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Assessment of Morphometric Characteristics of Gojeb Watershed, Omo-Gibe Basin, Ethiopia

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Abstract

In this work, morphological features and basin characteristics of the Gojeb watershed, Omo- Gibe Basin, were identified and analyzed using GIS and image processing techniques. Watershed delineation and analysis of morphological features based on Shuttle Radar Topography Mission (SRTM) DEM data were performed using GIS hydrology tools. This study also assesses the sub-basins' morphometric metrics, such as area, perimeter, stream frequency, maximum width and length, drainage density, and stream orders, as well as their geometric characteristics. The results led to delineate nine sub-watersheds with nine stream orders, the drainage density of these sub-basins is ringing between 0.75 to 0.99 km/km2. Stream orders were calculated, the outcomes allowed for the delineation of nine sub- watersheds with nine stream orders, having a drainage density of between 0.75 and 0.99 km2/km2. There are 1763 streams with a length of 941.26 km as the first order, 503 streams with a length of 307.09 km as the second order, 3755 streams with a total length of 1128.46 km as the third order, 1144 streams with a total length of 696.56 km as the fourth-order streams, and 519 streams with a total length of 425.86 km as the fifth order, 1284 streams with a length of 796.66 km as the sixth, 615 with a total length 429.69 km as seventh order, 873 with a total length 529.72 km as eighth-order streams, and 985 with a total length 708.38 km as ninth order. The stream length is greatest in the third order, and it gets shorter as the stream order gets higher. This finding may be helpful to regional planners and national decision-makers for agricultural and water management policies.

Keywords: GIS, STRM, DEM, Gojeb, Omo-Gibe Basin

Introduction

Measurement and mathematical study of the configuration of the earth's surface, as well as the size, shape, and location of its landforms, is known as morphometry [1]. Measurements of the linear, aerial, relief, gradient of the channel network, and contributing ground slope of the basin enable successful completion of the morphometric study [2]. According to numerous morphometric researches, a widely accepted morphometric concept is that drainage basin morphology reflects different geological and geomorphological processes across time [3]. It is commonly known that drainage morphometry has a big impact on our comprehension of how soils originate, how they behave physically, and how they erode. The arrangement of the earth's surface, as well as the size and shape of its landforms, are studied through measurement and mathematics in morphometry. Measurements of the linear, aerial, relief, gradient of the channel network, and contributing ground slope of the basin enable successful completion of the morphometric study [4].

A watershed is the perfect organizational unit for managing resources like land and water to lessen the effects of natural disasters and achieve sustainable development [5]. For water resources to be used sustainably, a catchment's available water must be quantified. The arrangement of the earth's surface, its shape, and the dimensions of its landforms are measured and mathematically analyzed through morphometry. The linear, aerial, and relief elements of the morphometric analysis in quantitative study of river basin evaluation, watershed prioritizing for soil and water conservation, and natural resource management at the micro level, morphometric characteristics are of great value [3]. In this study, which primarily focuses on geometry, evaluations of morphometric parameters like stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), and form factor ratio are given more weight (Rf) etc.

According to many morphometric researches, drainage basin morphology reflects different geological and geomorphological processes across time, which is a generally accepted morphometric principle. It is commonly known that drainage morphometry plays a major role in understanding how landforms form, the physical qualities of the soil, and how erosion occurs [6, 7]. The creation of quantitative physiographic methods to characterize the development and behavior of surface drainage networks has received significant attention in geomorphology during the past several decades [8, 9, 10].

The majority of earlier morphometric investigations relied on arbitrary regions or specific channel segments. The most sensible option is to use the watershed as the base unit in morphometric analysis [11, 12]. A watershed is the surface area that is completely or partially drained by one or more specific water courses. It can be thought of as a fundamental erosional landscape element where water and land resources interact visibly. These are, in reality, the basic building blocks of the fluvial environment, and a lot of research has been done on their geometrical features, such as the topology of the stream networks and the quantitative description of drainage texture, pattern, and shape [13, 9, 14].

