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Gis-Based Watershed Characterization Using Aster Data in Kardeh Watershed, Iran

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Abstract: One of the major steps in watershed studies including erosion and flood modeling is to identify and extract the physical parameters of the watershed. In traditional methods, these parameters based on their significant roles in simulating hydrological models are extracted using topographic maps. Through the recent years, with the development of earth observation technology, free digital elevation model become available such as SRTM and ASTER data. Spatial resolution is one of the main characteristics in surveying details from geographical features. A wide number of studies have been conducted to extract the physical parameters of watershed using SRTM data (Shuttle Radar Topography Mission) in different regions. In this study, ASTER elevation data was used to delineate watershed boundaries and physiographic parameters of Kardeh watershed. It was then compared with then compared with the derivatives from cartographic products. Based on the correlation coefficient index, it was found that DEM obtained from ASTER data provides a proper capability in determining the watershed boundaries, area, time of concentration and dranage network of the watershed. However, there is a significant inconsistency in estimating the average slope of sub-basins and the waterways' slope. Investigating the results for each of the sub-basins, it can be concluded that the DEM produced by ASTER is not appropriate for modeling watershed in areas with a slope of more than 35%.

Keywords: *ASTER, SRTM, Kardeh watershed, GIS, Remote sensing*

INTRODUCTION

Daylight based cell or photovoltaic cell is the optical contraption that adherents sun radiation to control. The green plant achieves some practically identical work, the follower light to substance energy so a social occasion of sun situated cells asserted regular daylight based cells. The sun supplies us an immaculate and boundless resource of energy and help us with moderating the One of the major steps in watershed studies, including erosion and flood control, is to identify and extract the physical characteristics of watershed. These parameters are the basic inputs for Rainfall-Runoff simulation models. In the traditional method, this data is extracted using topographic maps. But remote sensing technology makes it possible to provide watershed parameters using remotely sensed digital elevation models (DEM), including Shuttle Radar Topography Mission (SRTM) and Advanced Space borne Thermal Emission and Reflection (ASTER) data. A wide number of studies have been conducted to extract the physical parameters of watershed using SRTM and ASTER data and reasonable results have been obtained, relatively (Sreedevi. *et al*., 2009; Akbari. *et al*., 2011). In recent years, with the release of data from the ASTER gauge with much better discretion potential on the one hand and the development of DEM-based models and algorithms on the other hand, it is achievable to extract the basin border and physical parameters with optimal accuracy. The present study tents to provide a method and methodology based on the use of ASTER data in the extraction of the physical parameters of the Kardeh watershed using GIS tools.

Restructure Review

Through the recent decades, a wide range of studies have been conducted by both domestic and foreign researchers toward using remote sensing data. Rainfall-Runoff simulation is one of the issues considered by researchers in which significant progression has been achieved. DEM is the basis source to determine the watershed boundaries and physical parameters including area, environment, and basin slope and waterways' slope, time of concentration and shape factors. (Fairfield and Leymarie. 1991) introduced the first and most well-known numerical algorithm for extracting physical parameters of the watershed. The general form of this algorithm, known as D8, is presented in Figure (1) and uses DEM to determine the direction and route of the flow accumulation as a result of topography.

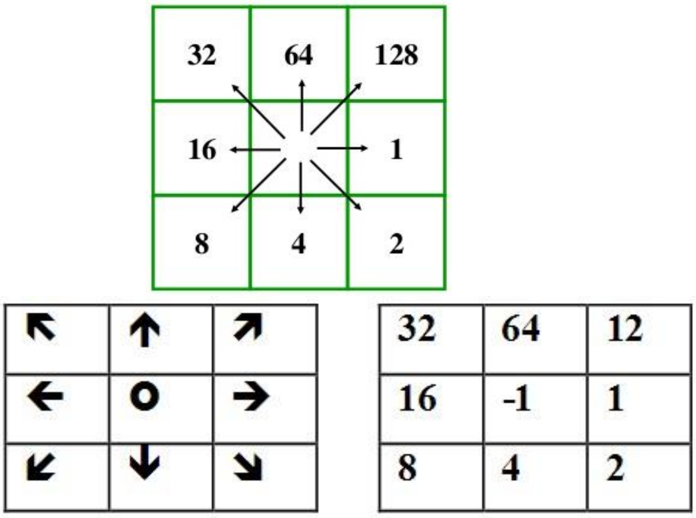

Figure 1: Coding method for the flow direction based on the D8 algorithm

In addition, a number of algorithms have been developed based on the triangular irregular network

