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GIS and Remote Sensing Based Morphometric Analysis of *Sile* Watershed: Southwest Ethiopia

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Abstract: Morphometry is measurement and mathematical analysis of landform. Its importance is that it plays crucial role in understanding the geohydrogical characteristics of river basins in terms of linear, geometry and relief characteristics. The objectives of this study was to examine the linear properties, calculate the geometry and measure the relief characteristics of the watershed. DEM with 30m resolution was the data input obtained from ministry of water, energy and irrigation. The watershed area was 228 sq. km and its form factor was 0.25 which indicates the elongated nature of its shape. Coarse drainage density with value of 0.5km/km2 implying the strong resistance of underlying lithology to erosive powers and stream frequency of 0.4 indicating relatively permeable rocks and gentle slope. Moreover the relief characteristics of the watershed reveal that high basin relief (2268.llm) and high ruggedness number 1.13 which imply the vulnerability of the watershed for erosion agents**.**

***Index Terms* – Morphometry, GIS, Remote Sensing**

INTRODUCTION

Morphometric analysis is the quantitative measurement and mathematical analysis of landform (Horton, 1945). It provides valuable information about underlying lithology, slope, shape, and resistance to erosive powers and generally about the drainage characteristics along river basins (Smith, 1950). Now a days its use and application has been increased widely since its introduction by Horton (1932, 1945). The aim of Horton (1932, 1945) was to study the river networks. It was supported by Strahler (1952, 1964) where he brought Strahler stream order scheme which is among the most commonly known schemes of stream order.

NEED OF THE STUDY.

Relief, areal/geometry and linear characteristics of river basins are the major parameters in quantifying, measuring and analyzing landforms along river basins (Hazir, 2023; Kumar , Singh , Narayan , & Prafull , 2018; Mohamed, 2020). The measurement and analysis of these parameters were improved because of the advancements of GIS and remote sensing technologies (Mohamed, 2020). It has played an important role in minimizing the time and resource needed to collect field data. In addition to this as the studies made by using the techniques revealed, up to date information of hydrological characteristics and landforms became possible.

In Ethiopia many studies were conducted to measure and quantify the three characteristics (linear, areal and relief) of the country's river basins (Daniel & Getachew , 2019; Tesfaye & Wondimu , 2014; Fayera, 2018; Shreedhara, Shankar, & Muhammed , 2018). Their findings also revealed the relevance of the technique to understand the hydrologic characteristics together with their implications such as identification of erosion prone areas.

2. Research Methods

2.1.Materials, methods and Study area

The study area is located in the southwest of the country in the present day of South Ethiopian People's Regional state. Geographically it lies in between 5º53'16'' and 6º4'12''N latitude and 37º19'22'' and 37º30'18'' E longitude. The streams of this watershed originate from *Gamo* highlands in the southwestern Ethiopia and its total area is estimated to be 228 sq.KM and it ends into Lake *Chamo.*

2.2. Data and Sources of Data

The study used digital elevation model (DEM) with 30m resolution as its primary input to achieve overall objectives. It was obtained from United States geological survey website and all the calculations of parameters were mainly done by using ArcGIS version10.3 and Microsoft excel.

2.3 Data analysis

New polygon shape file was created to be used as extraction mask to extract the study area DEM from the whole rift valley DEM. This was done to minimize the delay time while using the whole sub-basin DEM in the process of watershed delineation. After extracting the specific DEM where the watershed was confined, filling the artificial sinks was done using hydrology under analysis tool. Then using the fill raster as an input, flow direction was determined and flow accumulation was also measured by using this flow direction raster.

The remaining task to determine the area of the watershed was to prepare point data that was used as the control point of the watershed or the mouth of the river. Thus point shape file was created and its location was edited which finally determined the area of the watershed. The flow direction was used as an input raster and point data as a control point of the watershed. Thus the flow accumulation was converted into polyline by conversion tool and found to be the streams in the DEM. Finally, clip tool under analysis tool enabled to extract streams in the watershed from the whole DEM. Then by using tools in ArcGIS, the linear characteristics, geometry, and the relief of the watershed were measured.