Given that all hydrologic and geomorphic processes take place inside the watershed, the morphometric properties at the watershed scale may hold significant information on its formation and growth [15, 16]. The appraisal of river basins, the prioritizing of watersheds for soil and water conservation, and the management of natural resources at the watershed level all benefit greatly from the quantitative analysis of morphometric features. An essential component of the characterization of watersheds is the quantitative description of the drainage system [17, 18, 19].

A watershed's morphometric analysis offers quantitative information about how watersheds are described [20]. Many academics have used RS and GIS approaches to do morphometric analysis of river basins have worked on Sukhumi lake catchment in the Shiwalik hills for the delineation and prioritization of soil erosion areas by GIS and RS [5]. According to numerous morphometric researches, a widely accepted morphometric concept is that drainage basin morphology reflects different geological and geomorphological processes across time [21]. It is commonly known that drainage morphometry has a big impact on our comprehension of how soils originate, how they behave physically, and how they erode.

Materials and Methods

Study Area

The study was conducted at the Gojeb River watershed, a part of the Omo-Gibe basin in Ethiopia. The Omo-Gibe basin is the third-largest perennial river in Ethiopia next to the Baro Akobo and Blue Nile rivers it lies between 5° 31′ to 10° 54′ N and 33° 0′ to 36° 17′ E and covers about 79,000 km2 of land area in South and Southwest Ethiopia [22]. The Gojeb watershed is one of the major watersheds in the Omo-Gibe basin and is situated in the southern part of the country as shown in the below figure which covers an area of 6932.345 km2. Gojeb watershed is located between 07°00′N & 08°00′N latitude and between 35°40′E & 37°20′E longitude. Agriculture is the main occupation in the area.

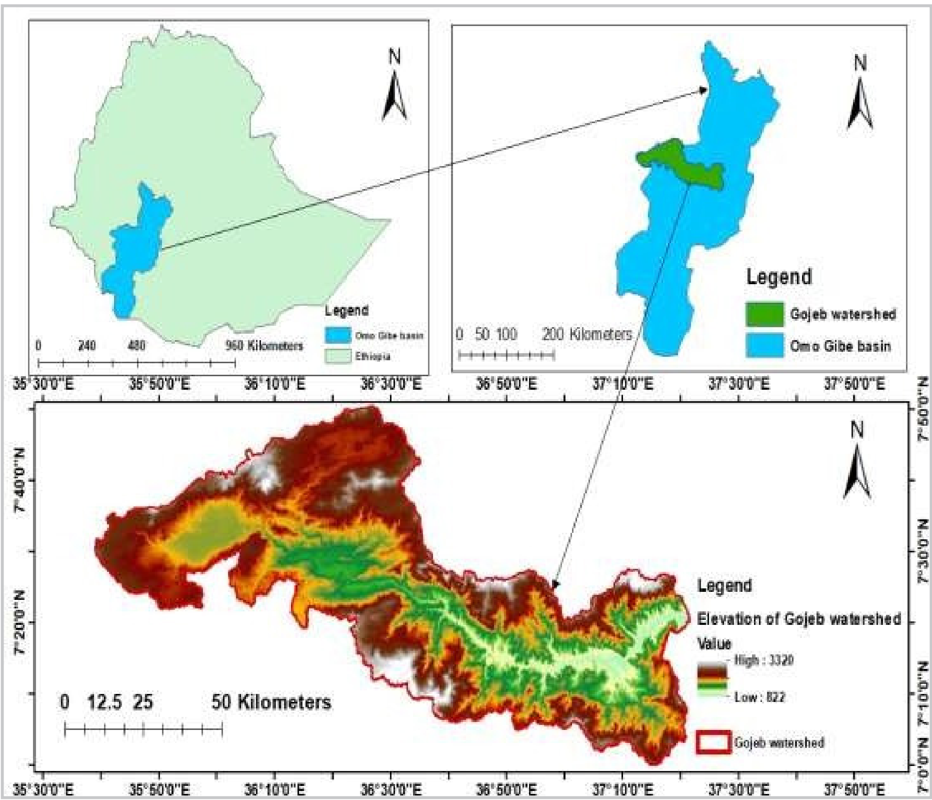

Figure 1: Study area location

Data and Methodology

With a spatial resolution of 12.5m*12.5m, SRTM v3 DEM data were used to perform the morphometric computation. Radar interferometry is used to create a nearly global digital elevation model using SRTM data. The sub-basins and morphometric analysis, such as linear and aerial features, were delineated using the hydrology tool of Arc GIS 10.4 (spatial analyst). Moreover, hydrological data was recovered using DEM, including drainage networks and the border used to define the watershed

