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2 **Erodibility prioritization and mapping of a Mid**
3 **Himalayan watershed using Technique of order**
4 **preference by similarity to ideal solution**
5 **(TOPSIS)**

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19
20 **ABSTRACT**

21 The productivity of soils is drastically affected owing to soil
erosion in human activities in the decline of the Western Nayar
watershed situated in the Pauri district of Uttarakhand. Therefore,
evaluation of these erodible areas is of utmost importance so that preventive
measures can be taken accordingly. It assessed the sub-
basins in the basin using morphometric parameters and several multi-criteria decision-
making models, such as Technique for Order Preference by Similarity
to Ideal Solution (TOPSIS), Utilizing

28 Advanced Space Thermal Emission Radiometer (ASTER) data and a 30m Digital
Elevation Model (DEM), morphometric parameters were extracted and analyzed. To
30 test the MCDM methods, percent and intensity of change indices were adopted. The
31 ranking results were such that sub-watershed 2 was ranked at top as the most
32 susceptible to erosion for TOPSIS model. In general, the morphometric
35 parameters were effective for identifying erosion-prone areas.

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40 *Keywords: [Morphometry, GIS, prioritization, TOPSIS, owing*

41

42 1.INTRODUCTION

43

44 The hydrological response of a basin is significantly influenced by its morphological
45 and climatic characteristics. Morphological attributes of a watershed are quantifiable
46 features that play a crucial role in understanding its hydrological behavior.

47 Therefore, linking these morphological parameters with hydrological characteristics
48 can provide a valuable method to simulate the behavior of various basins, especially
49 those that are not monitored.

50 Morphometric science involves the measurement, quantification, and mathematical
51 analysis of the earth's surface, including its layout, shape, and landforms'
52 dimensions. Analyzing the morphometry of a watershed offers a quantitative
53 description of its drainage system, which is essential for watershed characterization.
54 This analysis involves measuring linear features, area aspects, channel network
55 gradients, and ground slopes contributing to the drainage basin. Remote sensing
56 techniques, particularly satellite imagery, are convenient and effective methods for
57 conducting morphometric analysis over large areas.

58 Various geomorphological parameters such as stream order, length, frequency,
59 drainage density, texture ratio, form factor, circulatory ratio, elongation ratio,
60 bifurcation ratio, and compactness ratio are commonly used for sub-watershed
61 prioritization within a watershed.

62 The prioritization of watersheds involves ranking sub-watersheds based on the level
63 of conservation treatment they require. Once prioritized, assessing hydrological
64 parameters like peak flow and runoff volume provides crucial information for
65 implementing soil and water conservation measures. The physical characteristics of
66 land use/land cover within the basin greatly influence these hydrological
67 parameters, which are dynamic and subject to change.

68 Advancements in remote sensing technology have provided valuable tools for
69 surveying, identifying, and classifying earth resources, aiding in watershed
70 management decisions. GIS-based multi-criteria decision analysis (MCDA)
71 combines geographical data and value judgments to assist decision-makers. The
72 present study utilizes GIS techniques and MCDM technique to identify critical sub-
73 watersheds in the Western Nayar River watershed.

MCDM techniques are essential for a strategic, informed, and sustainable approach to watershed management by giving major considerations to watersheds, where the more serious environmental issues are proactively addressed. It will, therefore, maximize resource utilization and support long-term ecological and socio-economic stability.

The catchment of the Western Nayar River is highly prone to soil erosion due to its terrain, as it has steep slopes. Again, the soil erosion process in this area is further hastened with the natural terrain and heavy rainfall characteristic of monsoon seasons that allow water to run off these slopes.

The loose and friable nature of the soil in the region, along with deforestation, further erodes away, leading to sediment deposition in the river system soil erosion in the Western Nayar watershed of Pauri district presents a serious challenge to agriculture, water quality, infrastructure, and biodiversity. Sustainability in land management practices, along with proactive measures for its control, are always required to mitigate its effects.

- 74 The study aims to prioritize sub-watersheds in the Western Nayar watershed within
75 the fragile Mid-Himalayan ecosystem by MCDM techniques which utilizes open-
source GIS tools and remote sensing data to apply the TOPSIS approach.

77 2.MATERIALANDMETHODS

79

80 TheanalysiswasconductedintheWestern NayarRiver,whichisanon-glacial river located

81 intheUttarakhandstateofIndia.Withinthisregion,therearetwomaintributaries:

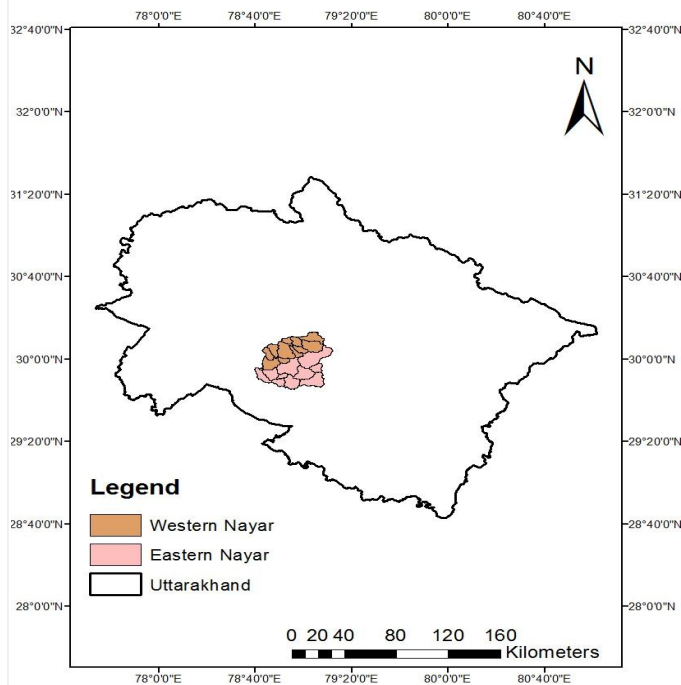
82 NayarEastandNayarWest.TheWesternNayarwatershedissituatedbetween

