EROSION HAZARD MAPPING FOR MICRO-WATERSHED PRIORITIZATION USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT:

Proper management of watersheds is essential for the conservation of water and land resources and their management for optimum productivity. A comprehensive watershed management programme needs to implement for this purpose, which is having multiple objectives. The assessment of erosion hazard and prioritization of watershed for treatment would be a better planning in combating this menace. While considering the watershed conservation work, it is not feasible to take whole area at once. This requires dividing the watershed in small units by considering its drainage system. As the condition of micro-watersheds may not similar, they can be prioritized for conservation work. The present study was carried out to prioritize the entire watershed area by considering their degradation condition and sensitivity toward erosion. The Universal Soil Loss Equation in conjunction with Remote Sensing and GIS has been utilized for estimating soil loss. Five major land use/cover classes were identified, which are built-up land, agricultural land, barren stony wasteland, wasteland with or without scrubs and water body. Agriculture is the major land use of the area covering 74% of the entire watershed area. For the priority fixing, the entire watershed area has been delineated into five micro-watersheds. The soil loss estimates were computed for all the micro-watersheds and the ranking were performed using the weighted index overlay model. It is found that the micro-watershed no. 1 is having the first ranking and need immediate attention for conservation activities to prevent further land degradation and reduction in productive land.

1. INTRODUCTION

After independence in 1947, efforts to increase agricultural production were concentrated on irrigation and improved inputs, such as seeds and chemical fertilizers. Major investments were made in large- and medium-scale irrigation projects. The negative effects of large dams, such as waterlogged soils are also becoming increasingly apparent. Many small and medium reservoirs are severely affected by siltation. According to a recent estimate by the National Bureau of Soil Survey and Land Use Planning, 96.4 % of the land area is degraded to various degrees, and 40.6% is degraded severely (greater than 40.6 million tons/ha). The detrimental effects of soil erosion are reflected in the land's declining productivity. Thus, there was an increasing resistance towards the large river valley development projects and it was often being made out that watershed management on lines of what is called "Wisdom of the Centuries" is the answer to all our irrigation water management and food security problem. Therefore, in the recent trend, watershed management has been recognized as a key strategy for improving the productivity of land in the dry land region of India.

The Govt. of India has also focused on the development of watershed at micro watershed scale. The aim of these programs was to conserve the water generated over that land and to hold the soil in-situe. The overall objectives were to make all the villages as self-sufficient in all respect and to meet the needs of the growing population. Hence, there was an obvious need for the proper management of watersheds for the conservation of water and land resources and their management for optimum productivity. A comprehensive watershed management programme needs to implement for this purpose, which is having multiple objectives. The assessment of erosion hazard and prioritization of watershed for treatment would be a better planning in combating this menace. While considering the watershed conservation work, it is not feasible to take whole area at once. This requires dividing the watershed in small units by considering its drainage system. As the condition of micro-watersheds may not similar, they can be prioritized for conservation work. The present study was carried out to prioritize the entire watershed area by considering their degradation condition and sensitivity toward erosion.

Integration of remote sensing and GIS techniques provides reliable, accurate and updates database on land and water resources and have efficiently used in generating input parameters of hydrological models. Hence, in the present study the Universal Soil Loss Equation (USLE) in conjunction with Remote Sensing and GIS has been utilized for estimating soil loss. The Universal Soil Loss Equation/GIS (USLE/GIS) methodology permits calculation of potential soil loss from sheet and rill erosion. The procedure utilizes the capabilities of map analysis and processing system (MAPS) to overlay data themes containing spatially distributed values for different USLE factors. The resultant soil erosion potential map can be used in various ways for further erosion modeling by recreating it again with some of the factors changed to simulate different conditions, such as seasonal change, change in precipitation, vegetation cover, terrain, and management practices. The USLE/GIS methodology was used by most of the researchers in India (Singh et al., 1981; Kothiyari and

Jain, 1997; Jain and Kothiyari, 2000; Chandramohan and Durbude, 2002) and found this method is effective and accurate for estimation of soil erosion as compare to conventional method.

2. STUDY AREA

The drainage area of the watershed is lying between $18^0 54'$ N to $18^0 57'$ N and longitudes of $74^0 23'$ E to $74^0 27'$ E (Figure 1).

