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Quantitative morphometric analysis of three selected Sub-basins using Remote sensing and GIS techniques, East Abu Zenima area, South west Sinai, Egypt

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ABSTRACT **: Sub-basin quantitative morphometric analysis supplies insights into its dynamics, vulnerability to floods, erosion capacity and possible inherent relations to structural features. Various GIS tools with remote sensing data in an integrative manner are a useful approach to determine the morphological parameters of the basin. In the current study, we analyze the drainage system of three selected sub-basins namely: EL-Seih, Um graph and Mukattab, located in East Abu Zenima (EAZ) area, southwest Sinai, Egypt. The present study concentrates on terrain (slope and aspect), drainage network, watershed geometry, drainage texture analysis and relief characteristic aspects of the three sub-basins. Slope and aspect maps of the sub-basins indicate the variety in there topographic surface. The morphometric analysis results revealed that the sub-basins are at late youth stage, faintly potential to soil erosion and flooding, low to moderate runoff rate and the geological structures do not deform the drainage pattern, except for W El-Seih. The present study indicates that the morphometric analysis is highly applicable in delineating water supply zones.**

KEYWORDS: Remote sensing, Morphometric analysis, East Abu Zenima, GIS, Terrain analysis

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I. INTRODUCTION

Groundwater exploration in Sinai Peninsula, Egypt has increased significantly during the last years because it is the only source of drinking and irrigation for Sinai inhabitants and Bedouins. Also in semiarid and arid areas there is importance to management sustainable watershed to overcome the needs of future generation from drinking water supply. Drainage basin morphometric analysis plays a fundamental role in hydrological investigations such as groundwater management, groundwater potential assessment and hydrological behavior. Moreover, morphometric analysis of a watershed promotes a quantitative description of the drainage system, which is an essential aspect of watershed characterization (Strahler, 1964). Generally, drainage basin morphometry is the measurement and mathematical analysis of the configuration of earth surface, dimension and shape of its landforms (Clarke, 1996; Agarwal, 1998; Reddy et al., 2002). In addition, it gives information about physical characteristics of the watershed in terms of topography, slope drainage density, surface water potentiality, runoff characteristics, etc.

Drainage network delineation within basins or sub-basins can be determined using traditional methods such as topographic maps and field observations or with advanced methods using remote sensing and GIS techniques (e.g. Mark, 1983; Rinaldo et al., 1998). Anciently, drainage characteristics of many basins and sub-basins in many parts in the world have been studied using conventional/traditional methods that depend on field observation (e.g. Horton, 1945; Miller, 1953; Strahler, 1957, 1964). But it is considered very difficult because of their extent throughout rough terrain. Contrary, using high spatial resolution remote sensing data and GIS techniques in addition to topographic data are considered significant tools in the morphometric analysis of drainage basins in the last decades. GIS is a functional tool in analyzing spatial and non-spatial data on geology, landforms and drainage parameters to understand their interrelationship; furthermore, its power in quantifying and processing topographic data (Altaf et al., 2013). Morphometric analysis using GIS techniques and remote sensing data have been studied by many authors such as Nag (1998); Biswas et al. (1999); Chavare (2011); Singh et al. (2014); Charizopoulos et al. (2019); Bogale (2021).

East Abu Zenima (EAZ) area is one of the most vital areas at the western side of Sinai Peninsula. It is dissected by two main wadis: Baba and Sidri valleys. These basins include a lot of tributaries (sub-basins) that represent surface and groundwater suppliers for the main basins and the whole area. The present study deals with processing and calculation morphometric analysis of three important sub-basins in southwest Sinai, El-Seih, Um Graph and Mukattab basins using remote sensing and GIS techniques.

II. STUDY AREA

The study area lies in the southwestern Sinai Peninsula in the East of Abu Zenima and Abu Rudeis cities between longitude 33º 22` to 33º 30` E and latitude 28º 50` to 29º 07` N as shown in (Fig. 1). The area is bounded from the north and east by El-Tih plateau and from the west by the Gulf of Suez and its coastal plain. The interested three wadis in the present study are W El-Seih, W Um Graph and W Mukattab, that characterize representative and important tributaries of the main valleys in the area (Sidri and Baba valleys). The general geology of study area is covered by a large variety of rock exposures belonging to two main divisions: the first exposure is Basement complex of Precambrian igneous rocks with intrusions from basic volcanics of Jurassic age and the second exposures are sedimentary formations ranging from early Carboniferous sediments to Recent (Fig. 2).

Geomorphological features of East Abu Zenima area are originated by physical and chemical processes working on or near the earth's surface. These features are divided into six categories (Fig. 3) including; (1) the coastal plain extends along the Gulf of Suez in the east of Abu Zenima and Abu Rudeis cities; (2) the hilly area with a little elevations covered the area between the coastal plain and the third category; (3) the mountains area that vary in elevation from low mountains toward the west into high elevation at the south eastern part; (4) the flat area with wadi deposits which observed at the north and east parts parallel to the mountains area; it extends till reach El-Tih plateau (5) passing through the last geomorphological category which is defined as highly scarps area (6). El-Tih plateau represents a main watershed in the east direction for the study area.

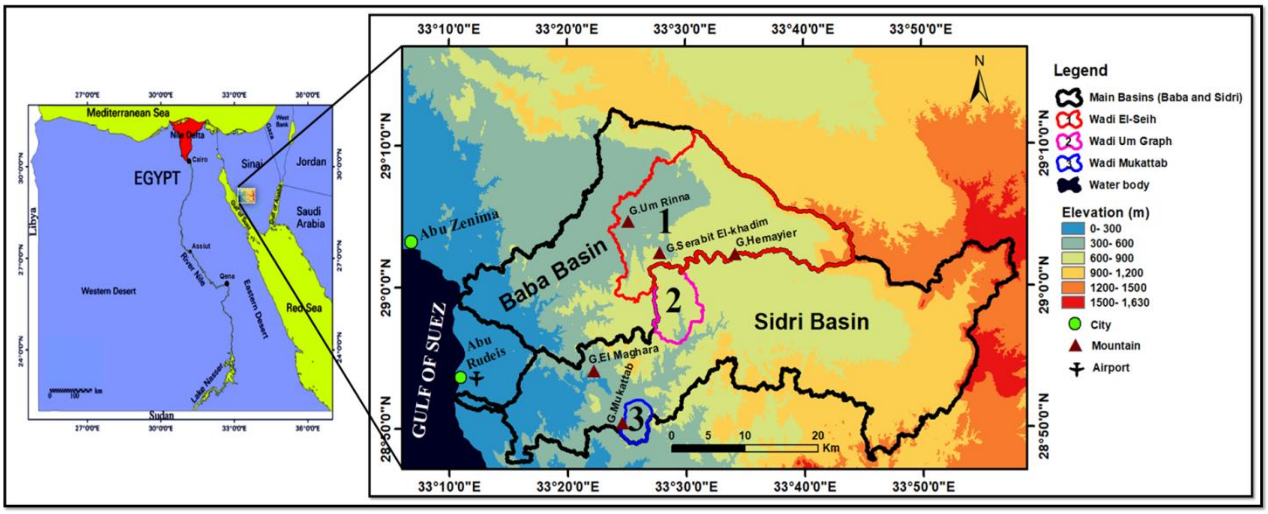

Fig. 1: Location and elevation maps of the study area, south west Sinai.

