Geomorphological parameters by remote sensing and GIS techniques (A case study of flash flood in Mikhili Village, Al Jabal Al Akhdar, NE of Libya)

Jamal, Zamot[1], Mohammed Afkareen [1],

1Benghazi University, Faculty of Science, Earth Sciences Department, Benghazi, Libya, Email: Jamal.Zamot@uob.edu.ly
1 Sirte Oil Company (SOC), Marsa El-Brega, Libya, Email: Mohammed_eff2010@yahoo.com

Abstract

Libya is located in north Africa which is an area influenced by Mediterranean depressions during winter season with fluctuated periods of intensive rain. These rain storms are well observed on the land areas in west, south and east of Libya and lead to cause floods. The flash floods are well-known phenomenon in Al Jabal Al Akhdar area and it causes many damages yearly, therefore, it can be considered as the main natural hazard in Al Jabal Al Akhdar area and in Libya as a whole. This study has documented and discussed the tragic flood that occurred on the 27th of September in 2018 in the Mikhili village, where the floods swept through the village and caused many damages in properties and lives and it washed away some travellers' cars and likewise cars of the local residents. Remote sensing and GIS techniques have been used in addition to field investigation for studying the geomorphic parameters of the target area for risk assessment of rain water discharge on Mikhili village. In spite of the study area is at low risk of flood, the current study has proved that the Mikhili village is a vulnerable area due to its location on the end of wadi Ar Ramalh. The drainage pattern, large area of water catchment, intensity of rain in short time, the speed of runoff water, low infiltration rate, area topography besides to hydrologic factors, all these reasons were behind a tragic flash flood on Mikhili village.

Keywords: Flash flood, Geomorphic parameters, Risk assessment, wadi Ar Ramlah, Morphometric parameters.

1. Introduction

Due to its location between 20° to 34° N, Libya is characterized by a sub-tropical climate, which is punctuated by periods of thunderstorms and intensive rain in winter time. These kinds of heavy showers are well observed on highland areas especially on Jabal Nafusah in the west and Jabal Al Akhdar in the east [1, and 2]. In the northern part of Libya, the averages annual rain fall are from 200 to 500 mm, and on Jabal Al Akhdar region where the highest recording of rainfall in

Libya was measured is with about 850mm [1]. Al Jabal Al Akhdar area is an integral part of north east Libya, which is extending form the Mediterranean sea in the north to about 300 km in southward where the Libyan deserts [2]. In terms of natural hazard, Al Jabal Al Akhdar region is not usually thought of as a seismically active area; however, a number of earthquakes are reported to have occurred ex; earthquake in 1963 (known as Al-Maraj earthquake) [3].

However, these earthquakes are rarely occurred at Al Jabal Al Akhdar area in comparison with seasonal flash flooding. The flash flood is well-known phenomenon that occurred in subtropical regions such as Al Jabal Al Akhdar area and it causes many damages yearly, therefore, it can be considered as the main natural hazard in Al Jabal Al Akhdar area [4]. Flash floods are defined as rising in water over a short period of time either during or within a few hours of the rainfall [5]. Besides that, a relatively small amount of rain or the intensity and duration of the rainfall with low rate of infiltration can trigger flash flooding. Flooding can occur virtually anywhere, in steep rocky terrain or even within heavily urbanized regions [5 and 6]. Many several factors have relevance to the occurrence of a flash flood ranging from topography, geomorphology, drainage, engineering structures, and climate. In fact, these are not all the factors that contributing the flood, there are other interrelated factors which influence flash floods severity, especially in desert areas, such as water loss (evaporation and infiltration) drainage networks, rainfall characteristics, drainage orders. [5, 6, and 7].

On the 27th of September in 2018, floods swept through the village of Mikhili and caused many damages. The water level reached about 1.5 m above the ground surface, where number of houses were fully and others partially devastated in addition to the hospital in the village (Fig,1). The water washed away some cars that were tried to pass through the flood, the hospital wall was demolished, some trees were uprooted and unfortunately two victims were died (Fig,2). Therefore, the current study has used remote sensing and GIS techniques in addition to field investigation to examine the geomorphic parameters of the target area to study the risk assessment of rain water discharge of wadi Ar Ramalh on Mikhili village.

Figure (1). Some pictures illustrate the severities of flood on 27th of September at Mikhili village.

