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Assessment of Morphometric and Hypsometric Analysis of the Ruste Basin Using Remote Sensing and Geographical Information System Techniques

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Abstract

A basin's characteristics and features need to be comprehended completely by conducting morphometric analysis, such as evaluating the basin's size, form, and surface features, to estimate floods and erosion rates properly. The main objective of this investigation is to evaluate morphometric measures and hypsometric analysis of Erbil's Ruste Basin employing remote sensing and geographical information system methods. To investigate the significant tributaries of the selected area, the hydrology tool within the Spatial Analysis Tools of ArcGIS, version 10.7, was utilized to define the basin boundaries, map the drainage networks, and obtain topographic data. The findings of the linear morphometric parameters revealed that the logarithmic relationship between stream orders and stream numbers was negative. The difference in stream order and number seen in the watershed is due to topography and bedrock influence. The results also showed a negative correlation between stream length and stream order, and a coefficient of determination of 0.972, which indicates that the basin is made of low-permeability formation and subsoil materials. Considering the areal morphometric parameters, the circularity ratio, elongation ratio, and form factor are 0.594, 0.853 and 0.572, respectively, suggested a semi-circular shape. A drainage density value of 2.259 km^{-1} showed that the Ruste Basin is a basin with steeply to very steeply sloping hilly terrain with varying plant covering. Furthermore, the Ruste Basin has high relief and slope with a relief ratio of 0.151 and basin relief of 2.576 km, both of which imply that it has a steep slope with high erosive force, limited infiltration, and a high runoff rate. Ruste Basin's ruggedness number was 5.819, indicating that it has badlands topography. The average hypsometric integral was 0.467, denoting a mature basin featuring S-shaped hypsometric curves. In conclusion, the results showed that analysis of morphometric parameters and hypsometric integral and curve provides us with a notion to basin characterization and guidance to making appropriate decisions to establish effective actions to sustainable water and soil conservation and natural resources management through applying water harvesting methods, check dams, and bench terraces.

Keywords: DEM, Hypsometry integral, Morphometric analysis, Ruste Basin.

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Introduction

Natural resources, such as water and soil, are scarce and are being used excessively and unsystematically at a high rate, and this lowers their quality and they will be less effective in the future [1]. Population growth, water irrigation systems, and industrialization are resulting in a reduction in the per capita availability of these two resources. Water is a priceless resource and a necessity for humans and organisms [2]. Fresh water supply is declining in many industries. The existing surface and groundwater resources are insufficient to fulfill the increasing water demands caused by rapid urbanization and population growth. Effective water planning and management are urgently required to promote long-term and sustainable development [3, 4].

The surface of the earth has been structured into watersheds. Geo-morphologists and hydrologists are interested in the investigation of spatial variability in a watershed [4]. A watershed is a region where runoff from precipitation runs and converges at one location to create a significant stream, lake, river, or ocean [3]. Watersheds are dynamic units that undergo temporal and geographical changes, such as runoff characteristics that affect basin intake and output, as evident in variations in discharge flow, sediment load, and other watershed features [5].

Basins need to be understood very well so that floods and erosion rates can be properly estimated. In order to understand the basin features, morphometric analysis is needed. Morphometric analysis is the study of measuring, assessing, and understanding the size, form, shape, and arrangement of the surface characteristics of Earth [6, 7]. It is a mathematical technique for calculating the linear, areal, and relief features of a drainage system, such as the number of streams, drainage density, bifurcation ratio, initial slope, and shape [6-9]. Morphometric features and parameters are extremely useful in evaluating basins, prioritizing watersheds, conserving soil and water, and managing natural resources [4]. Additionally, Gardiner [10] reported that the morphometric properties of drainage basins have been utilized to anticipate floods as well as estimate erosion rates and runoff yield.

The connection of the horizontal cross-sectional area of the catchment to its elevation is identified as hypsometric analysis. The relief graph of the catchment refers to the hypsometric curve (HC). Watershed conditions may be predicted using HCs and integrals [11]. The disequilibria degree in the balance of erosive forces and geologic tectonic forces is associated with differences in curve shape and hypsometric integral (HI) numbers [12]. The HC is linked to the quantity of the soil mass in the catchment and how much erosion has taken place in a basin versus the residual mass [13]. It is a continuous function of the watershed's relative area and the non-dimensional distribution of relative basin heights [14]. Steep slope has detrimental effect on land as it leads to strong erosive forces, and this needs to be addressed properly. One method of reducing the impact of steep slope and high relief on land is to use bench terraces in areas with shallow soil [15, 16, and 17]. In recent years, remote sensing (RS) technology has grown in relevance for geomorphological investigations since it is not just cost-effective but also accurate and timely [18, 19]. Globally, the integration of Geographic Information System (GIS) with Remote Sensing (RS) technology has been used to identify and investigate changes in the terrain and the associated environmental implications such as gully erosion and floods. Therefore, RS and GIS approaches have shown to be effective tools for the delineation, characterization, and morphometric characteristics analysis of catchments across the world [20].

The primary objectives of this study are to provide some meaningful insights about morphometric features including linear, areal, and relief, of the Ruste Basin in Erbil, Iraq, and to construct the hypsometric curve as well as to calculate the hypsometric number and curve of the Ruste Watershed using RS and GIS techniques.

Materials and Methods

1. Study area description

The study area is the Ruste Basin located in the Administrative Boundary of Choman District in the Erbil Province, Iraq. Ruste Basin is 150 kilometers (km) away from Erbil city in the south, 50 km from Sidakan District in the north, 40 km from Soran Independent Administration in the west, and 60 km away from Haji-Omaran Subdistrict (which is on the Iraqi-Iranian border) in the east. The Ruste basin has a total area of 164.742 square kilometers (km^2) and a perimeter is 59.017 km as determined by ArcGIS ver. 10.7. It is located between latitudes 36^o 36' 6'' to 36^o 45' 2" N and longitudes 44^o 38' 6" to 44^o 50' 20" E. Mainly, the lowest outlet elevation of the basin is 773 m a.s.l. (meters above mean sea level) and the highest elevation is 3345 m a.s.l. (Figure 1).

The study area is in the arid and semi-arid zones. The region's climate, and particularly that of the study area, is Mediterranean in nature. Summers are mildly hot, arid, and clear, while winters are very cold, dry, and partially cloudy. The coldest and warmest months of the year are January and August, respectively. The annual temperature seldom falls below −4 ℃ in the winter and rises over 35 ℃ in the summer. The region receives more than 680 mm of rain each year on average. The basin is located along the borders with Iran in the northeast (NE) extremes of the High Folded Zone, extremely close to the Zagros Thrust Zone. The formation is extensively spread in northeast Iraq, appearing in synclines and anticline flanks. It is made up of interbeds of sandstones, mudstones, and shales set up in graded turbidity cycles [21]. The most agricultural plants grown in the study area are wheat, barley, fodder, oats, fruit, and vegetables.

2. Morphometric investigation of Ruste Basin

The morphometric analysis gives systematic and precise drainage basin information. In the present study, multiple formulae for quantifying hydrological parameters are applied (Figure 2). These formulae are listed in Table 1. The Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) Version 3 (ASTGTM) provides a global digital elevation model (DEM) of land areas on Earth at a spatial resolution of 1 arc second (approximately 30 meter) was taken from the United States Geological Survey (USGS) on the Earth Explorer website (http://earthexplorer.usgs.gov/).

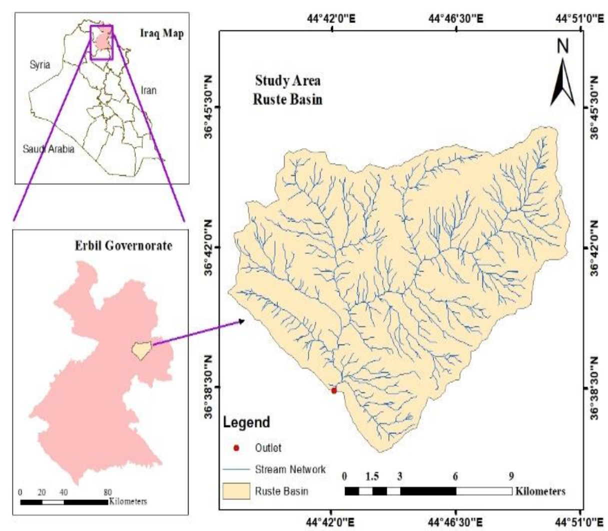

Figure 1: Location map of the Ruste Basin

The hydrology tool inside the Spatial Analysis Tools of ArcGIS, version 10.7, is used to delineate the basin boundaries, map the drainage networks, and extract topographic data, for instance, drainage characteristics and other basin parameters to explore the significant tributaries of the selected area.

