

# *Test of Hortonian Laws Using Bivariate Relationship with Basin Morphometric Data of Udi-Agwu Questa Enugu State Nigeria – Remote Sensing and GIS Approach*

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**Abstract** – The study used tools of GIS and remotely sensed enhanced multi-spectral data of Digital Elevation Model (DEM), Landsat ETM+ digital Image and aerial photos Arc GIS and Arc Hydra Wizard softwares were used to generate hydrologic maps for basin morphometric properties to evaluate parameters (Indices,) in Udi-Agwu Questa Regions, South Eastern Nigeria. The analyses was carried out using digitized hydrological maps geo referenced using 4 points (resampled and merged) and the sub map of the study area extracted and incorporated into the GIS spatial data base environment. The interpreted images were superimposed to create appropriate information platform to determining the morphometric properties and parameters using generated hydrological maps; analyzed, interpreted and classified at sub basins level using water divided concept. The mapping of the drainage networks was followed by ground truthing for confirmation with field observations undertaken during pre and post interpretative phases with elements of colour, tone, shape, pattern, shadow, site and association.. There is increased networks observed in the enhanced data evaluated for ETM and DEM than aerial photos due to higher resolutions. Generally there are major implications of the entire properties and parameters are represented. The data obtained with or without enhancement through manual or digital analysis, conform to the morphometric laws especially the laws of drainage composition (stream numbers, stream length and stream slope), basin area, basin relief and contributing areas though, the increased networks in the enhanced data (measured or evaluated) deviate graph plots, gradients and regression values

**Keywords** – Drainage; Basin Morphometry; Laws; GIS; Remote Sensing.

## I. INTRODUCTION

The topographical base map produced from aerial photos available to Nigeria researchers, is on the scale of 1:50,000 and until new ones with large scales are produced, the need still exists for the maps to be improved upon (using various enhancement procedure and techniques) to make them more useful for geomorphologic and hydrologic investigations. Generally, the use of blue lines to depict drainage networks on our medium to small scale maps has shown to produce incomplete network for morphometric studies (Ebisemiju, 1978, Richards, 1978 and Stagg, 1978). Therefore, lines produce artificial data rather than those of real networks on the ground. A number of techniques for enhancing Nigerian topographical maps on a scale of 1:50,000 were applied by Ebisemiju, (1978) while working in the study area used method such as contour crenulation for actual ground portrayal, The study further explored the enhancement techniques of aerial photograph and satellite data adopted by Ebisemiju, 1978) and Reddy et al., (2004) in a GIS environment for morphometric analysis. Researchers such as Adeniyi and Omojola (1997) used satellite images, aerial photographs and archival data for analyses of land use and

land cover for resource inventory. Also, digital analyses of satellite data was applied by Reddy et al, (2004); Das and Makhejee, (2007) and Koul et al, (2007) among others for morphometric studies whose results actually portray true field data.

Basin morphometry is little understood in the dynamic field of the hydrology and geomorphology as the evaluated indices are erroneously determined using wrong data from source of most available medium to small scale maps. There is problem in inaccurate discernment of the entire stream networks and landform features for hydrologic and geomorphic understanding of formation process of features. The articulated best result is basically from large scale maps that reflects the terrain configuration for quantitative data management of the environment Aerial photos and topographical map crenulation techniques in enhancing topographical maps on a scale of 1:50,000 were applied by Eyles (1975) and Schick (1964) and most medium to small scale maps were shown to produce incomplete network data for morphometric studies at various degrees or percentages.

The volume of data generated by morphometric studies often demand the use of secondary published map sources with attendant problems concerning the scale, for realism and network details. There is theorem the need for satellite data (that are timely, cost effective in a consistent manner with high resolution) will produce data reflecting terrain configuration. Thus, morphometric data (properties and parameters) together and landforms in the area will be mapped with confidence of discernment of totality of hydrological parameters and landform portrayal using Landsat (ETM+) and Aster. Linder radar, Digital Elevation Model (DEM) remotely sensed data format.

The aim of this research work is to use satellite remotely sensed multispectral data of digital elevation model (DEM) and Landsat ETM+) and aerial photos to generate hydrologic maps for measurement of morphometric properties to evaluate parameters (indices) using digital analysis. The specific objectives include to:

- generate hydrological maps using remotely sensed data i.e. Landsat enhanced thematic mapper (ETM+) and digital elevation model (DEM), data, and aerial photos.
- generated hydrological maps to digitally map the drainage basins and stream networks to generate morphometric properties.
- evaluate parameters (indices) in the drainage basins to present their implications and
- identify the various landforms in the area and adduced reasons for their formations

## II. STUDY AREA

The study area is a part of the Udi-Awgu cuesta in Enugu State, South Eastern Nigeria, The Udi-Awgu Cuesta is located in Udi and Awgu LGAs of Enugu State, Nigeria within the sector of the impressive Nsukka-Okigwe Cuesta running through North-South direction on the cuesta is bounded in the east by the Cross river plan and on the west by the Anambra/Mamu lowlands. The Udi-Awgu section of the cuesta is referenced by latitudes  $6^{\circ} 00'N$  and  $6^{\circ} 20'N$  as well as longitudes  $7^{\circ}2'E$  and  $7^{\circ}31'E$  with approximate area extent of  $4,200 \text{ km}^2$ . (fig. 1–3)

The Enugu and Awgu escarpments form the eastern portion of the Nsukka — Okigwe cuesta are “neither contemporaneous nor continuous but consist of two distinct escarpments which overlap for a distance and separated by five to six kilometers lowland of the Enugu shales. The Local Government Areas of Awgu and Udi is situated on much of the highlands of Awgu, Udi, Nsukka hills and the rolling low lands of the Ebonyi River basin to the east and the Oji-River basin to the west.

Udi-Agwu area lies in the humid tropical climate and it has fairly uniform annual rainfall and temperature. The climate is defined by high values of evapotranspiration, humidity, temperature and rainfall that characterized region using data obtained from Enugu Meteorological. Station, (2012). Climate variables do considerably influence water resources in the area as rainfall constitutes the major input into the hydrological cycle in the area. The temperatures are

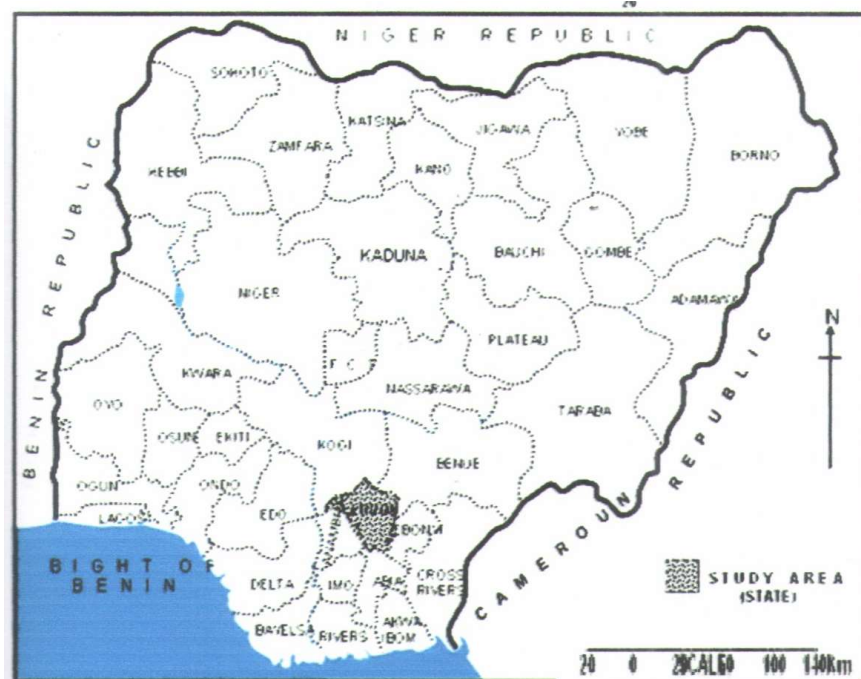


Fig 1; Map of Nigeria Showing Enugu State  
Source: Kena. Kaduna (2007)

