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ORIGINAL ARTICLE

AHP and TOPSIS Based Sub-Watershed Prioritization and Tectonic Analysis of Ami River Basin, Uttar Pradesh

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ABSTRACT

Soil erosion is a major consequence which usually reduces soil productivity. The identification of its susceptible zones is essential in order to apply preventive measures in any basin. A detailed morphometric evaluation of Ami river basin is done using Shuttle Radar Topography Mission (SRTM) data of 30m resolution. Technique for order of preference by similarity to ideal solution (TOPSIS) and analytic hierarchy process (AHP) based prioritization and characterization of sub-watersheds is important to plan and manage the natural resources of a region. Total 18 sub-watersheds with an outlet having 4th order drainage were selected for the prioritization purpose for soil erosion susceptibility zones with the help of 10 morphometric parameters. The sub-watersheds were ordered from SW-I to SW-XVIII. In this regard, SW-XV has the highest priority (0.628) and higher soil erosion while SW-XVIII (0.317) has lowest conditions for soil erosion.

Various tectonic and sinuosity related parameters are calculated and analyzed like hypsometric integral (0.49), asymmetric factor (50.1) and transverse topographic symmetric factor suggesting good symmetry of basin with no tectonic tilt. The value of standard sinuosity index (1.2) suggests that Ami river is naturally sinuous stream. Morphometric parameters suggest less structurally controlled and normal category of the basin. The basin has coarse texture of drainage with highly suspect to soil erosion and high run off.

INTRODUCTION

Soil is a naturally occurring resource and valuable for all the biotic components (Ameri et al. 2018). For its assessment, it is necessary to conduct management plans which can deal with the determination of soil erosion prone regions at macro and micro scale (Alexakis et al. 2013). Rivers are the most prominent geomorphic systems of landscape (Varma et al. 2020) which prompts morphometric change in any basin and transport of sediments in its fluvial process (Chopra et al. 2005). Morphometry based evaluation of any basin provides information about the shape (elongated or circular) and size (total area), altitude, slope and river basin characteristics (Romshoo et al. 2012). This information about river basin is useful in planning and management of water resources, soil erosion and many more (Nag and Chakraborty 2003). RS technique with GIS is convenient tool, being commonly used on the hydrological analysis of basin. The entire basin with existing streams is delineated in GIS environment using ArcGIS software.

The plausible expression of the hydrological characteristics was first proposed by Horton (1945) through mathematical and theoretical observations. He concluded a valid number of mathematical relationships and later developed laws for the river networks (Zavoianu 1985). These laws were further revised and modified (Schumm 1956; Morisawa 1957; Melton 1958; Strahler 1964). Tectonic movement controls the drainage pattern and landform evolution (Ouchi, 1985; Radhakrishna 1992; Sinha and Roy 2001; Flores-Prieto et al. 2015; Kothyari et al. 2019; Das 2020). Different researchers have performed morphotectonic analysis by using remote sensing and GIS technique (Bhatt et al. 2017; Bhatt et al. 2014). In tectonic geomorphology, river basin analysis is a fundamental approach for investigating and interpreting tectonics (Kothyari et al. 2017; Yadav and Singh 2021). Drainage network indicates the local or regional tectonic framework as the river follows weak zones of rocks (fracture zones) and fault lines (Kandregula et al. 2019).

Two important methods namely TOPSIS and AHP are used in the present paper to prioritize indices. The method of AHP, initially presented by Saaty (1988), is a flexible method which is based on the hierarchical structure for determining and compiling the prioritization for logical compatibility of judgments. It is also used for solving many complex problems related to decision making (Chan and Kumar 2007; Pishyar et al. 2020). Hwang and Yoon was the first to develop TOPSIS in the year 1981.

In eighteen selected fourth order wise sub-watersheds, prioritization is done using ten morphometric parameters viz. stream frequency, texture ratio, shape factor, length of overland flow etc. These parameters help to find out the high, moderate and low soil erosion zones. For the sinuosity analysis, various indices like topographic, hydraulic and standard sinuosity indices along with valley and channel index are calculated. The present study, thus, focuses upon the analysis of soil erosion in the drainage basin with MCDM and to analyze the tectonic implications on the Ami river basin.

