



## **Geomorphic indexes of tectonic activity through the analysis of the drainage systems in the Sangaw area, Kurdistan Region – NE-Iraq**

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### **Abstract**

Different geomorphic indicators like drainage basin asymmetry (AF), transverse topographic symmetry factor (T), mountain front sinuosity (Smf) and ratio of valley floor width to valley height (Vf) was obtained from the Sangaw basin to study the tectonic activities in Sangaw district area, which it located within the administrative boundaries of the Sulaimani City, Kurdistan Region – NE-Iraq. Geographic Information System (GIS) was used in the calculation of the geomorphic indicators and in order to study, analyze and classify tectonic activity. The results of geomorphic indicators with respect to the visual interpretation of satellite image, DEM and field observation shows that the area is tectonically active, and the activity is ranging between moderate to high activities.

### **Introduction**

Geomorphological tectonic studies are based on the application of a number of morphometric equations of geomorphological indicators which considered as evidence to tectonic activity, for these geomorphic indices are useful tools in evaluating tectonic activity. Many of previous studies deals with this subject in the arid zone like (Keller and Pinter, 2002; Molin et al., 2004; El Hamdouni et al., 2008) and also on the Zagros Mountain Range in Iran like (Dehbozorgi et al, 2010; Alipoor et al., 2011; Mumipour and Najad, 2011; Toudeshki and Arian, 2011).

A Geomorphometric index is used as a tool for understanding the evolution of tectonic and non-tectonic landforms, nature of deformation, uplift and valley degradation (Raj, et al. 2003). The study of modern tectonic activity depends on the use of geomorphological indicators that are sensitive to a number of variables, such as rocks resistance, climate change and tectonic processes, (Bhat, et al. 2013).

Results of geomorphological indicators show the extent of the area affected by tectonic activity on the one hand and the extent of acceleration geomorphological processes of erosion and deposition on the other hand. Most studies about such topics relevant today relies on software techniques in digital data processing like remote sensing and geographic information systems that contribute to the analysis and interpretation and building models to understand the changes in the earth's surface forms.

In the present study an attempt has been made to evaluate the geomorphic indicators of active tectonics through the analysis of the drainage systems in Sangaw area using remote sensing and GIS approach.

### Aims of the research

This study aims to evaluate the effectiveness of the techniques of remote sensing and geographic information systems in the processing of spatial data in order to study and determine the tectonic activity of the study area through the drainage network analysis, which is a standalone been digitally derived through remote sensing data.

### Research Methodology

The methodology adopted for this study is based on the interpretation of remote sensing and GIS data in both ways visual and digital interpretations, respectively with the data obtained from the field observation and data from previous works and reports which related to the aim of this research. The methodology can be divided in the following stages: Data collection, Field observation, Data analysis, Production of base map, Map interpretation and analysis.

The research methodology and style of work involved several steps marked by the following:

### 1- Geographical Location

The area under investigation is located in the boundary between Sulaimani Governorate and Kirkuk Governorate, it is surrounding by Qara Dagh area, Pebaz area, Qadir karam and Chamchamal area. The study area is located between longitude (44°55'00" and 45°26'00") E and between latitude (35°07'00" and 35°27'00") N, Fig (1). The study area is covering an area estimated by 864 km<sup>2</sup>.

According to the DEM, the study area is ranging in heights from 400 m to 1871m., highest area mostly covered northeastern part within Qara Dagh Mountain and within Ajdagh Structure (Chamchamal south anticline) and Qarawass anticline in the middle parts of the study area, Fig (2).

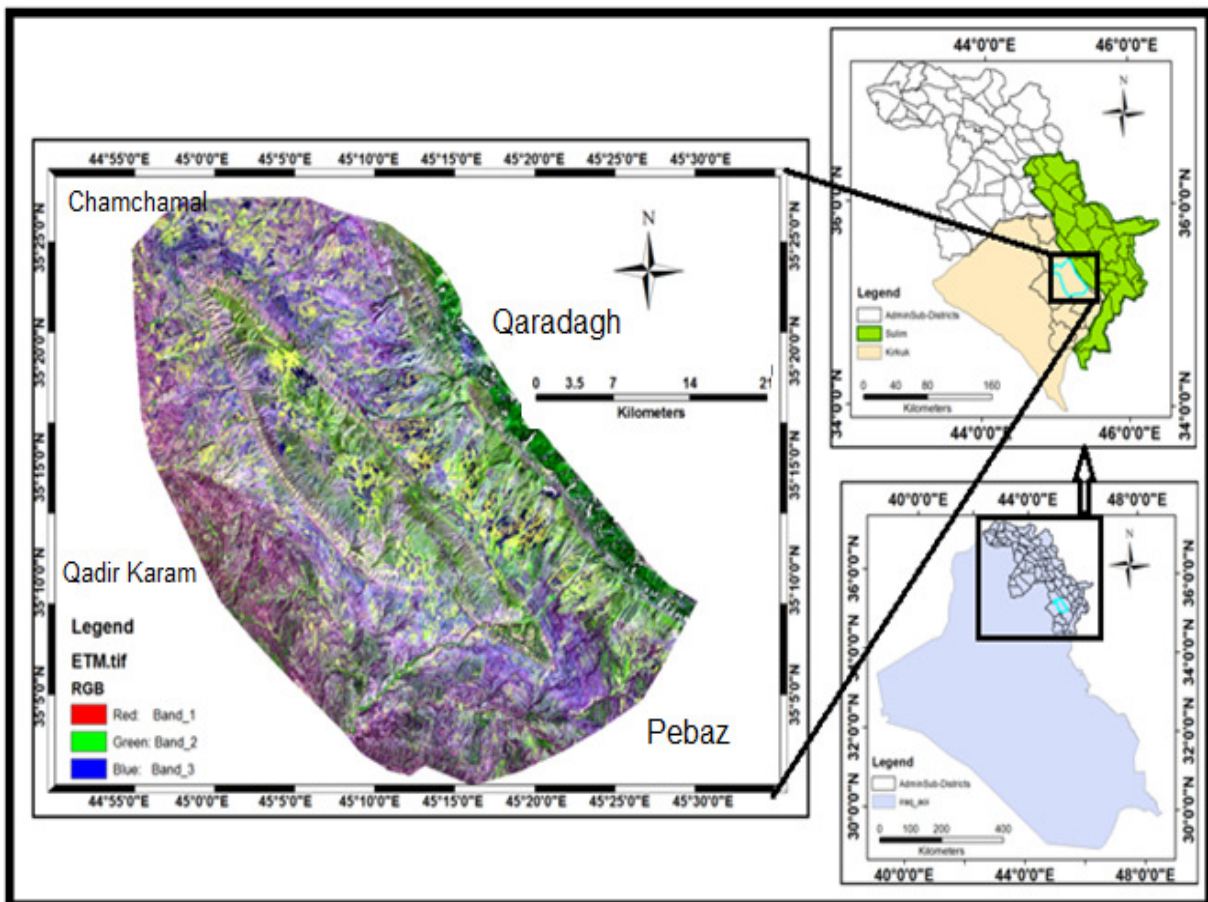


Fig.(1) The geographic location of the Sangaw area.

