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FLASH FLOODING HAZARD ASSESSMENT ON THE ECONOMIC AREA IN WADI GHOWEIBA COASTAL ZONE, GULF OF SUEZ, EGYPT

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ABSTRACT

Flooding risk assessment clearly shows the urgent need for an evaluation planning program to mitigate hazards for vital areas. Because of the rising urbanization and climate change, flood risk management has gained importance. to implement methods and policies for urban development that are sustainable. In recent decades, studies on the management of flood risk and spatial planning have shown that there is a shared understanding of the notion of flood resilience in the formulation of policies and strategies. A number of governmental and investment initiatives, including those related to industry and tourism, have recently been launched in the Wadi Ghoweiba coastline zone. The drainage network of Wadi Ghoweiba is made up of long, wide channels with steep sides and a floor that is highly inclined. Due to these characteristics, there is a good chance that significant volumes of rainfall may fall and cause damaging flash floods into the Gulf. Delineating drainage networks is essential to predict surface water runoff and consequently the flash flood hazards. Wadi Ghoweiba networks and sub-basins are studied here to compute its morphological and hydrological parameters as to assess their risk degree and classify their relative vulnerability. Using the calculated morphological and hydrological data, the investigated watershed is ranked in order of flood risk as part of the flood risk assessment technique. This research uses DEM data in GIS-Environment to analyze Wadi Ghoweiba's flooding risk. According to the ranking hazard and El-Shami method, two sub-basins are High of flooding hazard, one sub-basin of very high hazard, and two of extremely hazard. Therefore, we recommend that decision-makers build some dams downstream of sub-basins that have a high hazard degree to reduce the risk of flooding or create artificial lakes to receive rainfall water and for sustainable development in the present and future, especially in the promising areas like Wadi Ghoweiba basin. Our findings can be a potential guide to decision-makers in disaster geohazard reduction.

KEYWORDS: Flash flood, GIS, Remote sensing, Hazard assessment, Wadi Ghoweiba.

تقييم مخاطر الفيضانات الفجائية علي المنطقة الاقتصادية بمنطقة ساحل وادي غويبة، خليج السويس، مصر

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الملخص

أصبحت إدارة مخاطر الفيضانات أكثر أهمية في مواجهة التنمية الحضرية السريعة وتغير المناخ. من أجل سياسات واستراتيجيات التنمية الحضرية المستدامة. خلال العقود الأخيرة، أظهرت الأبحاث حول إدارة مخاطر الفيضانات والتخطيط المكاني وجود منصة نقاش مشتركة تقدر مفهوم القدرة على مقاومة الفيضانات في صنع السياسات والاستراتيجيات. تم اختيار منطقة وادي غويبة الساحلية في السنوات الأخيرة لمباشرة العديد من الأنشطة الحكومية والاستثمارية (الصناعية والسياحية). تتكون شبكة صرف وادي غويبة من قنوات واسعة ومستقيمة وطويلة ذات أرضية عالية الانحدار وجوانب شديدة الانحدار. توفر هذه الميزات ظروفًا مواتية لاستقبال كميات كبيرة من الأمطار المتدفقة على السطح كفيضانات مدمرة في الخليج. يعد تحديد شبكات الصرف أمرًا ضروريًا للتنبؤ بجريان المياه السطحية وبالتالي مخاطر الفيضانات المفاجئة. تتم هنا دراسة شبكات وادي غويبة وأحواضه الفرعية لحساب معالمه المورفولوجية والهيدرولوجية لتقييم درجة خطورتها وتصنيف مدى تأثرها النسبي. تشتمل منهجية تقييم مخاطر الفيضانات على تصنيف مستجمعات المياه المدروسة وفقًا لمخاطر الفيضانات بناءً على المعلمات المورفولوجية والهيدرولوجية المحسوبة. تهدف هذه الورقة إلى تقييم مخاطر الفيضانات في وادي غويبة باستخدام بيانات نماذج الارتفاعات الرقميه في بيئة نظم المعلومات الجغرافية. من خلال دراسات تحليل المعملات المورفومترية للحواض باستخدام طريقة الشامى وكذلك طريقة الترتيب الى ان حوضين فرعيين في منطقة وادي غويبة مصنفان على أن أحدهما شديد الخطورة، والآخر على انه خطير.

الكلمات المفتاحية: السيول، نظم المعلومات الجغرافيه، الاستشعار عن بعد، تقييم المخاطر، خليج السويس، وادي غويبه.

INTRODUCTION

Flooding in important areas has attracted increasing attention due to increasing flood events and damage, causing huge loss of life and property damage globally. Fast food is one of the most important risk phenomena in catastrophic natural disasters in the world, causing the most deaths and property losses [1- 4]. many reserchers deal with studied the topography and geology setting of the area, eg, [5 -15].

Geonatural hazards are extreme weather events causing damage and flash flooding, storm surges, and sand and dust storms. Rainfall is considered one of the most strong natural hazards; sometimes, it causes death for people. The development of sustainable new national projects always needs to be good planning by decision-makers. The detection and evaluation of geonatural hazards, such as flash flooding, are very important.

Wadi Ghoweiba basin is a promising desert region for sustainable development in the future. It is considered a part of the great national project of Egypt for economic industrial and tourism and for the development of new urban communities to accommodate the increase in population projects in Egypt’s vision 2030. As well as, the study area is one of the most important desert areas that decision-makers are concerned with in Egypt.

The Integration between Remote sensing data and the GIS environment is a very important tool to evaluate flash floods' hazard. Several studies have been carried out from different localities over the world interested of watershed basin using morphometric parameters analysis [16-24]. Syvitski et al. [25] observed that a strong flash flooding and high runoff due to rainfall intensities. Floods are one of the foulest geo-natural affecting the socio-economic life of people every year. In the period between 1985–2003, about 82% of the world's population occupied about one-third of the earth's surface are subjected to several flash flooding (World Bank 2005).

Recently, many authors were studied hydro-morphometric parameters of drainage basins to detect flash flood hazard to study and analyze impact resulting it on the sustainable development, the human life, infrastructure and vital sites of new urban communities [26-31].

