Environment and Ecology 38 (3): 446—455, July—September 2020
ISSN 0970-0420

Assessment of Active Tectonic With Geomorphic Indicators and GIS In the North of Karaj Region (North of Iran)

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ABSTRACT Geomorphological indexes are useful tools for the relatively active tectonic investigation in a region in this research aims to investigate the relatively active tectonic of basins North of Karaj area which is located in North of Iran and Alborz zone based on geomorphic indices by Global Mapper software and Arc GIS are discussed. The calculated Indices include: Hypsometric integral (Hi), index of drainage basin shape (Bs), Asymmetry Factor drainage basin asymmetry (AF), at the end of these features together, the index of relative active tectonic (Iat) was calculated the combination of the above indicators, based on the value of each class obtained from geomorphological indicators for the twenty basin and averaging them (S/n), the study is divided into three zones of tectonic area. The first group of tectonic activity high amounts of $1 < S/n \leq 1.5$, the second group with tectonic activity average values $1.5 < S/n \leq 2$ and the third group with tectonic activity down to levels $2 \leq S/n$ shows. For true analysis of study area, AHP model (analytical hierarchy process) with a criteria weight and prepared the final relatively tectonic layer that overlapped with applying module, using the techniques of the digital elevation model and interpretation in the Arc map to determine geomorphic indices and its impact on tectonic activity in the region basins with extensive field studies It was found that the relative distribution map index active tectonic (Iat) in the region is consistent with other parameters of active tectonic that demonstrate the uplift in large parts of the area study. Comparing the values obtained with high tectonic zone with class and asymmetry of the mentioned basin is confirmed and clearly with the values obtained are consistent tectonic geomorphological indicator classes.

Keywords: Geomorphic indices, Active tectonics, North of Karaj region basins, Analytical hierarchy process.

INTRODUCTION

Considering the location of Iran in the Alp-Himalayas seismic belt, this area is considered to be one of the most active tectonic regions of the world (Urbano*et al*. 2017). Because of this complex geological history, the taxonomical setting of Iran has a wide variety of morphological features. The Alborz area is also affected by these complexities as one of structural states. For this reason, the Alborz area, as one of Iran's tectonic sub-regions, is also affected by these complexities. The study area in this study is one of the most complex parts of the orogenicAlborz zone. This is evident from the position of structural bending, the change in seismic behavior and even the change in the topography of the Alborz in this part of orogenic zone. The Alborz mountain range is located at the southern margin of the southern Caspian basin, with a width of 100 km and a length of 2000 km from the small Caucasus in the Northwest to the Paropamiso Mountains in Northern Afghanistan in the East (Koukouvelas*et al*. 2017). This area, like many parts of Iran, is affected by continual convergence of the Indian plate from the Southeast, of Oman plate from the South side, of the Arabian plate from the Southwest side and from the side of the Eurasia plate from the North. Due to these convergences from the beginning of the Pontine period, we have seen uplifting and compaction in the Alborz area, which is resumed in the late Pliocene and early Quaternary periods. The study area in the Southern slopes of central Alborz has been formed from the sequential igneous rocks, andesitic volcanic rocks and palaeogenic intrusive components. Following the collision of the active continental margin of Eurasia (Turan) with the northern inactive continental margin of the Alborz, the formation of thrust and reverse faults made the ancient Tethys oceanic complexes on the northern edge of the Alborz. The first Alpine Orogenesis in the Paleocene occurred at the same time as the Laramide event, and as a result of the convergence between the Tazi and Eurasia plate. Following this convergence, we have witnessed the emergence of certain tectonic features, including: Tectonic folding, reverse faulting, and inter-mountain sedimentary basins, cumulative accumulation of siliciclastic rocks and clastic sedimentary rocksand prehistoric land migration to the South have been created. Moreover, a number of more or less parallel anticlines and synclines evidences the systematic tectonic evolution in the area. Figure 1 shows the location of the area under investigation on the map of Iran.

