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Assessment of morphotectonic properties of Mahan Tigrani watershed

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ABSTRACT

Tectonic geomorphology can be explained as the study of landforms produced by tectonic processes, or the application of geomorphic principles to the suggestion of tectonic problems. Tigrani's watershed is located in north part of hillside. Nayband Fault sub branch pass from the east of zone and kuhbanan fault from the north of zone supplies an appropriate theme for survey tectonic activities. For access to this aim geomorphic indexes contain Stream Length Gradient, Drainage Basin Shape Ratio, Ratio of Valley-floor with to Valley Height, Topographic Symmetry, Mountain Front Sinuosity and Asymmetry Factor with use of topographic maps, DEM, Arc GIS and Global mapper softwares have gained. The results of research which calculated with Iat index show west sub basin have medium tectonic activity (Iat=2), and east sub basin have high tectonic activity(Iat=1.5). Overall the results show that assessment of tectonic activities in Tigrani watershed this basin is active because of tectonic movements.

1. Introduction

Geomorphological analyses help us investigate on the modifications that affect hydrographic basins, more specifically modifications because of active tectonics, and the quantitative description of landforms. The study of geomorphic indices are normally used to appraise the influence of active faults on the hydrographic network.

Tectonic geomorphology can be explained as the study of landforms produced by tectonic processes, or the application of geomorphic principles to the suggestion of tectonic problems (Burbank & Anderson 2001). In quantitative measurement of landscape, we calculate the geomorphic indices using topographic maps, aerial photographs and field work. The results of several indices are incorporated to highlight tectonic activity and to provide an assessment of a relative degree of tectonic activity in an area (Keller & Pinter 1996, Keller & Pinter, 2002). Quantitative measurements and the calculation of geomorphic indices has been previously tested as a remarkable tool in different tectonically active areas, such as the SW USA (Bull & McFadden, 1977).

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Guarnieri and Pirrotta (2008) performed a geomorphological study on drainage basins of the northern portion of the Sicilian side of the Messina Strait. They explained that the area has experienced several disastrous earthquakes during the last centuries and remarkable uplift during the recent years. Their study disclosed the recent activity of some of the fault systems recognized in this area.

Acar & Dinçer (2005) studied instability along upstream cut slopes for an earthfill dam in differentially weathered rock in southern Turkey. They reported that there were some major instability problem in a 45-m high and 200-m long previously cut slope next to the main axis of the dam, above the diversion tunnels and water outlet structures where the slope was first designed and excavated in 1986 based on the temporary berm method. Since rising water level in the reservoir could change the shear strength characterizations and the pore-water pressure in the slope, they concluded that a probable deep failure could damage the entrance of the diversion tunnels and water outlet structures of the dam.

Guccione et al. (2001) studied stream response to repeated coseismic folding, Tiptonville dome, New Madrid seismic zone. Malik and Mohanty (2002) studied active tectonic influence on the evolution of drainage and landscape geomorphic signatures from frontal and hinter land areas along the North western Himalya, India.

García-Meléndez et al. (2003) studied the eastern portion of the Huercal-Overa Basin located in Spain and made the first investigation on reconstructing the long-term landscape development during the Plio-Quaternary. They integrated some geological and geomorphological data through field observations and GIS and remote sensing techniques and provided a case study, which helps us understand the landscape development within tectonically active shear zones.

Harvey et al. (2003) used mineral magnetic and soil iron oxide data to study of relative age correlation of alluvial fans and lake sediments in the Tabernas basin, southeast Spain, within a context of interaction between tectonics and climatic change. They concluded that although the locations of the fans and the existence of the lake are associated primarily with tectonics, the fan sequences themselves appear to be climatically controlled, and climatic influenced over the source of sediment input into the lake during the late Pleistocene. Silva et al. (2003) evaluated tectonic activity of SE Spain through the application of a general morphometric analysis over 17 different mountain fronts.

