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Saaty's Analytical Hierarchical Process based Prioritization of Sub-watersheds of Bina River Basin using Remote Sensing and GIS

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Abstract

To achieving sustainable development management of all Natural resources like land and water is necessary since alleviation the impact of natural disasters. In the present study, Saaty's analytical hierarchical process (SAHP) based multi-criteria decision-making approach has been developed for identification of priority sub-watersheds. Using different erosion hazard parameters (EHPs) affecting the process of soil erosion in the watersheds. Bina river basin lies in between 23^0 18' N to 23^0 45' N latitudes and 78^0 07' E to 78^0 32' E longitudes was selected as study area contributes total geographical area of 1111.58 km^2. To achieve the selected objectives of the study area thematic layer of nine Erosion Hazard Parameters, Universal Soil Loss Equation (USLE), Sediment Transport Index (STI) and Slope were generated in GIS environment and other parameters, Sediment Yield (SY), Sediment Production Rate (SPR), Drainage Density, Form Factor, Channel Frequency and Circulatory Ratio were estimated and analysed. Saaty's Analytical Hierarchical Process was adopted to prioritize sub-watersheds has been divided in to 28 sub-watersheds. Determination of priority for study area all the EHPs for 28 sub-watersheds have been determined, normalized and weight for each watershed are determine using the AHP comparison matrix and weight of EHPs. The priority of all sub-watersheds was categorized in to very high, high, moderate, low and very low.

Keywords: GIS and remote sensing; Erosion hazard parameter (EHP); Multi criteria decision making; Saaty's analytical hierarchical process (SAHP); Watershed prioritization.

1. Introduction

A watershed is an ideal unit for management of all Natural resources like land and water and for alleviation the impact of natural disasters to achieving sustainable development. Soil erosion from the watershed is the result of complex processes, which is controlled by climate, topography, geologic, geomorphic, and land use characteristics. Thus the erosion is one of the most serious environmental problems as it removes soil rich in fertility and increases natural level of sedimentation in the rivers and reservoirs reducing their capacity. Scientific planning of soil conservation requires knowledge of the relations among those factors that cause loss of soil and those that help to reduce such losses. Actual measurements of soil loss under field conditions would also be feasible for each level of these factors. Therefore, several soil erosion prediction models like WEEP (water erosion prediction and planning), WATSED (watershed model), USLE (universal soil loss equations) etc, have been developed during past50 years. Many case studies like soil loss prediction [1]Soil erosion and sediment yield estimation using GIS, [2,3,4] have proved that integration of remote sensing and GIS technique with USLE could be effectively used for predicting soil loss it has been an important tool to assess erosion by water. Erosion may also be exacerbated in the future in many parts of the world because of climatic change towards a more dynamic hydrologic cycle [5].

To re-establish the productivity of the soil and to prevent further damage from taking place, planning, conservation and management of the watersheds are essential. Therefore, an attempt is made to assess the erosion hazard and prioritization of sub-watersheds for treatment would serve in better planning to conflict this menace. Thus the Watershed prioritization is the ranking of sub watersheds in a watershed according to the order in which they have to be taken for treatment and soil conservation measures. Recent studies [6, 7, 8, 9] worked on morphometric analysis and prioritization of sub-watersheds using GIS and Remote Sensing techniques. This Remote sensing (RS) and Geographical Information System (GIS) have made it possible to automate the conventional approach of watershed prioritization.Remote Sensing (RS) and Geographical Information System (GIS) are the most advance tools for studies on prioritization of watersheds for their development and management. Also the prioritization of sub-watersheds can be done on the basis of sediment production rate [6, 10] On the basis of sediment yield index values to undertake soil and water conservation measures.

This prioritization process is a tool for the watershed manager to identify the priority pollutants, potential priority sources and targeted areas within the watershed. The outcomes of each step provide the watershed manager with the basis for development of a watershed activity implementation strategy In the present study, Saaty’s analytical hierarchical process (SAHP) based decision support system has been developed for identification of priority sub-watersheds using different erosion hazard parameters (EHPs) affecting the process of soil erosion in the watersheds.

1.1. Saaty’s Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced [11]. The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The pertinent data are derived by using a set of pair wise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency.

The Analytic Hierarchy Process (AHP) is an effective approach in dealing with many industrial engineering applications and stated that final decision is based on the evaluation of a number of alternatives in terms of a number of criteria [12]. This also applicable in problem arising in the water supply and sewage treatment system in Metropolitan cities like Chennai facing rapid urbanization [13]. AHP provides recommendation on strategic investment decision options in selection of investment in bank stock in circumstances in financial crisis of the Nigerian capital market.Analytical Hierarchy Process (AHP) considered as a means of assisting the implementation of integrated watershed management and means for assisting in the plan selection process in solving watershed management problems [14, 15]. From the review of literature, it has been observed that number of studies have been carried out using Saaty's (AHP) approach in diversified fields but limited research were conducted in the field of watershed prioritization using limited parameters. The present study has been carried out for the Prioritization of sub-watersheds to identify environmentally stressed sub-watersheds to ascertain conservation strategy using Saaty's analytical hierarchy process (SAHP) with nine erosion hazards parameters (EHPs).

2. Study Area and Data Used

2.1 About Study Area

In this study Bina river basin lies in between 23^0 18' N to 23^0 45' N latitudes and 78^0 07' E to 78^0 32' E longitudes was selected as study area. This contributes total geographical area of 1111.58 km^2. The study area belong agro climatic zone (V) of Madhya Pradesh having The mean monthly minimum air temperature during the winter is around 11.5^0C while the maximum mean air temperature in the hottest month (May and June) is around 40.7^0C. Temperature extremes vary between the minimum of 3.2^0C during December or January months to the maximum of 45.4^0C in May or June. The average annual rainfall of study area is about 1196 mm. The topography of the area is generally rolling to undulating. This undulating topography results in soil erosion. The major part of the area is covered by black cotton soil and the major crops grown in the area are soybean, jowar, urad, paddy and gram etc. the location map of the study area is shown in Figure 1.

