Analysis of Morphological Features of Sargalu Region in Sulaymaniyah Governorate, North of Iraq, by using Geographic Information System

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Abstract

It is an ideal area of research to examine related indicators to anticipate relative tectonic activities, where there is a broad range of geological formations with elements of different sedimentary rocks. This study includes assessing and evaluating the relative tectonic activities within the Sargalu area by using a morphometric approach, which involved the use of different indices that can explain and help understanding the geometry, development level, lithology, and structural disturbance on a sub-basinal level. The research was accomplished by using ArcGIS 10.5 hydrology tools to design the drainage system of each studied stream. The Advanced Spaceborne Thermal Emission Radiometer (ASTER) satellite imagery data and the Digital Elevation Model (DEM 90m) were used. Moreover, Global Mapper and Statistical Package for the Social Sciences (SPSS) were applied. DEM datasets of ASTER were used for watershed delineation. Also, 14 sub-basins were delineated in the Sargalu area. Morphometric indices used include Shape Related Indices, such as Rc, Bs, Rf, Ls, Re, T, and Af. Basin asymmetry factor (Af) and several geomorphic indices were also utilized. Based on the shape related indices (Rc, Rf, Re, Ls, and Cc), the results were found to be similar and, for most sub-basins, had an elongated nature. The elongated basins are connected with tectonically active areas, while the circulated basins are connected with the tectonically undisturbed environment.

دراسة و تحليل الخصائص الجيومورفولوجية لمنطقة ساركلو في محافظة السليمانية في شمال العراق باستخدام نظم المعلومات الجغرافية

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الخلاصة

إنها منطقة مثالية لفحص المؤشر لتنبؤ النشاط التكتوني النسبي ، بالإضافة إلى اعتباره منطقة مميزة للغاية. حيث توجد مجموعة كبيرة من التراكيب الجيولوجية. عناصر التكوينات من الصخور الرسوبية المختلفة. شملت دراسته تقييم وتقييم النشاط التكتوني النسبي داخل منطقة ساركلو باستخدام نهج مورفومتري ، والذي تضمن استخدام مؤشرات مختلفة يمكن أن تشرح وتساعد في فهم الهندسة ومستوى التطوير والليثولوجيا والاضطراب التركيبي على المستوى الأساسي. تم الانتهاء من البحث باستخدام تقنيات (ArcGIS 10.5) تم استخدام أدوات الهيدرولوجيا لتصميم نظام الصرف لكل مجرى مدروس. تم استخدام بيانات صور أستر الفضائية ، نموذج الارتفاع الرقمي (DEM 90m). علاوة على ذلك ، تم استخدام مخطط عالمي و (الحزمة

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الإحصائية للعلوم الاجتماعية– SPSS). تم استخدام مجموعات بيانات نموذج الارتفاع الرقمي للمقياس
الإشعاعي للانبعاثات الحرارية المحمولة في الفضاء المتقدم (ASTER) لتحديد مستجمعات المياه. كما تم
تحديد (14) حوض فرعي في منطقة ساركلو. تشمل المؤشرات المورفومترية المستخدمة ما يلي: مؤشرات ذات
صلة بالشكل مثل (Rc و Bs و Rf و Ls و Re و T و Af) يتم استخدام عامل التماثل في الحوض (Af)
والعديد من المؤشرات الجيومورفكية. استنادًا إلى المؤشرات ذات الشكل (Rc) و (Rf) و (Re) و (Ls) و
(Cc). وقد وجد أن هذه النتائج متشابهة وأن معظم الأحواض الفرعية لها طبيعة طوليه. ترتبط الأحواض
الممدودة بمناطق نشطة تكتونيًا ، بينما ترتبط الأحواض ذات الشكل الدائري بالبيئة غير المضطربة تكتونيًا.

Introduction

General geomorphometry is the calculation and investigation of the characteristics of landform which can be applied to any sort of rough continuous surfaces [1]. The current worldwide accessibility of DEM drives the designing of novel procedures to effectively apply the principles of geomorphometry in the territories for which the geomorphic mapping is immature and deficient [2, 3]. The explanation of the diversity of geomorphology can be provided through several morphogenesis affecting factors, e.g. tectonic and climate change history, that affect the region contrarily relying on its lithology [5]. Such factors result in landform diversity in a place of natural things separating the surface of the earth. as Also, such factors impact the definition of the conditions of boundaries for the methods operative in fields of pedology, ecology, hydrology, geomorphology, and several others [6, 7]. The geomorphological diversification was demonstrated to be an essential explaining feature to provide the variations in the functioning of the forest ecosystem and patterns of spatial biodiversity, which were detected at local scale and regional scales [9, 10, 11]. Landform quantitative measurements are achieved on the basis of geomorphic indices calculation. However, a single index is not adequate to measure an area's degree of tectonic activity. Quantification is usually subsequent to the procurement of essential information from satellite data, aerial photographs, and topographic maps [12]. An assimilated multidisciplinary method utilizing structural, geomorphological, and neotectonic data is extremely helpful in the active tectonics evaluation [13]. The morphotectonic characteristics are an exceptional indicator to explore the comparative tectonic activities [14, 15, 16]. Thus, we investigated 6 geomorphic indices, namely the valley floor width-valley height ratio (Vf), hypsometric integral (Hi) with a convex-up hypsometric curve, topographic asymmetry (TA), drainage basin asymmetry (AF), steam gradient index (SL), circulatory ratio (KA), basin shape of drainage (Eb), and mountain front sinuosity (Smf) to deduce the dynamic tectonic marks. The computed geomorphic indices were further associated to illustrate the comparative active tectonics.

