British Journal of Earth Sciences Research, 13 (2),42-65, 2025
Print ISSN: 2055-0111 (Print)
Online ISSN: 2055-012X (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

# A Review of Morphometric Studies of Drainage Basins in Nigeria

**M.I Ocheri[1], D.N Umar [2], Wuyep, S. Z.[3], I.S. Laka[4], L. A Odoma[5], P. Ali,[1], M.A Onah[1], P Tarzoho [6]**

[1]. Department of Geography, Benue State University, Makurdi
[2]. Department of Geology, Federal University, Lafia
[3]. Department of Geography, Plateau State University, Bokkos
[4]. Department of Geography and Planning, University of Jos
[5]. Department of Induistrial Safety &Engineering Technology,Bonny Island
[6]. Department of General Studies, College of Health Technology, Taraba

doi: https://doi.org/10.37745/bjesr.2013/vol13n24265 Published May 02, 2025

**Citation**: Ocheri, M.., Umar D.N., Wuyep, S.Z., Laka,I.S., Odoma L. A., Ali, P., Onah, M.A., Tarzoho, P. (2025) A Review of Morphometric Studies of Drainage Basins in Nigeria, *British Journal of Earth Sciences Research*, 13 (2),42-65

**Abstract:** *The review chronicles morphometric studies of drainage basins across the regions of Nigeria. This is done against the backdrop of the importance of the drainage basin in terms of its morphometric characteristics, water resources exploration, planning and development, and its associated environmental problems of flooding, erosion and drought. Both conventional and non-conventional methods are classified into pre- and Remote Sensing (RS) and Geographical Information Systems (GIS) era, where they were used. The results of analysis showed that the linear, areal and relief attributes of the basin varied across the country. The Nigeria drainage basins range: Basin Area($A_b$) 40.75km$^2$ to 9,926km$^2$, Stream Order($N_u$) 3$^{rd}$ to 7$^{th}$, Stream Number(N) 13 to 9205, Stream Length ($L_u$) 9.6km to 30,232.80km, Bifurcation Ratio ($R_b$) 0.9 to 6.0, Drainage Density($D_d$)0.03 to 1.27, Drainage Frequency(Nf) 0.01 to 1.35km-$^1$/ km-$^1$, Drainage Texture( Dt) 0.005 to 4.99, Form Factor(Ff) 0.02 to 0.85, Circularity ratio ($C_R$) 0.10 to 0.81, Elongation ratio ($E_R$) 0.14 to 1.40, Length of overland flow(Lg) 0.08-1.95, Infiltration number (IF) 0.02-1.71, Ruggedness number(Rn) 3.68 to 112.59, Hypsometric Integral (HI) 0.22 to 0.99. The basins were found to be predominantly a dendritic system pattern, suggesting that there were no structural controls. Basins with bifurcation ratio below the threshold of 3 to 5 were less susceptible to flooding and erosion while those above are more prone with a strong structural control on the drainage pattern. Catchments with low values of infiltration number were noted to experience higher infiltration and lower surface runoff. Where form factor values are small, the basins are elongated and have low peak flow of longer duration. Whereas basins with high values have high flows of shorter duration.*

**Keywords:** Morphometric, basins, streams, RS, GIS

## INTRODUCTION

Fundamental to the sound development of water resources for any purpose is the understanding of the dynamics of a drainage basin system with the interaction of hydrologic, geomorphologic, climatologic, geologic, environmental and social attributes that controls the operations of the system.

Drainage basin is recognized by geomorphologists and hydrologists as a fundamental unit for water resources investigation, planning and development for multifarious purposes (Ocheri, 2024) Drainage basin is described as an area drained by a system or systems of streams, such that all streams flow originating in the area is discharged through a single outlet. A country or region can therefore be delineated into drainage basins and sub-drainage basins for planning and water resources development (Strahler, 1964a, USGS, 2016,

In 1976, Nigeria, to develop her water resources, embarked on the establishment of River Basin Development Authorities (RBDAs)(Fig.1 and II). At inception eleven RBDAs were established to cover the whole country (Ayoade and Oyebande, 1983). This idea, however, was borrowed from the experience of the Tennessee Valley Authority (TVA) initiated effectively in 1933 by the United States of America and the success recorded in the development of its water resources. Apart from Nigeria, other countries of the world have adopted an integrated strategy in the development of their water resources using the drainage basin concept. These include Danube Valley Authority(DVA) in Europe; Jordan Valley Authority(JVA) in Jordan; Damodar River Development(DRD) in India; Rhone River Development(RRD) in France; Volga Valley Development (VV) in the then USSR; Hailo River Project(HRP) in China; Volta River Basin Development(VRBD) in Ghana.

According to Adakayi, 1991, Awopegba, 2001 and Aderogba, 2005, opined that the rationale for drainage basin development in Nigeria is based on the following reasons:

i. To meet the ever-increasing needs of water, as the available resources are limited due to increased utilization and diminishing supplies.
ii. To provide safe drinking water for the populace both in urban and rural areas
iii. To make water available for agricultural development through irrigation schemes
iv. For generation of electricity along the country's main watersheds
v. To reduce the negative impacts of water-related problems of flooding, drought, waterlogging, poor channelization, soil erosion, siltation, loss of biodiversity
vi. To meet the demand of rapid urbanization and associated water uses.

Statutorily, the River Basins Development Authorities in Nigeria are charged with the following responsibilities:

i. Undertake a comprehensive development of both surface and underground water resources for multi-purpose use with particular emphasis on the provisions of water infrastructures and control of floods and erosion and for watershed management.
ii. Operating and maintaining dams, dykes, polders, boreholes, irrigation and drainage system, land preparation for agriculture and hand over all lands to be cultivated under the scheme to the farmers
iii. Supply water from completed storage schemes to all users such as farmers, industries, government agencies
iv. Constructing, operating, and maintaining infrastructural services such as roads and bridges linking project sites for easy transportation of farm input and goods produced to market
v. Developing and keeping up to date a comprehensive water resources master plan, identifying all water resources requirements in the Authority's area of operation, through adequate collection and collection of water resources, water use, socio-economic and environmental data on river basins.
vi. Providing and keeping up to date records of water resources inventory in the country
vii. Dams to provide recreational services that generate revenue to the government from tourist.