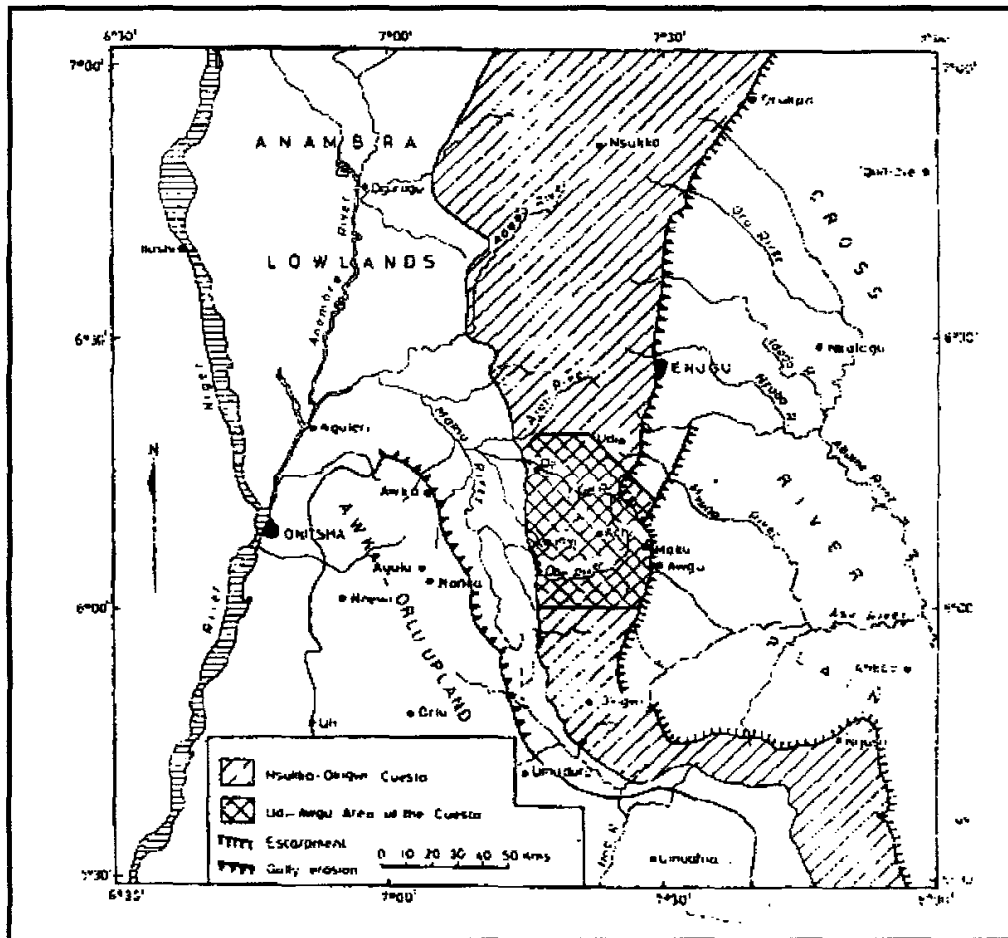


Fig. 2: Part of Eastern Nigeria showing the Nsukka-Okigwe cuesta. (Ebisemiju, 1976)

generally high throughout the year with a mean monthly temperature of  $28.5^{\circ}\text{C}$  with annual rainfall of about 1,150mm which decreases northward from over 1,200mm in the Niger Delta to less than 250mm in the extreme North Eastern parts. Convictional rainfall in the form of intensive violent showers accompanied by lightning and thunderstorm of short duration that generate floods in the area and gully due to erosional impact is prevalent in the area. In the study area, the mean annual rainfall of about 1,150mm was recorded. The rainfall tends to decrease westward due to differences in coastal alignment between the southeast and the southwest and the occurrence of the Hamattan (little dry season) i.e. August hiatus in the area.

The climate according to Ojo (1977) is influenced by imaginary migration line of inter-tropical discontinuity (ITD), a low-pressure zone that is fundamental to the understanding of the climatic phenomenon. The discontinuity migrates northward and southward of the equator with the overhead sun and reaches its maximum northward extent in July or August and maximum southward extent in January. The wet season occurs between April and October. The ITD during the wet season lies north of the area where it draws

moist, warm westerly wind (westerlies) of maritime (MT) air mass. It moves to the south during the dry season and it draws cool dry northeasterly wind (easterlies) or continental (CT) air mass locally called Hamattan wind from the Sahara desert. It blows generally from November to early April. The area therefore experiences wet and dry seasons that result mainly from the planetary wind system influence the movement of moist warm air and cool dry air.

The area is located in humid equatorial climate which favours rapid weathering and erosion of prevailing sedimentary rocks that result in red arenaceous soils. The deposits are very deep and the parent rocks are hardly exposed except along the sides of the incised valleys and the scalps. These soils are collectively known as acid sands. Ebisemiju (1976) observed that erosion processes acted primarily on the loose weathered materials, whose properties are fundamentally important in explaining the geology and spatial variations in basin morphology. The textural and mineralogical compositions of the soils are derived from these sandstone formations where ironstone concretions are abundant in many parts.

The prevailing climatic conditions are conducive for availability of abundant water in the area for major parts of the year. This aids high fluvial action with predominant erosion gullies, rills and sheet features. Mass wasting process is prevalent in the low coal measure zone. To combat it,

terrace farming is mostly practiced due to negative erosion consequences. On the landscape, sheet erosion is the dominant geomorphic process on the plateau surface and slopes of the dissected escarpments.

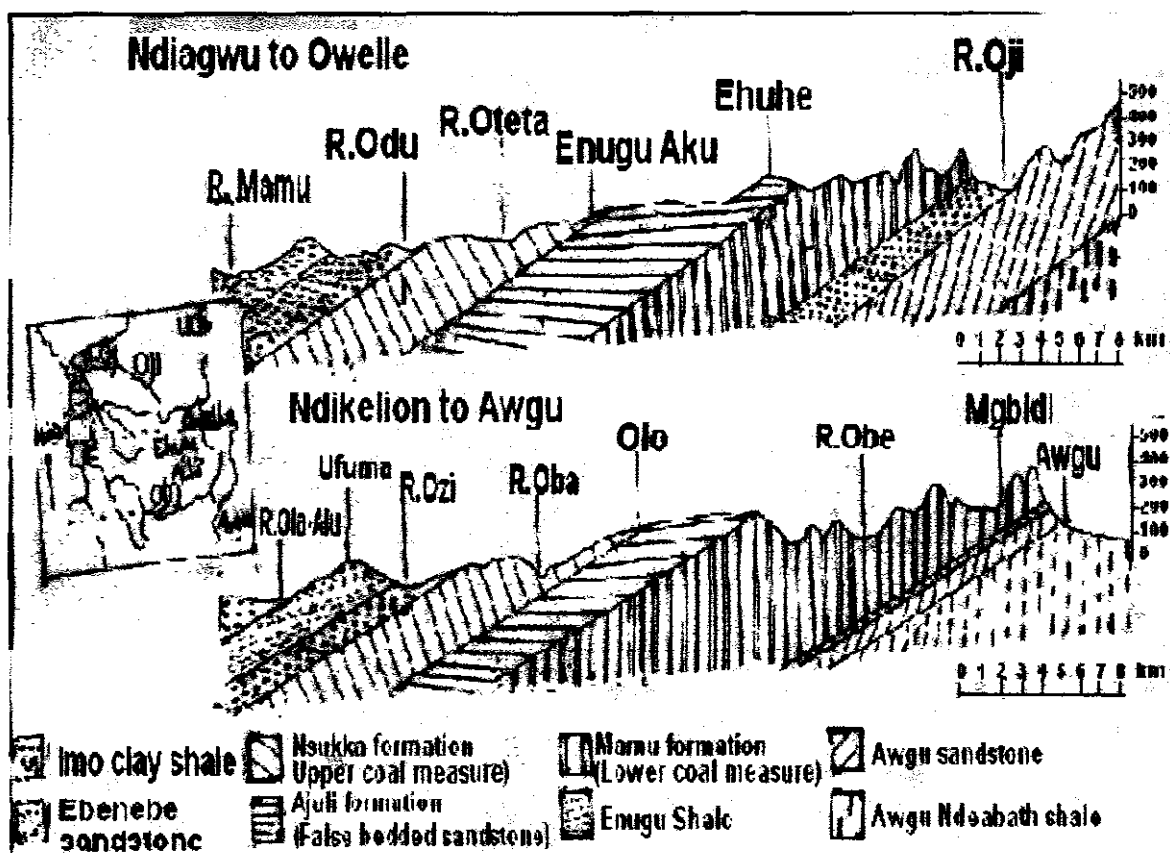


Fig. 3: Geologic Section of Udi-Agwu Cuesta Eastern Nigeria (Modified From Ebisemiju, 1976) (Modified from Ebisemiju, 1976)

The relief of the area (Fig 1b) shows a gently undulating plateau surface of the Udi-Agwu cuesta is sloping westwards direction to the lowlands of the Anambra and Mamu valleys. Furthermore, there exist west-flowing distributaries of the Mamu River in the rugged terrain, exhibiting an integrated dendritic drainage system within a long and broadly rounded divides and steep- sided slopes. The plateau surface is bounded by a minor scarp in the west. The scarp is broader in the northern part of the Nsukka - Okigwe Cuesta than Udi-Agwu due to the effect of dissection by Ozom and Obe rivers (tributaries of Oji), that consequently reduced it to rugged terrain. The Udi-Agwu cuesta is therefore made up of dissected terrains separated by a narrow belt of the plateau surface remnant. The drainage basins of this study are from the two zones of dissected terrain drained by three consequents (Oji, Ozom and Obe rivers).

### III. THEORETICAL AND CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

This study is built on the concept of basin morphometry. The concept of basin morphometry was introduced by Horton (1945). Basin morphometry is a term used to quantitatively and accurately describe the shape, form or configuration of the basin for the purpose of understanding basin features and their relationships to the hydrological performance or response of a drainage basin (Goudie et al, 1981). It provides a framework to accurately define the basin morphological characteristics, compare and contrast them (within and between basins) with precision. The interrelationship of basin morphometric properties which are examined in two major ways are expressed by various laws to establish the following

- 1 Relationship between certain morphometric linear properties (length of stream, stream slope and stream number) and basin order from which the laws of drainage composition are derived.



- 2 Examination of bivariate relationship among and between the planimetric (linear), areal and relief aspects of basin of the same order. Horton (1945) devised a number of morphometric laws exhibiting some elements of regularity between morphometric properties and hydrological processes.

**Morphometric laws:** These include Schumm (1956 law of basin lengths, law of basin areas, law of contributing areas and Maxuel (1950) law of basin relief. Studies of drainage stream related properties and parameters of most rivers in the world produce a straight-line graph of either positive or negative relationship, 'with exceptions resulting from local factors altering the relationship' (Waugh, 1995). Others include Laws of Drainage Composition that include law of stream numbers and law of stream lengths of relevance to this study.

