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**Original Article**

# Analysis of Basin Geometry in Ataq Region, Part of Shabwah Yemen: Using Remote Sensing and Geographic Information System Techniques

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**ABSTRACT**

Study of drainage and basin is important to understand the character of any basin geometry for implication of conservation of natural resources. Remote sensing and GIS is valuable tool and widely used in recent research for geometric analysis of basin. SRTM data was used to delineate the drainage network as well as sub-basin boundary; digital elevation model, aspect grid and slope map were prepared using SRTM data. Morphometric parameters (linear, areal and relief) has been analysed with the help of ArcGIS 10.2. in this analysis mean RB varies from 2.31-3.97, elongation ratio is 0.63-0.9 and relief ratio is 0.033 to 0.06; indicates that the area is highly structural controlled, steep ground slope, high drainage density and sub-dendritic to sub-parallel nature. These studies are very useful for understanding the structural control and inequalities in the rock hardness for the Ataq region.

**KEYWORDS**: Basin Geometry; Ataq area; Remote Sensing; GIS; Yemen

## INTRODUCTION

Drainage characteristics on different parts of the earth surface for numerous river basins and sub-basins have been studied using conventional procedures by many researchers (Horton, 1945; Strahler, 1964). The study of drainage morphometric parameters for the river basin comprises evaluation of streams through measurement of several stream properties (Ikbalet al., 2017; Ikbal and Ali 2017). Morphometric analysis generally provide quantitative description of the basin geometry for understanding the initial slope or inequalities in the character of rocks, structural controls, recent diastrophism, geological and geomorphic history of the drainage system; it is an essential aspect of characterization for the watershed (Strahler, 1964). In the basin and sub-basin the drainage is largely governed by rock structure, bed rock and also by soils; and also can be used for drawing deduction about lithology, structures and soil types. According to (Pandey, 2001) the higher order streams on the basin are frequently controlled by the rock structures, whereas the lower order streams are provide information about the status of the rocks and soil. Geometry description for the drainage basin and its stream channel network systematically requires measurement of linear, aerial and relief aspects of the drainage basin and contributing of the slope on the ground surface (Nautiyal, 1994). The quantitative description of the geometry of the drainage basin and its network is valuable in charactering the drainage network, associating the characteristics of different drainage networks and examine the effective of variables such as: lithology, rock structures, rainfall, landslide and other variables which related to the drainage network (Kale and Gupta, 2001). The analysis of basin geometry has been done on this paper for Ataq region with the helping of Remote Sensing and GIS techniques. The study area lies in the Shabwah Governorate, Yemen, between longitude 46° 20' E to 47°-00'E and latitude 14°20'N to 14°32'N, (Figure 1); the area is estimated at 729km2. Most of the north and south-eastern part belong to desert plain of Ramlat As-Sabatay’n; on the eastern part the area is covered by a plateau with average altitude 1325m (Aldharab et al., 2018). The major valleys in the area are drained in to the northwest direction and gradually disappear in the desert. The study area is located in region of arid climatic conditions, and the drainage system on the area arecomprises of dry water course of Wadis which flow periodically in times of torrential runoff during and after the heavy rainfall. The average annual temperature is 20.9 °C.

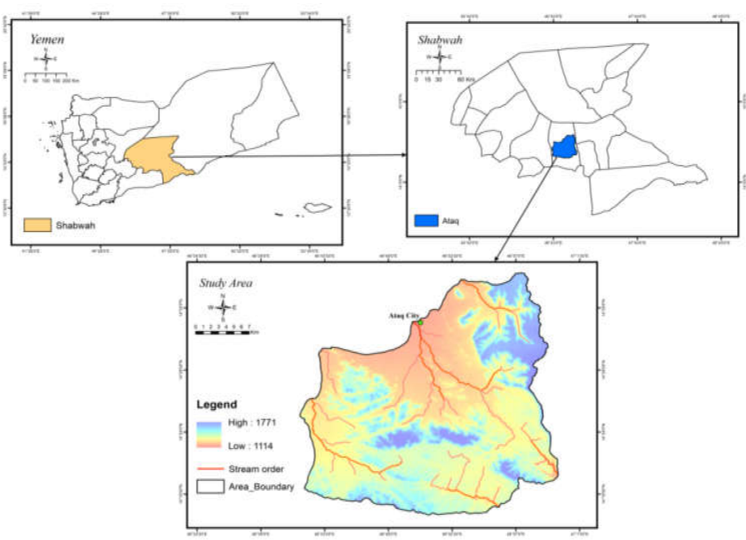


**Figure 1: Location map of Study area**

## METHODOLOGY

The freely available SRTM 30m data was downloaded for the area in Geo TIFF format from USGS with geographical latitude/longitude from website of USGS.The SRTM data has generated an unparalleled data set of global elevations that is freely available for modelling and environmental applications (Sreedevi et al., 2009). SRTM(30 m) data for the study area was reprojected to UTM (Universal Transverse Mercator) projection with zone of 38 and clipped to the extent of the study area. ArcGIS 10.2 software was used to extract and generate the drainage network and boundary for the area from SRTM data. Google earth was used as reference to visually inspect the ridges and boundaries. The resulted drainage network were verified and examined with the topographic map (1:100,000) of the study area. The resulted drainage orders were calculated according to Strahler, (1964) and Horton, (1932)-approaches of stream orders. A variety of morphometrical parameters like linear, aerial and relief parameters were calculated for each sub-basin, using ArcGIS 10.2 software; also the slope map, aspect grid map and topographic alterations were assigned from SRTM data using aspect,slope, and profile tools respectively in the ArcGIS 10.2 environment.