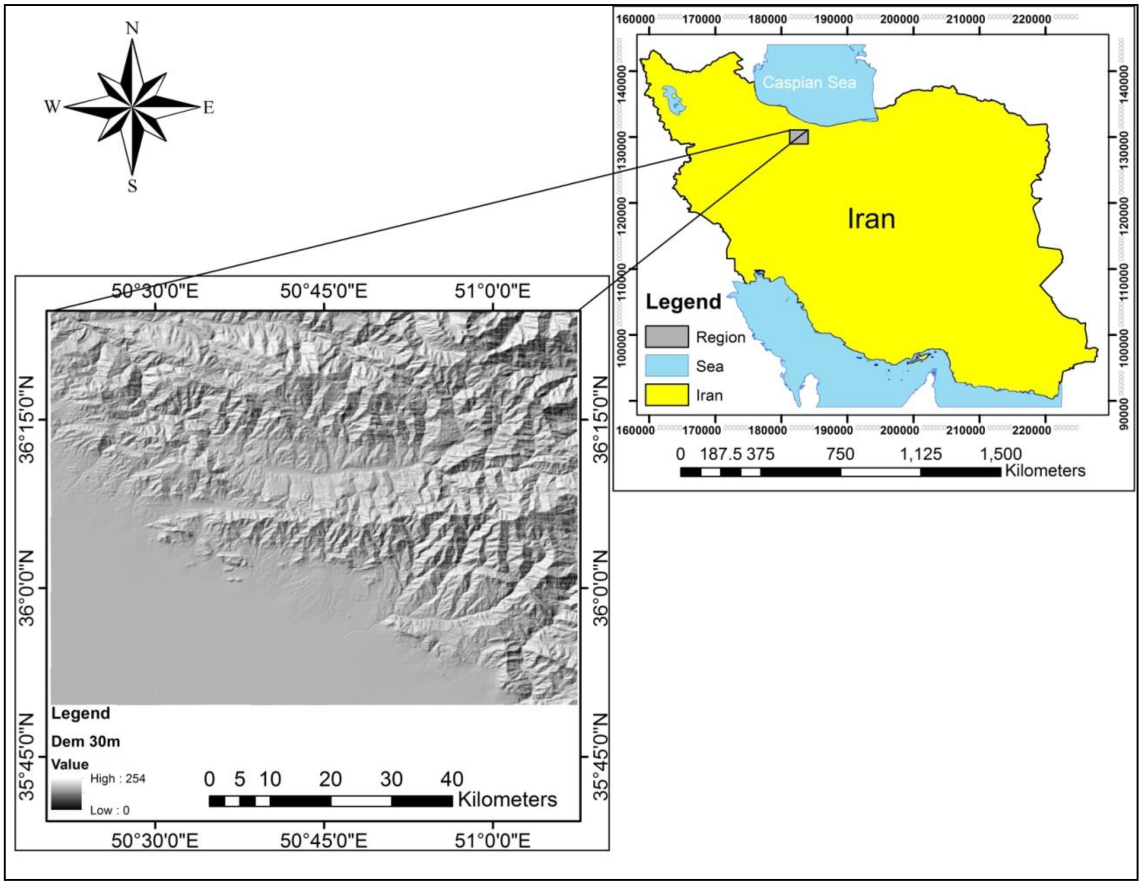

Figure 1. Location of the study area on the map of Iran (data extracted from digital maps of the Organization of Geological Survey and Mineral Exploration of the country).

Evaluation of morphometric indices

Geomorphology is a valuable tool in the investigation of active tectonics. Description of forms and ripples of the Earth's surface is performed with equations of size, height (maximum, minimum or average) and their gradient. In this research, three indices related to catchment basins have been investigated and by a single indicator (Iat), which results from the calculations of three morphology indexes, evaluates the relative tectonic activity of the area (El Hamdouni*et al.*2008, Figueroa and Knott 2010). Finally, considering the priority of the impact of each indicator in the study area and giving the expert weight to each of the morphology indicators and implementation of the AHP model, the amount of relative tectonic activity for each basin is separately calculated.