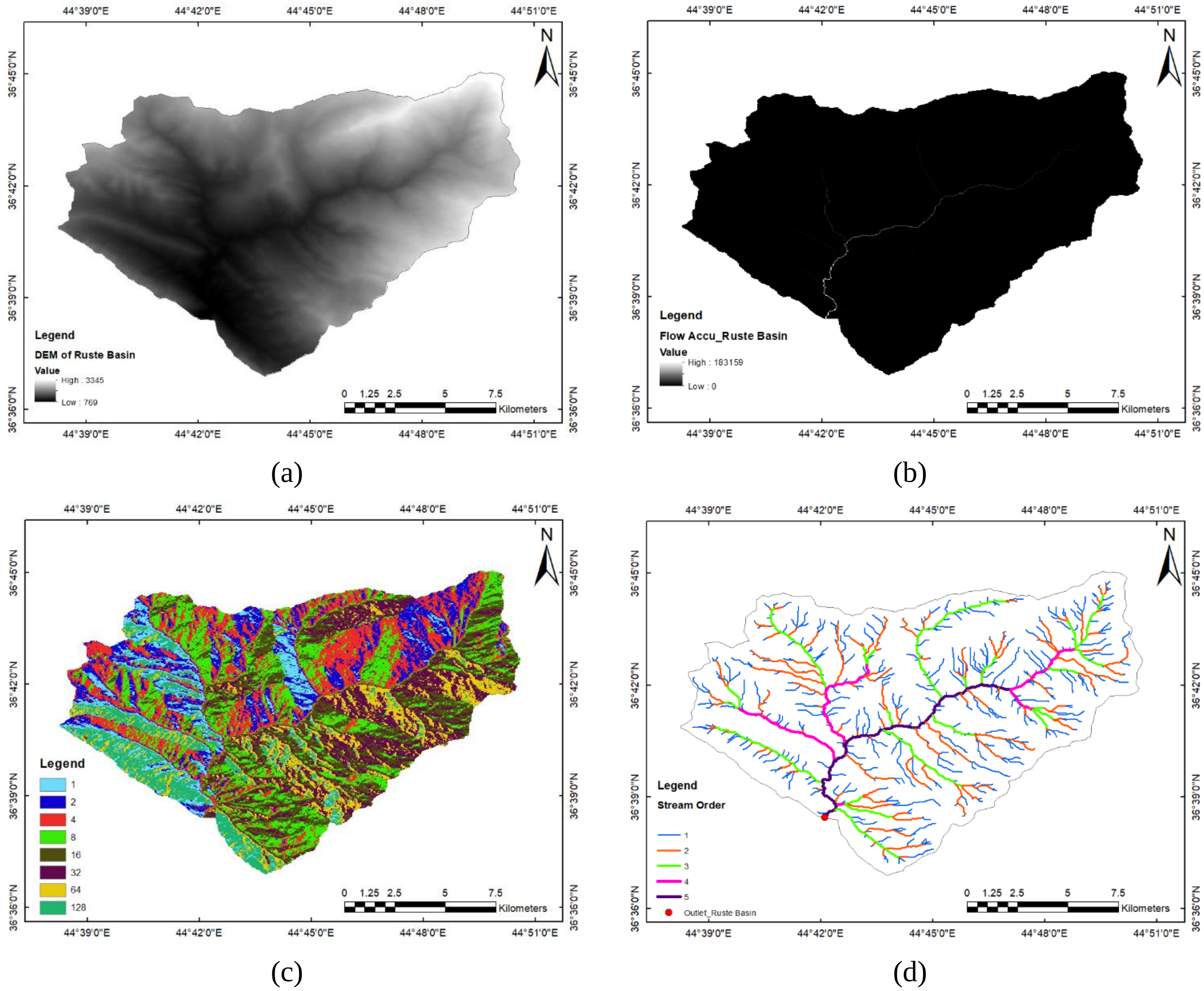

Figure 2: Basin delineation map of the major steps of Ruste Basin: (a) DEM, (b) flow direction, (c) flow accumulation, and (d) stream order

Results and Discussion

The Ruste Basin's morphometric characteristics regarding the drainage network, geometry and texture, and relief features were examined. A basin's morphometric investigation identifies the basin's features based on a quantitative examination of various criteria. Parameters are assigned based on their dimensional characteristics: linear, areal, and relief parameters.

Table 1: Equations and units used to calculate morphometric parameters

#	Parameters	Symbols	Formulae/ Equation	Units	References
			Linear Parameters		
1	Stream order	S_u	Hierarchical rank	Unitless	[8]
2	Stream length	L_u	$L_u = L_{u1} + L_{u2} + L_{u3} \cdots + L_{un}$	km	[22]
3	Stream number	N_u	$N_u = N_{u1} + N_{u2} + N_{u3} \cdots + N_{un}$	Unitless	[22]
4	Mean stream length	L_{sm}	$L_{sm} = (L_u/N_u)$	km	[22]
6	Bifurcation ratio	R_b	$R_b = N_u/N_{u+1}$	Unitless	[23]
7	Mean bifurcation ratio	R_{bm}	Average of bifurcation ratio of all orders	Unitless	[24]
			Areal Parameters		
8	Area of the watershed	A	ArcGIS 10.7 analysis	km^2	
9	Perimeter of the watershed	P	ArcGIS 10.7 analysis	km	
10	Stream frequency	F_s	$F_s = (\Sigma N_u)/A$	km^{-2}	[22]
11	Drainage density	D_d	$D_d = (\Sigma L_u)/A$	km^{-1}	[22]
12	Length of overland flow	L_g	See equation (1)	km	[25]
13	Basin length	L_b	ArcGIS 10.7 analysis	km	[26]
14	Drainage texture	D_t	$D_t = (\Sigma N_u)/P$	km^{-1}	[22]
15	Constant of channel maintenance	C_{cm}	$C_{cm} = 1/ D_d$	km	[22]
16	Infiltration number	I_f	$I_f = F_s \times D_d$	km^{-3}	[27]
17	Elongation ratio	R_e	$Re = (2 \sqrt{A/\pi})/L_b$	Unitless	[23]
18	Form factor	F_f	$F_f = A/L_b^2$	Unitless	[22]
19	Circularity ratio	R_c	$R_c = 4\pi A/P^2$	Unitless	[28]
20	Compactness coefficient	C_c	$C_c = 0.2821P/A^{0.5}$	Unitless	[22]
			Relief Parameters		
21	Maximum elevation	H	ArcGIS 10.7 analysis	m	
22	Minimum elevation	h	ArcGIS 10.7 analysis	m	
23	Basin Relief	R	$R = H–h$	km	[14]
24	Relief ratio	R_r	$R_r = R/L_b$	Unitless	[23]
25	Dissection index	D_i	$D_i = R/R_a$	$m\ km^{-1}$	[26]
26	Ruggedness number	R_n	$R_n = R \times D_d$	Unitless	[8]

1. Linear morphometric parameters

1.1 Stream order (S_u)

The degree of a stream that is splitting within a catchment is measured by stream order (S_u). Strahler [8] approach is used to compute stream ordering, with each smallest stream being the first stream order and the second stream order forming directly underneath the intersection where the two streams of the first-order meet (Table 1). According to Strahler [8] approach, the two streams of the same order unite to generate the subsequent S_u, and the process proceeds until the highest-order stream is formed. The Ruste Basin is a river of the fifth order (Table 2)

Table 2: The studied linear morphometric parameters for Ruste Basin

Stream order (S_u)	Stream number (N_u)	Total stream number	Stream length (L_u) (km)	Total stream length (L_u) (km)	Mean stream length (L_{sm}) (km)	Bifurcation ratio (R_b)	Mean bifurcation ratio (R_{bm})
1	443	579	196.261	372.228	0.443		4.602
2	108		95.022		0.88	4.102	
3	22		50.583		2.299	4.909	
4	5		16.705		3.431	4.4	
5	1		13.657		13.657	5	

1.2 Stream number (N_u)

The number of stream sections existing in each stream order is indicated by the stream number (N_u). The number of stream sections in each order, as reported by Horton [22], produces an opposite geometric series with the order number. The trunk stream is the highest-order stream section. The Ruste Basin's tributaries were revealed to be of the fifth order (Table 1). There were 579 streams found, with 443 being first order, 108 being second order, 22 being third-order streams, five being fourth-order, and only one being a fifth-order stream (Table 2). The logarithmic connection between stream orders and stream numbers demonstrated a quick decline from lower-order to higher-order streams, as well as a negative link between stream orders and numbers (Figure 3). The coefficient of determination was around 0.99. Sharma [29] also obtained an R^2 of around 0.99. An R^2 value of one indicates that the regression line impeccably fits the data. The linear pattern shows the homogenous rock material is subject to weathering and erosion characteristics of the basin. Ali *et al.* [30] discovered a similar association. The highest stream order was discovered in first- and second-order streams, indicating ephemeral streams that are more prone to erosion and abrupt floods [31]. The variance in stream order and number found in the watershed is mostly due to topography and bedrock effect. These characteristics indicate that the Ruste Basin was formed on hard rock, with a steep slope and high relief.

