MORPHOMETRIC ANALYSIS OF DUHOK WATERSHED

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ABSTRACT

This study was aimed to obtain morphometric parameters of Duhok watershed evaluated through three aspects. The area was located at Duhok governorate with covers 394.87Km^2. Depending on stream orders, ten of sub-watersheds were extracted from the main watershed. Furthermore, Duhok watershed stream orders ranged from 1 to 6, as well as the total number of segmented stream reported for the total number of orders was (4175). The results of the current study indicate the Duhok watershed has a high relief ratio (0.026 m/km) and relative relief (0.95) which refers to steep slopes and excessive runoff. The ruggedness value is (4.09) indicates the study region is rugged with high density of streams also the low value of hypsometric integral (0.37) indicates the mature stage of watershed age. However, the watershed's flatter flow regime and elongated shape are confirmed by the values of form factor (0.23), elongation ratio (0.54), and circulation ratio (0.40). The watershed mean bifurcation ratio is 4.13, indicating significant structural disruption, while the value of stream frequency (10.69 streams/km^2) suggests dense surface runoff and steeper topography. a very fine drainage texture (37.66) which leads to a higher risk of erosion. The findings of this study will be valuable in watershed management, water resources and protecting the environment in the future.

Keywords: GIS Techniques, Areal aspect, Relief aspect, Linear aspect

التحـليـل المـورفـومتـري لحـوض دهـوك

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المستخلص:

تم حساب الصفات المورفومترية لحوض دهوك من خلال ثلاثة جوانب وهي الصفات (الخطية و المساحية و التضاريسية)، بمساحة 394.8 كم^2. اعتماداً على رتبة الجداول، تم استخراج عشرة احواض ثانوية من الحوض الرئيسي. يبلغ مجموع الجداول في شبكة التصريف لحوض دهوك (41754) جدول موزعة على ستة رتب حسب تصنيف ستراهلر. تبين من هذه الدراسة ان حوض دهوك لها نسبة تضرس عالية (0.026 م/كم) والتضرس النسبي كان (0.95) والتي تشير الى انحدار شديد و جريان قوي داخل الحوض. وقيمة الوعورة (4.09) تشير الى ان منطقة الدراسة وعرة مع كثافة عالية للجداول، وايضاً ان القيمة الواطئة للتكامل الهبسومتري (0.37) تشير الى بلوغ الحوض لمرحلة النضج. وان الشكل المستطيل للحوض ونظام الجريان السطحي يمكن الاستدلال منه من خلال قيم كل من عامل الشكل (0.23) ونسبة الاستطالة (0.54) ونسبة الاستدارة (0.40). وان قيمة معدل نسبة التشعب في الحوض (4.13)، تشير الى أهمية البنية التشعبية، بينما قيمة كثافة التصريف العددية (10.69 جدول/ كم^2) تبين كثافة الجريان السطحي و الطبوغرافية الوعرة لحوض دهوك. منطقة الدراسة تتميز بنعومة عالية (37.66) والتي سوف تؤدي الى ازدياد مخاطر التعرية فيها.

الكلمات المفتاحية: تقنيات نظم المعلومات الجغرافية, الخصائص المساحية , الخصائص التضاريسية , الخصائص الخطية

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INTRODUCTION

Watersheds are an optimal unit for managing natural resources (land and water) in order to minimize the impact of natural disasters and promote long-term development (25). Morphometric analysis will assist in quantitating and comprehending hydrological characteristics, with the result providing valuable input for complete water resources management and strategies (46). Morphometry is the measured and analysis of the earth's surface and its dimensions (7). The morphometric analysis of the watershed is vital to understanding the hydrological of the watershed, as well as geomorphologic structure, flood analysis, and earth geology. Different topographical and morphometric aspects of watersheds are currently being studied remote sensing (RS) and geographical information system (GIS) approach because they provide a variety of environmental methods for editing and analyzing spatial data (42). The streams network extracted from DEM (digital elevation model) would be a more useful morphometric analysis assessment method. Gebre et al., (12) stated that geographical information system technique and remote sensing data present effectual tools for extracting the basins of river and its stream network. As the linear and form parameters of the watershed morphometric characteristics have a direct and indirect link with soil erodibility, they can be used as a basis for prioritization (26**)**. GIS technique and RS data has been widely used in morphometric analyze and it provides a vital tool in the estimation of morphometric characters. According to the results of Aziz et al. (2), the estimation of morphometric parameters and extraction of data (flow direction, flow accumulation, basin, and sub-basins) using GIS would be highly valuable in water harvesting site selection with minimal cost and time, and acceptable results when compared to traditional methods. There are many researches at all words, Iraq and Kurdistan region are investigated a research about morphometric analysis by using Geographical Information System techniques and RS data, like researches done by Biswas et al., (4), Swati et al. (41), Artoshy (1), Jeney, (18**)** Salim, (31) and Ibrahim, (19). Therefore, the present study was analyzed the main morphometric parameters of Duhok watershed depending on remote sensing and ArcGIS approach and study the correlation among the morphometric parameters.

MATERIALS AND METHODS

Study Area: Duhok watershed is the study area of present research that is located at the top of the main stream that flows within Duhok city. between the coordinates of (36° 55``50` - 36° 47``30` N) latitudes and (43° 7``30` - 42° 42`` 0` E), longitudes and it covers an area of 394.87 km^2. The Duhok watershed is bounded by Kamaka mountain from North, white mountain from South, Zawita mountain from east, Baikhair mountain from west. Physiographical, the Duhok watershed has a mountainous topography that is largely steep to very steep, but the northern part expands more and the topography becomes gentle at the bottom of the valley. The study area is 332 to 1389 meters above sea level in elevation. Duhok watershed is divided in this study to ten sub-watersheds. The watershed's geological component is mainly composed of sandstone, clay marl, poly clay-limestone, and dolomite (43). The average annual rainfall in the Duhok watershed is approximately 619.49mm, and the mean annual temperature is around 20.5 °C. the climate is hot and dry in the summer and cold and wet in the winter, which is nearly identical to the Mediterranean climate. The rainy season begins from October to May (2010-2022), with the remaining months of the year being considered dry.