**Law of stream numbers:** The law states that "the number of streams of different orders in a given drainage basin tends clearly to approximate an inverse geometric series in which the first older stream is unity and the ratio is bifurcation ratio"

**Law of Stream Lengths:** The law states that the average lengths of streams of each of the different orders in a drainage basin tend to closely approximate direct geometric series in which the first term is the average length of streams of first order and the ratio is the stream length ratio.

#### Laws of Drainage Composition

These laws consist of the law of stream numbers, law of stream lengths and law of stream slopes.

#### Law of stream numbers:

The law states that "the number of streams of different orders in a given drainage basin tends clearly to approximate an inverse geometric series in which the first order stream is unity and the ratio is bifurcation ratio".

Mathematically, it is expressed as

$$N_u = R_b^{(k-u)}$$

Where N = number of stream segment of order u, k is the order of trunk segment, u is the order of the segment under investigation and Rb is the bifurcation ratio which is expressed as

$$R_b = \frac{N_u}{N_{u+1}}$$

When number of stream segment of each order is plotted against stream order on a semi-log paper, a linear relationship of a resultant best-fit line is a straight line. The antilog of the coefficient of the regression line fitted by the method of least squares is the average bifurcation ratio for that basin.

The law of stream numbers has been found to apply well to natural and . simulated drainage networks. A marked up-concavity lower-end of the regression line is however generally noted suggesting that the geometric progression may not be closely observed in the higher orders (Schumm, 1956; Maxwell, 1960; Ebisemiju, 1978).

#### Law of Stream Lengths

The law states that the average lengths of streams of each of the different orders in a drainage basin tend to closely approximate direct geometric series in which the first term is the average length of streams of first order and the ratio is the stream length ratio. Mathematically,  $L_u$  is the mean length of order u is expressed as

$$L_u = L_1 R_L^{(u-1)}$$

Where,  $L_i$  is the mean length of l order streams, u is the order of the segment under investigation and  $R_L$  is the stream length ratio expressed as

$$R_L = \frac{L_u}{L_{u-1}}$$

When the logarithm of the mean length of streams of each order is plotted against stream order, a linear relationship is usually obtained with some scattered points about the regression line. The antilog of the coefficient is the average stream length ratio for that basin which has been found to vary from 1.5 to 3.0. Significant scatter of the points about the regression line has been attributed to variation in lithology and structure within a basin (Morisawa, 1962.).

**The Law of Stream Slopes:** According to Horton (1945) there is a fairly definite relationship between slope of the streams and stream order which can be represented by an inverse geometric series. The average slope is represented as

$$S_u = S_1 R_S^{(k-u)}$$

Where  $S_u$  is the average slope of stream of order u,  $S_i$  is the average shape of first order stream,  $R_s$  is a constant slope ratio, K is the order of the highest order stream and u is the

order of the segments under consideration. When the logarithm of the mean stream slope is plotted against stream order, a linear relationship is obtained and the antilog of the co-efficient is mean stream slope ratio for the basin. This law tends to be valid if strahler's . segment data are used (Broscoe, 1959; Morisawa, 1962).

#### Law of Basin Areas:

It states “the mean drainage basin areas of successive stream order tend to approximate closely a direct geometric series beginning with mean area of first order basin and increases according to a constant ratio” (Schumm, 1956). This law has been found to apply not only to natural basin but also to basins of ephemeral streams. Mathematically, it is expressed as

$$A_u = A_1 R_a^{(u-1)}$$

Where  $A_u$  is the mean area of basins of order  $u$ ,  $A_1$  is the mean area of 1st order,  $R_a$  is the area ratio, and  $u$  is the order of the segment under consideration. The mean area ratio is expressed as

$$R_a = \frac{A_u}{A_{u-1}}$$

#### The Law of Basin Length:

It states ‘the mean of basins length of different orders tend closely to approximate a direct geometric series in which the first term is the mean length of basin of first order and the ratio is basin length ratio’. The mean basin length is mathematically expressed as

$$L_{bu} = L_{b1} R_{Lb}^{(u-1)}$$

Where  $L$  is mean length of basin of order  $u$ ,  $L_{b1}$  is the mean length of order basin and  $R_{Lb}$  is the basin length ratio and  $u$  is the order of basin under investigation. The mean length ratio is expressed as

$$R_{Lb} = \frac{L_{bu}}{L_{b-1}}$$

#### The Law of Contributing Areas.

This law states that ‘the relationship between mean drainage basin areas of each order of any drainage network is

a linear function whose slope (regression coefficient) is equivalent to the area in square feet necessary on the average maintenance of one foot of drainage channel which is the constant of channel maintenance according to Schumm (1956).

This law has been modified by Strahler (1957) and stated by Chorley (1957) as follows:

‘The relationship between drainage basin areas of each order and the total stream lengths contained within and supported by these areas is a direct logarithmic function, the regression coefficient of which is unity, and the value of the area when the total stream lengths is unity equals Schumm’s constant of channel maintenance’.

In other words

$$\log A = \log C + \log \{L\}$$

Where  $A$  = drainage basin area,  $L$  = mean stream length and  $C$  = intercept.

#### 11.1.8 The Law of Basin Relief:

The law of basin relief according to Maxuel (1950), states ‘that the mean relief of basins of each order in a watershed, tend closely to follow a direct geometric series in which the ratio is the watershed relief ratio’. That is

$$H_u = H_1 R_R^{(u-1)}$$

Where  $H$  = the average relief of basins of order  $u$ ,  $H_1$  is the average relief of order  $u$  basin,  $R_R$  is the basin relief ratio and  $u$  is the order of basin under investigation. The relief ratio ( $R_R$ ) is the average slope within length while  $H$  is the ratio of the average relief of basin of order  $u$  to that of the next higher order That is

$$R_R = \frac{H_u}{H_{u+1}}$$

The lithological heterogeneity can however bring about some departure from a straight line.

#### The Cartographic Information Transferral

The development of detailed hydrologic and geomorphic data of the terrain for basin morphometry using analysis of maps as a medium of Information communication has prompted the application of cartographic information transferral (CIT) concept that involves cartographic communication process development, which comprises various stages of map production and utilization. Balogun

(1978) proposed the model of cartographic information transferral (CIT) that focuses on topographical map production information content at each stage of communication for effectiveness and efficiency.

A map is a geographical image of the environment and an important means of communicating information on spatial features and the relationship between them. Cartographic process of map-making is a dynamic system of information transmission. The real world is used as the source, the map symbolism represents encoding, and the channel refers to the map which is the 'eye minded mechanism' of the users realm (decoder). The real world is the source provider of the information (physical and human features) that the cartographer represents on the map. Due to the arrays of data (large volume and content), he cannot represent and present the entire features on the map. This leads to cartographic conception that adopts cartographic processes such as transformation, generalization, selection and classification for which some information are lost at these stages. The fact that all features cannot be represented in their exact form and number on the map, result in cartographic symbolization that uses symbols to represent features that are encoded and , decoded at the end of the system-recipient and interpreted as representation on the map. The model therefore deals with the amount of information and the various factors affecting cartographic information at each stage. It depends on the information contents at the different stages of communication (at the beginning, and what is retained at the end) to determine the efficiency of the system.

There are three concepts namely potential cartographic information (PCI), latent cartographic information (LCI) and retrieved cartographic information (RCI). These concepts are used for the purpose of examining maps as a means of communication of detailed representation of real world features; establish the relationship between the information content at the end of communication and what is initially obtained to determine the efficiency of the system. Balogun (1978) made the following cartographic information transferral (CIT) concepts:

- i. Potential Cartographic Information (PCI). It is the amount of information which the cartographer selects for mapping (from whatever the source), quality and forms and what the cartographer chooses to map is his potential database. It is represented thus,

$$PCI = Bd = n.$$

Where PCI=Potential Cartographic Information and

$$n = li \sum_{i=1}^n$$

Bd — is base data, a constant for mapping of similar element in the same geographic area.

li — is the information piece on all phenomena to be mapped.

- ii. **Latent Cartographic Information (LCI).** This is amount of information that survived cartographic abstraction process (generalization) that is actually put on the map. The following equation relates

$$LCi = PCI_n.$$

$$\text{Where } n = \sum_{i=1}^n$$

- iii. Where LCI=Latent Cartographic Information **PCI**, =is the sum of all bits of information lost in the process of mapping.
- iv. Retrieved Cartographic Information (RCI). This refers to the information extracted from the map by the map user, whose amount and quality are influenced by a number of factors in different ways and derived a functional relationship as follow

$$RCI = F(P, Eg, AE, C, M, O)$$

Where RCI- is retrieved Cartographic hiformation, where P- Visual perception of symbols that is a function of colors, shape, form, size, orientation, etc., Eg- general experience in map interpretation, AE- age and educational background of the user, C- cultural background, M imaginativ ability and 0- other factors e.g. interest, temperament, etc.

#### (a) First Law of CIT

That some information are lost in the process of transforming the real world phenomena into mappable form.

#### (b) Second Law of CIT

It states that, information is distorted in the process of retrieving the latent cartographic information from the map. The model finally points out the cartographic information at each stage and the cartographer should recognize area(s) of adjustment and possible improvement that is essentially

deserved. According to Balogun (1978) the cartographic objective is to obtain an ideal case whereby  $PCI=LCI=RCI$  and the attainment is very remote. Thus, the retrieved information could be enormously different in quality and quantity from the potential cartographic information. The two checkpoints by cartographers for determination of such discrepancies are to examine the information processing and mapping proceeding as well as look at the various factors that affect the retrieved information on the map.

