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The possible impact of the prevailing physiographic features of selected catchments upon their hydrological characteristics, Egypt (Comparative study).

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ABSTRACT

Physiographic features of the drainage basin are important controlling factors on the hydrologic response behavior and widely used in hydrologic studies and catchment modeling.Flash flood is an indicator and final result which depends on the physiographic features. Accordingly ten different catchments areas were chosen in Egypt to cover different climatic, topographic and geomorphologic conditions. These catchments are Wadi Al Ramla and WadiMadwar represent for north western coastal (Mediterranean Sea Coast), Wadi Al Assuity and WadiAbadi represent the western side of the eastern Desert (Nile River), Wadi Al Hawashyia and WadiDara represent the eastern side of the eastern Desert (Red Sea Coast), Wadi Al Arish represent Sinai Peninsula (Mediterranean Sea) WadiWatier represent Sinai Peninsula (Gulf of Aqbah) - while both WadiSudr and Sidri represent Sinai Peninsula (Gulf of Suez). Northwestern coastal zone area characterized by low to mild topography and semi-arid climate, Eastern Desert characterized by mild to high topography and hyper-arid climate, while the Sinai Peninsula characterized by high topography and arid to semi-arid region. Forty morphometric parameters and their interrelationships were measured in the present study depending on ASTER data of digital elevation model (DEM) with 30 m resolution, topographic maps (1:50,000), geologic maps (1:250,000). Some of these parameters are applicable to arid and semiarid regions while others not. Flash flood hazards were analyzed based on nine morphometric parameters which have an effect on hydrologic behavior of the study basins. These parameters have a direct influence on flooding prone area, by influence on time of concentration. The flash flood hazard of study basins were identified and classified into three groups (High, medium and low hazard degree). The present work proved that the physiographic features contribute to the possibility a flash flood will occur in any particular drainage area. This study aimed to investigate the possible impact of the prevailing physiographic features of selected catchments upon their hydrological response using basin morphometric parameters. Moreover, it provides details on the flash flood prone area depending on the physiographic features and the mitigation measures. This study also helps to plan rainwater harvesting and watershed management in the flash flood alert zones especially in un-gauged basins.

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INTRODUCTION

Physiography (also known as land surface characteristics) is the study of the physical features and attributes of the Earth's land surface (Sathymoorthy*et al.*, 2007). The detection of the physiographic features of a terrain is the first phase involved in the classification of the various landforms of the terrain (Sathymoorthy*et al.*, 2007). Lane and Lei (1950) and (Dingman, 1978) reported that the hydrographic basins generally are unknown except in basins with a highly permeable surface, the distribution of high flows is largely governed by climate, the physiography and the land-use of the basin. The shape of the hydrograph at the high end can indicate the storage capacity in the catchment, resistance and dynamics of reservoirs (surface storage in lakes and wetlands, and groundwater storage in aquifers) and the physiographic characteristics of the basin such as slopes and drainage distribution patterns. Moreover, they have been used in various studies of climate, geology, geomorphology and surface water hydrology such as rainfall - runoff relationships, hydrograph properties, soil erosion, sediment yield and behavior of basin hydrologic characteristics (Jolly, 1982; Ogunkoya*et al.*, 1984; Aryadike and Phil-

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Eze, 1989). Nevertheless, they havebeenlong believed to be the important controlling factors of surface water runoff (Horton, 1945; Strahler, 1957, 1958 & 1964).

Many studies have been focused on the study of the impact of the physiographic features of the catchment for modeling parameters (Bloschl, 2005). Topography is provided by means of DEM, data processing to create the drainage system of basin is well known but in development (Tarboton, 1997). The integration of GIS to create flood hazard maps and disaster decision support has been continually upgraded and widespread since beginning of this century (Zerger and Smith, 2003; Sui and Maggio, 1999, Merzi and Aktas, 2000; Guzzetti, and Tonelli, 2004; Sanyal and Lu, 2006; He *et al*., 2003; Fernadez and Lutz, 2010).

The application of geomorphological principles to flood potential or flood risk has drawn the attention of researches, attempting to identify the relationships between basin morphometric and flooding impact (Patton, 1988). Identification of drainage networks within basins can be achieved using traditional methods such as field observations and topographic maps, or alternatively with advanced methods using remote sensing and Digital Elevation Model (Macka, 2001; Maidment, 2002). Therefore, they have proposed to use a set of parameters that based on relationships between physiographic features and hydrologic response of watersheds, and regionalizing response characteristics as constraints on these sets model predictions (McIntyre *et al*., 2005; Wagener and Wheater, 2006).

Hydrographic basins in arid regions are commonly subjected to sporadic storm events that usually vary in scarcity and extremely high temporal and spatial variation. Most important herein is flash flood hazard evaluation of the ungauged arid basins through the integration between physiographic features of the study basins and GIS techniques depending on, field observations, Digital Elevation Model (ASTER 30 resolution), topographic maps (1:50,000) and geologic maps (1: 250,000).

Location And Hydrogeology Aspects Of The Study Basins:

The study selected 10 basins representing the three major different regions of Egypt. They differ in climatic, topographic and geomorphologic conditions. These catchments are Wadi Al Ramla and WadiMadwar represent for north western coastal zone (Mediterranean Sea Coast), Wadi Al Assuity and WadiAbadi represent the western side of the eastern Desert (Nile River), Wadi Al Hawashyia and WadiDara represent the eastern side of the eastern Desert (Red Sea Coast), Wadi Al Arish represent Sinai Peninsula (Mediterranean Sea),WadiWatier represent Sinai Peninsula (Gulf of Aqbah) while both WadiSudr and Sidri represent Sinai Peninsula (Gulf of Suez) as shown in Fig. 1.

Wadi Al Ramla and WadiMadwar are located in the middle part of the North Western Coast of Egypt which stretches along about 500 km on the Mediterranean Sea, west of Alexandria city. Northwestern coastal zone is characterized by homogeneous semi-arid climate conditions. In general, it is characterized by a temperate Mediterranean climate; it ranges from a moderate coastal climate in the north to an arid-semiarid Desert climate in the south. The maximum annual rainfall depth is 276.8 mm, while the minimum annual rainfall depth is 36.6 mm with an average value is 139.2 mm (Zaki, 2000). Geologically, it is characterized by the presence of Tertiary (Middle Miocene and Pliocene) to Quaternary as shown in Fig.2. Middle Miocene is represented by Marmarica Formation of shallow marine limestone, which covers an area about 36 % and 23 % of Wadi Al Ramla and WadiMadwar respectively; Pliocene covers an area nearly about 39 % in both Al Ramla and MadwarWadis, and is represented by marine limestone, while the Quaternary covers an area about 25 % and 28 % of Wadi Al Ramla and WadiMadwar respectively and is composed of gravels, marlyOolitic limestone and wadi deposits.

Wadi Al Assuity,WadiAbadi, Wadi Al Hawashyia and WadiDara are located in the Eastern Desert of Egypt. *Wadi Al Assuity and WadiAbadi* are located in the western side of the Eastern Desert and drain their surface runoff toward the Nile River. *Wadi Al Hawashyia* and *WadiDara* are located in the eastern side of the Eastern Desert and drain their surface runoff towards the Red sea. Generally the eastern Desert is characterized by an arid to hyper-arid climate, with long hot summer, short cold winter and scarce rainfall with rate of less than 50 mm per year. Large variations between maximum and minimum air temperatures, very high potential evaporation and medium to low relative humidity are further characteristics. Geologically, *Wadi Al Assuity*,is characterized by outcropping of Quaternary deposits of gravels, sand and sandstone (16 %), Middle Eocene of whit to grey, lagoonal to marine limestone (21.5%) and Lower Eocene of dense, thick and bedded limestone (62.5 %). While, *WadiAbadi* is covered with 10 % of Quaternary deposits (Gravels, sand and sandstone), 64 % of Cretaceous deposits of shale, chalk and Nubian sandstone, it is covered also with an area about 26 % of Basement rocks. *Wadi Al Hawashyia* basin is located in the sedimentary basin called West Bakr, based on the Egyptian general petroleum company (EGPC, 1987 and Conoco, 1989) the Basement outcrops in El Hawashyia basin cover 51 % of the area, Cretaceous outcrop rocks 24 % while the Quaternary deposits (Post-Miocene) are represented by 20 % of the exposed rocks in the whole area as shown in Fig. 2. *WadiDara* basin is covered by out crops of Basement rocks (27 %), Cretaceous rocks (5%), Miocene rocks (10 %), Pliocene (5 %) and Quaternary deposits (53 %).

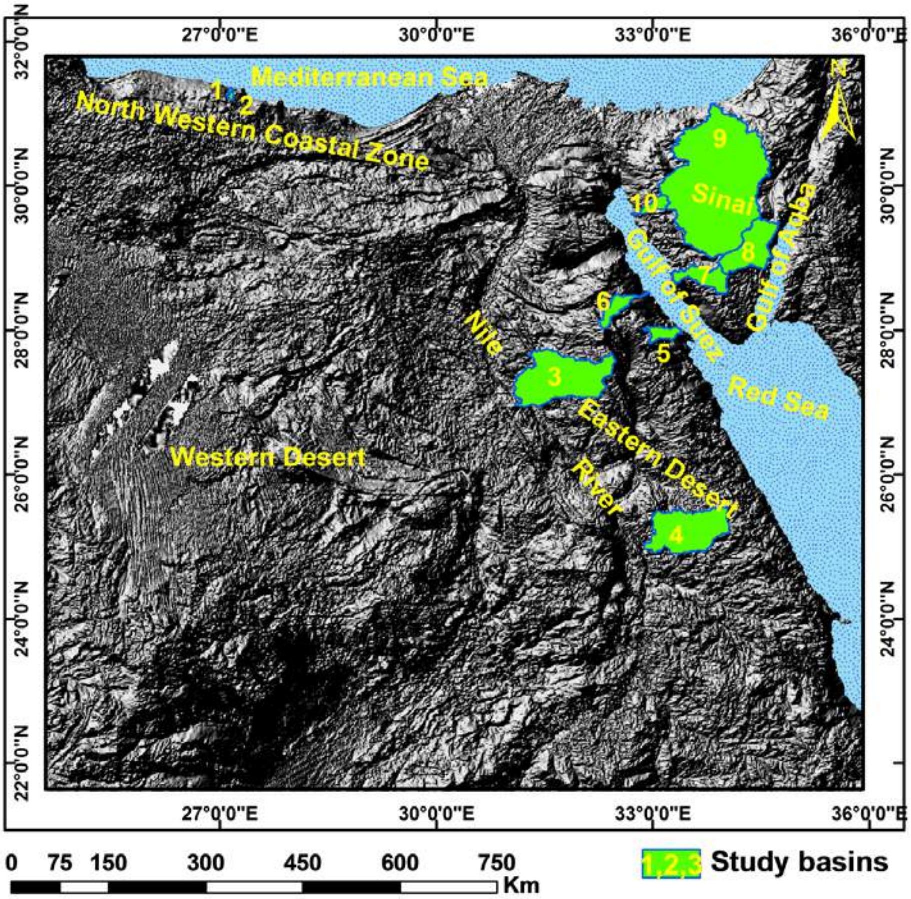

Fig. 1: Location map of the study areas

Wadi Al Arish, WadiWatier, WadiSudr and Sidri are located in Sinai Peninsula, which is characterized by arid to semi-arid climatic conditions. The average rainfall varies from 60 mm to 100 mm per year near Mediterranean Sea and decreases towards the West. The range of average annual rainfall in the southern heights is between 30 mm and 60 mm. Sinai has the most geological succession from pre-Cambrian (Basement) till the Quaternary deposits. *Wadi Al Arish's* surfaceis covered by outcrops from Jurassic (0.6 %) in the north western area to Quaternary deposits of sand dune, gravels and alluvial deposits (38 %). The Cretaceous deposits covers about 29 % of the area, Eocene deposits is occupied an area about 26 % while Pliocene deposits reaches to 6 %. *WadiWatier* is covered by Basement (12 %), Cretaceous (79 %) and Quaternary deposits (9 %). While, *WadiSidri* is covered by Basement (72 %), Cretaceous (6 %), Eocene (3 %), Miocene (6 %) and Quaternary deposits (11 %). The pre-Cambrian rocks (Basement) are associated with Paleozoic-Carboniferous dolomitic limestone deposits (2%) especially in WadiWatier and Sidri. Geology of *WadiSudr* is characterized by presence of Cretaceous rocks (63 %), Eocene (9 %), Miocene (17 %), Pliocene (3 %) and Quaternary deposits (8 %).