García-Tortosa et al. (2008) studied a mountain front within the Plio-Quaternary deposits belonging to the sedimentary fill of the Guadix-Baza Basin (Betic Cordillera, Southern Spain). The two main glacis described in previous works in the area of the Baza Fault – the Old Glacis in the Guadix Sub-basin and the Recent Glacis in the Baza Sub-basin – were assumed as a single one, displaced by the fault. They reported that the age and the transition of the basin from endorheic to exorheic must be much older than previous estimations. They also indicated that the Baza Fault could be one of the most active faults of the central part of the Betic Cordillera.

Hamdouni et al. (2008) presented a new technique for evaluating relative active tectonics based on geomorphic indices for evaluating morphology and topography such as stream length-gradient index (SL), drainage basin asymmetry (Af), hypsometric integral (Hi), ratio of valley-floor width to valley height (Vf), index of drainage basin shape (Bs), and index of mountain front sinuosity (Smf). They gathered different results from the analysis and presented as an index of relative active tectonics (Iat) and they divided them into four classes from relatively low to the highest tectonic activity.

Troiani and Della Seta (2008) in other study implemented stream length-gradient index (SL) in morphotectonic analysis of small catchments for a case study from Central Italy. They indicated that the SL index is a valid tool to find the long wavelength structural effect on topography as well as the incipient local response to regional processes but it seems not be a suitable tool for discriminating the local lithological influence from the tectonic one.

In this paper, we present a tectonic study for a region of Mahan Tigrani watershed in west part of Iran. The proposed method of this paper uses different techniques for the study and analyzes them. The organization of this paper first presents the geographical characterization of the case study in section 2 and the empirical results are given in section 3. Finally, conclusion remarks are given in the last section to summarize the contribution of this paper.

2. Geographical characteristics of Mahan Tagrani

The study of this paper focuses on the watershed region of Tigrani river located sought part of a city of Mahan, which is 35 kilometer from the city of Kerman. The region is located between $57^{\circ}10^{'}\mathrm{E}$ to $57^{\circ}20^{'}\mathrm{E}$ length and from $29^{\circ}50^{'}\mathrm{N}$ to $30^{\circ}5^{'}\mathrm{N}$ width covering 59.63 square kilometers of the area. The maximum latitude of the region is 3920 meter, which is associated with north part of the region and the lowest latitude of the region is 1900 meters. The region is located in sought east of the center of Iran and most of the land contains sedimentary rocks of Jurassic age. The region contains different components mostly made of limestone, dolomite, sandstone, silt stone, marl and shale. In terms of tectonic activities, the region has been very active and there have been many earthquakes in the region since it is very close to Naiband fault. One of active sub-faults of Naiband is also located 15 kilometers east of this region. There are some other important faults located in the region and one of them is 300 kilometer long from north west to sought east and 30 kilometers of this fault is located in this region. The other fault is located from north to sought and it is around 20 kilometers away from the region.
Geomorphology indices are used as tools to analyze different shapes of land and investigate tectonic activities of the region and to prepare different geological maps. When different tectonic activities are measured we can use the following equation to evaluate the data,

$$\mathrm{lat} = s / n, \tag{1}$$

where lat is the relative tectonic activity, s is the sum of all geomorphology criteria and n is the number of criteria. Any value of lat between 1 to 1.5 indicates sever geological activities and when lat increases from 1.5 but it is less than 2, it means that there are significant geological activities. When we have relatively medium geological activities we could expect value of lat to be in the region of 2 to 2.5 and once lat value is well above 2.5 we do not expect any meaningful geological activities.

3. Experimental results

In this section, we present the empirical results of our proposed study, which uses various indicies.

3.1 Stream length gradient index

Stream length Gradient index (SL) is one of well-known geomorphology indices, which is calculated as follows,

$$SI = \frac{\Delta H}{\Delta L}.L \, , \tag{2}$$

where ΔH is the difference in elevation for specific region of a river, ΔL is the horizontal distance of the region and L is length of the river from its origin. High irregularities in profile represent class one tectonic activities and low irregularities in profile represent class two tectonic activities. Since the calculation of SL is very sensitive to the changes of slopes in the river, therefore, it is possible to evaluate the relationship between tectonic activities, resistance of different units of stones and topography assessment. Table 1 summarizes the results of our SL calculations.

