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Identification of Critical Erosion Prone Areas using Remote Sensing and GIS: A Case Study of Sarada River Basin

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Abstract

Background/Objectives: Developed an integrated soil erosion model utilizing RS and GIS approach and mapped for prioritization of critical soil erosion prone areas in a watershed. **Methods/Statistical Analysis:** The geomorphologic parameters of the watershed have been extracted using Arc-GIS software. In order to evaluate effectively for the soil erosion prone areas, the selected basin has been divided into 143 micro-watershed basins. The micro basins were analyzed using Universal Soil Loss Equation (USLE) soil loss based on annual basis has been assessed for the entire basin. **Findings:** The soil erosion estimation in a river basin has significant impact on reduction of the reservoir capacities on downstream side if they are situated at the downstream side. In the present study, the soil erosion has been estimated and identified for soil erosion based on their classification. Accordingly, the selected basin has five main categories of soil loss varying from 5 ton per ha per year to more than 80 ton per ha per year. The results obtained based on the present findings, it can be inferred that the Sarada basin has 12.12% area is prone for soil loss of more than 80 ton per ha per year which is under very severe erosion class, 40-80 ton per ha per year under severe class, 11.95% under very high class and 3.10% under high class and 27.78% under moderate class apart from 36.37% under not affected areas for soil erosion. Remote Sensing (RS) technology and Geographic Information System (GIS) were utilized to create and spatially establish the data and maps were generated for soil erosion modeling in the selected region. **Applications/Improvements:** In the present study, soil erosion has been estimated and critical prone areas for soil loss in a watershed basin that have been generated using RS and GIS.

Keywords: RS and GIS. Soil Erosion, Topographic Factor, USLE, Watershed

1. Introduction

Soil erosion, which reduces storage capacity of any downstream reservoir and deteriorates the hydrology of watershed, is an important to consider for watershed development planning. Soil disintegration in any watershed includes removal, transport and affidavit of soil particles and totals in the region. Moreover it might influence the loss of productive soil spread furthermore may prompt different issues that are made because of the soil disintegration viz. trenches, supplies and streams statement of unfertilized soil on cultivable terrains, unfavorable impacts of provincial water supply, angling and era of force. Soil disintegration by water is a standout amongst the most genuine corruption issues in the Indian setting. Some researchers[1–3] reported by that on a normal the soil disintegration rate of 16.35 ton per ha per year in India. In another huge study, displayed a disintegration rate guide of India[4,5]. As indicated by their study, soil disintegration rates more than 80 ton per ha per year has been accounted for at the Siwalik Hills. The studies and administration measures to battle disintegration successfully in any range, broad data on disintegration status and disintegration conditions are required. This

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data can be verified by vast degree from satellite data[6,7]. The Universal Soil Loss Equation (USLE) is the best generally utilized ideal to gauge soil misfortune from basin. It was additionally reported that different parameters of USLE can be acquired after precipitation circulation, mud attributes, topographic parameters; vegetative cover and soil preservation practices[8], scientists have embraced GIS as a tool to display USLE as a result of the geographic way of the components and utilized it as a part of the model[9]. The aggregate soil disintegration from basin has been accounted for as anticipated, utilizing USLE model by giving spatial information to the RS and GIS model. Some researchers[10] have reported that GIS model applications are subjected to information impediments, since GIS licenses exact and viable utilization of the USLE for little watershed. Be that as it may, a few scientists have embraced these systems relying on the motivation behind displaying furthermore the accessibility of data. Recent studies[10,11] inferred that RS and GIS procedures of extraordinary use portrayal and ranking of basin regions. Thus, it is fascinating and more essential to contemplate the way to deal with analyze further the relevance of the USLE to register soil disintegration and distinguishing proof inclined regions at the Sarada basin arranged close Visakhapatnam, Andhra Pradesh, India. This concentrate obviously shows sensible estimation of the parameters, for example, rainfall-runoff erosivity (R), soil erodibility factor (K), topographic factor (LS), cropping management factor (C) and land use factor (P). The estimation of spatial circulation of disintegration and distinguishing proof of inclined zones will be valuable for some watering system ventures on the downstream of the basin.