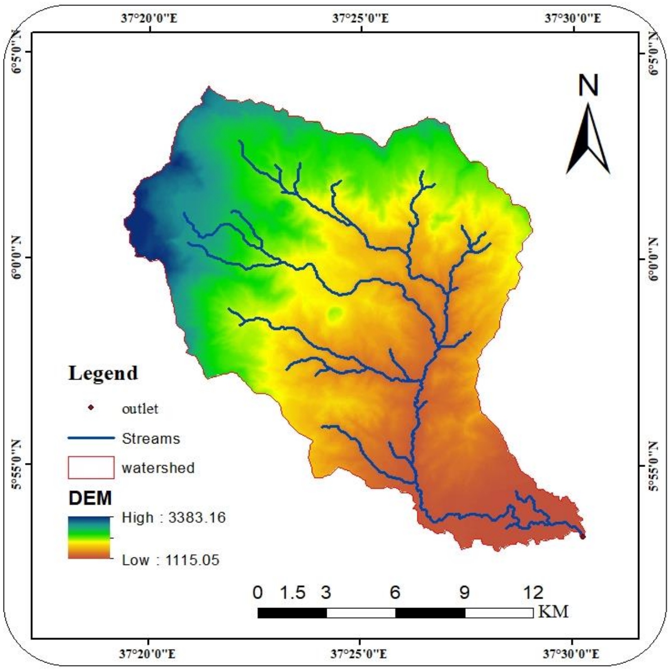

Figure 1: Study watershed

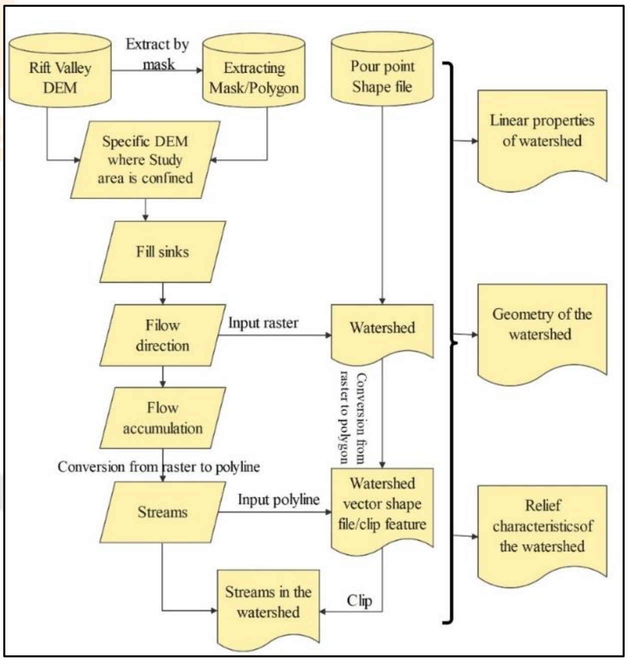

Figure 2: Methodological framework of the study

3. Results and discussions

3.1. Linear properties of the watershed

Stream number (N_u) and stream order (S_o)

According to Strahler (1964), stream number is the number of all streams in river basin. Stream order on the other hand side is the order of each streams in the basin (Strahler, 1952). Several methods of stream ordering are currently in use and among them Strahler method is the most common (Strahler, 1952). In this scheme, the streams with no tributaries are ordered as 1st order and in the junction of 1st order streams 2nd order streams are formed. Moreover in this scheme, the order of streams increase if and only if streams with the same order make junctions. This stream order scheme was used in this study and the relationship of this two parameters were found to be inverse as was stated in (Horton, 1945). The watershed order has ranged from 1st to 4th and 87 total number of streams were determined. The following figure states the relationship between stream number and its order.

