Determination of Watershed Characteristics Using GIS Technique (AL-Adhaim Watershed in Iraq)

Mohammed S. Shamkhi, Tabark J. Abdullah and Atyaf J. Mohson

Abstract The current research aims to investigate the relief, areal morphometric and linear characteristics of the basin of AL-Adhaim using GIS technique. This method is produced pertinent for the extraction of the basin stream and the drainage networks for basin. Advantageously, this technique saves time, effort and also improves the accuracy of the analysis of its drainage networks. The study depends on the analyses of the Digital Elevation Model of the Basin area taken from SRTM Satellite with a resolution of 3000 cm. Upon analyzing the results obtained from the morphometric analysis for streams, one can classify the basin as sixth stream order, and the watershed can be noted, with mean bifurcation ratio (4.43) which have an effect on runoff. Apart from this, the elongation proportion of the basin is 0.97 that in turn demonstrates that the study area is circularly elongated. Additionally, the drainage texture of the AI-Adhaim watershed is 2.33 which implies that coarse texture. Therefore, the present investigate can prove to be very helpful in planning the management and watershed and other hydrological investigates in the future.

Keywords AL-Adhaim · ArcGIS · Digital elevation model (DEM) · Watershed · Morphometric characteristics

1 Introduction

The science that describes the features and forms of the Earth's surface is Geomorphology in terms of elevation, reduction, and geological formation. Morphometric measurements are one of the most important geomorphological applications, where the term morphometric is clarify as the mathematically analysis and measurement of the earth's surface configuration, landforms dimension and shape [5, 19]. Principally, the analysis of morphometric supplies a description of quantifiable for the basin's geometry which assists in understanding the inequalities

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or initial slope in rock hardness [16, 27]. Indeed, morphometric characteristics like the shape of basin and relief of basin are found to affect the hydrograph's nature and variables of hydrological.

Primarily, the flow density of stream and the runoff amount could be measured by analyzing the parameters of morphological and their related geographic advantages [10]. Further, the areal measurement and linear parameter of the catchment zone can be considered as basic units of morphometric analysis [2, 3, 18]. The morphometry effect of drainage is so important in understanding the manners of landform, soil physical characteristics, and erosional properties. In a similar context, Machiwal and Jha [13] and Umrikar [28] stated that many determinants which exert a great effectuation on the surface water performance in catchment area are the tectonic framework of the basin, runoff, the prevailing climatic conditions, and slopes, etc.

The analysis further includes the following parameters: (i) order of stream, (ii) length of stream, (iii) mean stream length, (iv) perimeters and basin area measurements, (v) drainage density, (vi) drainage texture, (vii) ratio of bifurcation, (viii) circulatory ratio, (ix) elongation ratio, (x) stream frequency, (xi) stream length ratio, and (xii) relief ratio. Recently, using remote sensing (RS) and ARC GIS software is becoming more popular in comparison to the traditional technique that had been used to determine morphometric parameters measurements based on topographic maps [11, 17, 21]. The GIS technique is an accurate, rapid, and cheap way of carrying out the analysis of morphometric [7, 8]. Therefore, the current study endeavors to analyze different characteristics of the AL-Adhaim watershed using geoprocessing techniques in ArcGIS 10.5, with a major focus on linear, relief, and areal of the catchments using GIS tools. This type of analysis will assist the decision makers in developing and managing the basin as it provides a description of the hydrological properties of the area.

2 Methodology

2.1 The Description of the Selected Area

Al-Adhaim basin is situated on the northeastern boundary of Iraq nearby the Iranian border. Between 35° 43′ 20″ to 35° 8′ 28″ N and 44° 42′ 19″ to 45° 31′ 20″ E. The total basin area is 11908 km^2 (see Fig. 1), which lies totally inside Iraqi borders. The river of Adhaim is a major the Tigris river tributary, and Al-Adhaim Dam was built on AL-Adhaim River 19 years before. The climate in this area is mainly characterized as an arid due to the scarcity of rainfall, as the majority of rainfall occurs from October to May with an annual amount of 610 mm. Therefore, the river is essentially seasonal. Moreover, the temperature keeps fluctuating between −4 and 49 °C in winter and summer respectively [4].