Geomorphology of Study Basins:

The northwestern Mediterranean coastal zone extends between Alexandria and Sallum, occupies the northern extremity of the great MarmaricanHomoclinal plateau which extends to the north of the Qattara Depression (Shata, 1957). The surface of this plateau rises about 250 m above sea level and slopes gently to the northward direction, i.e. towards the Mediterranean Sea. This zone displays geomorphological features, which reflect the effect of both arid and wet climatic conditions. The present day landforms reflect the combined influence of several endogenetic and exogenetic processes, e.g. geologic structures lithological features, climatic conditions, pale-geographic elements. These landforms (tableland, ridges, depressions, dunes, drainage lines and near – shore lakes) influence the ground water conditions. Such landforms control the spreading of the surface runoff which either accumulates in the depressions or drains into the sea or the near-shore lakes as shown in Fig. 3.

Geomorphologically, Wadi Al Assuity is characterized by high elevation topography ranges from 48 m at downstream area to 874 m in the water-divide area and upstream portion and slopes generally to the Nile River. It can be divided to four main units: high land areas (Tableland); alluvial plain; piedmont plain and hydrographic network. The first is bounded the eastern parts of Wadi Al Assuity and composed of hard limestone rocks of Eocene age, while the second, which belongs to Quaternary deposits, is extended in the downstream portions of the basin and the delta of the Wadi. Piedmont plain occupies the foot slope of the limestone tableland and composed of cobbles, boulders, gravels, sand and clay. Hydrographic network (streams) is dissected the tableland and drain their surface runoff into Nile river as shown in Fig. 3 a. On the other hand, WadiAbadi is characterized by wide elevation of land surface ranges from 787 m at the upstream where the basement outcrops to 72 m at the downstream, and generally slopes towards the west as shown in the Digital Elevation model (Fig. 3 b). It can be divided into three main morphologic units namely; the Red Sea crystalline mountains, the southern sandstone plateau of Nubia sandstone, and the narrow coastal plain of downstream as shown in Fig. 3 b.

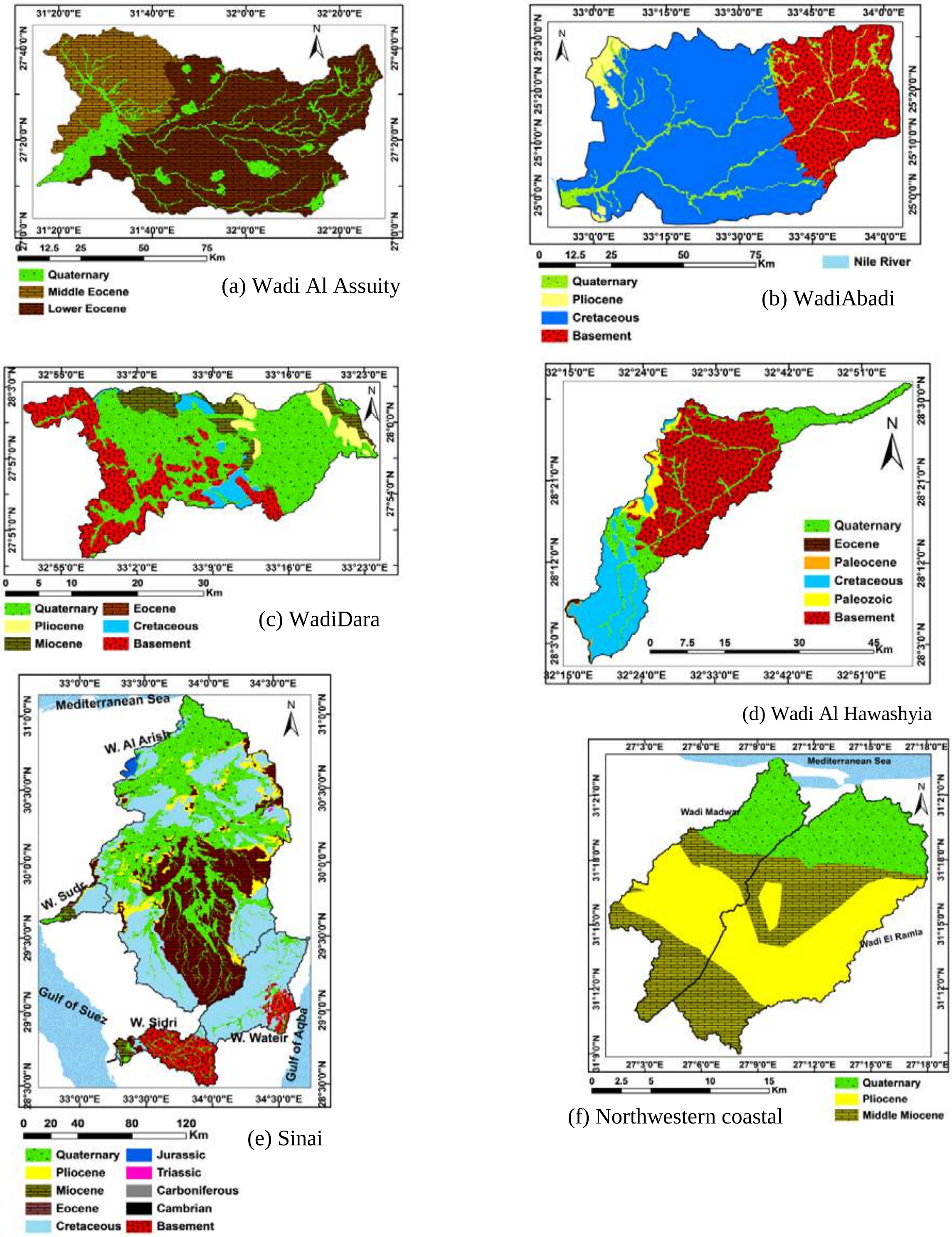

Fig. 2: Geological maps of the study basins

Wadi Al Arish is one of the largest hydrographic basins in Sinai. It is narrow in its upper reaches through cutting across the El Tih Plateau and becomes wider towards the central portions and downstream area. Wadi Al Arish can divide into three sections (upper, central and lower or coastal). The upper section is extending from the water divide in the upper stream toward the north about 82 km with relief about 1100 m with gradient around 0.013. The central sector is extending about 100 km with general relief about 400 m with gradient about 0.004, while the lower (coastal) section extending 50 km with relief of 195 m, resulting gradient about 0.004.

WadiWatier is characterized by mountainous hard rock landscape of Basement and limestone. Its elevation ranges from 14 m at coastal area to 1620 at upstream portions with mean elevation about 911 m and altitude of 847 m (table. 2).WadiSudr is characterized by three geomorphological units (Structural Plateau, elevated plain and Oolitic sand dunes). The Structural Plateau is represented in the western horn of El-Tih plateau which covers a wide area land stretch about 20 km in width. Its surface is barren and underline by compacted Palaeogene and Miocene limestone. The Elevated Plain is located between the foot of the scarp and the Oolitic sand dunes on the shoreline of the Gulf of Suez. It is include pediment plain, playa deposits and lagoonal depressions. The Oolitic Sand Dunes are elongated dunes running almost parallel to the shore line of the Gulf of Suez. These dunes are composed essentially of white calcareous Oolitic materials varying from loose to slightly cemented limestone. The relief of Wadi surd is 861 m with mean elevation about 422 m and altitude of 408 m (table 2).

WadiSidri is high elevated basin of the study area which the elevation ranges from 6 m to 2600 m, with mean elevation about 1018 m and altitude of 1004 m. It can be divided into three main morphological parts oriented NW-SE. These are, from east to west, the rift shoulder where Precambrian basement is exposed, the central subarea where highly faulted pre-rift sedimentary rocks are exposed, and the western part where slightly faulted syn-rift (Miocene) rocks are exposed (Fig. 3).

Morphometric Characteristics of Study Basins:

Tracing of the drainage network using digital elevation model (DEM) with 30 m resolution and topographic maps (scale 1:50,000) is the sole way to study of the morphometric analysis. Depending on Strahler 1957, the streams are ordered and the different parameters are measured and calculated according to Horton (1932, 1945) as shown in Tables 1 and 2. All the study basins are morphometrically evaluated to determine the possible impact of the prevailing physiographic features of selected catchments upon their hydrological characteristics and hazard degree.

Drainage network characteristics:

Stream order:

Stream ordering is the basic parameter of quantitative analysis of the drainage (Pareta, 2012). The stream ordering systems has first reported by Horton (1945), but Strahler (1952), has proposed this ordering system with some modifications. Stream order of the study basins has been done based on the method proposed by Strahler, Table 2 and Fig 4. The stream order of the study basins ranges from 6 to 8 as shown in Table 2. It has observed that the maximum frequency is in the case of first order streams. It has also noticed that there is a decrease in stream frequency as the stream order increases (Pareta, 2012).

Stream number:

The total of order is the outcome of stream segments which is known as stream number. (Horton,1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number (Pareta, 2012) as shown in Table 2.

Stream length:

The total stream lengths of the study basins have various orders, which have computed with the help of topographical sheets and ArcGIS software (Pareta, 2012). Horton's law of stream lengths supports the theory that geometrical similarity is conserved in watershed of increasing order (Strahler, 1964). Stream length has been computed based on the law reported by Horton (1945). The total stream length of the study basins ranges from 357.5 km of WadiMadwar to 20684.2 km of Wadi Al Arish. All the selected basins revealed a directly proportional linear relation relationship between the stream lengths and number of the streams, basin area, basin perimeter, and length of the basin as shown in Table 2 and Fig. 4. Hence, the stream length is an indicator of the relation between the climate, vegetation, and the resistance rock and soil to erosion. Under similar climatic conditions, impervious rocks exhibit a longer stream length.

