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INVESTIGATION OF THE TECTONIC ACTIVITY OF BAZARGAN MOUNTAIN IN IRAN

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In this paper, the neotectonic activity of Bazargan Mountain located in NNW of Kerman City in the central part of Iran has been analysed and mapped by a new method using the tectonic features available in the region. The method that has been used in this research is based on the potentials of Geographical Information System (GIS) and Fishnet model. In this study, the data have been extracted from topographical maps, aerial photographs, Google Earth and field checking. In this regard, morphotectonic indices, mountain front sinuosity, and mountain front faceting have been analysed to determine the tectonic activity of the mentioned region. Having combined these data, the Index of Active Tectonics (IAT) has been defined, based on which the region zoning has been performed. Overall, the results indicate that the western and northwestern side of the region is relatively active tectonically.

KEYWORDS:
Morphotectonic, Kuhbanan, Fault, Earthquake

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Introduction

Morphotectonics is one of the branches of tectonics, which deals with the forces and their developing factors by evaluating landforms present in the earth's surface and discussed by many types of research (Bull 2008; Derakhshani and Eslami 2011; Fadaie Kermani, et al. 2017; Keller and Pinter 1996). Since these landforms are generally related to the last movements of the earth's crust, their study can greatly help on issues related to active tectonics (Pérez-Peña, et al. 2010; Summerfield 2014; Topal, et al. 2016; Vijith, et al. 2017). On the other hand, the forms and shapes of the earth's surface are not merely the product of internal factors and forces. Rather, external factors also cause deformation in the forms and shapes resulting from the internal forces of the Earth. They are dealt with in geomorphological fields and their effect should also be taken into consideration in morphotectonic studies. Considering the close relationship between tectonics and geomorphology, a subject called tectonic geomorphology has been developed, which deals with the interactive effect of these factors (Summerfield 2014; Tepe and Sözbilir 2017). All of the forms and ruggedness of the earth's surface can be described based on their size, height, and slope and then be compared quantitatively (Das, et al. 2016; Prizomwala, et al. 2016; Ramirez-Herrera 1998; Silva, et al. 2003). While quantitative measurements of these forms allow for calculation of the special characteristics of a region such as their tectonic activity level in addition to comparing geomorphologic indices and parameters more accurately, the most important aim of applying morphotectonic indices and morphometric measurements in geomorphology is obtaining and studying the forms and ruggedness of the earth's surface from a qualitative and descriptive state to numerical (Crupa, et al. 2017; Dubey, et al. 2017; Kotlia, et al. 2017; Koukouvelas, et al. 2017; Mulyasari and Brahmantyo 2017; Sharma and Sarma 2017; Urbano, et al. 2017). The aim of this research is to examine active tectonics in Bazargan Region, based on geomorphologic studies and morphometric measurements using Fishnet model.

The studied region is affected by Kouhbanan Fault which is one of the active faults of Iran. Its geographical coordinates are of 56°51' to 57°17' of eastern longitude and 30°24' to 30°40' of the northern latitude, 15 km away from Kerman City (Fig. 1). The area of the studied region is 1219 km^2, and the front length of the mountain has been considered to be around 32 km (Fig. 2).

Fig. 1. *The geographical position of the studied region, which has been marked by a black square in Iran's map*

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Fig. 2. The map of the position of the mountain front, as well as the fronts, plotted in the region

Materials and Methods

For evaluation of the tectonic activity of the area, sinuosity of mountain front and mountain front faceting indices have been analysed. The sinuosity of mountain front index is calculated by the following formula:

$$Smf = \frac{Lmf}{Ls}$$

In this formula, Smf is the sinuosity of the mountain front, *Lmf* represents the mountain front length, and *Ls* denotes the straight line length of the mountain front (Fig. 3).

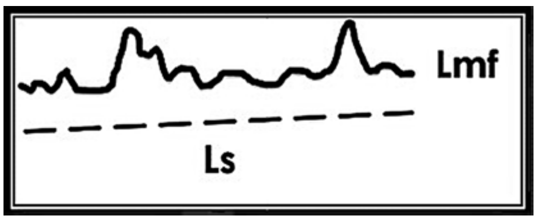

Fig. 3. A schematic view of the manner of calculation of the sinuosity index of the mountain front

This index indicates a balance between the intensity and tendency of drainages for developing an irregular and sinusoidal front with a vertical tectonic activity to develop a straight front. Accordingly, the degree of uplift for a mountain front can be related to certain sinuosity values. By calculating this index, the relative uplift values and the activity of the mountain front can be predicted. The mountain fronts that have young and active uplift, are straight (*Smf* ≈ 1). However, if the level of uplift declines or approaches zero, the erosion process causes the formation of a meandrous front. In this case, increasing of *Smf* index suggests lack of tectonic activity in that boundary of mountain and plain. Note that the lithology of mountain fronts and their resistance to erosion can be effective in the value of *Smf* index.