STUDY AREA

Geographically, Ami river basin is extends from 26°31'N to 27°15'N and 83°26'E to 83°35'E (Fig. 1). Ami river which flows

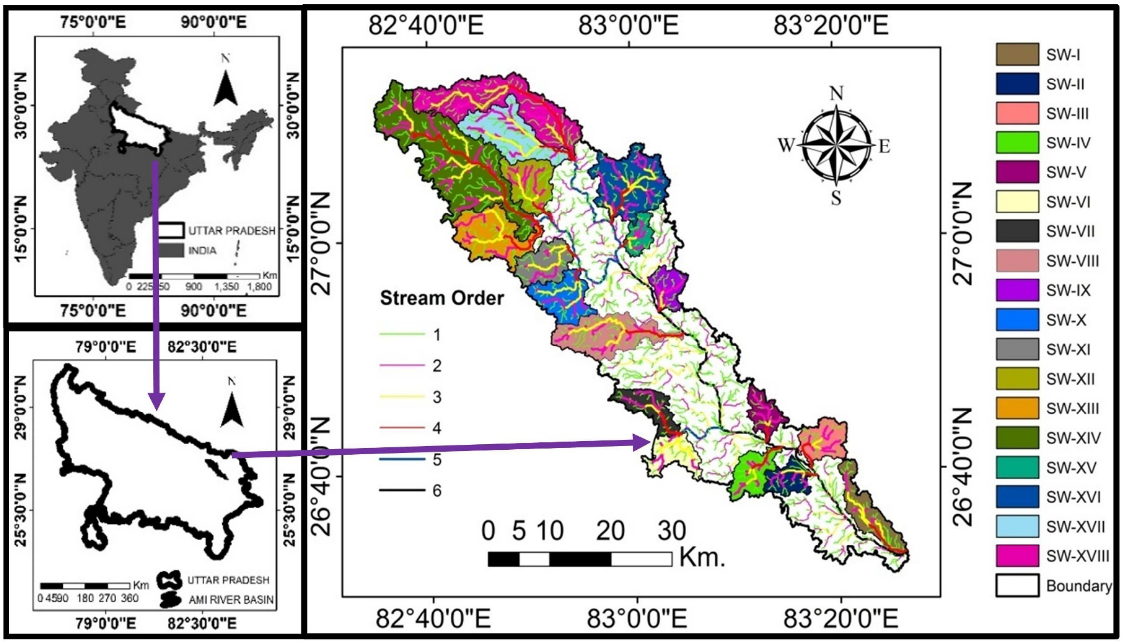

Fig. 1. Location, Stream order and Sub-watershed Map of Ami River basin.

through the Gangatic plain to find its way into Rapti on right bank. River Ami has mainly dendritic type of drainage pattern and it originates near Sonhara (Pargana Rasoolpur near village Shikara). Harsaudi and Suwan are the major tributaries of Ami river which joins it from left and right bank respectively.

River Ami is 6th order drainage (Fig. 1) with a well-defined channel that flows through the tract of stiff clay between the stable peninsula and the active Himalayan chain. The plain is formed of recent detritus and alluvium, brought by the rivers of the Himalayas. Many studies have focused upon the evolution of the Gangetic plains. According to Krishnan (1960), it was a fore-deep between the Peninsular India in south and Himalayas in the north which is filled with detritus by the Himalayan rivers since Pleistocene age. According to Burrard (1912), there was a deep rift valley with a maximum downthrows of 32 km and bounded by parallel faults on its both side.

Gravel, sand, clay and kankar are the major water bearing formations of the area. The whole basin is prone to flooding and water logging problem when the stream discharge exceeds the channel capacity, as it lies between Ghaghra and Rapti rivers. The study area has both kind of alluvial soil viz. older alluvial or Bangar (occupies high land) and younger alluvium or Khadar (occupies low land) comprising clay, silt, sand, loam, silica etc. with many rich humus components in varying proportions. The region experiences sub-humid to humid climate with an average annual rainfall of 1166 mm (CGWB, 2013). Most of the year has sporadic and scanty rainfall except the time span between mid June to September (occurs about 90% of total rainfall), due to onset of south west monsoon. January and May are the coldest and hottest months of the year respectively. The mean wind velocity of the study area is 4.1 km/hr however the potential evapotranspiration of the study area is about 1422.7 mm (CGWB, 2013).

METHODOLOGY

The whole drainage basin has been analyzed using Remote Sensing and GIS. DEM dataset is widely used to evaluate the hydrological characteristics along with morphometric and prioritization studies. SRTM DEM (30m) data is widely processed to prepare DEM map (Fig. 2). Various morphometric features have been evaluated by using standard methods like basin area, perimeter, length of overland flow, length area relation and compactness coefficient, drainage intensity, form factor, relative relief etc. to study various drainage basin characteristics with the help of ArcGIS software. Eighteen sub-watersheds of fourth order drainage have been delineated and prioritized to explore the soil erosion susceptibility through AHP and TOPSIS MCDM models. The pair wise comparison of ten-by-ten matrix in which weight determination for each parameter is done through AHP model (Ameri 2019). Ten morphometric parameters are selected. The relative importance is typically scaled as 1 to 9, hence it depends on factors involved in the decision. The least value or 1 (1/1) indicates the equal importance between two factors whereas the maximum value 9 (1/9) indicate the extreme importance of a factor. However, reciprocal of 1 to 9, (1/1 and 1/9) mean one factor is nine times more important than another. This method has lot of uncertainty which can be reduced by computing the entropic weights.