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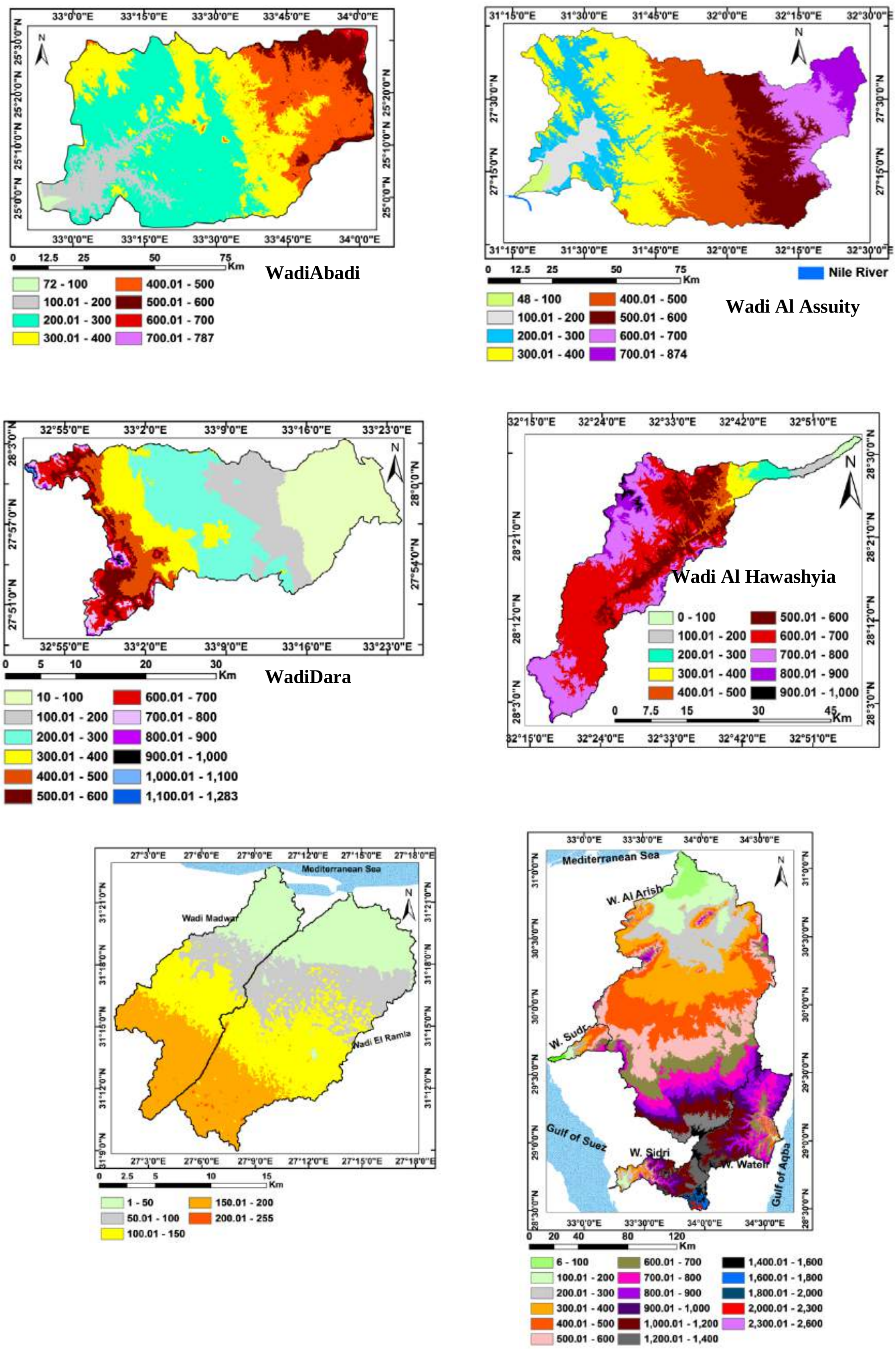


Fig. 3: Digital Elevation Model (DEM) of the study basins

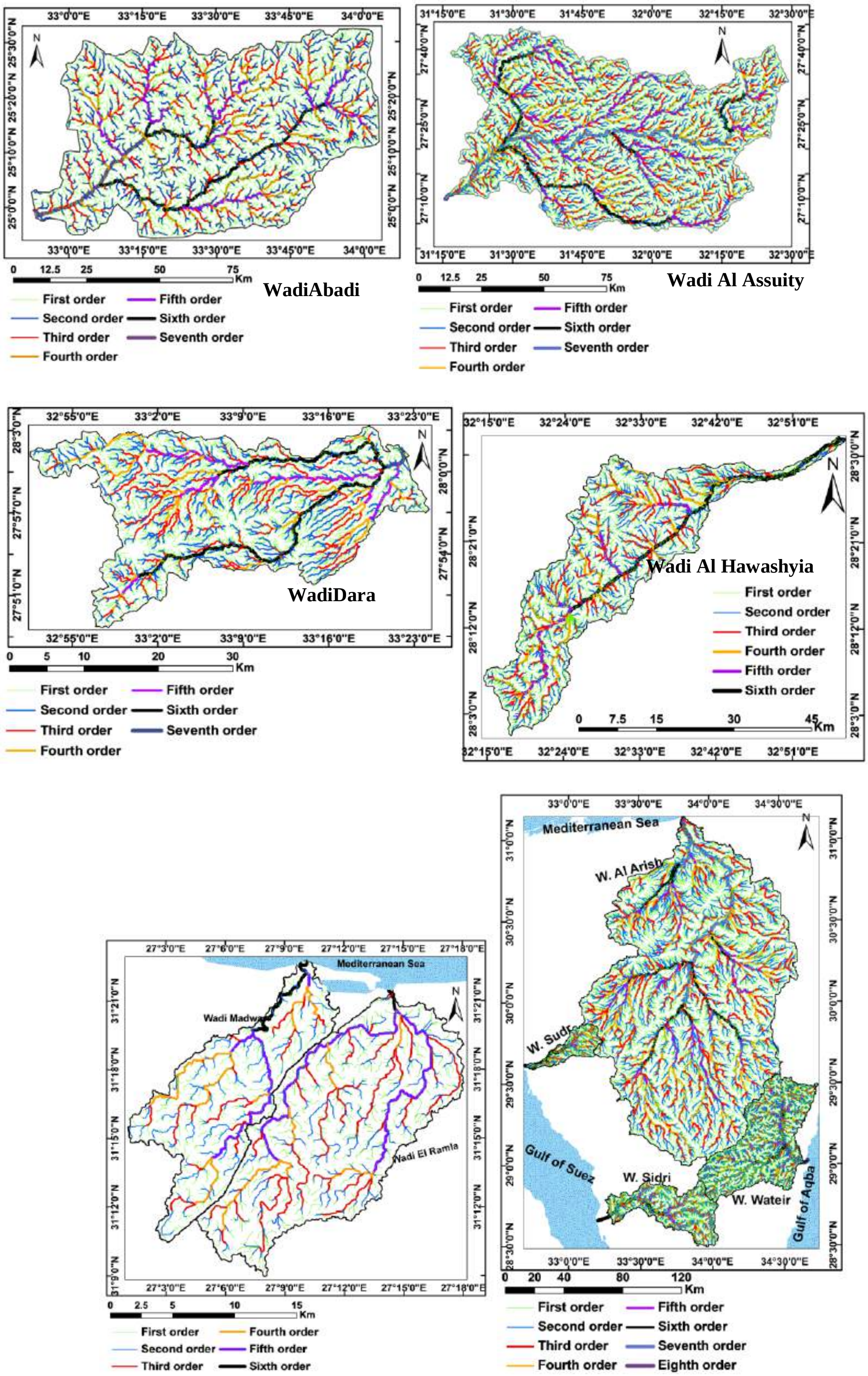
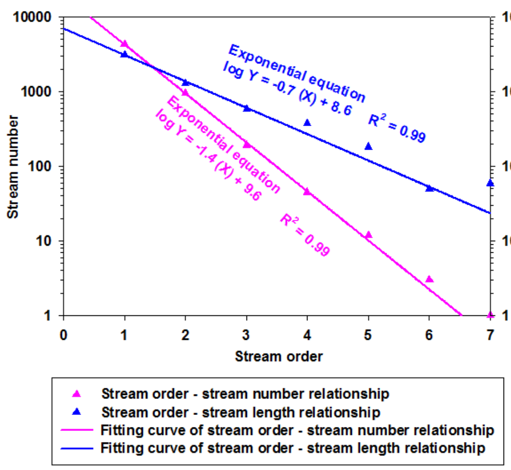


Fig. 4: Stream order maps of the study basins

When the logarithm of the stream number is plotted against the stream order, most drainage networks show a linear relationship (Fig. 5), with only a small deviation from a straight line (Chow, 1964). According to Horton's principle the number of streams is negatively correlated with the order (Horton, 1932). The study basins show a nearly perfect negative correlation with coefficient of correlation about 0.99 as shown in Fig. It is noticed that there is a difference in the geometric relationship between the stream length and its order for the basins of arid and semi-arid regions than for those of the humid regions. This latter geometric relationship between the stream length and the stream order is positive linear relationship as reported, (Schmidt, 1984; UNESCO/WHO/UNEP 1992 and White *et al.*, 2004). While a negative correlation as in this case of study basins (inverse relationship) are observed for other arid and semi-arid regions as also reported in India (Sreedevi*et al.*, 2005).



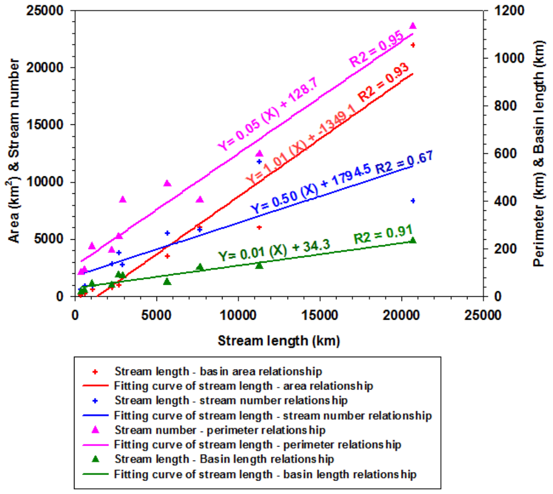


Fig. 5: Stream order, number and length relationship **Fig. 6:**Stream length, order, basin area, perimeter and basin length relationship

Hence, the stream length is an indicator of the relation between the climate, vegetation, and the resistance rock and soil to erosion. Under similar conditions, impervious rocks support a longer stream length, consequently higher drainage densities are observed than for permeable rocks. Arid and semi-arid regions show higher drainage densities than humid regions having the same geology, because of the flash flood and scarce vegetation in the former case. From Figs. 6 and 7, it is noticed that there is a proportional linear relationship between the areas and both stream number and the corresponding stream length for all the study basins.

