Research Article

Drainage Basin Morphometric Analysis of Galagu Valley

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Abstract **_In the present study, morphometric analysis of the Galagu valley basin was done to produce information on the morphometry of the Galagu valley basin and to assess its hydrological characteristics and flood potentials. Parameters worked out include variables related to: basin shape, relief basin and drainage network. The study depends on the analysis of data employed from Digital Elevation Models which is obtained from Shuttle Radar Topography Mission using spatial data obtained from Geographical Information Systems. The results show that Galagu valley occupies a large area with elongated shape. Meanwhile, the length, the width and the perimeter of the valley indicate high filtration, evaporation and transportation. The drainage network revealed that Galagu valley basin is of 5th order with a dendritic drainage pattern and coarse drainage texture. Values of bifurcation ratio, drainage density, circularity ratio, elongation ratio, stream frequency and drainage density indicate that the basin produces a flatter peak of direct runoff for a longer duration. A flood control structure could be constructed upstream of the valley tributary confluence point to raise the flow level and fill the meadow in this system. Investigation on groundwater availability to augment the surface flow is also needed.**

Index terms: **Morphometric study, Morphometric Analysis, basin shape, relief basin, Drainage network, Galagu Valley, Geomorphologic processes**

I. INTRODUCTION

The drainage basin analysis is important in any hydrological investigation like assessment of groundwater potential and groundwater management. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density, size and length of the tributaries [1]. The development of a drainage system over space and time is influenced by several variables such as geology, structural components, geomorphology, soil and vegetation of an area through which it flows [2] .

The terms river morphology and its synonym fluvial geomorphology are used to describe the shapes of river channels and how they change over time. The morphology of a river channel is a function of a number of processes and environmental conditions, including the composition and erodibility of the bed and banks (e.g., sand, clay, bedrock); vegetation and the rate of plant growth; the availability of sediment; the size and composition of the sediment moving through the channel; the rate of sediment transport through the channel and the rate of deposition on the floodplain, banks, bars, and bed; and regional aggradation or degradation due to subsidence or uplift [3].

Morphometric analysis of a river basin provides a quantitative description of the drainage system, which is an important aspect of the characterization of basins [4]. It is important in any hydrological investigation like assessment of groundwater potential, groundwater management, basin management and environmental assessment. Various hydrological phenomena can be correlated with the physiographic characteristics of a drainage basin such as size, shape, slope of the drainage area, drainage density, size and length of the contributories, etc.[5]The morphometric analysis can be performed through measurement of linear, aerial, relief, gradient of channel network and contributing ground slope of the basin. The dynamic nature of runoff is controlled by the geomorphologic structure of the catchment area and the induced runoff is very sensitive towards the morphometric characteristics of the contributing area[6].

Various morphometric parameters such as drainage pattern, stream order, bifurcation ratio, drainage density and other linear aspects are studied using Geographic Information Systems (GIS) techniques by Arc Map version 9.3software.

Pioneer work on basin morphometry has been carried out by Horton [7] and Strahler[2] Similar work has been emerged throughout the world by different researchers using different techniques. Most of them have used GIS technique for the estimation of morphometric parameters because the results obtained were reliable and accurate. The digital elevation data can be used for generating the elevation model of a landscape to any extent. The resolution of the image may vary with respect to the satellite sensors. The processed Digital Elevation Models (DEM) can be used for generating the stream network and other supporting layers. Geographical information systems (GIS) have been used for assessing various basin parameters, providing flexible environment and powerful tool for determination, interpretation and analysis of spatial information related to river basins. Geology, relief and climate are the primary determinants of a running water ecosystem functioning at the basin scale. Thus, detailed morphometric analysis of a basin is of great help in understanding the influence of drainage morphometric on landforms and their characteristics.

The present paper describes the drainage characteristics of Galagu Valley area in Dinder district obtained through GIS based morphometric analysis. It is felt that the study will be useful to understand hydrological behavior of basin. This study depicts the process to evaluate the various morphometric parameters of Galagu Valley using Geographic Information Systems (GIS) techniques. Three major morphometric characteristics are utilized namely: basin shape, relief basin and drainage network are computed using standard methods and formulae for planning and development of the valley basin.