To calculate the value of this index in the studied region, 26 fronts were detected. These fronts were individually introduced into GIS medium. Next, using Fishnet model, the value of *Smf* index was allocated to each of the fronts. Eventually, the zoning map of the region was prepared based on the sinuosity index of the mountain front using Kriging method. Evidently, the closer the values of *Ls* and *Lmf*, the close the value of *Smf* to 1, suggesting a straight front for the mountain and stating the tectonically active areas. In such regions, the uplift rate has increased in the region. The measurements done in the region show that Front 2 with a value of 1.59 claims the maximum *Smf* value, while Front 1 with the value of 1.01 has the lowest *Smf* level. Finally, by considering all of the measured fronts and preparing the zoning map, the region was divided into three separate zones in terms of tectonic activity, where the eastern and western parts of the region (the beginning and end) have a relatively lower tectonic activity than the central parts of the region (Figs. 4 and 5).

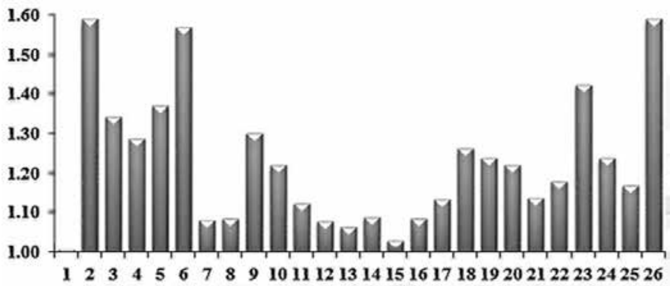

Fig. 4. The diagram of the sinuosity of the mountain front

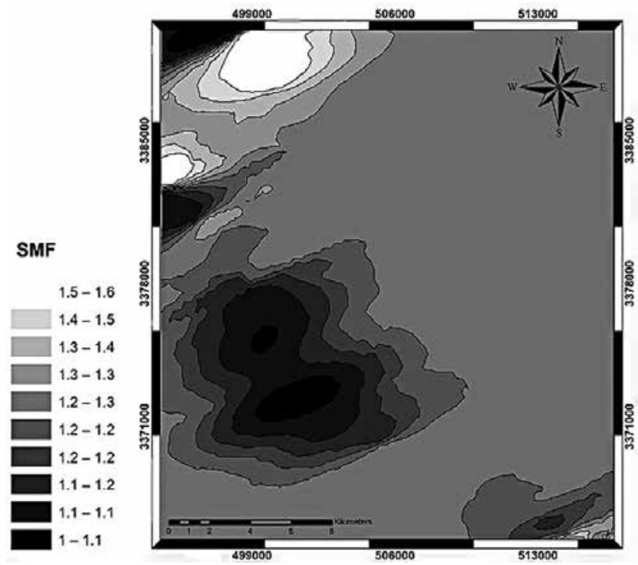

Fig. 5. The map of the tectonic activity level in terms of the sinuosity of the mountain front

The other morphotectonic index, the percentage of mountain front faceting (%Facet), is the ratio of the surface length in the mountain front (*Lf*) to the straight line length of the mountain front (*Ls*) (Fig. 6).

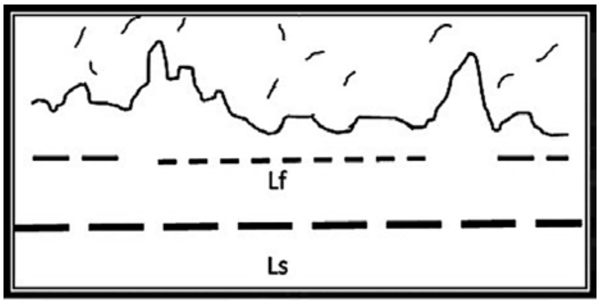

Fig. 6. *A schematic image of the parameters required for calculating the faceting percentage of the mountain front*

$$Facet\% = Lf/Ls \cdot 100$$

When calculating this index, we note that the high percentage of this index suggests that this mountain front is active. The calculations performed in 26 different stations indicate that Station 1 with 96.67% has the highest faceting value, while Station 19 with 69.67% indicates the lowest value of faceting. By introducing the data of all of the stations in GIS, the region's zoning map was prepared, where the central areas mostly shown by light grey colours have a lower tectonic activity. Furthermore, the eastern and western parts which have been shown by a dark colour in the map have a relatively higher tectonic activity (Figs. 7 and 8).

