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GIS-based morphometric analysis of the Dewana basin, Sulaimani, Kurdistan, Iraq.

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Abstract

An integrated remote sensing data are used in a detailed morphometric study of the Dewana drainage basin, Sulaimani Governorate of the northeastern part of Iraq. The basin is considered as a good example of a medium scale drainage basin of a mountainous terrain with variable geomorphological processes and landscapes. Major basin divides recognized by the homoclinal ridges of Baranan Mountain to the northeast and Sagerma Mountain to the southwest.

Satellite images as well as Digital Elevation Model with topographic, geologic, and structural maps were used in addition to field investigations to perform a GIS-based drainage network and morphometric analysis. An analysis which becomes important sources of the area with increasing agricultural development.

Arc GIS 9.3 was used for digitizing, measuring and drawing the spatial data of these analyses. Detailed morphometric analysis was applied to the Dewana basin, using variable geomorphological and hydrogeomorphological parameters, by calculating network aspects from two sets of topographic maps at scale of 1:20,000 and 1:50,000. Different sets of morphometric parameters were calculated such as: linear, relief and aerial parameters. Morphometric analysis results are discussed and correlated with each other and to standard values to evaluate fluvial-geomorphic evolution of the basin.

The study shows that the Dewana basin is of the 6th order drainage basin, with relatively, high values of drainage density and basin relief which implies that surface runoff is not rapidly removed from the basin, making it susceptible to gully erosion and landslides. Shape parameters of the basin indicate that it has elongated form, which reflects strong structural controls on the morphology of the basin. Drainage pattern is dominated by dendritic, sub-parallel to sub-trellis types which emphasize structural controls in addition to variable lithologic characters of the basin rocks.

Introduction

Dewana drainage basin as a part of Sulaimani area lacks detailed in geomorphological and morphometric studies. As the area faces rapid development and urban growth, similar kind of studies become important and necessary to establish a comprehensive background for any environmental, agricultural and even urban development's planning.

Geographic Information System (GIS) was used together with remote sensing to analyze basin network geometry and morphometry in an attempt to contribute to the evaluation and development of the basin water resources. In addition the links between the different measured morphometric parameters and the physical environmental conditions were discussed to enhance understanding of environmental evaluation of the basin area.

The linear, areal and relief aspects of the drainage basin are investigated using the methods of Horton (1932, 1945), Strahler (1957, 1964), Schumm (1956) and Miller (1953). Important morphometric parameters such as: stream order (Nu), bifurcation ratio (Rb), stream length (Lu), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), form factor ratio (Rf) were measured and discussed in term of their relation to geology and water resources of the basin.

Dewana basin is located in Sulaimani governorate, northeast Iraq.The basin area is located between $45^{o}14^{'}00^{''}$ E and $45\ ^{o}43^{'}00^{''}$ E longitudes, $35^{o}03^{'}00^{''}$ N and $35^{o}26^{'}00^{''}$ N latitudes, with a total area of 606 Km^2 (Fig. 1). It is situated in a mountainous terrain with rugged topography of low relief area with a high gradient. The basin is an intermountain valley of elongated shape. The Dewana perennial stream that flows between Sagrma and Baranan mountains and drain into Diyala river. It is surrounded from north by high mountain ridges, and from northestern part by Baranan Mountain with elevation, reaches 1400 meters, and from southwestern side by Sagrma and Gwllan Mountains with elevation exceeds 1800 meters. The central part of the study area includes the small Kalosh Mountain with elevation reaches 1400 meters. The highest points within the upper reaches of the basin is around 1050 meters and the lowest point of the basin at its confluent with Dyala river is at 421 meters.

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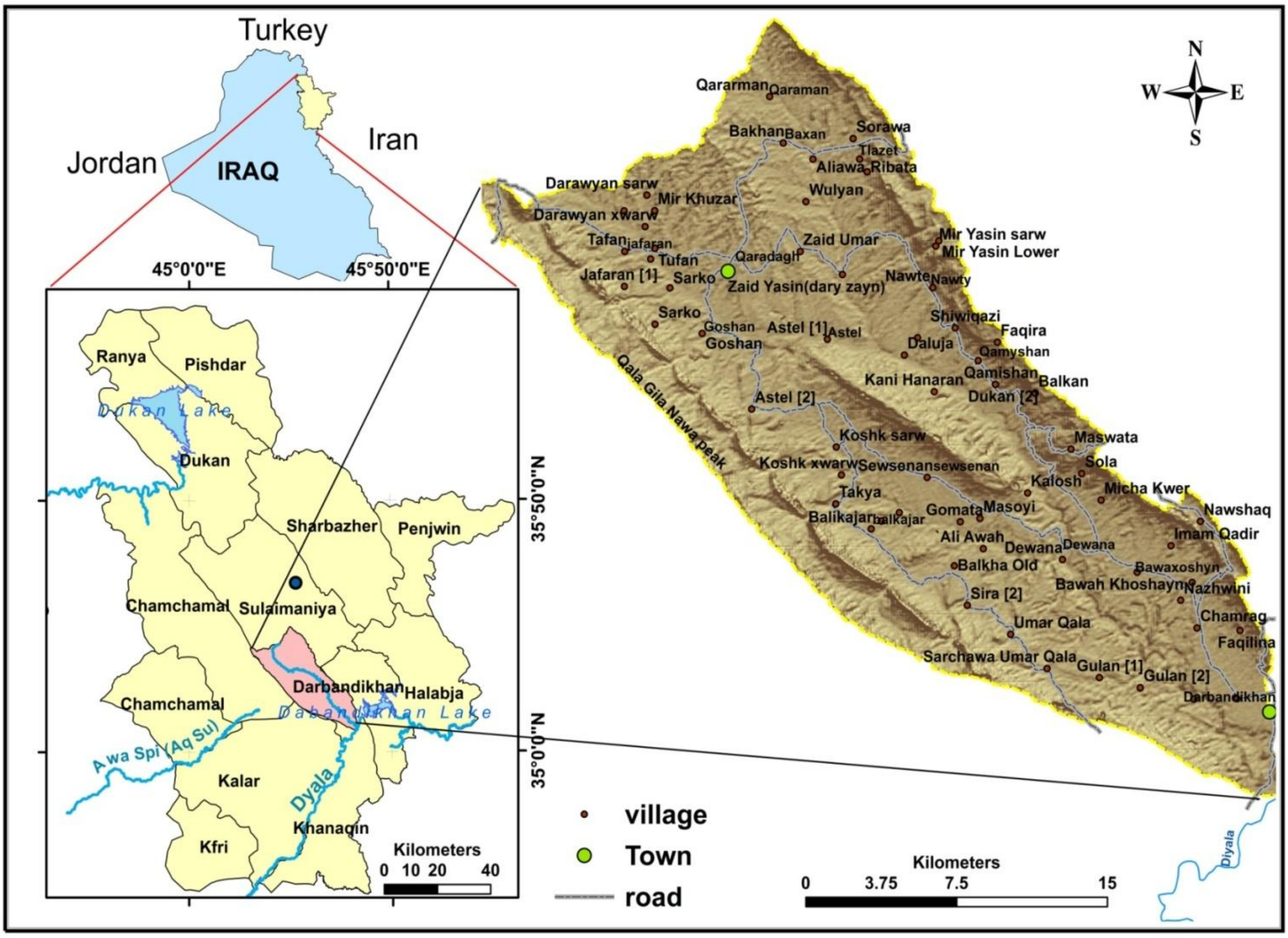


Figure _1: Location map and physiographic features of the study area

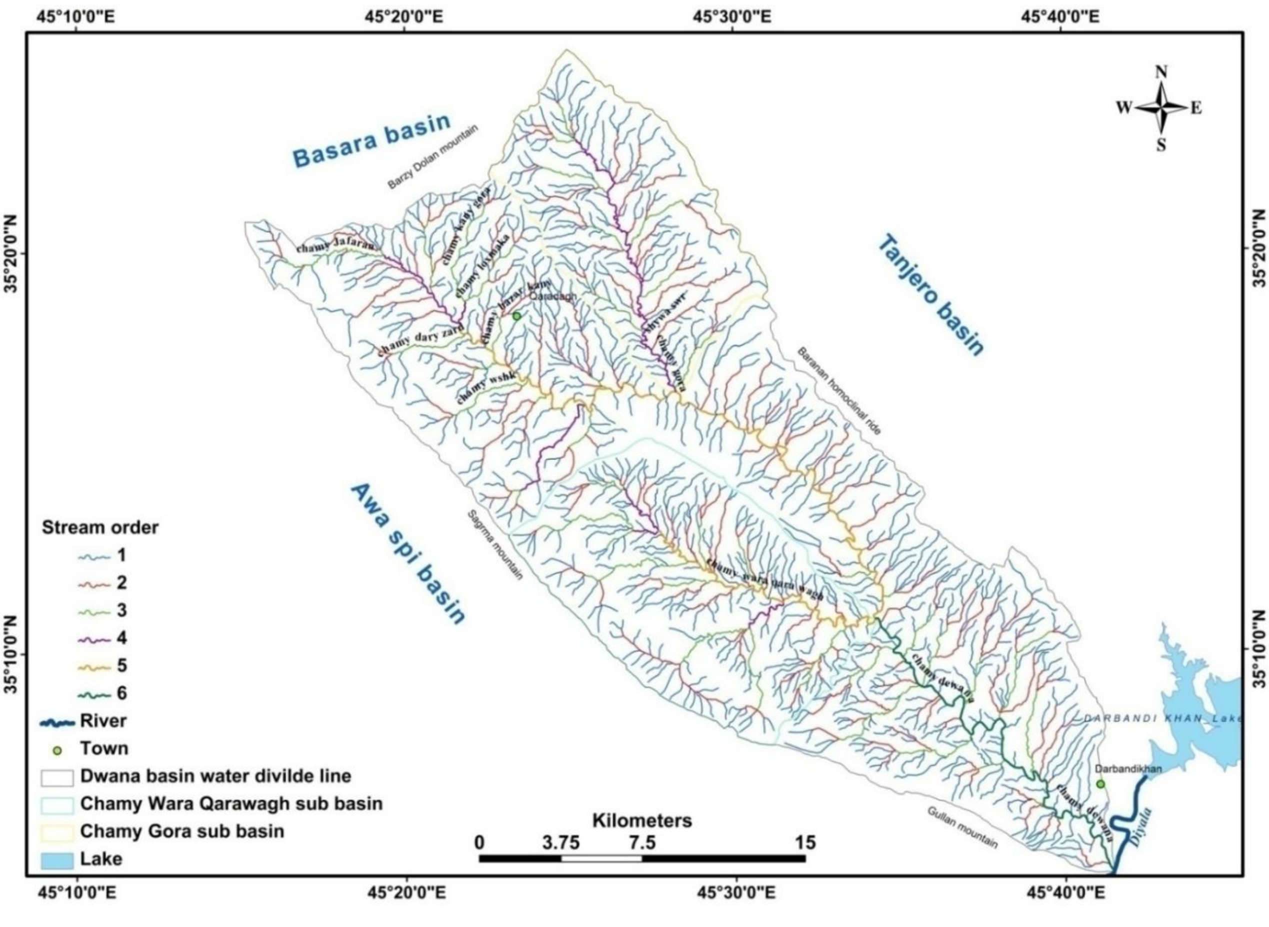
Methodology

Stream network in each area depends on topography, rock nature, structural position and tectonics of that area (Thornbury, 1954). The Dewana basin is delineated from surrounding basins based on location of water divide line by using 30m grid DEM and vector stream network following (Dillabaugh, 2002; Lin et al., 2005; Korkalainen et al., 2007; Mendas, 2010 ;Graves, 2001 and Djokic, 2008) by using Arc hydro tool

(Dartiguenave,2007) and Spatial Analyst extension following (Johnson, 2009) in Arc GIS 9.3. This model is calibrated by using topographic maps of different scales.

