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Hypsometric Properties of Sedeh Basins in SW Iran (South of Zagros Fold-Thrust Belt)

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Abstract — **Hypsometric analysis of basin has generally been used to reveal the stages of geomorphic development. It is estimated by the graphical plot of the measured contour elevation and encompassed area by using empirical formulae. The current research mainly deals with the using the hypsometric index to analyze the hypsometric properties of drainage basins in Sedeh basin. In constructing the hypsometric integral curve, a Digital Elevation Model (DEM) with 30 m spatial resolution has been used. The result of hypsometric curve shows that 6 drainage basins are in Sedeh basin. Three different approaches were used for estimation of hypsometric integrals. The hypsometric integral values (HI) ranges between 0.22 and 0.36 for all the basins of Sedeh basin. In the study area, two stages of erosion cycle development, namely mature and old stages are distinguished. The obtained results of drowned hypsometric integral curves in 6 basins indicate the high value of HI is coincided to fault zones and folds and the southwest of Sedeh basin is more active than other ones.**

Keyword — **Active Tectonics, Iran, Tectonics Geomorphology, Zagros Mountain**

1. Introduction

There is always a strong relationship between landscape and the geologic environment. Geomorphology is a significant tool in tectonics studies when using the geomorphic record. Such record includes several land forms and the Quaternary deposits that capture immense amount of information from the last few thousands and extend to about two million years [1]. Tectonics geomorphology deals with relations between tectonics and Geomorphologic processes shaping areas of active Cenozoic deformations [2].

In recent years, the advancements in computer technologies and digital data processing has led to the improvement of the knowledge of geomorphic processes and the development of the use of predictive models and quantitative measurements to analyze, monitor, and understand landform changes [3], [4]. Satellite images are useful in obtaining quantitative measurements and performing geomorphic analyses. They permit research at different scales, which is valuable in the investigation of lineaments and faults [5], [6]. Geographic information systems (GIS) provides geologists opportunity to enhance, manipulate, and combine digital remotely-sensed data with several types of geographic information that in turn increases the amount of extracted information related to topographic and geologic features [7]. In general, nowadays development of geomorphometric and geostatistic methods is connected especially with possibilities of fast derivation of parameters from a digital elevation model (DEM) which in GIS environment provides even exacting calculations practically unrealizable in analogue representation [8].

Morphometry has been a significant instrument of structural geomorphology [9] since the 1950's [10]. Morphometric parameter can use for determining the deformation, which has been created by tectonics activity [11]. The advantage of morphotectonics parameters is in their fast derivation, mutual comparison and possibility

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of statistic evaluation for arbitrarily vast areas. The morphometric parameters have been used in various studies of geomorphology and surface water hydrology and evolution of basin morphology [12]. One of this parameter is hypsometric integral.

Land degradation and topology changes within watersheds are accomplished by weathering processes, stream erosion patterns and sediment transportation by surface runoff. In attempt to simulate the geologic stages of development and to study the influence of varying forcing factors (i.e. tectonics, climate, lithology) on watershed topology, the hypsometry of drainage basins (area-elevation analysis) [9] has been evaluated by the researchers such as bishop et al.2002 and Ritter et al. 2002 [13].

Hypsometric analysis was first time introduced by Langbein (1974) to express the overall slope and the forms of drainage basin. Hurtrez et al. 1999a has been shown the hypsometric curve is related to the volume of the soil mass in the basin and the amount of erosion that had occurred in a basin against the remaining mass [13].

2. Study Area

The large alluvial Sedeh basin bounded between latitude $30^{\circ}15.7'$ to $30^{\circ}46.8'$ N and longitude $52^{\circ}6.5'$ to $52^{\circ}53.92'$ E, which is located about 170 km (Doroudzan Road) north-east of the city of Shiraz in Fars province in southwest Iran and have area about 1688 km^2. It is situated in the Zagros fold-and-thrust belt. The zagros fold-and-thrust belt is located between the tertiary Uromieh-Dokhtar magmatic arc to the northeast and the Arabian plate margin to the southwest. This range is divided into three tectonics zones (Fig. 1) from the NE to the SW: the High Zagros, the Zagros Simply Folded Belt, and the Zagros Foredeep Zone [14], [15]. The study area is located in the High Zagros which is considered to be tectonically active where damaging earthquakes have occurred. These ranges were uplifted by approximately 4550 m with respect to sea level following the collision between the Afro-Arabian and Central-Iranian plates [16], [17].

