Using Digital Elevation Model (DEM) and it's applications in morphometric analysis for the upper part of Tigris River basin northern west of Iraq

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Abstract

Most morphometric studies have been based upon map derived data, spatial information technology i.e. remote sensing, geographic information system and global position system has proved to be an efficient tool in delineation of drainage pattern and water resources management and its planning. The study area located approximately between 42° 00 E' to 43° 30'E and 36° 00 'N to 36°59 'N, it covered an area about 9814.33 square kilometer between Ninewa and Duhok governorate, this study focused on calculate morphometric parameters to the area under study using suitable remote sensing data and GIS technologies.

The morphometric parameters were computed using ARC GIS version 9.3software. The drainage pattern derived from digital elevation data showed that the basin is dendritic to sub dendritic with 9 stream order. The total number of stream is 192824. The summation of stream length is 238125 km. Basin area is 9814.33 square kilometers, drainage density is 24.26 kilometers/square kilometers, circulation factor is 0.522, elongation factor is 0.99, bifurcation ratio is 3.81, form factor is 7.76, texture ratio is 476.4, relief ratio is 10.55, and stream frequency is 19.64. The computed morphometric parameters showed the late youth stage of the river age.

Key terms: basin; morphometric; DEM; Ninewa; GIS.

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إستخدام نموذج الإرتفاعات الرقمية وتقانة نظام المعلومات الجغرافية في التحليل المورفومتري للجزء العلوي لحوض نهر دجلة شمال غرب العراق.

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الملخص

إن معظم الدراسات المورفومترية تستخدم تقانة المعلومات الفراغية مثل التحسس النائي ونظام المعلومات الجغرافية ونظام تحديد الموقع العالمي في رسم انماط التصريف وإدارة الموارد المائية. تقع منطقة الدراسة بين خطي الطول 43 درجة الى 43 درجة و30 دقيقة شرقا و36 درجة الى 36 درجة و 59 دقيقة شمالاوتغطي مساحة مقدارها 8914.33 كيلومترا مربعا بين محافظتي نينوى ودهوك شمال غرب العراق. ركزت هذه الدراسة على حساب المعاملات المورفومترية للمنطقة المختارة بإستخدام بيانات التحسس النائي المناسبة وتقانة نظام المعلومات الجغرافية.

8914.33 كيلومترا مربعا والكثافة النهرية 24.26 كيلو متر/كيلومتر مربع ومعامل الإستدارة 0.522, معامل الإستطالة 0.99, نسبة التشعب 3.81, معامل الشكل 7.76, نسبة النسجة 476.4, نسبة التضرس10.55, والتكرار النهري 19.64. المعاملات المورفومترية المحتسبة تبين أن النهر في نهاية مرحلة الشباب ضمن التطور الجيومورفولوجي للنهر.

الكلمات الدالة: الحوض, المورفومترية, نموذج الأرتفاعات الرقمية, نينوى, جي آى اس.

Introduction

Remote sensing, GIS, and GPS has effective Tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process. The discharge area may be defined as the area which contributed water to a particular channel or set of channels; it is the source area of the precipitation eventually provided the stream channels by various paths (Leopold, et al., 1964). Using SRTM data and GIS techniques (Map Maker) is a speed, precision, fast and inexpensive way for calculating morphometric analysis (Farr and Kobrick, 2000. Due to the decrease of surface water in Iraq there is a need to understand the drainage network that feed the main rivers inside the Iraqi's border. Using remote sensing and GIS technology to compute basin morphometric parameters is the main objective of this paper.

Climate of study area

The climate of the study area is subject to the conditions of the climate of Iraq and thus the climate of the Mediterranean which is considers rainy cold in winter ant dry hot in summer. Depending on meteorological data obtained from Mosul meteorological station for the period (1975-2008) and using Köppen-Geiger climate classification which depend on the annual and monthly mean precipitation and temperature (M. Kottek et al., 2006), the type of climate is (BSh) which means semi arid hot (steppe) climate.

Table 1: Monthly average of climate parameters of Mosul Station for the period (1975-2008)

parameters	months											
	October	November	December	January	February	March	April	May	June	July	August	September
Temperature	22.0	14.59	9.49	7.69	9.3	12.87	18.23	24.69	30.4	39.15	33.45	28.65
Evaporation	140.67	58.12	27.35	29.43	43.98	82.69	130.98	227.65	327.23	369.96	312.4	228.4
Rain fall	22.12	86.98	124.95	131.0	120.11	130.21	93.65	38.97	1.69	0.31	0.08	1.15
R. humidity	46.33	64.56	79.35	79.99	73.25	76.13	60.87	42.23	27.33	24.6	25.9	31.1