Band combination of Landsat TM image was created in ERDAS Imagine 8.2 software, for visual interpretation of drainage network and morphometric analysis The drainage network of the Dewana basin has been automatically extracted from 30m grid DEM according to Lin et al. (2005) and digitized from topographic map of scale 1:50000 (Fig. 2.). After digitizing stream networks according to Strahler system of ordering (Strahler, 1957). A variety of hydromorphometric parameters have been measured, such as drainage basin length, perimeter, and drainage area and presented in a GIS environmentas an integrated watershed analysis following (Dietz, 2000), (Yusuf et al., 2011). Two different map scales are chosen for experimental network analysis using two basic parts of the Dewana sub-basins: ChamyGawra sub-basin and ChamyWaraQarawagh sub-basin (Fig. 3 and 4) to attest the proper scale for the morphometric analysis. This is affect morphometric parameters such as bifurcation ratio, drainage density which has a great significance on geomorphological interpretations.

Figure-2:Dewana drainage basin network and sub-basins (Stream from digitizing 1:50000 scale topographic map).



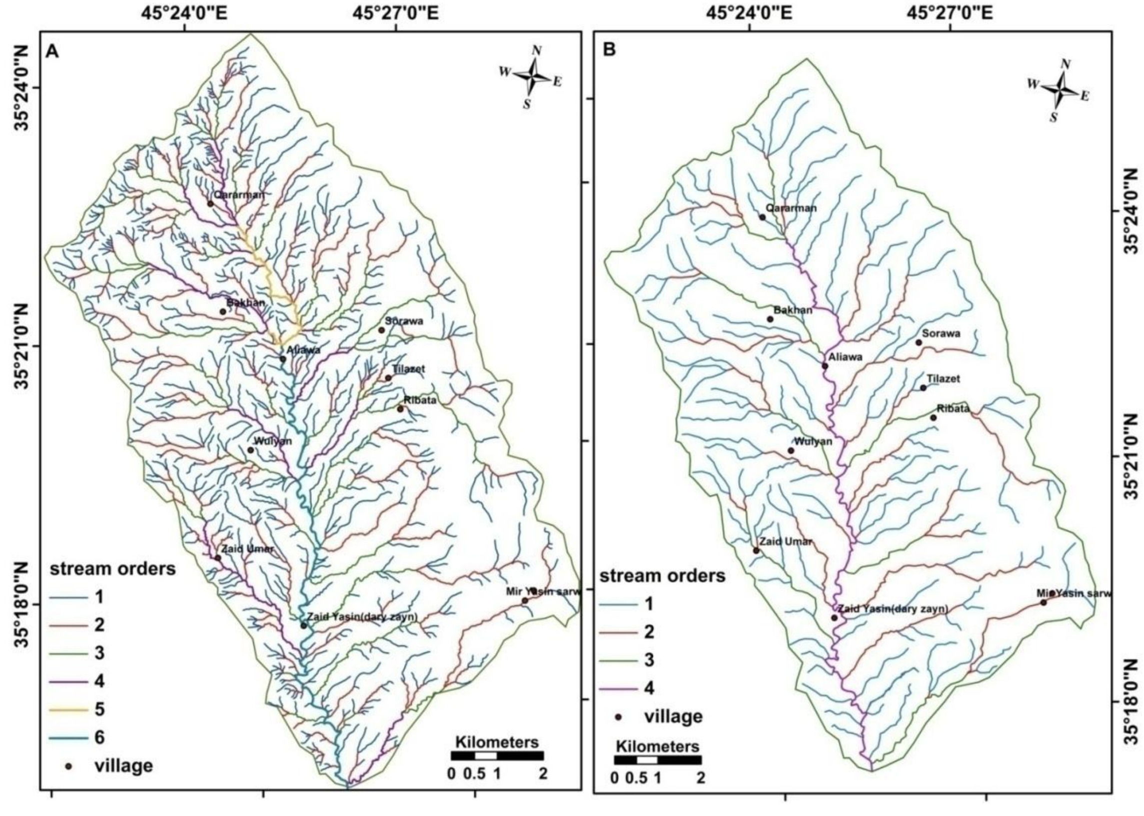


Figure-3:Chamy Gora networks prepared from different scales A. 1:20,000, B. 1:50,000.

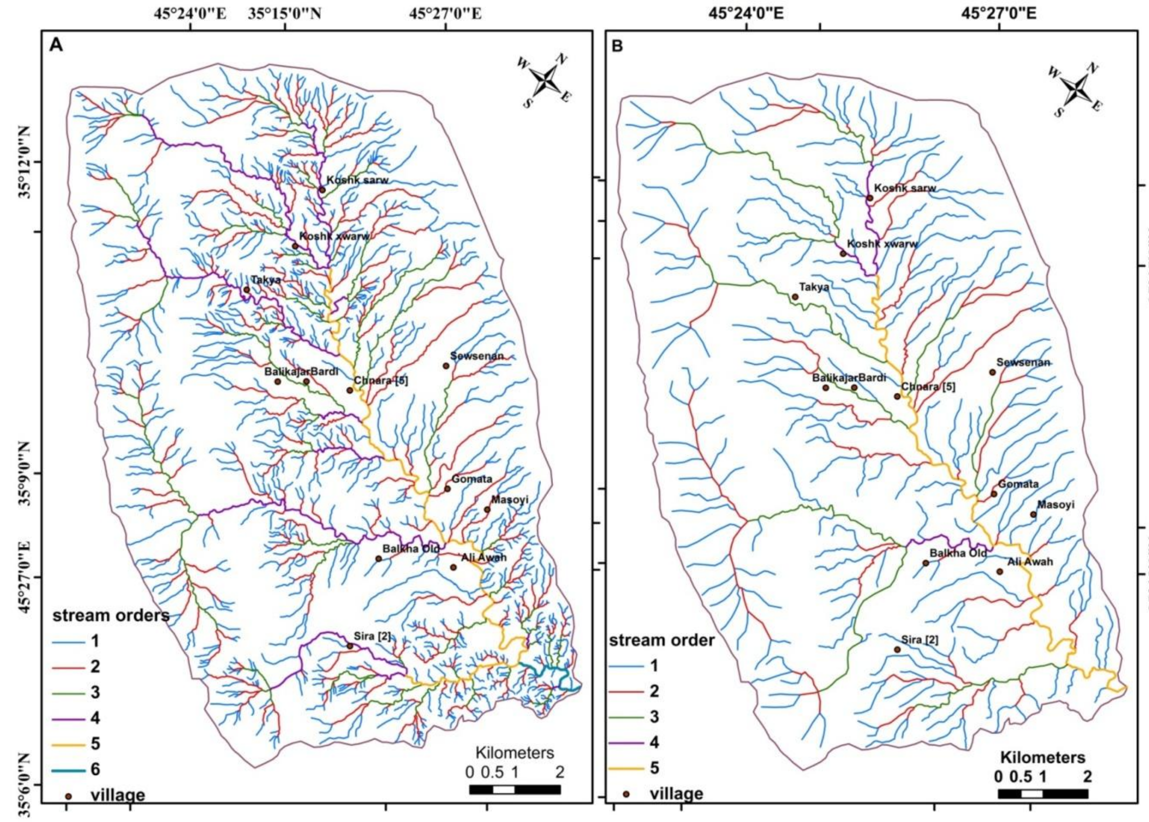


Figure-4: Chamy WaraQarawagh network prepared from different scale A. 1:20,000, B. 1:50,000.

Dewana Drainage Basin

Dewana basin includes the Dewana perennial stream and its main tributaries passing along the elongated basin, which covers an area of (606 km^2) from upper Darawyan village to Diyala River. Basin divides identified by several mountains and homoclinal ridges, which separate it from the surrounding basins. The Baranan range located to the NE of the basin that separates Dewana basin from Tanjero basin and Sagrma Mountain with Gullan Mountain separate it from Awa Spy basin. While to the north it is separated from Basara basin by Barzy Dolan Mountain, and from the south all channels drain into Diyala River (Fig. 2). Kalosh Mountain is located in the middle of the Dewana basin. The maximum altitude of the basin is 1878 m, above sea level at Qala Gila Nawa peak, while the minimum altitude is 365m, above sea level near Dewana stream before it reaches Diyala River. The central part of the study area includes the small Kalosh Mountain with elevation reaches 1400 meters.

The basin area is covered by several carbonate and clastic deposits of Tertiary sequence. Since carbonate rocks are dominant in the basin, a considerable amount of surface water recharges the aquifers. Dewana stream flows through tens of villages and farms, which makes it an important source for water need for agricultural project and encourage the planning of Dewana dam and reservoir project at downstream site.

