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Characterizing the Hydrologic and Hydromorphic Parameters in Wadiqena, Egypt

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***Abstract**: Topographic data was utilized and processed using Geographic Information Systemapproaches to compute the hydro-morphometric parameters of WadiQena. The morphometric analysis of the studied WadiQena basin and sub-basins revealedvaluable information about the hydrologic characteristics of the basin. The results revealed that the basincan be classified into twenty four sub-basins. The computed parameters that present information about the basin relief, geometry and texture were statistically analyzed and integrated to reveal the most hazard areas for flash flood. Using linear equation and integrated overly method, the hazard of the studied basin categorized into 5 classes include very low, most of the very ligh risk sub-basins emanates from the basement highlands resulting the high runoff in regions of high relief and slope. However, subbasins of low vulnerable to flood hazards are consistent to areas of low relief and flat land-surface.*

***Keywords:** WadiQena, GIS, hydrologic properties, Morphometric analysis*

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I. Introduction

The high and moderate resolution of topographic datawas used for analyzing the drainage systems (Biswas et al. 2014; Lyew-Ayee et al. 2007; Chopra et al. 2005; Rudraiah et al. 2008; Waikar and Nilawar 2014; Abdelkareem 2017).Higher rainfall intensities cause sizable runoff and flash flooding (Patton and Baker 1976; Syvitski et al. 2009; Hussein et al., 2019 a forthcoming article) that happened in a short duration (e.g., Bangira 2013). Flash floods cause harmful effects for social life and the economic aspects. Such events caused a loss of human lives and massive damage to the infrastructure.

The measurements process of the earth's surface and of the geometry and dimension of its landforms is called morphometry (Clarke, 1966). Estimation of erosion surfaces, slopes, relative relief and basinproperties, river basin evaluation, watershed prioritization for soil and water conservation activities in river basins are methods of morphometric analysis (Kanth, 2012).

Because of runoff is affected by slope, fracture, topography, rock formations and stream networks, the present investigation focused onextraction and identifying the quantitative information of the drainage basin WadiQena including thestream networks, geometry and relief of the basin. Moreover, characterize the vulnerable area for flood hazards.

II. Study area

WadiQenalies between latitudes 26 0 10\ to 28 0 5\ N and longitudes 320 31\ to 320 45\ E in the Eastern Desert of Egypt, covering an area of about 15746.5 km^2. It isa significant valley that links the Nile basin at Qena city (Abdelkareem and El-Baz 2015). Several strategic roadspasses through the wadi such as Qena-Safaga road, The Red Sea-Southern Egypt Road (Red Sea-Sohag-Asyut road that crossing the Ma'aza Plateau). However, it is hard to reach from north as a result of the absence of asphaltic roads and long distance. The area is characterized by dry climate (degree of aridity= 0.2284), with long hot summers and short warm winters. It is located in arid-hyper-arid climate condition. The maximum daytime temperatures range from 23^{0}C in winter to 42^{0}C in summer with a mean annual temperature of 33^{0}C (Rashed et al. 2006).

