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Evaluating Tectonics Activities of Sirch Basin by Morphometric Indices

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Authors' contributions

This work was carried out in collaboration between all authors. Author ME designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors NR and NS managed the project and improved the results, analyses of the study performed the spectroscopy analysis and improved the results and participate in the languages correction. All authors read and approved the final manuscript.

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ABSTRACT

Sirch basin, in the North of Kerman Province lays vicinity of Naiband fault zone. Approximately there is not where in the world during the years that is not affected by tectonics variation. So, evaluating and investigating tectonics condition, active tectonics processes and consequences of them is very important for human being activities such as design and formation of cities, powerhouses, dams, Industrial foundations, etc. Therefore by using them dangers and losses of these active processes could be minimized. For analyzing tectonic activities of Srich basin, we used morphotectonic reviews to evaluate morphometric indexes have been used to ascertain the tectonic instability/stability. To assess tectonic activities in the area geomorphic indices namely, mountain front sinuosity Sm_f, the scale of width of bottom of valley to its height VF, curved integral of hypsometry IH, asymmetry of canals in basin area AF, symmetry of transverse topography, index of main river swirls S, and index of evaluating pressure(density) of canals P have been used. In order

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to calculate these indexes we used digital elevation model, topographic map with a scale of 1:50,000, and geologic map of area (1:100000). Results from morphometric analysis are stated as relative index of active tectonics (RIAT). This index of tectonic activities put an area in four categories of activities: low, medium, high, very high. This index for basin shows extreme rate of activity.

Keywords: Morphotectonics; active tectonics; digital elevation model; sirch basin.

1. INTRODUCTION

Tectonic - Geomorphology, is a part of the earth sciences studying the interplay of tectonic and geomorphic [1]. Evaluation of structure and landforms during the history of their emergence is the subject of tectonic geomorphology knowledge [2]. Land forms, in tectonically active areas, are results of a complex combination of the effects related to vertical and horizontal movements of crust blocks and erosion or deposition by surface processes [3]. On other word, tectonic geomorphology studies surface, shapes and forms of ground that have been formed and evolved by tectonics effects [4]. Over the last few years different researchers along with qualitative indices morphotectonic in areas of active and young tectonics have attempted to quantify the tectonic behavior for this, various factors entitled "The morphometric indices" have presented. Geomorphic indicators of tectonic activity are useful and reliable; because they can be used in areas that previously have experienced tectonic activity or slow the rapid readily identified [5]. Geomorphic indicators are specifically used for active tectonics studies [6]. Morphometric analysis which are quantitative evaluation of geometric traits of geo-forms and views, review the active tectonic of an area by geomorphic indexes [7]. These tectonic indexes are useful tolls for studying tectonic activity in different areas. And by using them we can have information about special areas of a region that are exposed to relatively fast or even slow tectonic activities [8]. Notice to seismicity of Kerman province, it is necessary to evaluate active tectonic in basin area as a small section of province to analyze Effectiveness of this area.

These indexes around the world and Iran are used to check the active tectonics of which may include: [4, 8-12, 2, 13].

In present research we studied Sirch basin which is Located in the Northern Kerman Province Between 57°33' to 57°45' east Length and 30° to 30°30' north latitude and covers about 68.13 square kilometers as illustrated in Fig. 1. The purpose of this study was to determine the Neotectonic activity using geomorphological characteristics of the Sirch basin situated in the North of Kerman Province.

2. MATERIALS AND METHODS

For implementation this study in addition use to the usual method is to collect and document library, use Dem, topographic map of Sirch with a scale of 1:50,000 (Sheet: 7550III), Geological map of Shahdad with a scale of 1:100000. Also used from the below geomorphological indicators (Indicator that shows the general uplift) the study area for the analysis and evaluation of new tectonic:

1 – Mountain front sinuosity (Smf)
2 - Valley floor width to valley height ratio (Vf)
3 - Hypsometric integral (HI)
4 - Stream-length gradient (SL)
5 - Basin asymmetry factor (AF)
6 - Index symmetry topographic cross (T)
7- Index Bight main river(S)
8- Index Densitometry waterways (P)

Accordingly, topographic maps data as baseline data to Arc GIS software and in terms of geographic coordinate systems have been transported. Subsequently, the measurements should be done and then it was drawn maps and diagrams and after calculating geomorphic indexes of study area and according to achieved number, 3 classes were determined for each index:

class1: active class 2: moderately active and class3: inactive

Then by using RIAT, the tectonic activities of area were estimated.

