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MORPHOMETRIC EVALUATION OF KUBAYSA DRAINAGE BASIN USING GEOGRAPHIC INFORMATION SYSTEM

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Key words: Morphometry, Kubaysa basin, Linear aspects, Areal aspects, Relief aspects, Iraq

ABSTRACT

The hydrological analysis of Kubaysa drainage basin has been studied using a Geographic Information System (GIS) program as a tool to understand the morphological systems and their interrelationships. The study focuses mainly on the geometry, more emphasis being placed on the relationship between morphometric characteristics such as; stream order (Nu), stream length (Lu), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf), comprising the area properties and forming the base of analysis of the drainage basin. A total number of 383 streams are identified of which 297 are 1st order, 66 are 2nd order, 15 are 3rd order, 4 are 4th order and one is of 5th order.

The drainage pattern of the stream network is mainly of dendritic type, which indicates the homogeneity in texture and possible lack of structural control. The mean bifurcation ratio for the study area is 4.7 which falls within the standard range and shows that the basin conforms to the characteristics of a natural stream and indicating that the geological structures are less disturbing to the drainage pattern. The drainage density (D) of the study area is 0.91 Km/Km^2. This value indicates that for every 1.0 square kilometer of the basin, there is 0.9 kilometer of stream channel. This makes the study area lie within the group of low density basins, which suggests indicates that the basin consists of moderately permeable rocks. The elongation ratio (Re) is 0.48; the basin in the study area assumes a pear shaped characteristics indicating high degree of integration. The circularity ratio is 0.43, which indicates that the basin is oval; tending towards elongation in shape with high level of integration.

التقييم المورفوميتري لحوض تصريف كبيسة باستخدام نظام المعلومات الجغرافية

لؤي داود يوسف

المستخلص

تم اجراء تحليل مورفوميتري لحوض التصريف لمنطقة كبيسة لدراسة الأنظمة المورفوميترية باستخدام نظام المعلومات الجغرافية. ركز التحليل على هندسية الحوض وعلى العلاقات بين خصائصه المورفوميترية مثل: رتب مجارى الوديان وأعدادها وأطوالها ونسبة التشعب وشدة (كثافة) مجاري الوديان ونسبة استطالة الحوض ونسبة تكوره (دائريته) وعامل الشكل، متظمنةً خصائص الامتداد المساحي للحوض.

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تم تحديد 383 مجرى وادي موسمي، كان منه 297 مجرى ذو رتبة أولى و 66 مجرى ذو رتبة ثانية و 15 ذو رتبة ثالثة و 4 ذو رتبة رابعة ومجرى واحد فقط ذو رتبة خامسة. بلغ متوسط نسبة التشعب 4.7 وتصنّف انها اعتيادية (Normal) التشعب وحوض التصريف أقل تأثراً بالعوامل التركيبية. كثافة التصريف أو شدة (مجاري الوديان) كانت 0.91 كم^2 وهذا يجعل المنطقة تقع ضمن الأحواض قليلة الكثافة وان صخورها متوسطة النفاذية. أما متوسط نسبة الاستطالة فكانت 0.48 مما يعطي للحوض الشكل الكمثري وكذلك كانت نسبة التكور (الشكل الدائري) بمتوسط 0.43 والذي يدل على ان الحوض بيضوي الشكل مائل نحو الاستطالة وبدرجة عالية من التكامل.

INTRODUCTION

Arc GIS V.9.3 has been used as a helpful tool to quantify and understand the hydrological characters, since their results are a useful input for the morphometric analyses for a comprehensive water resource management and plans. Morphometric studies involve evaluation of streams through the measurement of various stream parameters. Horton's (1945) ‘law of stream lengths’ suggested a geometric relationship between the number of stream segments in successive stream orders and landforms. Quantitative description of the basin morphometry also includes the characterization of linear and areal features, gradient of channel network and contributing ground slopes of the drainage basin.

Morphometry is the measurement and mathematical analysis of the configuration of the earth’s surface, shape and dimension of its landforms (Babar and Kaplay, 1998 and Obi Reddy *et al*., 2002). The morphometric study of the drainage basin aims to acquire accurate data of measurable features of stream network. The drainage provides a base to understand initial slope, inequalities in rock hardness, structural control, geological and geomorphological history. The basin morphometric characteristics of various basins have been studied by many researchers using the conventional methods, remote sensing and GIS methods (Smith, 1950; Strahler, 1957 and Shah and Babar, 2009).

In various researches, morphometric analyses were used for basin characterization (Sinha *et al*., 1990; Kulkarni *et al*., 1994; Adyalkar *et al*., 1996; Bhagavan, 1998; and Patil *et al*., 1999). Accordingly, morphological characteristics such as stream order, drainage density, channel slope, relief, and length of overland flow, stream frequency and other morphological aspects of watershed are important in understanding the hydrology (Romshoo Shakil Ahmad *et al*., 2012).