Hypsometric integral (Hi)

Hypsometric integral shows the height dispersion in a specific region. The Hypsometric curve, which includes plotting the altitude ratio versus the area ratio and calculating the area under the curve, is independent of basin size and bulge. The beneficial use of the Hypsometric curve is that drainage basins of varying sizes can be compared with each other (Pérez-Pena *et al.* 2010). Hypsometric integral is not directly related to the active tectonic. The high values of this indicator indicate active and young areas and their low levels are related to the old areas where the erosion process is dominant and are less affected by the active tectonic in the region (El Hamdouni*et al.* 2008). In the study area, by drawing the curve from the digital elevation model and calculating the area which represents the value of the index of Hypsometric integral, using the Arc GIS software and Excel, this index was examined. The values of this index were classified into three categories: Hi ≥0.5; Hi <0.5 Hi> 0.4 and <0.4 (Figure 2).

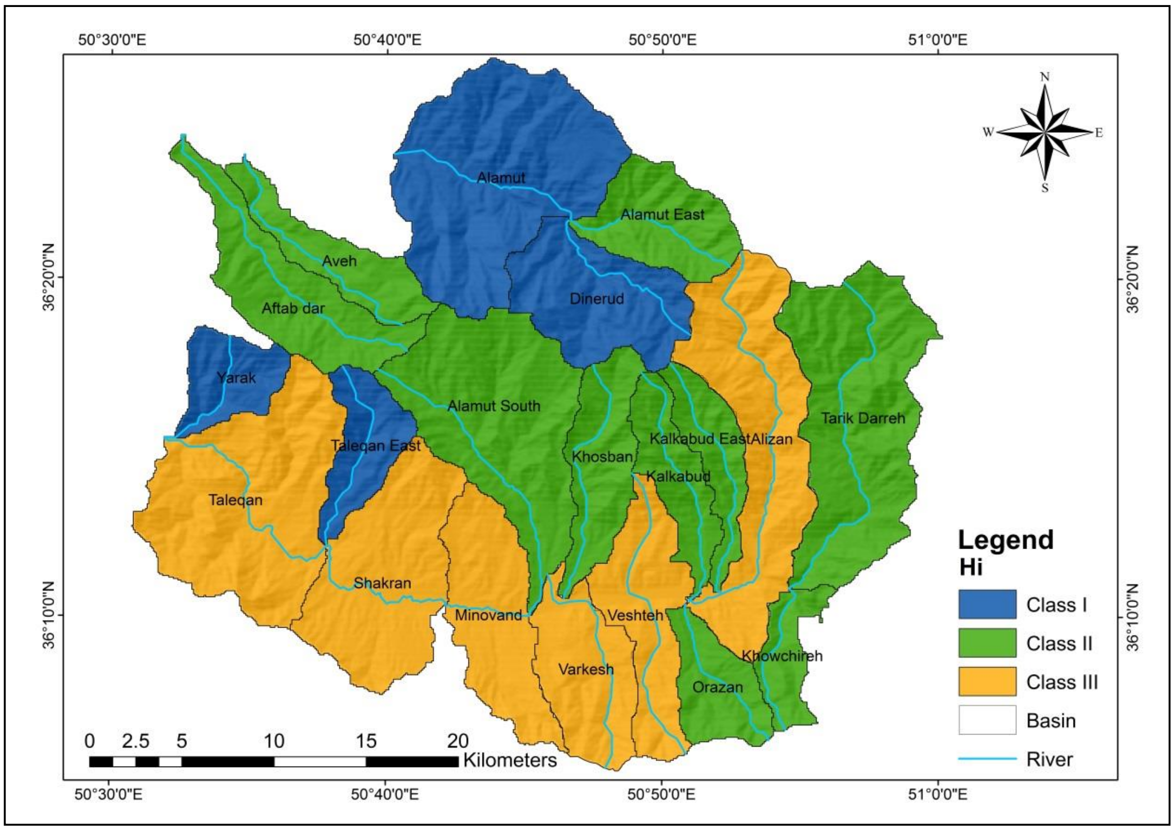

Figure 2 Spatial distribution of Hi values

Asymmetry factor (drainage basin asymmetry) (Af)