3. GEOLOGICAL FEATURES OF THE STUDY AREA

The study area is located in Sanandaj - Sirjan in a metamorphic belt which is similar to central

Iran and Zagros region in the geological structure. Sanandaj - Sirjan zone due to the remarkable geological and tectonic processes is given attention by geologists and geomorphologists. Positioning tectonically active zone in this area make the study of this area more important. According to the orogenic activity transformational phenomena in the zone to the greenschist facies and amphibolite phase of the Caledonian and Cambrian. The area is characterized by presence of metamorphic rocks viz. gneiss and schists and weak metamorphic rocks like Phillies stained mica-schist is seen [14]. This range is very active tectonically during the Quaternary and has been significant seismicity activities due to proximity to the fault zone Naiband (a main fault). It should be mentioned that Sirch fault zone, one of the secondary branches of Naiband fault, is located in this area (Fig.2).

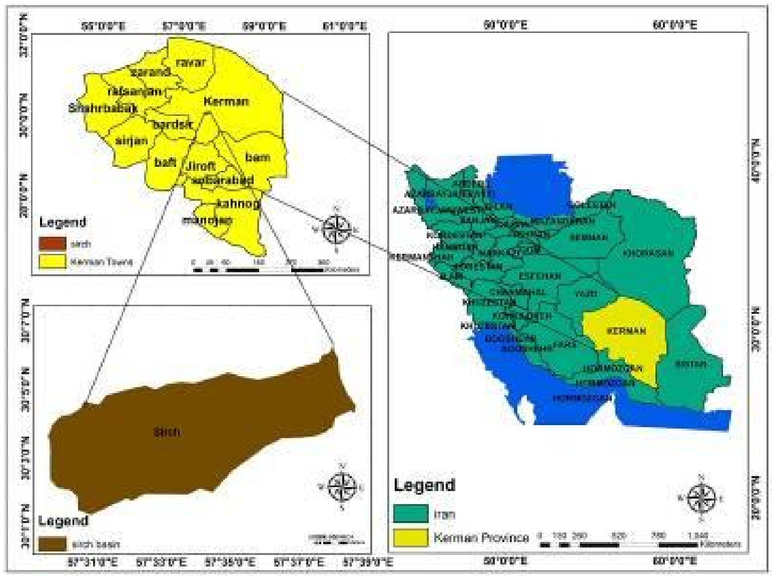

Fig. 1. Location of the studied area

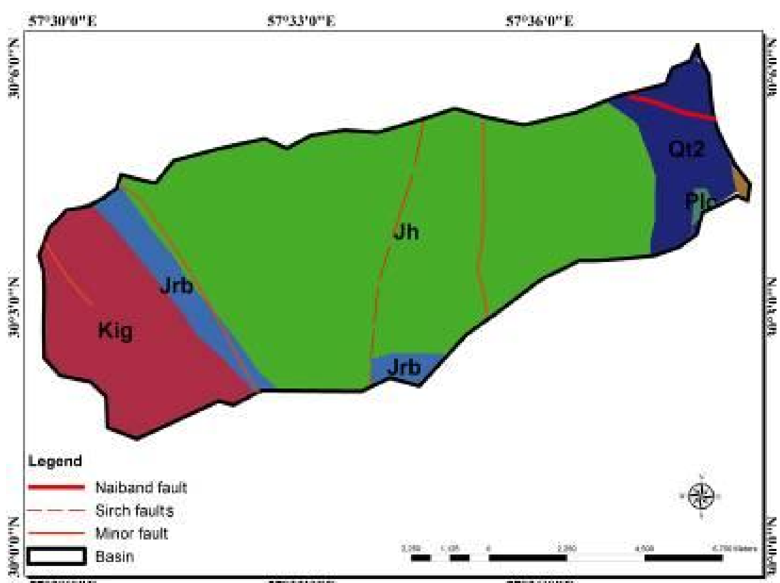

Fig. 2. Geological map of study area

4. DISCUSSION

4.1 Indices of Mountain front Sinuosity(S)

The winding index of Mountain front has a high ability to identify areas of tectonic [12]. On topographic maps, considering the winding contour lines at the junction of mountain to foothills, limits with desired length and according to the changes in the form of rate lines are chosen and a line is tangent to the rate contour, and linear curve is tangent to rate and by calculating the length of slope at gray of mountains and foothills(Lmf) and the length of tangent line along the mountain slope (LS),the Mountain front sinuosity or winding mountain slope (S) is Calculated from the following equation and tectonic activity or inactivity is determined. If sinuosity is close to 1 it indicates recent uplift and tectonic is active and as sinuosity is larger than 1, it indicates a drop in tectonic activity and dominates erosion.