The present study has set the following as its aims:

- Investigate the morphometric parameters and drainage pattern of the area watershed, which explain the main sub-basins that control the gathering of water to the main valleys.
- To extract and delineate drainage morphometric characteristics (Linear, Aerial and Relief).
- To understand the relationships of the morphometrical system.
- Assess the morphometric characteristics of the Kubaysa Drainage Basin, which drains in Euphrates River, north of Hit city, west of Anbar Governorate of Iraq.

The study area of Kubaysa drainage basin is geographically located between 33° 22' 30'' – 33° 45' 00'' N and 42° 00' 00'' – 42° 52' 30'' E covering an area of 716.14 Km^2 (Fig.1).

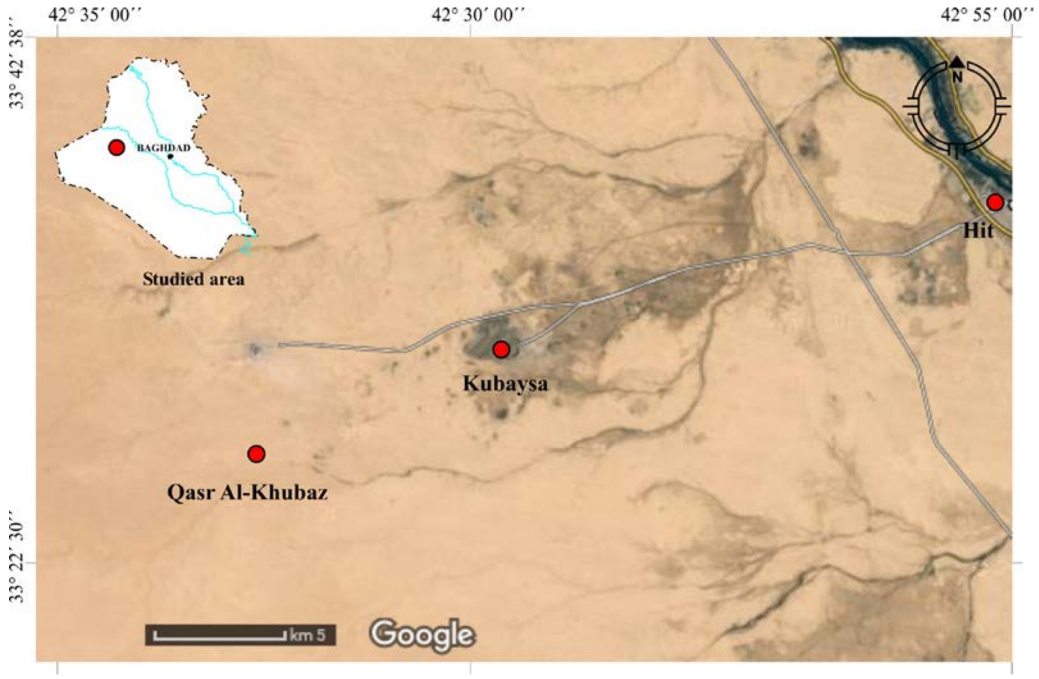

Fig.1: Location map and Satellite image of the studied area (Google Earth 2016)

- **Geological Setting of Kubaysa Drainage Basin**

The study area is a flat desert terrain, relatively gently sloping east- and northeast-words, dissected by some relatively, shallow (not more than five meters depth) ephemeral valleys and the topographic relief is low due to very gently dipping strata, towards the northeast (N 55° E). These strata are composed of the carbonate rocks of the Euphrates Formation (Lower Miocene) and comprised of the Lower Member in western and central parts and the Upper Member in the central and eastern parts of the area. The Euphrates Formation in Qasr Al-Khubaz − Hit area is (20 − 40) m thick and consists of "Shelly, chalky, well bedded, relatively hard recrystallized limestone and dolomitic limestone" (Bellen *et al*., 1959, and Hamza, 1975). The limestone is weathered, fractured and karstified near the surface (Al-Jiburi and Al-Basrawi, 2007).

In some places, the Nfayil Formation (with its two members) is exposed in the eastern parts of the studied area. The two members of the Nfayil Formation are of cyclic nature. The older Lower Member is composed of three cycles; each cycle consists of a thick bed of green marl, and a grey fossiliferous limestone. The second cycle is characterized by an oyster bed. The Upper Member consists of cyclic deposits; each cycle consists of reddish brown claystone, siltstone and sandstone (Sissakian and Mohammed, 2009). Hamza (1975) in Hit – Kubaysa vicinity, mapped the Nfayil Formation as "unit of alternating marl and limestone". He described the marl as soft and green, whereas the limestone as white and fossiliferous, with oyster and corals (locally). In most of the studied area, the Neogene rocks are covered by Quaternary sediments, in forms of residual soil and valley fill sediments (Fig.2). Large parts of the western part of the studied area are covered by residual soil, in contrast to the other two parts. The soil is brown to reddish brown, silty and clayey, very rarely sandy and calcareous, with small rock fragments, which increase in size and abundance depth wards. The thickness ranges from (0.5 – 1.5) m, but exceptionally may reach few meters. The main valleys are filled by different clastic deposits, which are highly variable in composition, size and thickness. The main composition is carbonate with silicate. The thickness ranges from (0.5 – 2.5) m.

