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# MORPHOMETRIC ANALYSIS OF MAIN DRAINAGE BASINS IN THE ZURBATIYAH VICINITY, EASTERN IRAQ

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## ABSTRACT

The study area covers about 5600 Km$^2$ comprising three main watersheds; Torsaq, Shosharin and Badrah. It is built up of sedimentary formations (Oligocene – Pliocene) beside various types of Quaternary sediments. Different morphometric parameters are computed in this study using Geographical Information system (GIS) and Remote sensing techniques through the ease of uses of high resolution Digital Elevation Models (DEMs). The highest stream order of the studied basins is 6th order. The drainage density analysis indicates medium value suggesting coarse to moderate drainage texture. The values of bifurcation ratio range from 2.2 to 11. The values of form factor and circulatory ratio indicate that the studied basins are elongated in shape. According to dissection index value, the overall basins are moderately dissected; however the upper parts of the basins, which are located within the Zagros Fold-Thrust Belt, are characterized by their high tectonic activity, whereas their lower parts, located within the Mesopotamian Zone, are characterized by low tectonic activity.

# التحليل المورفومتري لاحواض التصريف الرئيسة في منطقة زرباطية، شرق العراق

**هالة عطاء الموسوي، ثائر مظهر العزاوي و حامد حسن عبدالله**

**المستخلص**

تمتد منطقة الدراسة على مساحة بحدود 5600 كم$^2$ وتحتوي على ثلاثة أحواض تصريف رئيسة هي ترساق، شوشرين وحوض بدرة. تتكشف في منطقة الدراسة تكوينات رسوبية ذات أعمار مختلفة، تتراوح من الأوليغوسين الى البلايوسين مع ترسبات مختلفة للعصر الرباعي. تم حساب معاملات مورفومترية متعددة باستخدام نظام المعلومات الجغرافية وتقنيات التحسس النائي. أظهرت النتائج أن الرتبة النهرية السادسة هي أعلى الرتب في منطقة الدراسة وتحليل كثافة التصريف ذو قيم متوسطة والتي تؤشر نسيج تصريفي خشن الى متوسط. ان قيم نسبة التشعب لأحواض التصريف المدروسة تتراوح من 2.2 – 11. كما ان قيم معامل الشكل ونسبة الدائرية تؤشر الأشكال الطولية للأحواض وبالاعتماد على قيم معامل التقطيع فإن أحواض التصريف المدروسة هي متوسطة التقطيع حيث تتميز الأجزاء العلوية منها والتي تقع ضمن حزام طي زاغروس المتصدع بالنشاط التكتوني العالي، بينما تتميز الأجزاء السفلى من أحواض التصريف والتي تقع ضمن نطاق السهل الرسوبي بالنشاط التكتوني الواطى.

## INTRODUCTION

Morphometric analysis refers to a detailed evaluation of landforms by using mathematical measurement of the configuration of the earth surface shape and dimensions (Clarke, 1966). The morphometric analysis provides quantitative description of the basin geometry to

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understand initial slope or inequalities in the rock hardness, structural controls, geological and geomorphic history of drainage basin (Strahler, 1964).

The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992). The morphometric analysis of a river basin has two distinct branches; relief morphometry and fluvial morphometry (reference). Fluvial morphometry is carried out through measurement of linear, areal and relief aspects (Singh, 2007). The linear aspect deals with the stream order, stream number and length, bifurcation ratio, whereas, the areal aspect includes basin shape, basin area, stream frequency, drainage density and drainage texture. Moreover, the relief aspect covers relative relief, relief ratio and dissection index. The drainage basin morphology reflects various geological and geomorphological processes over time (Horton, 1945; Strahler, 1952 and 1964; Muller, 1968; Shreve, 1969; Evans, 1981; Chorley *et al*., 1985; Merritts and Vincent, 1989; Ohmori, 1993; Cox, 1994; Oguchi, 1997; Burrough and McDonnell, 1998; and Hurtrez *et al*., 1999). The aim of this study is to illustrate the influence of the drainage morphometry and its significance in understanding the landform processes, rock physical properties and erosional characteristics.

## THE STUDY AREA

- **Location**

The study area is located within the eastern part of Wasit Governorate, near the Iraqi – Iranian international borders. It occupies an area of about 5600 Km$^2$ (Fig.1). Zurbatiyah is the main city that exists within the study area and Torsaq, Shosharin and Badra are the main drainage basins. The study area is limited by the following coordinates:

Longitude 45$^o$05' 00'', 46° 00' 00'' and Latitude 32$^o$ 75' 00'', 33° 06' 00''

