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Morphometrical Evaluation of Sub-basins In Al-Arasah Area, Shabwah Province (Yemen), Using Remote Sensing & GIS Techniques

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Abstract: **The study area (1238 km^2) is located in a region of arid climatic conditions; the drainage system comprises of dry water courses of channels that flow only at the times of torrential runoff during and after heavy rains, in most events the running water doesn't reach the sea. Evaluation of morphometric parameters of sub-basins were carried for this area with the aid of remote sensing and GIS techniques. The stream networks for the area along with their orders were prepared from "ALARASAH toposheet D-38-47". For details study, ASTER DEM data with 30m resolution was used to delineate sub-basin boundaries using Arc GIS 10.1 software and also was applied to estimate linear aspects, areal aspects and relief aspects of the morphometric parameter. Morphometric parameters, such as; stream order, stream length, bifurcation ratio, stream frequency, drainage density, form factor, circularity ratio, elongation ratio, etc. were calculated. Updated drainage map shows dendritic to sub-dendritic drainage patterns on the higher elevations, and parallel to sub-parallel on the lower elevations, also it shows moderate drainage texture. The high values of bifurcation ratio for the study area indicate that there are strong structural controls for drainage on the basin. A Plot of the logarithm for stream number vs. stream order is good indicator to the unaffected upliftment. Regardless of mountainous relief, a low drainage density value indicates that the area is underlain by impermeable sub-surface rocks. Elongation ratio show that the sub-watersheds have elongated shapes which indicate effect of geological structures like faulting.**

Keywords — ASTER data, GIS, Morphometric evaluation, Remote Sensing, Shabwah, Sub-basins, Yemen

I. INTRODUCTION

Morphomtery attribute to measurement and mathematical analysis of the configuration of earth's surface, shape and dimensions of its landforms [7]; [14]. Morphometric analysis is accomplished through the measurement of linear, areal and relief parameters for the basin and slope contribution [26]; [2]; [8]; [6]; [20]. These analyses need measurement of linear features, gradient of channel networks and contributing ground slopes of the drainage basin [27]; [12]; [5]. The study of morphometric parameters give quantitative attributive for the basin geometry to understand primary slope of the basin and differences in the rock hardness, structural control, recent diastrophism, geological and geomorphological history of the drainage basin [39]; [12]. The development of drainage network relies upon the geology and precipitation apart from the exogenic and endogenic forces of the area [37]. The watershed is a natural hydrological entity, which allows to the surface run-off towards a defined drainage channel, drain, streams or river at a particular point; it is a basic unit for the water supply which evolves over time [12]. Different workers defined watershed differently; in the foreign literature, watershed refers to the drainage basin or catchment; watershed size varies from fractions of hectares to thousands of square kilometers. According to the watershed atlas, which prepared by AIS&LUS (1990), the mean area of the watershed is less than 500km^2 (±50). In its technical guidelines for IMSD project, NRSA (1995) has further classified the watershed into sub-watershed, with area ranging from 30 to 50 km^2, mini-watershed with area ranging from 10 to 30 km^2 , and micro-watershed with area ranging from 5 to 10 km^2 [12]. In this paper, remote sensing and GIS techniques were used to extract watershed, generate stream order automatically and to compute various parameters of morphometry to evaluate the basin characteristics.

II. STUDY AREA

The study area is located on the north-eastern part of

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Ataq City, Shabwah Province, Yemen, and bounded by the coordinates (Longitude 47°00'- 47°30' E and latitudes 14°40'- 15°00'N) (Figure 1). The total area covers (1239km^2.). The region of study area characterized by changed terrain comprises of generally low relief desert in the western part and prominent cliffs which gives ascent to an extensive Central and Eastern plateau that has been deeply incised by drainage. The vertical relief can reach (300m) resulting in an extremely low water table. The average altitude is (1500m) above mean sea level. The climate of the study area is tropic-arid. It is basically influenced by the monsoon winds of the Indian Ocean. Seasonal shifting on the zone of inner tropical convergence causes the alteration for the air currents [35]; [25]. Geologically the study area is covered predominantly by a carbonate plateau cut by deep Wadis, the western part of the study area covered by Quaternary to Recent sediments. The youngest outcropping sediments of the plateau are carbonates of Jeza formation (Lower Eocene), the Jeza formation consists of variegated argillaceous shale in alternation with marls and nodular Limestone representing, were preserved, a sub-horizontal layer on the top of the plateau. The sequences were already defined as marker formation of lower Eocene age [10].