Geological setting

The study area located in the north part of Iraq and comprises most of northern part of Ninewa governorate and the southwestern part of Duhok governorate between 42° 00 E' to 43° 30'E longitude and 36° 00 'N and 36°59 'N latitude (figure 1), it is comprise a sub basin that feed Tigris River inside Iraqi's borders . Geologically there were many formations exposed in the area under study, these formations are listed below and shown in figure 2. **Shiranish Formation** (Late Cretaceous (Campanian –Maasstrichtian) the type area of this formation comprises thin bedded argillaceous limestone overlain by blue pelagic marl (Bellen et al., 1959; in Jassim et al. 2006). **Sinjar - Aliji Formation: Sinjar Fn**. (Paleocene-Early Eocene) comprises of limestone of algal reef, lagoonal miliolid. The formation was deposited in predominantly in shallow water reef. **Aliji Fn.** (Paleocene-Early Eocene) comprises of argillaceous limestone and shale with occasional microscopic fragment of chert. **Khurmala - Gercus Formation: Gercus Fn**. M. Eocene(Lutetian) the type section in Duhok comprises 850m of red and purple shale, mudstone ,sandy and gritty marls, pebbly sandstone and conglomerate. **Khurmala Fn.** (Paleocene-Early Eocene) comprises dolomite and finely recrystallized limestone (Bellen et al., 1959; in Jassim et al. 2006). **Pilaspi - Avana Formation:** Middle-Late Eocene: Pilaspi & Avana Formations have the same age they are inter tongues with each other in many places in Iraq. Avana Formation consists of limestone, generally dolomitize and recrystallized. Pilaspi Formation consists of well bedded limestone, chalky and recrystalline with chert nodules in the upper part (Jassim et al., 2006). **Fatha Formation** (M. Miocene): The formation present in foot hill zone and Mesopotamian zone. In the high folded zone the formation is missing or replaced by clastic facies (Jameson, 1961; in Jassim et al. 2006). It is one of the most aerially widespread and economically important formations in Iraq, the rock composing this formation are anhydrite, Gypsum, and salt Interbedded with limestone and marl, the environment is evaporite lagoon (Buday&Jassim, 1984; in Jassim et al. 2006). **Injana Formation** (Late Miocene): The lithology of the formation is variable but it is essentially composed of mostly red or gray color silty marl or clay stone, the thickness is variable due to the original differences and the erosion (Buday &Jassim, 1980; in Jassim et al. 2006). **Mukdadiya Formation** (Late Miocene (messinian)): it is composed principally of clasitcs, mainly pebbly sandstone, sandstone and red mudstone. The sandstone is often strongly cross bedded. The formation is mostly distributed in foot hill zone and replaced almost by Bi Hassan formation; it was deposited in fluvial environment (Basi and Jassim, 1973); in Jassim et al 2006.

Quaternary deposits: These deposits are composed of alluvial fans, river terraces, floodplain deposits, which is usually consist of clay, loam, sand and conglomerate, as well as slope, and polygenetic deposits