Many methods can be applied to study the flash flood vulnerability of the watershed sub-basins such as El-Shamy approach and ranking method. El-Shamy [32] indicated that to minimize the deleterious effect of flash floods, it is required to analyze the morphometric parameters of the drainage basins that can identify catchments more vulnerable to flash flood generation. Abdalla et al. [33] studied the Southern Red Sea Coastal area and they used GIS-based morphometry and El-Shamy approach for relationships detection between the flash floods occurrence and groundwater aquifers recharge. Abdel-Lattif and Sherief [34] determined hazard degrees based on El-Shamy approach to make risk zone map of Wadi Sudr and Wadi Wardan, Gulf of Suez, Egypt, and they concluded that both wadies are affected by the flash flood hazard. Asode et al. (35) applied the morphometric analysis and El-Shamy approach for identification the flood hazard possibility for the four catchments of Hirehalla sub-basin, India. In the last decades, Egypt has been affected by several flash floods due to it exposed by heavy rainstorms; such as flash flood of November 1994, flash floods (17-18 January, 2010), (March and May, 2014), (3-4 November. 2015) and (27-28 October. 2016). On 23 October 2019, capital of Egypt affected flash floods leaved behind of 11 person deaths, (http://floodlist.com/africa/egypt). The morphometric parameters derived from DEM data in the GIS environment represent an important method for mapping the flash flood hazard for conservation and hydrological maintenance in the study area. Wadi Ghweiba mega-basin consists of five sub-basins.

Hydromorphometric parameters are divided into three categories: (1) linear aspects, (2) areal aspects, and (3) relief aspects. Linear, areal, and relief aspects. The linear morphometric aspects involve several one-dimensional (x-axis) stream properties, such as stream order, stream number, stream length, bifurcation ratio, and length of overland flow. The areal morphometric aspects consist of two-dimensional (x- and y-axes) parameters that characterize the drainage basin, such as basin length, basin perimeter, and basin area. Finally, the relief morphometric aspects consider the three-dimensional parameters such as basin relief, relief ratio and Ruggedness number.

The present paper is an attempt to detect, evaluate and manage the flash food risk of the Wadi Ghoweiba basin using Remote Sensing and GIS techniques. It aims to apply a quantitative scheme through calculating and analyzing the most effective hydrological morphometric parameters in order to provide more understanding hydrological behavior. In addition, it aims to examine the morphometric factors and topographic aspects in order to represent the flash flood hazard susceptibility map.

Description of the study area:

Wadi Ghoweiba is consedierd one of the most important wadis in east of Egypt at Gulf of Suez. Wadi Ghoweiba lies in the northwestern tip of the Gulf of Suez (Fig. 1). It covers the area between the north part of El-Galala El-Bahariya plateau and Gabal Abu-Treifa to the north. Wadi Ghoweiba is bounded by long. 31º 44` and 32º 24` E and lat.s 29º 31’ and 30º 00` N. it is covering an area of about 2897 km². Wadi Ghoweiba and its tributaries is draine and ultimately flow into the Gulf of Suez. Geologically, the Wadi Ghoweiba is mainly covered by different sedementary rock units. A geological map of the Beni Suef sector [36] was helped to identify the rock units (Fig. 2). Structurally, two structural provinces are affected in the study area; the Gulf of Suez watershed and the fold of Syrian arc system. So, the current area faces a complex of high lithology and tectonic forces. These forces are one of the main reasons for the formation of some river valleys east and west of the Gulf of Suez, such as the Ghoweiba Valley.

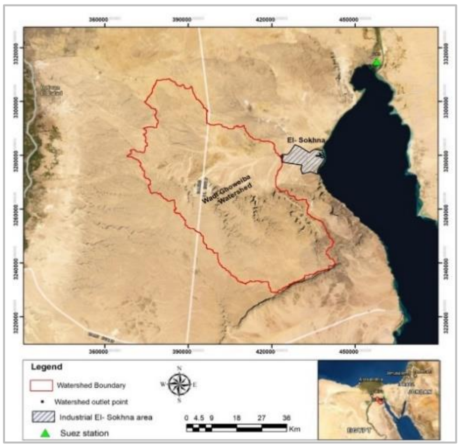

Fig. 1: Location of the Wadi Ghoweiba Watershed.

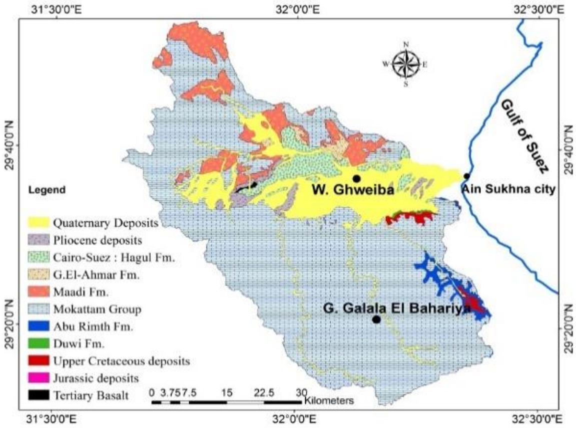

Fig. 2: Simplified geological map of the study area (after Conoco, 1987).

The current investigation is divided into three geomorphological zones. The eastern and central low-lying regions of the examined area were included in the first zone, which is the coastal plains sector (low lands) (0-300 m). The second sector is made up of hilly terrain that is between 300 and 900 meters above sea level. Gabal El-Galala plateau (300–600 m) is the third sector (Fig. 3a). Maps of elevation, aspect, and slope (Figs. 3b, c, d) allow us to compare low locations to adjacent areas and determine the likelihood of significant rainfall accumulating and running before floods occur. According to [5, 37], the present area includes six major geomorphic units, namely, Gulf of Suez coastal plain, Wadi Ghoweiba structural plain, El-Galala El-Bahariya, Akheider, Gabal Ataqa and Kehaliya-Um Zeita structural plateaux.

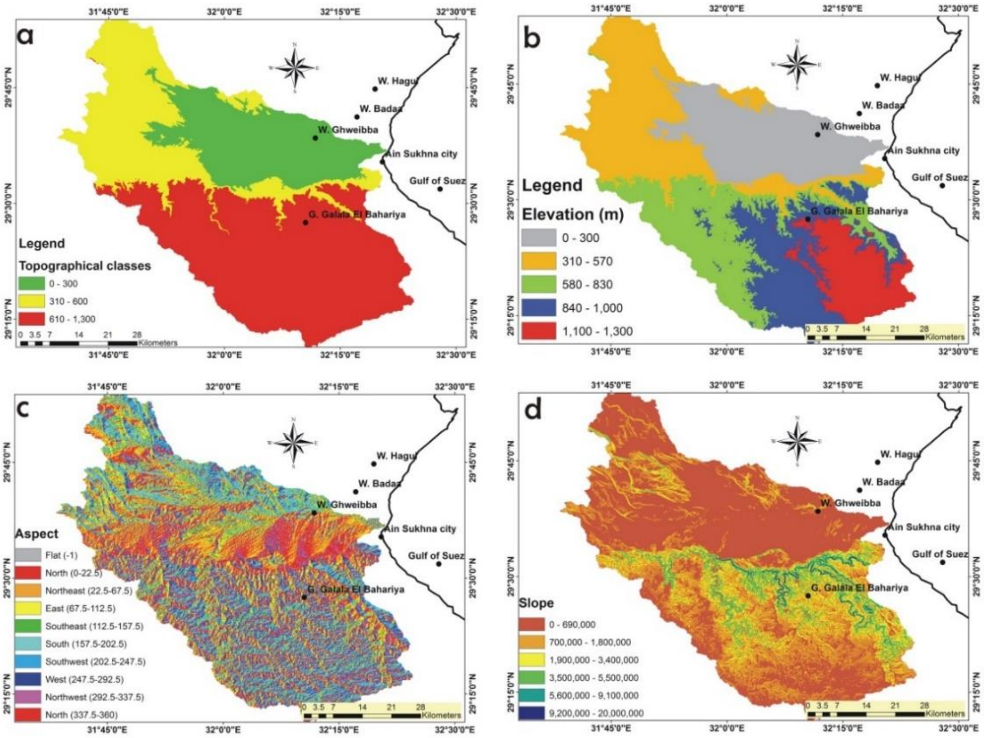

Fig. 3: Outputs derived from DEM data of the study area, (a)Topographic classes, (b) Elevation, (c) aspect, and (d) slope maps.