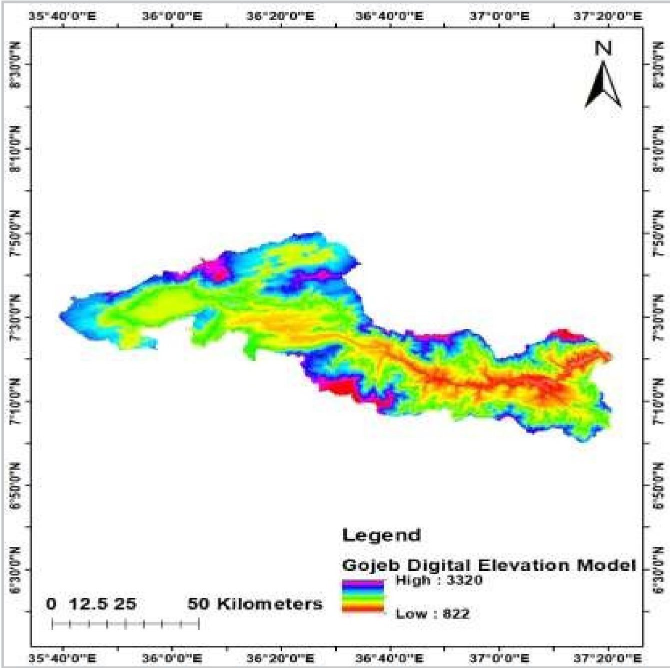

Figure 2: Digital elevation model map the study area

The Major Steps to Process Dem to Delineate a Watershed as Follows

Fill the Depressions

The cells in this step are referred to as depressed cells if their elevation is lower than that of the neighboring cells. In this instance, the noise in the sensors will cause DEM to produce depressed cells when extracting a watershed parameter from DEM data [22]. The fill option removed the sinks to lessen the drainage discontinuities. An eight-flow direction matrix (D8) is used in the depression filling technique to get accurate DEM data. One of the most popular techniques for obtaining drainage networks from DEM data is the D8 approach [12].

Flow Direction

Hydrologic modeling uses flow direction as a key step to determine the direction of flow for each cell. It is necessary to complete the filling procedure before choosing the flow direction. In this work, the filled DEM was utilized to identify the flow directions using the D8 methodology, one of the simplest ways to determine each cell's direction of flow based on the eight cells around it [23]. Water can flow from one cell to a single adjacent cell using ArcGIS-hydrology tools (Fig. 3), and the steepest descent's direction can be recorded in many ways [24].

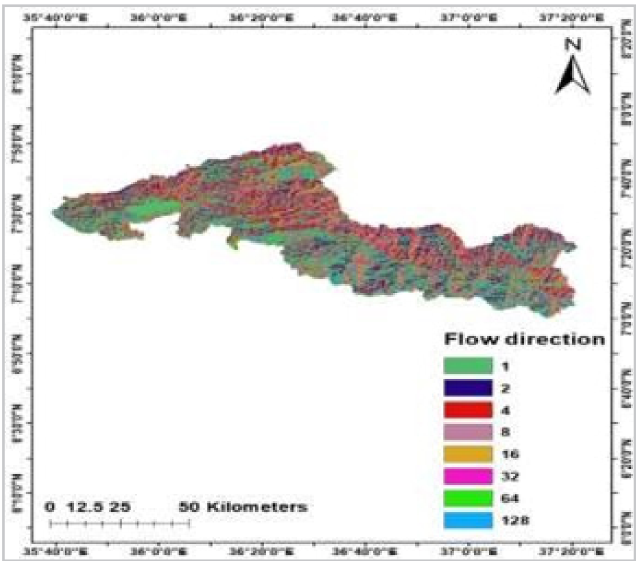

Figure 3: Flow direction map

Flow Accumulation

Each cell is given a value equal to the number of cells that flow into it in this stage [11]. The flow accumulation process (Fig. 4), which is dependent on the flow direction of each cell, was used to create the drainage network [25]. Pour points, where water rushes out of an area, which are the deepest points in the watershed boundaries, can be used to define the watersheds.

