Drainage Network Analysis, Comparis of Digital Elevation Model(DEM) from ASTER with High Resolution Satellite Image and Areal Photographs

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Abstract--**Digital Elevation Model (DEM) data have been used to derive hydrological features, which serve as inputs to various models. Currently, elevation data are available from several Major sources and at different spatial resolutions. This paper shows the quality and accuracy of drainage network analysis resulted from ASTER DEMs. Hydrology toolsets in the when we used the vector datasets for Analyzing in separate land features. The agreement degree between two layers is very low for spatial pattern, river frequency and drainage density in lowland areas. ArcGIS package was used to extract drainage networks from a grid DEM for cheshmehkhan catchment in the northeastern of Iran. We have compared the Extracted networks from DEM (DEM layer) with the one derived from aerial photographs and high resolution satellite Images as real ground (Geo layer). Results showed both the DEMs and current GIS algorithms have basic imperfections. However, the drainage morphometry results based on extracted rivers from DEM are similar of Natural network in the raster format and for whole catchment area but there are many large differences.**

***Index Terms*— DEM Analysis, Geomorphology, raster and vector data, River network extraction**

I. Introduction

Digital Elevation Models are elevation data that collect by remote sensing methods or by transforming the contour maps to raster format by digitizing and surface analyzing [9]. These data have been used vastly in Geomorphology, Hydrology, Geology and other studies. Currently, elevation data are available from several Major sources with low to high spatial resolutions (table 1).

Many algorithms have been developed to derive basic topographic characteristics or features from DEMs, such algorithms include extracting drainage networks [12] and delineating watersheds [1], [3]. Basic geomorphic or topographic attributes extracted from DEMs often serve as inputs to other Models. Thus, DEMS and related algorithms provide the foundations of scientific in queries related to environment and topography.

The degree of quality and accuracy of DEMS and the nature of algorithms are basic questions for above Analysis. In another words relationships between resolutions and analysis results are often not quite simple. Kienzle shows that liner relationship exists between resolution and certain terrain derivatives such as slope, but not others [10].

Therefore in this paper we examined the quality and accuracy of Advanced Space born Thermal Emission and Reflection Radiometer (ASTER) DEMs by Comparison of Extracted river networks resulted from an ASTER DEM with the one derived from high resolution aerial photographs and satellite Images.

TABLE I: DEM sources [17]

DEM creation method	DEM type	Nominal resolution (m)	Relative vertical resolution (m)
Space born Photogrammetric	Terra (ASTER)	30	2
	Spot 5	30	10
	Ikonos	2	15
	HRSC	50	20
	HRISE	1	0.2
Space born IfSAR	SRTM-c-band	90	10
	SRTM-x-band	30	6
	ERS Tandem	25	20
	Terra SAR	12	< 2
	Terra ASAR	25	20
Air born	IF SAR	1-5	2.1
	LIDAR	< 2	< 0.25
Other	MOLA	460(DEM)	0.38

II. Method and Materials

Focusing on data accuracy information may lead one to conclude that using the highest resolution data (in this case, LIDAR) is the most appropriate. However, many studies have shown that highest resolution data may not perform the best as the scale of data may not effectively capture the phenomenon under investigation or to be modeled. In addition, LIDAR data are not available everywhere at this point. Other sources of DEM of lower resolutions will be needed [10], [11], [8]. A single global Root Mean Squared Error (RMSE) is not sufficient to assess the spatial variability of DEM errors, especially for extensive regions. Therefore we need to comprise the DEM analysis results with a criteria near the real ground.

The method employed to evaluation of degree adjustment

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between the drainage network extracted automatically from a DEM and the network delineation from photographs and satellite Images comprises three steps:

Drawing rivers from aerial photographs and satellite Images, automated delineation from an ASTER DEM by ArcGIS package and comparison of the two results in raster and vector formats:

A. River delineation from aerial photographs and satellite Images

The river network of the study area was drawn from IRS pan satellite Image (2004) and photo interpretation of 1:20000 scale aerial photographs (1970) combined contour with field works. The criterion used to define first – order channels were they have channel morphology and a length of over 50m. River's network has been digitized by ArcGIS sketch tools after geometric transformation of image and aerial photographs in UTM coordinate system. This map has used as real ground to comprise the automated river network extraction in GIS method.

