Research Article

Comparative study of the drainage basin morphometry extracted from topographic maps and SRTM DEMs: an example from Ghadir watershed, Eastern Desert, Egypt

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KEY WORDS	ABSTRACT
Topographic sheets, Morphometric, SRTM DEM, Ghadir watershed, Eastern Desert, Egypt	The drainage network of Wadi Ghadir watershed, southeastern Desert, Egypt was extracted from topographic maps (1:50. 000), and from the 30 m digital elevation data (DEM) of the Shuttle Radar Topography Mapping Mission (SRTM). Four topographic sheets were digitized and used for extraction. Archydro function in ArcGIS 10x was utilized for network extraction and for morphometric analysis. Networks derived from topographic sheets and DEM were considerably coincident. Different morphometric parameters from both sources were evaluated to examine the accuracy of DEM for hydrologic applications. Results clarified 6th order streams for both drainage networks with moderate to high drainage density (D) of 2.51 km.km^2 (topographic) and 2.54 km.km^2 (DEM) reflecting that W. Ghadir drainage basin is impermeable with considerable surface runoff. DEM showed higher stream frequency (F) of 4.49 than those derived from topographic maps (4.38). Calculated bifurcation ratio (R$_b$) of streams derived from topographic sheets reached about 3.47 and about 4.60 for those derived from DEM. DEM-derived morphometric parameters provided good and satisfactory information about the catchment characteristics and revealed accurate watershed delineation confirming high potential of surface runoff of the W. Ghadir drainage basin. Finally, SRTM DEM proved advantageous over the topographic sheets for drainage delineation and basin morphometry for hydrologic analysis underpinned with the finer spatial resolution and the vertical accuracy.

1. Introduction

Before the introduction of Digital Elevation Models (DEMs), landforms and drainage networks were only manually identified by surveying means when available through interpretation of topographic maps and aerial photographs (Garbrecht and Martz, 2000). It is an arduous stint to manipulate depiction of a catchment institutionalized on topographic maps with contour lines of flat terrain land. Recently, the advent of DEMs, excess use of GIS by the hydrological community has led to development of computer algorithms that are

able to extract the drainage networks automatically from DEMs. This is to avoid the extremely time-consuming and tedious process of the convential methods and has the advantage of being independent of human decisions. Many authors were addressed these algorithms for automatic networks extraction (e.g. Tucker et al., 2001, Lin and Oguchi, 2004, Reddy et al., 2004, and Gelabert et al., 2005), and others made comparative studies between drainage network automatically extracted from DEM and drainage network delineated manually from traditional methods (e.g. Garcia and Camarasa, 1999). Several DEMs have been used for drainage networks extraction, such as SRTM DEM (90 m and 30 m) and ASTER (15 m) spatial resolution.

Unfortunately, the original SRTM data is not error free and incorporates error from different sources (Falorni et al., 2005) such as, systematic error (sometime appears as stripping), presence of missing data called voids (Kervyn, 2001). All these error provenances reduce its authenticity and reliability for practical applications. Many researchers (e.g. Becek, 2008; Miliaresis, 2008) have assessed the accuracy and sententiousness of SRTM DEM. Independent of the DEM's source preprocessing is a demandable step to avert artificial spikes and isolated pixels that will redound the generated surface (Wang and Liu, 2006). The availability of processing tools improved, to a large extent, within the last forty years. Tools based on sophisticated algorithms are now in the freeware domain.

However, recent advances in the availability and quality of digital elevation models (DEMs) have popularized automated DEM-based approaches for channel network extraction in catchment hydrology (Moore et al. 1991; Rinaldo et al. 1998) due to better efficiency and easy reproducibility (Tarboton et al. 1991). In addition, drainage courses generated from DEMs contain improved information on drainage-related topographic variables such as channel gradient, valley floor width etc., and the DEM-generated streams (representing as single lines) facilitate easier calculation of stream order and route stream networks (Clarke and Burnett 2003).

The quality of extracted channel networks depends chiefly on the quality of the DEM used and the extraction method. Since the stream network data assume greater importance in earth-environmental-modelling, the reliability of the extracted information should be properly assessed (Lindsay and Evans 2008). Several researchers (e.g. Zhang and Montgomery 1994; Wu et al. 2008) suggested comparative approach using DEMs of varying pixel sizes, to evaluate the effect of spatial data resolution on hydrologic models. The accuracy of DEM-derived drainage networks with respect to topographic maps was also analysed by Mahtab et al. (2003) and Ahmed et al. (2010), suggesting the applicability of DEMs in drainage network analysis.

In the present study, freely available 30 m-SRTM DEM, derived from (http://earthexplorer.usgs.gov) was used to extract and delineate W. Ghadir drainage system as well as morphometric parameters calculation. The obtained results were used to compare and asses DEM quality and accuracy with topographic maps-derived network. SRTM DEM has been evaluated across the study area using different reference elevation data including Global Positioning System (GPS) and field investigations during November 2016 and November 2017.

2. Study area

The study area is located in the extreme southern part of the Central Eastern Desert (30 km south of Marsa Alam city) and extends between latitudes 24° 40" to 24° 56" N and longitudes 34° 39" to 35° 05" E on the Red Sea coast (Fig. 1). Wadi Ghadir drainage basin occupies an area of about 499.7 km2 and about 162.3 km basin perimeter. The basin comprises five sub-basins. Wadi Ghadir basin possesses rugged mountainous relief and is considered as asymmetrical basin, where the catchment area is large and discharge on the southern side of the trunk wadi debouching into the Red Sea.

The geology of W. Ghadir basin was previously investigated and mapped (e.g. El Bayoumi, 1980, Takla et al., 1982, Basta, 1983, Takla et al., 1992, Abd El-Rahman et

al., 2009 and Kamel et al., 2016). In addition to the digital imageprocessing of Landsat 8 OLI using ENVI (V. 5.3) software, different techniques were applied to the remotely sensed data (such as false color composites (FCC), band ratios and principal component analysis (PCA)) to explore and discriminate the different rock units. Figure (2) shows the false color composite of RGB = 752 of Landsat 8 OLI, which discriminates between the different rock units in the investigated basin. The processed image (Fig. 2) shows also the linearity and straightness in the drainage segments which are dominantly oriented NW-SE and reflecting the structural control to the drainage network. A detailed field study was carried out to check the reliability of aforementioned interpreted image and to produce an improved and detailed geologic map to W. Ghadir drainage basin (Fig. 3). The studied basin is covered mainly by a widely distributed stretch of Neoproterozoic ophiolitic mélange constituted mainly of allocthonous ophiolitic (Fig. 4 b, c and d) fragments mixed firmly and incorporated in a sheared matrix, as well as, other different mappable units (Fig. 3). The most extensive and widely distributed rock unit in this area is the mélange assemblages and thrust over Gabal Zabara granite gneiss (Fig. 4a). The other mappable rock units in the studied area include metavolcanics, rhyolitic, gabbroic and granitic rocks (Fig. 4e and f).

