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Morphometric Analysis of a selected drainage system in the northern part of the Western Desert of Egypt.

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Abstract:

Geographic Information System (GIS) and image processing techniques wereemployedto study the geomorphic and the morphometric features of a selected drainage system in the Western Desert of Egypt. The computed morphometric parameters including linear, areal and relief aspects. Reveled that the basin is influenced by rainfall potential zone and the underlying rock unites. The studied watershed, stream frequency (1.4)indicating moderate frequency. This reflects a positive correlation with drainage density. The bifurcation ratio (3.6) revealed that the studiedstructurallycontrolled. Circulatory ratio and elongation ratio show elongated in shape,the high elongated channel gradient, low discharge of runoff and highly permeability revealing tectonically active and revealing the groundwater potential zones.

1. Introduction:

The morphometric analysis of the drainage systemreveals climate, geomorphology, structural, and geologic features. The geomorphologic investigation helps to describe the evolution of surface drainage (Horton, 1945; lopold and Maddock.1953; Abrahams, 1984). Morphometric analysis of watershed also gives a quantitative description of the drainage system (strahler, 1964). The important of morphometric analysis can be used to correlate the hydrologic characteristic with physiographiccharacteristics of drainage basins such as size, slope, shape, and drainage density, the slope of drainage area, size and length of the tributaries. Hydrologists and geomorphologists were identified that certain relation is significant between runoff and geographic and geomorphic characteristics of the drainage systems.(Abedkareem 2016),the drainage basin analysis can be also used in any investigation of ground water potential, andmanagement.Remote sensing data contributed in understanding the geomorphic characteristic, identification of erosion-prone area, evolving water conservation strategies selection of sites for cheek dams and reservoirs .Therefore, the present study was conducted using Geographical information system (GIS) techniques foranalyzing the morphometric parameters of the drainage system. In order to understand the geologic and geomorphic characteristics of the studied basin.

2. Material and method:

The present study is located in the northern part of theWestern Desert of Egypt. The morphometric analysis was performed by remote sensing and GIS techniques. In thisarticle the morphometric analysis was performed onthe selected basin of the Qattara Depression. Stream order was generated by Strahler law which branched stream as first order. The second order stream was formed when the two first orders was linked. Two second order connects together to form the third order. Morphometric parameters are processed by standard method and formula (Horton, 1932 &1945; Strahler, 1964; Smith, 1954; Miller, 1953; Schumn, 1956; Nookaratm, 2005). The computed parameters show in Table1.

3. Study area:

The Qattara Depression is located in the north Western Desert of Egypt. It covers about 5800km^2.It consists of sabkha, mixture of salt, and water, whose formation cannot have been produced by the evaporation of theseawater that has spread the depression. The stratigraphic sequence overlying the basement complex in the north Western Desert generally includes three major lithological divisions as reported by Said (1990), Barakat (1982) and Abdel Hady et al. (1988). From base to the top have lower clastic division of Pre-Cenomanian age, middle calcareous division of Cenomanian to Late Eocene age, and the Upper clastic division of Oligocene to Recent age. Sandstones and other Quaternary deposits with some minor Oligocene rocks are occupying the northeastern part of the study area.

