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Analysis of Tectonic Activity using Morphotectonic Indices (Case study: Kesmat Basin, Lorestan Province, Iran)

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ABSTRACT

Rivers are sensitive to tectonic movements, and there is a close relationship between river landforms and tectonic movements. Morphotectonic indices are used as an instrument to identify new and active structures of these movements. Kesmat catchment is a sub-basin of Dez River, which is located in Lorestan Province with a surface area of 34.33 square kilometers. The aim of this study was to analyze the tectonic activity of Kesmat Basin using topographic map and digital elevation model in the environment of remote sensing software and GIS. In this study, four morphotectonic indices including Stream Length-gradient Index (SL), Index of Drainage Basin Shape (BS), River Sinuosity Index (S) and Drainage Basin Asymmetry Factor (AF) were used, and the results of their analysis were expressed as Index of Active Tectonics (IAT). Based on the findings, the values of 207, 1.09, 1.27 and 66 were obtained for SL, BS,S and AF indices, respectively. The index of active tectonics (IAT) shows that the region has moderate tectonic activity.

1. Introduction

Earth is a dynamic system that is characterized by transformation (Ramesht et al., 2009; Azarafza et al., 2021). There is almost no area on earth not affected by new tectonic activities in the last few thousand years. In fact, it can be stated that active new plate tectonics is changing the shape of the earth's surface (Wallace, 1977). Among geological methods for studying active tectonic movements, geomorphological and morphotectonic 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. Morphotectonics is a branch of tectonics, which studies the forces and factors creating the shapes and forms in the outer crust of earth. In fact, morphotectonics is the study of landscapes created by tectonic processes, which expresses the relationship between geomorphology and tectonics. A complete assessment of tectonic activities, especially new tectonic movements such as landslides, earthquakes, etc., and the resulting hazards requires a thorough knowledge of the speed and arrangement of geomorphological processes. Therefore, this study was conducted with the aim of quantifying tectonic activities in the Kesmat Basin.

In this research, the tectonic activity of Kesmat Basin located in Lorestan Province has been analyzed using geographical information system and remote sensing. Remote sensing is the discipline that can present valuable information by observing and measuring an object or

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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 (Mousavi and Almasian, 2011). In the field of tectonic research, a number of studies have been conducted in Iran and other parts of the world, including the following:

Hamdouni et al. (2008) classified the active tectonics of southern Spain and identified its active areas using geomorphic and relative tectonic activity indices. Ezzati and Aqatabai (2014) analyzed the active tectonics of Bojnourd Basin using morphotectonic indices. In this study, which used various indicators including the shape of the basin, asymmetry of the drainage basin, hypermetric curve, hypermetric integral and IAT results of the region showed that the eastern part of the basin had a more active tectonics. Afshari et al. (2019) performed relative evaluation of the tectonic status of railroad tracks in Lorestan region using IAT and calculated seven geomorphological and morphotectonic indices such as hypermetric integral (Hi) and curve, Stream Length-gradient Index (SL), Index of Drainage Basin Shape (BS), Drainage Basin Asymmetry Factor (AF). Buczek and Gornik (2020) using morphotectonic indices to describe tectonic activity in the Tatra Mountains. Ngapna et al. (2020) investigated the IAT in Idea Esca region of southwestern Cameroon, and concluded that the study area is tectonically active. Habibi Mood et al. (2021) they studied active tectonics in the southeastern basins of Bazman volcanic region. The results of the analysis of morphotectonic indices indicated tectonic activity in and around Bazman volcano. Khalaj (2021) assessed Qorveh-Dehgolan drainage basin using five geomorphic indices of relative relief (Bh), drainage density (Dd), form factor (Ff), hypermetric intergral (Hi) and stream length-gradient Index (SL). Makrarai et al. (2022) analyzed tectonic activity in the Borpani River area, according to the results; about 24% of the studied indicators were in the active tectonic class. Kumar et al. (2022) used stream length-gradient Index (SL), hypermetric integral (HI), drainage basin shape (BS) and valley floor (VF) indices to evaluate the relative active tectonic index (IAT) in Dadra and Nagar Haveli.

2. Characteristics of Studied Basin

Kesmatdrainage basin with a relative surface area of 34 km^2 is located 50 km southeast to Khorramabad city in Lorestan Province (Fig. 1). The highest point of this basin is about 1776 m and the lowest point is nearly 921 m above sea level. From a tectonic viewpoint, the study area is located in Folded Zagros. To analyze and evaluate the tectonic movements in the basin under study according to authentic geomorphic indices, Stream Length-gradient Index (SL), river sinuosity (S), basin shape (BS) and asymmetry factor (AF) of drainage basin were used, and after calculating the desired indices, the tectonic activity of this region was evaluated using IAT (Table 1).