The deformation style and structural evolution of W. Ghadir area are very complicated as the area entirely is located in the zone of Najd Fault System (NFS) and mainly affected by Nugrus Shear Zone (NSZ) (Fowler and Osman, 2009). The structural pattern complexity became more intricate by the overprinting of the NW-SE trending tectonic structures in west Ghadir area (the area between G. Ghadir and G. Zabara, Fig. 3) on ENE-WSW to WNW-ESE structural fabrics of the east Ghadir area (the area to the east of Gabal Ghadir) and curving the western NW-SE trending tectonic structures into a NE-SW direction around Wadi Ambaut area (the area to the north of G. Ghadir).
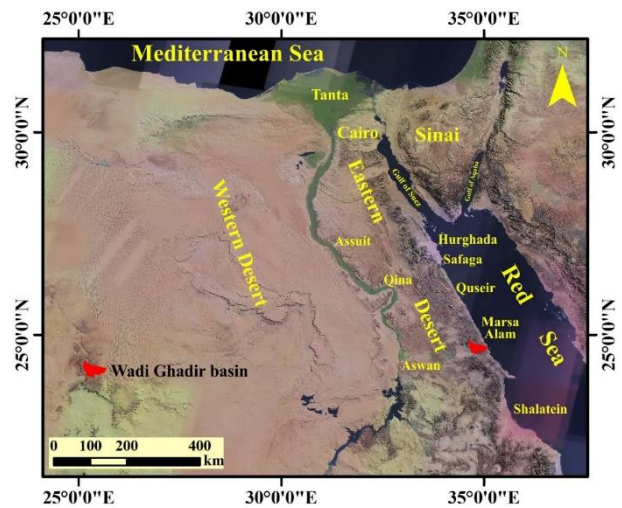

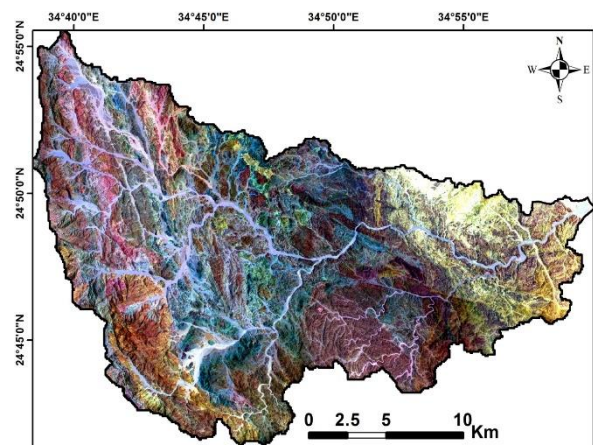**Figure (1)**: Location map of Wadi Ghadir drainage basin.

Figure (2): False color composite (RGB = 752) of Landsat 8 OLI of Wadi Ghadir basin showing rock units discrimination and linear structural features which controlled the drainage segments.
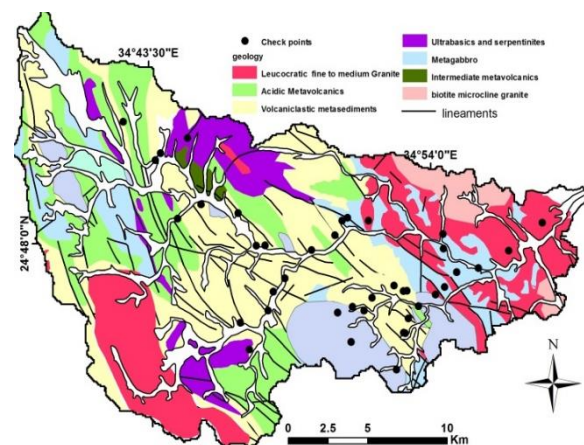

Figure (3): Geologic map of W. Ghadir basin (Improved and modified after Basta (1983). Note: the distribution of the field check points for validation and measurements.
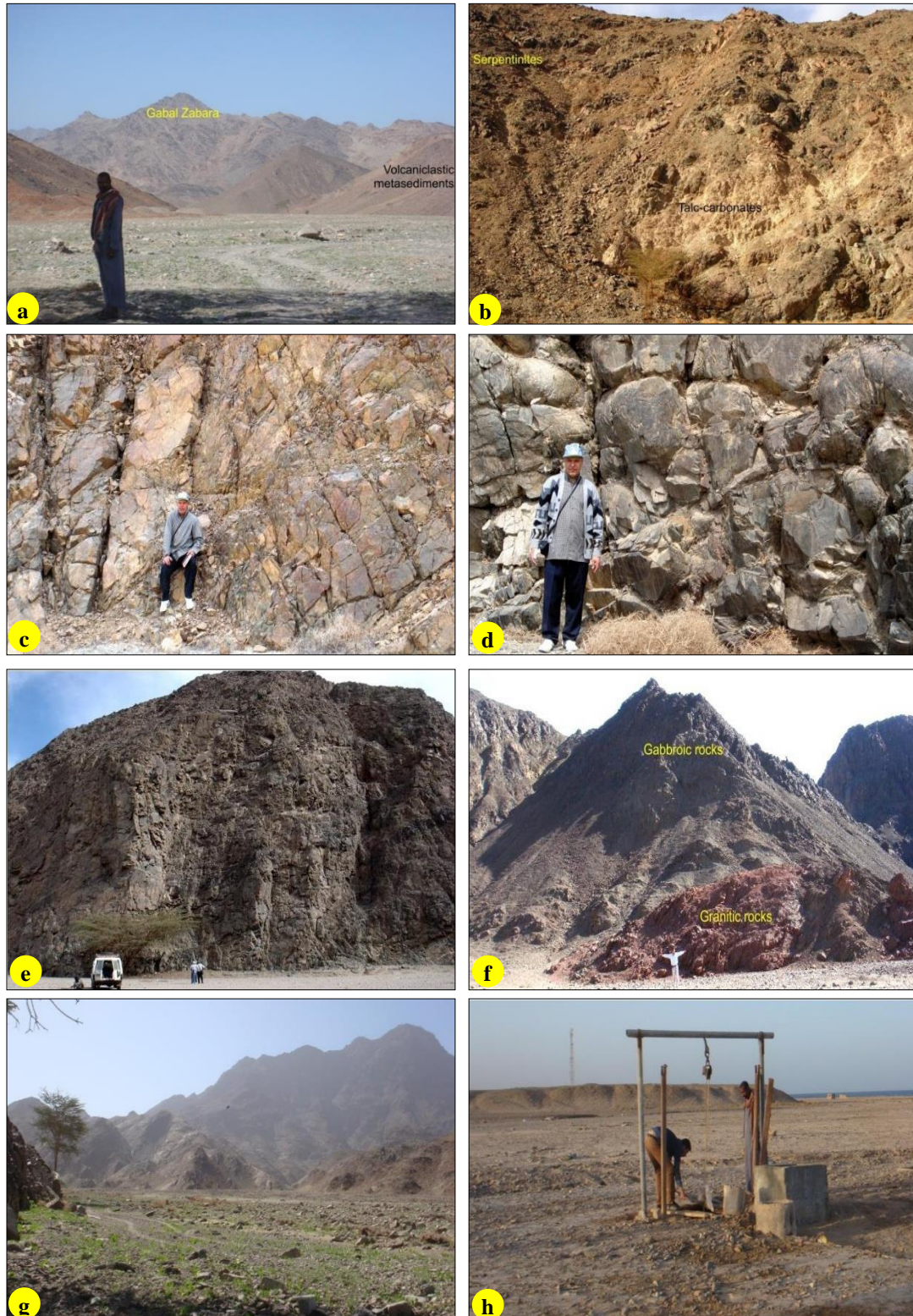
Figure (4): (a) Field photograph showing (a) Gabal Zabara granite gneiss at the background and volcaniclastic metasediments at the foreground, (b) Serpentinites altered to cream-colored talc-carbonate, (c) Close up view of sheeted dykes, (d) Close up view of an assortment of well-preserved large pillows with variable form and size, (e) General appearance metagabbroic rocks, (f) Sharp contact between gabbroic and granitic rocks, (g) Dense vegetation at the western part of the W. Ghadir drainage basin close to the water divide and (h) Hand dug water well at the entrance of the main stream course.