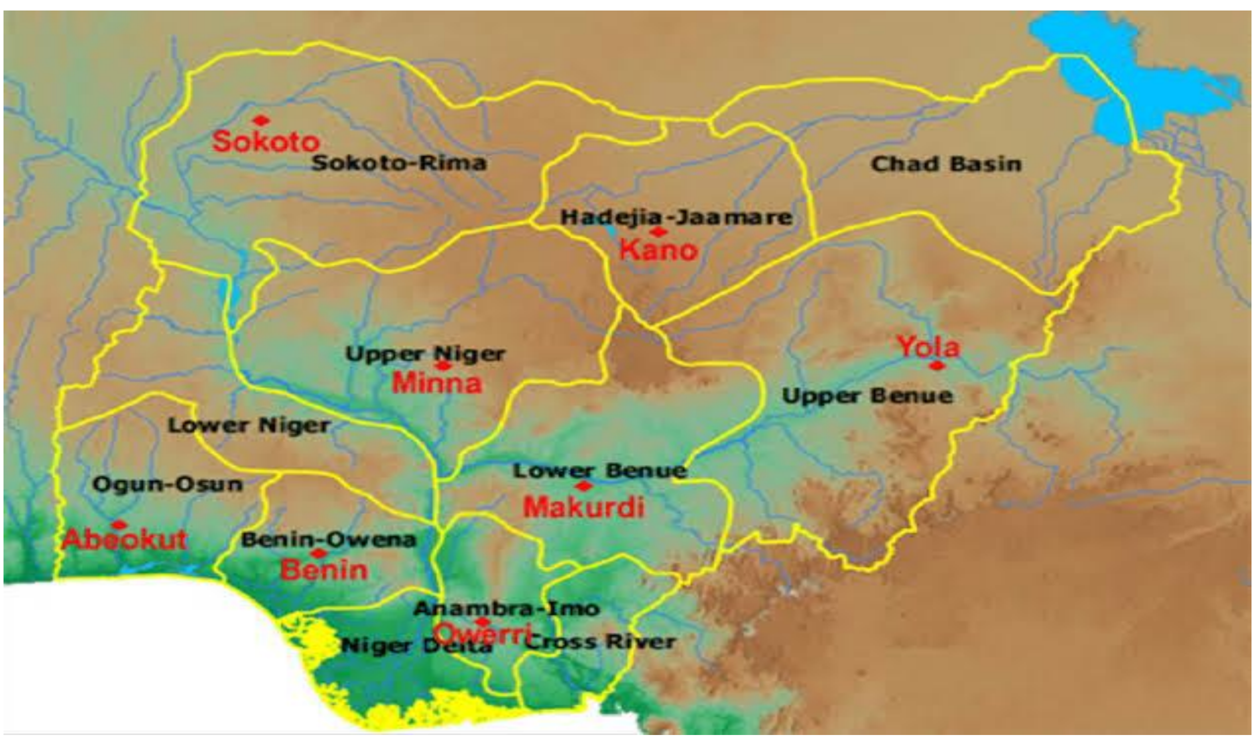


Fig.1 River Basin Development Authorities in Nigeria

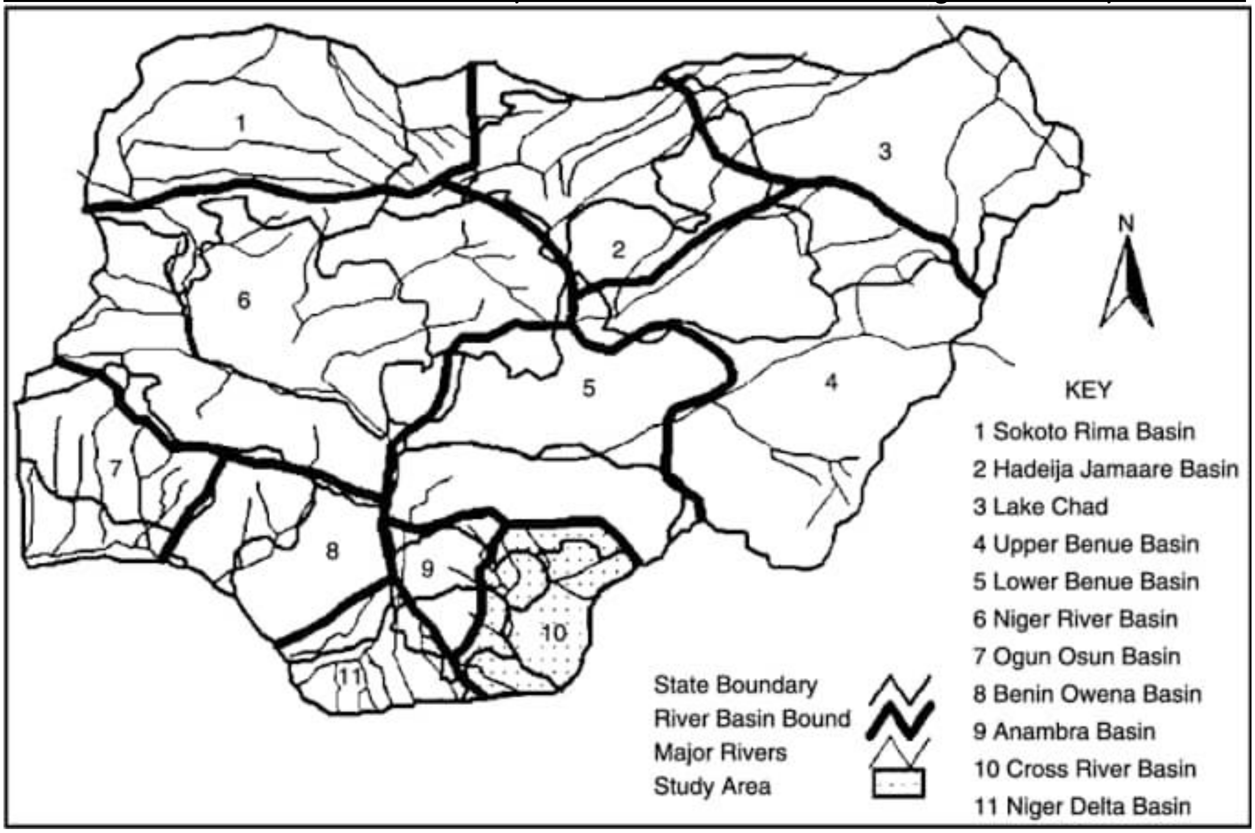


Figure 11: Nigerian Rivers Basin development Units

Looking at the objectives of the RBDAS at the time these basin authorities were established, not much is known about the characteristics of the basin as reflected in the paucity of data, which is supposed to be basic to water resources development. This perhaps may have contributed to the poor performance of the basin authorities over time as projects were executed with little or no appropriate data. This research therefore is a contribution in this regard. Drainage basin studies in Nigeria reviewed are classified under two periods, namely the pre-Remote Sensing (RS) and Geographical Information Systems (GIS) era and the RS and GIS era.

**Drainage basin studies in the pre-Remote Sensing (RS) and Geographical Information Systems (GIS)**

During the pre-RS and GIS era, drainage basin studies relied principally on conventional methods of the use of topographical maps as a basic tool for basin delineation, measurement of basin parameters, data collection which are then subjected to mathematical and statistical treatment, inferences. This kind of approach was quite laborious, energy-sapping, and time-consuming, and the results are more prone to error and less precise. This predates the era of digitization where Remote Sensing (RS) and Geographical Information Systems (GIS) are used.

In Nigeria, the study, which may be considered as a baseline study of the drainage basin system, is the Federal Government of Nigeria and was done by NEDECO Netherland Engineering Consultants, The Hague in 1957. The main thrust of the commission was to study conditions obtainable in Niger and Benue Rivers to determine how shipping conditions (transportation) on the rivers can be mostly effectively be improved. River Niger and Benue dominates or constitutes the major drainage basin system with others as sub-basins. The terms of reference for NEDECO study includes: determination of the characteristics and behaviour of the parts and the entire river system which will constitute a foundation on which project for the improvement might be based; composition using aerial survey supplemented by terrestrial measurements and soundings, of a complete series of sufficiently accurate river map covering the entire river system downstream from Baro and Garua on River Niger and Benue respectively; gather sufficient data or information on the regime of the rivers including flow discharges, water level, slopes, rainfall, evaporation, transportation of bed-load and sediment in suspension, and establishing the relation between these elements as well as their dependence from the seasonal cycle and variation, and possibly other factors; study the vagaries of channel configurations, depth, cross-section. The completion of the commissioned study culminated in the development of waterways both coastal and inland with ports at Port Harcourt and Lagos and small inland ports at Onitsha, Idah, Lokoja, Baro, Makurdi, Katsina-Ala, Ibi, Jimeta, Yola.

Subsequently, basin studies were carried out by researchers for academic purposes aimed at generating data on hydrologic and geomorphologic characteristics of the drainage basins parameters. According to Ifabiyi (2013), these studies were majorly on runoff in drainage sub-basins which he classified into five. First category focused on interrelationships among basin parameters (Okechukwu, 1974; Ebisemiju, 1974; 1979; 1982; 1989); Second is on run-off and basin parameters (Ogunkoya,et al,1984; Adejuwon et al, 1983; Anyadike and Phil-Eze.1989), Third, run off and erosion (Oyegun, 1982; Jeje and Agu, 1982; Jeje 1987), Fourth,run off and landuse (Lal, 1983; Odermirho, 1984a, 1984b), Fifth rainfall and run off studies (NEDECO,1959; Ledger,1964).

Adejuwon, Jeje and Ogunkoya(1983) pioneered a study on the hydrological response patterns of some 3rd streams on the basement complex of Southwestern Nigeria focusing on their regime, discharge variability, and recession of flow peak discharge among the seasons. The study showed that the minimum and maximum discharges of the rivers coincided with the rainy and dry seasons respectively. The rivers were noted to exhibit erratic flow with quick response to the storm and stormwater abating quickly, while some have a very low groundwater to stream flow, a phenomenon which accounted for their drying up for a considerable period in the year. The variability indices of discharge ranged from 0.25 – 2.12 while the recession constant ranged from 0.64 – 0.98 found to be higher than those of the basin similar in size as reported from other studies. Three types of rivers were identified on the basins of their hydrological response patterns, and surficial and solid geology have a greater influence on discharge characteristics than other factors such as depth of the regolith and rainfall. In a related study, Ogunkoya, Adejuwon, and Jeje (1984) examined the run–off response on monthly, seasonal, annual run-off coefficient of fifteen 3rd order basins in some parts of Southwestern Nigeria. The results showed that run-off values appear to be generally low and vary widely among the basins. They also vary strongly over hydrological year, reflecting the water yielding capacity of basins, saprolite rock, and moisture status. The last appears to be very important at the peak of the rainy season. They found that runoff coefficient ranges from 1-40% of annual rainfall and noted that runoff parameters were strongly influenced by the nature of the soil and geology of the basin. Ajibade et al(2010) were curious about how morphometric attributes of a drainage basin can influence the hydrologic and geomorphological processes embarked on a study of Ogunpa and Ogbere drainage basins in Ibadan in Southwestern Nigeria. Fifteen (15) morphometric variables were analysed and ANOVa was used to examine the differences in morphometric parameters both between and within in the basins. The result showed that Ogunpa has a basin area of 40.75km$^2$ Ogbere 52.99km2; basin length of 7.9km and 14.25km; bifurcation ratio of 4.67 and 4.57; drainage density of 1.22km/sqkm and 1.02km/sqkm;basin slope 0.32 and 0.41; relief ratio of 0.22 and 0.014 respectively. Basin area was identified as the most potent morphometric parameters that controls catchment run off pattern as the larger the basin, the greater the volume of rainfall it intercepts and the higher the peak discharge(Morisawa,1959;Nabegu, 2005).Higher correlation between basin area and discharge is that can influence run off is basin length, stream length, relief, shape and length (Greggory and Walling,1973; Ebisemiju,1976; Ifabiyi, 2004).The study found that Ogunpa basin though smaller in size recorded more flood events in the city than Ogbere basin which is larger in size. This was attributed to the fact that the longer the length of the basin, the lower the slope and the lower the chances that such a basin will be flooded when compared with a compact basin like Ogunpa. And again the time of concentration (lag time) in such a basin will be higher than a more compact basin which produce sharp hydrographic peak due to high bifurcation ratio. High concentration time thus exposes the water intercepted by Ogbere drainage basin to longer duration of infiltration, and evaporation process hence reduction in in run off volume. Other factors may include higher drainage density, relief and circulatory ratio. Relief ratio is an indicator of rates of erosion operating along the slope of a basin. Ogunpa basin has higher relief ratio than Ogbere hence higher erosive capacity and sediment yield which disposes the basin to higher flood peak (Okoko and Olujimi, 2023). Higher circulatory ratio recorded in Ogunpa basin is in conformity with Miller (1953). Shobogun et al(201) carried a morphometric study of Sokori river basin , Abeokuta, Nigeria with implications on hydrologic process. Analysis was done using topographical maps. The results showed that the basin area is 46.63km$^2$ , had 13 streams with a total stream length of 9.63km, drainage density and stream frequency of 0.20km-$^I$, and 0.34km-$^1$.These low values show that the basin is structurally permeable, has relatively thick vegetation cover, and low run off makes it susceptible to flooding, particularly downstream part of the basin. Circularity ratio 0.81 and elongated ratio of 0.82 showed the basin is non-circular but pear shaped. The form factor and texture ratio of 0.53 and 0.48 respectively indicative of oval shape tending toward elongation, lag time and high relief. A high bifurcation ratio of 4.12 was indicative of the natural drainage system. Low value of compact coefficient 1.11 indicate that the opposite sides of the drainage divide is closely spaced. High human activities within the Sokori river basin appeared to have been degraded and reshaped through urbanization.It is recommended that Sokori basin be protected through conscious planning and reorganization of socio-economic activities.