2. Study Area and Methods

The selected study region is Sarada River basin and it is situated within 82^0 13’0” East and 83^0 5’0” longitude and 17^0 25’ 0” and 18^0 17’ 0” North and latitude. The entire area of the study basin is 2046 km^2. The Sarada basin frames a piece of Survey of India (SOI) toposheets Nos. 65 O/1, 2, 3 and 6 and 65 K/13, 14 and 15 the size of 1:50000. The File guide of the study area is shown in Figure 1. The review, of the geographical region and observation the basin was demarcated on the premise of seepage route, land incline and passage point. Based on the premise of networks and terrestrial geology, the basin has been divided into five sub-basins viz., K. Kotapadu, Madugula, Chodavaram, Kasimkota and Anakapalli.

2.2 USLE-Model

The computation of soil loss has been changed throughout the years with a few strategies. The most well-known technique embraced by scientists utilizes a condition which is referred as Universal Soil Loss Equation (USLE) for soil loss forecast in any catchment. The USLE condition has been utilized to register the yearly normal soil loss (A) for the chose basin. This condition contains result of five distinct variables which will influence soil loss is given by Equation 1.

$$A=(R \times K \times LS \times C \times P) \qquad (1)$$

Where A is normal yearly soil loss per unit area in tons per ha every yr, R is erosivity (MJ.mm/ha.h.yr), K is soil erodibility (t.ha.h/ha.MJ.mm), LS is topographic, C is cover and editing administration element and P is supporting practices factors. The variables LS, C and P given in the Equation 1 are dimensionless. The data layers R, K, LS, C and P for the model remained isolated using GIS programming has been utilized as a part of the present study is appeared in Figure 1.

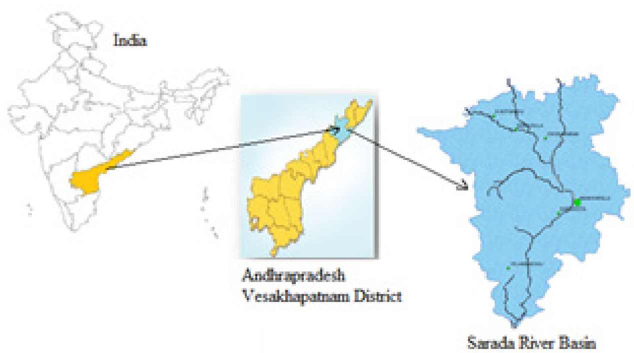

Figure 1. Index map of the study area.

3. Methodology

3.1 Erosivity Factor (R)

Rain fall data of 10 years (2001–2010) gathered from Central Water Commission (CWC), Bhubaneswar, Odisha, was used for calculating the R-factor. It was accounted for that in larger part of cases, rainfall intensity information are extremely unpredictable. Therefore tries have been made to decide erosivity element in perspective of consistently precipitation information. Along these lines, R has been resolved utilizing mean yearly rainfall as recommended[12–14] given Equation 2.

$$R=\sum_{i=1}^{12}1.75\times 10^{\left(1.5\log_{10}\left(\frac{P_i^2}{P}\right)-0.08188\right)} \quad (2)$$

Where, R is erosivity factor (MJ.mm/ ha. h.yr), P_1 is daily rainfall (mm) and P is monthly rainfall (mm). Hence empirical relationship has been developed[14] for Indian conditions been used in the current study to compute R factor values for five stations using daily rainfall data for 10 years as shown in Figure 2.