W. Ghadir drainage basin was subjected to rainy climate which is reflected by the present of dense vegetation at the upper reaches of the basin (Fig. 4g), as well as, present of shallow Quaternary aquifers at the entrance of the main stream course (Fig. 4h).

1. Data used and Methodology:

The data used in the present study include Landsat 8 OLI, 30 m SRTM DEM, published geologic maps (among of them El-Sharkawy and El-Bayoumi (1979), Basta (1983) and Kamel et al. (2016)), and four scanned topographic maps named as; East Ghadir, Ghadir, Hafafit and Sikait sheets at scale 1:50.000 with 20-m contour interval (Egyptian General Survey Authority, 1989).

Three main steps were performed to extract and analysis the drainage network of W. Ghadir basin which are summarized in a flow chart (Fig. 5). Tracing streams digitally and traditionally from W. Ghadir area topographic maps is the first step. The stream network of the study area was depicted by ArcGIS sketch tools after geometric transformation of topographic map scanned image using Universal Transverse Mercator (UTM) Projection, Zone 36 North with a World Geodetic System (WGS) 84 datum through digitizing blue lines. The digitized lines representing the fluvial channels on 1:50.000 topographic maps combined with contour lines, as well as, field works. Obviously, it is hard to examine all drainage network from field observations due to their extent throughout rough terrain and/or vast areas. However, blue lines do not give real drainage networks on the ground due to cartographic generalizations and subjective judgment of the cartographers (Chorley and Dale 1972; Drummond 1974; Mark 1983). The resulting map was used as real ground to comprise the automated river network extraction in GIS method in the present study.

The second step includes the automatic extraction of the drainage network of the study area carried out from SRTM DEM (Fig. 6a), in a raster format with a 30 m x 30 m grid cell size using the hydrological tools in ArcGIS software (V. 10.5). To enhance the interpretability of the elevation raster, a shaded relief or hill shade, is often generated first. Where shaded relief is a visually pleasing representation of the terrain (Marston and Jenny, 2015). Errors such as sinks and peaks were obliterated to elute discontinuities in the drainage network by creating the filled DEM (Fig. 6b) (A filled DEM or elevation raster is void of depressions or sinks; a depression is a cell or cells in an elevation raster that are surrounded by higher elevation values, and thus represents an area of internal drainage systems) using fill function hydrology toolset in ArcGIS.

Flow direction (Fig. 6c) was calculated for each pixel using the filled DEM, i.e. the direction in which water will flow out of the pixel to one of the eight surrounding pixels. This concept is called the eight-direction (D8) pour point model (Fairfield and Leymarie 1991). D8 is the most commonly used approach based on the deployment of a model for surface water flow accumulation. This method, designated D8 algorithm (eight flow directions), was introduced by O'Callaghan and Mark (1984) and has vastly utilized (Jenson and Domingue, 1988; Martz and de Jong, 1988; Morris and Heerdegen, 1988; Jenson, 1991; Tarboton et al., 1991; Martz and Garbrecht, 1992). This approach (based on a grid-based DEM) specifies flow directions by assigning flow from each cell to one of its eight neighbours, either adjacent or diagonal, in the direction with steepest downward slope (Tarboton, 1997). As the flow of water is traced downhill from a point, a counter is incremented for all the downstream points through which the water flows (Jones, 2002).

The drainage network is defined by the relative counts wherever the upstream drainage area exceeds a specified threshold (Martz and Garbrecht, 1995). There are several variants of the model, but the simplest, and the one used in ArcGIS, allows water from a given cell to flow into only one adjacent cell, along the direction of steepest descent. The resulting flow direction is encoded from 1 to 128 in different directions. Consequently, a flow accumulation map using the ArcGIS functions was extracted (Fig. 6d), which tabulates for each cell the number of cells that will flow to it.

Each pixel was assigned a value equal to the number of pixels drained through a given pixel in the flow accumulation. It records how many upstream cells will contribute drainage to each cell.

Stream network and stream link delineation have been done in the next steps. A stream network raster can be derived from accumulation raster. This step is based on a threshold accumulation value. The threshold value for the generation of stream network represents the minimum upstream drainage area (threshold area) necessary to maintain a stream and hence, the stream frequency (F) and the drainage density (D) are varied depending on the threshold value. A higher threshold value will result in a less dense stream network and fewer sub-basins than a lower threshold value. The drainage network was extracted by considering the pixels greater than a threshold of 100 (Fig. 6e) because this value generates total numbers of streams close to that of topographic maps.

A drainage network can be described quantitatively in terms of some attributes such as stream order (Fig. 6f), stream lengths and drainage density (Horton, 1945). A top-down stream order system developed by Horton (1945) and modified by Strahler (1952a) was used to classify stream segments based on the number of upstream tributaries. Based on the drainage net orders, both drainage networks were classified into different orders using the Strahler's method (Strahler 1952b). Stream ordering of drainage networks derived from topographic maps was executed manually, whilst those derived from the DEM were assigned automatically in GIS environment. The manually traced and automatically extracted stream order maps (Figs. 7a and b) show that W. Ghadir drainage basin attains the sixth order. To conform that Archydro tools have drawn the correct boundary and stream lines, the actual lines and divide points were visited and tracked through GPS device across more than 30 stations shown on Figure (3) to ensure better data validation (the projected catchment area was compared and with the real catchment area).
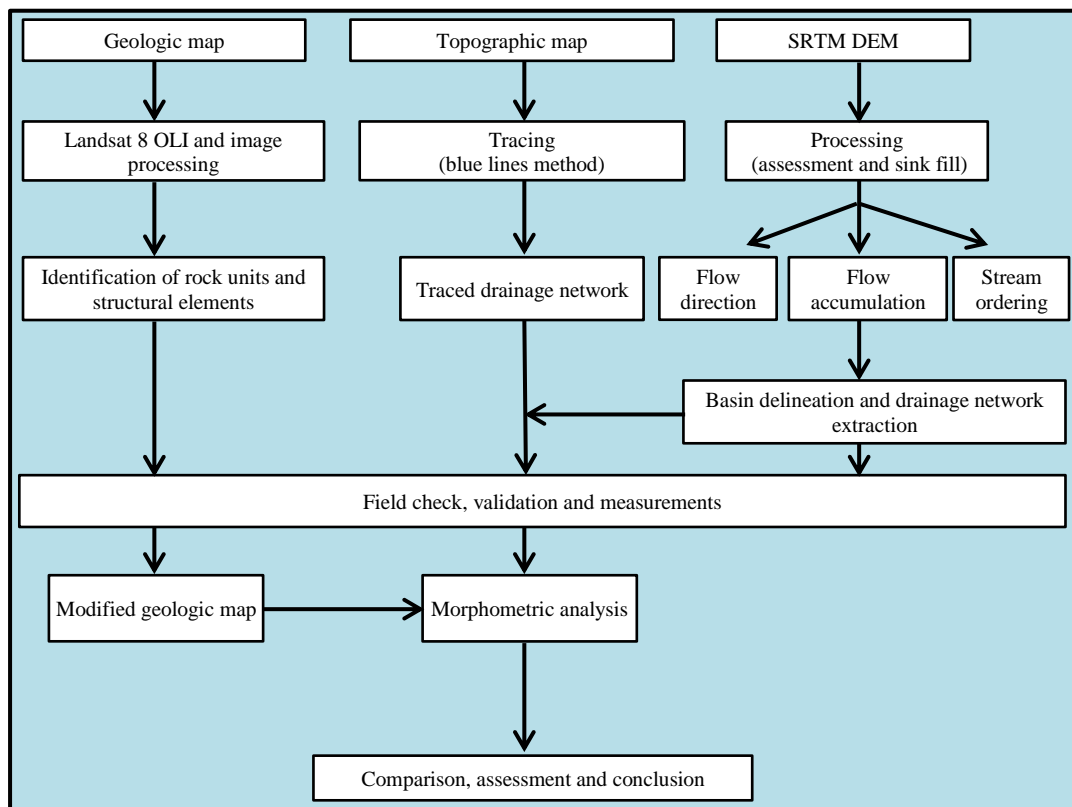

