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Calculated the Tectonic Activity of Catchments in the SAQEZ Geomorphology Unit (Iran and Kurdistan) Using Morphometric Indices

Semko Arefpanah[1, *], Alireza Sharafi[2]

[1] *Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran*
Semko.arefpanah@srbiau.ac.ir
[2] *Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran*
Alireza.sharafi@srbiau.ac.ir

Abstract

Landslides are tectonic and morphological indicators. The Morphotectonics Index is a suitable tool for probability estimation and earthquake planning in the region. Landslides are the most common natural threat in Iran. A sustainable management plan requires landslide hazard zoning planning. Therefore, the estimation of landslide risk in selected areas using the morphological index is the purpose of this study. Rivers are very sensitive to tectonic movements, and river landforms are closely radiated to tectonic movements. The Deformation Tectonic Index was used as a tool to identify new and active structures for these movements. The SAQEZ River Basin is located in the northwest of the country according to its characteristics. Its landform has a high flood capacity and a moderate slope of about 33.01%, resulting in severe erosion and flooding in the area. The purpose of this study was to analyze tectonic activity in the SAQEZ River Basin using remote sensing software and topographic maps and digital elevation models in a GIS environment. In this study, four morphological and structural indices, including river length gradient index (S_L), basin shape index (B_S), river tortuosity index (S_r), and basin asymmetry factor (A_f), were used, and their results were analyzed. An analysis is expressed as the Active Tectonic Index (IAT). According to the survey results, the values of the S_L, B_S, S_r, and A_f indices were 207, 1.09, 1.27, and 66, respectively. The Active Tectonic Index (IAT) shows moderate tectonic activity in the area.

Keywords: *SAQEZ RIVER Basin; GIS; Remote Sensing; Iran; Morphotectonic*

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I. INTRODUCTION

Few areas in the world have not been affected by tectonic processes in the last few thousand years. In general, the deformation of the Earth's surface occurs slowly over thousands of years. Morphometric measurements can be defined as quantitative measurements of the shape of the Earth's landscape. These quantitative measurements provide the conditions for using them to identify regions with active structures. Terrain tectonics is valuable knowledge in the study of dynamic tectonics, which can determine the impact of active tectonics on rivers. Structural topography is the knowledge of the study of shapes created on the ground by structural mechanisms. Topographical indices are useful for structural studies because they can be used to quickly assess large areas and the essential data can often be obtained from digital elevation maps and satellite imagery. Multi-regional studies of basins and channel networks using morphometric indices indicate their effectiveness in identifying areas of activity. Active structural processes can affect the shape and function of the steel. Among natural landscapes, rivers are the first types of environments that respond relatively quickly to changes in

Bedrock or changes in the margins of bedrock. The BANEH Basin is located in the MARIVAN - MAHABAD region, and the BANEH ABAD, SORMEH ALI, PARISHAN, MAHMUD ABAD, SIAH, AND KHALKHAL faults are some of the most important faults in the region. The purpose of this study is to evaluate new rescue activities using quantitative topographical indicators in the CHUMMAN BANEH drainage basin. The use of topographic indicators in the study of new structural activity was initiated by Bull and McFadden and used by other researchers such as Rockwell and Wells. CHUMMAN BANEH Drainage Basin is located in Kurdistan Province and is part of the SEFIDRUD BASIN.

Earth is a dynamic system that is characterized by transformation [1]; there is almost no area on earth not affected by

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new tectonic activities in the last few thousand years. It can be stated that active new plate tectonics is changing the shape of the earth's surface [2]. Among geological methods for studying active tectonic movements, geomorphological and Morphotectonics investigations play an important role because many geomorphic features are sensitive to active tectonic movements, and geometric analysis of these features offers evidence of the type, rate, and arrangement of active tectonic changes Morphotectonicss is a branch of tectonics, which studies the forces and factors creating the shapes and forms in the outer crust of the earth. Morphotectonicss is the study of landscapes created by tectonic processes, which expresses the relationship between geomorphology and tectonics.

In this research, the tectonic activity of the SAQEZ RIVER Basin located in Kurdistan Province has been analyzed using geographical information systems and remote sensing. Remote sensing is the discipline that can present valuable information by observing and measuring an object or terrestrial phenomenon from a distance without physical contact with it, and in the next stage, valuable data can be extracted through analysis of this data [3]. In the field of tectonic research, several studies have been conducted in Iran and other parts of the world, including the following.