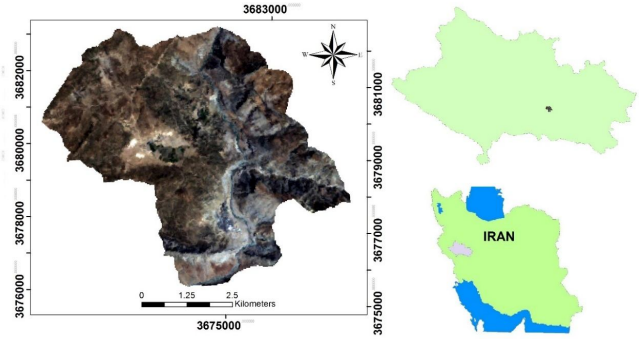


Figure 1. Location of Kesmat Basin in Iran

3. Results and Discussions

In recent years, morphotectonic indices have become important tools to identify and determine the extent of tectonic activity in active areas. In morphotectonic studies, the use of remote sensing software that automatically calculate 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.

Stream Length-gradient Index (SL): This is a useful tool for assessing relative active tectonics (Keller & Pinter, 2002). 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 (Molin et al., 2004). Accordingly, a change in river slope or gradient can change SL. If the riverbed is raised and elevated, the slope of the riverbed will change thatcan cause the change in value of SL index. There are different methods for measuring SL index, but the best method for this purpose is to use the longitudinal profile of the main waterway (Burbank and Anderson, 2011). In the study area, the SL index was calculated at five points for the main waterway where the slope of the profile changes (Fig. 2), the largest value of which represents the SL index of the river (Table 2). Based on the results of SL index calculation, the study area is in an inactive tectonic class.

River sinuosity index (S): The higher the S index, the closer the river to equilibrium and hence the lower the rate of tectonic activity in the area (Keller and Pinter, 2002). Therefore, in the study of this index by observing the general appearance of the river, if the river sinuosity is high, the first morphotectonic result can be the relative stability of the region in terms of tectonic activities. In the study region, the value of S index is estimated to be 1.27, which indicates that it has semi-active tectonics (Fig. 3).

Drainage basin shape index (BS): The basis of describing this index is the study of geometric shape of the basin through its elongation ratio. A high value of BS index is related to elongated basins in tectonically active

Table 1. Indicators used to evaluate active tectonics in the study area (Hamdouni et al., 2008)

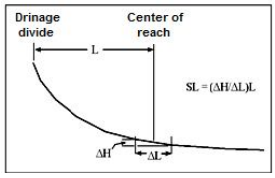
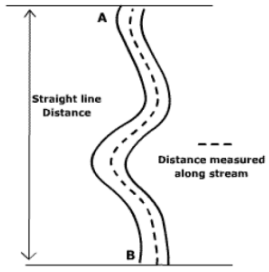
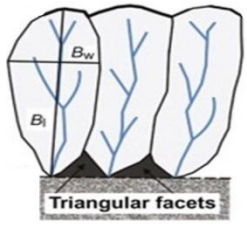
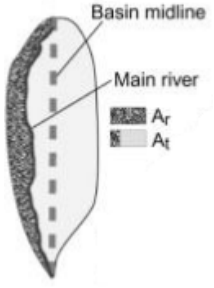
Morphotectonic indicator	The components of the equation	Measurement method	Significance
Stream Length-gradient Index (SL) SL=(ΔH/ΔL)L	ΔH: Height difference of the desired segment ΔL: The length of the desired branch L: The total length of the waterway from the center of the point where the index is calculated to the highest point of the waterway upstream		300>SL: Inactive 300<SL<500: Semi-active 500<SL: Active
River sinuosity index (S) S=C/V	S: River sinuosity index C: The length of the river V: The length of the valley in a straight line		1.3<S: Inactive 1.3<S<1.15: Semi-active 1.15>S: Active
Index of Drainage Basin Shape (BS) BS=BL/BW	BL: The length of the basin from the outlet to the end of the basin BW: Width of the basin in the widest part		BS: Inactive 3<BS<4: Semi-active 4<S: Active
Drainage Basin Asymmetry Factor (AF) AF=100(Ar/At)	AF: Asymmetry Factor Ar: Drainage basin area to the right of the main waterway At: Total surface area of the basin		If the numerical value of this index is nearly 50, it indicates the existence of symmetry
Index of active tectonics (IAT) IAT=S/N	S: Sum of the classes of calculated geomorphic indices N: Number of calculated indicators	----------	1<IAT<1.5: Intense activity 1.5<IAT<2: High activity 2<IAT<2.5: Moderate activity 2.5>IAT: Low activity

Table 2. Results of SE index calculation in Kesmat Basin

No.	ΔH (m)	ΔL (m)	L (m)	SL
SL1	12	300	1700	232.25
SL2	24	300	2250	2812.5
SL3	16	250	3125	2275.3
SL4	18	350	5825	4114.2
SL5	14	400	8300	1922.8

regions, while the small values indicate the circular basins in inactive regions (Bull and McFadden, 1977). In the study region, the value of BS index is estimated to be 1.09, indicating that Kesmat basin is tectonically inactive (Fig. 3).