Kowea and Ajayi (2022) assessed the geomorphic and morphometric characteristics of river Shasha and Opa that drains the Obafemi Awolowo University campus. The campus is drained mainly by 4$^{th}$ order stream, while northern and northwestern part of River Shasha a 3$^{rd}$ order stream. The main stream length for 1$^{st}$ , 2$^{nd}$ ,and 3$^{rd}$ of Shasha are 0.42, 0.54 and 1.03km respectively, while the main stream length of 1$^{st}$ , 2$^{nd}$ , 3$^{rd}$, and 4$^{th}$ of River Shasha are 0.40, 0.64, 1.84, and 4.07 km respectively. The average length of the overland flow within the Shasha sub-basin was 0.25km, while that Opa average overland flow of 0.15km stream segement densit y increased from 0.16km$^2$ to 3.18km$^2$ in River Shasha an 0.08km to 4.33km$^2$ in Opa increased stream segement density from lower to higher order.The predominant trend of streams were NE - SW and NW-SE suggesting the influence of differing lithologies or tectonic activities, where streams have developed by taking advantage of the local relief for the varying streamflow direction.

In Southeastern Nigeria, Ebisemiju (1979) used a reduced model approach in the study of drainage basin morphology. This was adopted against the backdrop of the existence of the groups of highly interconnected variable number of parameters widely used for quantifying drainage basin morphology. Through principal axis factor analysis of 37 morphometric properties of 52 3rd order basin in Udi-Awgu Cuesta of South-eastern Nigeria. Six factors identified as measure of intensity of dissection, stream network size, relief , shape , link length ratio and bifurcation ratio are found to account for 92% of the variance in the data.The factor defining variables were found to be total drainage density, total length, relief ratio, lemniscate ratio, link length ratio and bifurcation respectively. These findings were found to be consistent with similar results obtained for the 3$^{rd}$ order streams of southern Uganda, western USA. They concluded that irrespective of the difference in climate, lithology and vegetation cover, the morphology of drainage basins may be adequately be quantified by measurement and analysis of these six variables. Anyadike and Phil-Eze(1989) analysed run-off response to basin parameters in a 10 medium sized basin in the Southeastern Nigeria. Principal component analysis was used to reduce 14 run off, rainfall and physiographic indices to 5 orthogonal components, namely basin size, landuse, basin steepness, basin altitude which together explain 88.4% of the observed variance. Five component variables , basin area, percentage of basin area covered by forest, drainage density, dry season rainfall and channel slope are used as regression which provide a prediction of annual run off with a coefficient of determination of 0.72. Explanations were suggested for significance of these variables for the run off.

The effect of the environmental heterogeneity on the interdependence of the drainage basin morphometric properties and its implications especially flood control/abatement was investigated in the Upper Cross River, Nigeria (Udosen, 2009). A 22 3rd order streams in the upper cross river were analysed.Six 3rd streams were selected from diverse geologic formation of Precambrian Complex rocks and Asu River Formation of Abakaliki and Ikom –Maufe formation. The thirteen derived data on the morphometric parameters were tested for normalty and logarithm transformation. The result of Principal component analysis show the degree of inter-correlation among the 13 morphometric variable is weak as only 32.1% of 78 possible relationship were significant at 0.05 level. It is known that an increase in the interdependence of the morphometric properties of drainage basin is indicative of the lessening of environmental constraint (lithology) on the stochastic process that generate stream network. The result of the PCA show 4 factors model accounted for 83.9% of the variation in the original data. E.g index of drainage dissection is inversely related to basin size. The infrequent occurrence of flooding in the basin is caused by rain swollen tributaries discharged into the main channel at different period. In a related a study, Eze and Effiong (2010) examined the morphometric properties of Cross River basin as it affect the hydrologic processes in the basin. Data were obtained from topographic map along with field measurements. The results of analysis showed the basin area was 151km$^2$, having 223 streams with a total of length of 516.34km. The textural dissection was considered to be low as drainage density, stream frequency and drainage intensity values were 0.34$^{-1}$, 0.15km$^{-1}$ 0.05.The basin was found to be strongly elongated with circularity ratio of 0.64. The average bifurcation ratio was 2.83. The very low value of the drainage implies that drainage density and stream frequency have very little effect on the extent to which the surface has been lowered by agents of denudation. This also implies that surface run off is not quickly removed from the basin making it susceptible to flooding, gully erosion.

Okechukwu (1974) pioneered a study on the run off response focusing on the fluvial-geomorphic interrationships in some river catchment northern Nigeria Precambrian basement complex. In related study Ifabiyi (2013) used a rank – reduced analysis of run off components and their response to basin parameters in Northern basement complex of Nigeria. In attempt to study the response pattern of six hydrological parameters, namely surface flow, interflow and groundwater flow, the annual hydrograph separated into dry season wet season flow and total run off. 30 hydro-climatic variables were generated from 30sub-basin of the upper Kaduna catchment covering a period of 11years(1979-1989).Stream flow, interflow and groundwater flow were determined using a 3-component hydrograph separation procedure dry, wet and total run off were defined climatologically. A total of 660 hydrograph were separated. Factor regression method was used to identify the most significant factors which explain each component. The result showed that these variables differ slightly from one flow type to the other.

Morphometric characteristics of Obibia drainage basin of Awka urban area was investigated by Ezenwaji et al (2018). Basin was delineated with conventional methods from topographic map of Udi SW on scale of 1.50,000. Principal Component Analysis (PCA) was used to reduce the nineteen (19) variables into five (5) components. Principal Component Regression (PCR) was also used to reveal the relative contribution of morphometric variables. Result showed bifurcation ratio of 3.0 indicating a higher risk to flooding. The relationship between mean stream length and stream order 2 differ far away from straight line on the plotted graph suggesting strong structural imbalance. The drainage basin area 84km2, basin length 18.28km2, and is of the $4^{th}$ order , total stream length of 102.2km2.with mean bifurcation ratio of 4.09 implying no geologic control. It also has drainage density of 1.22, stream frequency 0.99, elongated ratio 0.57, form factor 0.25, circularity ratio 0.41 and compact coefficient 1.55.

**Drainage basin studies using Remote Sensing and Geographical Information Systems**

**Drainage basin studies in the southwestern Nigeria.**

Traditional approaches have been used to investigate the morphometric properties of various basins and sub-basins worldwide (Patel et al, 2013, Taofik et al2017, Odiji et al, 2017). However, with the introduction of remotely sensed data, it is now possible to better understand resources from broader basinal areas in much shorter time and with more details than traditional surveys. Remote Sensing(RS) and Geographical Information Systems(GIS) have been proven to be an effective tool in delineation, updating and morphometric analysis of drainage basins(Eze and Mozie, 2019,Pardeshi 2018,Hajam et al,2013).According to Rastogi and Sharma(1978),any hydrological inquiry, such as water potential, availability and water resources management require drainage basin analysis. Physiographic properties of drainage basin such as size, shape, slope of drainage area, drainage number and length of rivers can be linked to variety of crucial hydrologic phenomena. Grohmann(2004) posited that recent advancement in computational power of RS and GIS has accounted for the development in hydrological models and computational(rather than descriptive) interests in morphometry analysis. Application of remote sensing and geographical information systems is often preferred for potential and capacity for customized production of outputs( in terms of resolution ad data integration).Digital Elevation Models(DEMs) are frequently explored for morphometric analysis of river basins through the extraction of topographic parameters and stream networks, variation in relief, land surface form. Recent increase in the application of DEMs can be attributed to their easy integration within a GIS environment. The Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) are samples of advanced global DEMs. They have been adopted in variety of studies where terrain and drainage factors playing a prominent roles because of convenience of users and open-access availability of the DEMs.

In an expository review of remote sensing and river basin management in Southwest Nigeria Oreoluwa and Eludoyin ((2019) affirmed the relevance of remote sensing technology as efficient for providing decision support system for both gauged and ungauged river basins, and that freely available remote sensing data can efficiently fill the data gaps in many developing countries. It however warned on the need to consider variations in sensor capacity and mission as important attributes that can generate different spatial radiometric issues which may negatively affect the quality of result. It concluded that researchers on drainage basin analysis in developing countries will benefit immensely from the freely available remote sensing data in the region.