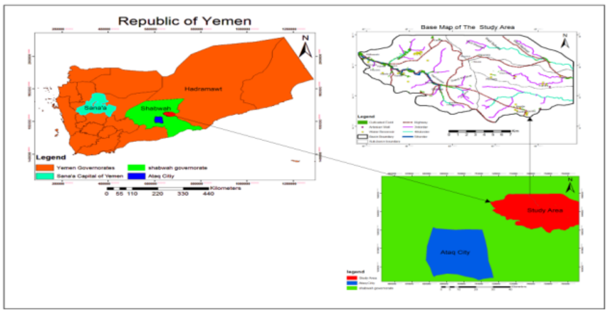

Figure 1 location map of study area

III. METHODOLOGY OF STUDY

In this paper the methodology of the study begins with review of the literature, and collection of the information and related data for the area. The morphometric parameters of the watersheds were calculated based on published topographic map on 1:100,000 scale and ASTER DEM data OF 30 meter resolution. The ASTER DEM has made an unparalleled data set of worldwide elevations that is available free of cost for modeling and environmental applications; also ASTER data is quick and cheap way for the regional geomorphological analysis. These Data were taken from (http://ASTER.GDEM/data/obtaining.html) and ArcGIS software was used for calculation. Based on these data we prepared the topographic elevations and slope maps for the watershed; stream network and micro watersheds were also prepared following processes of scanning, georeferencing and digitization with respect to the toposheet

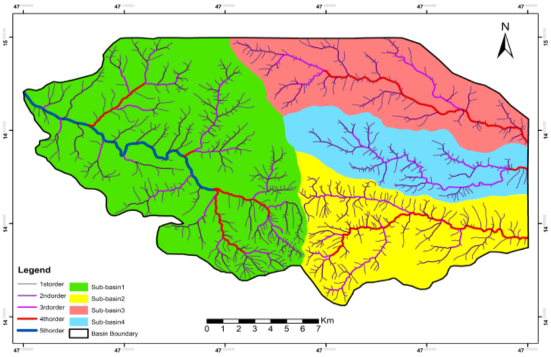

Figure 2 Drainage Map of Study area

of the study area (1:100,000 scale) (Figure 2). The drainage map and watershed boundary was updated by using ASTER DEM. The study area was divided into 4 sub-basins and the morphometric parameters were carried out for sub-basins level in the Arc GIS 10.1 software. The drainage channels were categorized into different orders according to [36]. Linear, Areal and Relief parameters were computed under GIS environment to identify the basin characteristics. Different morphometric parameters such as perimeter, stream length, and stream order were calculated and thereafter were used to calculate different parameters like bifurcation ratio, stream length ratio, stream frequency, drainage density, drainage texture, basin shape, elongation ratio, circularity index and form factor; these parameters were estimated with the assist of certain mathematical formulas.

IV. EVALUATION OF MORPHOMETRIC PARAMETERS

The morphometric parameters have been classified into linear, aerial and relief parameters, [17]; [30]; [39]; [36].

A. Linear Aspects

Linear aspects comprise different parameters as stream number, stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio; the calculations of these aspects are described below:

1. Stream Number (Nu)

The stream characteristics comply with “Horton’s law of stream numbers” which expressed that the number of streams of various orders in a given drainage basin tends closely to approximate an inverse geometric ratio [37]; [7]. According to Horton’s fundamental the number of streams in any given drainage is negatively correlated with the order of that drainage, i.e. Stream Number (Nu) decreases with increasing in stream order. For the study area, stream number (Nu) supports Horton’s law. The number of streams of each order and the total number of streams which were computed are given in (Table 1a).

2. Stream order (U)

Stream order is the first procedure in the drainage basin analysis [12]. The stream order of the study area has been ranked according to the stream ordering system which

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stated by Strahler (1964); these are presented in (Table 1a). Applying of this ordering system procedure through Arc GIS reveals that the drainage network on the study area is a 5th order basin. Sub-basin 1 was under 5th order and two sub-basins (2&3) were identified under 4th order. 1st and 2nd stream orders are dominating in sub-basins (1&2), the total number of streams is 1065, out of this 862 is 1st order, 161 is 2nd order, 33 is 3rd order, 8 is 4th order and 1 is 5th order. In general, logarithms of the number of streams plotted against the stream order shows that the points are lie on a straight line (Figure 3) [18]; [12].

3. Basin Perimeter (P)

Basin perimeter (P) refers to the length of the basin boundary that encloses the catchment area; it was used with

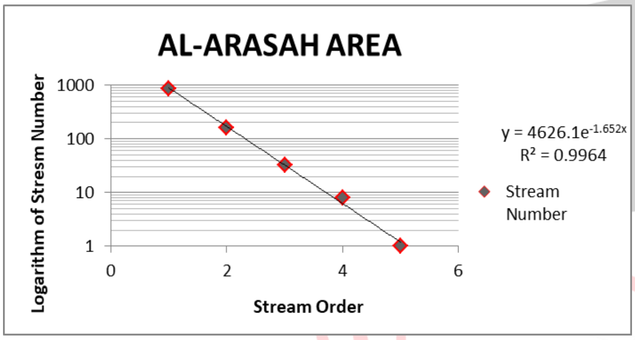

Figure 3 Regression of Number of Stream segments with stream order in Alarasah Sub-basins

the basin area to give a measure for the departure of the basin from a true circle, and also used with relief to give an amount of the general steepness of the basin [15]. For the study area, the basin perimeter is 158.01 km; while those of the other four sub-basins are shown in the (Table 5).

