Chapter 12
Applications of Remote Sensing Techniques in Earthquake and Flood Risk Assessment in the Cyrenaica Region, Al Jabal Al Akhdar Area, NE Libya

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Abstract Earthquakes and flooding are naturally occurrences events and they are known as natural hazards. These hazards considerably cause multiple harms and threaten human life. Libya is accounted among those countries that suffer from earthquakes and floods as natural hazard. Libya is located within the active plate boundaries of the African plate and the European plate, where these two continents are in a relative subducting motion. As consequence, the boundaries areas of these plates are seismically active. Furthermore, Libya is also characterized by an arid to semi-arid climate, which is punctuated by periods of thunderstorms and intensive rain in winter time on high land areas. The north-eastern part of Libya, which is called a Cyrenaica region, has experienced varying degrees severe and destructive earthquakes and floods. In this chapter, remote sensing and GIS applications have been used in linking the earthquakes and their relationship to local faults and linear features to areas most affected in the event of an earthquake in Cyrenaica. Besides that, geomorphic parameters of selected wadies have been analysed for risk assessment of flash flood on certain areas of the Al Jabal Al-Akhdar area.

12.1 Introduction

The Mediterranean region is a complex region where both of the African plate and the European plate are in a relative subducting motion. The African plate is slowly subducting beneath the European plate in the Hellenic Arc Subduction Zone. Within this area many earthquakes of great strength were recorded and caused a lot of damage in both the Greek islands and the Turkish state (Lagesse et al., 2017). The

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Cyrenaica region is located near this seismically active area, and as consequences it is considered as an earthquake zone that is affected by large earthquake activity.

In addition, Libya is characterized by a semi-arid climate that punctuated by periods of thunderstorms and intensive rain in winter time. These kinds of heavy showers are well observed in highland areas, especially on Jabal Nafusah in the west and Jabal Al Akhdar in the east (Elfadli, 2009; El-Tantawi, 2005). In the Cyrenaica region, the averages annual rain fall are from 200 to 500 mm. The highest recording of rainfall in Libya was measured with about 850 mm on Jabal Al Akhdar area, which is an integral part of Cyrenaica region (Elfadli, 2009). Moreover, the flash flood is a well-known phenomenon that frequently occurred 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 of Cyrenaica region.

However, the modern techniques of remote sensing show a successful approach in forecasting and vulnerability analysis, besides to damage assessment, caused by natural disasters. In this chapter, firstly, we focus on linking earthquakes and their relationship to local faults and linear features that extracted from digital elevation models of the areas most affected in the event of an earthquake. Next in order, many studies have used remote sensing and GIS applications for analysing the geomorphic parameters of some wadies in Al Jabal Al Akhdar area to assess the risk of rain water discharge. Here, three wadies are namely wadi Darnah, wadi Ar Ramlah and wadi Ash- Sharif; have been chosen as a representative for a risk assessment of flood in the area.

12.2 Geological Setting

The Jabal Al Akhdar area is located as an integral part of Cyrenaica region in the northeast of Libya. It is bordered by the Egyptian borders to the east, the desert region to the south and the Mediterranean Sea to the north and west directions. The study area is dominantly by two tectonic provinces, the Jabal Al Akhdar Uplift and fold belt in the north and the Cyrenaica Platform in the south. Al Jabal Al Akhdar started as basin and inverted to be uplifted mountain in two stages during Santonian and middle Eocene (Hallett, 2002). The exposed rocks in the Al Jabal Al Akhdar are made up of marine carbonate units ranging in age from the Late Cretaceous to Late Miocene (El Hawat & Shelmani, 1993). The total thickness of these units is about 2000 m, and they rest uncomfortably on each other due to their affecting by uplifted tectonic (Fig. 12.1; Hallett, 2002; El Hawat & Shelmani, 1993). The deposition environment of these carbonate rocks is mainly shallow to deep marine with Some or few evaporite rocks due to the Messinian event in the late Miocene (Hallett, 2002; El Hawat & Shelmani, 1993).

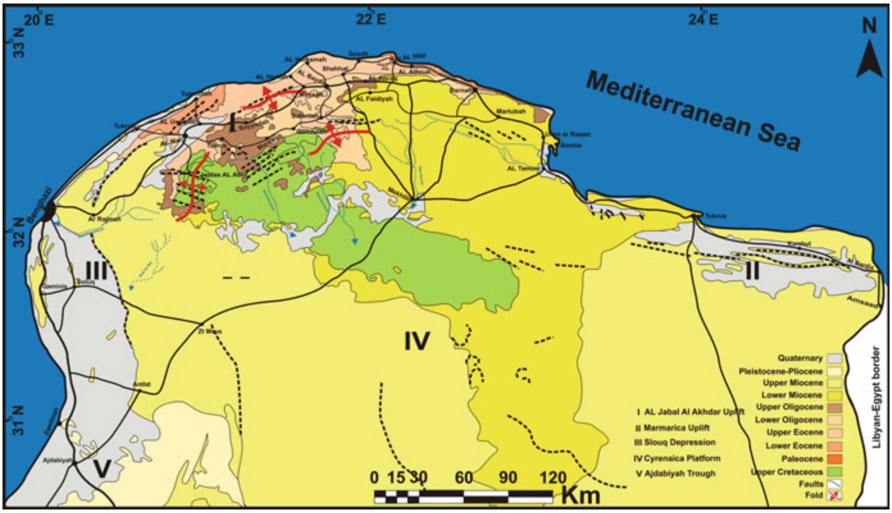


Fig. 12.1 Surface geological map with structure components of north-eastern Libya. (Shaltami et al., 2020)

12.3 Methodology

For earthquake assessment, some data have been collected from the Shuttle Radar Topographic Mission (SRTM) Multi- resolution (30 & 90 m), also Seismicity data are obtained from the United States Geological Survey (USGS) (https://earthquake.usgs.gov). In addition, the linear features extraction has done through maps of shadows and compared them with existing geological maps. For flood risk assessment, Digital Elevation Model (DEM) have been collected over the study area. This DEM for wadi Ar Ramlah and wadi Darnah was taken from ALOS PALSAR produced by (ASF) (ASF, 2020); with a spatial resolution equals to 12.5 meters, and 30 m as spatial resolution produced by (SRTM) for wadi Ash- Sharif. In order to visualize the digital data, ArcMap software were used to place location data collected by the GPS device, together with determination the maximum distance that flood reached to on a base map.

12.4 Seismicity of NE Libya

Earthquakes occur suddenly and without warning, and may cause a lot of issues in the infrastructure or deaths in the most severe earthquakes. Considering the vulnerability of Libya's infrastructure and despite a divergence of the earthquakes in time periods, the earthquakes cause many casualties and seriously damages. According to Hassen (1983) Libya has been divided into four regions in terms of earthquake magnitude, where the central and the north-eastern regions of Libya are considered the most active areas and the southern region is a region of limited activity.

The collected seismicity data from the United States Geological Survey (USGS) from (1955 to 2020) suggested that 35 earthquakes were recorded in the Cyrenaica region (Fig. 12.2a), and the most of these earthquakes are shallow (0–40 km). In addition, from the relationship between the depth and the earthquakes magnitude in Cyrenaica region (Fig. 12.2b), it is found that approximately half of the earthquakes that were recorded are with 3.3 to 5.3 magnitudes at the depth of 10 kilometres, while the largest earthquakes were recorded (5.6) are at a depth 25 kilometres.

It can be easily observed that all seismic activity in the Cyrenaica region is concentrated in the northern part, while in the southern part there are no records of seismic activity. The majorities of these earthquakes were recorded in offshore slightly apart from the coastline between Darnah city and Tubruq city. Nevertheless, although the area that extending from Benghazi City to the city of Al-Bayda is considered a fairly stable area, but the largest severe recent earthquakes were recorded in Al-Marj area; (e.g., Al-Marj earthquake in 1963).

Most earthquakes in the Al-Marj area (Fig. 12.4a, d), occurred approximately along the same line that extends from Tulmithah City to Taknis City around Al-Marj area. All these earthquakes occurred at the same depth of 10 kilometres, except the largest magnitude 5.6 that recorded at 25 kilometres.

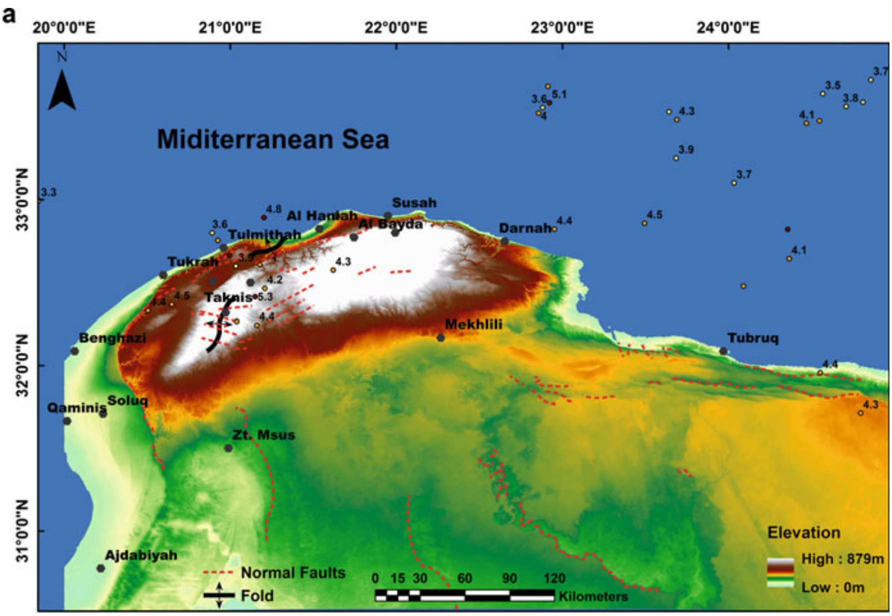


Fig. 12.2 (**a**) DEM of the north-eastern region of Libya shows the distribution of earthquakes and their magnitude; (**b**) Plot diagram illustrates depth and magnitude of earthquakes in north-eastern region of Libya

