

# Geomatics Approach for Morphometric and Spatial Analysis of Palar Watershed, Chittoor district, Andhra Pradesh

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**Abstract:** The increasing demand for water due to population growth, urbanization, industrialization, and unsustainable irrigation practices has significantly impacted water resources, particularly in developing regions. The situation is further worsened by irregular rainfall patterns, leading to a declining groundwater table. In this context, watersheds play a crucial role in water supply, irrigation, and resource management. Effective watershed management is essential for groundwater recharge and sustainable water resource development. Morphometric analysis involves the quantitative assessment of drainage network characteristics, such as drainage area, gradient, and relief features, which are fundamental to understanding geo-hydrological processes, geological evolution, and water resource potential. It aids in identifying water storage zones by using Spatial analysis optimal locations for water harvesting, and flood-prone areas, contributing to efficient watershed management strategies. This study focuses on evaluating the linear, aerial, and relief morphometric characteristics of the Palar Watershed using geospatial techniques. The analysis provides critical insights for decision-makers, planners, and resource managers to enhance flood mitigation, water conservation, and sustainable watershed development.

**Keywords:** Morphometric Analysis, Watershed Management, Geospatial Techniques, Sustainable Development, Hydrological Processes, Spatial analysis.

## I. INTRODUCTION

In the present scenario, where water demand is rising while accessibility remains limited, effective water resource management has become crucial. Additionally, land-use changes significantly impact river systems and their hydrological processes (Bhatt & Joshi, 2018). Morphometric analysis provides a quantitative assessment of watershed geometry, offering critical insights into runoff potential, hydrological processes, river basin management, and environmental sustainability. The scientific basis for

morphometric analysis was established through the works of Horton (1932, 1945), Miller (1953), Schumm (1956), Strahler (1964), and Clarke (1966), who developed systematic methods to evaluate drainage networks, watershed structure, and flood susceptibility. Drainage basin morphometry serves as a predictive tool for understanding long-term watershed dynamics and landscape evolution (Thompson et al., 2001). This approach has been widely applied across earth sciences and engineering disciplines as an indirect tool for assessing soil erosion susceptibility, landslide risk, groundwater movement, and topographical variations (Pike, 2000). The advancement of geospatial techniques, GIS, and remote sensing has significantly improved the accuracy and efficiency of morphometric studies, enabling better-informed watershed management and disaster mitigation strategies. This study applies an integrated geomatic approach to examine the morphometric and spatial characteristics of the Palar Watershed. The findings will contribute to prioritizing sub-watersheds based on flood risk, optimizing water conservation strategies, and developing sustainable watershed management plans. The advancement of geospatial technologies has revolutionized watershed delineation and morphometric analysis, offering a more accurate and time-efficient alternative to conventional manual methods. GIS-based digital processing enables the automatic extraction of morphometric parameters, significantly improving the efficiency of hydrological modelling and watershed assessment (Rao et al., 2010). These technologies have been widely utilized for evaluating water resources, assessing pollution vulnerability, and mapping groundwater quality (Bhatt & Joshi, 2019). The application of remote sensing and GIS in watershed studies has been extensively explored by various researchers, including Nag (1998), Chopra et al. (2005), Nookaratram et al. (2005), Thakkar et al.

(2007), Sreedevi et al. (2009), Magesh et al. (2013), Gajbhiye (2015), Dayal et al. (2015), Dahiphale et al. (2016), Rai et al. (2018), and Sahoo et al. (2019). Their studies emphasize the role of geospatial tools in hydrological analysis, groundwater potential zone identification, and prioritization of sub-watersheds for sustainable management. This research applies a geomatic approach to assess the morphometric and spatial characteristics of the Palar Watershed, focusing on linear, aerial, and relief parameters. The study aims to provide insights into drainage characteristics, flood susceptibility, and groundwater recharge potential, supporting effective watershed management and sustainable water resource planning.

## II. STUDY AREA

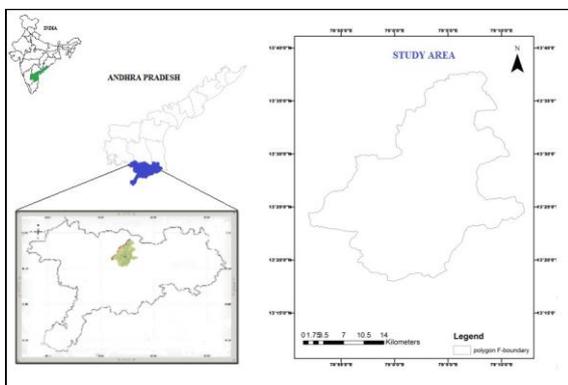


Fig 1: Study Area

The Palar Watershed, which includes Ponnai river located in Chittoor District, Andhra Pradesh, is a significant hydrological unit that contributes to regional water availability. The Palar River originates

from the Nandi Hills in Karnataka and flows through Andhra Pradesh and Tamil Nadu before draining into the Bay of Bengal. The study area extends between longitude 79° 05' E to 79° 30' E and latitude 13° 20' N to 13° 50' N, covering a length of approximately 90 km and an area of about 655 sq. km.