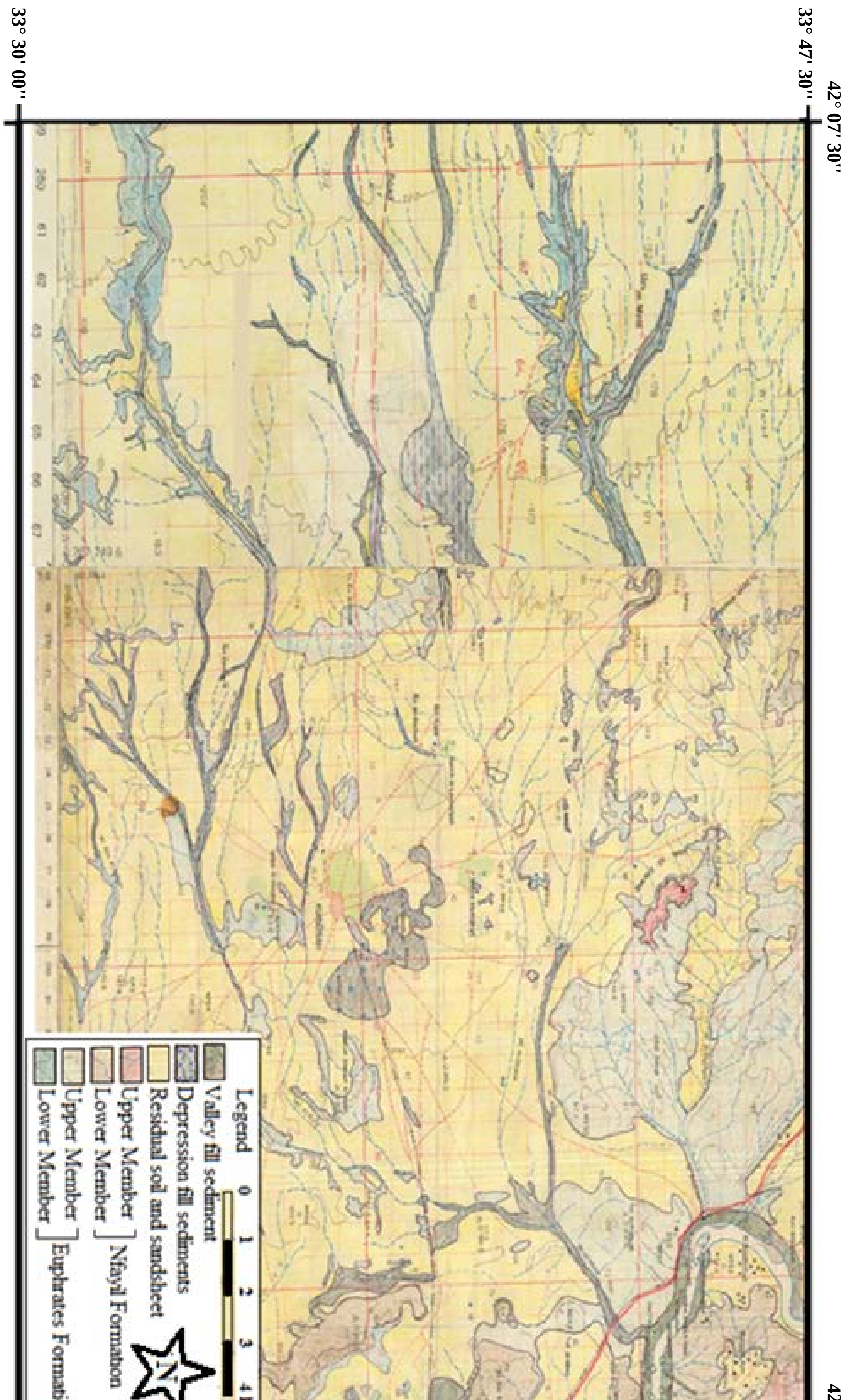

Fig.2: Geological map of the studied area (Amin *et al.*, 1988)

Physiographically, the studied area is located on the northeastern boundaries of the Inner Platform (Stable), and near Abu Jir Fault Zone, along the southwestern boundaries of the Outer (Unstable) Platform of the Arabian Plate (Fouad, 2008 and 2012). Abu-Jir Fault Zone, which trends northwest – southeast, separates the Outer Platform to the northeast from the Inner Platform to the southwest. The bedding nature, lithology and tectonic regime indicate three sets of orthogonal joints, with 0.1 − 0.5 m spacing, more than 80% are of extension and closed joints, (Amin *et al*., 1988). The general flow direction of both the surfacewater and groundwater coincides with the general slope of the area (from northwest towards southeast) with some exceptions, in which the water flows in different directions, (Amin *et al*., 1988). The studied basin is of an elliptical shape trending almost in W − E direction and forms part of the Euphrates River basin. The main part of the basin lies in Qasr Al-Khubaz − Hit district, which is demonstrated in topo-sheet No.: NI-38-M/NW and NI-M/NE, scale 1:100 000 (Fig.3).

