing, irrigation farming, and cultivation of tree crops. This is attributed to drainage morphometry. It is recommended that practices or activities that could impact negatively on the area should be discouraged.

The morphometric analysis of the drainage network revealed that the basin is of a dendritic pattern with forth order streams. The dendritic pattern indicates the homogeneity in texture. Remote sensing and GIS technologies are the best efficient tools in drainage delineation and also for updating the drainage pattern of an area. The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation as well as for natural resource management.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ndatuwong LG, Yadav GS. Morphometric analysis to infer the hydrogeological behavior in part of Sonebhadra District, Uttar Pradesh, India, using remote sensing and GIS technique. Int. Journ. of Remote Sensing and GIS. 2014;3(1):1−7.
2. Vineesha S, Singh UC. Basin morphometry of Maingra river, district Gwalior, Madhya Pradesh, India. Int. Journ. Of Geomatics and Geosciences. 2011;1(4):891–902.
3. Ramiah SN, Gopalakrishna GS, Srinivasa VS, Najeeb K. Morphometric analysis of sub-basins in and around Malur Taluk, Kolar District, Karanataka using remote sensing and GIS techniques. Journal nature Environment and Pollution Technology. 2012;11(1):89−94.
4. 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.
5. Ebisemiju SF. The structure of the interrelationships of drainage basin characteristics. Unpub. Ph.D Thesis, Department of Geography, University of Ibadan, Nigeria; 1976.
6. Faniran A, Ojo O. Man's Physical Environment: An intermediate physical geography. London: Heinemann; 1980.
7. 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.
8. Eze BE, Efiong J. Morphometric parameters of the Calabar basin: Implication for hydrologic processes. Journal of Geography and Geology. 2010;2(1):19−26.

9. Gardener V. Drainage basin morphometry. In Goudie A, (Ed.), Geomorphological techniques (pp.47-55). London: George Allen and Unwin; 1990.
10. Gregory KJ, Walling DE. Drainage basin form and process: A geomorphological approach, Edward Arnold, London; 1973.
11. Schumm SA. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geological Society of American Bulletin. 1956;67:597-646.
12. Strahler AN. Quantitative analysis of watershed geomorphology. Trans. Amer. Geophys. Union. 1957;38:913-920.
13. Horton RE. Erosional development of streams and their drainage basins, hydro-physical approach to quantitative morphology. Geological Society of American Bulletin. 1945;56(3):275-370.
14. Strahler AN. Quantitative geomorphology of drainage basins and channel network In. Handbook of Applied Hydrology, McGraw Hill Book Company, New York, Section 4-II; 1964. Vineesha S, Singh UC. Basin morphometry of Maingra river, district Gwalior, Madhya Pradesh, India. Int. Journ. of Geomatics and Geosciences. 2011;1(4):891–902.
15. Oyegun CN. The human environment: Its form and processes. Paragraphics: Port-Harcourt; 1997.
16. Schumm SA. A tentative classification of river channels. U.S. Geol. Survey Circular. 1963;477:10.
17. Nag SK. Morphometric analysis remote sensing techniques in the Chaka sub-basin Purulia district, West Bengal. Jour. Indian Soc. Remote Sensing. 1998;26:69-76.
18. Nageswara RK, Swarna LP, Arun KP, Krishna HM. Morphometric analysis of Gostani river basin in Andhra Pradesh State, India using spatial information technology. International Journal of Geomatic Sand Geosciences. 2010;1(2): 179–187.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/12748