Most of flooding is happening based mainly on climate change. Average rainfall amounts from 2013 to 2022 range from 0.1 mm/month in July to 17.783 mm/month in May (Fig. 4); recently, the study area is hit by several heavy rainstorms. The rainfall data were collected and obtained based on the PERSIANN-CCS site (http://chrsdata.eng.uci.edu). These data help to determine the amount of precipitation that should be assigned to each cloud's pixel based on a certain curve that depicts the correlation between the rate of precipitation and brightness temperature. Consequently, the study area based on these data, rainfall rate is rare in four mounths (June, July, August and september), while May, February, December and April were recorded highest amount of rainfall in the last ten years (Figs. (5a, b, c& d) and Table. 1).

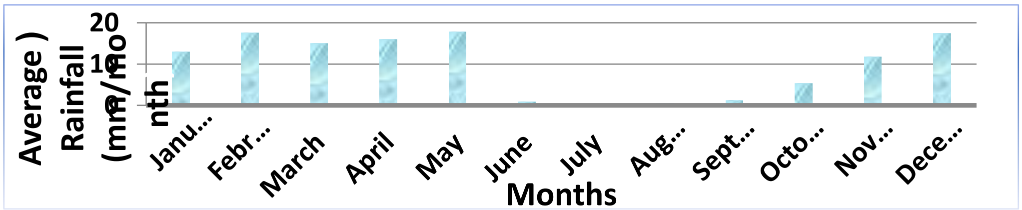

Fig. 4: Average monthly rainfall over the study area from 2013 to 2022.

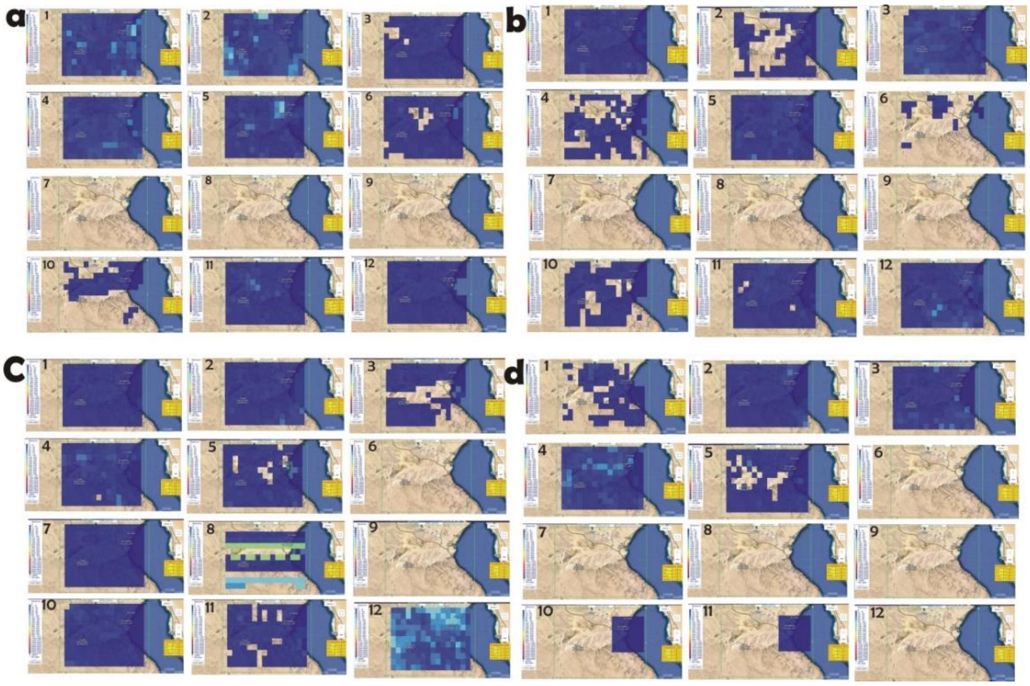

Fig. 5: Rainfall concentration from the PERSIANN-Cloud Classification System (PERSIANN-CCS) (a). 2019, (b). 2020, (c). 2021, (d). 2022 in the study area.

Table 1: Monthly average precipitations for the last 10 years collected rainfall data between 2013 and 2022 obtained from the PERSIANN-CCS.

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Average**
January	23.01	14.09	18.68	3.25	31.56	1.44	22.15	8.77	4.36	2.09	12.94
February	16.57	6.68	25.1	11.36	0.95	68.82	27.4	2.03	10.93	5.47	17.531
March	14.32	5.18	25.58	36.97	11.5	19.18	4.23	21.39	1.47	10.99	15.081
April	0.49	23.69	3.91	18.02	22.12	35.87	20.78	2.2	12.38	21.07	16.053
May	5.29	52.2	0.74	12.12	17.24	55.85	14.4	11.44	4.65	3.9	17.783
June	0.13	0.05	0.93	1.39	0	0	5.4	0.39	0	0	0.829
July	0	0	0	0	0	0	0	0	1	0	0.1
August	0	0	0	0	0	0	0	0	5.38	0	0.538
September	0	0	2.18	0	0.12	9.49	0	0	0	0	1.179
October	0.74	0	10.65	7.76	0.01	22.42	0.71	1.49	8.24	1.76	5.378
November	16.62	19.26	22.01	19.16	5.09	16.05	7.94	5.29	3.88	1.96	11.726
December	17.63	16.55	0.62	13.23	49.65	16.34	1.35	10.03	48.62	0	17.402

3. Data used and methods:

The DEM 90 m data have been applied and processed in GIS environments in this study. Through the use of GIS, digital elevation models (DEMs) were created using data from the SRTM with spatial resolution about 90 m cell size. Four thematic relief maps were extracted from DEM data: elevation, aspect, topographic contour, and slope maps. Moreover, these valuable data are useful to extract the hydromorphometric parameters of the sub-basins in the study area. ARC GIS 10.2.2, ERDAS IMAGINE 14, and ENVI 5.1 are very effective software programs used in preparing and processing DEM data to extract various hydromorphometric parameters as results maps.