The above laws were tested with generated data in the area in ascertaining basin morphometry concept and principles.

The literature review is based on works the various laws on basin morphometry, methodologies of data collection and brief discussion on some related applications using remote sensing and basin morphometric properties / parameters (indices). The various sources of data for morphometric studies include topographical maps, aerial photographs, satellite data and field data. These data are not independent of one another as maps are derived from aerial photos and field survey. The reviewed works are presented as follow:

Winoh (1976) worked on the most comprehensive reference sources of topographical map coverage in the world and revealed that, 1:25,000 large scale maps exist for most parts of Europe, Japan, New Zealand, some part of North African and South American countries, are adequate for analysis in morphometry. However, on the related progress made so far together with identified problems, limitations and precautions to be noted in its application as well as proffered solution on map accuracy and detailed survey in drainage network representation concerning maps generally as data source by workers worldwide include: workers Schnieder (1961); Schick (1964); Leopold (1964); Gregory (1966); Morisawa (1967); Werrity (1972); Eyles (1973); Gardiner (1975); Jarvis (1976); Ebisemiju (1976); Richards (1978); Stag (1978);

Maps at a large scale suitable for basin morphometry do not exist for most African countries with scales 1:50,000 and above are suitable. The maps production were sponsored by colonial masters (either institute géographique national du Paris or the directorate of overseas survey, Britain). In this case, it is necessary to resort to the use of available medium scale maps or aerial photographs in most African countries. Hilton (1999) in his work on Practical Geography in Africa for which he reviewed maps produced in these countries, observed that most of them are not well mapped and the published topographical map series are of different scales suitable for various purposes of planning and administration.

On Nigeria maps, he concluded on the mapping status is that of less well mapped than Ghana, though larger in size with greater human, material and natural resources. According to him, there exist various scales of mapping in Nigeria namely 1:500,000; 1:65,000 and 1:25,000). The small map scales in which the country is covered are in fifteen

sheets that were published between 1950 and 1952 respectively. However, the Nigeria surveys produced maps series of 1:50,000 coverage in the 1960s, for which most of the sheets have not been reviewed and updated to this day. Ebisemiju (1976) and Coates, (1958) therefore called for extreme caution in the use of these maps for morphological and morphometric studies while similar conclusions were drawn by Eyles (1966) with respect to Malaysian 1:63,000 topographical maps. Ebisemiju (1976) noted that, true drainage networks reflect the ground data in his work in Udi-Awgu area using aerial photos of 1: 40,000 with the scale corrected for errors of earth curvatures and atmospheric attenuation reflecting observation of Misra and Ramesh, 1984. With correct interpretation using specialized stereoscope or digitized data was for further analyses and on network, aerial photos could adequately enhanced and represented ground details (Misra and Ramesh, 1984).

On the other hand, high resolution spatial satellite data of infrared wavelengths radiation corrected and analyzed with specialized software (Arcview, Erdas, Idrisi, Span 70, etc.) were applied in morphometric studies for analysis, classification and presentation of hydrologic and geomorphic properties and parameters by Das and Mukhejee, (2005 ); Reddy et al, (2004); Mesa, (2006); Koul et al, (2007) and Maria et al (2007).

Satellite images are available at small scale of 1:250,000 and above it. The spatial resolutions are adequate for geomorphic studies and are useful in basin morphometric studies. Maria et al (2007) used landsat enhanced thematic mapper (ETM+) data for production of hydrological map for basin morphometry. Thus, large scale phenomena such as extent of major flood inundation and drainage network could be mapped and analyzed from images with increased ground resolution especially with Landsat-TM (30m), Landsat-ETM+ (1 Sin), SPOTHRV (high resolution visible (32m) and HRV IR (high resolution visible infrared) 10m, Ikonos image (3.2m) panchromatic (0.8m), Quick bird (2.4m) panchromatic (0.6m) and Worldview (the world highest resolution satellite) 0.5m resolutions respectively using various wavebands. They provide large to small scale images corrected for preprocess and enhancement corrections for earth curvatures and atmospheric attenuation at ground receiving stations.

Chisman (1977) on Landsat satellite image stated that, it could be invaluable for mapping inhospitable terrain like the impenetrable Himalayas. These sensors respond to infrared radiations bands outside the visible range of electromagnetic radiation (EMR) and provide for geomorphological and hydrological applications in various terrain analysis of drainage network channels. According to SPOT Director Jean-Marc (2003) on success of landsat and SPOT image space data process, he ascribed the main reason as in serving the global application request at a 1 Sin resolution image and for cost effectiveness.



GIS spatial data of hydrologic and geomorphic relevance derived from topographical maps as well as data from high resolution satellite image, constitute input data in a GIS operational environment. GIS techniques are now rapidly growing in importance and sophistication (Wedo, 2000). The GIS techniques for research use Landsat TM or ETM+ digital satellite data together with topographical map of 1:50,000 scale which are subjected to accurate Digital Elevation Model (DEM) using appropriate software package. According to Reddy et al, (2004); Das and Mukherjee, (2005); Mesa, (2006); Koul et al, (2007) and Maria et al, (2007), the presentation of the hydrologic mapdata, statistical data analyst are carried out using this methodology. Drainage basin development depends on the subsurface geology, rainfall, exogenic and endogenic geomorphic forces in the area. The drainage pattern of the basin ranges from sub dendritic pattern at higher elevations, parallel to sub parallel and radial in the lower elevations. Based on the drainage orders, river basins are classified using 3 order basins (for its maturity) in analysis of linear, relief and areal morphometric parameters according to Strahler, 1964.

The digital morphometric analyses procedures have made GIS a highly effective tool to understand and manage the natural resources (Srinivasan, 1988). The digital satellite research works of Maria et al, (2007) and Reddy et al, (2004) created appropriate information platform upon which to systematically proceed toward determining the morphometric parameters using hydrological maps of satellite-based images.

On Digital Elevation Model (DEM), the remotely sensed data is usually combined with other thematic data including DEM derivatives (slope, depressions, drainage) or other format such as aerial photos Landsat ETM+, topo map data etc. (Meijerink et al, 2007). This is used for enhanced presentation (pictorially) for clearer Landsat image articulation of the terrain attributes. Mark (1978) stated that DEM is designed to be more approximate and are normally sampled in the field or represented on the paper mark. In vector format, triangular group of elevation values are constructed that abstractly represents flat facets in creating a triangulated irregular network (TIN) model in visualization surface. This additional form of group products is collectively called Digital Elevation Models or DBMS.

#### **IV. RESEARCH METHOD**

##### **Mapping and Mapping Procedure**

Remotely sensed multispectral satellite digital data used and aerial photos constitute the primary data to generate hydrologic maps to determine of morphometric properties in evaluating parameters (indices). The image analysis was carried out using digital analysis method to produce hydrological maps. The maps generated in a GIS environment are input data used using ArcGIS and ArchydroWizard softwares for morphometric analysis of data generated, interpreted and classified based on sub basins

water divide concept of the features delineated and allocated into known categories (basins) on the base map. The maps were geo-referenced using coordinates of 4 points, resampled, and merged and the sub-map of the study area extracted and incorporated into the spatial data base. The images imputed in the system were geo-referenced. The mapping of the drainage networks was followed by ground trothing. This is ground-based confirmation by field observations undertaken during the pre and post interpretative phases using interpretative elements (colour, tone, shape, pattern, shadow, site and association). This is to define the drainage networks, delineate and classify the various catchment areas at sub- basins level. The digital elevation model (DEM) analysis of the study area were carried out in a continuous raster and vector formats to generate height and slope maps in which the data values represent the elevations for which the entire area drainage network are shown.

The analyzed hydrological maps were obtained from various data sources at sub basin level. Each of the streams segment were analysed using the software packages for data generated holistic result. The morphometric properties generated were used to evaluate the parameters. These morphometric analysis procedures have made GIS a highly effective tool to understand and manage the natural resources (Srinivasan, 1988). The digital satellite research works of Maria et al, (2007) and Reddy et al, (2004) created appropriate information platform upon which to systematically proceed toward determining the morphometric parameters using hydrological maps parameters. There is further enhancement procedure of satellite data combined or draped for upgrade with data of aerial photos and DEM. The topographic drainage divide of each of the prevailing third order basin, were examined on the topographical map and aerial photos mapped sheets were easily examined with the DEM profile. Together with ancillary or archival data, the mapping was finally carried out in line with the works of Maria et al (2007) and Reddy (2004) on watersheds in western Crete, Greece and on a basaltic terrain, central India analysed using IDRISI software spatial analysis system package.

On the drainage order, the drainage channels were classified into different order using Strahler (1957; 1964a&b). In a GIS environment, the drainage channel segments were ordered numerically as order number one from the stream's headwaters to a point downstream to nth order and the other parameter analyses procedure were followed. The linear, areal and relief aspects of the basin were generated from the hydrological maps and the parameters of each sub basin and the channel networks analyzed. The morphometric properties and parameters generated or evaluated using the data are shown in Table Ia. The properties include: cumulative length of stream, stream lengths, number of streams, stream order, bifurcation ratio, basin length, basin shape, basin perimeter, lengths of over land flow, length ratio

and area ratio. These were used for evaluation of parameters (with established equations) summarized as follows.