83 $29^{\circ}54'40''\text{N}$ - $30^{\circ}12'80''\text{N}$ latitudeand $78^{\circ}43'40''\text{E}$ - $79^{\circ}9'0''\text{E}$ longitude.TheNayar

84 Westtributaryoriginatesatanelevationof 2800meters.TheWesternNayar

85 tributaryisabout91kilometerslong.

Fig 1: Study Map



86

87 For thisstudy,RemoteSensingdatasuchasGoogleMapsofthestudyareaand

88 Digital ElevationModel (DEM) from theShuttleRadar TopographyMission(SRTM)

89 wereutilized.GeospatialanalysiswasconductedusingQGIS2.16,anopen-source

90 softwareplatform.

91 ThisresearchdemonstratestheusefulnessoftheMCDMTechniqueapproachfor

92 identifyingzonesensitivezonesinwatersheds,whichcanguidelandandwater resource

93 conservationpracticesforsustainabledevelopment.

94 2.1 Remotesensing and GIS techniques for watershed analysis:

95 RemoteSensingandGeographic InformationSystem (GIS) areessential toolsfor

96 watershedanalysis.Remotesensingtypicallyinvolvesusingsatelliteimageryand

97 aerialphotography.Satelliteimagery,inparticular,ishighlyadvantageousfor

98 studying watershed behavior due to its multispectral capabilities and broad
99 coverage. On the other hand, GIS focuses on analyzing different layers of data that
100 contains spatial information linked to specific geographic locations. GIS allows for the
101 integration of both machine-generated and user-generated spatial information,
102 facilitating operations management, analysis, and decision-making processes. It
103 encompasses all aspects of data acquisition and processing, making it a valuable
104 tool for monitoring and assessing various phenomena.

105 GIS plays a crucial role in bringing together remotely sensed data and spatially
106 referenced statistics, providing a comprehensive framework for analysis. Its ability to
107 seamlessly merge data from diverse sources, including remotely sensed data, has
108 significantly increased its use in applications such as mapping and change
109 detection.

110 **2.2 Delineation of watershed**

111 The DEM from the Shuttle Radar Topography Mission (SRTM) is obtained through
112 the Earth Explorer website (<https://earthexplorer.usgs.gov/>). This data will be utilized
113 to create a drainage map using QGIS 2.6.0 software, utilizing the UTM projection.
114 QGIS 2.6.0 provides spatial analysis tools that will be used to generate various
115 thematic maps. For this study, the SRTM DEM will have resolutions ranging from 1 arc-
116 second (30 meters) to as high as 30 arc-seconds (1 kilometer). Using QGIS
117 2.6.0 software, the study area will be delineated into sub-watersheds. This
118 delineation process will enable a detailed analysis of the watershed structure and
119 characteristics within the study area.

120

121 **2.3 Drainage map:**

122 The drainage networks for both the Western Nayar and Eastern Nayar watersheds
123 are constructed using the Strahler approach. The Strahler method is chosen for its
124 simplicity in stream ordering. The method follows these steps:

1251. First-order streams originate directly from a source.

1262. When two streams of order 'u' combine, they form a stream of order (u+1).

1273. If two streams of different orders join, the stream of the higher order is maintained.

128 By employing the Strahler method, the drainage networks of the Western Nayar and
129 Eastern Nayar watersheds are organized and classified according to stream order.
130 This approach allows for a straightforward and systematic way to understand the flow
131 patterns and hierarchy of streams within the watersheds.

132 table 1. **Morphometric Analysis:**

S.No.	Morphometric parameter	Formula	Reference
1	Streamorder	Hierarchical rank	Strahler,(1964)
2	Streamlength(Lu)	Lengthofthestream	Horton,(1945)
3	Meanstream Length(Lsm)	$L_{sm} = L_u / N_u$ Where, L_u =total stream lengthof order 'u' N_u = total no.ofstreamsegments of order 'u'	Strahler,(1964)
4	Streamfrequency (Ns)	$N_s = N_u / A$ where, N_u =totalno.ofstreams of all orders A = areaofbasin(km^2)	Horton,(1932)
5	Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ Where, N_u =No.ofstream segmentsofagiven order N_{u+1} =No.ofstream segmentsofnexthigher order.	Schumms,(1956)
6	Drainagedensity (D_d)	$D_d = L_u / A$ where, L_u =total stream lengthof allorders A =areaofbasin (km^2)	Horton,(1932)
7	Drainage texture (T)	$T = N_u / P$ where, N_u =totalno.ofstreams of all orders P = perimeter (km)	Horton,(1945)
8	Lengthof overland flow (L_o)	$L_o = 1 / D_d^2$ where, D_d = drainagedensity	Horton,(1945)
9	Elongationratio (R_e)	$R_e = 2\sqrt{(A/\pi)} / L_b$ where, A = areaofbasin(km^2) L_b =basinlength $\pi = \pi$ valuei.e.3.14	Schumms,(1956)
10	Circulatory ratio (R_c)	$R_c = 4\pi A / P^2$ where, $\pi = \pi$ valuei.e.3.14 A =areaofbasin (km^2) P =perimeter (km)	Miller,(1953)
11	Formfactor (R_f)	$R_f = A / L_b^2$ Where, A = areaof basin(km^2) L_b^2 =squareof basinlength	Horton,(1932)
12	Compactness coefficient(C_c)	$C_c = 0.2821P / A^{0.5}$ P =perimeter (km) A =areaofbasin (km^2)	NookaRatnamet al.(2005)