The length of the waterway and the minor drainages on the two sides of the main waterway can also be used to evaluate the active uplift. This index is defined as follows (Keller and Pinter2002):

$$Af = 100 (Ar / At)$$

Where, Af is Asymmetry index of waterway, Ar is the area of the basin including minor drainages on the right of the main stream (downward view of the main waterway) and a is the total area of the basin including minor drainages on the left and right of the main waterway. The numerical values of Af about 50 indicate the presence of drainage symmetry and, therefore, the absence of tilting due to uplift and numerical values greater than or equal to 50 represent a basin tilting which is the result of tectonic activity or structures derived from the characteristics of the rock study. Using ArcGIS, this index was measured for basins, the values of this index are classified into three categories:
AF-50> 15; 15> AF-50> 7 and AF-50 <7.The results show high tilting of the majority of basins to the west and it can be attributed to tectonic structures (Figure 3).

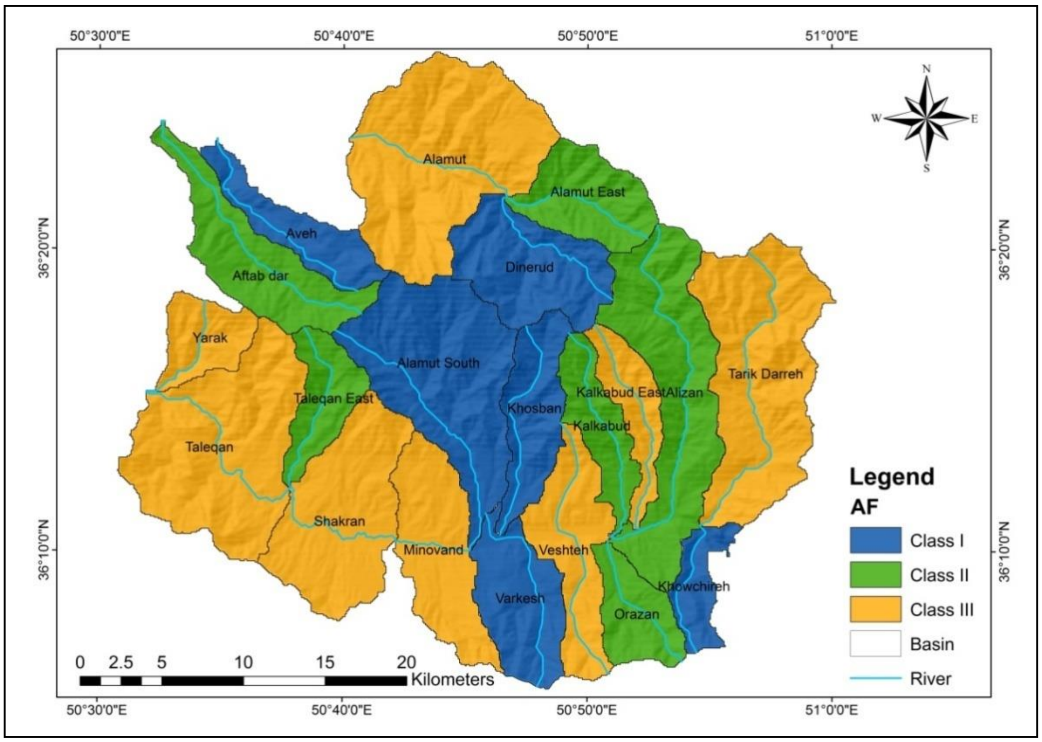

Figure 3. Spatial distribution of AF values

Index of drainage basin shape (Bs)

This index is expressed by the following equation (Sharma and Sarma2017):

$$Bs = Bl / Bw$$

Where, BI is the length of the basin is, the distance from the lowest point of the basin to the farthest point of it and Bw is the width of the basin Bw, which is measured in its widest part. The high rate of this indicator reflects the extended drainage basins, which are observed mostly in the younger areas of the basin and are mostly related to the Frontal Mountain Fronts due to the fast uplift associated with these structures (Bull2007). The values of this index are classified into three categories: Bs> 4; 4>Bs> 3 and <3. The rate of this indicator was calculated for all basins (Figure 4).