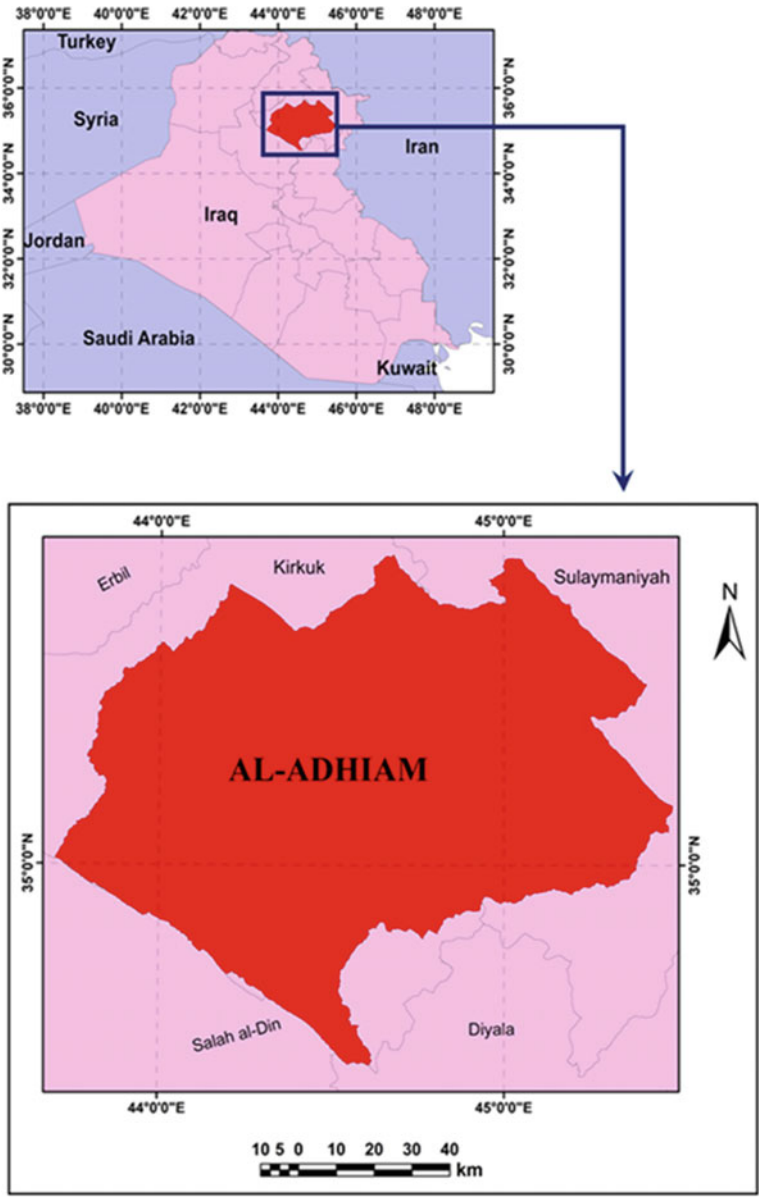

Fig. 1 The map of the location for the selected area

2.2 The Basin's River and Network's Stream Extraction

The classification and the watershed network characterization for the stream order based on the topographic map for a great area needs considerable time and effort. In this research, estimating the morphometric parameters that firstly, involved extraction of the boundaries of the river basin as well as its stream network automatically using STRM (the Shuttle Radar Topographic Mission) DEM. The regional projection (WGS1984_UTM_ZON 38_N) was the dependable project in extracting the results of the watershed and its stream networks.

2.2.1 Extraction of Basin's River

The data of the digital Elevation Model (DEM) which has been downloaded from the site (https://earthexplorer.usgs.gov), was used with a spatial accuracy of 30 m for the extraction of the AL-Adhaim River Basin. In addition to DEM, the extraction required pour point in order to obtain the basin boundary. However, after several geological processing techniques in ArcGIS 10.5 the dam location was identified, as a pour point.

2.2.2 Network's Stream Extraction

The network of stream of Al-Adhaim watershed extraction required series of geo-processing steps in GIS-10.5 software as illustrated in Fig. 2. The result of this method will be creating a network of stream grid with the classification of stream depending on Strahler [27]. The system of Strahler clarify as a slice without tributaries as an initial streaming. If two parts of the first-order stream join, they are part of a second-order stream and so on [16]. The highest current order in the AL-Adhaim watershed was calculated, as sixth. Further, standard mathematical equations were certified to extract the morphometric properties values with the results being tabulated in Table 1. Additionally, STRM DEM was utilized for the slope derivation and maps aspect of the present zone, by using slope and aspect in ArcGIS 10.5.