The High Zagros Belt (HZB) is an imbricated zone that marks the northeastern part of the Arabian passive paleomargin which separates Main Zagros Thrust (MZT) and Main Recent Thrust (MRF) [18].

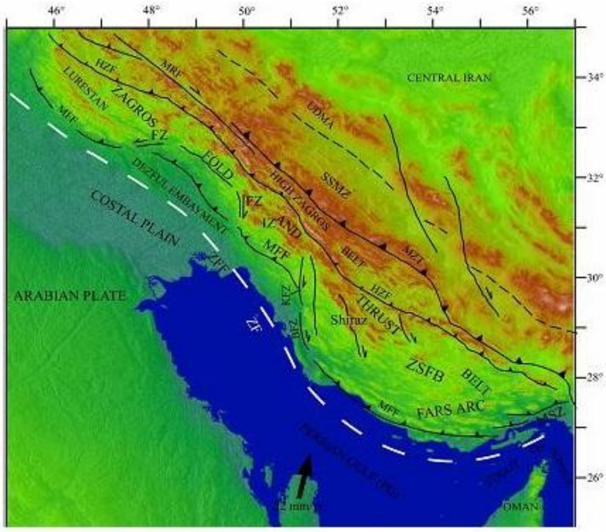

Fig.1. Regional tectonic map of the Zagros fold-and-thrust belt (modified after Navabpour et al., 2007). UDMA = Uromieh-Dokhtar Magmatic Arc; SSMZ = Sanandaj-Sirjan Metamorphic Zone; MZT = Main Zagros Thrust; MRF, Main Recent Fault; HZF = High Zagros Fault; ZSFB = Zagros Simple Fold Belt; MFF =Mountain Front Fault; IZ=Izeh Zone; BFZ = Borazjan Fault Zone; IFZ = Izeh Fault Zone; KFZ= Kazerun Fault Zone. ZF = Zagros Foredeep; ZFF = Zagros Foredeep Fault; MSZ= Makran Subduction Zone. Black arrow indicates GPS convergence vector fromVernant et al. (2004) [18]

The zagros imbricate belt (or high Zagros) which is highest part of Zagros, to the south west of the Main Zagros thrust, is a narrow NW-SE-trending thrust belt up to 80 km wide. It is bounded to the SW by the High Zagros fault [19], [20].

The study area is covered by young alluvial of quaternary age that it has been covered the geological structure and fractures. In the Basin of Sedeh, late Quaternary basin fills consist of loess, loess-like sediments and fine- or coarse-textured alluvium. The climate of the area is cold Mountain climate. The average annual rainfall of the area is more than 250 mm.

Sedeh basin has upland, broken anticlines and long synclines with northwest-southeast trend. Hardness and mainly calcareous deposits and Erodible sediments form highlands and Lowlands of basin. The strike of main geological structures is northwest-southeast which have been cut by faults with northeast-southwest trend. Khanehkat formation is the oldest formation belongs to Triassic (Fig. 2). It is consist of Limestone and Marl. Neyriz formation (lower Jurassic) is a clastic formation with lithological composition of shale and quartzite. Khami group is located on them that have upper Jurassic or early Cretaceous age. This group is composed of Sormeh, Fahliyan, the marly limestone of the Gadvan, and Daryan formations. The other formations are Kazhdomi formation and Bangestan group which is

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composed of Sarvak and Ilam formations belong to early Cretaceous to late Cretaceous. In the present paper the authors had made an attempt to hypsometric analysis of Sedeh sub basins.

We classified the level of rock resistance based on rock types shown in Fig. 3 and field observations: low (alluvial deposits), moderate (gypseous marl, dolomitic limestone) and high (limestone, sandstone and dolomite) [21]. Fig. 3 shows the distribution of the resistant levels (Fig. 3).