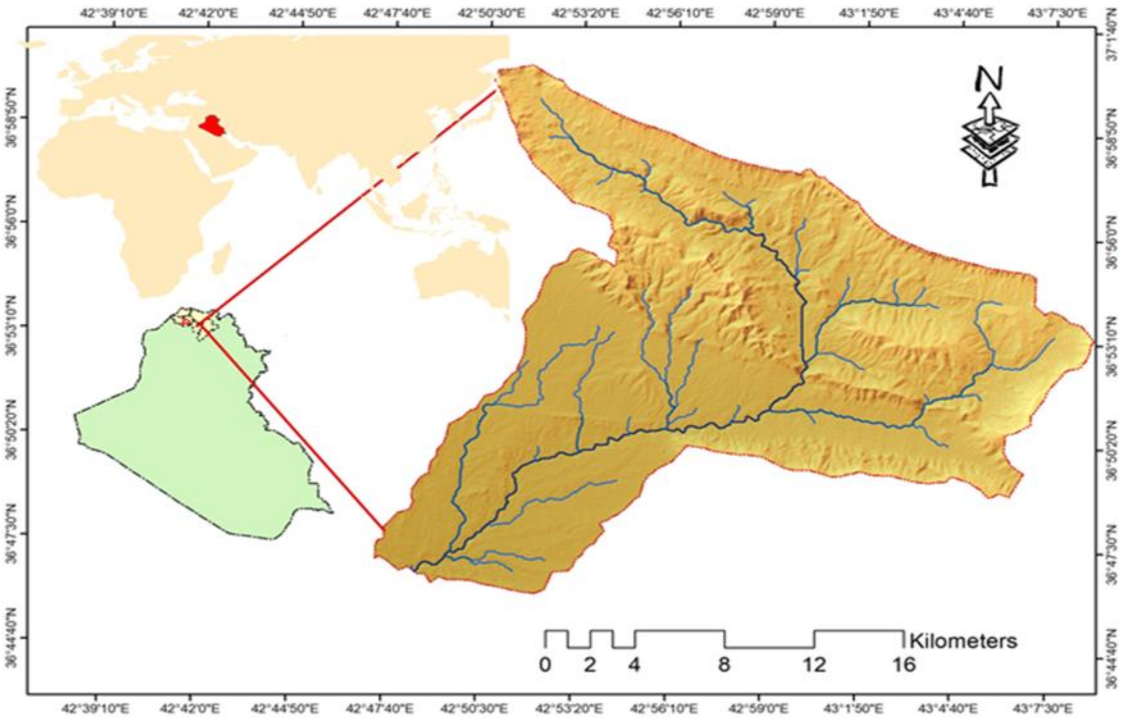

Fig. 1. Study area of Duhok watershed

Data sources and analysis

In this study a DEM with resolution (12.5m) used in ArcGIS 10.7 software pattern to delineate the Duhok watershed that divided in to 1-10 sub-watershed, the scale of the map (1:250 000) with Transverse Mercator Projection (grid: UTM zone 38N), and watershed parameters were determined using zonal statistics tools for ArcGIS .

Morphometric Parameters

The Duhok watershed's morphometric parameters are divided into three aspects as (linear, areal and relief):

Linear aspect

ArcGIS 10.7 software is used to perform stream order, length of stream, watershed perimeter, and watershed length. While the statistical formula in Table (1) was used to compute the mean stream length, stream length ratio, and bifurcation ratio.

Table 1. Shows the formulas and sources for calculating linear aspect parameters in the Duhok Watershed

N.	Linear aspect	Code	Formula	Source
1.	Stream Number	N_u	$N_u = N1 + N2 + \cdots Nn$	(15)
2.	Stream Length	L_u	$L_u = L1 + L2 \ldots Ln$	(38)
3.	Mean stream length	L_{sm}	$L_{sm} = {L_u}/{N_u}$ Where L_u= Total stream length in particular order, N_u= total number of streams of a particular order	(37)
4.	Stream length ratio	R_L	$R_L = L_u / L_{(U-1)}$ $L_u =$ total stream length in particular $L_{(U-1)} =$ total stream length of next lower order	(15)
5.	Bifurcation Ratio	R_b	$R_b = N_u / (N_u + 1)$ Where, $N_u =$ number of stream segments of a particular order $N_u + 1 =$ number of stream segments of next higher order.	(33)
6.	Watershed Perimeter	P	The watershed's outside edge, which defined its boundaries	(33)
7.	Watershed Length	L	Is the watershed longest dimension that runs parallel to its main drainage channel	(14)

Relief aspect

The digital elevation model 12.5 m resolutions have been used to qualify and determine the relief aspect listed in Table (2) with equations and sources. The hypsometric curve is a normalized area relationship curve that categorizes watersheds according to their geometric maturity, which is impact by a variety considerations such as the climate, lithology, and tectonics (37).

Table 2. Shows the formulas and sources for calculating relief aspect parameters in the Duhok Watershed

N.	Relief aspect	Code	Formula	Sources
1	*Watershed Relie*	H_r	$H_r = H - h$ Where, H = Maximum elevation (km), h = Minimum elevation (km)	(33)
2	*Relief Ratio*	R_h	$R_h = H_r / L$ Where, Hr = relief ratio (m), L = watershed length (m)	(15)
3	*Relative Relief*	R_{hp}	$R_{hp} = (H_r * 100)/p$ Where, Hr = relief ratio (m), P = watershed perimeter (km)	(27)
4	*Ruggedness Number*	RN	$RN = D_d * [H_r/1000]$ Where, Hr = watershed relief (m), Dd = Drainage density (Km/Km²)	(37)
5	*Hypsometric Integral*	H_I	$H_I=(H_{mean}-H_{min})/(H_{max}-H_{min})$ *Where H = elevation of the Watershed (m)*	(30)

Areal aspect: The watershed's areal aspects were estimated using morphometric methods proposed by various researchers are listed in table

Table 3. Shows the formulas and sources for calculating Areal aspects parameters in the Duhok Watershed