3 Results and Discussion

3.1 Slope and Aspect

The term "aspect" is refering to the direction to that a mountain slope faces. Predominantly, it has an effective impact on the climate. Apart from this, it also exerts substantial effect over the vegetation and other properties in the study area [15]. Figure 3 illustrate the aspect map of AL-Adhaim Basin.

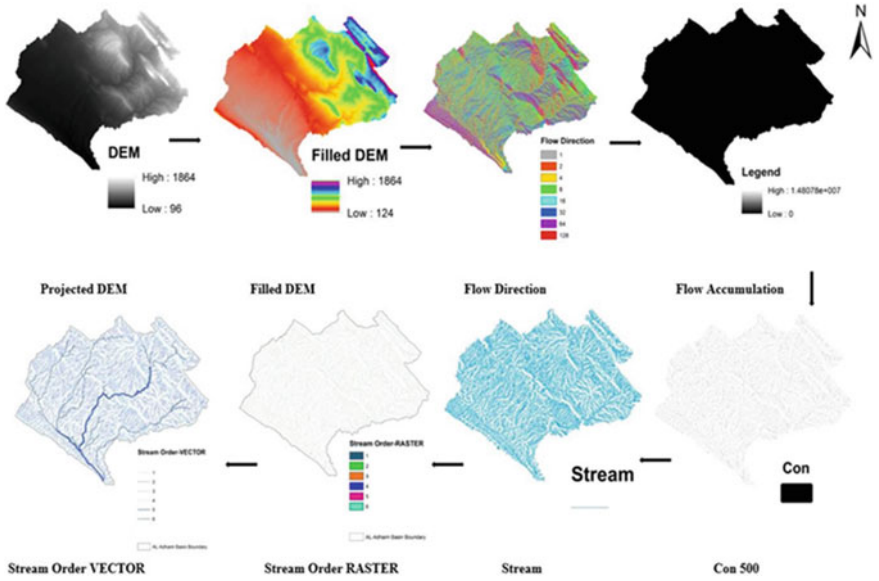

Fig. 2 The drainage networks extracted from DEM

Table 1 The parameters of the relief, linear, and areal morphometric

S. no	Parameters	Formulae	Cited by
1	Order of stream (S)	Hierarchial rank	[22]
2	Length of stream (Ls)	Length of the stream	[11]
3	Ratio of bifurcation (Br)	Br = Nu/Nu + 1	[22]
4	Mean ratio of bifurcation (Brm)	Brm = average ratios of bifurcation for all order	[22]
5	Relief (Rf)	Rf = H − h	[29]
6	Ratio of relief (Rfr)	Rfr = R/L	[12]
7	Form factor (Ff)	$Ff = A/L^2$	[16]
8	Ratio of circularity (Cr)	$Cr = 4\ \pi\ A/P^2$	[25]
9	Ratio of elongation (Er)	Er = D/L	[28]
10	Frequency of stream (Sf)	Sf = Nu/A	[16]
11	Density of drainage (D)	D = Lu/A	[22]
12	Texture of drainage (Td)	Td = Dd × Fs	[28]

The analysis of the slope is a significant geomorphological investigates parameter for the development of watershed data as well as for morphometric analysis. The map's slope gives planning data, mechanization, agriculture, settlement, deforestation, reforestation, engineering structure planning, etc. It is, therefore, necessary to understand the distribution of slopes [25]. As shown in Fig. 3