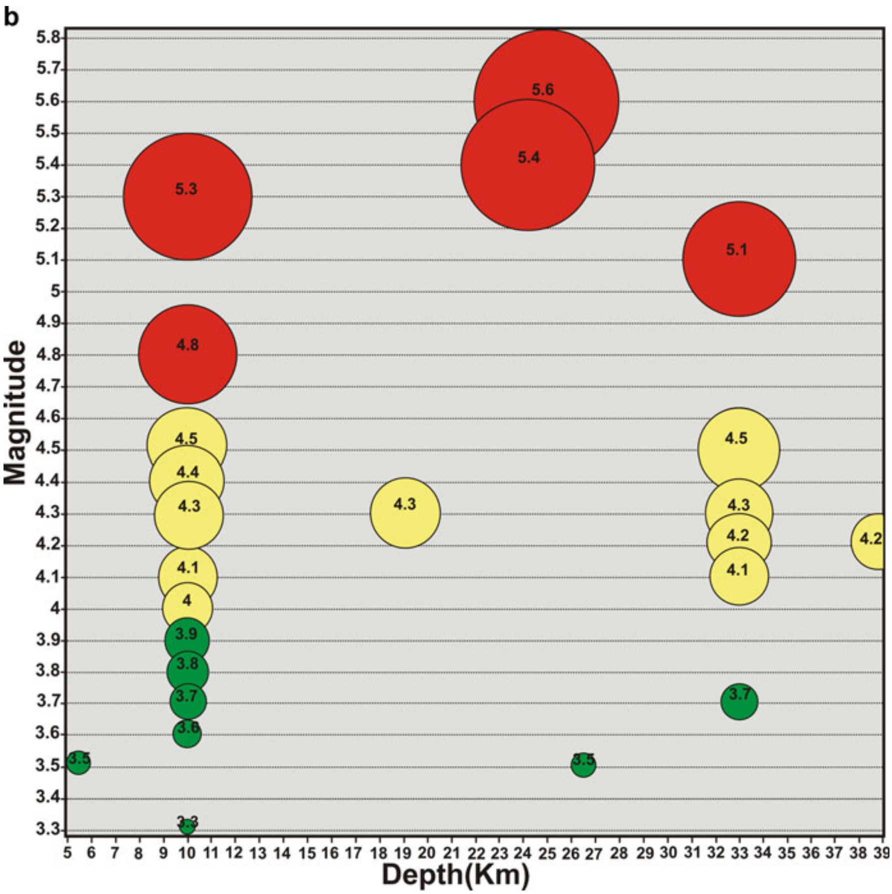


Fig. 12.2 (continued)

12.5 Results and Discussion

12.5.1 Active Deformation of NE Libya

Cyrenaica is formed by five-structural categories; Soluq Depression, Ajdabiyah Trough, Al Jabal al Akhdar Uplift, Cyrenaica Platform and Marmarica Uplift (Fig. 12.1). These structural deformations have resulted in a variety of structural elements of faulting and folding (El-Arnauti et al., 2008). The most active deformation structure is; Al Jabal al Akhdar Uplift, Marmarica Uplift and Soluq Depression.

Al Jabal al Akhdar area has been described as an anticlinorium inversion structure and the main folding took place during the Santonian and further uplifted in the middle Eocene (El Hawat & Shelmani 1993; Chrisite, 1955). Furthermore, the Marmarica Uplift in the northeast of Cyrenaica, are covered by mainly carbonates rocks of Tertiary age with a gentle slope. It represents a faulted step-down of the northern margin of the Cyrenaica Platform. The northern part of Marmarica Uplift is affected by a zone of normal faults with northwest orientation, while the south part is more stable and no faults showing on the surface of the region (El Deftar& Issawi, 1977). The Soluq Depression has very limited faults as the region was not exposed to significant tectonics after deposition, and as a result most of the sediments were preserved (Hallett, 2002).

12.5.2 Tectonic Geomorphology

Tectonic geomorphology is defined as the application of geomorphology to tectonic problems. It includes the study of landform assemblages and landscape evolution as well as development of process-response models for areas and regions affected by recent tectonic activity (Keller & Rockwell, 1984). Moreover, the terrain is formed and affected by the processes of faults and distinct shapes such as steep scarps, folds, elongate ridges offset terraces, and linear valleys, and deflected, offset and uplifted streams (Gupta, 2018).

Accordingly, the tectonic surface maps of the Al-Marj area (Fig. 12.4c, d and Fig. 12.5b) show that the Jardas Al Abid is highly dominated by faulting. The main trend of these structures is, ENE–WSW (Arsenikos et al., 2013). It can clearly observe that the offset of the liner valleys is substantially cut by an escarpment that resulted in forming triangular facets. This scarp is considered as fault.

Further, the fault scarps are prominent on the two escarpments from the northern part of Al Jabal al Akhdar, and they can be identified in the coastal direction in the east-west direction enclosing Al-Marj City (Fig. 12.5a; El Amawy et al., 2009; Campbell, 1968). Besides to the aforementioned fault scarps, two large anticlines folds are observed in the Al- Marj area between Jardas al Abid and in the east of Taknis City.

12.5.3 Lineament Extraction with Density

A lineament or Linear features can be defined simply as the shapes that appear straight line or curved feature on satellite images. It can be the result of man-made, such as roads or railroads, or the result of structural natural phenomena such as faults or fractures (Bashe, 2017). By comparing the existing faults and the linear features that extracted from digital elevation models (Fig. 12.3a, b) the interested area can be divided into three basic zonation:

Zone 1, It is the most intense in terms of severity and concentration of both faults and linear features, which is what is emphasized in this part of chapter.

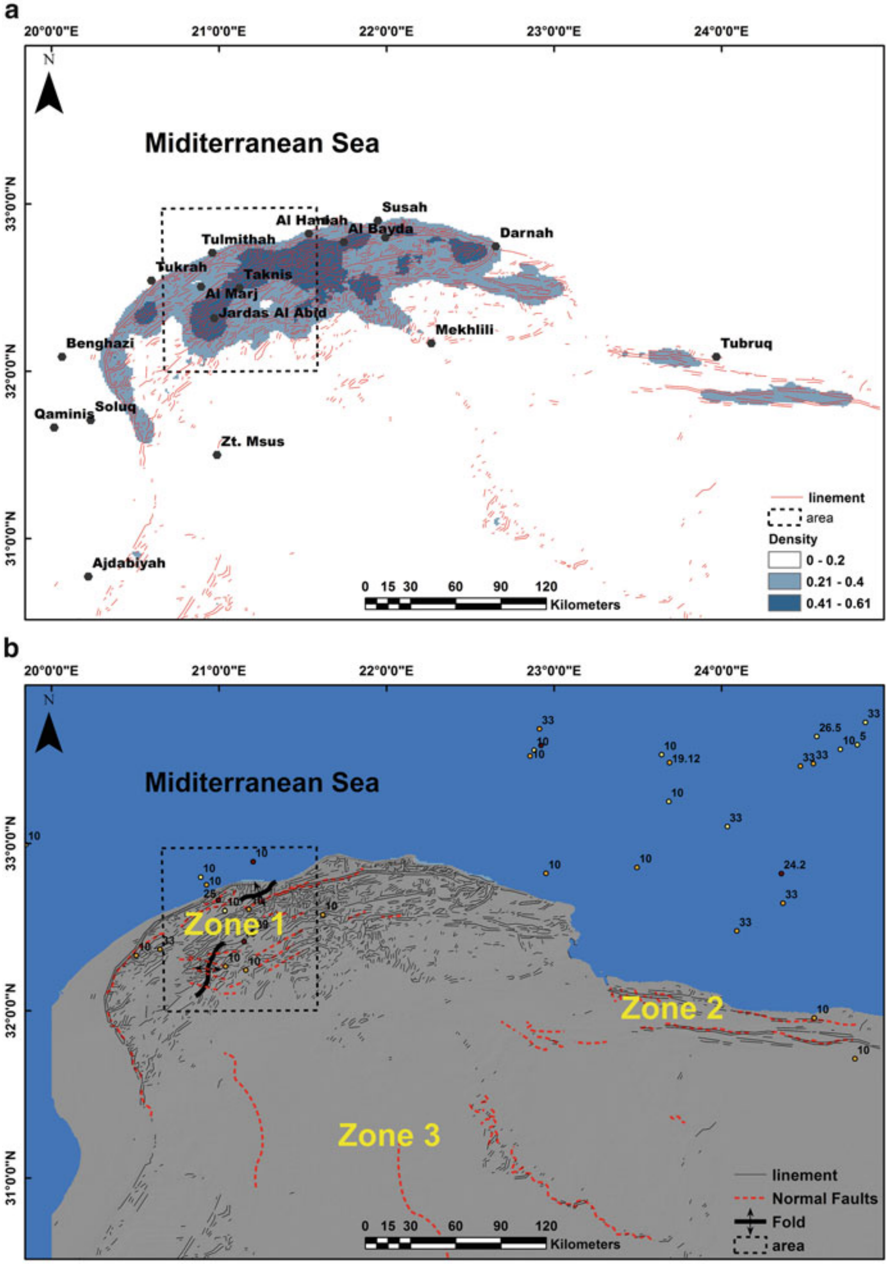


Fig. 12.3 (**a**) Lineament density map. (**b**) Lineament map with faults distribution and zonation based on severity and concentration of both faults and linear features

Zone 2, It is considered a limited concentration in terms of linear features and faults, with faults spreading clearly to the east-west direction, but the occurrence of earthquakes in a nearby area in marine areas has affected in some way the occurrence of some earthquakes.

Zone 3, This region has a very limited concentration of faults and linear features, as it is considered the most stable region in addition to its distance from the marine earthquake zone.

The linear data that was extracted from STRM and converted into the shadow models (Fig. 12.4a, b and c), found that most of the linear data are in a clear direction towards the Jardas Al Abid and eastern of the Tulmithah City and Taknis City. This is evident in the wide fold process of carbonate rocks in Jardas Al Abid, and in

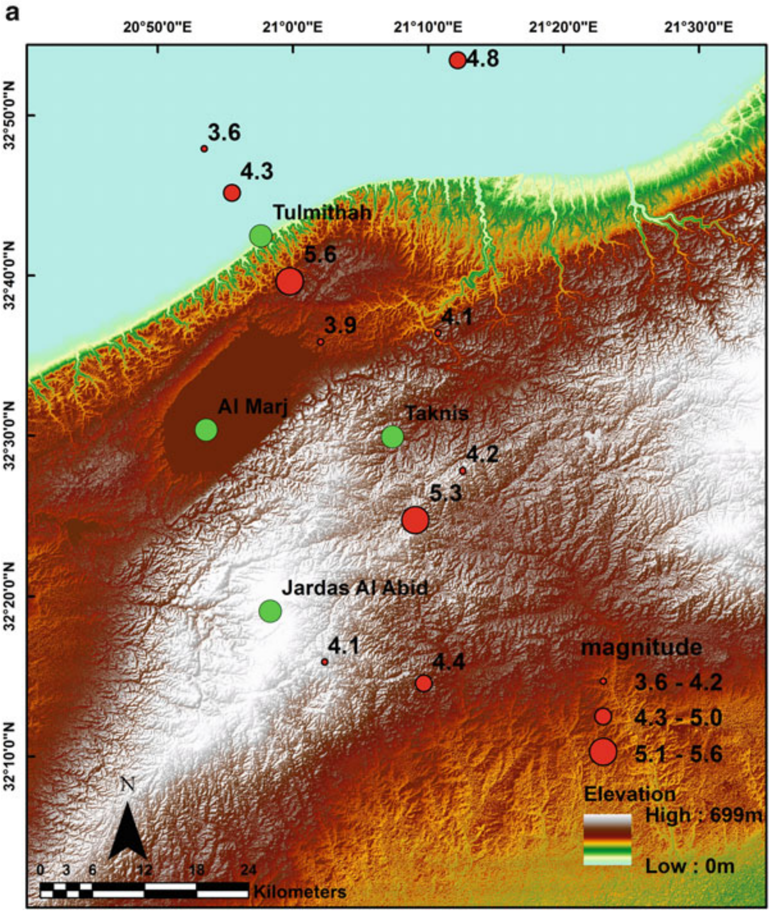


Fig. 12.4 (**a**) Displays Zone (1) with its recorded magnitudes of earthquakes. (**b**) Shadow relief map illustrates the depth of the recorded earthquake. (**c**) Lineament map shows faults distribution in the zone (1). (**d**) Lineament density map of the zone (1)