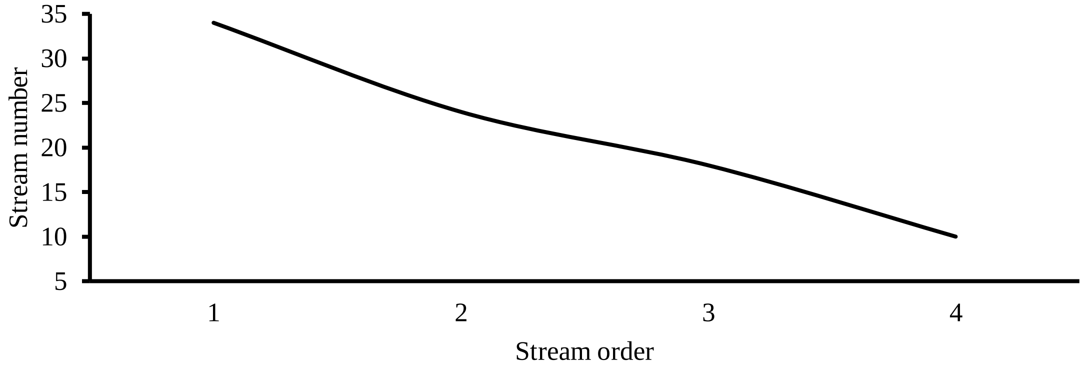

Figure 3: The relationship between stream number and stream order in the watershed

Stream length (L_u)

Stream length is the length of flow path of all streams in each order. It is the ground length of the streams and computed for each order *(Tesfaye & Wondimu , 2014)*. In this study stream length is found to be inversely related with stream order and the same results were found in empirical studies such as *(Daniel & Getachew , 2019; Tesfaye & Wondimu , 2014; Kumar , Singh , Narayan , & Prafull , 2018)*. But in this case mean stream length is lower for the first order and higher for the last order in all of these studies. The finding of this study is consistent with these studies where the mean stream length for the first order was found to be 1.3km and the highest order was 1.7km.

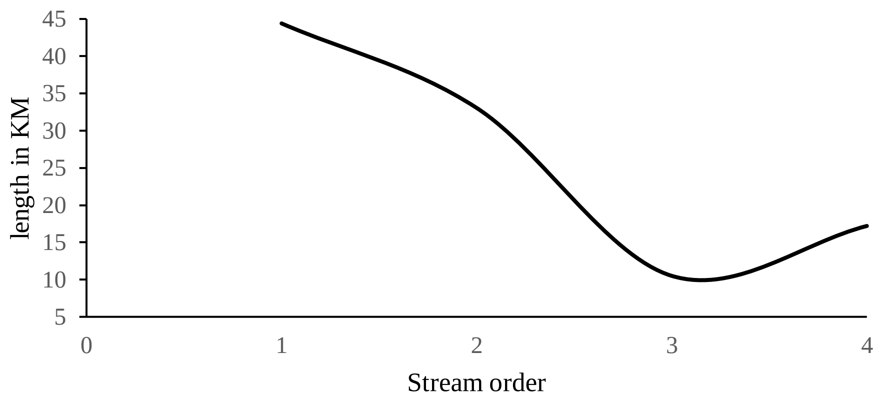

Figure 4: Relationship between stream length and stream order

Moreover stream length is the indicator of topography of the land surface (Tesfaye & Wondimu , 2014; Suma & Srinivasa, 2017). In the study only stream order 4 has 17.2 km having 10 streams and stream order 1 has only 44.4 km length with 34 streams. This resulted the mean stream length of the 1st order streams to be less than that of the 4th order stream. This indicates steep slopes in the upper catchment of the watershed where the 1st order streams are located.

Bifurcation ratio (R_b)

For a natural river, bifurcation ratio is a constant value between different orders of the basin (Hazir, 2023). Horton (1945), Strahler (1952) and Strahler (1964) state that bifurcation ratio is the ratio of stream numbers in any given order to stream numbers in the next higher order. The mean bifurcation ratio for streams in the watershed was 1.5, indicating lower structural control on the drainage pattern as well as less dissection of the terrain (Hazir, 2023).

Table 1: Summary of linear parameters.