13	ShapeFactor (Rs)	$Rs=Lb^2/A$ Lb^2 =squareofbasinlength A =areaof basin(km ²)	NookaRatnamet al.(2005)
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133 **2.4WatershedPrioritization:**

134 Watershedprioritization,combinedwith morphometricparameters,hasbeena
 135 focusofresearchbyvarioussscholarsinthefieldofwatershedmanagement.For the
 136 currentstudy,thefollowingmorphometricparameterswereselected:Mean
 137 BifurcationRatio,DrainageDensity,TextureRatio,Stream Frequency,Watershed
 138 Relief,ReliefRatio,CirculatoryRatio,Form Factor,CompactnessCoefficient,
 139 ElongatedRatio,andLengthofOverlandFlow.

140 Thechoiceoftheseparameterswasbasedonrecommendationsfromexisting
 141 literatureandpreviousresearch.SomeparameterssuchasMeanBifurcationRatio,
 142 DrainageDensity,TextureRatio,Stream Frequency,LengthofOverlandFlow,and
 143 RelativeRelief arepositivelycorrelatedwitherosion.Thismeansthat higher values
 144 ofthese parametersindicatehigher erosionpotential.Conversely,parameterslike
 145 CirculatoryRatio,ElongatedRatio,Form Factor,andCompactnessCoefficientare
 146 inverselyproportional toerosion,asindicatedbyNookaet al. (2005).Lower values
 147 oftheseparametersareassociatedwithhigher erosionpotential.

148 Thisselectionofmorphometricparametersprovidesacomprehensiveapproachto
 149 assessingwatershedcharacteristicsrelatedtoerosionpotential.Byconsidering
 150 theseparameters,thestudyaimstoprioritizesub-watershedswithintheWestern
 151 Nayarwatershed,takingintoaccounttheir erosionsusceptibilitybasedonthese
 152 establishedcorrelations.

2.5 Prioritization by TOPSIS Model

The reason why TOPSIS is effective in ranking watersheds is through the evaluation of multiple criteria in a systematic and objective manner. Its flexibility allows for factors ranging from environmental and hydrological data to socio-economic considerations. The integration of TOPSIS with GIS and its application in the themes of climate resilience, disaster risk reduction, and community-based management further points out its innovative potential regarding solving complex watershed management challenges.

New Applications of TOPSIS to Watershed Prioritization

GIS Integrations:

Most of the innovative applications of TOPSIS have experienced emergence in integrating GIS into spatial analysis. Its very core is to map watershed attributes like risk due to soil erosion, land usage, and availability of water. On the other hand, TOPSIS is applied to prioritize specific areas in need of intervention based on these mapped criteria.

Community-Based Watershed Management:

TOPSIS integrates socio-economic aspects such as poverty levels, local livelihoods, and the potential for community participation in watershed management. This makes TOPSIS a very effective tool for public participation in decision-making processes as well as ensuring supportive interventions for the achievement of sustainable development goals.

With the consideration of community needs and local knowledge, TOPSIS aligns watershed management with general social and economic objectives, thereby maximizing the chance of the project's successful outcome.

Disaster Risk Reduction in Watersheds

TOPSIS can be used to prioritize the watersheds exposed to natural hazards like landslides, flash floods, or soil erosions. It weighs criteria like the instability of the slope, the pattern of rainfall, loss of vegetation, and vulnerability of the population in order to determine the most exposed watersheds.

TOPSIS helps in disaster preparedness and mitigation through measures targeted towards watersheds most prone to a natural hazard to prevent disastrous impacts on the communities and ecosystems adaptation measures.

154 Morphometric analysis in drainage areas is helpful as sub-watersheds across
 155 various scales of priority (Biswas et al., 1999; Sureh et al., 2004). In this study,
 156 morphometric factors associated with the erosion hazard incorporated linear, shape
 157 and landscape properties of the watershed (Pate et al., 2013). The linear and
 158 landscape parameters are directly proportional to the erosion hazard whereas
 159 shape parameters have a negative correlation where by lower values indicate higher
 160 vulnerability to erosion (Patel and Dholakia, 2010; Patel et al., 2012). For instance, higher
 161 ranked sub-watersheds presented higher values of drainage density whereas
 162 the low ranked possessed lower values of drainage density.