## DATA ANALYSIS AND RESULTS

The results of drainage networks analysis for the Ataq sub-basins are discussed below:

*Drainage Pattern:*
Three drainage patterns are presented in the study area, these area are (Figure 2):dendritic, trellis to sub-trellis and parallel to sub-parallel drainage patterns. The presence of dendritic drainage patterns give indication tothe similarity and uniform on the soil type and rocks of the area; while the presence of parallel drainage pattern is indicating that the areaswith gentle and uniform slope will represent bed rock type of less resistant; and the trellis drainage pattern is indicatingfor the down-turned folds as synclines that forming the valleys on the study area.

**Linear Aspects of Ataq sub-basins:**
Linear aspects can be correlated to the structural and geometric events on the ground surface. The developments of linear features on the earth's surface are resulted from the tectonic deformation. In this study, the linear aspects for Ataq sub-basins such as stream order, stream number, stream length, stream length ratio and bifurcation ratio, have been carried out.

**Stream order (U):**
According to Horton (1932) and Strahler (1964), the stream orders are noted based on hierarchic ranking of streams; the first order stream has no tributaries, the second order stream has only first order streams as tributaries;likewise stream orders are increasing. The map of stream order (Figure 2) shows that the entire area is a fifth order stream. The numbers of streams (N) of each order (U) for the Ataq sub-basins aregiven in (Table 1). It has been observed from the stream number that, the maximum frequency is in first order streams and also noted that there is a decreasing in stream frequency as the stream order increases. The variable difference in order and size of sub-basins is essentially due to the physiographic and structural settings of the area.

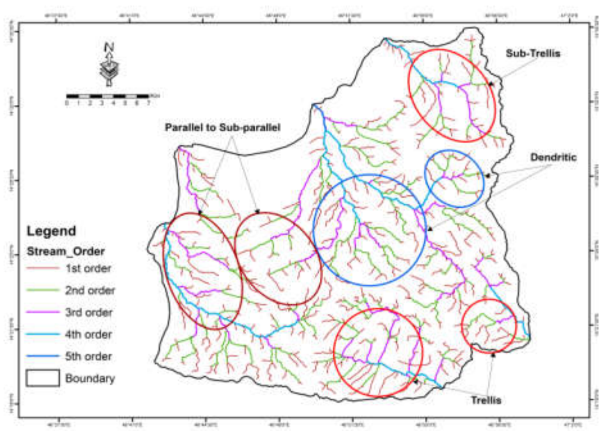


**Figure 2: Drainage Anomalies in Study area**

**Stream Number (Nu):**
The entire numbers of stream segments in each order on the drainage basin network are known as stream number. Horton, (1945) stated that the stream number decreases as increasing in stream order; according to Horton the number of stream segments in each order forms an inverse geometric sequence with the stream order. In this study stream number (Nu) support Horton's law as it seen that the stream number decrease with the increasing in stream order in all the sub-basins on the study area, as shown in (Figure 3).

**Stream length (Lu):**
In 1945, Horton stated that the length of a stream is represented by the total length of all streams in a particular order. The number of streams for various orders in sub-basins is counted whereas their lengths are measured. Generally, with theincreasing in stream order, the total length of stream segments willdecreases; the total length of stream segments is high in first order and decreases with the increasing in stream order (Aldharab et al., 2018; Waikar and Nilawar 2014). The deviation of stream length from its overall behaviour is give an indication that the terrain is characterized by highly relief and/or moderately steep slopes, underlain by varying lithology and possible uplifting across the basin (Singh and Singh, 1997). Stream length in the study area was considered according to Horton's law with the helping of ArcGIS 10.2 tools. The total stream length on the study area is 789.8 km; while for sub-basin I, II, III, IV, V, and VI are 78.91 320.8, 37.06, 180.5, 128.1 and 44.28 km respectively; as given in (Table 2) and shown in (Figure 3 B). According to Horton, (1945) when a logarithm of stream number is plotted against the stream order, the points willfall on a straight line; (Figure3 C) shows straight line which means that the stream numbersin the study area are supporting Horton's law (stream number decrease with increase in stream order in the sub-basin of study area).

**Mean stream length (Lsm):**
Mean stream length parameter for a river basin was defined by Strahler (1964) as a dimensional property that revealing the typical size of components for a drainage network and its contributing basin surfaces. This parameter can be estimated by dividing the total stream length of an order by the number of the stream segments for same order (Srinivasa et al., 2004). Generally, the mean length of stream segments for a given order is greater than the mean length for the next lower order and lessthan the next higher order. The mean stream length of different order streams for the study area is given in (Table 2). Mean stream length of Ataq sub-basins are varies from 10.40 km to 25.90 km; it reveals an increasing trend with the increasing in stream order, Figure (3.D).

**Stream length ratio (RL)**
The parameter of stream length ratio has a virtuous link with the surface flow, discharge and erosion stages of the drainage basin. Stream length ratio was considered as the ratio of the mean length for one stream order to the next lower order of the stream segments (Horton, 1945). The ratio between the streams of different order gives an indication to the changes in the drainage basin, which mayresultedfrom the variation in the slope and topography; the changes on the stream length ratio from one order to another orderwill indicates the late youth stage of geomorphic cycle (Ali et al., 2016; Arulbalaji and Gurugnanam 2017; Ali et al., 2018). In the study area, the values of the stream length ratios are differs from 0.11 to 0.97 for sub-basins; while it ranges from 0.04 to 0.60 for the entire study area; the variation of these values is due to changes in slope and topographic conditionson the study area. The results for stream length ratio are presented in (Table 2).