Bifurcation ratio (Rb) and Weighted mean bifurcation ratio (WMR):

Horton (1945) considered the bifurcation ratio as index of relief and dissertation (Pareta, 2011). Strahler, (1957) reported that the bifurcation ratios show a small range of variation for different regions or for different environment except where the powerful geological control dominates (Radhakrishnan*et al.*, 2011). It is observed from the Rb is not same from one order to its next order these irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler 1964). The bifurcation ratio is dimensionless property and generally ranges from 3.0 to 5.0. According to Nag 1998, the lower values of Rb are characteristics of the watersheds, which have suffered less structural disturbances (Strahler 1964) and the drainage pattern has not been distorted because of the structural disturbances (Pareta, 2011). In the study basins, the higher values of Rb indicates strong structural control on the drainage pattern as shown in Wadi Al Hawashyia, Sidri, Al Assuity and Abadi (Table 2), while the lower values indicative of basins that are not affect by structural disturbances as shown in Wadi Al Arish, Madwar and Wadi Al Ramla (Table 2). This variation may be attributed to the rock type where the study basins have a variety in the geological outcrops as shown in Fig. 2. The weighted mean bifurcation ratios (WMRb) have values greater than 3; this reflects high mountainous dissected areas and elongated basins as shown in Table 2.

Main channel Length:

It is the length along the longest watercourse from the outflow point of designated basin to the upper limit to the watershed boundary (Pareta, 2011). The main channel length has computed by using ArcGIS-10 software, it is ranges from 2 km of Wadi Al Ramla to 151.8 km of Wadi Al Assuity. The wide variations between the main channel lengths of the study basins are due to the variation of the geological features of the study basins

Main channel index (Ci):

It is suggested by Mueller (1968) it is an index of sinuosity characteristic which measures the deviation of the main channel from its geometric path.

Sinuosity (Si):

According to Gregory and Walling(1973), it deals with the pattern of channel of a drainage basin (Pareta, 2011).The sinuosity of the study basins ranges from nearly 0.1 of Wadi Al Ramla, WadiDara and Wadi Al Arish to 1.2 of Wadi Al Assuity as shown in Table 2. This reflects that Wadi Al Ramla, WadiDara and Wadi Al Arish has the shortest travel time of water flow to the outlet, while Wadi Al Assuity has the longest travel time with good chance for groundwater potentials.

Rho coefficient (ρ):

It is an important parameter relating drainage density to physiographic development of a hydrographic basin which facilitate evaluation of water storage capacity of drainage network and hence, a determinant of ultimate degree of drainage development in a given watershed (Horton, 1945). Low values of Rho indicate low capacity for storage of water, while high values of Rho indicate high capacity of storage of water. The climatic, geologic, geomorphologic, and anthropogenic factors determine the changes in this parameter (Pareta, 2011). Rho values of the study basins show limited variation and ranges from 0.5 of wadiAbadi to 0.8 of Wadi Al Ramla as shown in Table 2. Generally, these values of the study basins are suggesting higher hydrologic storage during floods and attenuation of effects of erosion during elevated discharge especially for Wadi Al Ramla, WadiMadwar, Wadi Al Hawashyia, WadiDara and WadiSudr.

Basin Geometry Characteristics:

Watershed Area (A):

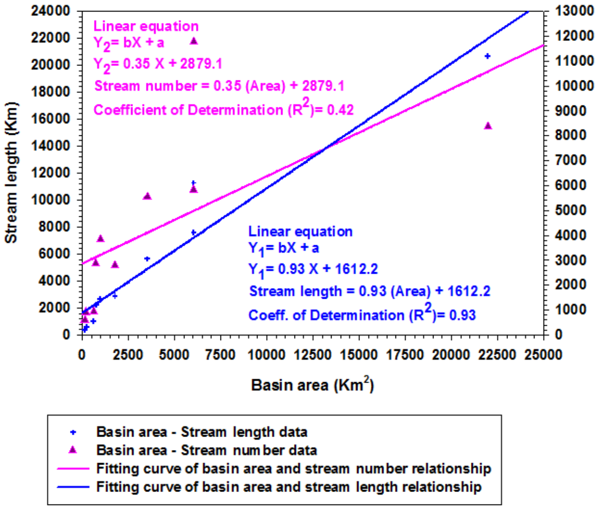
The area of the study basins were determined by using the ArcGIS software version 10.1. According to Horton (1945), all the areas were classified by size into the category of large basins i.e. all of them are more than 100 km^2. The area of the study basins ranges from 138.5 Km^2 of WadiMadwar to 21973 km^2 of Wadi Al Arish as shown in Table 2.

The basin length (LB):

It indicates the travel time of surface runoff especially the flood waves passing through the basin (Pareta, 2012). Basin length of the study basins ranges from 18 km of WadiMadwar to 232 km of wadi Al Arish as shown in Table 2. The travel time of Wadi Al Arish is greatest of the study basins and the shortest travel time of WadiMadwar.

The basin perimeter (Pr):

It ranges between 102 km of WadiMadwar and 1133.2 Km of Wadi Al Arish as shown in Table 2. The values of basin length and basin perimeter show a direct linear relationship with the basin area. It is noticed that there are direct positive relationship between the area, length and perimeter of study basins (Fig. 8)



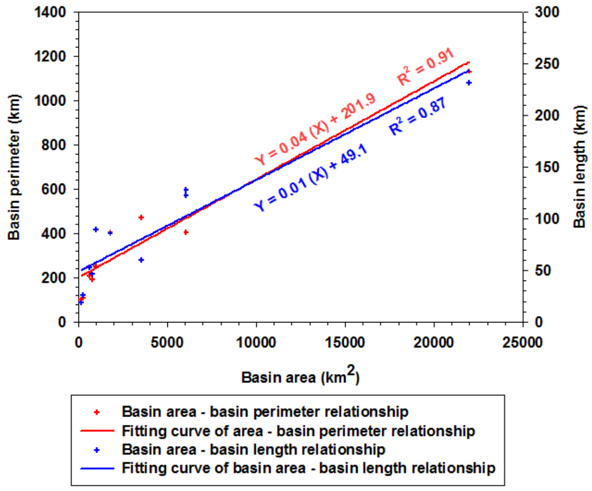


Fig. 7: Basin area, stream length and stream order **Fig. 8:**Basin area, perimeter and length relationship
relationship

Basin Width (W):

It ranges from 7.4 km of WadiMadwar to 94 km of Wadi Al Arish as shown in Table 2. The small values of the basin width indicate to the elongated shape which led to groundwater recharge potentiality more than the large values.

Circularity ratio (Rc):

The calculated values of the circularity ratio according to Strahler (1964) and Miller (1953) are range from 0.14 of WadiSidri to 0.46 of WadiAbadi as shown in Table 2. This reflects the dominance of elongation character of all the study basins except wadiAbadi. Miller (1953) has described the basin of the circularity ratios range 0.4 to 0.5, which indicates strongly elongated and highly permeable homogenous geologic materials. The circularity ratio value (0.46) of WadiAbadi corroborates the Miller's range, which indicating that the basin is elongated in shape, low discharge of runoff and highly permeability of the subsoil condition.

Elongation ratio (Re):

Table 2 shows the elongation ratios of the study basins that are generally less than unity which is 0.39 for Wadi Al Hawashyia and 0.99 for WadiWatier. According to Schumm's 1956, the higher the value of elongation ratio more circular shape of the basin and vice-versa. The variations of the elongated shapes the study basins are due to the guiding effect of geology and structure. Thus, the elongation ratio is important for evaluation the basin hydrology and flood hazards. Since, for a given rainfall event, the less elongated basin will generate a great peak run-off and faster travel velocities to the outlet. According Toy and Hadley (1987) the concentration time of flow towards the main channel is lower in circular basins than in elongated ones. Strahler 1964, states that this ratio runs between < 0.7 and0.9 > over a wide variety of climatic and geologic types (Pareta, 2011). Wadi Al Hawashyia, WadiSudr and WadiSidri reflect an ideal case of elongation with high time of concentration, and hence high groundwater potentialities. Wadi Al Ramla, WadiMadwar, Wadi Al Assuity, WadiAbadi, WadiDara and Wadi Al Arish have value of elongation ratio ranges nearly between 0.7 and 0.8 which is indicate that these Wadis are less elongated, while WadiWatier has elongation value aboutof 0.99 which indicates to oval to circular basin.

Texture ratio (Rt):

According to Horton (1945) it ranges from 4.53 km^{-1} for WadiSudr to 19.77 km^{-1} at Wadi Al Assuity. Smith (1958), classified the texture ratio of the basins into coarse (<6.4 km^{-1}), intermediate (6.4-16km^{-1}) and fine (>16 km^{-1}). Table 2 shows that the study basins have intermediate texture except of WadiMadwar and WadiSudr have coarse texture while Wadi Al Assuity has fine texture. According to Schumm (1965) texture ratio is an important factor in the drainage morphometric analysis which is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain. The wide variation of the texture ratios of the study basins is due to the variation of their lithology and geologic structure (Pareta, 2011). WadiMadwar and WadiSudr show low values of the texture ratio where most of their areas composed of soft rocks of Quaternary and less affected with geologic structure. Wadi Al Assuity has fine texture ratio due to its hard rock and less percentage of Quaternary and highly affected with the geologic structure. The lower values of texture ratio indicate that the has good chance for groundwater recharge, while the basins of high value where it is composed of hard rocks that have no ability for water infiltration and consequently has good chance to produce flash flood.

Form factor ratio (FFR):

According to Horton (1932) it is defined as a numerical index that shows shape of the basin (Pareta, 2011) and its value ranges from 0.1 to 0.8. Table 2; shows that the values of FFR of the study basins have a wide variation and range from 0.12 of Wadi Al Hawashyia to 0.98 of WadiWatier. Basins of low value of form factor are more elongated, less intense rainfall simultaneously and also have lower peak runoff of longer duration over its entire area than an area of equal size with a large form factor (Gupta, 1999). The basins with high values of form factor have a high peak runoff of longer duration. According to Gregory & Walling (1985) the form factor is the governing factor of the water courses which enter the main streams.

Basin shape index (Ish):

The calculated value of Ish of the study basins according to Haggett (1965) ranges from 0.15 of Wadi Al Hawashyia to 1.24 of WadiWatier. The higher the value of Ish is more circular shape of the basin and vice-versa. This is matching with the elongation ratio, form factor ratio and circularity ration

Compactness ratio (S_H):

According to Horton (1945) S_H is used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin. The values of compactness ratio of the study basins vary from 1.47 of WadiAbadi to 2.72 showing variations across the basins.