Location and Description of the Study Area

The study area is located in the northeastern part of Iraq. According to the tectonic map [17], it is placed within the High Folded Zone (HFZ) and the Imbricated Zone (IZ) [18], which is a part of the Unstable Shelf. It covers about 2980.788959 km², lying between the longitude of (44°58'- 45°21'E) and the latitude of (35°48'- 36°00'N), as illustrated in Figure-1. The folds in this area include weelana, bana bareek, yakhyan, kalo, khalikan, dolmazala, surdash, sulaimaniyah, pere magrun, and dokan.
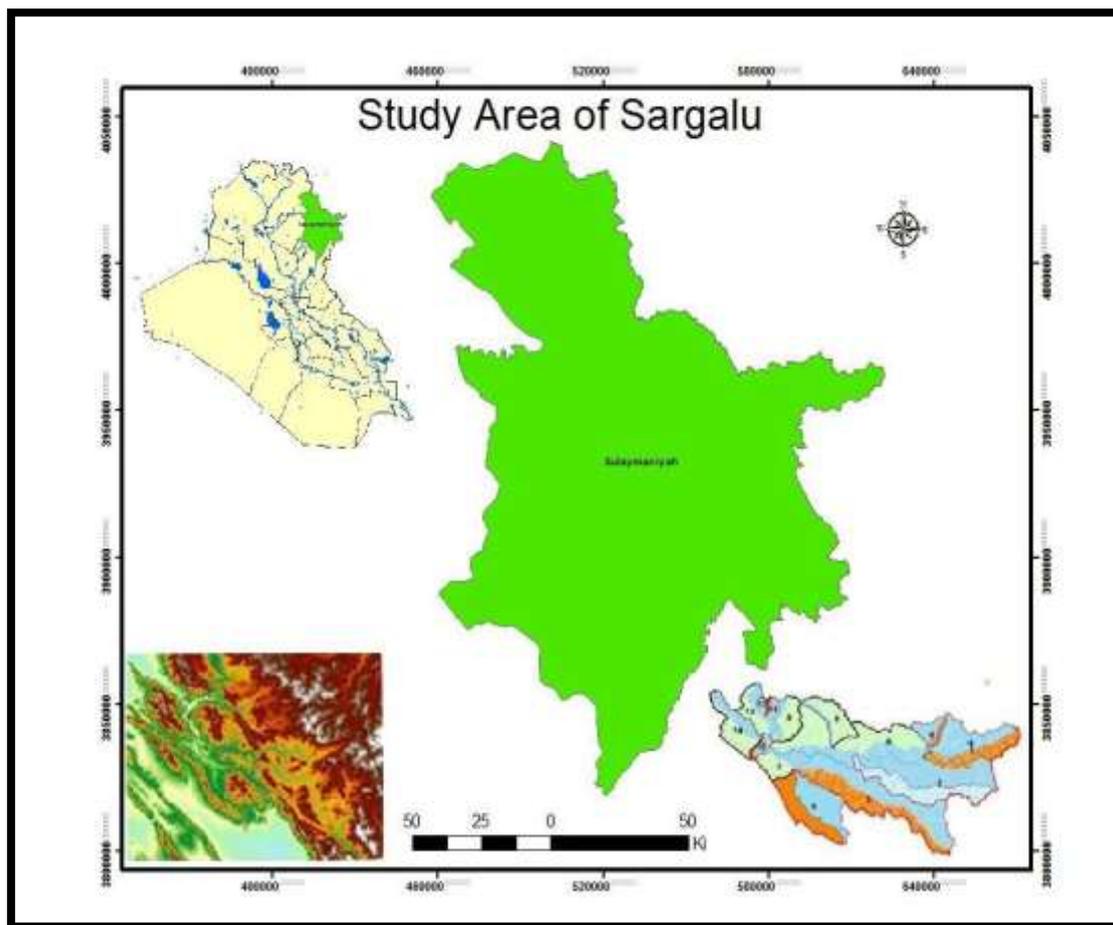
Figure 1-Location map of the Sargalu Area (SA).

The area of this study is located along the Iraqi - Iranian border, which is featured by the High Folded Zone, Imbricate Zone, Zagros Suture Zone, and Shalair Zone. Geomorphologically, the study area has a mountainous terrain with a peak of 3140 meters a.s.l. in the northeastern part and a minimum elevation of 459 meters a.s.l.. This implies that the area increases in height to the northeast. Geologically, it is a highly complicated study area. The age of the exposed formations is from Jurassic to Holocene with different types of quaternary sediments. The anticline folds include the oldest exposed rocks in Iraq, along with a major fault creep that runs from the northeast to the northwest, which forms the tectonic connection between the superposition regions and the elevated regions. The folds that are located in the northeastern part have the direction of the northeast-southwest, and they are parallel to the thrust belt, Zagross, whereas the northwestern wings extend to the greater Zab River where their directions change toward east-west. The Sargalu Area crosses the areas of weelana, bana bareek, yakhyan, Kalo, khalikan, dolmazala, surdash, Sulaymaniyah, pere magrun, and dokan folds.