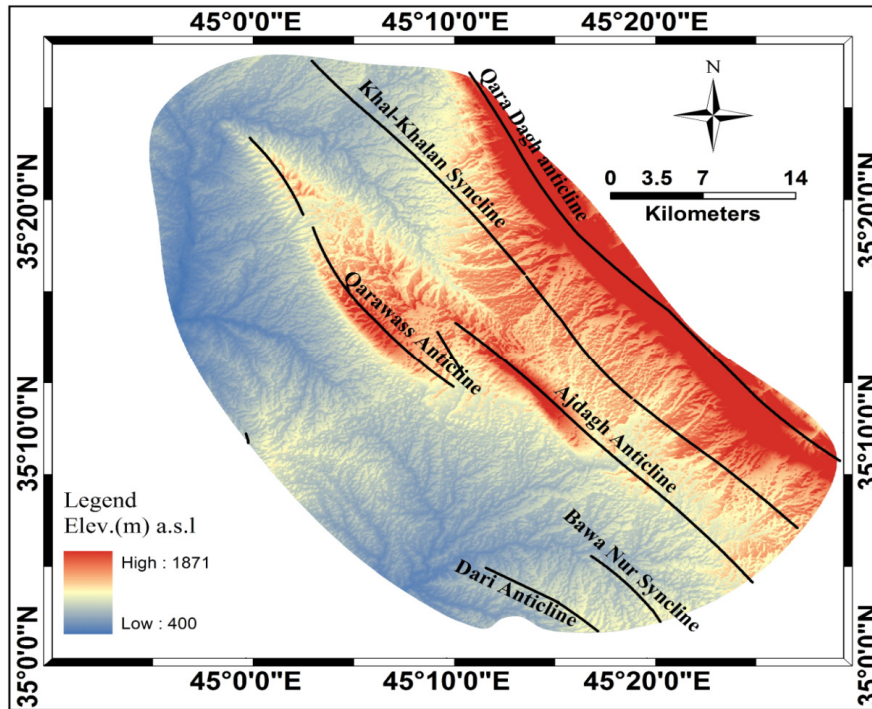


Fig.(2) DEM with main structure of the study area.

## 2- Tectonic Setting

The study area is situated within Zagros Low Folded Zone and Zagros High Folded Zone according to the tectonic subdivision of NE Iraq (after Al-Qayim et al., 2012), Fig.(3). In general, the folding and faulting in the NE Iraq are resulted from several phases of deformations during the Alpine Orogeny. The Iraqi mountains are formed by the same movements of orogenies that caused the building of the Alps in Europe and the mountains of Zagros and Taurus in Asia. It is called Alpine Orogeny, (Buday and Jassim, (1987). The trend of the folds and the strike of the strata are generally in NW-SE direction in accordance with the main trend of Zagros folds.

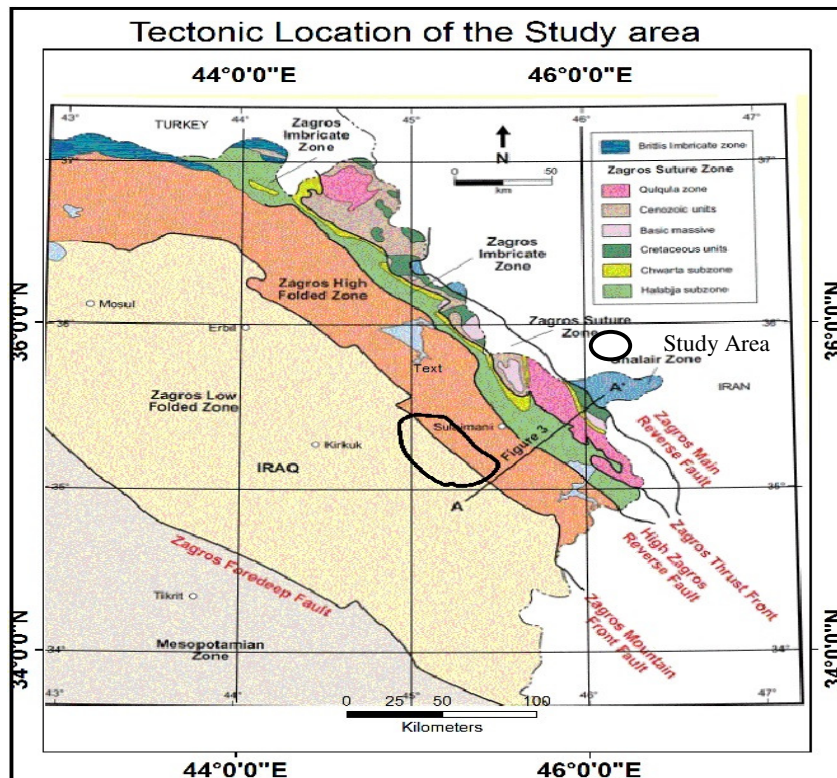


Fig. (3) Tectonic location of the study area (after Al-Qayim et al., 2012).

The Zagros Mountain Front Fault (ZMFF) which passes through the middle area of study, Fig (3), is clearly effected the Qara Dagh Mountain in the NE of study area and also within middle part through Ajdagh anticline (Chamchamal south anticline) and Qarawass anticline.

According to the seismic map of the Iraq, the study area is bounded by many seismic effecting with different magnitude and depth especially from N, E and W of Sangaw area.

### 3- Geological Setting:

According to the geological map of the Sulaimani Quadrangle sheet NI-38-3 (GEOSURV, 2008) the study area is covered by many Formations from Tertiary (foreland basin) and Quaternary deposits.