## III. METHODOLOGY

### Morphometric and Hydrological and Spatial Analysis for Estimation of Potential Runoff / Storage Zones:

The drainage network of the Palar Watershed has been extracted using Shuttle Radar Topography Mission (SRTM) data with a 90m resolution, along with Survey of India (SOI) topographical maps at a 1:50,000 scale as shown in Fig 2. The watershed boundary has been delineated using QGIS, ensuring precise identification of the drainage basin as shown in Fig 3. The morphometric analysis includes the computation of geometric characteristics such as area, perimeter, stream length, and stream order, which are derived using GIS-based techniques. Additional morphometric parameters, including drainage density, stream frequency, bifurcation ratio, and elongation ratio, have been calculated following the methodologies established by Horton (1945), Strahler (1964), Hardy (1961), Schumm (1956), Nookaratanm et al. (2005), and Miller (1953). The Spatial Analyst tool in ARCGIS AND QGIS has been utilized to analyze drainage density, height above nearest drainage, slope, Topographical wetness index, land use/ land cover maps across the watershed.

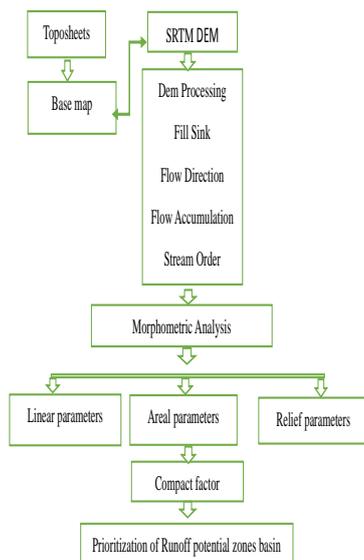


Figure 4: Flow chart showing prioritization of Runoff potential zones by Morphometric analysis

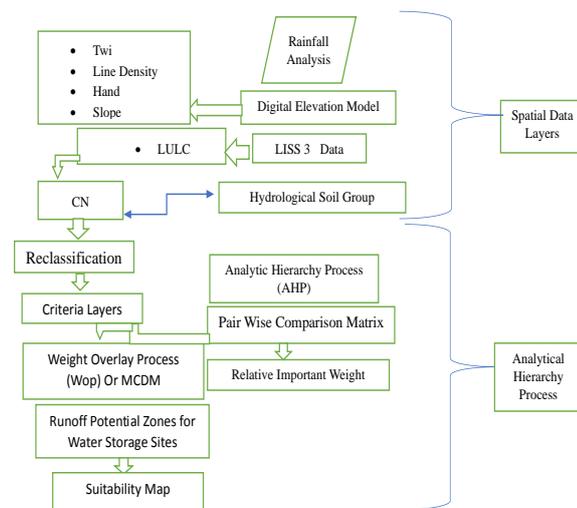


Figure 4.2: Multi criteria decision making (MCDM) technique workflow using AHP for identification of potential runoff storage zones for water storage.

Figure 5: Multi criteria decision making (MCDM) technique workflow using AHP for identification of potential runoff storage zones for water storage

IV. RESULTS AND DISCUSSION

Estimation of Morphometric Parameters

Morphometric analysis of a drainage basin provides a quantitative description of the drainage system. The geometry of a basin is formed by continuous flow through stream courses over a period of time and is a function of stream length, slope and roughness and, shape, slope and infiltration capacity of the basin.

Estimation of Linear Parameters

The stream orders (u) of the various streams were obtained using Strahler’s classification. The number

of streams (Nu) and corresponding lengths of streams (L) were obtained using GIS software. The stream segments at the outlets of sub-basins Watershed, as shown in Fig 3. The number of streams of various orders in the sub-basins is presented in table 6.1 that 538 streams are of first order, 277 streams are of second order, 132 streams are of third order, 88 streams are of fourth order, 41 streams are of fifth order. It may also observe that the number of streams decreases as the stream order increases following Horton’s law of stream numbers.

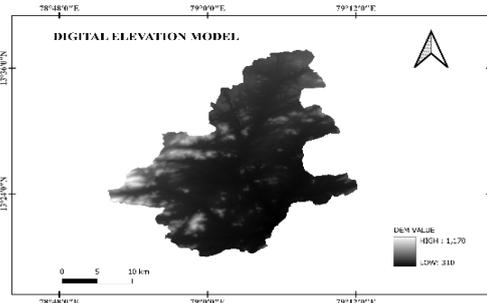


Fig 2: Stream Orders of Palar River

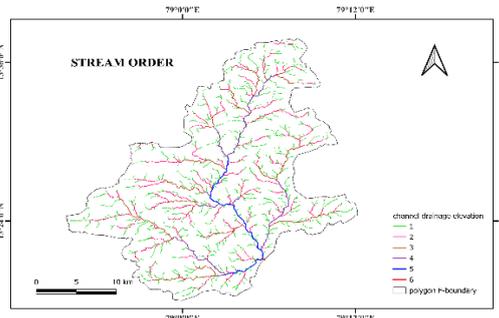


Fig 3: Stream Orders of Palar River Basin

Bifurcation ratio (Rb) of successive orders of palar basin W1 to W4 of a palar basin as presented in Table 1 (a) show that the mean bifurcation ratio is high for W2 (2.34) and low for W3 the higher Rb of sub-basin may be due to large variations in frequencies between successive orders indicating the matured topography. The mean Rb of palar basin was observed to be 2.19 indicating that the sub-basin is less affected by structural disturbances with drainage pattern, not much influenced by geological structures.