**Bifurcation Ratio (Rb):**
This parameter islinked to the branching of the pattern for the drainage network. Bifurcation ratio wasexplained as the ratio of the number of the stream segments for any given order to the number of stream segments on the next higherorder. Schumn, (1956) and Horton, (1945) stated that the bifurcation ratio is an index for relief and dissection; also Strahler, (1957) considered that the bifurcation ratio display a small range of variations for different regions or environment,except where the powerful of a geological control dominates. The high values of bifurcation ratio indicates some sort of geological control and lower values are suggests that the structure does not exercise a dominant influence on the drainage pattern of the terrain. According to Strahler, (1964) the anomalies

on the bifurcation ratio are depending upon the lithology and geology of the drainage basin. Lower values of the bifurcation ratioare characterize the basin which have suffered less structural effects (Nag, 1998); while the higher values are resultof a large variation in frequencies between the successive orders and will indicates a mature topography (Sreedevi et al., 2005). In the study area, the bifurcation ratios (Rb) are varies from 2.00 to 7.00, higher (Rb) values in $4^{th}$ and $5^{th}$ sub-basin indicates structural control on the drainage pattern. The mean bifurcation ratio of the Ataq sub-basin is 4.76, according to Horton, (1945) this value indicate that the area is a hilly dissected basin; the mean bifurcation ratio (Rbm) of sub-basins range between 2.31 and 3.95 which fall under normal basin category; (Table 1).

**Areal Aspects**

Areal aspects include parameters such as stream frequency, drainage texture, basin length, basin shape, basin area, form factor, circularity ratio, elongation ratio, length of overland flow, constant of channel maintenance and compactness coefficient; the computation of the linear aspects are described below:

**Basin length and width:**

Basin length was defined as the longest length of the drainage basin; it is the line from the mouth of the stream to the furthest point on the drainage divide of the basin; mean basin width is the ratio of the basin area to the basin length. The length of Ataq sub-basin is 40.07km; while the lengths forthe sixsub-basins are range between 9.42 km and 23.09 km (Table 5). The width is measured normal to the length of the basin; it is measured at the centre of the basin and perpendicular to basin length. The width of Ataq sub-basin is 24.23 km, while the widths of other sub-basins are range between 3.29 and 13.64 km, (Table 5).

**Table 1: Stream Number in different order and Bifurcation ratio in Study area**

| Basin/ sub-basin | Stream Number in different orders | | | | | Total | Bifurcation Ratio (BR) | | | | | Mean BR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $1^{st}$ | $2^{nd}$ | $3^{rd}$ | $4^{th}$ | $5^{th}$ | | 1/2 | 2/3 | 3/4 | 4/5 | Total | |
| **SBI** | 54 | 11 | 4 | 1 | 0 | 70 | 4.9 | 2.75 | 4 | - | 11.65 | 2.91 |
| **SBII** | 192 | 37 | 10 | 2 | 1 | 242 | 5.1 | 3.7 | 5 | 2 | 15.8 | 3.95 |
| **SB-III** | 21 | 4 | 1 | 0 | 0 | 26 | 5.25 | 4 | - | - | 9.25 | 2.31 |
| **SB-IV** | 98 | 26 | 7 | 1 | 0 | 132 | 3.77 | 3.71 | 7 | - | 14.48 | 3.62 |
| **SB-V** | 83 | 24 | 6 | 1 | 0 | 114 | 3.45 | 4 | 6 | - | 13.45 | 3.36 |
| **SB-VI** | 31 | 8 | 3 | 1 | 0 | 43 | 3.87 | 2.66 | 3 | - | 9.53 | 2.38 |
| **Total** | 479 | 110 | 31 | 6 | 1 | 627 | 4.35 | 3.54 | 5.1 | 6 | 19.05 | 4.76 |

**Table 2: Stream lengths and Stream length ratio**

| Basin/ Sub-basin | Order wise total Stream length in (km) | | | | | Total | Mean Stream Length (km) | | | | | | Stream length ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $1^{st}$ | $2^{nd}$ | $3^{rd}$ | $4^{th}$ | $5^{th}$ | | $1^{st}$ | $2^{nd}$ | $3^{rd}$ | $4^{th}$ | $5^{th}$ | Total | $2^{nd}/1^{st}$ | $3^{rd}/2^{nd}$ | $4^{th}/3^{rd}$ | $5^{th}/4^{th}$ |
| **SB-I** | 42.35 | 17.57 | 10.27 | 8.72 | 0.00 | 78.91 | 0.78 | 1.60 | 2.57 | 8.72 | - | 13.67 | 0.41 | 0.58 | 0.84 | 0.00 |
| **SB-II** | 150.22 | 95.35 | 46.47 | 25.9 | 2.88 | 320.8 | 0.78 | 2.58 | 4.65 | 12.9 | 2.88 | 23.86 | 0.63 | 0.487 | 0.56 | 0.11 |
| **SB-III** | 15.06 | 14.15 | 7.85 | 0.00 | 0.00 | 37.06 | 0.72 | 3.45 | 7.85 | - | - | 12.10 | 0.939 | 0.55 | 0.00 | - |
| **SB-IV** | 86.62 | 53.42 | 20.48 | 20.03 | 0.00 | 180.5 | 0.88 | 2.05 | 2.93 | 20.0 | - | 25.90 | 0.616 | 0.383 | 0.977 | 0.00 |
| **SB-V** | 66.63 | 31.24 | 22.34 | 7.91 | 0.00 | 128.1 | 0.80 | 1.30 | 3.72 | 7.91 | - | 13.74 | 0.468 | 0.71 | 0.354 | 0.00 |
| **SB-VI** | 21.32 | 9.85 | 6.94 | 6.16 | 0.00 | 44.28 | 0.69 | 1.23 | 2.32 | 6.17 | - | 10.40 | 0.462 | 0.70 | 0.88 | 0.00 |
| **Total** | 382.21 | 221.58 | 114.3 | 68.78 | 2.88 | 789.8 | 0.80 | 2.01 | 3.69 | 11.4 | 2.88 | 20.84 | 0.58 | 0.516 | 0.601 | 0.042 |