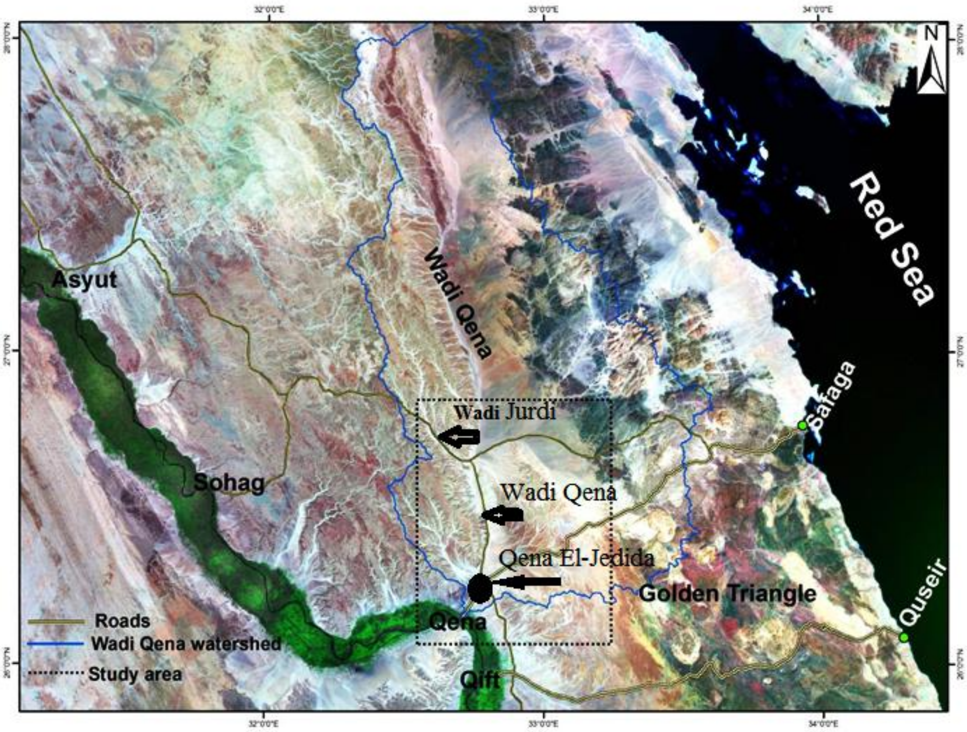


Fig. 1. Location map of WadiQena

III. Data used and methods

Topographic data obtained from Shuttle Radar Topography Mission (SRTM) was utilized in the present study. Such data covering the study area were obtained as a joint project of NASA and the National Geospatial-Intelligence Agency (NGA). SRTM data were processed using ARC GIS 10 software packages to obtain the stream-networks. This data was used in the extracting of the stream-networks and their watershed. This was done by employing surface flow routing based on the 8 D flow direction algorithm of Jenson and Domingue (1988). This was done using a hydrology module of spatial analyst in several steps (e.g., El Basstawesy et al., 2010; Abdelkareem 2017).The extracted stream-networks were ordered using Strahler (1957) method and, then, many morphometric parameters were computed to high light areas of flood potentials (Abdelkareem et al., 2015).Linear equation of Davis (1975); the grade of hazard for the most of the computed parameters (Table 1) is calculated using equation #1, but Rb and Lg (Table 1) are computed using equation #2. Therefore, the total hazard degree for each sub-basin is listed in Table 2.

$$\text{Hazard degree} = \frac{4(X - X_{\min})}{X_{\max} - X_{\min}} + 1 \qquad (1)$$

$$\text{Hazard degree} = \frac{4(X - X_{\max})}{X_{\min} - X_{\max}} + 1 \qquad (2)$$

IV. Results

The morphometric analysis of the studied basin using SRTM DEM providedgood information about the basin geometry, texture and roughness. WadiQena area is extending about 15746.5 km^2 that outlined by a perimeter of about 880.674 km. Despite the studied area of southern WadiQena area is about 6,000 km2 and covered by many sub-basins of WadiQena, we calculated the hydromorphic (morphometric) parameters for the entire WQ basin to understand the entire basin characteristics. This is because the tributaries drain to the southern WQ main stream. The extracted information employed to evaluate the flash flood hazards which governed by the basin relief, texture, geometry, and size. The calculated parameters and its formula are listed in a table (Table 1). We subdivided WadiQenainto 24 sub

In the present study the flash flood hazard map calculated by two methods as follow (1) using linear equation of Davis (1975) 4(X-Xmin)/(Xmax-Xmin)+1; (2) plotting both of Dd and Fs vs. Rb(El-Shamy 1992).