Two major sub-basins were identified from Dewana basin which shows local variation in basin network. These two sub-basins were delineated depending on their major tributaries of Dewana stream and their different geomorphologic setting. Both are clearly divided into Chamy Gora and ChamyWaraQarawagh basins. These sub-basins are named based on the local name of streams. The coverage areas of these basins are 99 and 131 Km^2 respectively (Fig. 3 and 4). Topographic variation are extremely variable and depicted in (Fig. 5).

Cold winters, warm and dry summers are characteristic of the climate of the studied area. During summer, the studied area falls under the influence of Mediterranean anticyclones and sub-tropical high pressure belts moving from the south-west to north. In the winter, the region is invaded by Mediterranean cyclones moving east to north-east of the region. The autumn and spring are very short with mild temperatures (Aziz, 2001 in Stevanovic and Markovic, 2003). Because of this difference in seasons, the climate plays big aeolian geomorphological activity in the studied area.

Basin topography , relief, and the trends of mountain ridges control the quantity and distribution of precipitations, as it determine the direction of precipitation and stream flow direction. Also the slope direction in the area determines the nature and direction of flow water. Because the semi- arid climate of the area, the ground remains moist and fed by water for a long period of over eight months. It does not dry up in some place throughout the year. Permeable soil type (gravel, cracks and fractures as spreading in the region), act to reduce the surface runoff, as well as the natural vegetation or crops of the cultivated area, especially in dense vegetation cover (areas which the interwoven grass and polychaetes). All of these factors will help in recharging ground water storage by additional source renewed annually and make it the vital water source for basin agricultural needs.

Surface water can be classified in two types: intermittent and ephemeral streams. It could be seen that the surface water is basically intermittent for some parts and others are perennial. Dewana Stream is considered as perennial stream in which snow and rain represent its source of recharge.

The Dewana stream peak discharge is 500 m3/sec (Working group, 2009 b). These major tributaries of the Dewana basin are; ChamyDarawyan ,WadyKany Gora ,WadyLoghmaka, WadyJafaran in the northern part of basin, ChamyDaryZard ,ChamyWshk ,WadyHazrkany in the northwestern part of basin, Chamy Gora in northeastern parts of the basin, and ChamyWaraQarawax in the SW part of basin, ChamyDewana.

Aquifers in the study area are of unconfined types. The PilaSpi and Sinjar Formations have fissured and karstic porosities whereas, inter granular porosities are common in the aquifers of the Muqdadya and Bi Hassan, clastic formations (Lawa, 2003).

Around (44) springs are reported in the study area, Most of them are concentrated in foot slopes of the main ridges around the basin. Astel spring is an important discharge point, which is located at the NW plunge of Kalosh anticline with high discharge, from the limestone of the PilaSpi aquifer.

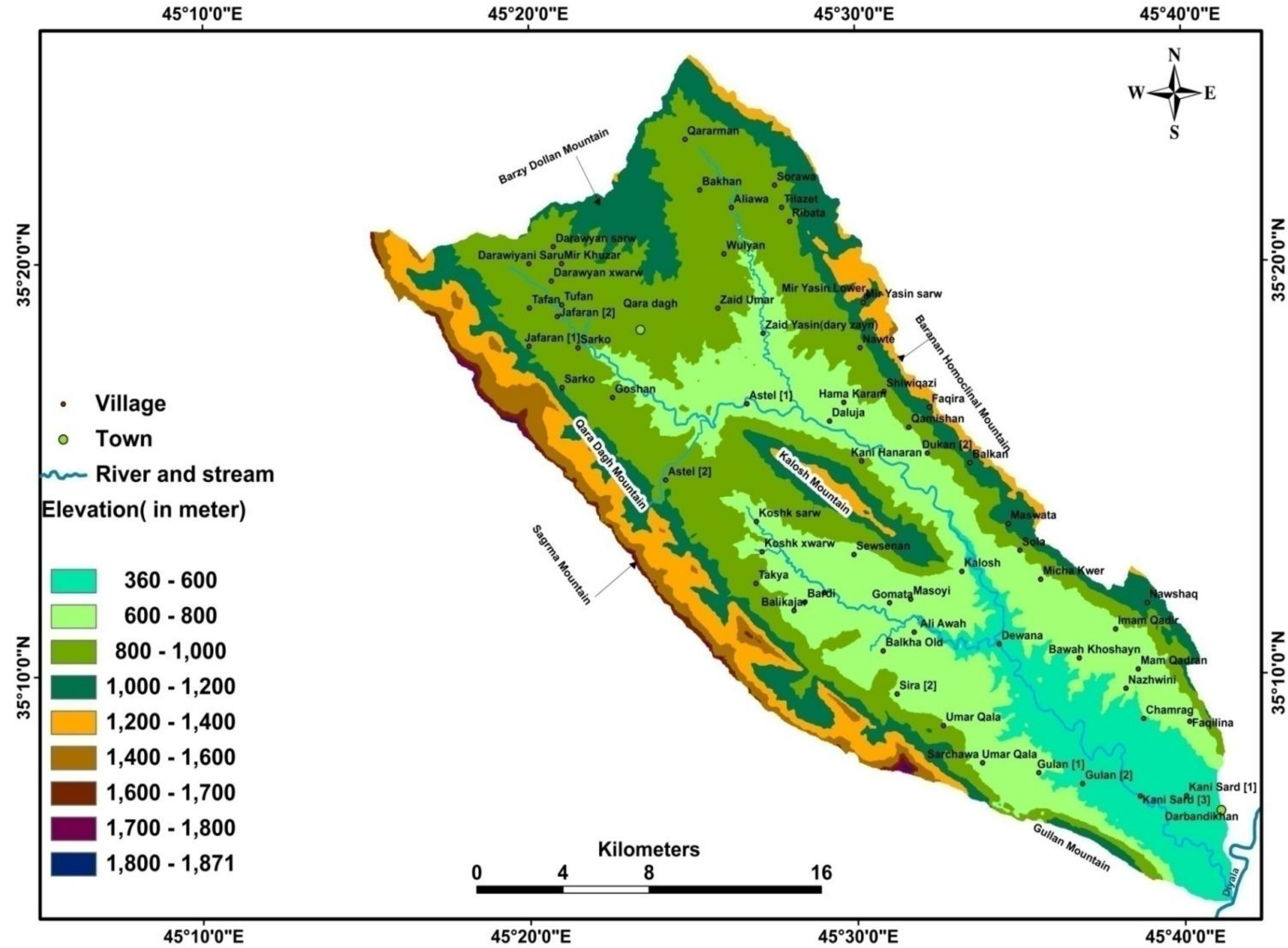


Figure-5: Digital elevation model of Dewana Basin.

Geologic Setting

The Dewana basin is located near the southwestern margin of the High Folded Zone of the Zagros Orogenic Belt of northern Iraq. It is represented by a low terrain of an inter-mountain elongated syncline that extends between Sagerma anticline and Baranan homoclinal ridge. It is developed as a synclinal valley shape bounded by two anticlines and has NW – SE trend. The syncline is generally symmetrical, with clear well shaped SE plunge.

Major structural trend follows the Zagros Fold-Thrust Belt of NW-SE regional orientation. The geology of the basin is controlled by two major structural features. The first known as Darbandikhan anticline which bound the basin at NE side, that diverges and splits in to the Baranan homocline ridge by Baranan back thrust fault (Ibrahim, 2009). The strata at this ridge dips between (20° – 40°). The second ridge known as Sagerma anticline which bounds the basin from SW. The eastern flank known as the QaraDagh Mountain and the western flank as the Sagerma Mountain. The only disturbing structural feature within the synclinebetween them is the local double plunging small anticline known as the Kalosh anticline. Its axis trending parallel to the major structural strike of the area. Its cap rock consists of hard resistant limestone of the PilaSpi Formation. Flanking the elevated ridges the soft claystone and evaporites of the Fatha Formation which is often form the lower slopes of these ridges. Other important structural features are transverse fault system, which dissect the main ridges and developing gorges of significant valleys.

The central area of the basin is dominated by the exposures of sub-horizontal clastic strata of alternating sandstone and claystone of the Injana Formation (Fig. 6). Younger strata of the Mukdadiyah, and Bi Hassan Formations are consists of coarse clastics of sandstones and conglomerates. These beds crops out in the central sector of the syncline which is located at the northwestern part of the basin. Patches and strips of Quaternary sediments are locally recognized especially at the downstream areas of the Dewana valley. These sediments are mainly of fluvial origin including channel deposits, flood plain deposits, and river terraces. Valley fills and slops foot deposits in addition to old alluvial fans are also reported from the basin (Al-Qayim and Ahmed, 2016).

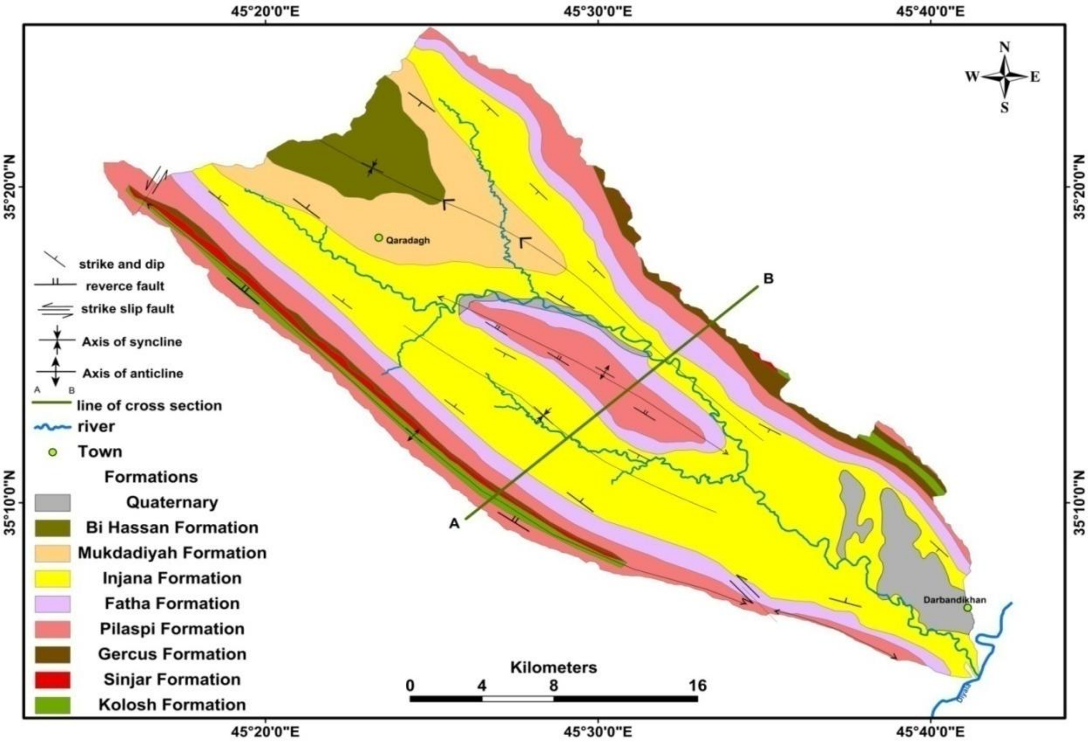


Figure-6: Geological map of Dewana basin (slightly modified after Ma'ala, 2008).