The stream length ratio indicates the surface flow characteristics of the basin. The stream lengths, mean stream lengths and their ratios for the sub-basins of palar basin are presented in Table 1(b). A decrease in the stream length with increased stream order for W1 to W4 sub-basins may be observed. The mean stream length ratio between the streams of different orders of the study area changed from 0.51 to 1.19. This change may be attributed to variation in slope and topography.

Table 1 Linear parameters of sub-basins

sub-basin	Total No. Of Streams (Nu)					Total (Nu)	Bifurcation Ration (Rb) (Nu/Nu+1)				mean (Rb)
	1	2	3	4	5		1/2	2/3	3/4	4/5	
w1	106	55	19	31	-	211	3	3.8947	1.6129	-	2.13
w2	134	74	34	14	11	267	2.8108	3.1765	3.4286	2.273	2.34
w3	105	45	38	21	-	209	3.3333	2.1842	2.8095	-	2.081
w4	193	103	41	22	30	389	2.8738	3.5122	2.8636	1.733	2.1965
total	538	277	132	88	41	1076				mean	2.19

(a) Number of streams and bifurcation ratios

sub-basin	Stream Length (Km)					total (L) km	Mean Stream Length, Lsm (Km)					Mean Stream Length Ratio RL			
	1	2	3	4	5		1	2	3	4	5	1	2	3	4
W1	84.9	45.83	17.77	14.8	-	163.4	0.8	0.8	0.93	0.47	-	1	1	0.5	-
W2	111.5	55.00	25.07	12.2	6.2	210	0.8	0.7	0.73	0.87	0.5	0.8	1	1.1	0.64

W3	86.9 6	37.31 7	24.12 8	12.9	-	161. 3	0.8 3	0.8 3	0.63 5	0.58 6	-	1	0. 8	0.9 2	-
W4	132. 5	92.69	34.70 3	13.8 5	20	294	0.6 9	0.9	0.84 6	0.63	0.6 8	1.3 1	0. 9	0.7 4	1.07 6

(b) Stream lengths and stream length ratios

Estimation of Areal Parameters

The basic parameters of sub-basins viz., length (L), perimeter(P) and area(A) were determined and presented in table 2. The areal aspects for the basin such as drainage density (D<sub>d</sub>), stream frequency (F<sub>s</sub>), drainage texture ratio(T), circularity ratio (R<sub>c</sub>) was computed and presented in Table 3.

Table 2 Basic parameters of sub-basins

SUB BASIN	BASIN AREA, A(KM2)	BASIN LENGTH, L(KM)	PERIMETER, P(KM)
W1	118.263	20.987	86.156
W2	116.865	31.472	103.973

Table 3 Areal parameters of sub-basins

SUB-BASIN	drainage density (D <sub>d</sub> )	stream frequency (F <sub>s</sub> )	drainage texture (T)	form factor (R <sub>f</sub> )	elongation ratio (R <sub>e</sub> )	circularity ratio (R <sub>c</sub> )	Length of overland flow (L <sub>g</sub> )
W1	0.1774	1.7841	2.4490	0.0043	0.5847	0.2001	0.0887
W2	0.2693	2.2846	2.5679	0.0043	0.3876	0.1357	0.1346
W3	0.1597	1.2601	1.8828	0.0037	0.5485	0.1690	0.0798
W4	0.1445	1.7375	3.2203	0.0025	0.5219	0.1927	0.0722

The drainage texture(T) of the sub-basins varied from 1.88 to 3.22. low T values indicate very coarse drainage texture. R<sub>c</sub> less than 0.4 of sub-basins W2 indicated elongated shape of sub-basins. R<sub>c</sub> less than 0.3 of W1, W2, W3, W4 indicate elongated sub-basins with moderate relief, low runoff a high subsoil permeability. Low F<sub>f</sub> values of sub-basins indicate elongated shape resulting in longer flow duration with flatter peak leading to more potential runoff storage zones.

Estimation of Relief Parameters

The relief parameters such as relief ratio (R<sub>r</sub>) and ruggedness number (R<sub>n</sub>) were computed and presented in Table 4. the relief ratio of sub-basins ranges between 0.0181 to 0.0277. Lower values indicate gentle slope. R<sub>n</sub> value 0.0770 to 0.2353. for the sub-basins. Low relief ratios and ruggedness numbers of sub-basins indicate the existence of promising runoff storage zones.