Akimwumiju and Olorunfemi (2016) assessed the morphometric characteristics of Osun Drainage Basin (ODB) in southwest Nigeria with particular reference to its infiltration potential. Data input were derived from SPOT DEM using ArcGIS103 platform. ODB has a basin area of 2,208.18km, drained by 1,560streams with a total length of 2,487,7km.Relief ratio of 5.6 suggests ODB is characterized with high and low topography. According to them, infiltration potential was low as surface run off would have less time to infiltrate before entering the drainage channel. With the drainage texture of 0.52, stream number 1,650, total stream length of 2,487.7m, mean stream length 119m indicate that larger percentage of annual rainwater would leave ODB as river discharge. Stream frequency, basin perimeter, length of overland flow and drainage density influences infiltration. As infiltration number increases with stream frequency of 0.83 and drainage density r=0.70 and length of overland flow increases with decreasing drainage density of r=0.83, stream frequency r=0.51 and infiltration number r=0.45.The study concluded that infiltration potential is moderate as noted in the mean infiltration number. Also noted is that basin order has strong positive correlation with basin area, perimeter, stream number, drainage texture and stream length with correlation valves of 0.72,0.81, 0.70,0.77 and 0.74respectively x=0.1. Result also showed that length of overland flow exhibit inverse but significant relationship with drainage basin density, stream frequency and infiltration number with values of 0.78 and 0.95 respectively at 0.01. Infiltration number increases with increasing drainage density and stream frequency and decreasing length of overland flow in the study area.

In Owu river sub-basin of Ogun-Osun river basin of southwestern Nigeria Samson et al (2016) used geospatial technique to map the flood vulnerability of the study area. Data used were the topographic maps and satellite images. Data were analysed by both hydrologic and GIS technique for basin delineation, stream ordering and DEM modelling. Result showed that the drainage basin has 429 stream segments, mean bifurcation ratio of 1.93 and that 32% of the entire basin area is susceptible to severe flooding. Potential flood prone areas were classified into vulnerable, highly vulnerable, less vulnerable and least vulnerable .Highly vulnerable areas identified are Temidire settlement, environ, southern part of Oyo National Park and upstream of Ikere gorge dam area with least vulnerable areas as army barrack Saki ,Iyanla hills and Tede. High rainfall, landuse and slope, as well as morphometric characteristics have been found to influence flood potential in the study area. Also, Jesuleye et al (2016) examined the morphometric properties of Oba river drainage basin in southwest with implications on flooding potentials.RS and GIS was used in the analysis. The results showed the basin is of the 6$^{th}$ order, with a total of stream length of 2754.48km. Total number of streams as 2979, basin area and perimeter of 2494.45km and 29km respectively, with the basin length of 96.1km. In Osun drainage basin of the western lithoral Hydrological zone of Nigeria Ashaolu(206) analysed 21 morphometric parameters of the basin using RS and GIS technique. Results showed that the basin is of the 4$^{th}$ order, with a basin area of 9926.22km$^2$ . The area covers two geologic types and 4 soil types were quantified and it also revealed that 93.28% of the basin is within the basement complex rocks,while 50.89% is covered by sandy and clay loam soil.They further concluded that all attribute have the capacity to influence discharge rate, chances of flood occurrence , peak flow, infiltration rate, recharging of Osun basin groundwater systems. In a of related study Lasisi et al (2018) embarked on morphometric synthesis of Oluyole catchment area of Ibadan a sub-basin of Ogun-Osun River basin in southwestern Nigeria. Digital Elevation Model and Geographical information systems were used in the analysis. The result reveal that, the catchment consist of high, medium and low elevation ranging from 105-195m. Slope area ranged from $0^0$-24.5 flow direction. Areas with high flow 64- 128 were noted to be more vulnerable to flooding and erosion, while areas with medium flow direction 32.1-64 were moderately susceptible to flooding and are with low flow direction 1-32 are less vulnerable to flooding and erosion. Areas with values ranging from 55,785.7-136,782m represents areas with highest flow or accumulation of water, while areas with 12873.6-55,785.6m represents areas of average concentration of river or stream in a channel. They concluded that areas with high flow accumulation are vulnerable to flooding while of medium accumulation are moderately susceptible to flooding, and areas with low flow accumulation were less susceptible to flooding. Balogun et al (2013) analysed the geometric attributes of Olomore sub-basin of Ogun- Osun river basin of southwest of Abeokuta with implication on hydrologic processes. Analysis was done using ArcGIS software package version 9.3, ESRI 2008.The result of analyses showed a total of 71 streams, total stream, basin area and drainage length of 98.85km, 41. 70km$^2$ and 10.75km. Bifurcation ratio of 1, 75, channel gradient of o.0071 dendritic system of drainage, Result of computation of stream frequency elongation and circulatory ratio showed that the risk of flooding in the basin is low.

In a related development Abayomi et al (2023) examined the morphometric characteristic of Yewa drainage basin an important sub-drainage basin of Ogun-Osun drainage in southwestern Nigeria. Data were analysed using ArcGIS.The results of analysis showed that basin is of the 4$^{th}$ order covering an area of 4832.40km$^2$ , bifurcation ratio of 2.03 indicating that the geological structure do not exercise a significant influence on the drainage pattern, drainage density of 0.256km-1 indicating coarse texture, high infiltration, permeability with thick vegetation and moderate to low relief, elongation ratio of 0.556, form factor 0.243 elongated in shape.

In a bid to proffer solution to incessant incidence of flooding in Ureje and Ogbese Drainage basin(UODRB) Southwestern Nigeria, Akindejoye et al(2022) carried out a morphometric analyses of the basin. A 30m Digital Elevation Mode l(DEM) from Shuttle Radar Topographic Mission(SRTM) was deployed in analysis of the basin properties. To determine the susceptibility within the study area, the total ranking technique was adopted to prioritize the sub waterhed. The results of the analyses showed UODRB is of dendritic pattern, with a total 5985 stream segment and drainage area of 2642km$^2$ and the basin is of the 6$^{th}$ order implying that the basin is controlled by lithology and geologic structure. Priortisation show that 37.5% of sub-watershed III and V is at a very high priority to flooding susceptibility, while 47.7% of the basin sub watershed II, VI and

VII at high priority to flood susceptibility. The study recommended that anthropogenic activities along identified sensitive slopes should be controlled and sensitization of high risk communities is necessary so adequate preparation be made to mitigate future occurrence of flood. In a related study, Aladejana et al(2018) adopted a geomorphic, morphometric and structural analyses of North West Benin Owena River Basin(NWBODB) with the implication on groundwater development. Geospatial technique of remote sensing and geographical information systems was used in the identification, extraction and mapping of the basin characteristics .The basin was delineated from topographical maps. Five (5) major sub-basins (SB) and each was quantitatively assessed for their geomorphic, morphometric and structural attributes. Parameters considered relevant to groundwater development were utilized for sub-basin prioritization identification of deficit/surplus zones. NWWBODB is of the $6^{th}$ order. It is dominated by rainfed at lower order streams which reflect a late youth to early mature stage of development of fluvial geomorphic cycle.It has a low stream frequency and moderate drainage density of 1.149, and bifurcation ratio lower than stream orders surging through a highly dissected, steep mountaineous terrain that create a seasonal low groundwater prospects, with exception occurring in the pediplain and flood plain areas. A comparison of the predominant orientation of the $2^{nd}$ ,$3^{rd}$ ,and $4^{th}$ orders with lineament direction indicates structural control within the basin. Sustainable water conservation techniques are suggested locally within the drainage basin SB II which is the most deficit zone, while SB V was found to be surplus zone of groundwater potential,

**Drainage basin studies in Southeastern Nigeria**

Amangabara(2015) embarked on the morphometric assessment of Imo basin in Anambra-Imo River , Imo State, Nigeria. The study delineated all the river sub-basin in the Imo basin of the Anambra- Imo River basin. Five(5) sub-basins were delineated into Imo, Upper Orashi, Njaba/Lower Orashi, Otamiri, and Ogechie basins.

Imo basin has a total area of 1,322.82km$^2$. Total area drained by Imo, Abia and River State is 7,770, with bifurcation ration of 2, drainage density of 0.11, stream frequency 0.1, drainage intensity of 9.945 at the lower reach become $5^{th}$ order stream with Otamiri, Ogbechie and Aba rivers as the main tributaries.

Upper Orashi sub-basin covers an area of 152.41km$^{2.}$ The river has three segments. Two are of the $1^{st}$ order streams and one of the $2^{nd}$ stream comprising a total length of 40.191km, drainage density of 0.27, stream frequency of 0.02, and drainage intensity of 0.052.

Njaba/ Lower Orashi sub basin is of the $7^{th}$ order stream. One is $2^{nd}$ order streams, two each of the $3^{rd}$ order, and $4^{th}$ order streams. Drainage density 0.15, drainage intensity 0.001, stream frequency 0.01. Bifurcatio ratio 2.84. Bifurcation ratio tends to remain constant from one order to the next.