The present area is highly tectonized region as it lies between the western and eastern flanks of the Red Sea Gulfs (i.e. Gulf of Suez and Gulf of Aqaba). Consequently, there are two main fault structures; the first of them runs along the contact between the basement complex and sedimentary section (NE trend), the other fault runs along the Gulf of Suez (NNW trend, El Rakaiby and El Aassy, 1990). These main faults are dissected by minor transversal faults such as N-S and ENE-WSW trends. As a result of this structural framework, EAZ area forms an interested site in which the hydrogeological exploration is a crucial point.

2.1 Wadi El-Seih sub-watershed

Wadi El-Seih is a sub-basin of Baba basin and it lies to the east of Suez Gulf in southwest to central Sinai between longitude 33˚ 22` 30`` and 33˚ 30` E and latitude 29˚ 00` and 29˚ 7` 30`` N and occupies an area of 340.1 km². Wadi El-Seih runs between Gebel Lehyian (623m), Gebel EL Zobar (643m), Gebel Sarabiet EL Khadem (996m) Gebel Um Rinna (577m) and Gebel Um Reglien (925m). This sub-watershed is recharged at El-Seih basin through the slopes of El-Tih plateau and Santé Katherine Mountain. Geologically, the exposed rocks at Wadi EL-Seih vary in ages from Cambrian-Ordovician age that is represented by lower sandstone facies in Wadi Sewiq and Bala to lower carboniferous age in Umm Bogma Formation in W Lehian and some parts in Um Rinna mountains, whereas the Quaternary age deposits appears along this wadi (EL Kassas, 1995). Wadi El-Seih area shows a transition from complete sedimentary rocks at the upstream to basement complex in the downstream with outcrops of Araba Formation which bounded by diorite and metadiorite basement rocks.

2.2 Wadi Um Graph sub-watershed

Wadi Um Graph is a sub-basin of Wadi Sidri. It is located between longitude 33˚ 29" E to 33º 34` E and latitude 28˚ 56"- 29˚ 0" N. It is bounded from the North by Gebel Sarabiet EL Khadem and Gebel Ghorabi and from the east there is Gabal Um Elaala. The main rock exposure around this valley is composed mainly of metamorphic rocks (schist and gneiss). The discharge of Wadi Um Graph is into Wadi Sidri. Geologically, Wadi Um Graph is located in a high mountain area that composed mainly of medium to highly grade of metamorphic rocks, granite gneiss, undifferentiated migmatitic gneiss, schist and amphibolite. The upstream part of Wadi Um Graph is containing metasediments, metamorphosed shelf sediments and volcanogenic rocks, partly including pyroclastics.

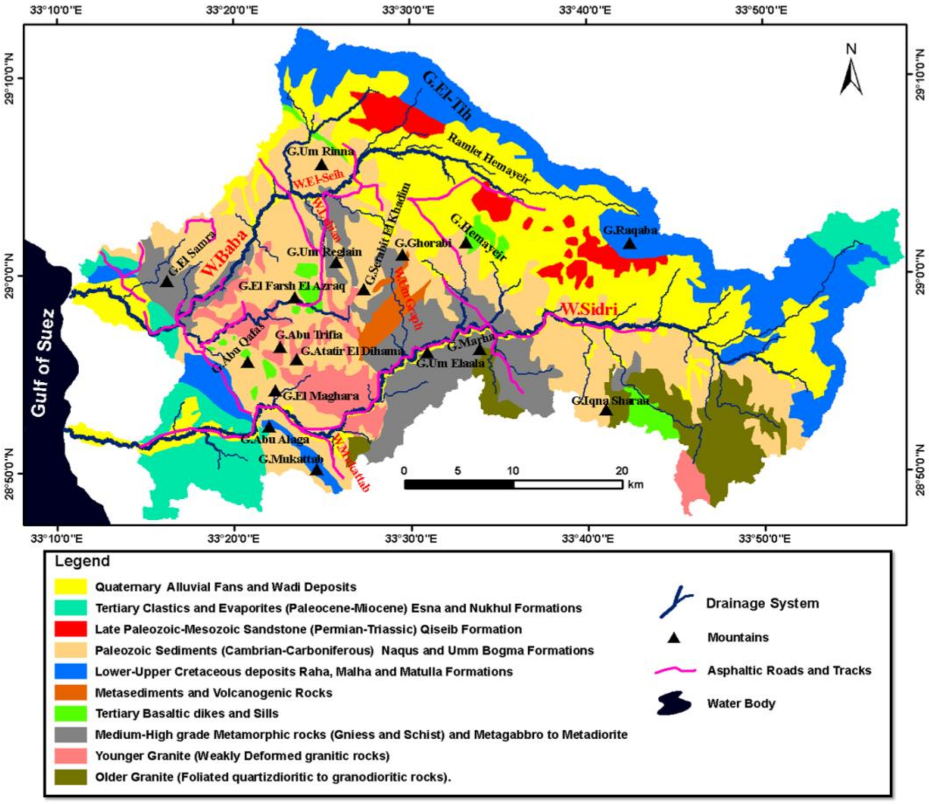

Fig.2: Surface geological map of the main basins with their branches at southwest Sinai area.

2.3 Wadi Mukattab sub-watershed

Wadi Mukattab is situated north of Wadi Feiran. It is a part of the hydrographic basin of WSidri at the contact between basement complex and sedimentary cover. It lies between longitude 33˚ 25” E to 33º 29` E and latitude 28˚ 48” N to 28˚ 52” N. Wadi Mukattab runs through Gebel Mukattab and there are two sources of recharging that feeds WMukattab, the first at Baga basin through WSeih-Sidri (from Tih plateau – Central Sinai) and the second through Wadi Nab’a (from Santé Katherine mountain). Geologically, WMukattab in is the eastern border is composed of basement rocks whereas its western border is composed of sedimentary rocks (Fig. 2). Sedimentary rocks are composed of Carboniferous, Cretaceous and Miocene rocks. Additionally, wadi floor contain wadi deposits (Conoco, 1987).