1.3 Stream length (L_u)

As reported by Dubey *et al.* [32], stream length (L_u) is one of the drainage basin's dynamic hydrological characteristics as it shows surface runoff characteristics. L_u represents the region of the basin that contributes to the specified S_u [33]. Total L_u might be computed by summing the lengths of all streams in a specified order [34].

The L_u was computed using Horton's [22] proposed law from 1945. Streams with shorter durations can be discovered in areas with higher slopes and considerably finer textures. Streams that are greater in length have a flatter slope. The length between two stream sections is normally greatest in the first streams and minimizes as the stream orders grow. The number of streams of numerous orders in a catchment is documented using a GIS tool, and their lengths from outflow to drainage area split are determined. The first-order stream of Ruste Basin is 196.261 km long, the second-order stream is 95.022 km, the third-order stream is 50.583 km, the fourth-order stream is 16.705 km, and the fifth-order stream is 13.657 km long (Table 2). Stream length is closely related to discharge and surface runoff. A large number of shorter streams indicate greater slopes and impermeable bedrocks, whereas a limited number of longer streams indicate considerably gentler gradients and permeable bedrock formations [35]. The total lengths of streams in the Ruste Basin were found to be highest in streams of the first order and decreased as stream order increased. Figure 4 revealed a negative and logarithmic correlation between L_u and S_u and the correlation of determination (R^2) of 0.972, indicating lower permeability and erosion properties. Huda [36] discovered a comparable link. According to Hlaing *et al.* [37], a larger number of shorter-length streams occur in a basin of low permeable bedrock formation and subsoil materials.

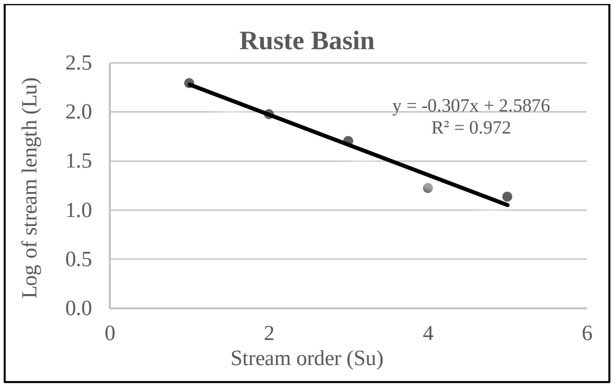

Figure 3: Graph of stream order versus log of stream number

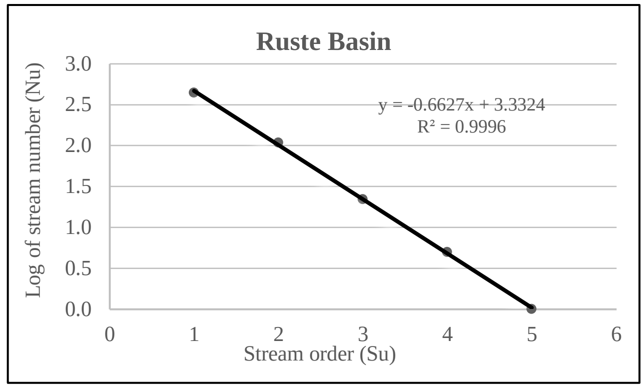

Figure 4: Graph of stream order versus log of stream length

1.4 Mean stream length (L_{sm})

Mean stream length (L_{sm}) is defined as the quotient of the length of a stream to the number of streams [22]. The study area's mean stream lengths for stream orders from first to fifth orders are 0.443, 0.88, 2.299, 3.431, and 13.657, respectively (Table 2). As can be seen from Figure 5, there is a linear positive correlation between the S_u and L_{sm}, and the slope of the regression line is almost 2.898 and the R^2 reaches 0.7071 .

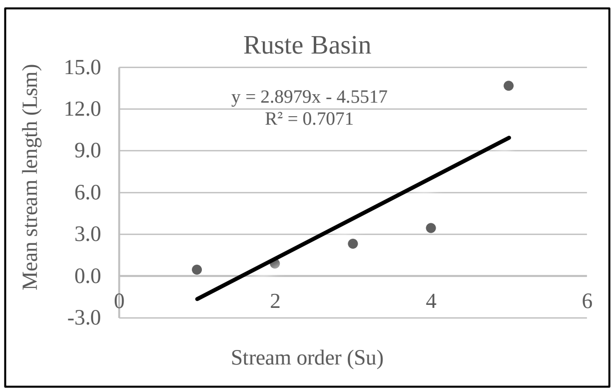

Figure 5: Graph of order of stream and mean stream length

1.5 Bifurcation ratio (R_b)

The bifurcation ratio (R_b) indicates the integration level existing between streams having various orders in a watershed. Horton [22] regarded the R_b as an index of relief and dissection. Strahler [24] believed that the R_b varies relatively slightly between locations with various environments, apart from where significant geological control predominates. Additionally, Schumm [23] defines the R_b as the ratio of the stream sections number of a particular stream order to the number of sections of the following higher orders. The R_b of the Ruste Basin ranges from 4.102 to 5.0 as shown in (Table 2). Strahler [8] stated that the R_b values are typically 3.0 – 5.0 for watersheds where geologic formations do not disrupt the pattern of the drainage.

1.6 Mean bifurcation ratio (R_{bm})

Strahler [24] used a weighted average R_b, which is the result of multiplying the mean bifurcation ratio (R_{bm}) for each consecutive group of orders by the total number of streams involved in the relation and taking the mean of these outcomes to end up with a better representation of bifurcation number. The bifurcation ratio is critical in drainage basin analysis because it aids in evaluating basin geometry and runoff behavior. The higher the bifurcation ratio values, the greater the flood danger. The Ruste Basin has a mean bifurcation ratio of 4.603 (Table 2).

2 Areal morphometric parameters

2.1 Stream Frequency (F_s)

A basin's stream frequency (F_s), which is expressed in km^{-2}, can be described as the total number of the basin's stream sections divided by unit area (see Table 1) [22]. The F_s is controlled by numerous factors, for example, rock and soil classes, vegetation coverage, infiltration capacity, runoff intensity, rainfall intensity, soil permeability, and land slope [38]. The F_s for the basin is 3.515, indicating that it has low permeability and infiltration rate and high runoff rate which leads to an increase in the possibility of flood occurrence (Table 3). This result can be supported by Kale and Gupta [39] who reported that the greater the F_s within a catchment, the quicker the runoff and hence a higher likelihood for the occurrence of flooding in the catchment area. Soil and water conservation practices can be employed as an effective solution to vary the natural structure features of the slope. These practices can also reduce raindrop kinetic energy and increase land roughness, and store and maintain runoff volume and sediment.

Table 3: The studied areal morphometric parameters for Ruste Basin

#	Areal Parameters	Results of Ruste Basin	Units
1	Basin area	164.742	km^2
2	Perimeter basin	59.017	km
3	Stream frequency	3.515	km^{-2}
4	Drainage density	2.259	km^{-1}
5	Form factor	0.572	Unitless
6	Drainage texture	9.811	km^2
7	Basin length	16.968	km
8	Elongation ratio	0.853	Unitless
9	Circularity ratio	0.594	Unitless
10	Length of overland flow	0.370	km
11	Infiltration number	7.941	km^{-3}
12	Constant of channel maintenance	0.443	km
13	Compactness coefficient	1.297	Unitless

2.2 Drainage Density (D_d)

Horton [22] claimed that drainage density (D_d), expressed in km^{-1}, is regarded as the quotient obtained by dividing the total length of channel sections (km) for all of the orders in a catchment by the area of the catchment (km^2) (Table 1). The low D_d proposes that the catchment has a relatively permeable and porous subsurface and extensive vegetation [40]. High D_d is produced by weak underlying material, limited vegetation, and bumpy landscapes. The D_d of the current study is 2.259 km^{-1}, indicating steeply to very steeply sloping hilly terrain with varying plant covering (Table 3).

2.3 Form Factor (F_f)

Horton [22] describes the form factor (F_f) as the ratio of the catchment area to the square of the catchment's total length (Table 1). The F_f is a numerical index that is typically utilized in order to denote the shapes of different basins and their flow intensity [41]. The F_f value ranges between zero and one, with zero representing an extremely elongated shape and one signifying a circular shape. If the form factor value is 0.7854, it represents a completely round basin [33]. Watersheds with a high form factor possess a higher peak runoff rate for a shorter time, whilst elongated basins having a low F_f have a flatter peak runoff rate for a longer time. If the basin is larger in width, the F_f will be larger and vice versa [42]. In the current study, the value of the form factor is assessed to be around 0.572 (smaller than 0.7854) which indicates that the watershed is semi-circular (Table 3). Nagal *et al.* [43] found a similar value for form factor in their study. For the purpose of reducing the impact of peak runoff rate, there are two methods to be used: mechanical measures and agronomic measures. The agronomic measures include contour farming, strip cropping, and crop rotation [44].