163 After calculating the linear, shape, and landscape morphometric parameters, as
 164 shown in Table 3, a decision matrix was structured in the first step of applying multi-
 165 criteria decision-making models. All the criteria used within the analysis, such as

166 slope, drainage density, and stream frequency, had different units of measurement,
167 which implies that normalization of data was needed to ensure comparability and
168 applicability. The TOPSIS model was normalized using the vector approach
169 assisted by the linear method of normalization.
170 TOPSIS, which stands for "Technique for Order of Preference by Similarity to Ideal
171 Solution," is a multi-criteria decision-making (MCDM) method used for ranking a set
172 of alternatives based on their proximity to the ideal solution. It was introduced by
173 Hwang and Yoon in 1981 and is widely employed in decision analysis, operations
174 research, and other fields. The TOPSIS method involves comparing alternatives to
175 both the ideal and anti-ideal solutions to determine their relative closeness.
176 TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a
177 compensatory aggregation method used to compare a set of alternatives in multi-
178 criteria decision-making. In TOPSIS, scores for each criterion are normalized, and the
179 geometric distance between each alternative and the ideal alternative (the one
180 with the best score in each criterion) is calculated. The method allows for trade-offs
181 between criteria, accommodating situations where a poor result in one criterion can
182 be compensated by a good result in another criterion.

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184

185 **3. RESULTS AND DISCUSSION**

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187 **3.1 Delineation of watersheds:**

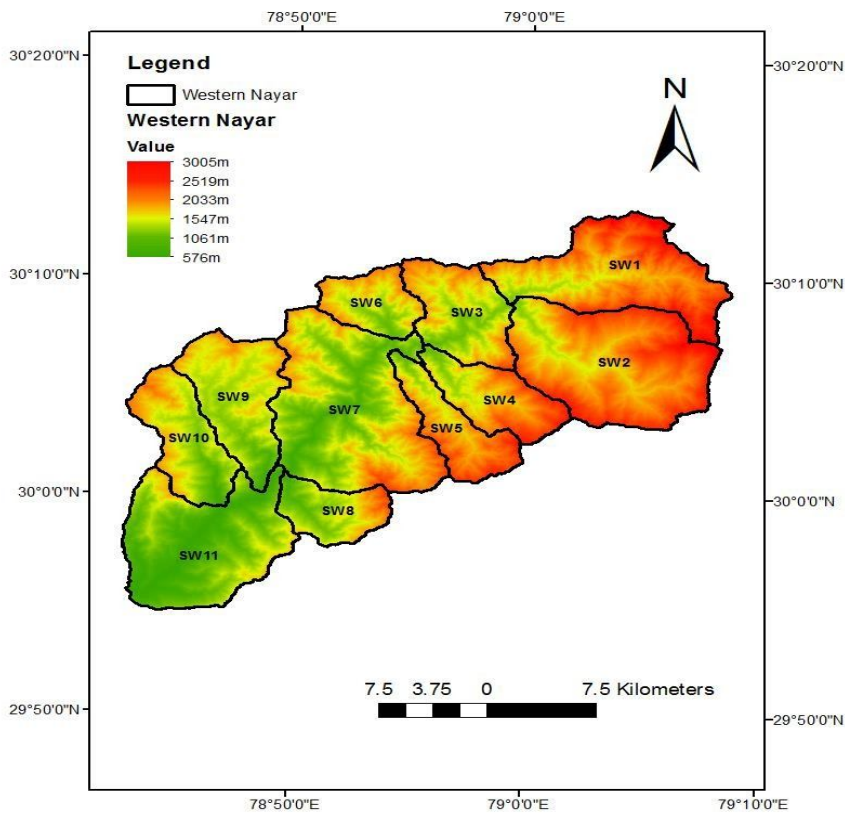
188 The Western Nayar watershed has been delineated utilizing QGIS 2.6.0 software.
189 Specifically, the Western Nayar watershed has been partitioned into 11 distinct sub-
190 watersheds. These delineations were made possible using digital elevation maps
191 (DEMs) sourced from the Shuttle Radar Topography Mission (SRTM) with a
192 resolution of 30 meters. The DEMs, depicted in [Fig. 1] for Western Nayar
193 watersheds, provided detailed representations of the elevation and terrain
194 characteristics of the regions. This information is instrumental in understanding the
195 topographical layout and morphological features of the watersheds, supporting
196 further analysis and the prioritization of sub-watersheds based on various
197 parameters.

198 **3.2 Drainage maps**

199 Using QGIS 2.6.0 software, the drainage networks of the Western Nayar watershed
200 have been established. Upon detailed examination of the drainage network map, it
201 was observed that there are:

202 The Western Nayar watershed is classified as a 4th order watershed. Analysis of the
203 drainage network map revealed the following:

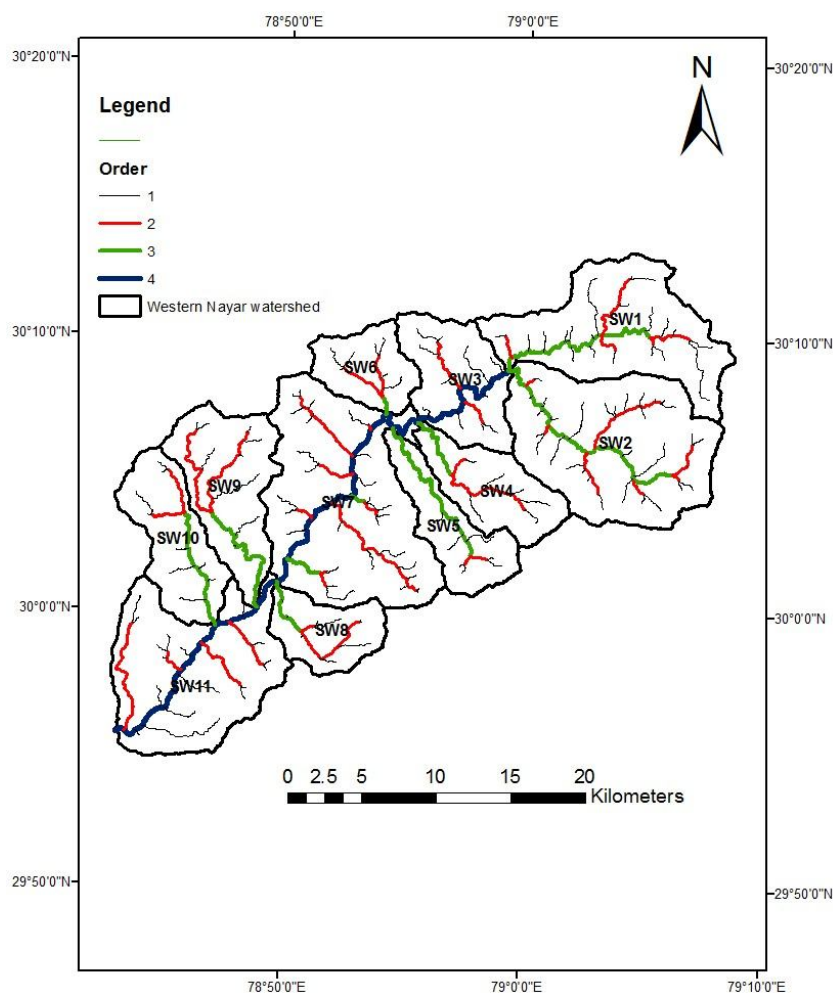
204 i) 163 first-order streams with a total length of 219.72 kilometers
 205 ii) 39 second-order streams covering 129.80 kilometers
 206 iii) 11 third-order streams with a combined length of 97.05 kilometers
 207 iv) fourth-order stream with a length of 48.33 kilometers
 208 These findings are summarized in Table. This detailed examination of the drainage
 209 network provides valuable insights into the stream order distribution and total stream
 210 length within each watershed.



211

212 **Fig 2: Digital Elevation Model (DEM) map of**

Western Nayar watersheds 213



214

215 **Fig 3.: Drainage network map of Western**

Nayar watershed

216 **3.3 Prioritization by TOPSIS Model**

217 In the TOPSIS model, the top three-ranked sub-watersheds have the highest
 218 scores, which are 0.740, 0.709, and 0.648, ranked 1 to 3, respectively. Thus, sub-
 219 watersheds ranked SW8, SW5, SW7 as described in fig 4. have been identified as
 220 being most susceptible to erosion. On the other end, the least sensitive to erosion
 221 are SW2, SW9, SW3 with scores of 0.540, 0.439 and 0.430 respectively. This area
 222 under study was then categorized into four classes: low (0–0.25), moderate (0.25–
 223 0.5), high (0.5–0.75), and very high (0.75–1).

224

225

226 **Table 2:SubWatershed wiseanalyzed morphometricparametersfor Western 227 Nayarwatershed**

	A	P	L _u	R _{bm}	D _d	N _f	R _c	R _f	C _c	R _e	R	L _o	T	R _h
SW1	93.55	68.9	20.88	4.62	0.65	0.28	0.25	0.21	2.01	0.52	1.75	0.77	0.30	84.13
SW2	118.6	68.2	19.68	5.64	0.60	0.32	0.41	0.31	1.56	0.62	1.68	0.82	0.50	85.71
SW3	50.15	42.7	9.50	4.62	0.75	0.52	0.34	0.56	1.70	0.84	1.31	0.66	0.49	137.89
SW4	42.37	41.5	12.97	2.50	0.64	0.54	0.31	0.25	1.80	0.57	1.58	0.77	0.14	122.48
SW5	37.88	46.45	13.23	2.75	0.62	0.26	0.22	0.22	2.13	0.53	1.58	0.80	0.15	121.53
SW6	30.74	32.03	6.44	2.75	0.57	0.33	0.38	0.74	1.63	0.97	1.17	0.87	0.22	182.81
SW7	134.62	79.99	18.34	3.87	0.77	0.30	0.26	0.40	1.94	0.71	1.70	0.64	0.38	92.89
SW8	31.63	32.75	10.60	2.75	0.65	0.32	0.37	0.28	1.64	0.60	1.69	0.77	0.21	169.00
SW9	60.94	51.59	17.45	3.25	0.68	0.2	0.29	0.20	1.86	0.50	0.78	0.73	0.17	44.59
SW10	48.51	44.38	12.42	3.25	0.56	0.25	0.31	0.31	1.80	0.63	1.24	0.89	0.20	103.33
SW11	100.61	8.144	16.54	4.00	0.64	0.21	0.27	0.37	1.92	0.68	1.34	0.78	0.23	81.21

228

229 **Table 3:Weightagevalues forninemorphometricparameters**

Morphometric parameters	R	L_o	D_d	R_{bm}	N_f	T	R_e	R_c	R_f
Weight (X_i)	0.24	0.18	0.19	0.13	0.08	0.05	0.05	0.05	0.03