Many of strata from Pliocene to Paleocene are distributed within study area; they are representing by Bai-Hassan, Mukdadiya, Injana, Fatha and Pila Spi Formation. Slope sediments represent by rock fragments with fine clastis and depression fill sediments represent by silt and mud are the main Quaternary deposits within the study area, Fig (4).

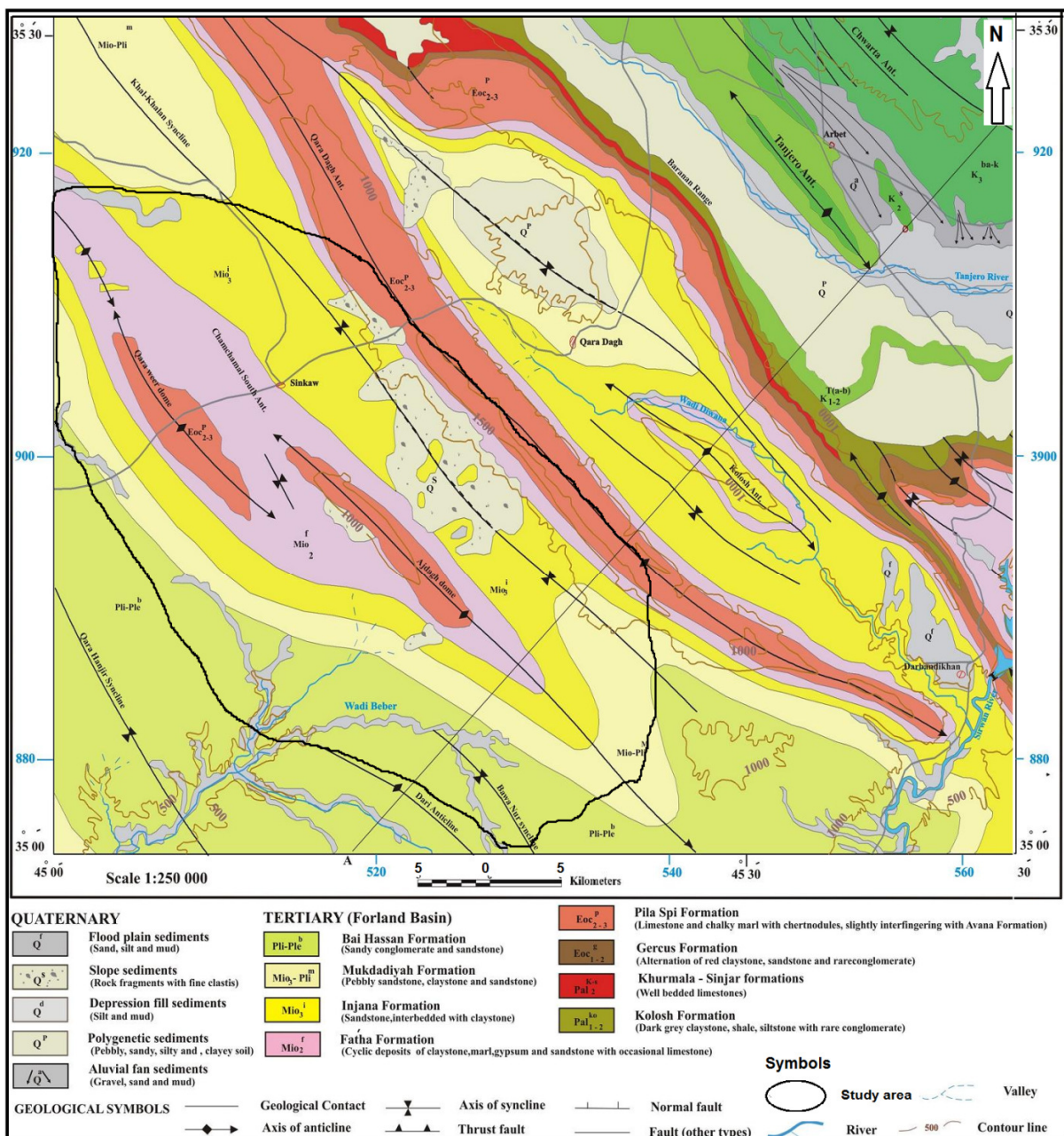


Fig. (4) Geological map of the study area, after (GEOSURV, 2008).

Structurally, many of folds are distributed through the study area as anticline and syncline; the main folds are Qara Dagh anticline, Khal – Khalan syncline, Ajdagh anticline (southern part of Chamchamal anticline) and Qarawass anticline. All the folds axes are oriented NW-SE direction with respect to the main trend of Zagros folds.

#### 4- Geomorphological Setting:

The climate of the study area is characterized by cold and snowy winters and warm dry summers. On the plains, typical semi-arid climatic conditions prevail. Precipitation occurs from October to May, decreasing from the NE to SW.

Regional geomorphological setting of Northern Iraq (include study area) are closely connected and controlled by tectonic fabric of the area, (Stevanonic and Markovic ,2003). The study area located in the middle part of the Northern Iraq territories, these parts are controlled by deep seated regional faults, mountains and valleys are oriented NW-SE within Zagros trend. The most important active geomorphological processes are karstic, Fig (5-a) fluvial and slope processes (delluvial, proluvial and colluvial).

Traces of aeolian process also can be seen. Structural relief forms caused by inner, endogenic forces, and exposed by activity of different exogenic forces are also abundant.

Northern Iraq is geomorphologically characterized by three major types of terrain: mountainous ranges, foothill pediments and agricultural plains. The general geomorphology of Foreland Fold Belt in Northern Iraq can be divided in to three main groups of landforms: Anticline ridges, structural denudation hills and slopes, and fluvial accumulation plains, (Numan, 2002).

The anticline ridges comprise the oldest rock units cropping out in the cores of the major anticlines with a characteristic dip slope and flat iron topography around the cores, which defines the shape of the folds. Between the limbs of anticlines, valleys are developed. The anticlines ridges are affected by fluvial erosion. The fluvial accumulation plains are mostly developed in synclinal valleys, Fig (5-b), they cover very wide part of terrains with nearly horizontal strata. The landform is covered by Quaternary age. Genesis of these sediments is connected with river flood plains, river terraces, alluvial fans, cone deposits and recent deposits and soil.