2.4 Drainage Texture (D_t)

One of the principal concepts in geo-morphology is drainage texture (D_t), which denotes the comparative spacing of lines of drainage. The drainage texture, which is expressed in (km^{-1}), is the ratio of the sum of stream portions belonging to all of the orders to the region's perimeter [22]. The D_t is determined by the terrain's lithology, infiltration capability, and relief parameters. Smith [45] states that D_t is affected by natural elements. He further explained that unconsolidated rocks with no vegetation cover cause fine texture, while huge and consolidated rocks lead to coarse texture. Finer drainage textures form on dry environment rocks than on humid environment rocks due to the sparse flora. Smith [45] divided drainage texture into five types: i) extremely coarse (less than 2), ii) coarse (2 to 4), iii) moderate (4 to 6), iv) fine (6 to 8), and v) very fine (more than 8). The D_t for the Ruste Basin is 9.811, indicating that it has an extremely fine drainage texture (Table 3).

2.5 Elongation Ratio (R_e)

By Schumm's perspective [23], the elongation ratio (R_e) is the quotient obtained by dividing the diameter of a circle with the same area as the catchment to the catchment's maximum length (Table 1). The R_e ranges between 0.6 and 1.0. Values near 1.0 are linked with extremely low relief while values from 0.6 to 0.8 correspond to significant relief and a steep ground slope. These values are categorized as i) circular (more than 0.9), ii) oval (0.9 to 0.8), and iii) elongated (less than 0.7). The Ruste Basin has a R_e of 0.853, indicating an oval form (Table 3).

2.6 Circularity Ratio (R_c)

The circularity ratio (R_c) is the ratio of a catchment's area to the area of a circle having an identical circumference as the catchment's perimeter [28]. The R_c values range from zero for elongated basins to one for circular basins. As the value of R_c increases, the basin tends to be more circular, and vice versa. The stream frequency, slope, terrain, geological structure, land cover, and climate, of the catchment all impact the circularity ratio. The R_c of the Ruste Basin is 0.594, as supported by Mohammed and Karim [46], suggesting a semi-circular shape, high runoff discharge, and poor subsurface permeability (Table 3).

2.7 Length of Overland Flow (L_g)

The length of overland flow (L_g), expressed in kilometers, is the length of water running on the surface before it joins the mainstream, which affects the drainage basin's hydrologic and physiographic development [22]. Overland flow length can be and was calculated using Eq.1 from [25]. Infiltration and percolation occurring in the soil, both of which vary in time and place, have a considerable influence on L_g [47]. The high L_g value implies that precipitation traveled a substantially longer distance prior to concentrating in streams and vice versa [31]. In the current study, the L_g was calculated to be 0.37 km (Table 3).

$$\boldsymbol{L_g = 0.255 + 0.001P - 0.003L_b + 0.002S + 0.005R_b} \quad \text{……………………………..} \ (1)$$

When L_g = length of overland flow (slope length) in km, P = perimeter in km, L_b = basin length in km, S = average slope basin in percent (%), and R_b = mean bifurcation ratio (unitless).

In order to reduce soil erosion by water, raindrop impact on soil, runoff volume, and runoff velocity should be reduced and soil resistance needs to be enhanced by practicing tillage perpendicular to the direction of the flow and using vegetation covers.

2.8 Basin length (L_b)

The basin length (L_b) of a drainage basin, which is expressed in km, is a geometric measurement of its shape and extent (Table 1). It is a basin's largest length within the greatest circle encircling the basin's boundaries and along the major river length [31]. Using the ArcGIS program, the maximum basin length in the current study was determined to be 16.986 km (Table 3).

2.9 Infiltration number (I_f)

Infiltration number (I_f), expressed in (km^{-3}), is defined by Faniran [27] as the value obtained by multiplying D_d and F_s (Table 1). I_f values specify a basin's infiltration potential. Values equal to or less than 6 indicate lower infiltration numbers, values greater than 10 indicate higher infiltration numbers, and those lying between 7 and 10 are moderate [48]. A lower infiltration number means the basin has a high infiltration rate and a low runoff rate [49]. The I_f of the Ruste Basin is 7.941 (Table 3), which belongs to the moderate range.

2.10 Constant of channel maintenance (C_{cm})

The inverse of D_d is the constant of channel maintenance (C_{cm}) [22]. C_{cm} is expressed in kilometers (Table 1). It is determined not only by the permeability of the rock, the climatic regime, the flora, and the relief but also by the soil erosion duration and the climatic profile. In places of near dissection, the constant is exceedingly low. The Ruste Basin's C_{cm} is 0.443 km (Table 3).

2.11 Compactness coefficient (C_c)

In accordance with Gravelius [50] and Horton [22], the compactness coefficient (C_c) of a catchment is the ratio of the catchment's diameter to the radius of the circle, which is relative to the basin's area (Table 1). The C_c is utilized to define the association of a hydrological watershed to a circle-shaped basin having an identical area. The shortest period of concentration prior to the occurrence of peak flow is caused in a circular basin. When the C_c value is equal to one, it is an indication that the watershed under study behaves completely as a circular basin. If the C_c is above one, some deviation away from the circular nature is noticed in the basin. However, if the Cc exceeds three, the basin can have a very elongated shape [51, 52]. Ruste Basin has a value of 1.297 (Table 3), which signifies that it has some deviation from a circular shape and similar results were found by [53].

3. Relief Morphometric Parameters

3.1 Basin relief (R)

Basin relief (R), expressed in kilometers, is the elevation difference between the uppermost point and the pour point of a catchment [14]. It is one of the crucial features in understanding the basin's denudational characteristics. It is also significant in drainage and landform developments, both surface and underground water flow, terrain erosional characteristics, and permeability. Ruste Basin relief was calculated to be 2.576 km (Table 4). As a result, the catchment's high relief suggests high water flow, and limited soil infiltration and strong runoff rates.

Table 4: The studied relief morphometric parameters for Ruste Basin

	Relief Parameters	Results of Ruste Basin	Units
1	Maximum elevation of basin	3345	m
2	Minimum elevation of outlet	769	m
3	Basin relief	2.576	km
4	Relief ratio	0.151	Unitless
5	Ruggedness number	5.819	Unitless
6	Dissection index	0.77	$m\ km^{-1}$

3.2 Relief ratio (R_r)

The relief ratio (R_r), a dimensionless ratio, is the height difference between a catchment's highest and lowest points divided by the greatest length of the catchment that runs along the major drainage line [23, 38]. The R_r evaluates the total steepness of the watershed and is also used to predict the severity of the erosion process on the watershed slopes [54]. High relief ratio values imply steep slopes and high R, and vice versa. In general, runoff is quicker in steeper slope watersheds, resulting in a higher peak flow watershed and increased erosive force [55, 56]. Steeper basins have a quicker runoff, resulting in higher peak basin flows and more erosive force. The Ruste Basin has a high relief and slope as its R_r value is 0.151 (Table 4). As the R_r is high, which means it has more erosive forces on land, this effect can be mitigated by using narrow terraces which reduces sediment loss. Han *et al.,* [57] used a similar method in their study in which their watershed had comparatively high rainfall intensity and coarse-textured soil.

3.3 Dissection index (D_i)

The dissection index (D_i), expressed in meters per kilometer, is the ratio of relative relief to absolute relief [26] (Table 1). The D_i is an essential drainage basin metric that depicts the size of vertical erosion and describes the stage of landscape or terrain development in any particular catchment [58]. Rawat *et al.* [26] reported that the Di values range from 0, indicating a total lack of vertical erosion and predominance of level ground, to 1, indicating vertical cliffs on land or at the seashore. Higher Di values indicate greater terrain undulation and thus instability [59]. Higher Di values cause more erosion, resulting in a high volume of sediment debris [26]. According to Bhunia *et al.* [60], the dissection index is grouped into five main classes: i) low Di (< 0.2), ii) medium to low Di (0.2 to 0.4), iii) medium Di (0.4 to 0.6), iv) high Di (0.6 to 0.8), and v) extremely high (> 0.8).

Nir [61] and Rawat *et al.* [26] reported that the dissection index was determined using Eq. 2.

$$D_i = R/R_a \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where D_i is the dissection index, R is basin relief, and R_a is absolute basin relief. Absolute basin relief (R_a) refers to the greatest height of any location in relation to the mean sea level.

The Ruste Basin's Di value is 0.77, indicating that the watershed is highly dissected (Table 4). To address this, a straightforward method is to reduce erosive force and lower sediment loss.