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(TIN) (Moore and Grayson. 1991). Varied studies have been conducted in this field, each depending on the subject (Kiss. 2004), spatial resolution (Vieux. *et al*., 2004; Wise. 2007), DEM supply source (De Ruyver. 2004; Rodriguez. *et al*., 2006; Pryde. *et al*., 2007), the type of GIS tool used for DEM processing (Taud. *et al*., 1999; Tate. *et al*., 2002) have examined the issue from a specific aspect.

At present, developments in remote sensing technology have provided new sources of data. One of the latest developments in recent years has been the global exploration of the Earth's digital elevation model by the US's National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA), which is realized at the operation of ASTER gauge (USGS. 2017). According to Figure (2), ASTER gauge is one of the five Terra satellite sensors (ISA. 2016).

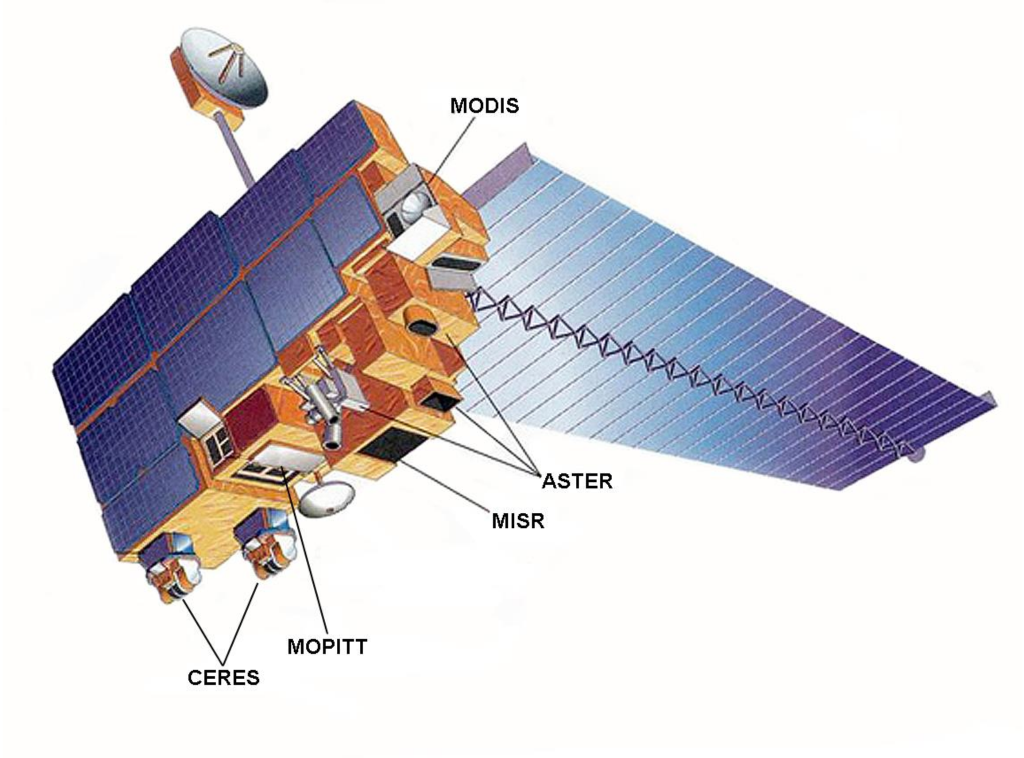

Figure 2: ASTER sensor on Terra satellite

ASTER launched in December 1999 and started data acquisition in March 2000. The swath width of 60 km and it is provided as standard 60 * 60 km tiles. The spatial resolution of this gauge is 28*28 meters and it is globally free available through the website (https://earthexplorer.usgs.gov).