### Morphonietric Properties

Table 1: Definition/Expression and Morphometric Parameters and their Mathematical Expressions

|    |                                                                                                                          |
|----|--------------------------------------------------------------------------------------------------------------------------|
| 1. | Cumulative length of stream: Summed Total length of streams of all order.                                                |
| 2. | Perimeter (P): Total length of streams of order u. $L = \sum N_u$ Measured basin peripheral limit.                       |
| 3. | Number of streams (N): Calculated from the total number of streams of order u.                                           |
| 4. | Basin Area(A): This areas of the basin surface projected into the horizontal plane of map                                |
| 5. | Stream order: Sequence of number in a hierarchy order of magnitude assigned to tributaries and the main river            |
| 6. | Basin length (LB): The length of the straight line from the south of the basin to the most distant basin perimeter point |
| 7. | Basin shape (BS): The planimetric shape is the circle or pear-shape standard figure of                                   |
| 8. | Bifurcation: This is ratio of no of stream segment of order u to the ratio of next stream segment.                       |

### Catchment characteristics Formulae

|     |                                                 |
|-----|-------------------------------------------------|
| 9.  | Basin Circularity (Shape) (Rc)= $4\pi A/P^2$    |
| 10. | Form Factor, (Rf)= $A/(Lb)^2$                   |
| 11. | Basin Elongation, (Re) $(2/Lb)XA/31A/\pi V$     |
| 12. | Texture ratio (T) = $N(1/p)$                    |
| 13. | Ruggedness no (Rn) = $Bh \times Dd$             |
| 14. | Drainage Density (Dd), $(Dd) = L/A$             |
| 15. | Stream Frequency, $(Fu) = N/A$                  |
| 16. | Index of Drainage Density (Id) = $Dd \times Fs$ |
| 17. | Basin Relief (Bh) = $Bh_{max} - Bh_{min}$       |
| 18. | Length of Overland Flow (Lof) = $l/2Dd$         |
| 19. | Constant of Channel Maintenance (C) = $Km^2/km$ |
| 20. | BiFurcation ratio (Rb) = $N \cup N_u H$         |

### DATA ANALYSIS AND PRESENTATION

The data analysis using Arc GIS and Arc Hydro Wizard for this study, is based on generated hydrologic maps from different primary data sources, derived at sub-basin levels.

The data include hydrologic properties (Table 2) determined directly and the indices (parameters) (Table 3) are mathematically derived. The in Arc GIS and Arc Hydro Wizard inferences drawn from the analysed data are valid, as the variables were carefully determined based on software packages.

Table 2: Showing the linear properties. Areal and Relief parameters measured or determined for the basin

| S/N | PROPERTIES                               | AERIAL PHOTOS               | LANDSAT ETM/DEM             | Topomap |
|-----|------------------------------------------|-----------------------------|-----------------------------|---------|
| 1.  | Cum length of stream (KM)                | L = 1019.6                  | 1146                        | 430     |
| 2.  | Stream-length (L) (Km) within A-C basins | 956.5                       | 1145.7                      | 840     |
| 3.  | Stream number                            | N = 925                     | N = 1048                    |         |
| 4.  | Stream order (U)                         | U1'615, U2'167, U3'32, U4'1 | U1'679, U2'204, U3'44, U4'1 |         |
| 5.  | Bifurcation Ratio                        | 4.35                        | 3.99                        | 4.32    |
| 6.  | Basin length Lb                          | Lb = 114                    | Lb = 123                    | 111     |
| 7.  | Basin Perimeter (Km)                     | A-C = 2300.50               | A-C = 2,058.60              | 2835    |
| 8.  | Length of overland flow                  | 0.18                        | 0.07                        | 0.20    |
| 9.  | Basin Area (Km <sup>2</sup> )            | A-C = 7161.04               | A-C = 9120                  | 6394    |
| 10. | Basin height (m)                         | Min 300                     | Mjn-9.1 Max 492             | 400     |

Table 3: Morphometric indices for plots on basin morphometric laws

| S/N | PROPERTIES                                      | AERIAL PHOTOS                   | LANDSAT ETM/DEM      | TOPOMAP |
|-----|-------------------------------------------------|---------------------------------|----------------------|---------|
| 1.  | Basin circularity (Re) = $4\pi A/P^2$           | 0.62                            | 0.59                 | 0.56    |
| 2.  | Form factor (Rf) = $A/(Lb)^2$                   | 0.80                            | 0.88                 | 0.88    |
| 3.  | Basin elongation (re) = $(2/Lb)XA/yA$           | 1.00                            | 3.05                 | 3.05    |
| 4.  | Cum stream Length (L)                           | 1019.60                         | 146.7                | 1146.7  |
| 5.  | Drainage Density (Dd) = $L/A$                   | 1.40                            | 1.30                 | 1.3     |
| 6.  | Stream Frequency (Fu) = $N/A$                   | 1.30                            | 1.10                 | 1.10    |
| 7.  | Index of Drainage Density (id) = $Dd \times Fs$ | 1.82                            | 1.40                 | 1.4     |
| 8.  | Constant of Channel maintenance (c) = $Km^2/km$ | 1160 (topomap contour Estimate) | 4010m (DEM estimate) |         |

|     |                                |      |       |      |
|-----|--------------------------------|------|-------|------|
| 9.  | Ruggedness no<br>(Rn) = Bh nod | 3.68 | 3.33  | 3.35 |
| 10. | Bifurcation ratio<br>(Rb)      | 3.26 | 4.24  | 3.33 |
| 11. | Texture ratio (T –<br>1/p)     | 2.77 | 13.26 | 4.20 |

## V. RESULT AND DISCUSSION

This research is predicated on analyses topographical map, aerial photographic Landsat-ETM+ and DEM data (Fig. 3) produced hydrological maps.. The digital analysis of data obtained with enhancement methods conformed to the morphometric laws especially Horton's law of drainage composition (stream numbers, stream length and stream slope), basin area, basin relief and contributing areas.

The modeled basins using raster and vector formats identified three basins A, B & C with the three methods. This is with more visible greater area extent for basin A with ETM+IDEM than aerial photos. Contrary to result of Ebisemju (1978) using manual analysis of topo/map and aerial photos (Figs. 12). The drainage maps produced from the two methods of aerial. Photos Landsat. ETM+/DEM are shown in Figs. 6-10, others were produced from draped and combined group, far clearer analysis because of greater enhancement capability.

The hydrological maps produced from DEM using Aster - Lidarradar data, shows a grid representation of the stream channels within Udi-Agwu questa based on vector segmentation (stream channels) from grid cells using software analysis application.

The hydrological maps below show a grid representation (Fig.4a) of the stream channels within the questa and the vector segmentation (stream channels) from grid cells in Fig.4b. This was achieved by defining the number of flow accumulation into the cells carried out before the actual stream channel was generated for realism and network details of hydrological parameters and I and form portrayal.

Essentially, questions were answered on how much area is required to generate sufficient runoff (energy) to incise the underlying bedrock to create and maintain a stream channel. Also important is how many grid cells our various drainage networks are based on. This involves using different grids change in stream network delineation and drainage density. Thus, in Figure 4 stream networks were created, one with threshold value of 500 and the other with threshold value of 1000. The number of river threshold refers to the number of cells to start a river within a sub watershed. The DEM developed from Aster, Linder radar data (30m resolution) is an input data used to determine the flow accumulation network, drainage segmentation, stream segmentation (stream order) and ultimately the watershed delineation.