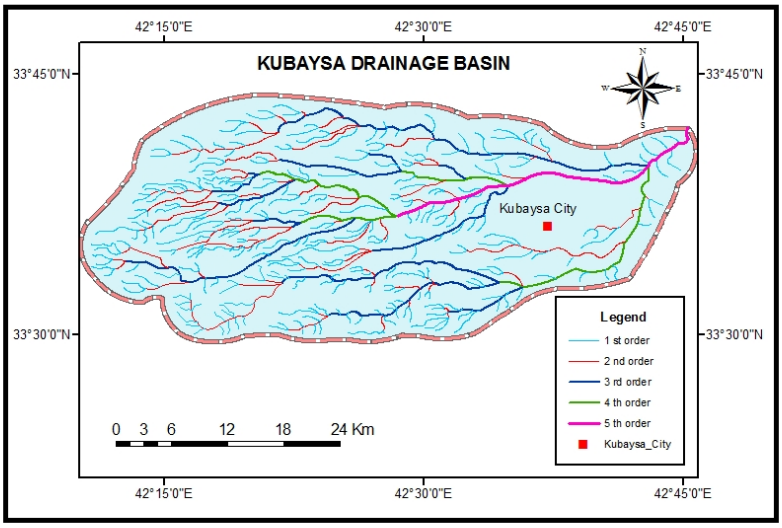

Fig.3: Stream orders system according to Strahler (1957)

- **Materials and Methodology**

"Qasr Al-Khubaz" and "Hit" topo-sheet maps (NI-38-M/NW/75 and NI-38-M/NE/76), on 1:100 000 scales, are used as reference for base map preparation. These topo-sheets were geometrically rectified and geo-referenced to world space WGS 1984 coordinate system using digital image processing software (Arc Map 9.3) and digitization was carried out for the entire analysis of basin morphometry. Stream order was given to each stream following Strahler (1957) stream ordering system (Fig.3). Analysis of various drainage parameters; namely ordering of various streams and measurement of area of basin, perimeter of basin, length of drainage channels, drainage density (Dd), drainage frequency, bifurcation ratio (Rb), texture ratio (T) and circulatory ratio (Rc), stream frequency (Fs), elongation ratio (Re), form factor (Rf), total basin relief (Rh) and relief ratio (Rh) of the basin were computed. Detailed qualitative analysis is carried out from the drainage map.

RESULTS AND DISCUSSION

Kubaysa drainage basin is divided into four sub-basins, named as; Sub-basin-1, Sub-basin-2, Sub-basin-3 and Sub-basin-4 (Fig.4). The sub-basins have been analyzed through the measurement of linear, aerial and relief aspects and slope contribution. Different morphometric parameters of the sub-basins are discussed hereinafter.

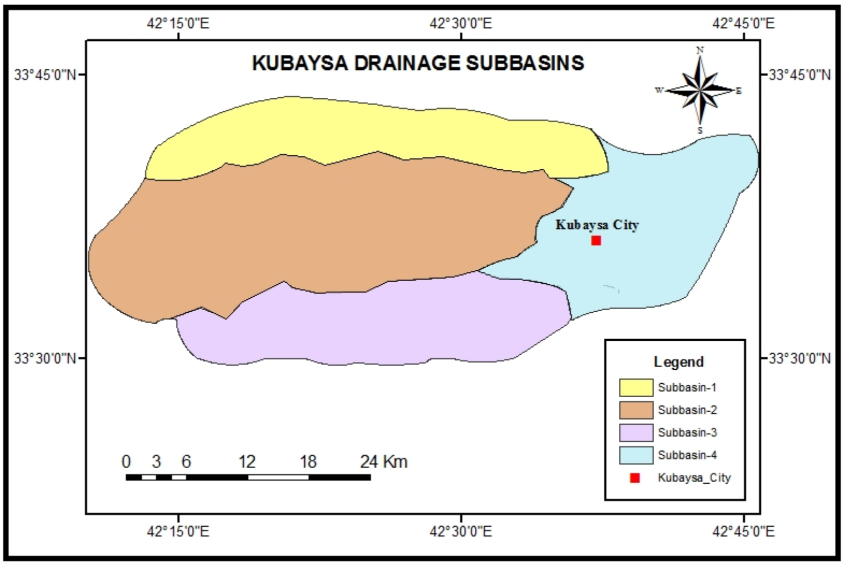

Fig.4: The four subbasins of Kubaysa drainage basin

- **Linear Aspects**

Linear aspect point of view; stream order, minimum, maximum, stream length and mean stream length of the stream orders are shown in Table (1). Drainage patterns of the stream network from the basin have been observed as mainly of dendritic type which indicates the homogeneity in texture and lack of structural control.