SRTM data has a spatial resolution of 30*30 m in the United States and Canada and resampled to 90*90 m for other parts of the world (Akbari. *et al*., 2011). Various studies have been conducted using SRTM data in connection with modeling watershed and Rainfall-Runoff simulation, including research conducted by (Pryde. *et al*., 2007); (Seyler. *et al*., 2009) and (Gopinath. *et al*., 2014). Subsequently, re-efforts were made to extract the physical parameters of the catchment basin after the availability of ASTER gauge data with better resolution, including researches conducted by (Ahmed. *et al*., 2010); (Anornu. *et al*. 2012); (Rusli. *et al*., 2014) and (Akbari. *et al*., 2016). Moreover, domestic researchers used DEM generated topographic data to extract the physical parameters of the catchment basin and Rainfall-Runoff Simulation using the GFHM hydrological model, including the research conducted by (Mohammadi. *et al*., 2013). The present study tends to simulate flooding based on GFHM and DEM hydrological models created by topography in Gamasiab catchment located in Hamedan province. In this study, the method and methodology of using ASTER data demonstrated to extract physical parameters and identify the basin and sub-basin boundaries using GIS tools.

METHODS AND METHODOLOGY

Study Area

The Kardeh watershed is located in Khorasan Razavi province, 47 km north of Mashhad, between the geographical latitudes of "10 '40 ° 36 to "05 '56 °36 on the North and longitudes "48 '28 ° 59 to" 40 '44 ° 59 on the East. According to Figure (3), the basin area is about 457 square kilometers. And the maximum and minimum heights of the basin are 2950 and 1300 meters above sea level (Rastegaripour and Sabouhi Sabouni. 2010). Dominant part of the basin is covered with rangelands, which are generally moderate to poor, and rangelands with good conditions can only be seen at the higher elevation. Kardeh watershed is a mountainous region with a relatively steep slope.

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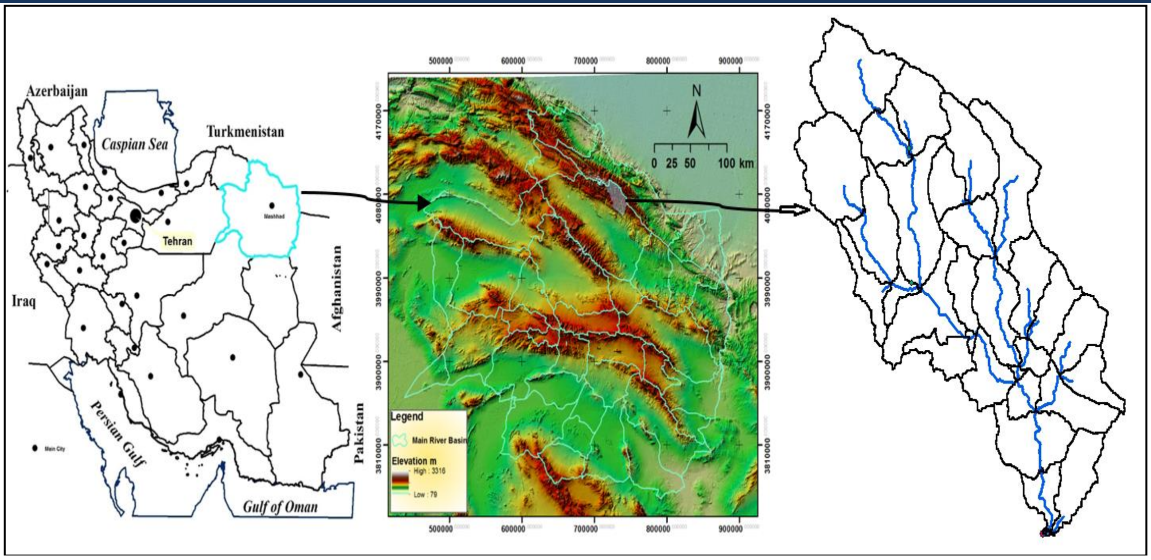

Figure 3: The location of the basin of Kardeh Dam in Khorasan Razavi province

GENERAL WORK METHODOLOGY

After downloading ASTER's digital data, it was optimized using HEC-GeoHMS extension in ArcGIS software. At this stage, due to the occasional systematic errors, including pits or artifact features, DEM should be hydrologically corrected and optimized. Therefore, it is necessary to use existing algorithms and complementary layers to correct the DEM, which is done in two steps called Fill Sink and Reconditioning. Then, firstly the catchment basin boundaries are extracted by HEC-GeoHMS software according to the flowchart presented in Figure (4) and then, the length of the largest main waterway and the concentration time in each of the sub-basins were calculated to determine the physical parameters of the basin and sub basins including area, drainage network, slope, average slope of sub-basins, and gravity center coordinates of the sub-basins, the results of which are presented in Table (1). Following the above operation, the same parameters extracted for DEM generated from topographic maps at a scale of 1: 25000, obtained from the National Survey Origination of Mashhad, Iran.