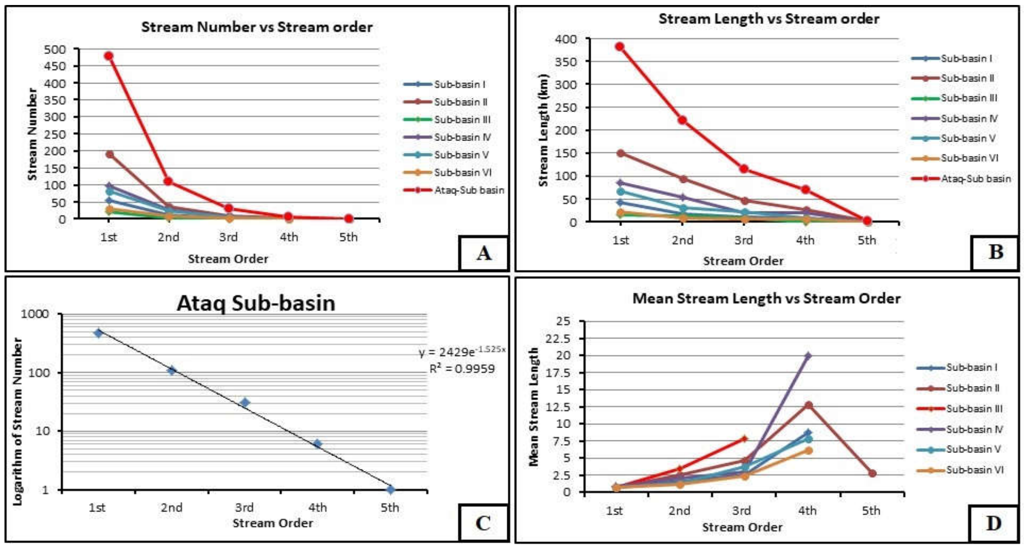


**Figure 3: A. Stream number relations to stream order, B. Stream length relations to stream number, C. Regression of Number of Stream segments with stream order of study area, D. Mean stream length relations to stream number**

**Area and Perimeter:**

Ataq sub-basin covered 729 km$^2$ while the areas of all sub-basins are between 34 km$^2$and 315 km$^2$. Ataq sub-basin perimeter is 126 km while other sub-basins range between 29 km and 103 km; (Table 5).

**Form Factor (Ff):**

Form factor is defined asthe ratio of the basin area to square of the basin length. Form factor was proposed by Horton (1945) to predict the flow intensity of the basin. Values of form factor less than 0.7854 is representing a perfectly circular basin and the smaller values of form factor will represent more elongated basin. The higher values of form factor are representing the basins with low peak flow for shorter period; and the lower values of the form factor are representing the basins with low peak flow for longer period. In elongated basin it is easy to manage the flash flood flows than those on the circular basins (Nutiyal, 1994). The value of form factor (Ff) for Ataq sub-basin is 0.45 which indicates the elongated shape; form factor values of six sub-basins are given in (Table 5). All sub-basins in the study area as well as Ataq sub-basin are represent elongated shape which suggest that their flood are easier to manage.

**Elongation Ratio (Re):**

Elongation ratio (Re) was introduced by Schumn (1956) as the ratio between the diameters of a circleequal to the area of the drainage basin with the maximum length of that particular basin. An elongation ratio value generally varies from 0.6 to 1.0 over a wide diversityof climatic conditions and lithology. The values of elongation ratios can be grouped into three classes as circular >0.9, oval 0.9 to 0.8 and less elongated <0.7; values close to 1.0 are normally found in regions of very low relief while values of 0.6 to 0.8 are frequently associated with the moderated to high relief and steep ground slope (Strahler, 1964). Commonly, circular basins are more efficient in the discharge of run-off than that of the elongated basin (Singh and Singh, 1997). The higher values of elongation ratio display high infiltration capacity and low runoff, while the lower values are characterized by high susceptibility to sediment load and erosion process (Reddy et al., 2004). The parameter of elongation ratio is considered by (Bull and MC. Fadden, 1997) as indication for recent tectonic activity. In arid and semi-arid climate elongation ratio is less than 0.05 for the tectonically active. The different values of the elongation ratios can be categorise into three groups as <0.05 for the tectonically active, between 0.05-

0.75 slightly active and more than 0.75 inactive setting (Bhatt et al., 2007). Elongation of the Ataq sub-basin is 0.76 and for the other sub-basins it varies from 0.63 to 0.90; these values are given in (Table 5). High values of elongation ratio in sub-basin V, II and VI respectively; are suggesting high infiltration capacity and low runoff; while sub-basin I, III, and IV suggesting their susceptibility to erosion and sedimentation load.

**Circularity Ratio (Cr):**

The circularity ratio was given by Miller, (1953) and Strahler, (1964) as the ratio of the drainage basin area to the area of a circle with circumference as the perimeter of the basin. Circularity ratio is affected by lithological character of the drainage basin; length and frequency of stream network; geological structures; land use and land cover; climate; relief and slope of the drainage basin. The circularity ratio of the Ataq sub-basin is around 0.57; which means that the area is not circular in its shape and the basin characterized by moderate to high relief; and the other sub-basins range in its values between 0.37 and 0.61(Table 5) which means they are not representing circular form.

**Drainage Density (Dd)**

Drainage density wasexplained as the ratio of the total length of all stream segments in a specified drainage basin to the total area of samedrainage basin (Strahler, 1958). Drainage densities represent the measure of average length of streams per unit drainage area. Ritter et al., (1995) describe drainage density as the reflectance of interaction between climate and geology; also (Horton, 1932) presented drainage density as an expression to specify the closeness of spacing of channels in a drainage basin. Drainage density factor generally linked to climate, rock types, terrain relief, vegetation cover,infiltration capacity, surface roughness and run-off intensity index. The foremost morphological factors controlling the drainage density parameter are gradient of slope and relative relief (Sreedevi et al., 2009). According to Strahler (1964) the low value of drainage density is representing low relief basin, and the high value of drainage density is representing high relief basin. Drainage density usually associated with the impermeable rock types Gardiner (1995); drainage density increase with the decreasing of infiltration capacity of the underlying material. The lower value of drainage density will result in the area which is extremely resistance rocks or permeable sub-soil material, dense vegetation and low relief; while high values of drainage density result in weak or impermeable sub-surface material, mountainous relief, andsparse vegetation (Nag, 1998); while the greater values of drainage density reflect the faster of runoff. Smith (1950) was categorising the drainage density into five different textures classes, these are shown in the (Table 3). In the study area drainage density of Ataq sub-basin is 1.08 km/km$^2$(Table 5). According to Smith classification; drainage density in the study area is less than 2 which characterize coarse drainage system. According to Strahler noted; drainage density gives prospective about the physical properties for the underlying rock types in the study area; low drainage density values in sub-basin indicate that there are some extent of permeable nature in the sub-strata and the basin relief is low; whereas the high values of drainage density in the other sub-basins are indicates of impermeable sub-surface materials and mountainous relief.