Table 1 Hydromorphic parameters of WQ basin

	Drainage				Basin Geometry								Drainage Texture			Relief characteristics		
Basin _NO	U	N_u	L_u	R_b	A	P	L_b	R_f	R_e	T	R_c	F_s	D_d	I_f	L_g	B_h	R_h	R_n
1	6	2240	2324.46	4.45	1469.35	336.6	59.872	0.41	0.722	5.15	0.16	1.52	1.58	2.41	0.32	0.795	0.0133	1.26
2	7	2724	3019.05	3.77	1796.26	324.2	75.275	0.317	0.635	6.51	0.21	1.52	1.68	2.55	0.3	1.6	0.0213	2.69
3	6	848	1036.24	3.5	1871.35	217.4	36.785	1.383	1.327	3.08	0.5	0.45	0.55	0.25	0.9	0.702	0.0191	0.39
4	5	760	737.89	4.96	493.81	183.2	41.708	0.284	0.601	3.23	0.18	1.54	1.49	2.3	0.33	1.487	0.0357	2.22
5	6	1200	1248.87	3.99	775.33	251.3	54.047	0.265	0.581	3.72	0.15	1.55	1.61	2.49	0.31	1.507	0.0279	2.43
6	6	670	807.318	3.62	465.82	215.1	42.003	0.264	0.58	2.47	0.13	1.44	1.73	2.49	0.29	0.442	0.0105	0.77
7	4	153	166.35	4.95	92.24	78.74	22.383	0.184	0.484	1.54	0.19	1.66	1.8	2.99	0.28	0.222	0.0099	0.4
8	5	274	333.12	3.9	195.89	123.6	14.411	0.943	1.096	1.73	0.16	1.4	1.7	2.38	0.29	0.393	0.0273	0.67
9	6	1125	1197.36	3.93	721.67	293.1	66.892	0.161	0.453	2.95	0.11	1.56	1.66	18.25	0.11	0.953	0.0142	1.58
10	6	825	1004.72	3.69	566.56	181.6	25.049	0.903	1.072	3.51	0.22	1.46	1.77	2.58	0.28	0.398	0.0159	0.71
11	5	221	244.432	0.64	157.26	130.9	35.838	0.122	0.395	1.33	0.12	1.41	1.55	2.18	0.32	0.434	0.0121	0.67
12	5	465	535.95	4.43	317.72	188.2	47.306	0.143	0.425	1.99	0.11	1.46	1.69	2.47	0.3	0.688	0.0145	1.16
13	5	495	484.09	4.97	271.88	135.8	20.022	0.678	0.929	2.2	0.19	1.82	1.78	3.24	0.28	0.431	0.0215	0.77
14	6	666	802.17	3.75	467.8	186.2	44.21	0.239	0.552	2.84	0.17	1.42	1.71	2.44	0.29	0.769	0.0174	1.32
15	5	642	766	4.91	439.12	132.1	27.556	0.578	0.858	3.81	0.32	1.46	1.74	2.55	0.29	0.438	0.0159	0.76
16	5	325	610.42	3.99	340.46	139.1	18	1.051	1.157	1.47	0.22	0.95	1.79	1.71	0.28	0.421	0.0234	0.75
17	5	344	381.51	4.4	228.37	125.1	31.471	0.231	0.542	2.16	0.18	1.51	1.67	2.52	0.3	0.91	0.0289	1.52
18	6	453	544.91	3.46	314.24	117.8	26.669	0.442	0.75	0.28	3.07	1.44	1.73	2.5	0.29	0.437	0.0164	0.76
19	6	812	1002.21	3.7	566.63	230.5	17.526	1.845	1.533	2.72	0.13	1.43	1.77	0.56	0.59	0.538	0.0307	0.95
20	6	1674	2196.42	4.24	1187.02	261.7	51.242	0.452	0.759	4.91	0.22	1.41	1.85	6.4	0.17	0.612	0.0119	1.13
21	6	1134	1194.96	3.95	757.9	244.9	56.73	0.235	0.548	3.64	0.16	1.5	1.58	0.71	0.58	0.47	0.0083	0.74
22	6	1969	2120.33	4.48	1377.65	373.4	92.398	0.161	0.453	4.07	0.12	1.43	1.54	2.2	0.32	0.559	0.0061	0.86
23	6	911	986.47	3.83	646.05	210.8	50.317	0.255	0.57	3.37	0.18	1.41	1.53	2.15	0.33	0.492	0.0098	0.75
24	6	1987	2495.28	4.47	1404.01	338.8	54.788	0.468	0.772	4.57	0.15	1.42	1.78	2.52	0.28	0.591	0.0108	1.05