The morphometric analysis of linear, areal and parameters of sub-basins presented in Tables 1, 3, 4 indicate that W4 possesses high bifurcation ratio with

W3	165.853	26.498	111
W4	223.878	32.353	120.795

Drainage density of sub-basins of the study area ranged between 0.1 to 0.269. low values of D<sub>d</sub> of sub-basins indicate the existence of coarse to very coarse drainage structure, highly resistant and permeable sub-soil with dense vegetated cover low relief. F<sub>s</sub> of sub-basins varied between 1.26 to 2.28. low F<sub>s</sub> values indicate a very coarse drainage structure with low relief and high infiltration capacity and, the existence of favourable sites for potential runoff storage zones.

short streams. It is less elongated with high stream frequency causing less infiltration rate, moderate drainage density and low ruggedness number.

Table 4 Relief parameters of sub-basins

SUB - BASIN	max basin height (H)	min basin height (h)	basin relief R (H-h)	relief ratio (R <sub>r</sub> )	ruggedness number (R <sub>n</sub> )
W1	841	398	443	0.0211	0.0786
W2	1185	311	874	0.0277	0.2353
W3	796	314	482	0.0181	0.077
W4	958	310	648	0.02	0.0936

PRIORITIZATION OF RUNOFF POTENTIAL ZONES USING COMPACT FACTOR ANALYSIS

The Run-off potential zones identification of sub-basins of palar was carried out through compact factor analysis of morphometric parameters. The compact factor analysis of morphometric parameters was carried out to prioritize sub-basin on the basin of run-off potential availability. Rank of 1 to 4, representing poor, moderate, good and very good potential zone, were used to rank the linear, areal, and

relief parameters, based on their contribution towards run-off. Higher rank indicates the greater degree of run-off recharge structures. The average rank value of the parameters becomes potential candidate for planning water recharge structures. The average rank

value of the parameters of the sub-basin indicates its compact factors 1 to 4 represent poor, to very good categories of Run-off potential zones. The ranks assigned and compact factors computed for the sub-basin are represented in Table 5.

Table 5: Compact Factor and Run-off potential availability

Sub-Basin	RANK										Compact Factor	Run off Potential
	Linear parameters		Areal parameters						Relief parameters			
	Rb	Rl	Dd	Fs	T	Re	Rc	Ff	Rr	Rn		
W1	3	3	1	2	2	4	1	2	2	3	2.3	Moderate
W2	1	1	2	1	1	3	4	1	1	1	1.6	POOR
W3	4	2	4	3	3	1	3	3	3	4	3	GOOD
W4	2	4	3	4	4	2	2	4	4	2	3.1	VERY GOOD

The Results showed that higher compact factors of 3.1 of W4 sub-basin indicate good to very good of run-off potential. The sub-basin W1 and W3 with compact factors 2.3 and 3 respectively fall in moderate to good Run-off potential zones. The sub-basin W2 was identified poor to moderate zones of Run-off potential. The Run-off potential zones map shown fig 5.

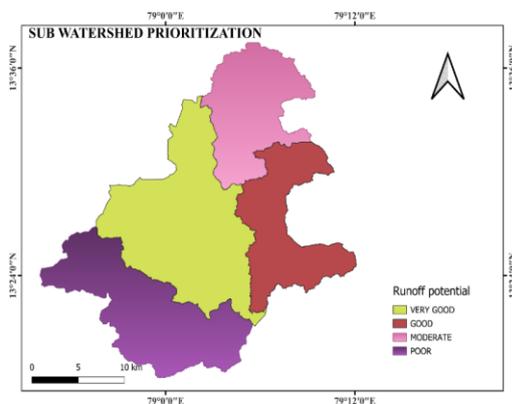


Fig 6: Runoff water potential zones based on compact factor analysis

**RAINFALL ANALYSIS**

**Standardized Precipitation Index (SPI)**

The standardized precipitation index (SPI) is a drought index that compares observed precipitation to the average for a given time period. It is used to monitor wet& dry condition over different time scale. The SPI was calculated by using Annual Rainfall data analysis of Rain gauge stations across The Palar watershed of 35 years (1988-2022).

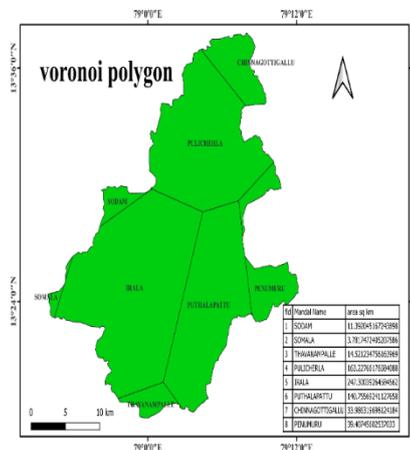


Fig 7: Voronoi/ Thiessen polygon of rain gauge stations for palar watershed.

Table 6: Classification of annual rainfall based on SPI.

