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Multiple Morphometric Characterization and Analysis of Malakan Valley Drainage Basin Using GIS and Remote Sensing, Kurdistan Region, Iraq

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Abstract The morphometric analysis of a drainage system is necessary in understanding the hydrological behavior of the watersheds. Agricultural development, through the investigations of the watersheds by using Remote Sensing (RS) and Geographic Information System (GIS) techniques can be a dynamic contributor to the economy and growth of the Kurdistan Region (KRG) that on long run can enhance the political and economic stability. The Shuttle Radar Topographic Mission (SRTM) was used to prepare Digital Elevation Model (DEM) for evaluation of morphometric components. Various aspects such as linear, areal, and relief morphometric parameters were calculated using hydrological tool and slope-aspect in ArcGIS. The current study shows that the integration of RS and GIS is an effective approach for analyzing the morphometric pattern and land use change. Future investigation will focus broaden over all sub-watersheds of the current study giving more importance to land use in the watersheds.

Keywords: *agriculture, linear, areal, relief, herringbone, patter*

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1. Introduction

The scarcity of water has become a major impediment to social and economic development and a threat to livelihoods in increasing parts of the world. Addressing water scarcity and quality is important for formulating policies at global, regional, national and local scales [1]. Rivers and lakes are the main source of fresh water [2]. Generally, studying a watershed is important for different socio-economic factors for sustainable development of any area of the world [3]. The economy of the most rural and peri-rural areas mainly depends on agriculture. Agriculture depends on groundwater and surface water resources [4]. Farmers rely on water to sustain their agriculture crops [5]. Thus, use of groundwater and surface water resources increases agricultural production, which improved incomes and contributed to food security [6], accordingly using lands for agricultural purposes prevent land degradation [7].

Studying the morphometric analysis contributes to the rural and agricultural development, and enhancing the support infrastructure [8]. Moreover, agricultural and rural sector economic growth has a much greater effect in poverty reduction and hunger than do urban and industrial growth [9].

The quantitative analysis of land surface is very important for watershed planning, as they are essential tools to determine the character of the basin such as water harvesting applications quality [10], various hydrologic modelling studies [11], soil hydraulic properties [12], infiltration capacity [13], surface runoff [14], irrigations [15], groundwater recharge projects on watershed basis [16], and further agriculture continuous development during the wet season for use at dry season, especially for agricultural and domestic water supply in study area. Moreover, growth in agricultural production leads to improvements in development outcomes, access to durable goods and basic infrastructure, and of the expansion of the agricultural land [17].

The above mentioned information is important in estimating of drainage discharge, especially at the time of the flood [14]. Irrigation, soil, livestock, public safety, socio-economic, and environmental sustainability’s can be severely affected by drought [18]. Therefore, building a dam is an answer to drought as it provides water for irrigation and storage, and flood, which hold back water in order to prevent flooding [19].

In common language, the concept of the words "watershed", "catchment area", and "drainage basins" are often used interchangeably. Any area of highland surrounding the river basin and catches all rainfall, snow and streams into lake, stream river or groundwater is known as watershed. Whereas, an area that characterized by all runoff being conveyed to the same outlet is called catchment area. While, drainage basin or river basin is any area of land where drained by a river and its tributaries which drains off into a common outlet [20]. Information on the morphometric parameters is crucial for water resource management of any watershed [21].

Morphometry is defined as the measurement and analysis of the earth’s surface, dimensions and shape of landforms [22,23]. Morphometric analysis of a drainage basin is a quantitative description and analysis of landforms, which is an important aspect to know the character of the basin [14]. Using morphometric parameters of a drainage basin [24] simplifies the aspect of the basin and can be achieved through measurement of linear, aerial, and relief aspects of the basin and slope contribution [25]. Moreover, several one-dimensional stream properties involve in linear morphometric aspects such as stream length, stream number, stream order, stream length ratio and bifurcation ratio. The areal morphometric aspects consider the two-dimensional parameters that describe the watershed, such as basin length, basin perimeter, and basin area. Lastly, the relief morphometric aspects consist of three-dimensional parameters such as relief ratio, total relief, relative relief, gradient ratio, and hypsometric analysis [13,26,27].

Now a days, geographical information system (GIS) and remote sensing (RS) techniques with their powerful tool for the manipulation and analysis of spatial information [28] are used for evaluating various terrain and morphometric parameters of the drainage basins and watersheds [29]. Furthermore, one of the most advantages of GIS application techniques is its suitability for spatial planning, which can handle complex issues and large databases for manipulation and retrieval [15]. A combination of satellite data and hydrological analysis in GIS environment make it easy to identify and distinguish the drainage area [30].

The importance of this valley is to integrate agricultural development with the local economy through rapid industrialization and growth. Moreover, studying the morphometric analysis contributes to reduce the threat of seasonal floods and bolster local economies. Thus, this work suggests an expansion of the agricultural production.