N.	Areal aspects	Code	Formula	Source
1	*Watershed Are*	A	*The location where snow and rain fall, delivering water to a stream.*	(38)
2	*Form factor*	R_f	$R_f = A/L^2$ *Where A = Watershed Ares (Km²). L = Length of the Watershed (Km)*	(30)
3	*Elongation rat*	R_e	$R_e = 2 * \sqrt{A/\pi}/L$ *Where A = Area of the Watershed Km2, L Watershed length (Km)*	(33)
4	*Circularity Ra*	R_c	$R_c = (12.57 * A)/P^2$ *Where A = Watershed Ares (Km²). P = Perimeter of the Watershed (Km)*	(29)
5	*Compactness Coefficient (Cc)*	R_p	$C_c = P/pc$ *Where P = Watershed Perimeter (Km), Pc = Perimeter of the cycle have the same area*	(13)
6	*Lemniscate Ra*	R_L	$R_L = (L^2)/4 * A$ *Where A Watershed Area (Km²)., L Watershed length (Km)*	(6)
7	*Drainage dens*	D_d	$D_d = L_u/A$ *Where, Lμ = Total stream length of all orders, A = Watershed Area (Km²).*	(16)
8	*nstant of Channel Maintenance*	C	$C = A/L_u$ *Where, Lμ = Total stream length of all orders, A = Watershed Area (Km²).*	(34)
9	*Stream Frequenc*	F_s	$F_s = Nu/A$ *Nμ = Total no. of streams of all orders A = Watershed area (Km²).*	(16)
10	*Infiltration numl*	I_f	$I_f = Dd * Fs$ *Where, Dd = Drainage density* $\left(\frac{Km}{Km2}\right)$ *s = Stream frequency*	(10)
11	*Texture Topogra*	T_t	$T_t = D_u / P$ *Where, Du = Steam number, P = Perimeter of the Watershed (Km)*	(16)

RESULT AND DISCUSSION

Morphometric parameters of Duhok watershed were studied in three portions (linear, areal, and relief aspects). Depending on stream order, ten sub-watershed are extracted from main watershed, and all result parameters are listed below.

Linear aspect: The stream number is a sum of total stream in all stream order (16). As stream order rises, the number of stream reduce, resulting in high infiltration in lower streams order in the watershed than in higher order streams (24). There are 4175 streams in the Duhok watershed, which are divided into six orders (Figure 3). The 1st order contains 3131 streams, 2nd stream order has 800 streams, the 3rd order has 195 streams, the 4th order has 39 streams, and 5th order streams 9 streams (Table 1). A Less permeability and infiltration are indicated by a higher stream number.

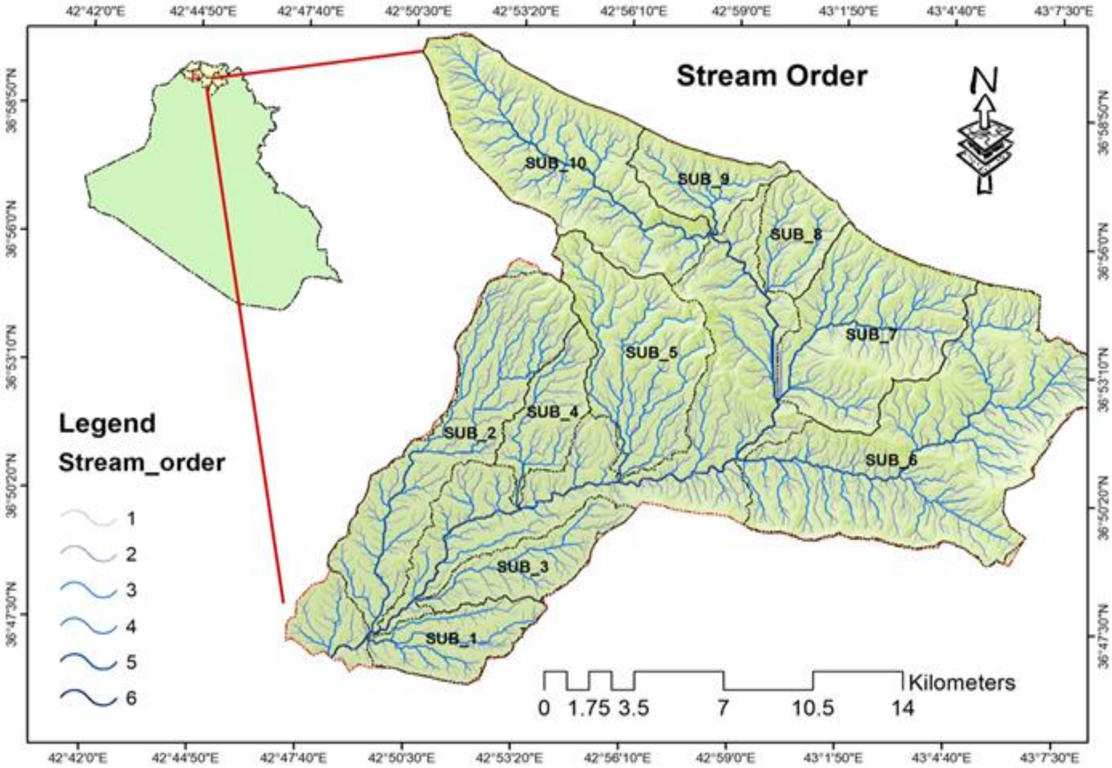

Fig. 2. Duhok watershed stream orders

There is the negative correlation between stream orders and stream numbers in Duhok watershed, (Figure 3), as stream order rises, the number of stream reduce. Then according to research area shows high significant correlation (R=1) between stream number and watershed area (Table 3), the largest sub-watershed (Sub_6) in size has maximum of streams (882) and smallest sub-watershed (Sub_8) in size has minimum of streams (127). The correlation values among linear parameters are showed in (Table 3).