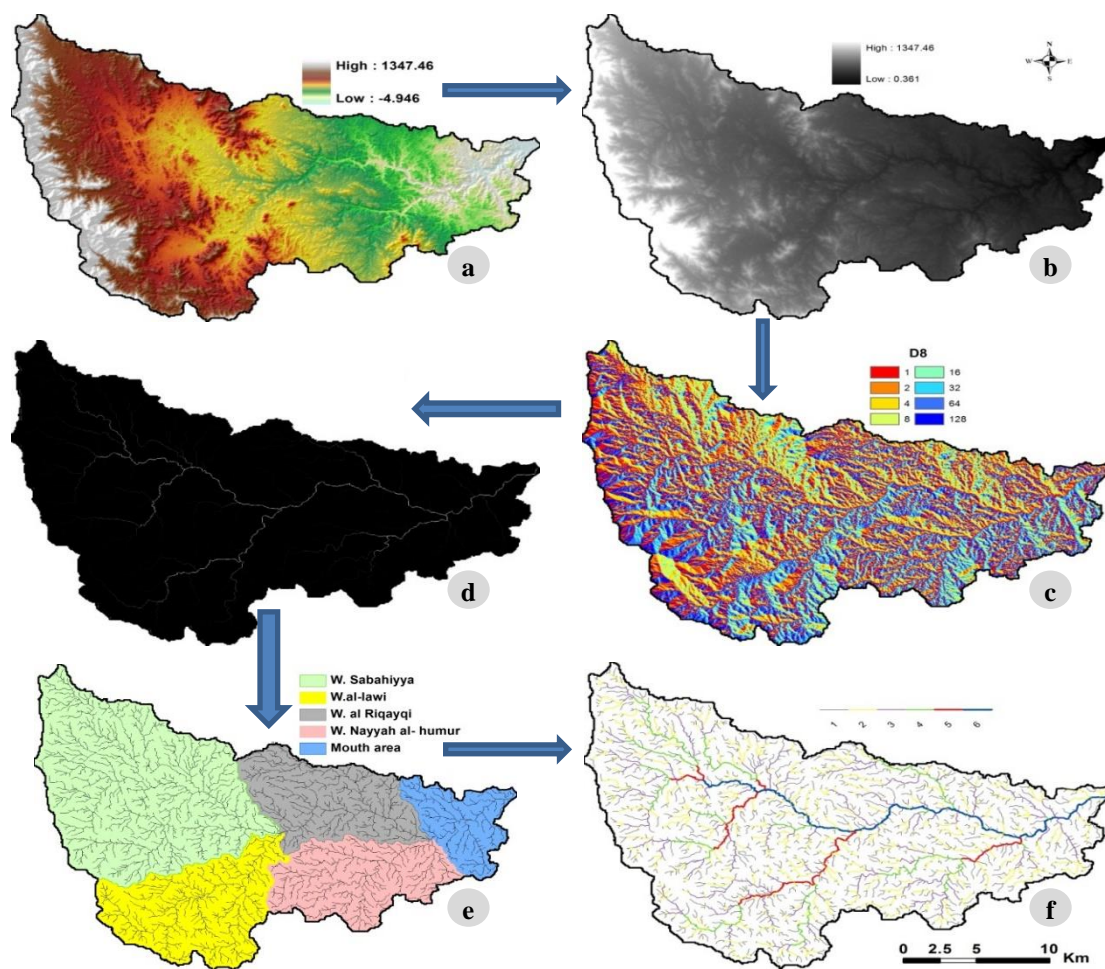**Figure (5):** Schematic flow chart diagram of the methodology adopted in the present study.

Figure (6): Automatic extraction of the drainage network of W. Ghadir from SRTM DEM, (a) The 30-m resolution DEM (b) Filled DEM, (c) Flow direction, (d) Flow accumulation raster, (e) The delineated five sub-basins of W. Ghadir basin, and (f) stream orders of the drainage network.
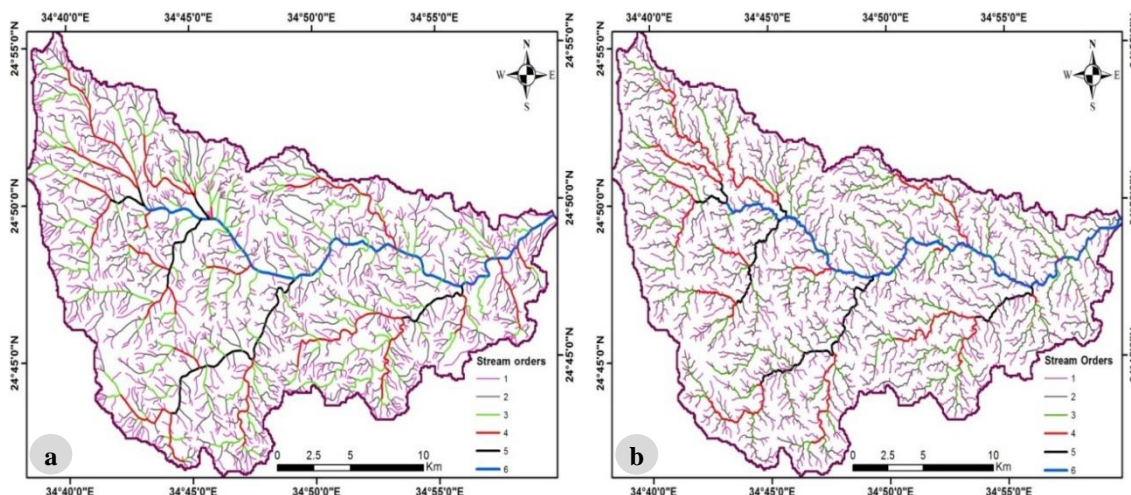