Structural Geology

According to Figure-2, 3 the studied region is placed inside the High Folded, Imbricate, Zagros Suture Zone and Shalair zone, all of which belonging to the Unstable Shelf of the Arabian Plate [19, 20]. Several anticlines and synclines are developed, all being in the NW – SE trend. However, in the extreme northwestern part of the area, their trend changes toward E – W. . The main anticlines, from the north to the south, within the studied area are Pera Magrun Anticline, Sulaimanya Anticline, Klo Anticline, Bana-Bareek Anticline, Weelana Anticline, and Khalikan Anticline. The names of the anticlines are based on [19], while the names of the thrust sheets are based on [20].
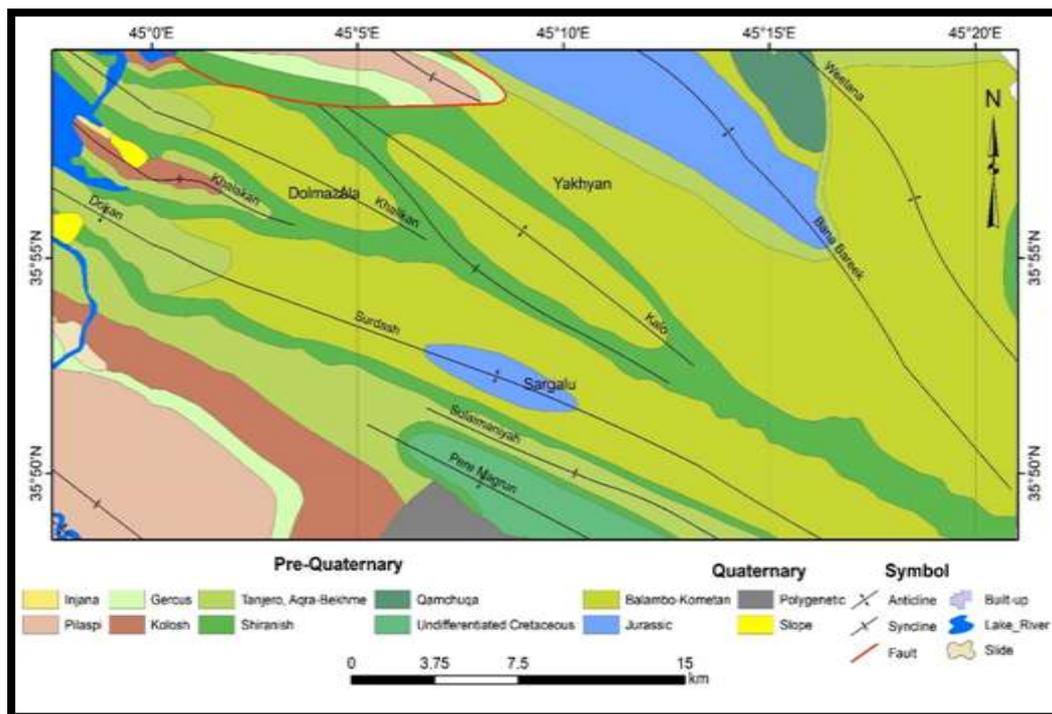
Figure 2-Geological map of the study area. The Sargalu is marked with the blue ellipse shape [21].
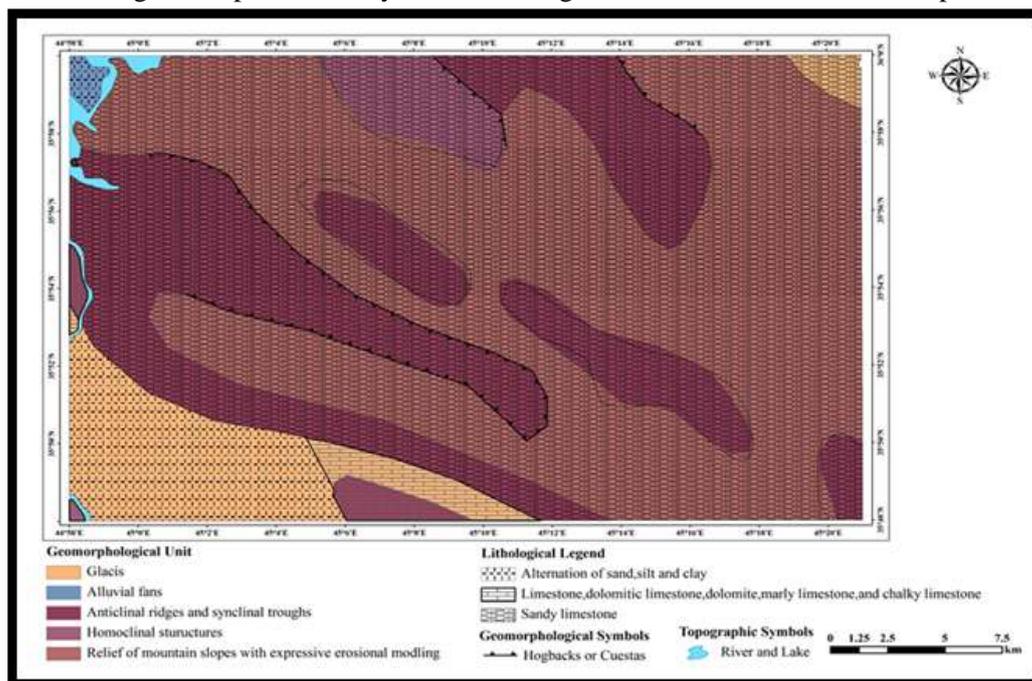
Figure 3-Geomorphological Map of the Study area [22].