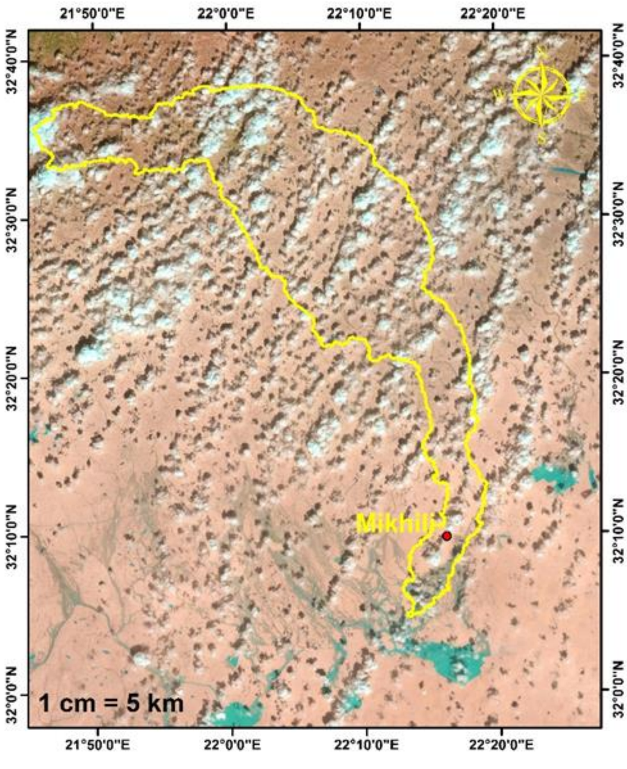

Figure (2). Landsat image shows the accumulation of discharged rain water after a day of flood at Balta Ar Ramalh, about 20 km in the south of Mikhili area.

2. Location of study area

The study area is part of Al Jabal Al Akhdar, which is located in NE of Libya. The Mikhili village is located in the southern part of Al Jabal Akhdar, about 85km in the south of Al Bayda City, NE of Libya; on the high way (locally known as desert road) that links between the Al Tamimi and Al kharouba villages, (Fig, 3).

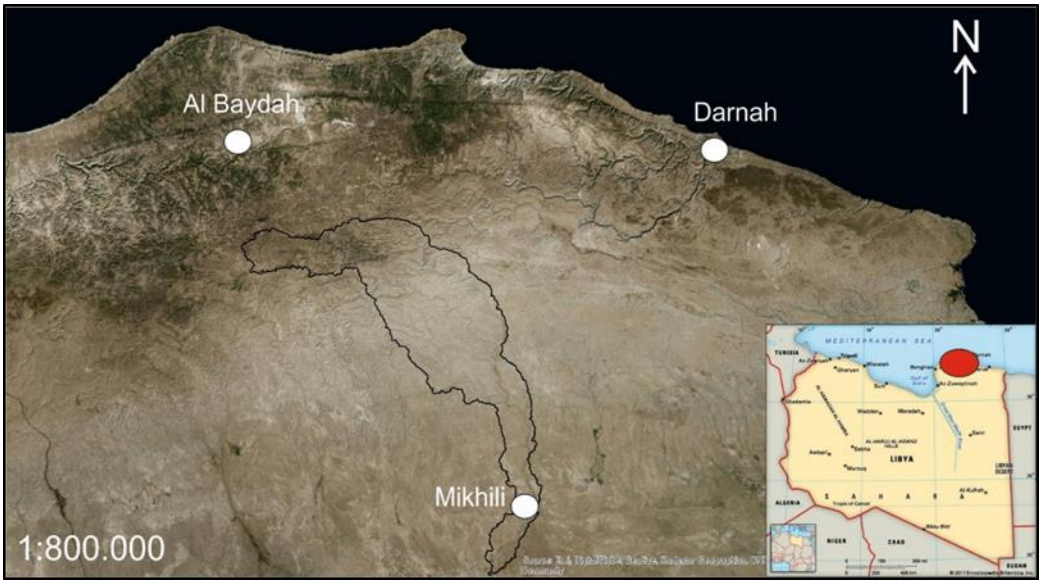

Figure (3). Aerial photograph shows location map of the study area, NE of Libya.

3. Methods

The methods that have been used in this study can be categorized into field investigations and office works. The aim of using these methods is to study and investigate closely the effects of geomorphic parameters on the study area, and to find out which possible causes that have led this village to be flooded.

For flood risk assessment at Mikhili village, several datasets have been collected. The main data set is a Digital Elevation Model (DEM) over the study area. This DEM was taken from **ALOS PALSAR** produced by (ASF) [8]; with a spatial resolution equals to 12.5 meters. In order to visualize the digital data, Google Earth and ArcMap software were used to place location data collected by the GPS device, together with determination the maximum distance that flood reached to on to a base map.

In addition, the average annual rainfall from (LaRC) [9]; grid files for the period from 1985 to 2018 were also used to alleviate problems arising from the insufficiency of rain gauges and their general distribution.