Stream order	Stream number	Stream Length in km	Mean stream length in km	Bifurcation ratio	Mean Bifurcation ratio
1	34	44.4	1.3	-	1.5
2	24	33.1	1.4	1.4	
3	19	10.5	0.6	1.3	
4	10	17.2	1.7	1.9	

3.2.Geometry of the watershed

Drainage texture (D_t)

Drainage texture is the spacing of drainage lines in a watershed measured by computing the ratio of the number of all the streams in all orders to that of the perimeter of the watershed. It indicates the nature of the underlying lithology, relief aspect and infiltration capacity of the terrain (Horton, 1945). According to Horton (1945) and Smith (1950), drainage texture can be characterized under five categories - very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). The computed drainage texture for the watershed under consideration was 1.1. This value leaves the watershed to be categorized under very coarse textured drainage.

Drainage density (D_d)

Drainage density is among the parameters which affect hydrological process of the watershed. It is calculated as the total length of all streams for the area of the basin and it indicates the drainage intensity in the catchment (Selenica, 2000). It also shows the balance between the erosive forces of the overland flow and the resistance of surface soil and rock formation. Factors that affect or govern drainage density include runoff intensity, soil type, rock type, infiltration capacity and percentage of rocky area. Drainage density for the study area was found to be 0.5km/km^2 indicating the value that is less than 1.24km^2 which is stated as very coarse which in turn implicates the high resistance to erosive forces (Suma & Srinivasa, 2017).

Stream frequency (F_s)

Stream frequency is the termed as the total number of streams per unit of area- the total number of streams in each order divided for the area of the basin (Horton, 1945). According to Mohamed (2020), high values of F_s indicate steep ground slope and impermeability of rocks in a given basin. the F_s value computed for this study was 0.4, which means <1 river segment per sq. km. hence it can be infered that the watershed is composed of more permiable rocks and relatively gentle slopes.

Form factor (R_f)

Form factor is the implication of the peak flow duration in a given watershed. Elongeted watershed has shorter peak flow duration than that of more circular shaped watersheds. It is best computed by the ratio of the area of the basin for its length (Vijay, 1992). Low values of R_f refer to high elongation and high elongation indicates low duration of peak flow in the watershed. Acording to Vinutha & Janardhana, 2014 cited in (Sukristiyanti, Maria, & Lestiana, 2018), there are two categories/classification of R_f. Values <0.78 stated as elongated and values >0.78 determined as circular. The R_F value for the present study is 0.25 which is less than 0.78 indicating elongated shape of the watershed and short duration of peak flow.

Drainage pattern (D_p)

Drainage pattern reveals the influence of slope, lithology and structure (Tesfaye & Wondimu , 2014). According to Howard (1967) cited in Tesfaye & Wondimu (2014) it is also related to geologic information. The ratio between successive stream orders indicates the drainage pattern. For instance the number of first order streams in trellis drainage pattern outnumber the second order streams 3 to 5 times. The drainage pattern of the present study is dendritic where the number of first order streams are nearly twice that of that of the second order stream. Dendritic pattern of stream indicates semi- pervious soil.

Table 2: geometry and relief characteristics of the watershed

Geometry of the watershed			
Drainage texture	Stream frequency	Form Factor	Drainage density
1.1	0.4	0.25	0.5
Relief characteristics of the watershed			
Relief height in M	Relief ratio	Ruggedness number	Relative relief
2268.11	0.07	1.13	2.87

3.3.Relief characteristics

Relief height (R_h) and relief ratio (R_r)

Before determining the relief ratio of a given watershed, first it is necessary to calculate the relief (H) or height of the watershed (Tesfaye & Wondimu , 2014). It is calculated by subtracting the lowest height from the highest point in the watershed. In the present study area the highest point is 3383.16m and the lowest point is 1115.05m. Thus the basin height equals 2268.11m and dividing this to the basin length gives us relief ratio. The basin length in this study area is 30.5km. So that the relief ratio equals to 0.07. Basin relief determines the slope and runoff as well as sediment transport (Babu , Sreekumar, & Aslam , 2016). As basin relief increases the magnitude and intensity of runoff and sediment yield increases. As indicated the basin height is 2268.11m which implies the high runoff and sediment transport. The relief ratio of the watershed was also found to be high and this in turn gives clue for high erosion process in the watershed.