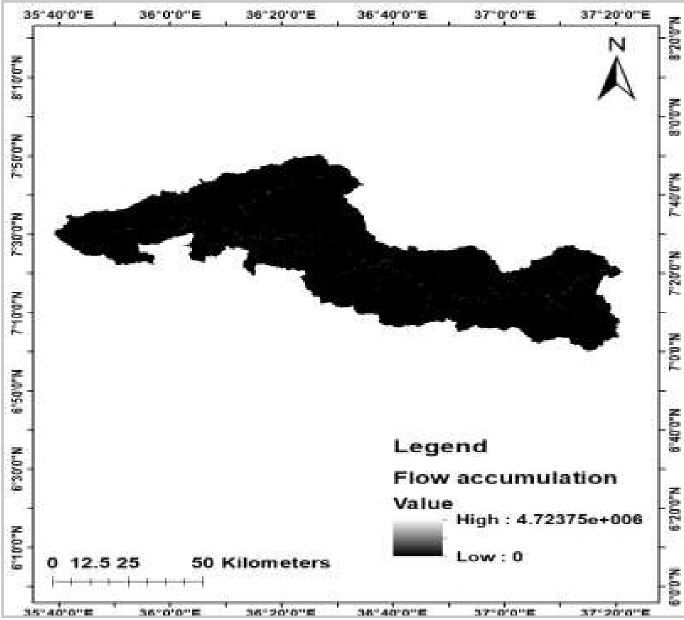

Figure 4: Flow accumulation map

Morphometric Analysis of Basin

The following paragraphs provide descriptions of several morphometric metrics. The morphometric parameters of the drainage basins in the research area are summarized in Table 1

A. Stream Order: Under Strahler's approach, the higher order is preserved when two channels with different orders connect. This study used Strahler's system, which is a slightly modified Horton system [18].

B. Stream Length: Using Horton's suggested law, the stream length was estimated. One significant hydrological aspect of the basin is stream length. The length of the stream segments as a whole often reaches its maximum in the first order and then declines as stream order rises. [19].

C. Drainage density: In terms of Km/Km2, drainage density is the ratio of the sum of all channel segment lengths for all orders inside a basin to the basin's surface area. It serves as a key indicator of the stream's linear scale [18].

D. Stream Frequency: This value is the sum of all the streams for all orders in a certain area [26].

Table 1: Morphometric Parameters of a Drainage basin

Type	Morphometric Parameters	Formula/Definition	References
Linear	Stream order	Hierarchical order	Strahler,1964
Linear	Stream Length	Length of the stream	Hortan, 1945
Aerial	Drainage density	$Dd = \frac{L}{A}$ L= total stream length A= The basin area	Hortan, 1945
Aerial	Stream frequency	$Fs = \frac{N}{A}$ N=Total number of the stream. A= The basin area	Hortan, 1945

The watersheds were separated from the DEM with a spatial resolution of 12.5*12.5 m using GIS Hydrology tools. The DEM is in Geo TIFF format and is related to the WGS84 geoid and UTM zone 37. The analysis was done to recondition the DEM, and numerous datasets were derived using the hydrology tools. The watershed delineation and extraction of the basin border are then shown in Figure 5 in order to construct the flow direction, flow accumulation, streams order, and a watershed delineation. The vector representation of the network of basins and streams was then created using this data. The data showed a large change in the elevation of the research region; an iterative procedure of the cell was used to estimate the flow direction based on the DEM. The flow accumulation layer in the contributing watershed is then used to determine the pour point. In order to calculate the flow direction and use it in the watershed function, the sub-basins were defined by pour point. Nine sub-watersheds have been established in the research region as a result.