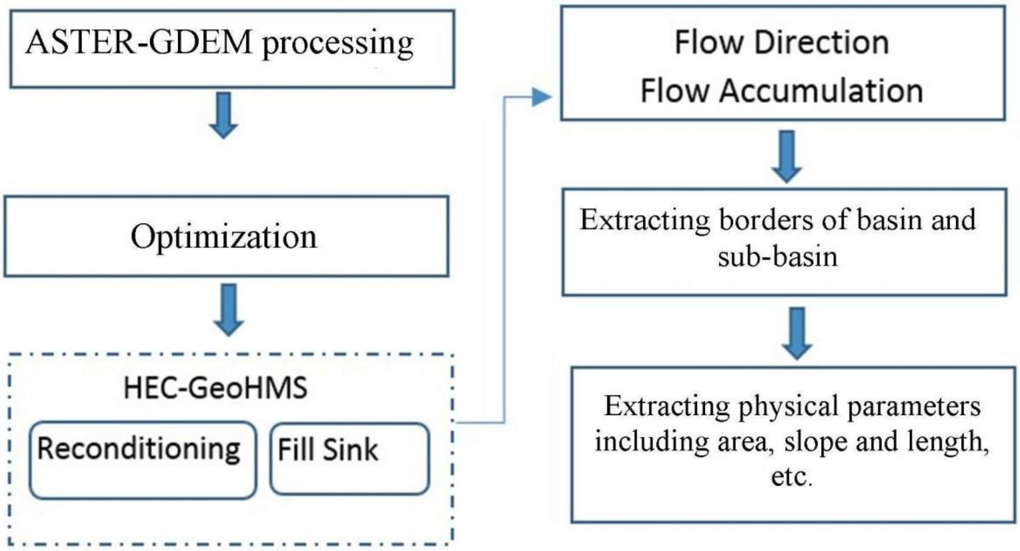

Figure 4: The process of extracting the basin and sub-basin boundaries and physical parameters from ASTER-GDEM

Analysis

Firstly, optimization steps including Fill Sink and Reconditioning were performed using HEC-GeoHMS, ASTER-GDEM software. Figure 5 indicates the steps before and after Reconditioning. Then, the pattern of flow direction and surface concentration was determined based on the D8 algorithm (Figure 6). Then, the sub-basin boundaries were identified as grid and then converted to vector through specifying the area threshold for the sub-basins (Figure 7). At this stage, it is possible to merge sub-basins or subdivide large basins into smaller basins, depending on the position of the hydrometric station or other hydro structures, to decide whether to merge or subdivide.