4. Stream Length (Lu)

Stream length refers to the length of streams in a particular order on the drainage basin [12]. The stream lengths for all sub-basins of the different orders have been measured on a digitized map and from ASTER data with the help of ArcGIS 10.1, given in (Table 1a); consequently after adding each stream for a given order, the total stream length of each order (Lu) was calculated. The maximum length for the total basin is (56.99 km) and that of the four sub-basins are (36.107 km), (26.75 km), (34.4 km) and (27.75 km) respectively given in (Table 1a). Mostly the total length of the stream segments decreases with the increase in stream order [18], the variation from its general behavior indicates that the terrain is characterized by high relief and / or moderately steep slopes, that mean it is underlain by varying lithology and probable uplift across the basin [33]; [12].

5. Mean Stream Length (RL)

Mean Stream Length for the channel is the characteristic size of a drainage network components and its contributing basin surface [41]. The mean stream Length for drainage basin calculated by dividing the total stream length of the order by the number of streams of segment in the order [39] (Table 1b). Generally, mean stream length of channel segments of a given order is greater than that of the next lower order, but less than the next higher order [7]; [39]. Mean stream length of AL-ARASAH sub-basins reveals that there is increasing trend with the increasing in stream order.

6. Stream Length Ratio (RL)

Stream length ratio (RL) was explained as the ratio of the mean length of one order to the next lower order of stream segment [18].

Table 1a, Linear Aspects of Alarasah Sub-basins

Sub-basin	Area (km^2)	Length (km)	Stream number in different orders						Orders total stream lengths(km)					
			1st	2nd	3rd	4th	5th	Total	1st	2nd	3rd	4th	5th	Total
Sub-basin1	560.69	36.107	378	78	20	5	1	482	287.56	133.2	72.8	26.4	29.18	549.22
Sub-basin2	254.81	26.75	206	44	7	1	0	258	163.08	64.34	32.3	27.4	0	287.12
Sub-basin3	246.72	34.40	151	22	3	1	0	177	92.630	48.88	20.7	26.9	0	189.13
Sub-basin4	176.68	27.75	127	17	3	1	0	148	72.558	34.57	32.2	2.41	0	141.66
Total Area	1238.9	56.97	862	161	33	8	1	1065	615.82	281	157	83.3	29.18	1167.1

Table 1b, Linear Aspects of Alarasah Sub-basins

Sub-basin	Mean Stream Length (km)						Stream Length ratio (RI)					Bifurcation ratios				
	1	2	3	4	5	Total	2/1	3/2	4/3	5/4	RI	Rb1	Rb2	Rb3	Rb4	Mean
Sub-basin1	0.76	1.70	3.64	5.29	29.18	40.59	0.46	0.5	0.36	1.10	0.61	4.84	3.90	4	5	4.436
Sub-basin2	0.79	1.46	4.60	27.4	-	34.33	0.39	0.5	0.85	-	0.43	4.68	6.28	7	-	5.988
Sub-basin3	0.61	2.22	6.88	26.9	-	36.68	0.52	0.4	1.30	-	0.56	6.86	7.33	3	-	5.731
Sub-basin4	0.57	2.03	10.7	2.41	-	15.72	0.47	0.9	0.07	-	0.37	7.47	5.66	3	-	5.376
Total Area	0.71	1.74	4.78	10.41	29.18	46.84	0.45	0.5	0.52	0.35	0.47	5.35	4.87	4.12	8	5.589

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Stream length declared that the mean stream length of each successive order of a basin tends to approximate a direct geometric series with stream length and increasing towards higher order of streams [41]. The stream length ratio tends to change indiscriminately on the basin and sub-basin levels [37]. The values of stream length ratio (RL) vary from (0.075) to (1.305) for sub-basins. It noticed that the RL between successive stream orders of the basin vary due to differences in slope and topographic conditions (Table1 b).