Classification	YEARS
Dry Extreme Years	----
Severely Dry Years	2018
Moderately Dry Years	2016 ,1992, 2003, 2014
Moderately Wet Years	1996, 2022, 2020
Near Normal Years	2002, 2012, 1994, 1989, 1999, 2006, 1990, 2013, 2019, 1995, 2011, 2009 ,2000, 1991, 1988, 2001, 1997, 1993, 2004, 1998, 2010, 2008, 2017 2007
Very Wet Years	2005
Wet Extreme Years	2021, 2015

Classification of annual rainfall of the study area based on SPI was shown in Table 6.2. The result therefore suggests that the overall drought events between these years were not severe. It was determined that the SPI indicates extremely dry years not there for past 35 years. severely dry years extremely dry years 2.85 % of the time, moderately dry years 11.42 % of the time, moderately wet years 8.57 % of the time, near normal years 68.57 % of the time, very wet years 2.85 % of the time and extremely wet years 5.71 % of the time. The precipitation analysis suggests that the water shortage in the region may be overcome by identification of suitable sites for water storage. The computed average annual rainfall is 700-950 mm.

Table 7 Study area are influenced by the rain gauge station

Sl no	Rain gauge stations	Latitude	Longitude	Area of station influenced km <sup>2</sup>
1	Somala	78.81	13.47	3.78175
2	Sadam	78.908	13.546	11.392
3	Pulicherla	79.04	13.6	163.228
4	Penumuru	79.2	13.37	39.4075
5	Puthalapattu	79.09	13.35	140.756
6	Irala	78.98	13.39	247.3
7	Thavanampalle	79.01	13.26	14.5211
8	Chinnagottigallu	79.08	13.65	33.9863
Total area				=655 km <sup>2</sup>

## SPATIAL ANALYSIS OF RUN OFF POTENTIAL ZONES

### THEMATIC MAPS

Download the SRTM DEM from USGS, NASA, or other geospatial sources. Import the DEM into QGIS or ArcGIS, converting the format.

**Topography wetness index (TWI) Map:** The Topographic Wetness Index (TWI) is a valuable tool in hydrological analysis. It quantifies the influence of topography on the distribution and movement of water across a landscape. Step by step procedure:

To calculate the Topographic Wetness Index (TWI) in QGIS, start by obtaining and loading the DEM into the software. Open the Processing Toolbox, navigate to SAGA Next Gen, and select Terrain Analysis → Hydrology. First, fill sinks in the DEM to remove depressions that could affect water flow. Next, compute the flow direction to determine how water

moves across the terrain, followed by flow accumulation to calculate contributing cells. Then, derive the slope values and convert them from degrees to radians. Finally, apply the TWI formula to generate the index.

The elevation of basin ranges from 310 to at low land area near somala and Irala to 1170 m at pulicherla of the basin. The Twi map of the study area is calculated TWI for the palar watershed shown in Figure 8. High values of the TWI are found in converging and flat areas and are expected to have much water accumulation and low slope. In contrast, steep locations and diverging areas receive a small index value and have relatively lower water accumulation. Consequently, the index is a relative measure of the hydrological conditions of a given location in the landscape.

**Slope map:** The slope map of the study area, generally the flat and gently sloping areas are capable of holding rainfall and facilitate ground water recharge, while elevated areas (steeply sloping ground) promote high run-off with low infiltration. Therefore, run-off potential is expected to be greater in flat and gently sloping regions. The slope map was generated from DEM of study area using Raster Analysis tool in QGIS.

To generate a slope map in QGIS, open the DEM file and access the Processing Toolbox. Navigate to Raster → Terrain Analysis → Slope, then select the DEM layer as the input. Choose the desired output file location and name, then click Run to create the slope map.

The elevation of basin ranges from 310 to at low land area near somala and Irala to 1170m at pulicherla of the basin. The slope map of the study area is shown in Figure 9. Slope plays a significant role in the amount of runoff and sedimentation, The speed of water flow and the amount of material required to construct a dyke (the required height). maximum area belongs to flat class, flat areas are never strictly horizontal, also, flat slopes leads to a decrease in the surface runoff velocity, which results in longer period of time for the runoff to drain, there are gentle slopes in a seemingly flat area.

**Land use/land cover:** The land use/land cover map of the study area was prepared from Sentinel LISS 3 data through visual interpretation techniques, Data collection from Satellite imagery (such as Landsat, Sentinel, or other remote sensing data).

To process LISS-3 data in ArcGIS, start by adding and mosaicking the data using the Composite Bands tool. Change the colour to False Colour Composite

(FCC) by rearranging the layers. Identify land features such as vegetation, water bodies, floodplains, barren land, and dense vegetation. Draw training samples using circles over different land types and save them. Convert the map to Land Use/Land Cover (LULC) classification using the Maximum Likelihood Classification tool. Assign suitable Curve Numbers (CN) based on soil types and calculate the area of each region, verifying the total by summing all land types.

The study area has seven major LULC types as shown in Fig 10: Agricultural land (338.74 km<sup>2</sup>), Sparsely vegetated (54%), Mixed Forest (72.47 km<sup>2</sup>, 11%), Built-up (120.31 km<sup>2</sup>, 18%), Barren land (25.25 km<sup>2</sup>, 4%), Waterbodies (5.70 km<sup>2</sup>, 1%), and Floodplain (92.08 km<sup>2</sup>, 14%). Soils are clay, loam, and clayey-loam, classified under Hydrological Soil Groups C & D, with moderate (C) to high (D) runoff potential. Barren and sparsely vegetated land are ideal for water storage structures.