**Table 3: Drainage Density Classification after Smith, 1950**

| Drainage Density (km/sq.km) | Texture |
|---|---|
| < 2 | Very coarse |
| 2 – 4 | Coarse |
| 4 – 6 | Moderate |
| 6 – 8 | Fine |
| > 8 | Very fine |

**Drainage Texture (Rt).**

Drainage texture considered as one of the most important parameters in the morphometric analysis; which give us idea about the relation between spacing of the drainage lines (Smith, 1950). Drainage texture was defined as the total number of the stream segments of all orders within a drainage basin to the perimeter of same basin (Horton, 1945); Horton also documented the infiltration capacity as the main factor affecting the drainage texture which comprisesthe drainage density and the stream frequency. Different parameters are affecting on drainage texture values as soil type, infiltration capacity (Smith, 1950). Smith categorised drainage texture into four classes these are shown in the (Table 4). In the present study, the drainage texture for Ataq sub-basin is intermediate (4.96), while those of six sub-basins area vary between 0.89 and 2.48 (Table 5). According to smith classification the values of six sub-basins are below 4 which belong to the coarse texture.

**Table 4: Drainage Texture Classification after Smith, (1950)**

| Texture value | Drainage Texture |
|---|---|
| < 4 | Coarse |
| 4 – 10 | Intermediate |
| 10 – 15 | Fine |
| > 15 | Ultra-fine |

**Stream Frequency (Fs)**

Stream frequency parameter was introduced by Horton (1932 and 1945) as the total numbers of stream segment of all the order per unit area. Theoretically, a drainage basin with similar drainage density may vary in stream frequency; likewise a drainage basin with the same stream frequency may vary in drainage density (Chow, 1964). Reddy et al., (2004b) was specified that the lower values of stream frequencymay indicate a permeable sub-surface material and low basin relief, while the higher values of stream frequencymay indicate resistant of sub-surface material, scarce vegetation and high basin relief. The stream frequency of Ataq sub-basin is 0.86 indicate that there are nearly one stream segment present per square kilometre on the area; the values of stream frequency for the six sub-basins are varies between 0.76 and 1.11 (Table 5). )Figure(4) show close relationship between stream frequency, drainage density and drainage texture; there are increasing in stream frequency with respect to increase in the drainage density, drainage density mainly depends on lithology of the drainage basin and reflects the texture of the drainage network.

**Table 5: Areal Aspects of Study Area**

| Basin/ Sub-basin | Basin Length (km) | Basin Width (km) | Area ($km^2$) | Peri-meter (km) | Form factor | Elong ation Ratio | Circu-larity Ratio | Drainage Density ($km/km^2$) | Drainage Texture | Stream Freque ncy |
|---|---|---|---|---|---|---|---|---|---|---|
| SB-I | 14.68 | 9.6 | 92 | 52 | 0.43 | 0.73 | 0.42 | 0.85 | 1.34 | 0.76 |
| SB-II | 23.09 | 21.18 | 315 | 103 | 0.59 | 0.86 | 0.37 | 1.02 | 2.35 | 0.77 |
| SB-III | 10.33 | 4.46 | 34 | 29 | 0.32 | 0.63 | 0.51 | 1.09 | 0.89 | 0.77 |
| SB-IV | 19.61 | 11.1 | 146 | 65 | 0.38 | 0.69 | 0.43 | 1.23 | 2.03 | 0.90 |
| SB-V | 12.67 | 9.6 | 103 | 46 | 0.64 | 0.90 | 0.61 | 1.24 | 2.48 | 1.11 |
| SB-VI | 9.42 | 4.65 | 39 | 32 | 0.44 | 0.75 | 0.48 | 1.13 | 1.34 | 1.10 |
| Total | 40.07 | 24.23 | 729 | 126 | 0.45 | 0.76 | 0.57 | 1.08 | 4.97 | 0.86 |