3.2 Erodibility Factor (K)

Soil erodibility component, which is an element that represents weakness of soil disintegration was evaluated for the study zone has been processed utilizing the condition given according to Equation 3[15].

$$100\,K=\{2.1\,M^{1.14}\,10^{-4}\,(12.0-A)+3.25\,(B-2.0)+2.5\,(C-3.0)\} \quad (3)$$

Where, "M" = particle size parameter, "A" = percent natural matter, "B" = soil structure code utilized as a part of soil grouping and "C" = soil penetrability class. The soil erodibility factor has been estimated to represent the entire watershed; soil samples from forty six locations were collected and analyzed to determine the textural classes. Soil erodibility factor 'K' values for each soil category were computed utilizing equation 3. The 'K' factor values obtained from the results were assigned to respective soils in the soil map prepared for the basin. The soil map thus prepared has been converted into grid format in Arc-GIS environment to prepare soil erodibility map of the entire study basin. The soil erodibility map obtained has been shown in Figure 3.

3.3 Topographic Factor (LS)

The topographic factor "LS" reflects the impact of geography on soil disintegration, where L and S independently speaks to the impact of incline length on disintegration and the impact of slant slope on soil disintegration individually. Some researchers[15] independently introduced a communication to register the slant length or L component as given in condition 4 has likewise been utilized for the present study.

$$L=\left(\frac{\lambda}{22.13}\right)^m \quad (4)$$

Where, λ is the field slope length (m) and m is dimensionless.The topographic factor (LS) is shown in Figure 4.

3.4 Crop Management (C) and Conservation Practice (P) Factor

The development and planning and erosion studies in any watershed area involves the land distribution for cropping pattern, fallow land, forest, wasteland and surface water bodies which are essential. Indian Remote Sensing satellite digital image file of year 2010 has been collected for the present study. These images were rectified and geometrically corrected with respect to rectified toposheet. The classified map of Sarada River basin is presented in Figure 2. The Sarada River basin includes eight unique classification of LU/LC. Notwithstanding, the real land use is agribusiness (64.72%) trailed by Plantation (19.44%). The water bodies, fruitless area, save woods, sloping territories, aquaculture and settlement represent around 16% of the aggregate range of area use example of the watershed. The basin has 5.51% fruitless area, 4.55% sloping ranges, 1.58% held timberland, 0.82% water tanks and aquaculture is additionally present here (0.26%). In Sarada river basin 3.12% area is covered by settlement. The information of Land Use/Land Cover (LU/LC) authorizes better understanding of the Land Use aspect. The LU/LC guide of the study zone is appeared in Figure 5. The qualities for specific area use class were allocated taking into account the rules from existing writing for various area use classes which are in comparative hydrological conditions. These qualities were allotted to the individual network in area use map in Arc-GIS programming to get crop administration variable (C) and protection hone element (P) and in like manner maps were readied. Taking into account the acquired results C values has range from 0.008 to 1 and P values have range from 0.8 to 1. The extent and spatial dispersion of yield administration component (C) and protection hone element (P) are appeared in Figure 6 and Figure 7 separately. The layers got for the study range viz. R, K, LS, C and P have been produced in Arc-GIS programming and were overlaid to acquired yearly soil loss (A) for the basin. The yearly soil loss values per ha per every year have been computed.

3.5 Development of Micro Basins

The micro basin of the study area has been carried out with Arc-SWAT (Soil and Water Assessment Tool) software. The Digital Elevation Model (DEM) has been developed and it is given as an input and the stream network was also used as predefined function in watershed in order to perform delineation module using Arc-SWAT software. Accordingly the basin has been divided into 143 micro basins is presented in Figure 8. The soil erosion class as suggested by All India Soil and Land Use Survey (AISLUS) has been adopted to divide into five soil erosion classes. These are very severe, severe, very high, high moderate and slight based on soil erosion value. The priorities for each critical micro basin was accorded based on range of soil erosion classes which were fixed on the basis of ranks assigned explained for Indian conditions[3]. The boundary map of micro basin is presented in Figure 7. The prioritization of these micro-basins has been carried out to suggest soil conservation measures and to prevent the soil erosion in the basin.

