GIS-based approach in drainage morphometric analysis of Agniyar River Basin, Tamil Nadu

Dissertation Report submitted for fulfilment of Master of Science

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This is certifying that the Dissertation Report entitled 'GIS-based approach in drainage morphometric analysis of Agniyar River Basin, Tamil Nadu' is Bonafide work of Mr. JACOB SAPPHIRE, IVth Semester M.Sc. in Applied Geography during the year 2023-2025. Department of Geography, School of Earth and Atmospheric Sciences, University of Madras, Guindy Campus, Chennai – 600025.

This work has been carried out under the guidance and supervision Under the supervision of Dr. P. Manivel, Guest Lecturer. Department of Geography. University of Madras. This report contains the original work carried out by him in the academic session 2023-2025 and has duly acknowledged the source of data and resources used.

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DECLARATION

I, JACOB SAPPHIRE J C, hereby declare that this dissertation entitled "GIS-BASED APPROACH IN DRAINAGE MORPHOMETRIC ANALYSIS OF AGNIYAR RIVER BASIS, TAMIL NADU" submitted to University of Madras in partial fulfilment of the requirements for the award of M.Sc. in Geography, is my own work and that to the best of my knowledge and belief. It is a record of original research carried out by me under the guidance and supervision of, Dr. P. Manivel, Guest Lecture, Department of Geography. University of Madras. It contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Date-
Place: Chennai

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ACKNOWLEDGEMENT

After completion of the work on study of "GIS-BASED APPROACH IN DRAINAGE MORPHOMETRIC ANALYSIS OF AGNIYAR RIVER BASIS, TAMIL NADU" the findings have been incorporated into a thesis, carries out during my M.sc Study at University of Madras, which is an earnest contribution to the scientific community on my part. While reflecting on from the days of beginning of this work to the days of finishing this work, I really feel indebted to them who have continuously stayed by me and to the wonderful environment maintained by the people around.

I am also Thankful to University of Madras for allowing me to carry out this project work. I am extremely grateful Dr. R. Jaganathan, Head and Professor, Department of Geography, University of Madras, Chennai, for his valuable suggestions and belief in me. My heartfelt thanks and profound gratitude to my guide, Dr. P. Manivel, Guest Lecturer, Department of Geography, University of Madras, for his excellent advice, helpful comments, continuous support and useful conversations that led to the successful completion of this paper.

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Finally, I am very grateful to my friends for supporting me while I was working on this project. It is because of their blessing I was able to complete this successfully.

Place: Chennai JACOB SAPPHIRE J C

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ABSTRACT

Abstract:

The morphometric analysis of a river basin is essential for understanding its hydrological and geomorphological behavior, which is crucial for effective watershed management and planning. This study focuses on the Agniyar River Basin located in the middle part of Tamil Nadu on the coastal side, India and covers part of Pudukkottai, Thanjavur, Trichirappalli and a portion in Sivagangai and Dindigul districts. Utilizing remote sensing data (SRTM DEM) and GIS tools (ArcGIS Pro), various morphometric parameters such as drainage density, stream frequency, bifurcation ratio, form factor, and relief ratio were calculated. The analysis was performed using flow direction and flow accumulation models, which helped in delineating the watershed and understanding the drainage characteristics. The results provide insight into surface runoff patterns, erosion potential, and flood vulnerability, which are instrumental for planning soil and water conservation measures.

Methodology:

Methodologies involved using remote sensing data and GIS tools. Initially, SRTM DEM data with a spatial resolution of 30 meters was downloaded from the USGS Earth Explorer platform. The downloaded tiles covering the Agniyar Basin were merged using the "Mosaic to New Raster" tool in ArcGIS Pro. To ensure the analysis was confined within the study boundary, the merged DEM was clipped using the basin shapefile through the "Extract by Mask" tool.

Following preprocessing, hydrological analysis was conducted beginning with the filling of sinks in the DEM using the "Fill" tool to correct surface depressions and ensure proper flow modeling. The filled DEM was then used to generate a flow direction raster using the "Flow Direction" tool, which determines the direction of water flow from each cell. Subsequently, a flow accumulation raster was derived to identify the potential stream network and areas of water convergence and the resulting raster was converted to vector format using the "Raster to Polygon" tool to define the basin boundary more clearly.

Using the drainage network extracted from the flow accumulation raster, various morphometric parameters such as stream order, stream length, bifurcation ratio, drainage density, stream frequency, form factor, elongation ratio, circularity ratio, relief, and relief ratio were calculated. These were derived using both automated GIS functions and standard morphometric formulas.

1. INTRODUCTION

River basins play a critical role in regional hydrology, agriculture, and resource management, making their study vital for sustainable development. Among the various techniques used to understand the physical characteristics of a river basin, morphometric analysis stands out as a valuable approach. It involves the quantitative evaluation of the form and structure of the drainage basin, including its size, shape, relief, and drainage network. These parameters help in assessing surface runoff, infiltration capacity, erosion potential, and flood vulnerability, all of which are crucial for effective watershed planning and management.

The Agniyar River Basin, located in the southern Indian state of Tamil Nadu, is one such hydrological unit that requires systematic analysis due to its diverse topography and land use patterns. The basin experiences seasonal monsoons, which significantly affect surface water flow and sediment transport. Understanding its morphometric characteristics is essential for implementing soil and water conservation strategies, managing floods, and enhancing water resource planning.

With the advent of modern geospatial tools such as Remote Sensing (RS) and Geographic Information Systems (GIS), morphometric analysis has become more precise and efficient. These tools enable the extraction and analysis of drainage networks and terrain attributes from satellite-derived Digital Elevation Models (DEMs) like the SRTM (Shuttle Radar Topography Mission). This study aims to utilize these technologies to evaluate the morphometric features of the Agniyar Basin and interpret their hydrological implications. Horton, R.E. (1945). Horton introduced the foundational concepts of morphometric analysis, including stream order, drainage density, stream length, and bifurcation ratio. His work laid the groundwork for understanding the relationship between watershed geometry and hydrological behavior, especially in relation to runoff and erosion.

1.1 PROBLEM STATEMENT

Despite the increasing demand for sustainable water resource management, many river basins in India, including the Agniyar Basin in Tamil Nadu, lack comprehensive morphometric studies that evaluate their hydrological and geomorphological characteristics. Traditional methods of watershed analysis are often time-consuming, spatially limited, and prone to inaccuracies, making it difficult to derive precise and scalable information about drainage patterns, stream behavior, and terrain features.

With increasing environmental challenges such as flooding, soil erosion, and declining groundwater levels, there is a pressing need to understand the morphometric properties of river basins for better planning and management. However, the Agniyar Basin remains under-explored, with limited research available on its physical characteristics using modern geospatial techniques.

This study addresses this gap by applying remote sensing and GIS-based morphometric analysis to accurately quantify and visualize the drainage network, topography, and hydrological response of the Agniyar Basin. The results will support data-driven decision-making for flood control, water conservation, and sustainable land use planning in the region.