The stream networks extraction of WadiQenadisplayseveral geometric characteristics such as dendriticand parallel patterns, particularly in the sedimentary rocks, but the igneous/metamorphic rocks shows rectilinear drainage pattern (Abdelkareem, 2012). The dendritic drainage pattern most likelyinvolved with the limestone rocksthat representthe homogeneous rocks (Feleb 2015). The stream network analysis of entire WadiQena basin revealed a 7^{th} order stream, suggesting a mature drainage pattern.The Bifurcation ratio (R_b) is calculated by dividing the number of streams in a given order by the number in the next higher order (Schumm 1956). Therefore, the estimated are categorized into (a) R_b values range from 4.482 to 4.973 that represent higher values such as sub-basins S4, S7, S13, and S15; and (b) R_b values 0.641 or lower such as in S11.The stream length ratio(R_l) is also estimated here and the value range from 0.4381 to 0.9512. Such values are higher in sub-basins S7 and S11 that display elongated geometry rather than S3, and S15 that are nearest to be sub-circular.

The basingeometry includes several parameters such as Area of the basin that is estimates as the total area projected upon a horizontal plane (Schumm1956). Therefore,the area of WadiQena's sub-basins rangesbetween 92.249 (S7) to 1871.351 (S3) km^2. The big areas in km^2includewide streams versus the small one.Therefore, they have probablyreceivedsizable water resources to the downstream(e.g., S1, S2, S3, S20, S22, and S24). Perimeter is also computed that is the length of the boundary of the basin (Schumm1956). It is measured along the divide between watersheds and may be used as an indicator of watershed size and shape. The computed perimeter herevaries from 78.743 (S7) to 373.401 (S22) km. Noteworthy that there is a positive relation between the Area and Perimeter, as the sub-basins of the high area are of high Perimeter e.g., S2, S22, S24, and S1. Moreover, according to Gregorg and Waling (1973) method, the measured lengths of WadiQena sub-basins varies from 14.41 (S8) to 92.39 km (S22).S2, and S22 area the most elongated basins in length based on the computed Lb.

Based on computing the elongation ratio (R_e) of Schumm, (1956), the R_e values (Table 1) varies from 0.39 (S11) to 1.53 (S19) and are higher in sub-basins S16 and S19 but lower in sub-basins S 11,S12,S19, and S22. Therefore, many sub-basins displaycircular shape such as S10, S8, and S3 but the more extended sub-basins are S11, S22, S9, and S7. This ratio is a very important index in the analysis of the basin geometry which aids to present an evidence of the hydrological properties of a basin. The varying slopes of river basins can be categorized with the aid of the index of elongation ratio, i.e. circular (0.9-1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and high elongated (less than 0.5).

The form factor (R_f) also computed to define the basin geometry (Horton, 1932).The values of form factor usually would be < 0.7584 (identical for a circular basin). The calculated Rf values varies between 0.12 (S11) and 1.84 (S19) (Table 1). Such Rf values are elevated in many sub-basin (e.g., S19, S3, S16, S8), but display lower values as in many sub-basins (e.g., S11,S2, S9, S22, S12, S6) and that range varies from 0.12 to 0.25. The elongated basin with low $R_f$reflects that the basin has a flatter peak with a longer duration. The Circularity Ratio (R_c) Miller (1953) also computed to define the geometry. The computed Rcvaries from 0.4 to 0.5 which indicates strongly elongated and permeable homogeneous geologic materials(Withanage et al., 2014).R_c ranges from 0.11 (S9, S12) to 3.07 (S18). Higher the value of R_cS18, S3, and S15 and lower values in S6,S9,S11,S12,S19, and S 22.

The texture ratio (T) of Schumm (1965) is the ratio of first order population Nu1 to the perimeter (P) of the basin. Based on the computed data in table 4.3 and the distribution of the T values on the studied sub-basins; the T values range from 0.28 to 6.5. This revealing that S1, S2, and S20 are of a higher population against the other sub-basins. This allowed collecting much surface water and promoting flood risks.

Horton (1932) described the stream frequency (F_s) as the total number of stream segments of all orders per unit area (Table 1). It depends on lithology, structures, infiltration capacity, vegetation cover, relief and amount of rainfall infiltrate to recharge the aquifers. The computed $F_s$range from 0.45 (S3) to 1,82 (S13). Higher values of $F_s$reveal fast runoff and a high peak of flood riskssuch as sub-basins S13 and S7.