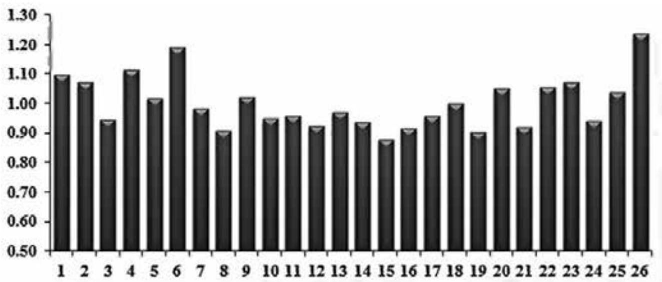

Fig. 7. *The diagram of the faceting percentage of the mountain front*

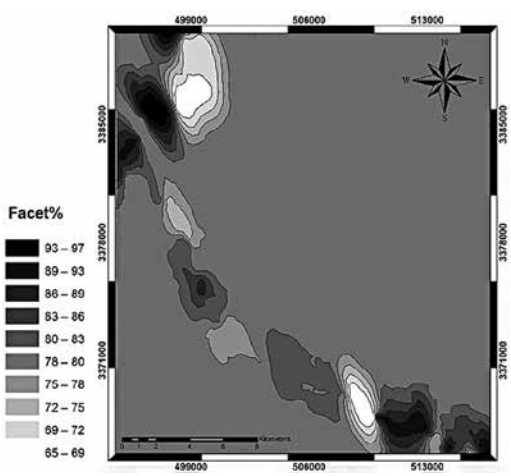

***Fig. 8**. The map of the activity level of the region in terms of the index of mountain front faceting*

To calculate the index of relative tectonic activity of the mountain front, following normalization of the sinuosity of mountain front and the faceting percentage of the mountain front and introduction of these data to GIS, the zoning map of the studied region was prepared by Kriging method, such that the western regions marked by a dark color reveal the regions with a relatively high tectonic activity. On the other hand, the eastern and central parts which have been shown by light grey highlight regions with a low tectonic activity (Figs. 9 and 10).

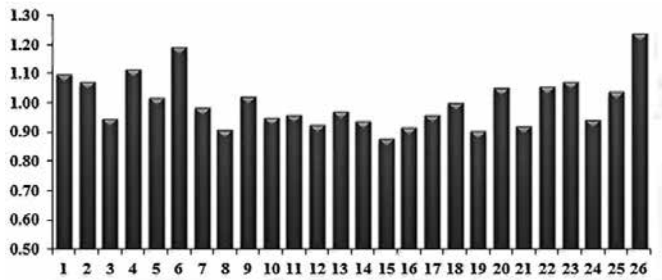

Figure 9: The diagram of the relative tectonic activity of the mountain front

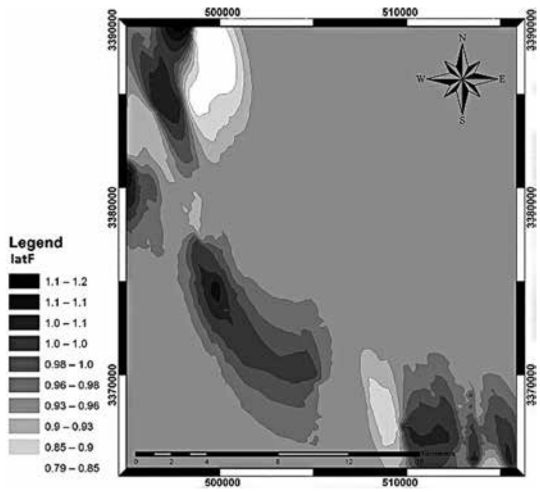

Fig. 10. *The final map representing the tectonic activity of the region*

Results and Discussion

Considering active tectonics, each basin can be studied from different characteristics including the status of peaks and troughs, form, lateral symmetry, the shape of valleys, the status of the mountain front, etc. Each of these characteristics can be investigated by two or several indices in many cases. In this research, to study these indices, Fishnet model has been used in GIS. For this purpose, a square network with a polygonal shape with dimensions of 23 * 26 km, while each cell has a size of 0.3 * 0.3 km, was considered in the studied region. It was then placed on the region in GIS using the following path:

Search/ Fishnet/ Create Fishnet/ output Feature Class/ Template Extent/ Cell Size Width/ Cell Size Height/ Number of Rows/ Number of Columns/ Geometry Type/ OK

In the Output feature class, the path of the output file is specified. In the template extent section, the linear file