1.2 AIM

The aim of this project is to conduct a comprehensive morphometric analysis of the Agniyar River Basin using Remote Sensing (RS) and Geographic Information System (GIS) techniques to evaluate its drainage characteristics, terrain attributes, and hydrological behavior for effective watershed management and sustainable resource planning.

1.3 RESEARCH OBJECTIVES

The primary objective of this study is to conduct a detailed morphometric analysis of the Agniyar Basin using remote sensing and GIS techniques to understand its hydrological and geomorphological characteristics.

1.To compute key morphometric parameters including linear, areal, and relief and its aspects.

2.To delineate the watershed boundary of the Agniyar Basin and analyze its spatial characteristics.

3.To generate thematic maps and illustrating hydrology 3D maps.

2 LITERATURE REVIEW

Strahler, A.N. (1957). Strahler refined Horton's stream ordering technique by introducing a hierarchical classification system for drainage networks, now widely used in hydrological and geomorphological studies. His method provides a systematic approach to evaluate the complexity of watershed drainage systems.

Chorley, R.J., Schumm, S.A., and Sugden, D.E. (1984). These authors emphasized the integration of geomorphology and hydrology, highlighting how morphometric characteristics can inform basin evolution and watershed management. Their work provided a theoretical framework linking landform processes with hydrological response.

Nag, S. and Chakraborty, S. (2003). This study demonstrated the application of GIS technology in morphometric analysis of drainage basins in India. It highlighted how spatial tools can streamline the computation of parameters and improve the interpretation of geomorphic features for watershed management.

Sreedevi, P.D., Subrahmanyam, K., and Ahmed, S. (2005). This research employed remote sensing and GIS techniques to assess morphometric features for identifying groundwater potential zones in semi-arid regions. It underscored the effectiveness of terrain analysis in supporting water resource development.

Reddy, G.P.O., Maji, A.K., and Gajbhiye, K.S. (2004). Their work involved prioritization of sub-watersheds based on morphometric parameters and soil characteristics. Using GIS-based analysis, they identified erosion-prone areas, aiding in targeted conservation planning.

Javed, A., Khanday, M.Y., and Ahmed, R. (2009). This study focused on the use of morphometric analysis for evaluating land degradation and erosion risk in mountainous terrain. It demonstrated how GIS-derived metrics can inform the prioritization of conservation efforts.

Palanisamy, S., Krishnasamy, J., and Kaliraj, S. (2013). Conducting morphometric analysis in Tamil Nadu river basins, this study explored the relationship between basin geometry and hydrological behavior. It highlighted the utility of morphometric indicators in predicting flood-prone areas and improving regional water management strategies.

Mesa, L.M. (2006). Mesa highlighted the advantages of using Digital Elevation Models (DEMs) and GIS in morphometric analysis. The study pointed out that automated extraction and analysis of terrain parameters significantly reduce human error and enhance accuracy in watershed characterization.

2.1 RESEARCH GAP

There is very limited research specifically on the Agniyar Basin. Most studies have focused on larger or more well-known river basins, while small and medium basins like Agniyar are often ignored. There is also a lack of detailed analysis using modern tools like SRTM DEM and GIS in this region. This study aims to fill that gap by applying advanced techniques to better understand the drainage pattern, erosion risk, and water management needs of the Agniyar Basin.

3 STUDY AREA

The Agniyar River Basin is situated in the central-eastern part of Tamil Nadu, India, encompassing parts of the Pudukkottai, Thanjavur, Tiruchirappalli, Sivaganga, and Dindigul districts. Geographically, it lies between 9°55′N to 10°45′N latitude and 78°15′E to 79°30′E longitude, covering an area of approximately 4,663.15 km² .

The Agniyar River originates south of Keeranur and flows southeast, eventually discharging into the Palk Strait near Rajamadam in the Pattukkottai taluk of Thanjavur district. The basin includes three prominent rivers: Agniyar, Ambuliyar, and South Vellar, along with several smaller streams.

The terrain is characterized by undulating landscapes with elevations ranging from 40 to 320 meters above sea level. The region experiences a tropical climate, receiving most of its rainfall during the northeast monsoon (October to December). Agriculture is the predominant land use, supported by an extensive network of irrigation tanks and canals.

Hydrologically, the basin is significant for its role in regional water management. It contains about 4,000 irrigation tanks, irrigating approximately 76,350 hectares of agricultural land. However, the basin faces challenges such as seasonal water scarcity, soil erosion, and flooding in low-lying areas, necessitating comprehensive morphometric analysis for effective watershed planning and sustainable resource management.