Table 1: Stream orders characteristics of Kubaysa Drainage Basin

Stream Order	1st Order	2nd Order	3rd Order	4th Order	5th Order
Stream Number	297	66	15	4	1
Minimum Length (Km)	0.383	0.539	0.904	9.174	30.0
Maximum Length (Km)	6.139	20.0	30.0	22.750	30.0
Stream Length (Km)	562.796	236.707	160.494	57.258	30.0
Mean Stream Length	1.895	3.586	10.697	14.306	30.0

- **Stream Order**

The properties of the stream networks are very important to study basin characteristics (Strahler, 2002). The primary step in any drainage basin analysis is order designation, stream which is based on ranking of streams. Ranking of streams is made according to the method proposed by Strahler (1957). Five stream orders have been ranked in Kubaysa Drainage basin derived from the source maps using Arc GIS 9.3. In all identified 383 streams, 297 are first order, 66 are second order, 15 are third order, 4 are fourth order and only one is of fifth order. It is observed that the maximum frequency is in the first order streams. It is also noticed that there is a decrease in stream frequency as the stream order increases, as shown in Figs. (5, 6, 7 and 8) and listed in Table (1).

The linear aspects of the four sub-basins are stream length ratio and bifurcation ratio which are measured and demonstrated in Table (2).