The objective of this work is to understand the hydrological, geological and topographical characteristics of the study area through the calculating the morphometric parameters using GIS and RS data [31] coupled with geoprocessing techniques.

2. Literature Review

Pioneering work in measuring basin shapes has been performed in last century by Horton [32], Horton [26], Smith [33], Miller [34], and Strahler [35]. Based on their methods, similar work has been appeared throughout the world by different investigators using different techniques. Furthermore, many scientists have performed the morphometric analysis of watershed for better watershed management and plan in different environments. Biswas [14] has conducted morphometric analysis of the Parbati River basin using Strahler's method of stream ordering for all stream related calculations with the help of RS and GIS techniques. Kannan, Venkateswaran [27] carried out quantitative morphometric analysis for Nagavathi watershed, Cauvery river basin in Dharmapuri district, Tamil Nadu, India using SRTM data independently by estimating their various aerial, linear, and relief aspects. Altaf, Meraj [23] during their study work in the Northwest Greater-Himalayan mountain range, demonstrated that the area is more prone to weathering due to very-coarse to coarse drainage texture. Whereas, Sanaullah, Ahmad [36] evaluated morphometric parameters of the river drainage basin in Northern Pakistan to determine flooding potential in the river basin. Adelalu, Yusuf [21] carried out the morphometric analysis of river Donga watershed in Taraba State using RS and GIS Techniques. Their study would serve futuristic hydrological investigation for sustainable water resources management of Kashimbilla dam on this catchment area of river Donga. The quantitative morphometric analysis was carried out by Gajbhiye, Mishra [37] in Manot river catchment in India of 14 sub-watersheds to determine the maximum soil erosion. Kottagoda and Abeysingha [38] used morphometric analysis of watersheds in Kelani river basin in Sri Lanka for soil and water conservation. Results of their study could be applied in watershed prioritization for soil and water conservation. Abboud and Nofal [39] in their work selected Wadi Khumal in the Radwa Mountains of the south Red Sea, Saudi Arabia for applying the certain morphometric parameters that influence water supply for delineating and updating the drainage systems in the study area. Adhikary and Dash [10] studied the morphometric characteristics of Katra watershed of Koraput, an ecologically sensitive region using GIS. They revealed that the lithological, structural and geomorphological expression of the watershed controls the flow direction of the entire drainage network. They also studied how the land use and land cover affects runoff infiltration rates, vegetation types and quality, which leads to presence of permeable sub-soil and low capacity to generate runoff.

From all of the above authors, it is clear that the evaluation of morphometric parameters of the river drainage basin gives a wide vision and understanding in terms of watershed management and protecting the natural environment as the surface water and groundwater are the main sources of water that meet the agricultural, industrial and household requirements.

3. Materials and Methods

3.1. Study Area

The study area is located within a valley locally called Malakan valley located at 70 kilometers northeast of Erbil city. Malakan valley is situated between 36°24′to 36°32′ N latitude and 44°29′to 44°30′ E longitude from 2520 meters to 932 meters average from mean sea level (Figure 1). Malakan river basin originates in the lower mountains in Malakan valley and flowing through the whole valley that finally flows in the Gali Ali-Beg Fall.