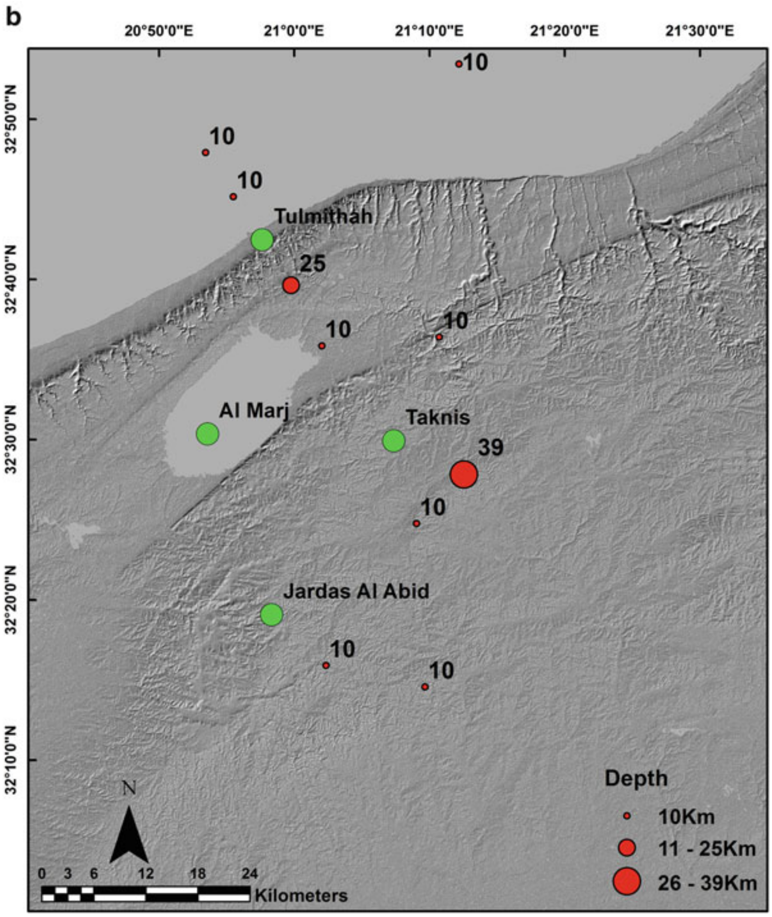


Fig. 12.4 (continued)

remarkably coincidence with most of the faults that were identified in the previous studies and in most of the existing geology maps.

The lineament density that extracted was categorized into three classes (Fig. 12.4c, d); (0–0.3 Km/Km^2, 0.4–0.5 Km/Km^2, and 0.6–0.8 km/km^2). Lineament with densities ranging from (0 to 0.3 Km/Km^2) covers about (25%) of the study area, which is part of the Al-Marj city. The low range of lineament density is due to massive accumulation of the soil and sediments that play a significant role in the absence of deductive linear features.

Lineament with densities ranging from (0.4 to 0.5 Km/Km^2) covers almost (50%) of the study area. This range can be the result of the influence of streams, valleys or linear ridges.

The third lineament densities are between 0.6 and 0.8 km/km^2, covers (25%) of the interested area. These ranges are concentrated between two locations; Jardas Al

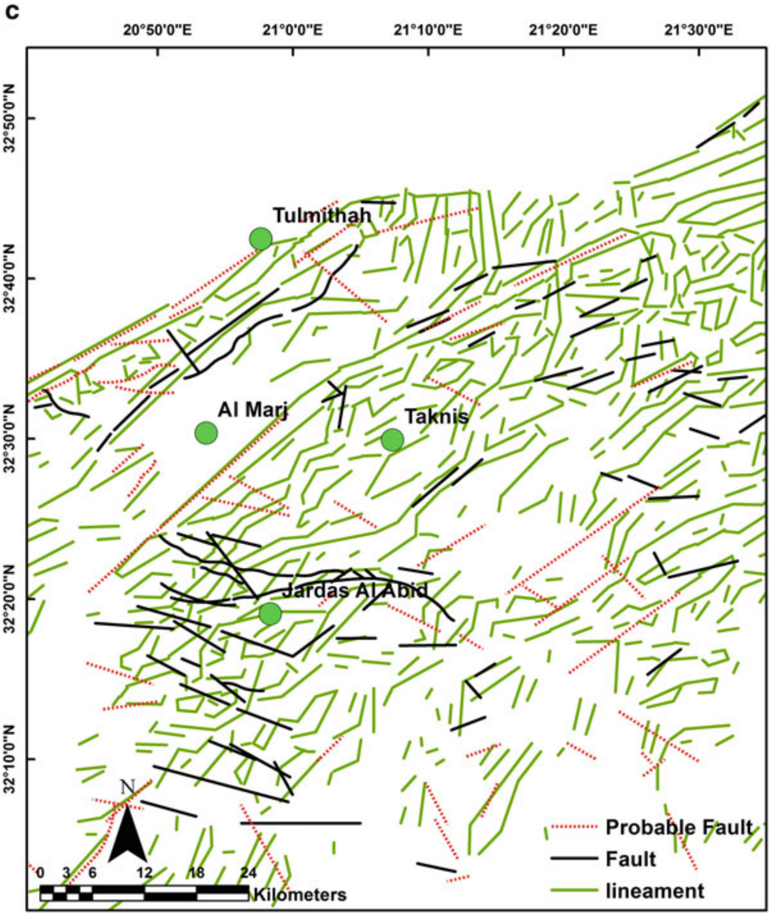


Fig. 12.4 (continued)

Abid and eastern the Tulmithah City and the Taknis City. It could be considered a fault zone of the area.

However, three topographic profiles had drawn (Fig. 12.5); the first profile is across in a direction of southwest to northeast. It crosses the Jardas Al Abaid area in the direction of the coast, where this region is affected by the intensity of faults resulting from deformation of folding. Likewise, this cross section represents two escarpments probable fault scarps to the coast region. The rest other profiles are drawn (2)(3) in the direction of northwest to southeast across the Al Marj City, Taknis City and Tulmithah City. These profiles have jointly crossed the activity line of earthquakes in the area (Fig. 12.4a, b), and reflect obviously two escarpments' lines as fault scarps.

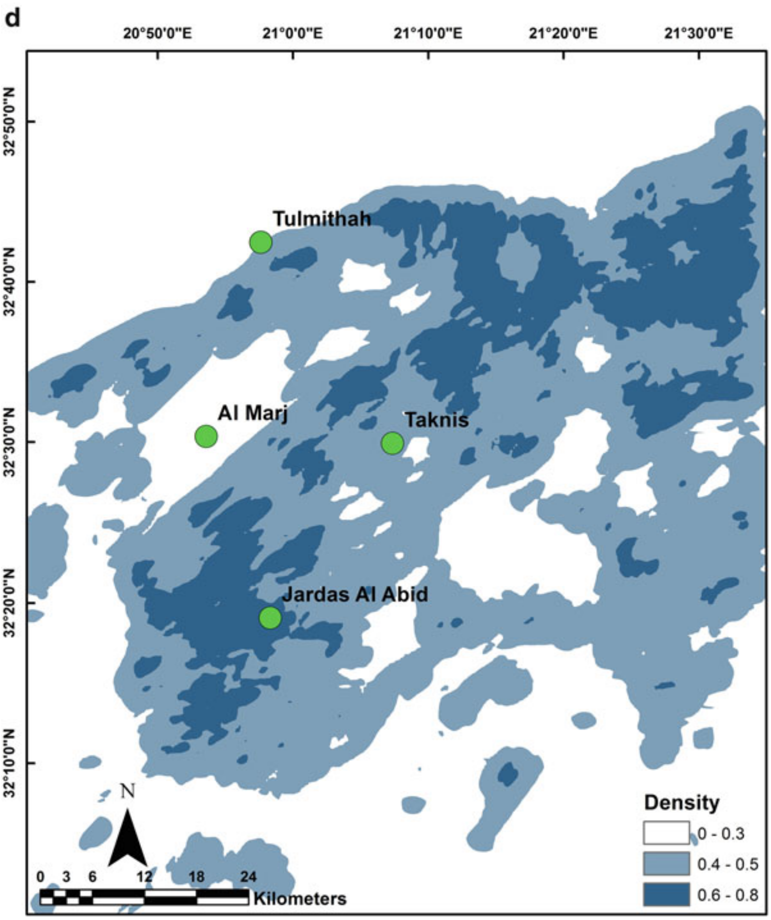


Fig. 12.4 (continued)

12.6 Flash Flood in Al Jabal Al Akhdar Area

Flash floods are defined as rising in water over a short period of time either during or within a few hours of the rainfall (Doswell, 2003). Besides that, a relatively small amount of rain or the intensity and duration of the rainfall with a low rate of infiltration can trigger flash flooding. Flooding can occur virtually anywhere, in steep rocky terrain or even within heavily urbanized regions (Youssef et al., 2011; Doswell, 2003). 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

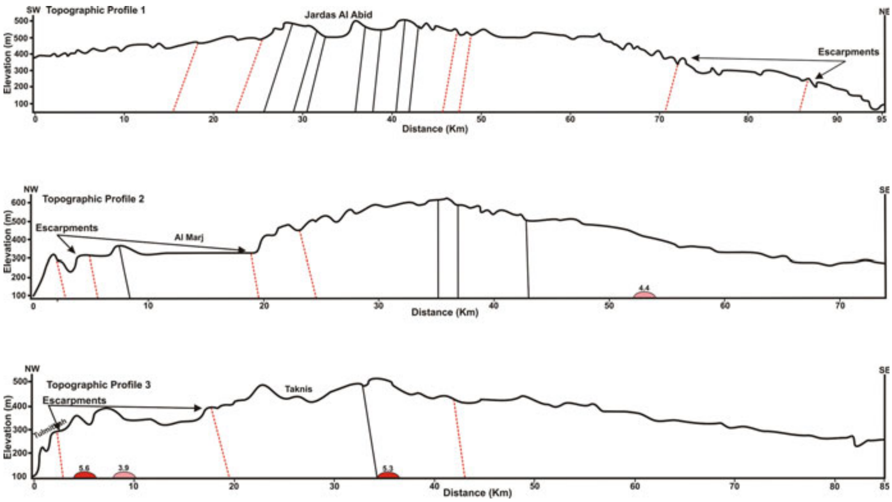


Fig. 12.5 Three topographic profiles dissect the fault scarps and uplifts along the zone (1)

characteristics, drainage orders (Youssef et al., 2011; Doswell, 2003). One of the documented floods in Al Jabal Al Akhdar area is on the 27th of September in 2018, flood swept through the village of Mikhili and caused many damages (Zamot & Afkareen, 2020). 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. The water washed away some cars that were trying to pass through the flood, the hospital wall was demolished, some trees were uprooted and unfortunately two victims have died.