Objectives of the Study

The objective of this study is to provide basic information and maps of Galagu valley, its basin and tributaries. Specifically, the paper emphasizes on studying the major morphometric characteristics of the Valley namely: basin shape, relief basin and drainage network.

Significance of the Study

Due to various reasons academic research in Sudan rarely tackles or interested in applied geomorphologic studies. Together, there is scarcity of detailed geomorphologic study about the area. Instead there are scattered data about the geographical, hydro-biological and environmental studies of the area. So, it is hoped that the paper would contribute to fill in the knowledge gap in the study area and eventually to encourage other researchers to consider real addition. Moreover, the study is vital for assessing groundwater potential, groundwater management, basin management and environmental assessment.

Study Area

Galagu Basin is located between 34°37′30′′ - 35°35′20′′ E and 11˚52‘43‘ - 12˚30‘10‘ N *(fig.1)*. It is a mountainous seasonal valley descending from the Ethiopian west mountains. It is one of the river Dinder tributaries which is itself a tributary of the Blue Nile[8].The flow in the valley starts in late June and early July extending to August[9] . When the water level increases it causes fast flow and sometimes flooding. Flood water covers the lands along the two sides for months. Then the water level starts to decrease in October and turns into a dry valley in November changing into isolated meadows along the channel which is considered as the main water source in the Dinder National Park.

This is considered as an important factor, because it plays a role in the flowing nature and to the network system of the valley in general. It determines the drainage water weight, deposition and also affects the number of length of the rank. Strahler (1964)[4] states that basins which have the same area and shape characteristic must be typical in geomorphologic characters.

The basin of Galagu valley incorporates an area of about 3880 (Km^2) from the source in highland in Ethiopia to the mouth in the Dinder National Park in Sudan junction of Galagu Camp *(table1)*. This area extends from south east to the north west covering three major relief and litho-logic zones.

The high basement complex slope in the south east comprises clay plain of superficial deposits of the central Galagu valley and the isolated mountains in the east adjacent to river Rahad.

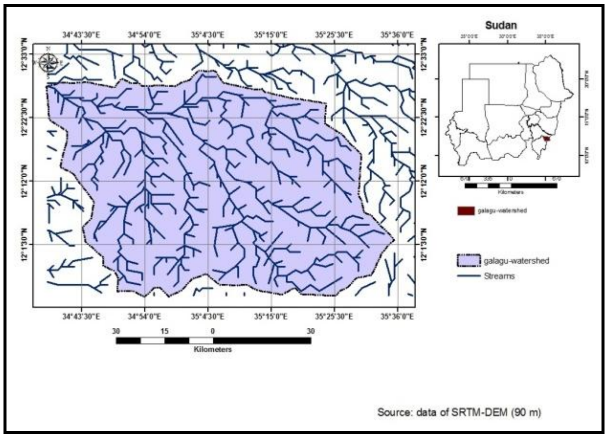

Fig. 1: The study Area of Galagu Valley

II. Materials and Methods

The study depends on the analysis of data employed from Digital Elevation Models (DEM) which is obtained from Shuttle Radar Topography Mission (SRTM)[10].

Three major morphometric characteristics are utilized namely: basin shape, relief basin and drainage network are computed using standard methods and formulae [4, 7, 11, 12]. First, basin shape characteristics which include the values of morphometric parameters namely; stream length, elongation ratio and circularity ratio are calculated based on the formulae suggested by Horton [7], Miller[13], Schumn[14] and Strahler[(4). Second, relief basin characteristics parameters include variables such as basin configuration, relief ratio and coarse ratio. Third, the characteristics of drainage network of Galagu Valley are also calculated which include rank length, rank number, drainage density, stream frequency, stream order, bifurcation ratio, texture ratio and drainage pattern.

III. Results and Discussion

Morphometric analysis of Galagu basin

1. Basin Shape Characteristic

The shape of the valley is considered as a master feature for the general shape of the valley basin, its hydrological characteristic and the area since it influences the flow. The study calculates the dimensions of the basin which include area, length, width, elongation and circular shape. It considers their effect on general characteristics of basin which helps in calculating the variable of valley Galagu by mathematic equation. Studying morphometric characteristics of any basin should discuss the following parameters *(Table1)*.

a. Dimensions of the basin

The basin dimension equals the length, the width and the perimeter.