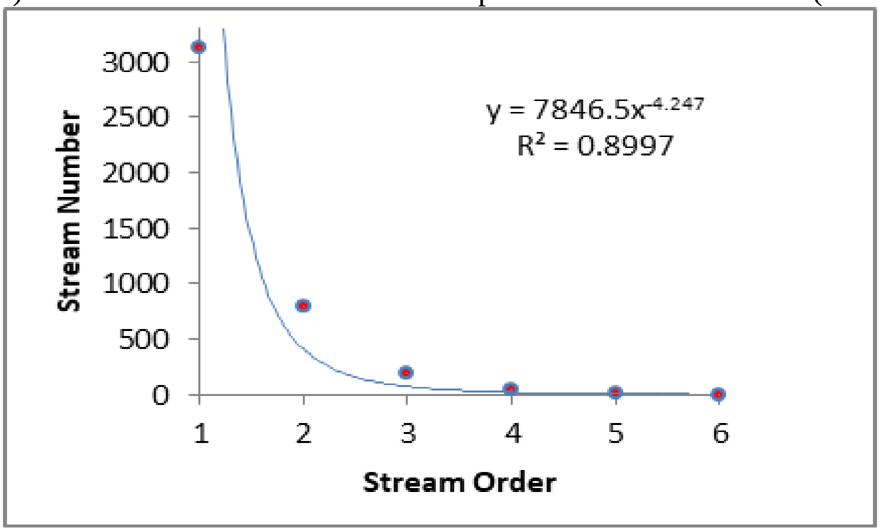

Fig. 3. Correlation between stream order and number of stream

Table 4. The Linear aspects results watershed of the Duhok

Linear aspect	Stream order	Sub Watershed										
		$Sub.1$	$Sub.2$	$Sub.3$	$Sub.4$	$Sub.5$	$Sub.6$	$Sub.7$	$Sub.8$	$Sub.9$	$Sub.10$	Wale watershed
Stream Number N_u	1	151	366	116	106	238	657	270	94	110	390	3131
	2	34	76	31	22	58	171	93	25	30	103	800
	3	8	16	5	6	13	46	21	5	6	36	195
	4	2	2	1	2	4	7	5	2	2	5	39
	5	1	1	0	1	1	1	1	1	1	1	9
	6											1
Stream Length L_u	1	29.42	88.61	30.92	24.95	54.33	158.41	71.87	20.41	21.71	92.73	745.79
	2	10.59	47.38	14.18	15.21	27.88	92.02	48.85	12.78	13.26	44.37	406.60
	3	11.00	26.85	5.22	5.46	20.44	45.97	18.59	6.03	8.05	27.60	207.18
	4	6.12	11.53	7.09	5.56	17.36	13.47	8.14	3.86	2.03	6.58	85.22
	5	1.36	9.33	0.00	1.91	2.76	12.71	7.17	0.23	1.51	11.23	48.84
	6											34.85
Mean Stream Length L_{sm}	1	0.19	0.24	0.27	0.24	0.23	0.24	0.27	0.22	0.20	0.24	0.24
	2	0.31	0.62	0.46	0.69	0.48	0.54	0.53	0.51	0.44	0.43	0.51
	3	1.37	1.68	1.04	0.91	1.57	1.00	0.89	1.21	1.34	0.77	1.06
	4	3.06	5.77	7.09	2.78	4.34	1.92	1.63	1.93	1.02	1.32	2.19
	5	1.36	9.33		1.91	2.76	12.71	7.17	0.23	1.51	11.23	5.43
	6											34.85
Stream Length Ratio R_L	2/1	1.60	2.57	1.72	2.94	2.11	2.23	1.97	2.35	2.24	1.81	2.13
	3/2	4.41	2.69	2.28	1.32	3.27	1.86	1.69	2.36	3.04	1.78	2.09
	4/3	2.23	3.44	6.79	3.06	2.76	1.93	1.84	1.60	0.76	1.72	2.06
	5/4	0.44	1.62		0.69	0.64	6.61	4.40	0.12	1.48	8.53	2.48
	6/5											6.42
Bifurcation Ratio (R_b)	1/2	4.44	4.82	3.74	4.82	4.10	3.84	2.90	3.76	3.67	3.79	3.91
	2/3	4.25	4.75	6.20	3.67	4.46	3.72	4.43	5	5	2.86	4.10
	3/4	4	8	5	3	3.25	6.57	4.2	2.5	3	7.20	5
	4/5	2	2		2	4	7	5	2	2	5	4.33
	5/6											9
Mean	3.67	4.89	4.98	3.37	3.95	5.28	4.13	3.32	3.42	4.71	5.27	3.67
Watershed Perimeter (P)		19.56	44.33	24.23	22.10	31.44	49.75	29.34	15.01	18.40	36.33	110.85
Watershed Length (L)		5.84	16.40	9.57	8.17	10.95	14.75	7.71	4.86	5.58	13.50	41.39

Horton (15) equation was used to calculating the stream's length, which is one of the most important hydrological variables because it represents surface runoff characteristics. The longer streams are found on lower and flatter terrain, while smaller streams are typically located on higher and steeper slopes, (24). Overall stream length of Duhok watershed is 1528.49 km, distributed on stream orders as follows: (745.79, 406.60, 207.18, 85.22, 48.84, and 34.85 km (Table 4). Figures 4 shows stream orders and length in Duhok watershed are negatively correlated, when the order of stream rise, Individual streams' geometric expansion frequently decreases.

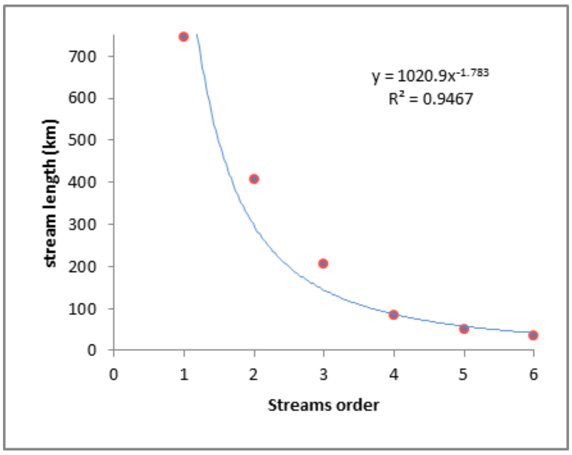

Fig. 4. Stream Length and Stream Order Correlation

The total stream length of an order is divided by the number of stream segments in that order to get the mean stream length, its describes the watershed size as a dimensionless property network with a contribution surface (37). The value of mean stream length of all sub-watersheds observed in (Table 2), for main watershed are ranged from 0.24 to 34.85. The unusual change in the mean stream length for sub-watersheds (Sub_1, Sub_4, Sub_8, Sub_9), is an indicate of the slope and topography change that have been used to evaluate the catchment area's age through time (31). Stream length ratio (R_L) is the proportion of one order's total stream length to the next lower order's total stream length. It has a strong connection to the stream's runoff, discharge, and erosion level (14). The Duhok watershed's value of stream length ratio is ranges from 2.13 to 6.42, as shown in Table 2. The shift in stream length ratio from one order to the next shows that the sub-watershed is approaching the end of its geomorphologic process, (35), this shift could be due to variance in slope and terrain.= Schumm (32) define a bifurcation ratio (R_b) is proportion of one order's stream numbers to the stream numbers higher order after that. The value of (R_b) ranged from 3.91 to 9 (Table 2). According to idea Strahler and Chow (39) when the bifurcation ratio for sub-watersheds falls between 3 and 5, it refers the geologic structure has minimum impact on the drainage pattern. From Table (2), mean bifurcation ratio varies between 3.32 and 5.28, this value suggesting that Duhok watershed is within the normal category.