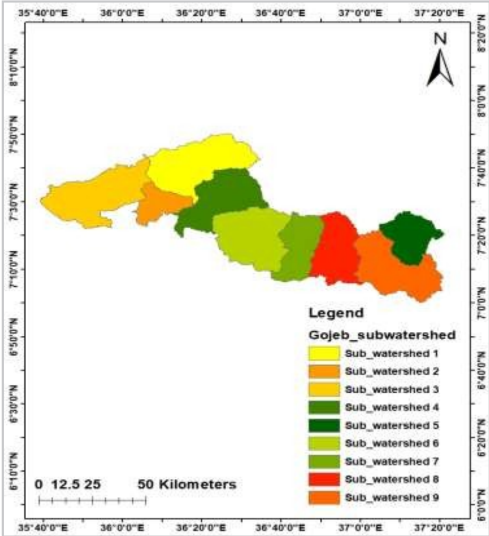

Figure 5: Sub-watershed of Gojeb watershed

Table 2: sub-watersheds information

Sub-watershed	Area	Perimeter
Sub-watershed 1	1040.48	185.37
Sub-watershed 1	344.33	115.11
Sub-watershed 1	1050.03	209.45
Sub-watershed 1	828.25	182.53
Sub-watershed 1	514.76	114.24
Sub-watershed 1	957.58	155.98
Sub-watershed 1	569.64	133.51
Sub-watershed 1	689.12	147.59
Sub-watershed 1	909.00	177.92

Result and Discussion

Morphometric Analysis of Basin

The following paragraphs provide descriptions of several morphometric metrics. The morphometric parameters of the drainage basins in the research area are summarized in Table 3. The delineation of nine sub-basins with nine streams in each has resulted in drainage densities of 0.90, 0.89, 1.07, 0.84, 0.83, 0.83, 0.75, 0.77, and 0.78 km/km2 (respectively). Results of the morphometric study were summarized in Table 3. In addition, the order of the streams was computed. There are 1763 streams totaling 941 meters in length. 2573 km are of first order, 503 are of second order, and 3755 have a total length of 1128 km. With a total length of 696, 1144 of the 46 km are third order. There are 519 fourth-order streams totaling 56 kilometers in length. With a total length of 796, 1284 km, 86 km are fifth order. 615 km, or 66 km, are sixth order, and they total 429 km. 7th-order streams make up 69 km, and there are 873 of them totaling 529 km. Sixth-order distances are 72 km, and ninth-order distances are 985, with a total length of 708.38 km.

Table 3:The morphometric analysis result

Basin No	Area Km2	Length km	Sum of stream	Drainage density	Stream frequency
1	1040.48	941.26	1763	0.90	1.87
2	344.33	307.09	503	0.89	1.64
3	1050.03	1128.46	3755	0.99	3.33
4	828.25	696.56	1144	0.84	1.64
5	514.76	425.86	519	0.83	1.22
6	957.58	796.66	1284	0.83	1.61
7	569.64	429.69	615	0.75	1.43
8	689.12	529.72	873	0.77	1.65
9	909.00	708.38	985	0.78	1.39

Stream Order

The sub-stream watershed's order is thought to be a crucial factor in determining how much water is discharged. The figures below explain the stream order for all of the sub-basins that were analyzed, with ninth order being the highest stream order in the study area (Fig. 6). The identification and characterization of watersheds using ArcGIS software in a methodical manner are represented in this study. Low-resolution DEM (12.5*12.5m) was employed in this investigation to cut down on computational time and storage needs. Nonetheless, it is advised that future research use high-resolution data because it frequently yields more precise results in terms of channel length and channel slope, particularly in flat regions. For better results, this research can be expanded to find additional watershed polygon properties, such as soil type and land use indicators. It provides a foundation for the definition and characterization of watersheds. The drainage system and watersheds have been identified using the above- described methods.