2.2 Data Base

In the study, nine different EHPs have been computed based on variety of data on topography, land uses, soils, rainfall etc. An extensive data base in GIS has been developed using toposheet, soil maps, testing, field surveys and remote sensing data. In the present study daily rainfall data of four rain-gauge stations namely Begamganj, Rahatgarh, Gairatganj and Silvani for the period of ten years (from 1996 to 2010) was used. The rainfall data was collected from State Water Data Centre, Water Resources Department, Government of Madhya Pradesh; Bhopal has been used for estimation of R- factor in soil loss estimation. The survey of India (SOI) toposheets numbered 55i/2, 55i/3, 55i/5, 55i/6, 55i/7 and 55i/11 has been used for delineation of watershed and sub-watershed, contours, point elevation and determination of geomorphologic parameters, slope map and STI map. The satellite data of the satellite (IRS-P6) having sensor LISS III scenes 23.5 m resolution (Path-99 and Row-54) of the area have been used for preparation of the land use/land cover (C & P-factor) maps for USLE model. The soil map collected from National Bureau of Soil Survey and Land use Planning (NBSS&LUP), Government of India have been used for the soil information soil types demarcated have been applied to derive K-factor map in soil loss estimation of the study area.

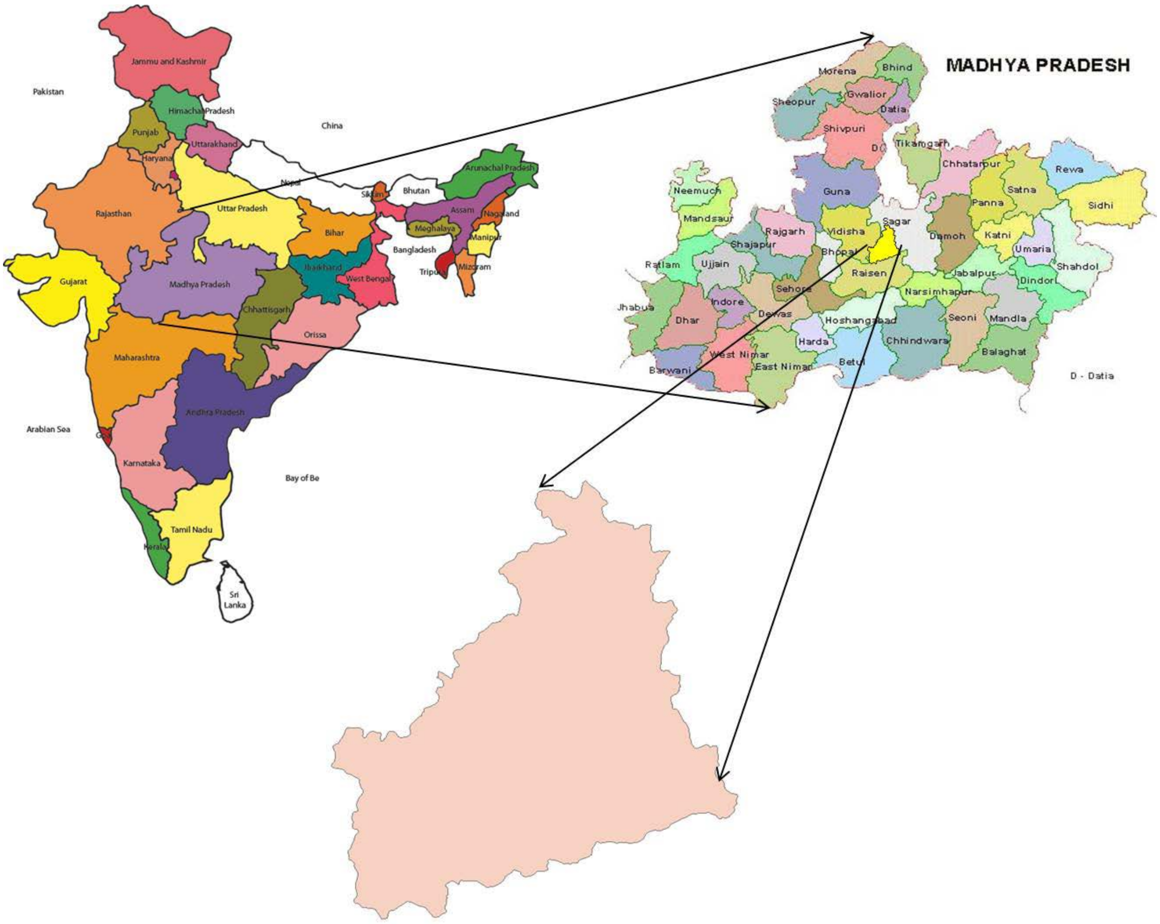

Fig. 1. Location map of study area

3. Methodology for Prioritization Using SAHP

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach constructs a matrix of pair-wise comparisons (ratios) between the factors responsible for erosion. In the present study nine different parameter factors may be termed as erosion hazards parameters (EHP) have been selected for construction of AHP matrix. If nine erosion hazard parameters (EHP) are scaled as 1 to 9, 1 indicates that the two factors equally important and 9 indicated that the one factor is more important than other. Reciprocal of 1 to 9 (1/1 and 1/9) show that one is less important than other. (Table 1) explains Saaty’s Rating Scale and the allocation of the weights for the identical EHP depends on the relative importance of factors and participatory group of decision makers. To fill the comparison matrix a comparison of each EHP parameter with other parameters are made. In this way the total no. of comparison will be n (n-1)/n. The diagonals elements of the matrix in that way if the judgment value is left side of 1, then for filling the upper matrix actual judgment value will be used. If the judgment value is right side of 1 than reciprocal will be used. The lower triangular matrix is filled by taking reciprocal of upper triangular matrix. In that way comparison matrix can be determined. From the comparison matrix priority vector is computed which is the normalized eigen vector of the matrix can be used to assign the weight for different EHP's.

Table 1. Saaty's Rating Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	Demonstrated importance An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute more importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

3.1 Consistency check

The consistency of subjective judgment can be checked by estimating consistency ratio which is the comparison between consistency index and random consistency index. The consistency index (CR) can be computed by the following equation:

$$CR = \frac{CI}{RI} \qquad \ldots\ldots\ldots\ldots.(1)$$

Where, CI is the Consistency index and RI is the Random consistency index. The consistency index is a measure of consistency can be estimated using following equation:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad \dots\dots\dots\dots\dots \ (2)$$

Where , λ_{max} is the Principle Eigen value obtained from priority matrix and n is Size of comparison matrix. Saaty has determined average random consistency index (RI) on the basis of various sample size. The average random consistency ratios for different size of matrix are given below:

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If the value of consistency ratio is smaller or equal to 10% the consistency is acceptable. If consistency ratio is greater than 10% we need to device the subjective judgment.