Table 1: Morphometric parameters formulas

Morphometric Parameters			Formula	Reference
Drainage Network	1	Stream order (u)	Hierarchical Rank	Horton (1945), Strahler (1952 & 1964)
	2	Stream number (N_u)	Nu = N1+ N2 + N3+…..Nn	Strahler (1952)
	3	Stream length (L_u)	Lu= L1+L2+...... Ln	Horton (1932)
	4	Bifurcation ratio (Rb)	$Rb = Nu / \mathrm{Nu} + 1$	Horton (1945) and Strahler (1964)
	5	weighted mean bifurcation ratio (WMRb)	$WMRb = \frac{\Sigma\,(Rbu / Rbu + 1)(Nu + Nu + 1)}{\Sigma\,N}$	Strahler (1953)
	6	Main channel Length	GIS software Analysis	
	7	Main channel index (Ci)	Ci = (Main channel length) / (Maximum straight of the main channel)	Mueller (1968)
	8	Sinuosity (Si)	$Si = VL/LB$	Gregory and Walling (1973)
	9	Rho coefficient (ρ)	$\rho = L_u r/Rb$	Horton (1945)
Basin Geometry	10	Watershed Area (A)	GIS software Analysis	Schumm (1956)
	11	The basin length (LB)	GIS software Analysis	Schumm (1956)
	12	The basin perimeter (Pr)	GIS software Analysis	Schumm (1956)
	13	Basin Width (W):	$W = A/LB$ (km)	Horton (1932)
	14	Circularity ratio (Rc)	$Rc = 4\pi A/\mathrm{Pr}^2$	Miller (1953)
	15	Elongation ratio (Re)	$\mathrm{Re} = (2\sqrt{A/\pi}/LB$	Schumm 1956
	16	Texture ratio (Rt):	$Rt = \Sigma\,Nu/\mathrm{Pr}$	Horton (1945)
	17	Form factor ratio (FFR)	$\mathrm{FFR} = A/LB^2$	Horton (1932)
	18	Inverse shape form (Sv) or Shape factor ratio (Sf)	$Sv = LB^2/A$	Horton (1932)
	19	Basin shape index (Ish)	$Ish = 1.27A/LB^2$	Haggett, 1965
	20	Compactness ratio (S_H)	$S_H = \mathrm{Pr}/2(\sqrt{\pi A})$	Horton (1945)
	21	Fitness ratio (Fr)	Fr = Channel length / Perimeter	Melton (1957)
	22	Lemniscate shape (Ls)	Le = (3.14) $(BL)^2$/ (4A)	Chorley *et al*. (1957)

Table 1: Morphometric parameters formulas

Morphometric Parameters			Formula	Reference
Drainage texture	23	Stream Frequency (F)	$F = \sum_{i=1}^{K} Nu / A$	Horton (1932 & 1945)
	24	Drainage density (D)	$D = \Sigma\,Lu/A$	Horton (1932 & 1945)
	25	Drainage Intensity (Di)	Di = F/D	Faniran (1968)
	26	Length of overland flow (Lo)	$Lo = 1/2D$	Horton 1945
	27	Infiltration Number (FN)	FN = (F)(D)	Faniran (1968)
	28	Drainage pattern (Dp)	Stream network using GIS software Analysis	Horton (1932)
Relief Characterizes	29	Maximum elevation (H_{max})	GIS software Analysis using DEM	
	30	Minimum elevation (H_{min})	GIS software Analysis using DEM	
	31	Relief (Rf)	Rf = Highest elevation-Lowest elevation	Strahler (1952)
	32	Internal relief (E)	E= (E85-E10)	Strahler (1952)

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	33	Mean Elevation (Hm)	GIS software Analysis using DEM	
	34	Altitude (Alt)	The elevation value at the 50 % of the accumulation area of the basin.	Strahler(1952),
	35	Relief ratio (Rr)	$Rr = (Rf / LB)100$	Schumm (1956)
	36	Slope index (SI %)	$SI = (E / 0.75VL)100$	Majure and Soenksen (1991)
	37	Mean basin slope (Sm)	GIS software Analysis using DEM	
	38	Ruggedness number (Rn)	$Rn = Rf.D$	Melton (1957)
	39	Basin flow direction (BFD)	GIS software Analysis using DEM	
	40	Hypsometric Integral (HI)	$HI = (Elev - Elev_{min}) / Elev_{max} -$ Elev is the mean elevation, $Elev_{max}$. is the maximum elevation and $Elev_{min}$ is the minimum elevation,	Strahler(1952)

Table 2: Morphometric parameters and hazard degree of the study basins

Morphometric Parameters			Region									
			Northwestern Coastal zone		Eastern Desert (Nile River)		Eastern Desert (Red Sea)		Sinai Peninsula			
			Name of Wadi									
			Al Ramla	Madwar	Al Assuity	Abadi	Al Hawashyia	Dara	Al Arish	Watier	Sidri	Sudr
Drainage Network	1	($_u$)	6.000	6.000	7.000	7.000	6.000	7.000	8.000	7.000	6.000	6.000
	2	(N_u)	922.000	594.000	11783.00	5834.00	3837.000	2867.00	8376.000	5528.00	2808.00	951.000
	3	(L_u)	582.100	357.500	11282.70	7631.70	2682.200	2243.40	20684.200	5648.40	2909.00	1051.50
	4	(Rb)	3.890	3.370	4.520	4.230	5.000	3.720	3.590	4.090	4.660	3.930
	5	(WMRb)	4.550	4.260	4.710	3.770	4.060	4.350	4.300	4.570	4.380	4.270
	6	(MC)	2.000	10.700	151.800	59.000	76.600	4.600	23.700	59.000	72.800	47.400
	7	(MCi)	1.180	1.430	1.300	1.280	1.200	1.440	1.320	1.690	1.490	1.350
	8	(Si)	0.080	0.570	1.190	0.480	0.850	0.100	0.100	0.980	0.850	0.890
	9	(ρ)	0.800	0.610	0.570	0.500	0.640	0.610	0.570	0.550	0.560	0.620
Basin Geometry	10	(A)	229.900	138.500	6035.50	6035.00	976.000	749.000	21973.000	3519.40	1770.80	612.900
	11	(LB)	26.000	18.800	128.000	123.000	90.000	46.500	232.000	60.000	86.000	53.000
	12	(Pr)	111.500	102.000	596.000	405.000	252.000	193.000	1133.200	473.400	405.700	210.000
	13	(W)	8.800	7.400	47.150	49.100	10.840	16.110	94.710	58.660	20.590	11.560
	14	(Rc)	0.230	0.170	0.210	0.460	0.190	0.250	0.220	0.200	0.140	0.180
	15	(Re)	0.660	0.710	0.680	0.710	0.390	0.660	0.720	0.990	0.550	0.530
	16	(Rt)	8.270	5.830	19.770	14.410	15.230	14.850	7.390	11.680	6.920	4.530
	17	(FFR)	0.340	0.390	0.370	0.400	0.120	0.350	0.410	0.980	0.240	0.220
	18	(Sv) or (Sf)	2.940	2.550	2.720	2.510	8.300	2.900	2.450	1.020	4.180	4.580
	19	(Ish)	0.430	0.500	0.470	0.510	0.150	0.440	0.520	1.240	0.300	0.280
	20	(S_H)	2.075	2.450	2.170	1.470	2.280	1.990	2.160	2.250	2.720	2.390
	21	(Fr)	0.020	0.110	0.250	0.150	0.300	0.020	0.020	0.130	0.180	0.230
	22	(Ls)	2.300	2.000	2.130	2.000	6.510	2.260	1.920	0.800	3.280	3.600

Table 2: Morphometric parameters and hazard degree

Morphometric Parameters			Region									
			Northwestern Coastal zone		Eastern Desert (Nile River)		Eastern Desert (Red Sea)		Sinai Peninsula			
			Basin name									
			Al Ramla	Madwar	Al Assuity	Abadi	Al Hawashyia	Dara	Al Arish	Watier	Sidri	Sudr
Drainage texture	23	(F)	4.010	4.290	1.950	0.970	3.930	3.830	0.380	1.570	1.590	1.550
	24	(D)	2.530	2.580	1.870	1.270	2.750	3.000	0.940	1.610	1.640	1.720
	25	(Di)	1.580	1.660	1.040	0.760	1.430	1.280	0.410	0.980	0.970	0.900
	26	(Lo)	0.200	0.190	0.270	0.400	0.180	0.170	0.530	0.310	0.300	0.290
	27	(FN)	10.150	11.070	3.650	1.220	10.810	11.490	0.360	2.530	2.610	2.670
	28	(Dp)	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic	Dendritic
Relief Characterizes	29	H_{max}	225.000	240.000	874.000	794.000	1000.000	1283.000	1620.000	1623.000	2600.000	861.000
	30	H_{min}	1.000	0.000	48.000	72.000	0.000	11.000	5.000	23.000	6.000	0.000
	31	(Rf)	224.000	240.000	826.000	722.000	1000.000	1272.000	1615.000	1600.000	2594.000	861.000
	32	(E)	100.000	100.000	500.000	300.000	550.000	250.000	350.000	600.000	1020.000	550.000
	33	(Hm)	101.000	111.000	428.000	326.000	625.000	272.000	503.000	911.000	1018.000	422.000
	34	(Alt)	75.000	96.000	374.000	258.000	508.000	196.000	410.000	847.000	1004.000	408.000
	35	(Rr)	0.009	0.013	0.007	0.006	0.011	0.027	0.007	0.027	0.003	0.020
	36	(SI%)	0.070	0.013	0.004	0.007	0.010	0.070	0.020	0.014	0.020	0.015
	37	(Sm)	4.000º	4.000º	2.950º	3.100º	4.500º	3.700º	2.400º	7.600º	10.100º	4.600º
	38	(Rn)	0.570	0.620	1.540	0.910	2.750	3.810	1.520	2.570	4.300	1.500
	39	BFD	16.500º	15.400º	256.000º	246.000º	72.400º	67.000º	346.700º	69.200º	270.000º	276.000º
	40	(HI)	0.450	0.460	0.460	0.350	0.560	0.200	0.310	0.570	0.400	0.490
Summation of Hazard degree			22.640	21.380	19.810	19.720	25.410	32.990	18.960	24.720	23.310	17.470
Hazard degree			2.000	2.000	2.000	2.000	3.000	5.000	1.000	3.000	3.000	1.000

Fitness ratio (Fr):

According to Melton (1957),Fr is the ratio of main channel length to the length of the basin perimeter which is a measure of topographic fitness (Pareta, 2011). The fitness ratio of the study basins ranges from 0.02 of Wadi Al Ramla, WadiDara and Wadi Al Arish to 0.3 of Wadi Al Hawashyia. This indicates that Wadi Al Hawashyia is more elongated and has a good chance for groundwater recharge than the other study basins.

Lemniscate shape (Ls):

According to Chorely (1957), the lemniscate’s value is one of the parameters which describe the shape and slope of the basin. The calculated lemniscate values of the study basins ranges from 0.8 of WadiWatier to 6.51 of wadi Al Hawashyia. The ideal values of lemniscate of elongated basins vary from 0.50 to 1.80. For values less than 0.50 the shape of the basin tends to be circular, while for values higher than 2 the basin is fully elongated (Lykoudi*et al*. 2004). So, all the study basins are fully elongated except for WadiWatier and Al Arish are ideal elongated. According Chorley *et al*.,(1957) and Morgan (2005) low values of lemniscate ratio as in WadiWatier and Wadi Al Arish tend to be circular and is more prone to erosion hazard. This is due to the shorter time of concentration from the remotest point in the basin to reach the outlet for runoff in compact basin compared to that in elongated ones.

Drainage Texture:

Stream Frequency (F):

According to Horton (1945), Fis may be directly related to the lithological characteristics. The basins of the structural hills have higher stream frequency, drainage density while the basins of alluvial deposits have low values. Stream frequency of the study basins ranges from 0.38 km^{-2} of Wadi Al Arish to 4 km^{-2}, in Wadi Al Ramla. The variation occurs due to rainfall, relief, infiltration rate, initial resistivity of terrain to erosion and total drainage area of the basin. Hence, Wadi Al Ramla, Madwar and Al Hawashyia show higher possibilities of runoff water collection than other basins.