Otamiri sub-basin covers an area of 1,719.2km$^2$. The major rivers includes Oraminikwa, Okitonko, Mbaa, Nwaorie and Efuru. The total length of the stream 228.km. They are all of 11 $1^{st}$ order streams, 3 2nd order streams, 2 , 3rd and 1 4th order and5th order with bifurcation ratio of 2.04 and drainage density of 0.20, stream frequency of 0.02 and drainage density of 0.003. In a related study Nnaji et al (2023) concerned over the environmental problems of flooding, water resources management and landslide emanating from the disruption of river basin assessed the morphometric attributes of Anambra –Imo River basins. RS and GIS with DEM were used in the analysis. The results showed that Anambra/ Imo basin 6th /5th order streams, both are of dendritic pattern of drainage, total stream of 1462/208, total stream length 13682.9km/1320.57km, drainage density 1.08km-1/0.23km-1, stream frequency 0.12/0.36, drainage texture 0.56/2.81, infiltration number 0.3/0.11, elongation ratio 0.49/0.84, circularity ratio 0.49/0.84, overland flow 0.46/2.18, constant channel maintenance 0.93/4.34, ruggedness number 0.19/1.5, compact index 1.4/1.06. The study concluded that underlying factors responsible for flooding and gully erosion in the study area is as result of the combination of climate and geological characteristics of the area.They further stressed that the low drainage density recorded in the basins suggests a high vulnerability to flooding, landslide and high groundwater potentials.

Udoka et al(2016) assessed the morphometric and land use land cover change(LULC) characteristics of Oguta sub watershed in Southeast Nigeria using remote sensing and geographical information systems SRTM DEM and Landsat 7 and ArcGIS 10.3). The results of LULC revealed 37.32% of the basin is farmland, 27.51% forest, 20.06 barelend, and 5.20% water, while Orashi drainage basin comprise 30.23% farmland, 10.35% urban settlement, 20.14% forest,15.13% bareland and 24.48% water.The Njaba has length of 21.48km2, Orashi 29.59km2, Njaba has basin area of 21.48km2, Njaba 29.59km2. Morphometric analysis revealed Njaba and Orashi basin have bifurcation ratio of 1.80 and 3.92, drainage density 0.54 and0.51, basin relief 0.0038 and 0.00867, form factor 0.31 and 0.189, Njaba is circular and Orashi ie elongated. Njaba is of 3rd order while Orashi is 4th order.

Ochuko(2020) used RS and GIS to model the morphometric attribute of drainage basin of Udi-Awgu Cuesta in Southeatern Nigeria. The basin as drainage area of 7,161.04, basin of 3rd order ,basin length 114, perimeter of 23.00.50, overland flow 0.18, bifurcation ratio 4.35, stream number 925, total stream length 1019.6 , drainage density of 1.40, stream frequency of 1.30, circulatory 0.62, form factor of 0.08, basin elongation1.00, constant channel maintenance 1160, ruggedness 3.68.From these characteristics the basin is elongated with oval shape , with geological and hydrological tending toward uniform infiltration, does not overflow as it takes long time for excess water to reach the basin outlet, high relief ,high run off,

To test the validity of Hortonian law in a drainage basin Ayogu et al(2019) used Anambra basin as a case study.According to them, since hydrologic and sedimentologic processes influence basin form and processes which are governed by Hortonian law underscored the basis of the application in the study area.Metrical dimension provides linearity, topographic and variables were used to validate Hortonian postulations in the basin.Topographic tools and ArcGIs 10.2 were used in the analysis.The stream number, length and areal quantities showed that the three laws of drainage basin composition postulated by Horton are valid.It is a $6^{th}$ order dendritic pattern with elongated shape and coarse texture. The drainage density, stream frequency and infiltration number low values: 0.10, 0.10 and 0.27 respectively, while the overland processes recorded 0.51, impling heavy dissection. The constant channel maintenance is $0.99km^2$. The relief characteristic is low. The authors concluded that the significance of the morphometric attributes of Anambra drainage basin has a lot of implications on agricultural practices and erosion processes.

In the morphometric study of Calabar river basin Effiong et all (2022) used a GIS based platform.Data were obtained from SRTM-30 DEM.Standard process was adopted in the extraction of the required morphometric parameters from DEM.The results showed that the basin area is 1,154.66km2, with 274 streams with a total length of 600.13km.The textural dissection was considered low as drainage density, stream frequency and drainage intensity values were 0.75km-1 and 0.18 respectively. The basin is elongated with circulatory ratio of 0.20, elongation ratio of 1.4, form factor of 0.31, bifurcation ration 4.04.The very low value of drainage intensity implies that the drainage density and stream frequency do not play a significant role in the denudational processes in the basin. The low values also imply that surface run off is not quickly removed from the basin, and particularly $2^{nd}$ bifurcation ratio.This portend serious danger to flooding at those bifurcations. The study also found a significant relationship between streams order, stream number on one hand, and between stream order and mean stream length on the other hand.

Ahuchaogu et al(2022) used RS and GIS to demonstrate their potency in characterization of basin attributes of River Niger basin in Delta State, Nigeria.Basin terrain and hydrological parameters such as slope aspect, 3-D landscape, sub catchment, flow direction, channel networks, drainage density, stream order, stream frequency were processed using Advance Space Boerne thermal emission and reflection data(ASTER DEM) in GIS environment. Ground truthing and accuracy assessment was carried to ensure reliability of the results.The drainage basin covers area of $17530km^2$, with drainage density of 0.1659km, basin length 337.60km, stream frequency of $7.017x10^{-3}$, bifurcation ratio range between 4.75-5.0, form factor of 0.154, circularity ratio 0.4.

**Drainage basin studies in Northern Nigeria**

The drainage studies here covers northern eastern, northwestern and north Central Nigeria.

The morphometric and hydrologic analysis of upper Yedzaram catchment of Mubi , Adamawa State Nigeria was carried out by Adegoke el al(2015). ArcGIS 10.0 was used in the basin delineation. Results showed that basin has an area of $191.17km^{2, total}$ stream number 61, total stream length of 161.97, bifurcation ration of 2.74, drainage density of 0.85. The values tends to associate the low density with high permeable top soil and thick vegetation cover. The value also indicates that in every $km^2$ of the basin there is 0.85km of drainage channel.

Concern over erosion and sediment yield of River Gada Katsina State , Nigeria, motivated Hassan and Kabir(2019) to embark on morphometric and vulnerability analysis of the drainage basin.The study was aimed at establishing a relationship between surface morphometry and hydrogeomorphic characteristics of the basin using ArcGIS and DEM. The results showed that the basin has an area of 2, 7490.72km$^2$, with total stream of 67, total stream length of 634.37km, stream frequency of 0.02, bifurcation ratio of 4.0 with dendritic pattern, drainage density of 0.23, drainage texture of 0.005,form factor 0.007, circularity ratio 0.23, elongation ratio 0.83, length of overland flow 0.71 , constant channel maintenance 0.35, texture ratio 0.50, basin relief 275m, relief ratio 1.15, dissection of 0.38 river is moderately dissected. The basin ruggedness is 0.063 indicating the basin is less vulnerable to erosion and has inherent complexity in association with relief drainage density while gradient ratio is 0.43 which reflect in the moderate relief of the study area. In a related vein, Yohanna et al(2022) assessed the morphometric characteristics of Jiberu drainage basin with implications on sediment loading into Lake Gwakra in Gerei in Adamawa State, Nigeria. Geospatial technique of GIS SRTM DEM along with mathematical analysis were used in the analysis. The results revealed the basin area is 338.71km$^2$, perimeter 91.34km, 5$^{th}$ order stream, bifurcation ratio of 3.83, a total stream of 259 stream segments, a total steam length of 428.52km, drainage density of 1.27km$^2$, stream frequency of 1.35km$^2$, infiltration number 1.71, texture ratio 4.99, form factor of 0.74, circularity ratio 0.51, elongation ratio 0.48, length of overland flow of 0.39, constant channel maintenance of 0.79.The areal and relief properties of the basin showed low to moderate morphometric behaviours showing structural distortions, landuse disturbances and change in climatic characteristics which in turn modify run off, soil erosion, sediment loading into Gwakra Lake.

River Hawul drainage basin morphometric analysis covering part of Adamawa, Borno and Yobe states was investigated by Mayomi et al (2018). Geospatial techniques using ArcGIS and remote sensing was used. Hawul basin area covers 11,617.26km$^2$, a 6$^{th}$ order stream, total stream number 2,134, stream length of 6930.09km, mean stream length of 238.68km, mean bifurcation ratio of 4.6, basin perimeter 617.92km,lemniscate 1.82, form factor 0.55, circularity ratio varies from 0-1, elongation ratio of 0.38,texture 2.51, basin relief 942m, ruggedness index 0.58, infiltration number 0.13, and constant channel maintenance 1.72, length of overland flow 1.72. They concluded the low value mean Hawul is more elongated than circular therefore peak flow and longer duration is expected. From the ruggedness index shows basin is of gentle slope and short.Low infiltration number means it has high infiltration capacity and low run off therefore less susceptible to flooding. Constant channel maintenance is high it means low drainage density network and more area is required to sustain overland flow of 1.72. Hawul is of a low relief with dominant highly permeable rocks, and that the basin in neither prone to flood or soil erosion.

Hassan et al(2024) assessed Hadejia River sub-basin morphometric properties with implications on groundwater recharge. The study used GIS DEM resolution to delineate the basin attributes. The results showed a basin area of 1486.86km, a total stream of 116streams, a 4$^{th}$ order stream, of dendritic pattern, total stream length of 616.46, mean bifurcation ratio of 4.68, stream frequency 0.098km$^2$, drainage density of 0.41km/km2, texture ratio 0.032, infiltration number of 0.032, circularity ratio 0.33, elongation ratio 0.52,form factor 0.22, texture ratio o.33, ruggedness number of 11.72.