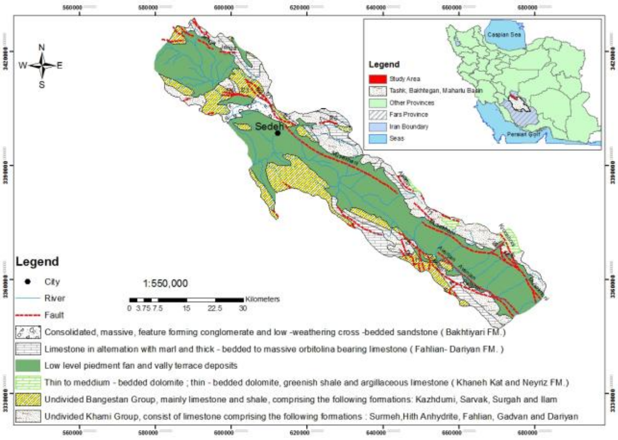

Fig.2. Geological map of the study area, at North of Shiraz, NW Fars, Iran (Derived from Sedeh, Doroudzan, Sivand and Eqlid 1:100, 000 scale map)

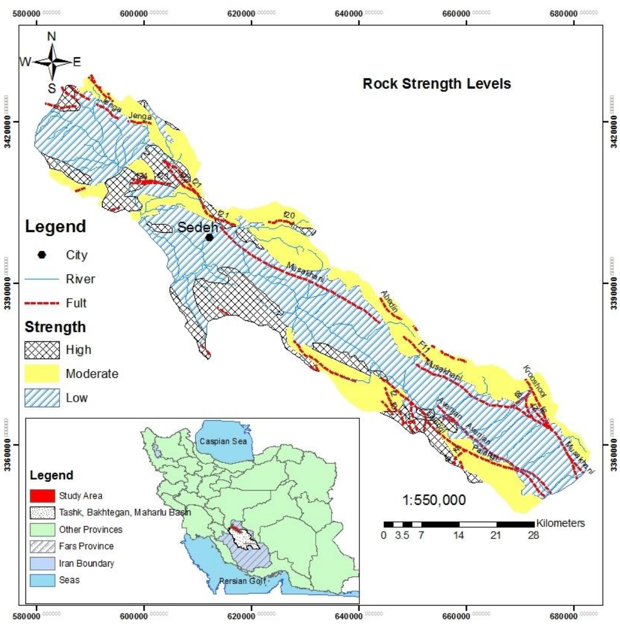

Fig.3. Distribution of rock strength levels

In the field of tectonics geomorphology and landscape evolution, the use of GIS is relatively recent. The availability of the DEM (Fig. 4) has produced a great revolution in this field. It has replaced old topographic maps, allowing for better and faster analysis of topographic parameters. One of the most important features of DEM is the possibility of extracting river networks with stream gradients and catchments areas [22].

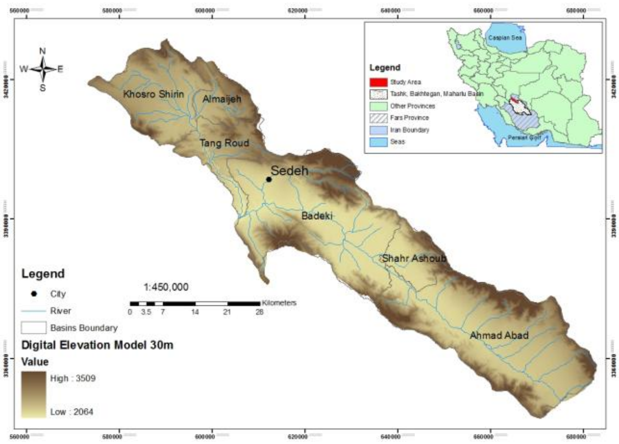

Fig.4. Digital elevation model with 30 m spatial resolution of study area showing 6 sub basins, they are indicated by names.

Geographical information system has been used for data preparation, data manipulation and analysis of data. ARCGIS 9.3 has been used for the present study. The digital elevation model (DEM) with 30 m spatial resolution has been used as a base map. The drainage basin's boundary have been identified through an extension called arc hydro tools 9 (fill, flow direction, flow accumulation, stream definition, stream segmentation) in ARCGIS software using DEM model as input. We have been controlled drainages obtained by DEM with drainages of the survey of Iran topographical map in 1:25000 scales. So that, 6 basins have been chosen the study (Fig. 4).stream ordering method as suggested by Strahler has been employed [9].