The first step is create and automatically retrieved of the stream networks and the watershed (38). The streams that were collected were automatically categorized using the drainage order proposed by [39, 40]. According to [41], the order shows the relative positions of stream segments within drainage basin networks. One of the important data used in recorded and estimated rainfall rate is the PERSIANN-Cloud Classification System (PERSIANN-CCS) which is a real-time global high resolution (0.04°× 0.04° or 4 km × 4 km) satellite precipitation product developed by the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine (UCI). A geologic map of Beni Suef sheet [36] was used to recognize the different rock types. Many tools are used to process, enhance, and interpret remotely sensed raw data. Two such tools are Envi 5.1 and ARC GIS 10.2.1, which are excellent programs for preparing and processing DEM data so that different morphometric parameter result maps may be extracted.

Based mainly on utilizing the Arc Hydro tools in spatial analyst of ARC GIS the morphometric parameters of the study area were extracted and mapped to the watershed system. The watershed and the morphometric parameters results were extracted automatically based on Arc Hydro functions such as Fill Sinks, Flow direction, Stream definition, Stream segmentation and Stream order.

Two methods were applied in the current study to detect flash flood hazards: El-Shamy’s [32] approach and the ranking method. Furthermore, the integration between these methods clearly helps us assess the flooding hazard of the studied sub-basins.

4. Results and discussion:

The Wadi Ghoweiba mega-basin classify into five sub-basins watershed to detect different properties of the hydrologic networks and define the most potential areas for flash flooding. These sub-basins from north to south are Wadi Gharaba, Wadi Ghoweiba, wadi Khafuri, Wadi No`at and Wadi Khashm El-Galala. Table 1 shows the formula of morphometric parameters which used in the present study.

This study discusses three primary hydromorphic parameter features, which are divided into three categories (real, relief areal aspects).

Table 2: Morphometric parameters of drainage network and their mathematical expressions.

	Morphometric Parameter	Definition and Formula	Reference
A	**Linear Characteristics of the Drainage Watershed**		
1	Stream Order (Su)	Hierarchical Rank	Strahler (1952)
2	Stream Number (Nu)	Nu = N1+N2+Nn	Horton (1945)
3	Stream Length (Lu) Kms	Lu = L1+L2 ……Ln	Strahler (1964)
4	Mean Stream Length (Lum):	GIS Software Analysis	Kant et al. 2015
5	Mean bifurcation ratio (MR_b)	The ratio between the number of streams of any given order to the number of streams in the next higher order	Schumm (1956) Strahler (1964)
6	The drainage basin length (L_b)	The longest dimension of the basin which parallels to the principal drainage (km)	Schumm(1956)
7	Length of overland flow (Lg)	Lg=1/(2xDd)	Horton (1945)
B	**Areal Characteristics of the Drainage Watershed**		
1	The area of drainage (A)	GIS Software Analysis	Schumm(1956)
2	Basin perimeter (P)	Total length of outer boundary of drainage basin GIS Software Analysis	Schumm(1956)
3	Stream frequency (F)	The ratio between total number of streams and area of the basin. F = Nu / A	Horton (1932)
4	Drainage density (Dd)	Dd = Lu / A	Horton (1932)
5	Constant of Channel Maintenance(C)	The length of stream channel per unit area of drainage basin. C = 1 / Dd or C=A/∑Lu	Schumm(1956)
6	Circularity ratio (Rc)	The ratio of basin area to the area of a circle having the similar boundary as the perimeter of the basin Rc = 12.57 * (A /P2)	Miller (1953)
7	Elongation ratio (Re)	The proportion between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin Re = 2 / Lb * (A /π) 0.5k	Schumm (1956)
8	Lemniscate Ratio (K):	K=L2/4A	Chorley (1957)
9	Compactness Ratio (Co)	the ratio of the perimeter of the basin (P) to the perimeter of a circle of an area equal to that of the basin $C_O=P/2\sqrt{A\pi}$	Wisler and Brater, 1949
10	Infiltration number (If)	This parameter represents a relationship between the stream density and frequency of a specific basin If= Dd/F	Faniran, (1968) and Zavoiance (1985)
C	**Relief Characteristics of the Drainage Watershed**		
1	Relief ratio (Rh)	The relief ratio is the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio	Taylor and Schwarz, 1952 Schumm (1956)

		$Rh = H / Lb$	
2	Form Factor (F):	mathematical factor that defines the ratio between the area of a basin and the square of that basin's length $Ff = A / Lb^2$	Horton (1932)
3	Texture ratio (T):	The ratio of the total number of all streams to the basin perimeter $R_t = \sum Nu/P$	Schumm (1965)
4	Ruggedness number (Rn)	The product of the basin relief and its drainage density $Rn = Dd * (H / 1000)$	Patton & Baker (1976)
5	Basin relief (Bh)	The maximum vertical distance between the lowest and the highest points of a sub-basin. $Bh = Hmax - Hmin$	Strahler (1952)
	Shape Index (Si)	$K = P^2/A$	----------

These criteria take into account the basin's surface and subsurface geology, structures, and hydrologic conditions in order to forecast areas that may be vulnerable to flooding. One-dimensional (x-axis) stream features, such as stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, and length of overland flow, are included in the linear morphometric aspects. These parameters are calculated using standard methods and equations. The areal aspect consists of two-dimensional parameters which discribe the drainage networks, such as basin length, perimeter, and area. These parameters are calculated from DEM data in the GIS environment. Others areal variables, such as basin form factor, elongation ratio, and infiltration rate are computed according to the equations in Table 2. Finally, the relief morphometric aspect considers has the three dimensional parameters such as Basin relief, relief ratio and Ruggedness number. There are notable topographic differences, ranging from 15 m (asl) downstream to 1300 m (asl) upstream, according to the SRTM DEM results. The northeastern region, which is the highest point on the slanted plateau, is where the catchment area is situated. The quantitative information of the morphometric analysis basin is supplied by the invaluable and efficient efforts of remotely sensed data via GIS. The Wadi Ghoweiba mega-basin's area (A) and perimeter (P) are approximately 2930.61 km2 and 753.64 km, respectively.

Hydromorphometric Parameters Analysis

5.1. Linear Parameters:

The linear hydromorphometric parameters of sub-basins at the study area were tabulated (Tables 3 and 4). Several important hydromorphometric parameters of linear aspect are discussed in this paper such as, stream orders (Su) and stream numbers (Ns).