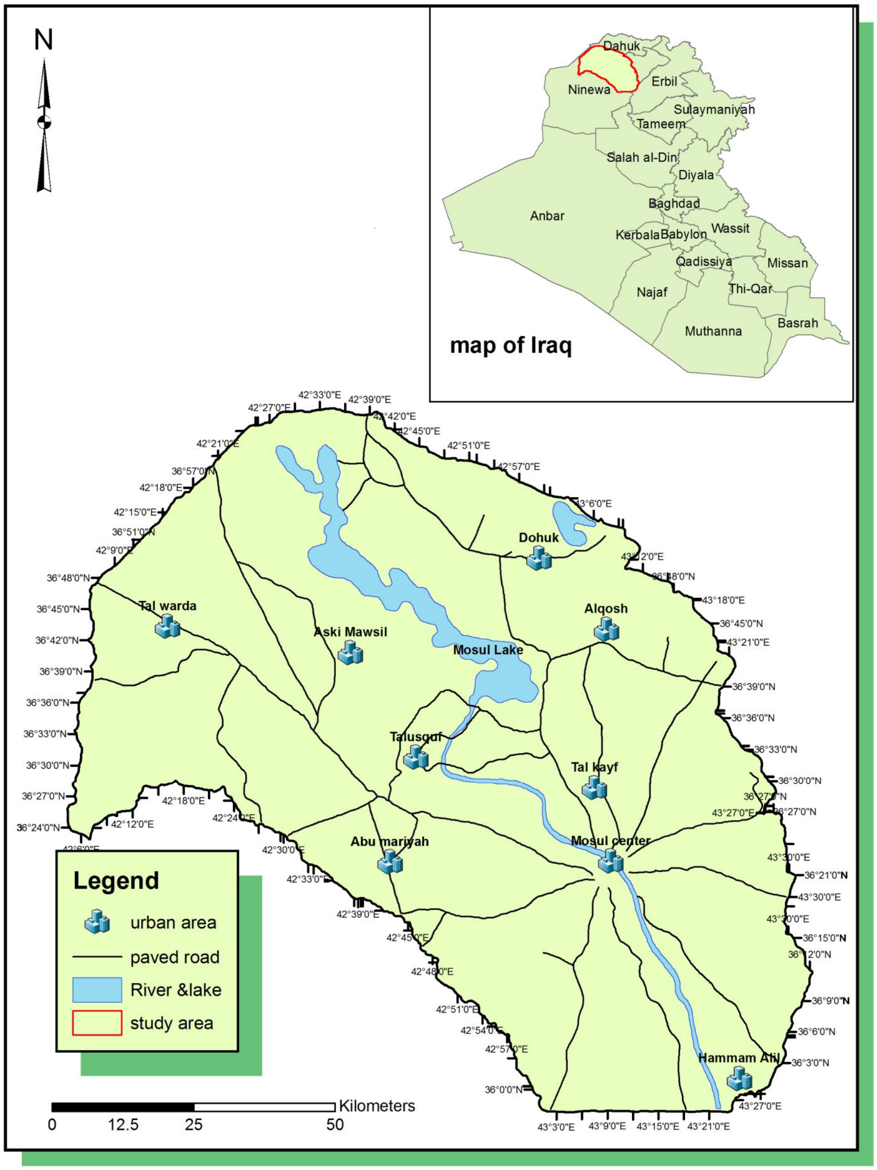

Figure 1: location map of study area.

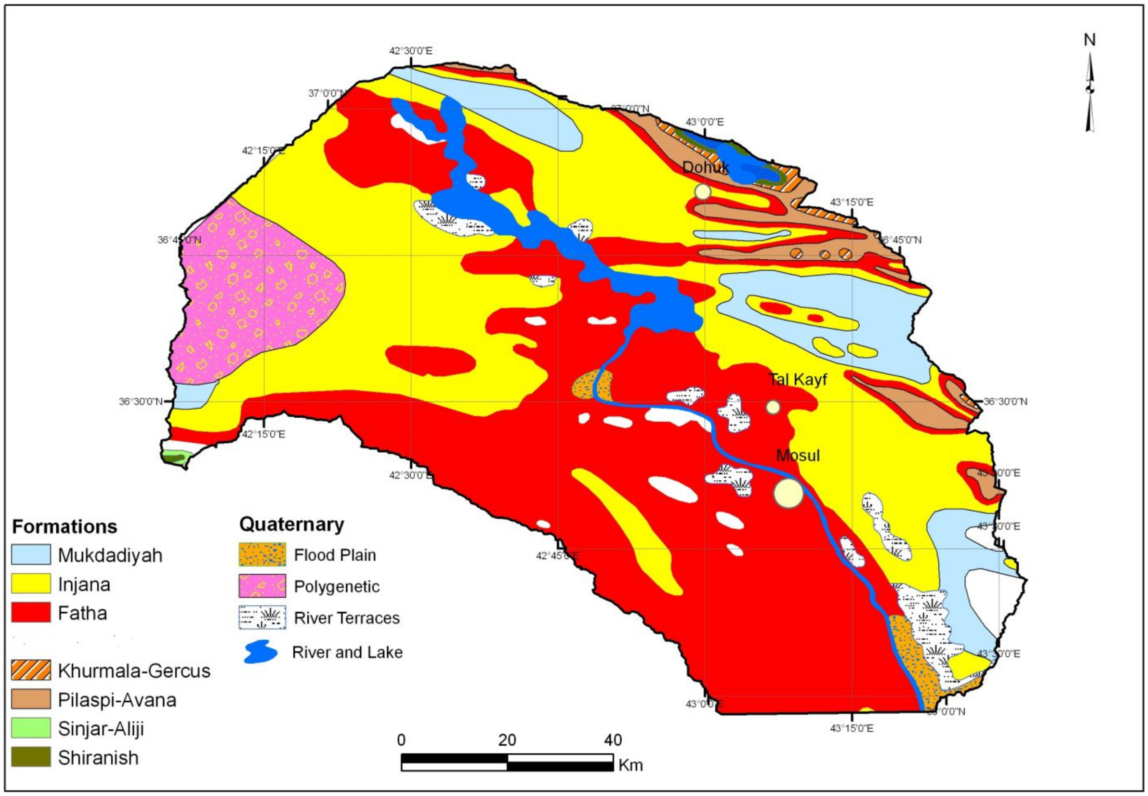

Figure 2: geological map of the study area.

Methodology

Digital elevation model (DEM) for Shuttle Radar Topography Mission (SRTM) image with ground resolution 90m was acquired in the year 2004 to be processed with the aid of Arc GIS 9.3 software to produce digital maps in order to calculate different morphometric parameters. Areal, linear, and relief features as well as hypsometric curve had been calculated based on the formula suggested by (Horton, 1945), (Strahler, 1964), (Schumm, 1956), and (Miller, 1953) in order to identify the characteristics of the basin under study.

Results and discussion:

The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the river basin (Nag and Chakraborty, 2003). The measurement of various morphometric parameters namely stream order, stream length (Lu), mean stream length

(Lsm), stream length ratio (RL), bifurcation ratio (Rb) mean bifurcation ratio (Rbm), relief ratio (Rh), form factor (Rf), circulatory ratio (Rc), elongation ratio (Re), drainage density (D), stream frequency (Fs) drainage texture (Rt) , has been carried out and the results are presented in Table 2and table 3.