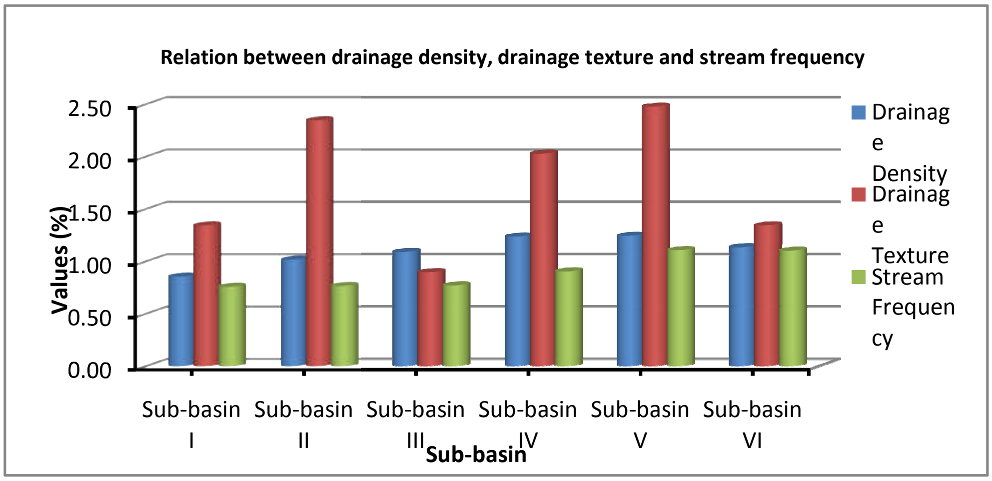


**Figure 4: Relation between drainage density, drainage texture and stream frequency**

**Length of Overland Flow (Lg):**

Length of overland flow was suggested by Horton, (1945) to refer to the length of the run water over the ground surface before it becomes localized into certain stream channels. Horton also considered length of overland flow as one of the most significant independent variables that affecting the hydrologic and the physiographic development of the stream channels. Length of over land flow is roughly equal to half the reciprocal of the drainage density (Horton, 1945). The length of overland flow value for Ataq sub-basin is 0.85 while those for six sub-basins are range from a lowest 0.65 to a highest 1.36, sub-basin IV and V show lower values since they have medium to high drainage density; whereas sub-basin I show higher values and have low drainage density.

**Relief Aspects:**

Relief aspects of the drainage basin are the function of the elevation measurements at several points in the basin or along the drainage channel. Relief aspects include drainage parameters such as basin relief, relief ratio, sinuosity index and ruggedness number; digital elevation model map (Figure5) was used to calculate these aspects, they are discussed below:

**Basin Relief:**

Basin relief is important parameter to know the extent denudation characteristics of the basin; it is also useful in interpret the geomorphic developments and landform characteristic of the drainage basin. Basin relief refer to the elevation changes between the highest points on the ridge and the lowest points on the valley floor of a drainage basin (Chow, 1964). Basin relief has an influence on the slope gradient of the channel that controls the flood pattern and the amount of sediments which get transported (Hadley and Schumn, 1961; Nilufer, A.(2009). The maximum height on the study area is 1771 m, and the lowest is 1118 m; the relative relief is 653 m and for the six sub-basins the values vary from 387 m to 653 m (Table 6).

**Relief Ratio (Rh)**

Schumn, (1956)presented relief ratio as the maximum relief in the drainage basin to the horizontal distance along the longest dimension of the drainage basin parallel to the main drainage line (Albaroot et al., 2018). Relief ratio is an important factor to measure the general steepness of a drainage basin; it is also good pointer to the intensity of the erosion process operation on the slope of the drainage basin, and is also closely related to the peak discharge and runoff intensity (Kumar A. et al., 2015). Relief ratio commonly increases with the decreasing of drainage area and size of the sub-watershed in a given drainage basin (Gottshalk, 1964). There are good relationships between the hydrological characteristic and the relief ratio of the drainage basin (Ahmed et al., 2010). In the present study; the values of relief ratios are given(Table 6) and range from 0.016 to 0.06. it is noticed that the highest value relief ratio (0.060) indicate steep slope and high relief (653 m); whereas the lower values (0.016) indicate low degree of slopes and presence pediplains and valley.

**Table 6: Relief Aspects of Study Area**

| Basin/ Sub-basin | Relief | | | | | Gradient | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Elevation in (m) | | Basin Relief (H-h) (m) | Longest axis (L) km | Relief Ratio (H-h/L) | Elevation in (m) at | | Fall in height (a-b) km | Length of main stream "L" km | Gradient Ratio (a-b/L) |
| | Max (H) | Min (h) | | | | Source (a) | Mouth (b) | | | |
| **SB-I** | 1637 | 1153 | 484 | 14.68 | 0.033 | 1589 | 1179 | 0.410 | 14.68 | 0.028 |
| **SB-II** | 1771 | 1139 | 632 | 23.09 | 0.027 | 1609 | 1140 | 0.469 | 23.09 | 0.020 |
| **SB-III** | 1567 | 1180 | 387 | 10.33 | 0.037 | 1376 | 1184 | 0.192 | 10.33 | 0.018 |
| **SB-IV** | 1769 | 1225 | 544 | 19.61 | 0.028 | 1513 | 1232 | 0.281 | 19.61 | 0.014 |
| **SB-V** | 1692 | 1205 | 487 | 12.67 | 0.038 | 1407 | 1206 | 0.201 | 12.67 | 0.016 |
| **SB-VI** | 1684 | 1118 | 566 | 9.42 | 0.060 | 1537 | 1119 | 0.418 | 9.42 | 0.044 |
| **Total** | 1771 | 1118 | 653 | 40.07 | 0.016 | 1590 | 1141 | 0.449 | 40.07 | 0.011 |

**Gradient Ratio:**

Gradient ratio was explained as an indicator for the channel slope from which the run-off volume could be evaluated (Sreedevi, 2004). In the study area the gradient ratio for Ataq Sub-basin is 0.011 and the values of six sub-basins are presented in (Table 6) and range from 0.014 to 0.044 indicate low to moderate gradient.