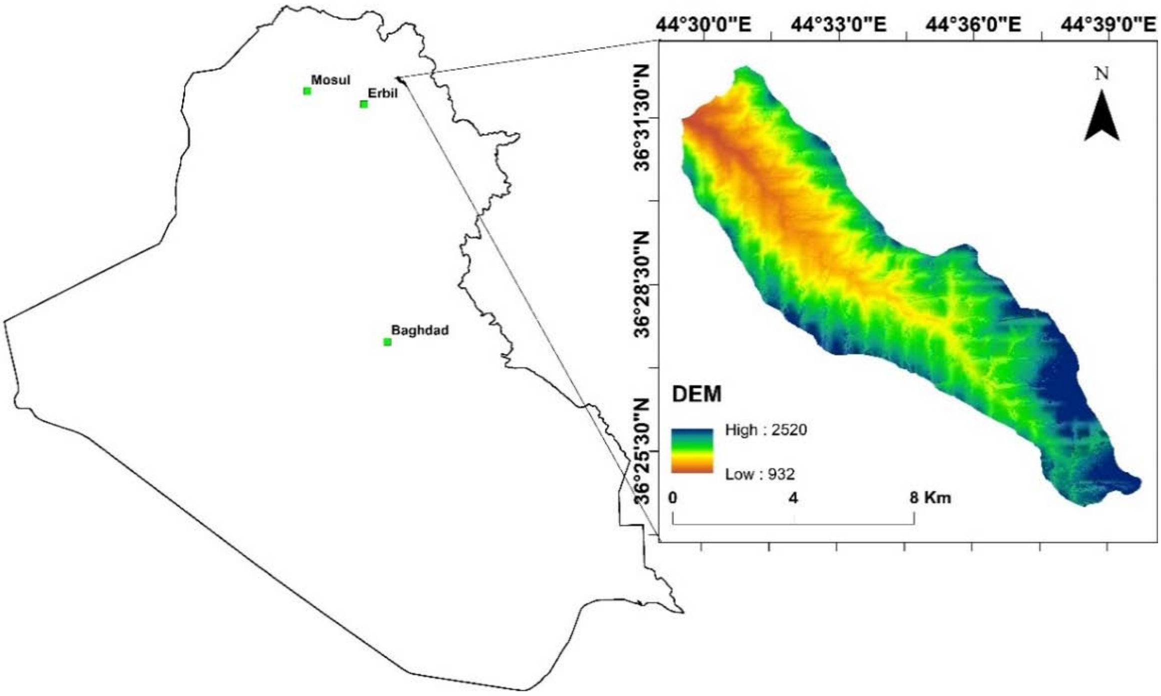

Figure 1. Study area showing Digital Elevation Map of Malakan valley derived from the Shuttle Radar Topography Mission [31]

There is a permanent and a seasonal water flow especially at winter and spring, while the rest of year the base flow is at its minimum flow which originate from two springs [40]. The source of water is from direct runoff of rainfall during winter and spring times and from melting of snow especial in spring and summer when the temperature become rising over 20°C in this area. The weather of the Malakan watershed is categorized by hot summer and well-distributed rainfall during the monsoon season [41,42].

The Malakan river basin, which is a significant tributary of Gali Ali-Beg Fall and also a most important tributary of Greater Zab river and contributes significant source of water resource of the area for surface and ground water resources [43].

3.2. Satellite Imagery and Data Processing

One Landsat 8 operational land imager (OLI) with 30 m resolution acquired in 2019 with one scene from the digital elevation data 30m resolution of the Shuttle Radar Topographic Mission, (1 arc) were used, Table 1. The common classified image; Supervised Maximum Likelihood Classification (MLC), which is one of the traditional image classification techniques was used for the LULC classification [44].

Table 1. Satellite (sub-scene) images used in this study to calculate the morphometric parameters

Satellite sensors	Path/row	Acquisition date	Resolution	Band Nos.
Landsat 8 LDCM	169/035	2015-08-24	30 m	1,2,3,4,5,7,8,9
SRTM (1 arc)	N36_E044/N36_E045	Sep 2014	30 m	GDEM

3.3. Land Use Land Cover

Land use and land cover affects runoff infiltration rates, vegetation types and quality [10]. The infiltration rate for the forest is higher compared with the meadow and the cultivated soil [45]. Decreasing infiltration capacity as a result of destruction of the soil structure [7] and vegetation leads to increased flooding frequency [46].

4. Results and Discussion

Figure 2 displays the height against the distance downstream of Malakan river. The source river originates at 1800 meters above mean sea level and it's rapidly decreasing to less than 1000 m above sea level. In fact, each of stream flow, the lithology of the underlying structure, flow velocity, flow resistance, width and depth of the channel, and regional slope has a strong relationship with the long profile of a river [14].

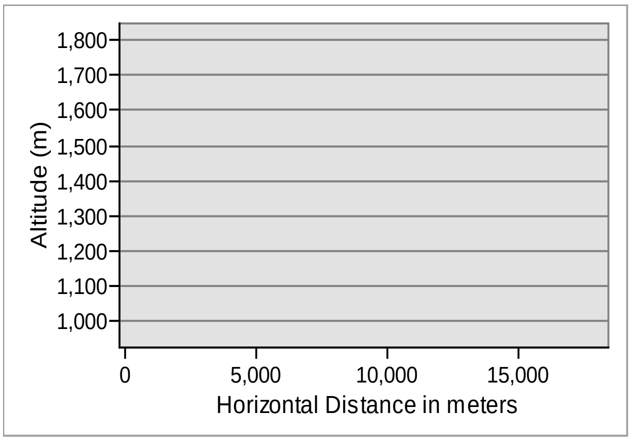

Figure 2. Long profile of the Malakan River

4.1. Land Use Land Cover

Open forest areas were the predominant landscape matrix in the study area, which occupied 42%, followed by dense forest that covered 27.24% of the total area. Barren land covered 23.75% and agricultural plantation covered 6.29%, while riparian zone occupied only 0.72%, as shown in Table 2 and Figure 3. Consequently, the present study covers more or less 70% by open and dense forest, which leads to presence of permeable sub-soil and low capacity to generate runoff.