Methodology

Morphometric features such as aerial, linear, and relief aspects, along with a number of geomorphic parameters, were collected using satellite digital images and supporting data. This approach was adopted due to the fact that the manual extraction of networks and assigning the stream order from the published topography map of Iraq and geo-referenced satellite data for a large area is a time consuming exercise. Geographic information systems (GIS) and remote sensing techniques are used as suitable tools to produce spatial variation in morphometric variables. Remote sensing data obtained from sensors such as ASTER Global Digital Elevation Model (GDEM), with a Resolution of 90 m, in addition to other supporting data, such as topographic (scale 1:2,500,000) and geologic maps

were also used to determine the drainage networks and the morphometric parameters of the Sargalu area (SA) and its sub-basins. ArcGIS 10.5 software was used to extract drainage networks and generate drainage basin characteristics. More specifically, the extracted SB and its sub-basins and stream networks are projected to the regional projection (WGS-1984, UTM Zone 38 N) and the hydrology of the ArcGIS software toolbox. The automated method for delineating drainage was performed using GIS. Different morphometric parameters were determined, as shown in Table-1.

Table 1-The relief linear and morphometric areal parameters used for Sargalu Area Watershed.

S.no.	Parameter	Formula
1	Stream length (Lu)	Length of the length stream
2	Stream order (U)	Hierachial rank
3	Stream length ratio (RL)	$RL = Lu/Lu - 1$
4	Mean stream length (Msl)	$MSL = Lu/Nu$
5	Mean bifurcation ratio (*Rbm*)	Rbm = Average of bifurcation ratios of all orders
6	Bifurcation ratio (Rb)	$Rb = Rb = Nu/Nu + 1$
7	Stream frequency (*Fs*)	$Fs = Nu/Ba$
8	Drainage density (Dd)	$Dd = Lu/Ba$
9	Elongation ratio (*Re*)	$Re = 2\sqrt{(Ba/\pi)} / Lb$
10	Drainage texture (T)	$T = Dd \times Fs$
11	Circularity ratio (*Rc*)	$Rc = 4 \times \pi \times Ba/P^2$
12	Form factor (*Rf*)	$Rf = Ba/Lb^2$
13	Compactness coefficient (*Cc*)	$Cc = 0.2841 \times (P/Ba^{0.5})$
14	Basin relief (*R*)	$R = H_{max} - H_{min}$
15	Relief ratio (*Rh*)	$Rh = H/Lb$
16	Constant channel maintenance (*C*)	$C = 1/Dd$
17	Drainage intensity (*Di*)	$Di = Fs/Dd$
18	Lemniscate shape ratio (Ls)	$Ls = (Lb) 2 * \pi/4 Ba$

Results
Extraction of the Watershed of Sargalu Area
    ASTER DEM imagery data with a spatial resolution of 90m for Sargalu Area were automatically extracted. The extraordinary geological processing techniques in ArcGIS 10.5 aided in extracting the basin area. The DEM and the pour point are the two input parameters required for the extraction. A pour point is a user-supplied point to the cells of the highest flow accumulation [22]. The method of the automatic extraction of the basin/watershed is displayed in Figure-4. These results of the process will begin to a watershed boundary polygon from the flow direction raster data. Using ArcGIS 10.5 the drainage network in Sargalu Area was obtained from an accumulation of geoprocessing tools. This process is considered as central to provide a stream/drainage network grid with stream order [23]. In the Sargalu Area, the highest steam order was distinguished as being the sixth order. Standard mathematical methods were followed using the parameters provided in Table-1. The various parameters interpreted, such as stream code, stream length, number, basin relief, stream length ratio, bifurcation ratio, basin length, basin area, elongation ratio, relief ratio, drainage density, etc.. To assist the drainage morphometric basin, the aspect and slope map of the study area was derived from the ASTER DEM using the aspect and slope tool in ArcGIS-10.5 spatial analyst module.
 Morphometric analysis and geomorphic indices
Active tectonics Morphometric Analysis of basin
    Morphotectonic quantitative parameters are used to study the active tectonics and morphological relationships [22- 27]. The drainage network of the watershed and stream ordering was examined based on several formulae used in this study, as shown in Table-2. The morphometric parameters were classified into three groups, namely the basic parameters, derived parameters, and shape parameters. The basic parameters contain area (Ba), perimeter (P), basin length (Lb), stream order (U), and stream length (Lu). The derived parameters include stream length ratio (Lur), bifurcation ratio (Rb), and Drainage density (Dd). The shape parameters include elongation ratio (Re) , circulatory ratio (Rc), and form factor (Rf).

Basic Parameters

The values in Table- 2   represent the morphometric analysis of Sargalu watershed. The elementary parameters include the watershed area, stream length, perimeter, stream order, and basin length.

Table 2-Characteristics of the drainage basins

Sub-basin	Order	Stream number	Stream length (km)	Basin area (km2)	Perimeter (km)	Basin length (km)
1	4	138	258.064	323.909	111.307	32.4
2	4	221	425.996	505.589	153.067	48.93
3	4	223	409.535	550.659	181.713	58.66
4	4	133	256.037	328.529	95.961	32.51
5	4	31	51.652	63.516	44.280	12.81
6	5	197	387.147	509.635	191.236	52.62
7	5	53	92.981	111.902	55.528	18.39
8	4	55	107.838	129.288	69.189	21.77
9	3	41	82.711	112.194	52.380	16.28
10	6	16	20.916	30.574	29.886	9.16
11	3	16	19.952	27.555	24.223	8.44
12	6	40	75.032	111.107	68.406	19.86
13	3	9	10.251	13.880	15.779	4.91
14	4	54	109.551	162.445	77.047	27.11

Perimeter and Area in Sargalu area

The elementary morphometric parameters of the delineated layer of the mini-watershed were examined, including area (A), length (L), perimeter (P), and number of streams (N). Basin length (Lb) was measured from the stream length, while the bifurcation ratio (Rb) was measured from the number of streams. Other linear and morphometric parameters were measured using the equations shown in Table-3.