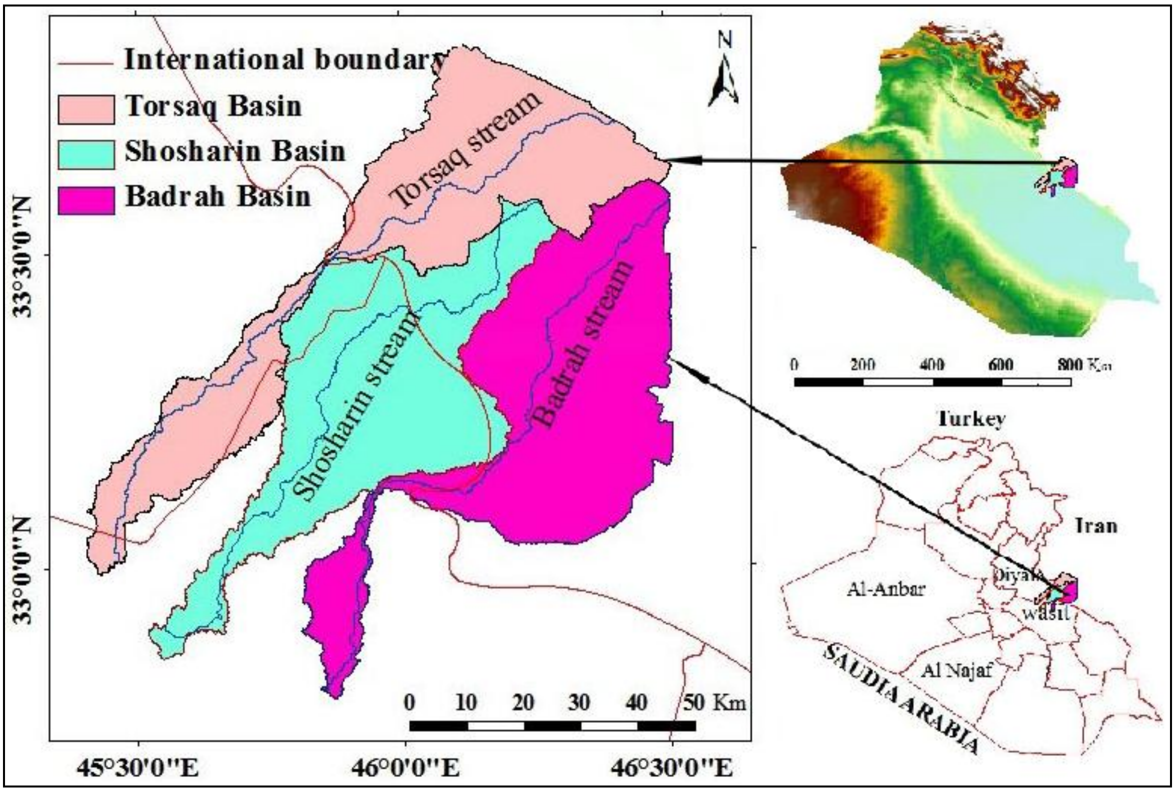


Fig.1: Location map of the studied basins

- **Climate**

The study area is characterized by hot, dry summer and cold wet winter**.** Based on the climate data of the Iraqi General Organization for Meteorological Information (I.M.O.), the study area is under the influence of arid climatic conditions (I.M.O., 2000). The most important climatic parameters are taken from Khanaqin meteorological station during the period 1970 – 2008 (Table 1).

Table 1: Mean values of climatic parameters (Khanaqin meteorological station during 1970 – 2008) (after I.M.O., 2000)

| Month | Rainfall (mm) | Temperature (°C) | Relative Humidity (%) | Evaporation (mm) | Wind Speed (m/sec) |
|---|---|---|---|---|---|
| January | 59.4 | 9.7 | 76 | 50.3 | 1.8 |
| February | 49.8 | 11.5 | 69 | 81.3 | 2.2 |
| March | 53.6 | 15.4 | 61 | 158.9 | 2.3 |
| April | 30.6 | 21.2 | 52 | 212.5 | 2.5 |
| May | 6.4 | 28.2 | 36 | 331.6 | 2.5 |
| June | 0.3 | 32.9 | 26 | 462.1 | 2.2 |
| July | 0.0 | 35.7 | 25 | 530.4 | 2.1 |
| August | 0.0 | 34.8 | 26 | 499.7 | 1.8 |
| September | 0.0 | 30.5 | 29 | 392.1 | 1.7 |
| October | 12.5 | 24.8 | 37 | 261.3 | 1.9 |
| November | 39 | 16.7 | 59 | 128.9 | 1.6 |
| December | 52.1 | 11.2 | 74 | 68.2 | 1.5 |
| Annual mean | 303.8 | 22.7 | 47.5 | 3177.3 | 2.0 |

## GEOLOGICAL SETTING

Stratigraphically, different sedimentary formations of different lithological constituents and age (Oligocene – Pliocene) are exposed within the study area, in addition to various types of Quaternary sediments (Fig.2). Brief description of the lithological units is mentioned hereinafter (from older to younger):

- **Ibrahim Formation (Upper Oligocene)**

This formation represents the oldest rocks unit within the hanging wall of the Koolic thrust fault, which is thrusted on the Dhiban and Jeribe formations (foot wall). It is exposed within the eastern part of the study area. It comprises 130 m of alternation of marl and marly limestone. The upper part of the formation is dominated by marl with thin beds of limestone, while the middle part is composed of thick bed of marly limestone. The lower part consists of alternation of marly limestone and marl (Mahmoud *et al*., 2018).

- **Serikagni Formation (Lower Miocene)**

It is exposed in the eastern parts of the study area and consists of 22 m of marl, marly limestone and limestone.

- **Dhiban Formation (Lower Miocene)**

It is exposed within in the eastern parts of the study area, consists of 30 m of white, nodular textured and massive gypsum.

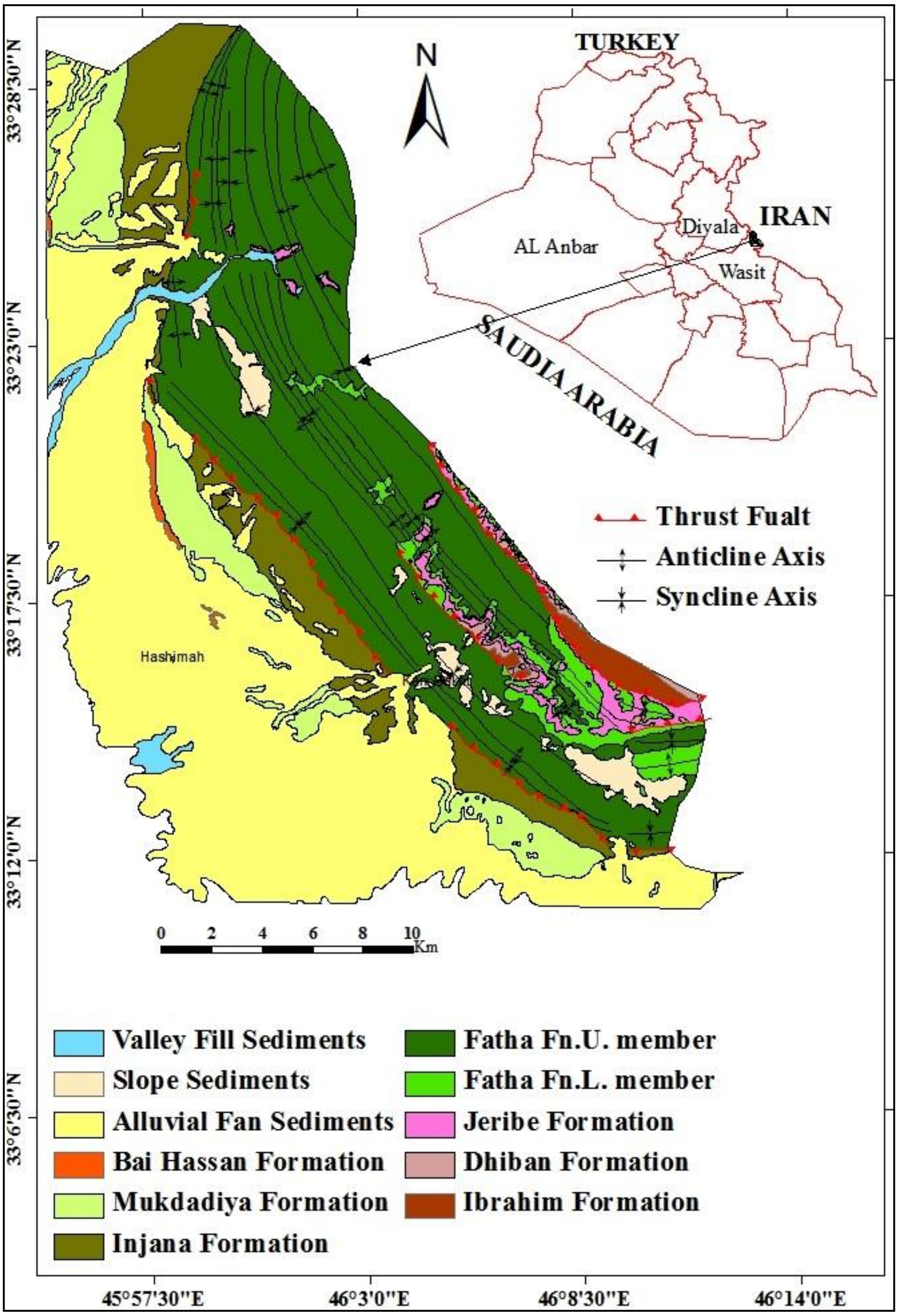


Fig.2: Geological map of the study area (Mahmoud *et al.*, 2018)

