Erodibilityprioritization andmappingofaMid Himalayanwatershedusing Technique of order preferencebysimilaritytoideal solution (TOPSIS)

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ABSTRACT

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, evaluationoftheseerodibleareasis of utmost importancesothatthepreventive measurescanbetakenaccordingly.It assessedthesub-basinsinthebasinusingmorphometricparametersandseveral multi-criteriadecision-makingmodels,suchas Techniquefor OrderPreferencebySimilarity toIdealSolution(TOPSIS),Utilizing AdvancedSpaceThermal EmissionRadiometer (ASTER)dataanda30m Digital ElevationModel (DEM),morphometricparameterswereextractedandanalyzed.To testtheMCDMmethods,percentandintensityofchangeindiceswereadopted.The rankingresultsweresuchthatsub-watershed2wasrankedattopasthemost susceptibletoerosionfor TOPSISmodel,Ingeneral,themorphometric parameterswereeffectivefor identifyingerosion-proneareas.

Keywords:[Morphometry, GIS,prioritization,TOPSIS,}

1.INTRODUCTION

Thehydrologicalresponseofabasinissignificantlyinfluencedbyitsmorphological andclimaticcharacteristics.Morphological attributesofawatershedarequantifiable features that play a crucial role in understanding its hydrological behavior. Therefore,linkingthesemorphologicalparameterswithhydrologicalcharacteristics canprovideavaluablemethodtosimulatethebehaviorofvariousbasins,especially thosethatarenot monitored.

Morphometricscienceinvolvesthemeasurement,quantification,andmathematical analysis of the earth's surface, including its layout, shape, and landforms' dimensions. Analyzing themorphometryof a watershed offers a quantitative descriptionofitsdrainagesystem,whichisessential for watershedcharacterization. Thisanalysisinvolvesmeasuringlinearfeatures,areaaspects,channelnetwork gradients,andgroundslopescontributingtothedrainagebasin.Remotesensing techniques,particularlysatelliteimagery,areconvenientandeffectivemethodsfor conducting morphometricanalysisover largeareas.

Variousgeomorphological parameterssuchasstreamorder, length,frequency, drainage density, texture ratio, farm factor, circulatory ratio, elongation ratio, bifurcation ratio,and compactness ratioare commonly usedfor sub-watershed prioritizationwithinawatershed.

Theprioritizationofwatershedsinvolvesrankingsub-watershedsbasedonthelevel ofconservationtreatmentstheyrequire.Onceprioritized,assessinghydrological parameters like peak flow and runoff volume provides crucial information for implementingsoilandwaterconservationmeasures.Thephysicalcharacteristicsof land use/land cover within the basin greatly influence these hydrological parameters,whicharedynamicandsubjecttochange.

Advancements inremote sensing technology have provided valuable tools for surveying, identifying, and classifying earth resources, aiding in watershed management decisions. GIS-based multi-criteria decision analysis (MCDA) combinesgeographicaldataandvaluejudgmentstoassistdecision-makers..The presentstudyutilizesGIStechniquesandMCDMtechnique toidentifycriticalsub-watershedsintheWesternNayarRiver 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.

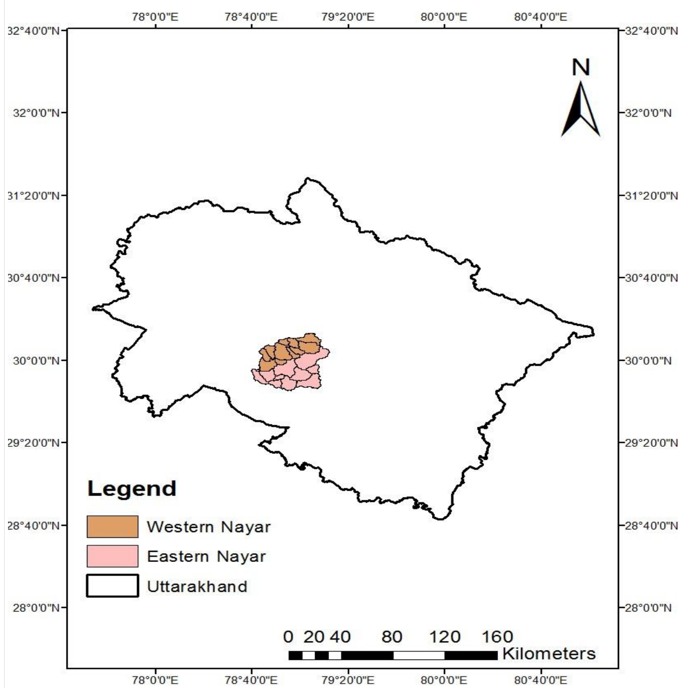
The catchment of the Western Nayar River is highly prone to soil erosion due to its terrain, as it has steep slops. Again, the soil erosion process in this area is further hastened with the natural terrain and heavy rainfall characteristic of monsoon seasons that allow water to run off these slopes.