Network Analysis

The Dewana main channel starts from the Tavan village; in the northwestern part of the basin and joins the other main tributaries from northeastern part of the basin and northwestern part behind Kalosh Mountain.

The main branches that collect water from their catchment areas are: Chamy Darawyan, Wady Kany Gora, WadyLoghmaka, WadyJafaran, in the northern part of the basin, and Chamy DaryZard, ChamyWshk, Wady Hazrkany in the northwestern part of the basin, and Chamy Gora in the northeastern part of basin, and Chamy WaraQarawagh in the southwestern part of the basin (Fig. 2).

Network Relation to Lineaments

Drainage network was generated from Digital Elevation Model (DEM) by using the Arc-hydro tool within Arc GIS software. This map combined with visual interpretation of Land Sat TM image was created in ERDAS Imagine 8.2 software, for constructing lineament map of the basin. The resulting map (Fig. 7) depicts relationship between network structure and lineaments distribution. The map shows that first order lineaments which are associated with the main geological structure such as plunge of the anticline in the north, curved shape of Kalosh anticline in the middle part of basin, and homoclinal ridges of both (NE-SW) parts control the distribution of major channels. Second, third and fourth order streams seems to be associated with features related to transverse faults and different fracture systems of the basin area (Fig. 7).

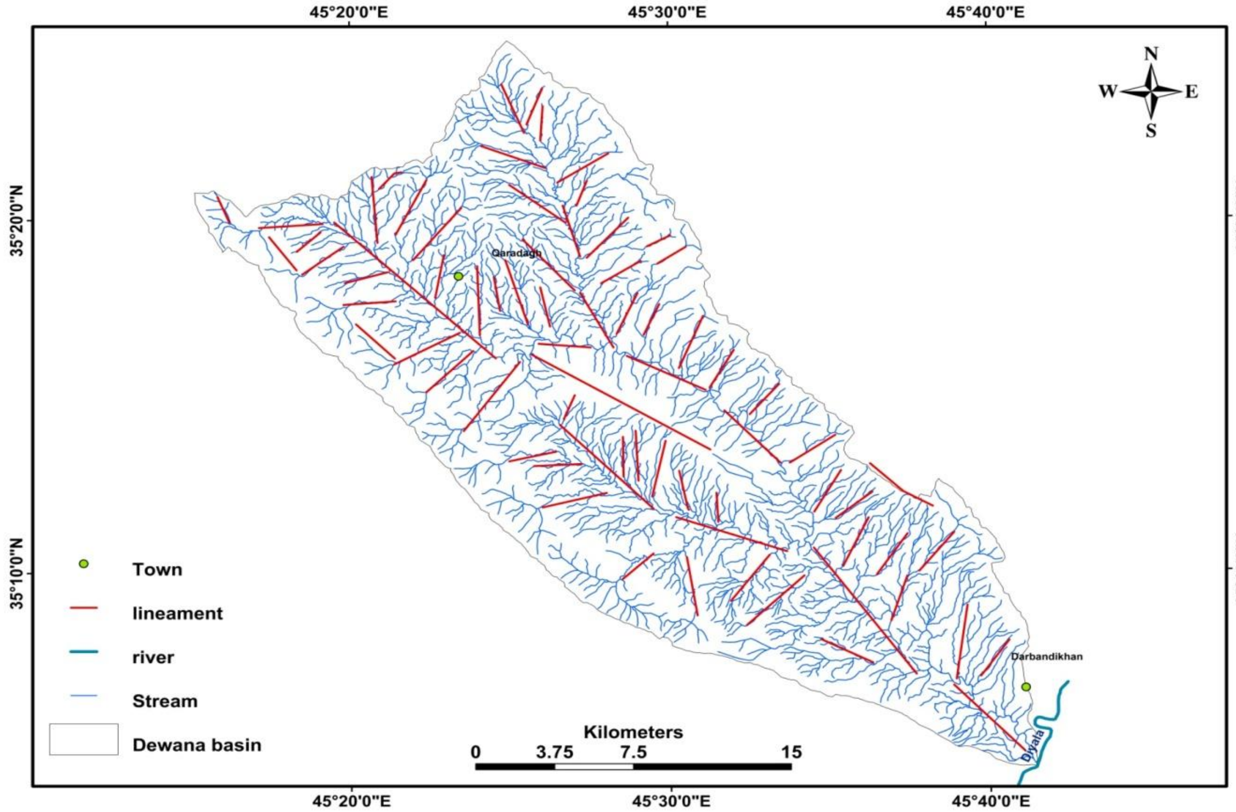


Figure-7: Lineament map of Dewana basin (stream network based on digitizing 1:50000 scale topographic map).

Network relation to Structure

The general flow direction of Dewana stream is parallel to the main direction of the regional structures in the area (from NW to SE). Therefore most of the major or higher order streams are of subsequent type, where the major flow lines coincide with the direction of formations boundary (strike line). The tributaries of lower orders are generally consequent, obsequent and insequent types as shown in Figure (8).

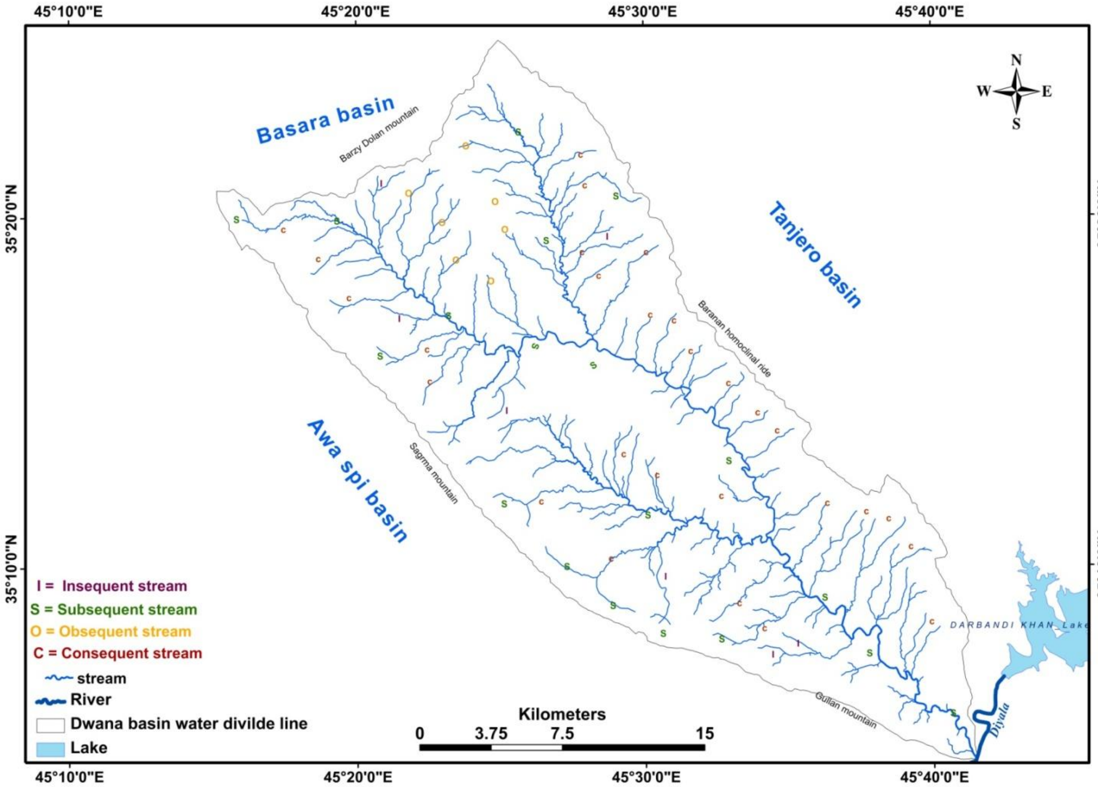


Figure 8. Drainage network and classification of streams and their relation to the bed attitude.

Drainage Pattern

The Drainage system shows several patterns in the studied area (Fig. 10), which in turn reflect mainly structural or lithologic controls of the underlying rocks (Al-Saud, 2009). From drainage pattern the type of landform and its morphometry can be indicated (Burberry et al., 2008).

Dendritic drainage pattern is the most common type in the studied basin and it is characterized by a tree like branching system in where the tributaries join the gently curving main stream at acute angle. The occurrence of this drainage system indicates homogeneous uniform soil and rock materials and it is typified by the landforms of soft sedimentary rocks (Way, 1973). It can be seen clearly in the northern and central part of the basin over areas covered by the subhorizontal strata of Bai Hassan Formation (Figs. 9.A and 10).

Sub-parallel drainage system is developed on a homogeneous, gently, uniformly sloping surfaces where the main collector indicate a fault or fractures. Tributary join the main stream approximately at same angle (Way, 1973). In the studied area this pattern can be seen clearly in the southwestern side of Baranan Range (Figs.9.B and 10).

Sub trellis pattern is represented by a modified dendritic form, with short and parallel tributaries occurring at right angles of both sides of a long major stream. This pattern indicates bed rock structure and/or tilted alternating hard and weak sedimentary rock in which the main channel flows parallel to the strike of the beds (Way, 1973). This pattern can be seen in Qara Dagh anticline, where the rocks are affected strongly by the structural deformation and fracturing (Fig.10).

Radial drainage pattern, which is a radiating network of almost diverging channels flowing away from a central elevated area, is not clearly identified. However, this pattern is partly recognized to be associated with the middle part of basin around the Kalosh Mountain.