3.4 Ruggedness number (R_n)

The ruggedness number (R_n) is the combination of R and D_d, and it binds slope steepness and L_g [8]. When R and D_d are large and the slope steepness is high, the ruggedness number experiences an excessively large value [24]. Catchments having low ruggedness values are less vulnerable to land erosion and have innate structural heterogeneity concerning D_d and R. There are five types of morphology based on the ruggedness number: i) subdued (< 0.1), ii) subtle (0.1 – 0.4), iii) temperate (0.4 – 0.7), iv) acute (0.7 – 1.0), and v) severe (>1.0). Severe morphology features badlands topography [62, 63]. According to Table 4, the ruggedness number for the Ruste Basin is 5.819, and this indicates that it has badlands terrain.

4 Slope

The slope is a significant element in the morphometric analysis of any drainage network. It is the slope of the topography with respect to the level plain [64]. The slope values in the Ruste Basin range from 0° to 66° and the average slope is 22.113^o (40.63%). The Ruste Basin slope was developed using ArcGIS 10.7 software's spatial analyst program for spatial analysis and the SRTM-DEM. The slope is divided into five classes, as shown in Figure 6a (0^o to $\leq 5^o$) is very gentle, ($> 5^o$ to $\leq 15^o$) is gentle, ($>15^o$ to $\leq 30^o$) is moderate, ($>30^o$ to $\leq 45^o$) is steep and ($>45^o$ to 66^o) is very steep [65]. The average slope is located moderate value. The geographic difference in slope value influences the flow direction, water velocity, soil and water erosion, and depositional characteristics of the basin's paths.

5 Aspect

An aspect is the direction the surface gradient faces along its horizontal axis. The aspect map is an important element for assessing the influence of the sun on the regional climate. Temperature varies significantly with aspect as well as height. According to Kang [66], differences in aspects can cause temperature changes in the basin. In the context of temperature variations between aspects when viewing in the West and the East, solar radiation that arrives at the surface during different times throughout the day slowly decreases, and the temperature varies consequently. The Ruste Basin aspect element was generated using the spatial analyst program in ArcGIS 10.7. The resultant raster map demonstrates the slope direction ranging from 0° to 360° for the Ruste Basin, with 0° to 22.5° indicating the north route, 22.5° to 67.5° indicating the northeast route, 67.5° to 112.5° indicating the east route, 157.5° to 202.5° indicating the south route, and so on. The contour interval is 200 m. The aspect map is depicted in Figure 6.

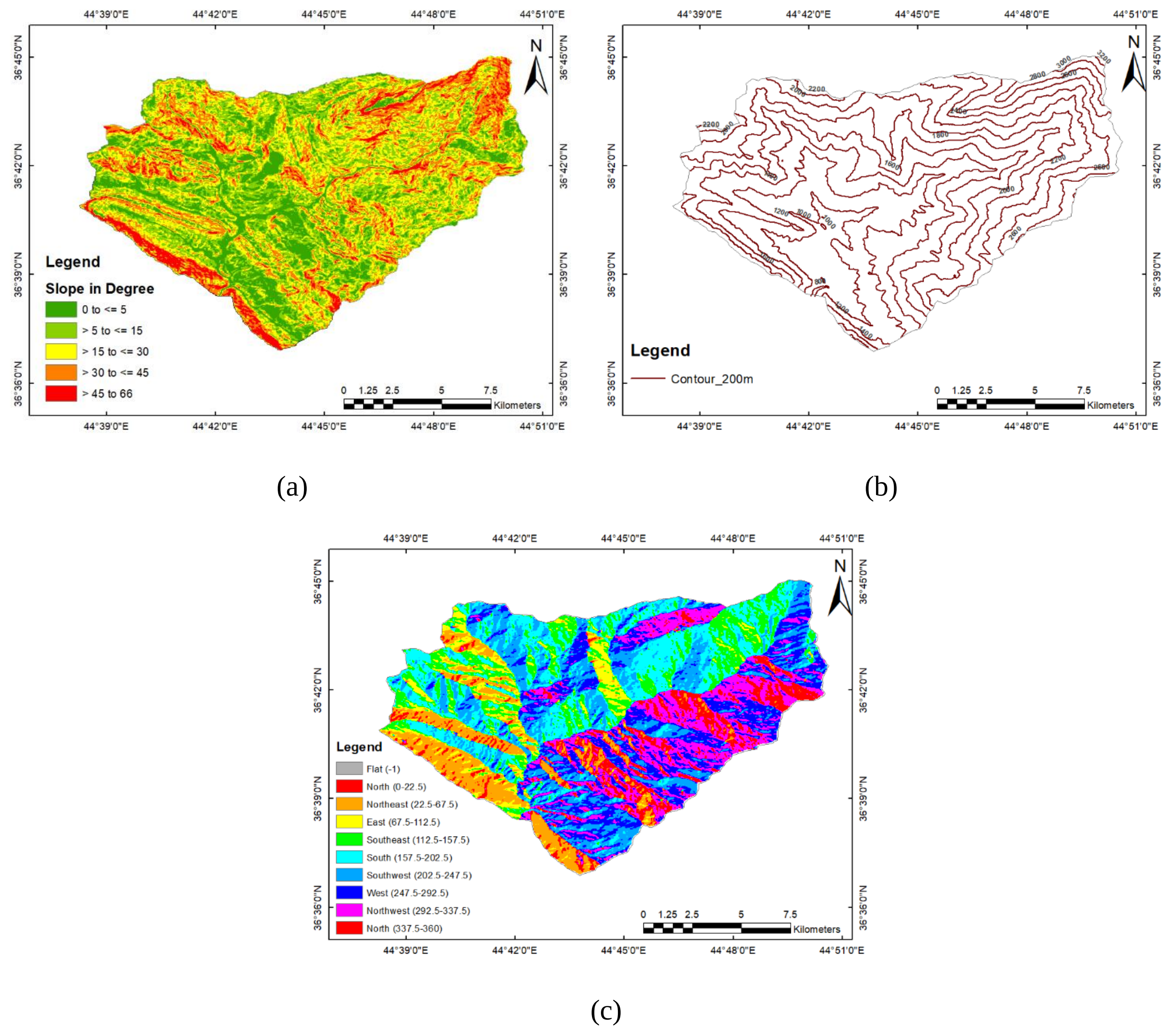

Figure 6: Basin delineation map of the Ruste Basin: (a) slope classes (%), (b) contour lines, and (c) aspect classes

6. Hypsometric curve and integral

Hypsometric curves and integrals are useful markers of a basin's condition [11]. They are critical for selecting water and soil conservation strategies and evaluating the erosion state in a basin [67]. The HI is a geomorphological quantity that is categorized according to the geologic phases of basin development. It is noteworthy in estimating the erosion condition of a basin and further prioritization in initiating soil and water conservation activities. The river network and basin shape place an important impact on hypsometry. For example, the aspect ratio has a significant effect on the HC shape [68]. The data from the contour thematic map created in ArcGIS was used to construct the HI, which was then estimated by the elevation-relief ratio approach described by [69]. The HI values were found using Equation 3.

$$HI = E_{mean} - E_{min}/(E_{max} - E_{min}) \ldots (3)$$

where HI is the hypsometric integral;
E_{mean} is the weighted mean elevation of the basin;
E_{min} and E_{max} are the minimum and maximum elevations within the basin.

Details of a basin's erosion stage, climatic conditions, and lithological conditions can be revealed by the computed HI value. Based on the HI value, Strahler [14] classifies basins into three types: young, mature, and old. A young basin (disequilibrium phase) is described to have a convex climbing HC with an HI value of more than 0.6, a mature basin (equilibrium phase) possesses an S-shaped HC with HI values ranging from 0.35 to 0.6, and an old basin has a concave HC with HI value less than 0.35. The average HI in the current study was discovered to be 0.467, signifying that the Ruste Basin is mature (equilibrium phase) and has S-shaped hypsometric curves (Table 5 and Figure 7). The Ruste Basin requires both water harvesting methods to conserve water at suitable locations in the basin and mechanical and vegetative measures to lessen sediment loss. Mechanical measures that can be applied are bench terracing and check dams. These measures maintains sustainability of agricultural production in the region around the basin.