The drainage density (D_d) Horton (1932) is an important evidence of the linear scale of landform elements in stream eroded topography. Based on Hortn method, the $D_d$values range from 0.5537 (S3) to 1.8503km/km^2 (S20). Therefore, areas of high drainage density relatively high runoff, promoting flood risk. Low D_d reflects erosion-resistant fractured hard rocks and most rainfall infiltrates to recharge the shallow aquifers.

Infiltration ratio (If) factor obtained bymultiplying the stream frequency(Fs) and drainage density(Dd) (Faniran 1968)(Table 1). The If values range from 0.25 (S3) to 3.24 (S13).Lower values of infiltration ratio revealing higher permeability and lower runoff.S7 and S13 revealing higher values as a result of the density of stream networks.

The length of overland flow (L_g) (Horton 1945) is the inverse of D_d that has a negative relationship with runoff, as with increasing value, the runoff decreases. It ranges from 0.27 to 0.90. Sub-basins S7, S16, and S23 revealing higher values; however, S3 is the highest value.

The basin relief is defined as the difference in elevation between the highest point (Z) of watershed and the lowest point (z) on the valley floor (Strahler, 1952). The elevation at Z of WadiQena basin is about 1058 m and z = 60m. Moreover, inWadiQena sub-basins; the B_h values range from 0.222 (S7) to 1.600 (S2) km. Sub-basins S2, S4, and S5 revealing higher values. The higher value of B_h indicates high runoff and higher peak of the flood.

The Relief ratio R_h can be obtained by dividing the $B_h$by the maximum basin length (L_b) which results in a dimensionless ratio (Schumm, 1956). Furthermore, it is a measure of the overall steepness of a river basin and it is an indicator of the intensity of erosion process operating on the slope of the basin. The R_h values of WadiQena sub-basin range from 0.006 (S22) to 0.857 km (S4).Higher values reveal higher runoff and high-risk areas. Sub-basins, S4, S5, S8, and S17 revealing higher value as a result of steepness landscape that connected to the mountains of the basement rocks.

The Ruggedness number can be computed by multiplying maximum basin relief (B_h) and drainage density (D_d). A higher value represents steep slope (Strahler 1957; 1964).The results of R_n values range from 0.39 (S3) to 2.69 (S2). Higher values reveal higher relief and runoff such as sub-basins S2, S4, and S5. Noteworthy a positive relation between B_h and R_n is recorded based on the similarity between higher values of studied sub-basins S2, S4, and S5.

Mapping flash flood hazards

Mapping flash flood hazards are estimated here using three methods including (1) integration of multi-criteria; (2) linear equation of Davis (1975); and (3) two dimensional graphs; Dd and Fs vs. Rb (El-Shami 1992)

1) Integrated Thematic maps through GIS

Utilizing GIS overlay approach several morphometric parameters of GIS layers were integrated to map the potential areas of a flash flood. Higher values of, R_e, R_f, R_c, T, F_s, D_d, I_f, B_h, R_h, and R_n promote runoff and higher flood peak (Abdelkareem 2017). Moreover, the higher values of T, F_s, D_d, and I_f reflects abundances of the streams per area and perimeter that accelerate the runoff. The higher values of R_e, R_f, and R_c revealed the circular sub-basins rather than elongated (Abdelkareem 2017). This reflects short travel time of the runoff rather than long travel time of elongated sub-basins. Higher values of B_h, R_h, and R_n revealed the steep slope and high relief terrain that promotes the runoff. However, low R_b and L_g revealed runoff (Table 2).