Laka(2023) in his study of flood risk assessment and management of Delimi Catchment analysed the morphometric characteristics of the basin using RS and GIS techniques. The results showed that the basin has area of 163.08km$^2$, 4$^{th}$ order stream and of dendritic system of drainage, stream number 112, bifurcation ratio of 6.0 suggesting the geology and lithology of the catchment exert strong structural control on the basin parameters; drainage density of 0.93, drainage frequency of 0.69, form factor of 0.17, circularity ratio 0.13, elongation ratio 0.46.

The morphometric characteristics and prioritization of Upper River Benue watershed in Northern Nigeria was the main preoccupation of Odiji et al(2021).The study was occasioned by the concern over the remarkable modifications due to man-made and physical processes shaping the basin and the need to adopt proper planning and management strategies. The watershed is bounded by Lake Chad to the north, to the east and south by Republic of Cameroun, and west by Lower Benue and Upper Niger watershed. In all 29 sub- watersheds in the basin were delineated for this study. ArcGIS10.5, 30m resolution SRTM, DEM were used in the analysis. The watershed has a basin area of 154,328.9km$^2$, has streams segment of 4,821 streams with a total length of 30,232.84km, 7$^{th}$ order with a mean bifurcation ratio of 4.5. Drainage density ranges 0.192 to 0.51km/km$^2$, which is very high in sub-watersheds 12,16, 24, 26, 28,and 29. Stream frequency of 0.03km$^2$, ranges from 0.028 to 0.91km which is low implies low water infiltration. Drainage texture of the basin 0.42 indicating very coarse. Drainage texture ranges from 0.075 to 2.02. Drainage intensity 0.27 which is low which implies that the stream frequency and drainage density have slight importance to the extent to which agents of denudation have lowered the land surface. Infiltration number of the basin ranges from 0.0056 to 0.33 with a mean of 0.024 which is low meaning that the amount of water entering into the soil is high and by implication run off is low, but it depends if the precipitation rate does not exceed infiltration does not exceed infiltration rate. Length of overland flow for the basin ranges from 0.98 to 2.61 with a mean of 2.4km, implies that the watershed has a long flow path with reduced run off. Form factor ranges from 0.1-0.8, with 0.002 as mean, which implies upper Benue River is elongated and has a low peak flow of longer duration. Elongation ratio of the basin ranges from 0.44 to 0.74 with a mean of 0.5 implies watershed is elongated. Circularity ratio of the basin is 0.10, varies from 0.048 to 0.144.The watershed is more or less elongated and is characterized by medium to low relief. The low relief is as a result of the structure of the rocks that controls the drainage. Constant channel maintenance of the basin is 4.44km/km$^2$, and varies from 1.96 to5.22.This means that the watershed is least erodible. Ruggedness number of the basin is 0.2 and varies from 0.019 to 0.364 implies the low value suggest the basin is matured with gentle slope. Hypsometric integral of the basin is 0.22, ranges from 0.10 to 0.40 which is low and that indicates an old stage largely influenced by erosion. In conclusion, out of 29 sub-watersheds, 12, 16, 18, 24,26, and 27 are classified as very high priority, 7, 9,14, 25,28,and 29 as high priority, and 2,3,6,11 and as moderate priority, 1,4,5,10,21 and 22 as low priority and

8,13,17,19,and 20 as low priority. The very high priority suggests the vulnerability of the sub-watersheds to erosion and flood.

In River Lamurde basin in Taraba State Oruonye et al(2016) assessed the morphometric characteristics of the basin with particular implications on the hydrologic and geomorphic process.The basin has an area 553.9km, perimeter 197.5km, 4th order stream with dendritic pattern system, bifurcation ratio 3.85, stream number of , stream segment, stream frequency of 0.11, drainage density 0. 389km/km2, length of overland flow 0.13km. Form factor 0.19, circularity ratio 0.5, and texture 0.3. They concluded that the drainage density, bifurcation ratio,and circularity values indicate that the basin has gentle slope, more elongated and highly permeable bedrock. The relief ratio is characterized by less resistant rocks and the low relief by implication has low response to surface run off, and has flatter peak of flow for longer duration. In a related study, Adelalu et al(2020) examined the morphometric characteristics of the basin hydrologic response to stormwater in River Taraba basin.Geospatial technique of ArcGIS and DEM were used in the analysis. The results showed the basin consist of 9(nine) sub-watershed, basin area of 15,777km$^2$, perimeter of 959, length of 164km, 7th order stream and dendritic pattern, bifurcation ratio 4.31, 9205 streams, total stream length of 19242.86km, overland flow of 1.64, drainage density of 1.22km/km2, Circularity ratio 0.22, elongation ratio 0.58, form factor 0.27, drainage density of 1.22, stream frequency 0.58, drainage texture 0.59, constant channel maintenance 0.82. According to them, there is no pronounced variation in the geomorphometric attributes characterizing the basin. Drainage density, relief ratio, elongated ratio, and ruggedness number are intermediate. From bifurcation ratio the basin indicate transitional zone of geological structure with less significant influence of structural instability. The landforms and geology of the basin do not vary from basin to basin. Variations in morphometric and morphological characteristic of the catchment did not notably influence the potential of flash flood occurrence. River Donga a sub-basin of River Taraba was assessed by Adelalu et al(2019) to ascertain its morphometric status. RS and GIS were used in the analysis.The result showed the basin area of 11,355km2, perimeter 727.40km, length of 164km2, stream number of 5817, total stream length of 14099.76km, bifurcation ratio 4.33, basin is of 7th order stream, stream frequency 0.51, form factor 0.42, circularity ratio 0.27, drainage density of 1.24, elongation ratio 0.73,

River Benue drainage basin and sub- basin morphometric characteristics have been investigated by several authors. Yiyeh et al(2024) assessed the morphometric characteristics of River Benue basin with the implications on surface water development .ArcGIS 10.2 and RS and GIS were deployed in the analysis. The results revealed basin area 233.032km2, 5th order stream, total streams 7,143, total stream length of 8,619.50km, bifurcation ration , drainage density of 0.037km, form factor 0.11, circularity ratio. With low drainage density, form factor and elongated ratio all suggest shape is prone to flooding. Relief attributes like relative relief and ratio and ruggedness number are relatively low values of 239m, 1.68 and 0.06 indicate a moderate topographic variation and less rugged terrain. The hypsometric integral of 0.50 and dissection index 0.99 reflect a balanced elevation distribution and moderate landscape dissection. The study concluded River Benue basin sub-basin has surface water resources, low topographic relief which has implication for hydrologic process and flood management. A comparative analysis of morphometry of Kereke and Ukogbor river Benue Basin sub-basins in Makurdi with respect to flood vulnerability of the catchment was undertaken by Oyatayo et al(2013). Topographical map and ArcGis 10.2 were used in the analysis. The results revealed that both the basins are of the 5$^{th}$ order with dendritic drainage pattern. Kereke and Ukogbor has basin area of 261.28km2/94.82km2, basin length of 26km/10.79km, perimeter 76.28km/40.15km, bifurcation ratio 3.51/3.09, length of overland flow 0.56km/0.42km, form factor 0.39/0.85, circularity ratio 0.56/0.70, relief ratio 0.45/0.91, drainage density 0.91/1.20, elongation ratio 0.40/0.60 and infiltration number of 0.53/1.32 respectively. A comparative results of linear and relief parameters indicate that Ukogbor constitutes fast peak flow and concentration time shorter hence higher flood vulnerability the kereke basin. Based on the areal morphometry, Kereke basin constitutes a more vulnerability to flooding in Makurdi Town than Ukogbor river basin with regards to hydrograph volume regime. The outcome according to the study is fundamental for prioritizing proactive and sustainable urban flood management, appropriate landuse planning and zonation especially along their floodable aareas, stormwater management and other urban degradation management.In 2019 Songu et al(2019) carried out a morphometric study of Kereke drainage basis with regard to its implication on hydrologic processes. Data were sourced from SRTM version 2009,30m resolution using GIS software.Results showed that basin area 372.41km$^2$, length 96.73km, bifurcation ratio 5.48 implying the basin is highly dissected with 1$^{st}$ and 2$^{nd}$ order stream, has potentials to experience flash flood and gully erosion during heavy torrential rainfall in the area due to concentrated peak flows. The basin has form factor 0.06, circularity ratio 0.45 and elongated ratio of 0.14 indicating that kereke drainage basin is at maturity stage of geomorphic cycle and highly elongated with permeable and homogenious structure. The elongated nature of the basin suggests that surface run off is not quickly removed from the catchment especially in times of high amount and intensity thereby enhancing gully erosion initiation and flooding in the area. It recommended that there should be controlled development and drainage system to control the run off. To determine the morphometric characteristics of Katsina-Ala watershed Aper and Hundu(2016) used RS and GIS in the process. The results showed basin area 9,434.23km2, perimeter 534.97km, length 237.44km, 6$^{th}$ order stream, dendritic pattern of drainage system, 5,891 streams, bifurcation ratio of 1.82, drainage density 0.75km/km2, stream frequency 0.62km, drainage texture 13.31, form factor 0.17, elongation ratio 0.46, circularity ratio 0.41, length of overland flow 0.66, constant channel maintenance 4.km. From the linear ,areal and relief properties of the basin, the basin has a homogenous geological sub-structure ,characterized by high infiltration capacity, low run off, have longer duration of flow peak, less susceptible to flooding. In related vein Ocheri et al(2024) assessed the morphometric status of River Mu sub-basin of the Lower Benue River Basin in Makurdi South against the backdrop of its implications on hydrologic processes. Geospatial technique of RS and GIS were used in the analysis. The result show that the basin has an area of

1259.26km2, perimeter 240.96km, 4th order stream with dendritic pattern, stream number 122, total stream length 505.68km,bifurcation ratio 4.62, drainage density 0.40km2, stream frequency 0.10km, drainage texture 0.51, form factor ratio 0,22, circularity ratio 0.27, elongation ratio 0.27, length of overland flow1.25. The study concluded the drainage basin, bifurcation ratio and circularity ratio values indicate the basin is of gentle slope, elongated, and infiltration capacity, low run off and may have a longer duration of flow peak, less susceptible to flooding. In Wadata area of Makurdi Town Songu et al (2019) examined the influence of basin morphometry and run off rate on vulnerability to gully erosion in the catchment.The results showed that old GRA, Benue crescent have moderate drainage intensity 0.5 and relatively more prone to gully erosion. New Garage and Wadata drainage intensities of less than equal 0.2 and 0.3. Demekpe has moderate drainage density of 0.78km2, drainage intensity 0.63, overland flow of 1.68km with the tendency of influencing the extent to which the earth surface is being lowered by agents of denudation, predicting a likelihood of gully incision by run off.Wadata catchment has a high peak rate run off of 83.05m2lSec. which is capable of influencing gully development.They recommend a storm drainage of 60m enbarkment and reservior capacity of 4000m3 be designed and constructed to contain excess run off in the wadata catchment for 10 years.