4. Results and discussion

- Geomorphological aspect

The studied wadi is called wadi Ar Ramlah and the Mikhili village is situated nearly at the end of its flanks. Wadi Ar Ramlah has an about 100km length which is extended from the Sidi Al Hamri in the north to about 20km into the south of the Mikhili village to an area known as Balta Al Ramalh where the wadi is terminated. The wadi Ar Ramlah passes through four types of carbonates rocks, and quaternary deposits that are represented by alluvial sediments and at same time cover the largest part of the southern part of Al Jabal Al Akhdar area, (Fig, 4). Al Jabal Al Akhdar area is more or less eroded by discontinuously flooded valleys (wadies), where most of them in the southern part are flatten, broaden and shallowing with a few meters deep. [10]. The elevation of wadi Ar Ramlah at Sidi Al Hamri is about **883m** above sea level, and ending at an elevation about **169m** above sea level. Wadi Ar Ramlah is considered as one of the longest wadies in south part of Al Jabal Al Akhdar area , and it has a sixth order of streams (Fig,5) [11].The depth of the wadi where it is passed the village is 6m in average, with roughly 65m width.

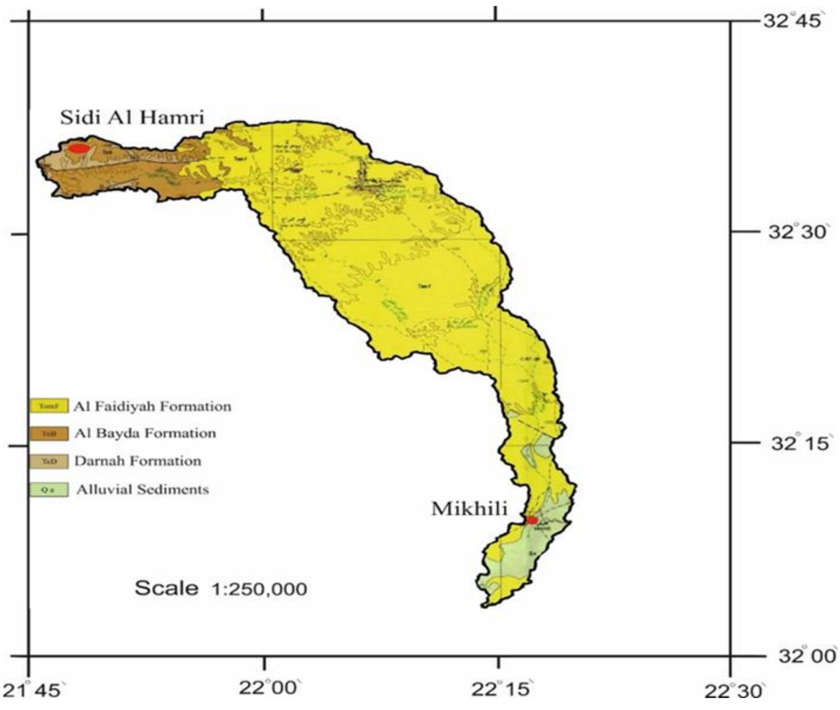

Figure (4). Map shows different lithology of carbonate rocks that are cut by wadi Ar Ramalh.

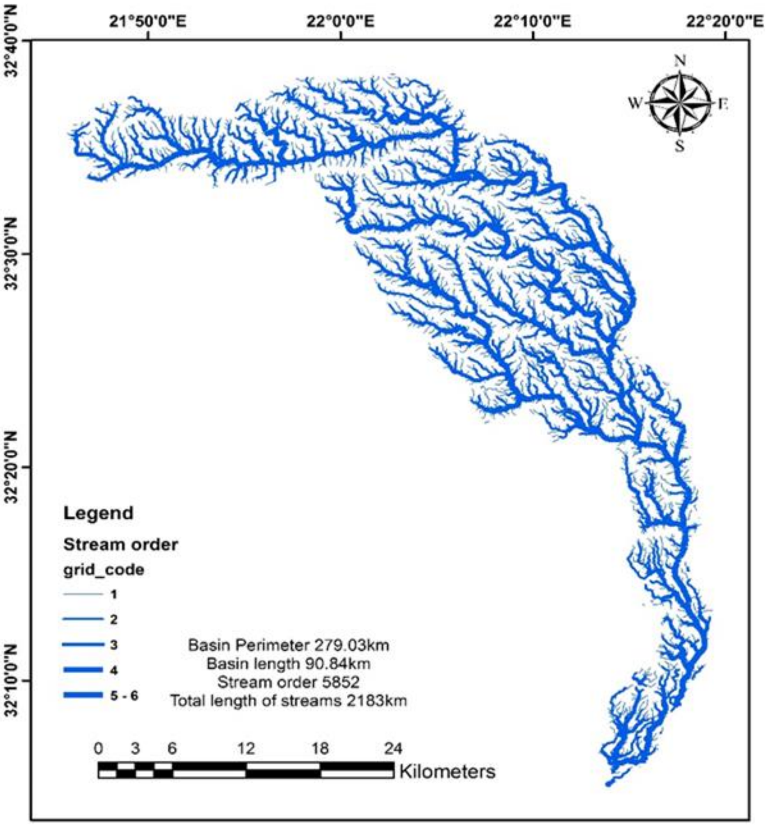

Figure (5). Map shows number of stream orders of wadi Ar Ramalh with a dendritic drainage pattern and boarder area of water catchment.