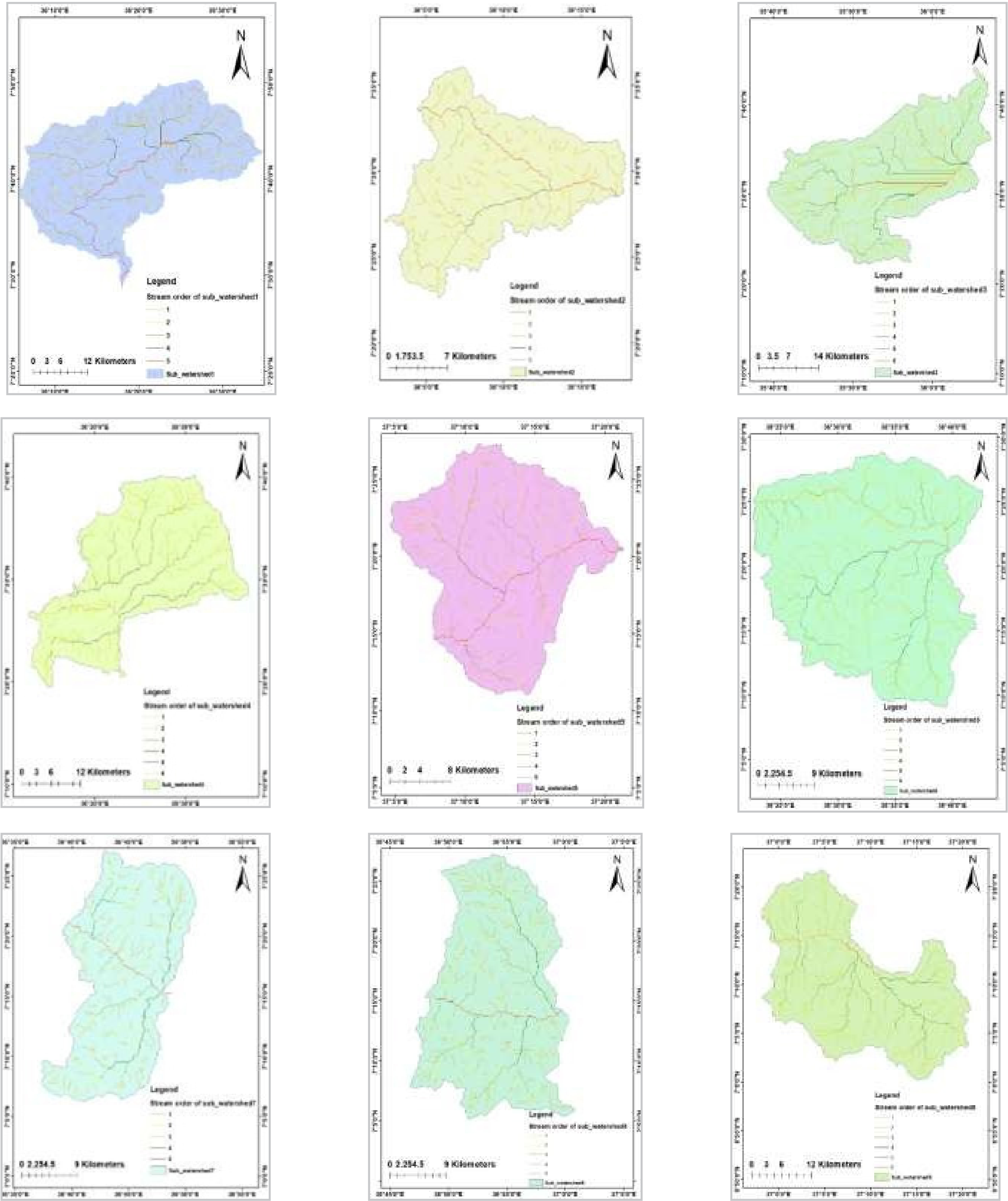

Figure 6: Streams order of the sub-watershed 1, 2, 3, 4, 5, 6, 7, 8 and 9

Conclusion

Before beginning any hydrological study, the drainage system must undergo morphometric analysis. Determining the behavior of stream networks and how they interact with one another is crucial in many studies of water resources. A reliable method for drainage delineation is remote sensing satellite data combined with GIS approaches. These have been updated, and this combined with older records creates a clear picture that allows geomorphologists to draw specific conclusions about the drainage basin. In the current study, morphometric analysis of the Gojeb River basin has been defined based on a variety of drainage parameters using remote sensing satellite data and the most modern GIS tools for drainage analysis. It is assumed that the Gojeb River is a part of a ninth-order basin. Lower order streams predominate primarily in the Gojeb watershed. Measurements of the linear, aerial, and relief characteristics of basins are used to carry out the morphometric analysis. A thorough morphometric analysis of each sub- watershed reveals dendritic drainage patterns that point to homogenous lithology and variations in Rb values among the sub-watersheds that can be attributed to topographic and geometrical development. First-order streams exhibit the highest stream order frequency, followed by second-order streams. As a result, it can be seen that the stream frequency decreases as the stream order increases and vice versa. The stream frequency results reveal a positive link between rising stream population and increasing drainage density in all the sub-basins. In this study, the Gojeb river watershed was delineated and its various morphometric parameters were computed using an integrated remote sensing and GIS technique. Each of the nine sub-watersheds was divided into nine streams, and each one's drainage density was determined to be 0.90, 0.89, 0.99, 0.84, 0.83, 0.83, 0.75, 0.77, and 0.78 km/km2. In addition, stream orders were calculated. There are 1763 streams with a length of 941.26 km as the first order, 503 streams with a length of 307.09 km as the second order, 3755 streams with a total length of 1128.46 km as the third order, 1144 streams with a total length of 696.56 km as the fourth- order streams, and 519 streams with a total length of 425.86 km as the fifth order, 1284 with a length 796.66 km as sixth-order, 615 with a total length 429.69 km as seventh order, 873 with a total length 529.72 km as eighth-order streams, and 985 with a total length 708.38 km as ninth order. In comparison to traditional approaches, the derivation of data (flow direction, flow accumulation, basin, and sub-basins) using GIS would be very helpful in choosing a water harvesting location because it requires less time and money and produces findings that are acceptable. A systematic approach is offered to define and describe watersheds, and this information is then used to a case study.

References

1. Kumar, P., & Kshitij, R. (2017). A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. Applied Water Science, 7, 217–232.
2. Wagh, S. (2022). A GIS-based morphometric prioritization of watersheds for soil erosion planning: A case study. https://doi.org/10.21203/rs.3.rs-795826/v1
3. Suma, B. N., & Srinivasa, C. V. (2017). A study on morphometric parameter of a watershed for sustainable water conservation. International Journal of Civil Engineering and Technology, 8, 271–278.