The index ranges is smf ≥ 1. In the studying field, we have calculated the index in 4 sections (Fig.3) and the amount of obtained S is listed in Table 1.

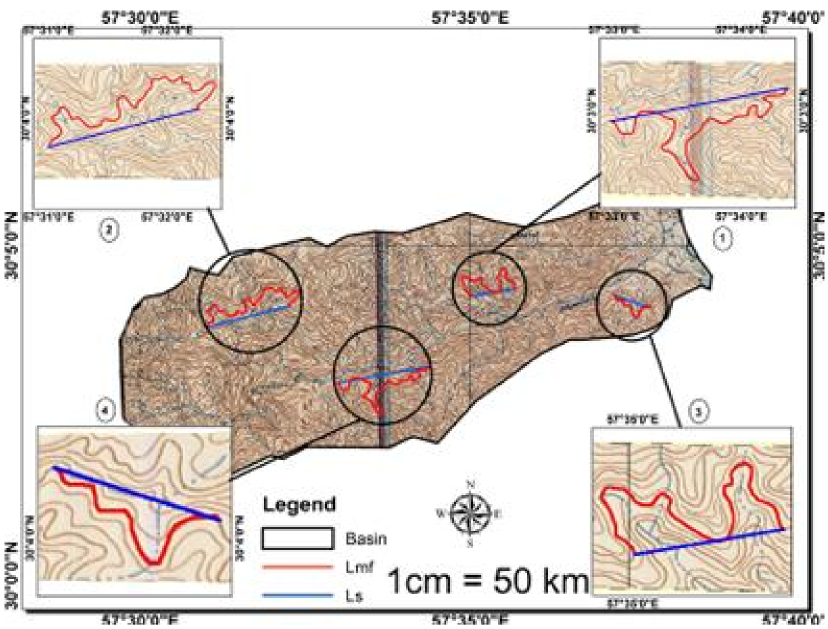

Fig. 3. Mountain front sinuosity index

Smf: Mountain front sinuosity which is calculated according to equation 1 [15]:

$$S = Lmf/Ls \qquad (1)$$

In this equation, S= Mountain front sinuosity or winding mountain precipice, Lmf = Over the precipice in the mountains between mountains and foothills (all connection points along the edge of mountain foothills), Ls= tangent line along the mountain precipice.

Table 1. Attribute values mountain front sinuosity sirch basin

Status tectonic	S	L_S (km)	L_{mf} (km)	Number of figure
inactive	3	1.1	3.3	1
moderately active	2.3	2.1	4.9	2
active	1.6	0.9	1.5	3
moderately active	2.2	2.2	5	4
moderately active	2.2	-	-	Mean

Based on aforementioned information and obtained value of table above (2/2) it is observed that tectonics state of the studied field is the semi-active

4.2 The Ratio of Valley Floor width to Valley Height Ratio (Vf)

Some of the valleys are V-shaped and some of them are U-shaped. Using these indicators detect what is going on may the river yet to be drilled in their bed or been side erosion and attempt to develop their bed [15]. Deep V-shaped valleys (Vf < 1) are connected with linear, active down cutting streams distinctive of areas subjected to active uplift, while flat floored (U shaped) valleys (Vf > 1) show an attainment of the base level of erosion mainly in response to relative tectonic quiescence [16]. In general, if the width of the valley floor is low and altitude of ridges is high, it indicates that the tectonic is active and as the width of the valley floor is high and the ridge height is reduced, it indicates that the area is tectonically quiet and overcome the erosion. The index ranges is 0< Vf <1.

To calculate the index 4 sections of the basin were selected and studied (Fig. 4). As you can see, the numbers obtained in different parts of the basin is indicative of active tectonics (Table 2). The average of this index is 0.39 that indicating the Uplift of the region.