Hypsometric is a continuous function of non-dimensional distribution of relative basin elevations with the relative area of the drainage basin [9] and can be estimated using the hypsometric curve or the hypsometric integral (HI). The index is defined as the relative area below the hypsometric curve and thus expresses the volume of a basin that has not been eroded [23]. The hypsometric integral can be approximated by means of the following equation [1]:

HI= (average elevation – min. elevation)/ (max. elevation - min. elevation) (1)

The elevation value of DEM has been used to find out the hypsometric integral for each basin in the Sedeh basin. Programming in excel has been used to determine the hypsometric curve values. In order to generate the map of hi value, at the first, polygon shape file converted to point features by xtools pro and then the spatial analyst has been used. Finally, we classified Sedeh basin based on three classifies called Strahler [9], El Hamdouni et al. [21] and Ramu and Mahalingam [24].

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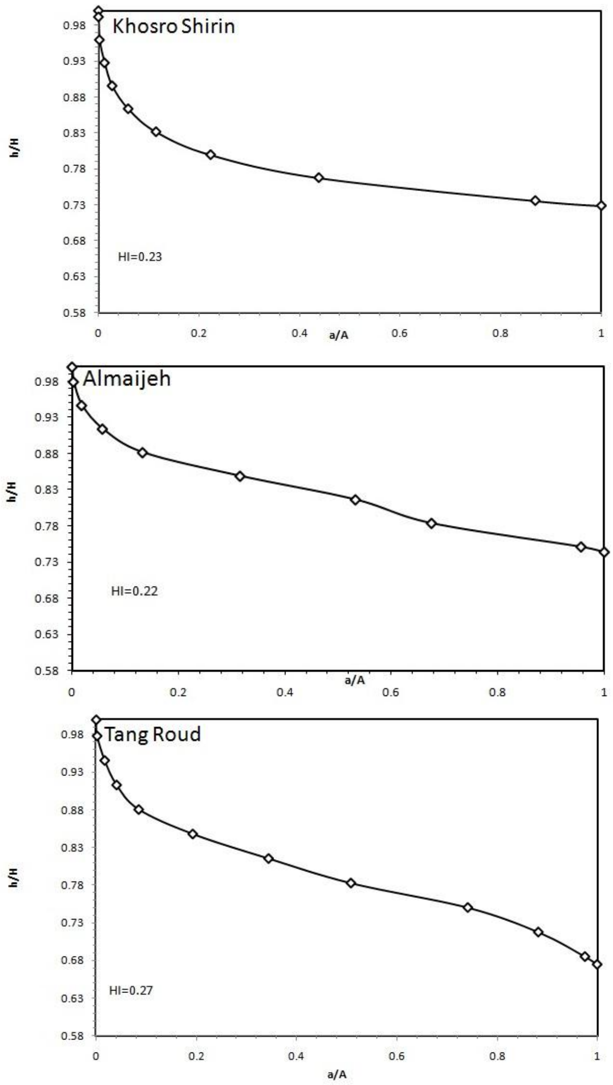
4. RESULTS

The hypsometric integral value ranges from 0.22 (sub basin Almaijeh) to 0.36 (sub basin Ahmad Abad). The hypsometric curve and the hypsometric integral are valuable tools in characterizing topography because they are correlated with the stages of geomorphic development of the landscape [22]. The values of elevation necessary for the calculation are obtained from a digital elevation model. The average elevation is from 50 points of elevation taken at random from the drainage basin. The hypsometric curve represents the relative proportion of area below (or above) a given height. Six drowned the hypsometric curve has been shown in Fig.5 (Fig. 5).