- **Slope, Aspect, and relative relief of the wadi Al Ramalh**

One of the most significant factors for morphometric analysis and watershed development in geomorphological studies is slope analysis. The rain water that need time to enter in the river beds for making a network of the river basin will be run-off under the effecting of slope elements, [12]. The slope degree of the study wadi varies from 2.9 in the south part which indicates nearly flat area to 58 in the northeast where the highest slope degree was determined in the area, (Fig, 6).

Furthermore, the Aspect determines the direction of terrain to which it faces, so that affecting the Pattern of precipitation, distribution of Vegetation and biodiversity in the study area [13]. The compass direction of the aspect was derived from the output raster data value. 0 is true north; a 90˚ aspect is to the east, an 180˚ is to the south. The study area is mainly dominated by two facing slopes, which are south facing slope and west facing slope. the south facing slopes occur mainly in the south direction of the area, whereas the west facing slopes are seen in the southeast part of the area, (Fig. 6). As result, south facing slopes have lower moisture content and higher evaporation rate than the west-facing slopes.

The topographical characteristic of an area is determined by using the relative relief of its catchment area [14]. The wadi is having highest relief as 883 m, while the lowest value is measured as 169 m (Fig, 6). The low relief designated in the southeast side suggests that this area of the basin is flat to gentle slope type, with low structure effect form hillshade map (Fig, 6).