Table 5: Summary of the values of the parameters used to calculate the hypsometric integral of Ruste Basin

#	Min	Max	Mean	Mean - Min	Max - Min	Area (km^2)	A	Relative area (a/A)	h	Relative height (h/H)	Hypsometric Integral (HI)	Avg. HI
1	769	1055	962.335	193.335	286	16.200	164.792	1.000	286	0.111	0.676	
2	1056	1341	1198.671	142.671	285	35.041	148.592	0.902	571	0.222	0.501	
3	1342	1627	1482.255	140.255	285	30.259	113.551	0.689	856	0.333	0.492	
4	1628	1913	1771.746	143.746	285	31.104	83.292	0.505	1141	0.444	0.504	
5	1914	2200	2043.737	129.737	286	23.638	52.187	0.317	1427	0.556	0.454	0.467
6	2201	2486	2338.337	137.337	285	16.332	28.549	0.173	1712	0.667	0.482	
7	2487	2772	2606.869	119.869	285	9.299	12.217	0.074	1997	0.778	0.421	
8	2773	3058	2875.323	102.323	285	2.543	2.918	0.018	2282	0.889	0.359	
9	3059	3345	3149.796	90.796	286	0.375	0.375	0.002	2568	1.000	0.317	

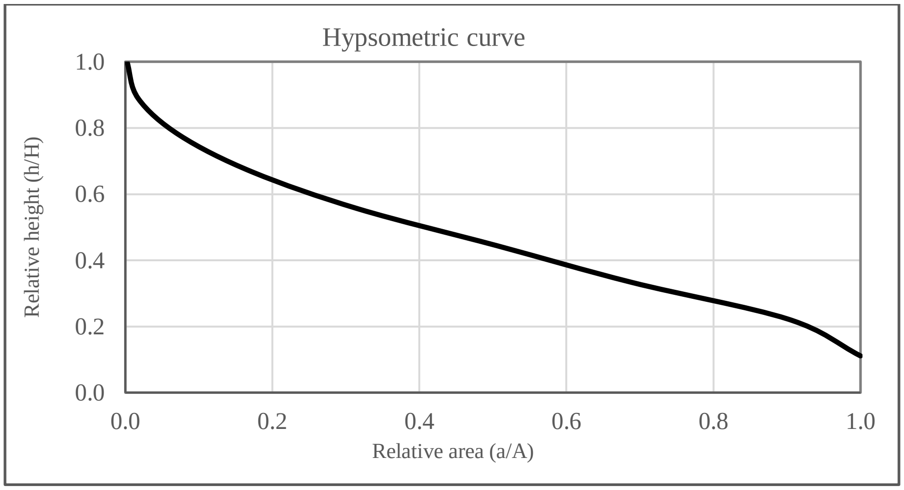

Figure 7: The hypsometric curve constructed from the relationship between relative area and relative height

Conclusion

The GIS and RS techniques were used to conduct the morphometric study and hypsometric analysis of the Ruste Basin. The Ruste Basin is a river of the fifth order and comprised of 579 streams. The findings of the linear morphometric parameters illustrated that the logarithmic relationship between stream orders and stream numbers shows a swift decline from streams of lower-order to streams of higher-order with an R^2 of 0.99. The variation in stream order and number seen in the basin is mainly attributable to topography and bedrock. These features suggest that the Ruste Basin originated from hard rock with considerable relief and a steep slope. A positive linear correlation was noticed between L_{ms} and S_u along with a regression line slope of almost 2.898. It was also discovered that there is a negative association between S_u and L_u with an R^2 of 0.972, indicating that the basin is composed of low-permeability formation and subsurface elements. The R_b of the Ruste Basin ranges between 4.102 and 5.0 with a mean bifurcation ratio of 4.603 and this signifies that the basin is vulnerable to floods.

Regarding the areal morphometric parameters, the Ruste Basin has an F_f of 0.572, an elongation ratio of 0.853, and a circularity ratio of 0.594, which means its shape is semi-circular. Along with a stream frequency of 3.515, the Ruste Basin has high relief and slope with a relief ratio of 0.151 and basin relief of 2.576 km, suggesting that it has a steep slope, poor subsurface permeability, and limited infiltration rate with a high runoff rate and erosive force and, which increases the potential of flooding. The ruggedness number of the basin is 5.819, which belongs to the severe type, indicating that it has a badlands landscape. By applying the elevation-relief ratio approach, the average HI of the Ruste Basin was discovered to be 0.467, showing that the Ruste Basin is in the equilibrium phase and is a mature basin, and features S-shaped hypsometric curves. Water harvesting methods along with mechanical and agronomic measures can be used to mitigate the impact of high runoff rate, rainfall intensity, and flood on the basin's surroundings.

References

[1] Sangle, A.S. and Yannawar, P.L., 2014. Morphometric analysis of watershed using GIS and RS: a review. *Int J Eng Res Technol*, *3*(11), p.499. https://www.ijert.org/morphometric-analysis-of-watershed-using-gis-and-rs-a-review#:~:text=DOI%20%3A%2010.17577/IJERTV3IS110546.

[2] Prakash, K., Rawat, D. and Singh, S., 2019. Morphometric analysis using SRTM and GIS in synergy with depiction: a case study of the Karmanasa River basin, North central India, *Journal of Applied Water Sciences, 9 (13)*, doi: 10.1007/s13201-018-0887-3. https://link.springer.com/article/10.1007/s13201-018-0887-3.

[3] Sebastian, M., Jayaraman, V. and Chandrasekhar, M.G., 1995. *Space technology applications for*

sustainable development of watersheds. Publications & Public Relations Unit, ISRO Headquarters. https://www.researchgate.net/publication/265854011_Space_Technology_for_Sustainable_Development_-_Vision_2020.

[4] Ashwini, B. Avinash, G., Shambhavi, B. N., Vignesh, V. and Gowda, B. N. 2021. Morphometric and hypsometric analysis of lokapavani river basin using arcgis. *International Journal of Creative Research Thoughts (IJCRT). https://ijcrt.org/papers/IJCRT2108212.pdf*.

[5] Parvez, M.B. and Inayathulla, M., 2019. Morphometry, hypsometry analysis and runoff estimation of Aam Talab watershed Raichur, Karnataka. *International Journal of Advance Research and Innovative Ideas in Education*, *5*(3), p.1713. https://www.researchgate.net/publication/333704843_Morphometry_Hypsometry_Analysis_and_Runoff_Estimation_of_Aam_Talab_Watershed_Raichur_Karnataka.

[6] Sutradhar, H., 2020. Assessment of drainage morphometry and watersheds prioritization of Siddheswari River Basin, Eastern India. *Journal of the Indian Society of Remote Sensing*, *48*(4), p.627. http://dx.doi.org/10.1007/s12524-020-01108-5.

[7] Khan, I., Bali, R., Agarwal, K.K., Kumar, D. and Singh, S.K., 2021. Morphometric analysis of Parvati Basin, NW Himalaya: a remote sensing and GIS based approach. *Journal of the Geological Society of India*, *97*, p.165. https://link.springer.com/article/10.1007/s12594-021-1648-8.

[8] Strahler, A.N., 1964. Quantitative geomorphology of drainage basin and channel networks. *Handbook of applied hydrology*.

[9] Clarke, J. I. "Morphometry from maps. Essays in geomorphology." (1996): 235-274. https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1152655.

[10] Gardiner V, 1990. Drainage Basin Morphometry. In: Goudie, A., Ed., Geomorphological Techniques, Unwin Hyman, London, p.71. https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1749504#:~:text=DOI%3A%2010.4236/jgis.2022.144019.

[11] Ritter DF, Kochel RC, Miller JR (2002) Process geomorphology. McGraw Hill, Boston. https://www.amazon.com/Process-Geomorphology-Dale-F-Ritter/dp/1577666690.

[12] Weissel, J.K., Pratson, L.F. and Malinverno, A., 1994. The length- scaling properties of topography. *Journal of Geophysical Research: Solid Earth*, *99*(B7), p.13997. http://dx.doi.org/10.1029/94JB00130.

[13] Hurtrez, J.E., Lucazeau, F., Lavé, J. and Avouac, J.P., 1999. Investigation of the relationships between basin morphology, tectonic uplift, and denudation from the study of an active fold belt in the Siwalik Hills, central Nepal. *Journal of Geophysical Research: Solid Earth*, *104*(B6), p.12779. https://doi.org/10.1029/1998JB900098.

[14] Strahler, A.N., 1952. Hypsometric (area-altitude) analysis of erosional topography. *Geological society of America bulletin*, *63*(11), p.1117. https://ui.adsabs.harvard.edu/link_gateway/1952GSAB...63.1117S/doi:10.1130/0016-7606(1952)63[1117:HAAOET]2.0.CO;2.

[15] Hussein, M. H., Kariem, T.H. & Raddad, A.H. (1989) Runoff and erosion analyses for a hilly area in northern Iraq. Proc. International Workshop on Conservation Farming on Hillslopes, Taichung, Taiwan, 20-29 March.

[16] Sulaiman, A.H. and Abdullah, Z.A., Empirical formula for determining bench terraces spacing In Duhok Governorate. Volume 17 December Number, P.23.

[17] Assaf, S. M. 2015. Design of terrace spacing in Shaqlawa District. A thesis submitted to the council of the college of Agriculture Salahaddin University-Erbil in partial fulfillment of master degree in soil conservation.

[18] Murthy, K.S.R., 2000. Ground water potential in a semi-arid region of Andhra Pradesh-a geographical information system approach. *International Journal of Remote Sensing*, *21*(9), p.1867. https://doi.org/10.1080/014311600209788

[19] Magesh, N.S., Chandrasekar, N. and Soundranayagam, J.P., 2012. Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. *Geoscience frontiers*, *3*(2), p.189. https://doi.org/10.1016/j.gsf.2011.10.007.