Table 1
Different characteristics of SL in the Tigani region

Sub-region	SL evaluation	Class
West	High	1
East	High	1

The highest value of SL is calculated as 735.7, which is on 2900 meters elevation, which belongs to sub-region one and the highest value of SL is calculated as 607.6, which is at 3100 meters elevation. Fig. 1, Fig. 2 and Fig. 3 show the changes of elevation, horizontal slope of river and length of the river in the west and east part and two classes of one and two, respectively.

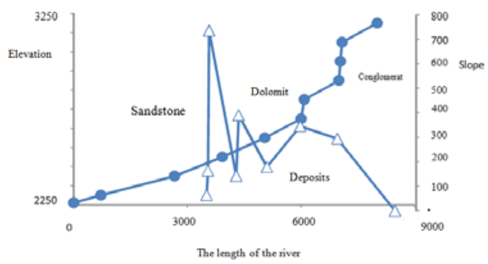

Fig.1. Longitudinal profile and slope of the curve length changes of the river basin number one (West)

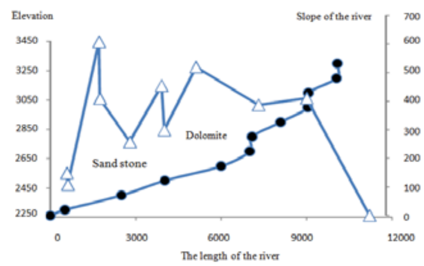

Fig.1. Longitudinal profile and slope of the curve length changes of the river basin number one (East)

Fig. 3. Mahan Tagrani

We have also measured details of the SL index for sub-group of the region and the information are summarized in Table 2.

Table 2
Characteristics of SL in different sub-region

Sub-region	Elevation	Length of the river	SL	Characteristics
	2300	0	0	Sandstone
	2400	1.7	294.1	Sandstone
	2500	1.1	345.5	Sandstone
1	2600	1.4	178.5	Sandstone
	2700	0.51	390.1	Sandstone, Fault
	2800	0.82	142.6	Dolomite, Fault
	2900	0.14	735.7	Cenomanaian
	3000	0.39	164.1	Cenomanaian
	3100	0.38	64.1	Conglomerate
	2300	0	0	Sandstone, Conglomerate, Fault
	2400	1.9	410	Gray sand stone
	2500	1.6	386.8	Dolomite
	2600	1	519	Cenomanaian, Fault
	2700	1.3	299.2	Cenomanaian, Fault
2	2800	0.7	454.2	Cenomanaian
	2900	0.89	257.3	Cenomanaian, Fault
	3000	0.26	408.8	Cenomanaian, Fault
	3100	0.26	607.6	Cenomanaian
	3200	0.76	107.8	Conglomerate, Fault
	3300	0.33	148.4	Conglomerate, Fault

3.2 Asymmetry factor

Asymmetry factor (AF) measures lateral tilt of the basin the main stream of the river based on tectonic forces and it is calculated based on the following,

$$AF = 100\frac{Ar}{AT}, \tag{2}$$

where AF is basin asymmetry factor and Ar is the main waterways in the catchment area. When there is little basin diversion, AF is calculated to be around 50. Any value greater than 65 represents class one and a value of AF between 57 to 65 represents class 2. Table 3 shows AF index in two regions of east and west.

Table 3
AF characteristics

Sub-region	Ar(Km²)	At(Km²)	AF	AF-50	Class
West	6.83	15.34	44.52	-5.47	3
Eat	8.47	18.35	46.15	-3.84	3

3.3 Topographic symmetry factor

Topographic symmetry factor is the other important index of our research and it is calculated as follows,

$$T = D_a / D_d, \tag{3}$$

where D_a is the distance from the midline of the drainage basin to midline of the active channel or meander belt, and, D_d is the distance from the basin midline to the basin divide and *T* is topographic symmetry factor. For perfectly symmetric basins T = 0; as asymmetry increases, T increases and approaches to a value of 1.0. This factor was 0.45 for class one, west region, and it was 0.33 for class two, which is located in the east region. Table 4 summarizes the result of our survey,

Table 4
Topographic symmetry factor characteristics for Tigrani region

Sub-region	D_a (m)	D_d (m)	T	Class
West	544	1200	0.45	2
Eat	500	1500	0.33	2

Fig. 4 shows the location of this factor in two regions in details.