Table 2: Areal aspects of the basin under study

Morphometric parameters	Area(sq.km)	Perimeter (km.)	Drainage density(km/ sq.km)	Stream frequency	Texture Ratio	Basin Length(km)	Elongation Ratio	Circularity Ratio	Form factor
symbols	A	P	$D=L_u/A$	$F_s=N_u/A$	$T=D_d * Fs$	L_b	Re	Rc	Rf
value	9814.33	485.615	24.26	20.4	476.4	112.43	0.99	0.522	0.77

Where L_u = Total stream length of all orders, N_u = Total no. of streams of all orders.

Linear aspects:

Stream order (N_u): Stream order determination represents the first step in the drainage basin analysis. Ranking of streams has been carried out based on the method proposed by Strahler (1964).The basin under study was represented a 9th order stream (Figure 3). The total number of streams are 200156 were identified of which 157029 are 1st order streams, 35795 are 2nd order, 5667 are 3 rd order, 1279 in 4th order, 294 in 5th order , 68 in 6th order and 18 in 7th order , 5 in 8th order , and one indicate 9th order. Drainage patterns of stream network from the basin have been observed as mainly dendritic to sub dendritic type which indicates the homogeneity in texture and lack of structural control.

Table3: linear aspects of the study area.

River basin	Stream order(u)	Stream Number(Nu)	stream Length(Lu) /km	Mean stream length	Stream length ratio(RL)	Bifurcation ratio	
						N^{rd}/N^{rd}	Ratio
Ninewa	1	157029	157029	1	1.59	1^{st}order/2^{nd}order	4.38
	2	35795	56926	1.59	1.88	2^{nd}order/3^{rd} order	6.31
	3	5667	17001	3	1.33	3^{rd} order/4^{th} order	4.4
	4	1279	5116	4	0.9	4^{th}order/5^{th} order	4.3
	5	294	1470	3.6	1.66	5^{th} order/6^{th} order	3.6
	6	68	408	6	1.16	6^{th} order/7^{th} order	3.7
	7	18	126	7	1.14	1^{st}order/8^{th} order	3.6
	8	5	40	8	1.12	8^{th}order/9^{th} order	0.2
	9	1	9	9		Average of the ratio	**3.81**

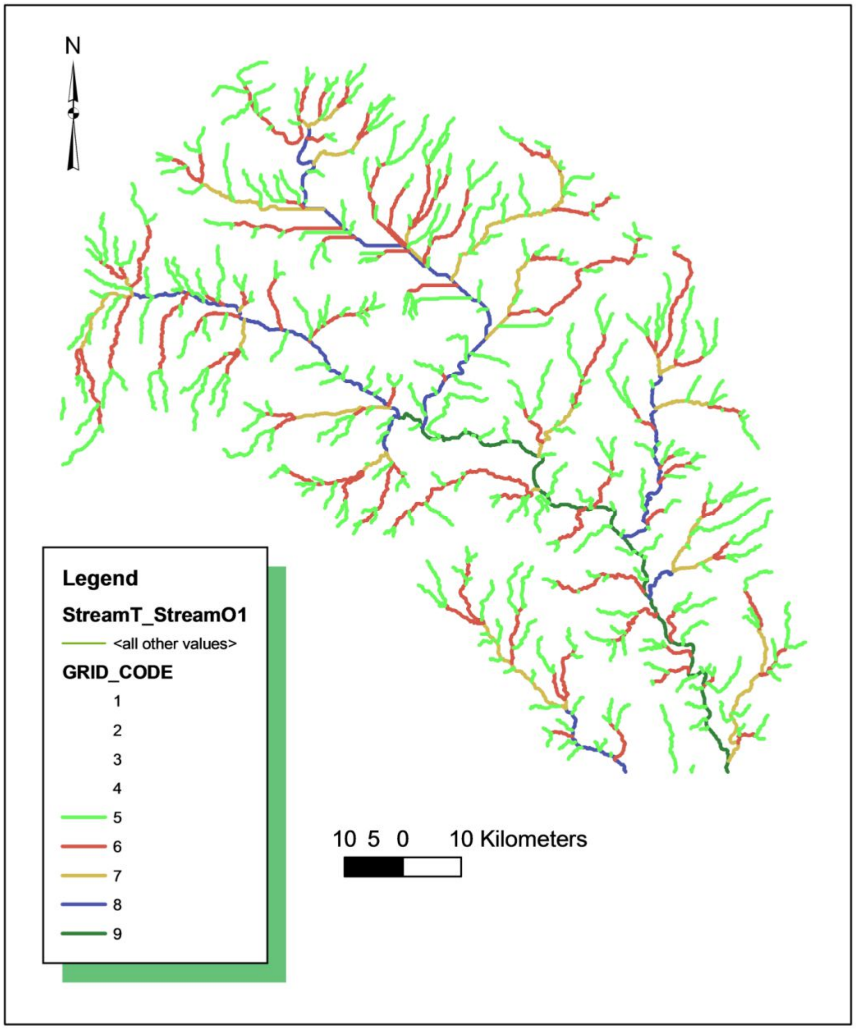

Figure 3: stream orders of the study area.

Stream Length (Lu):

Stream length is very important feature and related with the slope of the basin. When the streams lengths are relatively short, this situation is indicate steep slope and vice versa. The numbers of streams of various orders in the basin are counted and their lengths from mouth to drainage divide are measured with the help of GIS software (table3). Stream lengths were measured based on the law proposed by Horton (1945) in Garde (2006).