Table 4 Normalised weighted matrix and final ranking

Morphometric parameters	R	Lo	Dd	Rbm	Nf	T	Re	Rc	Rf	Si
Weight (Xi)	0.24	0.18	0.19	0.13	0.08	0.05	0.05	0.05	0.03	
SW1	0.085644	0.055038	0.056879	0.046676	0.019969	0.016357	0.011534	0.010762	0.004944	0.031
SW2	0.082218	0.058612	0.052504	0.056981	0.022822	0.027262	0.013752	0.01765	0.007298	0.042
SW3	0.06411	0.047175	0.06563	0.046676	0.037085	0.026716	0.018631	0.014637	0.013184	0.046
SW4	0.077324	0.055038	0.056004	0.025258	0.038512	0.007633	0.012643	0.013345	0.005886	0.031
SW5	0.077324	0.057182	0.054254	0.027783	0.018543	0.008178	0.011755	0.009471	0.00518	0.023
SW6	0.057259	0.062186	0.049879	0.027783	0.023535	0.011995	0.021515	0.016359	0.017422	0.034
SW7	0.083197	0.045746	0.06738	0.039099	0.021395	0.020719	0.015748	0.011193	0.009417	0.02
SW8	0.082707	0.055038	0.056879	0.027783	0.022822	0.01145	0.013308	0.015928	0.006592	0.020
SW9	0.038173	0.052179	0.059504	0.032835	0.014264	0.009269	0.01109	0.012484	0.004709	0.052
SW10	0.060685	0.063615	0.049004	0.032835	0.017829	0.010905	0.013973	0.013345	0.007298	0.034
SW11	0.065579	0.055753	0.056004	0.040412	0.014977	0.01254	0.015082	0.011623	0.008711	0.030
Best Fi+	0.085644	0.045746	0.049004	0.025258	0.014264	0.007633	0.021515	0.01765	0.017422	
Worst Fi-	0.038173	0.063615	0.06738	0.056981	0.038512	0.027262	0.01109	0.009471	0.004709	

The Relief (R) value of SW1 is 0.0856, indicating prominent elevational variations which may lead to greater surface runoff. It is moderately high. Length of Overland Flow (Lo) is 0.0550, which indicates water travels a moderate distance before recharging to streams and thus induces time effect upon the concentration of runoff. Drainage Density (Dd) has a value of 0.0569, meaning quite developed drainage pattern, and thereby efficiently draining water. A Bifurcation Ratio (Rbm) of 0.0467 suggests a complex stream network, possibly leading to localized flooding when it rains. The Texture Ratio is 0.0164, implying a fairly coarse drainage texture while the Stream Frequency (Nf) is 0.0200, which suggests a moderate number of streams per unit area. The watershed is slightly elongated, represented by the Elongation Ratio (Re) of 0.0115, the Circulatory Ratio (Rc) of 0.0108, and the Form Factor (Rf) of 0.0049, which impacts the runoff response of

the watershed. SW1 ranks fifth with a Pi value of 0.632 computed from its Si+ value of 0.0319 and Si- value of 0.0548 as shown in Tables 3 and 4.

- For SW2, its Relief (R) is at 0.0822, and this measures the elevation differences that happen to make the surface runoff become a bit slower. Length of Overland Flow (Lo) is at 0.0586, meaning the distance travelled before it drops into streams is more extensive, thus making it potentially delayed in concentration. Drainage Density (Dd) of 0.0525 would mean it happens with less dense drainage networks, hence the gradual release of water. A higher Bifurcation Ratio (Rbm) of 0.0570, a more intricate drainage network would be seen, and this watershed might be more prone to the localized flooding. The Stream Frequency (Nf) of 0.0228 indicates a high number of streams per unit area, and its Texture Ratio (T) is 0.0273, indicating a coarser drainage texture. The compact shape is denoted by a Re value of 0.0138, a value of Rc as 0.0177, and Rf value of 0.0073 resulting in swift runoff concentrations. SW2 ranks ninth with a value of Pi as 0.540, due to Si+ value of 0.0426 and Si- value of 0.0501.

- For SW3 the Relief, or R, stands at 0.0641 that is lower than both SW1 and SW2 which means fewer changes in elevation and slower overland flow. The Length of Overland Flow, Lo is 0.0472 meaning that distances traveled before falling into the drainage system will be shorter, meaning more concentration of runoff. Dd values stand equal to 0.0656 is rather high indicating more elements in the drainage network that support a faster water discharge. Rbm = 0.0467: moderately complex - should be beneficial in fighting flood conditions. Stream Frequency is 0.0371; therefore, very high, which aids in increasing drainage capacity. Texture Ratio is 0.0267. That's coarse drainage texture. The values for Elongation Ratio are 0.0186; Circulatory Ratio, 0.0146; and Form Factor, 0.0132. So, it tends to be more circular in shape, therefore, quicker response to hydrological events. SW3 is ranked eleventh with a Pi value of 0.430, which originates from a Si+ value of 0.0461 and Si- value of 0.0348.

- The Relief (R) stands at 0.0773 in SW4, meaning it will be a moderate elevation difference which would determine the rate of running of water over the surface. The Length of Overland Flow (Lo) is at 0.0550, where water runs a modest distance before reaching streams. The Dd value is 0.0560, representing a well-developed drainage network, which enables easy overflow of water. The lower value for Rbm is 0.0253, which implies the stream network is not that complex and would be less likely to flood areas. A Stream Frequency (Nf) of 0.0385 is very high, thus a sufficient number of streams per unit area exist. The value for Texture Ratio (T) of 0.0076 is very small, implying a finer drainage texture, that would slow the rates of discharge. The value of 0.0126 for Elongation Ratio (Re), 0.0133 for Circulatory Ratio (Rc) and 0.0059 for Form Factor (Rf) depicts a compact watershed shape, which advances the speed of runoff concentration. SW4 has been ranked on the fourth position due to its Pi value of 0.636 with help of Si+ = 0.0320 and Si- = 0.0561.