Authors of [4] classified the active tectonics of southern Spain and identified its active areas using geomorphic and relative tectonic activity indices [5]. Analyzed the active tectonics of BOJNOURD Basin using Morphotectonics indices. In this study, which used various indicators including the shape of the basin, asymmetry of the drainage basin, hypermetric curve, hypermetric integral and the like, IAT results of the region showed that the eastern part of the basin had more active tectonics. [6].performed the relative evaluation of the tectonic status of railroad tracks in the Kurdistan region using IAT and calculated seven geomorphological and Morphotectonics indices such as Hypsometric curves (Hi) and curve, Stream Length-gradient Index (S_L), Index of Drainage Basin Shape (B_S), Drainage Basin Asymmetry Factor (A_f) [7]. Investigated the IAT in the Idea Esca region of southwestern Cameroon and concluded that the study area is tectonically active [8]. assessed the QORVEH-DEHGOLAN drainage basin using five geomorphic indices of relatives relief (B_h), drainage density (D_d), form factor (F_F), hypermetric Integral (Hi), and Stream Length-gradient Index (S_L) [8]. Used Stream Length-gradient Index (S_L), hypermetric integral (H_i), drainage basin shape (B_S), and valley floor (V_F) indices to evaluate the relative active tectonic index (IAT) relative active tectonic index (IAT) [9].

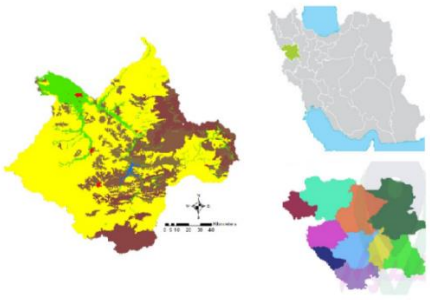


Fig. 1. The geographical location of SAQEZ RIVER Basin

II. MATERIALS AND METHODS

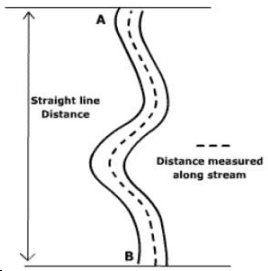
Digital elevation models can be used to accurately extract river indicators and analyze drainage basins. First, sub-watersheds and waterways in the study area were extracted using a digital elevation (DEM) with a horizontal resolution of 30^m in a geographic information system (GIS). Accordingly, the study area was divided into sub-basins. In the next step, using the 1:100,000 geological survey of the National Geological Survey, the geological units and major structures of the area including the faults in the area were determined [10]. Then calculated an index for each sub-watershed. For each indicator, a zoning map of current tectonic activity in the study area was drawn. In the next step, we divided the fore morphometric indices into four categories [11]. To analyze and evaluate the tectonic movements in the basin under study according to authentic geomorphic indices, Stream Length-gradient Index (S_L), river sinuosity (S_r), basin shape (B_S), and asymmetry factor (A_f) of drainage basin were used, and after calculating the desired indices, the tectonic activity of this region was evaluated using IAT (Table 1-4).

A. The sinuosity of the river (Sr):

based on this index and the presence of many twists and turns in the river indicates the basin's equilibrium (absence of tectonic activity) and its straight path indicates the youth of the region and high tectonic activity[12]. C The length of the river or the flow along the river along with its twists and turns from the beginning of the river in SARAB to the outlet point in meters. V The aerial length of the valley in meters from the beginning to the end where the river's ground length is measured [13-15].

$$Sr = \frac{C}{V} \tag{1}$$

TABLE 1. EVALUATION OF ACTIVE TECTONICS IN THE STUDY AREA BASED ON RIVER SINUOSITY INDEX

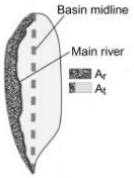
Morphotectonics indicator	River sinuosity index (S) $Sr = C/V$
The components of the equation	Sr: River sinuosity index C: The length of the river V: The length of the valley in a straight line
Measurement method	
Significance	1.3<S: Inactive 1.3<S<1.15: Semiactive 1.15>S: Active

B . Asymmetry of the drainage basin (Af)

The asymmetry index is an index to evaluate the tilts caused by tectonic activities on the scale of drainage basins. A_r It is the area on the right side of the main river and A_t is the total area of the drainage basin. The asymmetry factor A_f can be To investigate the tectonic rotation at the scale of the drainage basin, it used [13-15].

$$A_f = 100(A_r/A_t) \quad (2)$$

TABLE 2. EVALUATION OF ACTIVE TECTONICS IN THE STUDY AREA BASED ON DRAINAGE BASIN ASYMMETRY FACTOR

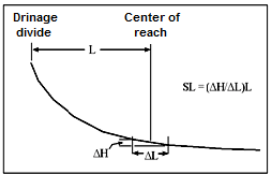
Morphotectonics indicator	Drainage Basin Asymmetry Factor (A_f) $A_f = 100(A_r/A_t)$
The components of the equation	A: Asymmetry Factor A_r: Drainage basin area to the right of the main waterway A_t: Total surface area of the basin
Measurement method	
Significance	If the numerical value of this index is nearly 50, it indicates the existence of symmetry

C . Longitudinal slope index of the river (SL)