Mean Stream Length

The Mean stream length has been calculated by dividing the total streams length of order (u) by the number of streams in the same order. The variation of mean stream length values might be due to change in topographic elevation and lithologic variation in the basin.

Stream Length Ratio (RL):

Stream length ratio (RL) is the ratio of the total mean length of an order to the total stream length of next lower order (Horton, 1945 in Garde, 2006).The variation in slope and topography, indicating the late youth stage of geomorphic development in the streams of the basin. This variation might be reflected on the values of RL table (3).

Bifurcation Ratio (R_b):

It is the ratio of the number of streams of any given order to the number of streams in next higher order it range between 3.0 and 5.0 (Huggett, R. J., 2007). Bifurcation ratio shows a small range of variation for different regions or for different environments except where the powerful geological control dominates .For the basin under study the mean bifurcation ratio value is 3.81 that mean drainage pattern is less affected by geologic structure.

Basin Length (L):

According to Gregory and Walling (1973), L is the longest length of the basin, represents the distance from the catchment (farthest point on the perimeter of the basin) to the mouth of the basin. The length of the river basin under study is 112.43 km.

Areal aspects of the study area:

Area of any basin (A) and perimeter (P) are important parameters in quantitative morphology. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins; it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps (Chorley, et al., 1957).the total area of the basin is 9814.33 km^2 and the perimeter value of the basin is 485.615 km.

Drainage Density (D_d):

It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area, it is indicates the closeness of spacing of channels and relates with resistant of subsoil materials, region relief, and vegetation cover. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahler, 1964). Drainage densities can range from less than 5 km/km2 when slopes are gentle, rainfall low, and bedrock permeable (e.g. sandstones), to much larger values of more than 500 km/km2 in upland areas where rocks are impermeable, slopes are steep, and rainfall totals are high (e.g. un vegetated clay). The drainage density (D_d) of the study area is 238125/9814.33 =24.26 km/sq. km which indicates low drainage density.

Stream frequency (F_S):

The stream frequency (Fs) of a basin defined as the ratio between the total numbers of segments for all orders within a basin and the basin area (Horton 1945):

$Fs = \sum N_u/A = 200156/9814.34 = 20.4\ km/km^2$

Where $\sum Nu$ = Total number of stream segments of all orders and A = Total area of the basin. The Fs of the basin of study area is 20.4 km/km^2.

Texture Ratio (T):

Texture ratio is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain. The soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate. The texture of a rock is commonly dependent upon vegetation type and climate (Dornkamp and King 1971). In simple terms T is the product of D_d and Fs. It can be expressed by the equation (Smith 1950)

$T = D_d * Fs$

In the present study the texture ratio of the basin is 476.4 and categorized as ultra fine in nature. According to Smith (1950), five different drainage textures have been classified based on the drainage density. The drainage density less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. The basin under study has high values of T, which indicates very fine drainage texture affected by the surrounding rocks

Elongation Ratio (Re):

Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). Values near to 1.0 are typical of regions of very low relief (Strahler, 1964). The value R_e of the study area is 0.99 indicates high relief of the terrain and extremely elongated in shape.

Circularity Ratio (R_c):

It is the ratio of basin area to the area of circle having the same perimeter as the basin (Miller, 1953). The circulatory ratio is mainly concerned with the length and frequency of streams; geological structures, land use – land cover, climate, relief and slope of the basin. The Circularity Ratio of the study area is 0.522 indicated that the shape of the basin between the circle and rectangle and reflected the beginning of mature stage.

Form Factor Ratio (R_f):

Form factor is the dimensionless ratio was defined as the ratio of the area of the basin and square of basin length (Horton, 1932 in Garde, 2006). Form factor of the study area is 0.77 which indicates that the form of the basin is sub-circular and elongated in shape.

Relief Ratio:

It is the dimensionless height-length ratio equal to the tangent of the angle formed by two planes intersecting at the mouth of the basin, one representing the horizontal, the other passing through the highest point of the basin. Relief ratio has direct relationship between the relief and channel gradient. The relief ratio normally increases with decreasing drainage area and size of the watersheds of a given drainage basin (Gottaschalk, 1964). The Relief ratio is calculated by using the following formula: Relief ratio = H - h=L where H = highest elevation in the basin, h = lowest elevation in the basin and L = longest axis of the basin (Schumm,

1963) in the present study this ratio is equal to (1370-183)/112.4= 10.56.All Areal aspects are represented in table 2.

The relation between river valleys shapes with stream order:

In this paper there is an attempt to study the shape of active channel with the order of the streams. By making cross sections on the streams of 6th, 7th, 8th, and 9th order we can see with the increasing in stream order the shape of river valley prone to wide whereas in the lowest order it takes v shape depending on the slope as shown in the figures(4A-D).Figure 4D shows the changes in river valley shape even in the same order according to the changes in slope as it appears in cross section 4, the valley is prone to widening because of decreasing in slope while in cross section 1, 2, and 3 the valleys takes V shape because of steep slope.