Table 5. Correlation matrix of linear aspect for the sub-watersheds

Variables	Area (A)	Watershed Perimeter	Watershed Length	Stream Number	Stream Length	Mean Stream Length	Stream Length Ratio	Bifurcation Ratio
Area (A)	1							
Watershed Perimeter (P)	0.940*	1						
Watershed Length (L)	0.934*	0.982*	1					
Stream Number	1.000*	0.940*	0.934*	1				
Stream Length	1.000*	0.945*	0.938*	1.000*	1			
Mean Stream Length	0.870*	0.971*	0.968*	0.870*	0.876*	1		
Stream Length Ratio	0.004	0.000	0.002	0.003	0.004	0.022	1	
Bifurcation Ratio	0.300	0.482	0.460	0.303	0.307	0.610*	0.401	1

(R>0.90) very high correlation, (0.90≥ R>75) high correlation, (0.75≥ R>60) moderate correlation, *Correlation is significance at 0.05 level

Relief aspects: The Data in Table 6, shows the result of calculated relief aspects parameters. The watershed relief is a measurement of the elevation difference between the highest and lowest points in a watershed, it has an impact on river flow patterns and sediment loads. (13). The Duhok watershed relief is 1057 meters, with the peak elevation of 1389 meters (AMSL) and the lowest point elevation of 332 meters (Table 3). While the watershed relief for sub-watershed was ranged from (348) m for the first sub-watershed (Sub_1), to (1389) m for the last sub-watershed (Sub_10), The Watershed Relief determined stream slope that influences the amount of sediment that can be moved (21).

Table 6. The Relief aspect results for the Duhok Watershed

Relief aspect	Sub Watershed										
	Sub.1	Sub.2	Sub.3	Sub.4	Sub.5	Sub.6	Sub.7	Sub.8	Sub.9	Sub.10	Wale wat
Minimum elevation (h)	348	351	370	421	471	526	611	646	691	690	332
Maximum elevation (H)	483	1124	714	915	1218	1342	1198	1211	1212	1389	1389
Watershed Relief (H_r) Km	0.135	0.773	0.34	0.49	0.74	0.816	0.587	0.56	0.52	0.699	1.05
Relief Ratio (R_h)	0.023	0.047	0.03	0.06	0.06	0.055	0.076	0.11	0.09	0.052	0.02
Relative Relief (Rhp)	0.69	1.74	1.42	2.23	2.38	1.64	2.00	3.76	2.83	1.92	0.95
Ruggedness Number (RN)	0.54	3.30	1.33	1.98	2.68	3.26	2.25	2.00	1.90	2.60	4.09
Hypsometric Integral (H_I)	0.54	0.22	0.26	0.25	0.37	0.37	0.40	0.34	0.39	0.38	0.37

According to the results of Schumm, (32), the ratio of watershed relief to watershed length is referred as the relief ratio, it's a symbol for amount of the processes of erosion as well as the rate of sediment delivers. (37). The data in table 3, showed the Duhok watershed has (0.026 m/km) amount of relief ratio, and for sub-watershed are differs from 0.023 m/km (Sub_1) and 0.116 m/km (Sub_8). For present study the Melton (26) equation was used to compute relative relief. The dimensions of the relief basin can be displayed using relative relief without relation to the sea level (3). According to the statistics in Table 6, the Duhok watershed had a relative relief value of 0.95, while the sub-watersheds had relative relief values ranging from (0.69 - to 3.76), this high number suggests that the sub-watershed has eroded surface activation and significant runoff. A ruggedness number was calculated as the result of watershed relief and drainage density (38). Ruggedness number, watershed relief, and drainage density all have a direct link. It can be used to describe the slope's steepness and the length of the watershed. Subdead (0.1), modest (0.1 to 0.4), moderate (0.4 to 0.7), and sever (>0.7), ruggedness numbers were classified by (10) based on their morphology. The ruggedness number for the current study is 4.09, reflecting that the terrain is rugged with a lot of relief and a lot of stream density. All correlation data among the relief aspects were calculated (Table 9). The most significant correlation was between the ruggedness number and watershed relief.

Table 9. Correlation matrix of Relief aspect for the sub-watersheds

Variables	(A)	P	L	WR	RR	R_{hp}	RN	H_I
Area (A)	1							
Watershed Perimeter	0.969*	1						
Watershed Length	0.966*	0.991*	1					
Watershed Relief	0.695*	0.781*	0.760*	1				
Relief Ratio	-0.423	-0.496	-0.516	-0.001	1			
Relative Relief	-0.428	-0.491	-0.482	0.027	0.967*	1		
Ruggedness Number	0.691*	0.798*	0.776*	0.989*	-0.075	-0.048	1	
Hypsometric Integral	0.053	-0.045	-0.107	-0.288	-0.094	-0.251	-0.339	1

(R>0.90) very high correlation, (0.90≥ R>75) high correlation, (0.75≥ R>60) moderate correlation, *Correlation is significance at 0.05 level

The hypsometric integral's high value suggests that the basin is relatively new and not been eroded yet (39). In this study determined using the formula published by Pike and Wilson (29). The hypsometric integral of Duhok watershed has a value of 0.37 (Figure 10), represents the mature age stage. A hypsometric curve of a mature watershed is an S-shaped graph that rises at higher elevations and falls at lower elevations (11).

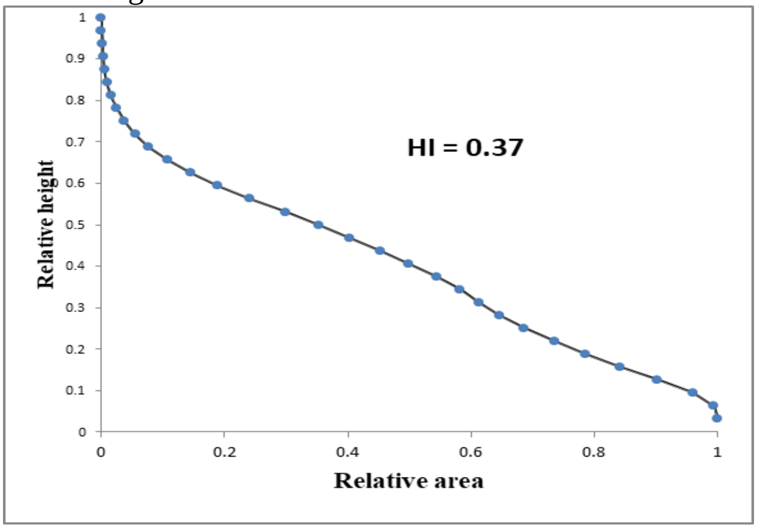

Fig. 5 Hypsometric curve of Duhok Watershed

Is one of the most critical elements in geomorphic analysis is watershed slope. As shown in Figure 5, the slope degree in the current study catchment ranged from 0 to 74°. As shown in Figure 5 The north part of watershed has a high slope compared to middle and South part of Duhok watershed, resulting in the lower sections reaches of fast sedimentation (24). A corroding to Zinck (45), Duhok watershed's slope is divided into five zones (fig. 6).