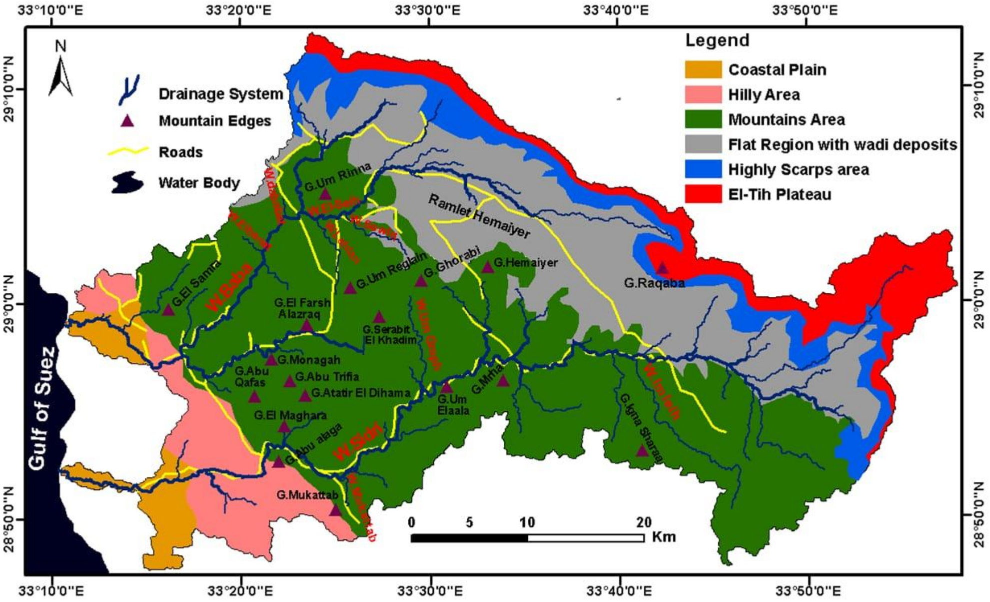

Fig.3: Geomorphological map of study area.

2.4 Climatic condition and rainfall

The climatic conditions of East Abu Zenima area are characterized by extreme aridity, less rainfall and long hot in summer, and a mild sporadic rainy winter. Precipitation is frequently occurring during the autumn season (October and November) and winter season (January and February). Heavy precipitation occurs for very short periods during winter and causes torrential floods in the wadis. The temperature values vary from 35.1°C in summer (August) and 18.75°C in winter (January). Relative humidity reaches to its maximum value (75%) in August and a minimum value (60%) in December. The potential evapotranspiration ranges from 1.9 mm/day in January to 5.5 mm/day in July (EMA, 1994).

III. METHODOLOGY

This study employed remote sensing data and GIS applications supported by field investigation. The study maps were achieved and extracted using ArcGIS 10.4.1 (ESRI 2016). The geological map was collected from digitizing the geological map of Sinai of a scale 1:500,000 (Conoco, 1987). The data of geomorphological characteristics of the study area were collected by analyzing three dimensional (3D) view and elevation contour map from ASTER Global Digital Elevation Map (GDEM, with 30 m spatial resolution). Firstly, this map is downloaded at Universal Transverse Mercator (UTM) projection, World Geodetic System (WGS 1984) Zone 36N. Secondly, the slope and aspect maps were calculated from GDEM using surface analyst tools in ArcGIS. Moreover, the drainage networks of the investigated three sub-basins were extracted with available hydrologic and geoprocessing tools based on the followed orders: fill, flow direction, flow accumulation, stream order and stream to feature as a final drainage network map. The drainage density maps were obtained by density spatial analyst tool. Finally, the morphometric parameters of the studied sub-basins were classified into four categories

(Table 1). Some parameters such as basin area, perimeter, basin length, stream order and stream number were extracted from GDEM with spatial analyst tools using ArcGIS software. While, the other morphometric parameters such as bifurcation ratio, elongation ratio, form factor, stream frequency, ruggedness number were calculated from mathematical equations (Table 1).

IV. RESULTS AND DISCUSSION

Quantitative morphometric analysis was carried out of the interested three sub-basins (El-Seih, Um Graph and Mukattab). The total investigated area is 1809 km². The terrain analysis results (slope and aspect) computed from GDEM, are utilized to express the topographic surface of the studied sub-basins in 3D. Slope is considered as an effective factor in geomorphological investigations for basin development and also it is important for morphometric analysis. Slope affects groundwater distribution, flow, storage as well as surface runoff (Yeh et al., 2016; Abdalla Fathy et al., 2020). The movement of surface water during runoff is governed with slope and the infiltration has inverse relation with slope (Surabuddin et al., 2007; Singh et al., 2013). The hydraulic gradient decreases with lower slope angels and vice versa; so the flat and little slopes promote infiltration capability through water slowly flows down and takes time to infiltrate and recharges the groundwater aquifers. In contrast, steep and highly slope areas make the water received from precipitation runs down quickly and the time of infiltration decreases. The slope maps of the sub-basins were classified into five classes (Fig. 4a, b and c): little slope (0-4.7), gentle slope (4.7-11.3), moderately slope (11.3- 19.3), steeply slope (19.3-29.8) and extremely steep slope (29.8-69.6).

The aspect concept refers to the directions the physical slopes face. Aspect can make a significant influences on temperature and local climate and these influences can affect on the vegetation distribution that needs large quantities of moisture in which the sun rays are in the west direction during the hottest time of day in the afternoon, this makes the west facing slope in most cases warmer than the other sheltered east facing slope (Rai et al., 2014). The Aspect map of the investigated area was classified into ten classes (Fig. 5a, b and c). It is clear that the area has east facing slopes that characterized with lower evaporation rate and high moisture content more than west facing slopes that have high evaporation rate and low moisture content.

Table 1: The morphometric parameters computed in this present study area.