The loose and friable nature of the soil in the region, along with deforestation, further erodes away, leading to sediment deposition in the river systemsoil 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.

ThestudyaimstoprioritizesubwatershedsintheWesternNayarwatershedwithin thefragileMid-Himalayanecosystem by MCDM techniques whichutilizesopen-sourceGIStoolsandremotesensingdatatoapplytheTOPSISapproach.

2.MATERIALANDMETHODS

TheanalysiswasconductedintheWestern NayarRiver,whichisanon-glacial river located intheUttarakhandstateofIndia.Withinthisregion,therearetwomaintributaries: NayarEastandNayarWest.TheWesternNayarwatershedissituatedbetween 29°54'40"N- 30°12'80"N latitudeand78°43'40"E-79°9'0"Elongitude.TheNayar Westtributaryoriginatesatanelevationof 2800meters.TheWesternNayar tributaryisabout91kilometerslong.



For thisstudy,RemoteSensingdatasuchasGoogleMaps ofthestudyareaand Digital ElevationModel (DEM) from theShuttleRadar TopographyMission(SRTM) wereutilized.GeospatialanalysiswasconductedusingQGIS2.16,anopen-source softwareplatform.

Thisresearchdemonstratestheusefulness ofthe MCDMTechniqueapproachfor identifyingsensitivezonesinwatersheds,whichcanguidelandandwater resource conservationpracticesfor sustainabledevelopment.

2.1 Remotesensing and GIStechniques forwatershed analysis:

RemoteSensingandGeographic InformationSystem (GIS) areessential toolsfor watershedanalysis.Remotesensingtypicallyinvolvesusingsatelliteimageryand aerialphotography.Satelliteimagery,inparticular,ishighlyadvantageousfor studyingwatershedbehavior duetoitsmultispectral capabilitiesandbroad coverage.Ontheother hand,GISfocusesonanalyzingdifferentlayers of datathat containspatial informationlinkedtospecificgeographiclocations.GISallowsforthe integrationof bothmachine-generatedanduser-generatedspatial information, facilitatingoperationsmanagement,analysis,anddecision-makingprocesses.It encompassesall aspects of dataacquisitionandprocessing,makingitavaluable toolfor monitoringandassessingvariousphenomena.

GISplaysacrucial roleinbringingtogether remotelysenseddataandspatially referencedstatistics,providingacomprehensiveframeworkforanalysis.Itsabilityto seamlesslymergedatafrom diversesources,includingremotelysenseddata,has significantlyincreaseditsuseinapplicationssuchasmappingandchange detection.

2.2 Delineation ofwatershed

TheDEMfromtheShuttleRadar TopographyMission(SRTM) isobtainedthrough theEarthExplorer website(https://earthexplorer.usgs.gov/).Thisdatawillbeutilized tocreateadrainage mapusingQGIS2.6.0software,utilizingtheUTMprojection. QGIS2.6.0providesspatial analysistoolsthatwill beusedtogeneratevarious thematicmaps.For thisstudy,theSRTMDEMwillhaveresolutionsrangingfrom 1 arc-second (30 meters) toashighas30arc-seconds(1kilometer).UsingQGIS 2.6.0software,thestudyareawill bedelineatedintosub-watersheds.This delineationprocesswillenableadetailedanalysisofthewatershedstructureand characteristicswithinthestudyarea.

2.3 Drainagemap:

Thedrainagenetworksfor boththeWesternNayarandEasternNayarwatersheds areconstructedusingtheStrahlerapproach.TheStrahlermethodischosenfor its simplicityinstreamordering.Themethodfollows thesesteps:

1. First-order streamsoriginatedirectlyfromasource.
2. Whentwostreamsof order 'u'combine,theyformastreamof order (u+1).
3. Iftwostreams of different ordersjoin,thestreamofthehigher order ismaintained.