Table 3-Characterisitcs of the Sargalu Area

Coverage area	2980.78
Length of the basin	99.81
Width of the basin	41.78
Length of the stream	114.90
Highest point in basin	3140
Lowest point in basin	459
Perimeter of the basin	1170
Channel Sinuosity: Before outlet/ After outlet	Regular
Lengths are in Km, areas in Km2, height and width in m	

Shape Parameters of Sargalu area

Table-4 lists the results of Form factor (Rf), Basin Shape index (Bs), Circulatory Ratio (Rc), Elongation Ratio (Re), Lemniscate shape ratio (Ls) (Ls) and Compactness Coefficient (Cc). Their results were found to be similar and indicated that most of the sub-basins had an elongated nature, as illustrated in Figure-5. In the area, the values of elongation ratio ranged from 0.05 (sub-basin 3) to 0.11 (sub-basin 13) symbolizes which the very elongated to the near-circular form of the basins severally. The more elongated basins are located in the north-west while those less elongated are present in the north-eastern part of the study region.
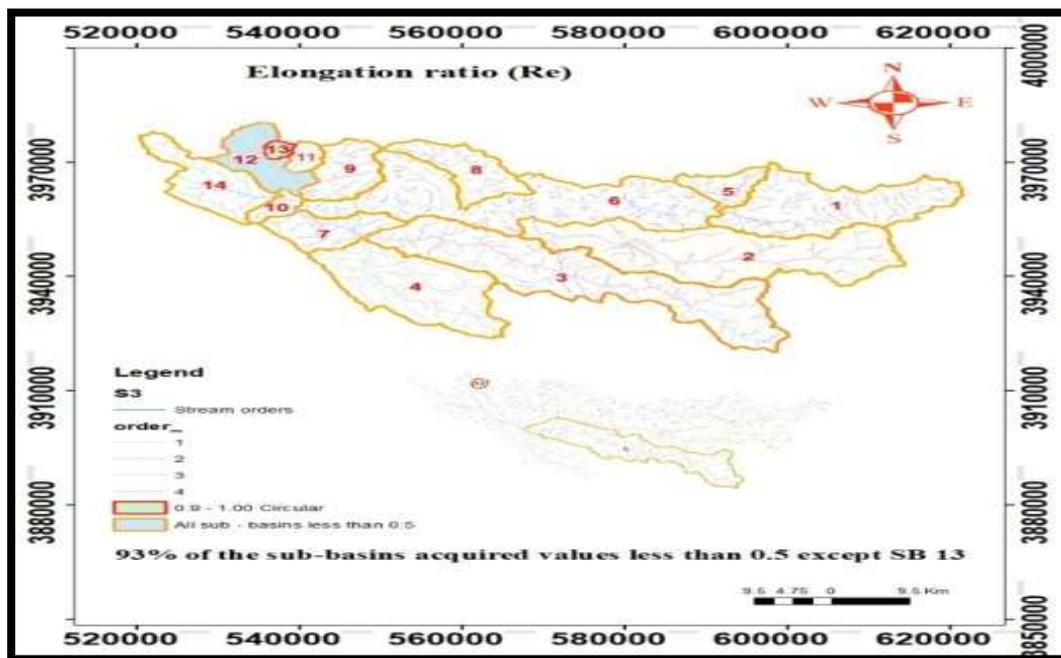
Figure 4-Distribution of (Re) throughout the study area

Table 4-Detailed results of the shape and symmetry related indices.

Sub - basin	(Rf)	(Re)	(Rc)	(Ls)	(Cc)
1	0.30	0.08	0.32	3.24	0.04
2	0.21	0.06	0.27	4.73	0.04
3	0.15	0.05	0.21	6.24	0.04
4	0.31	0.08	0.45	3.21	0.04
5	0.38	0.09	0.40	2.58	0.09
6	0.18	0.06	0.17	5.43	0.05
7	0.32	0.08	0.46	3.02	0.07
8	0.27	0.07	0.34	3.66	0.07
9	0.42	0.09	0.52	2.36	0.06
10	0.35	0.08	0.44	2.74	0.13
11	0.37	0.09	0.58	2.58	0.12
12	0.28	0.07	0.30	3.54	0.08
13	0.53	0.11	0.72	1.73	0.16
14	0.22	0.07	0.34	4.52	0.06

Geomorphic parameters

A mix of two types of parameters, namely the mountain front sinuosity and valley floor width to valley height ratio, was utilized to provide semi-quantitative data of related level of tectonic activity of mountain fronts [28, 29]. Two subjects applying certain signs provide an assignation to various tectonic activity groups.

Mountain front sinuosity (S_{mf})

The length the complete the rate of the hill front as included along with the prominent fracture in slope along the foot of a mountain and the straight-line length of the mountain Front, [30]. It is calculated by the following equation:

Smf = Lmf / LS

The index presents a scale between the tendency of streams and slope methods to provide an irregular (sinuous) mountain front and vertical active tectonics that tend to give a prominent straight front [29].