I. Length of the basin

The length of the basin is about 114 km. This value indicates that Galagu valley induces filtration and evaporation which have direct influence on the water in the basin and meadow that receives its water from the valley. This has got indirect effect on the wildlife and other inhabitants in the park.

II. Width of the basin

The width of the basin affects the precipitation level and flooding flow[15].

The measured width of the basin is about 36 km. This value is wider in the middle of the basin. So this leads to the increase in the volume of filtration, evaporation and transpiration. It also increases surface runoff which leads to increase transported material and consequently leads to increase the deposition of material in the mouth of the basin.

III. Perimeter of basin

The perimeter of valley Galagu is about 314.5km. This coefficient is considered as an important modulus which determines other enumerated deals that represent the relief and discharge basin shape. It is also considered as the water divide of Galagu valley and the neighboring area. It is used in clarifying the shape of the basin with regard to diffusion and enlargement. As the perimeter increases in length, it means an increase in diffusion, enlargement and development of morphology of Galagu valley.

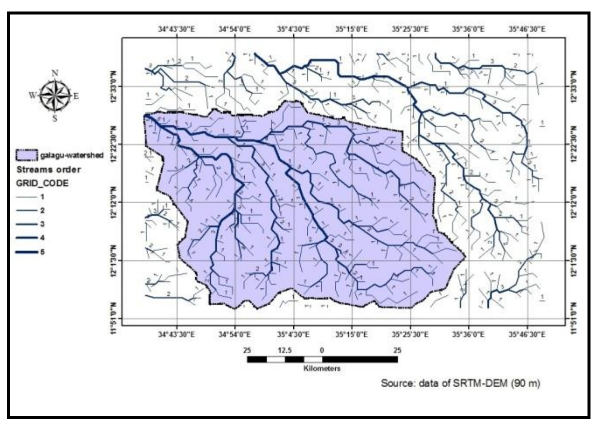

Fig. 2: Basin Area of Galagu Valley

b. Ratio of length to width

This ratio considers the relationship between length and width, and how the basin is affected by this ratio. This is measured by the flowing equation:

Length/ width=114/ 36=3.17km

c. Circulation ratio

This considers whether the shape of a basin is close to a circular shape or not. If the value is close to one accurate this means the shape of the basin is close to a circular shape and then it is considered as geomorphologic mature. In this equation the area of the basin is divided by the area of a circle having the same perimeter of the basin. For Galagu the result of this calculation is about 0.31. This indicates that Galagu valley is elongated. This characteristic leads to sudden floods in short time when the area of precipitation is large and the flow is accelerated. Thus leading to the increase of material transported and deposited in the mouth. The degree of circulation of a basin affects the relationship between flowing speed and time factor, especially during the flood seasons[13] It reflects the basin advance in denudation stage and predomination of vertical degradation and so it reaches its maturity stage. This factor clarifies the development of the basin more than elongation because it takes the whole area. The high value result indicates the closeness of a circular basin shape as it approaches from 0 to 1.

d. Elongation ratio

Schumm (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin. Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope[3] These values can be grouped into three categories namely (a) circular (>0.9), (b) oval (0.9-0.8), (c) less elongated (<0.7).

Elongation ratio= *dimension of basin circle km^2/ basin length*

Basin dimension=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb

Basin dimension=49.69

So the elongation ratio for Galagu valley = *49.69*/114= 0.43

The Re values in the study area is 0.43 indicating an elongated shape *(Table1) (Fig.2)*.

TABLE 1:
BASIN SHAPE CHARACTERISTIC OF GALAGU VALLEY

Discharge basin Characteristics	Area/km^2	Length/km	Width/km	Perimeter/km	Elongation/km	Circularity/km	Length/width ratio/km
Galagu valley	3880	114	6	314.5	0.43	0.31	3.17

Source: Data of SRTM-DEM (90m).