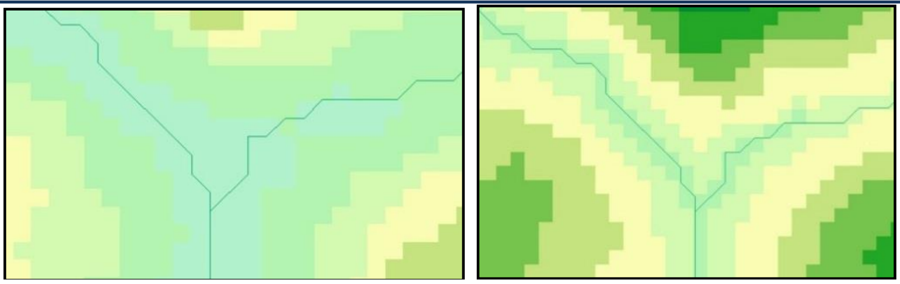

Figure 5: (a) Before Reconditioning (b)After Reconditioning

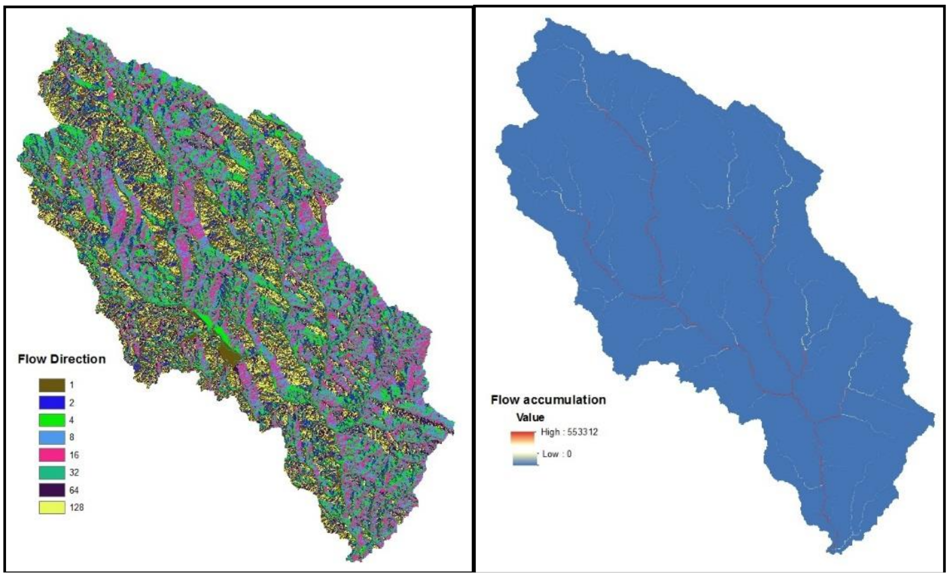

Figure 6: (a) Flow direction (b)Flow accumulation

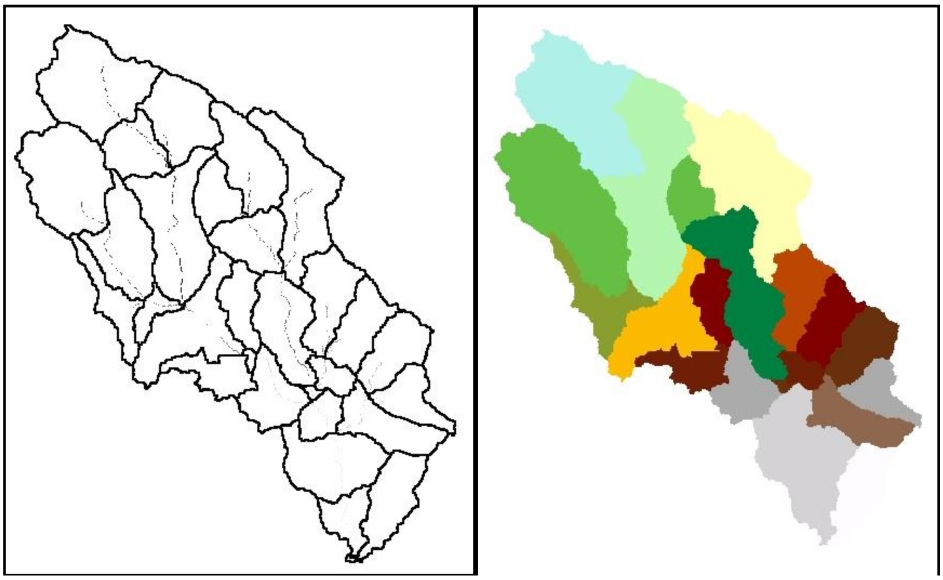

Figure 7: (a) Extraction of the basin border as a polyline (b) Conversion to polygon

Then, the length of the largest main waterway and the time of concentration in each of the sub-basins were calculated as well as other physical parameters of the basin and sub basins including area, perimeter, river slope, watershed slope, and gravity center coordinates of the sub-basins. According to the results obtained from HEC-GeoHMS software and according to the steps performed based on DEM extracted from ASTER gauge, firstly the basin and sub-basin borders with the results of DEM produced by Topographic maps were compared at a scale of 1:25000, and the comparison between the two DEMs produced was shown in Figure (8). However, in some parts, especially in areas with a mild slope, there are discrepancies between the extracted borders, indicating that the DEM produced by ASTER which means ASTER is not accurate enough in the flat areas or gentle slopes; while in other parts, there are satisfactory performances by ASTER data. In relation to the parameters examined according to Table (1), the area and perimeter of the watershed and the sub-basins and the length of the drainage network are determined with 85% accuracy, but in the case of the average slope of catchment basin and the main waterway slope, there is a significant difference in low-slope and lowland areas.