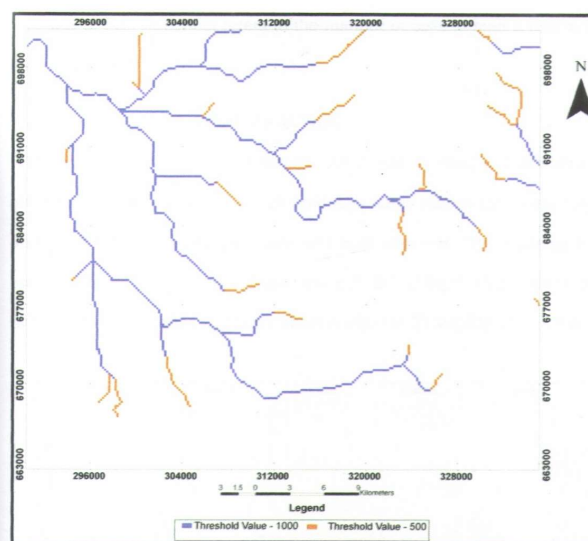


Fig. 4: Vector model showing flow accumulation pattern

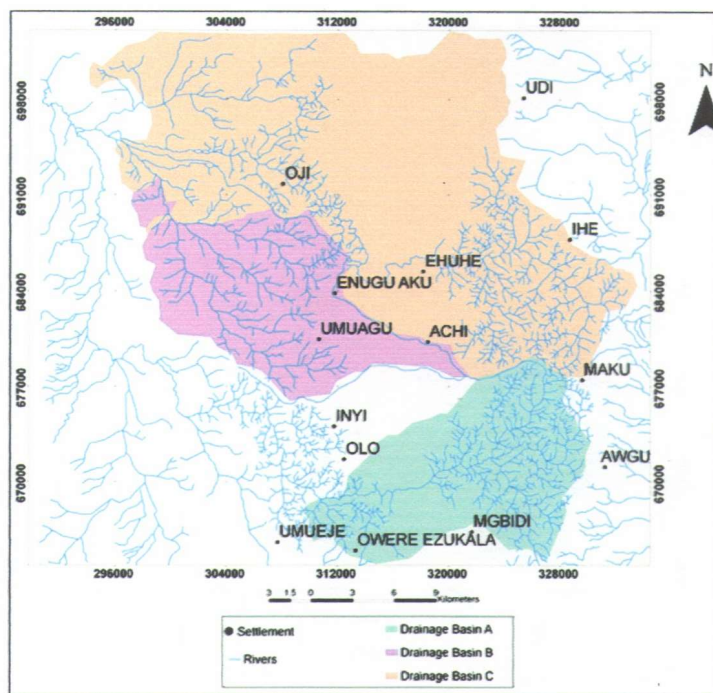


Fig 6: Vector layer of watershed belts using aerial photos in the study area

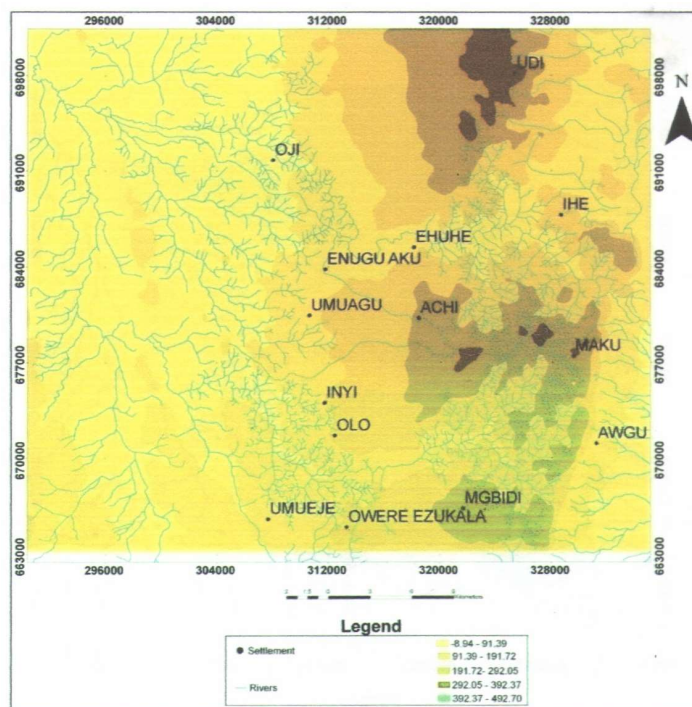


Fig 7: Digital elevation model drainage map of the study area.



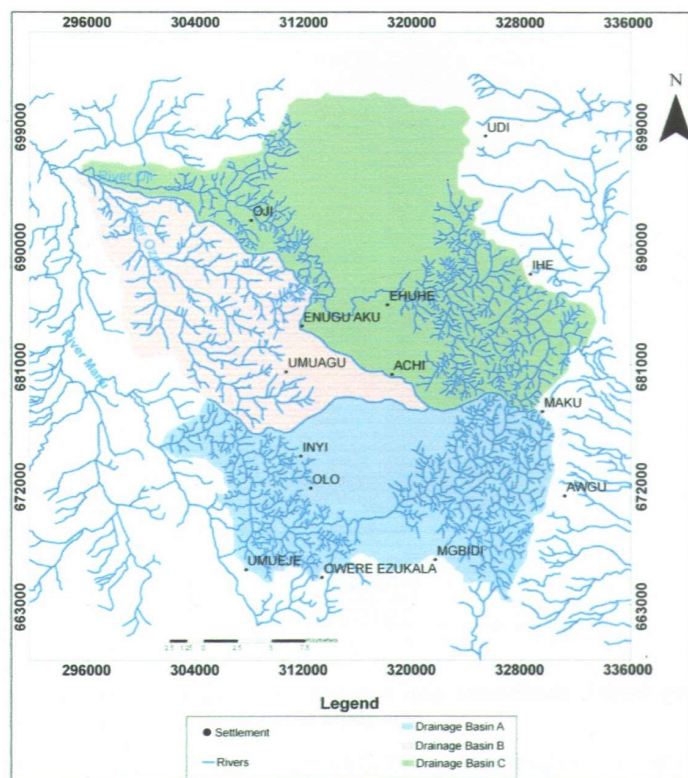


Fig 7: Watershed belt derived from Aerial photos produced drainage map of the study area

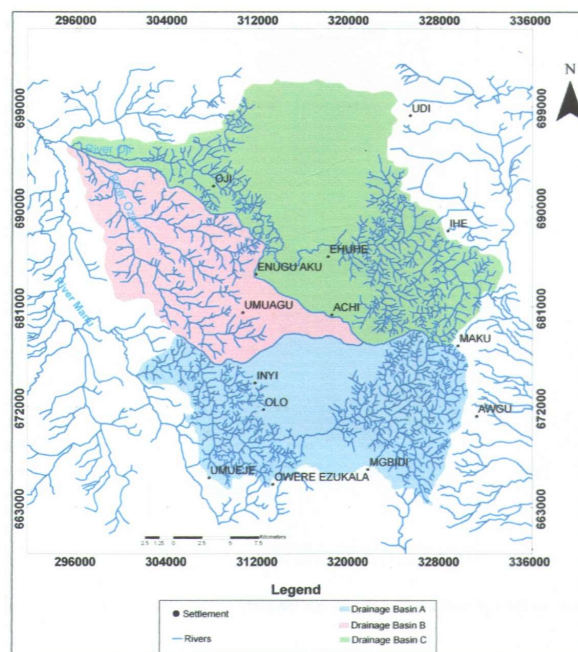


Fig. 9: Watershed belt derived from ETMIDEM of the study area

## DERIVED DATA (PROPERTIES) AND EVALUATION OF MORPHOMETRIC PARAMETERS

The prominent 3<sup>rd</sup> order basins in Udi-Agwu questa are large enough to attain state of equilibrium and stability, geomorphologically and morphologically significance and small enough to evaluate data at sub-basin level to enable comparison with previous studies observed by Ebisemiju (1976). The linear, areal and relief properties together with the parameters of each basin were determined from the hydrologic maps. This is invariably observed in details of aerial photographs that portray ground details differ from enhanced satellite data. Landsat ETM image and DEM/produced truly hydrological maps.

## HYDROLOGIC DATA AND HORTON'S LAWS OF DRAINAGE COMPOSITION

The various graphical plots on the basin morphometric laws using properties derived from hydrological maps of the methodologies of Landsat ETM/DEM, and aerial photographic methods produced details of the terrain for conformity of graphical plots of data generated with Horton's and other morphometric laws.

The Parameters for plots on basin morphometry were used to evaluate parameters in Table 2 and Table 3 is used for plots on basin morphometric law, to ascertain the implications of drainage network in the areas. The analyzed

data obtained, conformed to the morphometric laws especially Horton's law of drainage composition (stream numbers, stream length and stream slope), basin area, basin relief and contributing areas. See plots.

## EXPLANATIONS FOR THE HORTON'S LAWS OF DRAINAGE COMPOSITION

According to Waugh (1995) on Horton's laws on stream number, 'if the number of the segment is plotted on a semi-log graph against stream order, the resultant best-fit-line is a straight line of perfect negative correlation'. This relationship exists between stream order and mean stream length, mean total relief and stream slope with attendant positive correlation. Thus, as the stream order (independent variable) increases, the number of streams, mean stream length and mean total relief or stream slope (dependent variables) decrease. Therefore, as the stream order (independent variable) increases the mean stream length and mean stream slope of the drainage basin (dependent variables) increase. The various graphical plots on the basin morphometric laws using the indices on Table 10, are derived from hydrological maps of 1:50,000 and Landsat TM that produced same details of the terrain as crenulated contour of 1:50,000 topographical map and aerial photograph methods, are shown in Figures 8a-f(1-3) respectively using Tables 10 below.

Table 10; Morphometric parameters' indices for plots on laws on basin morphometry.

**Table 10; Morphometric parameters' indices for plots on laws on basin morphometry.**

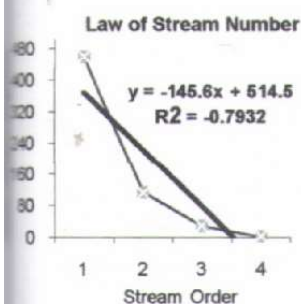
| Parameters             | (A) Topo Map |        |        |      | (B) Aerial Photos, Contour Crenulation map |        |        |      | (C) Landsat ETM/DEM |        |      |    |
|------------------------|--------------|--------|--------|------|--------------------------------------------|--------|--------|------|---------------------|--------|------|----|
|                        | 1            | 2      | 3      | 4    | 1                                          | 2      | 3      | 4    | 1                   | 2      | 3    | 4  |
| 1 Streams orders       |              |        |        |      |                                            |        |        |      |                     |        |      |    |
| 2 Mean streams length  | 2.01         | 2.21   | 1.37   | 0.54 | 2.77                                       | 2.49   | 2.14   | 1.19 | 1.11                | 2.61   | 1.0  | -  |
| 3 Mean stream segment  | 459          | 113    | 28     | 02   | 615                                        | 167    | 32     | 01   | 666                 | 472.97 | 157  | -  |
| 4 Mean basin length    | 135.60       | 255.01 | 945.46 | -    | 163.2                                      | 309.75 | 201.88 | -    | 41.50               | 10.69  | 108' | -  |
| 5 Mean basins area     | 3.14         | 1.81   | 3.26   | -    | 0.68                                       | 2.36   | 3.10   | -    | 2.64                | 2.08   | 2.39 | -  |
| 6 Mean basins relief   | 3.14         | 2.43   | 3.26   | -    | 0.68                                       | 2.67   | 3.10   | -    | 2.07                | 3.11   | 2.88 | -  |
| 7 Total streams length | 459          | 113    | 28     | 02   | 615                                        | 167    | 32     | 01   | 830.3               | 490.4  | 202  | 02 |

Source: Field work, (2009).