Table 2. Flash flood potentiality using weighted morphometric parameters

Factor	classes	risk	Factor	classes	risk
(R_b)	0.65	5	(D_d)	0.55	1
	0.65-3.77	4		0.56-1.61	2
	3.78-3.99	3		1.62-1.71	3
	4.00-4.48	2		1.72-1.78	4
	4.49-4.97	1		1.79-1.85	5
(R_e)	0.39-0.48	1	(L_g)	0.27-0.28	5
	0.49-0.58	2		0.29	4
	0.59-0.64	3		0.30	3
	0.65-0.93	4		0.31-0.33	2
	0.94-1.53	5		0.34-0.90	1
(R_f)	0.12-0.18	1	(I_f)	0.25	1
	0.19-0.32	2		0.26-0.20	2
	0.33-0.68	3		2.21-2.44	3
	0.69-1.05	4		2.45-2.61	4
	1.06-1.84	5		2.62-3.24	5
(R_c)	0.11-0.13	1	(B_h)	0.22	1
	0.14-0.17	2		0.23-0.49	2
	0.18-0.22	3		0.50-0.70	3
	0.23-0.32	4		0.71-0.95	4
	0.33-0.50	5		0.96-1.60	5
(T)	0.28-1.54	1	(R_h)	0.01	1
	1.55-2.47	2		0.01-0.02	2
	2.48-3.37	3		0.02	3
	3.38-4.57	4		0.02-0.03	4
	4.98-6.51	5		0.03-0.04	5
(F_s)	0.45-0.95	1	(R_n)	0.39-0.40	1
	0.96-1.43	2		0.41-0.86	2
	1.44-1.46	3		0.87-1.26	3
	1.47-1.56	4		1.27-1.58	4
	1.57-1.82	5		1.59-2.69	5

(2) Apply linear equation of Davis (1975)

Several morphometric parameters (R_e, R_f, R_c, T, F_s, D_d, I_f, B_h, R_h, and R_n) which have a positive relationship with the runoff and flood potential were calculated using(Eq.1). However,those have negative relationships such as the bifurcation ratio (R_b) and Length of overland flow (L_g) were calculated using (Eq.2). A hazard scale number starting with 1 (lowest) to 5 (highest) has been given to all parameters. The distributions of the hazard degrees for the studied basin and its sub-basins have been carried out as follows:

(a) Define the minimum and maximum values of each morphometric parameter for all the sub-basins.

(b) Evaluate the actual hazard degree for allparameters which are in between the minimumand maximum values were depending on a trial toderive the empirical relation between the relativehazarddegree of a basin with respect to flash floodsand the morphometric parameters; the equal spacing or simple linear interpolation between data pointsprocedure was chosen.

(c) Suppose a straight linear relationship exists between thesample points, the intermediate values can be calculatedfrom the geometric relationship (Davis 1975), using Eq.1 and Eq.2.In these equations, X is the value of the morphometric parameters to be assessed for the hazard degree for each basin, Xmin and Xmax are the minimum and maximum values of the morphometric parameters of all basins, respectively.

(d) The summation of the hazard degrees for each sub-basin represents the final flood hazard of that sub-basin (Table 2).