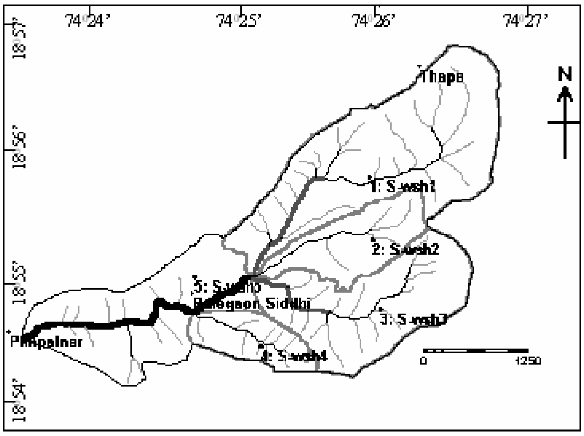

Figure 1. Location map of the study area

The total geographical area of the watershed is 1070.52 ha. Physiographically, the area is surrounded by small hillocks with fractured rocks. The average temperature of the area varies between 12^0C to 44^0C. The average annual rainfall of the region is 601 mm. As per the census record, the agriculture is predominant with Jowar, Groundnut and Maize as major growing crops. Three types of soil textures are identified in the area namely, gravelly sand, sandy loam and sandy clay loam with sandy clay loam as a dominant soil texture. Depth of the soil ranges from 0 to 45 cm. The hilly portion (high relief) of the watershed is containing a shallow depth of kankars, while the valleys are accompanied with very good soil depth of nearly 45 cm. As per the land capability criteria, the land of watershed can be categorized under three types of land capability classes. Almost, 44% of the land is under land capability class VI, while land capability class III covers 24% and class IV covers 32% of watershed area.

3. MATERIALS AND METHOD

3.1 Data Use

The IRS satellite data (images) for the different periods during the year 2000-2001 along with the Survey of India topo map were used for the preparation of land use/cover map. The satellite data were digitally processed using the GIS software namely Integrated Land and Water Information System (ILWIS 3.0) of International Institute for Aerospace Survey and Earth Sciences, The Netherlands (ITC, 1997).

3.2 Generation of Base Maps and Thematic Maps

The base map of the watershed boundary and different thematic maps were prepared using the various contours and drainage lines. Digital Elevation Model (DEM) was created using the contour map, which was further used for the assessment of soil erosion. The infiltration tests were carried out at different sites in various land use and soil type combinations using gulph and disc permeameter, which is used for the classification of hydrologic soil groups and soil permeability status. The field survey has been conducted to collect soil samples from various locations throughout the entire watershed area and prepared the soil texture map. The soil characteristics in association with the different land use/cover were used for the hydrological soil grouping, which can be further used for the computation of the soil erodibility factor in USLE method.

3.3 Soil Loss Estimation

For the priority fixation, the entire area of the watershed has been delineated into five micro-watersheds by considering its drainage system. The USLE erosion model was applied for each of them to estimate the rate of soil erosion and total soil loss from the watershed area. This model is designed to predict the long-term average field soil losses under specified conditions. The basic USLE is described by Wischmeier and Smith (1978) and it is given as follows;

$$A = RKLSCP \qquad (1)$$

Where A = the computed soil loss per unit area, usually in tons per ha per year;
R = the rainfall erosivity factor, the number of rainfall erosion index (EI) units, plus a factor for runoff from snowmelt or applied water, where such runoff is significant; K = the soil erodibility factor, the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6 ft length of uniform 9% slope in continuously clean-tilled fallow;
L = the slope length factor, the ratio of soil loss from the field slope length to that from a 72.6 ft length under identical conditions;
S = the slope steepness factor, the ratio of soil loss from the field slope gradient to that from a 9% slope under otherwise identical conditions;
C = the cover and management factor, the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow;
P = the support practice factor, the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to that with straight row farming up and down the slope.

3.4 Calculation of USLE Parameters

Rainfall Erosivity Factor, (R factor): The R-factor was calculated using the average annual and seasonal rainfall of four raingauge stations. The following equation was used to estimate annual and seasonal R-factor (Singh et al. (1981)).

$$R \text{ factor} = 38.5 + 0.35 * P \qquad (2)$$

Where P is the rainfall in mm

In ILWIS environment, a rainfall distribution map was created using the interpretation technique. Rain erosivity map was then developed by applying the above equations through map calculation function.

Soil Erodibility Factor, (K factor): Soil erodibility nomograph (USDA, 1978) was used for determining K-factor based on the particle size, the organic matter present, and the permeability class. An attribute table was prepared using these values for different soil types. The soil erodibilty map was prepared using the K-factor attributed with soil map.