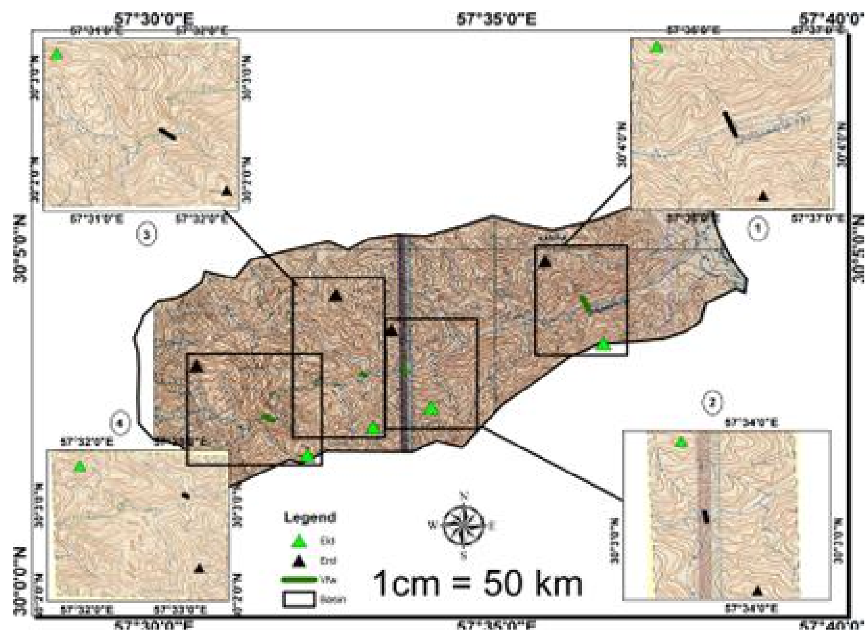

Fig. 4. Calculate the valley floor width to valley height ratio

Vf: The ratio of valley floor width to valley height or depth Which is calculated according to equation 2 [11]:

$$Vf = (2 \times Vfw)/[(Eld - Esc) + (Erd - Esc)] \quad (2)$$

In this equation, Vf = The ratio of valley floor width to valley height or depth, Vfw = The width of the valley floor and valley floor width, Esc= The average height above sea level valley floor, Erd = right ridge height or altitude right ridge river valley, Eld = left ridge height or altitude left ridge river valley.

Table 2. Attribute values than the width of the valley floor of the sirch basin

Status tectonic	V_f	V_{fw} (m)	E_{ld} (m)	E_{rd} (m)	E_{sc} (m)	Number of figure
active	0.58	354.52	2485	2521	1900	1
active	0.27	127.86	2780	2760	2300	2
active	0.10	63.10	2887	3080	2250	3
active	0.63	242.17	3045	3520	2900	4
active	0.39	-	-	-	-	Mean

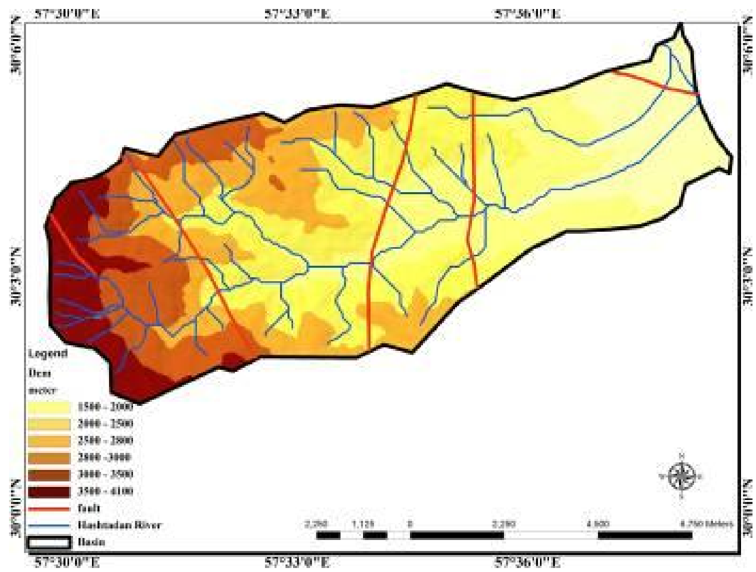

Fig. 5. Calculate the hypsometric integral (HI)

HI: Integral Curves Hypsometry which is calculated according to equation 3 [8]:

$$HI = (Hmean - Hmin)/(Hmax - Hmin) \quad (3)$$

HI = Hypsometric integral, Hmean= Mean elevation, Hmin = Minimum height of basin, Hmax = the maximum height of the basin