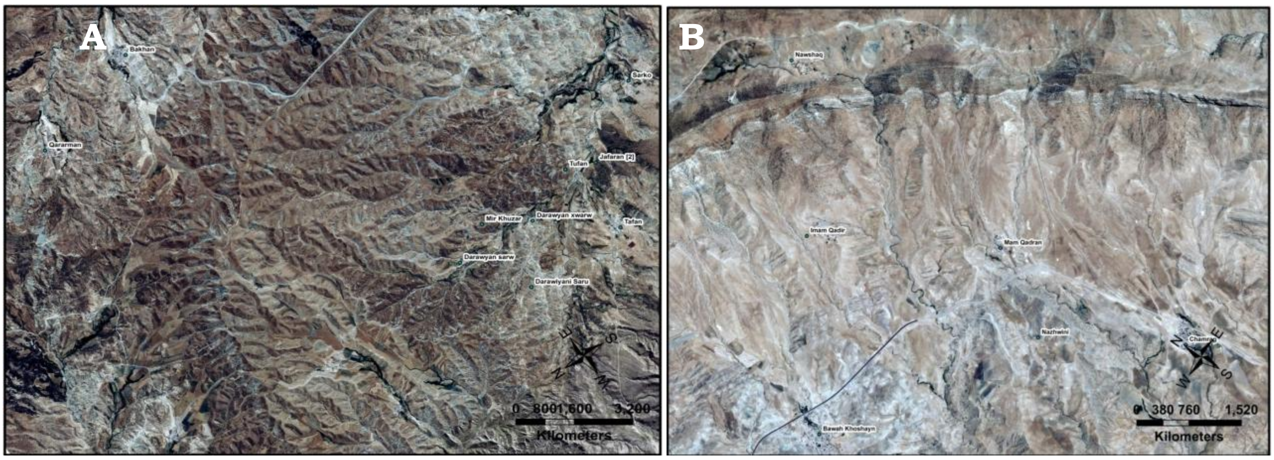


Figure-9: Satellite image showing (A) dendritic (B) Sub parallel drainage pattern in Dewana basin.

Morphometric Analysis

The drainage basin is the fundamental unit of the fluvial landscapes, which has been the focus of researches aimed at understanding the geometric characteristics of the master channel and its tributary network. This geometric character of a drainage basin is referred to as the basin morphometry (Ritter et al., 2002). A drainage basin is not a simple linear or areal (spatial) unit, but it is the dynamic system which is engaged in transfer of energy and sediments from one point to other in the whole course. The drainage basin acts as an open dynamic system (Howard, 1965). Direct measurement of the inputs and outputs in the drainage system are most complicated, but the nature of the measurement of various dimensional and dimensionless parameter are conspicuous.

The quantitative analysis of the drainage basin was initiated by Horton (1945) who first applied the quantitative techniques. Following Horton's rules, Schumm(1956), Strahler (1957) and others developed quantitative methods by adding new parameters and investigating regional variations in morphology within a wide range of geologic and climatic environments.

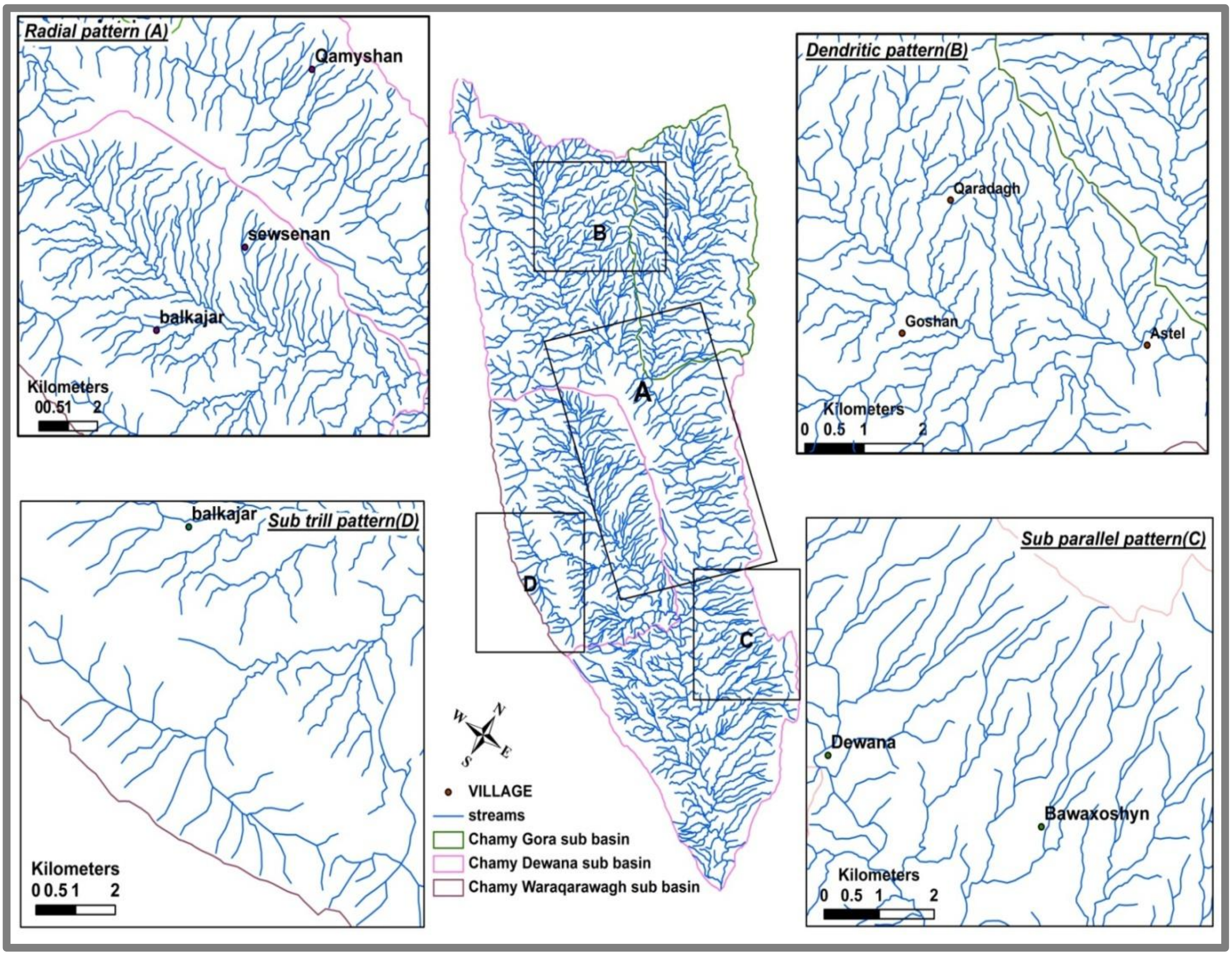


Figure-10: Major types of drainage patterns of Dewana basin.

In the present study morphometric analysis have been applied to describe the linear, areal, and relief characteristics of the watershed (Table 1) to infer the interrelation between various parameters of drainage basin and their impact on the evaluation and development of its water resources and basin geomorphic evolution.

The morphometric analysis of Dewana Basin has been carried out using the digitized stream network from mosaic of a set of topographic maps of 1:50,000 and 1:20,000 scales in addition to Quick-bird satellite image. The measurement of morphometric parameters which are presented in Table-1 and discussed in the following sections can be broadly classified into three categories: linear morphometric relationship, areal morphometric relationships, and relief morphometric relationships.

Linear Morphometric Relationship

The establishments of stream ordering led by Horton (1945) to realize that certain linear parameters of the basin are proportionately related to stream order and that these could be expressed as basic relationships of the drainage network composition (Ritter et al., 2002). Below are the measured morphometric parameters in this category and their interpretation.

Basin Length (L)

This is the straight line from the mouth of the basin to the farthest point on the basin perimeter (Schumm, 1956)(Table 3). In this study the farthest point on the ridge at the basin perimeter is determined visually and the calculation of the distance between this point and the mouth is done by measure tool in Arc GIS 9.3 environment. The Dewana basin length is 50 Km but for Chamy Gora and ChamyWara sub basins the lengths are equal to, 17 km and 18 Km, respectively (Table 2).

Stream Orders (u)

Horton (1945) and Schumm (1956) and others discussed the relationship between stream order and factors composing a drainage basin. The most important results are as follows:

As stream order increases, the number and the mean gradient of streams decrease in an inverse geometric ratio. As stream order increases, the mean length of streams and the mean area of drainage basin increase. The shortest and the steepest streams have the smallest drainage basins.

In the present work Strahler's (1975) stream ordering system is followed because it is convenient in computing various parameters and variables of the drainage basin. The channel segment is ranked according to Strahler's stream ordering system in two different scales using Arc GIS 9.3 software. The main Dewana basin represents a 6th order drainage basin according to 1:50,000 scale on digital topographic map, and 7th order according to 1:20,000 scale on paper topographic map. This difference in the number of order is due to the difference in scale of detailed mapping between the two surveys. The ordering of the network is presented with different color for each order. The sub basin ordering are: Chamy Gora and ChamyWara Qarawagh sub basin falls in 4th and 5th orders ,respectively on scale of 1:50,000 and 6th orders stream on scale 1:20,000 (Figs. 3 and 4, Table 2) .

Stream Number (Nu)

The count of stream channels in each order is known as "stream numbers". According to Horton (1945) law of stream numbers expresses the relation between the number of streams of a given order and the stream order in terms of an inverse geometric series.

A total of 1116 stream segments were identified, among them 181 and 264 are located in Chamy Gora and Chamy WaraQarawagh sub basins, respectively in scale 1:50,000 and 931 and 1316 in Chamy Gora and Chamy WaraQarawagh sub-basin, respectively in scale of 1:20,000 (Table 4, Figs. 3 and 4)

The differences in the stream number are expressing morphometic relation such as bifurcation ratio, length ratio, etc. In this study, 1:50,000 scales are used for all parameters because there is no much difference among results of different scales.

According to Horton's method, the relationship between the stream order and the stream number is represented graphically. The resulting relations indicated by a straight line which indicates a progressive decrease in the number of streams as there is progressive increase in the stream order. This relationship on the studied streams (Fig. 12) reveals that the streams in all sub basins and whole basin are generally linear and indicates that the basin gradually entering the maturarity stage (Ghareeb, 1983).

Table-1: Formulae, equations, and references adopted for the computation of the applied morphometric parameters for Dewana basin.