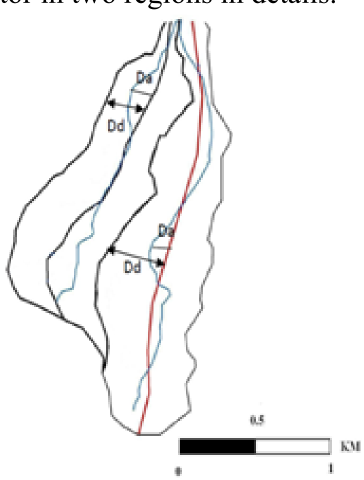

Fig. 4. Topographic symmetry factor

3.4 Drainage basin shape ratio

Drainage basin shape ratio is the other topographic factor, which is calculated as follows,

$$B_s = B_I / B_W \,, \tag{4}$$

where B_l is the length of a basin measured from the highest point, and B_w is the width of a basin measured at its widest point. Relatively young drainage basins in tectonically active areas tend to be elongated in shape, normal to the topographic slope of a mountain (Bull & McFadden, 1977) so Bs may reflect the rate of active tectonics. Table 5 summarizes the result of our survey,

Table 5
Drainage basin shape ratio characteristics for Tigrani region

Sub-region	B_I (m)	B_W (m)	B_S	Class
West	8768	2782	3.15	2
Eat	11220	2750	4.08	1

3.5 Mountain front sinusity

Mountain front sinusity ratio is another topographic factor, which is calculated as follows,

$$S_{mf} = L_{mf} / L_S \,, \tag{5}$$

In Eq. (5), L_{mf} is the planimetric length of a mountain front along, L_S is the straight-line length of the front and S_{mf} is the mountain-front sinuosity index. Table 6 summarizes the result of our Mountain front sinusity ratio,

Table 6
Mountain front sinusity ratio characteristics for Tigrani region

L_{mf} (m)	L_S (m)	S_{mf}	Class
420	400	1.05	1

3.6. Ratio of valley-floor with to valley height

Another index sensitive to tectonic uplift is the valley floor width to valley height ratio, which is calculated as follows,

$$V_f = 2V_{fm} / \left[(E_{ld} - E_{sc}) + (E_{rd} - E_{sc}) \right], \tag{6}$$

where V_{fm} is the width of the valley floor and E_{ld}, E_{sc} and E_{rd} are the altitudes of the left and right divides (looking downstream) and the stream channel, respectively. Table 7 summarizes the results of this ration for Tgrani region.

Table 7
Ratio of valley-floor with to valley height for Tigrani region

Region	V_{fm}	E_{SC}	E_{rd}	E_{ld}	V_f	Class
West (1)	26	2900	3250	3126	0.9	1
East (2)	29	2600	2690	2700	0.047	2

Based on the results reported from Table 1 to Table 7, we may apply Eq. (1) to find index of relative active tectonic and the results are summarized in Table 8 as follows,

Table 8
The summary of all indexes and lat

Region	S_{mf}	V_f	S_l	AF	B_s	T	lat	Class
West	-	2	1	3	2	2	2	Medium
East	1	1	1	3	1	2	1.5	High

4. Conclusion

In this paper, we have calculated different indexes to study tectonic activities of an active region of Tigrani located near the city of Kerman, Iran. In this study, we have divided the region into two classes of west and east in an attempt to simplify the calculations. There were two faults in the region, which are believed to play a key role on our investigation. These two relatively large faults significantly cause some tectonic activities in the region but these activities are different in various points of the region. Our results indicated that more tectonic activities are located in sought and east part of the region. In summary, we could conclude that the region is experiencing semi-active tectonic activities in most of the region except in the east where there are some relatively strong tectonic activities. Overall, we may conclude that the region has active geological activities. We hope the results of this survey could help for the development of cities located near the region.

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