7. Bifurcation Ratio (Rb)

The ratio of number of streams of a given order (Nu) to the number of segments of the next higher order (Nu+1) was termed as the Bifurcation ratio 'Rb' (Schumn, 1956; Strahler, 1964). Wherever the values of bifurcation ratio are not same from one order to its next order, then these irregularities are attributed to the geological and lithological development of a drainage basin (Strahler, 1964). The lower values of the bifurcation ratio are characteristics of the basin which suffered less structural disturbances, whereas the higher values of the bifurcation ratio are the results of large variation in frequencies between successive orders and indicates to the mature topography on that basin [37]. [13] stated that the value of bifurcation ratio 'Rb' that ranging between 3 to 5 indicates that the geologic structure does not exercise a dominant influence on the drainage pattern. [38] demonstrated that bifurcation ratio 'Rb' shows only a small variation in different terrains on different environment except where powerful geological control dominates. In the study area mean bifurcation ratio 'Rb' varies from 4.436 to 5.988, the mean 'Rb' of the entire basin is 5.589 (Table 1b).

B. Areal Aspects

Area of the sub-basin was computed by converting the map of the area into polygon form with the help of ArcGIS software. The total area is found to be ($1238 km^2$), and the different areal aspects computed are explained below:

1. Drainage Density (Dd)

Drainage density (D) explains the closeness of spacing of the channels [17]; [12]; [29]. [18] introduced the drainage density as the stream length per unit area in a region, i.e., the cumulative length of all the streams in a drainage basin divided by the area of that basin. Several field studies demonstrates that the high drainage density is preferred in arid regions with sparse vegetation cover, as also in temperate and tropical regions which attributed to the frequent heavy rains [24]; [39]. [1]; [37] demonstrated that the there are several climatic factors simultaneously affect the drainage density in a complex way. Slope gradient and relative relief are the main morphological factors that effect on the drainage density [37]. [22]; [12] recognized that the significance of the drainage density as a factor determining the time of travel by water and stated that the drainage density values ranging between 0.55 and 2.09 km/km^2 correspond to the humid regions. [26]; [3] set that the low drainage density generally results in areas of less resistant rocks or permeable subsoil material, dense vegetation and low relief; while high drainage density results due to hard or impermeable subsurface material, sparse vegetation and mountainous relief, also low drainage density leads to coarse drainage texture. AL-ARASAH area possess low drainage density i.e. 0.942, while the four sub-basins are shown in (Table 2).

2. Stream Frequency (Fs)

"[17] introduced stream frequency as the ratio of total number of stream segments of all orders to the basin area". [28] found that the low values of stream frequency indicate a permeable sub-surface material and low relief, whereas higher values of stream frequency are refer to the resistant sub-surface material, sparse vegetation and high region relief. Stream frequency of the AL-ARASAH area is (0.859) per unit area, that's mean there are nearly one stream segment present per square kilometer of the area in the basin, while the stream frequency 'Fs' for the 4 sub-basins are shown in (Table 2). A close correlation of stream frequency with the drainage density values in all sub-basin (Figure 4); indicated that there are increase in stream frequency with respect to the increase in drainage density. It mainly depends upon the lithological status of the basin and reflects the texture of the drainage network.

3. Drainage Texture (T)

Drainage texture (T) depends upon a various of natural factors like climate, rainfall, vegetation, rocks and soil type, infiltration capacity, relief and stages of development [37]. It is one of the substantial drainage parameters in the morphometric analysis, this parameter is more prominent in an impermeable material compared to the permeable ones [7]. [18] explained the drainage texture as the total number of stream segments of all orders on the drainage basin, divided by perimeter of that basin. [34]; [12] have been classified drainage density into five different classes of drainage texture, these are: very coarse (< 2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). Soft or weak rocks unprotected by vegetation give a fine texture, while massive and resistant rocks produce coarse texture; likewise sparse vegetation of arid climate produce fine texture [37]. In simple terms drainage texture 'T' is the result of Dd and Fs. The drainage texture 'T' of the whole basin is (6.74) per unit area, whereas those of the 4 sub-basins are shown in (Table 2). The relations between drainage density, stream frequency and drainage texture are shown in (Figure 4).

4. Elongation Ratio (Re)

Elongation Ration 'Re' refers to the ratio between the diameter of the circle of the same area as the drainage basin, and the maximum length of that basin [12]. "According to [33], circular basin is more efficient in run-off discharge than the elongated basin". [39]; [12] stated that the value of elongation ratio varies from 0.6 to 1.0 related to high relief and steep ground slope.