- **Jeribe Formation (Middle Miocene)**

It is exposed as relics along the thrust fault, and in the core of Koolic anticline. It is comprised of 70 m thick massive dolomitic limestone.

- **Fatha Formation (Middle Miocene)**

The formation consists of cyclic alternation of calcareous claystone, limestone and gypsum. It is divided into upper and lower members (Al-Mubarak and Youkhanna, 1976), both members are exposed in the study area. Its maximum exposed thickness is 330 m. The Fatha Formation is thrusted over the Injana Formation along the major thrust fault.

- **Injana Formation (Upper Miocene)**

The formation is exposed only within the southwestern limb of the Hemrin South anticline. The Injana formation consists of alternation of claystone, siltstone and sandstone, with total thickness of 350 m. The uppermost part is characterized by thick (up to 30 m) claystone and thin sandstone beds.

- **Mukdadiyah Formation (Upper Miocene – Pliocene)**

It consists of 110 m of rhythmic clastic cycles of sandstone and claystone, which are lenticular in shape with many lateral changes.

- **Bai Hassan Formation (Pliocene – Pleistocene)**

The formation consists of thick coarse conglomerates with lenses of sandstone. The total exposed thickness is 25 m (Mahmoud *et al*., 2018).

Tectonically, the Zagros Fold-Thrust Belt, within Iraq is divided into several NW – SE trending longitudinal tectonic zones (Buday and Jassim, 1987 and Jassim and Goff, 2006). The study area lies in the Low Folded Zone, which represents part of the Outer Platform of the Arabian Plate (Fouad, 2012). The main structures within the study area are Hemrin South Anticline and Kani Sakht Anticline (Fig.2). The first is the major anticline within the study area. It is a NNW – SSE trending anticline, 33 Km in length and its width ranges from 0.7 Km up to 7 Km. The NE limb of Hemrin South Anticline is thrusted over its SW limb (Al-Shwaily and Al-Obaidi, 2018). The second anticline is a narrow asymmetrical NWN – SES trending structure, located along the northeastern limb of the Hemrin South Anticline, with length of about 30 Km and variable width of up to 1.5 Km. The dip of the southwestern limb ranges between (40° – 65°), whereas the dip of the northeastern limb ranges between (47° – 52°). The study area is characterized by the presence of three large scale thrust faults of NW – SE trend, these are: Kachaa Fault, which extends for 25 Km, Cea Koran Fault, which extends for 25 Km and Koolic Fault, which runs parallel to the Iraqi – Iranian international borders and extends for 12 Km (Mahmoud *et al*., 2018).

The study area represents the extreme margin of the Low Folded Zone, which is physiographically, known as the Foothill Zone, located between the High Amplitude Mountainous and the Mesopotamian Plain provinces of Iraq (Yacoub *et al*., 2012). From the topographic point of view, the study area descends in relief from its northeastern part, where the mountainous area exists, towards W and SW parts, where alluvial fans and sheet run off sediments are well developed. Geomorphologically, the area is dissected by three main streams which have similar characters and behaviors. They are characterized by narrow and deep courses after leaving the alluvial fans and drain within the Tigris River and Hore Al-Shuwaicha depression. The main geomorphological units in the study area are: **1)** Units of Structural – Denudational Origin, include fault escarpments, hogbacks and cuestas. **2)** Units of Fluvial Origin, developed as numerous alluvial fans, which are divided into three types depending on the lithological composition as; alluvial fans composed of conglomerate, alluvial fans consist of carbonate conglomerate and alluvial fans consists of gypcrete mixed with gravels and rock fragments (Mahmoud *et al*., 2018).

## METHODOLOGY

ArcGIS 9.3 software and a 30 m resolution Digital Elevation Model (DEM) are used for evaluation the morphometric parameters of the studied three basins. The extracted basins and stream networks are projected to the regional projection WGS-1984, UTM zone 38-N. The morphometric parameters of the study area were computed using the formulae of different worker's shown in Table 2.

Table 2: Methodology adopted for computations of morphometric parameters for the study area

| No | Morphometric Parameters | Formula | Reference |
|---|---|---|---|
| 1 | Stream number (Nu) | Number of stream segments | (Strahler, 1952) |
| 2 | Stream order (U) | Hierarchical rank | (Strahler, 1964) |
| 3 | Stream length (Lu) | Length of the stream | ( Horton, 1945) |
| 4 | Mean stream length (MSL) | MSL = Lu/ Nu<br>Lu = Total stream length of order 'u'<br>Nu = Total no. of stream segments of order 'u' | (Strahler, 1964) |
| 5 | Stream length ratio (RL) | RL = Lu/ Lu – 1; Lu = Total stream length of order 'u'; Lu – 1 = Total stream length of its next lower order | ( Horton, 1945) |
| 6 | Bifurcation ratio (Rb) | Rb = Nu/ Nu + 1; Nu = Total no. of stream segments of order 'u'; Nu + 1 = No. of segments of next higher order | (Schumm, 1956) |
| 7 | Mean bifurcation ratio (Rbm) | Average of bifurcation ratios of all orders | (Strahler, 1957) |
| 8 | Basin length (Lb) | Straight line distance from a basin's mouth to the point on the water divide intersected by the projection of the direction of the line through the source of the main stream. | (Horton, 1932) |
| 9 | Perimeter (P) | Horizontal projection of its water divide | (Zăvoianu, 1985) |
| 10 | Basin area (Ba) | The entire area drained by a stream or system of streams | ArcGIS 9.3 |
| 11 | Drainage density (Dd) | Dd = Lu/ Ba; Lu = Total stream length of all orders; Ba = Area of the basin ($Km^2$) | (Horton, 1932) |
| 12 | Stream frequency (Fs) | Fs = Nu / Ba ; Nu = Total no. of streams of all orders<br>Ba = Area of the basin ($Km^2$) | (Horton, 1932) |
| 13 | Drainage texture (Dt) | Dt = Nu/ P; Nu = Total no. of streams of all orders; P = Perimeter (Km) | ( Horton, 1945) |
| 14 | Form factor (Rf) | $Rf= A/L^2$<br>A= Area of the basin ($Km^2$); $L^2$ = Square of basin length | ( Horton, 1945) |
| 15 | Basin relief (R) | $R=H_{max}-H_{min}$ | (Strahler, 1952) |
| 16 | Relative relief (Rhp) | Rhp=R/P | (Huggett and Cheesman, 2002) |
| 17 | Elongation ratio (Re) | $Re = 2\sqrt{(Ba/\pi)}$ / Lb; Ba = Area of the basin ($Km^2$); Lb = Basin length | (Schumm, 1956) |
| 18 | Circularity ratio (Rc) | $Rc = 4 * \pi *$ Ba/ $P^2$; Ba = Area of the basin ($Km^2$); $P^2$ = Square of the perimeter ((Km) | (Miller, 1953) |
| 19 | Length of overland flow (Lg) | Lg = 1/ 2* Dd, Dd = Drainage density | ( Horton, 1945) |
| 20 | Relief ratio (Rh) | Rh = H/ Lb; H = Total relief (Relative relief) of the basin (m); Lb = Basin length | (Schumm, 1956) |
| 21 | Dissection Index (DI) | DI = Rhp/ Ar<br>Rhp is Relative relief of the basin<br>Ar is absolute relief | Dov Nir (1957) |