AHP method has following steps (Jozaghi et al. 2018):

Step 1: Determination of the objective, main-criteria, sub-criteria, alternatives and structure of the hierarchy

Step 2: The pairwise comparison of the criteria with respect to the goal

Step 3: The pairwise comparison of the alternatives with respect to the criteria

Step 4: Calculation of priority vectors

Step 5: Calculation of the consistency ratio (CR)

Step 6: Analysis of the AHP scores

TOPSIS method has following steps (Jozaghi et al. 2018):

Step 1: Determination of the weight of criteria and construction of the decision matrix

Step 2: Calculation of the normalized decision matrix

Step 3: Calculation of the weighted normalized decision matrix

Step 4: Determination of the positive ideal solutions and negative ideal solutions

Step 5: Calculation of the separation of each alternative from the positive ideal solution and the negative ideal solution

Step 6: Calculation of the relative closeness to the positive ideal solution

Step 7: Determination of the rank of the alternatives according to the relative closeness

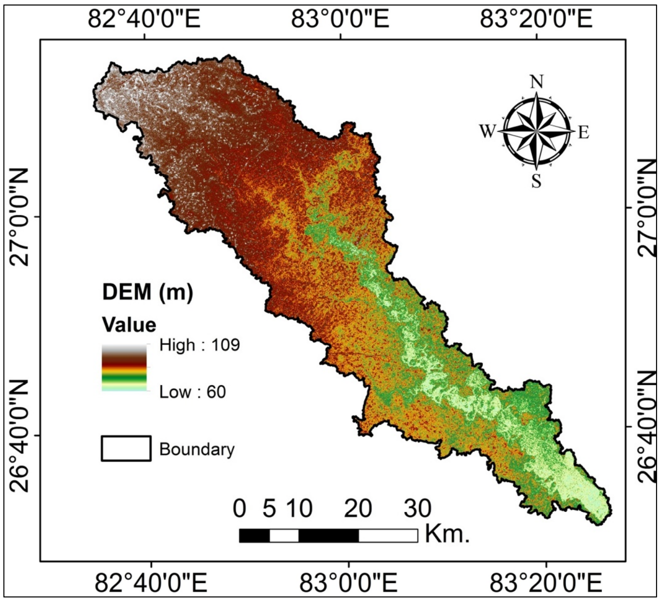

Fig. 2. Digital Elevation Model (DEM) map of Ami river basin.

According to Hwang and Yoon (1981), TOPSIS is a distance-based method which calculates Euclidean distance related with decision making alternatives from negative ideal solution (D_i^-) and positive ideal solution (D_i^+). It also has the preferred alternative as the higher distance from the D_i^- and the alternative that has the least distance from the positive ideal solution D_i^+. The results of these two distances are denoted in the form of closeness coefficient or cl_i^+ (Olson 2004). Priorities for different parameters were set up and decision matrix with weight of each parameter was computed. The computed weight and matrix of AHP was further used in TOPSIS for the calculation of Relative closeness value, D_i^+, D_i^- and other values.

RESULTS

Linear Parameters

The Stream order (S_u) designation is the first step in the analysis of any watershed. It is done through hierarchical ranking of streams. When all the streams of each order is counted collectively, it is called as Stream number (N_u). Ami River basin has a total 1569 stream segments present (Table 1). Stream Length (L_u) is the calculation of length of streams of each order Horton (1945). Ami drainage basin has a total length of streams 2313.88 km (Table 1). Stream Length Ratio (L_{ur}) is the next parameter, computed as the ratio between mean lengths of any order to the next lower order. The value of L_{ur} varies in the basin from 1.49 to 4.23. Bifurcation Ratio (R_b) is an index which shows relief as well as dissections (Horton 1945). It is computed by dividing number wise segments of stream of any given order (lower order) to the total segments of the next higher order (Schumm 1956). The R_b varies from 3 to 6 for the present study (Table 1). Mean Bifurcation Ratio (R_{bm}) is the average value of R_b of all orders. For Ami River basin, the calculated value of R_{bm} is 4.23 (Table 1). Main Channel Length (C_l), Basin Length (L_b) and Basin Perimeter (P) are also computed for the study area as 146.22 km., 112.3 km. and 468.74, respectively (Table 1). Texture Ratio (R_t) depends upon terrain relief, infiltration capacity as well as lithology of the basin (Schumm 1956). It is computed by the division of total segment of first order streams in the basin to the basin perimeter. 2.55 is the computed value of R_t for Ami River basin (Table 1).

Areal and Relief Parameters

The Ami River basin has a total area of 2049.1 km^2 (Table 2).