ByemployingtheStrahlermethod,thedrainagenetworks oftheWesternNayarand EasternNayarwatershedsareorganizedandclassifiedaccordingtostreamorder. Thisapproachallowsfor astraightforwardandsystematicwaytounderstandthe flow patternsandhierarchy ofstreamswithinthewatersheds.

table 1.**MorphometricAnalysis:**

S.No.	Morphometric parameter	Formula	Reference
1	Streamorder	Hierarchical rank	Strahler,(1964)
2	Streamlength(Lu)	Lengthofthestream	Horton,(1945)
3	Meanstream Length(Lsm)	Lsm =Lu/Nu Where,Lu=total stream lengthof order ‘u’ Nu= total no.ofstreamsegments of order ‘u’	Strahler,(1964)
4	Streamfrequency (Ns)	Ns=Nu/A where,Nu=totalno.ofstreams of all ordersA= areaofbasin(km^2)	Horton,(1932)
5	Bifurcation ratio (R_b)	R_b=Nu/Nu+1 Where,Nu=No.ofstream segmentsofagiven order Nu+1=No.ofstream segmentsofnexthigher order.	Schumms,(1956)
6	Drainagedensity (D_d)	D_d= Lu/A where,Lu=total stream lengthof allorders A=areaofbasin (km^2)	Horton,(1932)
7	Drainage texture (T)	T=Nu/P where,Nu=totalno.ofstreams of all ordersP= perimeter (km)	Horton,(1945)
8	Lengthof overland flow (Lo)	Lo=1/Dd*2 where,Dd= drainagedensity	Horton,(1945)
9	Elongationratio (Re)	Re=2√(A/Pi)/Lb where,A= areaofbasin(km^2) Lb=basinlength Pi =Pi‘ valuei.e.3.14	Schumms,(1956)
10	Circulatory ratio (Rc)	Rc= 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/Lb^2 Where,A= areaof basin(km^2) L_b^2=squareof basinlength	Horton,(1932)
12	Compactness coefficient(Cc)	Cc= 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)

2.4WatershedPrioritization:

Watershedprioritization,combinedwith morphometricparameters,hasbeena focusofresearchbyvariousscholarsinthefieldofwatershedmanagement.For the currentstudy,thefollowingmorphometricparameterswereselected:Mean BifurcationRatio,DrainageDensity,TextureRatio,Stream Frequency,Watershed Relief,ReliefRatio,CirculatoryRatio,Form Factor,CompactnessCoefficient, ElongatedRatio,andLengthofOverlandFlow.

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

Thisselectionofmorphometricparametersprovidesacomprehensiveapproachto assessingwatershedcharacteristicsrelatedtoerosionpotential.Byconsidering theseparameters,thestudyaimstoprioritizesub-watershedswithintheWestern Nayarwatershed,takingintoaccounttheir erosionsusceptibilitybasedonthese establishedcorrelations.

2.5Prioritization byTOPSISModel

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 successfully 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.

Morphometricanalysisindrainageareasishelpfulassub-watershedsacross variousscalesof priority(Biswasetal.,1999;Surehetal.,2004.Inthisstudy, morphometricfactorsassociatedwiththeerosionhazardincorporatedlinear,shape andlandscapepropertiesofthewatershed(Pateletal.,2013).Thelinearand landscapeparametersaredirectlyproportionaltotheerosionhazardwhereas shapeparametershaveanegativecorrelationwherebylower valuesindicatehigher vulnerabilitytoerosion(Patel andDholakia,2010;Patel et al.,2012).For instance, higher rankedsub-watershedspresentedhigher valuesof drainagedensitywhereas thelow rankedpossessedlower valuesofdrainagedensity.

Aftercalculatingthelinear,shape,andlandscape morphometricparameters,as showninTable3,adecisionmatrixwasstructuredinthefirststepof applying multi-criteriadecision-makingmodels.All thecriteriausedwithintheanalysis,suchas slope, drainagedensity,andstreamfrequency,haddifferentunitsofmeasurement, whichimpliesthatnormalizationof datawasneededtoensurecomparabilityand applicability.TheTOPSISmodel wasnormalizedusingthevector approach assistedbythe linear methodof normalization.

TOPSIS,whichstands for"TechniqueforOrderofPreference by SimilaritytoIdeal Solution,"isamulti-criteriadecision-making(MCDM)methodused forrankingaset ofalternativesbasedontheirproximityto theidealsolution.Itwasintroduced by HwangandYoonin1981andiswidely employedindecisionanalysis, operations research,andother fields.TheTOPSISmethodinvolvescomparingalternativesto boththeidealandanti-ideal solutionstodeterminetheir relativecloseness.