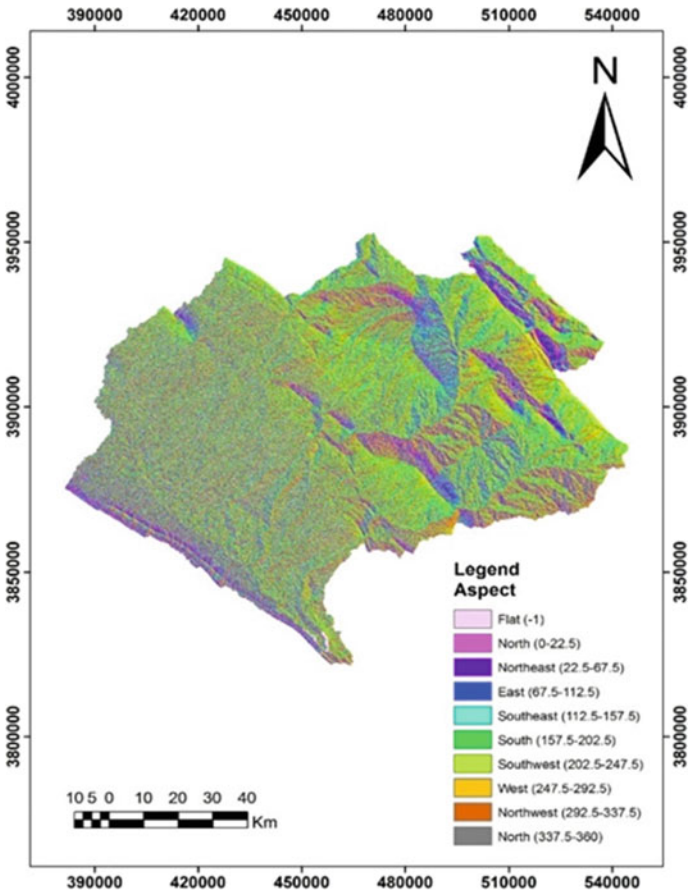

Fig. 3 Aspect map of selected zone coefficient

Al-Adhaim basin slope differs from 0 to 74.5777. The slope degree has a proportional impact on the overland flow speed, runoff, rate of infiltration, and eventually on transportation of soil (Fig. 4).

3.2 Order of Stream (S)

The assignment of flow orders is the initial step in analysis of drainage, which mainly depends on the hierarchy of currents. In this study, flows are arranged using the proposed technique by Strahler [27]. Fundamentally, the basin order is the order of the highest stream. Following the above description, one can designate AL-Adhaim River as sixth order stream (see Fig. 2). The stream orders and the total

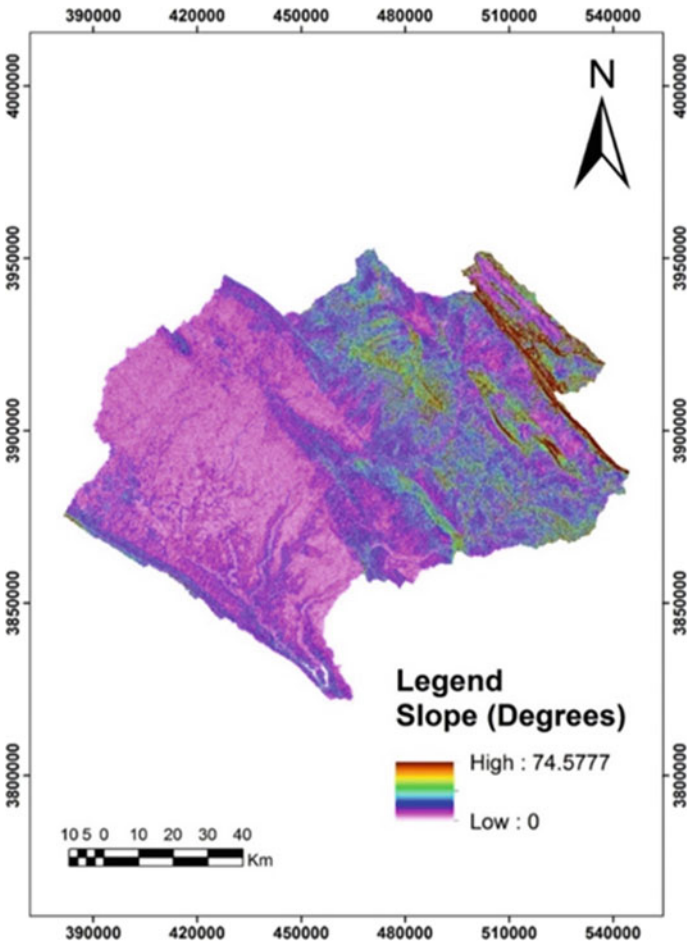

Fig. 4 Slope map of the selected zone coefficient

streams number present in every watershed arrangement are listed in (Table 2). The table reveals that the stream of a first degree has the maximum frequency while lower frequency has been noted for the stream of second-order. Moreover, it has been observed that with an increase in the flow order, the flow frequency decreases.