The first step in the calculation of a drainage basin analysis is stream order (Su). It is one of the most significant parameters of hydrogeomorphology to investigate and measure the size of the catchment water paths. Stream orders range from the fifth order to sixth order of sub-basins (Fig.6a). The stream numbers values are obtained using the Horton`s [42] method. The total number of streams is the number of channels through a fixed order [42] and it progressively decrease with the increase of stream orders. The highest of the steam numbers are recorded in Wadi Khafuri and Wadi Ghoweiba sub-basins (948 and 887, respectively) (Fig.6b). These results are extremely important in investigating catchment characteristics such as the drainage pattern [43-45]. We noted that the nature of the rocks is considered an important factor for observing why lower order streams have high numbers.

When examining a drainage network system, total stream length (Lu) and basin length (Lb) are crucial variables to consider. The Wadi Khashm El Galala sub-basin has the shortest known value of Lu at 105.73 km, while the Wadi Khafuri sub-basin has the longest recorded value at roughly 1502.10 km. The Wadi Ghoweiba sub-basin has the longest values of L_b at 58.5 km, whereas the Khashm El Galala sub-basin has the smallest values at 11.05 km (Table 4, Figs. 6 c & d).

Table 3: The total number of streams (Nu) with different Orders in Km, in each of the drainage sub-basin in the study area.

Wadi name	1st	2ed	3rd	4th	5 th	6 th	Total stream numbers	BR1	BR2	BR3	BR4	BR5	BR6	MBR
No`at	230	52	16	7	1		306	4.4230	3.25	2.2850	7	0	0	4.23
Khashm el galala	52	20	4	2	1		79	2.6	5	2	2	0	0	2.9
Wadi-Gharba1	248	55	22	3	1		329	4.5090	2.5	7.3330	3			4.335
wadi-khafuri1	723	174	44	6	1		948	4.1551	3.954	7.3330	6			5.360
Ghweibba	677	158	37	10	4	1	887	4.284	4.27	3.7	2.5	4	0	3.751

Table 4: Morphometric parameters of drainage network derived from DEM.

	Area (km2)	total Length	basin length	permeters	basin width	**Circularity**	compactness	Constant of Channel Maintenance	**density**	Frequency	Elongation Ratio	infelt ration number	lemniscate	length of overland	Reilef Ratio	**Ruggedness**	Shape Index	Form factor	Texture Ratio
No`at	347.511279	546.251008	40.456	122.096569	10	0.29	1.848095	0.636175	0.344233	0.880547	0.519839	1.384127	1.177435	0.318088	0.026943	**0.00857**	42.8981	0.001165	2.506213
Khashm el galala	70.234487	105.734047	11.053	47.981811	5.1	0.383471	1.615499	0.664256	0.411177	1.124804	0.855387	1.693328	0.43486	0.332128	0.047046	**0.015625**	32.7954	0.006282	1.646457
Wadi-Gharba1	353.962458	438.29811	33.3	100.142277	12.11	0.443667	1.50191	0.807584	0.537704	0.929477	0.637385	1.150936	0.783197	0.403792	0.006907	**0.002789**	28.33203	0.001843	3.285326
wadi-khafuri1	1149.8069	1502.106435	44.5	183.176539	21.5	0.430745	1.524272	0.765463	0.502183	0.824486	0.859647	1.077108	0.430561	0.382732	0.022135	**0.008472**	29.18198	0.00051	5.175335
Ghweibba	1009.103189	1265.572133	58.5	300.248525	29.45	0.140705	2.666971	0.797349	0.298972	0.878998	0.612604	1.1024	0.847844	0.398675	0.007521	**0.002999**	89.33593	0.00063	2.954219

The area (A) of the sub-basins in the present study vary ranges from 70.23 to 1149.80 Sq km are recorded in Wadi Khashm El Galala and Wadi kauri sub-basins respectively, while the perimeter values are between km 47.98 km in Wadi Khashm El Galala sub-basin to 300.24 km in the Wadi Ghoweiba sub-basin (Table 4, Figs.7 b, c).

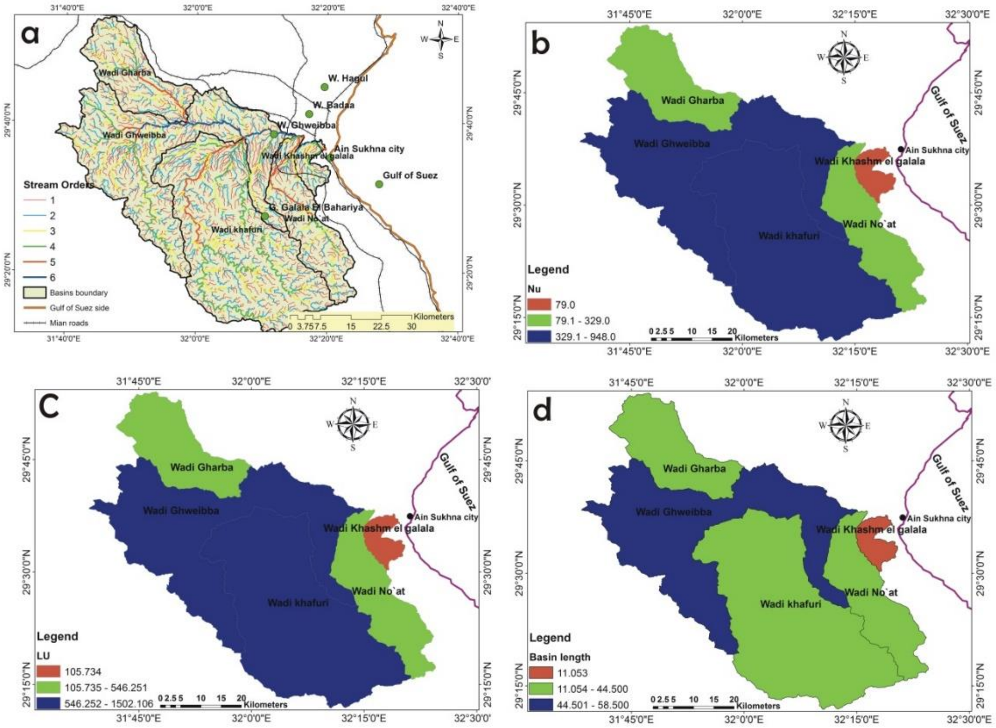

Fig. 6: (a) Extraction of stream orders of drainage network, (b) Stream numbers, (c) Stream length and (d) basin length of studied sub-basins.

5.2. The Bifurcation Ratio (Rb):

Rb values in the studied sub-basins range from 2.9 to 5.36 (Table 3, and Fig. 5a).thses values refer to that sub-basin is less structurally controlled in the study area. Strahler, [40] stated that sub-basins which have bifurcation ratio values range 3.0 to 5.0 are characterized by little or no geologic structure distortion. The highes values of Rb are recorded in (Wadi Khafuri sub-basin, the highest values indicate a slow surface flow. This values of Rb mean elongated shape of sub-basin, therfore, flooding hazard may be tends to reduce. On the other hands wadi khash El-Galala and Wadi Ghoweiba sub-basins have lower values of Rb about 2.9 and 3.751 respectively; these indicate increase the efficient of flood potentials [46] reported that small MRb values in drainage sub-basins indicate a higher flooding risk, whereas high MRb values suggest that sub-basins have decreased flooding potential. Structural complexity and significantly lower permeability of a region are marked by high values of MRb [40].