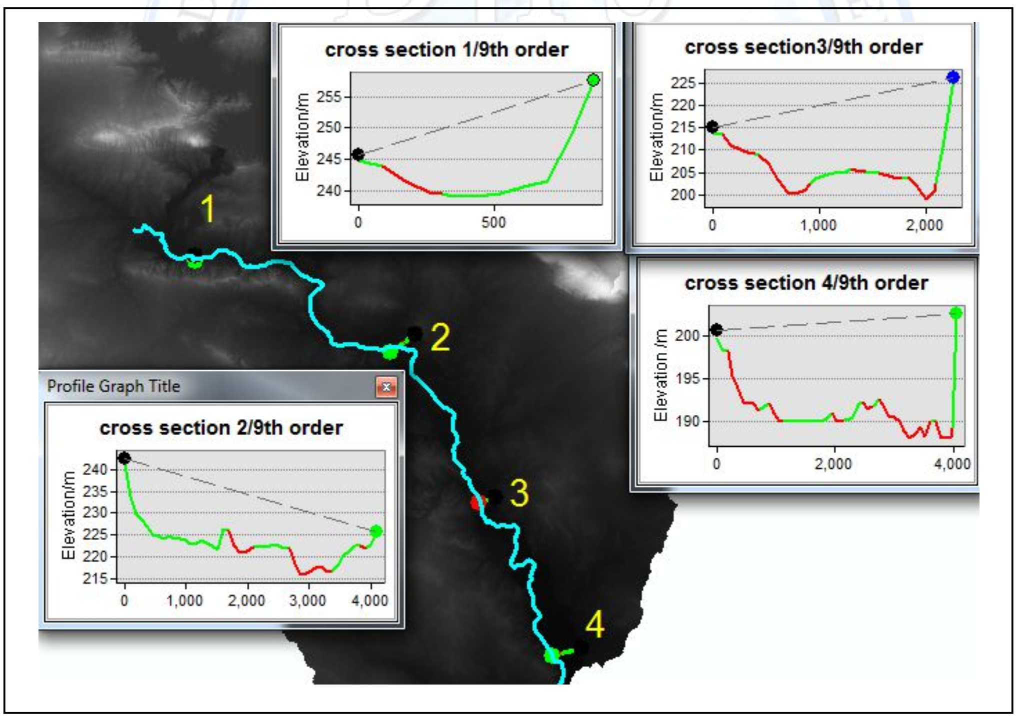

Figure (4A): valley shape for order 9.

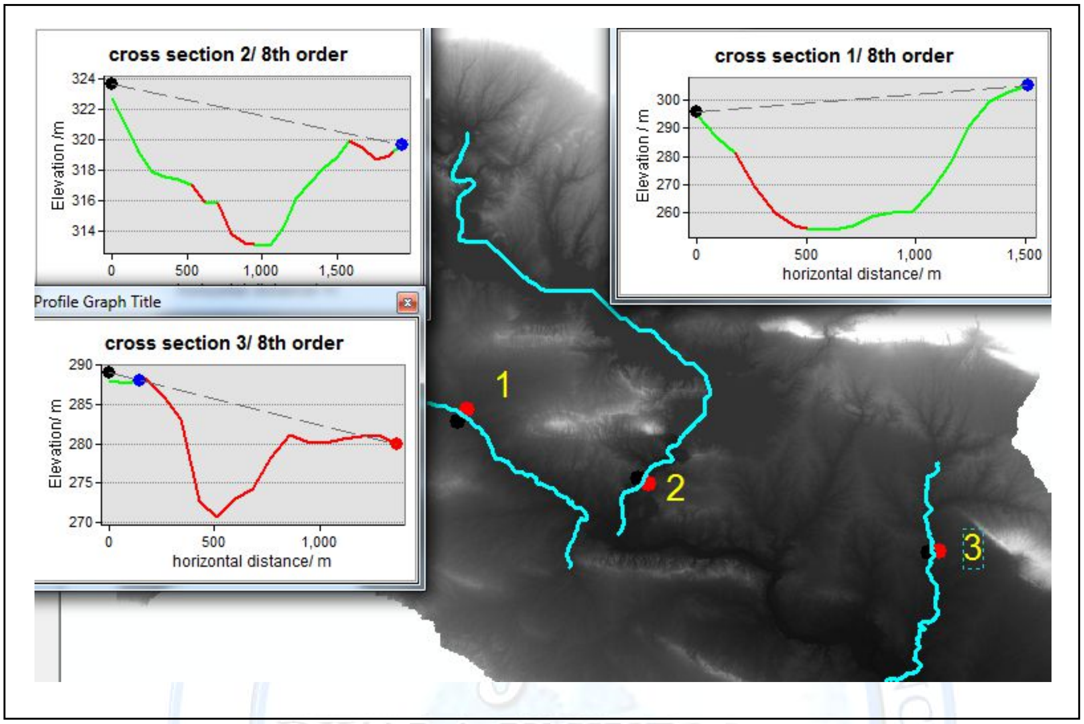

Figure (4B): valley shape for order 8.