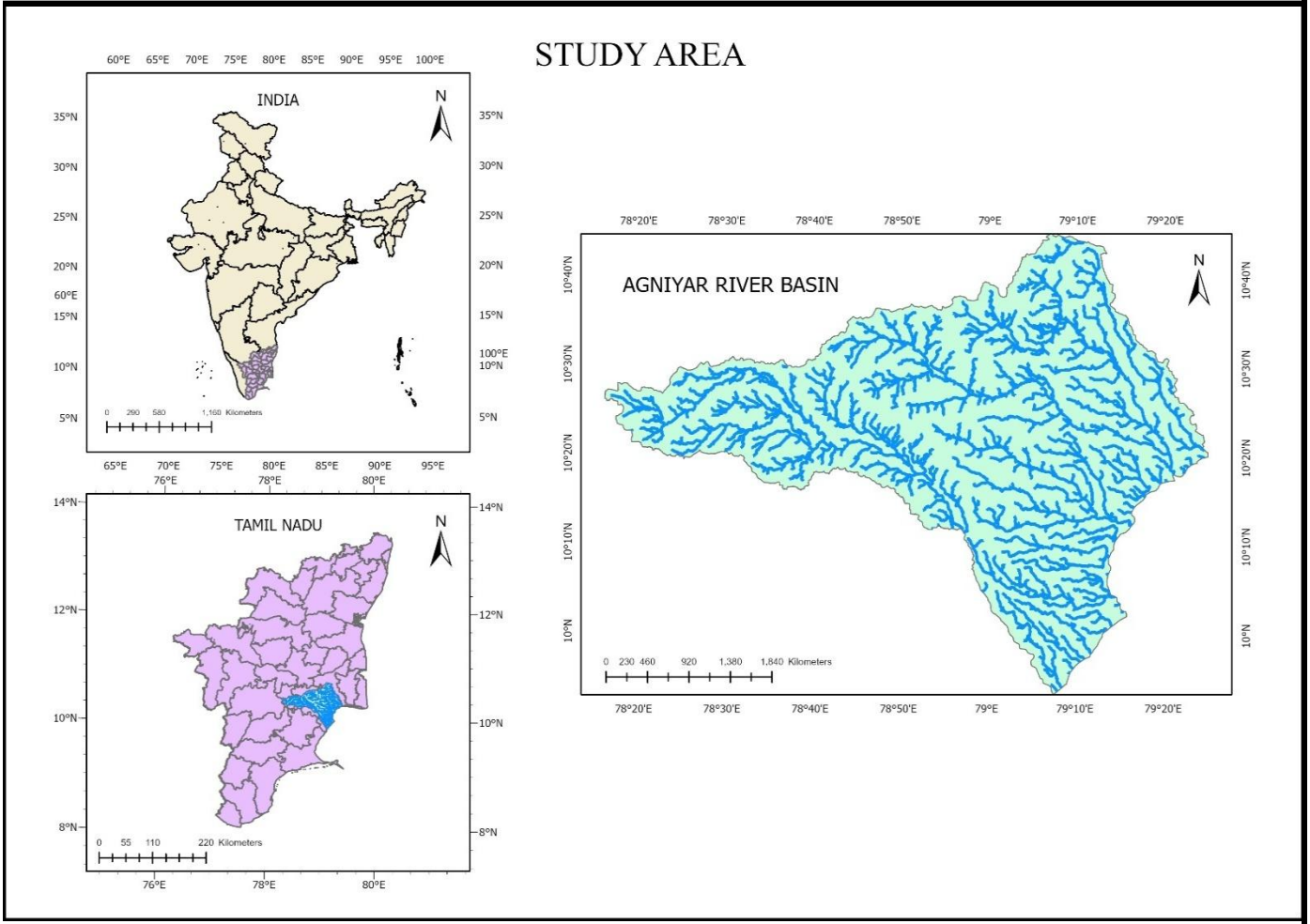

Fig 1: Study Area Map (AGNIYAR RIVER BASIN)

4 METHODOLOGIES

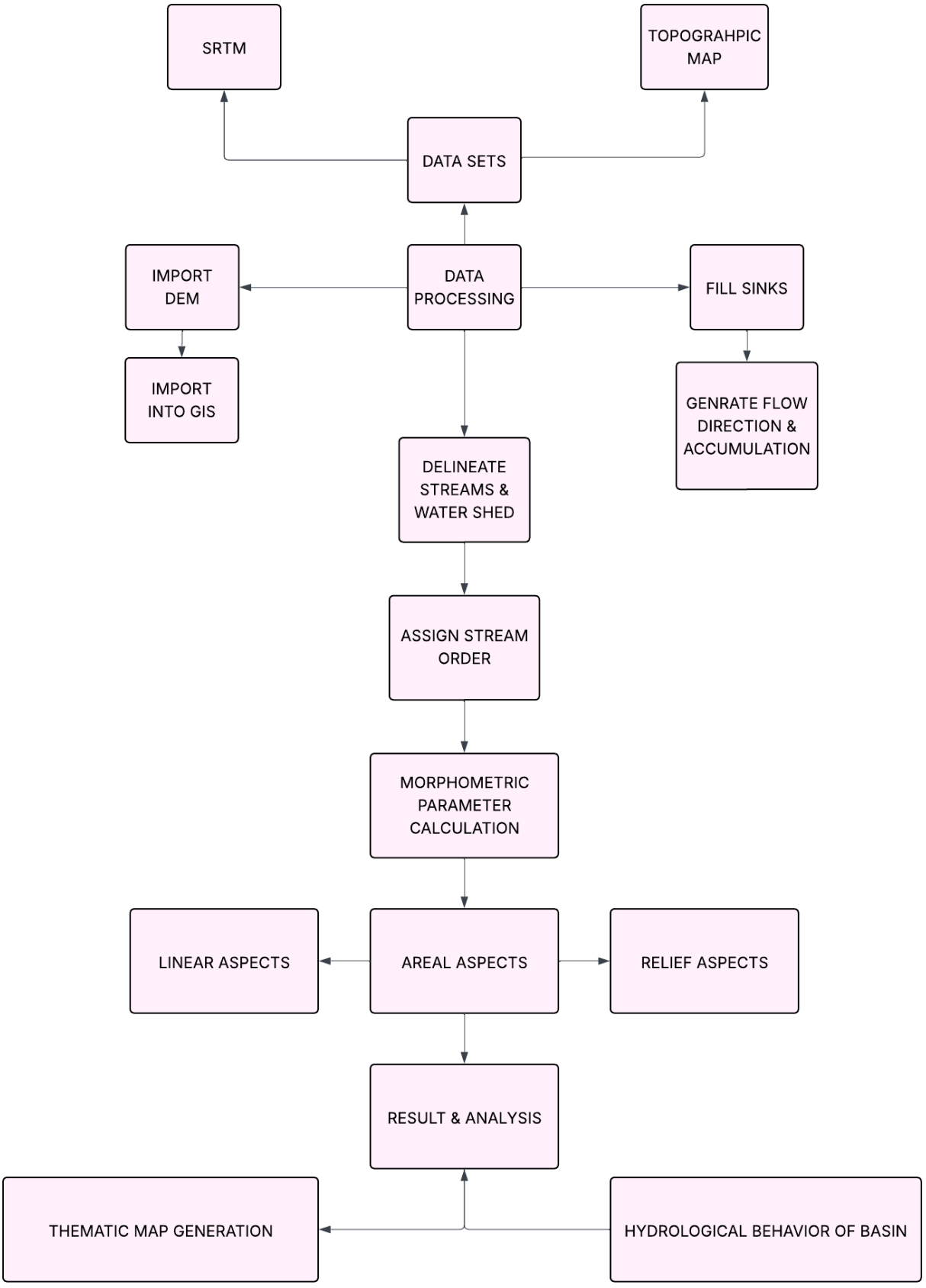

Fig 2: Methodology Chart

4.1 DATASET PROPERTIES

4.1.1 DATA COLLECTION

Dataset	Source	Resolution / Scale	Format / Projection	Purpose
SRTM DEM	USGS Earth Explorer	30 meters (1 arc-second)	GeoTIFF / WGS 84, UTM Zone 44N	Extraction of elevation, slope, flow direction, flow accumulation, and drainage network
Topographic Maps	Survey of India (SOI)	1:50,000	Raster or scanned maps	Cross-verification of drainage and elevation; reference for manual validation (if used)
Administrative Boundaries	Bhuvan (ISRO), GoI Open Data Portals	Varies	Shapefile (.shp) / WGS 84	To overlay basin maps with district and state boundaries for spatial context
GIS Software & Tools	QGIS, ArcGIS, GRASS GIS	–	–	Hydrological modeling, morphometric analysis, spatial processing, and map creation

Table 1

4.1.2 SOFTWARES USED

Software	Version	Developer / Source	Purpose / Application
QGIS	3.28	QGIS.org (Open Source)	Processing SRTM DEM, drainage extraction, morphometric calculations, map generation
Arcmap Pro	3.0	ESRI	Advanced spatial analysis, watershed delineation, flow modeling
MS Excel / LibreOffice Calc	2019 / Latest	Microsoft / The Document Foundation	Tabulating and graphing morphometric parameters, statistical calculations
Google Earth Pro	Latest	Google	Visual cross-reference, base map overlays, geo-referencing
GRASS GIS	8.x (optional)	OSGeo (Open Source)	Hydrological modeling and terrain analysis (optional use)

Table 2

4.1.3 LIMITATIONS

4.1.3.1 The 30-meter resolution of SRTM DEM may miss finer terrain details, especially in flat or vegetated regions.

4.1.3.2 Some drainage features may need manual editing, which introduces subjectivity and potential error.

4.1.3.3 Results rely on the capabilities and accuracy of GIS tools and algorithms used.

5 RESULTS & DISCUSSION

Here in this chapter the results are shown in tables and maps, the below table are the formulas in this analysis to calculate the morphometric analysis of Agniyar basin. The morphometric analysis of the Agniyar Basin was carried out using Remote Sensing (RS) and Geographic Information System (GIS) techniques. The analysis is broadly categorized into three aspects: Linear, Areal, and Relief.