B. extraction of network from ASTER DEM by GIS

The extraction of the drainage network of the study area carried out from an ASTER DEM, in raster format with a 30m*30m grid cell size, which was provided by Japanese scanner has been installed on the Terra satellite in 1999[17]. Hydrological tools in ArcGIS software, version 9.3 (ESRI 2008) was used to extract drainage channels. The automated method for delineating streams followed a series of steps (figure 4) starting with a filled DEM. the recognition of individual DEM cells as channel cells, where a cell is classified as a channel if certain cells surrounding it are higher than that cell [4],[15],[19]. A common problem with drainage network delineation using DEM is the presence of sinks [13], in fact the main problems are the positioning of the ends of drainage networks and the assignment of flow directions to individual cells, particularly in flat areas and depressions [20]. Therefore the sinks are commonly removed prior to DEM processing for drainage identification [16].

A filled DEM or elevation raster is void of depressions. 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 [3]. Therefore sinks must be removed from a DEM. A common method for removing a sink is to increase its cell value to lowest overflow point out of the sink [7]. There were 152 depressions in our elevation raster. We used the fill function in the Hydrology toolset of ArcGIS software to remove the depressions.

In the next step we made the flow direction raster. A flow direction raster shows the direction water will flow out of each cell of a filled DEM.A widely used method for deriving flow direction is the D8 method. This method used by ArcGIS, assigns a cell's flow direction to one of its eight surrounding cells that has the steepest distance – weighted gradient [14]. The D8 method produces good results in high gradient slops but it tends to produce flow in parallel lines along low steep areas [2]. Some researchers have suggested dividing the study areas to separate geomorphologic units and using the different values for each one to improve the extraction results [5]. Then We used the flow accumulation function in the ArcToolbox to extraction a flow accumulation raster which tabulates for each cell the number of cells that will flow to it. 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 rater. This activity is based on a threshold accumulation value. A higher threshold value will result in a less dense stream network and fewer sub basins than a lower threshold value. In this paper, we extracted several river network maps by definition of different threshold values. fter a stream network is derived from a flow accumulation raster, each section of the stream raster line is assigned a unique value and is associated with flow direction. A stream link raster therefore, resembles a topology –based stream layer that junctions are like nods, and river sections between junctions are like arcs or reaches. In the last stage, the rivers are ordered by Strahler method ordering [18] and transformed to vector layer for further analysis.

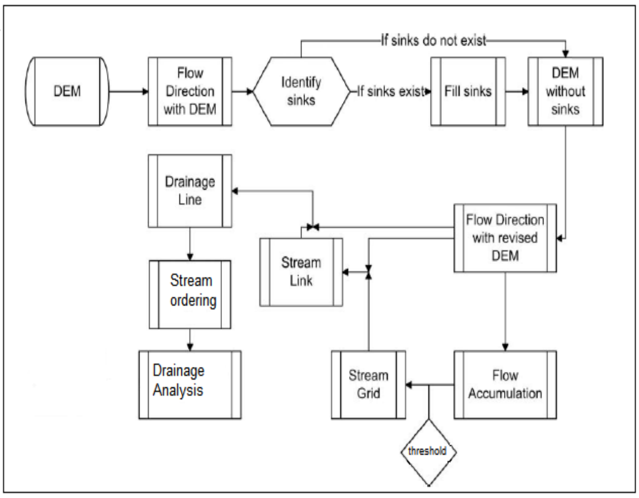

Fig.1. Conceptual work flow for drainage network Delineation [8]

C. Comparison Between two Drainage Networks

Obviously, both networks contain errors. For our comparison, we took the extracted networks from aerial photographs and images to be real stream channels. This is partly because the more detailed scale of the aerial photos and satellite images guarantees a good reference map with which to compare the network obtained from the DEM. The comparison process has been done in both raster and vector Formats. These comparisons are included morphometric characteristics as the river frequency, stream length, stream density and drainage ratio as well as the spatial pattern of the drainage lines, which was evaluated by visual analysis and calculating the degree of coincidence between two networks.

III. Study Area

The study area is a sub basin of Madarsu river located in the northeastern of Iran (Figure 2), drains an area of 520 km2. The catchment is situated upstream of the Madarsu basin, and it is overall terrain presents distinct variability with elevation varying from 960 to 2440 m. the basin is been divided to four geomorphologic units, mountain, pediment, alluvial fans and aggraded plain.