Figure (7): Drainage network of W. Ghadir basin: a) manually-traced from topographic maps and b) automatically-extracted from 30-m spatial resolution SRTM DEM.
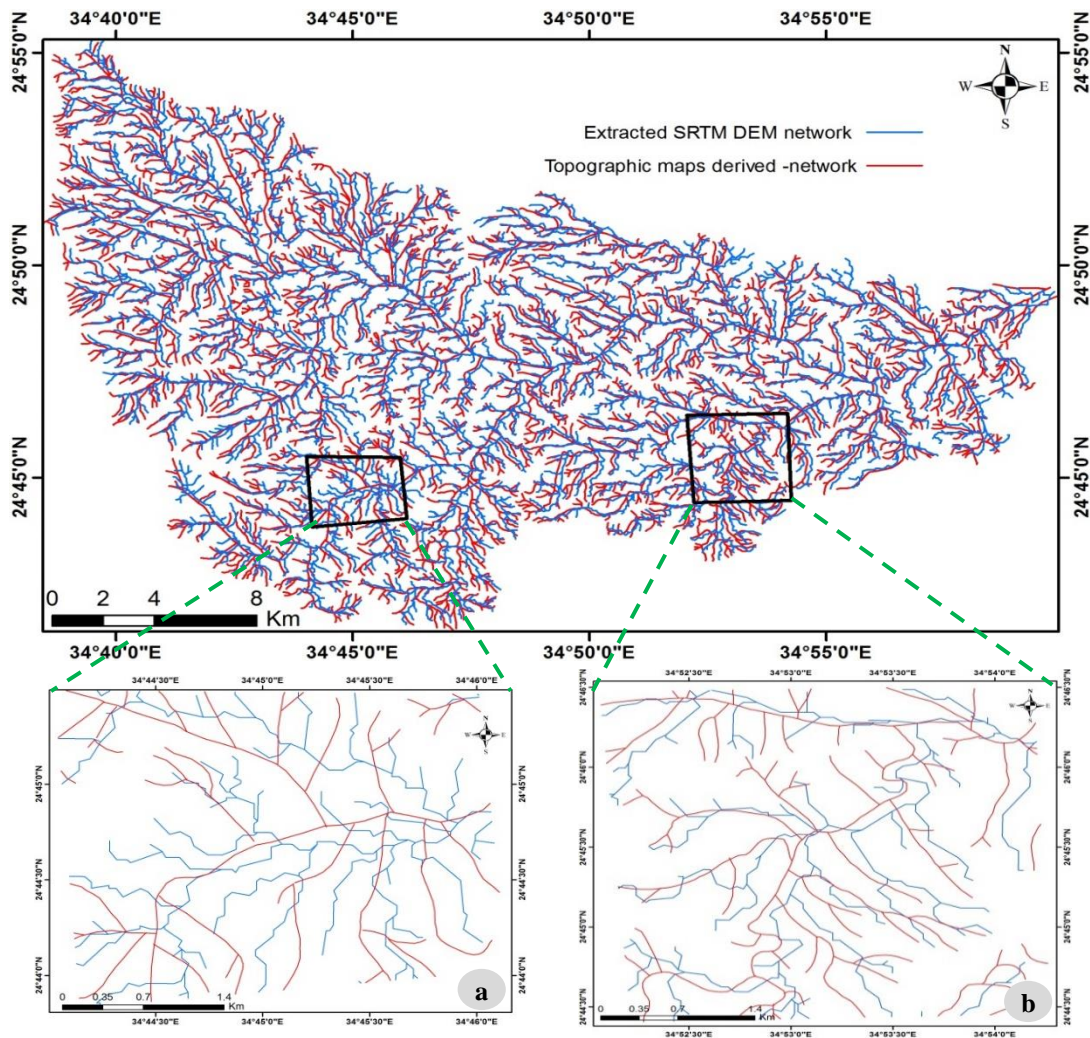
Figure (8): Cross-comparison of drainage networks derived from topographic maps and SRTM DEM and (a, b) two large scale tested areas for clarification.

The drainage network derived from topographic maps was superimposed on the drainage network extracted from SRTM DEM (Fig. 8) to enhance the agreements and differences between the two networks. Morphometric parameters of W. Ghadir drainage basin and its sub-basins were estimated and listed in Table (1). The basic morphometric attributes estimated such as basin area (A); basin perimeter (P); stream order (Nu); stream length (Lu); bifurcation ratio (Rb); drainage density (Dd); stream frequency (F) ... etc. The comparison of the morphometric characteristics of the two networks was evaluated and graphically represented in Figure (9).

2. Results and Discussions

Results showed that both the DEMs and current GIS algorithms have basic imperfections. However, the drainage morphometry results based on extracted rivers from DEM are similar to natural network in the raster format and for whole catchment area but there are many differences. The comparison also showed better agreement in the mountainous areas and marked differences were found in the alluvial fans and plain areas. Some basic parameters (assessed from the two data sources) needed for comparison and the geomorphometric analysis are summarized in Table (1) and accentuated by graphical representation (Fig. 9) to protrude differences between both data sources. Such results will be discussed in the following sections.
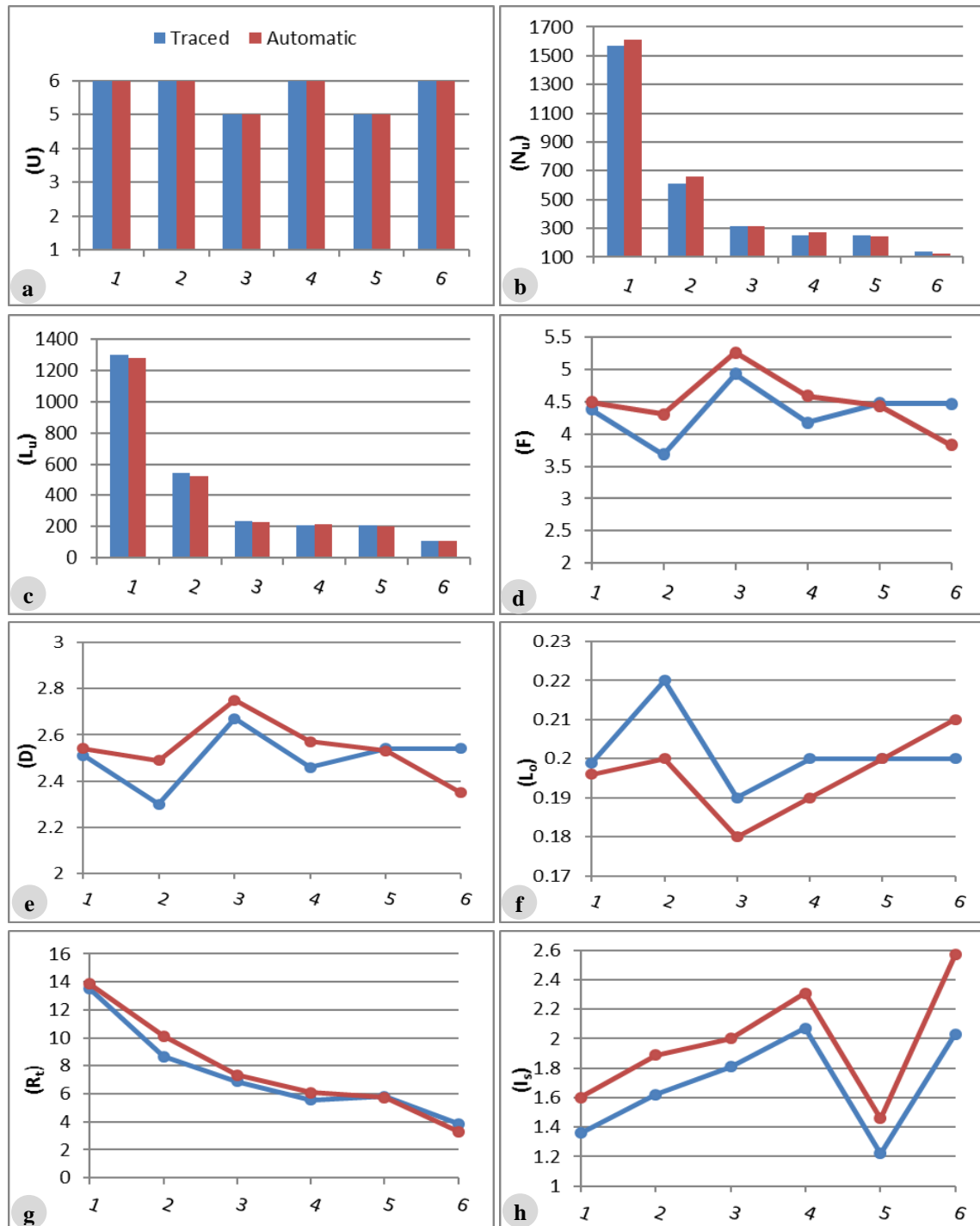
Figure (9): (a-h) Diagrams show differences and agreements between some drainage network characteristics and morphometric parameters of both convential (traced) and automatic drainage networks of W. Ghadir drainage basin and its sub-basins. Note: (1) W. Ghadir (2) W. Sabahiyya, (3) W. al-lawi, (4) W. al Riqayqi, (5) W. al- Humur and (6) Ghadir down area. For abbreviations see table (1).