Table 2. The percentage of land use land cover categories from Landsat 8 of Malakan valley

	LULC categories	%
1	Barren land	23.75
2	Dense Forest	27.24
3	Open Forest	42
4	Agriculture Plantation	6.29
5	Riparian zone	0.72
		100

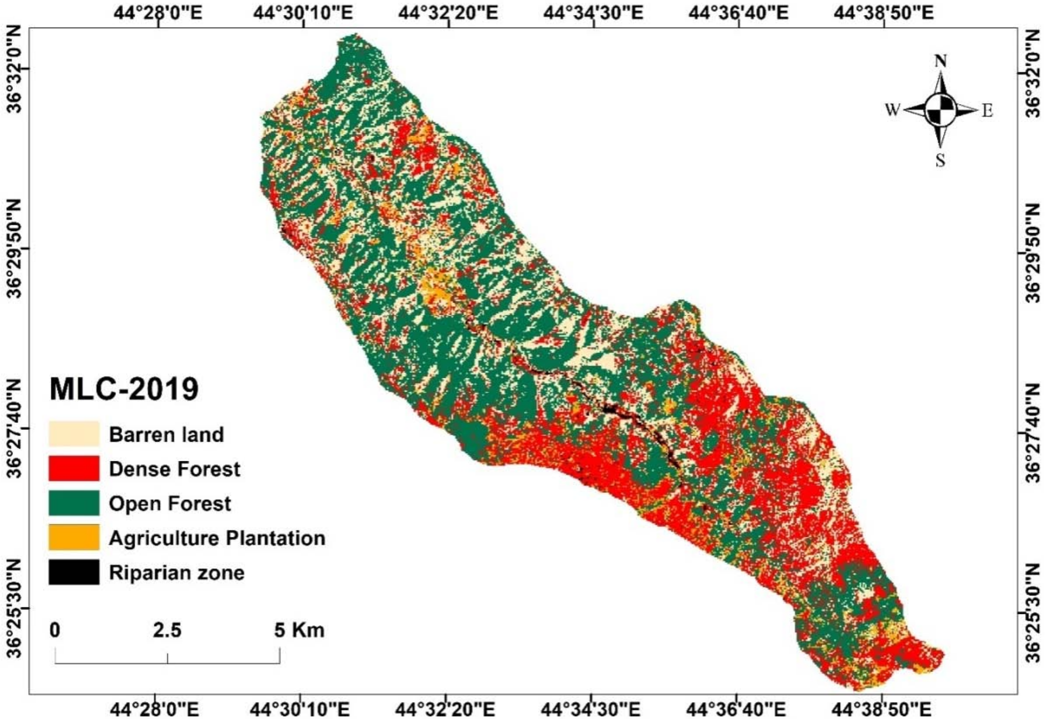

Figure 3. The classified LULC map for Malakan valley for year 2019 from maximum likelihood classifier with Landsat data