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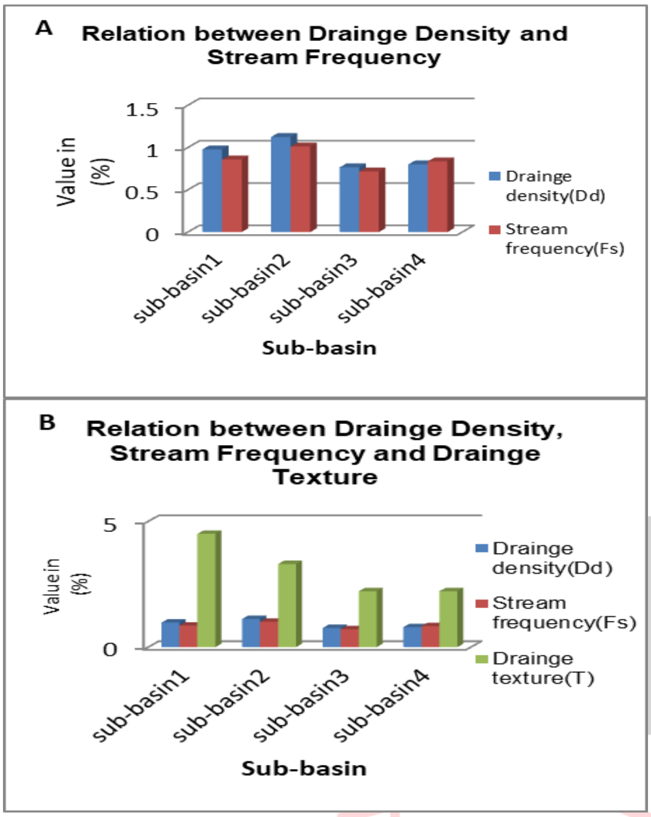

Figure 4, A) Relation between drainage density and stream frequency, B) Relation between drainage density, stream frequency and drainage texture

The values very close to 1.0 are typical for the regions of very low relief, whereas that ranging from 0.6 to 0.8 are associated with the high relief and steep ground slope [39] these values also can be grouped into three categories, namely as: circular greater than 0.9, oval 0.9-0.8, and less than 0.7 is less elongated [12]. For the study area elongation ratio 'Re' for the basin is (0.393) indicates that the basin is less elongated to elongated and low to moderate relief. In (Table 2) the different values of elongation ratio 'Re' for the sub-basins.

5. Circularity Ratio (Rc)

The circularity ratio was introduced as an aerial aspect, and is expressed as the ratio of the basin area (Au), to the area of a circle (Ac) 'having perimeter same as the basin' [37]. Circularity ratio affected by the length and frequency of the streams, geological structures, land use/land cover, relief, climate and slope of the river basin [12]. The values of circularity ratio are changes from basin to basin; when it close to 1 it indicates that the basin is circular in its shape; and as a result, it gets scope for uniform infiltration and takes long time to achieve excess water at the basin outlet, which likewise depends upon the common geology, slope and land cover [37]; [20]. The circularity ratio is more influenced by length, frequency and gradient of different orders in the drainage basin [9]. The circularity ratio 'Rc' for the whole area is (0.623), which indicates that the drainage basin is characterized by moderate to high relief, and the drainage system is structurally controlled (Table 2).

6. Form Factor (Ff)

Form factor for a drainage basin was defined as the ratio between the basin area to the square of the basin length [18]; [41]. [18] was introduced form factor to estimate the flow intensity for a basin of known area.

The values of form factor would be always less than 0.7854 (for a perfectly circular basin); smaller the values of form factor, more elongated will be the basin; the drainage basin with high form factors experienced larger peak flows of shorter duration, whereas, elongated sub-basin with low form factors experience the lower peak flow of longer duration (Bali R et al., 2011; Wilson et al., 2012). The form factor 'Ff' for the whole basin is (0.381); this low value indicates that the basin is elongated in shape, suggesting low peak flow for longer duration; while the (Ff) of 4 sub-basins are shown in (Table 2). The index of form factor 'Ff' shows the inverse relationship with the square of the axial length and a direct relationship with peck discharge [37].

C. Relief Aspects

Digital Elevation Model map Figures 5and 6 were used to calculate the relief aspects for the basin; these aspects are discussed on the following:

1. Relief

Relief refers to the maximum vertical distance between the lowest and the highest points on the basin area; also basin relief is an important factor in understanding the denudation characteristics of the drainage basin [23]; [4].

Table 2, Areal Aspects of Alarasah Sub-basins

Sub-basin	Drainage density (km^{-1})	Drainage Texture (km^{-1})	Stream Frequency (km^{-2})	Elongation ratio	Circularity ratio	Form factor
Sub-Basin1	0.979	4.506	0.859	0.417	0.615	0.172
Sub-Basin2	1.126	3.305	1.012	0.380	0.525	0.078
Sub-Basin3	0.766	2.224	0.717	0.290	0.489	0.075
Sub-Basin4	0.801	2.225	0.837	0.305	0.501	0.054
Total Area	0.942	6.740	0.859	0.393	0.623	0.381

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The maximum height on the study area is 1659 m and the lowest is 1039 m above mean sea level, (Figure 5 and 6). Therefore, the relative relief of AL-ARASAH area is (0.620) (Table 4).