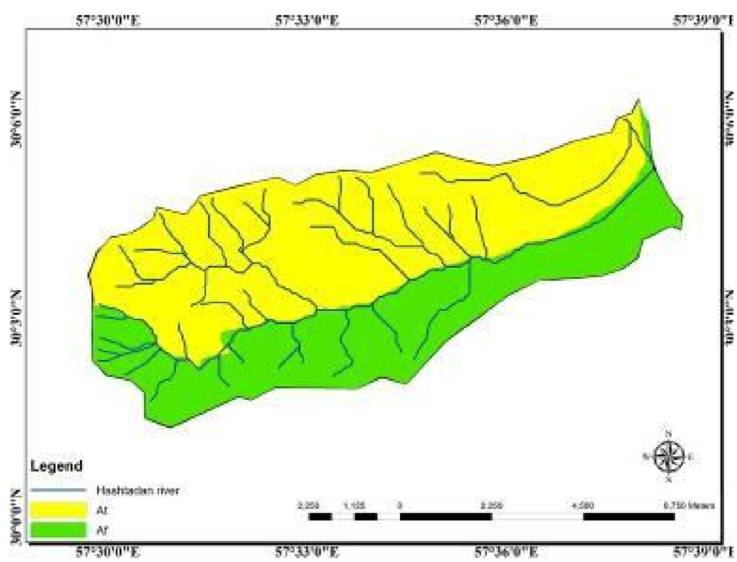

Fig. 6. Calculated asymmetry index of streams in the watershed

AF: The asymmetry index of streams in the basin Watershed which is calculated according to equation 4 [17]:

$$AF = 100(Ar/At) \quad (4)$$

Af = Asymmetry index waterways, Ar = Minor drainage area encompasses the right bank of the main stream, At = The area includes the drainage basins of the sub left and right banks of the main stream

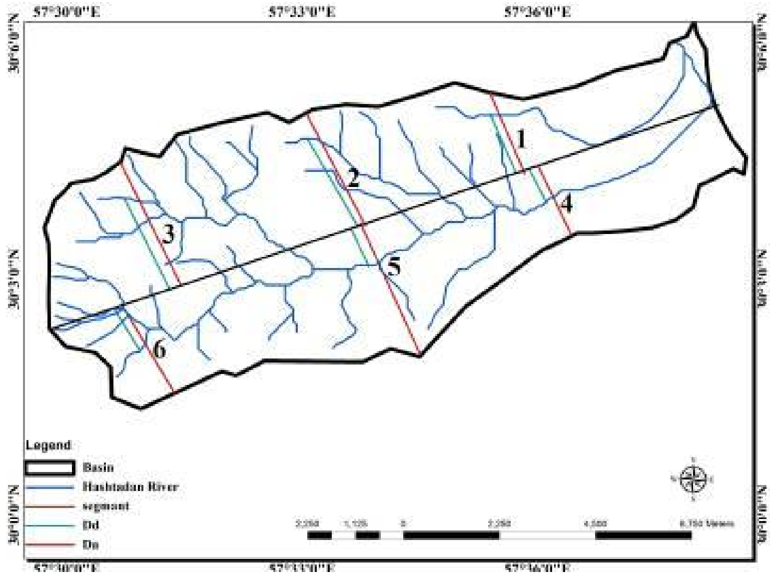

Fig. 7. Transverse topographic symmetry index

T: Index symmetry topographic cross which is calculated according to equation 5 [15]:

$$T= Da/Dd \quad (5)$$

T = Index symmetry topographic cross, Da = is the distance from the midline of the drainage basin to the midline of the active meander belt, Dd = Distance from the basin midline of the water catchment basin boundary.

4.3 The Hypsometric Integral (HI)

One of the simple methods for recognizes active Tectonic is integral of the curve hypsometry in a region. The index parameters can easily be calculated from topographic maps (Fig.5). Large values (close to one) for this indicator show young topography (Many ups and downs along the river valley, vertical drilling process) and the numerical average and low values, indicating that the topography of mature and old. This method is further compared with each other basins.

Table 3. Calculated of hypsometric integral

HI	Hmeam	Hmax	Hmin
0.2	2350	4059	1661

As you can see the value of this index (Table 3) for the studying field is nearly (0.2), therefore we conclude that the topography of the area is relatively old (low active).

4.4 The Asymmetry Index of Streams in the Basin Watershed (AF)

Other evidences of active tectonic are comparison of waterways and drainage sub-basin area includes both sides of a main channel. When a basin in one side of the main channel is active therefore the area of the front side will be Uplift so the other side of the stream, happen subsidence. AF significantly greater or smaller than 50 shows influence of active tectonics/ litho logic control or differential erosion, as for example the stream slipping down bedding plains over time [10]. If the value of this index is around 50, indicating symmetry in both the main channel and show that tectonic is not active. If the level of the index is up than 50, show that Uplift and less than 50 shows down lift. Since the obtained value is smaller than 50, so we left the main stream of tectonic activity [12].