12.7 Location of Study Wadies

The selected wadies are namely; wadi Darnah, wadi Ar Ramlah, and wadi Ash Sharif. wadi Darnah, and wadi Ash Sharif are placed in northern part of the Al Jabal Al Akhdar area and terminated in Mediterranean Sea, while wadi Ar Ramlah is located in the southern part of the Jabal Al Akhdar and discharged into a flat desert area in the south (Fig. 12.6).

12.8 Results and Discussion

According to (Singh et al., 2019) linear aspect, relief aspect, and aerial aspect of the river basin are generally the main three categories of morphometric parameters. These include basin area, perimeter, basin length, stream order and stream length,

Fig. 12.6 Illustrates the location map of the three studied wadies

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, dissection Index (DI), and constant channel maintenance. The main results of morphometric analysis and relief parameters of the studied wadies are listed in the Tables 12.1 and 12.2 respectively.

12.8.1 Geomorphological Aspect

Al Jabal Al Akhdar area is more or less eroded by discontinuously flooded valleys (wadies), where most of these wadies that are located in the southern part are flatten, broaden and shallowing with a few meters deep, while those in the north are deeper and narrower (Röhlich, 1974). The studied wadies passe through different types of marine carbonate rocks, besides to the quaternary deposits that cover the large part of the Al Jabal Al Akhdar area by alluvial sediments and terra-rossa soil.

Wadi Darnah is one of the longest wadies in the northern of Al Jabal Al Akhdar, it starts from Al Abraq Village at an elevation 889 m and ending at elevation 27 m in Darnah city where it is discharged into the Mediterranean Sea. Its length is about 77.773 km with water catchment area 554.89 km^2, and it has a fifth order of streams (Fig. 12.7).

Wadi Ar Ramlah has an about 100 km length, which extends from the Sidi Al Hamri in the north to about 20 km into the south of the Mikhili village to an area known as Balta Al Ramlah where the wadi is terminated. The elevation of wadi Ar Ramlah at Sidi Al Hamri is about 883 m above sea level, and ending at an elevation about 169 m 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. 12.8).

Table 12.1 Shows results of some calculated morphometric parameters at study area

Morphometric parameters	Formula	Results of Wadi Darnah	Results of Wadi Ar-Ramlah	Results of Wadi Ash-Sharif	Refernces
Basin length (L)	GIS software	77.773 km	90.84 km	14.024 km	Schumm (1956)
Basin perimeter (P)	GIS software	279.255 km	279.039 km	48.228 km	Schumm (1956)
Basin area (A)	GIS software	554.89 km^2	832.99 km^2	41.072 km^2	Schumm (1956)
Drainage density (Dd)	Dd = Lu / A; where Lu total length of streams; A area of watershed	0.9 km/km^2	2.62 km/km^2	2.5 km/km^2	Horton (1932)
Stream frequency (sf)	Sf = nu / A; where nu total number of streams; A area of watershed	0.77 n/km^2	7.03 n/km^2	5.04 n/km^2	Horton (1932)
Texture ratio (Rt)	Rt = ΣNu/P, where nu the total number of streams, P perimeter of watershed.	1.53 n/km	20.97 n/km	4.29 n/km	Schumm (1956)
Form factor (Rf)	Rf = A/(L)2; where A area of watershed; L basin length.	0.092	0.10	0.20	Horton (1932)
Circularity ratio (Rc)	Rc = 4πA/P 2; π = 3.14, A area of watershed, P perimeter of watershed.	0.089	0.14	0.22	Miller (1953)
Elongation ratio (re)	Re = 2√(A/π)/L; where π = 3.14, A area of watershed, L length of watershed.	0.34	0.358	0.51	Schumm (1956)
Length of overland flow (Lof)	Lof = 1/2Dd; Dd drainage density	0.45	0.19	0.2	Horton (1945)
Infiltration number (in)	In = Dd * sf; sf stream frequency, Dd drainage density.	0.69	18.4	12.6	Faniran (1968)
Constant channel maintenance (Ccm)	Ccm = 1 / Dd; where Dd drainage density	1.11	0.38	0.39	Schumm (1956)

Wadi Ash- Sharif is about 14 km long with water catchment area of 41 km^2, it extends nearly from Al-Bayda city in the south at an elevation 527 m, pass through Al Haniah village and ending into Mediterranean Sea in the north with a fourth order of streams (Fig. 12.9).

Table 12.2 Shows results of some calculated relief parameters at study area

RELIEF PARAMETERS	Wadi Darnah	Wadi Ar Ramlah	Wadi Ash Sharif	Formula	References
Maximum Elevation in the area (hMax)	889 m	883 m	527 m	_	_
Minimum Elevation in the area (hMin)	27 m	169 m	0 m	_	_
Basin relief (H)	862 m	714 m	527 m	H = hMax - hMin	Schumm (1956)
Relief ratio (Rf)	11.08	7.85	37.57	Rf = H/L	Schumm (1956)
Ruggedness number (Rn).	0.78	1.87	1.31	Rn = H* Dd	Melton (1957)
Dissection Index (DI)	0.97	0.8	1	DI = H/ hMax	Schumm (1956)

12.8.2 Slope, Aspect, and Relative Relief of the Study Wadies

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, (Chow, et al., 1994). Therefore, one of the most significant factors for morphometric analysis and watershed development in geomorphological studies is slope analysis. The slope degree of the studied wadies varies from (2.6 to 62) which the low degree indicates a nearly flat area while the high degree shows the highest slope degree determined in the area, (Figs. 12.7, 12.8 and 12.9).

Furthermore, the Aspect determines the direction of the terrain to which it faces, so that affecting the pattern of precipitation, distribution of vegetation and biodiversity in the study area (Khakhlari & Nandy, 2016). 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 wadi Ar Ramlah is mainly dominated by two facing slopes, which are south facing slope and west facing slope. Wadi Darnah is with northeast to southwest facing slope, while wadi Ash- Sharif is southeast to southwest facing slopes (Figs. 12.7, 12.8 and 12.9).

As a result, the direction of the facing slopes in these wadies has low moisture content and high evaporation rate.

The topographical characteristic of the study area is determined by using the relative relief of its catchment area (Singh et al., 2019). Wadi Ar Ramlah has a low relief designated in the southeast side suggests that this area of the basin is flat to gentle slope type, and form the shadow relief map, it is with low structure effect. On the other hand, the relief and shadow relief maps of wadi Darnah and wadi Ash-Sharif show high structure effect with steep slope in the north of the wadi Darnah and in the south of wadi Ash- Sharif (Figs. 12.7, 12.8 and 12.9).

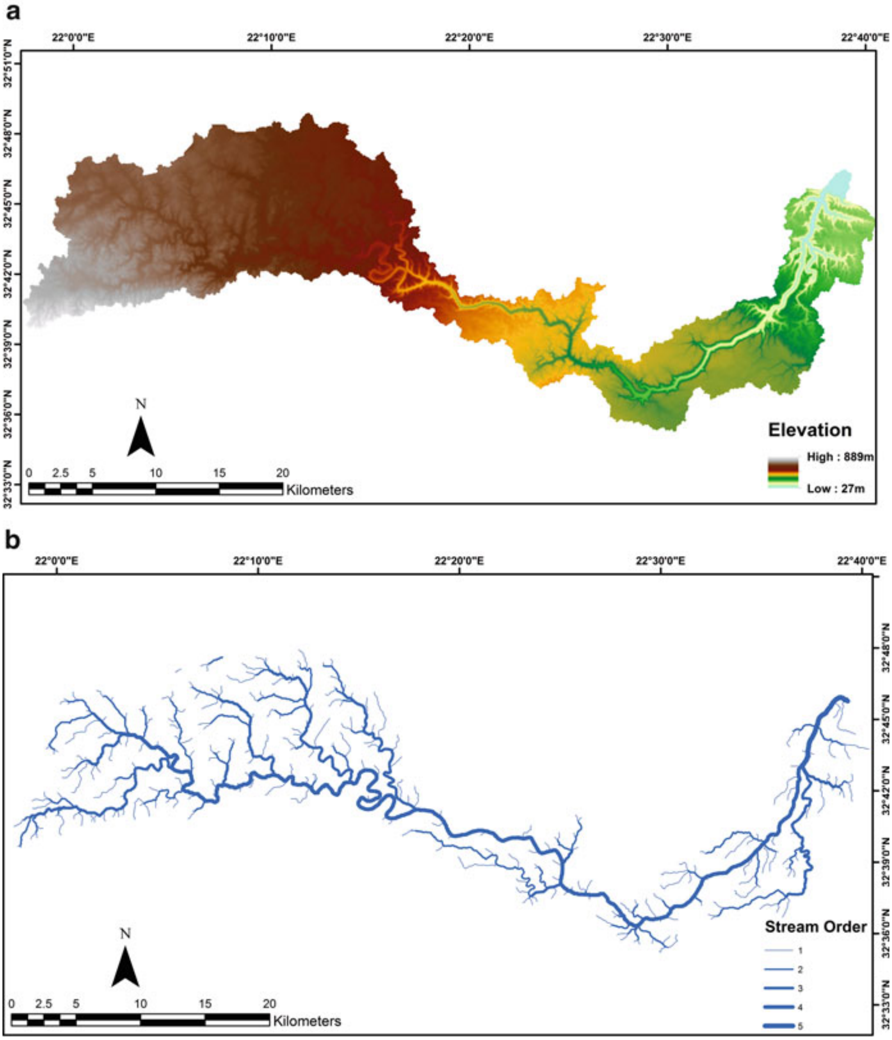


Fig. 12.7 Illustrates different types of geomorphic maps of wadi Darnah; (**a**) Elevation map; (**b**) Stream orders; (**c**) Stream frequency; (**d**) Shadow relief map; (**e**) Slope map; and (**f**) Aspect map