S. No.	Morphometric Parameters	Symbol	Formula	Reference
Drainage Network				
1	Stream Order	$S\mu$	Hierarchical order	Strahler (1952)
2	Bifurcation Ratio	Rb	$Rb = N\mu / N\mu +1$ $N\mu$ = Total no. of stream segments of order 'μ' $N\mu+1$ = Number of segments of the next higher order	Schumm (1956)
3	Mean Bifurcation Ratio	Rbm	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
4	Stream Length	$L\mu$	Length of the streams (kilometers)	Horton (1945)
5	Mean Stream Length	Lsm	$Lsm = L\mu/N\mu$ Lu = Total stream length of order 'μ' Nu = Total no. of stream segments of order 'μ'	Strahler (1964)
6	Stream length ratio	RL	$RL = L\mu / L\mu - 1$, $L\mu$ = The total stream length of the order 'μ' $L\mu-1$=The total stream length of its next lower order	Horton (1945)
Watershed Geometry				
7	Basin Length	Lb	Software Analysis	Schumm (1956)
8	Basin Area	A	Software Analysis	Schumm (1956)
9	Basin Perimeter	P	Software Analysis	Schumm (1956)
10	Elongation Ratio	Re	$Re = (2/Lb) \times \sqrt{(A/\pi)} = 1.128 \times \sqrt{(A)} / Lb$ Lb=Basin Length, A= Basin Area	Schumm (1956)
11	Compactness coefficient	Cc	$Cc = P/2\sqrt{(\pi A)} = 0.2821 \times P/\sqrt{(A)}$ P=Basin Perimeter (km), A= Basin Area (km²)	Gravelius (1914)
12	Circularity Ratio	Rc	$Rc = 4\pi A / P^2$ A=Basin Area (km²), P=Basin Perimeter (km)	Miller (1953)
13	Form Factor Ratio	Rf	$Rf = A/Lb^2$ A=Basin Area (km²), Lb=Basin Length (km)	Horton (1932)
Drainage Texture Analysis				
14	Length of Overland Flow	Lg	$Lg = 1/2Dd$ Dd= Drainage Density	Horton (1945)
15	Drainage Density	Dd	$Dd = L\mu/A$ (km/ km²) $L\mu$=Total stream length of all orders (km)	Horton (1945)
16	Stream Frequency	Fs	$Fs = N\mu/A$ $N\mu$=Total number of streams, A= Basin Area (km²)	Horton (1932)
17	Drainage Texture	Dt	$Dt = N\mu /P$ $N\mu$=Total number of streams P= Basin Perimeter (km)	Horton (1945), Smith (1950)

Table 1(continued): The morphometric parameters computed in this present study area.

18	Constant of channel maintenance	C	$C = 1/Dd$ Dd= Drainage Density	Schumm (1956)
Relief characteristics				
19	Basin Relief	H	H = Z Max Elevation – z Min Elevation	Strahler (1952)
20	Ruggedness Number	Rn	$Rn = Dd \times (H/1000)$ H=Maximum basin relief, Dd= Drainage density	Schumm (1956)
21	Relief ratio	Rh	$Rh = H / Lb$ H=Basin Relief, Lb=Basin Length	Schumm (1956)

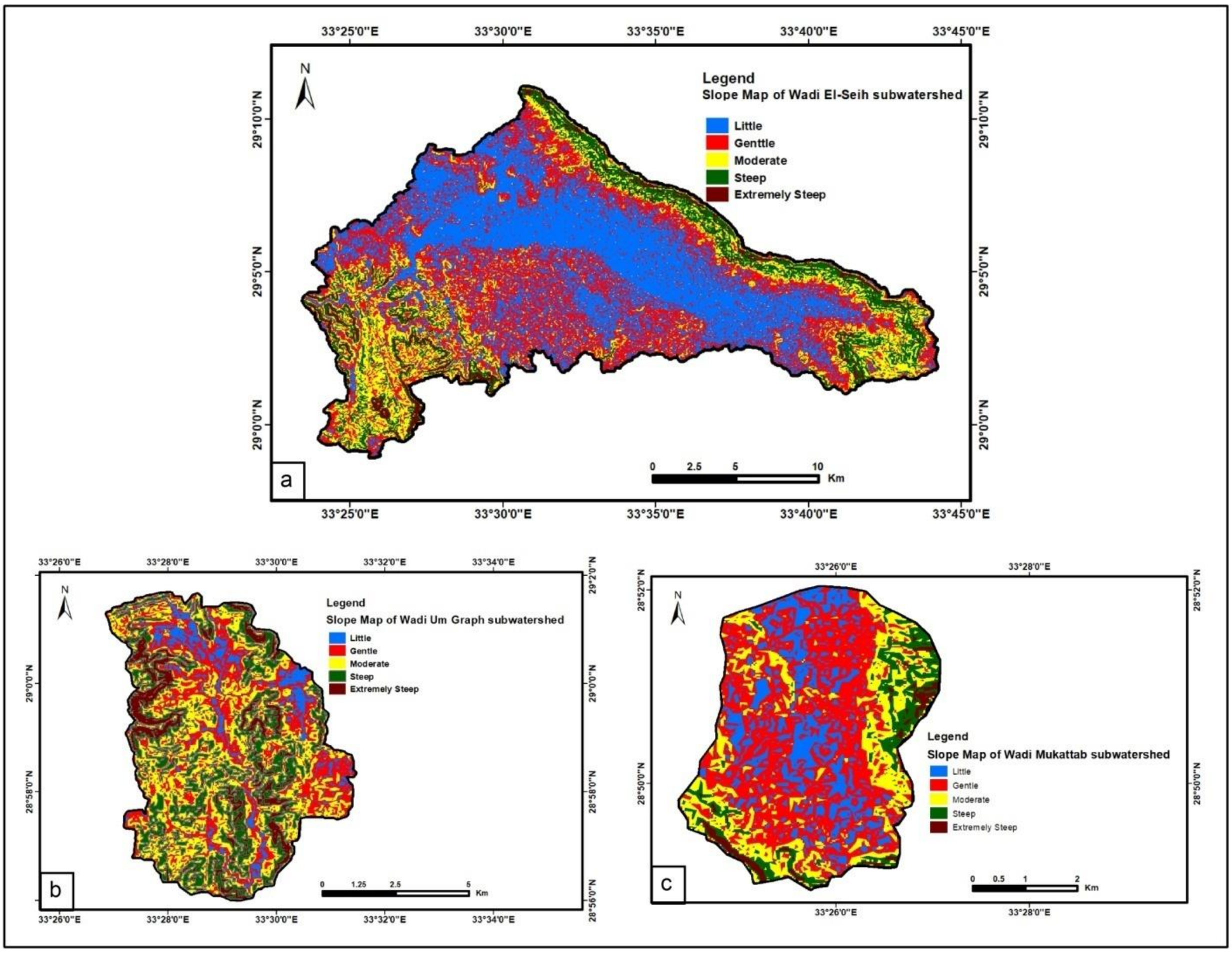

Fig.4: Slope maps of the present sub-basins.