**Drainage density/Line Density:** Drainage density is a measure used to describe the total length of streams and rivers in a drainage basin divided by the total area of the basin. we have used DEM data.

To calculate drainage density, first, obtain and load the DEM of the study area. Fill sinks to remove depressions, ensuring proper water flow. Next, compute flow direction and flow accumulation to determine contributing cells. Identify drainage channels by calculating the Strahler Stream Order. Open the study area and channel drainage layer, then search for Line Density and set channel drainage as input. Enter stream order in the population field. Finally, go to Environment → Processing Extent (Study Area) → Raster Analysis → OK to generate the Drainage Density output.

The basin elevation ranges from 310m in the lowlands near Somala and Irala to 1170m at Pulicherla. The Line Density Map (Figure 11) indicates values between 0 and 7.48. To determine optimal locations for surface water storage structures, 1st, 2nd, and 3rd order streams were extracted from the drainage network. The area exhibits a sixth and fifth-order drainage system, with a well-defined network in the eastern section.

Height Above Nearest Drainage (HAND) is a terrain-derived parameter that represents the relative elevation of a location above the nearest stream or drainage channel. It is useful for flood modelling, hydrological analysis, and identifying flood-prone areas.

To generate a HAND (Height Above Nearest Drainage) map, first, convert the DEM to PC Raster scalar format. Then, create a local drain direction (LDD) raster using the Ldd create tool and compute flow accumulation with accflux. Extract the drainage network by applying a flow accumulation threshold and assign unique IDs to each drainage cell using the unique tool, converting the result into a nominal raster. Next, define sub-catchments for each drainage ID with the sub catchment tool and determine the lowest elevation in each sub-catchment using the area minimum tool, which represents the drainage elevation. Finally, use Raster Calculator to subtract the drainage elevation from the DEM, generating the HAND map as the final output.

Low-lying regions near streams are more prone to flooding than elevated areas. The HAND values in the study area range from 0 to 862 meters. A HAND raster was created for 6th, 5th, and 4th order streams in the Palar watershed, as these zones are highly flood-prone. In the suitability assessment, lower values (0-2 meters) were marked as least suitable due to high flood risk, making them unfit for water storage structures. Likewise, very high HAND values (>48 meters) were also given low suitability since they indicate locations farther from the river. Figure 12 presents the HAND map of the study area.

#### RECLASSIFY THEMATIC MAPS

Thematic maps were rasterised and reclassify should be done based on the classes. we have taken five spatial layers classes to represent the reclassify thematic maps like Topographical Wetness Index (TWI), Slope, Land use /Land cover, Drainage density, Height above nearest drainage (HAND), reclassify maps as shown in the below Fig 13,14,15,16,17.

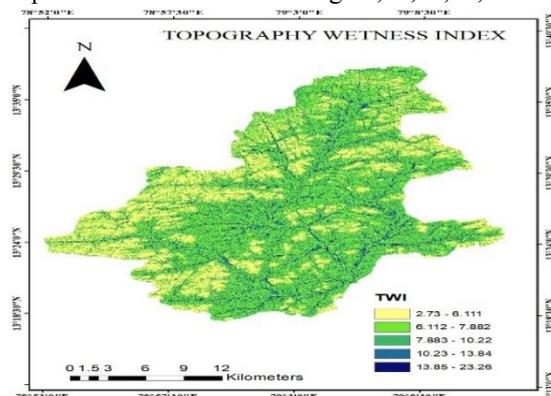


Fig 8 : Topography wetness index map

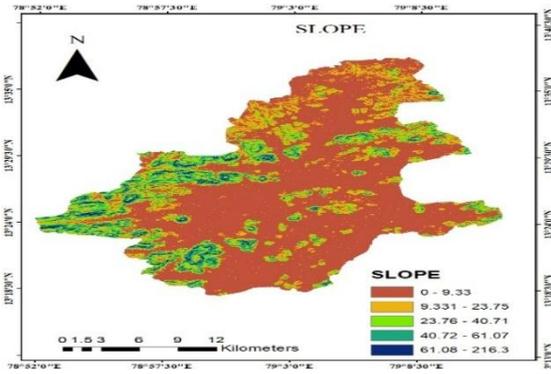


Figure 9 : The slope map

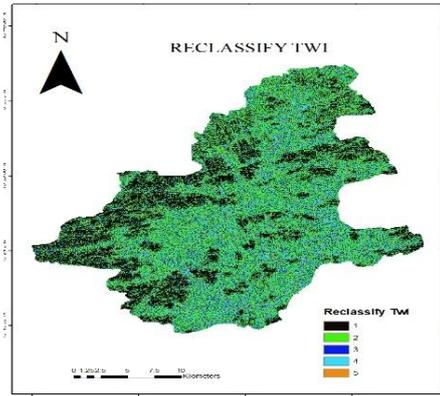


Figure 13 : Reclassify Twi map.