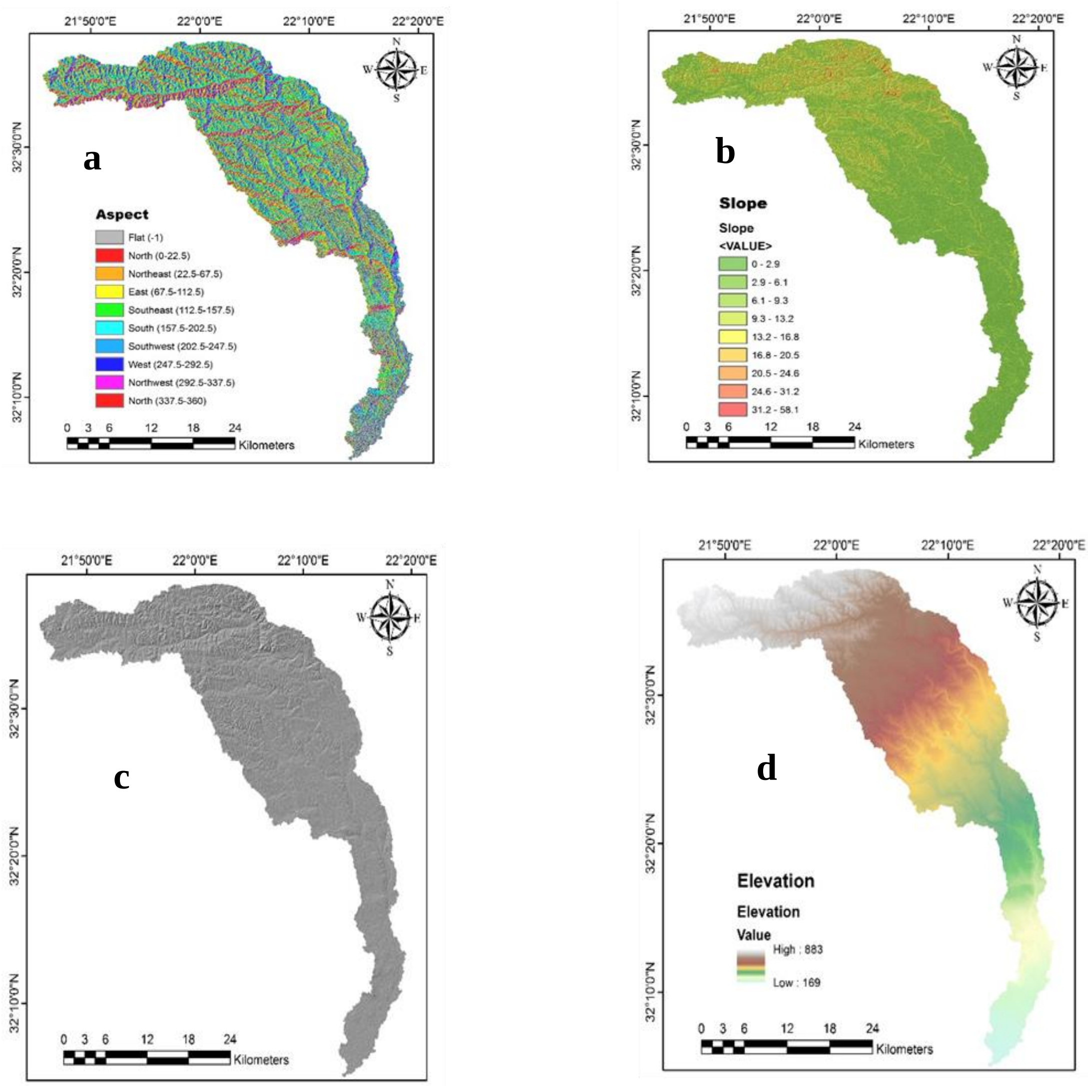

Figure (6). Maps show some significant factors for morphometric analysis; aspect (a), slope (b), hillshade map (c), and elevation map (d).

Based on continuous field models many hydrologic indices have been proposed to map soil moisture conditions, soil erosion, and soil sediments, [15]. The present study analysed three factors, namely, stream power index (SPI), Compound Topographic Index (CTI), normalized difference vegetation index (NDVI). Areas with high CTI values are more susceptible to flash flooding and inundation as compared to those with low CTI. We can observe that the SPI and the CTI reflect the tendency of water accumulation in the landscape and highlight areas prone to both fast moving and pooling water. The index map (Fig,7) indicates low rick of flash flooding in Mikhili Village, while the normalized difference vegetation index (NDVI) represents poor vegetation in all area with values between 0.4 to -0.1 which indicate low covering by vegetation.