Sl.N	Mophrometric Parameters	Formula	Reference
		linear Morphometry	
1	Stream order(u)	Hierarchical rank	Strahler (1945)
2	Stream length (Lu)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm =∑Lu / Nu Where, Lsm = Mean stream length ∑ Lu = Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'	Strahler (1964)
4	Stream length ratio (RL)	RL = Lu / Lu – 1 Where, RL = Stream length ratio Lu = The total stream length of the order 'u' Lu – 1 = The total stream length of its next lower order	Horton (1945)
5	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of order 'u' Nu + 1 = Number of segments of the next higher	Schumm (1956)
6	Mean bifurcation ratio (Rbm)	Rbm = ∑Rb/Total No. of orders where, Rbm=Average of bifurcation ratios of all orders	Strahler (1957)
7	Length of over land flow(Lo)	Lo = 1/ 2 D Where, Lo = Length of overland flow D = Drainage density	Horton (1945)
8	Basin length (Lb)	length of the basin	Schumm(1956)
9	Basin Perimeter (p)	length of basin boundary	Smith (1950)
		Areal Morphometry	
10	Drainage Area (A)	Area of drainage basin	
11	Drainage Density (D)	D = Lu / A Where, D = Drainage density Lu = Total stream length of all orders A = Area of the basin (km^2)	Horton (1932)
12	Stream Frequency (Fs)	Fs = Nu / A Fs = Stream frequency Nu = Total no. of streams of all orders A = Area of the basin (km2)	Horton (1945)
13	Drainage texture (T)	T = Nu / P Where, T= Drainage texture Nu = Total no. of streams of all orders P = Perimeter (km)	Horton(1945)
14	Circularity Ratio (Rc)	$Rc = 4 * Pi * A / P^2$ Where, Rc = Circularity ratio Pi = 'Pi' value i.e., 3.14 A = Area of the basin (km2) P^2 = Square of the perimeter (km)	Miller (1953)
15	Elongation Ratio (Re)	$Re = 2 \sqrt{(A / Pi^2)} / Lb$ Where, Re = Elongation ratio A = Area of the basin (km2) Pi = 'Pi' value i.e., 3.14 Lb = Basin length	Schumm(1956)
16	Form Factor (Rf)	$Rf = A / Lb^2$ Where, A = Area of the basin (km2) Lb^2 = Square of basin length	Horton (1932)
		Relief Morphometry	
17	Basin relief (H)	Hmaxi-H mini where H=elevation (m)	Bhawan(1998)
18	Relief ratio (Rh)	Rh=H/Lb where H=Basin relief , Lb=Basin length	Schumm(1956)
19	Ruggedness number (Rn)	Rn=H*D where H=Basin relief, D=Drainage density	Verstappen(1983)

Table-2: Linear Morphometric parameters of Dewana Basin and sub-basins based on maps of scale 1:50,000.

Name of basin	Stream order (U)	Stream number (Nu)	Bifurcation ratio (Rb)	Mean bifurcation ratio (Rbm)	Stream length in Km(Lu)	Stream length ratio (RL)	Stream mean length (L¯u) in Km	Cumilative mean length	Length of over land flow in Km	Basin perimeter in Km(P)	Basin length (Lb) in Km
Chamy Gora	1	134	3.622	5.578	147.103		1.098	1.098	0.206	45	17
	2	37	4.111		51.526	0.350	1.393	2.490			
	3	9	9.000		23.301	0.452	2.789	5.279			
	4	1			18.186	0.780	18.186	23.465			
	5										
	Total	181			240.115						
Chamy Wara Qarawagh	1	198	3.960	3.782	207.104		1.046	1.046	0.204	48	18
	2	50	4.167		56.312	0.272	1.126	2.172			
	3	12	4.000		36.688	0.652	3.057	5.230			
	4	3	3.000		7.310	0.199	2.437	7.666			
	5	1			16.672	2.281	16.672	24.339			
	Total	264			324.087						
Whole Dewana basin	1	841	3.912	4.171	902.261		1.072	1.072	0.266	132	50
	2	215	4.300		289.205	0.321	1.345	2.417			
	3	50	7.143		134.372	0.465	2.687	5.104			
	4	7	3.500		38.215	0.284	5.459	10.563			
	5	2	2.000		52.515	1.374	26.257	36.821			
	6	1			24.238	0.462	24.238	61.059			
	Total	1116			1440.806						

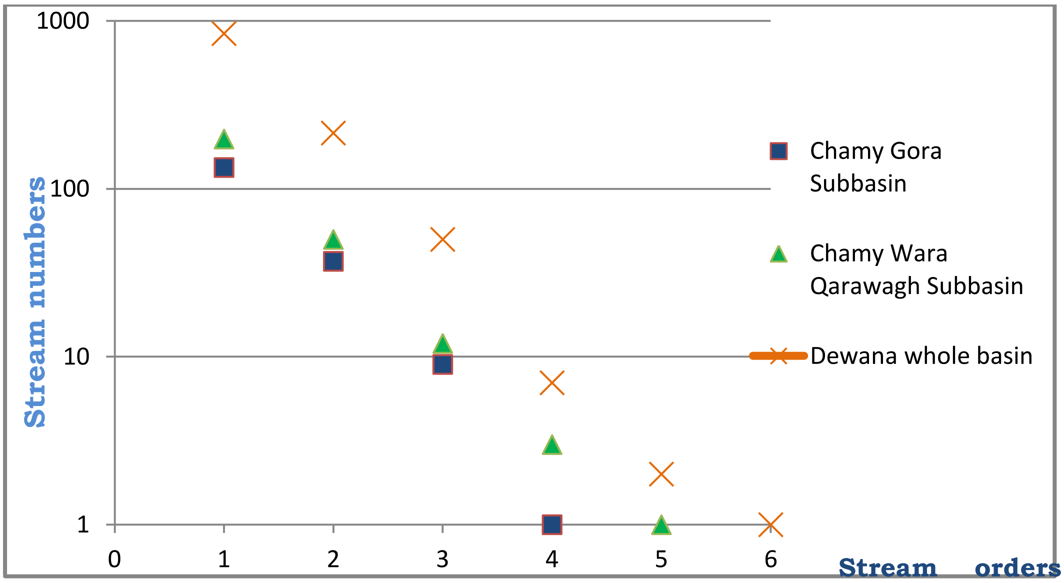


Figure -12: Relationships between stream order and stream numbers of the studied basin and the two sub-basins.

Bifurcation Ratio (Rb)

The term bifurcation ratio is used to express the “ratio of number of streams of any given order to the number of streams in next higher order” (Schumm, 1956,Strahler,1957) had demonstrated that the bifurcation ratio shows a small range of variation for different regions or for different environments. The irregularities of the bifurcation ratio from one order to the next order are mainly dependent upon the lithological and geological development of the drainage basin (Rudraiah et al., 2008). Bifurcation ratio characteristically that ranges between 3.0 and 5.0, and value of 2 as minimum for basin in which the geologic structures do not distort the drainage pattern (Christopher et al., 2010). Bifurcation ratio that ranges between 3 and 4 indicate universal range of maturally dissected drainage basins (Subramanyan,1974). High Rb is due to the effect of local geological structure , but the shape of basin also has important effect, Rb tends to be high value when the shape is elongated (Verstappen,1983).

In the present work the bifurcation ratios and mean bifurcation ratios are calculated for all studied sub basins (Table 2). The bifurcation ratio of Chamy Wara Qarawagh sub basin lie between 3 and 4.1, but the exception are in in Chamy Gora sub basin which lie between 3.62 and 9, the bifurcation ratio for hole dewana basin ranges between 2 to 7.1.
These high values in the bifurcation ratio in 3/4 orders and more may reflect strong tectonic control (neo-tectonics) on the basin especially in the northern part (Fig. 2)

Stream Length (L_u)

The stream length is one of the most significant hydrological features of the basin; as it reveals surface runoff characteristic of the areas. Generally the total length of stream segments is maximum in first order streams and decreases as stream order increases (Christopher et al., 2010).

The total lengths of streams of each order are measured by a measuring tool in Arc GIS 9.3 environments. The high L_u value is often due to structural complexity, high relief and impermeable bedrock (Reddy et al., 2004).

From Table (2) it can be noticed that the total lengths of streams (L_u) for the selected basin range between 240.115 to 1440.806 km. If this considered in relation with the basin area, will indicates an increase in stream length with the increasing of basin area, because the action of erosin and drainage growing. It could be noted that the 1st order segment is shorter than the higher order, because lower order stream flow over slopping area and as stream order increase, slope become gentler and the streams almost lay on plain surface. In Table (2) it can be seen that the total length of 4 th order streams in the basins is much less than the 5th orders. The reason is that due to accelerated headward erosion along zones of structural weakness and the higher order stream collect water from lower orders stream all around the basin which extends their length over most of the basin so the total length of higher order streams is more than that of normal.

Mean Stream Length ($L\text{-}_u$)

Mean length of a stream segment of order u is a dimensional property revealing the characteristic size of components of drainage network and its contributing basin surface. To obtain the mean length L-u of order u, the total cumulative length of the ‘u’ order stream is divided by the number of segments Nu of that order (Chow,1964). It is observed that mean stream length increases with the increase in the stream order (Table 2). The mean stream length is plotted on log scale versus stream orders on ordinary scale (Fig. 13). The plot shows that the increasing trend in average length with increasing order following Horton’s law of stream length, which states that “The average length of streams of different orders in a drainage basin tends closely to approximate a direct geometric series in which the first term is the average length of streams of the first order".