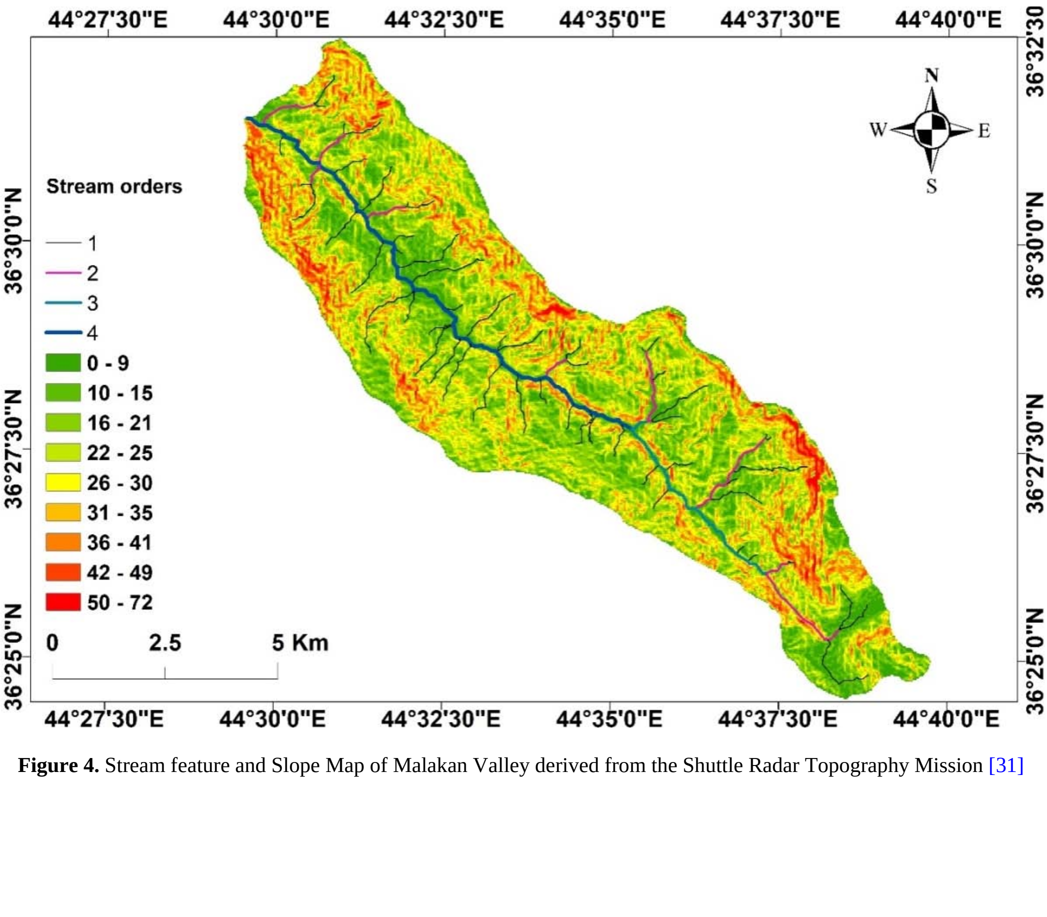

Figure 4. Stream feature and Slope Map of Malakan Valley derived from the Shuttle Radar Topography Mission [31]

4.2. Slope

Figure 4 shows the derived slope map of the Malakan river basin, which varies from 0° to 72°. High slope can be observed in both sides of the study area and low slope in middle part of Malakan watershed. Thus, higher slope gradient results rapid runoff with potential soil loss. In general, it also shows that there is a negative relationship between stream length and slope. Decreasing in the slope leads to increasing in the stream lengths. Thus, the fourth order streams of the study area gained an advantage to increase their length. This agreed with the stream number of fourth stream order which is 44 compared to second and third stream orders which have 25 and 10, respectively, Table 3.

Table 3. Total Stream length and Total Stream Number (Nu) of the study area

	I	II	III	IV	Total
Total Stream Number (Nu)	109	25	10	44	188
Total Stream length (Lu)	48.03	11.9	5.3	12.7	77.93

Very little of the first and second order streams drain over a steep slope area with slope value ranges between 31-72%. Whereas, all segments of the third and fourth order streams are draining over gently slope area with a value of slope less than 10%. Thus, the fourth order streams travel longer distances than third and other order streams.

The slope map (Figure 4) of Malakan watershed is classified into nine divisions. An area of 52% of total area has a slope between 16 and 30 (moderate slope) which is the dominant. Twenty five percent of the area has low slope 0-15 and high slope occupied an area around 23% of the total area ranges between 31-72%, Table 4.

Moreover, in the current study, herringbone type of drainage pattern develops over the sedimentary rocks, where the streams tributes to the mainstream at almost a right angle. It reflects the controls of the underlying rock structure.

Table 4. Distribution of areas under different slope classes

	Slope	Percentage	
1	0-9	9	**25%**
2	10-15	15.9	
3	16 - 21	19	**52%**
4	22 - 25	18	
5	26 - 30	15	
6	31 - 35	11.2	**23%**
7	36 - 41	7.7	
8	42 - 49	3.4	
9	50 - 72	0.8	

4.3. Linear Aspect

The drainage network in watershed was analysed to calculate various linear parameters like: Stream Order, Stream Number, Stream Length and Bifurcation Ratio for the Malakan drainage network shown. Results of the watershed morphometric analysis are presented in Table 5. The quantitative morphometric analysis was carried out of Malakan watershed using GIS technique for determining Drainage Network, Drainage Texture Analysis, Shape, and Relief Characterization and are discussed in the following sections.

4.3.1. Basic Parameters

The basic morphometric parameters of the basin include geometry, stream order, stream length and mean stream length.

4.3.2. Basin Geometry

Drainage area (A) is a key watershed characteristic for hydrologic analysis and design. The total drainage area of the Malakan river basin is 72 km2. The perimeter of the study area is 47.10 km^2. The basin length of the watershed is 19.23 km, which corresponds to the maximum length of the main drainage line.

4.3.3. Stream Order (U)

Horton [32] presented stream order concept. The Malakan river basin is designated as a fourth-order basin. Stream order is a valuable pointer of stream size, discharge and drainage area. Stream order of the Malakan basin area was calculated based on Strahler [35].

4.3.4. Stream Number (Nu)

Table 3 presents the number of streams (Nu) in each order. One hundred eighty eight stream segments were recognized in Malakan drainage basin, out of which 109 is 1st order, 25 is 2nd order, 10 is 3rd order and 44 is 4th order. The maximum amounts of first order streams reflect the intensity of permeability and infiltration. As a result the 4th order has larger stream numbers than 2nd and 3rd order streams therefore, a care should be taken, because there would be a risk of sudden flash floods after heavy rainfall in the down streams reported Chitra, Alaguraja [49].

4.3.5. Stream Length (LT) and Mean Stream Length (Lu)

The mean stream length of the watershed is 0.43 and most of stream lengths (1st and 2nd orders) of the current study are relatively short. However, short length streams are representative of steep slopes areas, while low gradients represent longer lengths [49]. The calculations of the stream length and mean stream length were based on Horton (1945)'s law. Horton [26].