In parts of North Central Nigeria,Bunmi et al (2017) embarked on the morphometric analysis of Asa and Oyun drainage basin in Kwara State. RS and GIS tools were deployed in the analysis . The results showed that Asa and Oyun drainage basin has an of 4th order dendritic pattern of drainage system, bifurcation ratio 0.9/ 1.42,stream number 54/ 56, drainage density 0.39km/km2/ 0.36km/km2, stream length 177.81km/160.62km, stream frequency 0.12/0.11, ruggedness number 112.59/105.1, texture 0.32/ 0.33, form factor 0.02/ 0.11, circularity 0.22/0.16, elongation ratio 0.14/ 0.15, length of overland flow 0.195/ 0.153, constant channel maintenance 138.44/85.72. From the values of relief ratio, ruggedness number indicate moderate to low relief, low run off and low infiltration, with late youth mature stage at erosion development. Drainage density, texture, circularity ratio and elongated ratio show the basin is moderate, shape elongated. The study concluded that the basin has a good surface water prospect.

Ahuchaogu et al(2022) assessed the morphometric attributes of Ajaokuta drainage with view to understanding its hydrologic, geomorphic and geologic properties. SRTM and ArcGIs 10.5 geospatial techniques were used in the analysis.The results showed that the basin has an area of 5393km2, basin length of 84km, 57 streams with a total length of 607km. It is of the 4th order stream is dendritic in pattern.Results further revealed the drainage density 0.1125km-1, stream frequency of 0.0105, circularity ratio of 0.765, bifurcation ratio varies from 3 to 4, elongation ratio 0.960, form factor 0.729. The geometric attributes attest that the basin is coarse textured, oval in shape structurally controlled and average infiltration and discharge potential. In a related study Alfa et al(2018) analysed the hydrologic and morphometric characteristics of Ofu River sub-basin with regard to flooding potential using RS and GIS. The results showed that the basin area 1604.56km2, perimeter 556.98 covering parts of Kogi and Enugu States. The basin is of 3rd order with a bifurcation ratio 3.29, stream number 39, total stream length of 241.47,stream frequency 0.11, drainage density 0.26, drainage intensity 0.42, texture 0.31, circularity ratio 0.45, elongation ratio 0.45, form factor 0.16, length of overland flow 1.95, constant channel maintenance 3.90.

## REFERENCES

Abayomi,B.A.and Lanre, A.T(2023) Morphometric characteristics of Yewa drainage basin, South West Nigeria, Malaysian Journal of Tropical Geography, 49(1), 1-21.

Aladejana, O and Fagbohun,B.J( 2018) Geomorphic morphometric and structural analysis of Northwest Benin Owena River Basin, Nigeria: Implication for groundwater development, Sustainable Water Resources Management, 5, 715-735.

Adakayi,P.E(1991) Harnessing water resources for better life for Nigerians, A paper presented at the 34th Annual conference of Nigerian Geographical Association, held at Alvan Ikoku College of Education, Owerri , 7-11 April, 1991.

Adegoke, K.N and Gadiga,B.L (2015) Hydrological and morphometric analysis of Upper Yedzaram Catchment of Mubi, in Adamawa State using Geographical Information Systems(GIS). World Environment 5(2), 58-66.

Adejuwon,J.O.,Jeje,L.K and Ogunkoya,L.K (1983)Hydrological response pattern of some third order streams on the basement complex of South Western Nigeria, Hydrological Science, 5, 377-391.

Aderogba,K.A(2005) Groundwater development in Nigeria: A study of Abeokut-Ewekoro-Ifo-Ota- Agbara Axis in Ogun State, Nigeria, International Journal of Environmental Issue 3(1), 51-68.

Adelalu, T.G, Yusufu,M.B, Ibrahim,A , and Idakwo.V.I(2019) Morphometric analysis of River Donga Watershed in Taraba State using RS and GIS,Journal of Geography, Environment and Earth Science International, 20(3), 1-13

Adelalu, T.G, Mohammed, B.Y and Bwadi,B.E(2020) Morphometric analysis and flash flood assessment of River Taraba basin in Taraba State, Nigeria, European Scientific Journal, 16(20) 156-175.

Ahuchaogu,U.E,Ojinnaka, O.C,Akajiaku,C.C, Duru,U.U, Ugwu, O.J and Chukwuemaka,O.G(2022) Delineation of morphometric attributes of Ajaokuta River basin in Nigeria using Earth Observation system based data and GIS, Open Access Library Journal, 9

Ahuchaogu, U.I,Ojinnaka,O.C, Akajiaku, O.C, Chukwuocha and Baywood, C.N(2022) Morphometric analysis of Delta State River Niger Basin in Nigeria using RS and GIS, Volunteering for the Future

Ajibade, L.T, Ifabiyi,I.P,Iroye, K.A and Oguntеru, S (2010) Morpometric analysis of Ogunpa and Ogbere drainage basin, Ibadan, Nigeria, Ethiopian Journal of Environmental Studies and Management, 3(1) 13-19.

Akindejoye, A.E., Alabi,o and Adedoja,T.B(2022) Watershed prioritization to flood susceptibility using Geospatial techniques in Southweatern Nigeria basin, Journal of Geography and Natural Disasters, 12, 256-263.

Akinumiju, A.S and Olorunfemi, M.O(2016)Morphometric analysis of Osun drainage basin, Southwestern Nigeria, Geography and Geology,8(4) 9-22.

Alfa,M.I,Ajibike, M.A, Adie,D.B and Mudiare, O.J(2019) Hydrologic and morphometric analysis of Ofu River sub- basin using RS and GIS , Nigerian Journal of Technological Development 16(2), 49-55.

Amangabara, G(2015) Drainage morphology of Imo basin in Anambra-Imo River basin Area of Imo State, Southern Nigeria, Journal of Geography, Environment and Earth Science International, 3(1), 1-11

Anyadike, R.N.C and Phil-Eze, P( 1989) Run off response to basin parameters in South Eastern Nigeria, Geografiska Annaler 71A(1-2), 75-84.

Ashaolu,E.A(2016) The Osun drainage basin in the western Lithoral hydrologic zone of Nigeria: A morphometric study, Journal of Society and Space, 12(8), 71-88.

Awopegba,P.O(2001) Overview of the planning and management of social services in Nigeria, NCEMA, Ibadan.

Ayoade,J.O and Oyebande, B.L(1983) Water Resources in Geography of Nigerian Development, Oguntoyinbo, J, Areola, O.O and Filani, M.P(eds), Basil and Associates Ltd, Ibadan.

Ayogu,C.N, Phil-Eze, O,Ayogu, P.O and Maduka, R.I (2019) Morphometric analysis and the validity of Hortonian postulations in Anambra basin, Nigeria, Korean Spatial Information Research, 1-18.

Balogun,I, Adegun,O, Ayodele-Olajie,D , Adega, O and Gamaliel (2013) Geometric characteristics of Olomore drainage basin, Abeokuta, and implications for hydrologic process, Lagos,Journal of Geo-Infoermation Science 3(1) ,73-80.

Bunmi, M.R, Olawuyi, M.F and Adekunle, O.M(2017) Morphometric analysis of Asa and Oyun River basin, North Central Nigeria using GIS, American Journal of Civil Engineering, 379-393.

Ebisemiju, F.S(1976) AThe structure of the interrelationship  of drainage basin characteristics, Unpublished Ph.D, Thesis, University of Ibadan, 321.

Ebisemiju, F.S(1979) A reduced ranked model of drainage morphology, Geografiska Annaler 16A,(1-2), 103-112.

Eze B.E and Efiong, J(2010) Morphometric parameters of Calabar River basin: Implication for hydrologic processes, Journal of Geography and Geology, 2(1), 18-26.

Eze, C.U and Mozie, A.T(2019) Correction to: Morphometric analysis of the Idemili basin using geospatial techniques, Arabian Journal of Geosciences , 12(9) 298.