5.3. Length of Overland Flow (Lg):

Lg is a length of water over the land before it gets concentrated into certain stream channels. It is an independent factor, also it have direct affected on hydrologic and physiographic development of the watershed basin, which measures the level of erodibility and influenced by infiltration and percolation through the soil [47]. There are an inverse relationship between the values of Length of Overland Flow and hazard of flash floods, and a direct relationship with infiltration rate. There is an inverse relationship between Lg values and general slope of the drainage basin. Low value of Lg means more runoff, high elevation, short flow paths and less infiltration. Three categories values of Lg are recorded low (< 0.2), moderate (0.2-0.3), and high (>0.3). According this classification all studied sub-basins in the current area belong to high class. Lg values are described in Table 4 (Fig. 7d) for all sub-basins in the study area.

5.4. Stream Frequency (Fs):

Stream frequency is very important parameter of hydromorphometric parameter, which it depends on several factors such as the structures and lithology setting, infiltration condition, land cover, and topography. It ranges from 0.824 (Wadi Khafuri sub-basin) to 1.125 (Wadi Khashm El Galala sub-basin) (Fig. 7e) with 0.93 mean value, indicating a low relief [48]. The sub-basins which have high values of Fs indicate more possibilities for flooding.

5.5. Drainage Density (Dd):

Dd is a vital index that used to controls the runoff, where higher values can accelerate the runoff [49]. It refers to the permeability and roughness potential of the surface layer of watershed basins. Strahler, [40] counculded that drainage Density is important factor of the linear scale of land-form in stream-eroded topography and as wells as it may be thought of an expression of the closeness or spacing of channels. Dd values of studied sub-basins are range between 1.238 (Wadi Gharba sub-basin) and 1.571 (Wadi No`at sub-basin) (Fig. 7f).

5.6. Constant Channel Maintenance (C):

C is the minimum area required for a stream channel with unit length to sustain in a river basin and can calculate through the assessment of the inverse of the drainage density [47]. Constant Channel Maintenance values of Sub-watersheds range from 0.636 (Wadi No`at sub-basin) to 0.807 (Wadi Gharaba sub-basin) indicating spatial variation in structural setup and terrain characteristics of the river basin. All examined sub-basins in the study area shows relatively high C value (> 0.50) table (4) (Fig 7g), indicating comparatively low structural complexity, greater permeability and limited runoff characteristics.Low values of Constant Channel Maintenance indicate the structural complexity of the region with less permeable rocks and high surface runoff whereas high values indicate high permeability and less structural complexity [40].

5.7. Circularity Ratio (Rc):

Circularity Ratio values in the study area range from 0.140 to 0.443; these values refer that all basins are elongated shape, as the circularity reached at Rc=1. (Fig. 7h). There is a direct relationship between structural setting of a sub-basin and it`s circularity ratio value. In other words, the high value of Rc refers to that study area was subjeced to strong structural deformation, while the low Rc value indicates no structural disturbances on sub-basins.

5.8. Elongation Ratio (Re):

The elongation ratio is vailt factor oh hydromorphometric parapmeters. In the study area, Re values of the sub-basins range from 0.519 in Wadi No`at sub-basin) to 0.859 in Wadi Khafuri sub-basin, revealing that they are oval to more elongated (Fig. 3b). According to [47], the Re values are grouped into five categories more elongated (< 0.5), elongated (0.5–0.7), less elongated (0.7–0.8), oval (0.8–0.9) and circular (0.9–1.0). Based on Schumn classification the studied sub-basins fall under two groups elongate (Wadi No`at, Gharba and Ghweiba sub-basins) and oval (Wadi Khashm El-Galala and Khafuri sub-basins). Table (4) (Fig. 7i).

5.9. Infiltration Number (If):

The infiltration number factor (If) is very important parameters due to use to identify the infiltration characteristics of various watershed. In the present study, the highest infiltration value results were recorded in Khashm El Galala sub-basin is 1.693, indicating suitable conditions for a high ratio value of the infiltration process and a high quantity of runoff. The lowest value of (If) is 1.077 recorded for Wadi Khafuri sub-basin, (Table 4, Fig j).

5.10. Relief Ratio (Rh):

Rh factor is one of the important relief hydromorphometric parameters that show the relief characterization of the drainage watershed. Relief ratio values in the study area range from 0.0075 to 0.069. The highest value recorded in Wadi Gharba and Khashm El Galala sub-basins, while lower results were observed for Wadi Ghoweiba sub-basin (Table 4; Fig. k). Generally, the low value of relief ratio means low relief and the high value means steep slope and high relief. The higher Rr parameter results define low lag times, sudden peak discharge events, and high potentialities of flash flood conditions.

5.11. Texture Ratio (Rt):

The texture ratio is an interaction among climate, rainfall, slope, topography, rocks, soil, and vegetation [45,48]. The highest value of Rt recorded in Wadi Khafuri sub-basin with value of 5.175, while the lowest value recorded in Wadi Khashm El Galala sub-basin about 1.646 (Table 4; Fig. 7l). Morisawa [46] classified basins based on the texture ratio into four categories; (>8 km coarse texture), (8–20 km medium texture), (20–200 km soft texture) and (<200 km very soft texture). Consequently, all drainage sub-basins in the present area belong to the first category (coarse texture). The Rt of the studied sub-basins range from 1.506 to 5.175 which refers to a moderate drainage texture.

5.12. Ruggedness Number (Rn):

The ruggedness number (Rn) parameter defines the slope steepness and length describing the extent of the surface instability. In the studied sub-basins, the Rn values range from 0.0085 recorded in Wadi Gharaba sub-basin to 0.070 in Wadi Khashm El Galala sub-basin. High ruggedness number results refer to sub-basins which have steep and long slopes and rugged relief surface and quick peak flow signatures.