3.2 *Priority Assessment*

For the determination of priority of the each sub-watershed values of the entire EHP factor are normalized in a standard scale such as 0 to 1. The following equation has been used to normalize all the EHP parameters on the 0 to 1.

$$N_i = \frac{(U_{nor} - L_{nor})}{(U_{act} - L_{act})}(X_i - L_{act}) \qquad \dots\dots\dots\dots \ (3)$$

Where, N_i is the Normalized value of a parameter for i^{th}watershed, U_{nor} ia the Upper value in the standard scale (1), L_{nor} is the Lower value in the standard scale (0), U_{act} is the Maximum value of the parameters, L_{act} is the Minimum value of the parameters respectively and X_i is the Observed value of parameters for i^{th} watershed. After computing the normalized values of different EHPs and the weight of different EHPs using Saaty's AHP for various watersheds the final priority is using the following equation.

$$P_j = \sum_{i}^{1=n} W_i N_{ij} \qquad \dots\dots\dots\dots\dots\dots (4)$$

Where, P_j is the Final priority for j^{th} watershed, W_i is the Weight of i^{th}EHP and N_{ij} is the Normalized value of i^{th}EHP for j^{th} watershed. After determining the final priority for all sub-watersheds it has been grouped in five classes of priority namely very high, high, moderate, low and very low on the basis of priority ranking.

3.3. Determination of EHPs for Sub-Watersheds

The prioritization of sub-watersheds identified using various erosion causing factors termed as erosion hazard parameters (EHP) responsible for the soil erosion. There are nine erosion hazards parameter including Sediment production rate (SPR), sediment transport index (STI), sediment yield (Sy), universal soil loss equation (USLE), slope (S), drainage density (D_d), form factor (R_f), circularity ratio (R_c) and channel frequency (C_f), These parameters are discussed below:

3.3.1. The Universal Soil Loss Equation (USLE)

The universal soil loss equation was used to determine the average annual soil loss and its spatial distribution in the watershed. The USLE [16] predicts soil loss for a given site as a product of five major erosion factors whose values at a particular location can be expressed numerically. The limitation of this model is that it does not estimate deposition, sediment yield, channel erosion, or gulley erosion. Thus the USLE is suitable for predicting long-term averages and can be expressed as, $A=R\times K\times LS\times C\times P$ ……...…… (5)

Where, A is the Average annual soil loss rate (t/ha/yr), R is the Rainfall erosivity factor (MJ-mm/ha/h/yr), K is the Soil erodibility factor (t-ha-h/ha/MJ/mm), LS is the Soil length & steepness factor, C is the Crop cover and management factor and P for Conservation supporting practice factor.

3.3.2. Sediment Production Rate (SPR)

Sediment Production Rate (SPR) is useful in deciding the method of soil conservation practice and for fixing the priority of watersheds for adopting conservation measures. Sediment production is the volume of sediment produced per unit drainage area per unit time. The Sediment production rate (ha-m/100 km^2/yr) has been estimated using geomorphology based model proposed by [17] and also model used by [18] for priority of sub-watersheds. The SPR model can be mathematically expressed as:

$\text{Log (SPR)} = 4919.80 + 48.64 \log (100+R_f) - 1337.77 \log (100+R_c) - 1165065 \log(100+C_c)$ ………..(6)

Where, R_f is the form factor, R_c is the circulatory ratio and C_c is the compactness coefficient.

3.3.3. Sediment Transport Index (STI)

The Sediment Transport Index characterizes the process of erosion and deposition. Unlike the length-slope factor in the Universal Soil Loss Equation (USLE) it is applicable to three-dimensional surface [19]. The sediment transport index is defined by the equation below.

$$STI = \left(\frac{As}{22.13}\right)^{0.6} \left(\frac{\sin\beta}{0.0896}\right)^{1.3} \quad .. \dots\dots\dots\dots (7)$$

Where, As is the upstream area and β is the slope at a given cell.

3.3.4. Sediment Yield (Sy)

One measure of geomorphic activity is sediment yield which is defined as the amount of sediment per unit area removed from a watershed by flowing water during a specified period of time (Usually measured in t/ha/yr). Sediment yield is strongly affected by surface materials, topography, rainfall seasonality and vegetation cover and can be increased by soil disturbance which often occurs as the result of land use. A simple empirical model under Indian condition quoted in literature [20, 21] has been used for analysis and model used by [22]. According to this model the sediment yield can be expressed as:

$$Sy = 1.067 \text{ x } 10^{6} \text{x } p^{1.384} \text{ x } A^{1.292} \text{ x } D_{d}^{0.392} \text{ x } S^{0.129} \text{ x } F^{2.51} \qquad \text{..........…… (8)}$$

Where, Sy is the Sediment yield (Mm^3 x 10^{-3}/yr), P is the Annual precipitation (cm), A is the Sub-watershed area (km^2), D_d is the Drainage density (km/km^2), S is the Average slope and F stands for Vegetative cover factor can be expressed as:

$$F = \frac{0.21F1 + 0.2F2 + 0.6F3 + 0.8F4 + F5}{\sum_{i=1}^{5} Fi} \qquad \ldots\ldots\ldots\ldots..(9)$$

Where, F1 is the area under reserved and protected forest, F2 is the unclassified forest area, F3 is the cultivated area, F4 is the grass & pasture land and F5 is the wasteland.

The above equation (8) indicates that all the parameters except precipitation are essentially mapping inputs which can be derived conveniently from drainage map, topographic/contour map and land use derived from remote sensing analysis. As this model is empirical, it incorporated those parameters which essentially contributed to the sediment yield process to produce more realistic estimation of erosion rates for planning and development processes.

3.3.5. Slope (S)

The slope is an important topographical factor responsible for degradation of watershed as due to the steep slopes more and more soil erosion resulting development of gullied and losing the fertility and moisture holding ability of soils. For generation of slope map, the contour map and point elevation map of study area has been used. Using the GIS based software ILWIS (3.6), the slope map for the region is generated. The slope map for each of sub-watershed has been generated and using statistics of that map, the average slope from sub-watersheds have been computed separately.