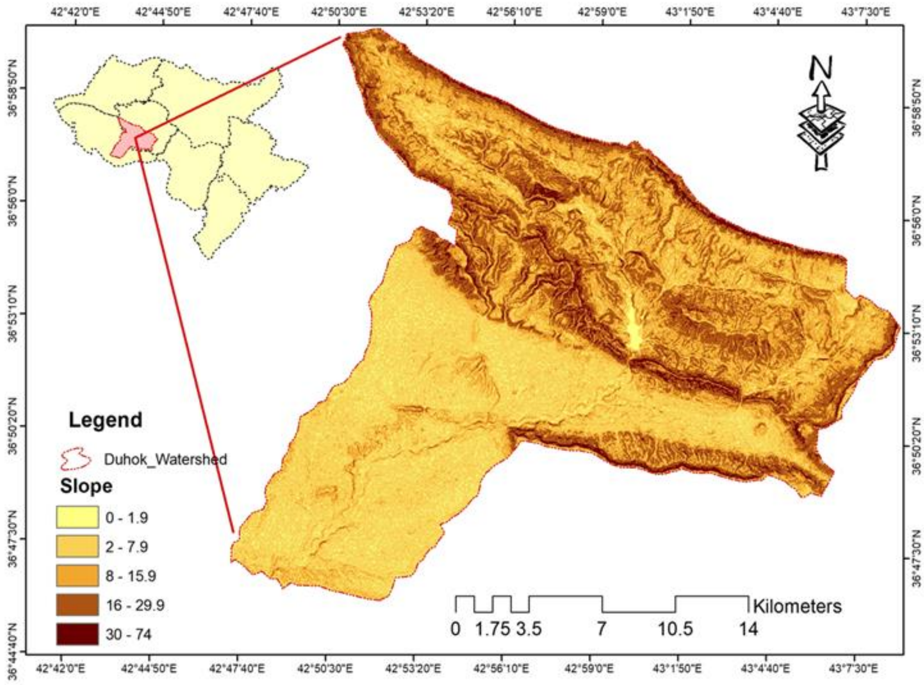

Fig. 6. Slope map, of Duhok watershed

Data in Table 10 shows the flat or almost flat area has 14.41 km2, while the Undulating area is a prevalent in Duhok watershed cover 162.22 km2, equivalent 41.08% of total area, whereas the rolling, hilly, and mountains area has respectively (26.94%, 21.99% and 3.65%) from total area of watershed.

Table 7. Slope classification in Duhok Watershed

No	slope (degree)	Area	Area %	Classification
1	0 - 1.9	23.78	6.02	flat or almost flat
2	2 - 7.9	162.22	41.08	Undulating
3	8 - 15.9	106.37	26.94	Rolling
4	16 – 29.9	86.81	21.99	Hilly
5	30 <	14.41	3.65	Mountains

The aspect is defined as face of the mountain slope, that directly affected by the local weather conditions. In the morning, slopes that face east receive more sunlight, whereas, face west slopes receive even more in the afternoon (9). The watershed aspect has an impact on the area's biodiversity and agricultural productivity (44). The aspect map was extracted from DEM 12.5 m resolution (Fig 7).

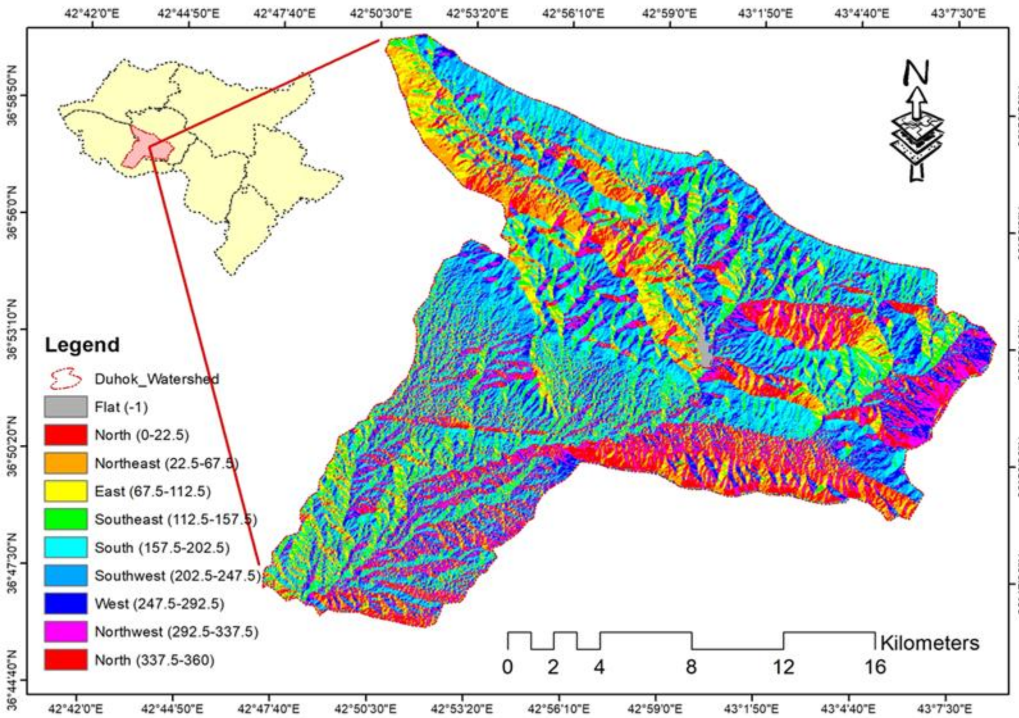

Fig. 7. Aspects of Duhok watershed

The South and Southwest aspects are common in the Duhok watershed, which has an area of 62.85 and 70.38 km^2 respectively, as seen in Table (11).