4.3.6. Maximum and Minimum Elevation (H and h)

The Malakan river basin has a higher difference in elevation (relief), which leads to greater discharge. The maximum and minimum elevation of the present work is 2520 m in the southeastern sector and 932 m in the northwestern sector respectively thus, the total relief is 1588m.

4.4. Derived Parameters

4.4.1. Bifurcation Ratio (Rb)

The mean bifurcation ratio of the watershed is 2.36. In general, Bifurcation ratio (Rb) is a dimensionless parameter that tells the geometric similarity of the basin and expresses the effect of the drainage network [35].

Table 5. Linear, areal and relief aspects calculated for morphometric analysis

		Morphometric Parameters	Formula /Definition	Reference	Observed Values
Linear Aspect	1.	Perimeter (P) km	Length of the drainage basin boundary	----	47.10
	2.	Basin length (Lb) km	Maximum length of the basin measured parallel to the main drainage line	Strahler [35]	19.3
	3.	Stream length (Lu) km	Length of the Major stream	Horton [26]	77.93
	4.	Mean stream length (Lsm)	Lsm = Lu / Nu , Lu = Total stream length of order ‘u’ Nu = Total no. of stream segments of order ‘u’	Strahler [35]	0.41
	5.	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1, Nu = Total no. of stream segments of order ‘u’ Nu + 1 = Number of segments of the next higher order	Schumm [47]	2.36
	6.	Stream length ratio (Rl)	Rl = Lu / Lu – 1 , Lu = The total stream length of the order ‘u’ Lu – 1 = The total stream length of its next lower order	Horton [26]	0.43
Aerial Aspect	7.	Total Area (A) km^2	Total area of river basin	---	72
	8.	Drainage density (Dd)	Dd = ∑Lu / A	Horton [32]	1.08
	9.	Stream frequency (Fs)	Fs = ∑Nu / A	Horton [32]	2.61
	10.	Form factor (Rf)	Rf = A / Lb^2	Horton [32]	0.19
	11.	Circularity ratio (Rc)	Rc = 4 π A / P^2	Miller [34]	0.40
	12.	Drainage texture (T)	T= Dd × Fs	Horton [26]	2.82
	13.	Elongation ratio (Re)	Re = 1.128√A / Lb	Schumm [47]	0.28
	14.	Length of overland flow (Lg)	Lg = 1/2Dd	Horton [26]	0.45
Relief Aspects	15.	Basin Relief (R)	R = H− h , H is maximum elevation and h is minimum elevation within the basin.	Schumm [47]	1588
	16..	Relief Ratio (Rr)	Rr = R/Lb	Schumm [47]	0.13
	17.	Ruggedness number (Rn)	Rn = Dd× H/1000 R is the basin relief and Dd is the drainage density	Strahler [48]	1.71

4.4.2. Stream Length Ratio (Rl)

Stream length ratio shows a significant relation with surface flow discharge and erosion stage of the basin. The mean stream length of the watershed is 0.43.

4.4.3. Drainage Density (Dd)

Drainage density was presented as an important morphometric parameter by Horton [32]. It is defined as the total length of all streams per unit area. Drainage density is a very important features of drainage basin as it influenced the texture of a drainage system and it depends on a number of factors like lithology, topography, and vegetation [50,51]. Drainage Density classified into five ranges after Smith [33]. Low drainage density results in a coarse texture, while high drainage density gives rise to a fine drainage texture [35]. The drainage density of the study area is 1.08 km/km2. Thus, according to the Horton [32]’s classification the low drainage density value of the Malakan river basin reveal very coarse drainage texture, dense vegetation, and a permeable subsurface in the study area, Table 6.

Table 6. Drainage density and drainage texture classification of Malakan basin after Horton [32]

Drainage density (km/km^2)	Drainage Texture
<2	Very Coarse
2 – 4	Coarse
4 – 6	Moderate
6 – 8	Fine
>8	Very Fine

4.4.4. Drainage Texture (T)

Drainage texture is expressed by relative terms; very fine, fine, medium, coarse and very coarse texture. Many natural factors such as rainfall, climate, vegetation, infiltration capacity, soil, and rock type affect the drainage texture. For instance, massive and resistant rocks produce coarse texture while, soft and weak rocks without a vegetative cover show a fine texture [33,52]. Furthermore, the drainage texture of the study area is 2.82 hence, it can be categorized as coarse texture stated Smith [33].

4.4.5. Length of Overland Flow (Lo)

The higher length of over land flow specify slower runoff process and the shorter length of over land flow indicate the quicker runoff process (Horton [26]. The length of overland flow in the Malakan basin is 0.45, which almost shows low surface runoff in the study area. Furthermore, rain water will enter the stream relatively quickly with smaller values of overland flow [24]. Moreover, the shorter length of overland flow, the quicker surface runoff will enter the stream.

4.5. Shape Parameters

There are some parameters that describe the basin shape such as Elongation ratio (Re), Circularity ratio (Rc), and Form factor (Ff).