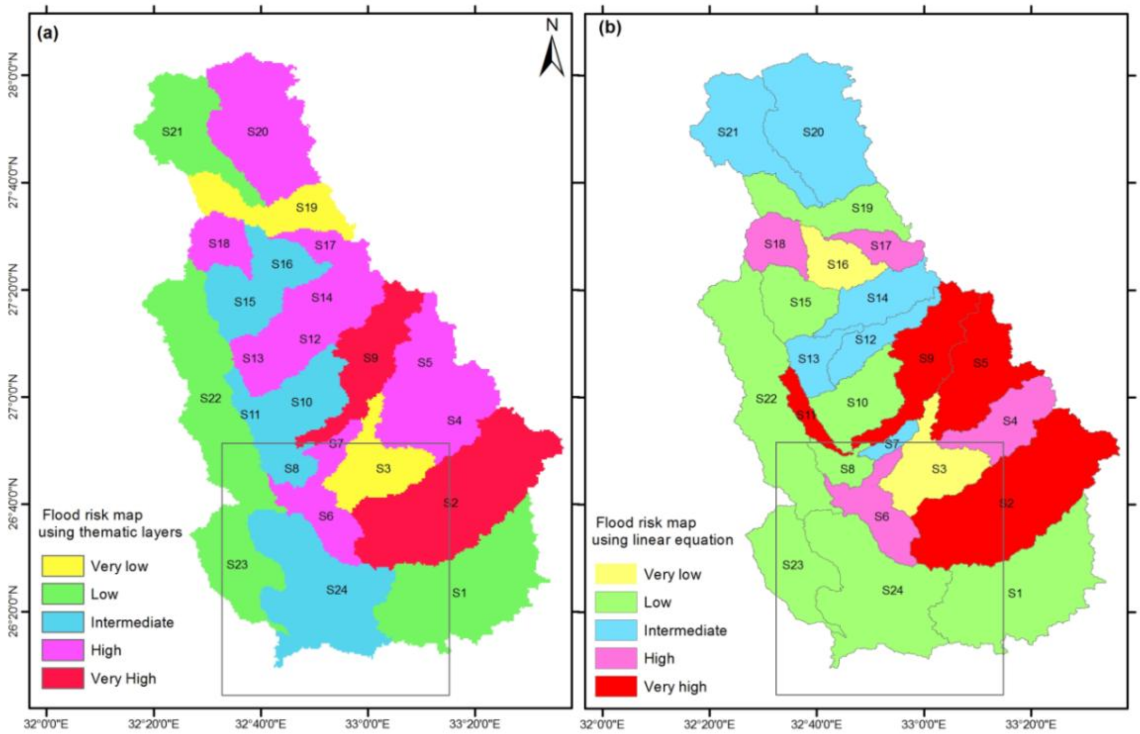


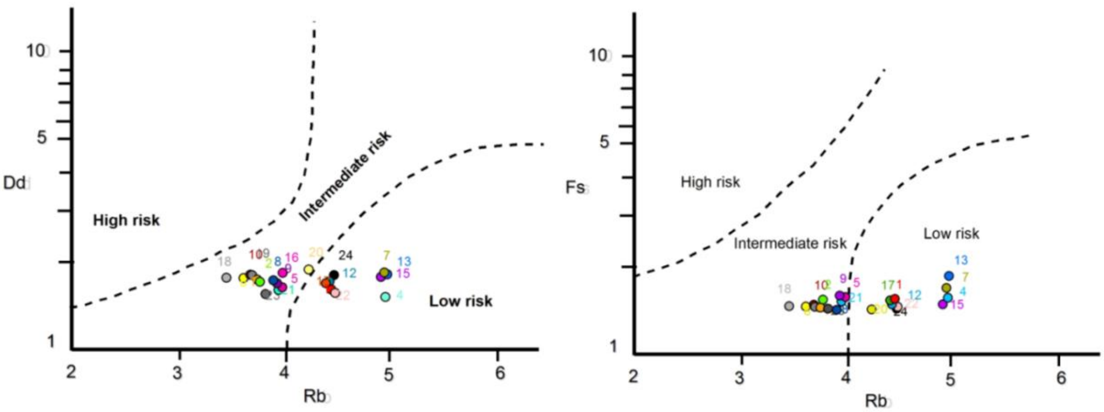
Figure 2.(a) Flash flood hazard map using thematic maps; (b) flash flood hazard map using linear equation of Davis (1975).

Table 3. Hazard degree of the studied WadiQena sub-basins using morphometric parameters