Stream order analysis shows that the basin attains the sixth order in both drainage networks derived from DEM and topographic maps (Fig. 9a). The number of the stream orders about 2224 from DEM and 2182 from topographic maps and the number of the first-order streams about 1614 from DEM and 1568 from topographic maps, which are underestimated by the lower ground resolution topographic data compared to DEM (Figs. 8a, b and 9b). This is demonstrating the DEM sensitivity to the hydrological analysis.

Table (1): Statistics of various geomorphometric characteristics of the both drainage networks (extracted from topographic maps and SRTM DEM) of W. Ghadir drainage basin and its sub-basins.

Morphometric parameters of W. Ghadir drainage basin and its sub-basins

Catchment area	A	L	W	P	H	Rr	Rg	Rf	Rc	Re	Co
Ghadir	499.7	33.1	14.7	162.3	1365	41.2	4.17	0.45	0.23	0.76	2.04
Sabahiyya	204.0	18.5	15.7	86.6	1300	14.9	3.05	0.59	0.34	0.78	1.71
al-lawi	89.7	13.5	7.7	64.2	1160	18.0	2.88	0.49	0.27	0.79	1.91
al Riqayqi	80.0	12.1	6.2	60.2	512	8.49	1.29	0.54	0.27	0.83	1.90
al-Humur	78.0	13.7	7.5	60.5	520	8.50	1.43	0.41	0.26	0.72	1.93
Ghadir down	41.8	7.4	4.7	48.3	230	4.75	0.59	0.76	0.22	0.98	2.11

Numbers and lengths of each order stream segments in W. Ghadir drainage basin and its sub-basins for both topographic maps and DEM-extracted drainage nets

Catchment area	1st				2nd				3rd				4th				5th				6th				Total			
	N_{dem}	N_{top}	L_{dem}	L_{top}	N_{dem}	N_{top}	L_{dem}	L_{top}	N_{dem}	N_{top}	L_{dem}	L_{top}	N_{dem}	N_{top}	L_{dem}	L_{top}	N_{dem}	N_{top}	L_{dem}	L_{top}	N_{dem}	N_{top}	L_{dem}	L_{top}	N_{dem}	N_{top}	L_{dem}	L_{top}
Ghadir	1614	1568	622	624	457	460	316	325	127	124	174	192	19	23	81	95	6	6	33	30	1	1	40	35	2224	2182	1278	1301
Sabahiyya	657	611	254	260	170	188	127	141	36	52	64	78	10	12	42	42	4	5	13	17	1	1	18	17	879	869	521	545
al-lawi	314	313	116	120	126	101	54	55	28	24	32	31	3	4	15	15	1	1	8	7	-	-	-	-	472	443	226	235
al Riqayqi	270	250	105	100	79	68	48	55	14	15	31	27	2	1	10	10	1	-	0.3	-	1	1	16	13	367	335	211	207
al-Humur	245	254	97	99	59	70	58	49	39	20	27	35	3	3	13	17	1	1	6	5	-	-	-	-	346	351	201	206
Ghadir down	128	140	50	55	23	33	29	25	7	10	15	15	1	3	0.32	4	-	-	-	-	1	1	12	9	160	187	108	108

Selected morphometric parameters for both topographic maps-traced drainage net and SRTM DEM-extracted drainage net.

Catchment area	U_{dem}	U_{top}	$R_{t\,dem}$	$R_{t\,top}$	$R_{b\,dem}$	$R_{b\,top}$	F_{dem}	F_{top}	D_{dem}	D_{top}	$L_{o\,dem}$	$L_{o\,top}$	$I_{S\,dem}$	$I_{S\,top}$
Ghadir	6th	6th	13.85	13.5	4.60	3.47	4.49	4.38	2.54	2.51	0.196	0.199	1.60	1.36
Sabahiyya	6th	6th	10.14	8.67	3.74	4.36	4.304	3.68	2.49	2.30	0.20	0.22	1.89	1.62
al-lawi	5th	5th	7.35	6.90	4.83	4.33	5.262	4.93	2.75	2.67	0.18	0.19	2.00	1.81
al Riqayqi	6th	6th	6.10	5.56	4.52	7.7	4.588	4.18	2.57	2.46	0.19	0.20	2.31	2.07
al-Humur	5th	5th	5.72	5.79	5.43	4.20	4.435	4.48	2.53	2.54	0.20	0.20	1.46	1.22
Ghadir down	6th	6th	3.31	3.87	5.28	3.63	3.828	4.47	2.35	2.54	0.21	0.20	2.57	2.03

Note: basin parameters include: Basin area (A, km²), Basin length (L, km), Basin width (W, km), Basin perimeter (P, km), Basin relief (H, m), Relief ratio (R_r), Ruggedness number (R_g), Form factor (R_f), Circularity ratio (R_c), Elongation ratio (R_e) and Compactness coefficient (C_o). (dem) and (top) parameters estimated from the extracted from drainage network from SRTM DEM and topographic maps, respectively. Drainage networks statistics for each order include: Number of streams derived from SRTM DEM (N_{dem}), Number of streams derived from topographic maps (N_{top}), Total length of streams extracted from DEM (L_{dem}, km) and Total length of streams traced from topographic maps (L_{top}, km). Drainage networks morphometric parameters include: Stream order (U), Texture ratio (R_t), Bifurcation ratio (R_b), Drainage density (D, km.km-2), Stream frequency (F, n/km²), Length of overland flow (L_o) and Sinuosity index (I_s).