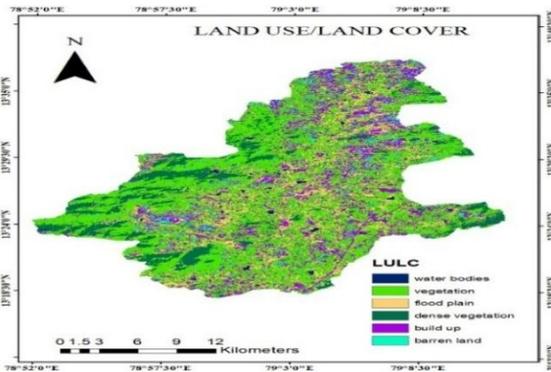


Figure 10 : Land use/land cover map

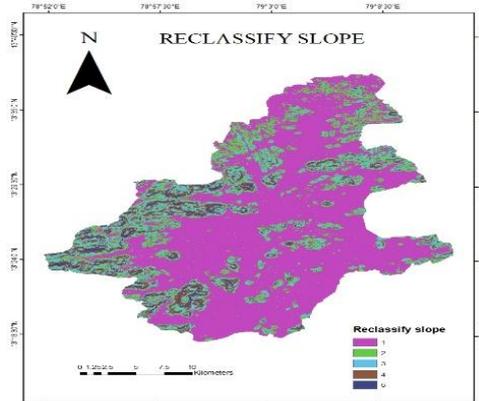


Figure 14 : Reclassify Slope map.

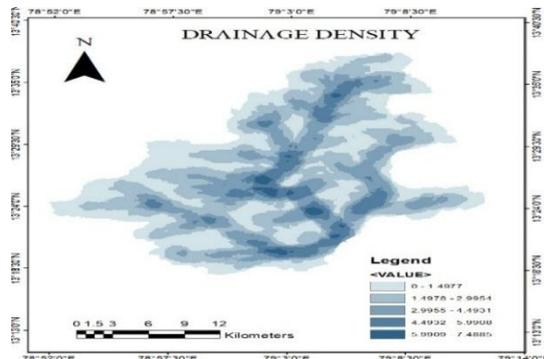


Fig 11 : Drainage density map.

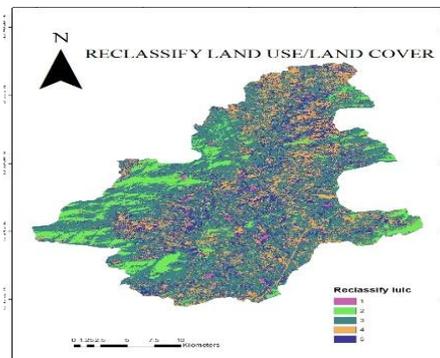


Figure 15 : Reclassify LULC map

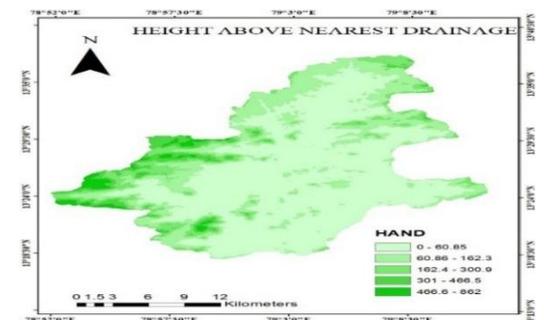


Figure 12 : HAND map.

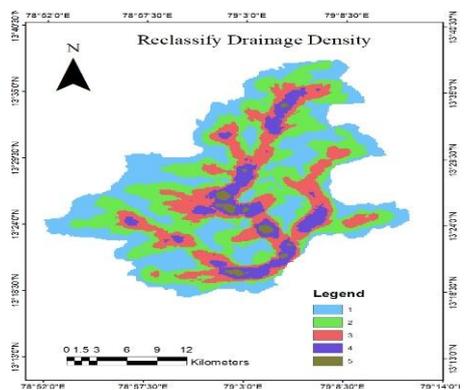


Figure 16 : Reclassify Drainage map.

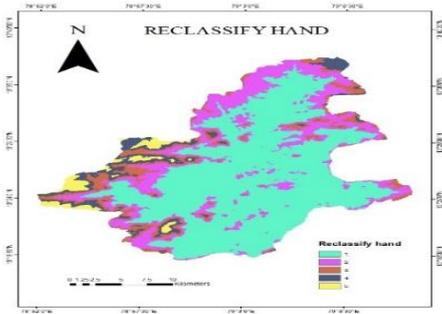


Figure 17 : Reclassify HAND map.

Determining criteria weights using AHP

The AHP method helps in making structured decisions by comparing multiple criteria. To create suitability maps for runoff storage zones, the criteria maps were aligned with the AHP results. The

Table 8 : Resulting weights for the criteria based on pairwise comparisons.