3.3.6. Geomorphologic Parameters

The geomorphology plays an important role in development of land forms and erosion process. In the study, drainage density (Dd), channel frequency (Cf), form factor (Rf) and circulatory ratio (Rc) have been used as EHPs based on geomorphological characteristics. The drainage system shows the geomorphologic status of the region and an important indicator of the linear scale of land form elements in stream eroded topography. Drainage density into American hydrologic literature as an expression to indicate the closeness of spacing of streams [23] It is defined as the total length of streams of all orders per drainage area denoted as:

$$D_d = L_u/A \qquad \text{………….. (10)}$$

Where, L_u is the Total stream length of all orders and A is the Area of the watershed (km^2).The drainage density indicates closeness of spacing of channels thus providing a quantitative measure of average length of stream channel for entire watershed. Channel frequency is the number of streams per square unit area which along with drainage density gives the character of underlying lithology in a particular area [24] given by formula:

$$C_f = N_u/A \qquad \text{…………. (11)}$$

Where, N_u is the Total number of Channel of all order and A for the Area of the watershed. The circulatory ratio is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin [25] using formula as:

$$R_c = 4\pi A/P^2 \qquad \text{.....……….. (12)}$$

Where, A is the Area of the watershed (km^2) and P for the Perimeter. Compactness coefficient is computed as ratio of watershed perimeter to perimeter of circle of watershed area. It may be expressed as:

$$C_c = P/P_A \qquad \text{........……….. (13)}$$

Or $$C_c = P/\ \{2\sqrt{(A\pi)}\} \qquad \text{....………… (14)}$$

Where, A is the Area of the watershed (km^2), P_A is the Perimeter of circle of watershed area (km) and P is the Perimeter (km).

4. Results and Discussion

Demarcation of sub-watersheds within a watershed and their prioritization is first step for proper planning and management of natural resources and determination of soil and water conservation measures. For prioritization purposes, the watershed of Bina river basin has been divided in to 28 sub-watersheds namely SW-1 to SW-28 (Figure 2). In the study, spatial distribution of all selected EHPs for all sub-watersheds in Bina river basin have been computed and converted to its normalized value. Considering relative importance of each parameter, the priority matrix and subsequently the weights for each parameters using SAHP have been estimated. The final priority for each watershed has been computed as product of multiplication of priority weights and normalized values of all parameters. The priority ranking has been performed to determine environmentally stressed sub-watersheds. The results obtained during computation of EHPs and priority assessment is being presented below

4.1 Computation of EHPs

The soil loss for sub-watersheds was calculated by using annual average R (based on daily rainfall data of 1996 - 2010), K, LS, C and P factors. All the layers viz, R, K, LS, C and P were generated in ILWIS GIS software and over layed to obtain the product which gives soil erosion map (Figure 4) for the study area. This soil loss map was over layed with sub-watershed map of study area which contains 28 sub-watersheds to get sub-watershed wise soil loss. The soil erosion rate (t/ha/yr) of a sub-watershed was estimated as total soil loss of ith sub-watersheds (t/yr)/total geographical area of ith sub-watersheds (ha).

Sediment production rate has been estimated using equation (6) in this equation form factor, circularity ratio and compactness coefficient has been used as inputs. The sediment production rate of study area ranges from lowest 0.70 (SW-11) to highest 2.26 (SW-23) ha m/100 km^2/year. Annual precipitation, sub-watershed area, drainage density, average slope and vegetative cover had been used as inputs in the empirical equation (8) and (9) to compute Sediment yield. The slope map (Figure 3) of the study area has been generated with the help of DEM. The slope of Sub-watersheds varied between 1.40 to 4.84 per cent. The upper stream area and slope have been used as inputs and STI map was prepared through ILWIS (3.6) for the basin as shown in (Figure 5). The sediment transport index was calculated for all the sub-watersheds of the study area using the equation (7). The average slope, Sediment yield, Sediment production rate, and sediment transport index, has been computed for a sub-watershed using the information from histogram of that sub-watershed as presented in Table 2. Also the slope (S), drainage density (D_d), form factor (R_f), circularity ratio (R_c) and channel frequency (C_f) has been used in AHP compression and AHP weight given in Table2 and Table 3 respectively was estimated using equations given under section Geomorphologic Parameters description.

4.2 Prioritization of Sub-watersheds using Saaty's Analytical Hierarchical Process (AHP)

Considering the massive investment in the watershed development programme it is important to plan the development activities on priority basis for achieving fruitful results which also facilitate addressing the problematic area to arrive at suitable solution. The resources-based approach is found to be realistic for sub-watershed prioritization since it involves an integrated approach. Delineation of sub-watersheds from the study area and their prioritization is required for proper planning and management. Determination of priority for study area all the EHPs for 28 sub-watersheds have been determined, normalized and weight for each watershed are determine using the AHP comparison matrix (Table 3) and AHP weight(Table 4). The final priority of each sub-watershed are determined and priorities of all sub-watersheds are grouped in five categories Priority of different sub-watersheds with their Priority index of study area as shown in (Table 5) and spatially depicted in(Figure 6).On the basis of EHP's analysis out of 28 sub-watersheds 4 sub-watersheds come under the very high priority,7 sub-watersheds come under the high priority,7 sub-watersheds come under the moderate priority,7 sub-watersheds come under the low priority and 3 sub-watersheds come under the very low priority category.