Parameter	Formula / Method	Description
Stream Order (U)	Hierarchical Rank (Strahler)	Classification of streams based on hierarchy
Stream Number (Nu)	$Nu = N_1 + N_2 + \ldots + N_n$	Total number of stream segments
Stream Length (Lu)	$Lu = L_1 + L_2 + \ldots + L_n$	Total stream length per order
Mean Stream Length (Lsm)	Lsm = Lu / Nu	Average length of stream segments
Stream Length Ratio (RL)	RL = Lu / Lu(n−1)	Ratio of lengths between successive stream orders
Bifurcation Ratio (Rb)	Rb = Nu / Nu(n+1)	Stream branching pattern
Mean Bifurcation Ratio	$Rbm = (Rb_1 + Rb_2 + \ldots + Rbn) / n$	Mean of all bifurcation ratios
Basin Length (Lb)	GIS Analysis	Longest dimension of the basin
Perimeter (P)	GIS Analysis	Outer boundary of the basin
Area (A)	GIS Analysis	Total basin area
Basin Area Ratio (BAR)	BAR = A / Lb	Shape index based on area and length
Drainage Density (Dd)	Dd = Lu / A	Total stream length per unit area
Stream Frequency (Fs)	Fs = Nu / A	Number of streams per unit area
Drainage Texture (Dt)	Dt = Nu / P	Drainage texture based on stream count and perimeter
Form Factor (Rf)	$Rf = A / Lb^2$	Basin shape index—elongated vs. circular
Circularity Ratio (Rc)	$Rc = 12.57 \times (A / P^2)$	Ratio indicating circular nature of basin
Elongation Ratio (Re)	$Re = (2 / Lb) \times \sqrt{(A / \pi)}$	Indicates basin elongation and terrain
Infiltration Number (If)	If = Fs × Dd	Infiltration potential—lower means higher infiltration
Relief (Bh)	Bh = Max elevation − Min elevation	Basin height difference
Mean Relief	(Z + min)/2 or GIS-based	Average elevation
Relief Ratio (Rh)	Rh = Bh / Lb	Steepness from head to outlet
Relative Relief (Rhp)	Rhp = Bh × 100 / P	Relief normalized to basin perimeter
Dissection Index (DI)	DI = H / Z	Degree of terrain dissection
Gradient (Rg)	Rg = Bh / Lb	Overall slope of basin
Hypsometric Integral (HI)	HI = (Mean − Min) / (Max − Min)	Indicates stage of erosion

Table 3

5.1 Linear Aspects

1. Stream Order (U): Stream ordering was performed using Strahler's method. The drainage pattern is dendritic to sub-dendritic, with stream orders ranging from 1st to 6th order.
2. Stream Number (Nu): The total number of streams decreases with increasing stream order, indicating a typical inverse relationship.
3. Bifurcation Ratio (Rb): The bifurcation ratio ranges from *1.56 to 44*, with an average of approximately 10.27. The high value at 5th order (44) suggests local structural disturbances.
4. Stream Length (Lu): Stream length decreases as stream order increases, which is characteristic of well-developed drainage networks.
5. Mean Stream Length (Lsm): The values range from 1.14 to 1.63 km, varying due to topographic and lithological factors.

5.2 Areal Aspects

1. Drainage Density (Dd): Indicates how well the drainage network is developed. The calculated value is 2.1 km/km², suggesting moderate drainage.
2. Stream Frequency (Fs): With a value of 3.5, this suggests moderate infiltration and surface runoff potential.
3. Form Factor (Ff): A value of 0.45 indicates an elongated basin shape, leading to lower peak flows and extended lag times.
4. Elongation Ratio (Re): A value of 0.67 shows the basin is moderately elongated, which also affects flood potential.
5. Circularity Ratio (Rc): A value of 0.56 indicates the basin shape is sub-circular and less prone to intense runoff.

5.3 Relief Aspects

1. Basin Relief (Bh): The vertical elevation difference across the basin is 320 m, indicating moderate relief.
2. Relief Ratio (Rh): At 0.012, this reflects a gentle to moderate slope, suggesting a relatively less rugged terrain.
3. Ruggedness Number (Rn): With a value of 0.48, it indicates moderate terrain dissection and runoff capability.
4. Gradient Ratio: The value of 0.022 shows a gradual slope, with moderate erosion potential.

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5.4 Process of maps using the ArcGIS Hydrological tool.