4. Gajbhiye, S. (2015). Morphometric analysis of a Shakkar River catchment using RS and GIS. International Journal of u- and e- Service, Science and Technology, 8, 11–24.
5. Patil, N. P., Kadale, A. S., & Mhetre, G. S. (2015). Assessment of morphometric characteristics of Karwadi-Nandapur micro watershed using remote sensing and geographical information system. International Journal of Scientific & Technology Research, 4, 175–179.
6. Kuntamalla, S., Nalla, M., & Saxena, P. R. (2018). Morphometric analysis of drainage basin through GIS: A case study from south Western part of rangareddy district, telangana state, India. International Journal of Advance Research in Science and Engineering, 7, 13-25.
7. Iqbal, M., Sajjad, H., & Bhat, F. A. (2013). Morphometric analysis of Shaliganga Sub Catchment, Kashmir Valley, India using geographical information system. International Journal of Engineering Trends and Technology, 4, 10–21.
8. Moid, M. A., Abhilash, M., Lakshmi, T. V., & Kesava, P. (2019). Remote sensing and GIS based morphometric analysis for three sub-watersheds of Manair River Basin in Telangana, India. Journal of Spatial Hydrology, 15.
9. Mengesha, T. E., Awoke, B. G., & Belay, W. A. (2022). Spatial morphometric characterization of Akaki Watershed. Journal of Remote Sensing & GIS, 11, 1–9.
10. Krishnan, A., & Ramasamy, J. (2022). Morphometric assessment and prioritization of the South India Moyar River Basin sub-watersheds using a geo-computational approach. Geology, Ecology, and Landscapes, 1–11.
11. Lokare, P., Deshmukh, S., & Zende, A. (2021). Geo-morphometric assessment of Nandani River Basin, Western Maharashtra, India using geospatial techniques. International Research Journal of Engineering and Technology, 8, 2637–2646.
12. Lakshminarayana, S. V., Singh, P. K., Patil, P. R., & Jain, A. (2022). Determination of morphological parameters of Tidi Watershed using remote sensing and geographic information system approaches. Water Supply, 22, 3756–3768.
13. Mohamed, E. (2020). Watershed delineation and morphometric analysis using remote sensing and GIS mapping techniques in Qena-Safaga-Bir Queh, Central Eastern Desert. International Journal of Water Resources and Environmental Engineering, 12, 22–46.
14. Qadir, A., Yasir, M., Abir, I. A., Akhtar, N., & San, L. H. (2020). Quantitative morphometric analysis using remote sensing and GIS techniques for Mandakini River Basin. IOP Conference Series: Earth and Environmental Science, 540, 012021.
15. Farhan, Y. (2017). Morphometric assessment of Wadi Wala Watershed, Southern Jordan using ASTER (DEM) and GIS. Journal of Geographic Information System, 9, 158–190.
16. Sukristiyanti, S., Maria, R., & Lestiana, H. (2018). Watershed-based morphometric analysis: A review. IOP Conference Series: Earth and Environmental Science, 118, 012028. https://doi.org/10.1088/1755-1315/118/1/012028
17. Tesema, T. A. (2022). Erosion hotspot mapping using integrated morphometric parameters and land use/land cover of Jigjiga Watershed, Ethiopia. Heliyon, 8, e09780. https://doi.org/10.1016/j.heliyon.2022.e09780
18. Obeidat, M., & Awawdeh, M. (2021). Morphometric analysis and prioritisation of watersheds for flood risk management in Wadi Easal Basin (WEB), Jordan, using geospatial technologies. Journal of Flood Risk Management, 14(3), e12720. https://doi.org/10.1111/jfr3.12720
19. Said, S., Siddique, R., & Shakeel, M. (2018). Morphometric analysis and sub-watersheds prioritization of Nagmati