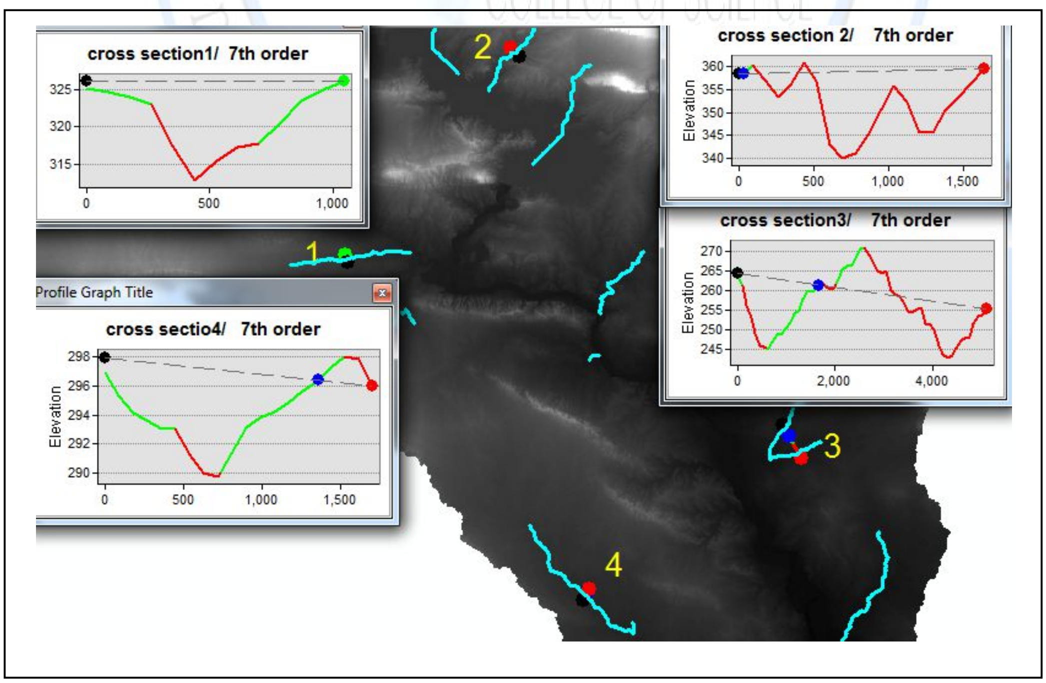

Figure (4C): valley shape for order 7.

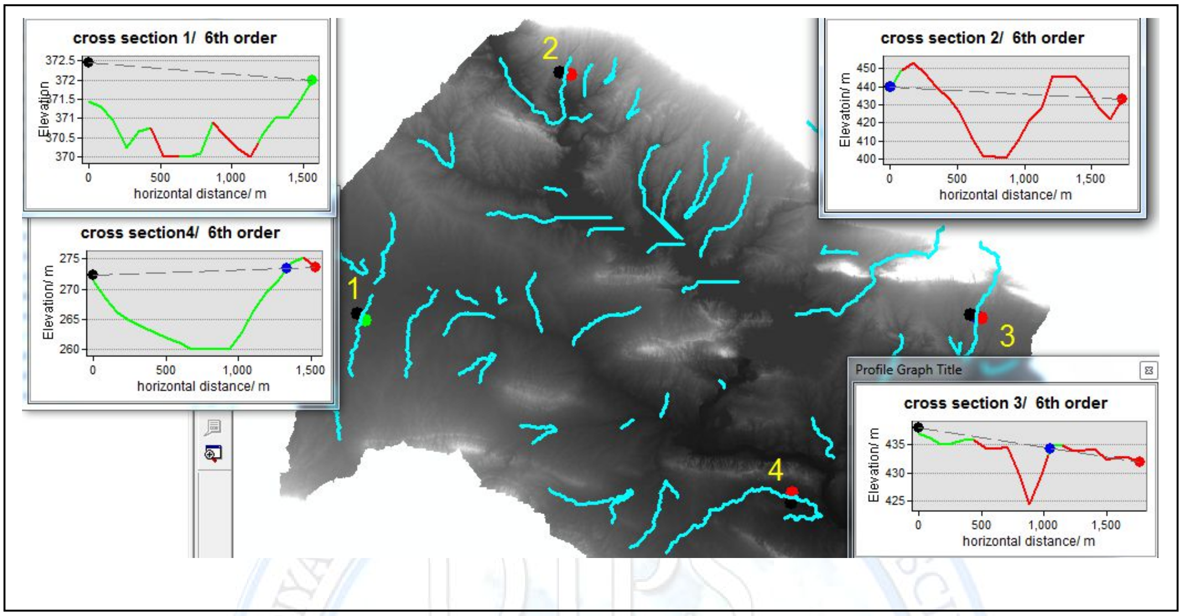

Figure (4D): valley shape for order 6.