Table 2. Slope, Sediment Yield, SPR and Sediment Transport Index for sub-watersheds of study area

Sub-watershed	**Slope (%)**	**Sediment Yield (Mm^3 x 10^{-3}/km^2/yr)**	**SPR (ha-m/100km^2/year)**	**Sediment Transport Index**
SW-1	2.35	2.4649	2.1787	11.9823
SW-2	1.40	1.8661	1.7126	9.7003
SW-3	2.23	4.2913	1.8048	10.8868
SW-4	1.84	5.3283	2.0345	9.7867
SW-5	1.93	11.7930	2.2276	20.0775
SW-6	1.85	2.4204	1.2491	10.1961

SW-7	2.37	3.8660	2.1479	11.9095
SW-8	2.00	5.7464	2.2436	10.0189
SW-9	3.08	3.7317	2.2582	17.2372
SW-10	2.08	14.1846	2.0385	10.9099
SW-11	3.41	4.2310	0.7037	20.5829
SW-12	2.37	23.1122	2.1101	17.7596
SW-13	2.57	8.3395	2.0093	13.7456
SW-14	4.66	13.7256	2.1965	35.0066
SW-15	3.09	3.5292	2.1550	18.1474
SW-16	2.92	9.2922	1.8228	25.5950
SW-17	2.92	4.3120	2.1741	49.7919
SW-18	2.26	4.3776	1.9297	10.2748
SW-19	3.18	10.6577	1.9237	43.3107
SW-20	3.04	10.5237	2.2098	34.1478
SW-21	3.08	1.7430	1.9178	72.7713
SW-22	3.77	2.8935	1.9313	22.3166
SW-23	4.84	3.3047	2.2612	52.0673
SW-24	4.47	6.5890	1.8437	43.2649
SW-25	2.64	5.2869	2.1444	16.5784
SW-26	5.01	6.6054	1.3908	31.8058
SW-27	4.31	21.0288	1.8756	56.8776
SW-28	3.29	6.4240	2.2395	19.4580

Table 3. AHP comparison of different erosion hazard parameters

	SL	**SPR**	**SY**	**STI**	**S**	**D_d**	**C_f**	**R_f**	**R_c**
SL	1	5	3	3	5	7	7	9	9
SPR	0.200	1	0.333	0.333	0.333	3	3	3	3
SY	0.333	3	1	3	3	5	5	7	7
STI	0.333	3	0.333	1	3	3	5	7	9
S	0.200	3	0.333	0.333	1	3	3	5	7
D_d	0.143	0.333	0.200	0.333	0.333	1	3	3	5
C_f	0.143	0.333	0.200	0.200	0.333	0.333	1	3	3
R_f	0.111	0.333	0.143	0.143	0.200	0.200	0.333	1	3
R_c	0.111	0.333	0.143	0.111	0.143	0.143	0.333	0.333	1
SUM	2.57	16.33	5.68	8.45	13.34	22.67	27.66	38.33	47