The stream lengths about 1278 km from DEM and 1301 km from topographic maps (Fig. 9c). However, a common spatial pattern of stream network is observed. The spatial pattern of the stream networks shows lateral shift in the streams derived from DEM (Figs. 8a and b).

Bifurcation ratio (Rb), a proxy of the degree of drainage integration, has a significant control over the runoff peakedness (Horton 1945; Strahler 1964). (Rb) has a theoretical minimum value of (2) which is rarely approached under natural conditions, and typical values range between 3 and 5 for flat and mountainous dissected areas, respectively (Strahler, 1957). The measured (Rb) values of the manually-traced topographic maps network (3.47) are lower than that of DEM-extracted network (4.60) of W. Ghadir basin. Relatively and collectively, (Rb) values of the studied drainage basin are moderate to high, indicating the structural disturbance in the area (Reddy et al., 2004), which is simply shown on the given geologic map as lineaments (Fig. 3).

The stream frequency (F) analysis of the drainage network derived from the topographic maps has a slightly lower F (4.38) value than that derived from the DEM (4.49) (Table 1 and Fig. 9d). W. al-humur sub-basin shows a high agreement of stream frequency between the two-derived drainage networks (Fig. 9d). Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity (Reddy et al. 2004; Shaban et al. 2005) which constitute the common conditions for the widely outcropping basement rocks of W. Ghadir drainage basin.

Drainage density (Dd) reasonably indicates the landscape dissection, runoff potential, infiltration capacity of the land, climatic conditions and vegetation cover of the basin (Verstappen 1983; Patton 1988; Macka 2001; Reddy et al. 2004). W. Ghadir drainage network derived from the DEM has a slightly higher (D) value (2.54) than that derived from the topographic maps (2.51). the resulting values of (D) for the four sub-basins are relatively coincides (Fig. 9e).

Length of overland flow (Lo) shows a witness agreement of their values of the two drainage systems of the W. Ghadir basin and its sub-basins (Fig. 9f) and ranged from 0.196 to 0.99 (Table 1).

Ruggedness Number (Rg) is sensitive to runoff process, where the increasing in (Rg) value means increasing in relief and drainage density of the basin. DEM is excellent tool for giving relief of W. Ghadir basin. Ruggedness number (Rg) is particularly useful because it summarizes the interaction of relief and dissection. Where highly dissected basins of low relief are as rugged as moderately dissected basins of high relief. Flooding (runoff) is increased with increasing drainage basins ruggedness (increase relief and drainage density). Ruggedness number values range from as low as 0.06 in subdued relief to over 1.0 in badlands (Strahler, 1958). The registered value in the study area is (4.17). Due to using the same basin parameters, the (Rg) value for the drainage network derived from the DEM is very close to that of the drainage network derived from the topographic maps (Fig. 9g).

Sinuosity index (Is) for the two drainage networks displayed parallel and positive agreements for the values of W. Ghadir drainage basins and its sub-basins (Fig. 9h). Generally, (Is) values for the drainage network extract from DEM recorded higher values and this reflect the sensitivity and accuracy of DEM to produce a detailed drainage network.

3. Conclusion

The present study aims to assess the morphometric parameters of the drainage networks extracted from 30-m resolution SRTM DEM and that derived from topographic maps at scale of 1:50.000. Generally, the drainage networks derived from both sources emerge considerable agreements and plausible accord. DEM-derived drainage network exhibits overestimation of lower order streams, which might be attributed to spatial variation of elevation, raster grid size and vertical accuracy of the DEMs, as well as, incapability of the surface hydrologic analysis functions in the GIS platform. This study also revealed that a comparison of the morphometric attributes of both drainage networks derived from topographic maps and DEMs should be considered to determine their differences.

From SRTM DEM, Archydro function in ArcGIS have deciphered and predicted a conceivable accurate boundaries and drainage networks of watershed areas accentuating DEM competence and potency for watershed modeling with satisfactory performance. Furthermore, results accuracy provides scientific base to use remote sensing and GIS techniques for continuous mapping hydrological systems. The results of the present study offered that SRTM (despite the coarser spatial resolution) provides better results, in drainage delineation and basin morphometry, compared to topographic maps. Further, the variability of basin morphometry among the data sources might be attributed to spatial variation of elevation, raster grid size and vertical accuracy of the DEMs, as well as, incapability of the surface hydrologic analysis functions in the GIS platform.

References

Abd El-Rahman, Y., Polat, A., Dilek, Y., Fryer, B.J., El-Sharkawy, M. and Sakran, S. (2009): Geochemistry and tectonic evolution of the Neoproterozoic Wadi Ghadir ophiolite, Eastern Desert, Egypt: Lithos, 113:158–178.

Ahmed S.A., Chandrashekarappa K.N., Raj S.K., Nischitha V, Kavitha G. (2010) Evaluation of morphometric parameters derived from ASTER and SRTM DEM: a study on Bandihole subwatershed basin in Karnataka. J Indian Soc Remote Sens. 38:227–238.

Basta, F. F. (1983): Geology and geochemistry of the ophiolitic mélange and other rock units in the area around and west of Gabal Ghadir, Eastern Desert, Egypt. Ph.D. Thesis, Cairo University, 137.

Becek, K. (2008): Investigating error structure of shuttle radar topography mission elevation data product. Geophys. Res. Lett. 35 (15).

Chorley, R. J. and Dale, P. F. (1972): Cartographic problems in stream channel delineation, Cartography 7:150–162.

Clarke S, Burnett K. (2003) Comparison of digital elevation models for aquatic data development. Photogramm Eng Remote Sens. 69:1367–1375.

Drummond, R. R. (1974): When is a stream a stream? Professional Geographer, 26:34–37.

Egyptian General Survey Authority (1989): Topographic sheets of East Ghadir, Ghadir, Hafafit and Sikait, Scale 1:50.000, Cairo.

El-Bayoumi, R. M. (1980): Ophiolites and associated rocks of Wadi Ghadir, East of Gebel Zabara, Eastern Desert, Egypt. Ph. D. thesis, University of Cairo, Egypt, 227 p.

El-Sharkawy, M. A. and El-Bayoumi, R. (1979): The ophiolites of Wadi Ghadir area, Eastern Desert, Egypt. Ann of Geo Surv of Egypt 9: 125-135.

Fairfield, J. and Leymarie, P. (1991): Drainage networks from grid digital elevation models. Water Resources Research, 27(5): 709-717.

Falorni, G., Teles, V., Vivoni, E.R., Bras, R.L., Amaratunga, K.S., (2005): Analysis and characterization of the vertical accuracy of digital elevation models from the Shuttle Radar Topography Mission. J. Geophys. Res. F: Earth Surface 110 (2).