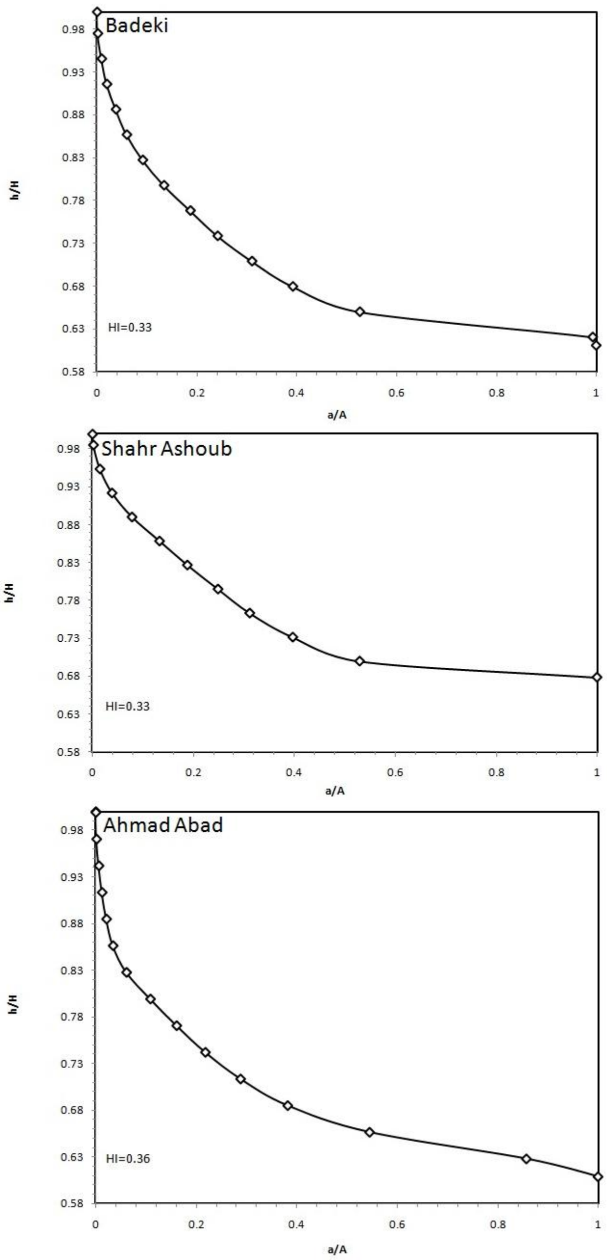


Fig.5. Hypsometric curves of basins (A) is the total surface area within the basin above a given line of elevation (h), (H) is the highest elevation of basin.

Strahler (1952) interpreted the shapes of the hypsometric curves by analyzing numerous drainage basins and classified the basins as youth (convex upward curves), mature (s-shaped hypsometric curves which is concave upwards at high elevations and convex downwards at low elevations) and peneplain or distorted (concave upward curves) [13]. The study basin was in peneplain or distorted in all portions (table1).

HI values were grouped into three classes with respect to the convexity or concavity of the hypsometric curve by El Hamdouni et al. [21]: class 1 with convex hypsometric curves ($HI \geq 0.5$); class2 with concave-convex

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hypsometric curves ($0.4 \leq HI < 0.5$); and class3 with concave hypsometric curves ($HI < 0.4$). On based it, Sedeh basin was located into class2 and3 (table 1) whereas Ramu and Mahalingam [24] have been classified the HI values as following. If the result value was between 0.6 and 1; it indicates the youthful state of dissection; If the result value was between 0.3 and 0.60, it indicates a maturely dissected landform; and if the result was less than 0.35, then it indicates an equilibrium or old state of dissection. Our area indicates a maturely dissected landform and old state of dissection based this classification (table1).

Table (1) Hypsometric integral value in Sedeh basins, Classification of HI by [9], [21] and [24]

Row No.	Basin Name	HI	Classifications of HI		
			Strahler[9]	El Hamdouni[21]	Ramu, Mahalingam[24]
1	Khosro Shirin	0.23	3	3	3
2	Almaijeh	0.22	3	3	3
3	Tange Roud	0.27	3	3	3
4	Badeki	0.33	3	3	3
5	Shahr Ashoub	0.33	3	3	3
6	Ahmad Abad	0.36	3	2	2

Hypsometric integral data were derived for each of the six drainage basins from 30 m DEM has been shown in table1. The result of the hypsometric integral shows all drainage basins are in the class 3 in all of classifications, except one basin which is in class 2. The result of hypsometric integral values have been mapped (Fig. 6) to see the visual interpretation of HI values between drainages basins.