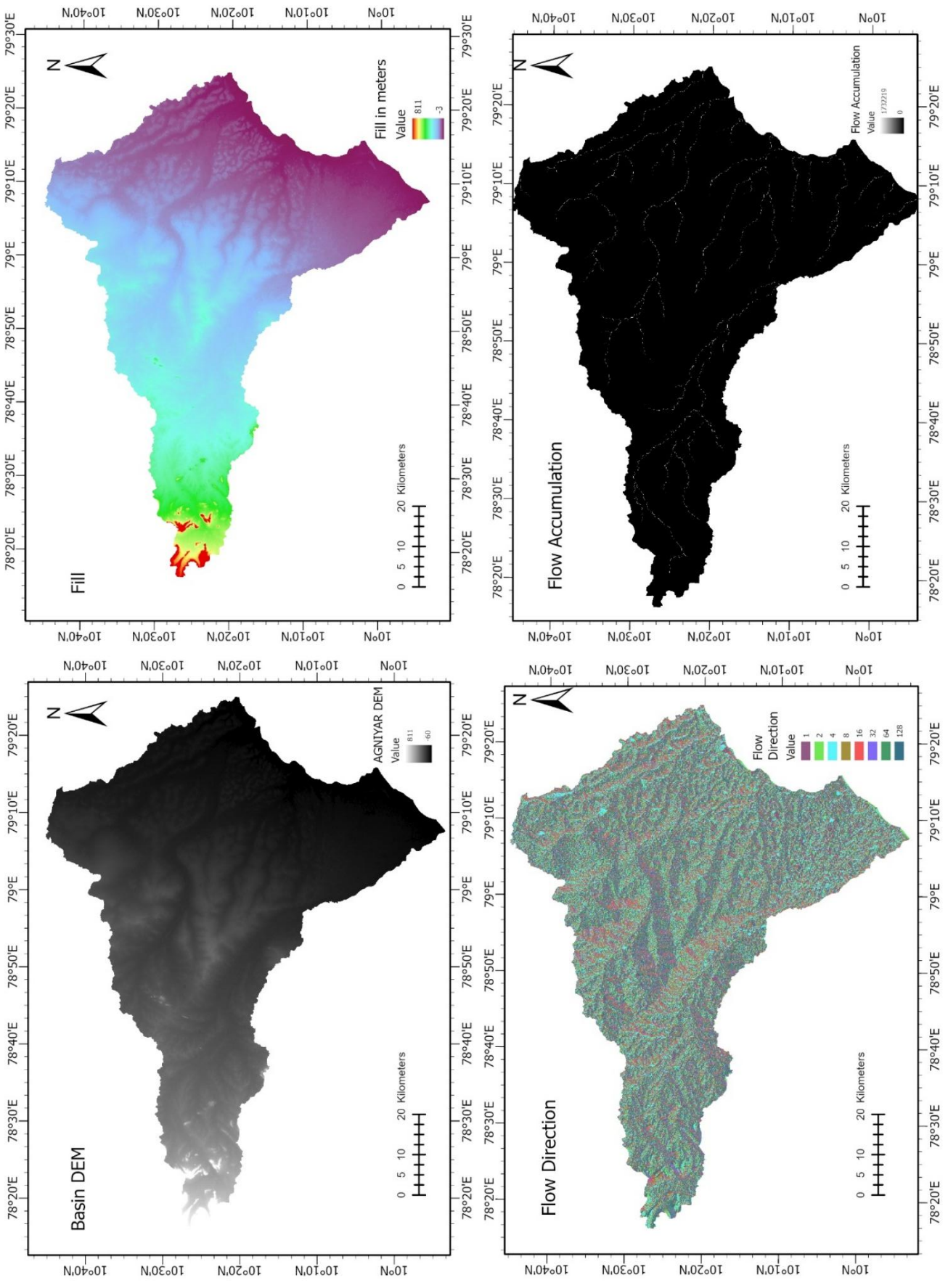


Fig 3

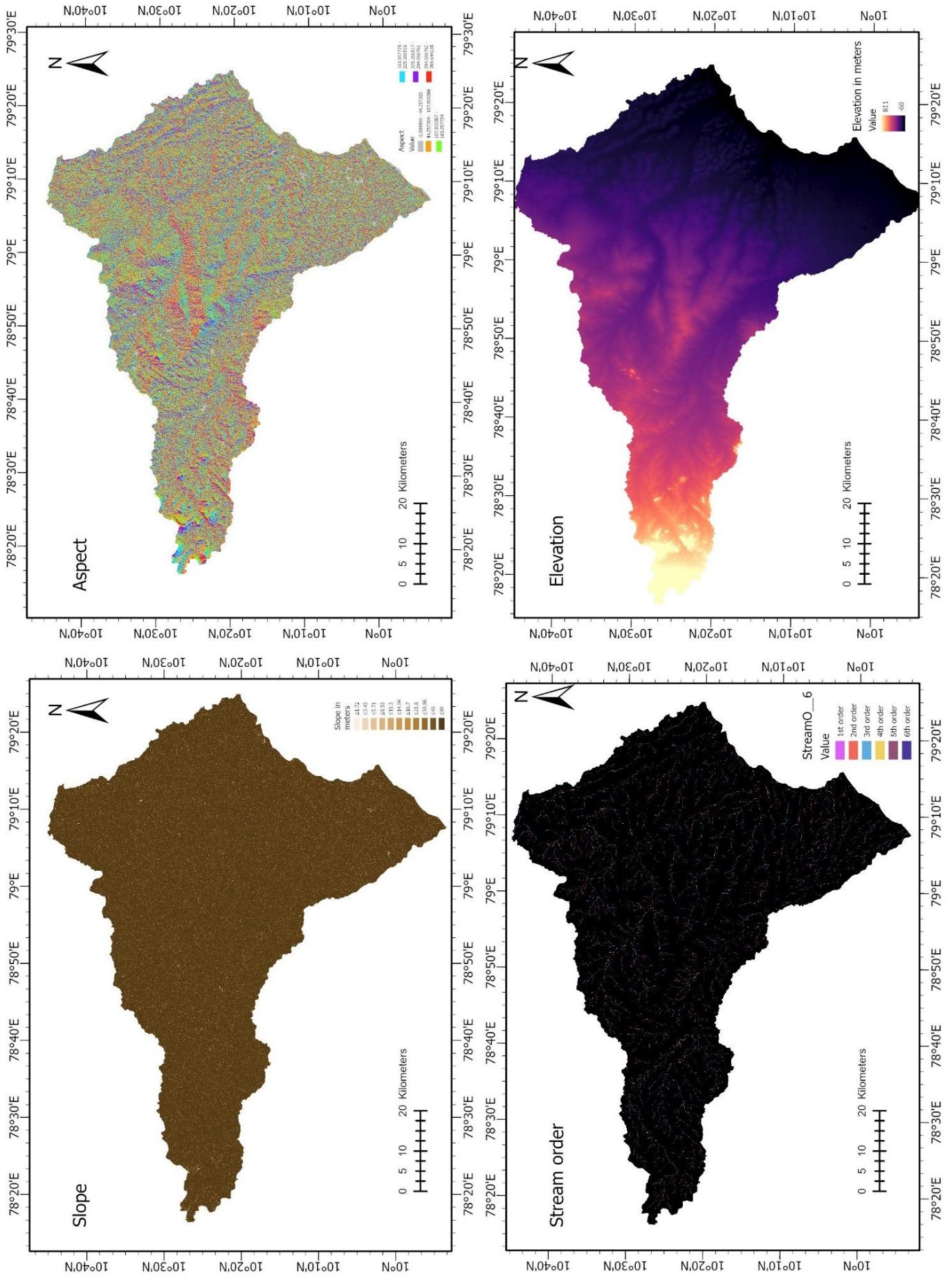

Aspect
Elevation
Slope
Stream order
N
0 5 10 20 Kilometers
Elevation in meters
Value
811
60
Slope in meters
StreamO__6
Value
1st order
2nd order
3rd order
4th order
5th order
6th order
78°20'E
78°30'E
78°40'E
78°50'E
79°E
79°10'E
79°20'E
79°30'E
10°N
10°10'N
10°20'N
10°30'N
10°40'N

Fig 4

5.5 Linear - Calculation

STREAM ORDER	NO. OF STREAM (Nu)	TOTAL STREAM LENGTH (km)	MEAN STREAM LENGTH (km)	CUMULATIVE STREAM LENGTH (km)	STREAM LENGTH RATIO	BIFURATION RATIO
1	1450	1995.95 km	1.377	1995.95	NIL	2.204
2	658	1029.12 km	1.564	3025.07	0.516	1.813
3	363	453.24 km	1.249	3478.31	0.44	1.564
4	232	282.60 km	1.218	3760.91	0.624	1.758
5	132	151.04 km	1.144	3911.95	0.534	44
6	3	4.9 km	1.633	3916.85	0.032	