12.8.3 Aerial Morphometric Parameters

12.8.3.1 Drainage Density (Dd)

According to (Bhat et al., 2019) 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

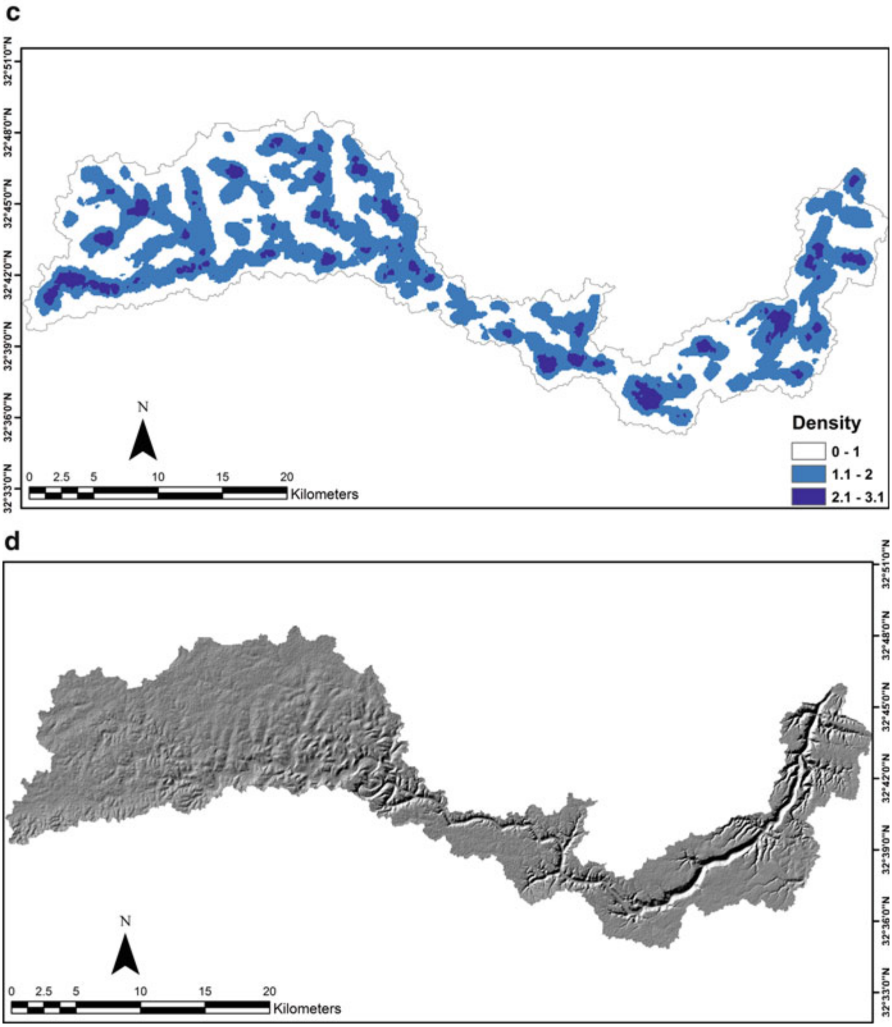


Fig. 12.7 (continued)

cover of the basin, is a Drainage density which also indicates the closeness of spacing of channels. Drainage density is calculated as the total length of streams of all orders per unit area divided by the area of drainage basin (Bhat et al., 2019). Moreover, high and low Drainage density values depend on sub-surface material either impermeable or permeable rocks, vegetation density, relief, surface runoff and infiltration capacity. Wadi Ar Ramlah and wadi Ash- Sharif have high drainage density values which reveal high runoff surface, fine drainage texture with impermeable subsurface, while Wadi Darnah has a low drainage density value with (0.9 km/km^2) indicates low runoff with denser vegetation.

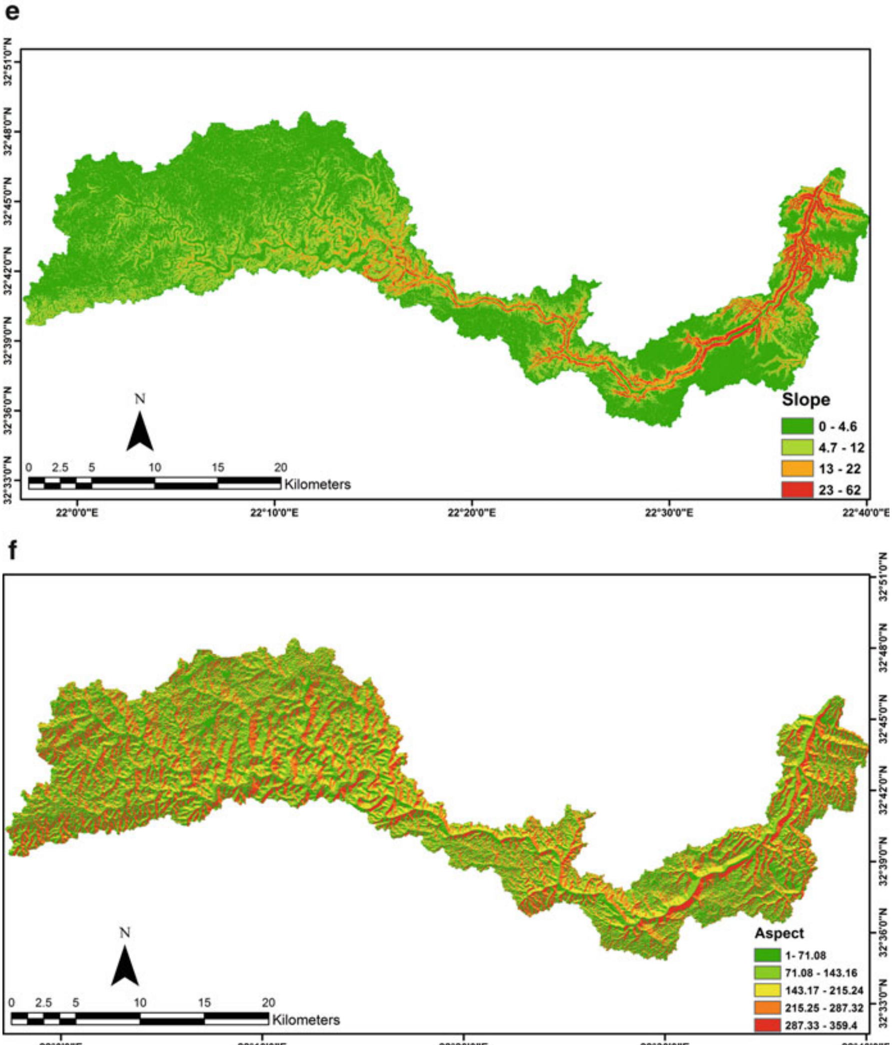


Fig. 12.7 (continued)

12.8.3.2 Texture Ratio (Rt)

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 (Fenta et al., 2017). Drainage texture can be classified into; coarse texture (< 4 / km), intermediate (4 to 10 / km), fine (10–15 / km), and very fine texture (> 15 / km) (Fenta et al., 2017). The drainage texture values of wadi Ar Ramlah and wadi Ash-

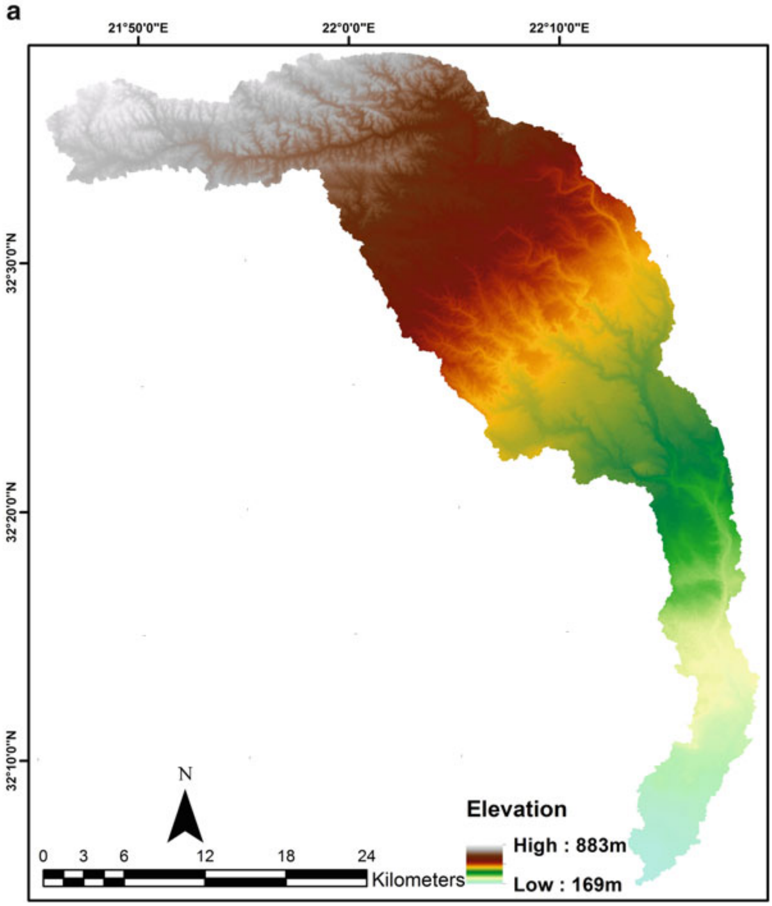


Fig. 12.8 Illustrates different types of geomorphic maps of wadi Ar Ramlah; (**a**) Elevation map; (**b**) Stream orders; (**c**) Stream frequency; (**d**) Shadow relief map; (**e**) Slope map; and (**f**) Aspect map

Sharif are higher than the drainage texture value of wadi Darnah, where higher values indicate impermeable sub-surface material, high relief conditions, and low infiltration capacity with very fine texture. Although wadi Darnah and Wadi Ash-Sharif pass through almost the same type of lithology which is Darnah Formation, but they have different values of drainage texture.

The significant low drainage texture value of wadi Darnah could be related to the diagenetic process of the lithology with highly affecting of joints structure, which display a coarse texture with medium permeable subsurface materials.