Hypsometric Analysis

Hypsometric analysis is the study of the distribution of topographic surface area with respect to altitude (Figure5). The hypsometric curves express not only the stage of the 'geomorphic cycle' but also the complexity of denudation processes and the rate of the geomorphological changes in drainage basin. Such changes take place through subsequent stages of dynamic equilibrium between tectonic uplift and denudation (Ciccacci *et al.*, 1992).Hypsometric factor reflects the development stages for water basin as time scale factor, which is calculated as follows:

Hypsometric factor = relative height / relative area = (h/H) / (a/A)

The relative area was plotted versus relative heights for the basin under study; the shape of the curve reflects mature stage of river geomorphic cycle (figure 6). The hypsometric curve is a graph of area-altitude distribution that is dimensionless, meaning that its factor out of both the total size of the area being studied and the total amount of relief. The hypsometric curve is a plot of relative height (h/H) versus relative area (a/A) as in table 4. Using the hypsometric curve, different areas can be compared in order to study the effects of different bedrock types or the balance between tectonics and erosion. Strahler's, 1964 hypsometric curves and integrals identify quantitatively the stages of the division geomorphic cycle. Convex curves, with hypsometric integrals higher than 0.60, indicate equilibrium stage of 'youth'. Smoothly S-shaped curves that cross approximately the centre of the diagram and have integrals ranging from 0.60 to 0.40; express the equilibrium stage of maturity or the old stage.

Table4: Hypsometric factor for the basin under study.

Zone	Elevation (m)		Area of the zone (a) in Km²	% Relative area a/A	Relative heights h/H	Hypso-metric Factor	Average of hypsometric value
	from	To					
A	183	383	6045.2	61.59	200/200 = 1	0.016	0.354
B	383	583	3086.62	31.45	200/400 = 0.5	0.15	
C	583	783	363.51	3.70	200/600 = 0.33	0.089	
D	783	983	235.87	2.40	200/800 = 0.25	0.10	
E	983	1183	72.98	0.74	200/1000 = 0.2	0.27	
F	1183	1370	10.15	0.10	187/1178 = 0.15	1.5	

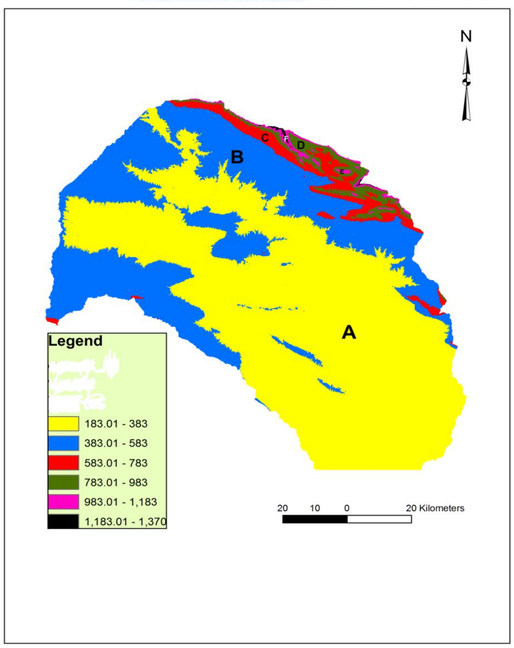

Figure (5): subdivision area for the basin under study.

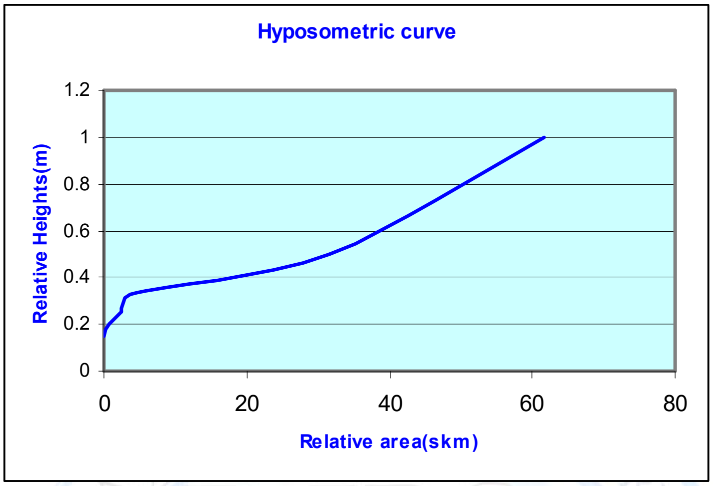

Figure (6): hypsometric curve for the basin under study.

Conclusions

Morphometric analysis curried out in the upper part of Tigris River basin northwest of Iraq showing moderate to high relief of the terrain and sub circular to elongation shape .Drainage network of the basin exhibit dendritic to sub dendritic network type which indicates the homogeneity in texture. The variation in stream length ratio might be due to change in slope and topography. The values of form factor and circulatory ratio indicate sub-circular and elongated shape in the basin. Hypsometric analysis reflects the maturity to old stage of river geomorphologic evolution. DEM with resolution (30*30M) prefer for drainages delineation because it gives more details and corresponding with surface than (90*90 M). Depending on subdivision area map we can consider that most of the basin area is within the range 183 to 383 m above sea level that leading to concentration of highest orders of streams because of decreasing in slope which gives more opportunities to accumulate water volume in this area. The variation in valley shapes of all orders is due to variation in slope and the topography.

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