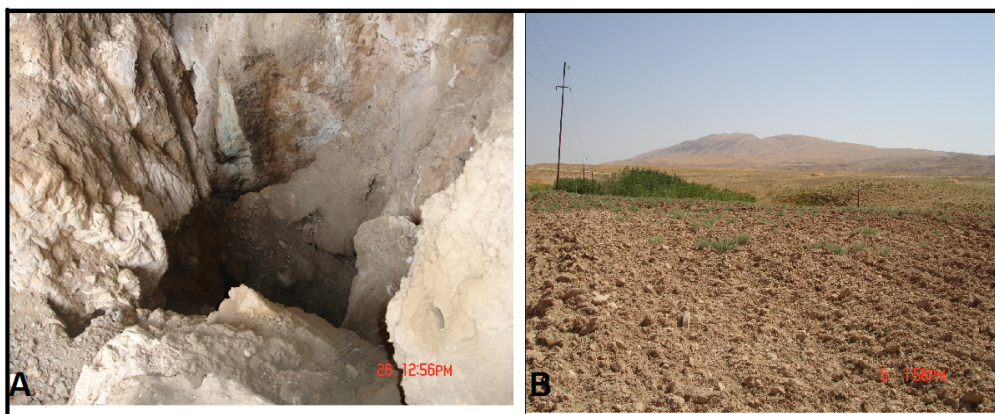


Fig.(5) a-Karst

b-Fluvial accumulation

#### 5- Geomorphologic Analysis of the Drainage Network Characteristics

The drainage basin is recognized as a fundamental geomorphological unit and is frequently used as the primary landscape unit for hydrological, water supply and ecological investigations and for land management activities (Goudie et al, 2005). In the Iraqi Zagros Mountain Range a generally dendritic pattern is usually observed. Locally, a control of stream segments by fractures and faults is clearly recognizable and the pattern can change to angulate. This is a variation of dendritic in which linear features have modified the original shape. Furthermore, in this area a frequent orientation of valleys in the alpine direction (NW-SE) can



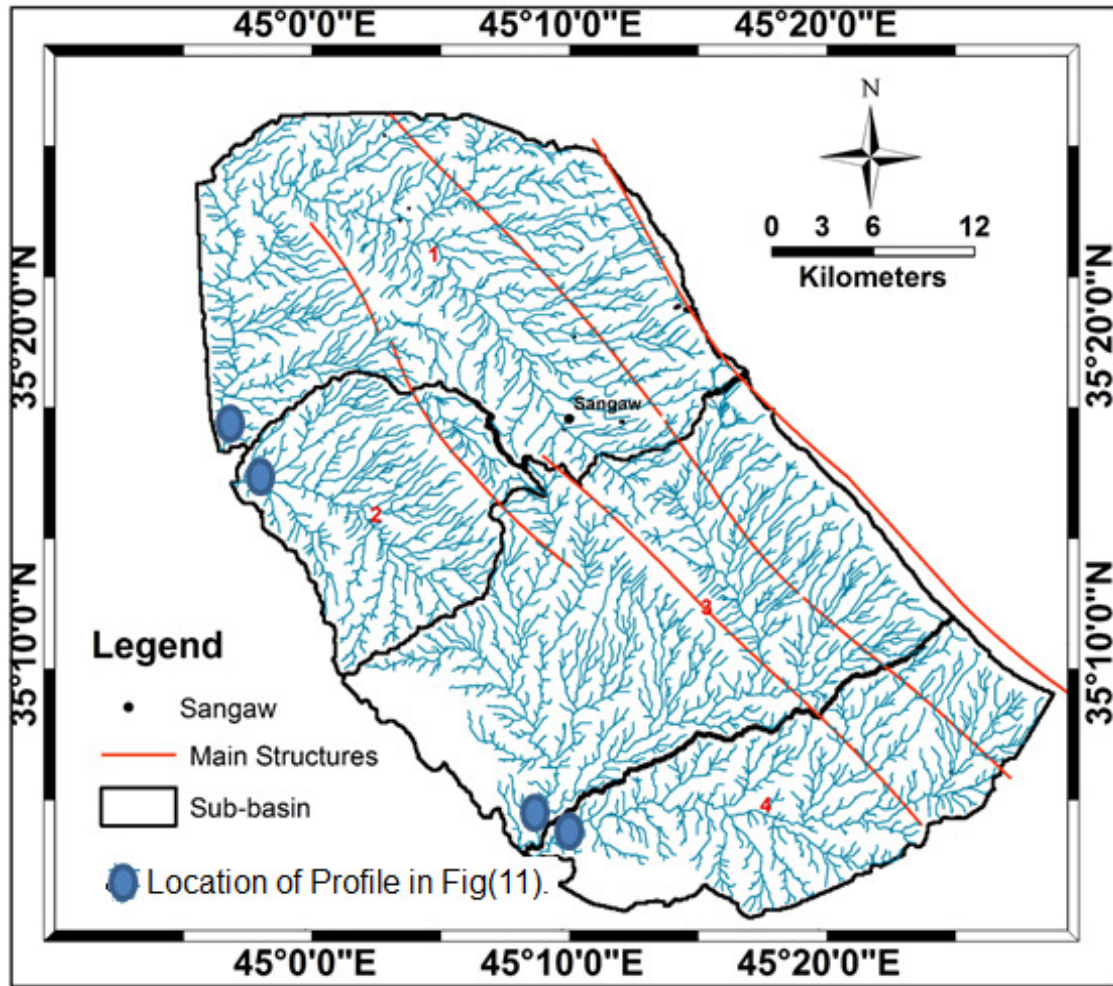


Fig. (7) The drainage system for the study area.

### 6.1- Drainage Basin Asymmetry (AF):

Asymmetry factor (AF) is defined as:  $AF = 100 (A_r / A_t)$ , Where:  $A_r$  is the area of the basin to the right (facing downstream) of the trunk stream, and  $A_t$  is the total area of the basin, Fig (8). The asymmetry factor is developed to detect tectonic tilting transverse to flow at drainage basin or larger scale, (Hare and Gardner, 1985). For most stream networks that are formed and continue to flow in stable setting, AF should be equal to about 50, whereas unstable setting would give a deflection from normal value either less or more than 50.