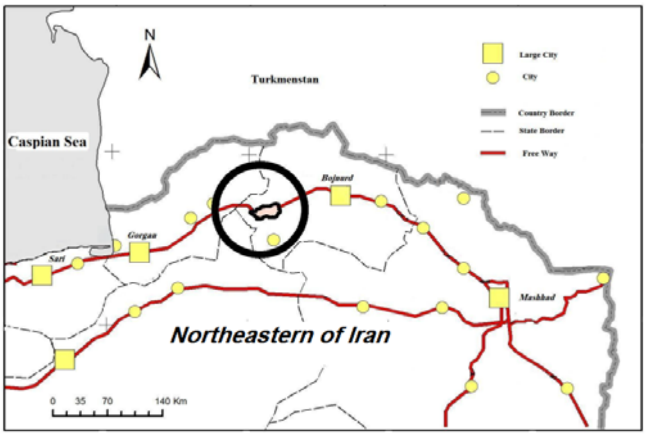

Fig .2. Study area is located in the northeastern of Iran

IV. RESULTS

A. *Comparison of stream attributes*

Visual study and numerical results highlight only a network Map which is derived in 25 thresholds value is near to the real network map (Geo). We recognized decreasing of river orders and cell frequencies in higher threshold values. The comparison of the cell and river frequencies show good agreement for all stream orders but there are large differences for 4, 5 and sixth- order streams. The differences have been measured 77, 73 and 76 percents for 4, 5 and sixth-order rivers respectively (table II). It means the distribution of first-Order Rivers have a big difference with natural drainage patterns. Thus, we have done the comparison analyzing in the separate geomorphologic units of mountain, pediment, alluvial fans and plain (figure 3).

TABLE II: THE RIVER FREQENCY DIFFRENCES

Stream order	Stream Frequency (from Geo)	Stream Frequency (from DEM)	Differences Amount (%)
1	4779	5348	11
2	1187	1443	18
3	337	437	23
4	137	415	77
5	31	116	73
6	11	46	76
7	1	1	0
Sum	6483	7806	17

Comparison results for stream frequency have been presented in figures 5 to 8. In the Cheshmehkhan catchment, the comparison between two extracted networks showed better agreement in the mountain areas only for first and second-order streams (70 percent agreement between two maps). The highest differences were found in the alluvial fans and plain area (between 32.6 to 87.5 percents in different orders).

The results for river lengths show satisfied agreement degree for pediment and mountain sectors, especially for second-order Rivers (92.5 and 86.3 percents for pediment and mountain areas respectively). We found the lower agreement degrees for alluvial fans and plain sectors (Figure 9). We found the raster comparisons give higher agreement in all geomorphologic units than the vector results. Many researchers have shown their results based on rater analysis but its not correct method because drainage morphometry needs to vector data and cell frequency lead us to incorrect analysis.