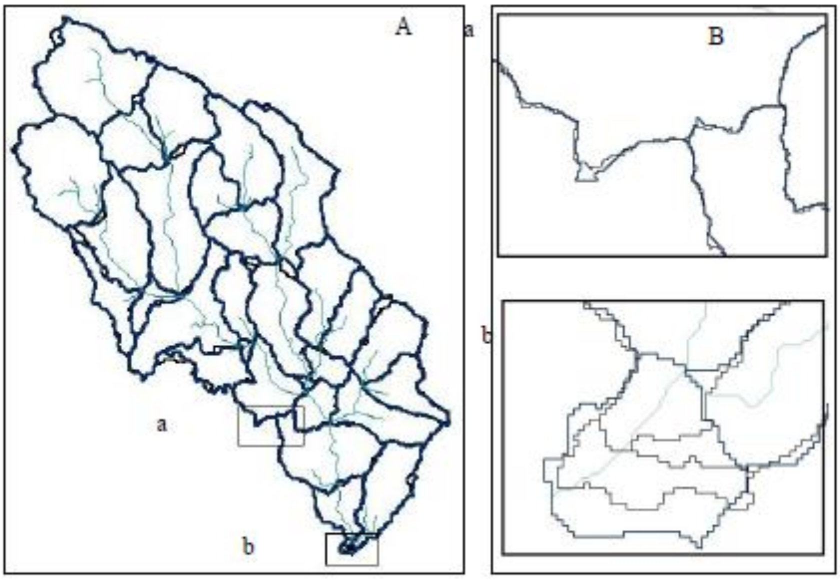

Figure 8: (a) Comparing boundaries extracted from TOPO-DEM and ASTER-DEM
(b) Comparing details of boundaries extracted in two areas of a and b

Table 1: Physical characteristics of sub-basins extracted from ASTER-GDEM

No.	Basin ID	Sub-basin ID	Environment	Area	Basin slope	Upstream height	Downstream height	Main waterway length	Waterway slope	**TC**
			KM	KM2	%	m	m	M	m/m	min
1	61	W610	21.04	12.789	33.62	2602	1958	7,644	0.068	21
2	29	W290	26.32	19.513	39.59	2686	1958	8,196	0.083	21
3	30	W300	39.00	30.592	39.28	2660	1741	13,747	0.038	42
4	31	W310	29.28	20.243	41.76	2691	1919	10,638	0.063	28
5	32	W320	43.61	27.883	38.90	2681	1806	16,121	0.043	46
6	33	W330	19.62	10.320	30.54	2627	1919	7,056	0.059	21
7	56	W560	31.73	21.489	36.45	2628	1790	11,390	0.068	29
8	35	W350	22.23	13.998	29.83	2518	1806	7,324	0.060	22
9	36	W360	29.51	19.830	34.24	2250	1546	10,471	0.028	38
10	37	W370	31.39	10.513	21.98	2466	1790	9,223	0.041	30
11	38	W380	16.89	4.729	24.01	2253	1741	5,459	0.067	17
12	39	W390	41.96	24.913	24.82	2199	1737	10,618	0.038	35
13	40	W400	28.26	16.501	41.17	2572	1646	9,610	0.056	28
14	41	W410	24.90	13.702	37.61	2428	1646	8,066	0.094	20
15	42	W420	21.49	10.0	28.43	2204	1639	7,648	0.060	23