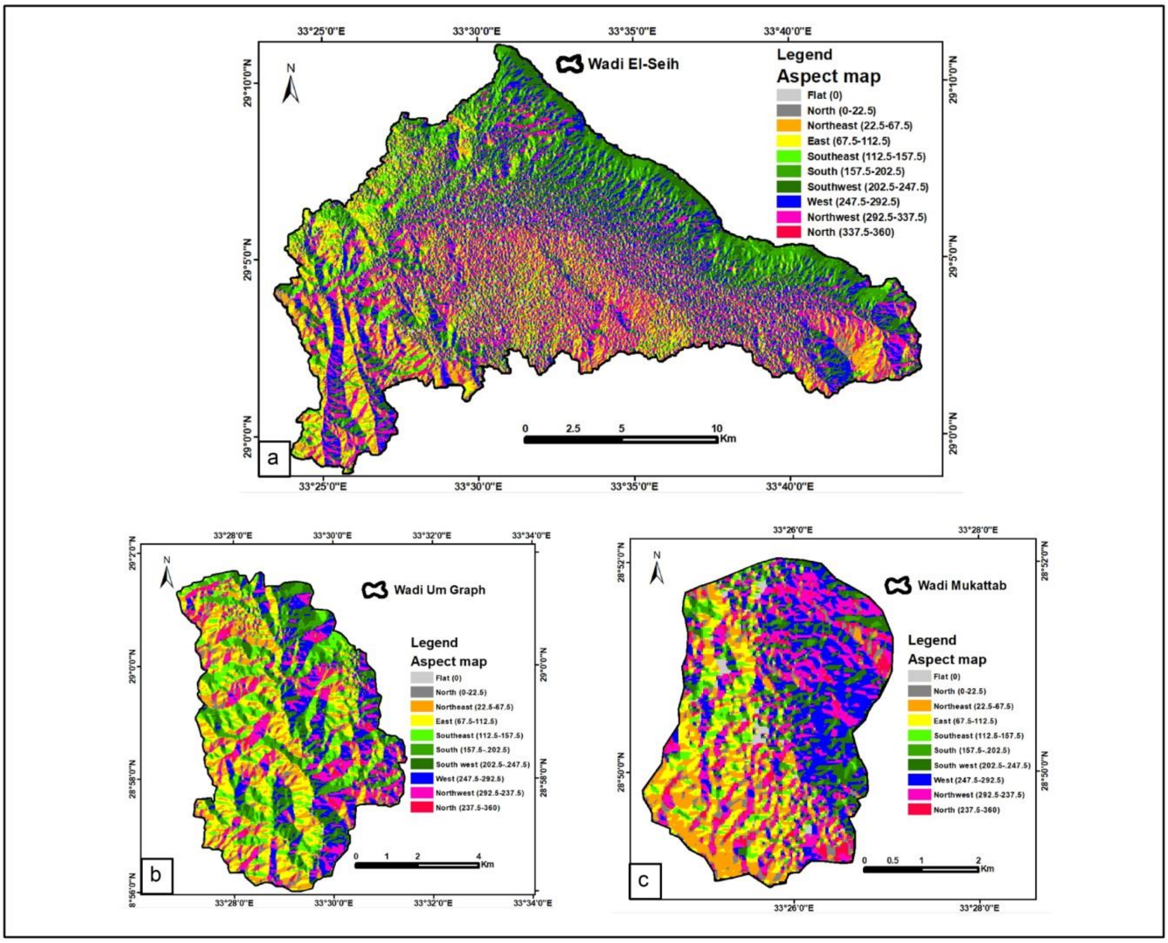

Fig. 5: Aspect maps of the present sub-basins

4.1. Morphometric analysis

The morphometric parameters have been calculated using the previously mentioned equations in Table 1 and the results are presented in the next sections:

A. Drainage Network

Stream order (Sμ): it is the first stage in morphometric analysis of a drainage pattern basin is stream order. The stream ordering is defined as the measurements of position of a stream in the hierarchy of tributaries or its rank in the graded ranks of branches of drainage network. There are different systems of ordering streams (e.g. Horton, 1945; Strahler, 1952; Shreve, 1967). Strahler's system which is a faintly modified of Hortons system, has been followed because of its simplicity. The smallest unbranched streams are designated as (1st) first order, the gathering of two (1st) order channels gives a channel segment of (2nd) second order, two (2nd) order streams join together forming a segment of 3rd order and so on. When two channels of different order join, the higher order is obtained. The trunk stream takes the highest stream order of the stream segment. The stream order has a direct relation with the number of streams, channel length and drainage area. Where by simple geometric relationships between the streams order plots against these variables are straight lines on a semi logarithmic paper. The first order stream does not have any tributaries but the second stream order has only first streams order as tributaries and by this method the third order has first and second order streams as tributaries and so on. The higher amount of stream segments in an order indicates that the topographical surface of the area is still under erosion.

In the present study the stream orders are classified up to six orders in EL-Seih sub-basin, but Um Graph sub-basin has five stream orders, while Mukattab sub-basin has four stream orders (Fig. 6a, b and c). It is observed that the first stream order has a maximum stream order frequency then the second order. There is inverse relation between stream order and stream frequency.

Stream Number (Nu): The total number of order wise stream segments is "stream number". Stream number has inverse relation with stream order by means the number of streams decreases with increasing the order of the stream Horton's (1945) law. The total stream number of El-Seih, Um Graph and Mukattab sub-basins are 1025, 150 and 61 segments, respectively. The detailed stream number of all orders and the number of segments comparing with the total stream segments is shown in Table 2. The high values of stream number in the first order may cause unexpected flash flood in the downstreams after heavy rainfall (Chitra et al., 2011). The presence of high number of streams in a basin shows that the area topography is still under erosion and the low stream numbers indicate a mature topography (Pande and Moharir, 2015).

Table 2: Stream number of El-Seih, Um Graph and Mukattab sub-basins

Stream Order	Wadi El-Seih		Wadi Um Graph		Wadi Mukattab	
	Number of segments	Percent to total stream segments	Number of segments	Percent to total stream segments	Number of segments	Percent to total stream segments
1	789	76.97 %	115	76.66 %	47	77.04 %
2	179	17.47 %	24	16.0 %	10	16.39 %
3	43	4.19 %	8	5.34 %	3	4.91 %
4	11	1.07 %	2	1.33 %	1	1.63 %
5	2	0.2 %	1	0.66 %		
6	1	0.09 %				
Total	1025	100 %	150	100 %	61	100 %

Stream length (Lu): is an important hydrological feature of the basin in which it reveals the characterization of surface runoff. Stream length of different stream order is measured by calculating the total length of stream segments of the respective order and numbers of stream segments of different order have been counted. The large number of streams with smaller length is developed when the bedrocks and formations are less permeable. The longer length of streams is generally indicates flatter gradient while the areas of high slope and finer textures are generally characterized by smaller basin stream length (Strahler, 1964). In the investigated area the total stream lengths of study sub-basins El-Seih, Um Graph and Mukattab are 885, 99.3, 44.5 km, respectively. The detailed stream length of all orders is shown in Table 3. It is noticeable that the cumulative stream length in first order streams is higher and decreases with increasing the stream order. These may be due to the variations in rock/soil types, slope and vegetation in these sub-basins. So, the stream length is a sign of the link between the climate, and the rock resistance rock to erosion. Impervious rocks exhibit a longer stream length.