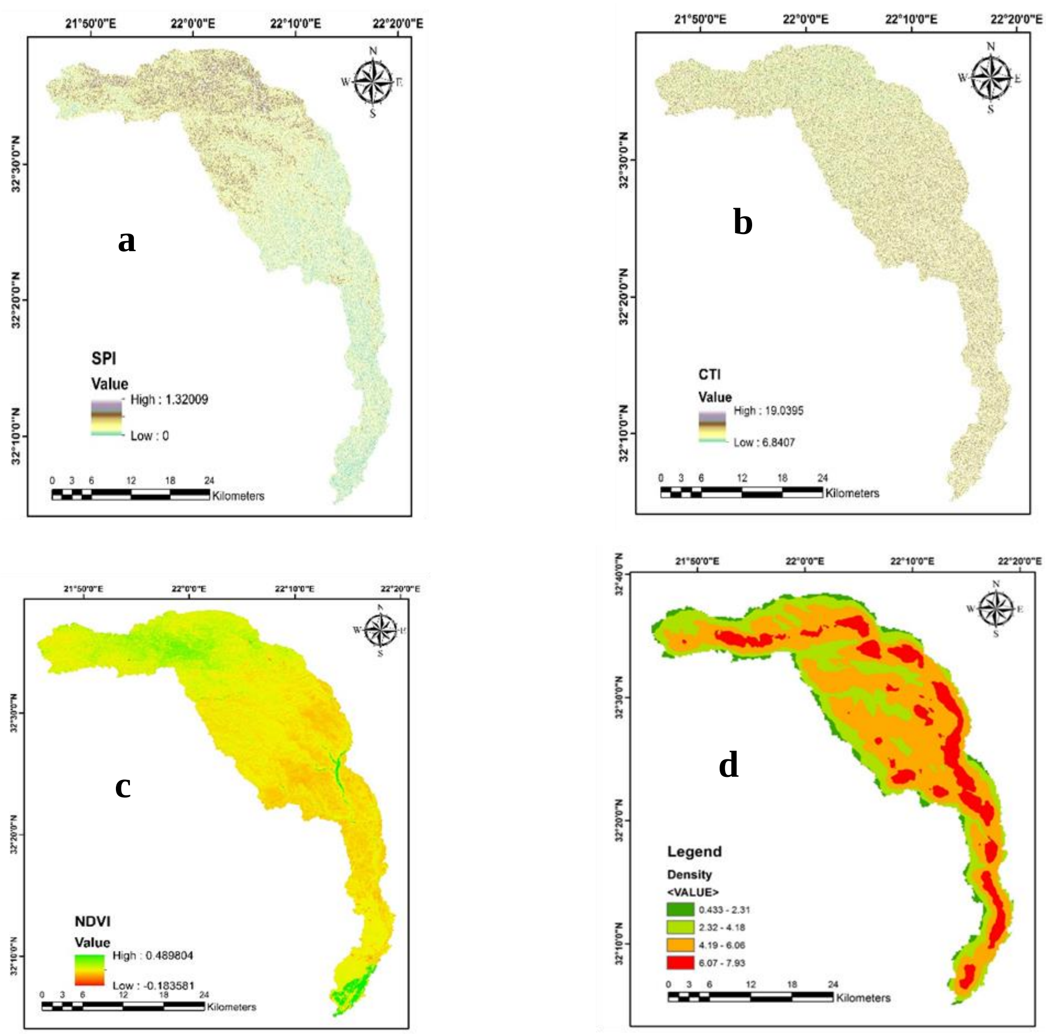

Figure (7). Maps show; SPI (a), CTI (b), NDVI (c), and drainage density map (d).

- **Aerial morphometric parameters**

According to [14] linear aspect, relief aspect, and aerial aspect of the river basin are generally the main three categories of morphometric parameters. These includes basin area, perimeter, basin length, stream order and stream length, mean stream length, stream length ratio, bifurcation ratio, basin relief, relief ratio, ruggedness number, drainage density, stream frequency, drainage texture, form factor, circulatory ratio, elongation ratio, length of overland flow, Infiltration number, and constant channel maintenance. The parameter value (Table 1) has a great help in understanding the relationship between the drainage morphometric and risk of flash flood.

Table (1), shows results of some calculated morphometric parameters at study area.

MORPHOMETRIC PARAMETERS	**FORMULA**	**RESULTS**
Basin length (L)	GIS Software	90.84km
Basin perimeter (P)	GIS Software	279,039km
Basin area (A)	GIS Software	832.99sq km
Drainage density (Dd)	Dd = Lu / A where Lu is total length of streams	2,62km/sq km
Stream frequency (Sf)	Sf = Nu / A where Nu is stream order	7.03n/sq km
Texture ratio (Rt)	Rt = Sf *Dd	20.97n/km
Form factor (Rf)	$Rf = A/(L)^2$	0.10
Circularity ratio (Rc)	$Rc = 4\pi A/P^2$	0.14
Elongation ratio (Re)	$Re = 2\sqrt{(A/\pi)}/L$ where $\pi = 3.14$	0.18
length of overland flow (Lof)	Lof = 1/2Dd	0.19
Infiltration number (In)	In=Sf * Dd	18.40
Constant channel maintenance (Ccm)	Ccm = 1 / Dd	0.38

However, the table (2) illustrates the overall Bifurcation ratios of the various stream orders of the studied wadi. A lower Bifurcation ratios range between 3 and 5 suggests that structure does not exercise a dominant influence on the drainage pattern, while higher Bifurcation ratios greater than 5 indicates some sort of geological control. If the Bifurcation ratio is low, the basin produces a sharp peak in discharge and if it is high, the basin yields low, but extended peak flow [16]. In general, the flat terrains have Bifurcation ratios 2, whereas mountainous or highly dissected terrains have values from 3 to 4. The results of Bifurcation ratios in the study area of the various stream orders range from 1 to 2.2, which indicates that the area dose not structurally controlled with a higher sharp peak in discharge and flat terrains.

Table (2), illustrates the overall Bifurcation ratios of the various stream orders of the study wadi.

Rb = Nu/Nu + 1, where Nu = Total number of stream segments of order Nu + 1 = Number of segment of next higher order	**Bifurcation ratios (Rb)**
1^{st} /2^{nd}	2.2
2^{nd}/ 3^{rd}	1.8
3^{rd}/4^{th}	1.8
4^{th}/5^{th}	1.6
5^{th}/6^{th}	1.0

- **Areal parameters**

According to [17] said that a very useful parameter to understand the landscape dissection, runoff potential or travel time of water in a basin, infiltration capacity of the land, relief, underlying lithology, climatic conditions, and vegetation cover of the basin, is a Drainage density which also indicates the closeness of spacing of channels. It is calculated as the total length of streams of all orders per unit area divided by the area of drainage basin. Moreover, high and low Drainage density values are gained due to sub-surface material (impermeable/permeable), vegetation (sparse/good), relief (high/ low), runoff/infiltration (high/low), and flood volumes (high/ low). The studied wadi has a high drainage density values (2.62 km/km2) which reveals high runoff surface with fine drainage texture, impermeable subsurface and sparse vegetation (Table, 3). The results of the stream frequency ratio are >3 that shows a very rough texture and high run-off on medium-to-high relief of low permeability.