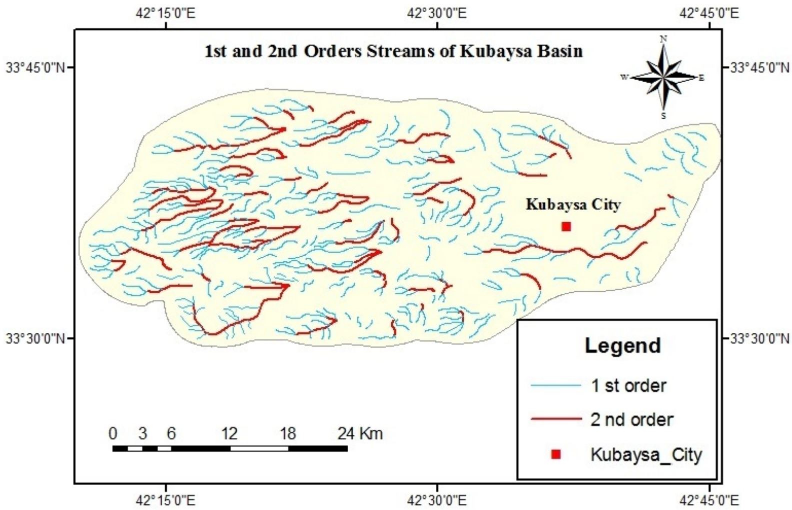

Fig.5: First order watershed

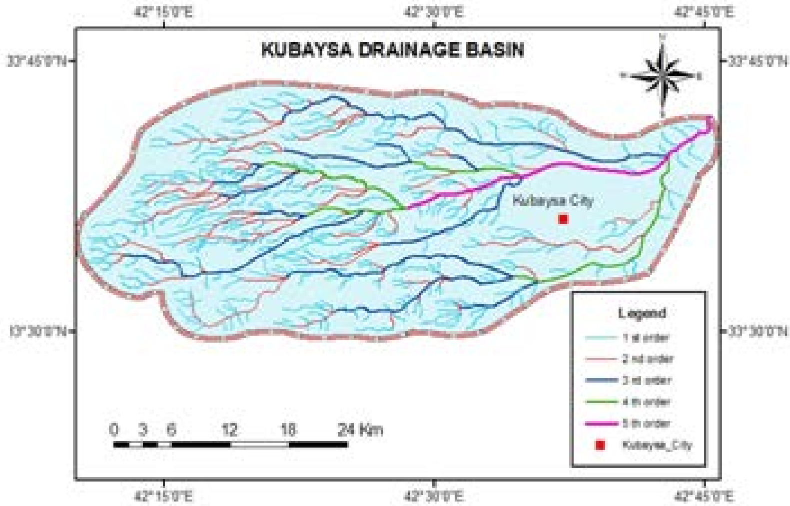

Fig.6: First and second orders watershed

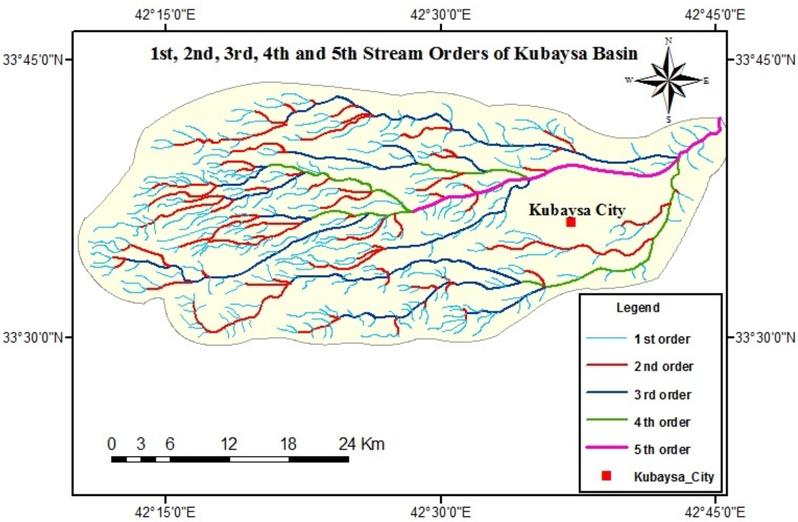

Fig.7: The watershed of the five stream orders

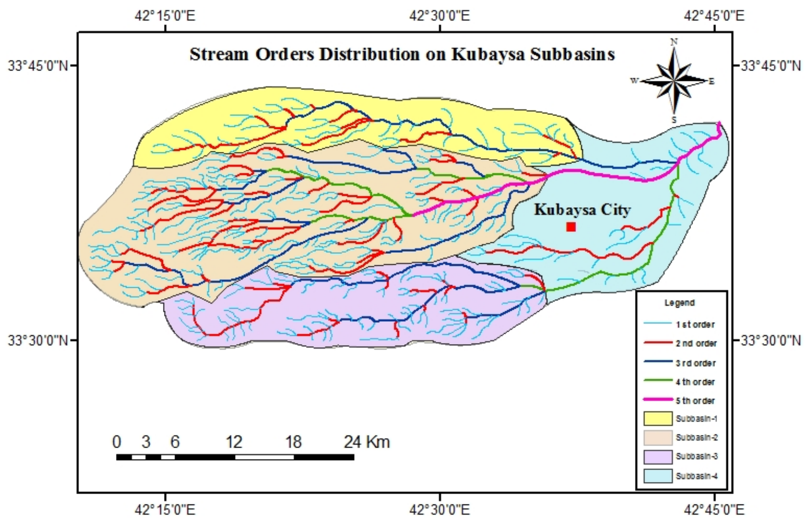

Fig.8: Stream orders distribution in the four sub-basins

Table 2: Linear aspects of Kubaysa drainage basin

Watershed	Stream Order	Number of Streams	Bifurcation Ratio	Stream Length (Km)	Str. Len. Ratio (Km)	Mean str. Len. Ratio	Relief Ratio
Sub-basin-1	1, 2 and 3	52	7.3	141.486	0.52	7.4	4.39
Sub-basin-2	1, 2, 3, 4 and 5	203	3.5	563.508	0.46	3.4	4.7
Sub-basin-3	1, 2, 3 and 4	99	4.5	216.082	0.57	1.96	4.6
Sub-basin-4	1, 2, 3, 4 and 5	32	3.4	126.179	1.02	7.3	2.15
Total/Mean		383	4.7	1047.255	0.64	5.02	3.96

- **Stream Length**

Stream length is one of the most important hydrological feature of the basin as it reveals the surface run-off behavior. The length of various stream segments of the watershed and the entire Kubaysa drainage basin was found using Arc GIS 9.3. Linear referencing tool was used and the result is shown in Table (1). Among the watershed, stream length is found to be moderate (100 – 200 Km) for sub-basins (1 and 4) and high order (> 200 Km) for sub-basins (2 and 3), while there is no sub-basin with stream length of Low order (< 100 Km).

Generally, the total length of the stream segments parameter are maximum in the first order streams (562.796 Km) and decreases (236.707, 160.494, and 57.258 to 30 Km) as the stream order increases

- **Mean Stream Length**

The mean stream length is a dimensionless property, characterizing the size aspects of drainage network and its linked surface (Strahler, 1957). It is obtained by dividing the total length of stream order by total number of segments in the same order.

In Kubaysa area, it is observed that the mean stream length value of a given order is greater than that of the lower order and less than that of the next order, Table (1). Table (2) show that the mean stream length of the sub-basins varies from 1.96 of sub-basin-3 to 7.4 of sub-basin-1.

- **Stream Length Ratio**

It is the ratio between total lengths of stream segments of any two successive orders. The law of stream length states that the mean length of stream segments of each of the successive orders of a basin tends to form roughly a direct geometric series, with stream lengths increasing towards higher stream order (Horton, 1945). The study area shows variation in stream length ratio between any successive stream orders. Change of stream length ratio from one order to another indicates their late youth stage of geomorphic development. According to Singh's procedure (2000), the average length ratio is found to be moderate (0.5 − 1.0) for Sub-basins-1 and 3, low (< 0.5) for Sub-basin-2, and high (> 1.0) for Sub-basin-4.

- **Bifurcation Ratio (Rb)**

The bifurcation ratio (Rb) is related to the branching pattern of a drainage network which equals to the number of stream segments of a given order 'Nu' to the number of streams in the next higher order (Nu + 1). Horton (1945) considered the bifurcation ratio as index of relief and dissections. Bifurcation ratios range from 3.0 to 5.0 for sub-basins in which the geologic structure does not distort the drainage pattern (Strahler, 1964). The higher value of Rb indicates strong structural control in drainage pattern, while the lower values are indicative of the absence of structural disturbances (Nag, 1998).

Strahler (1957) demonstrated that bifurcation ratio shows only a small range of variation for different regions or for different environments; except for those where powerful geological control dominates.The mean bifurcation ratio (Rbm) may be defined as the average of bifurcation ratios of all orders (Table 2). In the present case, the high Rbm value of 4.7 indicates strong structural control on the drainage pattern disturbance.