Table 8. Area of aspects in Duhok Watershed

No	Area	Area	%
1	Flat (-1)	13.66	3.46
2	North (0-22.5)	17.67	4.48
3	Northeast (22.5-67.5)	39.57	10.02
4	East (67.5-112.5)	34.20	8.66
5	Southeast (112.5-157.5)	45.57	11.54
6	South (157.5-202.5)	62.85	15.92
7	Southwest (202.5-247.5)	70.38	17.82
8	West (247.5-292.5)	49.61	12.56
9	Northwest (292.5-337.5)	44.18	11.19
10	North (337.5-360)	17.18	4.35
	SUM	394.87	100

Areal aspect: Stream length per unit of watershed is known as drainage density (D_d) (14). Vittala et al., (45), classified the into five classes: $[\text{extremely coarse } (<2), \text{coarse } (2-4), \text{moderate } (4-6), \text{fine } (6-8), \text{and extremely fine } (>8)]$.

Duhok Watershed has a drainage density of 3.87 km/km^2, and for sub-watershed it ranged from 3.54 to 4.27. According (44) Duhok watershed has coarse drainage density classification. The upper sub-watershed has coarse drainage density, while the lower sub-watershed has moderate drainage density, as shown in Figure (8). The fine drainage texture, heavy runoff, and potential erosion are due to high drainage density (37).

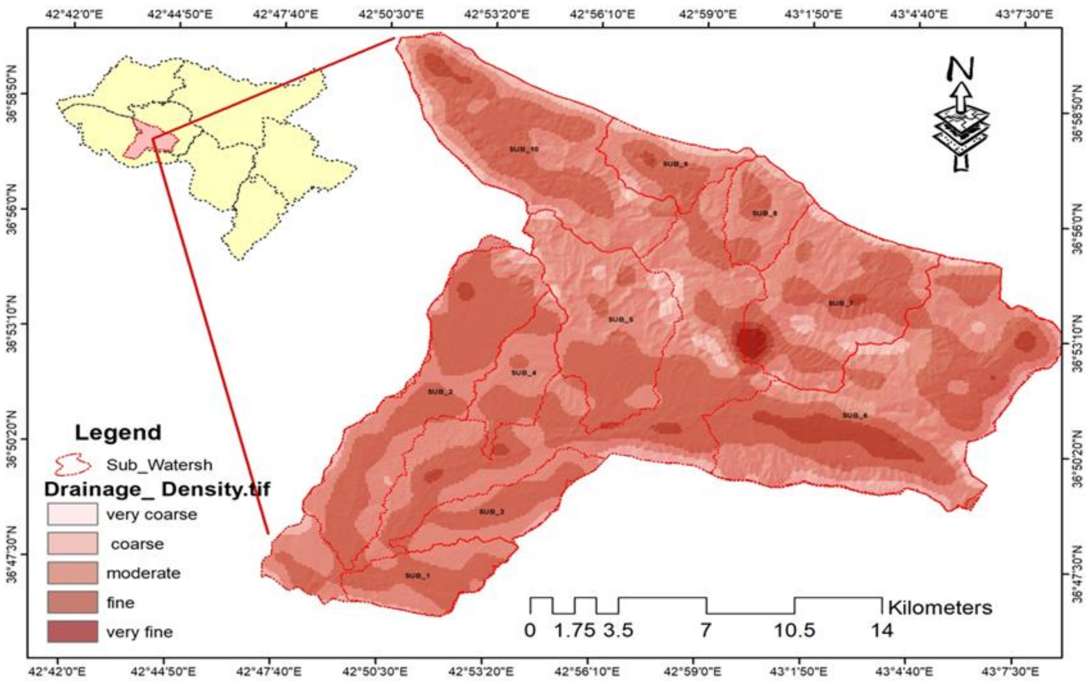

Fig. 8. Duhok watershed drainage density

Horton, (14) described as ratio of the area of watershed to the square length of watershed is referred as the form factor (R_f) . It's linked to the watershed shape, as well as its drainage texture and relief. The zero value denotes a watershed with an elongated shape, whereas the one value denotes a watershed with a circular shape. Low value of form factor will lead to flatter peak flow for a longer duration in watershed (4). In the Duhok watershed form factor is 0.23 and in the sub-watersheds ranged from 0.16 in (Sub_2) to 0.67 in (Sub_7). Table-10. which shows a moderately elongated shape with a flatter peak flow. According to Schumm, (32) the elongation ratio is calculated as the proportion of the diameters of a circle with same area as the watershed length. Dahiphale et al., (8). Reported, a watershed with a smaller than 0.7 elongation ratio, which is recognized by an elongated shape with significant relief and steep slopes resistant to head erosion. The elongation ratio is divided into four categories (5) [elongated (0.7), less elongated (0.7-0.8), oval (0.8-0.9), and circular (>0.9) elongated (0.7), less elongated (0.7-0.8), oval (0.8-0.9), and circular (>0.9)]. In Duhok Watershed was observed to be 0.54, indicating that the watershed has elongated shape, according to the value of the elongation ratio (Table 9), Most sub-watersheds have a shape that ranges from elongated to oval-shaped, but the (Sub_7) has a circular shape. Circularity ratio (Rc) is dividing the watershed area to the area of a circle with the same perimeter (27). A value closer to one indicates a more circular shape (37).The stream length, watersheds slope, geological structure, climatic conditions, land use, and vegetation cover all influence the circularity ratio (36). Table 10 shows it that the amount is 0.40, observing that it has an elongated shape. Both sub-watersheds (Sub_7 and Sub_8) have a value of circularity ratio of less than 0.5, which infers their near-circular shapes, while the other sub-watersheds have a value of more than 0.5, which means an elongated shape.

Table 9. Areal aspect results for the Duhok Watershed

Areal aspect	Sub − Watershed										
	Sub. 1	Sub. 2	Sub. 3	Sub. 4	Sub. 5	Sub. 6	Sub. 7	Sub. 8	Sub. 9	Sub. 10	Wale watershed
Area (A)	14.59	43.04	14.83	13.26	34.26	80.66	40.05	12.24	12.75	49.12	394.87
Form factor (R_f)	0.43	0.16	0.16	0.20	0.29	0.37	0.67	0.52	0.41	0.27	0.23
Elongation Ratio (Re)	0.74	0.45	0.45	0.50	0.60	0.69	0.93	0.81	0.72	0.59	0.54
Circularity Ratio (R_c)	0.48	0.28	0.32	0.34	0.44	0.41	0.58	0.68	0.47	0.47	0.40
Compactness Coefficient (	2.09	3.64	3.15	2.93	2.30	2.44	1.71	1.47	2.11	2.14	2.48
Lemniscate Ratio (R_l)	0.58	1.56	1.54	1.26	0.87	0.67	0.37	0.48	0.61	0.93	1.08
Drainage density(D_d)	4.01	4.27	3.87	4.01	3.58	4.00	3.84	3.54	3.65	3.72	3.87
Constant of Channel Maintenance (C)	0.25	0.23	0.26	0.25	0.28	0.25	0.26	0.28	0.27	0.27	0.26
Stream Frequency(F_s)	13.43	10.71	10.32	10.33	9.16	10.93	9.74	10.38	11.68	10.89	10.57
Infiltration Number (I_f)	53.85	45.72	39.94	41.39	32.84	43.73	37.40	36.71	42.65	40.48	40.93
Drainage Texture (T_t)	10.02	10.40	6.31	6.20	9.99	17.73	13.29	8.46	8.10	14.73	37.66