				70						
16	43	W430	5.57	0.845	40.04	2000	1634	1,872	0.236	5
17	44	W440	25.64	10.072	24.52	2076	1737	7,583	0.036	27
18	45	W450	13.87	4.965	33.58	1937	1546	4,503	0.090	13
19	46	W460	22.46	14.314	37.84	2508	1655	7,737	0.090	19
20	47	W470	6.71	0.786	36.71	1868	1518	1,844	0.166	5
21	48	W480	27.52	15.132	42.28	2307	1478	9,458	0.074	25
22	49	W490	22.52	10.863	45.40	2404	1649	6,999	0.097	17
23	50	W500	24.05	13.577	39.19	2051	1518	7,700	0.053	24
24	51	W510	14.56	6.615	40.42	1979	1478	5,504	0.050	19
26	53	W530	28.14	15.756	29.51	2225	1322	11,275	0.070	29
27	54	W540	3.58	0.235	19.58	1457	1321	1,228	0.135	4
28	57	W570	31.95	31.782	32.55	2933	2016	11,338	0.055	32
29	62	W620	35.31	34.034	34.35	2832	2053	12,578	0.058	34
30	71	W710	20.58	8.546	34.65	1790	1322	6,378	0.069	19
31	72	W720	30.13	22.571	35.22	2005	1406	8,659	0.048	27

Evaluating and Comparing Results

Regular statistical indicators including correlation coefficient (r), root mean square error (RMSE) and change coefficient (CV) were used to evaluate and compare the parameters extracted from ASTER-DEM with TOPO-DEM, whose equations are expressed in Equations 1 to 3, as follows:

Equation (1)

$$r = \frac{\sum_{i=1}^{n}(\mathrm{T}_i - \bar{\mathrm{T}})(\mathrm{A}_i - \bar{\mathrm{A}})}{\sqrt{\sum_{i=1}^{n}(\mathrm{T}_i - \bar{\mathrm{T}})^2}\sqrt{\sum_{i=1}^{n}(\mathrm{A}_i - \bar{\mathrm{A}})^2}}$$

Equation (2)

$$RMSError = \sqrt{1 - r^2}SD_y$$

Equation (3)

$$\mathrm{CV(RMSD)} = \frac{\mathrm{RMSD}}{\bar{x}}.$$

It was possible to evaluate the results through comparing the results obtained from the two digital elevation models (DEMs) based on the above indicators. According to Table 2, the highest correlation coefficient was obtained for the area parameter (r = 0.84) and the lowest value for the waterway slope parameter (r = 0.45). Comparing CV and RMSE also indicated that the error rate in estimating some parameters is significant, including the length and slope of the main waterway with 39 and 48% error compared to the topographic values. This error value can be attributed to the inability of ASTER data to survey the details of land surface features.

Table 2: Comparison of the quantities extracted from ASTER-DEM with TOPO-DEM

CV	**RMSE**	**R^2**	**Correlation coefficient (r)**	**Parameter**
0.26	4.02	0.71	0.84	Area

0.23	5.73	0.53	0.73	Environment
0.08	3.10	0.33	0.57	The average slope of the basin
0.48	0.02	0.20	0.45	The main waterway slope
0.30	6.14	0.62	0.79	Time of concentration
0.39	2.0	0.62	0.79	The length of the main waterway

CONCLUSION

In the present research, the success rate of ASTER data in extracting the watershed boundaries and physical parameters, which are generally the main factors in hydrological modeling, especially Rainfall-Runoff, was investigated and compared with the results of DEM produced from topographic maps in the scale of 1:25000. The determination of the watershed boundaries and physical parameters including area, perimeters, basin slope and waterways' slope, concentration time and basin shape coefficients were examined toward this purpose.

The analysis was performed in two identical methods using HEC-GeoHMS software that relies on ArcGIS. The results of this study indicate that GIS tools and remote sensing data are appropriate facilities for analyzing the watershed characteristics. The high correlation coefficient between the investigated parameters based on two data sources indicates the high performance of ASTER data in detecting the watershed boundaries and sub-basins of its related physical parameters. The lowest error value is observed in the area estimation (r=0.84), and the highest error value is observed in the estimation of the main waterway slope (r=0.45) and the average basin slope (r = 0.57), respectively. Also, in terms of concentration time (r = 0.79), main waterway length (r = 0.79) and perimeter (r = 0.73), significant consistency is observed between the two data sources.

Studies have shown that ASTER data is highly accurate in determining the watershed boundaries in areas with steep topographic changes, and as it approaches low-slope and mild slope areas, the degree of inconsistency increases and it can be concluded that on the slopes in less than 35%, the inconsistency increases significantly, or in other words, in these scopes, the determination of the basin and sub-basin boundaries is associated with a high relative error. Therefore, it can be concluded that ASTER data is a desired option for modeling watershed in mountainous areas that are associated with steep topographic.

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