TOPSIS(TechniqueforOrderofPreferencebySimilaritytoIdealSolution)isa compensatory aggregationmethod usedtocompareasetofalternativesinmulti-criteriadecision-making.InTOPSIS,scoresforeachcriterionarenormalized,and the geometricdistancebetween each alternative andtheideal alternative(theone withthebestscoreineachcriterion)iscalculated.Themethodallows fortrade-offs betweencriteria, accommodatingsituationswhereapoorresultinonecriterioncan becompensatedbyagoodresultinanother criterion.

3.RESULTSAND DISCUSSION

3.1Delineationofwatersheds:

TheWesternNayarwatershedhasbeendelineatedutilizingQGIS2.6.0software. Specifically,theWesternNayarwatershedhasbeenpartitionedinto11distinctsub-watersheds,Thesedelineationswere madepossibleusingdigitalelevationmaps (DEMs) sourcedfrom theShuttleRadar TopographyMission(SRTM) witha resolutionof30meters.TheDEMs,depictedin[Fig.1]forWesternNayar watersheds,providedetailedrepresentationsoftheelevationandterrain characteristics oftheregions.Thisinformationisinstrumentalinunderstandingthe topographical layoutandmorphologicalfeaturesofthewatersheds,supporting further analysisandtheprioritizationofsub-watershedsbasedonvarious parameters.

3.2 Drainagemaps

UsingQGIS2.6.0software,thedrainagenetworksoftheWesternNayarwatershed havebeenestablished.Upondetailedexaminationofthedrainagenetworkmap,it wasobservedthatthereare:

TheWesternNayarwatershediclassifiedasa4thorder watershed.Analysis ofthe drainagenetworkmaprevealedthefollowing:

i)163first-order streamswithatotal lengthof219.72kilometers
ii)39second-order streamscovering129.80kilometers
iii)11third-order streamswithacombinedlengthof97.05kilometers
iv) fourth-order stream withalengthof48.33kilometers

ThesefindingsaresummarizedinTable.Thisdetailedexaminationofthedrainage networkprovidesvaluableinsightsintothestreamorder distributionandtotal stream lengthswithineachwatershed.