Table 4. Calculated of asymmetry of rivers in the basin

Ar	At	AF
26.33	68.13	38

Since the obtained value is smaller than 50 (Table 4), so we have tectonic activity on the left of main stream (Fig. 6). On the right we are faced with sinking phenomenon.

4.5 Index Symmetry Topographic Cross (T)

For calculating the index, first midline area (symmetry line) is plotted and then considering states of middle lines and area in different places, the symmetry index of transverse topography is calculated. In areas with complete symmetry T is 0 and the T value represents a vector with values between 0 and 1. As the asymmetry increases, the value of T increases [18]. Values close to one indicate Uplift in the region and as a result, tectonics is active.

In the studying field, we have calculated the index in 6 sections (Fig.7). The amount of each of them is calculated according to the following equation in which the average is 0.7 (Table 5). As you can see, the obtained value is greater than zero and close to 1, so we can say that the tectonic zone is active and the river is eroding its bed.

4.6 Stream-Length Gradient (SL)

This index (SL) is one of the characteristics of geomorphic, and used to assess the dynamics and tectonic activity. These parameters are measured from topographic maps. SL index depends on stream power so very sensitive to changes and fluctuation Gradient of river. This sensitivity, possible assesses relationships between tectonic activity, rock strength and the topography. Gradient of the river is the most important criteria for the separation of active and inactive tectonic regions are considered. If index SL is more than 500 it indicates an active tectonic, if it is 300-500 it means a semi-active tectonic and if it is less than 300 it indicates an inactive situation [10]. In the study area was calculated by using 1:50000 topographic maps. To calculate the gradient of the longitudinal profile of the main channel of the river basin, the basin input to the outlet of the watershed were obtained from topographical map (Fig 8).

Table 5. Transverse topographic symmetry index values

Path	Da (km)	Dd (km)	T
1	1.5	2.3	0.6
2	2.7	3.2	0.8
3	1.2	1.6	0.7
4	1.6	2	0.8
5	2.3	2.8	0.8
6	2.5	3.1	0.8
Mean	-	-	0.7

Then at a certain height - Typically 100 m - amount of SL was measured. For the entire path from source to output this river basin, 100 m and 100 m, respectively, was performed (Fig. 9). And were averaged from the SL is obtained to SL entire stream or river is obtained (Table 6).

Table 6. Index gradient along the river

Path	Height (m)	ΔH	ΔL	L	SL
1	3600-3500	100	189.56	7.86	4.14
2	3500-3400	100	145.22	196.86	135.55
3	3400-3300	100	143.52	324.08	225.80
4	3300-3200	100	234.25	485.6	207.29
5	3200-3100	100	373.71	719.85	192.62
6	3100-3000	100	640.80	1093.56	170.65
7	3000-2900	100	599.83	1693.39	282.31
8	2900-2800	100	368.79	2293.22	621.82
9	2800-2700	100	100.82	2662.01	2640.35
10	2700-2600	100	201.02	2762.83	1374.40
11	2600-2500	100	157.45	2920.28	1854.73
12	2500-2400	100	416.64	3077.73	738.70
13	2400-2300	100	1216.41	3494.37	287.26
14	2300-2200	100	1358.45	4710.78	346.77
15	2200-2100	100	1228.74	6069.23	493.93
16	2100-2000	100	1653.17	7297.97	441.45
17	2000-1900	100	1634.45	8951.14	547.65
18	1900-1800	100	1501.48	1058.59	70.50