Table 5-Tectonic activity and the relation between results

Class	Tectonic activity	Value
1	Extremely active	< 1.02
2	Moderately active	>1.02- 1.04
3	Active	>1.04

The Smf index is essential since it can be simply estimated by using the satellite, aerial photographs, or other high altitude imagery or topographic maps. Can mountain fronts be calculated manually from the topographic maps of high-resolution and satellite images? To measure mountain front sinuosity in the Sargalu region, DEMs produced by stereo image bands 3N and 3B of ASTER were used. 3-D surfaces were produced by using Global Mapper version 11. Smf Uses of approach 1.0 on the common tectonically active fronts, whereas Smf develops if the rate of uplift is decreased and erosional processes start to form a front that displays further irregular with time. Rates lower than 1.4 symbolize tectonically active fronts [21, 31]. while more chief Smf uses (3N) are usually correlated with inactive fronts, Smf rates lower than 1.4 stewarded sub-basins (1,3,5,6,9 and 11). The region of Sargalu was divided into 14 sub-basins. Any protection in all of these sub-basins was traced and included, depending on the area of the basin. Hill front can be delimited as one main front separated into segments of many fronts of the same length or fronts connected with different lengths [31, 32, 33]. In this study, the latter approach was adopted because it has been more commonly used in research. Also, with this process, one can achieve better conclusions about the tectonics of the region. As for the sub-basins within the study area, the degree values were found to be ranging from 1.15 (sub-basin 3) to 2.29 (sub-basin 8).

The Valley floor width to valley height ratio (*Vf*)

V_f is another index of valley floor width to valley height rate, which is used evaluate the city the tectonic activity on the base of, [29]. The sign promotes the differentiation between the V-shaped valleys down cutting in response to active uplift, wherever the stream is dictated through the impact of a base level sin at some spot downstream that mention an almost high valleys with especially tectonic activity, and the U-shaped broad-floored lateral erosion into the near hill slopes in answer to related base-level balance or tectonic quiescence that signifies a relatively low tectonic activity. Accordingly, this tool achieves one vertical and one horizontal dimensions at a given point along the stream in the erosional system. The ratio of valley floor width to valley height is defined as: $V_f = 2V_{fw} / ((E_{ld}-E_{sc}) + (E_{rd}-E_{sc}))$. The elevation and floor width values were obtained from the DEM of the knowledge space by saving the main stream for each sub-basin to a digital format, with three engineering pieces and three profiles that are drawn at the meeting points of segment, (upper, middle, and downstream), as demonstrated in Figure-5. According to an earlier report [34], through this parameter, the geometry of the transverse river profile can be described quantitatively and its possible tectonic influence on the river cross-section shape can be assessed.
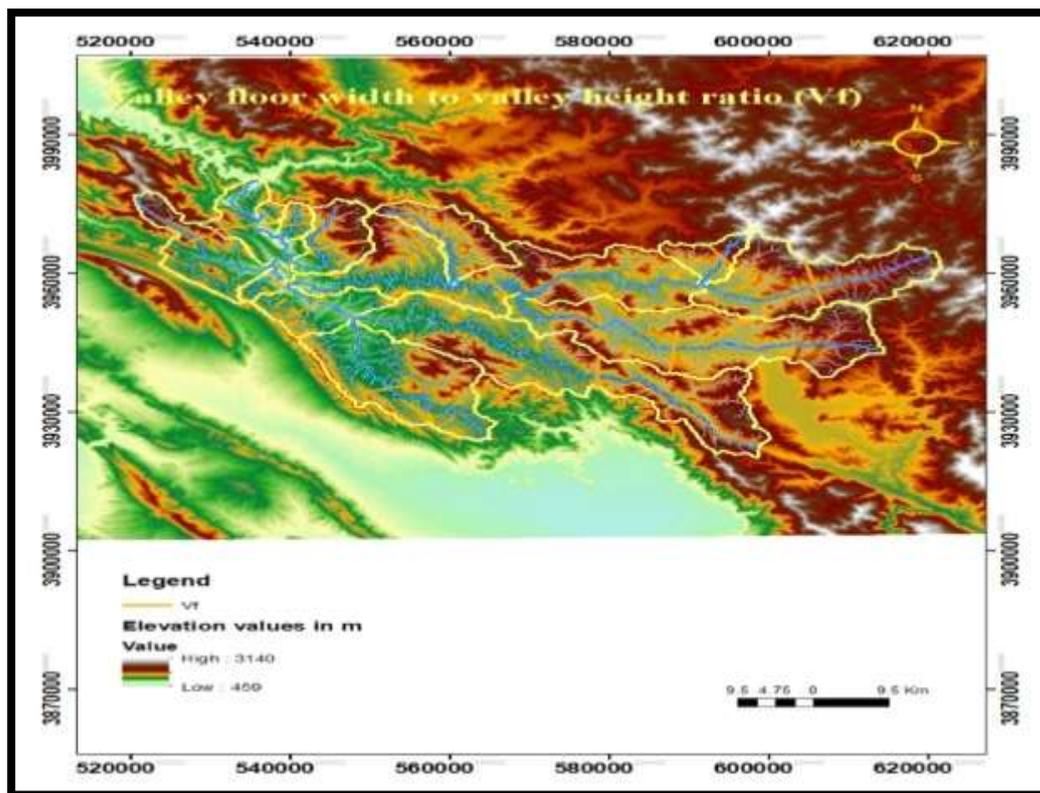
Figure 5-Profiling Locations for the calculation (*Vf*).

As related to the sub-basins within the study area, the ratio values were found to be ranging from 0.09 (sub-basin 6) to 2.07 (sub-basin 11), as listed in Table-6. The lowest values fall within the sub-basin that covers the upper part of the main river (ZSZ). It was also shown that the values tend to increase for the sub-basin that covers the lower part of the main river basin (HFZ).