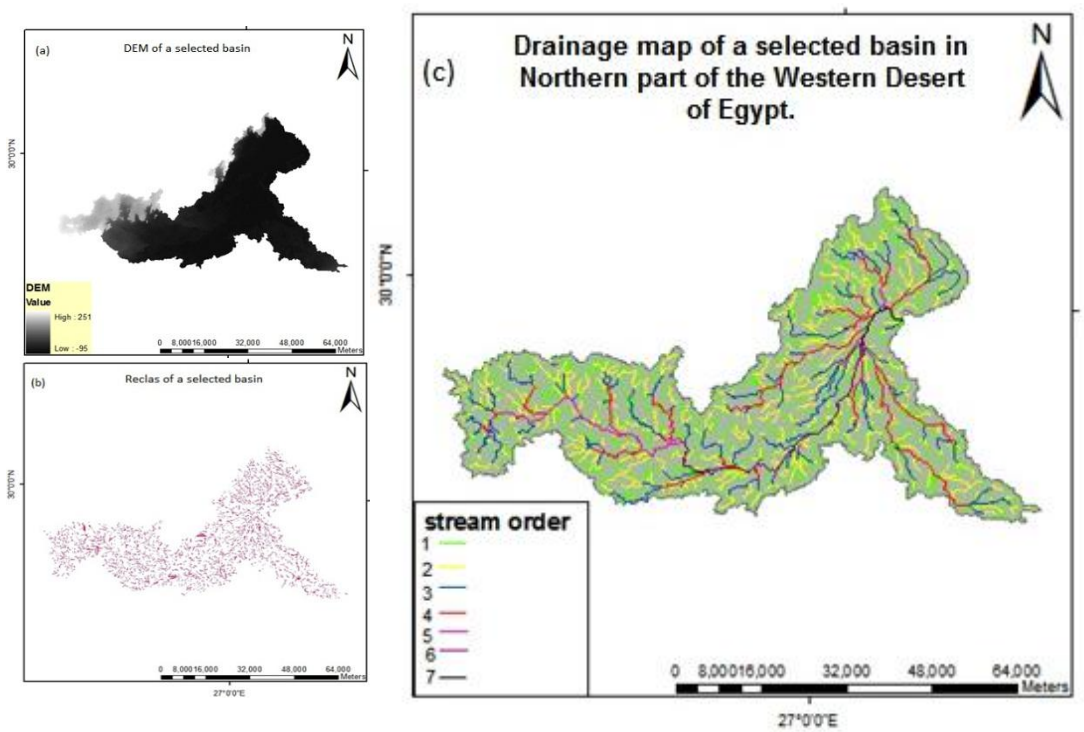

Fig1.

Stream-network extraction of studied basin (a); Digital elevation model(b) stream-networks; (c) stream-order.

4. Result of morphometric analysis:

4.1. Stream order:

The stream segmentswere orderedaccording toStrahler (1952). It described the relative position of stream segments in an erosional drainage basin network (Golts and Rosenthal, 1993).The stream order was first supported by Horton (1945). While Strahler (1952) was reformed it. Strahler (1967) method used for analysis the study area. It depended on the intersection of two first-order links will follow with a second-order link. Consequently, the intersection of two second-order link will follow with the third-order link etc. It was noticed that there is a decrease in the stream frequency as the stream order increases.Based on Strahler(1952,1967)The studied basin was classified into seven orders (Fig.1c).

4.2. Stream length:

Thestream of relatively smaller lengths reflects of areas with higher slopesand finer textures. Stream lengths increase in the first order and decrease as the stream order increases. This represents the relation between the climate, vegetation, and resistance rock and soil to erosion. The stream lengths of the studied basin range from 13.85 mto 1775.51m with an averaged about 502.73 m.

4.3. Stream number (Nu):

Each order has a number of streams that is computed as stream number. Longer lengths of streams show flatter gradients. The stream number values are listed in Table 2.

4.4. Bifurcation ratio (R_b)

Bifurcation ratio defines the ratio of the number of streams of any given order to the number of streams in the next higher order. The bifurcation ratio of the studied basin ranges from 2 to 4.3 (Table2).The low bifurcation values reveal relatively less structured-controland structures has not distorted the drainage pattern (Strahler, 1964). Little differences in the environmental conditions of the sub-basin is indicated by values of the bifurcation ratio.The mean bifurcation ratio value ofthis basin is 3.6which indicate that the geological structure is less disturbing the drainage pattern.