2. Relief Basin Characteristics of Galagu valley

This factor clarifies to what extent the activation of erosion process and the age stage of the basin that breaks from erosion stage. It also indicates the changes of basin characteristic e.g. the Area, drainage network and river capture feature and type of rock. It includes parameters such as basin configuration, relief ratio and Coarses ratio *(Fig. 3, 4, 5)*.

Basin configuration

It means the general relief of the basin (high and low topography). It determines the speed with which the runoff will reach a basin. Clearly rain that falls in steep mountainous areas will reach the river faster than flat or gently sloping areas. It is measured by the difference between the highest point in the basin and lowest point at the mouth level of the valley: 703-453=250 m

Relief ratio (RR)

The relief ratio, (RR) is ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line[14]. The RR normally increases with decreasing drainage area and size of watersheds of a given drainage basin. Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin[14]. RR = Bh / Lb Where, Bh=Basin relief, Lb=Basin length

Therefore for Galagu Valley RR= 250/114=1.84.

This value indicates that the configuration of the basin is plane.

Drainage Density

It is the relationship between the sum of valley length in the basin and its area and measured by following equation:

The sum of valley lengths in the basin/the area of the basin:

2050/3880=0.53

This means that there is 0.53 km of river valleys for every km2 of the basin area. Therefore, according to Strahler (1957)[15] as the value of the drainage density is less than 5 it is coarse, 5.0-13.7 moderate and 13.7-15.3 fine and 15.3+ above fine. This low value of drainage density implies that drainage density is coarse.

***Coarses ratio** (CR)*

This value is taken as the difference between highest and the lowest levels of a basin divided by the perimeter of the basin (Melton, 1958). This value expresses the relationship between basin relief and drainage network density. According to Choreley[14] its value starts low at the youth stage of the life cycle of the basin, then it increases to its maximum at the maturity stage and then it starts to decrease again by the end of the life cycle. That means the value of the coarse ratio increases with the increase in drainage density of the basin together with the increase in the basin relief.

CR = Bh*Dd/1000 Where, Bh=Basin relief, Dd=Drainage density

=250*0.53/1000 = 0.1325

Accordingly, Galagu watershed has a coarse ratio of 0.1325. This low value of watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