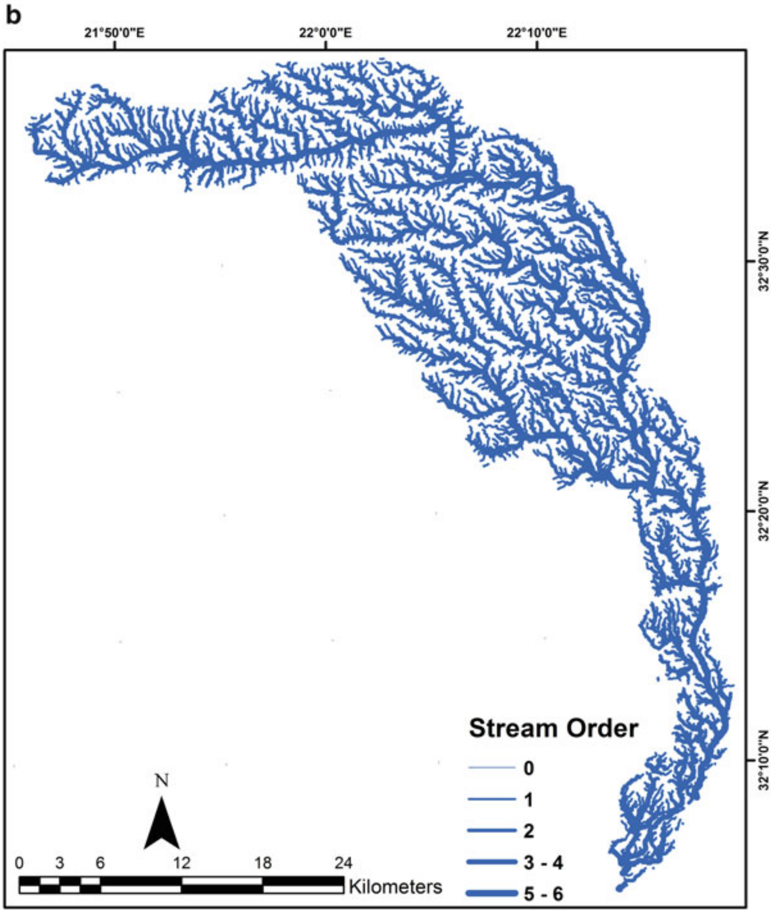


Fig. 12.8 (continued)

12.8.3.3 Stream Frequency (Sf)

The stream frequency was first introduced by Horton (1932), it is expressed as the ratio of the total number of streams in a drainage basin to the area of that basin. The stream frequency depends on the nature of rock and soil permeability of the area and it is used as an index of various stages of landscape development (Biswas, 2016). In the study area, the stream frequency values of wadi Ar Ramlah, wadi Darnah and wadi Ash- Sharif are (7.03, 0.77, 5.04) respectively. The stream frequency of wadi Ramlah and wadi Ash- Sharif are greater than 3 that shows a high run-off on medium-to-high relief of low permeability. The stream frequency value of Wadi Darnah is lower which indicates low runoff.

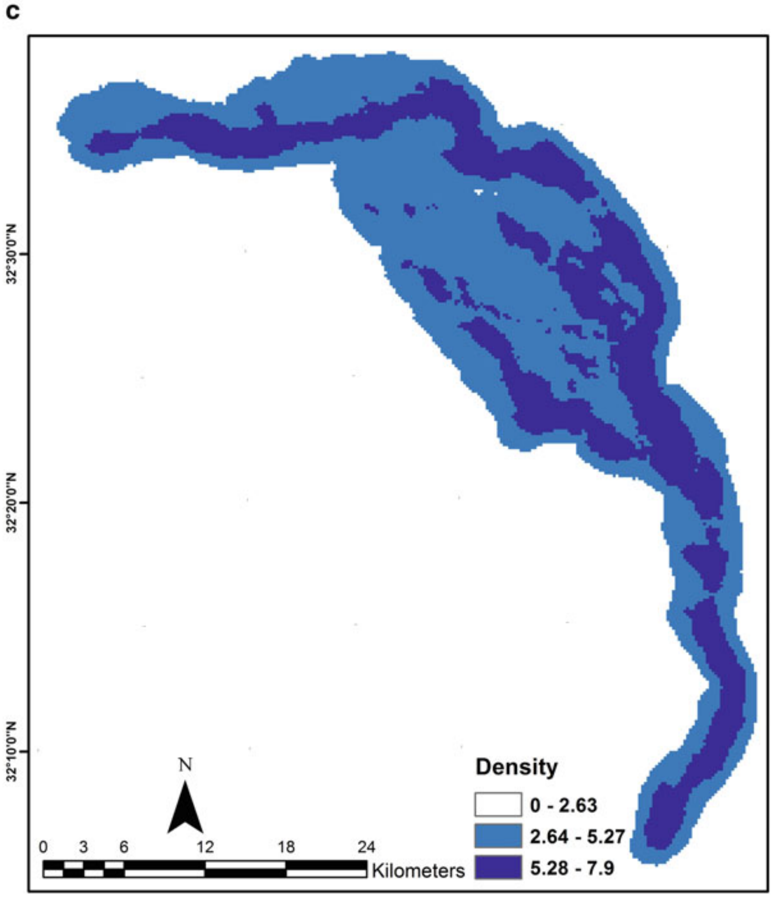


Fig. 12.8 (continued)

12.8.3.4 Infiltration Number (In)

It is a parameter of infiltration capacity of the basin. Lower infiltration numbers indicate higher infiltration and lower run-off (Prabhakaran & Raj, 2018). Measurement of the infiltration number for wadi Ar Ramlah and wadi Ash- Sharif resulted in a high value of (>12.59), indicating that the drainage basin of the both wadies are capable of producing high runoff, while wadi Darnah is with low value (0.69) that indicates on high infiltration with low run off.

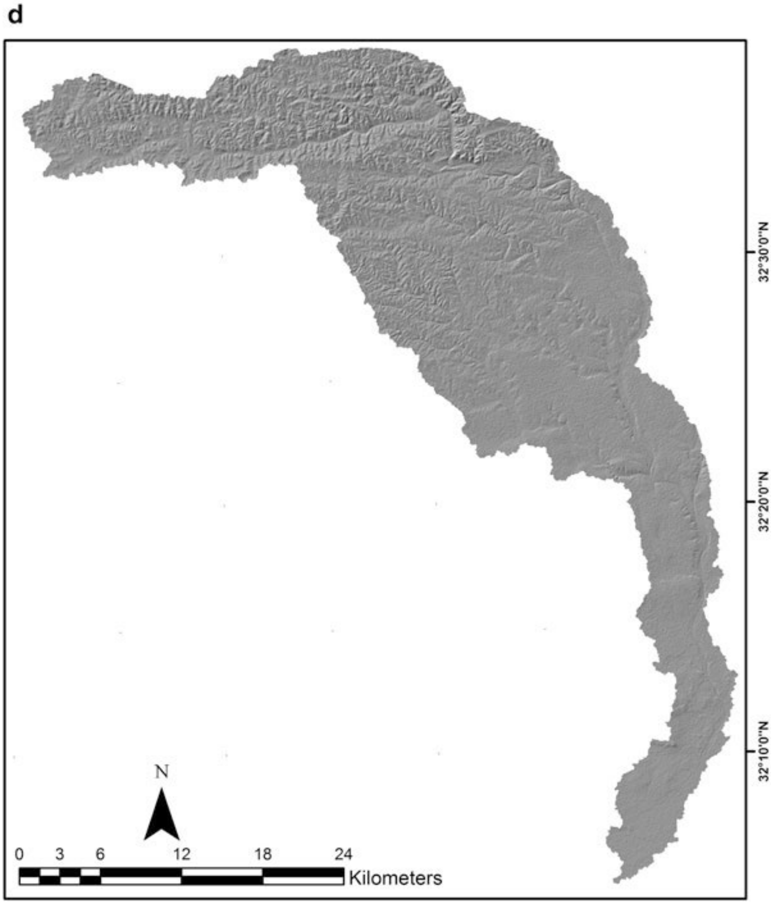


Fig. 12.8 (continued)

12.8.3.5 Form Factor (Rf)

According to (Singh et al., 2019) 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. The values of Form factor in wadi Ar Ramlah and wadi Ash- Sharif are generally low, but they are higher than the value of wadi Darnah. These Form factor values of wadi Ar Ramlah and wadi Ash- Sharif are indicating more elongated nature with higher peak run off of shorter duration than wadi Darnah.

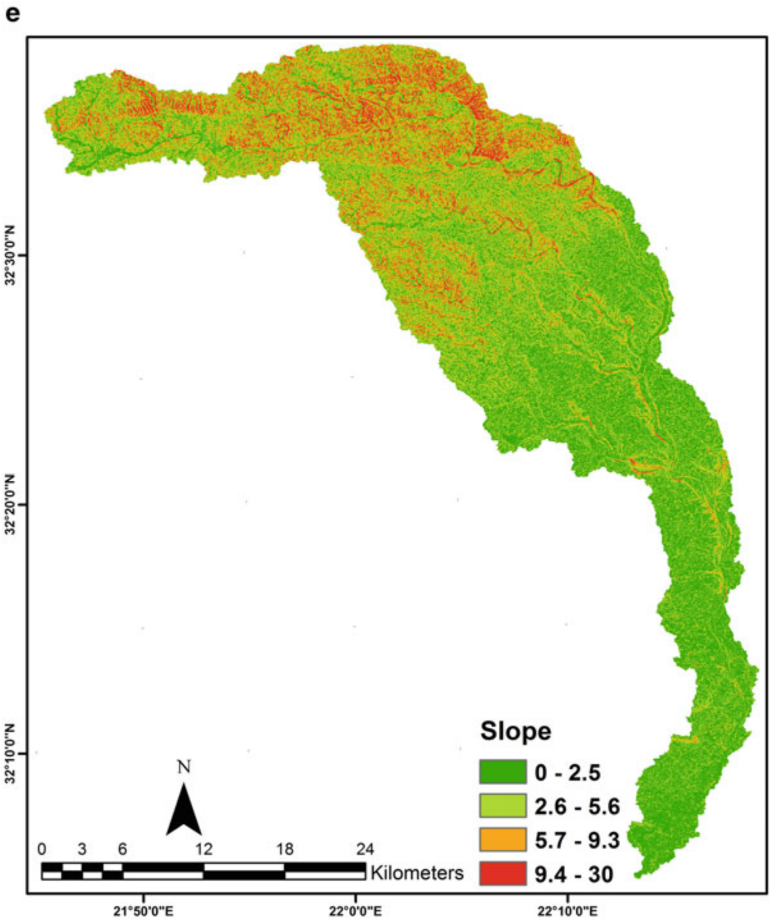


Fig. 12.8 (continued)

12.8.3.6 Elongation Ratio (Re)

The Elongation ratio is a parameter describes the shape of the basin (Schumm, 1956). The lower value of the elongation ratio indicates low infiltration capacity and high run-off conditions and vice versa (Singh et al., 2019). Whereas, the higher value elongation ratio describes a more circular shaped basin and vice-versa (Talampas & Cabahug, 2015). From the calculated elongation values of wadi Ar Ramlah and Wadi Darnah, a value of 0.35 depicts a less elongated basin shape with low relief, while wadi Ash- Sharif is slightly elongated with high relief with a value of 0.51.