4. Results and Discussion

The erosivity factor (R) acquired in the present study depends on estimations of 10-year (2001-2010) normal rainfall and its spatial circulation in the basin is appeared in Figure 2. The normal yearly R variable qualities are differing from 255.89 MJ.mm/ha.h to 345.51 MJ.mm/ha.h with a mean estimation of 304.35 MJ.mm/ha.h. The soil erodibility variable (K) esteem in the study region was differing from 0.11 Mg.h/MJ.mm and 0.58 Mg.h/MJ.mm is introduced in Figure 3. The consolidated spatial dissemination of LS component has been inferred utilizing the DEM for the selected region. LS component values in the study range fluctuate from 0.1 to 87 with a mean estimation of 15 were introduced in Figure 4. The spatial appropriation "C" variable is inferred for the year 2010 and is introduced in Figure 6. It is found that "C" is exhibited in Figure 7 and "P" values in the study basin differ from 0.008 to 1.0 and 1 to 0.8 separately.

The entire erosion map for the study basin has been set up after the planning of fitting information layers as maps. So as to get the maps, the rules suggested[3] for Indian conditions have been used. They have given arrangement with sizes of needs as slight, moderate, high, high, extreme and exceptionally serious relying upon soil disintegration amount. It was additionally seen from the Table 1 that 27.78% of the aggregate watershed basin falls under moderate disintegration class 5-15 ton for every ha every year, 3.10% under high disintegration class 15-20 ton for each ha every year, 4.74% under high disintegration class 20-25 ton for every ha every year, 3.76% under disintegration class 25-30 ton for every ha every year, 3.45% under high disintegration class 30-40 ton for each ha every year, 8.67% under extreme class 40-80 ton for every ha every year and 12.12% under exceptionally serious disintegration class more prominent than 80 ton for every ha every year. The soil loss information of the USLE model demonstrates that 32.75% range (>20 ton per ha every year) of Sarada River basin requires quick consideration from the soil protection perspective is exhibited in Figure 8.

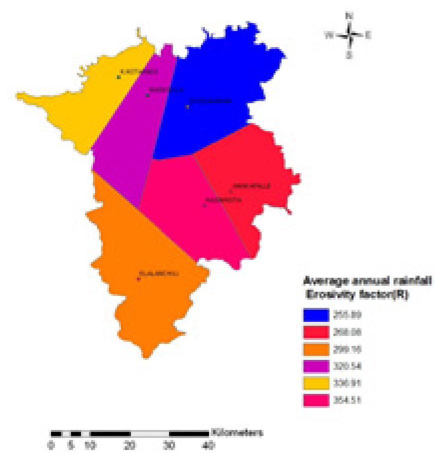

Figure 2. Average annual rainfall of erosivity factor (R).

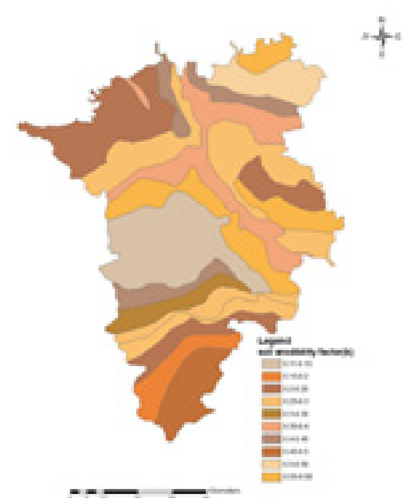

Figure 3. Spatial distribution of soil erodibility factor (K).

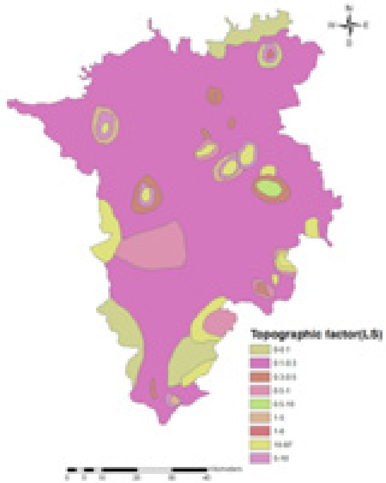

Figure 4. Spatial distribution of topographic factor (LS).