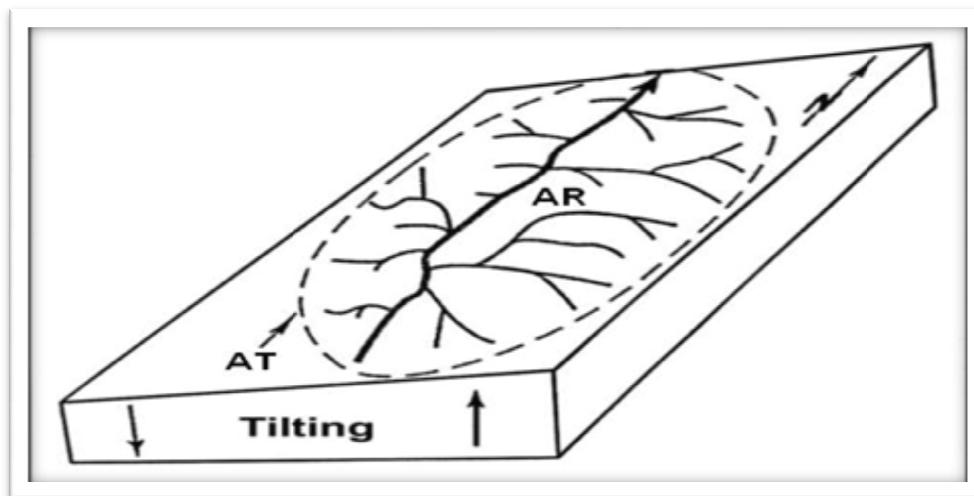


Fig. (8) shows the way of calculated (AF) factor, after (Keller and Pinter, 2002).

There are three categories depending on the tectonic activity which related to AF, these are shown in the Table (1) as follows:

Table (1): The three categories of the AF factor, after (Keller and Pinter, 2002).

Ranges	Class	Degree
> 65	1	High
57-65	2	Moderate
< 57	3	Low

For the area under studies, the asymmetry factor is obtained and the result is shown in the table (2) with their classes and degree for all basins within the area of study.

Table (2) The classes and degree for AF factor in basins within the area of study.

Region	AR (km <sup>2</sup> )	AT (km <sup>2</sup> )	AF	CLASS	Degree
Basin (2)	119	183	65.02	1	High
Basin (3)	269	433	62.12	2	Moderate
Basin (4)	153	246	62.19	2	Moderate
Basin (1)	236	497	47.47	3	Low

### 6.2 - Transverse Topographic Symmetry Factor (T):

The Transverse Topographic Symmetry Factor is defined as  $T=(D_a / D_d)$ , where  $D_a$  is the distance from the stream channel to the middle of its drainage basin (measured perpendicular to the median line of the basin), and  $D_d$  is the distance from the midline to the basin divide, Fig (9).

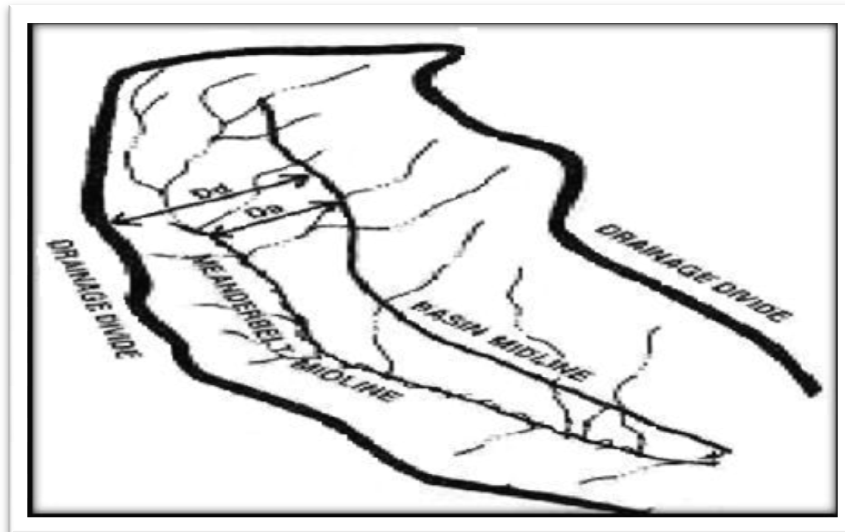


Fig (9) The way of calculate the T factor after (Burbank &Anderson, 2001).

These vectors indicate migration of stream perpendicular to the drainage basin axis (Cox, 1994). ‘T’ is a vector with a bearing and magnitude from 0 to 1 and is calculated for different segments of stream channels. For a perfectly symmetric basin,  $T= 0$ . As asymmetry increases, T increases and approaches a value of 1, which shows the state of erosion, sinuous bottom layer (below the surface) or cracking, which leads to the displacement of the main stream of the basin with the direction of the cracks subsurface. According to (Burbank &Anderson, 2001) the results of index (T) was put within three categories (classes and degree) according to the ranges of (T) values, Table (3).

Table (3) The categories of the Transverse Topographic Symmetry Factor, after (Burbank & Anderson, 2001).

Ranges	Class	Degree
> 0.6	1	High
0.3-0.6	2	Moderate
< 0.3	3	Low

For the area under studies, the T factor is obtained and the results for the fourth sub basins are shown in the Table (4) with their classes and degree.

Table (4) The classes and degree of (T) factor within the area of study.

Region	Da (m)	Dd (m)	T	class	Degree
Basin (2)	2688	6303	0.42	2	Moderate
Basin (1)	3727	10664	0.34	2	Moderate
Basin (4)	2448	8619	0.28	3	Low
Basin (3)	2792	16190	0.17	3	Low

### 6.3 - Mountain – Front Sinuosity

Mountain front sinuosity ( $S_{mf}$ ) is an index that reflects the balance between erosion forces that tend to cut embayment into a mountain front and tectonic forces that tend to produce a straight mountain front coincident with an active range- bounding fault (Zygouri and Kokkalas, 2004).

Mountain front sinuosity is defined by the equation  $S_{mf} = L_{mf} / L_s$  Where:  $S_{mf}$  is the mountain – front sinuosity;  $L_{mf}$  is the length of the mountain front along the foot of the mountain, at the pronounced break in slope; and  $L_s$  is the straight-line length of the mountain front, Fig (10). The description of Mountain front sinuosity with their classes and degrees was put in the Table (5) according to (Bull and Mcfadden, 1977).