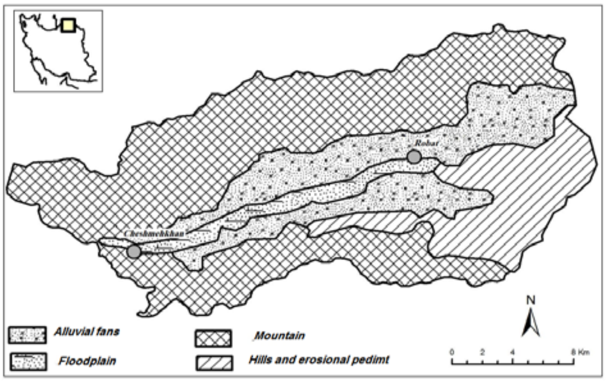

Fig.3.The map of Geomorphology units study area

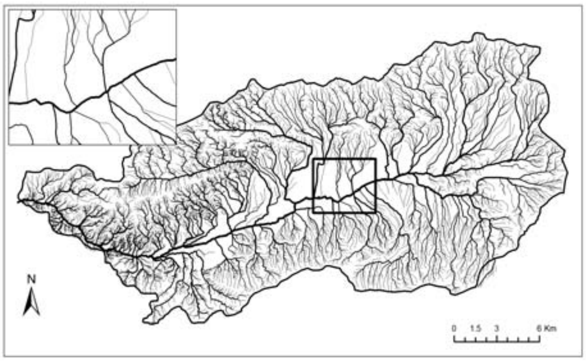

Fig.4. The Rivers extracted from areal photos and satellite images

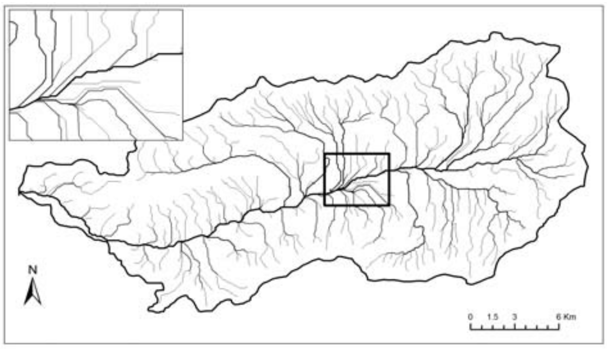

Fig.4. The Rivers extracted from DEM in 500 threshold

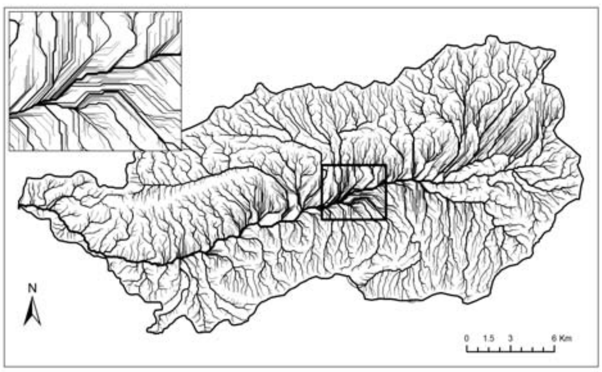

Fig.4. The Rivers extracted from DEM in 500 threshold

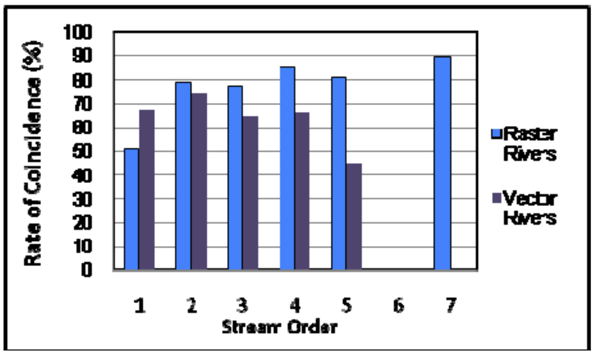

Fig.5. Agreement degree of river frequencies (%) between delineated networks from ASTER DEM and Satellite images in the mountain area

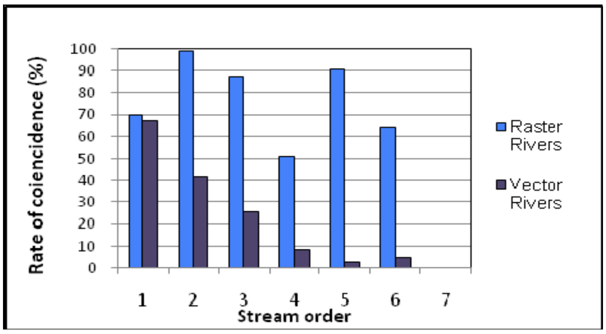

Fig.6. Agreement degree of river frequencies (%) between delineated networks from ASTER DEM and Satellite images in the pediment area

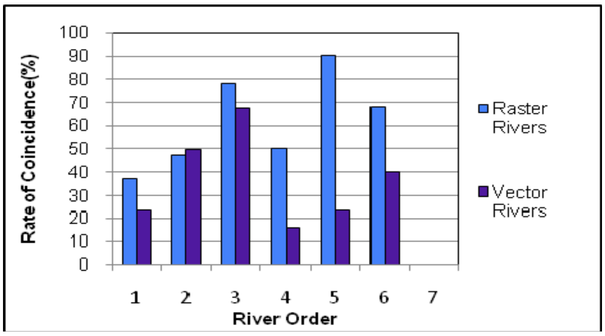

Fig.7. Agreement degree of river frequencies (%) between delineated networks from ASTER DEM and Satellite images in the alluvial fans

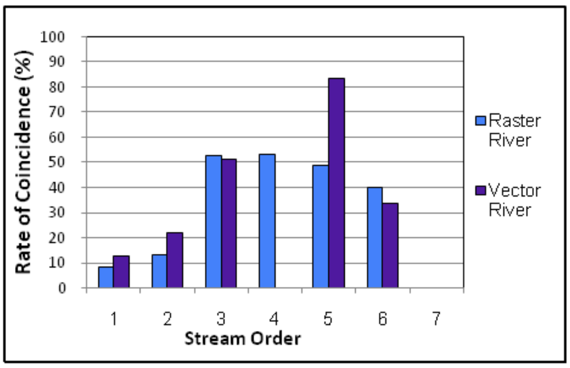

Fig.8. Agreement degree of river frequencies (%) between delineated networks from ASTER DEM and Satellite images in the plain area

B. Comparison of stream Spatial patterns

The comparison of the spatial patterns of the two drainage networks (Figure 10) reveals poor agreement. It has been measured only 31.75 percent for whole catchment area and all rivers but between 15-20 percent for first to fourth river order and lower than 10 percent for other orders. The maximum of overly degree has been found on the pediment area for fourth-order streams. It means the DEM resolution of 30*30 meters is not enough to locate the rivers in accurate locations. We avoided of any increasing cell size of Raster Rivers for overlay analysis, because the high drainage density in both layers causes unreal stream junction and changes the river courses.