Ruggedness number (R_n)

The product of drainage density and basin relief gives us ruggedness number (Babu , Sreekumar, & Aslam , 2016). This is another implication of the relief of a watershed – i.e. high ruggedness number implying high basin relief. In the current study area the ruggedness number was 1134 (1.13) which can be categorized under high basin relief and according to Schum (1956) cited in (Babu *et.al.* , 2016), this indicates mountainous region of tropical climate with high rainfall.

Relative relief

The percentage relief to the perimeter of the basin is called relative relief. It indicates the steepness of the slope in the watershed (Tesfaye & Wondimu , 2014). In the study area as indicated above on basin relief is 2268.11m and its perimeter is 79km thus the relative relief is 2.8

4. Conclusion

As usual GIS and remote sensing technologies were proved to be important in studying the morphometric analysis of river basins. All the parameters under consideration in this study witnessed that these technologies remain powerful to get insight about river basins and their characteristics. Drainage density from stream geometry found to be good implication for watershed managers and other beneficiaries in the watershed because its result implies the underlying lithology is resistant to erosive powers. Stream frequency on the other hand side also revealed the watershed is composed of fairly permeable rocks and relatively gentle slopes. In contrast to this the relief characteristics of the watershed indicates that high relief and ruggedness number of the watershed which may increase the erosive power of erosion agents in the watershed. Finally the author recommends that additional studies in the watershed is important with better resolution of remotely sensed data to further investigation of these parameters.

References

Babu , K. J., Sreekumar, S., & Aslam , A. (2016). Implication of drainage basin parameters of a tropical river basin of South India. *Appl Water Sci*.

Daniel , A., & Getachew , W. (2019). Quantitative analysis of morphometry on Ribb and Gumara watersheds: Implications for soil and water conservation. *International Soil and Water Conservation Research*.

Fayera, T. G. (2018). Morphometric analysis of Kito and Awetu Sub Basins. *American Journal of Water Science and Engineering*.

Hazir, C. (2023, November 17). *Morphometric analysis of Llap river watershed (Kosovo).* Retrieved from researchgate: https://www.researchgate.net/publication/371556556

Horton, R. (1945). Erosional development of streams and their drainage basins:hydro-physical approach to quantitative morphology. *Bulletin of the Geological Society of America*, 1117-1142.

Horton, R. E. (1932). *Drainage basin characteristics.* Transaction of American Geophysics Union.

Kumar , P. R., Singh , R. C., Narayan , V. M., & Prafull , S. (2018). Hydrological inferences through morphometric analysis of lower Kosi river basin of India for water resource management based on remote sensing data. *Applied Water Science*.

Mohamed, E. (2020). Watershed delineation and morphometric analysis using remote sensing and GIS mapping techniques in Qena-Safaga-Bir Queh, Central Eastern Desert . *International Journal of Water Resource and Environmental Engineering*.

Selenica, A. (2000). *Hidrologjia Inxhinierike.* Albanien: Tiranë.

Shreedhara, V., Shankar, K., & Muhammed , H. (2018). A Morphometric Analysis of Wonji Drainage Basins Around Centeral Rift valley. *International Journal of Science and Research*, 1-8.

Smith, K. (1950). Standards for grading texture of erosional topography. *American journal of science*, 655-688.

Strahler, A. (1952). Hypsometric (area-altitude) analysis of erosional topography. *Bulletin of Geological Society of America*.

Strahler, A. (1964). *Quantitative geomorphology of drainage basins and channel networks.* New York: Mac.

Sukristiyanti, S., Maria, R., & Lestiana, H. (2018). Watershed-based Morphometric Analysis: A Review. *IOP Conference Series: Earth and Environmental Science*, 4-6.

Suma, B., & Srinivasa, C. (2017). A study of morphometric parameter of a watershed for sustainable water conservation. *Global Academy of Technology*.

Tesfaye , M., & Wondimu , M. (2014). Morphometric Analysis of Didessa River Catchment in Blue Nile Basin Western Ethiopia. *Science, Technology and Arts Research Journal* .

Vijay, S. (1992). *Elementary Hydrology*. Prentice-hall of India.