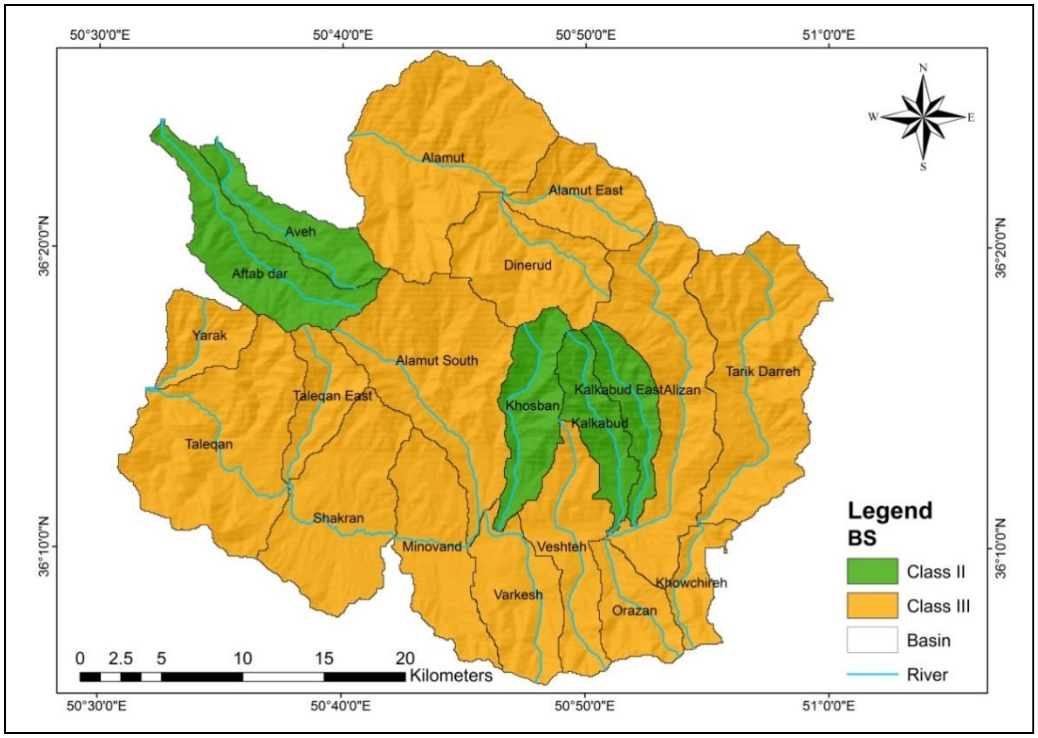

Figure 4. Spatial distribution of Bs index values

Relative tectonic activity index (Iat)

In this research, tectonic activity in the North of Karaj region has been evaluated using morphotectonic variables. By averaging various classes of morphotectonic indices, relative tectonic activity index (Iat) is achieved (El Hamdouni*et al*. 2008) to evaluate the distribution of tectonic relative activity in the study area, which can be divided into four categories:

Class 1, from the point of view of tectonic activity, is very high with 1 <Iat≤ 1.5, class 2, from the view of active tectonic is high 1.5 <Iat≤2, class 3, from the viewpoint of tectonic activity is moderate with 2 <Iat<2.5 and class 4, is low in terms of tectonic activity with 2.5L Iat. The relative tectonic activity classes (Iat) were obtained by collecting three geomorphological indices in the study area. Based on the value of each of the classes derived from the geomorphic indices for each basin and their average (S / n), the studied area is divided into three tectonic zones. The first group with high tectonic activity with values of 1 <S / n ≤ 1.5, the second group with moderate tectonic activity with values of 1.5 <S / n ≤ 2 and the third group with low tectonic activity with values of 2 ≤ S / n are shown based on the calculation of Iat index in the North of Karaj region in three classes 2, 3 and4 (Figure 5 and Table 1).