Slope Length and Steepness Factor, (LS factor): For slope steepness up to 21%, the original USLE formula (USDA, 1978) for estimating the slope length and slope steepness was used:

$$SL= (L/72.6) * (65.4 * \sin (S) + 4.56 * \sin (S) + 0.065) \quad (3)$$

Where L is the slope length in m and S is the steepness in per centage

For slope steepness of 21 % and more, the Gaudasamita equation (USDA, 1978) was used:

$$SL = (L/22.1)^{0.7} * (6.432 * \sin (S^{0.79}) * \cos (S)) \quad (4)$$

The slope map was generated from the DEM in ILWIS environment by applying the gradient filters dfdx and dfdy. The relationship between the slope steepness in percentage (S) and slope length in metres (L) for the study area was estimated as;

$$L = 0.4*S + 40 \quad (5)$$

From the slope map, using the above equation in map calculation function, slope length map was created. By combining the slope steepness and slope length map, SL-factor map was generated.

Cover and Management and Support Practice Factor, (CP factor): The calculation of CP factor for each land cover unit was made on the basis of management practices, physical conditions and characteristics of cover units. The CP factor map for the USLE was created by linking the attribute table of CP factor with the land use map.

3.5 Decision Rules for Watershed Prioritization

After the characterization and estimation of various parameters facilitating the erosion hazards and land productivity of the area was completed, the decision rules for the priority fixing will be formulated based on the erosion hazard and productive land occupies by each micro-watershed. A weighted index overlay model will be used for prioritizing the micro-watershed for conservation measures. In this model, the individual parameters facilitating the land degradation will assign the weights on the basis of their relative contribution towards the output. The micro-watershed having more sensitivity toward erosion and rate of soil loss will be given highest weights. The ranking will be made as per the total weights computed for each micro-watershed. The micro-watershed having more weights will be given first ranking and further first priority for conservation activities. This decision rules will help to integrate characterization information and to develop some relative risk, opportunity and/or stronghold rankings for each of the micro-watersheds. The rankings were subsequently used to assist the collaborators in developing micro-watershed.

4. RESULTS AND DISCUSSION

4.1 Land Use/Cover

The five major land use/land cover categories were identified as shown in figure 2.

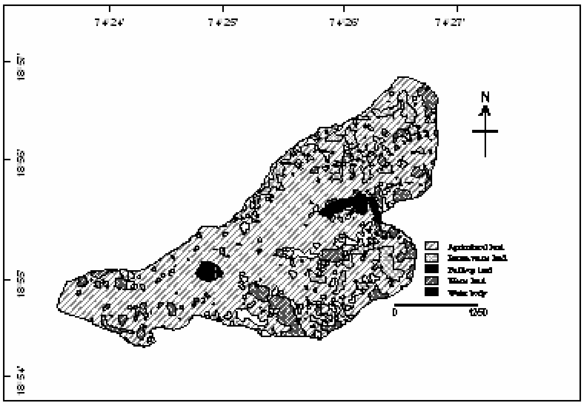

Figure 2. Land use/cover map

These are built-up-land, agriculture land, barren waste land, waste land with or without scrub and water bodies. As stated in methodology, for the priority fixing, the entire watershed has been delineated into five micro-watersheds. The spatial and temporal distributions of these major land uses/covers have been computed and tabulated as shown in following Table 1.

Sl. No.	Land use/cover	Micro-watershed Area (ha)				
		1	2	3	4	5
1.	Built-up	0	0	0	0	8.29
2.	Agriculture	258	91	184	55	213
3.	Barren waste	52	2	34	1	2
4.	Waste land	83	7	22	18	23
5.	Water body	0	18	0	0	0

Table 1. Micro-watershed wise coverage of land use/cover

From the table, it is observed that agriculture is major land use/cover unit (74 %) in the area. Hence, it is necessary to protect this valuable land resource.

4.2 USLE Parameters Estimation

For soil loss estimation, USLE has been applied. All the data has been transferred to GIS database and base maps were prepared. These maps were used to generate USLE parameters, which were stored in ILWIS under various conditions. All the parameters were then combined to assess the seasonal soil erosion and the potential soil erosion for the study area. The USLE parameters estimated from the data is given in Table 2.

Sl. No.	USLE Parameters	Micro-watershed				
		1	2	3	4	5
1.	R factor	186	190	182	197	200
2.	K factor	0.08	0.05	0.08	0.07	0.09
3.	LS factor	2.67	2.47	2.08	2.33	1.51
4.	C factor	0.29	0.28	0.24	0.20	0.32
5.	P factor	0.21	0.26	0.17	0.19	0.32

Table 2. Estimation of RUSLE parameters

4.3 Potential Soil Loss Calculation

The rain erosivity, soil erodibility, and the slope factor as elements of USLE can be considered as naturally occurring factors determining the sheet and rill erosion processes (without considering management factors). In ILWIS terms, the multiplication of the three maps showing the variation of R-factor, K-factor, and LS-factor, potential soil loss maps were created for each micro-watershed. The K, LS, and CP factors were combined together to generate a map of KLSCP as shown in the Figure 3.