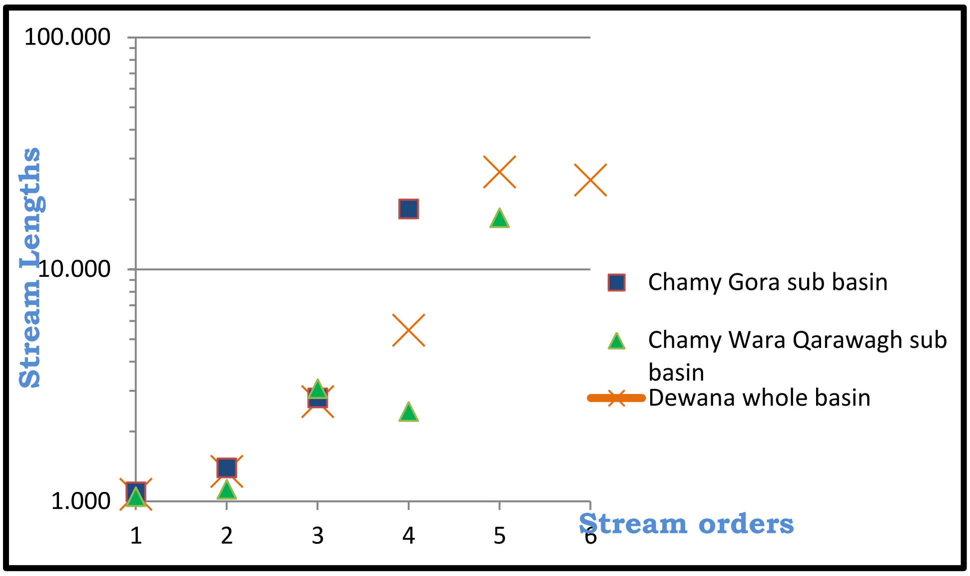


Figure-13: Relationship between mean stream length and stream order of the studied basin and the two sub-basins

Length of Overland Flow (Lo)

It is the length of flow of water over the ground before it becomes concentrated into definite stream channels (Table 1). Length of over land flow is approximately equal to half the reciprocal of the drainage density (Horton, 1945). Overland flow is sustained by a relatively thin layer of surface detention, these disappear quickly often in few minutes-through absorption by soil or infiltration after rain ends.This factor basically relates inversely to the average slope of channel and is quite synonymous with the length of the sheet flow to the large degree. From Table (2), it could be noticed that the length of overland flow for Chamy Gora and ChamyWaraQarawagh sub basins are 0.206 and 0.204 km, respectively, but for the whole Dewana basin is 0.266 km which means that the rain water has to run over these distances before getting concentrated in stream channels.

Stream Length Ratio (RL)

This is the ratio of length Lu of segments of order u to length of segments of the next lower order Lu-1 (Table-1). Horton (1945) stipulated that RL tend to be constant throughout the successive orders of a watershed. Its value is normally between 1.5 and 3.5, in natural drainage networks (Bhawan, 1998**).** From Table (2), it could be noticed that most of the length ratio values are almost less than 1, except in some orders, this is due to variable lithological and topographic control on the different parts of the basin.

Basin Perimeter (P)

Basin perimeter is the total length of the basin boundary to length measured along the divide between basins. It was emphasized by Smith (1950) as an indicator of basin size and shape, the perimeter of whole basin. The basin perimeter of Dewana basin, Chamy Gora and ChamyWaraQarawagh sub basins are equal to 132, 45 and 48 Km, respectively (Table 2).

Areal Morphometric Relationship

Drainage Area (A)

Drainage area is defined as the collecting area from which water would go to a stream or river. The boundary of the area is determined by ridge separating water flowing in opposite directions (Bhawan, 1998).With increasing the basin size the peak flow decreases and hydrograph tends to be smoother if compare to smaller size (Verstappen, 1983).

In this study, the catchment area has been delineated on 1:50,000 topographic map with field checks and verified by DEM analysis. The areas of basins are measured by Arc GIS measuring tool. The area of the whole Dewan basin, Chamy Gora and ChamyWaraQarawagh sub basins are 606, 99 and 132 km^2 respectively (Table 3).

Drainage Density (D)

The drainage density is the average length of stream within the basin per unit area (Horton, 1945 in Table 3). Beside rainfall and relief in determining drainage density there are important controlling factors to be considered. These are; infiltration – capacity of the soil or terrain, and the initial resistance of the terrain to erosion which means rock type and other climatic conditions.Horton (1932) suggested that the low drainage density indicates that the basin is highly permeable subsoil with thick vegetative cover and where relief is low. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Heavy rain fall, annual and seasonal are largely responsible for high value of D (Aqrawi, 1990). Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahler, 1964 and Reddy et al., 2004).Low drainage density is associated with run-off processes dominated by infiltration and subsurface flow (Christopher et al, 2010).

It has been observed from drainage density measurements made over a wide range of rock types that the drainage densities of whole Dewana basin, Chamy Gora and ChamyWaraQarawagh sub basins are 2.378, 2.425 and 2.455 1/km respectively (Table 3).

Stream Frequency (Fs)

The stream frequency has been defined as the number of streams per unit area (Horton, 1945 in Table 1). Stream frequency also is an indication of dissection that depends on climate and rock type.

The values of stream frequencies in the studied basin are 1.842/km^2, 1.828/km^2 and 2 /km^2 for the whole Dewana basin, Chamy Gora and Chamy WaraQarawagh sub basins, respectively (Table 3).

Table- 3:Areal morphometric parameter of Dewana basin and sub-basins based on maps of scale 1:50,000.

Name of basin	Daringe area (A) in km2	Total stream length in km	Drainge Density (D) km/km2	Stream Frequency (Fs)	Basin length (Lb) in Km	Drainage texture (T)	Circularity ratio (Rc)	Elongation ratio (Re)	Form factor (RF)
Chamy Gora	99	240.115	2.425	1.828	17	4.022	0.614	0.373	0.343
Chamy wara qarawa	132	324.087	2.455	2.000	18	5.500	0.720	0.405	0.407
Whole Dewana basin	606	1440.806	2.378	1.842	50	8.455	0.437	0.314	0.242

Drainage Texture (T)

Drainage texture is the total number of stream segments of all orders per perimeter of that area (Horton, 1945 in Table 3). It is one of the important concepts of geomorphology, which indicate the relative spacing between drainage lines. According to Horton, (1945), infiltration capacity is a single important factor, which influences drainage texture and is considered drainage texture, which includes drainage density and stream frequency.
According Horton's scale for texture:

Texture ratio Scale

4 and below	Coarse
4 to 10	Intermediate
10 to 49	Fine
50 and above	Ultra fine.

The drainage textures of stream network are evaluated in the study area, and was found that all basins have the intermediate texture ratio, which are 4.022 and 5.5 /km for Chamy Gora and Chamy Wara Qarawagh sub- basins respectively, and 8.455 /km for the whole Dewana basin (Table 3). This medium texture indicates generally low runoff rate due to low precipitation rate over most of the variable lithologic units.

Circularity Ratio (Rc)

The circularity ratio is the ratio of the area of a drainage basin to the area of a circle having the same perimeter as a drainage basin (Miller, 1953 in Bhawan, 1998). It is a dimensionless index to indicate the form of outline of drainage basins (Strahler, 1964). The circulatory ratio (Rc) is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin (Vijith and Satheesh, 2006).

Elongated basin has smoother curve of hydrograph because greater time lag for the water from the upper catchment to reach the outlet. In circular basin water in upper and middle of catchment reach the outlet in less time and causes higher discharge during short period (Verstappen, 1983). The basin's circularity ratio which range between (0.4 and 0.5) often indicates strongly elongated over highly permeable homogenous geologic materials (Miller, 1953 in Bhawan, 1998).

Dewana basin has value of Rc equal (0.437) indicating that it tends to be elongated in shape. Whereas Chamy Gora and Chamy waraQarawagh sub basin have Rc of 0.614 and 0.720 respectively suggesting that they have sub circular shape (Table 3). Circularity bears an inverse relation to basin area (Yusuf et al., 2011), but the correlations is not followed in the present study and hence indicates drainage system of Dewana basin is generally structurally controlled which leads flow to go in an elongated pattern.

Elongation Ratio (Re)

Schuum, (1956) used an elongation ratio and defined to indicate the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Table 3). It is a very significant index in the analysis of basin shape, which helps give an idea about the hydrological character of a drainage basin. Values near to 1.0 are the characteristics of near circular basin in a region of very low relief, while values range between 0.6 - 0.8 usually occur in elongated basin over areas of high relief and steep ground slope (Chow, 1964) (Nageswara et al., 2010). Values are further categorized as circular (>0.9), oval (0.9-0.8) and less elongated (<0.7) (Yusuf et al., 2011).

The Re value for Dewana basin is measured as 0.314 but for Chamy Gora and ChamyWara Qarawagh sub basins are 0.373 and 0.405 respectively (Table 3). This generally indicates an elongated basin with conceivably high relief and steep ground slope basin. However this is not exactly the case because the elongated shape in our example is strongly influenced by the elongated bounding structural ridges of the basin (Fig. 5).

Form Factor (RF)

The form factor is defined as the" ratio of the area of the basin and square of basin length" (Horton, 1932 in Rudraiah et al., 2008) (Table 3). It means comparison of basin shape to the triangle shape. The amount of form factor decreases if the shape of basin is wide in upstream of the basin and narrow in the outlet. This shape factor may be interpreted in reference to basin flooding potential in a comparative analysis as low values of form factors are associated with fern shaped basin with large time of concentration and long lag time. In other words, basins with low Rf usually have less side flow for shorter duration and high main flow for longer duration and vice versa (Reddy et al., 2004).

In the study area, the form factor of Dewana basin is equal to 0.242 but for Chamy Gora, ChamyWaraQarawagh sub basin is 0.343 and 0.407, respectively (Table 3). This support the near triangle shape of the Dewana basin. Such shapes depict delayed hydrograph peaks; however elongated basins are unlikely to realize uniform rainfall over the entire basin at same time. Flood flows of such elongated basins are easier to manage than of the circular basin (Christopher et al., 2010).

Relief Morphometric Relationship

A third group of parameters shown in Table (4) indicates the vertical dimension of drainage basin characters. These are:

Basin Relief (H)

Basin relief is the elevation difference between reference points defined in any one of the several ways. Total relief within a region of given boundary is simply the elevation difference between the highest and lowest points (Bhawan, 1998) (Table 1). The high basin relief value indicates high water flow rate, low infiltration, and high runoff conditions (Reddy et al., 2004).

Dewana basin has relief difference of 1506 m, which is considered relatively high as compared to Chamy Gora and Chamy Wara Qarawagh sub basins which have H value of 685 and 1280 m, respectivly (Table 4). Steep slopes surface generally have high surface run-off values and low infiltaration rates, and high peak discharge, which lead to sheet, rill and gully erosion (Verstappen,1983). These features are common to the whole Dewana basin

Relief Ratio (Rh)

The relief ratio is defined as the "ratio between the total relief of a basin and the maximum measured length of the drainage basin" (Schumm, 1956) (Table 1). Relief ratio has direct relationship between basin relief and channel gradient.

The relief ratio normally increases with decreasing drainage area and size of watersheds of a given drainage basin, high relief ratio indicates high slope area and vice versa. It is strongly depend on rock type and rock system (Rudraiah et al., 2008).