3.3 Stream Length (Ls)

The flows length was determined, with the help of Arc GIS10.5 software. The stream length is a hydrological properties gauge of the basic rocks and the extent of

Table 2 The tables reveals the morphometric analysis results for AL-Adhaim Watershed

No.	Parameters	Calculated value					
		1	2	3	4	5	6
1	Order of stream (S)	1187	315	70	11	2	1
2	Length of stream (Ls) (km)	1945.9	826.3	374.6	373	172.3	31.7
3	Ratio of bifurcation (Br)		3.77	4.5	6.36	5.5	2
4	Mean ratio of bifurcation (Brm)	4.43					
5	Perimeter (P) (km)	680					
6	Basin length (Bl) (km)	126.47					
7	The area of basin (km^2)	11908					
8	Total relief (Rt) (m)	1768					
9	Ratio of relief (Rfr)	13.98					
10	Ratio of elongation (Fr)	0.97					
11	Density of drainage (km/km^2)	0.31					
12	Frequency of stream	0.13					
13	Texture of drainage	2.33					
14	Form factor (Ff)	0.74					
15	Ratio of circulatory	0.32					

drainage. Consequently, the stream length is calculated from the river mouth up to the drainage, with the division being near the source [11].

3.4 Frequency of Stream (Sf)

The frequency of stream (Sf), as described cited by [16], is the proportion between the total area and the total flow segments number for all orders. Rainfall pattern, rainfall amount, vegetation covers, and surface soil nature are in regard to the stream segments present as well as the stream segments associated with various stages of the landscape [16]. In the current research area, the stream frequency value was found to be 0.31.

3.5 Ratio of Bifurcation (Br)

The proportion of the streams number to any given order to the flows number in the next greater order in the drainage watershed is known as the bifurcation ratio [22]. Horton [9] demonstrated that the ratio of bifurcation is allied with dissections and relief, while Strahler [26] insisted that the value of bifurcation does not change

dramatically for various areas or various environmentally conditions unless powerful geological control dominates. Table 2 shows that Br value varies from 2.0 to 6.36 for Al-Adhaim Watershed. Further, the average ratio of bifurcation (Brm) can be described, as the average of Br for all orders (see Table 1). From the table, one can observe that the Brm value for AL-Adhaim basin was found to be 4.43 (see Table 2).

3.6 Relief (Rf)

Relief is known as the maximum height in the basin minus the bottom point in the basin. The relief of basin is an effective factor to understand the manner of geomorphic and properties of landform and it has a significant function in the improvement of sewage, permeability, flows of groundwater and surface water, land improvement, and characteristics of erosion for the terrain [29]. The high value of relief demonstrates the water flow gravity, less infiltration, and high conditions of runoff. In the current research, the total relief values of AL-Adhaim watershed is 1768 (see Table 2). The basin relief generally increased with reducing drainage zone and a given drainage basin size [22].

3.7 Relief Ratio (Rfr)

The height variations of highest and lowest points of a basin and the longest distance of the watershed parallel to the major drainage line is known as the relief ratio [12]. The Rfr value increases immediately after the drainage area and subsequently, the volume of the catchment in a given basin decreased. On a similar note, Ahmed et al. [1] have confirmed the inverse relationship between the relief ratio and the hydrological characteristics. The relief ratio of the selected area for the research is 13.98 (see Table 2).

3.8 Drainage Density (D)

It can be gained by dividing the length of all streams by the total basin area [22]. It supplies a numerical landscape anatomy measurement, infiltration capacity, surface runoff potential, climatic conditions, and vegetation the basin's cover [14, 24]. The drainage density of the Adhaim basin is 0.31 km/km^2. However, according to Strahler [27], who classified the discharge density into three categories: (a) low (>12), (b) medium (12–16), and (c) high (>16) [11] the value obtained for the density of discharge, in the present research, is low. Principally, the drainage

density controls the drainage texture; where fine texture resulted from high drainage intensity while coarse texture resulted from low drainage density [31].

3.9 Texture of Drainage (Td)

The total flow segment number for all orders per perimeter in the region is defined as drainage texture [30]. It relies on a number of normal factors like rock, rainfall, type of soil, vegetation, climate, relief, the capacity of infiltration, and development stage [28]. Depending on the value of the drainage texture, it has been identified into five various categories, (1) Td > 2; indicates very coarse, (2) Td = 2.0–4.0 indicates coarse, (3) Td = 4.0–6.0 indicates moderate, (4) Td = 6.0–8.0; indicates fine, and (4) Td > 8; indicates very fine texture. The value obtained for drainage texture, in the present analysis, is found to be 2.33, which implies that area under study has a coarse texture.