2. Relief Ratio

Relief ratio was stated as the dimensionless height-length ratio equivalent to the tangent of the angle formed by two planes intersect at the mouth of the drainage basin, one representing the horizontal while the other passing through the highest point on that basin [31]; [40]. The relief ratio can be computed with the helping of mathematical equation: Relief ratio=H-h/L, where H is the highest elevation in the basin, h is the lowest elevation in the basin and L is the longest axis of the basin [32]; [19]. The highest values of relief ratio are distinctive of hilly regions, while the lowest values of relief ratio are distinctive of pediplains and valley [37]. Relief ratio of the total area is 0.0108, while those of the four sub-basins are presented in (Table 4).

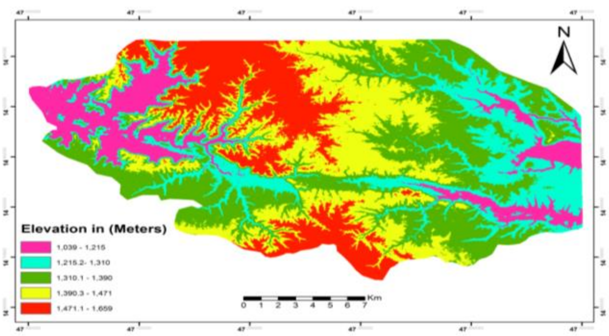

Figure 5 Digital Elevation Model Map of Study Area (DEM)

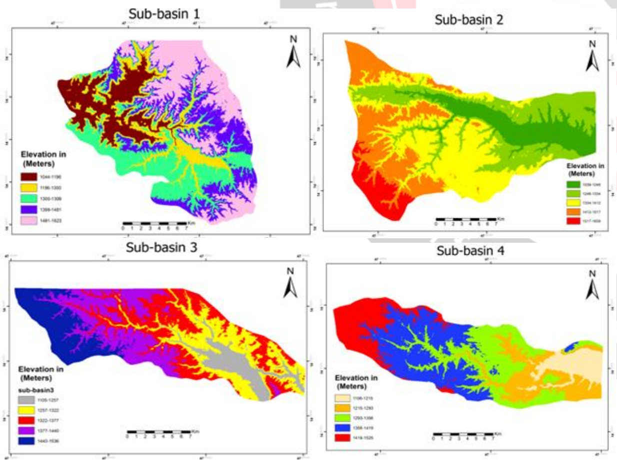

Figure 6 Digital Elevation Model Maps of Sub-basins

3. Slope

Slope analysis is a critical parameter in the geomorphic studies; the slope component thus is controlled by the climatomorphogenic processes in the region having the rock of varying resistance [23]. An understanding of slope dispersion is fundamental as a slope map provides data for planning, settlement, mechanization of agriculture, deforestation, planning of engineering structures, morpho-conservation practices etc [23]; [15]. Slope grid is identified as the maximum rate of change in value from each cell to its neighbors, using the methodology described in [11]. Aspect grid is recognized as "the down-slope bearing of the maximum rate of change in the value from each to its neighbors" [37]; [15]. For the study area the Slope map was prepared based on ASTER data DEM, which were converted into slope map and aspect grid with the helping of ARC GIS 10.1, Figures 7 and 8. In the study area, slope varies from 0° to 47° with a mean slope of 8.44° and Slope Standard Deviation 6.43°. A higher degree of slope is seen in the northwestern part of the area and southern part of the area (Figure 7).