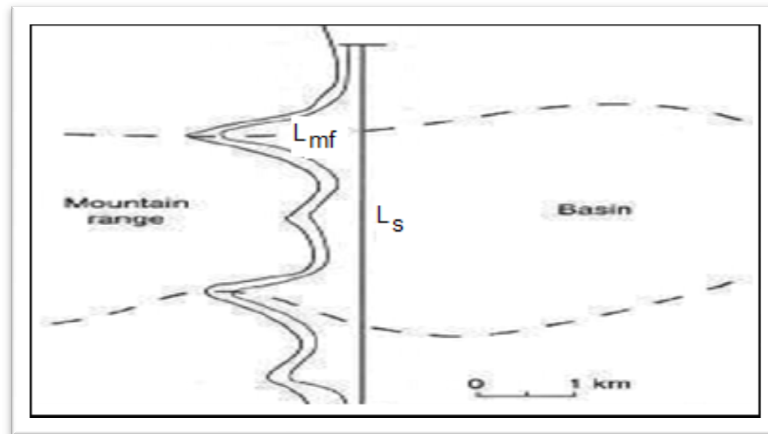


Fig. (10) Calculation of mountain front sinuosity, after (Keller and Pinter, 2002).

Table (5) The categories of the Mountain front sinuosity, after (Bull and Mcfadden, 1977).

Value of $S_{mf}$	Description	Class	Degree
1.0 – 1.6	active mountain front	1	High
1.6 – 3.0	lesser activity	2	Moderate
3-5	Inactive mountain-fronts	3	Low

The results of the  $S_{mf}$  factor for the studies area was obtained and classified to the three main categories as shown in the Table (6).

Table (6) The results of the  $S_{mf}$  within study area.

Ranges	Class	Degree
< 0.5	1	High
0.5-1	2	Moderate
> 1	3	Low

#### 6.4 - Ratio of valley floor width to valley height (V<sub>f</sub>):

We had further calculated ratio of valley floor width to valley height, which differentiate between broad floored valleys and V shaped valleys. The ratio of valley floor width to valley height ( $V_f$ ) may be expressed as  $= 2V_{fw} / (E_{ld}-E_{sc})+(E_{rd}-E_{sc})$ , where  $V_f$  is the valley floor width to height ratio;  $V_{fw}$  is the width of valley floor;  $E_{ld}$  and  $E_{rd}$  are elevations of the left and right valley divides respectively and  $E_{sc}$  is the elevations of the valley floor (Bull and McFadden, 1977).

High values of  $V_f$  are associated with low uplift rates, so that streams cut broad valley floors. Low values of  $V_f$  reflect deep valleys with streams that are actively incising, commonly associated with uplift (Keller and Pinter, 1996). The Table (7) shows the categories of  $V_f$  according to (Bull and Mcfadden .1977) classification and Fig (11) shows the profile of the fourth sub basin within study area, the location of each profile is shown in Fig.(7).

Table (7) The categories of  $V_f$ , after (Bull and Mcfadden .1977).

Region	LMF	LS	SMF	class	Degree
Basin (2)	12418	10059	1.23	1	High
Basin (4)	32815	25582	1.28	1	High
Basin (3)	33763	22911	1.47	1	High
Basin (1)	39090	19078	2.04	2	Moderate

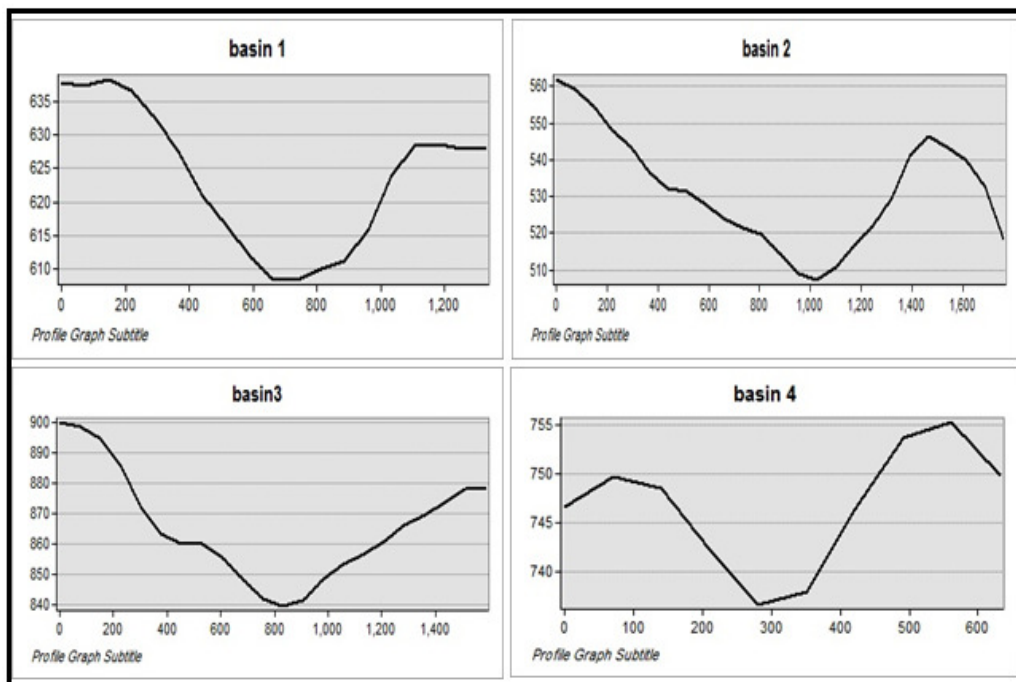


Fig (11) The profile of the fourth sub basin within study area.

The results of the  $S_{mf}$  factor for the studies area was obtained and classified to the three main categories as shown in the Table (8).

Table (8) The categories of  $V_f$  within study area.

Region	Vfm(m)	Esc(m)	Erd(m)	Eld(m)	Vf	Class	Degree
Basin (2)	77	507	546	562	1.6	3	Low
Basin (3)	95	839	869	900	2	3	Low
Basin (1)	85	608	628	638	3.4	3	Low
Basin (4)	110	736	755	750	6.6	3	Low

### The final rating of the indicators of tectonic LAT

The final rating of tectonic indicators LAT is represent the final classification of the compilation of the results of the values and classifications of geomorphological indicators for all the previous equations which derived from digital elevation model (DEM) using GIS.