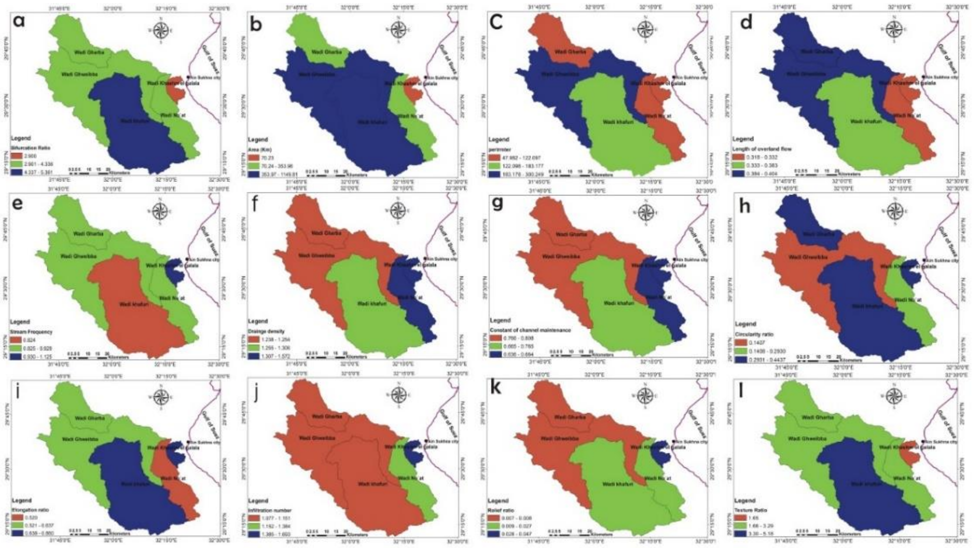

Fig. 7: Morphometric parameters of the study area; a-Mean bifurcation ratio (MRb), b-area (A), c-perimeter (P), d-length of overland flow (lg), e-stream frequency (fs), f-drainage density (Dd), g-Constant of Channel Maintenance (C), h-circularity ratio (Rc), i-elongation ratio (Re), j-i infiltration number (if), k-relief ratio (Rh), and l-texture ratio (T).

6. Mapping areas of flash flood potentials:

In this work, two methods were used to identify the flash flood threats in the Wadi Ghoweiba sub-basins are the ranking and El-Shamy's (1992) approachs. In the first, three morphometric parameters utilize to detect flash flood potentials are drainage density, drainage frequency, and mean bifurcation ratio as will as they are related in the El-Shamy approach.

6.1 El-Shamy approach

This technique is employed to identify the connection between the risk of flash floods and the potential for aquifer recharging. [50, 31, 51 and 35] were among the researchers who used the El-Shamy technique.Two relationship graphs (drainage density and stream frequency against bifurcation ratio) by El-Shamy’s model (1992) were produced to show the relationship between flood hazard types and recharge of groundwater aquifers (Figs.8a, b). This approach has segmented the relationship graph into three fields: Field (A) denotes a high potential for groundwater recharge and a low likelihood of flash floods; Field (B) denotes a high likelihood of floods and a low potential for groundwater recharge; Field (C) denotes sub-basins with a moderate potential for groundwater recharge and an intermediate likelihood of floods. Based on the two relationship graphs a detailed hazard degree map is extracted for all sub-basins by considering the most conservation condition.

The result values of El-Shamy approach compute using equations (1) and (2) to assess hazard degree using the same three parameters.

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

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

In the above equations, X is the value of the morphometric parameters to determine the hazard degree for each sub-basin. “Xmax” and “Xmin” are the maximum and minimum values of the parameters of all sub-basins, respectively. However, due to the assessment presented by El-Shamy which has only three degrees (low, moderate and high), the steps to evaluate flash flood hazards by the ranking method had been restructured where the hazard scale number has been set to all parameter starting with 1 (the lowest) to 3 (the highest). So we used number 2 in the two equations (1 and 2). The actual hazard degree for the sub-basins which have values between the minimum and the maximum values can be calculated.

According to the El-Shamy approch and two relationship graphs between density and frequency vs mean bifurcation ratio parameters; one sub-basin represented in the A field is Wadi Khafuri (no. 4). Two sub-basins are plotted in the B field (Wadi Khashm El-Galala (no. 2) and Wadi Ghweibba (no. 5). Two sub-basins (Wadi No`at (no. 1) and Wadi Gharaba (no. 3) are plotted in the field C. (Fig. 8 a b & c) (Table 5).

6.2 The ranking method

The ranking method, this method is completed based on equation (3 and 4); herein, the flash flood hazards directly correlate with the most quantitative morphometric parameters. So, the flood potential was estimated using calculating the intermediate values between the sample points, considering a straight linear relationship between them. Equations (3) and (4) are used for direct and inverse relationship parameters respectively. The hazard degree for all morphometric parameters are calculated using Eq. 3, but MRb and Lg parameters are computed using Eq. 4.

$$\text{Hazard degree} = \frac{4(X-Xmin)}{(Xmax-Xmin)} + 1 \qquad 3$$

$$\text{Hazard degree} = \frac{4(X-Xmax)}{(Xmin-Xmax)} + 1 \qquad 4$$

After being extracted, six hazard degree classes were weighted as follows: There are six different levels of hazard: 1, extremely low, 2, low, 3, moderate, 4, high, 5, very high, and 6, extreme. As a result, Table 5 lists the total danger degree for each sub-basin that was determined.

Wadi Gharaba and Wadi No`at are two sub-basins with a high hazard degree (4) based on the hazard degree ranking algorithm. Wadi Khashm El-Galala sub-basin has been assigned a very high hazard degree of five. The highly hazard table (6) is the strongest one of the hazard degree effects in the study area. The Wadi Ghoweiba and Wadi Kharufi sub-basins are represented by this category. The flood hazard potential map for each of the sub-basins under study is displayed in Figure 9.

Table 5: Flood hazard assessment using the ranking method based on the three parameters used in El-Shamy approach.

Wadi name	(Rb) Mean bifurcation ratio	(Fs) Stream Frequency,	(Dd) Drainage density	**Sum of hazard degree**	Hazard Degree	
No`at	3.177	1.746	5	9.9243	3.308	Highly
Khashm el galala	1	5	4.20	10.20	3.40	Highly
Wadi-Gharba1	3.333	2.39	1	6.73	2.24	Moderately
wadi-khafuri1	5	1	1.82	7.816	2.60	Moderately
Ghweibba	2.383	1.726	1.190	5.3	1.76	Slightly

Name`s Wadi	NU	Lu	A	(P)	(Lb)	(W)	(MRb)	(Re)	(Rf)	(Rc)	(Rt)	(Fs)	(Dd)	(Lg)	(If)	(Rh)	(Rn)	C	Shape Index	K	**Sum** Hazard **Degree**	General **Hazard** **Degree**	classes
No`at	2.044	2.26	2.027	2.175	3.478	1.804	3.177	1	1.37	3.011	2.188	1.74	5	1	2.99	2.996	3.171	1	1.955	5	49.4	4	High
Khashm el galala	1	1	1	1	1	1	1	4.949	5	4.205	1.389	5	4.20	1.655	5	5	5	1.655	1.291	1.023	52.3	5	very high
Wadi-Gharba1	2.1507	1.95	2.051	1.827	2.875	2.151	3.33	2.383	1.923	5	1	2.398	1	5	1.47923	1	1	5	1	2.88	47.41	4	High
wadi-khafuri1	5	5	5	3.143	3.819	3.694	5	5	1	4.82	1.0767	1	1.816914	4.0170	1	2.5175	2.3080	4.017	1.055	1	61.296	6	Extreme
Ghweibba	4.719	4.32	4.47	5	5	5	2.383	2.091	1.085	1	5	1.726	1.19	4.761	1.164	1.061	1.056	4.761	5	3.2348	64.034	6	Extreme

Table 6: Flood Hazard degree for morphometric parameters based on the ranking method.