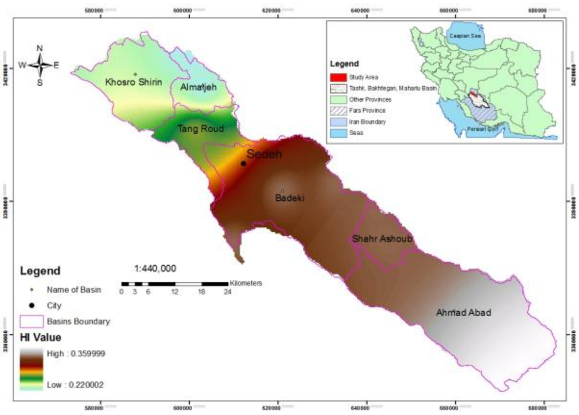

Fig.6. it shows the distribution of obtained hypsometric integral value at Sedeh basin.

Then, HI value was contoured (Fig. 7) by spatial analyst extension and the hypsometric integral value of Sedeh basin map has been used as a base map.

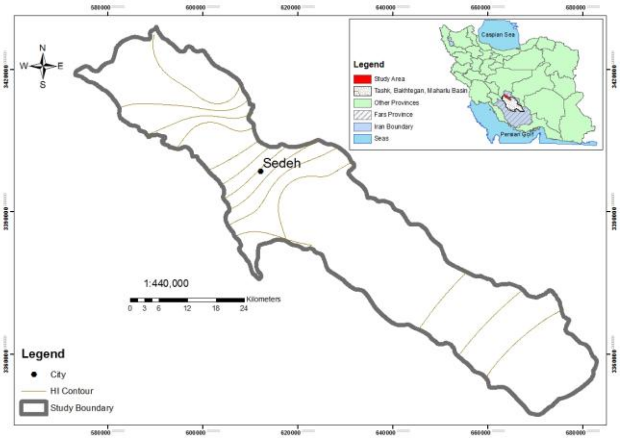

Fig.7. it shows the hypsometric integral value countered map of Sedeh basin. Contour interval was selected 0.1 according to HI value. It shows Hi changes in the southern part of basin is more than other parts

We compare the results in three above mentioned classification and provide HI distributions maps based on them (Figs. 8 to 10). In Stahler classification, all of basins are in class 3 and indicate peneplain stage (Fig. 8). As saw in Fig. 9 and 10, only one basin locates in class 2 and indicates mature stage.

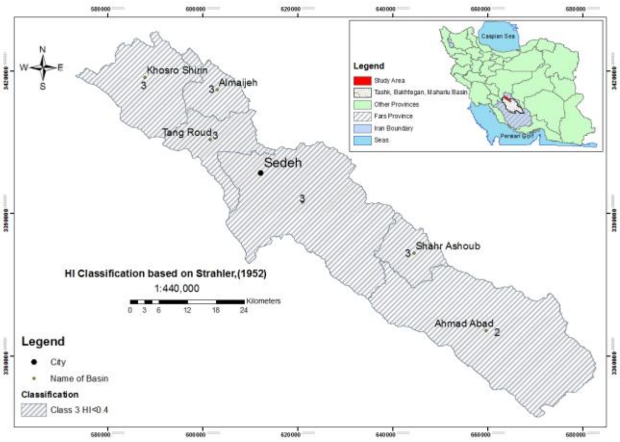

Fig.8. it shows the first HI classification map of study area, this classification is based on Strahler approach [9]. All of the basins are in class 3.

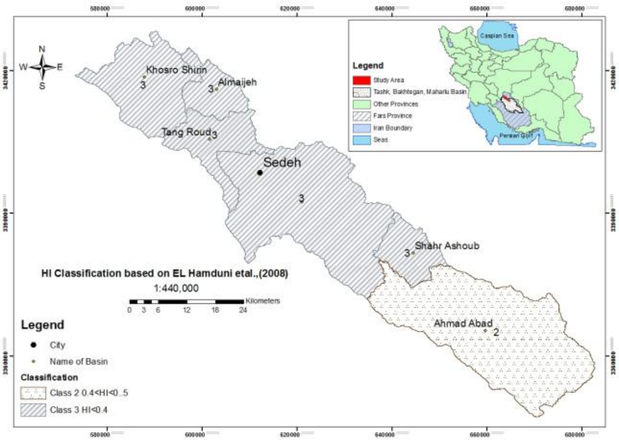

Fig.9. it shows the second HI classification map of study area, this classification is based on El-Hamdouni approach [21].