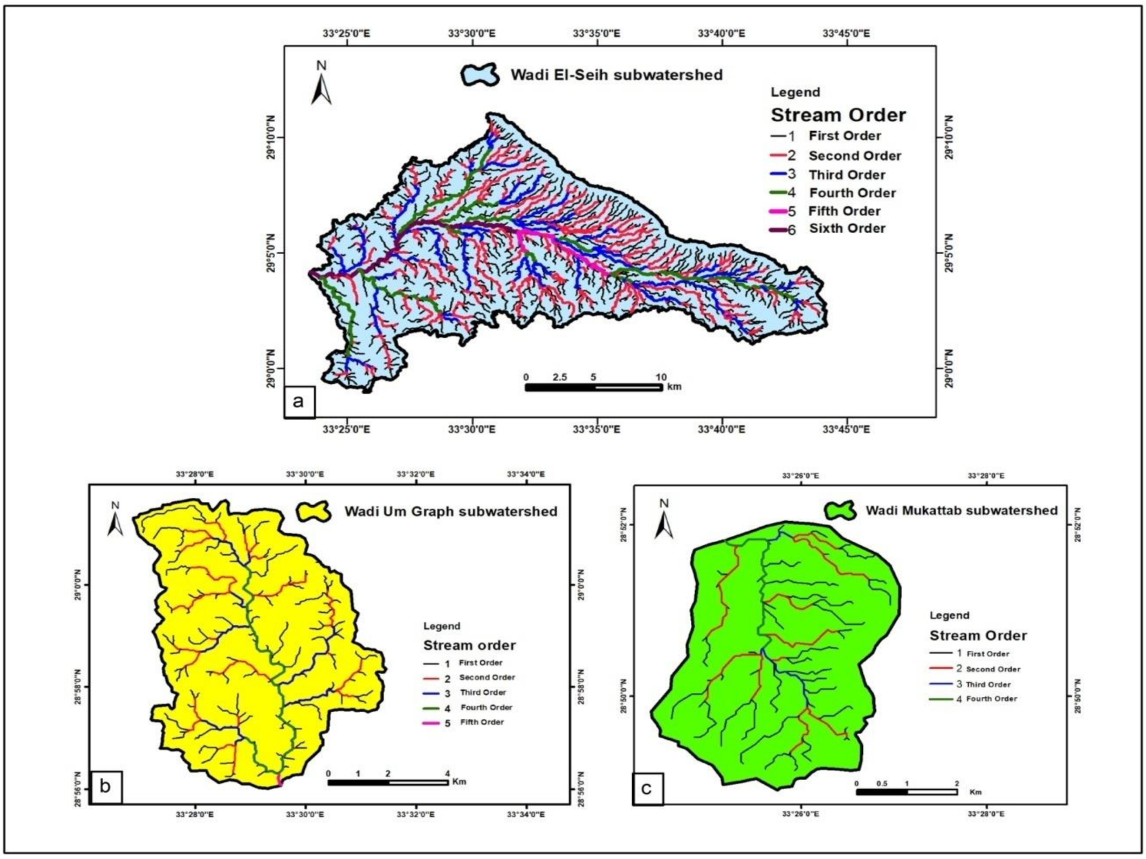

Fig. 6: Drainage network maps of the three sub-basins.

Mean Stream Length (Lum): is a dimensional property informative the attribute size of components of a drainage network and its contributing sub-basin surfaces (Strahler, 1964). It is obtained as a ratio between the total length of stream of an order with total number of segments in the order. The mean Lum values of sub-basins El-Seih, Um Graph and Mukattab are 5.75, 1.87 and 1.57 km and the orders ranges values are shown in Table 3. Lum values are directly proportional to the size of drainage network and topography of a basin.

Stream Length Ratio (RL): it means the ratio of mean stream length of an order to the next lower order (Horton, 1945). The RL values of the studied sub-basins are presented in Table 4. The RL values of streams with different orders show changes in the sub-basins. These changes might be attributed to slope variation and topography, indicating the late youth stage of geomorphic development in the streams of the three sub-basins (Vittala et al., 2004).

Table 3: Stream length of all orders in the investigated sub-basins.

Wadi Name	Stream order	No. of stream of different order						Stream length (km)					
		I	II	III	IV	V	VI	I	II	III	IV	V	VI
W.El-Seih	6	789	179	43	11	2	1	427	241.6	126	61.1	10.5	18.8
W.Um Graph	5	115	24	8	2	1		50.9	23.9	12.4	11.7	0.4	
W.Mukattab	4	47	10	3	1			25.2	13.2	2.5	3.6		

Table 4: Mean stream length and stream length ratio of the study sub-basins.

Wadi Name	Mean stream length in Km (Lsm)						Stream length ratio (RL)					
Order No.	I	II	III	IV	V	VI	I	II	III	IV	V	VI
W.El-Seih	0.54	1.35	2.9	5.6	5.3	18.8	2.5	2.1	1.9	0.93	3.6	
W.Um Graph	0.44	0.99	1.6	5.9	0.4		2.25	1.6	4.7	0.06		
W.Mukattab	0.54	1.3	0.83	3.6			2.4	0.64	4.3			

Bifurcation ratio (Rb) and mean bifurcation ratio (Rbm): The term bifurcation ratio was introduced by Horton (1932). Bifurcation ratio expresses the ratio of the number of stream segments of any given order with the number of stream segments in the next higher order. Strahler (1957) described that Rb values show only a small variation between different drainage basins on different environments except where a powerful geologic control dominants. High Rb values indicate high runoff producing potential of a watershed and short lag time (Howard, 1990) and also reflect strong structural control, whereas the lower Rb value is a characteristic of structurally less disturbed regions. The Rb values less than 3 are found in flat regions zones (Horton, 1945), but the Rb ranges from 3 to 5 are found in zones where geological structures do not distort the drainage pattern (Shreve, 1967). Rb values more than 5 indicate lithological and structural controls (Strahler, 1964). The average values of Rb of all sub-basins mainly ranges between 3 to 5, confirming that geological structures do not distort the drainage pattern. However, El-Seih sub-basin (4th and 5th orders) has Rb greater than 5, indicating lithological and structural control which can be indicative for structural complexity and low permeability (Argyriou et al., 2017). The mean bifurcation ratio (Rbm) is defined as the average of Rb of all orders. Rbm values of all the sub-basins are varied from 3.45 to 5.1 with general average of 4.15 (Table 5). These Rbm values may indicate little difference in the environmental conditions of the three sub-basins as well as they have low to moderate runoff potential.