This classification leads to give a holistic view of all these indicators which are influenced by geomorphological tectonic activities within the study area. For the purpose of the establishment of the final classification of the extent of the study area affected by tectonic activity has been to rely on the classification of (Hamdouni, 2008) which shown in Table (9).

Table (9) The categories of LAT classification, after of (Hamdouni, 2008).

Degree	Class	Ranges
Very High	1	1-1.5
High	2	1.5-2
Moderate	3	2-2.5
Low	4	> 2.5

To illustrate the effect of tectonic activity for each index of the previous indicators alone, a map was produced to showing the distribution of tectonic activity by their various degrees on the study area, Fig (12). Results were collected for all indicators in one table, Table (10), in order to produce a final map which represents the final assembly of the tectonic activity indicators to showing the distribution of tectonic activity through the study area, Fig (13).

Table (10) The LAT classes and degree of study area.

Degree	CLASS LAT	S/N	LAT	AF	SMF	T	VF	Region
High	2	1.7	7	1	1	2	3	Basin (2)
Moderate	3	2.2	9	2	1	3	3	Basin (3)
Moderate	3	2.2	9	2	1	3	3	Basin (4)
Moderate	3	2.5	10	3	2	2	3	Basin (1)

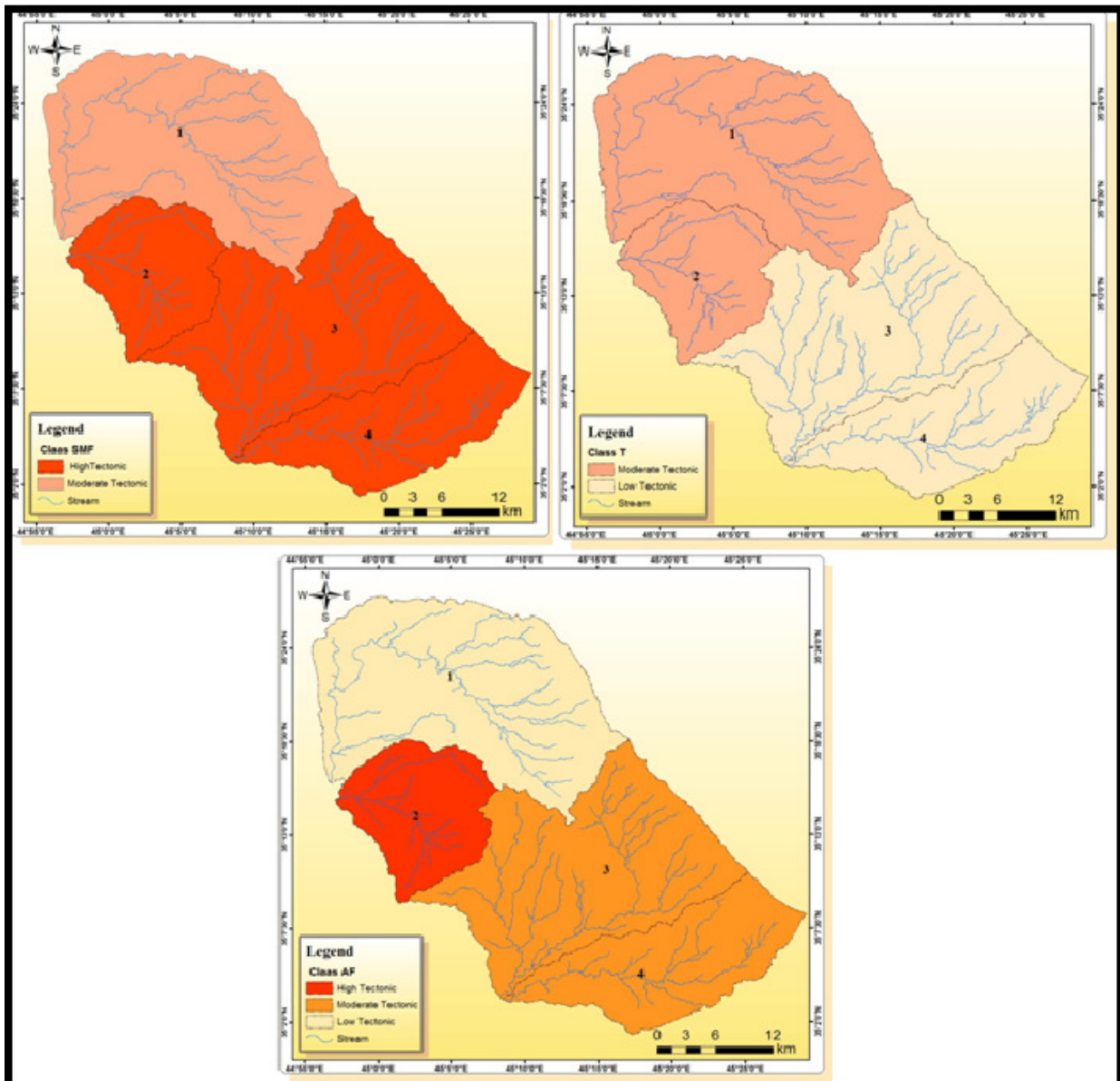


Fig.(12) The maps of geomorphic indicators of active tectonic.

### Discussion of Results:

The drainage basin within the study area was divided to four sub basins, named as 1, 2, 3 and 4 .According to the asymmetry factor results, the area shows high values of AF factor, mostly more than (50) which reflect severity of the regression within the basin area, that mean the main tributaries or drainage channels are subjected to tectonic curvature (convexity) and this will be reflected on the lengths of tributaries on either side of the main channel of the basin. This leads to the hypothesis that the development of tributaries to the left of the basin be shorter compared to the right side, which reflects the asymmetry, (Keller and Pinter, 2002).

Based on the analysis of the results of Transverse Topographic Symmetry Factor (T), the sub-basin 2 shows high value of T which means asymmetry basin, also sub-basins 1 and 4 are shown moderate migration or displacement of the main stream of the basin axis, while sub-basin 3 shows the lower value and influence Mountain front sinuosity (Smf) is indicator reflects the balance between the decline of the highlands to perpetuate the very integrity and interface, and the erosion caused by streams that lead to the formation of irregularly in the interface. Over time winding topographic situation arises, the index (smf) reflects the

balance between the forces of erosion and tectonic problem of the facade of the mountain. If the index values (SMF) is less than (1.6), like the value of sub-basin 2, 3 and 4 within study area, it refers to the active tectonic processes (erosion processes, rugged and Winding Mountain front), and if the index figure mentioned for the values increased, like the sub-basin 1, they indicate tectonic processes less or low relatively.