The longitudinal slope index of the stream was defined by Hook in a study of the role of rock resistance in the river flow in the Appalachian Mountains in the southeastern United States of America. Δ_H The height difference between two measured points and Δ_L the horizontal distance between two measured points L is the length of the river from the central point of the two the measured point is the source of the river [13-15].

$$S_L = (\Delta_H/\Delta_L)L \quad (3)$$

TABLE 3. EVALUATION OF ACTIVE TECTONICS IN THE STUDY AREA BASED ON STREAM LENGTH-GRADIENT INDEX

Morphotectonics indicator	Stream Length-gradient Index (SL) $S_L = (\Delta_H/\Delta_L)L$
The components of the equation	Δ_H: Height difference of the desired segment Δ_L: The length of the desired branch L: The total length of the waterway from the center of the point where the index is calculated to the highest point of the waterway upstream
Measurement method	
Significance	300>S_L: Inactive 300<S_L<500: Semiactive 500<S_L: Active

D. Recitative active tectonic index (IAT)

The whole area is classified according to the index of relatives active tectonic index, and geotechnical, different areas are classified into four classes: Intense activity, High activity, Moderate activity, and Low activity [13-15].

TABLE 4. EVALUATION OF ACTIVE TECTONICS IN THE STUDY AREA BASED ON AN ACTIVE TECTONIC INDEX

Morphotectonics indicator	Index of active tectonics (IAT) $IAT = S/N$
The components of the equation	S: Sum of the classes of calculated geomorphic indices N: Number of calculated indicators
Measurement method	----------
Significance	1<IAT<1.5: Intense activity 1.5<IAT<2: High activity 2<IAT<2.5: Moderate activity 2.5>IAT: Low activity

E. Drainage basins (Bs)

Almost young drainage basins in tectonic active areas tend to be elongated. With the constant evolution of tectonic processes, basins tend to be elongated rather than circular. B_L length of the watershed is measured from the source to the outlet and B_W width of the basin is measured at its widest point [13-15].

$$B_S = \frac{B_L}{B_W} \quad (4)$$

III. RESULTS AND DISCUSSION

In recent years, morph tectonic indices have become important tools to identify and determine the extent of tectonic activity in active areas. In morph tectonic studies, the use of remote sensing software that automatically calculates the indicators is of great importance because despite such advanced software, if the user participates in the calculation process, the two issues of error and long computation time always prevent the achievement of definitive results [17].

Stream Length-gradient Index (S_L): This is a useful tool for assessing relatives' active tectonics. The stream length gradient index is sensitive to and dependent on changes in river slope; this dependence and sensitivity can provide a criterion to estimate the relationship between tectonic activities as well as the topography of the river course [18]. Accordingly, a change in river slope or gradient can change S_L. If the riverbed is raised and elevated, the slope of the riverbed will change which can cause a change in the value of the S_L index [19].

There are different methods for measuring the S_L index, but the best method for this purpose is to use the longitudinal profile of the main waterway [20]. In the study area, the S_L index was calculated at five points for the main waterway where the slope of the profile changes (Figure 2), the largest value of which represents the SL index of the river (Table 5). Based on the results of the SL index calculation, the study area is in an inactive tectonic class [21].

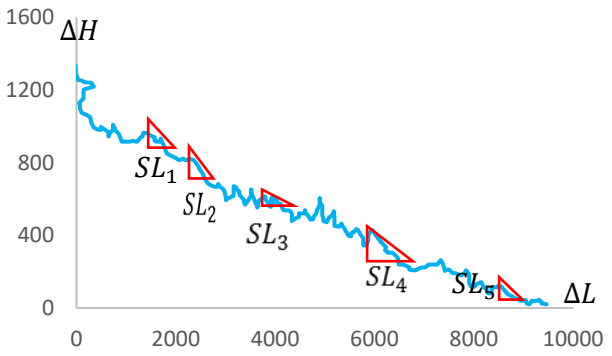


Fig. 2. Longitudinal profile of the main waterway in SAQEZ RIVER Basin

TABLE 5. HOW THE BASIN IS CLASSIFIED BASED ON TECTONIC ACTIVITY

Row	Indicator	Low[1]	Moderate[2]	High [3]
1	T	1-0.66	0.33-0.66	0-0.33
2	Hi	>0.5	0.4-0.5	<0.4
3	A_f	AF-50<7	AF-50>7-15	AF-50>15
4	B_S	>4	3-4	<3
5	S_L	>500	300-500	<300
6	S_r	1-1.5	1.5-2	>2
7	P	>0.6	0.5-0.6	<0.5
8	B_r	>4	3-4	<0.3

River sinuosity index (S_r): The higher the S_r index, the closer the river to equilibrium and hence the lower the rate of tectonic activity in the area [22]. Therefore, in the study of this index by observing the general appearance of the river, if the river sinuosity is high, the first morph tectonic result can be the relative stability of the region in terms of tectonic activities. In the study region, the value of the S_r index is estimated to be 1.27, which indicates that it has High active tectonics.