## RESULTS AND DISCUSSION

Twenty one morphometric parameters are evaluated in this study to identify various characteristics of the three basins in the Zurbatiyah area as shown in Table 2. The work is executed based on linear, areal and relief aspects. Linear aspect deals with stream order, stream number and length, and bifurcation ratio. Areal aspect includes basin shape, basin area, stream frequency, drainage density and drainage texture. Relief aspect covers relative relief, relief ratio and dissection index. The total drainage area of the basins is 5602 $Km^2$. The number of streams is calculated in each watershed after assigning the stream order of each stream and it is found that the number of stream decreases as the stream order increases. The values of the length of overland flow for the three analyzed drainage basins are the same, which indicates the same age of development. The drainage density value in all basins indicates medium value due to the existence of permeable and impermeable rocks in addition to the moderate relief of the study area. The drainage basins in the study area extend within different lithologies and structures, these differences are reflected in the behavior and the areal extent of the catchment area of each drainage basin. The existence of very narrow areas in the middle part of each basin is due to the formation of a very deep gorge, where the stream drains within very hard and very steeply dipping strata and the expansion of the areal extent of the lower part of each drainage basin is due to the existence of the soft Quaternary sediments

## LINEAR ASPECTS

- **Stream Orders and Numbers**

The primary step in drainage basin analysis is to designate order for quantitative analysis of the watershed. There are various systems of ordering the stream (Horton, 1945; Strahler, 1957; and Shreve, 1966 and 1969). Strahler's system is followed in the present study because of its simplicity. The highest stream order in the three main basins in the study area is $6^{th}$ order (Fig.3), which merge with Hur Al-Shwaicha which is located to the southwest, outside the study area. Horton's law (1945) of stream numbers states that the number of stream segments of successively lower orders in a given basin tend to form geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio. The total number of streams in the Torsaq, Shosharin and Badrah basins is 2278, 1343 and 1694 respectively (Table 3).

- **Bifurcation Ratio (Rb) and Mean Bifurcation Ratio (Rbm)**

The Bifurcation Ratio is an index of relief and dissections; it is the ratio between the number of streams of any given order and the number of streams in the next higher order. In the present study, the bifurcation ratio values are not uniform from one order to next order (Table 4). These differences depend on the geological and lithological development of the drainage basin (Strahler, 1964). According to Giusti and Schneider (1965), this variation means that the basins are of equal order but variable areas tend to have the smallest bifurcation ratio in the smallest area. The ratio increases with increasing areas up to a certain size beyond which the bifurcation ratio tends to become constant. The bifurcation ratio value is generally high in mountainous area and low in flat area (Horton, 1945).

The Rbm is defined as the average of bifurcation ratios of all orders. Strahler (1957) suggests that the powerful geological control dominates in a basin when Rbm shows a small variation for different areas. Within the three drainage basins of the study area, there is very little variation in the mean bifurcation ratio.