Table 5: Bifurcation ratio and mean bifurcation ratio in the study area

Wadi Name	Bifurcation ratio (Rb)					Mean bifurcation ratio (Rbm)
	I/II	II/III	III /IV	IV /V	V/VI	
W.El-Seih	4.4	4.2	3.9	5.5	2.0	4.0
W.Um Graph	4.8	3.0	4.0	2.0		3.45
W.Mukattab	4.7	3.3	3.0			3.70

B. Watershed Geometry

Basin Length (Lb): Schumm (1956) defined the basin length as the longest dimension of the basin parallel to the principal drainage line. Basin length refers to the longest length of the basin from the head water to the point of confluence (Gregory and Walling, 1968). The basin length determines the basin shape where high basin length reveals to the elongated basin. The Lb of sub-basins El-Seih, Um Graph and Mukattab are 33.7, 10.7 and 5.7, respectively (Table 6).

Basin Area (A): it is an important parameter as basin length of the stream drainage. Basin area by itself has an independent importance, also it is used in calculation other parameters that are useful in clarification the geomorphology of basins. Schumm (1956) established an remarkable relation between the total sub-basin/watershed areas and the total stream lengths, which are supported by the causative areas. The three sub-basins El-Seih, Um Graph and Mukattab have areas of 340.1, 51.1 and 17.6 km² (Table 6).

Basin Perimeter (P): it is the length of the watershed boundary that surrounds the catchment area. It is used in determination of other morphometric parameters including the geometric characteristics of drainage basins in general, such as: basin area, basin length and basin perimeter which are considered significant affected aspects especially in the precipitation level, evaporation and infiltration, as well as surface runoff. El-Seih has the largest perimeter between study sub-basins of 144.5 km, then Um Graph with 35.1 km and the lowest perimeter is mukattab has a perimeter of 17.4 km (Table 6).

Elongation Ratio (Re): it is the ratio between the diameter of a circle with the same region as the drainage basin and the greatest basin length (Schumm, 1956). Elongation ratio is considered as a significant index in the shape analysis of a watershed. It depends on the climatic and geologic types affect the area and help to give an idea of the hydrological character of a watershed (Schumm, 1956). According to Pareta and Pareta (2012), Re is circular (0.9 to 1.0), oval (0.8 to 0.9), less elongated (0.7 to 0.8), elongated (0.5 to 0.7) and more elongated (less than 0.5). Circular basins are more efficient in runoff discharge than elongated basins (Singh and Singh, 1997). Regions with high values relate to high penetration capacity and low runoff whereas areas with low elongation ratio values are characterized by high susceptibility to erosion and load sediments (Reddy et al., 2004). Values of elongation ratio commonly vary from 0.6 to 1.0 through a wide diversity of climatic and geologic types. Re values close to 1 can characterize regions with low relief, whereas values in the range of 0.6 to 0.8 indicates steep slope region with high relief. Re of El-Seih, Um Graph and Mukattab sub-basins are 0.62 (elongated), 0.75 (less elongated) and 0.83 (oval), respectively. Elongated sub-basins have high infiltration capability and low runoff while less elongated ones have moderate infiltration capacity as well as runoff (Table 6).

Compactness coefficient (Cc): it is the ratio of P of watershed to border of circular (Gravelius, 1914), which equals the area of the watershed. It is reliant only on the slope and independent of size of sub-basin. If the basin was a perfect circle, then Cc value would be equal to (1), while Cc value more than (1) this indicates more deviation from the circular nature of the basin. The values of compactness coefficient for present study sub-basins are 1.9 for El-Seih, 1.4 for Um Graph and 1.2 for Mukattab sub-basins (Table 6). This means that El-Seih sub-basin has a greatest deviation from the circular nature but Mukattab and Um Graph sub-basin appear close to the circular nature.

Circulatory Ratio (Rc): it is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). There are many factors that highly affect Rc highly as the frequency and length of the streams, geological structures, climate, land use/land cover in the area and slope and relief of the basin (Bali et al., 2012). The low, medium and high values of Rc are indicatives of the youth, mature and old stage in the life cycle of the tributaries of a watershed (John et al., 2012). Higher values of Rc indicate no more time for surface runoff for infiltration and thus flooding. The range of (0.4 to 0.5) of Rc values reveals to strongly elongated basin shape and high infiltration rate (Aparna et al., 2015). The sub-basins Rc values are shown in Table 6, are 0.28 for El-Seih, 0.52 for Um Graph and 0.73 for Mukattab and these values indicate moderate to high relief and the drainage system of the investigated study area seems to be more influenced by structural disturbances.

Form factor ratio (Rf): The principle of form factor ratio was stated by Horton (1932), as the ratio of the basin's area and square of the basin length. In completely circular basin the value of Rf would always be greater than 0.78. With Smaller the values of form factor, the basin will be more elongated. Flood flows of elongated basins are easier to manage than of the circular basin (Christopher et al., 2010). The Rf value of the three sub-basins El-Seih, Um Graph and Mukattab are 0.29, 0.45 and 0.54, respectively (Table 6). These values represent the elongated to sub circular shape of the sub-basins. Low Rf indicates that the basin will have a flatter peak of flow for longer duration.

Table 6: Geometric Morphomertic parameters of investigated area

Wadi name	Basin Length Lb (km)	Basin Area A (Km²)	Basin Perimeter (P, Km)	Elongation Ratio (Re)	Compactness coefficient (Cc)	Circularity Ratio (Rc)	Form Factor Ratio (Rf)
W.El-Seih	33.7	340.1	144.5	0.62	1.9	0.28	0.29
W.Um Graph	10.7	51.1	35.1	0.75	1.4	0.52	0.45
W.Mukattab	5.7	17.6	17.4	0.83	1.2	0.73	0.54

C. Drainage Texture Analysis

Length of overland flow (Lg): it is defined as the distance that water flows over the ground surface before it becomes concentrated into specific stream channel (Horton, 1945). Lg is an important morphometric variables controlling both physiographic and hydrologic development of a drainage basin. It expressed by reciprocal of twice the drainage density. The Lg is related inversely to the average slope of the channel, with the shorter in the Lg, the quicker the surface runoff will be and vice versa. The values of Lg of the three sub-basins are shown in (Table 7). Lg values vary from 0.19 to 0.26 km (convergent values), indicating overall moderate to high relief in study area with moderate to steep slopes and shorter flow paths.