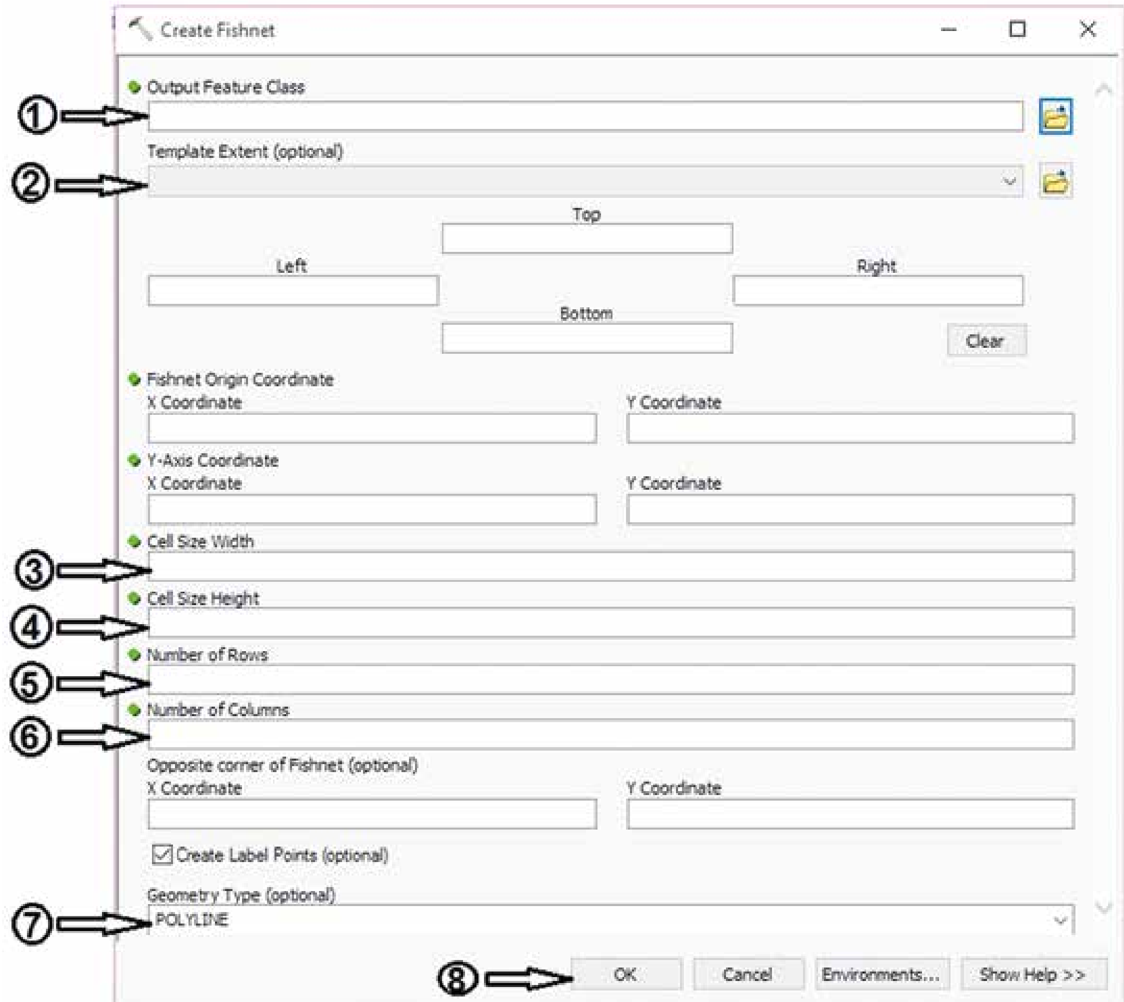

Fig. 11. The path of development of Fishnet model in GIS medium.