4.5. Stream length ratio (RL):

Stream length ratio plays an important role in detecting the relationship between the surface flow, discharge and erosion stage of the basin. Mean stream length represents a dimensional property that illustrating the components of drainage network. It is computed by dividing the total length of the stream of an order by a total number of segments in the order (Table.1). Streamlength ratio is the ratio of the mean (LU) of a segment of order to mean length of segments of the next lower order which was likely to constant throughout the successive orders of the basin. The stream lengths show that the mean stream lengths of the stream segments of each of the successive orders of the watershed have approximately a direct geometric sequence.The first term is the average length of segments of the first order.The stream lengths (Rl) value is (3512.2), which prove the variations in the slope and

Table.1 indicate morphometric parameters

parameters	symbol	formula	reference
Linear aspect			
Stream order	S_u		Straheler(1952)
Number of streams	N_u	N_u=No.of stream segments 0f given order	Horton(1945)
Total length of streams	L_u	L_u=Length of stream (Km)	Straheler(1964)
Bifurcation Ratio	R_b	$R_b=N_u \backslash N_u+1$ N_u+1 = No. of stream segments of next higher order N_u = known above	Straheler(1964)
Mean Bifurcation Ratio	R_{bm}	R_{bm} = average of bifurcation ratios of all orders length of the stream (KM)	Straheler(1964)
Stream length Ratio	R_l	$R_l = L_u \backslash L_u-1$ L_u = know above L_u-1 = stream length of next lower order	Straheler(1964)
Mean Stream length Ratio	L_{sm}	L_{sm} = average of stream length of all orders	Horton(1945)
Basin Geometry			
Basin Area	A	Area from which water drains to common stream and boundary determined by opposite ridge	Schumm(1956)
Basin length	L_b	L_b = Largest horizontal distance between 2 points	Schumm(1956)
Basin perimeter	P	P = outer boundary of drainage basin measured in kilometer	Schumm(1956)
Areal and relief aspect			
Drainage density	D_d	$D_d = \Sigma L_u / A$ D_d = Drainage density $(Km \backslash Km^2)$ L_u = total stream length A = Area	Horton(1932)
Stream frequency	F_s	$F_s = \Sigma Nu / A$ Nu and A = known above	Horton(1932)
Basin relief	B_h	$B_h = Z_x - Z_m$ B_h = Basin relief in kilometer Z_x = maximum elevation of basin Z_m = minimum elevation of the basin	Straheler(1952)
Relief ratio	Rh	$R_h = B_h / L_b$ R_h = Relief ratio in kilometer B_h = Basin Relief and L_b = Basin Length	Schumm(1956)
Ruggedness number	R_n	$R_n = B_h \times D_d$ Bh = Relief ratio and D_d = Drainage density	
Texture ratio	T	$T = N_1 / P$ N_1=No.of streams in given order and P=Perimeter	Schumm(1965)
factor Form	R_f	$R_f = A / (L_b)^2$ A= Area and L_b length	Horton(1932)
Circulatory ratio	R_c	$R_c = 4\pi A / P^2$ A=Basin area (Km2) and P=perimeter of Basin (Km)	Miller(1953)
Elongation ratio	R_e	$R_e = \sqrt{(A/\pi)} / L_b$ A= Area (Km^2) and L_b= length of basin (Km)	Schumm(1956)
Length of overland flow	L_g	$L_g = 1 / 2D_d$ D_d= Drainage density (Km2\Km)	Horton(1945)
Constant channel maintenance	L_{of}	$L_{of} = 1 / D_d$ D_d= Drainage density	Schumm(1956)
Infiltration number	I_F	$I_F = D_d \times F_s$ D_d= Drinage density and F_s= stream frequency	Faniran(1968)
Channel gradient	C_g	$C_g = B_h / [(\pi / 2) \times L_b]$ C_g=longest dimension parallel to the principal drainage line B_h= basin relief , L_b= length of basin	Broscoe(1959)
Main channel length	C_l	C_l= long of longest stream in kilometer	

The stream length ratio varying between 1.2 to 4.3(Table 2).

4.6. Basin area: (A)

Basin area (A) defined as the total area projected upon a horizontal plane. Schumm (1956) founded an interesting relation between the total watershed area and the total stream lengths, which are reinforced by the contributing areas (Table.1). Horton (1945), watershed was sorted by size into the category of large basin. The total basin area is 2705 Km^2(Table.3).

4.7. Basin perimeter (P):

Basin perimeter is the length of the boundary of the basin. It is also determined the length of the divides between watersheds.It used as a sign of watershed size and shape.The perimeter of this basin is about510.80 Km.