Table 6-Relationship between results and Shape of the Valley

Class	Shape of the Valley	Values
1	indicates less eroded basin and v-shapedValleys	0.05 – 0.12
2	indicates eroded basin	0.12 – 0.24
3	indicates highly eroded basin and U-shaped Valleys	0.24 – 0.4

Basin shape index (Bs)

The horizontal projection of a basin form may be explained by the basin shape index or the elongation ratio, Bs [27]. Bs was calculated by using the DEM and classified into three classes: Class 1 (Bs≥4), Class 2 (3≤Bs≤4), and Class 3 (Bs≤3) [28]. Bs ranges from 0.55 (sub-basin 1) to 2.86 (sub-basin 11). Most of the maximum values of the examined sub-basins belong to classes 1 and 2, which are elongated with higher (Bs) values as compared to class 3 which reflects nearly circular shapes, as shown in Figure-6. High Bs values are associated with elongated basins, which are commonly associated with almost higher tectonic activity. Low Bs values reflect more circular-shaped basin, normally associated with low tectonic activity. Quickly uplifted mountain fronts generally provide elongated, steep basins; when tectonic activity is diminished or desists, the widening of the basins occurs from the mountain front [35].

Table 7-Values of different geomorphic indices in Sargalu region

Sub-basin No.	B_S	S_{mf}	V_f
1	0.55	1.30	0.45
2	1.36	1.60	0.32
3	1.86	1.15	0.48
4	1.60	1.48	0.18
5	2.09	1.30	0.56
6	1.55	1.15	0.09

7	1.48	1.71	0.16
8	1.65	2.29	0.39
9	1.45	1.38	0.75
10	1.06	1.66	0.36
11	2.86	1.34	2.07
12	1.40	2.05	0.26
13	1.98	1.45	1.009
14	2.57	1.61	0.47
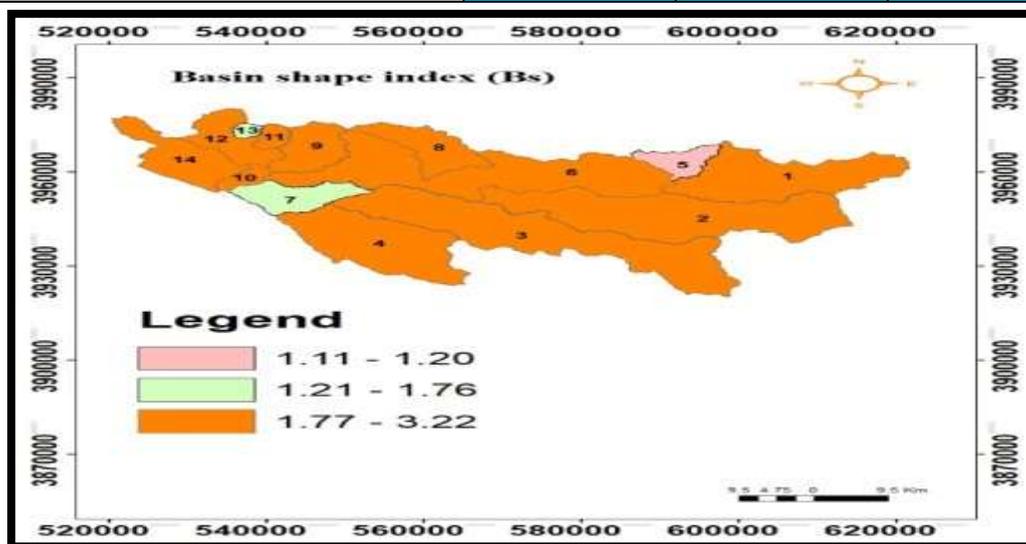
Figure 6-Distribution of (Bs) throughout the study area
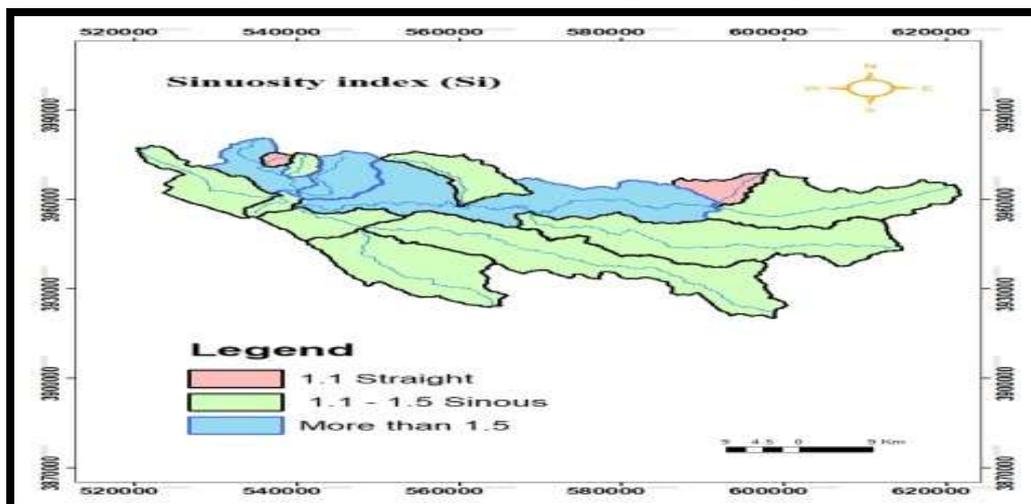
Figure 7-Distribution of (Si) throughout the study area