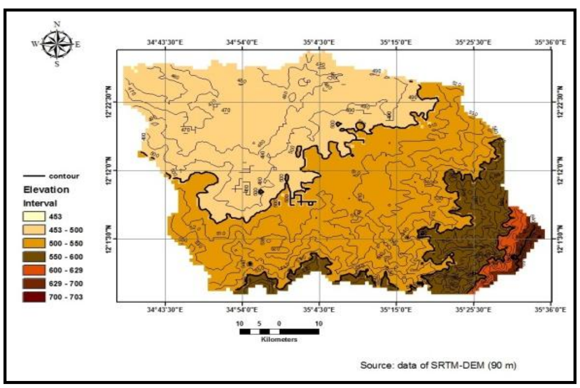

Fig. 3: Galagu Valley Basin Elevation Model

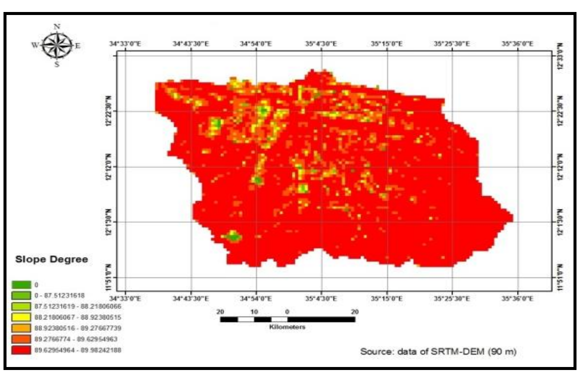

Fig. 4: Galagu Valley Basin Slope

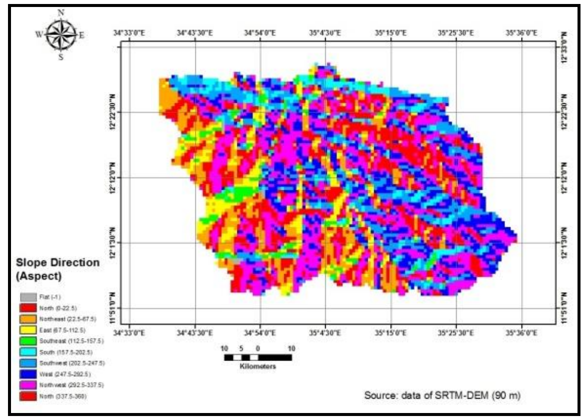

Fig. 5: Galagu Valley Basin Aspect

3. Drainage Network Characteristics of Galagu Valley

Strahler's system, which is a slightly modified of Horton's system, has been followed because of its simplicity, where the smallest, un-branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of nd order, two 2nd order streams join to form a egment of 3rd order and soon.

The ranks of the valley course by using athematical rules are shown in *(Table 2)*. It is found at Galagu Valley tributaries are of 5th order.

Rank length

It means the sum of ranks length in the basin. here is a close relationship between the Area of the asin and the length of ranks. The sum length rank of e Galagu Valley is 2050/km. *(Table2)*.

Rank Number

Streams number means the total number of the ater courses in a given drainage basin. It indicates e ability of the discharge of the valley. If it creases this lead to increase the geomorphologic processes e.g. denudation, transport and deposition. It is also the factor that leads to increase of ranks number and the lack of vegetation cover especially in the dry area. The total rank number of Galagu valley is 210 *(Table 2)* which is 166, 33, 8.0, 2.0 and 1.0 for the first, the second, the third, the fourth and the fifth orders respectively.

That means there is a stream in every 0.6 km in length which indicates intensive drainage system in the basin valley.

Stream Frequency

Stream frequency is expressed as the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. As the value is near to 1.0 that means the rocks are fragile and/or high humidity. When it approaches 0.0 it denotes solid type of rocks and/or drought.

Stream frequency = Total number of streams/the area of the basin

250/3880=0.064

The above-mentioned value reveals that the rocks of valley are solid in nature.

TABLE 2

DRAINAGE NETWORK CHARACTERISTICS OF GALAGU VALLEY

Rank Order	Rank No.	Mean rank length/km	Sum of rank length/km	Bifurcation ratio
1	166	5	830	5.03
2	33	24	792	4.13
3	8	36	288	4.00
4	2	67	134	2.00
5	1	6	6	-
Total	210	-	2050	15.16 (mean) 3.79

Source: Data of SRTM-DEM (90m).

Bifurcation ratio

Bifurcation ratio may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order[14]. It is the factor that affects the rate of a river discharge particularly after rainfall. According to Strahler (1964)[4], the bifurcation ratio (Rb) greater than 5 is an indication of structural control on the drainage, therefore, the bifurcation of this basin indicates the predominance of structural control over this basin. A lower Rb range between 3 to 5 suggests that structure does not exercise a dominance influence on the drainage pattern. Higher Rb indicates some sort of geological control. The mean bifurcation ratio for Galagu valley is**:**

Mean= Total ratio/rank no. =15.16/4=3.79

This value indicates that the geological composition and structure of the area does not affect the drainage pattern.

Texture ratio

Drainage texture ratio (T) is the total number of stream segments of all orders per perimeter of that area[7]. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development.

Based on the values of T it is classified as[12] 0 -4 Coarse; 4-10 Intermediate; 10–15 Fine; 15>Ultra-Fine (bad l and topography)

T=N/P Where, N=Total number of orders stream, P=Perimeter of basin.

210/314.5=0.67

In the present study the texture ratio of the basin is categorized as coarse in the nature.

Drainage Patterns

Drainage pattern is closely related to rock types and the geological structure[17]. Galagu Valley is considered as an important source of watering the Dinder Natural Park with least 14 ponds.

IV. CONCLUSION

GIS techniques have proved to be accurate and an efficient tool in drainage delineation and their updating. Three major morphometric characteristics are utilized namely: basin shape, relief basin and drainage network are computed using standard methods and formulae for planning and development of the valley basin.