4.5.1. Elongation Ratio (Re)

It is a very important indicator for shape basin analysis, which aids to provide an idea about the hydrological character of a drainage basin [49]. Values close to 1.0 are typical of regions of very low relief, high infiltration capacity and low runoff, Table 7, whereas values close to zero are usually associated with high relief and steep ground slope [35], which are described by high vulnerability to erosion and sediment load [30]. Thus, lesser the value of elongation ratio, more elongated will be the shape of the basin and vice-versa. The elongation ratio for Malakan watershed is 0.28, showing more elongated shape, which is characterized by high exposure to erosion and sediment loading.

Table 7. Standard and classification of the river basin elongation proposed by [47] and later interpreted by [35]

Elongation Ratio	Shape of Basin
<0.7	Elongated
0.7-0.8	Less elongated
0.8-0.9	Oval
>0.9	Circular

4.5.2. Circularity Ratio (Rc)

Circulatory ratio of the Malakan basin is 0.413, indicating an elongated basin, with a herringbone drainage pattern, which means low discharge of runoff and high permeability of the subsoil condition. According to Miller [34], the circularity ratios range between 0.4 and 0.5 reflects the highly permeable and highly elongated geologic materials. Therefore, gradient, stream frequency, and basin lithology of various orders are affecting the circulatory ratio [35].

4.5.3. Form Factor (Ff)

Horton [26] suggested this parameter, which is the dimensionless ratio of basin area to the square of basin length in order to predict the flow intensity of a basin in a defined area. The value of form factor varies from 0 (for basins with highly elongated shape) to 1 (for a basin with perfect circular shape). Smaller the value of form factor, more elongated will be the basin. The form factor of the watershed is 0.19, which reflecting the basin has highly elongated shape.

4.6. Relief Characteristics

Generally, the highest point of a basin or high relief value indicates high gravity of water flow, high runoff, and low permeable conditions [53]. The differences between the highest and the lowest points in elevation of any valley floor of a basin are defined as relief [54]. The relief aspect embraces basin relief (Bh), relief ratio (Rh), and Ruggedness number (Rn) studies, respectively, Table 5.

4.6.1. Basin Relief (Bh)

The maximum relief value of Malakan basin was carried out from the morphometric analysis, which has 2520 m and the height of the mouth was 932 m above sea level. Moreover, the relief of catchment varies in between 1588 m indicates the gravity of water flow, low infiltration and high runoff conditions. Therefore, the watershed relief for Malakan valley is seems to be very high where the erosional forces is relatively more.

4.6.2. Relief Ratio (Rh)

The relief ratio of the whole basin in the current study is 0.13 m/km. This high value of Rh specifies steep slope and high basin relief (2520 m). In contrast, the lower values indicate the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope reported Chitra, Alaguraja [49].

4.6.3. Ruggedness Number (Rn)

Ruggedness number measures the relationship between relief and drainage density. Strahler [48] expressed ruggedness number (Rn) as the product of basin relief and drainage density. The value of Malakan basin is 1.71 however, this value is high which implies high drainage density and high relief.

5. Further Discussion

To make the agriculture a common source of income for the livelihood of local people the relevant information about terrain's properties and hydrological behavior of the watershed is prerequisite for economic growth and development. Therefore, the investigation of hydrological nature of the rocks within the watershed is essential stated Soni [55]. It serves a useful contribution to the development of a comprehensive soil and water resources, and watershed management plan [56].

Studying the drainage network, relief and shape factors, and lithology of soil identifies detailed watershed problems such as drought affected area, erosion status of watershed, and flood proneness. Hence the morphometric analysis will improve living standard of people in the watershed by making proper plan for watershed management reported Bragança [17].

Furthermore, the quantifying analysis parameters provides an understanding of the useful hydrologic characteristics of the watershed such as surface runoff, infiltration capacity, peak flow, etc. [56]. Analysis of different morphometric parameters can be used effectively to prioritize watersheds, natural resources management, and soil and water conservation at the watershed level argued Ajay, Mahmoud [57]. Additionally, It helps to better understanding the possible ground conditions for efficient watershed planning and management [58]. Thus, an appropriate land and water conservation practices can therefore be adopted in any basin [59].

Additionally, most of the abandonment of agricultural land in KR in last four decades can be linked to socio-economic-politic factors, which leads to degradation of the ecological and economic value of whole area. Furthermore, KR has been seriously influenced by various events such as international sanctions, isolation from many agricultural technology and development for more than 20 years, and poor government policies [28]. Therefore, a greater morphometric analysis of KR as a whole is needed as this region locates in an area which is facing an escalating water crisis due to low water levels of the Tigris river, which originate from Turkey [60]. Hence, groundwater is essential for sustaining life and represents an important input into the KR's economy, particularly agriculture and tourism.