Ezenwaji, E.E, Nwabineli, F.O and Phil-Eze, O(2018) Investigation into morphometric characteristics of Obibia drainage basin , Awka urban Area, Nigeria, Open Journal of Modern Hydrology, 8, 1-12

Efiong, J, Eze, B.E , Obianuju, E,A and Uqueta, I.U(2022) A GIS-based morphometric analysis of Calabar  River Basin: A preliminary findings, Proceedings Nigeria Association of Hydrological Sciences Conference on Climate Change: Issues and Challenges for sustainable water management  in Nigeria, 347-362,

Gregory, K.J and Walling, D.E(1973) Drainage basin form and process: A Geomorphological Approach, Edward Arnold , London, 456.

Grohman,C.H(2004) Morphometric analysis of in geographic information systems: Application of free Software Computers and Geosciences, 1055-1067.

Hajam, R.A, Hamid,A and Bhat,S(2013) Application of morphometric analysis for geo-hydrological studies using geospatial technology: A case study of Vishav drainage basin, Hydrology and Current research,

Hassan,M and Kabir, A(2019) Morphometric and vulnerability analysis of Gada River basin to erosion and sediment yield, FUDMA Journal of Sciences, 3(2) 58-66.

Hassan,M and Ruma,M(2024) Investigation of the basin characteristics through morphometric analysis of Hadejia River sub-basin: Implication for groundwater recharge, African Journal of Environment and Natural Science Research, 7(3) 21-35.

Ifabiyi,I.P(2004) A reduced rank model of drainage basin response to run off in Upper Kaduna Catchment of Northern Nigeria, Geo-Studies Forum, 2(1) 109-117.

Jeje,A.K(1987) Run off and loss from erosion plot in Ife Area of South Western Nigeria, International Geomorphology part II , Gardinar V (ed), Chichester Wiley, 459-472.

Jeje,L.K and Agu,A.N(1982) Run off from bounded plot in Alakowe in Southwestern Nigeria, International Journal of Applied Geography, 10, 63-74.

Jesuleye,I.A, Okeke, L.U, Atijosan, U.H, Baderu, A.O, Adewoyi, J.E and Alaga, A.T(2016) Morphometric assessment of Oba basin and its implications for flood, Journal of Geography,Earth Science International, 8(3)

Konwea, C.I and Ajayi,O(2022) Assessment of geomorphic and morphometric characteristics of Shasha and Opa River basin in Obafemi Awolowo University Campus southwest Nigeria, Ife Journal of Sciences, 24(2)

Lasis,M.O, Ogunnakan, A.F and Akinwamide, O.G(2018)Morphometric analysis of a drainage basin.A case study of Oluyole Catchment Area, Ibadan,International Journal of Trends in Research and Development,5(6) 1-5.

Laka, I,S(2023) Flood risk assessment and management of the River Delimi in Jos Area of Nigeria, Unpublished Ph.D Thesis, Department of Geography and Planning, University of Jos

Ledger,D.C(1964) Some hydrological characteristics of West African Rivers, Institute of Britis Geographers

Miller,V.C(1953) A quantitative geomorphic study of drainage basin characteristics in the Clinch MountainArea NR Technical Report Project.

Morisawa, M.E(1959) Relations of morphometric properties to run off in the little Mill Creek, Ohio drainage basin, Columbia University, Department of Geology, Technical Report,17, Office of Naval Research Project NR 389-042.

Mayomi, I, Manu, H, Yelwa,B and Abdussalam (2018) Geospatial analysis of morphometric characteristics of River Hawul basin , North-East Nigeria, Resources and Envirfonment, 8(3) 103-126.

Nabegu, A. B (2005) Determination of sediment yield in river basins: Implication for reserviour management, International Journal of Environmental Issues 3(2) 40-48.

NEDECO (1957) River studies and recommendation on improvement of Niger and Benue, Netherland Engineering Consultants, North Holland, Pub. Con. Amsterdam, 100p.

Nnaji, C .C, Onyekachi, M.N, Nwanko, E.J,Emenike, P, Chibueze , C.V and Ogarekpe, N(2023)Hydrological and morphometric characterization of Anambra-Imo River Basin using Remote Sensing, Water Conservation Science and Engineering, 1-18.

Ocheri, M.I,Ali,P, Onah, M.A and Tarzoho, P(2024) Morphometric status of River Mu sub-basin in South Makurdi, International Journal of Research Innovation and Applied Sciences,9(8) 2000-2010.

Ochuko,E.D(2020) Modelling of drainage basin in Udi-Awgu Cuesta, Southeatern Nigeria using Remote Sensing and Geographical Information Systems, International Journal of Research and Scientific Innovation, 7(11), 2321-2705.

Okechukwu, G. C (1974) Fluvial geomorphic interrelationship in some river catchments in Nigerian Precambrian basement complex, Unpublished Ph.D Thesis , Department of Geography, University of Ibadan

Odemirho, F.O (1984a) A reduced rank production model on stream channel response to traditional landuse practicesin Southwestern Nigeria, Journal of Hydrology, 7085-100.

Odiji,C.A, Aderoju,O.M, Eta, J.B, Shehu, I, Mai-Bukar, A and Onuoha, H(2021) Morphometric analysis and prioritization of Upper Benne River watershed, Northern Nigeria, Applied Water Science 11(2), 1-28.

Okogbue,E.C, Balogun,I.A, Akinbobola, A,Adeyeri, O, Oluleye, A, Ajayi, V.O, Akinwuiju, A,S and Ige,S.O(2021) GIS-based analysis of drainage morphometriy and landuse/Landcover dynamics in River Ogun-Osun basin, Southwestern Nigeria, Journal of Sustainable Technology, 11(20),145-162.

Okoko,E.E and Olujimi,J.A.B(2003) The role of geomorphic features in urban flooding : The case of Ala River in Akure, Nigeria, International Journal of Environmental Issues 1(1) 192-201.

Ogunkoya,O.O, Adejuwon, J.O and Jeje, L.K(1984) Run off response to basin parameters in Southwestern Nigeria, Journal of Hydrology, 72, 67-84.

Oreoluwa, A.A and Eludoyin, A.O(2019) Remote sensing and river basin management: An expository review with special reference to Southwest Nigeria, Current Practice in Fluvial Geomorpology-Dynamics and Diversity.

Oruonye,E.D, Ezekiel,B.B, Atiku, H.G and Musa, N.I(2016) Drainage basin morphometric parameters of River Lamurde: Implication for hydrology and geomorphic processes, Journal of Agriculture and Ecology Research International 5(2) 1-11.

Oyatayo, K.T, Bello, I, Ndabula, C, Jidauna,G.G and Ademola,S.J(2017) A comparative analysis of drainage morphometry on hydrologic characteristics of Kereke and Ukogbor basins on flood vulnerability in Makurdi Town, Nigeria, Hydrology, 5(3),32-40.

Oyegun,R.O(1980) The effect of tropical rainfall on sediment yield from different landuse surface in sub-urban, Ibadan, Unpublished Ph.D Thesis, University of Ibadan

Patel,D.P, Gajjar,C.A, Servastava, P.K(2013) Prioritisation of Malesari mini-watershed through morphometric analysis: A remote Sensing and Geographical Information System perspective, Environmental Earth Sciences, 69(8) 2643-2656.

Rastogi, R.A, and Sharma, T.C(1976) Quantitative analysis of drainage basin characteristics Journal of Soil and Water Conservation in India,6(1and 4), 18-25.

Samson, S.A, Eludoyin, A.O, Ogbole, A.T, Alaga, MOloko-Oba, M.H, Okeke and Popoola (2016) Drainage basin morphometric analysis for flood potential mapping of Owu using geospatial technique, Journal of Geography, Environment and Earth Science International 4(3) 1-8.

Salami,A.W,Amoo,O.T,Adeyemo,J.A, Mohammed,A.A and Adeogun , A.G(2016) Morphometric analysis and peak run off estimation for the sub-Lower River basinm Nigeria,Slovak Journal of Civil Engineering, 24(6-16.

Shobogun, S.O, Martins,O and Idowu, O.A(2016) Morphometric analysis of Sokori River basin, Southwest Nigeria, Proceedings, Nigeria Association of Hydrological Sciences conference on Water and Sustainable Development, 135-141.

Songu, G.A, Ocheri, M.I and Abu, R, D(2019) Morphometric analysis o the kereke drainage basin and its implications on hydrologic processes, Proceedings, Nigeria Association of Hydrological Sciences conference o Water Security, Society and Partnership for sustainable Development,285-292.

Strahler,A.N(1964a) Quantitative geomorphology of basin and channel networks: Handbook of Applied Hydrology, McGraw-Hill Book Company, New York.

Udoka, U.P, Nwankwor G.I, Ahamefula, A.C, Iheanyichukwu, Embarga, T.T and Inyang, G.E(2016) Morphometric analysis of sub-watershed in Oguta and Environs, Southeastern Nigeria using GIS and Remote Sensing Data,Journal of Geosciences and Geomatic, 4(2) 21-28.

Udosen, C (2009) Environmental constraints on the interdependence of drainage basin morphometric properties in Upper Cross River, Global Journal of Geological Sciences 7(2) 119-124.

Yiyeh , G.H, Ocheri, M.I, Mage, J.O, Onah, M.A and Ali,P(2024) Morphometric analysis of River Benue basin, Nigeria: Implications for surface water development, International Journal of Research Publication and Review,5(8) 4174-4188.

Yohanna,P, Ezekiel,Y, Ibrahim, S and Falu, N.D(2022) Morphometric analysis of Jiberu drainage basin and its implication on sediment loading into Lake Gwakra in Gerei, Adamawa, State Nigeria, Journal of Environment and Material Science, 2, Issue 4,1-12.