Theme	SLOPE	TWI	LULC	Drainage density	HAND	Total	eigen vector	1*2
SLOPE	1	1	1	1	3	4	0.233	0.932
TWI	1	1	1	1	2	4.5	0.216	0.972
LULC	1	1	1	1	3	4.33	0.233	1.00889
Drainage density	1	1	1	1	3	4.33	0.233	1.00889
HAND	0.33	0.5	0.333	1/3	1	12	0.084	1.008
total	4.33	4.5	4.333	4.333	12	principal eigen vector		4.929

Weighted Overlay Process (WOP) within GIS

The potential runoff storage zones in the study area (Figure 6.12) were identified using GIS by integrating key factors like slope, land use/land cover (LULC), HAND, stream order/drainage density, and TWI through the Weighted Overlay Process (WOP). The final map categorized the area into four suitability levels: Not Suitable, Marginally Suitable, Moderately Suitable, and Optimally Suitable. The analysis found that 13% of the area is highly suitable for water storage, 82% is moderately suitable, and 1% is not suitable. A total of 16 optimal sites were identified for potential water storage structures, as shown in Figure 6.12. The selection of these sites was based on three main factors: proximity to agricultural fields, location on unused or barren land, and narrow valley sections with high shoulders to reduce construction material requirements for structures like small dams, check dams, nala bunds, gully plugs, and bundhis. The findings were further validated by existing water storage structures already present in the highly suitable zones, as shown in Figure 18.

pairwise comparison matrix in Table 5.16 shows how different factors were ranked based on their importance, resulting in a standardized scale from 0% to 100%. Among the selected criteria, Slope (22.50%) was found to be the most important, followed by LULC (21.20%), HAND (14.50%), Stream Order (14.40%), and TWI (12.60%). The principal eigenvector, calculated as 6.47, was obtained from the reciprocal matrix used in pairwise comparisons. Since AHP can sometimes introduce inconsistencies, a consistency ratio (CR) was calculated, following Rincón et al. (2018). The CR value of 7.5%, which is below the 10% threshold, confirms that the comparisons were made logically and the assigned weights are appropriate for the weighted overlay process.

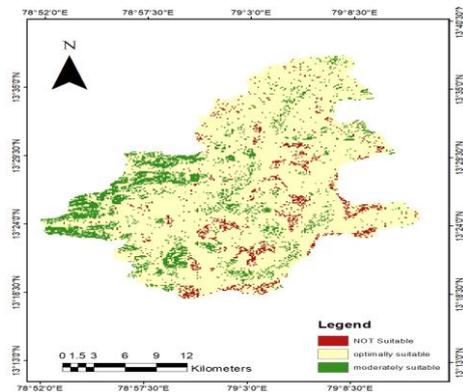


Fig 18: Potential runoff storage zones of the study area.

Table 9: Areal Extent of Runoff Potential Zones.

Runoff Water Potential Zones	Area	
	Km2	%
moderately suitable	83.591	13%
Optimally suitable	537.653	82%
not suitable	32.923	5%

Resulted raster was classified into four classes namely (a) Not suitable (b) optimally Suitable (c) Moderately Suitable. Result shows that 82% of the

area is optimally suitable, 13% of the area is moderately suitable, and 5 % of the area is not suitable for water storage zones/structures. Sixteen suitable sites on such zones (optimally suitable class) have also been identified for water storage structures.

### CONCLUSION

The quantitative morphometric characteristic of basin in the study area shows that the basin is elongated, with low relief and gentle slope. The analysis drainage basin result shows that the basin has a dendritic pattern with fifth order stream. The maximum stream order frequency is of first-order streams and followed by other order streams. Hence, there is decrease in stream frequency and the stream order. High bifurcation ratio in study area indicates a strong control of geological structure. "The results indicate that the W4 sub-basin, with a compactness factor of 3.1, exhibits a good to very good runoff potential. The W1 and W3 sub-basins, with compactness factors of 2.3 and 3, respectively, fall within the moderate to good runoff potential zones. In contrast, the W2 sub-basin is categorized as having poor to moderate runoff potential." The quantitative analysis of morphometric parameters in river basin evaluation can be very valuable in water resource management. Geographical Information System (GIS) is a competent tool to delineate drainage basin and water resources planning. The present study is valuable contributing to planning and optimal sustainable management of watershed.

The suitability map for potential runoff storage zones was created by combining key factors like slope (derived from the Topographic Position Index), land use/land cover (LULC), curve number, height above the nearest drainage (HAND), stream order, and topographic wetness index (TWI) using the Analytic Hierarchy Process (AHP) and Weighted Overlay Process (WOP) in GIS. This approach provides a reliable and accurate assessment of suitable locations for water storage structures. The findings show that 82% of the area is highly suitable, 13% is moderately suitable and 5% is not suitable for water storage. The GIS-based suitability map can serve as a valuable tool for future water conservation efforts, helping to tackle water scarcity caused by climate change at both regional and global levels. This method is versatile and applicable beyond the study area, particularly in developing countries, regardless of hydrological or ago-climatic differences. It is efficient, precise, and helps in identifying the best

locations for water management interventions in large watersheds. The results of this study can guide policymakers and planners in making informed decisions, reducing reliance on groundwater, addressing water shortages, and ensuring a sustainable water supply for both agriculture and local communities.

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