Table 4

5.6 Areal - Calculation

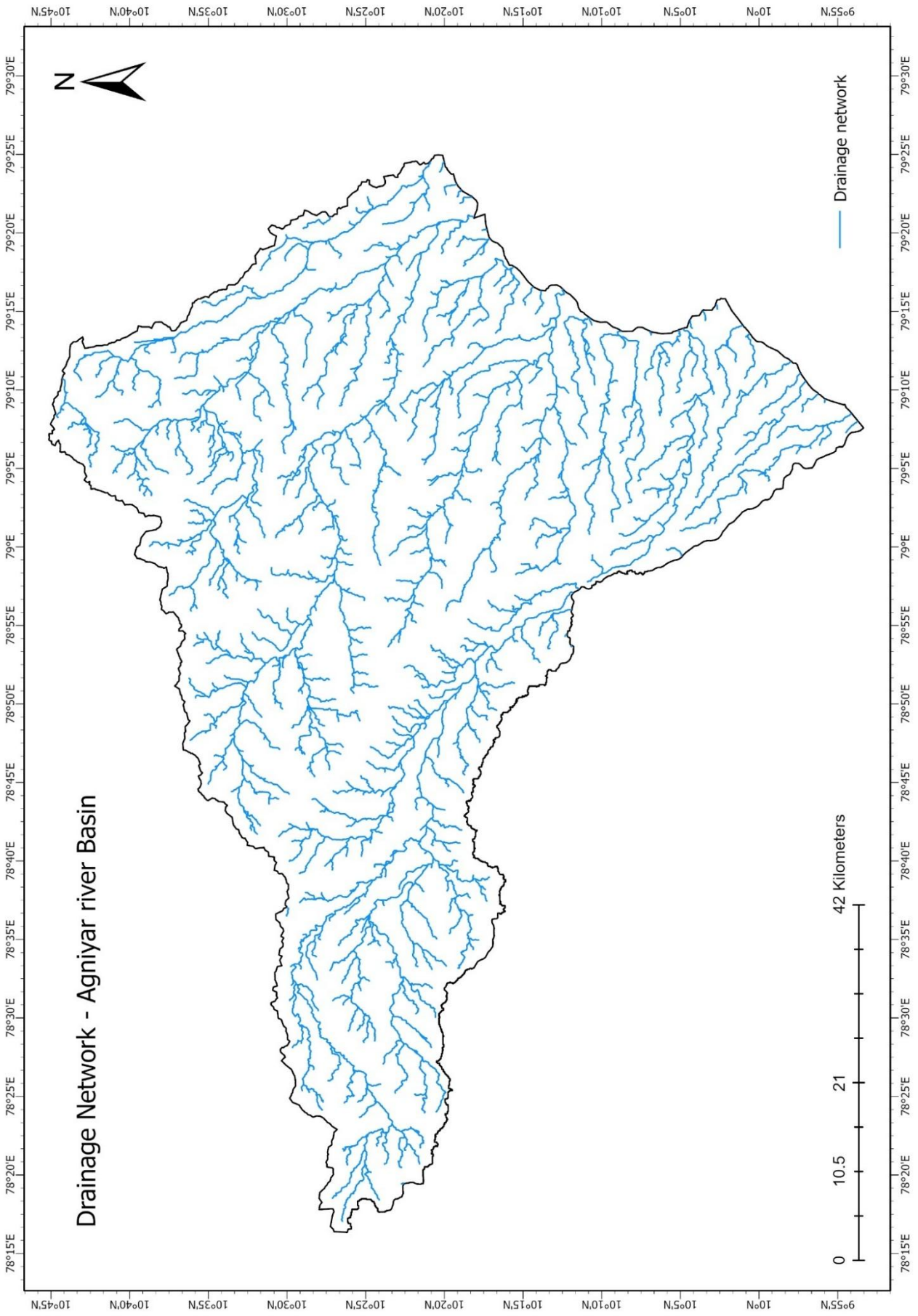
Basin Length (km)	487.843
Perimeter (km)	295.9
Area (km^2)	2824
Basin area ratio (BAR)	84.66
Infiltration number (If)	1.394
Drainage density (D)	1.387
Stream frequency (Fs)	1.005
Drainage texture (Dt)	9.59
Form factor (Rf)	0.0118
Circularity ratio (Rc)	0.406
Elongation ratio (Re)	0.123

Table 5

5.7 Relief - Calculation

Maximum relief	487.843km
Minimum relief	0
Mean relief	243.921km
Mean Bifurcation Ratio (Rb)	10.268
HI	5.5
Relief ratio	0.007
Relative relief	58.5%
Dissection index	1.9
Gradient	0.007m/km

Table 6


Drainage Network - Agniyar river Basin
N
Drainage network
0
10.5
21
42 Kilometers
78°15'E
78°20'E
78°25'E
78°30'E
78°35'E
78°40'E
78°45'E
78°50'E
78°55'E
79°E
79°5'E
79°10'E
79°15'E
79°20'E
79°25'E
79°30'E
9°55'N
10°N
10°5'N
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10°30'N
10°35'N
10°40'N
10°45'N