4.8. Basin length (L_b):

Basin length was the travel time of surface runoff especially the flood waves passing through the basin. The length of this basin is about 18.593 Km.

4.9. Drainage density (Dd):

Drainage densityis defined as the closeness of spacing of channel, thus it gives a quantitative measure of the average length of stream channel for the whole basin. Low drainage density proved the erosion resistant fractured rocks and evidence for that the rainfall infiltrates to recharge the ground-wateraquifers. The high drainage density indicate weak or impermeable sub-surface material, and mountainous region which have coarse drainage texture appeared with low drainage density.The fine drainage texture characterized by high drainage density.Thecomputed drainage density (Dd) of the present study is1.3 that represents a moderate drainage density.

4.10. Stream frequency (F_S):

It is the total number of stream segments of all orders per unit area (Horton, 1932). It reflectsthe lithological characteristics. The basins of the structural hills give high-level of stream frequency and drainage density, while the basins of alluvial deposits revealing low values (Horton, 1945). The stream frequency of the studied basin is about 0.9 that reveals moderate Fsandindicates the positive correlation with the drainage density values which theincrease in stream population with respect to increasing in drainage density (Abdelkareem 2016).

Table. 2. Result morphometric analysis of the studied basin.

Stream order	Stream number	Stream length	Stream length Ratio	Bifurcation Ratio
1	1817	1775.518787	2	4.3
2	419	886.497493	2	4.3
3	98	450.938354	1.8	3.9
4	25	252.174587	3.4	4.2
5	6	73.160487	1.2	3
6	2	60.017406	4.3	2
7	1	13.850007	-	-
Mean	-	_	2.5	3.6

4.11. Basin relief (B_h):

The basin relief is defined as the difference between the maximum elevation and minimum elevation of the basin (Table 1).It is about 0.4 of the studied basin that reveals a moderaterelief.

4.12. Relief ratio (R_h):

According to schumm (1956), the relief ratio is the ratio between the total relief of the basin and the longest dimension of the basin parallel to the main drainage line. It determines the overall steepness of adrainage basin and expressed the intensity of erosional process operating on the slope of the basin.The loosesediments are closely correlated with relief ratio which shows the relation between the relief ratio and hydrologic characteristics of a basin (schumm, 1956).The relief ratio of the studied basin is 0.02 reveling a low relief.

4.13. Ruggedness (R_n):

Ruggedness number represents slope index and gives a good description of a relief ruggedness within the watershed (melton, 1965). High values of ruggedness number lead to asteep and long slope of the basin. Strahler's (1968) suggested that the ruggedness number calculated with the drainage density basin relief and the slope steepness related with its length. Low ruggedness value of the basin means less prone to soil erosion and yield intrinsic structural complexity in association with relief and drainage density.The ruggedness number is about 0.52 that reveal low value (table 3).This low value infers to less prone to soil erosion and has a complexity of true in a relationship with relief and drainage density.

4.14. Texture ratio:

Texture ratio playsan important role in analysis of the drainage basin which is influenced by relief aspect ofthe terrain. Smith (1958) classified the texture ratio of the basins into three classes as the following: coarse (<6.4 km^{-1}), intermediate (6.4-16 km^{-1}) and fine (>16 km^{-1}).The computed texture ratio of the studied basin is about 3.6that indicate a finetexture (Table.3).

4.15. Form Factor (R_f):

The Form Factor (Horton, 1932) represents a mean numerical index that indicates the shape of the basin and its valued ranges from 0.1 to 0.8. Also, known as the dimensionless ratio of basin area to the square of basin length. Basin shape detected by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998). Basins that have a low value of form factor mostly like to be more elongated, less intense rainfall simultaneously and take lower peak runoff of longer duration (Gupta 1999). The basins of high values of form factor represent a high peak runoff of longer duration. The studied basin donates the high value ofform factor which is about7.8(table 3). This impels a larger peak of flows of short duration.