Drainage Basin Asymmetry Factor (AF): 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 AF 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 AF value is >50 and <50, the slope and elevation is related to the right and left side of the basin, respectively (Fig. 4). To describe the tectonics, we use the difference between the value of AF 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 related to semi-active regions; and if it is<7, it shows inactive regions. In this study, the value of AF is 66 and the absolute value of AF difference with 50 equals 16, indicating the active tectonic zone and slope on the right side of the basin.

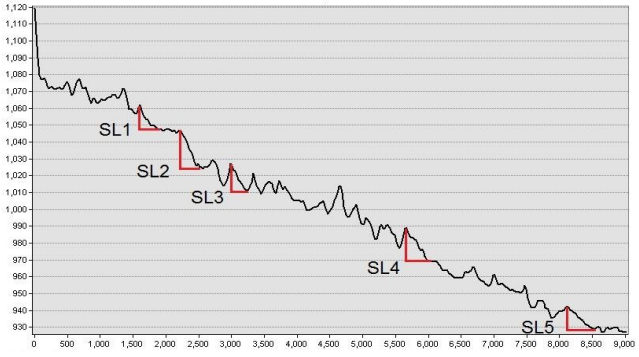


Figure 2. Longitudinal profile of the main waterway in Kesmat Basin

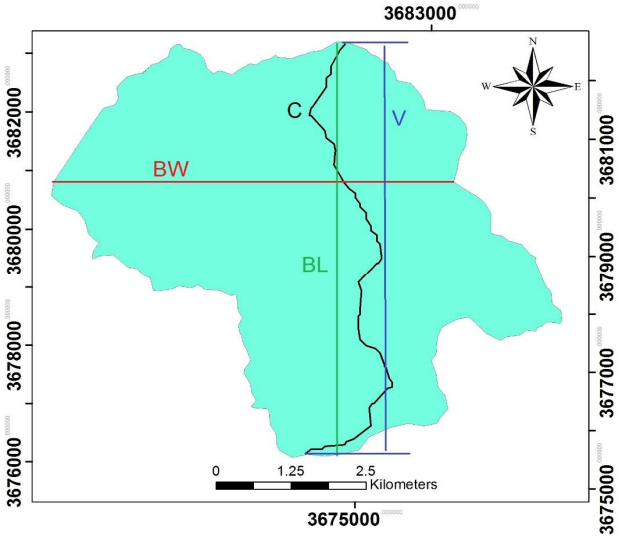


Figure 3. The parameters of S andBsin Kesmat Basin

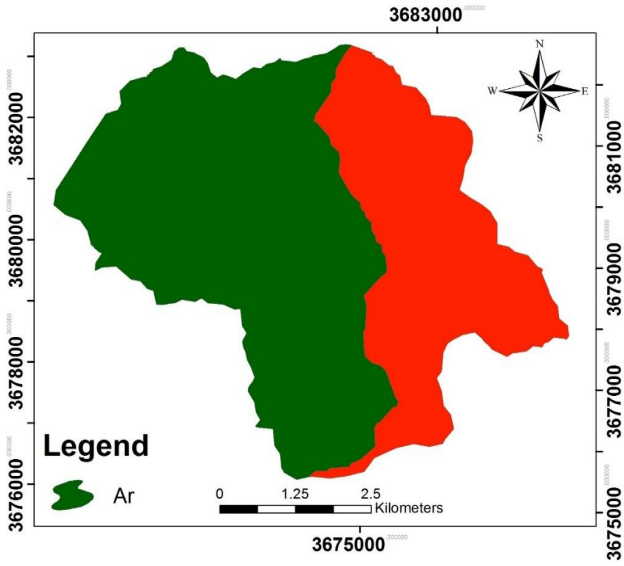


Figure 4. The parameters of AF in Kesmat Basin

Table 3. Range of changes in morphotectonic indices and their classification

Morphotectonic Index	Activity Class		
	High	Moderate	Low
SL	500 <	300 - 500	300 >
AF	15 <	7 - 15	7 >
BS	4 <	3 - 4	3 >
S	1.15 >	1.15 - 1.5	1.5 <

Index of active tectonics (IAT): This index is determined by averaging ten morphotectonic 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 presented in Table 3 (Hamdouni et al., 2008). According to the calculation of active tectonics index, the study area with an IAT value of 2.25 has moderate tectonic activity.

4. Conclusion

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 (S) and drainage basin asymmetry factor (AF) were calculated to study the active tectonics of Kesmat Basin. Based on the results, the two indices of SL and BS are in inactive class of tectonic activity, S is in semi-active and AF inactive class.

After determining the activity of morphotectonic indices, index of active tectonic (IAT) was calculated by averaging the mentioned indices. Based on the results of relative active tectonics index (IAT = 2.25), Kesmat Basin is in moderate activity class and it is semi-active 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 map reveals the absence of active fault system in the region, which can be a reason for the moderate or semi-active tectonic activity of this area.

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