Table 1. Computation of linear aspects for the analysis of Ami river basin

Morphometric Parameter	Formula	Reference	Result
Stream Order (S_u)	Hierarchical Rank	Strahler (1952)	6
Stream Number (N_u)	$N_u = N_1+N_2+..N_n$	Horton (1945)	1569
Stream Length (L_u) km	$L_u = L_1+L_2+...L_n$	Strahler (1964)	2313.88
Stream Length Ratio (L_{ur})	Table 1	Strahler (1964)	1.49 to 4.23
Bifurcation Ratio (R_b)	Table 1	Strahler (1964)	3 to 6
Mean Bifurcation Ratio (R_{bm})	Table 1	Strahler (1964)	4.234
Main Channel Length (C_l) km	GIS Software	-	146.22
Basin Length (L_b) km	GIS Software	Schumm (1956)	112.3
Basin Perimeter (P) km	GIS Software	Schumm (1956)	468.74
Texture Ratio (R_t)	$R_t = N_1 / P$	Schumm (1956)	2.55

Form factor (F_f) is computed by the division of basin area and the square of basin length (Horton, 1932). F_f is responsible to describe the shape of basin. The F_f value for the present study is 0.16, indicating a highly elongated basin by shape (Table 2). Shape Factor (F_s) measures the irregularity of basin shape (Avinash et al. 2011). F_s is calculated by dividing the square of basin length and basin area. Ami drainage basin has F_s value of 6.15 (Table 2). Circularity Ratio (R_c) is calculated by the division of basin area to the circle area having identical circumference since the perimeter of region (Rai et al. 2014). Ami drainage basin has the R_c value of 0.11 (Table 2). The Compactness coefficient (C_c) is computed for the study area by the division of Basin perimeter to the circumference of circular area, also equals to the area of basin (Gravelius, 1914). The computed value of C_c for the Ami drainage basin is 2.94 (Table 2). Stream Frequency (S_f) is dependent on the geology and lithology of the basin. It is the total drainage segments per unit area. Ami drainage basin has the S_f value of 0.76 (Table 2). Drainage density (D_d) can be calculated as stream length per unit area. D_d value for the present study is 1.129 km/km^2 (Table 2). For Ami basin D_d shows extremely coarse texture of drainage. Drainage intensity (D_i) is calculated by dividing drainage frequency to the drainage density. The D_i of Ami river basin is 0.67 (Table 2). The constant of channel maintenance (C_{cm}) value for Ami drainage basin is 0.88 (Table 2), suggests that on an average, 0.88 km^2 of terrain is required for maintaining each kilometer of channel length. Length of overland flow (L_o) is the water length on the terrain before it localized into a particular channel (Horton, 1945). The computed L_o value for Ami drainage basin is 0.56 (Table 2). Drainage texture (D_t) is related to the geomorphology of any watershed which studies the relative spacing of the drainage lines. The D_t value for the Ami River basin is calculated by the formula, $D_t = N_u/P$ results the value 3.34 (Table 2), indicates the coarse texture of the river basin.

Basin relief (H) is the elevation difference between the lowest and the highest points in any watershed. The H of Ami basin is 49m (Table 3). Relief ratio (R_{hl}) is a dimensionless index to calculate the ratio of height-length between the relief and basin length (Avinash et al. 2011). The R_{hl} of Ami drainage basin is 0.43 (Table 3). Ruggedness number (R_n) shows the structural complexity of basin (Schumm 1956). R_n and Melton Ruggedness Number (MR_n) are calculated for the study area which is 0.043 and 1.08 respectively.

Sinuosity Indices

Channel Index (CI) and Valley Index (VI)

The computed CI value is 1.30 while the computed VI value is 1.08 for the Ami drainage basin (Table 4). These values indicate that the river is not yet matured and is undergoing valley formation (Kumar 2009).

Table 2. Computation of areal aspects for the analysis of Ami river basin.

Morphometric Parameter	Formula	Reference	Result
Basin Area (A) (km^2)	GIS Software	Schumm (1956)	2049.1
Form Factor (F_f)	$F_f = A / L_b^2$	Horton (1932)	0.16
Shape Factor (S_f)	$S_f = L_b^2 / A$	Horton (1932)	6.15
Circularity Ratio (R_c)	$R_c = 12.57 * (A / P^2)$	Miller (1953)	0.116
Compactness Coefficient (C_c)	$C_c = 0.2841 * P / A^{0.5}$	Gravelius (1914)	2.94
Stream Frequency (F_s)	$F_s = N_u / A$	Horton (1932)	0.76
Drainage Density (D_d) (km /km^2)	$D_d = L_u / A$	Horton (1932)	1.129
Drainage Intensity (D_i)	$D_i = F_s / D_d$	Faniran (1968)	0.67
Constant of Channel Maintenance (C) (km^2/km)	$C = 1 / D_d$	Schumm (1956)	0.88
Length of Overland Flow (L_o) (km)	$L_o = D_d / 2$	Horton (1932)	0.56
Drainage Texture (D_t)	$D_t = N_u / P$	Horton (1945)	3.34

Table 3. Computation of relief aspects for the analysis of Ami river basin.