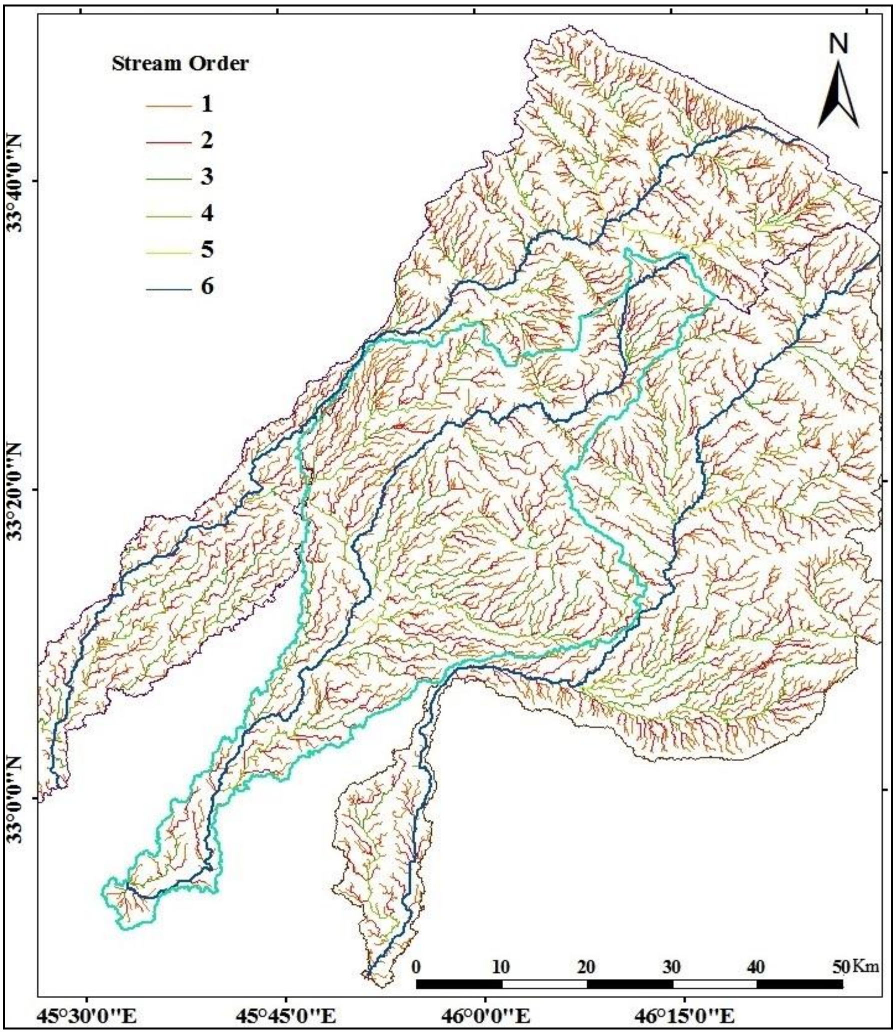


Fig.3: Stream orders of the studied basins

Table 3: Stream order and number of the studied watersheds

| Basin name | Stream order | Number of Streams | Total number of streams |
|---|---|---|---|
| Torsaq | 1 | 1456 | 2278 |
| | 2 | 650 | |
| | 3 | 152 | |
| | 4 | 14 | |
| | 5 | 5 | |
| | 6 | 1 | |
| Shosharin | 1 | 857 | 1343 |
| | 2 | 394 | |
| | 3 | 76 | |
| | 4 | 13 | |
| | 5 | 2 | |
| | 6 | 1 | |
| Badrah | 1 | 975 | 1694 |
| | 2 | 489 | |
| | 3 | 195 | |
| | 4 | 31 | |
| | 5 | 3 | |
| | 6 | 1 | |

Table 4: Bifurcation ratio and mean bifurcation ratio of the studied basins

| Basin name | Torsaq | | | | | Shosharin | | | | | Badrah | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bifurcation ratio (Rb) | 1/2 | 2/3 | 3/4 | 4/5 | 5/6 | 1/2 | 2/3 | 3/4 | 4/5 | 5/6 | 1/2 | 2/3 | 3/4 | 4/5 | 5/6 |
| | 2.2 | 4.3 | 11 | 2.8 | 5 | 2.2 | 5.2 | 6 | 6.5 | 2 | 2 | 2.5 | 6.3 | 10.3 | 3 |
| Mean bifurcation ratio (Rbm) | 5.0 | | | | | 4.4 | | | | | 4.8 | | | | |

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

The Length of Overland Flow is defined as the mean horizontal length of flow-path from the divide to the stream in a first order basin and is a measure of stream spacing and degree of dissection. It is one of the most important morphometric variables, which affects the hydrological and topographic development of the basins (Chorley, 1969). The relationship between the drainage density and overland flow is reverse. It is generally observed that the early stage of basin development is marked with maximum length of overland flow, while mature and old stages register marked reduction in Lg. However, there is no definite parameter or limit or scale of overland which flow has been suggested (Singh, 2007). Within the study area, the calculated values of Lg for the three analyzed drainage basins are the same and equal to 0.4 Km, which indicates that these basins have the same age of development.

## AREAL ASPECTS

- **Basin Geometry**

Basin geometry includes area (Ba), length (Lb) and perimeter (P). The area of the watershed is very important morphometric parameter; it represents the area enclosed within the boundary of the watershed divide. It reflects the volume of water in the watershed that can be generated from rainfall and the length of the stream draining. The Badrah watershed has the largest area of 1998 $Km^2$. Basin length is defined as the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956). Basin perimeter is the outer boundary of the watershed that encloses its area. It is measured along the divides between watersheds and may be used as an indicator of watershed size and shape. The basin geometry in the studied area is computed using Arc GIS software and shown in Table 5.

Table 5: Length, area and perimeter of the studied basins

| **Basin name** | **Basin length (Km) (Lb)** | **Basin area ($Km^2$) (Ba)** | **Basin perimeter (Km) (P)** |
|---|---|---|---|
| Torsaq | 118 | 1828 | 435 |
| Shosharin | 104 | 1776 | 360 |
| Badrah | 106 | 1998 | 390 |

- **Basin Shape**

The basin shape is defined as paramount significance in drainage basin morphology which helps in the description and comparison of different forms of the drainage catchment. The ideal drainage catchment is usually of pear shapes (Singh, 2007). There are various methods to compute the basin shape such as Form Factor (Rf), Circularity Ratio (Rc) and Elongation Ratio (Re). Values of Rf, Rc and Re of the three drainage basins are shown in Table 6.

Table 6: The Form Factor, Circularity Ratio and Elongation Ratio of the studied drainage basins

| Basin name | Form Factor (Rf) | Circularity Ratio (Rc) | Elongation Ratio (Re) |
|---|---|---|---|
| Torsaq | 0.13 | 0.12 | 0.40 |
| Shosharin | 0.16 | 0.17 | 0.40 |
| Badrah | 0.17 | 0.16 | 0.47 |

– **Form Factor (Rf):** It is a dimensionless property and is used as a quantitative expression of the shape of a basin form (Kumar and Sarda, 2017). According to Horton (1945), the Form Factor is the ratio of the area of the basin divided by the square of basin length.

The smaller value of the Rf is; the more elongated will be the basin shape (Siddaraju, *et al*., 2017). According to Babar (2005) the value of Form Factor varies from 0 (in elongated basins) to 1.0 (in circular basins). Rf values of the study area indicate that the three basins are of elongated shape.

– **Circularity Ratio (Rc):** Miller (1953) defined basin Circularity Ratio as the ratio of basin area to the area of a circle having circumference equal to the perimeter of the basin. It is influenced by the length and frequency of streams, geological structures, climate, relief and slope of the basin. The Circularity Ratio ranges from 0 (a line) to 1.0 (a circle). The higher the value of Rc is, the more circular shape of the basin is, and vice versa. The Rc of the study area indicates that the three basins are elongated or have less circular shape.

– **Elongation Ratio (Re):** Schumm (1956) defined the Elongation Ratio as the ratio between the diameter of a circle with the same area as the basin and basin length. The value of Re approaches 1.0 as the shape of the basin approaches to a circle. Values close to 1.0 are typical of regions of very low relief whereas that of 0.6 to 0.9 are associated with high relief and steep ground slope (Strahler, 1964). The higher value of Re indicates mature to old stages topography which have circular shape. The various shapes of a watershed can be classified with the help of the Index of Elongation Ratio, i.e. circular (0.9 – 0.10), oval (0.8 – 0.9), less elongated (0.7 – 0.8), elongated (0.5 – 0.7) and more elongated (less than 0.5) (Pareta and Pareta, 2012). In the present study, the maximum Re value is 0.47; calculated in the Badrah watershed, whereas it is 0.4 in both the Torsaq and Shosharin watersheds (Table 6). These values reflect elongated shape.