- For SW5, the Relief (R) value is also zero point 0773, which shows the least in elevation changes leading to moderate surface runoff. Lo= The Length of Overland Flow is 0.0572. This implies that quite a long journey of water till reaching the stream network. The Drainage Density is 0.0543, implying a very well-developed and strongly contributing drainage system that ensures discharge of water in an efficient way. A Bifurcation Ratio of 0.0278 speaks of a significantly complicated stream network that could also assist in the dissipation of the water during heavy falls. The Stream Frequency (Nf) is 0.0185, which is lower than in other watersheds, meaning there are fewer streams per unit area. Texture Ratio (T) of 0.0082 is an indicator of finer drainage texture. Elongation Ratio (Re) of 0.0118, Circulatory Ratio (Rc) of 0.0095, and

Form Factor (Rf) of 0.0052 indicate that the watershed has a compact shape so that runoff water can be collected and with faster hydrological reactions. SW5 has the second highest Pi value, being 0.709, derived by its Si+ value of 0.0238 and Si- value of 0.0580.

• The Relief (R) value is 0.0573 for SW6, meaning elevation variations are smaller in this case and thus may lead to slower runoff. The Length of Overland Flow (Lo) is 0.0622, meaning it flows further through the landscape before entering the stream system. A Dd value of 0.0499 signifies a less dense drainage network which will lead to more time for outflow. The Bifurcation Ratio, Rbm = 0.0278 indicates a moderately complex stream network. The Stream Frequency, Nf = 0.0235 is comprised of a moderate number of streams per unit area. The Texture Ratio, T = 0.0120 designates coarser drainage texture. Values of 0.0215 for the Elongation Ratio (Re), 0.0164 for the Circulatory Ratio (Rc), and 0.0174 for the Form Factor (Rf) indicate an elongated shape for the watershed, which might mean slower runoff and additional recharge into the groundwater. SW6 ranks seventh with a Pi value of 0.581 considering a Si+ value of 0.0345 and a Si- value of 0.0480.

• For SW7, R = 0.0832 value; this means more lateral flow changes and possibly a higher runoff rate. Lo = 0.0457, meaning that the distances traveled by the water reach the streams very fast, hence increasing the concentration of runoff. Dd = 0.0674, which is high; there is an excellent connection to a drainage network; the rainwater will be drained off very fast. A Bifurcation Ratio of 0.0391 denotes that the stream drainage network is complicated. This complicates the drainage network, making it prone to flooding with heavy rainfalls. Stream Frequency value of 0.0214 reveals a moderate number of streams per unit area. Furthermore, the Texture Ratio value of 0.0207 denoted a more aggressive drainage texture. With an Elongation Ratio (Re) of 0.0157, Circulatory Ratio (Rc) of 0.0112, and Form Factor (Rf) of 0.0094, the watershed is elongated; thus, it might delay runoff, allowing for enhanced recharge of groundwater. Third from the ranking is SW7, for which a Pi value of 0.648 was determined using its Si+ value of 0.0299 and Si- value of 0.0552.

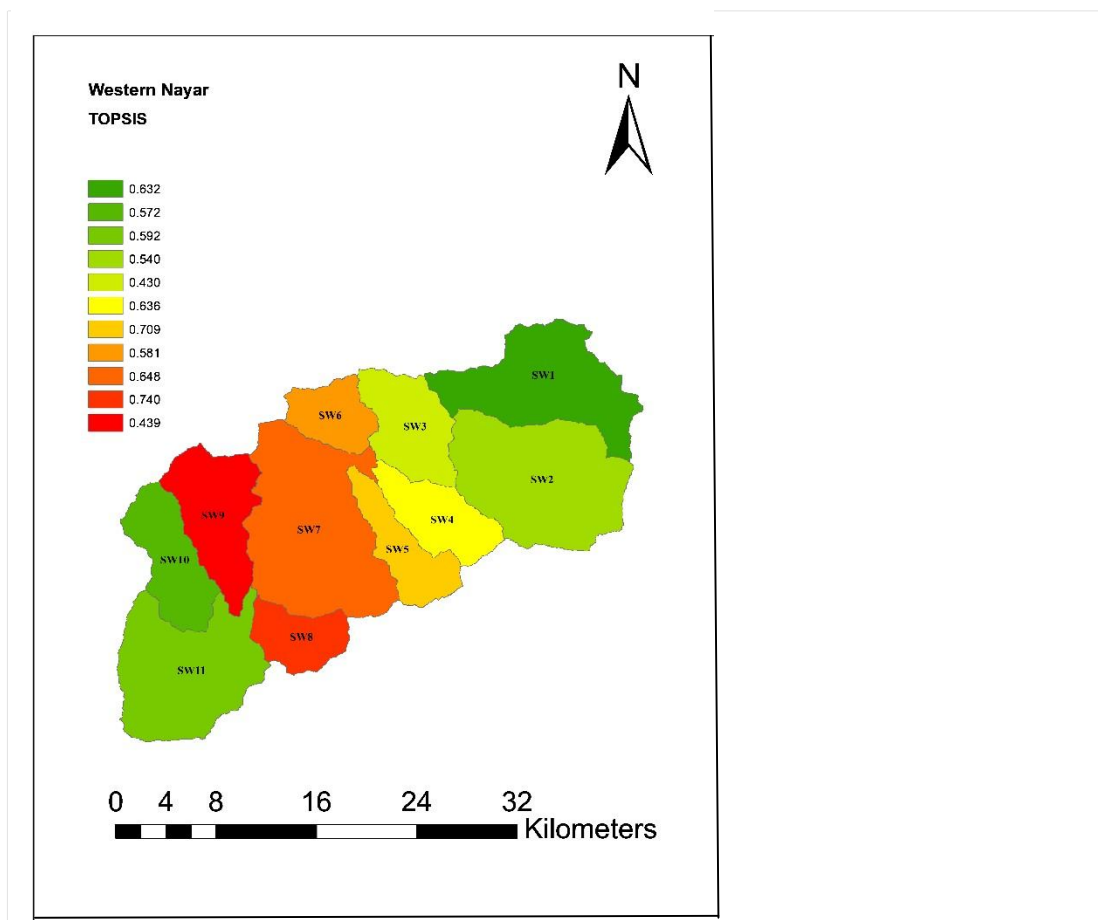
• For SW8, the Relief value is 0.0827, meaning areas of extreme elevation changes, and thus could result in faster surface runoff. The Lo or Length of Overland Flow is 0.0550, which would imply that water could travel moderate distances. The value for Dd or Drainage Density is 0.0569, showing an advanced level of drainage discharge support. Rbm or Bifurcation Ratio is 0.0278, meaning that the stream branching pattern is slightly complex. Stream Frequency (Nf) is at 0.0228, indicating a moderate number of streams and the coarser texture of drainage with Texture Ratio (T) at 0.0114. The Elongation Ratio (Re), Circulatory Ratio (Rc), and Form Factor (Rf) both indicate an elongated shape for this watershed at 0.0133, 0.0159, and 0.0066, respectively. SW8 has the highest Pi with a value of 0.740, gotten from its Si+ of 0.0209 and Si- of 0.0597.