Morphometric Parameter	Formula	Reference	Result
Basin Relief (H) m	$H = Z – z$	Strahler (1952)	49
Relief Ratio (R_{hl})	$R_{hl} = H/L_b$	Schumm (1956)	0.43
Ruggedness Number (R_n)	$R^n = D_d * (H /1000)$	Patton and Baker (1976)	0.043
Melton Ruggedness Number (MR_n)	$MR_n = H / A^{0.5}$	Melton (1965)	1.08

Standard Sinuosity Index (SSI), Topographic Sinuosity Index (TSI) and Hydraulic Sinuosity Index (HSI)

SSI classifies any stream course into three parts which are as follows: (i) When the classified river course is straight (SSI=1.00), when it is sinuous (SSI= 1.00-1.50), when it forms meander (SSI>1.50). The Ami river basin SSI value is 1.20 (Table 4). According to Hajam et al. (2013), this value suggests that Ami river is categorized as sinuous. By using standard formulas as shown in Table 4, the values of TSI and HSI are also determined as 0.26 (26%) and 0.73 (73%) respectively.

Morphotectonic Analysis

Hypsometric Integral (H_i)

H_i helps to differentiate tectonically active and inactive regions (Bhat et al. 2013). H_i is related with the degree of dissection of any drainage basin. The low to medium values of H_i indicates evenly dissected basin while its high values are suggestive of smooth upland surfaces which were cut by deeply incised streams (Keller and Pinter, 2002). Its high value indicates tectonically active basin (El Hamdouni et al. 2008). It is used for describing the elevation distribution across the river basin area (Strahler 1952; Kale and Shejwalkar, 2008; Kumar and Singh, 2021) and expresses the basin landmass which has not been eroded (Pike and Wilson, 1971). H_i could be correlated with the curve shape and it ranges between 0-1. The value and shape of H_i and its curve suggests the stage of geomorphic development (Yadav and Singh, 2021). It can be calculated with the formula proposed by Pike and Wilson (1971) which is as follows:

$$H_i = (h_{mean} - h_{min}) / (h_{max} - h_{min})$$

Where, H_i is the hypsometric integral, h_{min}, h_{max} and h_{mean} are the minimum, maximum and the mean elevation respectively. The calculated value of H_i for the Ami drainage basin is 0.49 (Table 4).

Table 4. Computation of sinuosity and morphotectonic parameters for the analysis of Ami river basin

Sinuosity Parameter	Formula	Result
Channel Index (CI)	CI = CL/AL	1.3
Valley Index (VI)	VI = VL/AL	1.08
Standard Sinuosity Index (SSI)	SSI = CL/VL	1.2
Topographic Sinuosity Index (TSI)	TSI = (VI-1)/(CI-1)	0.26
Hydraulic Sinuosity Index (HSI)	HSI =(CI-VI)/(CI-1)	0.73
Tectonic Parameter		
Hypsometric Integral (H_i)	$H_i = (h_{mean} – h_{min}) / (h_{max} – h_{min})$	0.49
Drainage Basin Asymmetry (A_F)	$A_F = (A_r / A_t) \times 100$	50.1
Elongation Ratio (R_e)	$R_e = (1.128\sqrt{A})/L_b$	0.45
	Formula (T= Da/Dd) For points	Result
Transverse Topographic Symmetry Factor (T)	A	0.46
	B	0.57
	C	0.14
	D	0.14
	E	0.16
	F	0.69
	G	0.03
	H	0.05
	I	0.2
	J	0.35

Drainage Basin Asymmetry (A_F)

A_F analysis determines the tectonic tilting of drainage basin over a large area as well as small area (Cox, 1994). It can be calculated with the following formula:

$$A_F = (A_r / A_t) \times 100$$

Where, A_r is drainage area on the downstream right of the main drainage line, A_t is the total drainage area and A_F is asymmetry factor.

By following Strahler (1957), Ami river basin has the A_F value of 50.1 (Table 4), suggests that the Ami river main channel flows nearly central part of the basin which shows nearly symmetric nature of the basin.

Elongation Ratio (R_e)

Schumm (1956) discussed that R_e is an index which gives idea about the hydrological character as well as shape of the basin. It can be computed by using the formula,

$$R_e = (1.128\sqrt{A}) / L$$

Where, L is the length of basin (km) and A is the area of basin (km^2).

The Ami river basin has R_e value 0.45 which indicates highly elongated shape of basin (Table 4).

Transverse Topographic Symmetry Factor (T factor)

T factor analyses the symmetry of basin. It is the ratio between D_a (distance from the midline of the meander belt to the midline of the river basin) and D_d (distance from the basin divide to the basin midline). The T factor helps to investigate the lateral tilting of a river basin for its mainstream (Cox et al. 2001; Cox 1994).