In addition, the results of drainage texture represent almost the same products above. Drainage texture ratio depends on several factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief, drainage density, and stage of development, and it is obtained as a ratio between total number of streams and area of a basin [18]. It can be classified into four categories: coarse (< 4 per km), intermediate (4–10 per km), fine (10–15 per km), and very fine (> 15 per km) [18]. In the study area, the stream frequency is (7.03) and drainage texture is (20.97 per km) which indicate impermeable sub-surface material, high relief conditions, and low infiltration capacity with very fine texture, (table, 3).

On the other hand, the present results of Form factor show a negative correlation with drainage density, stream frequency and drainage texture, where the values of Form factor in the study area are (0.100) that indicating elongated nature with low peak runoff of longer duration (table, 3). According to [14] are believed that Form factor is a useful parameter to obtain a relationship of flow intensity of drainage basins along with their peak discharge, where high Form factor values occur in the basins having potential to produce high peak flows in short duration and low Form factor values are vice versa.

Furthermore, runoff in circular shape basins gets more time to stay, therefore, circular-to-elongate basin is inversely related to their character of movement (rapid or slow) of run-off to outlet and infiltration [14]. In the study area the elongation ratio is low with (0.18) and circularity ratio is (0.14) which indicate on elongated basin with low relief and impermeable surface resulting in lower peak flow for longer duration. The lower value of the elongation ratio indicates low infiltration capacity and high run-off conditions and vice versa [14]. Values of Circularity ratio that ranging between 0.6 and 0.8 represent the steep ground slope and high relief, whereas values near to one are correspond to low relief [19 and 20]. The varying slopes of basin can be categorized using index of elongation ratio i.e. oval (0.8-0.9), circular (0.9 – 1.0), less elongated (0.7-0.8), elongated (0.5-0.7) and more elongated (<0.5) [21].

In the study area, however, the Length of overland value is (0.19) showing relatively youthful stage of the drainage development, and the infiltration number of the basin is 18.40 indicating low infiltration and high run-off (Table 1). Constant of channel maintenance (Ccm) it is the inverse of drainage density and expressed with dimension of square per unit [22]. Rock type, permeability, vegetation, relief and duration of rainfall are the affecting factors of the constant of channel maintenance. The low value (0.38) of constant of channel maintenance indicates low permeability, moderate slope, and high surface run-off.

Table (3), Summarize relation between results of morphometric parameters and risk flood.

MORPHOMETRIC PARAMETERS	RESULTS	Permeability	Surface Run-Off	Risk
Drainage density (Dd)	2,62km/sq km			
Stream frequency (Fu)	7.03n/sq km			
Texture ratio (Rt)	20.97n/km			
Form factor (Rf)	0.10			
Circularity ratio (Rc)	0.14			
Elongation ratio (Re)	0.044			
Ccm	0.38			
Lof	0.19			
In	18.40			
Low **High**				

- **Relief morphometric parameters**

The morphometric investigation of the relief parameters of the basin includes Basin Relief (H), Relief Ratio (Rf) and Ruggedness Number (Rn). Relief ratio (Rh) of water catchment basin is 7.85, which indicates that the basin low to moderate relief and slope are characterized by moderate value of relief ratios, and the ruggedness number (Rn). of basin is 1.87, which indicates the moderately soil erosion in this area, (table, 4).

Table (4) shows results of some calculated relief morphometric parameters at study area.

RELIEF PARAMETERS	RESULTS
Maximum Elevation In The Area	883m
Minimum Elevation In The Area	169m
Basin Relief (H)	714m
Relief Ratio (Rf)	7.85
Ruggedness Number (Rn).	1.87

5. Conclusion

GIS techniques have a great help in drainage characterisation of runoff with systematically analysis the morphometric parameters in understanding the relationship between the drainage morphometric and risk of flash flood.

The drainage pattern, large area of water catchment, stream frequency, drainage density and bifurcation ratios indicate that the study area dose not structurally controlled with a higher sharp peak in discharge, flat terrains, fine drainage texture, with impermeable subsurface.

In addition, Stream frequency, infiltration number and the constant of channel maintenance indicating low infiltration capacity, moderate slope low permeability and high run-off.

However, form factor, elongation ratio, and circularity ratio indicate on elongated basin with low relief and impermeable surface resulting in lower peak flow for longer duration.

The current study has proved that the Mikhili village is a vulnerable area at low risk of flood due to its location, besides the drainage characteristics and the morphometric parameters of wadi Ar Ramalh.

6. References

[1] Elfadli, K.I., 2009. Precipitation data of Libya. Libyan National Meteorological Center.

[2] El-Tantawi, A.M.M., 2005. Climate change in Libya and desertification of Jifara Plain: using geographical information system and remote sensing techniques (Doctoral dissertation, Verlag nicht ermittelbar).