[20] Paulinus, U.U., Ifedilichukwu, N.G., Ahamefula, A.C., Iheanyichukwu, O.A., Theophilus, E.T. and Edet, I.G., 2016. Morphometric analysis of sub-watersheds in Oguta and environs, southeastern Nigeria using GIS and remote sensing data. *Journal of Geosciences*, *4*(2), p.21.

[21] Sissakian, V.K. and Fouad, S.F., 2014. Geological Map of Sulaimaniyah Quadrangle, scale 1: 250 000. Iraq Geological Survey Publications, Baghdad, Iraq. http://dx.doi.org/10.13140/RG.2.1.5109.0642.

[22] Horton, R.E., 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. *Geological society of America bulletin*, *56*(3), p.275. https://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2.

[23] Schumm, S.A., 1956. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological society of America bulletin*, *67*(5), p.597. http://dx.doi.org/10.1130/0016-7606.

[24] Strahler, A.N., 1957. Quantitative analysis of watershed geomorphology. *Eos, Transactions American Geophysical Union*, *38*(6), p.913. https://doi.org/10.1029/TR038i006p00913.

[25] Mohammed, K.M. and Karim, T.H., 2020b. Models to predict slope length from other watershed attributes. Iraqi Journal of Agricultural Sciences, 51(4). https://doi.org/10.36103/ijas.v51i4.1081.

[26] Rawat, U., Awasthi, A., Gupta, D.S., Paul, R.S. and Tripathi, S., 2017. Morphometric analysis using remote sensing and GIS techniques in the Bagain River Basin, Bundelkhand Region, India. *Indian J. Sci. Technol*, *10*(10). https://indjst.org/articles/morphometric-analysis-using-remote-sensing-and-gis-techniques-in-the-bagain-river-basin-bundelkhand-region-india.

[27] Faniran A., 1968. The index of drainage intensity: a provisional new drainage factor. Austr J Sci 31(9), p.326. https://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=GEODEBRGM6918018443#:~:text=http%3A//pascal%2Dfrancis.inist.fr/vibad/index.php%3Faction%3DgetRecordDetail%26idt%3DGEODEBRGM6918018443.

[28] Miller, V. C. 1953. A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee, Proj. NR 389-402. Technical report 3. Columbia University. Department of Geology. ONR, New York. https://ui.adsabs.harvard.edu/link_gateway/1957JG.....65..112P/doi:10.1086/626413.

[29] Sharma, S.A., 2014. Morphometrical analysis of Imphal River basin using GIS. International Journal of Geology, Earth & Environmental Sciences2014, 4(2), p.138-144.

[30] Ali, K., Bajracharya, R.M., Sitaula, B.K., Raut, N. and Koirala, H.L., 2017. Morphometric analysis of Gilgit river basin in mountainous region of Gilgit-Baltistan Province, Northern Pakistan. Journal of Geoscience and Environment Protection, 5(07), p.70. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=77652&#abstract

[31] Chitra, C., Alaguraja, P., Ganeshkumari, K., Yuvaraj, D. and Manivel, M., 2011. Watershed characteristics of Kundah sub basin using remote sensing and GIS techniques. International Journal of geomatics and geosciences, 2(1), p.311.

[32] Dubey, S.K., Sharma, D. and Mundetia, N., 2015. Morphometric analysis of the Banas River Basin using geographical information system, Rajasthan, India. Hydrology, 3(5), p.47. https//:doi: 10.11648/j.hyd.20150305.11. http://dx.doi.org/10.11648/j.hyd.20150305.11.

[33] Choudhari, K., Panigrahi, B. and Paul, J.C., 2014. Morphometric analysis of Kharlikani watershed in Odisha, India using spatial information technology. International journal of Geomatics and Geosciences, 4(4), p.661 https://www.semanticscholar.org/paper/Morphometric-analysis-of-Kharlikani-watershed-in-Choudhari-Panigrahi/617845410d2efd670ee26351a961ad78940c5185. .

[34] Nagaraju, D., Siddalingamurthy, D., Balasubramanian, S., Lakshmamma, A. and Sumithra, S., 2015. Morphometric analysis of Byramangala Watershed, Bangalore Urban District, Karnataka, India. International Journal of Current Engineering and Technology, 5(3). https://www.geospatialworld.net/article/study-of-watershed-characteristics-using-google-elevation-service/.

[35] Sethupathi, A.S., Narasimhan, C.L., Vasanthamohan, V. and Mohan, S.P., 2011. Prioritization of miniwatersheds based on Morphometric Analysis using Remote Sensing and GIS techniques in a draught prone Bargur–Mathur subwatersheds, Ponnaiyar River basin, India. International Journal of Geomatics and Geosciences, 2(2), p.403. https://www.researchgate.net/publication/236329783_Prioritization_of_miniwatersheds_based_on_Morphometric_Analysis_using_Remote_Sensing_and_GIS_techniques_in_a_drought_prone_Bargur-Mathur_subwatersheds_Ponnaiyar_River_basin_India.

[36] Huda, E.A., 2017. Morphometric characteristics of Dikrong River catchment in the foot-hills of Arunachal Himalayas. IOSR Journal of Humanities and Social Science, 22(7), p.51. https://www.iosrjournals.org/iosr-jhss/papers/Vol.%2022%20Issue7/Version-13/H2207135160.pdf.

[37] Hlaing, K.T., Haruyama, S. and Aye, M.M., 2008. Using GIS-based distributed soil loss modeling and morphometric analysis to prioritize watershed for soil conservation in Bago river basin of Lower Myanmar. Frontiers of Earth Science in China, 2, p.465. https://link.springer.com/article/10.1007/s11707-008-0048-3.

[38] Adhikari, S., 2020. Morphometric analysis of a drainage basin: A study of Ghatganga River, Bajhang District, Nepal. The Geographic Base, 7, p.127. https://doi.org/10.3126/tgb.v7i0.34280.

[39] Kale, V.S. and Gupta, A., 2001. Introduction to geomorphology. Orient Longman. https://doi.org/10.4236/ojg.2020.102009.

[40] Nag, S.K. and Chakraborty, S., 2003. Influence of rock types and structures in the development of drainage network in hard rock area. Journal of the Indian Society of Remote Sensing, 31, p.25. https://link.springer.com/article/10.1007/BF03030749.

[41] Thronbury. 1966. Principles of geomorphology. 10th print, John Wiley and Sons, Inc. New York, p. 618. https://www.scribd.com/document/519492443/Thornbury-William-D-Principles-of-Geomorphology-John-Wiley-Sons-1954.

[42] Sharma, S.A., 2014. Morphometrical analysis of Imphal River basin using GIS. International Journal of Geology, Earth & Environmental

Sciences2014, 4(2), p.138. https://www.semanticscholar.org/paper/MORPHOMETRICAL-ANALYSIS-OF-IMPHAL-RIVER-BASIN-USING-Sharma/e69e558b792d0606a3fd08701250bf59faf6e73c.

[43] Nagal, S., Tignath, S. and Pandey, A., 2014. Morphometric analysis of the adwa river basin, tributary of belan river, India. International Journal of Advanced Technology and Engineering Research, 4(2), p.39. https://www.semanticscholar.org/paper/MORPHOMETRIC-ANALYSIS-OF-THE-ADWA-RIVER-BASIN%2C-OF-Nagal-Tignath/aa0451f7c0eb7775e91578c22cfb4f219b61aecb.

[44] Suresh, R., 2012. Soil and water conservation engineering. Standard Publishers Distributors.

[45] Smith, K.G., 1950. Standards for grading texture of erosional topography. American journal of Science, 248(9), p.655. http://dx.doi.org/10.2475/ajs.248.9.655.

[46] Mohammed, K.M. and Karim, T.H., 2020a. Watershed prioritization across Erbil province for soil erosion management via morphometric analysis. The Iraqi Journal of Agricultural Science, 51(5), p.1262. https://doi.org/10.36103/ijas.v51i5.1134.

[47] Schmid, B.H., 1997. Critical rainfall duration for overland flow from an infiltrating plane surface. Journal of hydrology, 193(1-4), p.45. https://ui.adsabs.harvard.edu/link_gateway/1997JHyd..193...45S/doi:10.1016/S0022-1694(96)03152-6.

[48] Das, A.N.U.P. and Mukherjee, S., 2005. Drainage morphometry using satellite data and GIS in Raigad district, Maharashtra. *J Geol Soc India*, *65*, p.577. https://www.geosocindia.org/index.php/jgsi/article/view/82326.

[49] Joji, V.S., Nair, A.S.K. and Baiju, K.V., 2013. Drainage basin delineation and quantitative analysis of Panamaram Watershed of Kabani River Basin, Kerala using remote sensing and GIS. *Journal of the Geological Society of India*, *82*(4), p.368. https://link.springer.com/article/10.1007/s12594-013-0164-x.