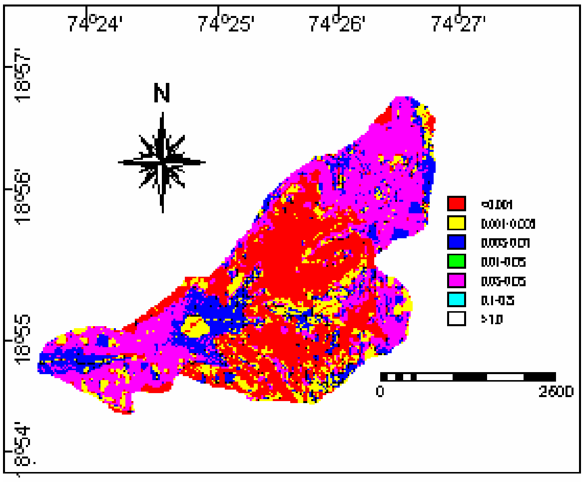

Figure 3. Erosion potential (KLSCP) map

This parameter (KLSCP) is independent of storm events in the watershed and represents the erosion potential of the area. The potential erosion and erosion potential for each micro-watershed is given in Table 3.

Sl. No.	Soil loss estimates	Micro-watershed				
		1	2	3	4	5
1.	RKLS	39.17	18.71	27.31	26.86	25.69
2.	KLSCP	0.016	0.004	0.007	0.006	0.014
3.	RKLSCP	2.97	0.70	1.40	1.30	3..05
4.	TSL	1166	82	336	96	752

Note: RKLS- Potential erosion (T/ha/yr),
KLSCP- Erosion potential of the watershed,
RKLSCP-Rate of soil loss (T/ha/yr),
TSL-Total soil loss (T/yr)

Table 3. The soil loss estimates

4.4 Soil Loss (A) Calculation

The actual rate of soil loss was estimated for each micro-watershed by multiplying the maps of R, K, LS, and CP factors to generate a map of RKLSCP as shown in Figure 4.

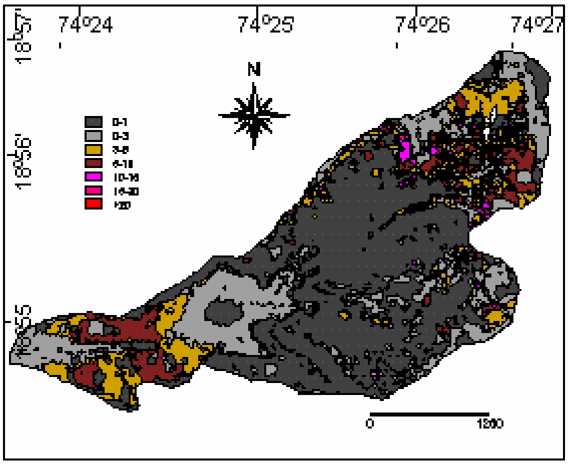

Figure 4. Soil loss (RKLSCP) map

From the erosion potential of each micro-watershed, the storm erosion can be computed by adding R-factor. The rate of soil loss and total soil loss for each micro-watershed is also given in Table 4. By comparing the actual and potential soil loss, the effect of management practices can be understood.

4.5 Watershed Prioritization

On the basis of decision rules formulated using the weighted index overlay model, each micro-watershed was given the weights for various parameters facilitating the output and accordingly the ranking was made as given in the following Table 4.

Sl. No.	Parameters	Weights for various Micro-watershed				
		1	2	3	4	5
1.	Agril. land	5	2	3	1	4
2.	KLSCP	5	1	3	2	4
3.	RKLSCP	4	1	3	2	5
4.	TSL	5	1	3	2	4
5.	Total weights	19	5	12	7	17
6.	Rank	1	5	3	4	2

Table 4. Ranking of various micro-watersheds

From the table, it is found that the micro-watershed no. 1 is having first ranking, while the micro-watershed no.2 is having last ranking. Hence, the highest priority will be given to micro-watershed no. 1 for conservation activities.

5. SUMMARY AND CONCLUSIONS

The IRS LISS data of the year 2000-2001was digitally analyzed using ILWIS GIS software. Five major land uses/covers identified namely, agricultural land, Built-up land, waste land with or with out scrub, barren stony waste land and water body. Agriculture and waste land are the major land uses in the area. By using the USLE method, the potential soil loss as well as the actual rate of soil loss was calculated for each micro-watershed. Using the weighted index overlay model for ranking of the micro-watershed, it is found that the micro-watershed no. 1 is having first ranking and need immediate attention for conservation activities to prevent further land degradation and reduction in the productive land.

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