[3] Suleiman, A.S., Albini, P. and Migliavacca, P., 2004. A short introduction to historical earthquakes in Libya. Annals of Geophysics.

[4] Moawad, M.B., Abdel Aziz, A.O. and Mamtimin, B., 2016. Flash floods in the Sahara: a case study for the 28 January 2013 flood in Qena, Egypt. Geomatics, Natural Hazards and Risk, 7(1), pp.215-236.

[5] Doswell III, C.A., 2003. Flooding. Encyclopedia of atmospheric sciences.

[6] Youssef, A.M., Pradhan, B. and Hassan, A.M., 2011. Flash flood risk estimation along the St. Katherine road, southern Sinai, Egypt using GIS based morphometry and satellite imagery. Environmental Earth Sciences, 62(3), pp.611-623.

[7] Saleh, A.S., 1989. Flash floods in deserts. A geomorphic study of desert Wadis. Institute of Arab Research, Special Studies Series, 51, pp.1-93.

[8] Dataset: ASF DAAC 2008, ALOS-1 PALSAR_Radiometric_Terrain_Corrected_low_res; Includes Material © JAXA/METI 2018. https://vertex.daac.asf.alaska.edu/#, accessed 12 November 2018.

[9] POWER Data Access Viewer, 2018, NASA Langley Research Center (LaRC) POWER Project. https://power.larc.nasa.gov/data-access-viewer/?fbclid=IwAR1NhnG8BvaJmp8WuvjQXpVYaBtl8nsWvZZsrTn62CVFR43gpnG6anVMvNE, accessed 1 December 2018.

[10] Röhlich, P., 1974. Geological map of Libya, 1: 250 000. Sheet Al Bayda (NI 34–15). Explanatory Booklet. Ind. Res. Cent., Tripoli.

[11] Salloum, F.M., An Assessment of the Hydrogeology and Hydrochemistry of the main Aquifers in Darnah Region, NE. Libya. The Scientific Journal of the University of Benghazi SJUB EDITORIAL BOARD, p.4.

[12] Villela, S.M. and Mattos, A., 1975. Hidrologia aplicada. In Hidrologia aplicada. McGraw-Hill.

[13] Khakhlari, M. and Nandy, A., 2016. Morphometric analysis of Barapani river basin in Karbi Anglong District, Assam. International Journal of Scientific and Research Publications, 6(10), pp.238-249.

[14] Singh, S., Kanhaiya, S., Singh, A. and Chaubey, K., 2019. Drainage network characteristics of the Ghaghghar River Basin (GRB), Son Valley, India. Geology, Ecology, and Landscapes, 3(3), pp.159-167.

[15] van Griensven, A.V., Meixner, T., Grunwald, S., Bishop, T., Diluzio, M. and Srinivasan, R., 2006. A global sensitivity analysis tool for the parameters of multi-variable catchment models. Journal of hydrology,

324(1-4), pp.10-23.

[16] Dikpal, R.L., Prasad, T.R. and Satish, K., 2017. Evaluation of morphometric parameters derived from Cartosat-1 DEM using remote sensing and GIS techniques for Budigere Amanikere watershed, Dakshina Pinakini Basin, Karnataka, India. Applied Water Science, 7(8), pp.4399-4414.

[17] Bhat, M.S., Alam, A., Ahmad, S., Farooq, H. and Ahmad, B., 2019. Flood hazard assessment of upper Jhelum basin using morphometric parameters. Environmental earth sciences, 78(2), p.54.

[18] Fenta, A.A., Yasuda, H., Shimizu, K., Haregeweyn, N. and Woldearegay, K., 2017. Quantitative analysis and implications of drainage morphometry of the Agula watershed in the semi-arid northern Ethiopia. Applied Water Science, 7(7), pp.3825-3840.

[19] Strahler, A.N., 1964. Part II. Quantitative geomorphology of drainage basins and channel networks. Handbook of Applied Hydrology: McGraw-Hill, New York, pp.4-39.

[20] Miller, V.C., 1953. Quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. Technical report (Columbia University. Department of Geology); no. 3.

[21] Dash, B., Nagaraju, M.S.S., Sahu, N., Nasre, R.A., Mohekar, D.S., Srivastava, R. and Singh, S.K., 2019. Morphometric Analysis for Planning Soil and Water Conservation Measures Using Geospatial Technique. Int. J. Curr. Microbiol. App. Sci, 8(1), pp.2719-2728.

[22] Kumar, D. Singh, P. K. Kothari, M. Singh, R.S. Yadav, K.K. 2017. Application of rs and gis techniques in the analysis of morphometric characteristics of upper berach river basin, rajasthan state. International Journal of Agricultural, Vol. 7, Issue 5, Oct 2017, 521-530.