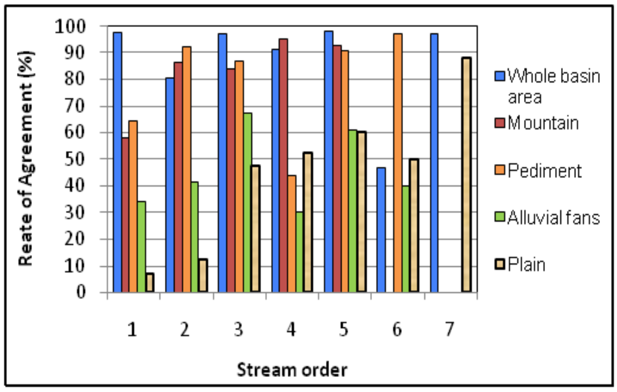

Fig.9. Agreement degree (%) of river length between delineated networks from ASTER DEM and Satellite images

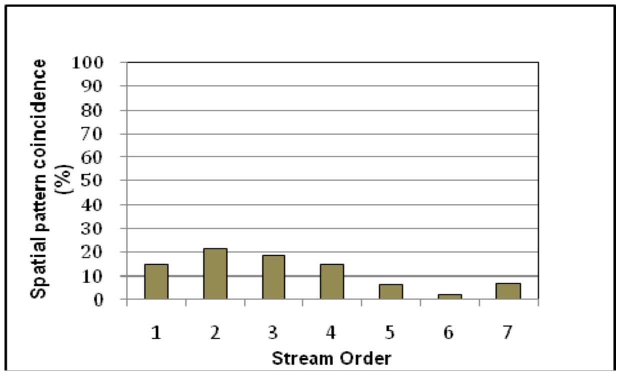

Fig.10. Agreement degree (%) of spatial location between delineated networks from ASTER DEM and Satellite images in the pediment area

C. Comparison of Drainage Density

The Drainage density calculated for whole basin area shows good agreement between rivers, which extracted by different methods. Obviously, differences appear in separate Geomorphologic units as we can see completely incorrect results for alluvial fan and plain sectors for rivers delineated from DEM (Figure 11). The best agreement of drainage density is been recognized for the pediment where the surface slop is moderate. In the mountain area drainage density for Geo's layer is higher than the layer extracted from DEM while the results are inversely for alluvial fans and plain areas. Then it should be better to use the results only for mountain and pediment units.

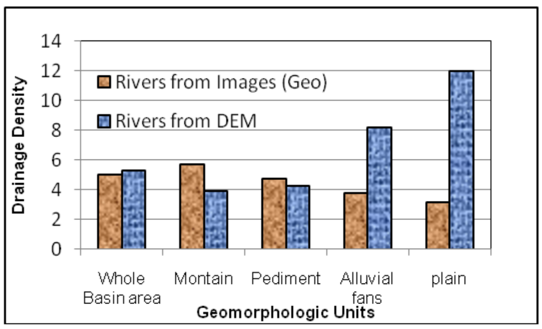

Fig.11. Comparison of Drainage Density in different land units

V. Conclution

ASTER DEMs have an enough resolution for extracting of first and second-order rivers in mountain areas with 25 thresholds values without of resampling elevation data. The morphometric analysis based on extracted networks from ASTER DEMs give incorrect results through alluvial fan and plain areas but there is a good agreement for river length in the mountain and pediment sectors. 30*30 in resolution of ASTER DEMs is not enough to derive river networks in the alluvial fan and plain sectors. It is possible to increase the threshold values for network extraction on the alluvial fan and plain sectors (250 for alluvial fans and 500 for plain area). Therefore, we suggest that automated river extraction from DEMs can be improved by dividing the basin into geomorphological units and using a different threshold in each unit. The best method for river extraction can be using the high resolution of aerial photograph and satellite images; however, it takes a long time than the automated method.

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