4.16. Circulatory ratio (Rc):

Miller (1953) defined the circulatory ratio as the ratio of basin area to the area of the circle with the same perimeter of the basin. He described the basin of the circularity ratio of numeric number 1 (one) value was of circular shape indicating uniform infiltration and takes long time to reach excess water at basin outlet. The basin of circularity ratios ranges 0.4 to 0.5 representsa strongly elongated and highly permeable homogeneous geologic material that refers to low active tectonic.The studied basinis about 0.5 value of the circulatory ratio referring to anelongated shape, low discharge of runoff and highly permeability of the subsoil condition (Table.3).Circulatory ratio of the studied basin is 0.13 that reveals a very elongated basin.

4.17. Elongation ratio (R_e):

Schumm (1956) presented a relation between the total watershed areas and the total stream lengths. He groupedthe ratio such as 0.9-1 circular, 0.8-0.9 oval, 0.7-0.8 less elongated, 0.5-0.7 elongated, <0.5more elongated. The higher the value of elongation ratio, the more circular shape of the basin. Geology and structure effects on the variations of the elongated shapes of basin. Low elongation ratio of the values tends to more erosion. Where the region of high value reveals high infiltration capacity and low runoff. Strahler (1964) summarized that the ratioranges from <0.7 and 0.9 over a wide variety of climatic and geologic conditions. The Elongation ratio of the study area is 0.5 indicating high elongatedshape resulting of tectonically active area.

Table.3. Areal and relief aspect

Parameter	Value
Area	2705.680495
Perimeter	510.807387
Basin order	**7**
Drainage density	1.3
Stream frequency	0.9
Zx	251
Zm	-95
Basin relief	0.4
Basin Length	18.593
Relief ratio	0.02
Ruggedness number	0.52
Texture ratio	3.6
factor Form	7.8
Circulatory ratio	0.13
Elongation ratio	0.5
Length of overland flow	0.4
Constant channel maintenance	0.8
Infiltration number	1.2
Channel gradient	0.01
Main channel length	70

4.18. Length of over land flow (L_x):

Length of over landflow was very important factor which affected with both hydrologic and physiographic development of the drainage basin. Horton (1945) defined it as the runoff of the rain water on the ground surface before it excitesinsures channels. The average of this length is about half the distance between the stream channels. It influenced with infiltration through the soil that varies in time and space. Basin of the study area confirmsthe low range of length of overland flow that is about0.4. The low value means that surface water concentrates faster than the basin of high value.

4.19.Constant channel maintenance (L_{of}):

The constant channel maintenance(Schumm, 1956) hasa dimension of length and increase in magnitude because the scale of the land-form unit increases. Strahler (1957) indicate of that the relative size of landformunits in a drainage basin and give specific genetic connotation in this method.The value ofConstant channel maintenance basin is0.8 indicates that the surface needs in basis for a creation of one linear foot of the stream channel.

4.20. Channel gradient (C_g):

Horton's low of stream slopes reflects that there is a fairly based relationship between the slope of the streams and their orders. This show that an inverse geometric channel slope reduces with increasing order number. The slope of channel decreases by increasing the order number of thebasin. Also, we notice that the stream not be linear but it is braided form. The channel gradient of the studied basin is 0.01that refers to the low slope ofchannel.

4.21. Infiltration number (L_f):

Infiltration number describes as the results of drainage density and stream frequency that provides us with an interpretation of the infiltration characteristics of the basin. Low runoff and high infiltration appeared when the infiltration number was low value. This factor presented by Faniran (1968). It provided an important information about impermeable lithology and higher relief. The value of the computed infiltration number is about 1.2 that reflects low runoff.

4.22. Main channel length (C_l):

Themain channel length refers to the length of the longest basin from the outflow point of designated basin to the upper limit to the basin boundary. The longest channel founded in thisbasin having70 km.

5. Conclusions:

The morphometric analysis carried out in a selected drainage system in northern part of the Western Desert of Egypt indicated that the basin of low relief terrain, ruggedness, high elongated in shape and fine texture thatrevealed structural control. The morphometric parameters evaluated using GIS-assisted to understand various terrain parameters such as nature of the bedrock, infiltration capacity, and runoff. The computed values refer to low runoff and high infiltration capacity. The overall results revealed that analysis of drainage system displayed significant information on geomorphic and hydrologic conditions.

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