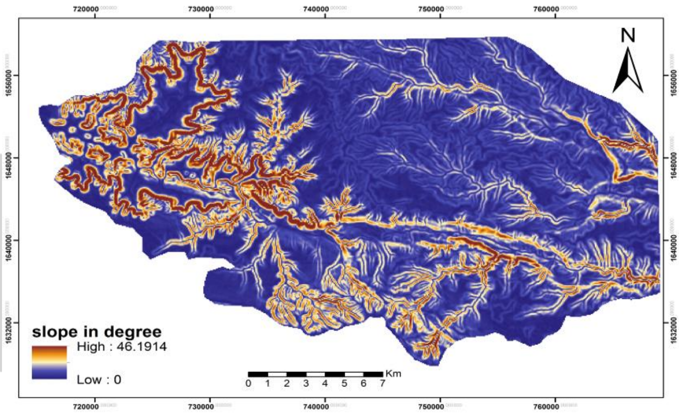

Figure 7 Slope Map of Study Area

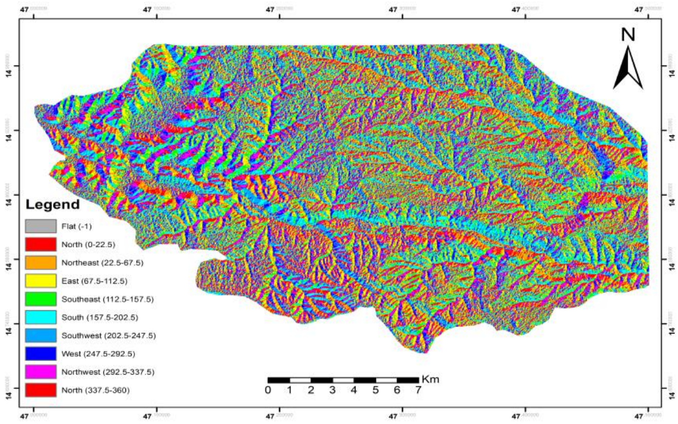

Figure 8 Aspect Grid Map of Study Area

4. Gradient Ratio

Gradient ratio refers to the channel slope from which the runoff volume could be raised [12]; [37]. For the study area, gradient ratio is 0.0097, while for the four sub-basins the values are shows in (Table 3). These values were calculated with the helping of the DEM.

5. Infiltration Number

Infiltration number is the result of the drainage density and the stream frequency of the basin [7]. The infiltration number of the area is (0.810) indicating high infiltration and low run-off, whereas those for the four sub-basins shown in (Table 5).

6. Length of overland flow (Lg)

Length of the overland flow was stated by [18] as the length of water over the ground before it gets concentrated into the definite stream channels.

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Table 3, Gradient Aspects of Alarasah Sub-basins

Sub-basin	Elevation in 'm'		Fall in height (a-b)(m)	Fall in height (a-b)(km)	Length of main stream 'L'(km)	Gradient ratio (a-b/L)
	Source 'a'	Mouth 'b'				
Sub-Basin1	1547	1059	488	0.488	36.107	0.0135
Sub-Basin2	1617	1160	457	0.457	26.75	0.0170
Sub-Basin3	1505	1167	338	0.338	34.4	0.0098
Sub-Basin4	1445	1118	372	0.372	27.75	0.0117
Total Area	1617	1059	558	0.558	56.99	0.0097

Table 4, Relief Aspects of Alarasah Sub-basins

Sub-basin	Elevation in 'm'		Relative relief (H-h)(m)	Relative relief (H-h)(km)	Longest axis 'L'(km)	Relief ratio (H-h/L)
	Max 'H'	Min 'h'				
Sub-Basin1	1623	1044	579	0.579	36.107	0.0160
Sub-Basin2	1655	1039	616	0.616	26.75	0.0230
Sub-Basin3	1563	1105	458	0.458	34.4	0.0133
Sub-Basin4	1525	1106	419	0.419	27.75	0.0150
Total Area	1659	1039	620	0.620	56.99	0.0108

[18], consider length of the overland flow as one of the most essential independent variables influencing hydrologic and physiographic development of drainage basins, average length of the overland flow is roughly half the average distance between stream channels and is therefore approximately equals to half of the reciprocal of drainage density [21]; [7]; [20]. The value of the length of overland flow of the basin is 0.530. The values of length of overland flow 'Lg' for the sub-basins in the study area are presented in the (Table 5).

7. Constant of Channel Maintenance (c)

The average of the drainage density was named as Constant of Channel Maintenance by [30]. It gives the quantity of square feet of the watershed surface area required to maintain one linear feet of channel [12]. Constant of channel maintenance has measurements of length and in this way increase in magnitude as the size of the landform units increases [7]. The constant of channel maintenance for the AL-ARASAH area is (1.06), while those for the 4 sub-basins are shown in (Table 5).

V. RESULTS AND DISCUSSION

AL-ARASAH sub-basins are represented by fifth and fourth order streams, the variety in the order and size of the tributary drainage basin are predominantly due to physiographic and structural situations of the region. The drainage pattern of the study area in nature is predominately dendritic in whole basin, and it is sub-parallel in northern part of sub-basin 1, centripetal appear in southern part of sub-basin 1 and western part of sub-basin 2 and 4, (Figure 2). Stream numbers of the drainage basin decrease with increasing in stream order (Figure 3), this support Horton's law. The total length of stream segments on the study area is decreases with the increase in stream order; first order in the whole basin has stream length of 615.82 kms, whereas fifth order has stream length of 29.185 kms.

Mean stream length of the AL-ARASAH area reveals an increasing trend with the increase in stream order, i.e. first order has mean stream length of 0.714 km, while the fifth order has mean stream length of 29.185 km. The stream length ratio of AL-ARASAH area ranges from 0.363-1.305. The stream length ratio (RL) for the streams of different orders reveals variation in the basin which may be attributed to variation in slope and topography. The bifurcation ratio of the basin range from 3 to 8, and the mean bifurcation ratio of the basin is 5.589, which suggests that the geological structures have moderate to strong control on the situation of drainage pattern in the area. A higher value of elongation ratio indicates that the area is having the infiltration capacity and low runoff. In the study area, the sub-basins having low elongation ratio values which show that they are vulnerable to high erosion and sedimentation load. The low drainage density (0.942 km/km^2) indicates high to moderate permeable materials, sparse vegetation cover and mountainous relief; also low stream frequency (0.859) in the basin, appears that the basin as a whole is good organized. The channel constant maintenance of the AL-ARASAH area is 1.06 which means 1.06 square meters of area is supporting each meter of channel length in the basin.