Bifurcation ratio, length ratio and stream order of basin indicates that the basin is fifth order basin with dendritic type of drainage pattern with homogeneous nature and there is no structural or tectonic control. Relief ratio and visual interpretation of DEM of the study area indicate moderate and high relief, low run off and high infiltrations and evaporation with early mature stage of erosion development. Drainage density, texture ratio, circulatory ratio and elongation ratio show that texture of basin is moderate and shape of basin almost elongated. The complete morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect. The study revealed that Galagu Valley is an important tributary of the Dinder River. It can be classified as a valley in its youth stage (erosion) because it is a mountainous valley descending very fast, erode and carry large amount of load. When it enters Sudan it flows on a flat surface (plain) with many bends and meanders, exactly it carries the characteristics of an old stage river as it tears apart (separates) into ox-bow lakes. Therefore, a flood control structure could be constructed just upstream of the valley tributary confluence point to raise the flow level and fill all or part of the meadow in this system. Investigation on groundwater availability to augment the surface flow is also needed. It should be stressed that any implementation must take into account the sensitive environmental conditions which must be preserved and to avoid any undesirable impact which may arise. Most of the previous studies in the study area have discussed the state and condition of the wildlife and birds, their diversification, reproduction and of diseases. Likewise, some studies deal with the water in the park. For future research, the study concludes that the Dinder River and its tributaries, together with the Dinder National Park, is a promising area for the application of geomorphologic and water management studies.

REFERENCES

[1]. Waikar, M. L. (2014, 4 25). Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case study. International Journal of Multidisciplinary and Current Research, Vol.2 (2321-3124), 180-184.

[2]. Clarke J I. (1996) "Morphometry from Maps: Essay in Geomorphology". Elsevier Publication: 235–74.

[3].https://en.wikipedia.org/wiki/River_morphology. "River morphology": Wikipedia, the free encyclopedia; 7/7/2015.

[4]. Strahler A N. (1964) "Quantitative Geomorphology of Drainage Basin and channel Networks". U.S.A.: INV. T chow (ed).

[5]. R.A. Rastogi T C S. (1976) "Quantitative Analysis of Drainage Basin Characteristics". Soil Water Conservation. India 26(1–4):18–25.

[6]. M. Rudraiah S G, V.S. Srinivas. (2008) "Morphometry using Remote Sensing and GIS Techniques in the Sub-basins of Kagnariver basin, Gulburga district, Karnataka, India". Indian Society Remote Sense. 36:351–60.

[7]. Horton RE. (1945) "Erosional Development of Streams and their Drainage Basins: A Hydrophysical Approach to Quantitative Morphology". Geological Society of America Bulletin.56 (3):275-370.

[8]. Abdel-Hammeed SM. (1996) "Report on Classification of Mayas of theDinder National Park". Sudan: Wildlife Research Center Khartoum.

[9]. El-Moghrabi. (1985) "Hydrology of the Dinder National Park". Sudan: HCENR.

[10]. http://srtm.csi.cgiar.org. "SRTM 90m Digital Elevation Data" CGIAR-CSI

[11]. Horton RE. (1932) "Drainage Basin Characteristics". Transactions of American Geophysics Union.13:350-61.

[12]. Smith KG. (1950) "Standards for grading textures of erosional topography". Am Jour Sci. 248:655-68.

[13]. Miller VC. (1953) "A Quantitative Geomorphic Study of Drainage Basin Characteristics on the Clinch Mountain Area". New York: Columbia University, Department of Geology, Contract No.: Proj. NR.

[14]. Schumm S A. (1956) "Evolution of Drainage systems and Slopes in Badlands at Perth Amboy, New Jersey". Geological Society of America Bulletin. 67:597-646.

[15]. Chorley RJ.(1986) "The Application of Statistical Methods to Geomorphology. In: Essays in Geomorphology". London: G.H. Dury (ed).

[16]. Strahler AN. (1956) "Quantitative Slope Analysis". Geological Society of America Bulletin.67.

[17]. Abu-Elenin H S.(1971) "Characteristic and evolution of the drainage Pattern in the Maghara District ". Bullsocde Geog. d'Egypte.XLIV:25-51.