3.10 Form Factor (Ff)

According to Sreedevi et al. [25] and Raj and Azeez [23], the calculation of the form factor is carried out by dividing the area of the basin into the length square of the basin. Narrow and deep channels have a low proportion of shape, while wide shallow channels have a high proportion of shape. The form factor of the Adhaim watershed is 0.74 (see Table 2).

3.11 Ratio of Circularity (Cr)

The circularity ratio is affected by plenty of factors mentioned by Das et al. [6] such as the length of streams and its frequency, land cover, and relief of the basin. The basin area ratio to the circle area have similar circumference as the basin perimeter is known as Cr [25], and its value for AL-Adhaim watershed is determined to be 0.32 (see Table 2).

3.12 Ratio of Elongation (Er)

It is discribed by Umrikar [28] as the proportion of a circle diameter which has the similar area as of the basin and the maximum length of basin. The elongation ratio is one of the major indicator in the basin shape analysis, which helps to understand the hydrological character of the drainage catchment. Basically, Er is allied with

high relief and steep ground slope, and for most basins, the Er magnitudes change from 0.6 to 1.0. Based on the elongation values, the shape of the basins are classified as follows: (1) circular shape (0.9–1.0), (2) oval shape (0.8–0.9), (3) less elongated (0.7–0.8), (4) elongated (0.5–0.7), and (5) more elongated (<0.5) [20]. The elongation coefficient value is 0.97 (see Table 2), which suggests that the basin should have circular shape.

4 Conclusions

Several basin characteristics such as infiltration capacity, runoff, and the basin shape obtained from the morphometric analysis, which can be extracted with the help of the geographic information systems (GIS) based on DEM, were utilized in the research area to estimate the parameters required for accurate analysis. There are 15 morphometric parameters as shown in Table 2. The study region has a sixth stream arrangement. Furthermore, the analysis reveals high degrees of hierarchization and ramification. Further, area analysis shows that the percentage of elongation of the watershed is circular. Apart from this, the drainage density and flow current are a major criterion for morphological organization for basins of drainage, which positively controlled the hydrological parameters. D shows to be much lower in the Adhaim watershed that demonstrates the presence of impermeable rocks and medium relief. Thus, the present research has shown the effective use of geological processing technology in GIS for calculating and analyzing various morphometric parameters of the catchment. Therefore, one can deduce that this type of analysis is one of the most important steps that help decision-makers involved in management of watershed.

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References

1. Ahmed SA, Chandrashekarappa KN, Raj SK, Nischitha V, Kavitha G (2010) Evaluation of morphometric parameters derived from ASTER and SRTM DEM—a study on Bandihole sub-watershed basin in Karnataka. J Indian Soc Remote Sens 38:227–238
2. Ali SA, Alhamed M, Ali U (2016) Morphometric analysis of Abdan Basin, Almahfid basement rock, yemen: using remote sensing and GIS. Int J Adv Remote Sens GIS 5:1605–1617
3. Ali U, Ali SA (2014) Analysis of drainage morphometry and watershed prioritization of Romushi-Sasar catchment, Kashmir Valley, India using remote sensing and GIS technology. Int J Adv Res 2:5–23
4. Al-Kadhimi AM, Ahmed LA, Al-Mphergee RYA (2011) Runoff curves development for Al-Adhaim catchment using digital simulation models. Jordan J Civ Eng 159:1–16