River watershed, Kutch District, Gujarat using GIS based approach. Journal of Water and Land Development, 39, 131–139. https://doi.org/10.2478/jwld-2018-0059
20. Aziz, N. A., & Abdulrazzaq, Z. T. (2020). GIS-based watershed morphometric analysis using DEM data in Diyala River, Iraq. Iraq Geological Journal, 53, 36–49.
21. Sisay, M. K. (2022). Catchment morphometric characterization of the Akaki River in the Upper Awash Sub-Basin, Ethiopia. Research Square, 1–18. https://doi.org/10.21203/rs.3.rs-1424071/v1
22. Mekuria, E. T. (2022). Assessment of spatial soil erosion using RUSLE model integration with GIS and RS tools: A case study of Gojeb Catchment, Omo-Gibe Basin, Ethiopia. International Journal of Environmental Protection and Policy, 10(4), 130–139. https://doi.org/10.11648/j.ijepp.20221004.12
23. Jena, R. K., & Dandapat, A. K. (2019). Estimation of morphometric study on Shetrunji River using remote sensing and GIS. EasyChair Preprint. https://doi.org/10.21203/rs.3.rs-1485911/v1
24. Bharath, A., Kumar, K. K., Maddamsetty, R., Manjunatha, M., & Tangadagi, R. B. (2021). Drainage morphometry-based sub-watershed prioritization of Kalinadi Basin using geospatial technology. Environmental Challenges, 5, 100027. https://doi.org/10.1016/j.envc.2021.100027
25. Dhanusree, M. M., & Bhaskaran, G. (2019). GIS-based approach in drainage morphometric analysis of Bharathapuzha River Basin, India. Journal of Geography, Environment and Earth Science International, 20(3), 1–12. https://doi.org/10.9734/jgeesi/2019/v20i330101
26. Mohammed, A., Adugna, T., & Takala, W. (2018). Morphometric analysis and prioritization of watersheds for soil erosion management in Upper Gibe Catchment. Journal of Degraded and Mining Lands Management, 6(1), 1419–1426.