Basin_NO	(R_b)	(R_f)	(R_e)	(T)	(R_c)	(F_s)	(D_d)	(I_f)	(L_g)	(B_h)	(R_h)	(R_n)	Σ of hazard degree	Hazard degree
1	1.47	1.67	2.15	4.13	1.59	4.13	4.17	3.89	4.71	1.98	1.98	2.51	32.39	3
2	2.1	1.45	1.85	5	2.11	4.11	4.48	4.07	4.83	3.05	3.05	5	38.05	5
3	2.03	3.93	4.28	2.79	5	1	1	1	1	2.76	2.76	1	25.79	1
4	1	1.37	1.73	2.89	1.81	4.18	3.9	3.74	4.59	5	5	4.19	34.4	4
5	1.9	1.33	1.66	3.2	1.5	4.2	4.26	4	4.75	3.95	3.95	4.54	35.29	4
6	2.24	1.33	1.65	2.41	1.21	3.88	4.64	4	4.88	1.6	1.6	1.66	29.51	2
7	1.01	1.14	1.31	1.8	1.83	4.53	4.85	4.66	4.96	1.52	1.52	1.02	28.64	2
8	1.98	2.91	3.46	1.93	1.57	3.77	4.54	3.85	4.85	3.87	3.87	1.49	34.2	4
9	1.95	1.09	1.2	2.72	1	4.23	4.41	4.12	4.8	2.12	2.11	3.07	30.7	2
10	2.18	2.81	3.38	3.07	2.12	3.93	4.76	4.12	4.93	2.33	2.33	1.55	35.19	4
11	5	1	1	1.67	1.1	3.79	4.09	3.59	4.67	1.82	1.82	1.5	29.22	2
12	1.49	1.05	1.11	2.09	1.07	3.96	4.5	3.97	4.83	2.15	2.15	2.34	28.55	2
13	0.99	2.29	2.88	2.23	1.81	5	4.78	5	4.93	3.09	3.09	1.66	34.67	4
14	2.12	1.27	1.55	2.64	1.65	3.84	4.58	3.93	4.86	2.53	2.53	2.62	31.61	3
15	1.04	2.06	2.63	3.27	3.15	3.95	4.67	4.08	4.9	2.33	2.33	1.65	33.73	3
16	1.9	3.16	3.68	1.76	2.18	2.47	4.82	2.95	4.95	3.34	3.34	1.64	32.84	3
17	1.51	1.25	1.52	2.2	1.8	4.08	4.45	4.03	4.82	4.09	4.09	2.97	32.71	3
18	2.39	1.74	2.25	1	2.82	3.89	4.64	4.01	4.89	2.4	2.4	1.64	31.67	3
19	2.16	5	5	2.56	1.29	3.87	4.75	4.05	4.92	4.33	4.33	1.98	39.92	5
20	1.67	1.77	2.28	3.97	2.15	3.8	5	4.15	5	1.8	1.8	2.29	33.88	3
21	1.94	1.26	1.54	3.15	1.54	4.05	4.16	3.82	4.7	1.3	1.3	1.61	29.08	2
22	1.44	1.09	1.21	3.43	1.19	3.86	4.04	3.61	4.65	1	1	1.82	27.34	1
23	2.05	1.31	1.62	2.98	1.79	3.8	4	3.54	4.64	1.5	1.5	1.63	28.86	2
24	1.45	1.8	2.32	3.75	1.49	3.81	4.77	4.03	4.93	1.64	1.64	2.15	32.16	3

Based on applying the linear equation ofDavis (1975), the risk of the studied sub-basins also categorized into 5 classes include very low (S3, S16), low (S1, S22, S23, S10, 15, S19, S24,), intermediate (S12, S13, S14, S20, S21), high (S4, S6, S17, S18), and very high (S2, S5, S11 and S9).

(2) Apply two dimensional graphs;D_d and F_s vs. R_b (El-Shami 1992)



A **B**

Flood risk can be calculated based on El-Shamy(1992) by applying two scattered diagrams; (a) bifurcation ratio (R_b) vs. drainage density (D_d), (b) the ratio between bifurcation ratio (R_b) and stream frequency (F_s)(Fig. 3).

Figure 3.Flash flood potentials using two dimensional graphs (a) R_b vs. D_d showing flood risk (modified from El Shamy 1992) of WQ sub-basins ; (b) Plotting R_b vs. F_s showing flood risk (modified from El Shamy 1992) of WQ sub-basins

Using R_b vs. D_d two-dimensional scattered diagram (Fig. 3), reveal that the plotted sub-basins occupy two fields of low and intermediate risk. Sub-basins 4, 7, 12, 13, 15, 22, and 24 revealing low flood potentialities but high groundwater recharge through alluvial aquifers. However, several sub-basins revealed intermediate flood potentials, such as S18, 19, 2, 20, 5, 1, 16, and 8. Two sub-basins are not plotted as their D_d values < 1. Similarly, plotting R_b vs. F_s supporting the hazard of the plotted sub-basin values (Fig. 3).

V. Conclusions

Topographic data derived from SRTM DEM data was applied to characterize the potential areas of flash flood hazards in WadiQena, Egypt.The stream networks geometry of WadiQenadisplayed various patterns includingradial, dendritic, and parallel. Several morphometric parameters including bifurcation ratio, drainage density, circularity ratio, elongation ratio, form factor, stream frequency and drainage intensity were measured and integrated to initiate flash flood potential map. Based on this output map several sub-basins such as S5, S2, S9 and S11are displaying high runoff capabilities. This is because the high runoff causes destruction of the infrastructures. Therefore, we recommend that building a dam to break the runoff potentials at the junction of WadiJurdi, WadiQena, and before Qena El-Jedida.

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