Drainage basin shape index (B_S): The basis of describing this index is the study of the geometric shape of the basin through its elongation ratio. A high value of the B_S index is radiated to elongated basins in tectonically active regions, while the small values indicate the circular basins in inactive regions [20]. In the study region, the value of the B_S index is estimated to be 1.09, indicating that the SAQEZ RIVER basin is tectonically inactive [23].

Drainage Basin Asymmetry Factor (A_f): Studying the geometric shape of the system of waterways in a basin is the basis for determining this index that is proportional to the rate of tectonic activity. In areas with high rates of tectonic activity, asymmetries in the geometry of waterways and drainage basins can be identified and traced (Keller and Pinter, 2002). If the A_f value is lower or higher than 50, the basin is affected by tectonic forces, and in this case, asymmetry has occurred in the basin. In such cases, if the A_f value is >50 and <50, the slope and elevation are radiated to the right and left sides of the basin, respectively (Figure 3). To describe tectonics, we use the difference between the value of A_f and 50. If the absolute value of this difference is >15, it indicates active tectonic regions; if it is between 7 and 15, it is radiated to semi-active regions; and if it is <7, it shows inactive regions. In this study, the value of A_f is 66 and the absolute value of A_f difference with 50 equals 16, indicating the active tectonic zone and slope on the right side of the basin [24].

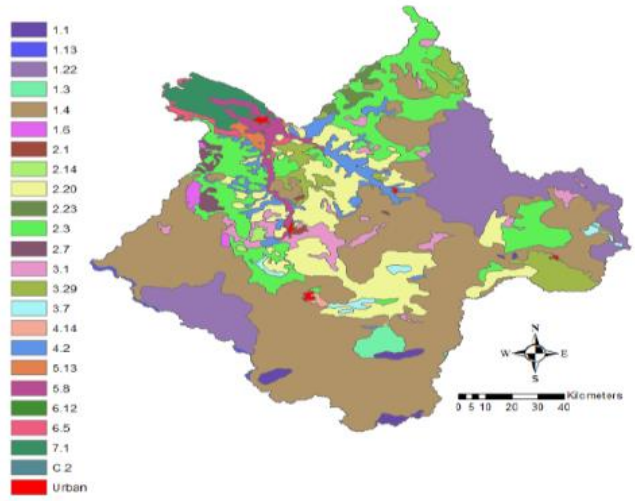


Fig. 3. The parameters of A_f in SAQEZ RIVER Basin

Index of active tectonics (IAT): This index is determined by averaging ten Morphotectonics indices. In this respect, after examining the tectonic indicators of the study area and determining the rate of activities of each indicator, the classification or prioritization of these activities is done (Table 6).

TABLE 6. RANGE OF CHANGES IN MORPHOTECTONICS INDICES AND THEIR CLASSIFICATION

NO	Δ_H m	Δ_L m	L m	S_L
S_{L1}	18	300	1900	114
S_{L2}	20	250	2550	204
S_{L3}	10	350	4525	129.28
S_{L4}	23	300	6825	523.25
S_{L5}	12	400	8500	1020

IV. CONCLUSION

In this research, the stream length-gradient index (S_L), basin shape index (B_S), river sinuosity index (S_r), and drainage basin asymmetry factor (A_f) were calculated to study the active tectonics of SAQEZ RIVER Basin. After determining the classification method, the class of the watershed is determined in terms of each index, and finally, by summing them, the overall class of the watershed is obtained, which is shown in Table 5-6 and Figure 2. Considering that the points given are between 1 and 3, the tectonic activity status of the basin will be evaluated in such a way that the basin with an average of less than 1.75 is an active tectonic state, a basin with an average of 1.75 to 2.5 is an almost active tectonic and basin with an average of more than 2.5 They have inactive tectonic status; Based on the results, the two indices of SL and BS are in an inactive class of tectonic activity, Sr is in semi-active, and Af is in an active class. After determining the activity of morph tectonic indices, the index of active tectonic (IAT) was calculated by averaging the mentioned indices. Based on the results of the relative's active tectonics index (IAT = 2.25), SAQEZ RIVER Basin is in moderate activity class and it is semi-active (Moderate) in terms of tectonics, as a result of which we observe elevation in the western part of the drainage basin. Examination of satellite images and topographic maps reveals the absence of an active fault system in the region, which can be a reason for the moderate or semi-active tectonic (Moderate) activity of this area.

The calculation of geomorphological indices is one of the most important tools for studying the tectonic activity of any region. In this research, the stream length-gradient index (SL), basin shape index (BS), river sinuosity index (Sr), and drainage basin asymmetry.

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