VI. CONCLUSIONS

Morphometric parameters are very useful to know about the drainage basin by which proper plan could be taken for natural resource management for development purpose. Remote Sensing data under GIS environment is very convenient tool for evaluation of drainage morphometry.

Based on the drainage order, AL-ARASAH area classified as 5th order in first sub-basin, and as 4th order on other three sub-basins. The drainage system of the study area shows dendritic to sub-dendritic drainage patterns with centripetal drainage pattern in some parts of the sub-basins, which is

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the result of occurring sinkholes and also show sub-parallel drainage pattern. Larger numbers of first order streams indicates that the area is uniform in lithology and the slope gradient is gentle. Alarasah sub-basins possess a low drainage density indicate high to moderately permeable material, and moderate relief, fine drainage texture, high mean bifurcation ratios (8) manifest a strong structural control on the drainage and control of drainage network is mainly declared by geomorphology and the lower value of the bifurcation ratio (3) indicates that the drainage basin is underlined by regular materials and the streams are generally branched systematically. Plotting of logarithm of number of stream vs. stream orders shows straight line and it means, in this case stream number supports Horton's law, i.e. stream number decrease with increase in stream order in this basin, with mountainous relief. This low drainage density indicates that the area is underlain by resistant permeable rocks, Circularity and Elongation ratios show that the basin has less elongated to elongated shape, this is due to the guiding effect of thrusting and faulting. Relief ratio indicates that the discharge capability of these sub-basins is high and the groundwater potential is meager. First order and second order streams are not helpful for constructing check dams in the study area because these streams are located on hilly terrain. Infiltration number indicates high infiltration and low run-off.

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Table 5, Results of Parameters for Morphometric analysis in Alarasah Sub-basins

Parameter	Sub-basin1	Sub-basin2	Sub-basin3	Sub-basin4
Total length of 1st order in (km)	287.566	163.066	92.630	72.558
Total length of 2nd order in (km)	133.186	64.346	48.888	34.564
Total length of 3rd order(km)	72.800	32.234	20.652	32.132
Total length of 4th order (km)	26.489	27.475	26.967	2.410
Total length of 5th order(km)	29.185	0.00	0.00	0.000
Total Stream length of all order	549.226	287.121	189.137	141.664
Total No. of 1st order	378	206	151	127
Total No. of 2nd order	078	044	022	017
Total No. of 3rd order	020	007	003	003
Total No. of 4th order	005	001	001	001
Total No. of 5th order	001	000	000	000
Total No. of all order	482	258	177	148
Mean stream length of 1st order	0.76	0.79	0.61	0.57
Mean stream length of 2nd order	1.70	1.46	2.22	2.03
Mean stream length of 3rd order	3.64	4.60	6.88	10.7
Mean stream length of 4th order	5.29	27.4	26.9	2.41
Mean stream length of 5th order	29.1	-	-	-
Stream length ratio of 1st order	0.463	0.394	0.527	0.476
Stream length ratio of 2nd order	0.546	0.501	0.422	0.929
Stream length ratio of 3rd order	0.363	0.852	1.305	0.075
Stream length ratio of 4th order	1.101	-	-	-
Bifurcation Ratio of 1st order	4.84	4.68	6.86	7.47
Bifurcation Ratio of 2nd order	3.90	6.28	7.33	5.66
Bifurcation Ratio of 3rd order	4.00	7.00	3.00	3.00
Bifurcation Ratio of 4th order	5.00	-	-	-
Mean bifurcation Ratio	4.43	5.989	5.73	5.37
Area of the basin in (km^2)	560.697	254.818	246.721	176.684
Perimeter of the basin in km	106.96	78.04	79.57	66.51
Maximum basin length in km	36.107	26.75	34.4	27.75
Drainage Density	0.979	1.126	0.766	0.801
Stream Frequency	0.859	1.012	0.717	0.837
Drainage Texture	4.506	3.305	2.224	2.225
Form factors	0.172	0.078	0.075	0.054
Circularity Ratio	0.615	0.525	0.489	0.501
Elongation Ratio	0.417	0.380	0.290	0.305
Length of overland flow	0.510	0.443	0.652	0.623
Constant channel Maintenance	1.020	0.887	1.304	1.247
Basin Shape	0.128	0.209	0.278	0.314
Infiltration number	0.842	1.140	0.549	0.671

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