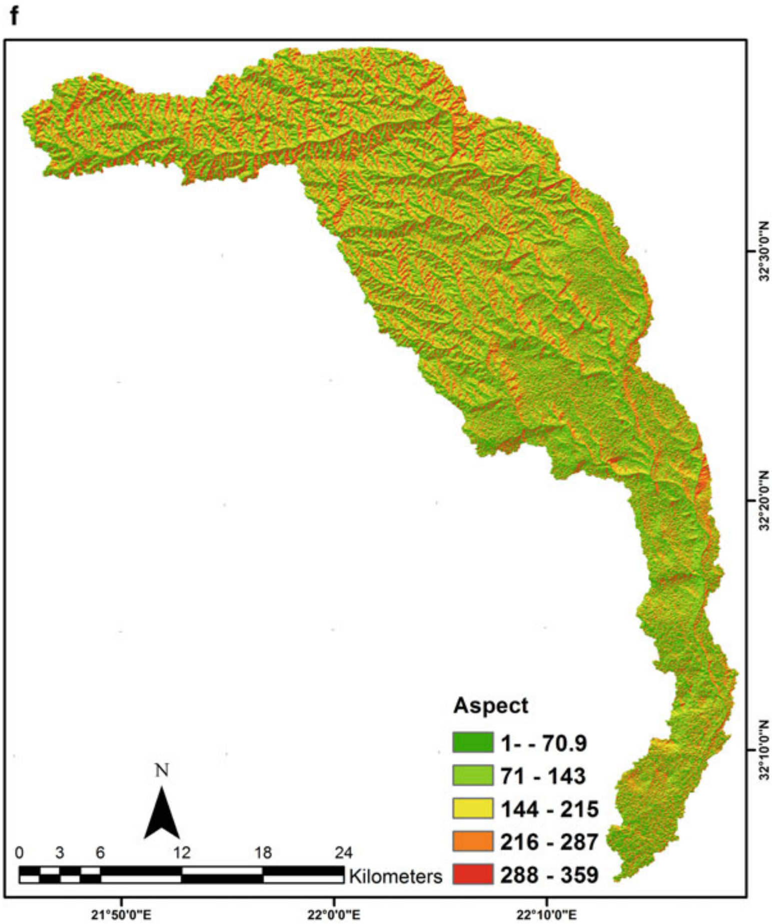


Fig. 12.8 (continued)

12.8.3.7 Circularity Ratio (Rc)

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 (Singh et al., 2019). The higher value of Circularity ratio represents more circularity in the shape of the basin and vice-versa (Talampas & Cabahug, 2015). 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 correspond to low relief (Strahler, 1964; Miller, 1953). In the wadi Ar Ramlah, the circularity ratio is (0.14) and wadi Ash- Sharif is (0.22) indicating impermeable surface resulting in lower peak flow for longer duration. The Wadi Darnah show

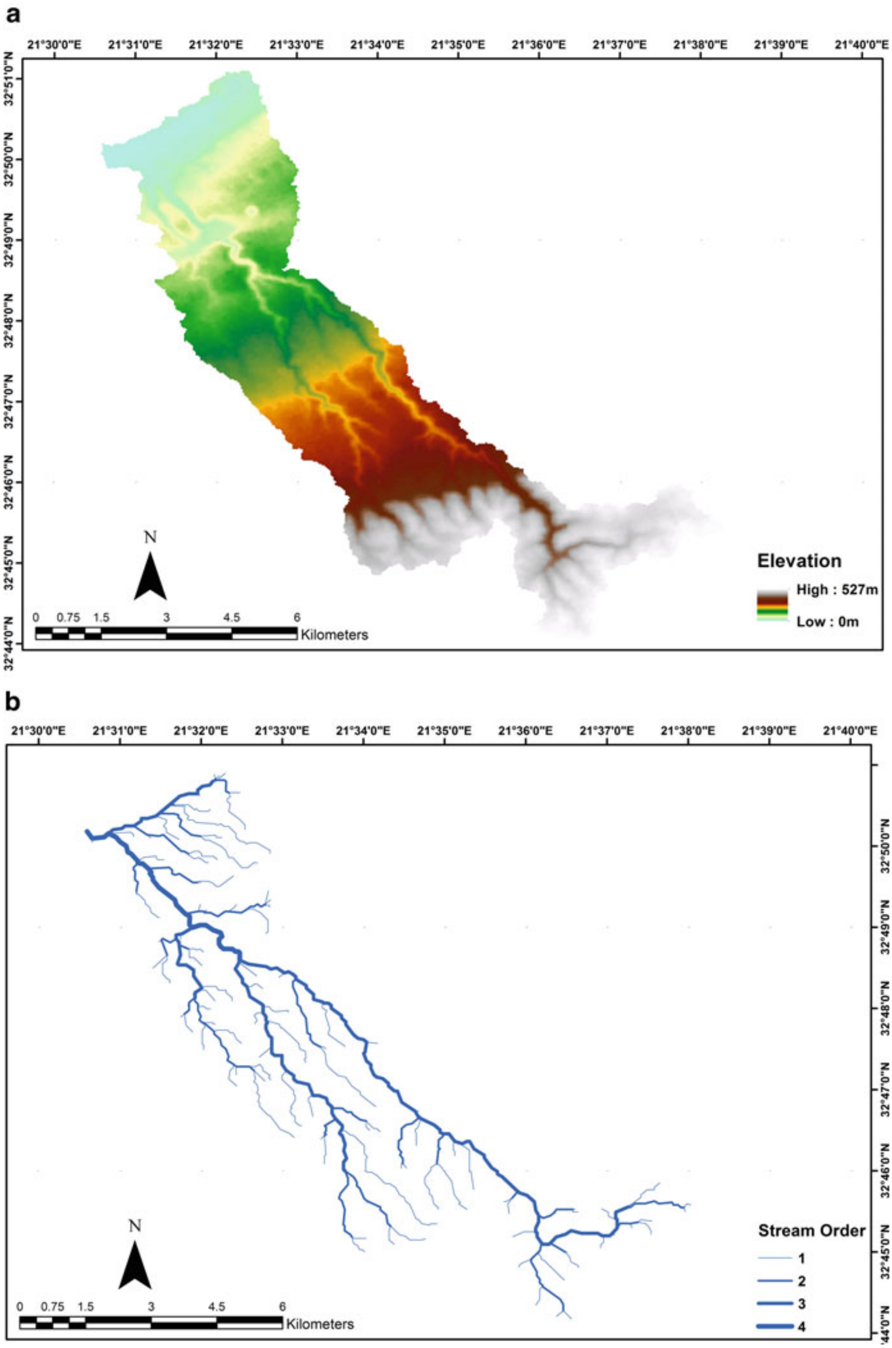
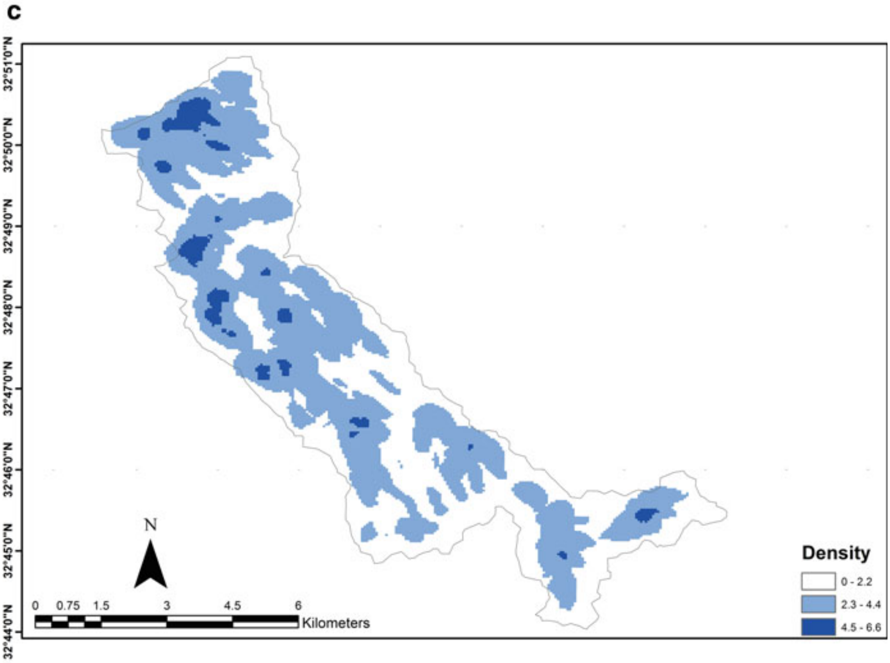


Fig. 12.9 Illustrates different types of geomorphic maps of wadi Ash Sharif; (**a**) Elevation map; (**b**) Stream orders; (**c**) Stream frequency; (**d**) Shadow relief map; (**e**) Slope map; and (**f**) Aspect map



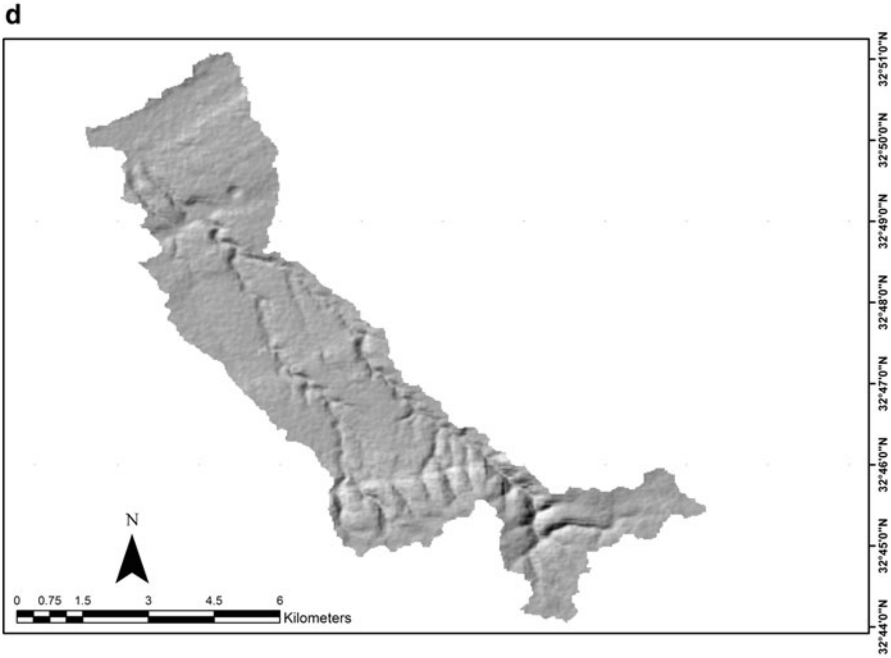


Fig. 12.9 (continued)