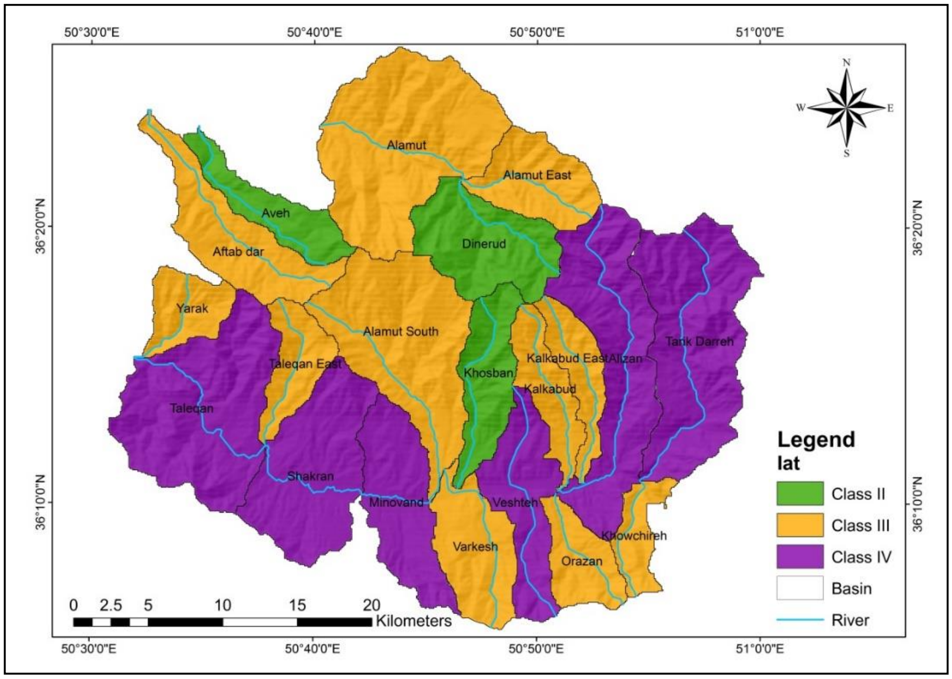

Figure 5. Relative tectonic activity classes (Iat) by color

Table 1: Classification of the relative tectonic activity (Iat) in the basins of north of Karaj region

Ref.No	Basin	Class of: Bs	AF	Hi	S/n	Iat class	Assessment
1	Aftabdar	2	2	2	2.00	3	Moderate
2	Alamut	3	3	1	2.33	3	Moderate
3	Aveh	2	1	2	1.67	2	High
4	Alamut East	3	2	2	2.33	3	Moderate
5	Dinerud	3	1	1	1.67	2	High
6	TarikDarreh	3	3	2	2.67	4	Low
7	Yarak	3	3	1	2.33	3	Moderate
8	Alamut South	3	1	2	2.00	3	Moderate
9	Taleqan	3	3	3	3.00	4	Low
10	Khosban	2	1	2	1.67	2	High
11	Taleqan East	3	2	1	2.00	3	Moderate
12	Kalkabud East	2	3	2	2.33	3	Moderate
13	Kalkabud	2	2	2	2.00	3	Moderate
14	Khowchireh	3	1	2	2.00	3	Moderate
15	Veshteh	3	3	3	3.00	4	Low
16	Shakran	3	3	3	3.00	4	Low
17	Orazan	3	2	2	2.33	3	Moderate
18	Minovand	3	3	3	3.00	4	Low
19	Alizan	3	2	3	2.67	4	Low
20	Varkesh	3	1	3	2.33	3	Moderate
Iat classification: 1(High Activity) ,, 2(Moderate Activity) ,, 3(Low Activity)							