Drainage density (D):

It ranges from 1.27 km^{-1} of wadiAbadi to 3.0 km^{-1} of WadiDara. A high value of basin drainage density indicates that a large amount of the precipitation runs off, while a low drainage density reflect erosion-resistant fractured hard rocks of the study area and indicates that the most rainfall infiltrates to recharge the groundwater storage. To evaluate the relationship between drainage density and stream frequency, linear plot of drainage density vs. stream frequency is prepared. The regression line indicates the existence of direct relationship between the two parameters as shown in Fig. 9.

Drainage Intensity (Di):

It is defined as the ratio of the stream frequency to the drainage density (Faniran, 1968). Drainage density value of the study basins ranges from 0.76 of wadiAbadi to 1.58 and 1.66 of Wadi Al Ramla and Madwar respectively. Low value of drainage intensity implies that drainage density and stream frequency have little effect on the extent to which the surface has been lowered by agents of denudation. Low drainage densities are often associated with widely spaced streams due to the presence of less resistant materials (rock types) and consequently the surface runoff is not rapid removed from the basin, or those of high drainage intensity with high infiltration capacities which give good chance for groundwater recharge.

Length of overland flow (Lo):

According to Horton (1945), Lo refers the length of surface water flow over the ground before it becomes concentrated in definite stream channels. It is an important independent variable, which greatly affect the quantity of water required to exceed a certain threshold of erosion. In the study basins, Lo ranges from 0.17 of WadiDara to 0.53 of Wadi Al Arish. Basins that have low values of Lo as WadiDara, Wadi Al Hawashyia, wadiMadwar and Wadi Al Ramla indicate that surface water concentrates faster than the basins of high values of Lo as in Wadi Al Arish and Abadi. Basins which have more alluvial plain (Quaternary) are elongated and have a high length of course.

Infiltration Number (FN):

According to Faniran (1968) the infiltration number is defined as the product of drainage density and stream frequency. It gives an idea about the infiltration characteristics of the basin reveals impermeable lithology and higher relief. The higher the infiltration number the lower will be the infiltration and consequently, higher will be surface runoff. This leads to the development of higher drainage density.

Drainage pattern (Dp):

According to Howard, (1967) basin drainage pattern helps in identifying the stage of the cycle of erosion and reflects the influence of slope, lithology and structure (Pareta, 2011). Dendritic pattern is the main pattern is of the study basins. This formed in a drainage basin composed of fairly homogeneity in texture and lack of structural control. The study basins are characterized by dendritic pattern especially for WadiDara, WadiAbadi, Wadi Al Assuity, Wadi Al Ramla, WadiMadwar and Wadi Al Arish. The remaining Wadis (Al Hawashyia, Sudr, Sidri and Watier) are sub-dendritic with some of rectangular and parallel pattern, where most of the basin is dendritic but, in some parts of the basin, the dipping and jointing of the topography reveals parallel and rectangular and radial pattern. The linear (parallel) pattern of the graphical representation indicates the weathering erosional characteristics of the area under study.

Relief Characteristics:

The study basins can be grouped into three groups; *low elevated group,* as in Al Ramla and Madwar where the mean elevation about 101 m and 111 m respectively; elevated group as in eastern Desert (Wadi Al Assuity, WadiAbadi, WadiDara and Wadi Al Hawashyia) as shown in table 2*; high elevated group* as in Sinai area (Wadi Al Arish, wadiSudr, Wadisidri and WadiWatier) as shown in table 2.

The slope index (SI %):

Or main channel slope is an indication for the channel slope from which an assessment of the runoff volume can be evaluated. Generally the basins under investigation are characterized by high relief and high topography except the Wadis of northwestern coastal zone. The slope index (SI %) ranges from 0.004 of Wadi Al Assuity to 0.07 of WadiDara and Al Ramla.

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Relief ratio (Rr):

The high values of Relief Ratio in WadiWatier, WadiDara and WadiSudr as shown in table 2, can be explained by the presence of highly resistant rocks of Basement and limestone which covered the basin. The high values of Rr indicate steep slope and high relief and while the lower values may indicate presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope. Relief controls the rate of conversion of potential to kinetic energy of water draining through the basin. Run-off is generally faster in steeper basins, producing more peaked basin discharges and greater erosion process. Both Rr and SI are directly proportional to flooding and inversely to the time of concentration. Study basins match with Gottschalk (1964) relief ratio normally increases with decreasing the area of a given drainage basin as shown in Fig. 10.

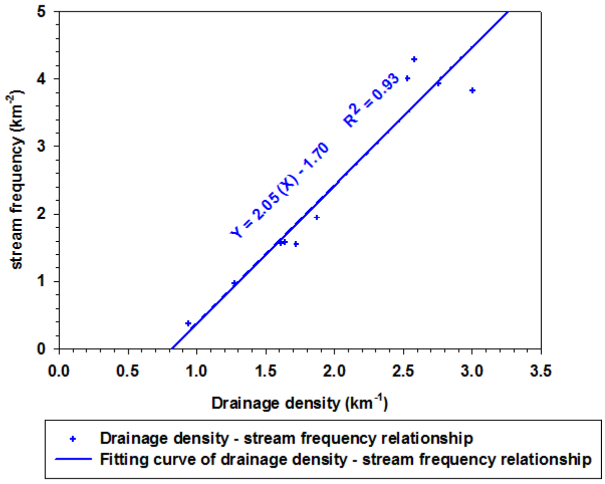

Fig. 9: Relation between Drainage density and stream frequency

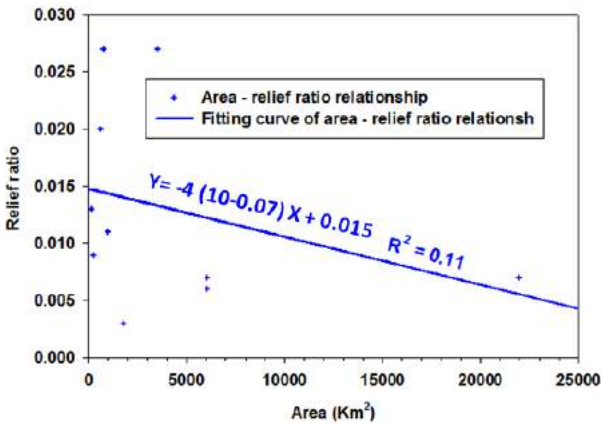

Fig.10: Relationship between the area and relief ratio

Mean basin slope (Sm):

Slope is the most important and specific feature of the drainage basin form. Maximum slope line is well marked in the direction of a channel reaching downwards on the basin. Slope maps of the study basins (Fig. 11) have created by using Surface Analysis Tool in ArcGIS-10. The mean slope of the study basins are range from 2.4° of Wadi Al Arish to 10.1° of WadiSidri as shown in Fig 11. and Table 2. The wide variations between the values of mean slope are due to the variation of the topography and lithology of the basins. Generally, the slope of the terrain affects the total runoff volume and time of concentration to the peak of hydrograph. Basins of gentle slope produce less runoff volume and smaller peaks of the runoff hydrograph. In gentle slope basins, the velocity of overland flow will be low and there will be more time for water to infiltrate thereby reducing the amount surface runoff reaching the stream as in Wadi Al Arish, and WadiAbadi. A steep slope produces greater velocities and allows faster removal of the runoff from the watershed; therefore, shorter concentration times to peak of hydrograph as in WadiSidri, and WaadiWatier.

Ruggedness number (Rn):

According to Melton 1965, it is a slope index that provides specialized representation of relief ruggedness within the watershed. Extremely high values of ruggedness number occur when the basin has steep and long slope. Rn of the study basins ranges from 0.57 of Wadi Al Ramla to 4.3 of WadiSidri as shown in table 2.

Basin flow direction (BFD):

Using ArcView and ArcGIS tools, the direction of flow could be determined. The calculated main direction of the study basins are matching with the direction of the main channel as shown in Figs. 4 and 12. The main directions of the study basins flow are north east for Wadi Al Ramla, WaddiMadwar (drain into the Mediterranean Sea), Al Hawashyia, WadiDara (drain into the Red Sea) and WadiWatier (drains toward the Gulf of Aqaba). While Wadi Al Assuity and WadiAbadi have the flow direction of southwest (drain toward the Nile valley), WadiSudr and WadiSidri have flow direction northwest toward the gulf of Suez while Wadi Al Arish has northwest flow direction towards the Mediterranean sea as shown in Table 2 and Fig. 12

Hypsometric Integral (HI):

Hypsometric curves are dimensionless measure of the proportion of the drainage area above a given elevation. According to Schumm (1956), Strahler (1964), Leopold *et al*. (1964) and Hurtrez*et al*.(1999), hypsometric curves are related to geomorphic and tectonic evolution of drainage basins in terms of their forms and processes (Herlekar and Sukhtankar, 2011). Strahler (1952, 1957, and 1964) identified three types of landforms, namely, young, mature and old (monadnock) on the basis of hypsometric curve shape. Two competing factors, namely, tectonic uplift and down wasting due to erosion control landscape form and its evolution. The shape of hypsometric curves depends on the degree and type of down wasting. Landscape evolution can be formulated as a continuity equation relating uplift, elevation and erosion for sediment transport. (Willgoose and Hancock, 1998). The hypsometric curves can be interpreted as youth (convex upward curves), mature (S-shaped curves) and peneplain or distorted (concave upward curves) stages of landscape evolution. Convex hypsometric curves are most likely for plateaus with little erosion, which can evolve into S shape, while concave hypsometric curves indicate a greater importance of erosion (Hurtrez*et al*., 1999). The study basins show the three types of hypsometric curve shapes as shown in Fig. 13. WadiDara is the oldest and peneplain as result of the geologic structure, while WadiWatier and Wadi Al Hawashyia are the youngest and the remaining Wadis are mature.

The hypsometric integral assists in explaining the erosion that has taken place during the geological time scale (Bishop *et al*. 2002). The comparison of the shapes of the hypsometric curves for different basins under similar climatic conditions and an approximately equal area also provides relative insight into the past soil movements in the basins. For the selected basins, the range of basin altitude was divided into equal intervals. For each interval, the proportion of the basin area was calculated. Elevations and areas were then divided by the relief and total basin area, so that they range from 0 to 1. The hypsometric integral (HI) represents the area under the hypsometric curve and is computed as follows (Hurtez*et al*., 1999). Generally, most of HI values range from 0.2 to 0.8, higher values indicate to the youngest basins, while the lower values indicate to the oldest basins (Chorley and Morley, 1959; Hann and Johnson, 1966; Pike and Wilson, 1971). Singh *et al*. (2008) presented an HI-based classification for the main landscape development stages. According to their classification, basins with HI values above 0.6 were classified as young, whereas catchments with HI values below 0.3 were classified as old or Monadnock. Mature stage catchments have HI values greater than 0.3 and lower than 0.6. The study basins have hypsometric integral ranges from old (0.2) of WadiDara to young (closed 0.6) of WadiWatier and Wadi Al Hawashyia. Basins of low hypsometric integral values indicate that these are old, eroded and dissected drainage basins, while basins of high values of hypsometric integral indicate that these basins are less eroded and highly relative to the mean elevation such as young uplifted basins cut by deeply incised streams.