The value of T-factor for a perfectly symmetric basin is zero. The T factor for the Ami drainage basin is calculated at different segments of stream channels. The computed value of transverse topographic symmetry factor ranges from 0.03 to 0.69 (Table 4), but most of the computed values lies within the range of 0.03 to 0.35, indicates the symmetric nature of the basin with no tectonic tilt (Fig. 3).

Stream Length Gradient Index (S_L Index)

It determines the stream power and its ability to river bed erosion and sediment transportation in any river (Hack, 1973). S_L index determines the relationship among topography, rock resistance and possible tectonic activity (Keller and Pinter, 2002; Pérez-Peña et al. 2009). It is also related with the changes in channel slope (Yadav and Singh 2021).

From the S_L index profile (Fig. 4), it is found that anomalously high value of S_L profile is not observed in any part of the drainage basin which indicates that this area is not influenced by tectonic activity.

Soil Erodibility Based Sub-Watershed Wise Prioritization

According to Masselink et al. (2017), soil erosion is a continuous phenomenon in which particles of soil separates, aggregates, transported to another place by water and deposited in new areas. Fourth order wise eighteen sub-basins (Fig. 4) were identified and evaluated using various morphometric parameters in Ami river. Based on same morphometric parameters, AHP and TOPSIS based analysis was performed. The decision matrix and weights were computed for each morphometric parameter. The TOPSIS MCDM model was used to analyze the soil erosion susceptibility in the Ami drainage sub-watersheds. All the obtained values of each parameters in every fourth order sub-watershed were processed, normalized and weighted (through AHP) to obtain distance between each options from the D_i^+ and D_i^-. The results were further ranked on the basis of TOPSIS model and it is found that SW-XV and SW-XII has the least distance from positive ideal (0.0181 and 0.0187, respectively) while SW-XVIII and SW-XIV has the highest scores (0.0328 and 0.0309, respectively, Table 6). It is also observed that SW-XVIII and SW-XIII has the greatest distance from negative ideal (0.0152 and 0.0166, respectively) while SW- XV and SW- II has the highest score (0.031 and 0.0285, respectively) (Amiri et al. 2019). The resultant values of morphometric parameter of every sub basin were ranked from 1 to 18. Plate 1 show the field photographs which suggest that the river is facing anthropogenic threats.

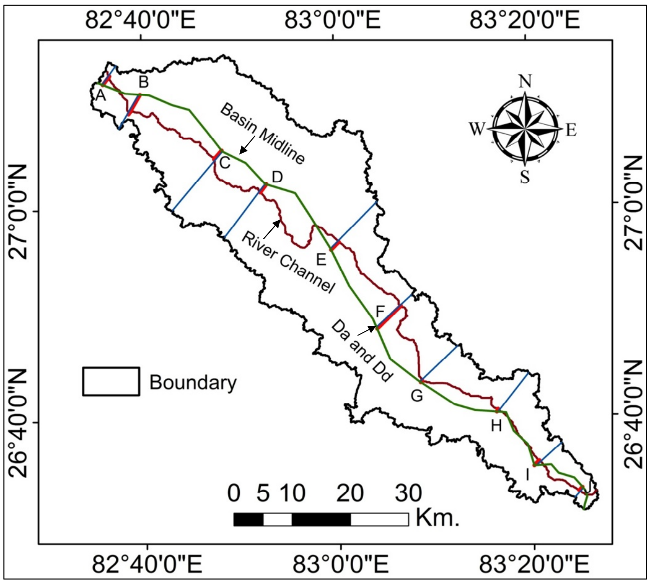

Fig. 3. Transverse Topographic Symmetry Factor Map.

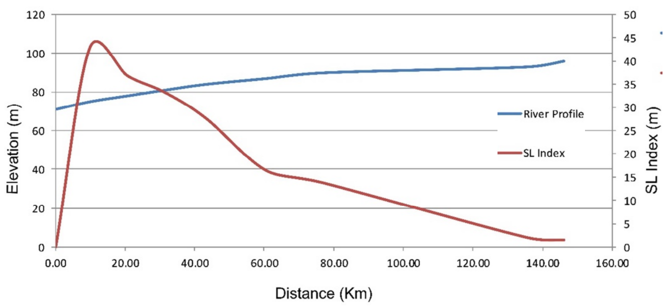

Fig. 4. S_L Index graph of Ami River basin.