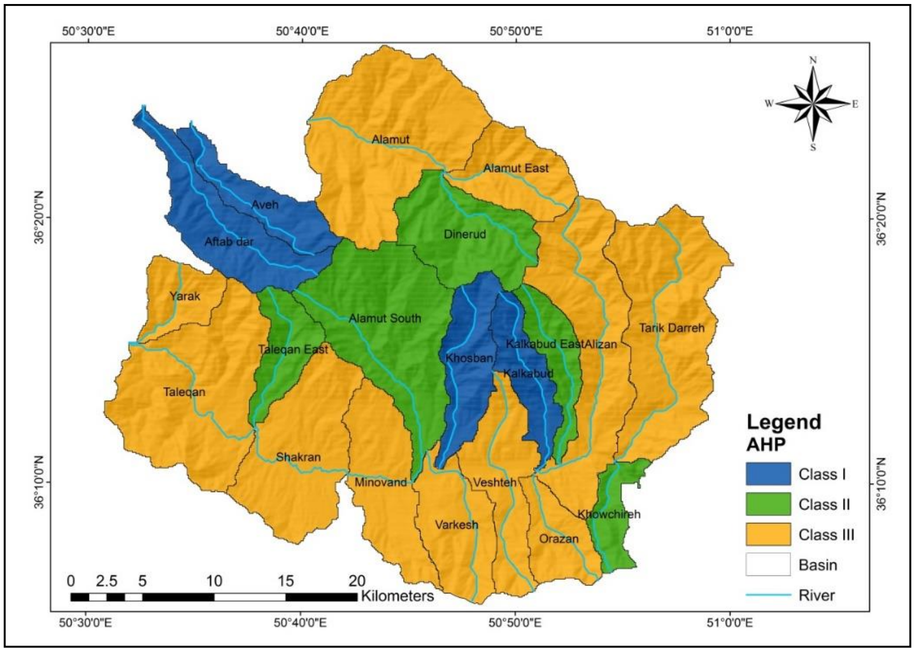

Figure 6 The relative tectonic activity categories using Analytical Hierarchy Process (AHP)

Hierarchical analysis process (AHP)

AHP is the hierarchical analysis process and is one of the most popular multi-purpose decision-making techniques. The basis of this decision-making method is the pairwise comparison and the decision maker decides by providing the hierarchical tree, then a series of pairwise comparison is performed. These comparisons show the weight of each of the factors in line with the competing items being evaluated in the decision. Finally, the logic of the hierarchical analysis process combines the matrices derived from the pairwise comparison to achieve the optimal decision. It seems that by evaluating the effective factors in each index and by information and results of calculation of indices, we can determine the weight and priority of each of layer of the above indices that instead of relying solely on the average of each indicator in the method (Iat), the weight and importance of each index compared with other indicators of the basis of work in determining the amount of tangible activity of the range is studied, the Iat index is not based on the weighting of the indicators and in calculating it, all indicators are considered to be of equal importance, on the basis of the fact that some indicators are directly and indirectly related to the tectonic activity of the region. It seems reasonable that some of the indicators have a higher weight than other indices, to perform analysis in this system, we provided the maps of classification of indices in the form of Raster and valued layers in GIS and to identify the priorities and integrating the maps, the geomorphic indices are prioritized using the decision making rules in order to integrate all the indices by maintaining the rank they have, then the impact coefficients were applied and the output raster was achieved using expert choice and ArcGIS. The applied coefficients for indices are determined Hi=1.2,BS=1.0,Af=1.1 and the final layer of relative active tectonic overlapped with the coefficients was provided by