- **Drainage Density (Dd)**

The drainage density is defined as a ratio of total length of channels of all orders in the basin to the drainage area of the basin (Horton, 1945). The characteristics of stream length are controlled by resistance of the exposed rocks to weathering, climate, vegetation, permeability of rocks, etc. The drainage density indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin (Siddaraju *et al*., 2017). According to Deju (1971), the drainage density is classified into three types: poor (0.5), medium (0.5 – 1.5) and excellent (1.5). In the present study, the drainage density value of the studied basins varies from 1.17 – 1.25 (Fig.4 and Table 7), which indicate medium Dd value. This is attributed to the existence of permeable rocks (sandstone, conglomerate and the Quaternary sediments) and impermeable rocks (clay and gypsum) in the study area.

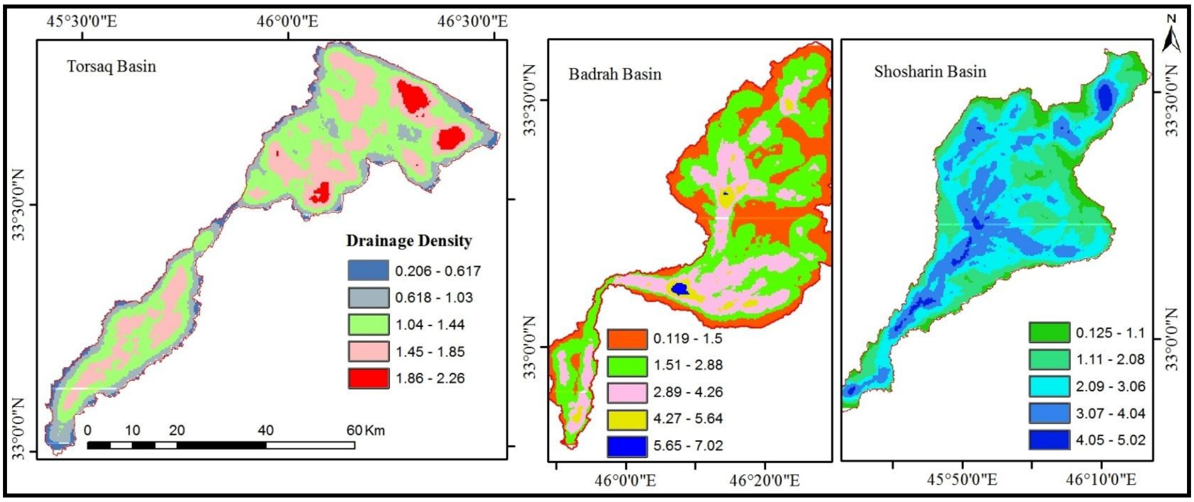


Fig.4: Drainage density of the studied basins

Table 7: Drainage density, stream frequency and drainage texture of the studied basins

| Basin name | Drainage density (Dd) | Stream frequency (Fs) | Drainage texture (Dt) |
|---|---|---|---|
| Torsaq | 1.20 | 1.24 | 5.23 |
| Shosharin | 1.25 | 0.75 | 3.73 |
| Badrah | 1.17 | 0.84 | 4.34 |

- **Stream Frequency (Fs)**

Stream frequency is defined as the measure of number of streams per unit area (Singh, 2007). There is a close relationship between stream frequency and run-off, the higher stream frequency has more run-off and vice-versa. Rekha *et al*. (2011) and Vijith and Sateesh (2006) stated that a stream frequency is related to factors like permeability, infiltration capacity, and relief of a basin.

Within the study area, the values of Fs vary from 0.75 up to 1.24 which show positive relation between the drainage density values of the basins with the stream frequency. Accordingly, suggesting that there is an increase in stream population with respect to increasing of drainage density.

- **Drainage Texture (Dt)**

Horton (1945) recognized infiltration capacity as the single important factor which influences drainage texture and considered the drainage texture to include drainage density and stream frequency. Smith (1950) stated that, Dt is controlled by factors such as climate, rainfall, vegetation, lithology, infiltration capacity, relief and stage of development. Soft rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks to erosion cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate (Kumar Raju and shetty, 2010). The drainage texture has been classified into five different textures according to Smith (1950) including: very coarse (< 2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8), and very fine (> 8). The drainage texture of the Torsaq and Badrah basins falls under moderate drainage texture category, whereas in the Shosharin basin it has coarse texture (Table 7).

## RELIEF ASPECTS OF THE BASIN

The relief aspects of the drainage basins are related to the study of three dimensional features of the basins involving area, volume and altitude of vertical dimension of landforms (Singh, 2007). The most important relief aspects parameters include hypsometric analysis, relative relief, slope and profile analysis.

- **Basin Relief (R)**

The Basin relief is the difference between the maximum and minimum elevations in the basin. It is an important parameter which helps in understanding the denudational characteristics of the drainage basin. It controls the stream gradient and, therefore, influences the surface run-off, amount of sediment and the flood pattern in the basin (Hadley and Schumm 1961 in Yadav, *et al.*, 2014). The basin relief is the maximum vertical distance from the stream mouth to the highest point on the divide, it has been defined, according to Schumm (1956) who measured it along the longest dimension of the basin parallel to the principal drainage line. Whereas, Strahler (1952 and 1957) obtained it by determining the mean height of the entire watershed divide about the outlet. The basin relief is an indicative of the potential energy for a given watershed about a specified datum available to move water and sediment down slope.

The highest elevation value in the study area is 2725 m, which is located in the eastern part of the study area. Whereas, the lowest elevation value is 17 m and exists southwest of the study area. The elevation and basin relief of each basin is shown in Table 8.

- **Relative Relief (Rhp)**

The relative relief is a very important morphometric parameter which is used for the overall assessment of morphological characteristics of terrain and degree of dissection (Singh, 2007). It is defined as the ratio of the basin relief (R) to the perimeter of the basin. According to Huggett and Cheesman (2002), relative area and terrain shape on a regional scale tend to be particularly influential properties (Al-Saady, 2016). The relative relief values are approximate values in the three watersheds of the present study which vary from 5.13 to 6.93 (Table 8).

Table 8: Elevation and basin relief of the study area

| Basin name | Elevation (m) | | Basin relief (R) | Relative relief (Rhp) |
|---|---|---|---|---|
| | Max | Min. | | |
| Torsaq | 2575 | 19 | 2556 | 5.87 |
| Shosharin | 1866 | 17 | 1849 | 5.13 |
| Badrah | 2725 | 20 | 2705 | 6.93 |

- **Relief ratio (Rh)**

The relief ratio is defined as the ratio between the basin relief and the basin length. It is the ratio between basin relief and the longest dimension of the basin parallel to the principal drainage line according to Schumm (1956). Rh depends mainly on the area and size of a watershed. It increases with decreasing of drainage area (Kiran Kumar *et al.*, 2018). If the Rh value is high, it indicates a hilly region and a low value of relief ratio represents pediplain and valley region and an indication of the intensity of erosional process operating on slope of the basin (Mangesh *et al.*, 2013). The Rh in the watersheds in the present study are of equal value which is 0.05 in both the Torsaq and Shosharin basins, whereas it reaches 0.06 in the Badrah basin.