- **Relief Ratio (Rh)**

The elevation difference between the highest and lowest points on the valley floor of a sub-watershed is its total relief, whereas the ratio of maximum relief to the horizontal distance along the longest dimension of the basin parallel to the principal drainage line is Relief Ratio (Rh) (Schunm, 1956). It measures the overall steepness of a drainage basin and is an indicator of intensity of erosion processes operating on the slopes of the basin. Areas with high relief and steep slope are characterized by high value of relief ratios. Low values of relief ratio are mainly due to the resistant basement rocks of the basin and low degree of slope (Mahadevaswamy *et al*., 2011). The Rh normally increases with decreasing drainage area and size of a given drainage basin (Gottschalk, 1964). In the present study, Rh values for subbasins (1, 2, and 3) range from 4.39 to 4.7, except for subbasin-4 where it is 2.15. This low value indicates that the intensity of erosion processes in subbasin-4 are less than that in the other parts of the entire Kubaysa Basin. This variation is due to the flat depression like form of subbasin-4, which may have be developed by the activity of Abu Jir Fault Zone.

- **Aerial Aspects**

Basin area is an important morphological attribute as it is related to the spatial distribution of a number of significant attributes; such as drainage density, stream frequency, relative relief, etc. For the present analyses, the basin area was measured using Arc GIS 9.3 linear referencing tool. The area thus computed for Kubaysa basin and the watershed basins are shown in Table (3).

Table 3: Areal aspects of Kubaysa drainage basin

Watershed	Area (Km²)	Perimeter (Km)	Length (Km)	Form Factor	Circulator Ratio	Elongation Ratio	Drainage Density	Stream Frequency	Length of Overland Flow
Sub-basin-1	192.9	85.26	38.73	0.13	0.33	0.41	0.73	0.27	0.36
Sub-basin-2	442.6	98.0	40.65	0.27	0.58	0.58	1.27	0.46	0.63
Sub-basin-3	219.0	80.1	31.74	0.21	0.43	0.52	0.99	0.45	0.49
Sub-basin-4	200.0	80.0	24.97	0.33	0.39	0.64	0.63	0.16	0.31
Total/ Mean	1054.5	93.9	34.02	0.23	0.43	0.48	0.91	0.34	0.45

- **Drainage Density**

Drainage density is simply the ratio of total channel segment lengths accumulated for all orders within a basin to the area of the basin and its unit is usually expressed as km per Km². Drainage density in general gives an idea about the spacing between channels. This factor is related to the geomorphology and hydrology, and reflects the flow method of surface water, which is effected by geology, gradient, plant cover, quantity and intensity of precipitation (Jabbori, 1988). Langbein (1947) recognized the significance of drainage density as a factor that determines the travel time of water within the basin and suggested that it varies between 0.55 and 2.09 Km/Km² in humid region. The related situation of lithology and geological structures in semi arid regions have finer drainage density generally resulting in areas of highly resistant to weathering or permeable subsoil material, dense vegetation and low relief. High drainage density is the result of weak or impermeable subsurface material, thin vegetation and mountainous relief (Nag, 1998). Drainage density of the studied area varies from 0.63 Km/Km² for Sub-basin-4 to 1.27 for Sub-basin-2. The mean value of Kubaysa drainage basin is 0.91 indicating moderate drainage densities which denotes weak, moderately permeable rocks (through fractures and karstification of the Euphrates carbonate rocks), sparse vegetation, moderate relief and coarse drainage texture.

- **Stream Frequency**

Stream frequency of the basin may be defined as the ratio of the total number of segments cumulated for all orders within a basin to the basin area (Horton, 1945). Hypothetically, it is possible to have basins of the same drainage density; differing in stream frequency and basins of same stream frequency; differing in drainage density. The low value indicates that the sub-basin (especially Sub-basin-4) is of low relief and almost flat topography. Due to the moderately permeable rocks, the surface runoff is low and infiltration capacity is moderate within the study area.

In the present study, the value of stream frequency exhibits positive correlation with the drainage density values of the sub-basins indicating increase in stream population with respect to increase in drainage density (Table 3).

- **Form Factor**

The ratio of the basin area to the square of basin length is called the form factor (Horton 1932). It is a dimensionless property and is used as a quantitative appearance of the shape of basin form. A form factor near zero indicates a highly elongated shape and a value close to 1 indicates circular shape. Basins with high form factors have high peak flows of shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flow of longer duration. Rf values of the study area are presented in Table 3. It is noted that the Rf values vary from 0.13 of Sub-basin-1 to 0.33, which indicate that they are of elongated shape and suggesting flatter peak flow for longer duration. Flood flows of such elongated circular basins are easier to manage than those of the circular basin, such as Sub-basin-4.