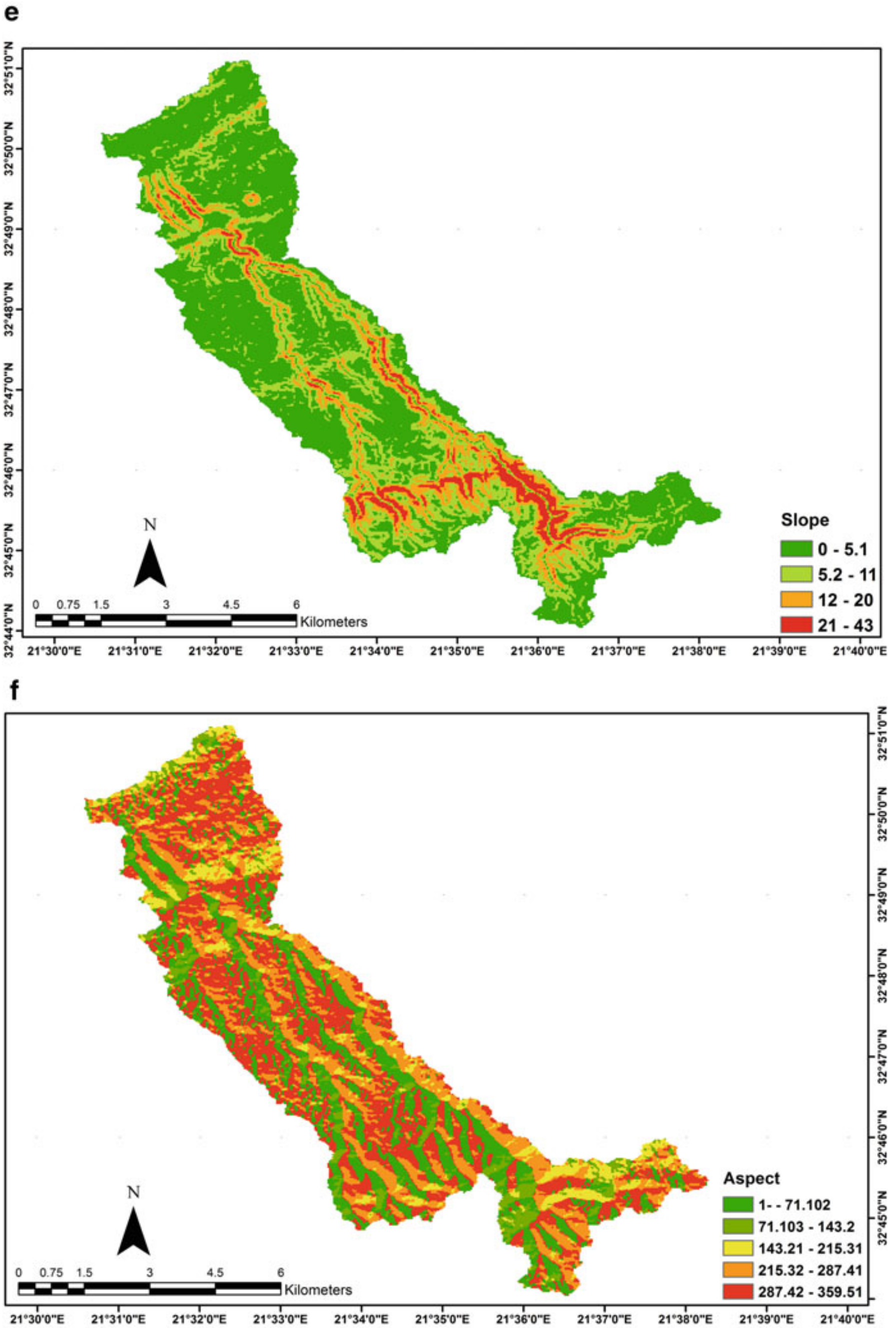


Fig. 12.9 (continued)

more elongated shape with very low value of Circularity ratio (0.089) resulting in higher peak flow for shorter duration.

12.8.3.8 Length of Overland Flow (Lof)

Length of overland flow is a length of water over the ground before it gets concentrated into certain stream channels (Sukristiyanti et al., 2018). The lower value of the length of overland flow parameter represents a well-developed drainage network.

In the study area, the Length of overland value of wadi Ar Ramlah and wadi Ash-Sharif is almost (0.2) showing relatively youthful stage of the drainage development, while wadi Darnah is measured at (0.45) an indication that the drainage basin will have a quicker surface runoff will enter the streams.

12.8.3.9 Constant of Channel Maintenance (ccm)

Constant of channel maintenance (Ccm) is the inverse of drainage density and expressed with dimension of square per unit. Drainage basins having lower values of Constant of channel maintenance will have higher value of drainage density. The most affecting factors of the constant of channel maintenance are rock type, permeability, vegetation, relief and duration of rainfall. The low values (0.38 and 0.39) of constant of channel maintenance of wadies Ar Ramlah and Ash- Sharif indicate low permeability, moderate slope, and high surface run-off. Computed value of Constant of channel maintenance of wadi Darnah is (1.11) would indicate that the drainage basin has a relatively high erodibility, medium permeability, steep slopes and high surface runoff.

12.8.3.10 Bifurcation Ratio

The Table 12.3 illustrates the overall Bifurcation ratios of the various stream orders of the studied wadies. A lower Bifurcation ratios range between 3 and 5 suggests that the structure does not exercise a dominant influence on the drainage pattern, while higher Bifurcation ratio 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 (Dikpal et al., 2017). In general, the flat terrains have Bifurcation ratios 2, whereas mountainous or highly dissected terrains have values greater than 3. The results of Bifurcation ratios of the study wadies are ranging from 1.68 flat terrains with low structure effect in wadi Ar Ramlah, to greater than 3.0 in wadi Darnah and wadi Ash- Sharif that show high dissected terrains with structure control.

Table 12.3 Illustrates the overall Bifurcation ratios of the various stream orders of the study wadies

Rb = Nu/Nu +1, where Nu = Total number of stream segments of order	Bifurcation ratios (Rb) of Wadi Ar Ramlah	Bifurcation ratios (Rb) of wadi Darnah	Bifurcation ratios (Rb) of wadi Ash-Sharif
1st /2nd	2.2	2.25	2.1
2nd/ 3rd	1.8	1.52	1.1
3rd/4th	1.8	1.28	6.4
4th/5th	1.6	10.14	–
5th/6th	1.0	–	–
Mean bifurcation ratios	1.68	3.8	3.2

12.8.4 Relief Morphometric Parameters

The morphometric investigation of the relief parameters of the basin includes Basin Relief (H), Relief Ratio (Rf), Ruggedness Number (Rn) and Dissection Index (DI).

12.8.4.1 Relief Ratio (Rh)

Relief Ratio (Rh) is the difference in the elevation of the highest and lowest points in a watershed. Relief ratio (Rh) of water catchment of the study basins is various, (7.85) for Ar Ramlah catchment area, indicates that the basin is low to moderate relief and slope, whereas Darnah and Ash Sharif water basins are with high values (>11) illustrating that the area have high potential energy for transporting water and sediment downslope due to the steep slope of high relief.

12.8.4.2 The Ruggedness Number (Rn)

The ruggedness number indicates the extent of the instability of land surface (Strahler, 1957). The high value of the ruggedness number shows a rugged topography, highly susceptible to soil erosion and structurally complex. In the case of the study basins, the ruggedness number (Rn) values are considered moderate, which indicates the moderate soil erosion in this area with the slight complexity of structure Table 12.3.

12.8.4.3 Dissection Index (DI)

According to Singh (2000), It is an important morphometric indicator of the nature and magnitude of dissection of terrain or vertical erosion. Dissection index (DI) is expressing the ratio of the maximum relative relief to maximum absolute relief. The

Table 12.4 Summarize relation between results of morphometric parameters and risk flood

MORPHOMETRIC PARAMETERS	SURFACE RUN-OFF			PERMEABILITY			RISK		
	I	II	III	I	II	III	I	II	III
Drainage Density	Low	High	High	High	Low	Low	Low	High	High
Stream Frequency	Low	High	High	Low	Low	Low	Medium	High	High
Texture Ratio	Low	High	High	High	Low	Low	Low	High	High
Form Factor	Low	High	High	High	Low	Low	Low	High	High
Circularity Ratio	Low	High	High	High	Low	Low	Low	High	High
Elongation Ratio	Low	High	High	High	Low	Low	Low	High	High
Length of Overland Flow	High	Low	Low	Low	High	High	High	Low	Low
Infiltration Number	Low	High	High	High	Low	Low	Low	High	High
Constant Channel Maintenance	High	High	High	Medium	Low	Low	High	High	High

| Wadi Darnah
|| Wadi Ar Ramlah
||| Wadi Ash-Sharif

High
Medium
Low

Dissection index value is between zero, which indicates on complete absence of dissection or vertical erosion, to one that reveals vertical cliff. Generally, the areas with high DI indicate high relative relief where slope of the land is steep and unstable that results in enhanced erosion. On the contrary, low DI corresponds with low relative relief, and with the subdued relief or old stage where the land is flat and more stable (Mustak, 2012). The Dissection index of Wadi Ash Sharif is (1) and wadi Darnah is (0.97) which indicate the basin is a highly dissected, whereas the Ar Ramlah is (0.8) which indicates the basin is a moderately/highly dissected.

However, the parameter values that extracted by using GIS applications have a great role in understanding the relationship between the drainage morphometric and risk of flash flood as shown in Table 12.4.

12.9 Conclusion

Remote sensing and GIS techniques had shown a great help in risk assessment of earthquake in Cyrenaica region. By comparing the linear features inferred from models of digital elevations and local faults in the study region; it is found that there is a great agreement between both of them in terms of focus and spread. It was also found that the first zone is the most concentrated zone by faults, and it is the most affected by earthquakes occurrence. However, the area with high intensity of faults is considered to be the region most affected by earthquakes, and vice versa. Furthermore, the GIS techniques have a great support in drainage characterization of runoff with systematically analysis the morphometric parameters in understanding the relationship between the drainage morphometric and risk of flash flood. The studied wadies show similarities in some results of their morphometric analysis and dissimilarity in others. Generally, it can easily say that most wadies in the Jabal Al Akhdar area have a potential to produce either high peak flows in short duration, or low peak flows in longer duration depending on different geomorphic parameters. However, the most effective geomorphic parameters that make most wadies in Jabal Al Akhdar area flooded are; the relief topography and slopes, where other parameters are considered. The most vulnerable areas that are expected to be flooded are those in low-lying lands.

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