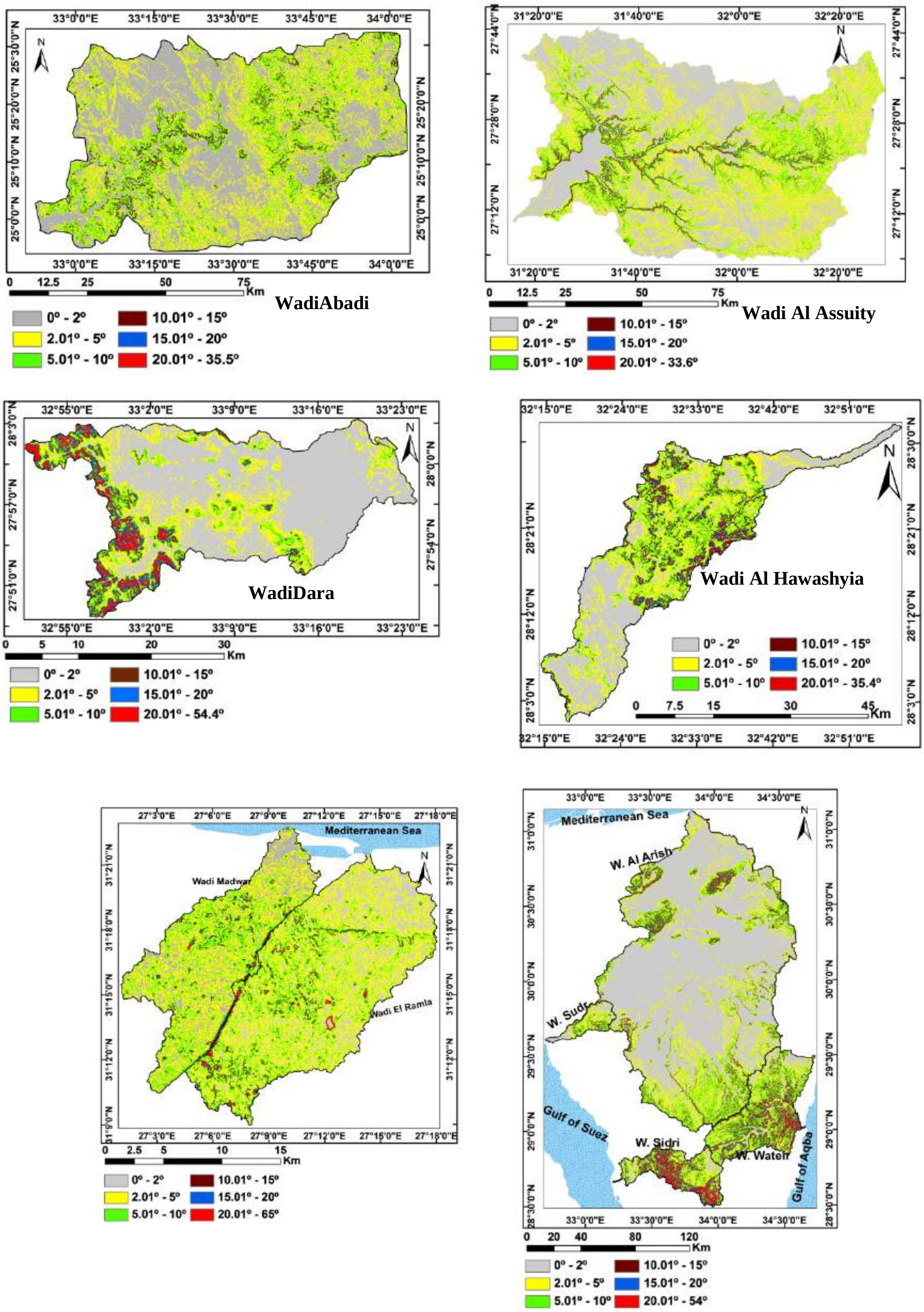

Fig. 11: Slope maps of the study basins

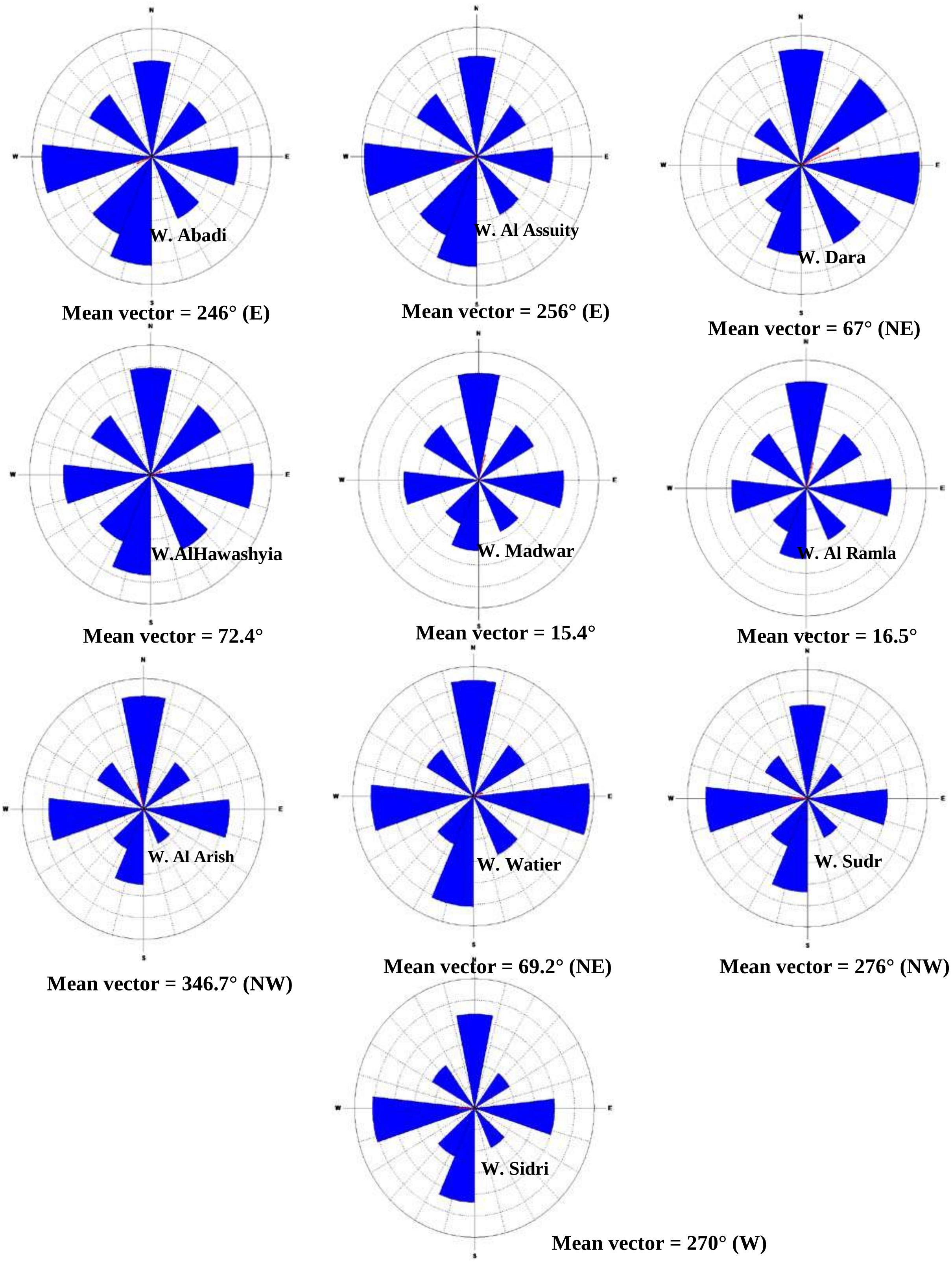

Fig. 12: Flow direction rose diagram of the study basins

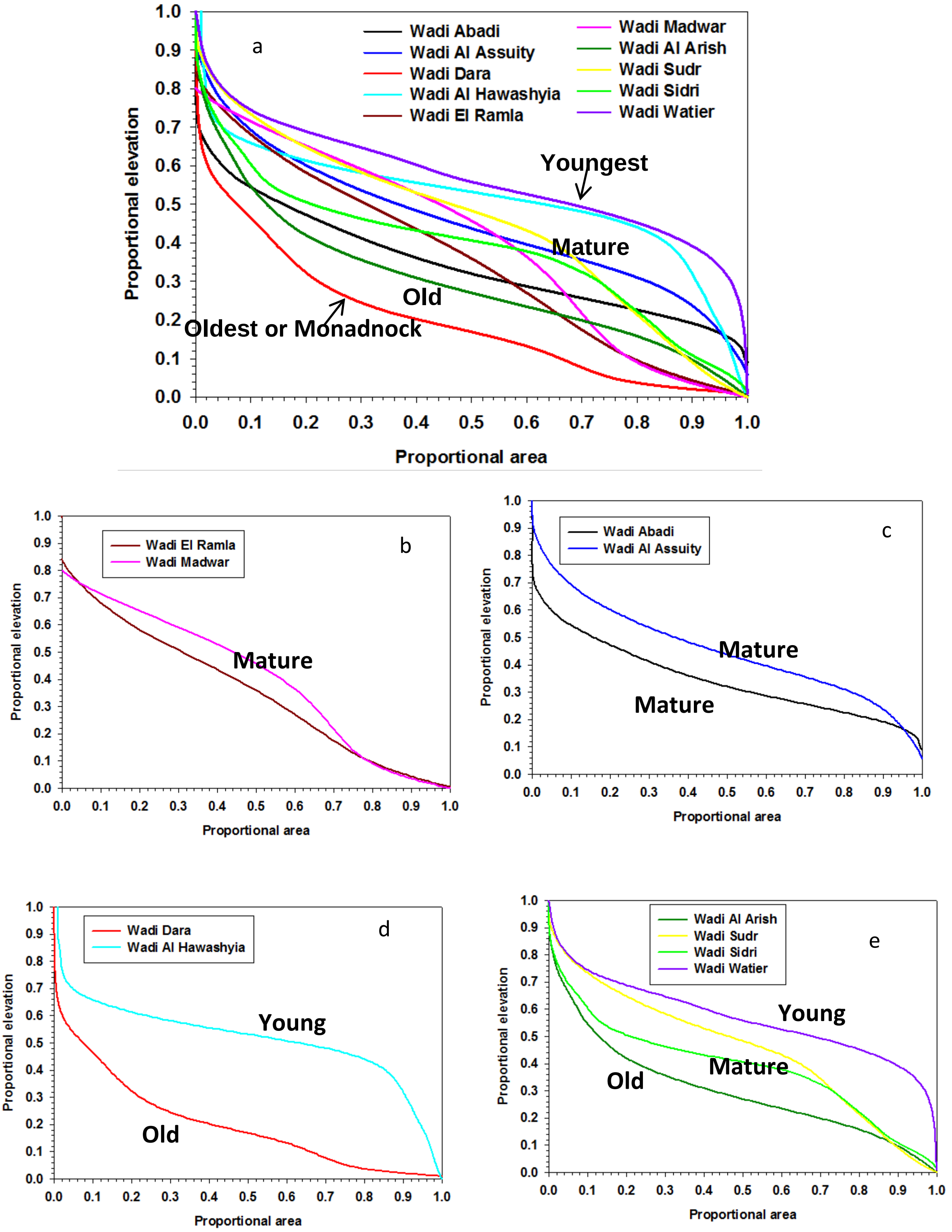

Fig. 13: Hypsometric curves of the study basins

Flood hazard evaluation:

To evaluate theflood hazard of the study basins, nine morphometric parameters having a direct effect on flooding were chosen, and their relationship with the flash flood were analyzed. These parameters are: watershed area (A), drainage density (D), stream frequency (F), shape index (Ish), slope index (SI), relief ratio (Rr), ruggedness ratio (Rn), texture ratio (Rt) and weighted mean bifurcation ratio (WMRb).All these parameters have a directly proportional relationship with the hazard morphometric parameters except for the weighted mean bifurcation ratio which shows an inverse proportion. A hazard scale number starting with 1 (lowest) to 5 (highest) has been assigned to all parameters. The distributions of the hazard degrees for the study basins have been carried out as follows:

- Determination of the minimum and maximum values of each morphometric parameter for the study basins
- Assessments of the actual hazard degree for all parameters which are located between the minimum and maximum values were depending on a trial to derive the empirical relation between the relative hazard degree of a basin with respect to flash floods and the morphometric parameters, the equal spacing or simple linear interpolation between data points procedure was chosen.
- Assuming a straight linear relation exists between the samples points, the intermediate values can be calculated from the geometric relationship (Davis, 1975).

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

For the weighted mean bifurcation ratio (WMRb) which shows an inverse proportion, the hazard degree was calculated using the following equation (Davis 1975).

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

Where X is the value of the morphometric parameters to be assessed for the hazard degree for each basin, X_{min}&X_{max} are the minimum and maximum values of the morphometric parameters of all basins respectively.

The hazard degree for the study basins is calculated by equations (1) and (2). The summation of the hazard degrees for each basin represents the final flood hazard of that basin (Tables 2). These values range between 14.47 (WadiSudr) and 32.99 (WadiDara). The actual hazard degrees for all study basins are tabulated in Table 2. From the calculated values, according to their hazards one can classify the study basins into three groups; ***Basins of low hazard degree*** (WadiSudr, Wadi Al Arish, Wadi Al Ramla, WadiMadwar, Wadi Al Assuity and WadiAbadi); ***Basins of medium hazard degree*** (WadiSudri, WadiWatier and Wdai Al Hawashyia); ***Basins of high hazard degree*** (WadiDara)

REMARKS AND DISCUSSION

All the study basins have an area that exceeds 100 km^2; therefore all of these basins can be grouped as large size basin which gives good chance to collect more water than the small basins. The drainage patterns of the study basins are dendritic especially for WadiDara, WadiAbadi, Wadi Al Assuity, Wadi Al Ramla, WadiMadwar and Wadi Al Arish. This indicates less percolation and maximum run-off especially in the highly areas. It is noticed that the stream orders of each drainage network show that the courses of the main channels and their tributaries are affected by the lineament structures and lithology, where many of these main channels and their tributaries are parallel to the lineament structures. Most of the segments up to the 3rd order traverse parts of high altitudinal zones, forming steep slopes, while the other stream segments (4th–8th order) occur in relatively low altitudinal zones. Also, the stream lengths are directly proportional to the number of streams, basin area, basin length and perimeter. Basin length is an important parameter for the travel time of water, especially for the flash floods where the long basin has more travel time and consequently good chance for groundwater recharge than the short basin. All the study basins have values of bifurcation ratio greater than 3; this reflects high mountainous dissected areas and elongated basins especially in Wadi Al Hawashyia, WadiSidri, WadiWatier, WadiAbadi and Wadi Al Assuity as shown in Table 2, where these basins characterized with highest value of elevation and more percentage of basement rocks as shown in geological maps Fig 2.

Based on the elevation of the study basins, it is concluded that the complex topography of the study basins plays a major factor affecting the aerial characteristics of those watersheds and three main groups can be distinguished as shown in Fig. 3;

1. **Low elevated group** as in northwestern coastal zone (AWadi l Ramla and WadiMadwar) where the mean elevation about 101 m and 111 m respectively
2. **Elevated group** as in eastern Desert (Wadi Al Assuity, WadiAbadi, WadiDara and Wadi Al Hawashyia) as shown in table 2
3. ***High elevated group*** as in Sinai area (Wadi Al Arish, wadiSudr, Wadisidri and WadiWatier) as shown in table 2.

The relationship between stream number and stream order of the study basins show a perfect negative correlation with coefficient of correlation about 0.99 as shown in Fig. This matches with many studies for humid and arid regions. The relationship between the stream length and stream order for the study basins show also negative direct relationship with coefficient of correlation about 0.99, this doesn't match with many studies which are is positive linear relationship as reported, (Schmidt, 1984;Unesco/WHO/UNEP, 1992; and White *et al*., 2003).

Hence, the stream length is an indicator of the relation between the climate, vegetation, and the resistance rock and soil to erosion. Under similar conditions, impervious rocks support a longer stream length, consequently higher drainage densities are observed than for permeable rocks. Arid and semi-arid regions show higher drainage densities than humid regions having the same geology, because of the flash flood and scarce vegetation in the former case. It is noticed that there is a proportional linear relationship between the area and both stream number and the corresponding stream length for all the study basins

The shape characteristics of the study basins (circularity, elongation and compactness ratios), reflect the dominance of moderate to high elongation characters. The elongation ratio is an important parameter for the basin hydrology and for the estimation of flood hazard. For a given rainfall event, the less elongated basins will generate a greater peak run-off and faster travel velocities to the outlet as shown in WadiWatier, WadiDara, WadiMadwar and WadiAbadi. The higher the value of elongation ratio more circular shape of the basin and vice-versa.

The study basins reflect the dominance of intermediate texture ratio except of WadiMadwar and WadiSudr have coarse texture while Wadi Al Assuity has fine texture. Texture ratio is an important factor in the drainage morphometric analysis which is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain. The wide variation of the texture ratios of the study basins is due to the variation of their lithology and geologic structure. WadiMadwar and WadiSudr show low values of the texture ratio where most of their areas composed of soft rocks of Quaternary and less affected with geologic structure. Wadi Al Assuity has fine texture ratio due to its hard rock and less percentage of Quaternary and highly affected with the geologic structure. The lower values of texture ratio indicate that the basin has good chance for groundwater recharge, while the basin of high value where it is composed of hard rocks that has no ability for water infiltration and consequently has good chance to produce flash flood.

The study basins show the three types of hypsometric curve shapes as shown in Fig 13. WadiDara is the oldest and peneplain as result of the geologic structure, while WadiWatier and Wadi Al Hawashyia are the youngest and the remaining Wadis are mature. The study basins have hypsometric integral ranges from old (0.2) of WadiDara to young (closed 0.6) of WadiWatierand Wadi Al Hawashyia. Basins of low hypsometric integral values indicate that these are old, eroded and dissected drainage basins, while basins of high values of hypsometric integral indicate that these basins are less eroded and highly relative to the mean elevation such as young uplifted basins cut by deeply incised streams. Basins of HI values greater than 0.3 and lower than 0.6 are mature stage (Wadi Al Ramla, WadiMadwar, Wadi Al Assuity, Wadi Al Arish, WadiAbadi, WadiSidri and WadiSudr).

Based on the hazard degree the sub-basins of Wadi Al Lith can be grouped into three groups as follow; ***Basins of low hazard degree*** (WadiSudr, Wadi Al Arish, Wadi Al Ramla, WadiMadwar, Wadi Al Assuity and WadiAbadi); ***Basins of medium hazard degree*** (WadiSudri, WadiWatier and Wdai Al Hawashyia); ***Basins of high hazard degree*** (WadiDara)

Summary and Conclusion:

The selected study basins are represented to different climatic and geologic conditions. Basin physiographic features are the important controlling factors of surface water runoff and flood hazard assessment especially in the ungauged basins of arid regions. Flood hazard mapping is very important for the catchment managements especially for the sustainable development of the water resources and for the protection from the flood hazard and drought. Flash floods can be intensified by many factors which depend on the physiographic features of basins such as, topography, watershed area, geology and climatic conditions. In this study, 40 morphometric parameters were calculated and many relationships between these parameters were done. Some of these relationships between these parameters are directly applicable to arid or semi-arid regions and also can apply to the humid basins but the other relationships have no similarity between arid, semi-arid and humid basins.

From the integrated analysis of the results on the morphometric characteristics of the study basins, it is concluded that the hydrological behavior of the study basins have a direct function of the geomorphology, the topography and the existing vegetation conditions. Topography is the result of geology and climate that determine landforms, slopes and local of micro-topography. So in this study the topography and the geology are considered as the important controlling factor on the hydrological response to flash flood. This study is proved that the hydrological characteristics of the basin are controlled with the basin physiographic features. The flash flood and groundwater recharge is the main results which express about the hydrological characteristics of basin.

The study basins show a nearly perfect negative correlation between the stream number and stream order with coefficient of correlation about 0.99. This negative relationship is noticed for the study arid and semi-arid basins and similar to humid basins. It is noticed that there is a difference in the geometric relationship between the stream length and its order for the study basins of arid and semi-arid regions than for those of the humid regions. This latter geometric relationship between the stream length and the stream order is positive linear relationship. While a negative correlation as in this case of study basins (inverse relationship) are observed for other arid and semi-arid regions as also reported in India. So, authors recommended that many comparative studied should be carry out to confirm the differentiation between the morphometric parameters relationships for the arid, semi-arid and humid basins.

According to the study area is suffering from the scarcity of measured data (rainfall and runoff), and the flood inundation maps are dependent on the physiographic features of basins, so, this study based on the integration between physiographic features of the study basins and GIS techniques. All the effective morphometric parameters of study basins were measured and calculated. From the results it could be classified the study basins into three groups according the hazard degree where WadiDarahas high hazard degree, Wadi Al Hawashyia, Watier and Sidri have medium hazard degree and Wadi Al Ramla, WadiMadwar, Wadi Al Assuity, WadiAbadi, Wadi Al Arish and WadiSudr have low hazard degree. It is noticed that the WadiDara of high hazard degree is low of hypsometric integral (old), medium hazard degree of Wadi Al Hawashyia, Watier and Sidri have high hypsometric integral (young) while the Wadis of low hazard degree are mature and medium hypsometric integral. Authors recommended should be many detailed studies carryout to confirm like these relationship between flash flood hazard degree and hypsometric curves.

It is recommended that some dams and dikes are very important to construct for erection of the runoff water to infiltrate and recharge the shallow aquifer at the crossing point between the fourth stream order and fifth stream order. So, study provides details on the flash flood prone area of the study basins and the mitigation measures. This study also helps to plan rainwater harvesting and watershed management in the flash flood alert zones.

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