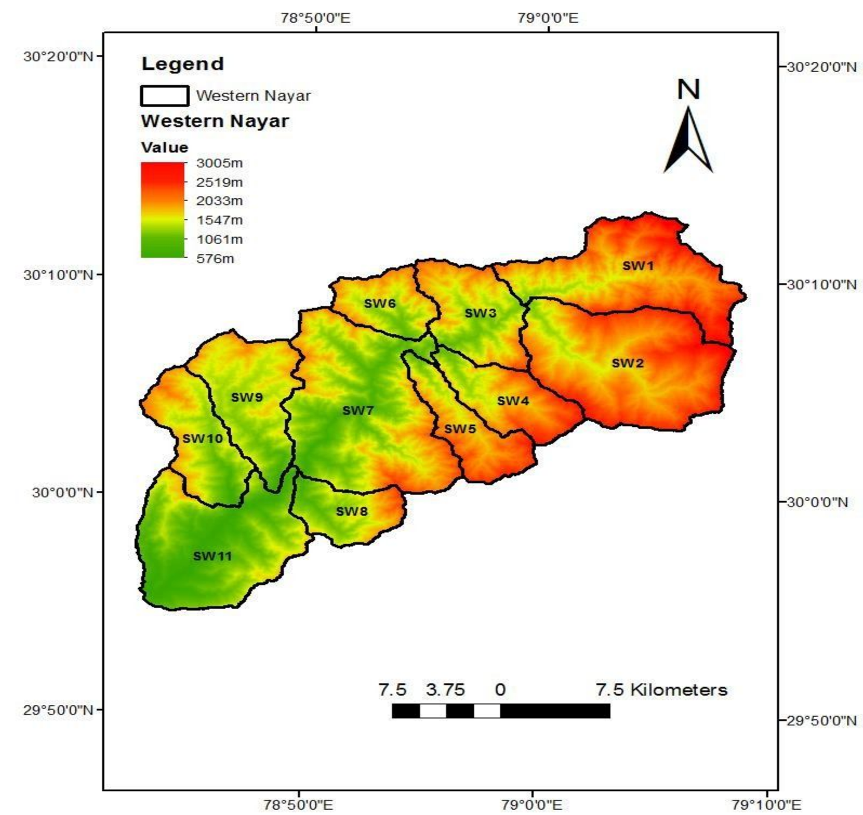


Fig 1:DigitalElevationModel (DEM) map of WesternNayarwatersheds

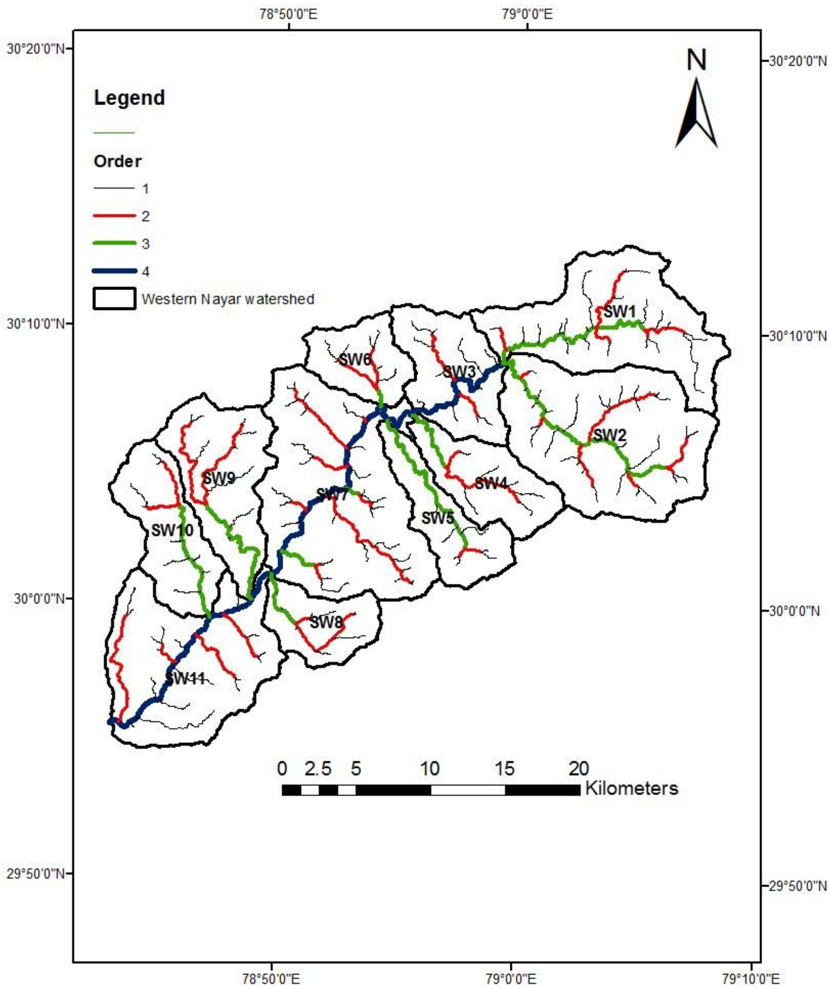


Fig 2.: Drainage network map of Western Nayarwatershed

3.3Prioritization byTOPSISModel

IntheTOPSISmodel,thetopthree-rankedsub-watershedshavethehighest scores,whichare0.740,0.709,and0.648,ranked1to3,respectively.Thus,sub-watershedsrankedSW8,SW5,SW7asdescribedinfig4.havebeenidentifiedas beingmostsusceptibletoerosion.Ontheother end,theleastsensitivetoerosion areSW2,SW9,SW3wihscoresof0.540,0.439and0.430respectively.Thisarea under studywasthencategorizedintofour classes:low (0–0.25),moderate (0.25–0.5),high(0.5–0.75),andveryhigh(0.75–1).

Table 2:SubWatershed wiseanalyzed morphometricparametersfor Western 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

Table 3:Weightagevalues forninemorphometricparameters

Morphometric parameters	**R**	**L_o**	**D_d**	**Rbm**	**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 3 Normalised weighted matrix and final ranking

Morphometric parameters	R	L_o	D_d	Rbm	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	S_i
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	0.029
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 F_i^+	0.085644	0.045746	0.049004	0.025258	0.014264	0.007633	0.021515	0.01765	0.017422	
Worst F_i^-	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 4.11 and 4.12.

• 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 operand flow. The Length of Overland Flow, Lo is 0.0472 meaning that distances traveled before falling into the drain-age 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 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.