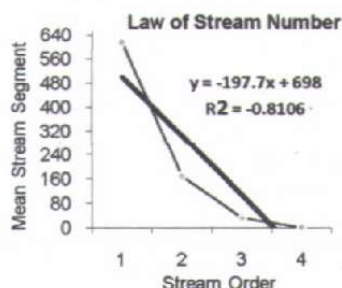
**TOPO MAP PLOTS**  
**Figs. 31a(1) – f(1)**

**AERIAL PHOTOS/CRENULATED**  
**MAP PLOTS**  
**Figs. 31b(2) – 22f(2)**

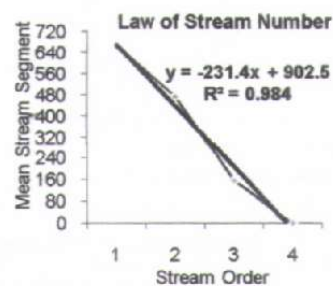
**ETM+/DEM PLOTS**  
**Figs. 31a(3) – 22(3)**



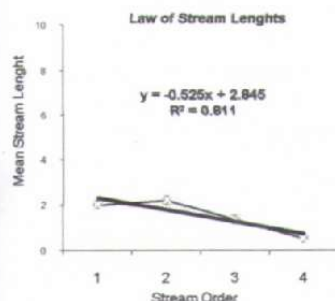
**Fig. 31a(1): The Law of Stream Number**



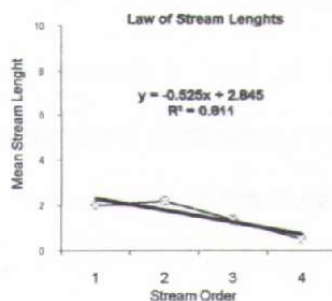
**Fig. 31a(2): The Law of Stream Number**



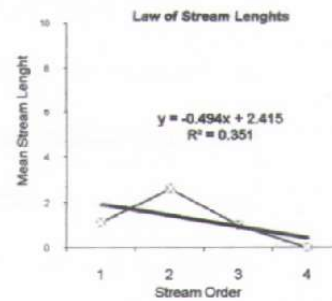
**Fig. 31a(3): The Law of Stream Number**



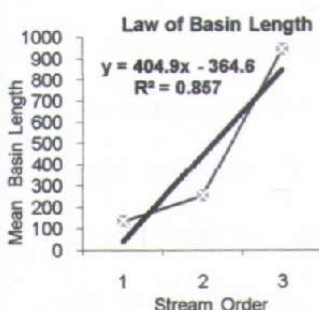
**Fig. 32b(1): The Law of Stream Lengths**



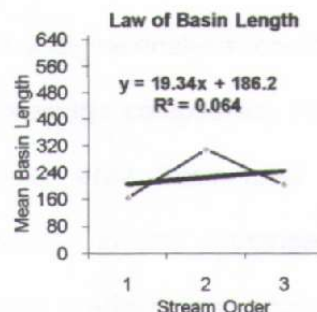
**Fig. 32b(2): The Law of Stream Lengths**



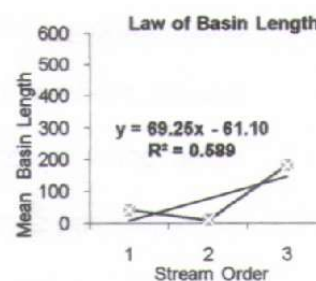
**Fig. 32b(3): The Law of Stream Lengths**



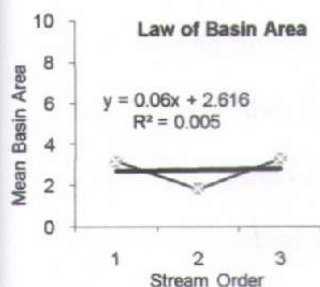
**Fig. 33c(1): The Law of Basin Lengths**



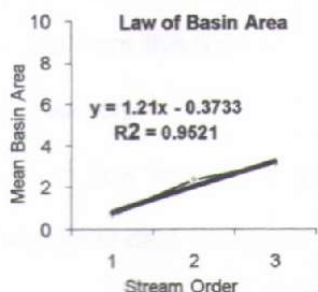
**Fig. 33b(2): The Law of Basin Lengths**



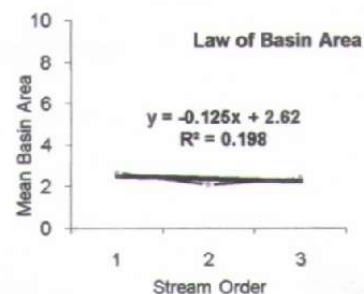
**Fig. 33(3): The Law of Basin Lengths**



**Fig. 34d(1): The Law of Basin Area**

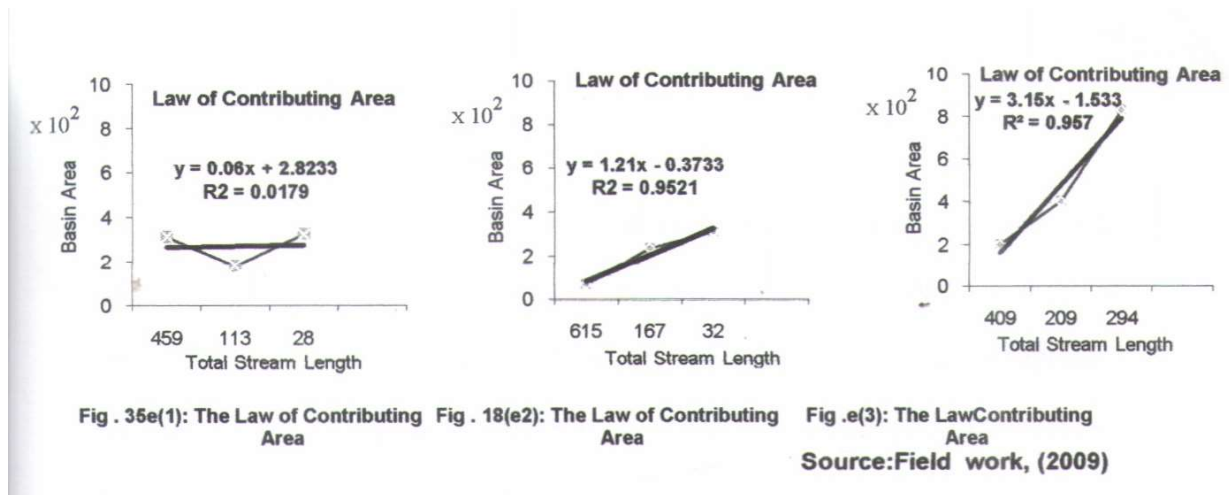


**Fig. 34d(2): The Law of Basin Area**



**Fig. 34d(3): The Law of Basin Area**





The results in the study of interrelationships amongst measurable and quantifiable elements of the landscape form the basis of formulation of theories for the scientific explanation of observed events, relationships and spatial patterns. Horton's empirical laws of drainage composition have been formulated and theories applied to explain the empirical regularities especially in the local and regional studied variations in basin morphology, as established with data of this research work. The data obtained with or without enhancement through manual or digital analysis, conform to the morphometric laws especially the laws of drainage composition (stream numbers, stream length and stream slope), basin area, basin relief and contributing areas though, the increased networks in the enhanced data (measured or evaluated) deviate graph plots, gradients and regression values. The data obtained for the study area follow the pattern of studies reviewed in most part of the world and did not deviate from the fundamental morphometric laws. These form the basis for geomorphic and hydrologic explanations and conclusion drawn on the area in line with the objectives of study, research questions together with the statistical data analyses.

## STATISTICAL DATA ANALYSES

### Hypothesis I and 2

Ho1. There is no significant difference between linear properties of drainage network (hydrologic) generated morphometric data of the Nigeria survey 1:50,000 topographical map with those of crenulated contour topographical map (1.50, 000) and aerial photograph (1.40, 000) at 0,05 level of confidence in the study area.

. Ho2 There is no significant difference between linear properties of drainage network (hydrologic) generated morphometric data of the Nigeria survey topographical map (1:50,000) with those of landsat ETM satellite image (1:100, 000) and OEM (1.50, 000) at 0, 05 level of confidence in the study area.

The null hypotheses therefore state that there are no significant differences between the means of the population from which the measurements of the two sets of data were taken.

### Student's 't' Test Application

As earlier stated, hypotheses 1 and 2 are tested using Student's 't' test parametric statistical technique for the independent samples generated. For this research analysis, a record of measurement for randomly selected morphometric properties for topographical map, aerial photo/crenulated contour topographical map and landsat ETM!DEM data using table 8. 135

### Table11: Showing the Linear properties Areal and Relief Parameters measured or determined' for the basin.

The computer programme for the Student's 't' test parametric statistical method was carried out to determine the variables for the test of the hypotheses. Using the t-test conducted values shown in appendix 2 for hypothesis land 2, revealed that t-observed for x,y,c (1.931),(1.785) and (1.644) respectively are less than the t-critical (test sample distribution table) value (2.31) at 0.05 level of confidence with two-tailed test. Again, the average t-test values of the three variables (1.7866) are less than 2.31 at 0.05 level of confidence. Thus, the average t-test values are greater than the table values and the null hypotheses are rejected for the alternatives which state that

I. Ho There is significant difference between linear properties of drainage network (hydrologic) generated morphometric data of the Nigeria survey 1:50,000 topographical map with those of crenulated contour topographical map (1.50, 000) and aerial photograph (1.40, 000) at 0,05 level of confidence in the study area.

ii. Ho There is significant difference between linear properties of drainage network (hydrologic) generated morphometric data of the Nigeria survey topographical map



(1:50,000) with those of landsat ETM satellite image (1:100,000) and DEM (1.50, 000) at 0, 05 level of significance in the study area.