Table 5. Estimation of AHP based decision matrix for morphometric parameters

Para-meters	D_d	F_s	L_o	R_t	R_c	F_f	S_f	R_e	D_t	C
D_d	1.00	2.00	2.00	7.00	6.00	6.00	7.00	6.00	9.00	9.00
F_s	0.50	1.00	2.00	7.00	6.00	5.00	6.00	6.00	6.00	5.00
L_o	0.50	0.50	1.00	6.00	6.00	6.00	5.00	6.00	7.00	7.00
R_t	0.14	0.14	0.17	1.00	1.00	2.00	6.00	2.00	7.00	4.00
R_c	0.17	0.17	0.17	1.00	1.00	2.00	2.00	2.00	6.00	6.00
F_f	0.17	0.20	0.17	0.50	0.50	1.00	2.00	2.00	6.00	5.00
S_f	0.14	0.17	0.20	0.17	0.50	0.50	1.00	1.00	6.00	2.00
R_e	0.17	0.17	0.17	0.50	0.50	0.50	1.00	1.00	6.00	2.00
D_t	0.11	0.17	0.14	0.14	0.17	0.17	0.17	0.17	1.00	1.00
C	0.11	0.20	0.14	0.25	0.17	0.20	0.50	0.50	1.00	1.00
Weight	0.28	0.23	0.20	0.07	0.06	0.05	0.04	0.04	0.02	0.02

DISCUSSION

The geomorphological phenomenon is important indicators to understand the erosion and physical properties of soil (Strahler 1964). Various morphometric parameters of the basin has been computed by using the standard methods, proposed by researchers such as Horton (1932, 1945), Strahler (1952, 1964), Schumm (1956), and Miller (1953) etc. The linear parameters suggest that the river Ami is of the 6th order. The study depicts that from first to fifth order streams, L_u

Table 6. Ranking of sub-watersheds based on TOPSIS.

Sub-watersheds	D_i^+ Values	D_i^- Values	Relative value closeness (cl_i^+)	Rank	Priority
SW-I	0.0192	0.0167	0.4653	10	Medium
SW-II	0.0203	0.0285	0.5836	3	High
SW-III	0.0296	0.0172	0.3681	15	Low
SW-IV	0.0258	0.0201	0.4388	11	Medium
SW-V	0.0207	0.0270	0.5657	6	High
SW-VI	0.0257	0.0232	0.4749	9	Medium
SW-VII	0.0266	0.0182	0.4059	13	Low
SW-VIII	0.0272	0.0167	0.3807	14	Low
SW-IX	0.0258	0.0273	0.5143	8	Medium
SW-X	0.0221	0.0258	0.5385	7	Medium
SW-XI	0.0195	0.0255	0.5660	5	High
SW-XII	0.0187	0.0245	0.5677	4	High
SW-XIII	0.0300	0.0166	0.3565	16	Low
SW-XIV	0.0309	0.0168	0.3520	17	Low
SW-XV	0.0181	0.0307	0.6287	1	High
SW-XVI	0.0195	0.0280	0.5890	2	High
SW-XVII	0.0252	0.0184	0.4226	12	Medium
SW-XVIII	0.0328	0.0152	0.3174	18	Low