<35	1	very low
35-40	2	Low
40-45	3	moderate
45-50	4	High
50-55	5	very high
>55	6	extreme

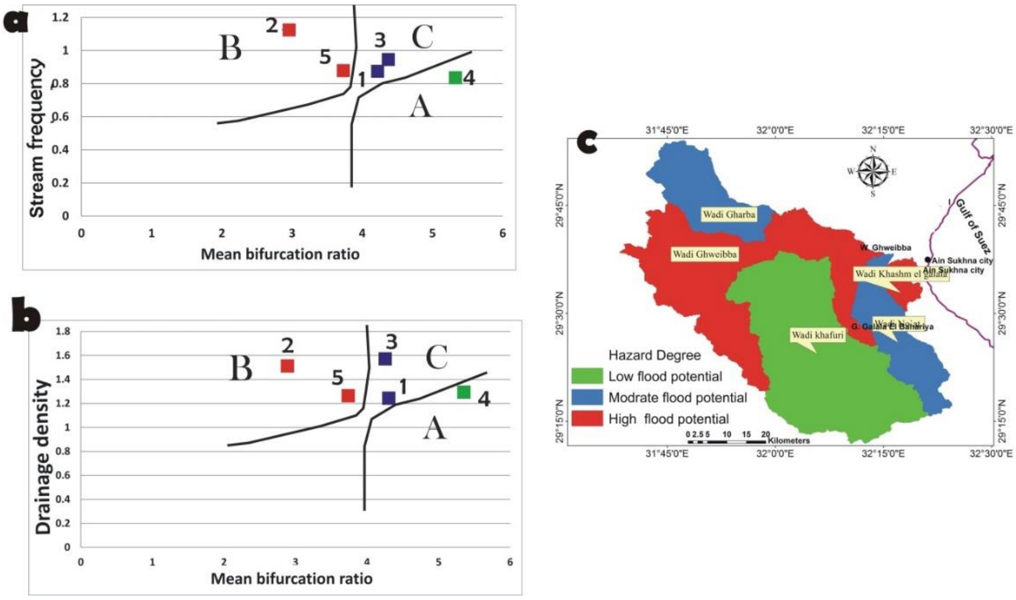

Fig. 8: Flooding susceptibility: (a) bifurcation ratio vs stream frequency, (b) the bifurcation ratio vs drainage density, and (c) flood hazard map of the El- Shamy approach in Wadi Ghweibba watershed.

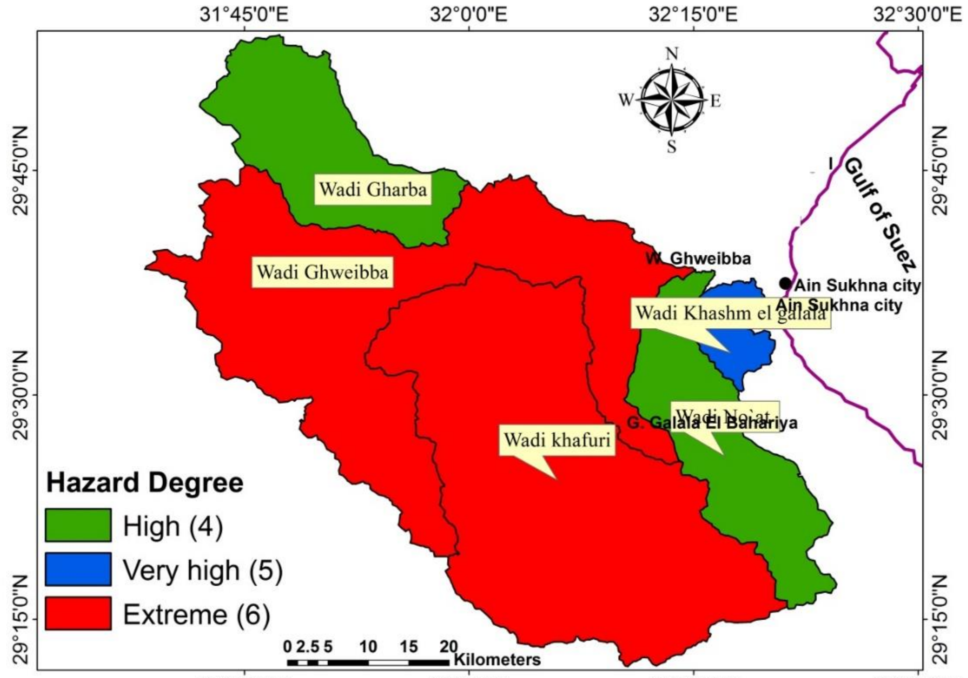

Fig. 9: Flood hazard map of Wadi Ghoweiba watershed based on the ranking method.

CONCLUSIONS:

This article reveals that a comparison of the morphometric parameters within drainage networks derived from DEMs should be considered to determine their differences in the Wadi Ghoweiba mega-basin. The values for morphometric parameters will vary depending on the data source used to identify the drainage network, therefore affecting the outcome of the sub-basins on the main channel.

DEMs remote sensing data and their integration in a GIS environment are very useful for introducing high progress in flood analyses; then, the impact on social-ecological systems can be avoided. The data obtained from this work might provide helpful information to the decision-makers for better action plans and appropriate adaptation strategies. The outcome of this study showed that remotely sensed data provide useful information on the morphometric properties and flash flooding potential zones of drainage basins.

According to the current analysis, if the government makes a political choice, sustainable development on the Wadi Ghoweiba shore might expand quickly along with other economic activity. The Wadi Ghoweiba watershed's outlet is scattered along the study area's coast and is home to numerous existing factories, businesses, roads, communities, and tourist attractions in addition to other human activities that could be built. As a result, flash floods are mostly concentrated in the steep primary research region of the basins under investigation; the main streams in these locations provide a moderate risk.

The sub-basins of Wadi Ghoweiba and Wadi Khafuri are highly hazardous, according to the results above. These sub-basins feature broad canals, level terrain, and large areas where manufacturing, urban development, and other human activities are located (Fig. 10). Consequently, when flash floods, these regions roads, cities, and factories have frequently been destroyed.

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CONFLICT OF INTEREST

The authors have no financial interest to declare in relation to the content of this article.

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