Fig 5

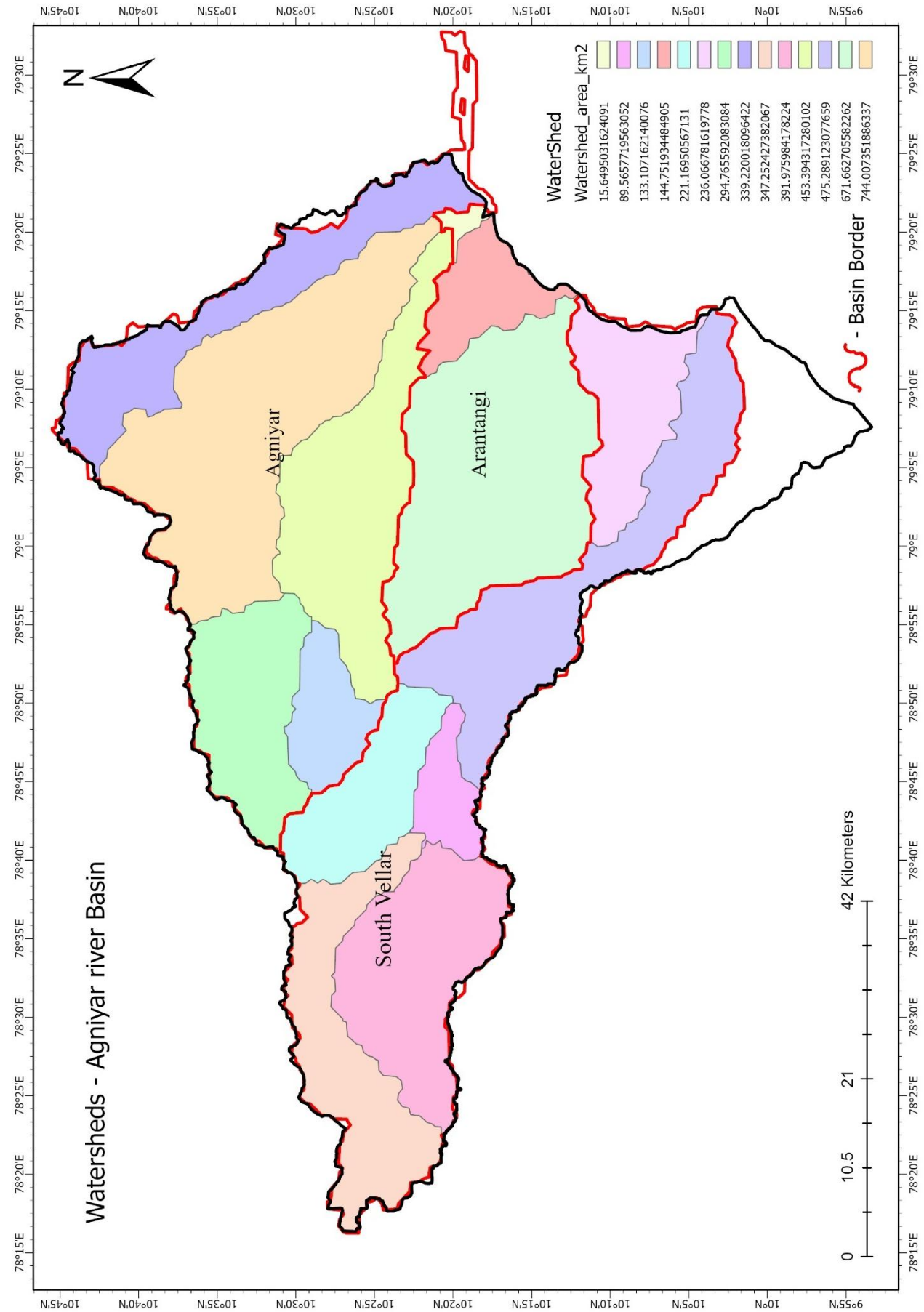
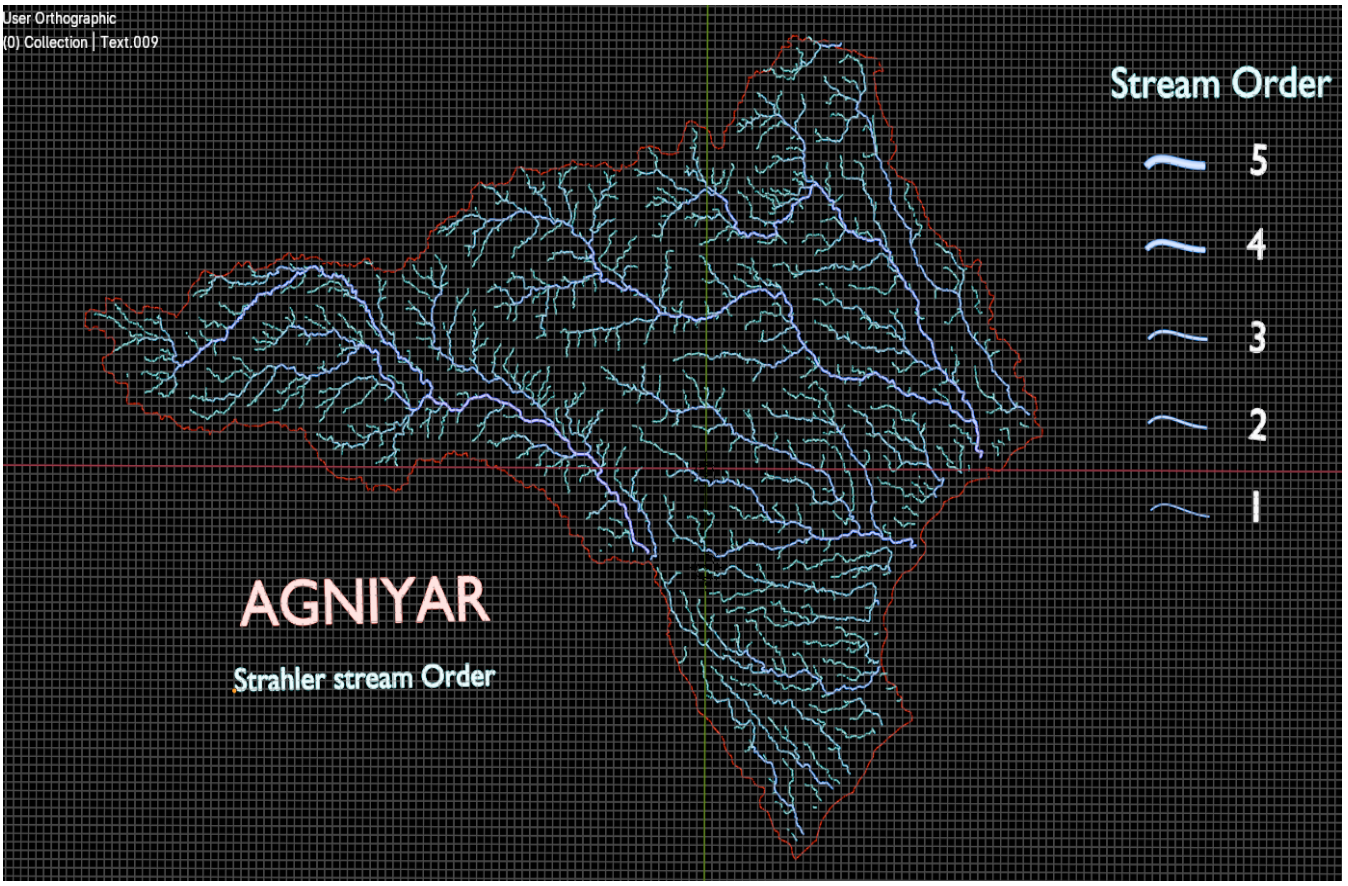

Watersheds - Agniyar river Basin
N
WaterShed
Watershed_area_km2
15.6495031624091
89.5657719563052
133.107162140076
144.751934484905
221.16950567131
236.066781619778
294.765592083084
339.220018096422
347.252427382067
391.975984178224
453.394317280102
475.289123077659
671.662705582262
744.007351886337
- Basin Border
Agniyar
Arantangi
South Vellar
0
10.5
21
42 Kilometers