Hypotheses 3 and 4.

Ho3 There is no significant variation between the basin morphometric parameters (six-factor reduced rank model - drainage density, total stream length, relief ratio, basin shape, link length ratio and bifurcation ratio or the entire parameters determined) of generated morphometric data of the Nigeria survey topographical map (1:50,000) with those of crenulated contour topographical map (1.50, 000) and aerial photos (1.40, 000) at 0, 05 level of confidence in the study area.

Ho4 There no significant variation between the basin morphometric parameters (six-factor reduced rank model - drainage density, total stream length, relief ratio, basin shape, link length ratio and bifurcation ratio or the entire parameters

determined) of generated morphometric data of the Nigeria survey topographical map (1:50,000) with those of landsat ETM satellite image (1 :000,000) and DEM (1.50, 000) at 0, 05 level of confidence in the study area.

Analyses of Variance (ANOVA) or F ratio test Application

Hypotheses 3 and 4 are tested using the analyses of variance ¶ (ANOVA) or simply F ratio test. In these analyses, computed morphometric parameters evaluated at sub-basins levels are presented in Tables 11 & 12 of the three methods of data acquisition. In testing the hypotheses, Tables 11 & 9 are used to present values of six parameters of reduced rank model data, and for the entire morphometric parameters evaluated for drainage basin morphology respectively.

Table 11: Reduced rank model data of drainage basin morphology of six parameter observed frequency table

**Table 11: Reduced rank model data of drainage basin morphology of six parameter observed frequency table**

| Parameters                 | Topographical Map     | Aerial photos/TopoMap contour crenulations/ Landsat TM /DEM |
|----------------------------|-----------------------|-------------------------------------------------------------|
| 1. Basin Circularity (Rc)  | 0.56                  | 0.62                                                        |
| 2. Relief Ratio            | H <sub>1</sub> - 750  | H <sub>1</sub> - 750                                        |
| 3. link length ratio       | L <sub>1</sub> -163.2 | L <sub>1</sub> -135.6                                       |
| 4. Cumm. Stream length (L) | 830                   | 1019.6                                                      |
| 5. Drainage Density (Dd)   | 5.37                  | 5.49                                                        |
| 6. Bifurcation Ratio       | 4.06,                 | 3.68                                                        |

SOURCE: Fieldwork, (2009)

**Table 9: Morphometric parameters and evaluated values for the basin.**

| Parameters                                         | (A)TopoMap | (B)Aerialphotos/Cont our Crenulation Map | (C) Landsat ETM/DEM |
|----------------------------------------------------|------------|------------------------------------------|---------------------|
| 1. Basin Circularity (Rc) = $4\pi A/P^2$           | 0.56       | 0.62                                     | 0.59                |
| 2. Form Factor (Rf) = $A/(Lb)^2$                   | 0.80       | 0.80                                     | 0.88                |
| 3. Basin Elongation (Re) = $(2/Lb)XA/yA/\pi$       | 0.98       | 1.00                                     | 3.05                |
| 4. Cum. Stream length (L)                          | 830        | 1019.60                                  | 1146.7              |
| 5. Drainage Density (Dd) = $L/A$                   | 1.30       | 1.40                                     | 1.30                |
| 6. Stream Frequency (Fu) = $N/A$                   | 0.90       | 1.30                                     | 1.10                |
| 7. Index of Drainage Density (Id) = $Dd \times Fs$ | 1.17       | 1.82                                     | 1.40                |
| 8. Constant of Channel Maintenance (C) = $Km^2/km$ | 0.77       | 0.70                                     | 0.80                |
| 9. Basin Relief (Bh) = $Bh_{max} - Bh_{min}$       | 1150       | 1150 (Topomap contour Estimate)          | 401                 |
| 10. Ruggedness no (Rn) = $Bh \times Dd$            | 4669       | 4332                                     | 1335.33             |
| 11. Bifurcation Ratio (Rb)                         | 4.06       | 3.68                                     | 3.33                |
| 12. Texture ratio = $T = N(1/p)$                   | 2.77       | 3.26                                     | 4.24                |

SOURCE: Fieldwork, (2009)

The computer programmes for calculation of one-way and two — way

Analyses of variance is carried out for testing the hypotheses using the above tables. The variance estimates using Kruskal-wallis one-way and Friedman two-way non parametric methods for the sample values obtained (appendix 3) were applied. The summary of the values obtained for the Analysis of variance have the following conclusions. (see appendix) (a)A& B The Anova table of A and B variable shows that F-observed (8.7857) is greater than ( $>$ ) F-critical value (4.74) at 0.05 level of confidence. It means that there is overall significance in the results obtained (b)A&C F-observed value (8.5714) is greater than f-critical value 4.74) at 0.05 level of confidence. It means that there is significance in the results obtained. (c)C&B For the Anova table above containing variables C and B, it shows that the f-obtained (11.786) is greater than f-critical value (4.74) at 0.05 level of confidence. This implies that there is overall significance in the results obtained. (d) Anova (within groups)

The Anova test conducted for hypotheses 3 and 4 reveals the f-value to be 0.3. The observed f-value (0.3) is less than the critical f-value (5.41) at 0.05 level of confidence and the null hypothesis is rejected for the alternative. (e) Anova (between groups) The Anova test conducted between group A\*B, B\*D and C\*D are (0.345), (0.008) and (0.34) respectively. Since these values are less than the f-critical 1-

(4.12) at 0.05 level of significant difference within the values of the variables, thus the null hypothesis is rejected for the alternative as follows:  $H_0$  There is significant variation between the basin morphometric parameters (six-factor reduced rank model - drainage density, total stream length, relief ratio, basin shape, link length ratio and bifurcation ratio or the entire parameters determined) of generated morphometric data of the Nigeria survey topographical map (1:50,000) with those of crenulated contour topographical map (1:50,000) and aerial photos (1:40,000) at 0.05 level of confidence in the study area. iv.  $H_0$  There is significant variation between the basin morphometric parameters (six-factor reduced rank model - drainage density, total stream length, relief ratio, basin shape, link length ratio and bifurcation ratio or the entire parameters determined) of generated morphometric data of the Nigeria survey topographical map (1:50,000) with those of landsat ETM satellite image (1:000,000) and DEM (1:50,000) at 0.05 level of confidence in the study area. The implication of the result of the hypotheses tested to the overall study is that DEM/ETM method is that there is significant difference and variation with topographical map and aerial photograph data generated as it produced greater details of the terrain especially the stream network due to higher resolution in producing fine details and invariably the true detail of the terrain. Therefore, it is suggested that further morphometric analysis should adopt the use of DEM/ETM methodology.

## VI. CONCLUSION

The cyclic model of Huxley (1924) based on law of allometric growth explains that the basin manifests itself in the variables of a system growing geometrically with order. This is the case with Udi-Agwu basin morphometric properties of drainage systems. However, the system grows through the formation of self-similar networks in the monolithologic formation (Strahler, 1958). The digital formats of data analysis adopted for this research produced similar graphical results. A number of well-defined sub-basins are distinguished that possess similar drainage properties with the stream order analysis of main basins are of 3 order streams with main basins of 37 sub basins evaluated for topographical map, 58 for aerial photos and contour crenulation map, and 100 for landsat ETM/DEM. The 1:50,000 topographical map used for morphometric analysis in the study area depicts less stream length compared with aerial photos/contour crenulation map with 18.60% and 29.57% in landsat ETM/DEM respectively. The topomap's stream number is 605, aerial photos/contour crenulations map is 925 and 1048 for landsat ETM/DEM. The topographical map's stream number is less compared with aerial photos/contour crenulations map by 320 and 443 for landsat ETM/DEM respectively. The aerial photos/contour crenulation map has 123 less stream number compared with DEM updated with landsat ETM. Thus, the later method (ETM/DEM) adequately portrays the total drainage networks to represent the true field observation.

The methodological framework used data of satellite image and aerial photos hinges digital analysis demonstrate potential results derived from the applications using theoretical framework based on basin morphometry and related laws. The literature reviewed are generally on work carried out internationally on basin morphometry using remote sensing, GIS/DEM data. The issues of limitation of application on the use of available 1:50,000 scale aerial photos and small scaled Topo maps form the basis on the use of satellite remote sensing methodology as further approach to the study. This is followed by the presentations and descriptions to develop a methodological framework based on the available satellite data whose operationalization highlight the adequacies of the approach, aimed at better understanding of the subject of basin morphometry. Thus, important guidelines were employed to determine the morphometric properties and parameters, analyzed together in a GIS environment.

The methodologies of Topo map, aerial photography produced different details of the terrain as compared with enhanced landsat ETM/DEM. The true drainage network on the ground is therefore correctly represented using these enhanced landsat ETM/DEM methods. Also, there is conformity of graphical plots with Horton's and other morphometric laws using the two sources of data for the study hence, the large scaled topo map and aerial photos can only

be used for morphometric to give actual network of the terrain.

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