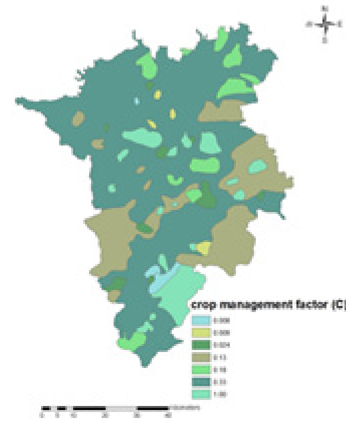

Figure 6. Spatial distribution of crop management factor (C).

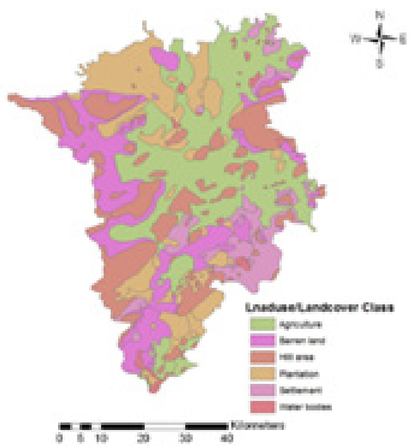

Figure 5. Land Use/Land Cover classification.

Figure 7. Spatial distribution of conservation practice factor (P).

Table 1. Soil loss classes according to annual average soil loss soil loss category

Priority	Soil loss Category (ton per hact per year)	No. of MBs	Area (km2)	Area (%)	Avg. Slope	Avg. LS factor	Avg. K factor
1	>80	15	248.06	12.12	10.01	5.68	0.35
2	40-80	12	177.48	8.67	7.20	3.46	0.23
3	30-40	7	70.53	3.45	5.26	2.93	0.29
4	25-30	7	77.00	3.76	6.02	2.68	0.42
5	20-25	5	97.04	4.74	5.61	2.33	0.31
6	15-20	5	63.38	3.10	3.70	1.04	0.25
7	5 -15	36	568.46	27.78	1.70	0.57	0.30

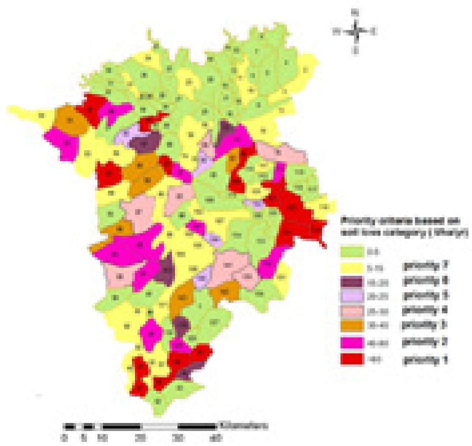

Figure 8. Priority criteria based on soil loss category.

5. Conclusion

The soil erosion of the selected basin has been carried out using conservation practice factor, crop management factor, slope length factor, topographic factor and soil erodibility factor. Thematic maps have been prepared for the above factors using RS and GIS technique. Micro-basin map has been prepared considering 143 sub-basins and thematic maps have been created. The areas which are prone for more soil loss have been identified for prioritization has been carried out to demarcate the sensitive areas of high soil loss in the entire basin. The computed soil loss has been graded as suggested[4] has been utilized to classify the soil loss grade as very severe, severe, very high, high, moderate, slight classes. In view of the study, it was found that 32.75% of study basin which has more than 20 ton for every ha every year of Sarada basin requires prompt consideration from the soil conservation perspective. Conservation practice factor, crop management factor, slope length factor, topographic factor and soil erodibility factor.

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