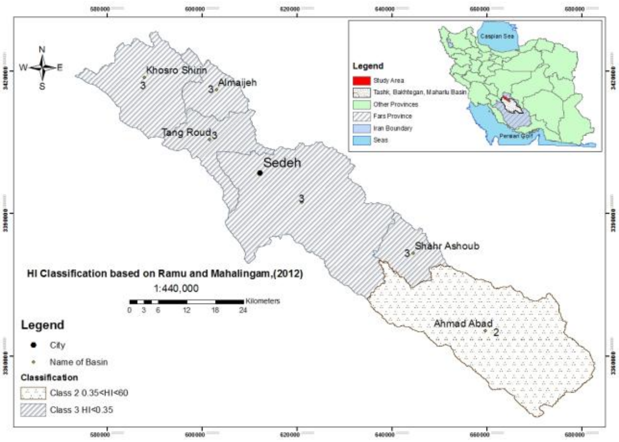

Fig.10. It shows the third HI classification map. This classification is extracted [24].

Finally, the results of these three classifications have been mapped totally to see the visual situation of basin according them. 16.7 % basins are in class 2 and 83.3% are in class 3 in three classification comparing.

5. Discussion

Hypsometric is affected principally by tectonics, lithology, and climatic factors [22] so that these factors considered in interpretation. The hypsometric curves not only have been used to infer the stage of development of the drainage network but also it is a powerful tool to differentiate between tectonically active and inactive areas [1].

In this study, spatial variations of tectonic activity at Sedeh basin were investigated by hypsometric integral analysis. The changes of hypsometric integral point to a general trend of increasing tectonics activity towards the southwest but it is gradually decreasing towards the northeast.

We matched hypsometric integral value, tectonics and geomagnetic fault map, lithology and climatic data (Figs. 11) for distinguishing their effects. We extract faults from field, geology map and raw geomagnetic data of geological survey of Iran. The results show that basins located at southwest of Sedeh basin have high values of HI. This portion of basin has been covered by limestone and other high strength rocks so that it has low erosion rather than other portions. So that, in this part the role of tectonics is more than other factors because Sedeh basin has a same climate in all of itself and lithology less vast.

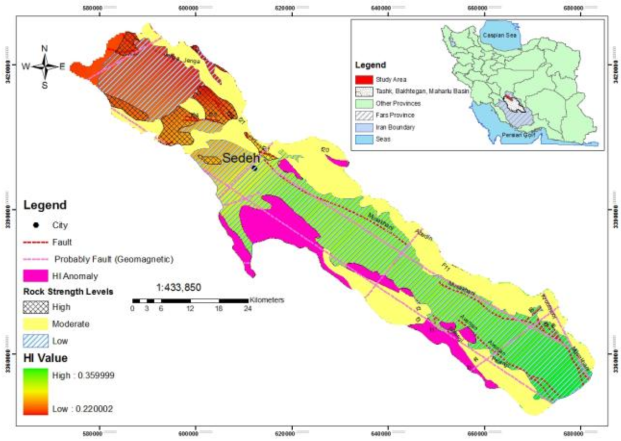

Fig.11. it shows HI changes map for the study area on rock strength map. It indicates high values of HI are consistent with fault trends and high strength rocks.

HI value Distribution in Lithology data is same and it doesn't differ significantly from one lithology to other one but in the strike of tectonics structures such as faults and folds variation of HI value has been happened. In fact, high hypsometric integral values indicated more tectonics activity and less eroded areas. There are HI anomalies in two basins such as Badeki and Ahmad Abad.

9. Conclusion

Hypsometric integrals for the all of the basins have been computed using GIS following Strahler [9], El Hamdouni et al. [21] and Ramu and Mahalingam [24] and plotted. It is considered to be suitable for evaluating these basins. The following conclusions have emerged from this study:

The study of hypsometric integral and curve has been retrieved in that the integral values vary from 0.22 to 0.36.

The maximum hypsometric integral belongs to Ahmad Abad sub basin.

Among the six drainage basins, one drainage basin is in maturely whereas five basins show the old state. No drainage basin comes in youthful state in the study area.

The resultant hypsometric curve graphs drowned by excel has shown that s-shaped less rather than concave curve.

The value of HI was found to be high along major faults and folds.

The emphasis of the hypsometric integral on the active tectonic region in the southwest of basin is completely in agreement with structures in this part. So that this part of Sedeh basin is more active than other parts.

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