- **Circularity Ratio**

It is the ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). The circularity ratio is influenced by the length and frequency of stream, geological structures, land use, land cover, climate relief and slopes of the basin. Miller and Summerson, (1960) have described a basin of circularity ratio range of 0.4 − 0.7, which indicates strongly elongated and highly permeable homogenous geologic materials. In the present study, the circularity ratio is 0.43. The circularity ratio of 0.33 in Sub-basin-1 indicates that it is less circular, more elongated and is characterized by moderate to low relief and drainage system may be structurally controlled. The circularity ratio of 0.58 in Sub-basin-4 reflects that this watershed is close to a circle shape.

- **Elongation Ratio**

It is the ratio between the diameter of the circle of the same area as the drainage basin and circular the maximum length of the basin. A circular basin is more capable for discharge of run-off than an elongated basin (Singh and Singh, 1997). The value of elongation ratio (Re) generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology. Values close to 1.0 are typical of regions of very low relief, whereas those of 0.6 to 0.8 are associated with high relief and steep ground slope (Strahler, 1964). These values can be grouped into 4 categories namely **(a)** Circle (> 0.9), **(b)** Oval (0.9 to 0.8), **(c)** Less elongated (0.8 to 0.7) and **(d)** Elongated (< 0.7). Thus, the elongation ratio of the basin in the study area is 0.48 indicates elongated sub-basin (Table 3).

- **Length of Overland Flow**

Length of overland flow (Lof) is one of the most important independent variable affecting both hydrological and physiographical development of drainage basins (Schumm 1956). It is the distance covered by surface runoff before turning into a stream channel. Or, the length of overland flow is the length of water over the ground before it gets concentrated into definite stream channels, (Horton, 1945). It usually equals to one half of the reciprocal of the drainage density.

From Table (3), it can be seen that the mean length of overland flow of Kubaysa basin is 0.45. It means, the rain water on an average has to run over 0.45 Km before getting concentrated in stream channel, which indicates low surface runoff because of low relief.

- **Hydrogeology**

Seasonal rain water, is the main surface water of the main valleys and their tributaries of Kubaysa drainage basin, which drains either to the rock exposures by percolation or to the Euphrates River in the eastern and southeastern parts. The carbonate rocks of the Euphrates Formation include water-bearing layers (aquifers). The permeability and/or transmissivity of these layers are variable depending on voids, cavities and fissures. The direction of the groundwater flow coincides with the ground slope of the area towards east and southeast (Amin *et al*., 1988).

CONCLUSIONS

The three morphometric aspects; Linear, Areal and Relief, for the origin and destination of Kubaysa drainage system, are analyzed. Kubaysa drainage basin is divided manually into four sub-basins named as; Sub-basin-1, Sub-basin-2, Sub-basin-3 and Sub-basin-4.

- Dendritic drainage pattern is developed in Kubaysa drainage basin, which reflects the homogeneity in texture and weak structural control.
- Quantitative analysis of Kubaysa drainage network shows that there are a total number of 383 stream segments, of which 297 segments are 1st order, 66 are 2nd order, 15 of 3rd order, 4 of 4th order and only one stream segment of 5th order.
- Depending on the drainage orders, Kubaysa drainage basin has been classified as fifth order basin.
- Bifurcation ratio values obtained for the entire Kubaysa basin in addition to each of the four sub-basins. Bifurcation ratio values for the entire Kubaysa basin are; 4.5, 4.4, 3.75 and 4.0 with average of 4.16, while the mean bifurcation ratio values, for the four sub-basins is 4.7. These average and mean values indicate that this basin has a structural control on the drainage development.
- Drainage texture of the investigated watershed indicates resistant rocks and coarse texture. In the study area it is restricted mostly to the zones of secondary porosity developed due to fractures, joints and weathering. All the sub-watersheds show dendritic to sub dendritic drainage pattern with course drainage texture.
- Low drainage density indicates that the basin is made of highly permeable soil and subsoil, low relief and coarse drainage texture. This case is well represented in subbasin-4 (Dd = 0.63).
- According to the topography, Sub-basin-4 has a depression like landform with relatively different drainage characteristics, represented by relatively flatter elevated area and low number of stream segments. This geomorphological feature may be due to its closeness to Abu - Jir fault Zone and the high permeability of soil and the rock beneath.
- Circulatory and elongation ratios show that most of the sub-watersheds are more or less elongated or oval. The mean Rb indicates that the drainage pattern is not influenced by geological structures. The Dd of the basin reveals that the nature of subsurface strata is permeable. This is a characteristic feature of coarse drainage as the density values are less than 5.0.
- The study reveals that the drainage areas of the basin are passing through an early mature stage of the fluvial geomorphic cycle. Lower order streams mostly dominate the basin. The development of stream segments in the basin area is more or less affected by rainfall only.
- Low surface runoff in the study area, is due to low relief; it is indicated by the overland flow of relatively high values.

- GIS software's are shown to be of immense utility in the analysis of the Linear and Areal morphometric aspects of the drainage basins. The study reveals that GIS based approach in evaluation of drainage morphometric parameters at river basin level is more appropriate than the conventional methods. GIS based approach facilitates analysis of different morphometric parameters and to explore the relationship between the drainage morphometry and properties of landforms, soils and eroded lands.

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