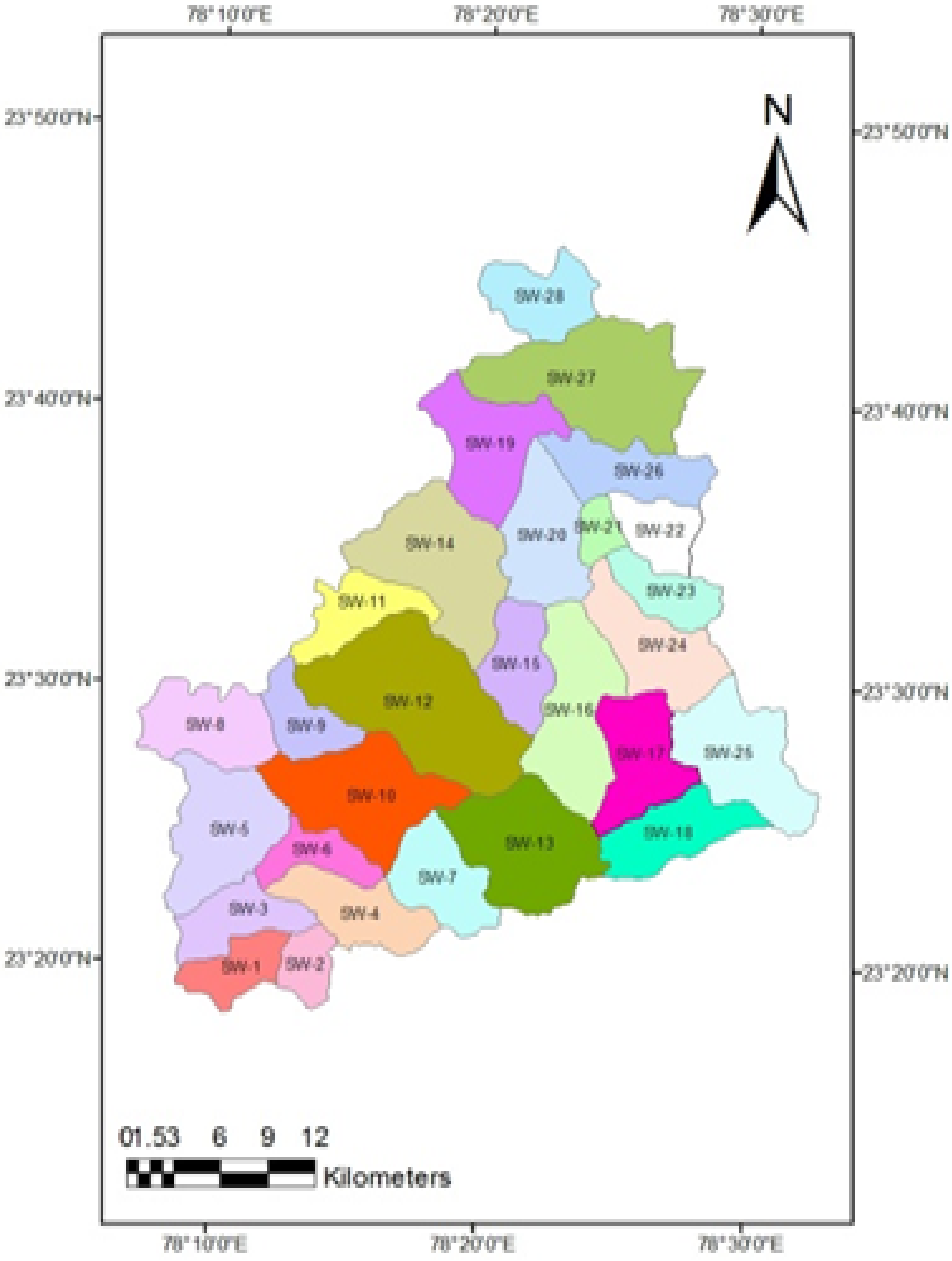

Fig. 2. Sub-watershed map of Study Area

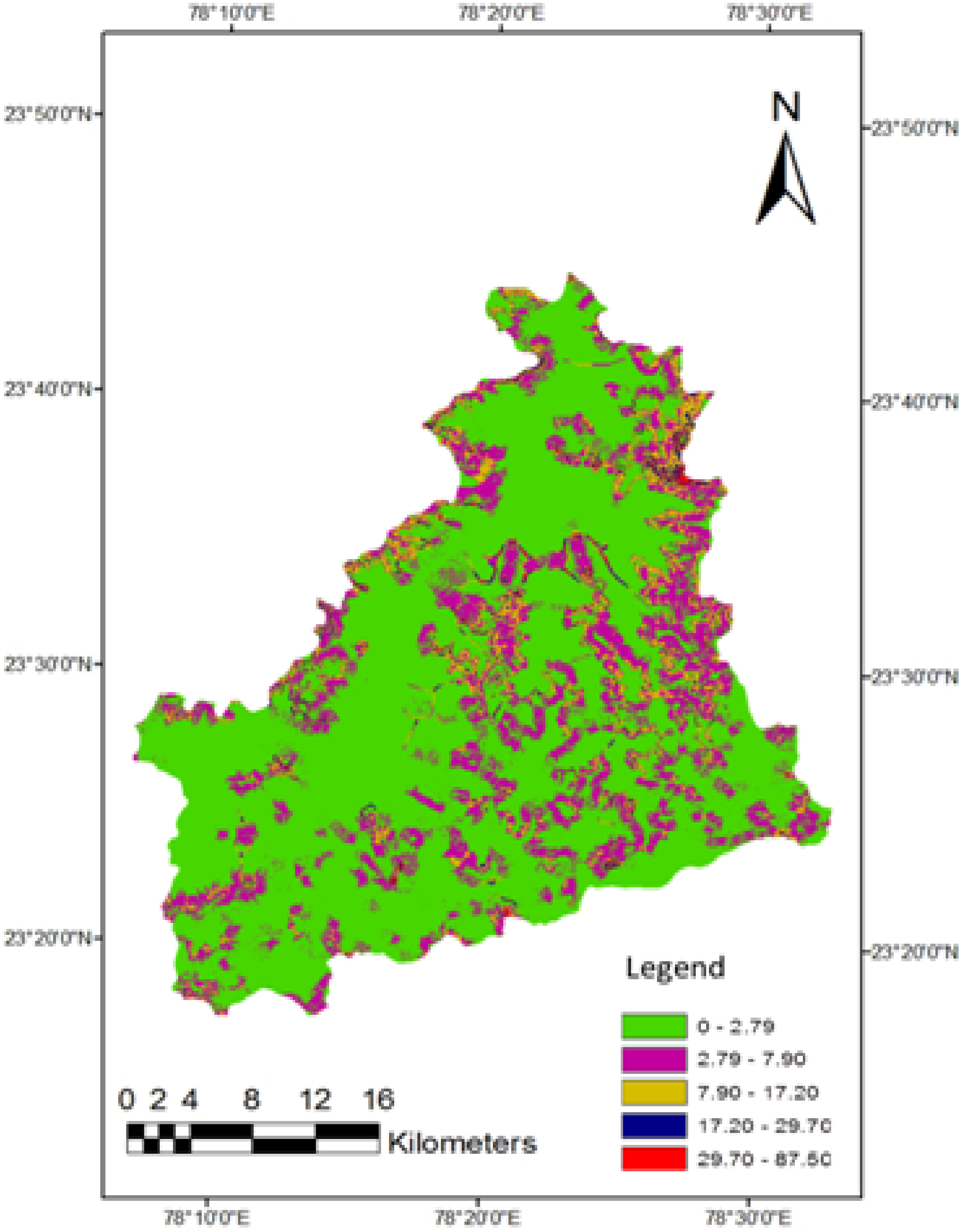

Fig. 3. Slope map of study area

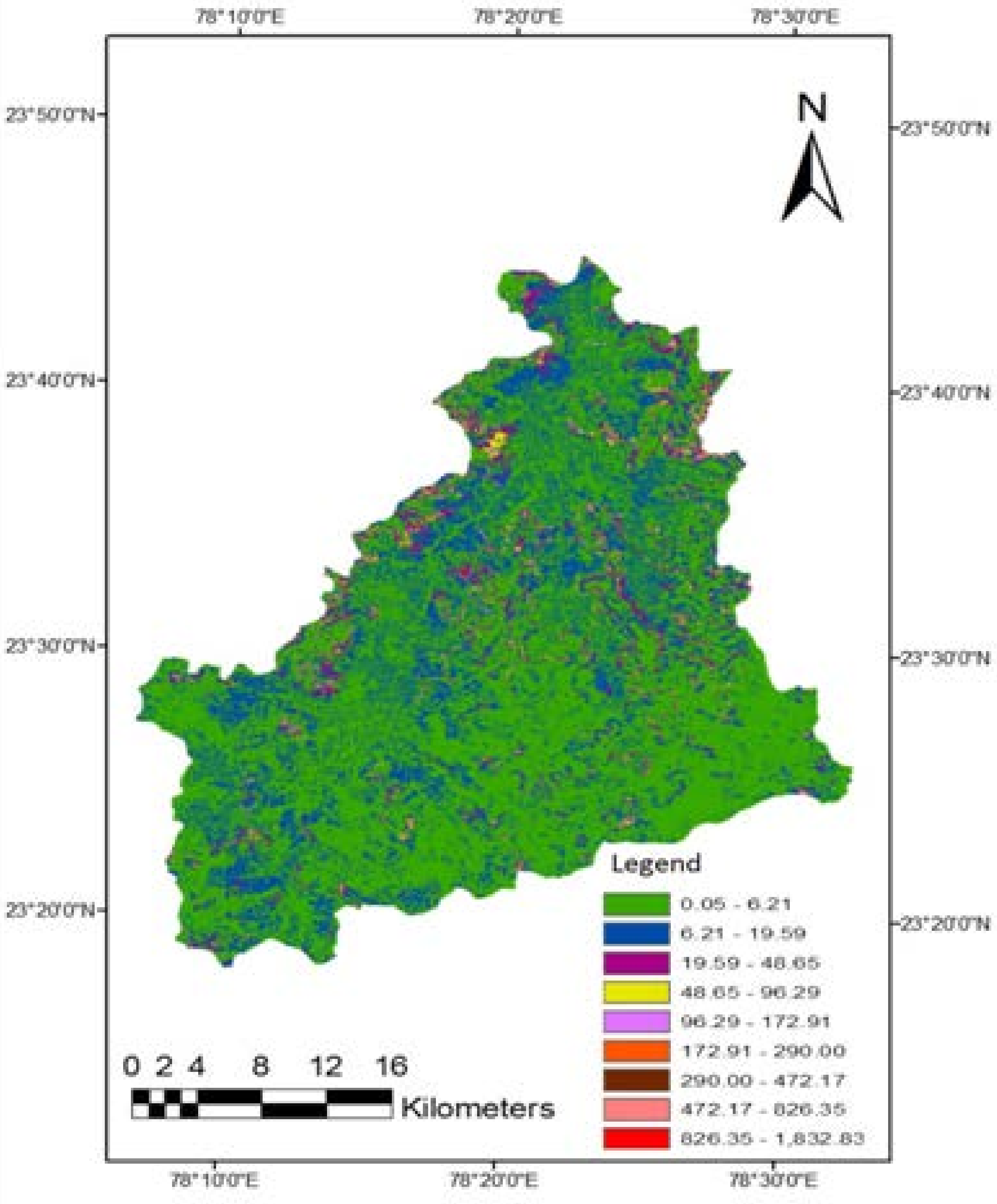

Fig. 4. Soil Loss map of study area

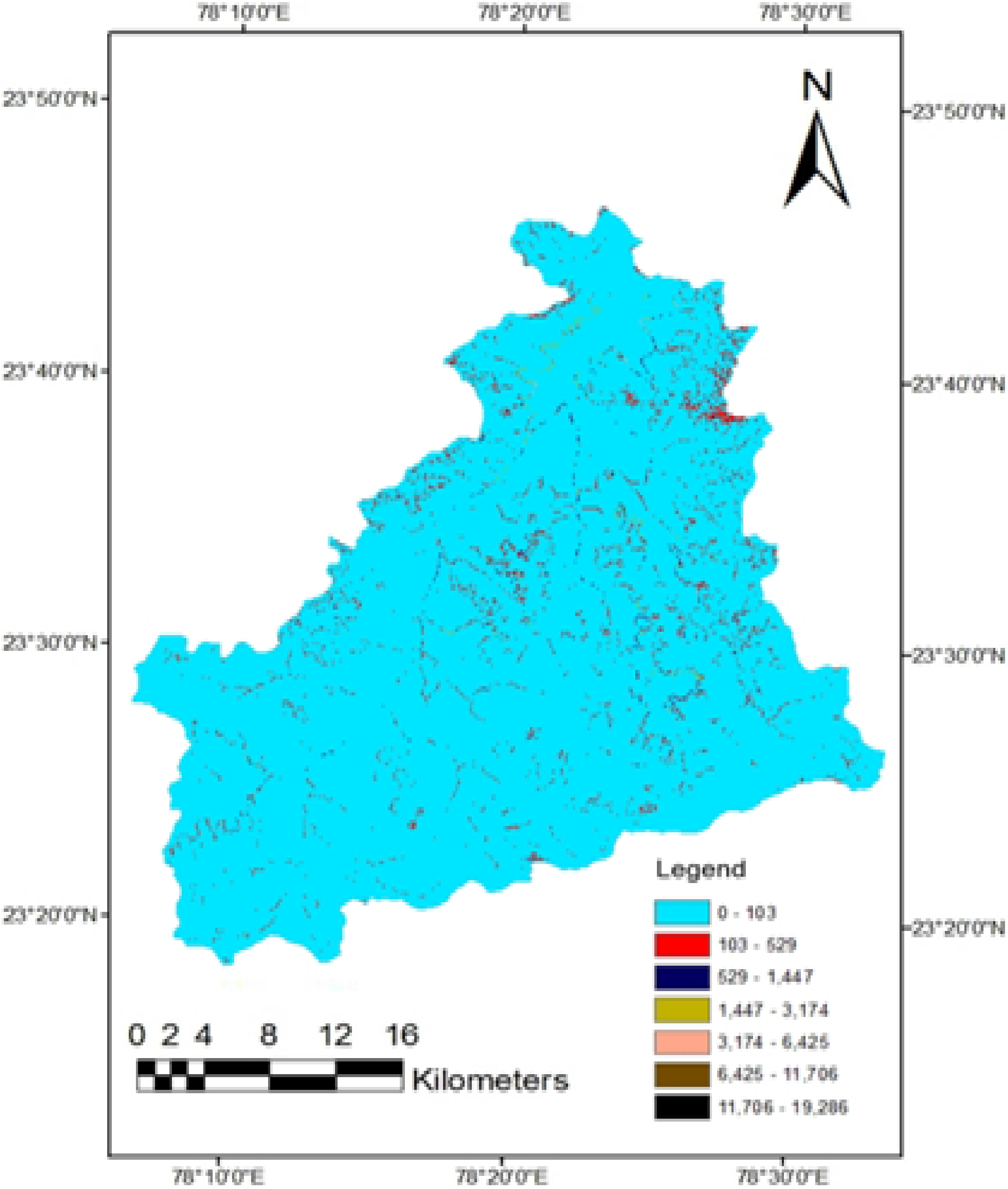

Fig. 5. Sediment Transport Index map of study area

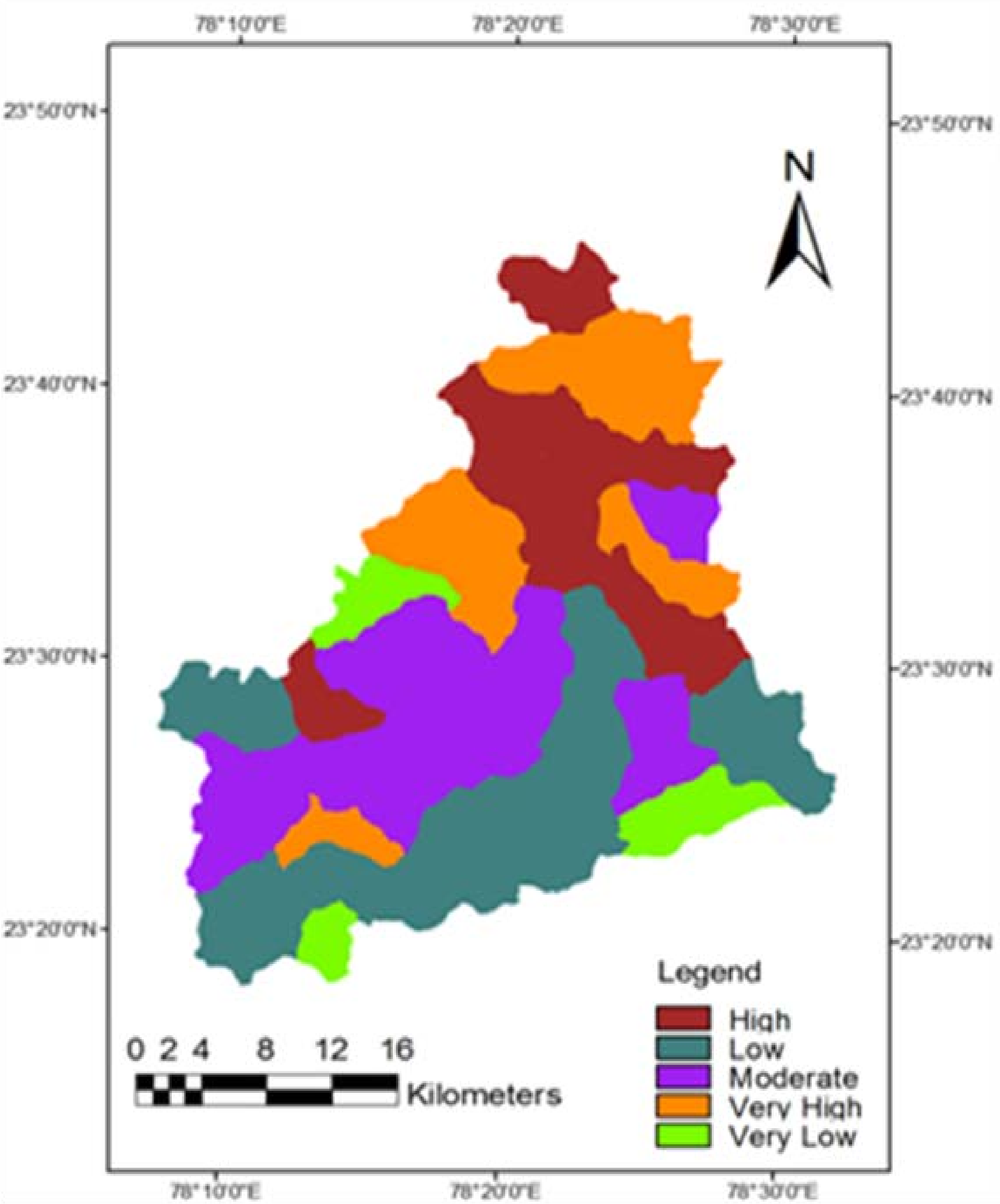

Fig. 6. Priority map of study area

Table 4. AHP weight for different erosion hazard parameters

	SL	**SPR**	**SY**	**STI**	**S**	**D_d**	**C_f**	**R_f**	**R_c**	**Average**
SL	0.3886	0.3061	0.5277	0.3549	0.3748	0.3087	0.2530	0.2348	0.1915	0.33
SPR	0.0777	0.0612	0.0586	0.0394	0.0250	0.1323	0.1084	0.0783	0.0638	0.07
SY	0.1294	0.1837	0.1759	0.3549	0.2249	0.2205	0.1807	0.1826	0.1489	0.20
STI	0.1294	0.1837	0.0586	0.1183	0.2249	0.1323	0.1807	0.1826	0.1915	0.16
S	0.0777	0.1837	0.0586	0.0394	0.0750	0.1323	0.1084	0.1304	0.1489	0.11
D_d	0.0555	0.0204	0.0352	0.0394	0.0250	0.0441	0.1084	0.0783	0.1064	0.06