Fowler, A. and Osman, A.F., (2009): The Sha'it-Nugrus shear zone separating Central and South Eastern Deserts, Egypt: a post-arc collision low-angle normal ductile shear zone. J. Afr. Earth Sci. 53:16–32.

Garbrecht, J. and Martz, L. W. (2000): Digital elevation model issues in water resources modeling. In: Maidment D, Djokic D. (Eds.) Hydrologic and Hydraulic Modeling Support with Geographic Information Systems. ESRI Press: Redlands, USA, 1-28.

Garcia, M. J. and Camarasa, A. M. (1999): Use of Geomorphological units to Improve Drainage Network Extraction from a DEM, JAG J., 1(3/4): 187-195.

Gelabert, B., Fornos, J. J., Pardo, J. E., Rossello, V. M. and Segura, F. (2005): Structurally controlled drainage basin development in the south of Menorca (western Mediterranean, Spain) geomorphology, 65: 139-155.

Horton, R. E. (1945): Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. Geol. Soc. Amer. Bull., 56: 275-370.

Jenson, S. K. (1991): Applications of hydrologic information automatically extracted from digital elevation models. Hydrological Processes, 5(1):31-44.

Jenson, S. K. and Domingue, J. O., (1988): Extracting topographic structure from digital elevation data for geographic information system analysis. Photogrammetric Engineering and Remote Sensing, 54(11):1593-1600.

Jones, R., (2002): Algorithms for using a DEM for mapping catchment areas of stream sediment samples. Computer and Geosciences, 28(9): 1051-1060.

Kamel, M., Youssef, M., Hassan, M. and Bagash, F. (2016): Utilization of ETM+ Landsat data in geologic mapping of wadi Ghadir-Gabal Zabara area, Central Eastern Desert, Egypt. The Egyp J of Rem Sen and Spa Sci, 19 (2): 343-360.

Kervyn, F. (2001): Modelling topography with SAR interferometry: illustrations of a favourable and less favourable environment. Comput. Geosci. 27 (9): 1039–1050.

Lin, Z. and Oguchi, T. (2004): Drainage density, slope angle, and relative basin position in Japanese bare lands from high-resolution DEMs. Geomorphology, 63: 159-173.

Lindsay J.B., Evans M.G. (2008): The influence of elevation error on the morphometrics of channel networks extracted from DEMs and the implications for hydrological modelling. Hydrol Processes. 22:1588–1603.

Macka, Z. (2001): Determination of texture of topography from large scale contour maps. GeograFki Vestnik 73(2): 53–62.

Mahtab A, Narender B, Ajai. (2003): Satellite derived digital elevation model and terrain parameters: generation, accuracy assessment and validation. J Indian Soc Remote Sens. 31:19–24.

Mark, D. M. (1983): Relations between field-surveyed channel networks and map based geomorphometric measures, Inez, Kentucky. Ann. Assoc. of American Geographers, 73(3):358-372.

Marston, B. E., Jenny, B. (2015): Improving the representation of major landforms in analytical relief shading. International Journal of Geographical Information Science, 59(7): 1144-1165.

Martz, L. W. and de Jong, E., (1988): A FORTRAN program for measuring catchment area from digital elevation models. Computer and Geosciences, 14(5):627-640.

Martz, L. W. and Garbrecht, J., (1995): Automated recognition of valley lines and drainage networks from grid digital elevation models: a review and a new method - comment. J. of Hydrology, 167: 393-396.

Miliaresis, G. C. (2008): The land cover impact on the aspect/slope accuracy dependence of the SRTM-1 elevation data for the Humboldt range. Sensors 8(5): 3134–3149.

Moore I.D., Grayson R.B., Ladson A.R. (1991): Digital terrain modelling: a review of hydrological, geomorphological, and biological applications. Hydrol Processes. 5:3–30.

Morris, M. E. and Heerdegen, R. G., (1988): Automatically derived catchment boundary and channel networks and their hydrological applications. Geomorphology, 1(2):134-141.

O'Callaghan, J. and Mark, D. M. (1984): The extraction of drainage networks from digital elevation data. Comput Vis Graph Image Proce, 28: 323–344.

Patton, P. C. (1988): Drainage basin morphometry and floods. In: Baker VR, Kochel RC, Patton PC (eds) Flood geomorphology. Wiley, USA, 51-65.

Reddy, G. P., Maji, A. K. and Gajbhiye, K. S. (2004): Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India - a remote sensing and GIS approach. Int. J. Appl Observ Geoinf, 6: 1-16.

Rinaldo A, Rodrıguez-Iturbe I, Rigon R. (1998); Channel networks. In: Jeanloz R, Albee AL, Burke KC, editors. Annual review of earth and planetary sciences. Palo Alto, CA: Annual Reviews,. 26: 289–327.

Shaban, A., Khawlie, M., Abdallah, C. and Awad, M. (2005): Hydrological and Watershed characteristics of the El-Kabir River, North Lebanon. Lakes Reserv Res Manage 10:93–101.

Strahler, A. N. (1952a): Dynamic basis of geomorphology. Bull Geol Soc Am 63:923–938.

Strahler, A. N. (1952b): Hypsometric (area-Altitude) analysis of erosional topography. Geol. Soc. American Bull., 63: 1117-1142.

Strahler, A. N. (1957): Quantitative analysis of watershed geomorphology. Trans Am Geophys Union. 38: 913-920.

Strahler, A. N. (1958): Dimensional analysis applied to fluvially eroded landforms. Geol Soc Am Bull. 69:279–300.

Strahler, A. N. (1964): Quantitative geomorphology of drainage basin and channel networks. In: Chow VT (Ed) Handbook of applied hydrology. McGraw Hill Book Co., New York, 4–76.

Takla, M. A., Basta, F. F., Shenouda, H. H. and El-Maghraby, A.M. (1992): Geochemistry of gneisses and granitoids of Wadi Ghadir area, Eastern Desert, Egypt. Geology of the Arab World 1st., 477–506.

Takla, M. A., El-Sharkawi, M. A. and Basta, F. F. (1982): Petrology of the basement rocks of Gabel Mohagara-Ghadir area, Eastern Desert, Egypt. Annals. Geol. Surv. Egypt. XII:121-140.

Tarboton D. G., Bras R.L., Rodriguez-Iturbe I. (1991): On the extraction of channel networks from digital elevation data. Hydrol Processes. 5:81–100.

Tarboton, D. G. (1997): A new method for the determination of flow directions and upslope areas in grid digital elevation models. Water Resources Research, 33(2): 309-319.

Tucker, G. E., Catani, F., Rinaldo, A. and Bras, R. L. (2001): Statistical analysis of statistical analysis of drainage density from digital terrain data. Geomorphology, 36: 187-202.

Verstappen, H. Th. (1983): Applied geomorphology. ITC, Enschede.

Wu S, Li J, Huang G.H. (2008) A study on DEM-derived primary topographic attributes for hydrologic applications: sensitivity to elevation data resolution. Appl Geography. 28:210–223.

Zhang W, Montgomery D.R. (1994): Digital elevation model grid size, landscape representation, and hydrologic simulations. Water Resour Res. 30:1019–1028.