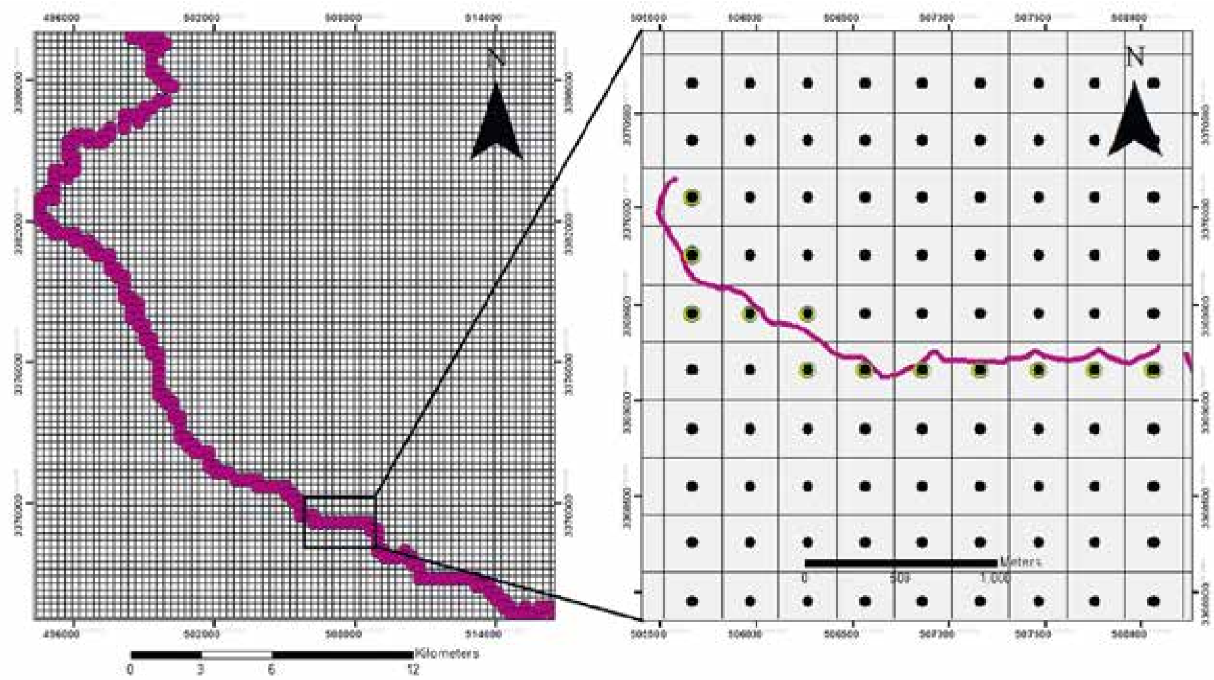

Fig. 12. The map of fishnet model prepared out of the mountain front indices

related to the mountain front is selected. The Cell Size Width is related to the width of each of the small cells of the Fishnet network. Further, in the Cell Size Height, the height of each of the cells is introduced arbitrarily. In Section Number of Rows, the Top and Bottom numbers present in the window are subtracted from each other and then divided by the Cell Size Width term. Similarly, in the Number of Columns field, the Left and Right numbers are subtracted from each other and then divided by Cell Size Height. In the frame Geometry type, the shapefile type is selected as Polygone. Finally, OK button is pressed to develop the Fishnet network (Fig. 11).

Once this network was overlaid on the studied region, every small cell of this network through which the mountain front lines have passed, a point is allocated by developing a point shapefile. Note that for the cells which include two lines of the mountain front, we apply two lines on average. Following this, for each of these points in the table which has been developed by point shapefile for this developed file, the numerical value of each of the measured indices of the mountain front (sinuosity of the mountain front and mountain front faceting) is introduced individually (Fig. 12).

By introducing every single point in the table related to each of these indices, eventually using Kriging interpolation method, the region's zoning map associated with each of these indices is prepared separately. Once this map is achieved, the degree of tectonic activity can be evaluated across various regions (Figs. 5, 8, 10)

Conclusion

In the final map of the relative tectonic activity of the mountain front in the studied region, the parts which have marked by dark colour indicate the area that has a relatively high tectonic activity, where the mean value of this index is measured as about 1.1-1.2 for these regions. Moreover, the pale parts, for which the mean value of the index has been calculated as around 0.79-0.85, have a lower tectonic activity than the darker parts. Based on the zoning map of the relative tectonic activity of the mountain front, the western parts of the region have a higher tectonic activity than other parts.

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ИССЛЕДОВАНИЕ ТЕКТОНИЧЕСКОЙ АКТИВНОСТИ ГОРЫ БАЗАРГАН (ИРАН)

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В данной работе анализируется тектоническая активность горы Базарган, расположенной в северо-западной части города Керман в центральной части Ирана и проводится картирование с помощью нового метода, применяя тектонические характеристики региона. Метод основан на потенциале ГИС и модели Фишнета. В данном исследовании данные получали из топографических карт, воздушной фотосъёмки, ресурсов Google. В этой связи морфотектонические индексы, слоистость горы и трещиноватость анализировались с целью определить тектоническую активность в указанном регионе. Объединив эти данные, получили Индекс Активной тектоники (ИАТ), на основании которого провели зонирование региона. В целом результаты указывают, что западная и северо-западная части региона являются относительно тектонически активными.

Ключевые слова: морфотектоника, Кухбанан, землетрясение, трещина.

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