- **Dissection Index (DI)**

The dissection index is a ratio of the maximum relative relief to the maximum absolute relief. It is an important morphometric indicator of nature and magnitude of dissection of the terrain. The values of dissection index range from 0 – 1, it is 0 in complete absence of vertical dissection or erosion and hence dominance of flat surface and it is 1 at vertical escarpment of hill slope or at seashore (Pareta and Pareta, 2011). In the present study, the DI values are 0.99 for the three basins (Table 9) which indicate that the watersheds are moderately dissected.

Table 9: Dissection index of the study area

| **Basin name** | **Absolute relief (Ar)** | **Dissection index (Di)** |
|---|---|---|
| Torsaq | 2575 | 0.99 |
| Shosharin | 1866 | 0.99 |
| Badrah | 2725 | 0.99 |

## CONCLUSIONS

The quantitative geomorphologic analysis of the watersheds in the present study shows that the watersheds are of sixth order. The number of streams is calculated for each watershed after assigning the stream order of each stream. There is little variation in the mean bifurcation ratio within the study area due to the powerful geological control dominating each of these basins. It varies from 4.4 in the Shosharin watershed, 4.8 in the Badrah watershed and the maximum value is 5.0 recorded in the Torsaq watershed. The values of the length of overland flow for the three analyzed drainage basins are the same (0.4), in addition to the values of dissection index, indicating moderately dissected basins. The three basins have elongated shape. The drainage density value in the studied basins (1.17 – 1.25) indicates medium value due to the existence of permeable and impermeable rocks in the study area. The existence of very narrow areas in the middle part of each basin is due to the formation of a very deep gorge, where the stream drains in very hard and very steeply dipping strata, whereas the expansion of the areal extent of the lower part of each drainage basin is due to the existence of soft Quaternary sediments. However, the upper reaches of the basins, which are located within the Zagros Fold-Thrust Belt, are characterized by high tectonic activity, whereas their lower parts, which are located within the Mesopotamian Zone, are characterized by low tectonic activity.

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## REFERENCES

Al-Mubarak, M.A. and Youkhanna, R.Y., 1976. Report on the regional geological mapping of Al-Fatha – Mosul area. GEOSURV, int. rep. no. 753.

Al-Saady, Y.I. 2016. Environmental impact assessment of land use expansion on Lesser Zab river basin, Northeast of Iraq. Unpublished Ph.D. Thesis, University of Baghdad .

Al-Shwaily, A.Kh. and Al-Obaidi, M.R., 2018. Determination of the paleostress magnitude of the eastern part of the Low Folded Zone, East Iraq. Indian Journal of Natural Sciences, Vol.9, No.50, p. 15145 – 15160.

Babar, M., 2005. Hydrogeomorphology: Fundamentals, Applications and Techniques. New Delhi, New India Publishing, 274pp. ISBN9788189422011.

Buday, T. and Jassim, S.Z., 1987. The Regional Geology of Iraq, Vol.2, Tectonism, Magmatism and Metamorphism. GEOSURV, Baghdad, 352pp.

Burrough, P.A. and McDonnell, R.A., 1998. Principles of Geographical Information Systems. Oxford University Press Inc., New York, p. 17 – 34.

Chorley, R.J., 1969. The drainage basin as the fundamental geomorphic unit. In: Chorley, R.J. (Ed.). Introduction to Physical Hydrology. Water. Earth and Man, Methuen, London, p. 77 – 100.

Chorley, R.J, Schumm, S.A. and Sugden, D.E., 1985. Geomorphology. Methuen and Co. Ltd., London, New York, 605pp.

Clarke, J.I., 1966. Morphometry from Maps. In: G.H. Dury (Ed.), Essays in Geomorphology. New York, Elsevier Publishing Company, p. 235 – 274.

Cox, R.T., 1994. Analysis of drainage-basin symmetry as a rapid technique to identify areas of possible Quaternary tilt-block tectonics: An example from the Mississippi embayment. Geol. Soc. Am. Bull. Vol.106, No.5, p.571 – 581. doi: 10.1130/0016-7606(1994)106<0571:AODBSA>2.3.CO;2

Deju, R.A., 1971. Regional Hydrology Fundamentals. Newark, New Jersey, United States. Gordon and Breach Science Publishers, ISBN-13: 978-0677038605, 204pp.

Dove Nir. 1957. The ratio of relative and absolute altitude of Mt Camel: A contribution to the problem of relief analysis and relief classification. American Geographical Society. Vol.47, No.4, p. 564 – 569. doi:10.2307/21 1866https://www.jstor.org/stable/211866.

Evans, I.S., 1981. General Geomorphometry. In: A. Goudie (Ed.) Geomorphological Techniques, George Allen and Unwin, London, p. 31 – 36.

Fouad, S. A., 2012. Western Zagros Fold-Thrust Belt. Part I. The Low Folded Zone. Iraqi Bull. Geol. Min., Special Issue, No.5, p. 39 – 62.

Giusti, E. and Schneider, W.J., 1965. The distribution of branches in river network. USGS, Geological Survey Professional Paper 422 G. 10pp.

Hadley, R. and Schumm, S., 1961. Sediment sources and drainage basin characteristics in upper cheyenne river basin. USGS, Water-Supply Paper no. 1531-B: 198pp.

Horton, R.E., 1932. Drainage basin characteristics. Eos, Transactions American Geophysical Union, Vol.13, No. 1, p. 350 – 361. https://doi.org/10.1029/TR013i001p00350.

Horton, R.E., 1945. Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative geomorphology. GSA Bulletin, Vol.56, No.3, p.275 – 370. https://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2

Huggett, R.J. and Cheesman, J., 2002. Topography and the Environment. Prentice Hall, 247pp.

Hurtrez, J.E., Sol. C. and Lucazeau, F., 1999. Effect of drainage area on hypsometry from analysis of small-scale drainage basins in the Siwalik hills (central Nepal). Earth Surf. Process. Landform Vol.24, No.9, p. 799 – 808. https://doi.org/10.1002/(SICI)1096-9837(199908)24:9<799::AID-ESP12>3.0.CO;2-4

I.M.O. (Iraqi General Organization for Meteorological Information), 2000. Atlas of Climate of Iraq for the years (1981–2000).

Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Prague and Moravian Museum, Brno, 341pp.

Kiran Kumar, K.M, Govindaiah, S. and Nagabhushan, P., 2018. Morphometric analysis of the Tumkur-Gubbi Watershed of Shimsha River Basin, Karnataka, India, by using Remote Sensing and GIS Techniques. International Journal of Creative Research Thoughts (IJCRT), Vol.6, No.1, p. 1627 – 1640.