The morphometric analyses of the current study, was very representative of the study area by determining different size and numbers of streams and rivers, shape of landscape, and any other aspects. Studying different morphometric aspects have allowed for a better understanding of the inter-linkage for the sustainable management of land and water resources.

On the other hand and concerning the geomorphology of the current study. The watershed of Malakan river basin has high and moderate slope as shown by herringbone drainage pattern. First-order streams accounted as a predominant of the total number of streams in the basin for nearly 58%, followed by fourth-order streams, which covered around 23%. Second-order streams covered 13%. Whereas third-order stream has the least amount of the total number of streams with 5%.

The regression direction of the stream order and the stream number carries the power function relationship with the negative correlation, except in the case of fourth-order streams, which can be due to local differences in slope and topography.

First, second, and third orders have positive relationship. Frankly speaking, higher the order, longer the length of streams is noticed in nature. This is true for all first three orders. However, the fourth-order stream is an exception where the number of fourth order (44) is much higher than second and third-order streams (25 and 10), respectively, Table 3. This exception includes also stream length. These differences from general observation may be due to the flowing of streams from high altitude, differences in slope and topography [52,61,62].

In order to understand the run-off and infiltration, the shape aspect presents and provides a wide vision of the geomorphology basin. In general, a lower elongation ratio (Re) is associated with elongated basin and a higher Re with circular shape [35]. However, Malakan river basin has an elongated shape which has value of 0.28, Table 7.

In the present study, the highest bifurcation ratio (Rb) (109/25= 4.36) is found between the first and second order which indicates corresponding highest overland flow due to high slope of mountains rock formation. Whereas the lowest value of Rb is found between third and fourth order (10/44= 0.23), which reflects that it has suffered less structural disturbances. The mean bifurcation ratio (2.36) is relatively low value and suggests higher permeability, geological heterogeneity, and lesser structural control in the study area [35]. Typically, the values range from 3 to 5 stated Chow [63] for any watersheds, which indicates that the geologic structures does not influence on the drainage pattern.

6. Conclusion

Studying the specific characteristics of the stream orders would mean to understand the importance of the preservation of their unique natural and agricultural aspects of any area. This work demonstrates the significant role of GIS and remote sensing in preparation of morphometric analysis and drainage maps. Remote sensing and GIS techniques are convenient tools for morphometric analysis. Numerous of linear, areal and relief factors of morphometric regression were counted and considered with respect to hydrological process. Thus, this study is essential for watershed management and sustainability.

The morphometric analysis of the drainage network of the watershed showed a herringbone drainage pattern with very course drainage texture. The variation in stream length ratio could be due to change in slope and topography. Furthermore, the value of the circulatory ratio (0.413) and form factor (0.19) for the watershed suggested that the basin was elongated in nature and was characterized by an environment of medium to high relief and steep slope. Drainage density of watershed is very low (1.08), and drainage texture indicates coarse texture (2.82), suggests permeable subsurface/subsoil, and dense vegetation cover. The elongation ratio shows that basin is close to more elongated shape (0.28).

To conclude, morphometric analysis supports in analyzing the landforms precisely for any planning and development purposes. It is also very beneficial as it compute the landform features for evolutionary significance that is everything for today. Such knowledge would contribute to developing a stable, economical and sustainable agriculture to enhance food security. It also protects the natural environment and rural incomes.

7. Recommendations

Moreover, many studies should be reported to the Ministry of Agriculture and Water Resources, and Ministry of Planning such as geology, hydrology, geophysics, surveying, geo-technique and environmental impact assessment achieved of the whole area of Kurdistan.

Increasing a well-planned agriculture strategy in the region brings the economic boom, which is directly generates demand for rural labor in term of a key relationship between growth in agriculture and poverty. Thus, growth in agriculture benefits the poor in both rural and urban areas through shifting from low value to high value crop production [64]. The active role of agriculture in growth and development is a successful agriculture plan, which leads to an effective development process.

In order to prevent water becoming a scarce element, threating humanity in present and future, decision makers in KR should be informed and obtained greater knowledge of the following themes; groundwater resources, hydrological characteristics of drainage basins policy, watershed development and management options through addressing the quantitative geomorphological analysis and LULC changes, and that in order to understand various terrain parameters such as surface runoff, infiltration capacity, nature of bedrock, etc. Thus, there is an urgent need to assess water resources.

A well-organized water planning, operation dams, hydropower stations and irrigation schemes are necessary for agricultural sustainable development through proper groundwater and surface water exploitation of the whole region. Making suitable land and water availability for farmers by policymakers leads to developing manpower of the agriculture and irrigation sector.

To conclude, further studies on regional landscape as a whole encourage the sustainability of the agriculture sector through selecting suitable areas for agriculture. Hereafter, in order to determine and identify the suitable soil erosion the quantitative parameters are required of sub-watersheds to preserve the land maintain the ecological environment.

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Compliance with Ethical Standards

Conflict of interests Author has declared that no competing interests exist.

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