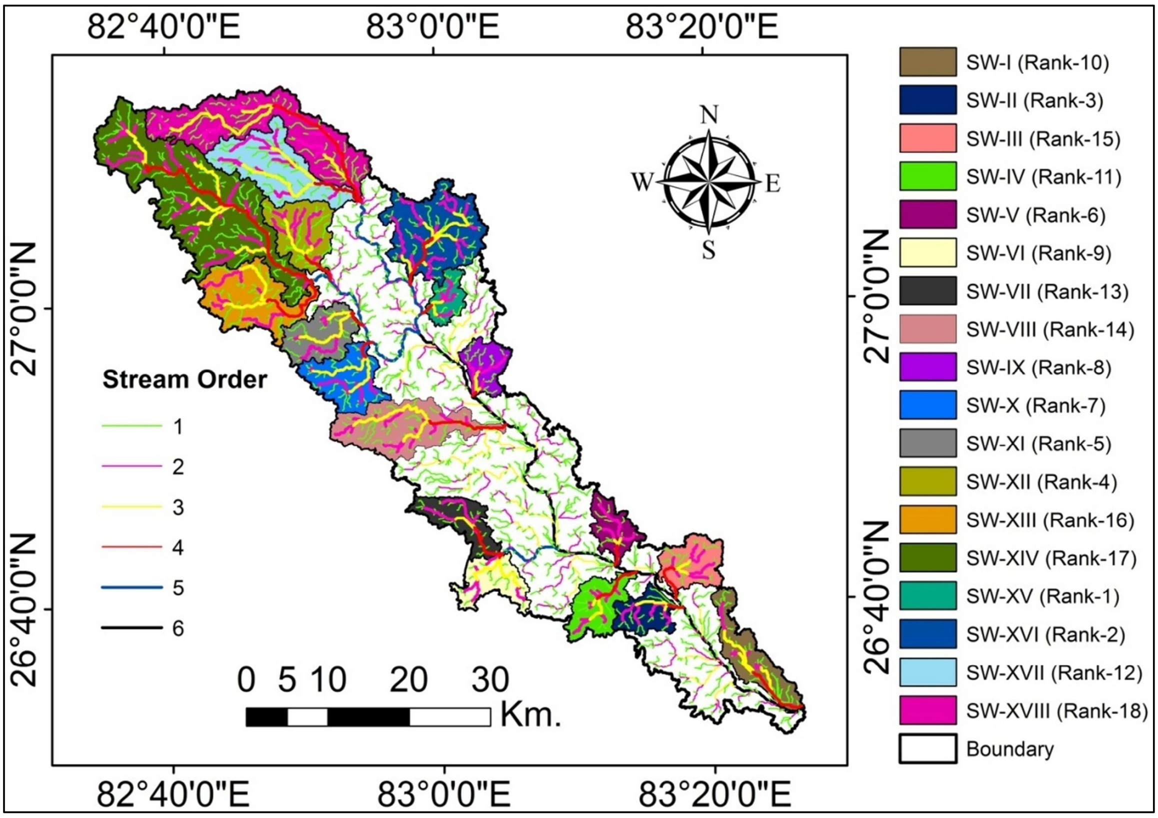

Fig. 5. Sub-watershed map showing soil erosion potential ranking in eighteen sub-watersheds

decreases gradually but for sixth order, L_u increases significantly. The R_{bm} value (4.23) is suggestive of the fact that the Ami river basin is not prone to much structural disturbances (Vittala 2004; Nag 1998). Areal parameters like F_f and R_c are the quantitative and significant indices of drainage basin analysis which suggests elongated shape of basin (Table 2). The circulatory ratio (R_c) indicates a difference in relief and aspect pattern, in a particular segment of the river basin (Miller 1953). The value of S_f (0.76) shows high runoff rate, low infiltration capacity and low relief (Hajam et al. 2013). However, the results of D_d and D_t depicts an extremely coarse texture of drainage. Since, the computed value of D_i is very low (0.67), signifying to the fact that the area is highly prone to flood and gully erosion due to the high surface erosion (Pareta and Pareta 2011). Relief Ratio measures the steepness of any river basin which indicates the erosional intensity on the basin slope (Hajam et al. 2013). The value of Relief Ratio (0.43) shows low relief and gentle slope of the basin (Yadav et al. 2016). By following Avinash et al. (2011), the lower value of ruggedness number (0.043) suggesting plain region with low basin relief. Following Kumar (2009), the results of sinuosity indices suggest the sinuous category of Ami mainstream with almost developed flood plains of the basin. The result also infers the lesser irregularity of initial surface (Kumar 2009). Various morphotectonic parameters like hypsometric integral (0.49), S_L index and elongation ratio (0.45) suggest the youthful stage with elongated shape and tectonically

Plate 1. Field photographs.

inactive basin (Bhat et al. 2013). Parameters like drainage basin asymmetry and T-factor suggests the symmetrical nature of the basin.

The prioritization of sub-watersheds is done for the purpose of soil erosion susceptibility analysis by using TOPSIS and AHP method with the help of ten morphometric parameters. Fourth order wise eighteen sub-watersheds were identified and morphometric parameters were computed for each of them. Weights for different morphometric parameters were assigned and decision matrix was calculated through AHP method (Table 5). By using TOPSIS MCDM technique, D_i^+ and D_i^- values were further calculated. These calculated values were further helps in the computation of relative closeness value (cl_i^+). By following Amiri et al. (2019), ranks were assigned to different sub-watersheds as SW-XV was ranked 1st for its highest cl_i^+ value (0.628) followed by SW-XVI (0.589) and SW-II (0.583). Following their ranks, the priorities were assigned on the basis of cl_i^+ values. The result shows that SW-XV has the 1st priority suggesting highest soil erosion zone while SW-XVIII is categorized as lowest soil erosion susceptibility zone.

CONCLUSION

TOPSIS and AHP based evaluation helps to facilitates soil erosion susceptibility analysis. River Ami is a 6th order drainage basin. The linear parameters infer that L_u gradually decreases in most of the cases. The value of R_b and R_{bm} (4.23) is indicative of normal basin category which is less affected by structural disturbances. The areal parameters suggest that basin has high rate for runoff with low infiltration capacity. Parameters such as drainage texture (3.34) and drainage density (1.129) shows coarse texture of drainage. The value of R_c (0.116) and F_f (0.16) indicate elongated shape of the basin. The value of D_i (0.67) is suggesting that surface erosion is highly prone to gully erosion and flood like conditions. Various relief parameters like high value of R_n (0.043) and MR_n (1.08) infers that basin is highly rugged and suspects to soil erosion while R_{hl} indicates gentle slope with low relief of basin.

Morphotectonic parameters like H_i suggest that basin is in youthful stage of the basin. A_F and T-factor indicates the symmetric basin while elongation ratio infers elongated shape of the basin. The value of sinuosity indices suggests that stream course is sinuous with lesser irregularity of initial surface. Based on TOPSIS, 18 sub-watersheds were prioritized for soil erosion susceptibility. The results suggests that SW-XV has highest relative closeness value, hence ranked as first and which need to be given high priority for susceptibility of the soil erosion followed by SW-XVI and SW-II while SW-XVIII has the lowest priority for soil erosion potential.

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