**Slope:**

Slope for a terrain refer to the inclination extent of the topographic landforms to the horizontal surface. Slope analysis is one of the essential parameters in the morphometric studies; it is important parameters to analysis the land use of any terrain. Slope is influence by some factors as lithology, climate, and metrological parameters to analysis the land use of any terrain. Slope is influence by some factors as lithology, climate, metrological parameters, runoff, vegetation, geological structures and processes of denudation. The understanding of the slope distribution is an essential because the slope map introducesthe data for the purpose of planning settlement,deforestation, planning of the engineering structures, and morpho-conservation applies(Sreedevi et al., 2005; Dhawaskar, 2015). Usually the maximum development of slopes is found in the hilly regions on the earth's surface, low degree of the slope is indicative of nearly level to gently sloping; while the high degree of inclination in the terrain is indicative of steeply sloping land (Almuliki, 2007). Highest value of slope indicative to the higher of run-off and erosion; lower value of slope is less the run-off (Dinakar, 2005; Pareta, 2004). Morphological characteristics of the landmasses are analysed only on the basis of slope forms. Slope map provides information regarding the distribution of various slope classes and helps in understanding the run-off characterization of the watershed. In the study area slope map was prepared from (SRTM) data; which were converted into slope map and aspect grid map using ARC GIS 10.2, (Figure 6 and 7) respectively; Aspect grid was identified as the down slope direction of the maximum rate of changes in the value from every cell to its neighbours (Sreedevi et al., 2009). Slope grid identified as the maximum rate of changes in the value from each cell to its neighbours (Burrough, 1986); aspect map illustrate the direction of the slope on all directions for the entire area. The degrees of slope exhibited in Ataq sub-basin are varies from $0^o$ to $72^o$ with a mean slope of $10.56^o$ and slope standard deviation is $10.50^o$. The general classes of land slope are classified into five categories given in (Table 7). First one is dominated by nearly level slope varying from $0^o$ – $5^o$; it is seen on the major parts of the area (45.8%). The second one is gently sloping $5^o$ – $10^o$ it is seen on 14.40% of the study area; and moderately sloping $10^o$ – $20^o$ are found in internal plateau and hills of the area. The finally, is strongly sloping $20^o$ – $30^o$ and very steep sloping $30^o$ – $72^o$ found in high mountain in the northern part of the study area; the higher slope gradient in the study area belongs to the Hilly rocks in the south-western part of the area and north-eastern part of the study area.

**Ruggedness number (R):**

As indicated by Strahler, 1957 and Melton, 1958, ruggedness number is the result of drainage basin relief and drainage density, with same unit to both parameters. Ruggedness number demonstrates the steepness of slope and indicates to the structural complexity of a terrain. High values of Ruggedness number in the basin indicate that the basin is highly susceptible to erosion (Reddy et al., 2004). In the present study, the ruggedness value for Ataq sub-basin is 0.17, while for the other six sub-basin it is 0.42, 0.64, 0.42, 0.67, 0.61 and 0.64 respectively. The ruggedness number of sub-basin I and III is low and show presence of alluvial material. While for the other sub-basins the values are relatively high indicate the highly susceptible to erosion.

**Table 7: Slope Categories**

| Slope In degree | Slope Type | Category | Area (Km$^2$) | Percentage |
|---|---|---|---|---|
| $0^o$ – $5^o$ | Nearly Level | I | 334.47 | 45.8% |
| $5^o$ – $10^o$ | Gently sloping | II | 105.12 | 14.4% |
| $10^o$ – $20^o$ | Moderately sloping | III | 144.90 | 19.8% |
| $20^o$ – $30^o$ | Strongly Sloping | IV | 99.47 | 13.65% |
| $30^o$ – $72^o$ | Very steep sloping | V | 45.01 | 6.17% |
| Total | | | 728.98 | 100.0% |