5. Bhunia GS, Samanta S, Pal B (2012) Quantitative analysis of relief characteristics using space technology. Int J Phys Soc Sci 2:350–365
6. Das A, Mondal M, Das B, Ghosh AR (2012) Analysis of drainage morphometry and watershed prioritization in Bandu Watershed, Purulia, West Bengal through remote sensing and GIS technology-a case study. Int J Geomat Geosci 1
7. Gafeira J, Dolan M, Monteys X (2018) Geomorphometric characterization of pockmarks by using a GIS-based semi-automated toolbox. Geosciences 8:154
8. Grohmann CH, Riccomini C, Alves FM (2007) SRTM-based morphotectonic analysis of the Poços de Caldas Alkaline Massif, Southeastern Brazil. Comput Geosci 33:10–19
9. Horton RE (1945) Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Geol Soc Am Bull 56:275–370
10. Kaliraj S, Chandrasekar N, Magesh NS (2015) Morphometric analysis of the river Thamirabarani sub-basin in Kanyakumari District, South West Coast of Tamil Nadu, India, using remote sensing and GIS. Environ Earth Sci 73:7375–7401
11. Kant S, Meshram S, Dohare R, Singh S (2015) Morphometric analysis of sonar sub-basin using SRTM Data and Geographical Information System (GIS). Afr J Agric Res 10:1401–1406
12. Khadri SFR, Moharir K (2013) Detailed morphometric analysis of man river basin in Akola and Buldhana Districts of Maharashtra, India Using Cartosat-1 (DEM) data and GIS techniques. Int J Sci Eng Res 4
13. Machiwal D, Jha MK (2014) Characterizing rainfall-groundwater dynamics in a hard-rock aquifer system using time series, geographic information system and geostatistical modelling. Hydrol Proc 28:2824–2843
14. Macka Z (2001) Determination of texture of topography from large scale contour maps. Geografski Vestnik 73:53–62
15. Magesh NS, Chandrasekar N, Soundranayagam JP (2011) Morphometric evaluation of Papanasam and Manimuthar Watersheds, Parts of Western Ghats, Tirunelveli District, Tamil Nadu, India: a GIS approach. Environ Earth Sci 64:373–381
16. Magesh NS, Jitheshlal KV, Chandrasekar N, Jini KV (2013) Geographical information system-based morphometric analysis of Bharathapuzha River Basin, Kerala, India. Appl Water Sci 3:467–477
17. Monteiro E, Fonte C, Lima J (2018) Analysing the potential of openstreetmap data to improve the accuracy of SRTM 30 DEM on derived basin delineation, slope, and drainage networks. Hydrology 5:34
18. Nag SK, Chakraborty S (2003) Influence of rock types and structures in the development of drainage network in hard rock area. J Indian Soc Remote Sens 31:25–35
19. Nongkynrih JM, Husain Z (2011) Morphometric analysis of the manas river basin using earth observation data and geographical information system. Int J Geomat Geosci 2:647–654
20. Pareta K, Pareta U (2011) Quantitative morphometric analysis of a Watershed of Yamuna Basin, India Using ASTER (DEM) data and GIS. Int J Geomat Geosci 2:248–269
21. Radwan F, Alazba AA, Mossad A (2017) Watershed morphometric analysis of Wadi Baish dam catchment area using integrated GIS-based approach. Arab J Geosci 10:256
22. Rai PK, Mohan K, Mishra S, Ahmad A, Mishra VN (2017) A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. Appl Water Sci 7:217–232
23. Raj PN, Azeez PA (2012) Morphometric analysis of a tropical medium river system: a case from Bharathapuzha River Southern India. Open J Mod Hydrol 2:91
24. Reddy GPO, Maji AK, Gajbhiye KS (2004) Drainage morphometry and its influence on landform characteristics in a Basaltic Terrain, Central India–a remote sensing and GIS approach. Int J Appl Earth Observ Geo-inform 6:1–16
25. Sreedevi PD, Subrahmanyam K, Ahmed S (2005) The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. Environ Geol 47:412–420
26. Strahler AN (1957) Quantitative analysis of watershed geomorphology. Transc Amst Geophy Union 38:913–920

27. Strahler AN (1964) Quantitative geomorphology of drainage basins and channel net-works. In: ByVenTe Chow (ed) Handbook of applied hydrology. McGraw Hill Book Company, New York
28. Umrikar BN (2017) Morphometric analysis of Andhale Watershed, Taluka Mulshi, District Pune, India. Appl Water Sci 7:2231–2243
29. Vincy MV, Rajan B, Pradeepkumar AP (2012) Geographic information system-based morphometric characterization of sub-watersheds of Meenachil River Basin, Kottayam District, Kerala, India. Geocarto Int 27:661–684
30. Wandre SS, Rank HD (2013) Assessment of morphometric characteristics of Shetrunji River Basin using remote sensing and GIS. Int J Agric Environ Biotechnol 6:503–514
31. Wilson JJ, Ch N (2012) Morphometric analysis of major sub-watersheds in Aiyar and Karai Pottanar Basin, Central Tamil Nadu, India Using Remote Sensing and GIS Techniques. Bonfring Int J Ind Eng Manag Sci, 2(Special issue special issue on geospatial technology development in natural resource and disaster management): pp 08–15.