C_f	0.0555	0.0204	0.0352	0.0237	0.0250	0.0147	0.0361	0.0783	0.0638	0.04
R_f	0.0431	0.0204	0.0251	0.0169	0.0150	0.0088	0.0120	0.0261	0.0638	0.03
R_c	0.0431	0.0204	0.0251	0.0131	0.0107	0.0063	0.0120	0.0087	0.0213	0.02
SUM	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00

Table 5. Priority of different sub-watersheds with their Priority index of study area

Priority	**Range**	**Sub-watersheds**	**Area (km^2)**	**Area covered (%)**
Very high	0.50 and above	SW-14, SW-21, SW-23, SW-27	197.59	17.78
High	0.50 to 0.40	SW-9, SW-12, SW-19, SW-20, SW-24, SW-26, SW-28	217.27	19.55
Moderate	0.40 to 0.30	SW-5, SW-10, SW-11, SW-15, SW-16, SW-17, SW-22	298.46	26.85
Low	0.30 to 0.20	SW-1, SW-3, SW-4, SW-7, SW-8, SW-13, SW-25	323.47	29.10
Very Low	Less than 0.20	SW-2, SW-6, SW-18	74.79	6.73
Total		28	1111.58	100.00

5. Conclusion

Watershed prioritization is the ranking of different sub-watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures. Morphometric parameters is essential in order to devise a sustainable watershed management plan. RS and GIS are the most advance tools for studies on prioritization of watersheds for their development and management. The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. On the basis nine Erosion Hazard Parameters, all the 28 sub-watersheds were prioritized on the basis of Saaty's Analytical Hierarchical Process. The priority of all sub-watersheds was categorized in to very high, high, moderate, low and very low. SW-14,SW-21, SW-23 and SW-27 are coming under very high priority class, whereas SW-9, SW-12, SW-19, SW-20, SW-24, SW-26 and SW-28 are under high priority class, SW-5, SW-10, SW-11, SW-15, SW-16, SW-17 and SW-22are under moderate priority class, SW-1, SW-3, SW-4, SW-7, SW-8, SW-13 and SW-25 are under low priority class, SW-2, SW-6 and SW-18are under very low priority class.

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