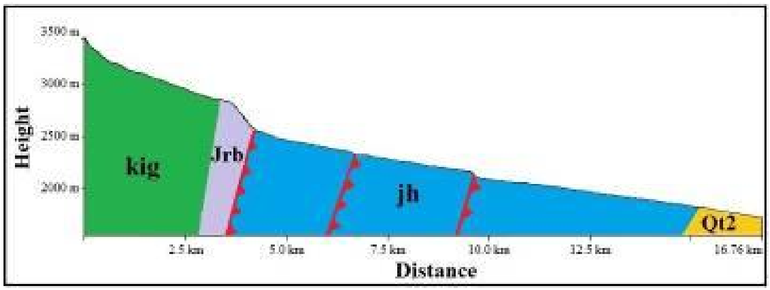

Fig. 8. The longitudinal profile of the main channel

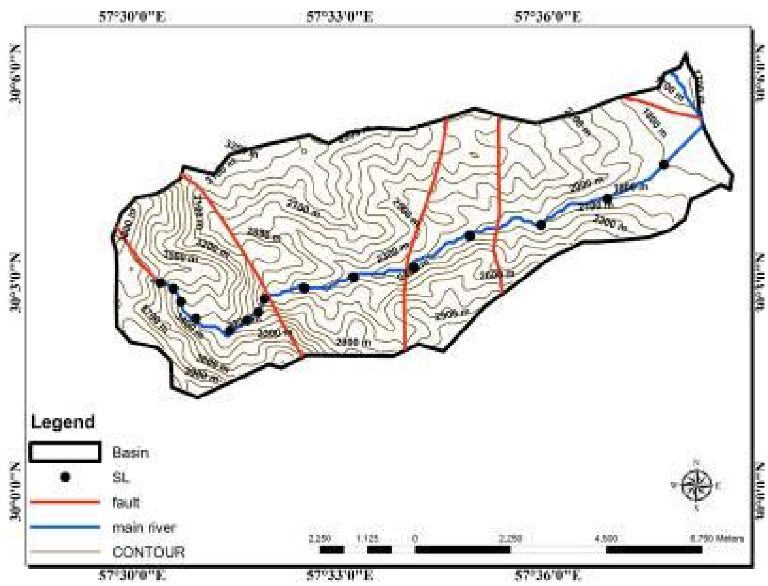

Fig. 9. Index stream-length gradient

SL: Index Stream-length gradient which is calculated according to equation 6 [9]:

$$SL = (\Delta H/\Delta L).L \quad (6)$$

In this equation, SL = index Stream-length gradient, ΔH =the difference height in a particular section of the river, ΔL = the horizontal distance from the spot, L = along the river from the central point to the location of the source of the river.

In the case of SL for the main stream or river basin is measured, the gradient index for this area of 4.41 SL is the fluctuating 2640.35 (Table 6).

In general it can be said that the division of SL in the northern part of the study area, most of the central and southern parts of the Since the difference in the basin lithology does not exist (Because almost all of the area covered sandstone and the slope is almost uniform), The difference in the SL in the basin can be attributed to tectonic activity and weather conditions It should be noted that the gradient index is sensitive to changes in slope, If the length of the river changes its slope and displacement of tectonic activity arises.

4.7 Index bight of main rivers(S)

The S index is more indicative of active tectonics in the region [13]. S index (Table 7) show that the Hastadan River has not reached equilibrium and this area has been active tectonic movements (Fig. 10).

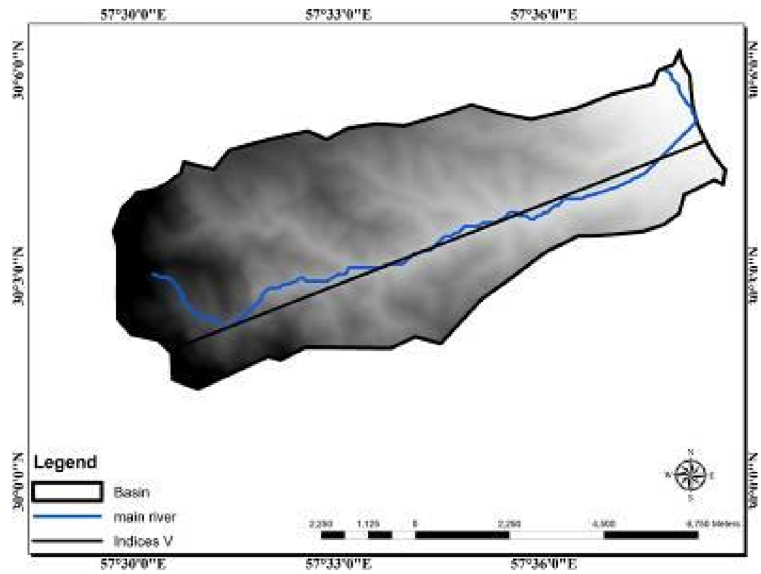

Fig.10. Index bight main river

S: Bight Main River that is defined in the following ways:

S= C/V (7)

In this equation, S = index Bight main river, C= Length of main river, V= Length of valley (The straight line).