Kumar Raju, B.C. and Shetty, A., 2010. Morphometric analysis of Netravathi river basin using GIS techniques. Conference Paper. doi:10.13140/RG.2.1.2311.8886.

Kumar, R.A. and Sarda, V.K., 2017. Morphometric analysis of a semi-arid region using GIS. Journal of Engineering Research and Application, Vol.7, No.6, (Part 1), p. 8 – 17.

Magesh N.S., Jitheshal K.V., Chandrasekar, N. and Jini, K.V., 2013. Geographical information system based morphometric analysis of Bharathapuzha River Basin, Kerla, India. Appl. Water Sci: p. 1 – 11. doi:10.1007/s13201-013 – 0095-0.

Mahmoud, A.A., Ali, M.A., Mohammed, A.J., Al-Mikhtar, L.E., Al-Kubaysi, K.N., Hussien, M.S., Al-Obaidy, R.A., Mohammed Ali, S.M., Tawfeeq, G., Jassim, M.K., Shnaen, S.R. and Kareem, A.Y., 2018. Detailed Geological Mapping Project of Iraq, Zurbatiyah region, East Iraq, scale 1: 250 000. GEOSURV, int. rep. no. 3650.

Merritts, D. and Vincent, K.R., 1989. Geomorphic response of coastal streams to low, intermediate, and high rates of uplift, Mendocino junction region, northern California. Geol. Soc. Am. Bull. Vol.101, No.11, p. 1373 – 1388. https://doi.org/10.1130/0016-7606(1989)101<1373:GROCST>2.3.CO;2

Miller, V.C., 1953. A quantitative geomorphic study of drainage basin characteristics in the Clinch mountain area Virginia and Tennessee. New York (NY): Department of Geology, ONR, Columbia University, Virginia and Tennessee (Proj. NR 389 – 402, Technical Report 3).

Muller, J.E., 1968. An introduction to the hydraulic and topographic sinuosity indexes. Ann. Assoc. Amer. Geogr., Vol.58, No.2, p. 371 – 385.

Oguchi, T., 1997, Drainage density and relative relief in humid steep mountains with frequent slope failure. Earth Surf Process Landforms, Vol.22, No.2, p. 107 – 120. https://doi.org/10.1002/(SICI)1096-9837(199702)22:2<107::AID-ESP680>3.0.CO;2-U.

Ohmori, H., 1993. Changes in the hypsometric curve through mountain building resulting from concurrent tectonics and denudation. Geomorphology, Vol.8, No.4, p. 263 – 277. https://doi.org/10.1016/0169-555X(93)90023-U.

Pareta, K. and Pareta, U., 2011. Quantitative morphometric analysis of a watershed of Yamuna Basin, India using ASTER (DEM) data and GIS. Int. J. Geomat Geosci, Vol.2, No.1, p. 248 – 269

Pareta, K. and Pareta, U., 2012. Quantitative geomorphological analysis of a watershed of Ravi River Basin, H.P. India. International Journal of Remote Sensing and GIS, Vol.1, No.1, p. 41 – 56.

Rekha, V.B., George, A.V. and Rita, M., 2011. Morphometric analysis and micro-watershed prioritization of Peruvanthanam sub-watershed, the Manimala River Basin, Kerala, South India. Environmental Research, Engineering and Management, Vol.3, No.57, p. 6 – 14.

Schumm, S.A., 1956. The evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. GSA Bulletin. Vol.67, No.5, p. 597 – 646. https://doi.org/10.1130/0016-7606(1956)67[597:EODSAS]2.0.CO;2

Shreve, R.L., 1966. Statistical law of stream numbers. Journal of Geology, Vol.74, No.1, p. 17 – 37. https://doi.org/10.1086/627137.

Shreve, R. L., 1969. Stream lengths and basin areas in topologically random channel networks. Journal of Geology, Vol.77, No.4, p. 397 – 414. https://www.jstor.org/stable/30065752.

Siddaraju, K., Nagaraju, D., Bhanuprakash, H.M., Shivaswamy, H.M. and Balasubramanian, A., 2017. Morphometric evaluation and sub basin analysis in Hanur watershed, Kollegal Taluk, Chamarajanagardistrict, Karnataka, India, using Remote Sensing and GIS techniques. International Journal of Advanced Remote Sensing and GIS, Vol.6, No.1, p. 2178 – 2191. doi: 10.23953/cloud.ijarsg.265.

Singh, S., 1992. Quantitative geomorphology of the drainage basin. In: Readings on Remote Sensing Applications. T.S. Chouhan and K.N. Joshi (Eds.), Scientific Publishers, Jodhpur, India. p. 176 – 183

Singh, S., 2007. Geomorphology, 5th edit. Prayag Pustak Bahawan, Allahabad, India, 652pp.

Smith, K.G., 1950. Standards for grading texture of erosional topography. American Journal of Science, Vol.248, No.9, p. 655 – 668.

Strahler, A.N., 1952. Hypsometric (area-altitude) analysis of erosional topography. GSA Bulletin, Vol.63, No.11, p. 1117 – 1142. https://doi.org/10.1130/0016-7606(1952)63[1117:HAAOET]2.0.CO;2.

Strahler, A.N., 1957. Quantitative analysis of watershed geomorphology. Eos, Transactions-American Geophysical Union, Vol.38, No.6, p. 913 – 920. https://doi.org/10.1029/TR038i006p00913.

Strahler, A.N., 1964. Quantitative geomorphology of drainage basin and channel networks. In: V.P. Singh. Handbook of Applied Hydrology. New York: McGraw Hill Book Company, p.439 – 476. ISBN-10: 0071835091.

Vijith, H. and Satheesh, R., 2006. GIS based morphometric analysis of two major upland sub-watersheds of Meenachil river. In: Kerala. J. Indian Soc. Rem. Sens. Vol.34, No.2, p. 181 – 185. https://doi.org/10.1007/BF02991823.

Yacoub, S.Y., Othman, A.A. and Kadim, T.H., 2012. Geomorphology of the Low Folded Zone. Iraqi Bull. Geol. Min., Special Issue, No.5, p. 7 – 37.

Yadav, S.K., Singh, S.K., Gupta, M. and Srivastava, P.K., 2014. Morphometric analysis of Upper Tons basin from Northern Foreland of Peninsular India using CARTOSAT satellite and GIS. Geo. Carto. International, Vol.29, No.8, p. 1 – 20. doi:10.1080/10106049.868043.

Zăvoianu, I., 1985. Morphometry of Drainage Basins. Elsevier Science, 237pp. eBook ISBN: 9780080870113.