Depending to Horton, (15), result a stream frequency is dividing the total number of streams and the area of a watershed. In a watershed with a maximum drainage density and stream frequency, flooding is very common (17). Malik et al., (24) categorized stream frequency into four categories, [>2.5 suggested low stream frequency, (2.5-3.5) medium stream frequency, (3.5-4.5) dense stream frequency, and over 4.5 suggested very dense stream frequency]. The amount it in the current area was 10.69 (streams/km^2), with sub-watersheds ranging from 9.16 to 13.43 (streams/km^2) (Table 9). This reflects the high frequency of the stream. A high stream frequency causes maximum surface runoff and a steeper slope. The lemniscate's value has been used by Chorley et al., (6) to determine the watershed's slope, in addition, the lower value of the lemniscate refers to the increase in the length and number of streams in first orders of stream. For the Duhok watershed, the lemniscate (Rl) value is 1.08, with sub-watershed values ranging from (0.37 - 1.56) at (Table-10). There is high significant correlation (r=0.93) between lemniscate's ratio and the Compactness Coefficient in sub-watersheds. Also found negative significant with the each of Form factor, Elongation Ratio, and Circularity Ratio (r= −0.91, −0.95, −0.87) respectively (Table 10). The watershed area wanted for create and retain a unit length of stream channel is defined as constant of channel maintenance (C), (32). Also its opposite of drainage density and has a square per unit dimension (15). The rainfall duration relief, permeability, vegetation, and rock type, are all elements that influence channel maintenance. The constant of channel maintenance value for current research is 0.26. (Table 9). It means that to support 1 km of canal, 0.26 km^2 of land is required. The infiltration number (I_f) is an essential parameter for evaluating the infiltration aspects from watershed. That calculated by multiplying the drainage density (D_d) by the stream frequency (F_s). According to Khadri and Moharir, (22), results a maximum infiltration number indicates maximum surface runoff and low infiltration capacity. Infiltration number in Duhok watershed is 40.93, and for the sub-watershed are varies from 32.84 to 53.85. Lower infiltration capacity and higher runoff in Duhok watershed due to a higher infiltration number. The Compactness Coefficient (Cc) is a term acclimated to describe the connection between a watershed hydrologic and watershed circular with a similar location, and only influences by the watershed slope (18). The results showed in Table-10, that the watershed has a value of (2.48), which reflects the elongated shape for Duhok watershed. There are negative significant between compactness coefficient and each of Form factor, Elongation Ratio, and Circularity Ratio (r= −0.842, −0.877, −0.956) respectively (Table 11). Drainage texture (T_t) is calculated by dividing the total number of stream segments of all orders by the watershed's perimeter (14). Vegetation, lithology, soil type, infiltration capacity, relief, climate, rainfall, and stage of growth are some of the natural elements that influence drainage texture (35). The texture ratio is divided into four categories (35): [coarse texture < 4, intermediate texture (4-10), fine texture (10-15), and very fine texture >15]. The amount of the it for the Duhok watershed is 37.66, suggesting that the main watershed has a very fine drainage texture and it is more likely to erosion. The drainage texture of the sub-watershed various between (6.20 to 17.73), ranging from intermediate to very fine drainage texture. The data in (Table 10), showed very high significant correlation (r=0.97) between drainage texture and sub-watersheds.

Table 11. Correlation matrix of Areal aspect for the sub-watersheds

Variables	Area	F	E	CR	CF	LR	DD	CM	SF	IN	DT
Area	1										
Form factor	-0.213	1									
Elongation Ratio	-0.203	0.994*	1								
Circularity Ratio	-0.137	0.868*	0.883*	1							
Compactness Factor	0.054	-0.842*	-0.877*	-0.956*	1						
Lemniscate Ratio	0.127	-0.916*	-0.954*	-0.873*	0.931*	1					
Drainage density	0.084	-0.380	-0.419	-0.675*	0.722*	0.515	1				
Constant of Channel Maintenance	-0.101	0.373	0.413	0.677*	-0.711*	-0.506	-0.998*	1			
Stream Frequency	-0.084	0.078	0.123	0.009	-0.077	-0.199	0.292	-0.301	1		
Infiltration Number	-0.034	-0.097	-0.078	-0.276	0.242	0.057	0.655*	-0.660*	0.913*	1	
Drainage Texture	0.971*	-0.084	-0.067	-0.038	-0.063	-0.021	0.073	-0.093	-0.039	-0.002	1

(R>0.90) very high correlation, (0.90≥ R>75) high correlation, (0.75≥ R>60) moderate correlation, *Correlation is significance at 0.05 level

Conclusion

The morphometric characteristics of Duhok watershed were calculated and analyzed by using remote sensing integrated to GIS techniques to identifying hydrological performance, as well as planning and implementing land and water management. Three aspects of morphometric parameters have been identified (linear, areal, and relief) aspects. The total number of streams is 4175, which is dispersed in the sixth stream order, and the negative correlation found between number of stream and stream order, the number of streams reduces as the stream order rises. The studied area is classified as coarse texture, which has a drainage density of 3.87 km/km^2, the permeable subsurface and gentle slope of the Duhok watershed is indicated by the value of stream frequency (10.58). While the value of form factor e (0.23) reveals a flatter peak flow for a longer duration in the watersheds moderately elongated shape. With an elongation ratio of 0.54, the Duhok watershed has an elongated shape that is prone to significant erosion and, as a result, a higher sediment load in the channels. The watershed's constant of channel maintenance (0.82) implies subsoil permeability, and a gentle-to-moderate slope. The low value of the hypsometric integral (0.37) suggests that the watershed is in its mature age stage.

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