[50] Gravelius H., 1914. Grundrifi der gesamten Gewcisserkunde. Band I: Flufikunde (Compendium of Hydrology, vol. I. Rivers, in German). Goschen, Berlin, Germany. https://doi.org/10.4236/jhepgc.2021.71013.

[51] Zăvoianu I. 1985. Morphometry of drainage basins, Edit. Elsevier, Amsterdam – Oxford - New York – Tokyo. https://shop.elsevier.com/books/morphometry-of-drainage-basins/zavoianu/978-0-444-99587-2.

[52] Savita, R.S., Satishkumar, U., Mittal, H.K., Singh, P.K. and Yadav, K.K., 2017. Analysis of hydrological inferences through morphometric analysis a remote sensing-GIS based study of Kanakanala Reservoir Subwatershed. International Journal of Agricultural Science and Research (IJASR), 7(6), p.378-388.

[53] Altaf, F., Meraj, G. and Romshoo, S.A., 2013. Morphometric Analysis to infer hydrological behaviour of Lidder watershed, Western Himalaya, India. Geography Journal. https://doi.org/10.1155/2013/178021.

[54] Suresh, R. (2012). Soil and water conservation engineering. Standard Publishers Distributors. Delhi. p.793. https://www.amazon.in/Soil-Water-Conservation-Engineering-PB/dp/8180141861.

[55] Palaka, R. and Sankar, G.J., 2016. Study of watershed characteristics using Google Elevation Service. *Geospatial world*. http://dx.doi.org/10.13140/2.1.5103.0080.

[56] Asfaw, D. and Workineh, G., 2019. Quantitative analysis of morphometry on Ribb and Gumara watersheds: Implications for soil and water conservation. International Soil and Water Conservation Research, 7(2), p.150. https://doi.org/10.1016/j.iswcr.2019.02.003.

[57] Han, Y., Feng, G. and Ouyang, Y., 2018. Effects of soil and water conservation practices on runoff, sediment and nutrient losses. Water, 10(10), p.1333. https://doi:10.3390/w10101333.

[58] Sarma, P.K., Sarmah, K., Chetri, P.K. and Sarkar, A., 2013. Geospatial study on morphometric characterization of Umtrew River basin of Meghalaya, India. International Journal of Water Resources and Environmental Engineering, 5(8), p.489. doi 10.5897/IJWREE2012.0367.

[59] Pareta, K. and Pareta, U., 2011. Quantitative morphometric analysis of a watershed of Yamuna basin, India using ASTER (DEM) data and GIS. International journal of Geomatics and Geosciences, 2(1), p.248. https://www.indianjournals.com/ijor.aspx?target=ijor:ijggs&volume=2&issue=1&article=022.

[60] Bhunia, G.S., Samanta, S. and Pal, B., 2012. Quantitative analysis of relief characteristics using space technology. International Journal of Physical and Social Sciences, 2(8), p.350. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=19805fd7b8f93ad9713cff549bb9792afc5376d9.

[61] Nir, D., 1957. The ratio of relative and absolute altitudes of Mt. Carmel: a contribution to the problem of relief analysis and relief classification. Geographical Review, 47(4), p.564. https://doi.org/10.2307/211866.

[62] Farhan, Y., Anbar, A., Enaba, O. and Al-Shaikh, N., 2015. Quantitative analysis of geomorphometric parameters of Wadi Kerak, Jordan, using remote sensing and GIS. Journal of Water Resource and Protection, 7(06), p.456. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=55519&#abstract.

[63] Ibrahim, S.A., 2019. Morphometric analysis of the Al-Teeb River basin, SE Iraq, using digital elevation model and GIS. Iraqi Bulletin of Geology and Mining, 15(1), p.59. https://www.iasj.net/iasj/download/515bcfedef6fec3d.

[64] Shekar, P.R. and Mathew, A., 2022. Morphometric analysis for prioritizing sub-watersheds of Murredu River basin, Telangana State, India, using a geographical information system. Journal of Engineering and Applied Science, 69(1), p.1. https://jeas.springeropen.com/articles/10.1186/s44147-022-00094-4.

[65] Mani, A., Kumari, M. and Badola, R., 2022. Morphometric analysis of Suswa River Basin using geospatial techniques. Engineering Proceedings, 27(1), p.65. https://doi.org/10.3390/ecsa-9-13225.

[66] Kang, D.H., 2005. Distributed snowmelt modeling with GIS and Casc2d at California Gulch, Colorado (Doctoral dissertation, Colorado State University). https://www.engr.colostate.edu/~pierre/ce_old/resume/Theses%20and%20Dissertations/Kang%20Thesis.pdf.

[67] Joy, M.A.R., Upaul, S., Fatema, K. and Amin, F.M., 2023. Application of GIS and remote sensing in morphometric analysis of river basin at the south-western part of great Ganges delta, Bangladesh. Hydrology Research. https://doi.org/10.2166/nh.2023.087.

[68] Yadav, S.K., Singh, S.K., Gupta, M. and Srivastava, P.K., 2014. Morphometric analysis of Upper Tons basin from Northern Foreland of Peninsular India using CARTOSAT satellite and GIS. Geocarto International, 29(8), p.895-914. http://dx.doi.org/10.1080/10106049.2013.868043.

[69] Pike, R.J. and Wilson, S.E., 1971. Elevation-relief ratio, hypsometric integral, and geomorphic area-altitude analysis. Geological Society of America Bulletin, 82(4), p.1079. https://doi.org/10.1130/0016-7606(1971)82[1079:ERHIAG]2.0.CO;2.

مجلة جامعة كركوك للعلوم الزراعية

تقييم التحليل المورفومتري والهيبسوميتري لحوض روستي باستخدام تقنيات الاستشعار عن بعد ونظام المعلومات الجغرافية

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الملخص

ان مفهوم لخصائص الحوض واشكاله بشكل كلي يحتاج الى التحاليل المورفوميتريه التحليل، مثل تقييم حجم الحوض والمظهر وشكل الخارجي،و ذلك لتقيم الفيضانات و معدل التعرية بشكل عام. وان الهدف الرئيسي لهذه الدراسة هي تقييم المقاييس المورفوميتري والتحاليل الهيبسومتري لحوض روستي في أربيل وذلك باستخدام طرائق الاستشعار عن بعد (RS) ونظام المعلومات الجغرافية(GIS)، وللبحث عن معنوية تفرعات الجداول لمنطقه المختارة، والادوات الهيدرولوجيه التي هي من ضمن أدوات التحليل المكاني لبرنامج (ArcGIS)، المجدد 10.7، الذي استخدمت لتحديد حدود الحوض، وخريطة شبكات الصرف، والحصول على البيانات الطبوغرافية. واوضحت نتائج المعلمات المورفوميتريه ان علاقة اللوغاريتمية بين رتب وعدد المجري المائي هي سالبة. والاختلاف ترجع الى تأثير الطوبوغرافية ومادة الاصل على رتب المجرى المائي وعددها في الحوض، ومعامل الارتباط هي 0.972 وهذا يدل على أن الحوض متكونة من مواد ذات نفاذية منخفيضه ومواد تحت السطحيه للتربة. باعتبار ان مساحة المعلمات المورفولوجيه، نسبة دائرية نسبة الاستطالة ومعامل التشكل هي 0.594 و0.853 و0.572، على التوالي، واقترحت ان شكله شبه دائري. أظهرت قيمة كثافة الصرف البالغة 2.259 كم ‎-1 وهذا يدل على أنه حوض روستي عبارة عن حوض ذات تضاريس جبلية منحدرة إلى شديدة الانحدار مع تغطية نباتية متفاوتة. بالاضافة الى ذالك، يتميز حوض روستي بأنه مرتفع وشديدة الانحدار ونسبة تضاريس تبلغ 0.151 وتضاريس الحوض يبلغ 2.576 كم ، وكلاهما الى انه تحتوي انحدار حاد مع قوة التعرية عالية، ومحدوديه قابله الترشيح، ومعدل السيح عالي. ودرجة الصلابة لحوض روستي 5.819، وهذا يدل على أنه يحتوي على تضاريس الأرض الرديئه.و كان معدل قياس التكامل الهيبسوميتري 0.467، وهذه دلاله على أنه حوض ناضج ذات الهيبسوميتري متميز على شكل حرفS انجليزي. كأستنتاج أظهرت النتائج أن تحليل المعلمات المورفومترية والتكامل والمنحنى الهيبسوميتري يوفر لنا فكرة لتوصيف الأحواض والتوجيه لاتخاذ القرارات المناسبة لإنشاء إجراءات فعالة وذلك للحفاظ على استدامة التربة والمياه وإدارة الموارد الطبيعية من خلال تطبيق طرائق مختلفه لحصاد المياه، والسدود صغيرة، وصنع مصاطب على المنحدرات

الكلمات المفتاحية: نموذج الارتفاع الرقمي، قياس الهيبسوميتري، التحليل المورفومتري، حوض روستي