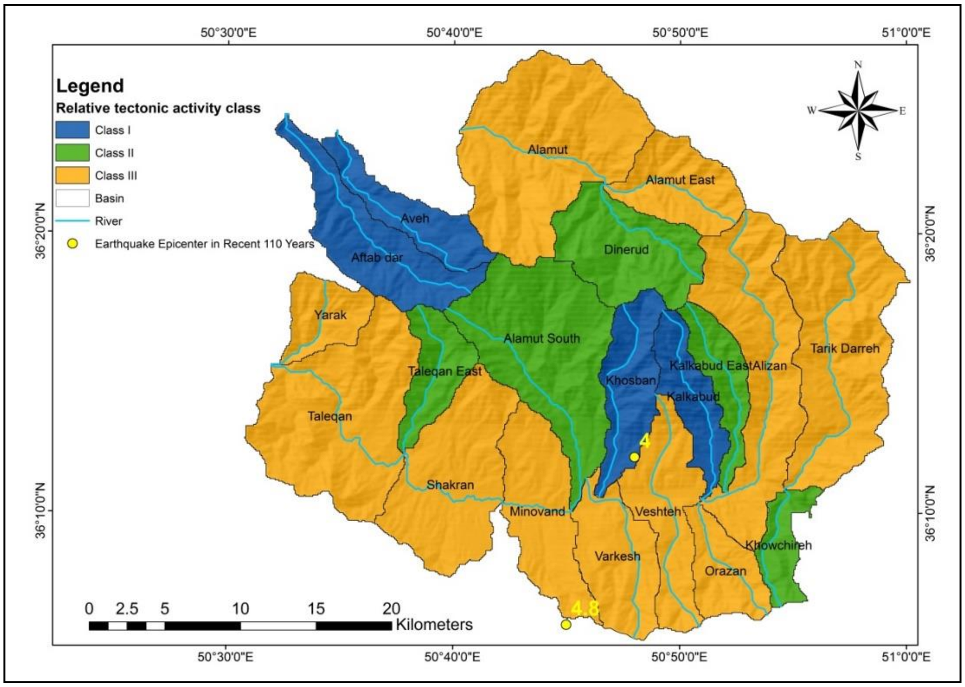

Figure 7. The distribution map of the center of earthquakes in the recent 110 years in the study area

which only four basins of Aftabdar, Aveh, Khasban and Kalkabud were in class 1 with the very high relative tectonic activity and TaleghanSharghi, AlamutJonubi, Dinerud, KalkabudSharghi and Khochire were in the high relative tectonic activity and the rest of basins of the region was placed in the class with moderate tectonic activity (Figure 6). Based on the map, the center of earthquakes in the recent 110 years (Figure 7), it shows the stress concentration in the extensive parts of the study area and based on the values, we can say the study area is in the pre-earthquake stage and the concentration of earthquakes is in line with the obtained data and the seismic activity is observed in the South of area to the North of Karaj region.

CONCLUSION

Tectonic indicators provide a useful tool for evaluating the level of tectonic activity. The study on morphometric complications, indices calculations, and the relative tectonic activity of class has good consistency with the regional index structures. After examining the geomorphological indices and calculating them in the study area, the area with a very high relative tectonic activity level (class 1) with an area of 147.49sq km, high (class 2) with an area of 216.89sq km and moderate (class 3) with an area of 708.36sqkm were identified.

Using DEM data techniques and GIS interpretations to determine geomorphic indicators and its effect on tectonic activity in area basins and with extensive field studies to find definitive findings to confirm tectonic activity with evidence from the area such as deep valleys, sudden changes in river cycles and fault surfaces are clearly consistent with the values obtained and the classes of geomorphologic tectonic indexes. The geomorphic indices calculated of DEM using GIS are suitable for the identification of neo-tectonic activities in the South of the study area. The movement of waterway is one of the best methods of the identification of subsurface structures and one of the most important morphological evidences and regarding the tectonic effect on the movement of river path, this movement can be observed well in the end of waterway of Khosban basin in the center of region well, here the presence of active tectonic structures can create deep valleys and the diversion of the river path.

Most of the regions with the relative moderate to high tectonic activity are in the regions in which rock sediments in these areas have high and deep fracture and have created important folding in its path. According to the relative tectonic activity of Khosban and Minovand basins and based on the values obtained from the device earthquakes of the recent 110 years by 2019, we can analyze that the mentioned basins have fast uplifting and brittle shape changing. By field observing from the tectonic fault and thin valley in these regions shows tectonic activity and uplift in the region. More than half of the total area of the study area in the classes is in the classes with the relative moderate tectonic activity and based on the recent earthquakes, we can say the active tectonic structures in the North of Karaj region namely in Shokran region have been created due to brittle and right slide deformation.

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