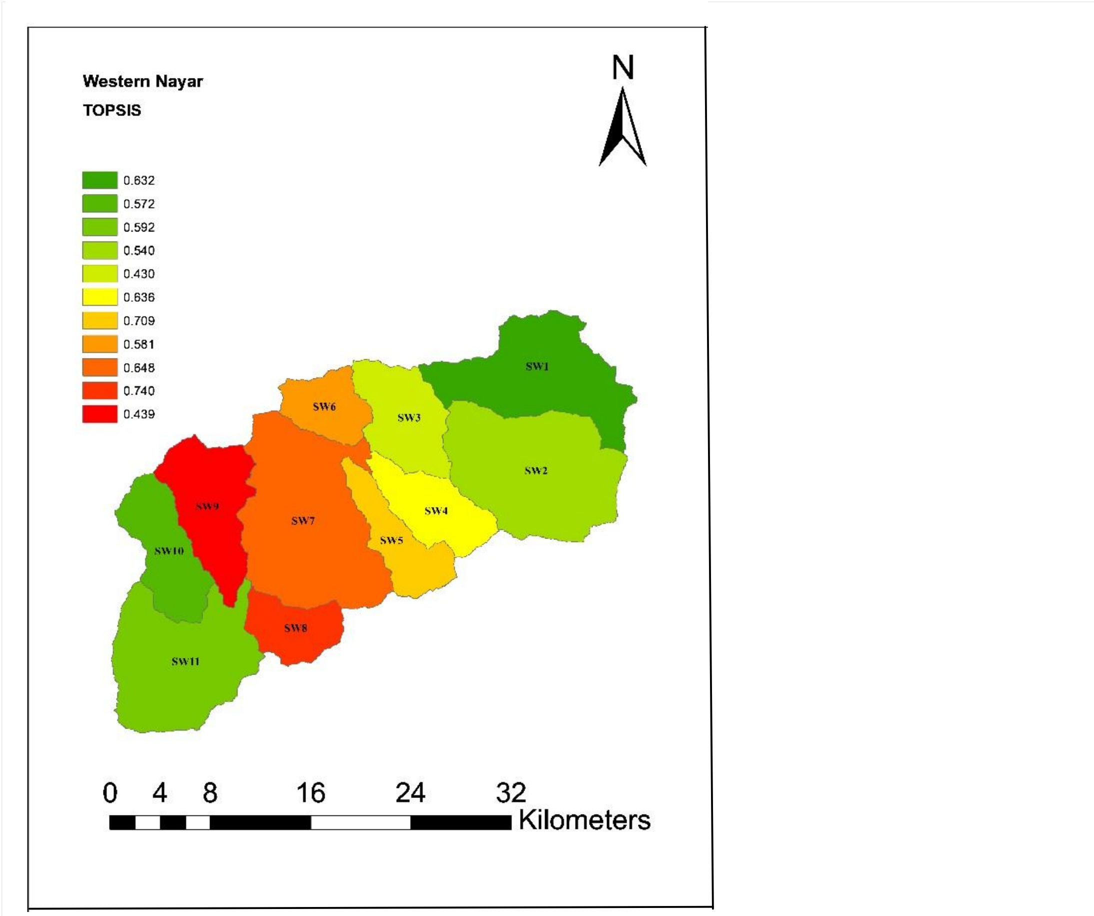


Fig 3.:Prioritymap of WesternNayarwatershed based onTOPSIS

4. CONCLUSION

WiththeapplicationofGIStechniquesandSRTMDEM,thisresearchdemonstratedthe current potential effectiveness of this tool in further geomorphometricanalysis and identification of sub-watersheds for further morphometric characteristic extraction. The TOPSISmodelprovidedfourclasses:veryhigh,high,moderate,andlow.TheHimalayan Basinisveryhighlypronetoerosion,andhence,thenecessityforproperconservation measuresstandshighinordertoreducesoilerosion,decreasesedimentationinreservoirs, stabilizesteepslopessoasnottocauselandslides,andreducetheriskoffloodhazardsin thefuture.ThisstudyfocusesontheapplicabilityofGISandremotesensingmethods combinedwithMCDM,suchasTOPSIStowardshelpingdecision-makersandplannersin soilandwaterresourcemanagement.Thus,theapproachofprioritizingsub-watersheds itselfisaviablemethodthatmayimproveonwatershedmanagementandpreservationof waterresources.

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2.

3.

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