Discussion

   The geomorphic index is an extensive means to analyze the influence of active tectonics. GIS and remote sensing packages serve over large areas as a reconnaissance tool to identify geomorphic anomalies that are probably connected to active tectonics [36]. Based upon the shape related indices, e.g. (Rf), (Rc), (Re), (Ls), and (Cc), the events were found to be similar for most sub-basins, which also had an elongated nature [31]. The circularly formed basins are connected with the tectonically undisturbed environment, while the elongated basins are connected with tectonically active regions. It is worth mentioning that the results of some of these indices can be caused by the irregularities in the designs of the sub-basins. The lower part of the chief branch basin, primarily in the high folded zone, can be found in many structures affecting the drainage system. The difference between the Zagros Suture Zone and the High Folded Zone is very important during the examination of the (R) indicator, which, in turn, can be related to higher incision rates and erosion. Regarding the results of the

geomorphic indices, the most maximum readings were found when using mixed parameters (Mountain front sinuosity and Valley floor width to valley height ratio) to provide semi-quantitative data of related rate of tectonic activity of mountain fronts. These coupled indices provide an assignation to different tectonic activity classes [29, 30]. A sample of different mountain fronts was analyzed in 14 sub-basins of the Sargalu area. Mountain front examination demonstrated that the lowest result was 1.15 in basin no.3 and the highest result was 2.29 in basin no.8. Therefore, on the basis of the obtained results, all the mountain fronts in the 14 sub-basins of the Sargalu area fall within the „tectonically active front" class 1.

Table 8-Sub-basins location according to the Tectonic Zones

Tectonic Zones			
Shalair Zone	Zagros Suture Zone	Imbricate Zone	High Folded Zone
Sub-basins (1,2,5& 6)	**Sub-basins (4 and 9)**		**(4,7,10 &14)**
Sub-basins (3,6,8,9,11&12)			
	Sub-basins (3,6 &12)		

Drainage basin asymmetry values of (Af) for the 14 sub-basins range between 51 (sub-basin 8) and 71 (sub-basin 5). This simply indicates strong asymmetry. The results reveal the difference in spatial tectonic tilting at the unity plane because of the inequilibrium between the uplift and incision. Ideally, a tectonically constant area should show the value of 50, suggesting no tilting and incision. Drainage asymmetry higher or lower than 50 suggests tilting of the basin. This implies that values higher than 50 indicate that the main river channel is moving towards the left side of the basin downstream , while values lower than 50 indicate that the main river channel is shifting towards the right side of the basin downstream. That balance of uplift and tectonic activity ensures a high local diversify inside the region. Amongst geomorphic systems, drainage systems are highly receptive to active deformation, particularly in the folded and thrust areas. Distinguishes Drainage basin asymmetry that the sub-basins in the touching vicinity of thrust sand faults, should almost more chief values while sub-basins converge with the chief river channel and rising distance of the chief structures suggest approximately symmetric drainage system (Figure-7), In relation to the (T) index, the values are highly correlated with the Af values, which describes the high rates of asymmetry within the area. the idea For estimating the comparative active tectonics, the positive difference is what is essential, and values of Af-50 range from about 1 to 31. In this study, we displayed the information on geomorphic indices other subjects that must be used to help the landscape in names of possible tectonic activity. Within common, the signs along with a special mountain front or region are examined and a judgment made concerning related tectonic activity [20, 29, 37, 38].

Conclusions

1- The study area is found in a very distinct tectonic area of northeastern Iraq, which involves three tectonic zones (Zagros Suture Zone, shalair zone, High Folded Zone and Imbricate Zone).

2- Different geomorphic indices must be examined in the Sargalu area to explain tectonic actions by using satellite remotely sensed datasets.

3- The study area contains 14 sub-basins; the sub-basin (3) has the highest altitude (550.659104 Km2) and the sub-basin (13) has the lowest (13.880404 Km^2).

4- Different morphometric indices showed consistent results that indicate that most sub-basins have an elongated nature.

5- In the 14 sub-basins of the study area, transverse topographic symmetry (T) analysis was performed. The parameters of Dd and Da were measured in various points within the mainstream of the entire basin . Within all sub-basin, chief aqueduct results explain that no-follow the basin this midline of, that flows both left or right show of the main channel. We measured this T about diverse points inside all basins count on at that length from the after calculation the basin and from the T in any areas, we studied the medium the basin rate of. Area In that study, geomorphic characteristics have a large influence on the movement from the canal from the middle. Underlying lithology, changed slope, and presence of various kinds of land cover and irrigation channels affected the tectonic structures. The analysis of T index in Sargalu area revealed that a tectonic incline has started within the North-West direction.

6- Channel sinuosity (Si) for the full SA to measure the importance from sinuosity during explaining the role of neotectonic activity that shifts the large distance channels are in a direction. It further

produces evidence of the interplays of various patterns and processes that are effective inside the basin. Results of within 14 sub-basins range between 1.06 and the channel sinuosity 1.91. In common large sinuosity in the SA found values more than 1.4 (basin no. 6, 9, 10 and 12) are showing powerful sinuosity that communicates to the within that shape of tectonic structures predominating tectonic activity.

7- The main river basin's lower part, especially in the high folded zone, can be found in many structures affecting the drainage system. The difference between the Zagros Suture Zone and High Folded Zone was very distinguished during the analysis of the (R) indicator, which, in turn, can be related to higher incision rates and erosion. Regarding the geomorphic indices results, to classify tectonic activity categories and provide data for the degree of activity of the mountain fronts, most of the researches applied a combination of two indicators. The lowest value of mountain fronts was 1.12 (SB7) and the highest result was 2.10 (SB6). Thus, the area may be classified as being of class 1 „tectonically active front".

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