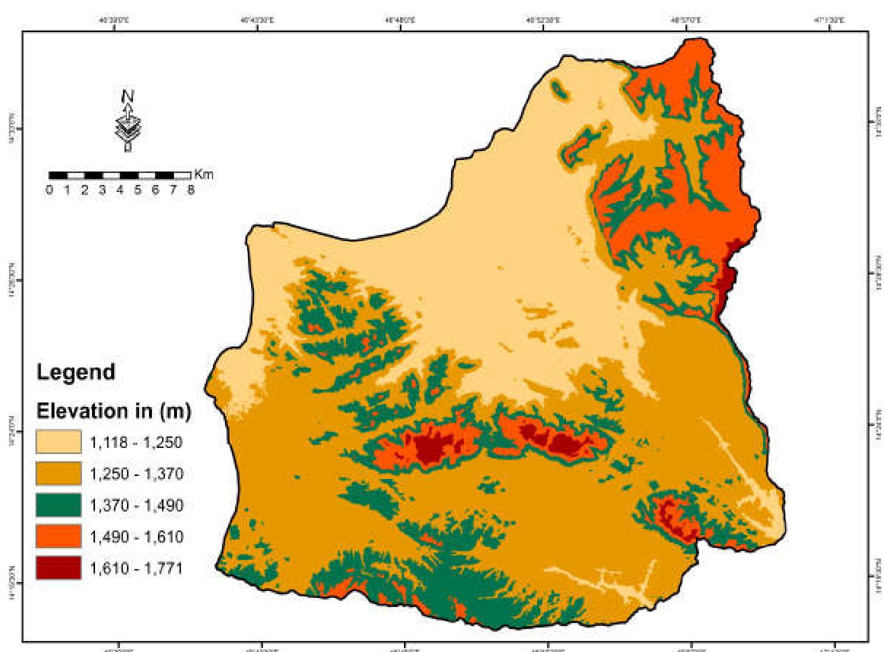


**Figure 5: Digital Elevation Mode of Study Area**

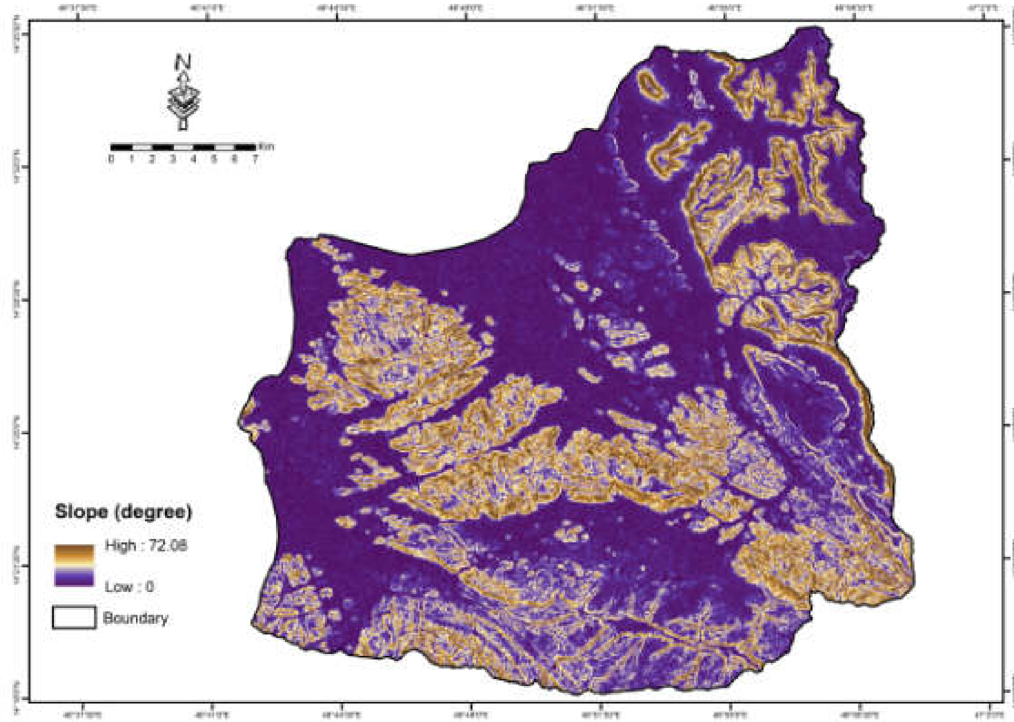


Figure 6: Slope Map of Study Area

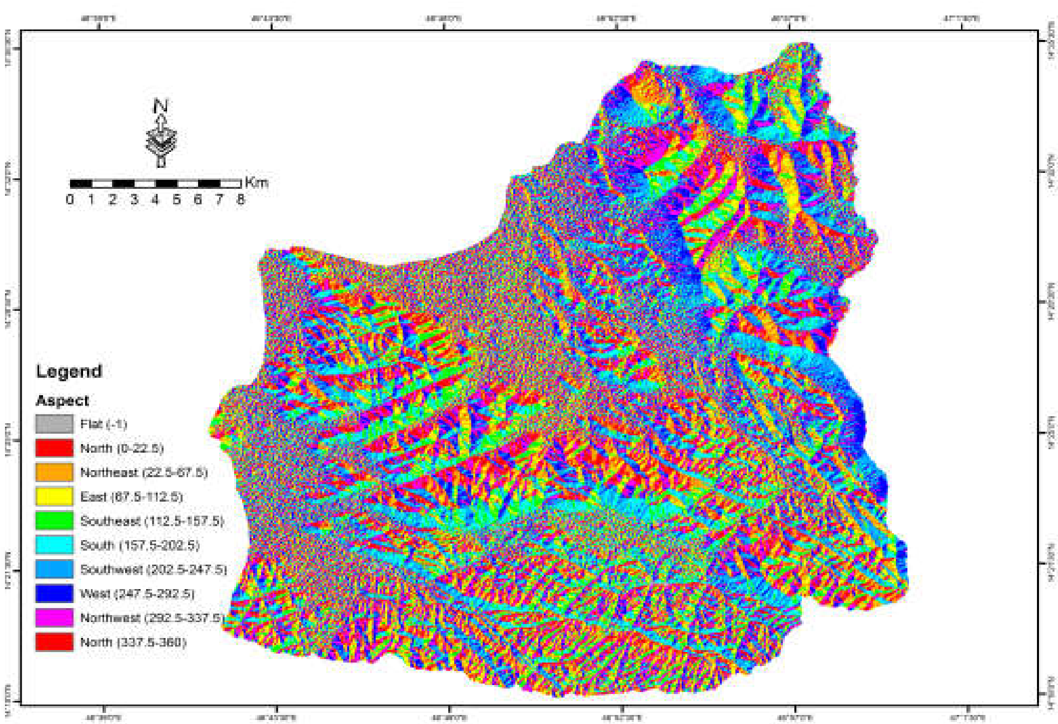


Figure 7: Aspect Grid Map of Study Area

**Infiltration Number:**
Infiltration Number was presented as the result of the drainage density and stream frequency of the drainage basin; infiltration number parameter assigns an idea about rate of the infiltration and exposes the impermeable lithology and high relief areas in the drainage basin (Umrikar 2016 and Gurugnanam 2017). Low values of the infiltration number indicate that the runoff is very low and the infiltration capacity will be very high; while the high values of infiltration number will indicate low infiltration capacity and high runoff. In the present study; infiltration number for basin is low (0.93); and for other six sub-basins it range between 0.65 and 1.38, these low will indicate that the runoff in the study area is moderate to low and the infiltration capacity is very high.

## CONCLUSION

The techniques of remote sensing and GIS have been used for the drainage basin geometry in the study area; Ataq sub-basin cover an area of 729 sq.km, it has been divided into six sub-basins they are shown dendritic, parallel to sub-parallel and trellis to sub-trellis drainage patterns. Ataq sub-basin is a fifth order stream with elongated basin shape. The total length of the basin is 40.68 km. The shape of the drainage basin affects the stream discharge development in a specific basin. The basin contains total 627 numbers of streams. The mean bifurcation ratio is 4.76 indicate that area is a hilly dissected basin. Ataq sub-basin has low drainage density of 1.08 km/km$^2$ indicating high to moderate permeable material and moderate relief; fine drainage texture indicate highly resistant subsurface material; stream frequency is 0.86 indicating poor stream frequency. The logarithm plotting of the number of streams against the stream order shows straight line, it means that the stream number supports Horton’s low (stream number decrease with increase in stream order). Circularity and Elongation ratios show that the basin have less elongated to elongated shape; this is due to effect of thrusting and faulting on the area; relief ratio indicate that the discharge capability of these sub-basins is high and the groundwater potential is meager. Infiltration number for the study area reveals that the infiltration capacity is very high and the runoff is low.

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