SW9 has the lowest Relief (R) with a value of 0.0382, meaning that elevation varies little, and, therefore, runoff is slower. Its Lo is 0.0522, so water travels a considerable distance before entering into streams. A Drainage Density (Dd) of 0.0595 indicates a very dense drainage system favorable to effective discharge. The value of Bifurcation Ratio, Rbm is 0.0328, which indicates relatively complex stream network. A lower value of Stream Frequency, Nf of 0.0143 suggests fewer streams per unit area and a finer drainage texture is indicated by the value of Texture Ratio, T which is 0.0093. This watershed displays a more elongated shape with an Elongation Ratio (Re) of 0.0111, the Circulatory Ratio (Rc) of 0.0125,

and the Form Factor (Rf) of 0.0047. SW9 is tenth with a Pi value of 0.439 based on a Si+ value of 0.0526 and Si- value of 0.0412.

• Relief (R) value for SW10 is 0.0607, showing moderate elevation differences. Lo = The Length of Overland Flow is 0.0636, meaning that "water travels a significant length before entering the drainage network". Dd = The Drainage Density is 0.0490, which is less dense. Rbm = The Bifurcation Ratio is 0.0328, meaning that the stream network is moderately complex. T = The Texture Ratio indicates a drain texture is somewhat coarse with a value of 0.0109. Nf = The Stream Frequency, on the other hand, indicates fewer streams per unit area with a value of 0.0178. The watershed is only very slightly elongated, according to the elongation ratio of 0.0140, the circulatory ratio of 0.0133, and the form factor of 0.0073. SW10 ranks eighth with a Pi value of 0.572 derived from a Si + of 0.0347 and Si- of 0.0464.

• SW11 has a Relief (R) value of 0.0656, indicating that moderate relief exerts its influence over the speed of runoff. The Length of Overland Flow (Lo) is 0.0558, which indicates there is moderately long water travel before entry to the drainage system. The Drainage Density (Dd) is 0.0560, indicating a relatively well-developed drainage network. The Bifurcation Ratio (Rbm) is 0.0404, which indicates that the stream network is more complex; thus, at the time of intensive rains, there is increased risk of flooding. An Nf value of 0.0150 means that there exist fewer streams per unit area; a T value of 0.0125 means that drainage texture is more finely distributed. Compactly shaped watersheds are indicated through values of Re = 0.0151, Rc = 0.0116, and Rf = 0.0087. SW11 ranked sixth with a Pi value of 0.592 based on a Si+ value of 0.0310 and Si- value of 0.0450.



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232 **Fig 4.:Prioritymap of WesternNayarwatershed based onTOPSIS**

233 **4. CONCLUSION**

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235 WiththeapplicationofGIS techniquesandSRTMDem, thisresearchdemonstratedthe
 236 current potential effectiveness of this tool in further geomorphometricanalysis and
 237 identification of sub-watersheds for further morphometric characteristic extraction. The
 238 TOPSISmodelprovidedfourclasses:veryhigh,high,moderate,andlow. TheHimalayan
 239 Basinisveryhighlypronetoerosion, andhence, thenecessityforproperconservation
 240 measuresstandshighinordertoreducesoilerosion, decreasesedimentationinreservoirs,
 241 stabilizesteepslopessoasnottocauselandslides, andreducetheriskoffloodhazardsin
 242 thefuture. ThisstudyfocusesontheapplicabilityofGISandremotesensingmethods
 243 combinedwithMCDM, suchasTOPSIS towards helpingdecision-makersandplannersin
 244 soilandwaterresource management. Thus, theapproachofprioritizingsub-watersheds
 245 itselfisaviablemethodthatmayimproveonwatershedmanagementandpreservationof
 246 waterresources.

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Disclaimer (Artificial intelligence)

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Details of the AI usage are given below:

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