Relief ratio is an indicator of rates of erosion operating along the slope of a basin (Schumm, 1956). The Dewana basin has Rh equal to (0.030), while Chamy Gora and ChamyWaraQarawagh sub basins have Rh of 0.04 and 0.071 respectively (Table 4).

Ruggedness Number (Rn)

It is the product of maximum basin relief (H) and drainage density (D) (Verstappen, 1983). An extreme high value of ruggedness number occurs when both variables are large and slope is not only steep but long as well (Yusuf et al., 2011). Ruggedness number indicates the structural complexity of the terrain and high values are highly susceptible to erosion (Reddy et al., 2004). In the present study, the ruggedness number are computed and found to be 1.661 and 3.143 for Chamy Gora and ChamyWaraQarawagh sub basins respectively, and 3.581 for the whole Dewana basin (Table 4).

Longitudinal Profiles of Dewana Stream

Long profile is the reflections of the major geomorphic factors within a drainage. All streams that show the same concave-up profile result from balance of erosion and deposition, and base level controls on the elevation of the longitudinal profile.

Whithin alluvial channels it is generally accepted that a concave –up longitudinal profile is associated with rivers in equilibrium (Ritter et al.,2002, Rantitsch et al., 2009) and abrupt discontinuities in the gradients indicate the presence of knick points, which may be interpreted as profile disequilibria point.

Table-4: Relif Morphometric Parameter of Dewana basin and sub-basins based on maps of scale 1:50,000.

Name of basin	Maximum Elevation	Minimum Elevation	Basin relif(H) in m	Relief ratio (Rh) in m	Ruggedness number (Rn)
Chamy Gora	1370	685	685	0.040	1.661
Chamy wara qarawa	1790	510	1280	0.071	3.143
Whole Dewana basin	1871	365	1506	0.030	3.581

From longitudinal profile of Dewana stream (Fig. 14) it could be noticed that it has generally smooth linear graph in the upper part when confluence with Chamy Gora stream and passes beside Kalosh Mountain. However, it shows little convex-up shape (or noticeable disturbance) when it confluence with ChamyWaraQaraWagh stream near the plunging of Kalosh anticline (Fig. 14). At this point it becomes gradually dropping down till it reaches its mouth with the Diyla River. From measuring of the slope of the profiles in different location it show that there is change in this zone of Kalosh anticline, which shows evidence that stream profile is affected by structural growth of the anticline. The shape of profile indicates that the stream doesn't reach a stage of equilibrium (concave- up curve) and valley development is in young state and erosional processes are still active (Rantitsch et al., 2009). Similar conclusions have been derived from the result of morphometric analysis for selected sub basins from Dewana valley.

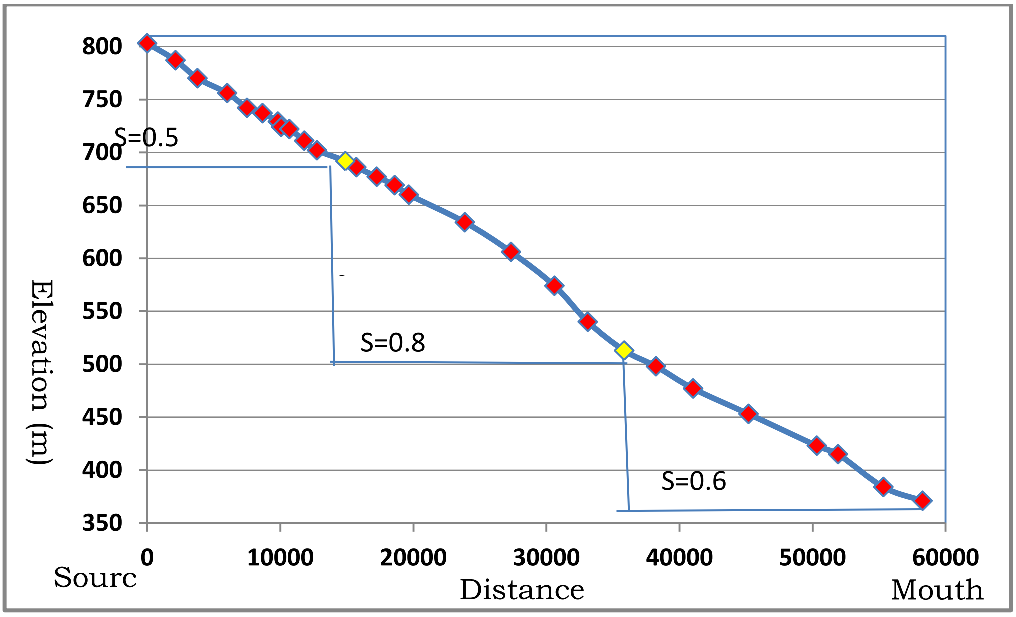


Figure-14: Longitudinal profile of Dewana stream.

Discussion of results

The Dewana stream catchment has a perimeter of 132 km (Table 2).The area of the Dewana basin and its sub basins has been computed and show that Dewana basin is small scale basin which has an area of 606 km^2 (Table 3). The size of basin will control catchment runoff pattern (discharge) and hydrograph shape (Verstappen, 1983). This is because the larger the basin, the greater the volume of rainfall it intercepts, and the higher the peak discharge that results. According to this Dewana basin has low Peak discharge and smooth hydrograph will be produced.

The catchment is drained by stream network of the 6^{th} order made up of 1116 streams with 1440.8 km long. The total length of Dewana basin is 50 km. These are characteristic of small scale basins. The natural stream has a dendritic, sub trellis, sub parallel and radial patterns which are attributed to the different resistance of rocks and structural control in the basin.

Analysis of bifurcation ratio (Rb) shows local high value (7.1 and 9) in Dewana basin and Chamy Gora sub basin in the 3^{rd} and 4^{th} order streams especially in the northern part of the basin indicate that this part is structurally controlled, but in ChamyWaraQarawgh sub-basin Rb show low values which range between 3 - 4, attributed to the characteristics of less structural disturbances in this part. In addition the analysis of drainage density (D) shows that Chamy Gora and ChamyWaraQarawaghsub basins have 2.425 and 2.455 1/km respectively, and Dewana basin has 2.378 1/km. This relatively high (D) value in a tilted stratum terrain indicates that the region is composed of impermeable surface materials, sparse vegetation cover and high mountainous relief.

The analysis of total length of streams (Lu) shows that Dewana basin has 1440.8 km. The relation between mean stream length and stream order satisfies Horton's law of stream length except in Chamy Wara Qarawagh sub basin that show decreasing of mean stream length in 4^{th} order stream, possibly due to variation in the slope and topography in this sub basins.

The length of over land flow **(**Lo) value of Dewana basin has 0.266 km, if we compare it with 606 km^2 basinarea it is a short distance so may the surface run off reach the trunk stream channels within a short period and may be responsible in developing storm hydrograph within the basin.

Stream length ratio (RL) analysis show that most of the length ratio values are near to each other,this follows Horton's law, except in some orders, this is due to lithological variation and topographic control on the different patrs of the basin.

Circularity ratio (Rc) of the area are computed and show that Dewana basin is more or less elongated in shape, whereas Chamy Gora and Chamy waraQarawagh sub basins are more or less sub circular in shape. Elongation ratio (Re) has computed and shows again indicates that Dewana basin is elongated in shape while Chamy Gora and Chamy WaraQarawagh sub basins are sub circular in shape.

The elongation shape of Dewana basin often lead to smoother curve of hydrograph because water needs more time from the upper catchment to reach the outlet. This is due to the strong control of the bounding homoclinal ridges on the shaping of drainage system of the basin, and forced flow to go in elongated pattern. From this we can conclude that Dewana basin still in young stage of erosional process because it doesn't have circular shape.

The form factor (Rf)analysis of the Dewana basin show that it has low value which is 0.242 it show its shape are somewhat fern like or triangle, wider in upstream and narrow in outlet, need more time to reach the outlet so it is less danger for flooding.

Basin relief (H) difference of Dewana basin is 1506 m which is high value of basin gradient which indicates high rate of water flow, low infiltration and high runoff conditions which lead to active sheet, rill and gully erosion. Relief ratio (Rh) determined of the basin is medium-scale (Rh= 0.030 m, Table 6). This also implies that the erosional development of drainage basin is still in young stage.

The computed Ruggedness number (Rn) has value 3.581 (Table 4) which indicates structural complexity of the terrain in association with relief and drainage density. It also implies that the area is susceptible to soil erosion. The longitudinal profile of the Dewana stream was plotted (Fig. 14) shows that the stream doesn't reached a stage of equilibrium state (concave- up curve) and valley development is in young state and erosional process are still active. The disturbance of the profile again points towards effective structural growth of the area.

Summary and Conclusions

Detailed morphometric analysis using Quick-bird image, 1/50000 topographic sheets in a GIS environment of the Dewana basin of Sulaimani area, reveals important points regarding the evaluation of the basin water resources in addition to the geomorphic evolution of the basin. The summary of these points as follow:

1- The aerial morphometric analysis of the Dewana basin indicates relatively small mountainous drainage basin of 6^{th} order stream network. The basin includes two important sub-basins: the Chamy Gora (4^{th} order), and ChamyWaraQarawagh (5^{th} order).

2- Shape parameters such as form factor, circularity ratio, and elongation ratio of the basin display clear elongated form reflecting strong structural controls on the bounding divides. This elongation shape affect its smoother curve of hydrograph.

3- Basin topographic variation parameters such as: basin relief, relief ratio, and ruggedness number indicates high rate of water flow, low infiltration and high runoff conditions which lead to active sheet, rill and gully erosion.

4- The natural stream network shows the domination of a dendritic pattern, in addition to sub-trellis, sub-parallel and radial patterns which is attributed to the variability in rocks types and strong structural control over the basin area.

5- Analysis of bifurcation ratio, drainage density and drainage texture of the Dewana network indicate moderate to high but variable network density. This reflects the variable geological conditions (structures and stratigraphy) of the basin area.

6- The stream length, ratio, and overland flow parameters shows results leads to a short distance of the surface run off and overland flow and flooding within a short period and may be responsible in developing storm hydrograph within the basin.

7- The longitudinal profile of the Dewana stream shows that the stream doesn’t reached a stage of equilibrium state (concave -up curve) and valley development is in young state and erosional process are still active.

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