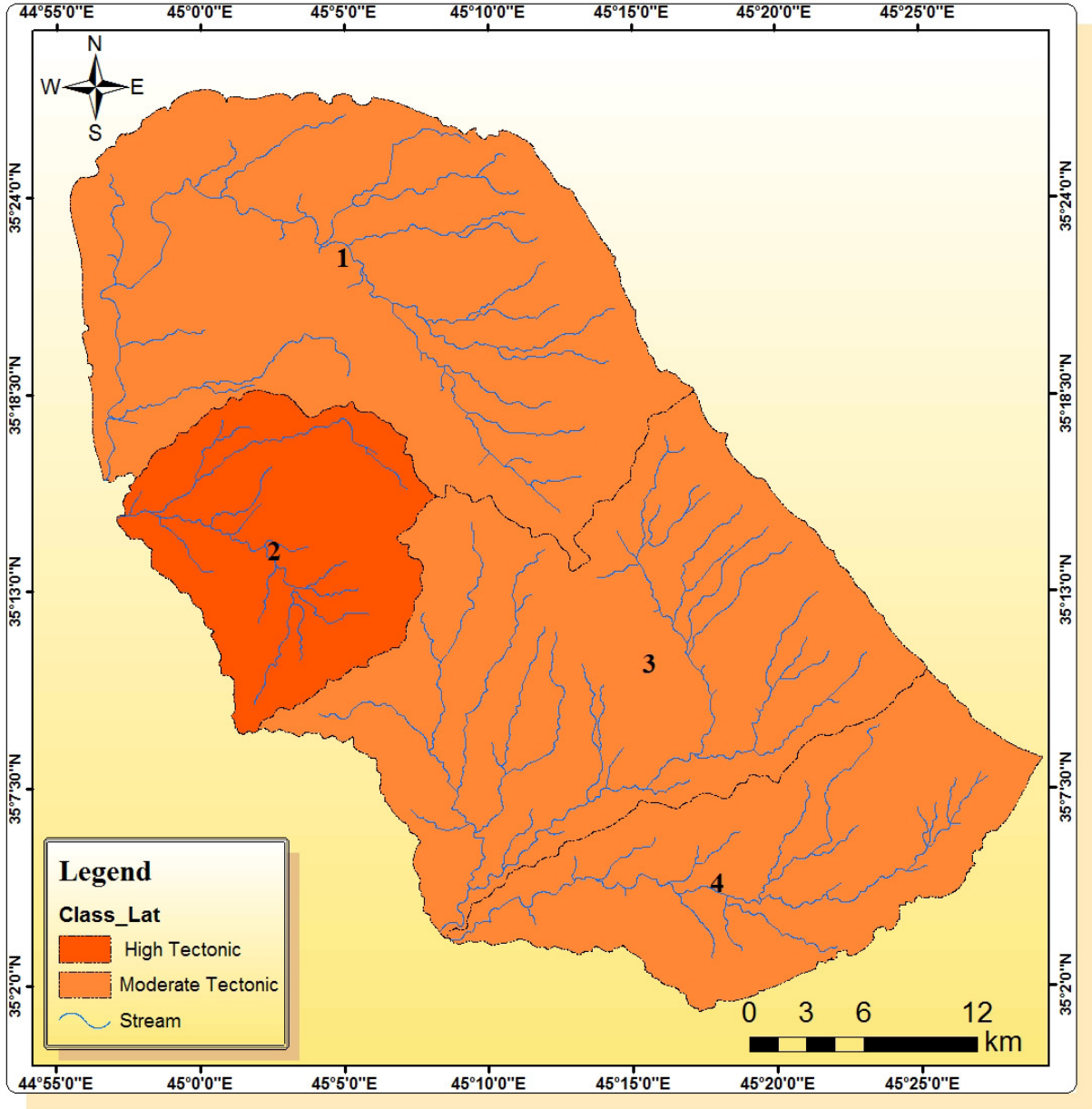


Fig (13) The LAT classes of tectonic activity within the study area.

Index values (Ratio of valley floor width to valley height) reflect the more tectonic valleys when values are low. Sub-basin 2 within study area reflect the more tectonic activities than others sub-basins within the area. This index values increased gradually with the stream down the valley toward the downstream region, which is characterized by low tectonic, and index values also vary according to energy drainage and basement rocks.

The location of study area was building through the Alpine Orogeny, it seems that heavily influenced by the prevailing structural geology in the area. From structure point of view many of folds and faults were distribute within study area ,

The activity of tectonic is mainly due to the longitudinal faults which passes through or surrounding the area of study. The tectonic location within Zagros Mountain Front Fault and Kirkuk Fault has the greatest impact in the tectonic activity in the study area. Most of the anticline folds within the study area are asymmetrical and the Southwestern limb of those folds is steeper than the Northeastern limb as a result of increasing intensity towards SW direction.

It was found that the moderate tectonic activity controls the majority of the study area, sub-basins 1, 3 and 4 while high tectonic activity covered sub-basin 2 as a particular part within SW of the study area. Low and very high classes of activities does not exist in the general area of study.

## Conclusions

- 1- The study area located at a critical area near by the Zagros Mountain Front of the folded belt of the Zagros range.
- 2- Investigation of geomorphical indicators of a neotectonic activity such as Drainage basin asymmetry, Transverse Topographic Symmetry, Mountain front sinuosity and Ratio of valley floor width to valley height shows that the area is subjected to moderate to high tectonic activities.
- 3- Subdivisions of the study area into sub-basins show that some areas have more activities as compared to the others, such as sub-basin 2.
- 4- Tilting and differential uplifts are related to activate movement on regional longitudinal fault passes through the study area as Zagros Mountain Front Fault, Bassara and Awa Spi faults.
- 5- Operations of erosion and Aggradation on the surface played important role in the revitalization of geomorphological processes in the study area, which reflects the prevailing climate role in the study area.
- 6- Satellite data and GIS techniques proved highly efficient in the analysis and interpretation of the results.

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