Fig 6

5.8 3D graphics in Blender



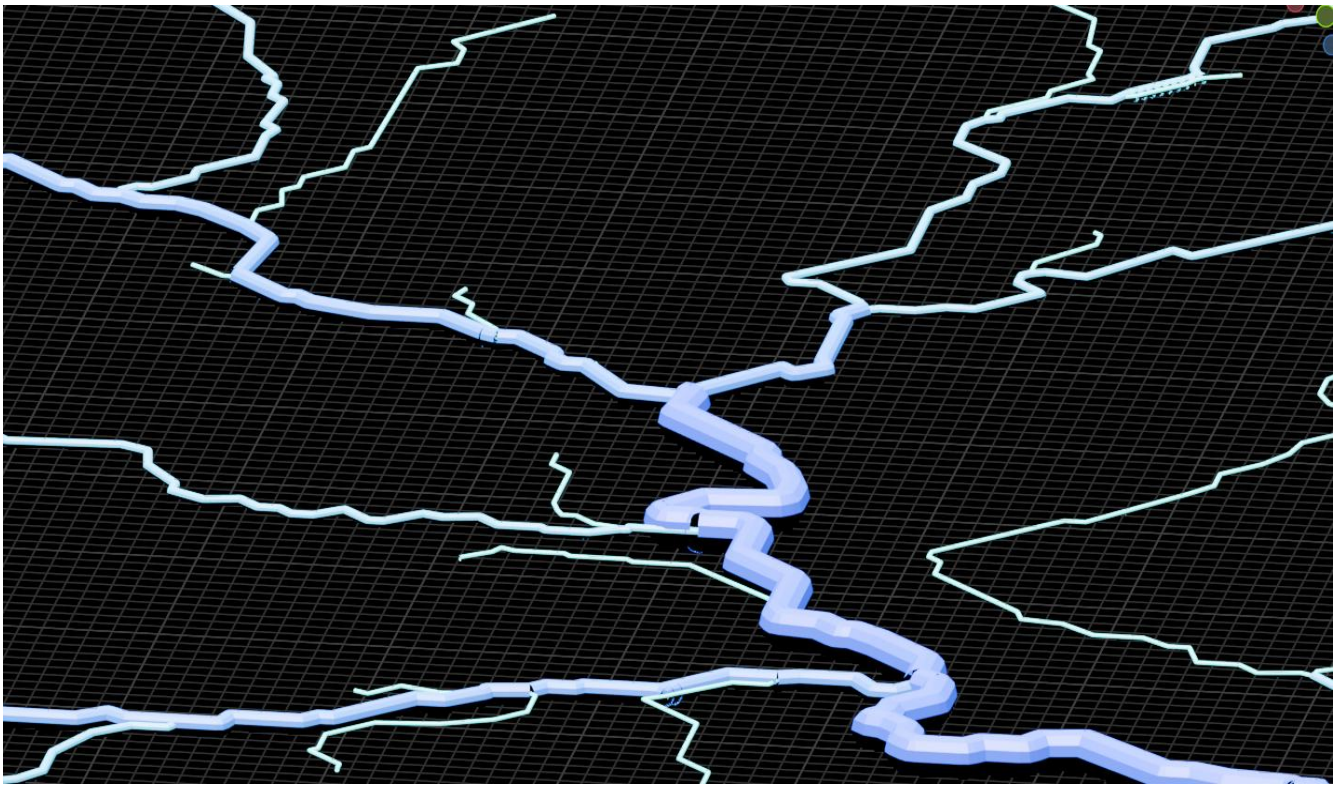


Fig 7

5.9 DISCUSSION

The morphometric analysis of the Agniyar River Basin was conducted using Remote Sensing and GIS tools, with the SRTM DEM forming the basis for extracting the drainage network and watershed characteristics. The analysis categorized parameters into three aspects: linear, areal, and relief, providing insights into the basin's hydrological behavior, surface runoff potential, and geomorphic evolution.

The linear aspects of the basin include parameters such as stream order, stream number, stream length, bifurcation ratio, and mean stream length. The Agniyar River Basin is classified as a fifth-order drainage basin, and the number of streams decreases with increasing stream order, aligning with Horton’s law and reflecting a typical dendritic drainage pattern. The bifurcation ratio, generally ranging between 3.0 and 5.0, suggests moderate structural control over the drainage development. Additionally, the mean stream length increases with stream order, indicating that higher-order streams traverse longer distances, consistent with geomorphic maturity.

The areal aspects encompass drainage density, stream frequency, form factor, elongation ratio, and circularity ratio. The moderate drainage density observed indicates a balance between surface runoff and infiltration processes. The form factor and elongation ratio suggest an elongated basin shape, contributing to lower peak flows and extended runoff duration, which are favorable for flood management. The circularity ratio further supports this elongated morphology, indicating a basin with moderate relief and runoff potential.

Relief aspects include parameters such as basin relief, relief ratio, and ruggedness number. The significant basin relief, which is the difference between the highest and lowest elevations, influences the potential energy of runoff and sediment transport. The relief ratio reflects a moderate slope, indicating moderate erosion potential within the basin. The ruggedness number suggests a terrain that is not excessively rugged, promoting moderate levels of surface runoff and erosion.

The combined morphometric parameters highlight that the Agniyar River Basin has moderate drainage efficiency and a low to medium flood potential. The elongated basin shape contributes to delayed peak discharge, which is advantageous for managing flood risks. The moderate drainage density and bifurcation ratio indicate that the basin's development is influenced by both structural factors and natural lithological and slope conditions, making it a dynamic yet stable hydrological system.

5 .9.1 Recommendations and Future Scope

Based on the findings of the morphometric analysis of the Agniyar River Basin, it is recommended that watershed management practices integrate morphometric parameters to identify erosion-prone areas and guide conservation efforts. Authorities should make use of GIS-based drainage analysis to support effective planning for flood control, water harvesting, and land use management. Incorporating land use/land cover data along with morphometric results would provide a more holistic understanding of watershed behavior

For future research, the integration of time-series satellite imagery could help monitor changes in drainage characteristics due to urbanization or climate variation. Further, the use of high-resolution DEM data, such as LiDAR, can improve the accuracy of terrain-based measurements. Hydrological models combining rainfall, runoff, and infiltration data can also be developed to enhance flood prediction and water resource planning. Additionally, conducting similar studies across multiple sub-basins in Tamil Nadu would allow for better regional-level watershed prioritization and sustainable development planning.

6 CONCLUSION

The morphometric analysis of the Agniyar River Basin provides a comprehensive understanding of its drainage characteristics, relief features, and hydrological behavior. The integration of GIS and remote sensing techniques has enabled precise calculations of linear, areal, and relief parameters, offering valuable insights into the basin's geomorphological and hydrological processes. The dendritic drainage pattern observed reflects the homogeneity of lithology and minimal structural disturbances, indicative of a naturally evolved basin with moderate structural control.

The study highlights the basin's moderate drainage density, suggesting a balanced interaction between surface runoff and infiltration, which is critical for sustainable water resource management. The form factor and elongation ratio reveal an elongated basin shape, associated with a longer runoff concentration time, reduced peak discharge, and lower flood potential—key considerations for flood management strategies. Similarly, the relief aspects, including basin relief and ruggedness number, underscore the moderate energy potential of surface runoff and the terrain's moderate erosion susceptibility.

This analysis not only reaffirms the potential of morphometric studies in understanding basin behavior but also emphasizes their practical applications in watershed management, flood control, and sustainable development planning. By identifying geomorphic characteristics and hydrological responses, the study contributes to building resilience against the challenges posed by climate variability and anthropogenic pressures.

The findings strengthen the belief that leveraging geospatial tools and morphometric methods fosters data-driven decision-making for environmental management. Such integrative approaches empower stakeholders to design effective conservation strategies, improve land-use planning, and mitigate risks associated with water-related hazards. This study stands as a testament to the potential of GIS and remote sensing in addressing complex geomorphological challenges and building a sustainable future for river basin management.

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