Drainage Density (Dd): it is a term introduced by Horton (1945) to express the length of streams segments per unit area. Dd expresses the closeness of tributaries reflecting the nature of subsurface layer, its permeability and roughness, where the low values of drainage density indicate areas of highly permeable sub-soil and/or flat areas of intense vegetation cover and vice versa (Strahler, 1964). The high values of Dd is observed in the weaken regions and impermeable subsurface material, mountainous relief and sparse vegetation. The factors that control the characteristic length of stream like resistance to weathering, climate, permeability of rock formations and vegetations affect the drainage density. Langbein (1947) make a suggestion that the Dd value varies between 0.55 and 2.09 km/km2 in humid regions. The drainage patterns in the study area was dendritic, sub dendritic, rectangular, pinnate and trellis. The drainage network is an important for delineation the watersheds and suggestion water-harvesting structures. The Dd for sub-basins ranges from 1.95 to 2.6 as (Table 7). Values of Dd for all the study area reveal to moderate Dd and this suggests that the area has moderate to highly resistance or moderate permeability subsurface material with intermediate drainage and moderate relief.

Stream Frequency (Fs): it is a term introduced by Horton (1945) for the number of streams per unit area. It reveals the texture of the drainage pattern and depends upon the lithology of the basin. High values of Fs reflect greater surface runoff, steep ground slopes occurrence, with lower permeability rocks and this reflects less infiltration but low Fs values indicate surface watershed material and low relief (Reddy et al., 2004). In the present study, the Fs values of sub-basins El-Seih, Um Graph and Mukattab are 3.0, 2.9 and 3.5, respectively (Table 7). The Fs ranges in study area are ranging from 2.9 to 3.6 with an average 3.08 and this indicates the development of about three streams in an area of 1 km² in the basin and this shows moderate to high Fs, indicating the occurrence of moderate and steep ground slopes, with lower to moderate permeability rocks, which facilitates less infiltration and greater run-off.

Drainage Texture (Dt): it is an important conception of geomorphology which reveals to the comparative spacing of drainage lines. The formula of Dt is total quantity of stream segments of all orders per P of that area (Horton, 1945). Smith (1950) showed that Dt is a measure of closeness of the channel spacing depending on rainfall, lithology, climate, penetration capacity and topographical aspect of the terrain. Smith (1950) has classified drainage texture into five different categories: Dt < 2 (Very coarse), Dt is from 2-4 (Coarse), Dt is from 4-6 (Moderate), Dt is from 6-8 (Fine) and Dt > 8 (Very fine). In the present case, very fine texture appears on El-Seih sub-basin that gives Dt is 8.2 and Um Graph sub-basin indicates moderate Dt, while Mukattab sub-basin shows coarse Dt indicating higher permeable rock formation and enhanced ground water potentiality (Table 7).

Constant of channel maintenance (C): it represents the drainage area required to maintain one unit of stream/channel length therefore, it is a measure of watershed erodibility. It has an inverse relation with drainage density (Schumm, 1956). A lower constant of channel preservation of a basin reveals to higher permeability of rocks of that basin and vice versa. The C values of study sub-basins ranged from 0.38 to 0.52 (convergent values), with average 0.43 km² that is required to support each linear one kilometer of stream channels (Table 7). These C values are revealing to moderate range of C and reflect moderate infiltration and permeability in the study area.

D. Relief characteristics

Basin relief (H): it is an important factor in considerate the geomorphic and landform characteristics. It is the most vertical distance between the highest and the lowest points of a basin (Strahler, 1952). The high basin relief value indicates the gravity of water flow, low infiltration, and high runoff conditions (Magesh et al., 2013). El-Seih, Um Graph and Mukattab sub-basins have H value of 995, 596 and 488 m, respectively (Table 8). The basin relief indicates the textural dissection of the investigated area and it is considered to be high and the land has moderate to steep.

Table 7: Drainage Texture Analysis of investigated sub-basins.

Wadi name	Length of Overland Flow (Lg, km)	Drainage Density Dd (km/km²)	Stream Frequency (Fs)	Drainage Texture (Dt)	Constant of channel maintenance (C)
W.El-Seih	0.19	2.6	3.0	8.2	0.38
W.Um Graph	0.26	1.95	2.9	4.3	0.52
W.Mukattab	0.20	2.5	3.5	3.5	0.40

Ruggedness Number (Rn): it is the product of H and Dd, where both parameters are in the same unit (Schumm, 1956). The Rn is directly related to erodibility in which increasing of Rn reflect increasing of erosivity. Rn analysis is useful for slope and steepness of the drainage network. For the sub-basins, Rn values are in the range of 1.16 to 2.58 (Table 8). The Rn of Um Graph sub-basin was the lowest and El-Seih sub-basin has the maximum Rn. Higher Rn value of El-Seih sub-basin indicates higher soil erosion susceptibility.

Relief Ratio (Rh): it is considered fundamental morphometric parameters. Rh is defined as the relation between the basin relief and the highest basin dimension parallel to the main drainage line; it is the parameters that capture the overall slope of a drainage basin (Schumm, 1956). It is an indicator of the strength of erosion process working on slope of the basin and shows sediment release processes and flooding seriousness that happen in the branches of the catchment (Strahler, 1957). Low values of Rh are mainly attributed with flat and gentle slopes, that relates to highly permeability of the subsoil that can be used in agricultural activities but higher values may indicate higher degree of slope. As given in Table 8, El-Seih has lower Rh between sub-basins, while Mukattab has highly Rh that indicates strong relief and steep slope. The result is also visually calculated and interpreted by using a topographical map 1:50,000 and Google earth map.

Table 8: Relief characteristics of the investigated sub-basins.

Wadi name	Basin Relief H (m)	Ruggedness Number (Rn)	Relief ratio (Rh)
W.El-Seih	995	2.58	29.5
W.Um Graph	596	1.16	55.7
W.Mukattab	488	1.22	85.6

V. CONCLUSION

Quantitative morphometric parameters calculated from remote sensing data, especially the digital elevation map extracted from ASTER data (GDEM) using GIS analysis tools are significant and valuable information of basins and sub-basins hydrology. In addition, it helps to evaluate the potential prioritization of sub-basins, effective soil, drainage pattern, water preservation work and groundwater resource management. The morphometric analysis was applied for three selected sub-basins in East Abu Zenima, southwest Sinai, Egypt. The result revealed that the sub-basins indicating vulnerable to soil erosion and low to moderate runoff that indicate to high groundwater potential infiltration especially at Wadi Mukattab sub-basin. Moreover, evaluation terrain analysis of the sub-basins using spatial analyst tools helped us to understand topographic surface parameters such as slope and aspect that affect the hydrological process of the interested sub-basins. Additional studies with very high resolution satellite data verified with the help of ground-based points will facilitate us to better recognize and propose more effective sub-basins management system.

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