Table 7. Calculated of Index bight main river

C	V	S
14.09	13.89	1.01

4.8 Index Densitometry Waterways (P)

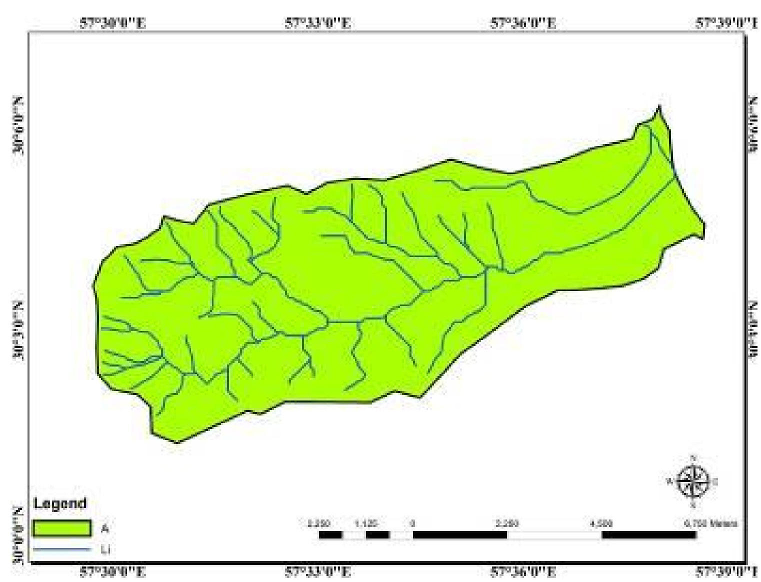

Fig. 11. Index densitometry waterways

P: Densitometry waterways

That the ratio of channel length is calculated in the same area, efficient tool for the identification of active tectonics. Especially in areas where there is less evidence of active tectonic movements [16]. Active tectonic areas with a high density stream. Drainage density in this area shown in Fig. 11 and obtained from the following formula:

$$\mu = \Sigma Li/A \quad (8)$$

μ =Network congestion River Basin, Li= Length each of the drainage basin(kilometers)
, A= Area (square kilometers)

Table 8. Calculated of index densitometry waterways

μ(Km)	A(Km^2)	P
48.24	68.13	0.7

Continued tectonic movements increased height and density (Table 8), thus increasing the drainage Sirch basin shows in this region active tectonics.

4.9 Assessment of the Basin Tectonic Activity

After calculating geomorphic indexes in this area. The RIAT is calculated as:

$$RIAT= S/n \quad (9)$$

Here RIAT is relative index of active tectonic, s is collection of classes of calculated geomorphic indexes and n is number of calculated indexes. If RIAT=1-1.5 we have extreme active tectonic, if 1.5-2 we have high active and if 2-2.5 we have medium active and if higher than 2.5 we have weak active tectonic [8]. Table 8 shows the RIAT for basin. As it is observed the basin has extreme active tectonic. We have three classes: class1: active class2: moderately active and class3: inactive

By calculating the geomorphic indices area and estimated Relative Index of active tectonic (RIAT) index was determined (Table 9). The assessment shows that the area of activity is high tectonic activity.

Table 9. RIAT index values and class active tectonic sirch basin

Status tectonic	S_{mf}	V_f	HI	AF	T	SL	S	P	RIAT	Activity
The mean values obtained from each indicator	2.2	0.39	0.2	38	0.7	590.89	1.01	0.7	-	-
Class of tectonic activity	2	1	2	2	1	1	1	1	1.3	Intense

4. CONCLUSION

In this study we relatively evaluate tectonic activities by using relative indes of active tectonics (RIAT). For evaluating the situation of tectonic of Sirch, eight geomorphologic "indexes have been used. The average value of Sinuosity of mountain front (smf), which represents a balance between tectonic and erosion forces along the Mountain Front, in this area is 2.2 m which indicates active tectonics. The ratio of (Vf) index which is based on a ridge and valley floor was calculated and the value is 0/39 meters and represents active tectonic basin. Index (HI) which is 0/2 meters expresses a relatively young (active) topography. Index (AF) which points diversion of the main channel of the river to sides is 38 km 2 so on the left we have main channel tectonic activity and on the right we have subsidence. Topographic symmetry of the transverse (T) is 0.7 which represents medium neotectonic activity and tectonic bending of this basin toward main canal to the exit of basin.

Index (SL) which reflects the strength and slope of the river bed is 580/81 meters. The high amount of this index indicates active tectonic. Index bight of main rivers(S) which is 1/01, this value shows we have active tectonic in area. Index densitometry waterways (P) which is 0/7 and indicates active tectonic in region. Finally after calculating geomorphic indexes in the area and estimating RIAT, the tectonic activity of the region was determined this was base on all calculated indexes and supplying changeable and dynamic base. also existence of the whole Nayband Fault to north - south direction and other regional faults which almost all of them follow the trend of the main fault also emphasis on the tectonic activity in the region. This domination leads to supplying necessary bases for locating human groups and also is a threat for installations and equipments for morphological dangers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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