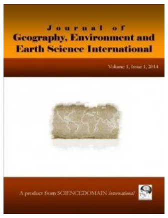

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Detection of Soil Erosion Potential Zones and Estimation of Soil Loss in Kushkarani River Basin of Eastern India

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Kushkarani river basin (172 Sq.km), a Chottonagpur plateau fringe river basin of Mayurakshi master stream. Most part of the basin is characterized by coarser lateritic soil with greater erodibility and high potentiality of erosion. Seasonal fluctuation of rainfall energized the process of weathering and generation of regolith. Present work thrusts on identification of soil erosion potential areas based on multi criteria decision approach. Seventeen parameters are employed in this work (i.e. drainage frequency, drainage frequency, soil type, hydraulic gradient, NDVI, ferrous mineral etc.) and weighted linear combination is used for extracting results. For estimating different potential soil erosion zones Revised Universal Soil Loss Equation (RUSLE) is used. RUSLE is computed using Arc GIS 9.3 and ERDAS Imagine 9.2 softwares. For validating these models, surface lowering rate measured by pegging operation and 107 sites of have been selected for measured. From the analysis it is noticed that the region where soil erosion potentiality is very high, is also experienced high rate of soil erosion (>19 tons/ha./year) and upper catchment is highly susceptible for erosion. Stream frequency, stream density, relatively steeper slope, coarser soil texture, exposed land etc. are some of the major reasons behind such accelerated erosion. Surface lowering measured from field also shows high lowering rate in the erosion susceptible region (>1.73 mm/year). These growing soil erosion especially fertile top soil

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loss is negatively impacted agriculture and sediment accretion within channels. People in most part of the basin area depend on agriculture, so, soil loss issue is linked with livelihood challenges of them.

Keywords: Soil erosion; erosion susceptible zone; RUSLE; surface lowering; weighted linear combination.

1. INTRODUCTION

Soil erosion rate is rapidly increased all over the world due to unscientific human activities on land use pattern and socio-economic participant [1]. Intense soil erosion is observed at topical region where rainfall is more acute and soil is highly erodible [2]. Globally, 2 billion ha of land is affected by human-induced soil degradation. Among this, 1100 M ha land is eroded by water and 550 M ha by wind [3]. Soil erosion is more dangerous in the developing countries since farmers intrinsic land ownership and they are unable to enhance the soil fertility [4]. Average soil erosion rate in Asia is 16.6 Mg/ha/ year which is second rank in world followed by South America (22.1 Mg/ha/year) [5]. NRSA and NBSS&LUP estimated that almost 130 M ha soil is eroded in India [6] affected by gorge and gully, shifting cultivation, coarse soil texture, lacking of organic matter, seasonal rainfall, steepness of slope, land use and land cover, agricultural practices, forest conservation [7,8] and vegetation cover factor(NDVI) [9]. Kushkarani is a non perennial river. Heavy rainfall (110-120 cm.) in monsoon season (June to September) is caused maximum soil erosion in this time [10]. According to Narayan et al. [11] in India 19% soil are eroded by rivers and 10% are deposited in reservoirs which decrease their storage capacity. Eroded materials are usually deposited in Tilpara barrage which is situated at the confluence segment of the river.

Since 1951 to 2011 in India the total population increased from 0.4 billion to 1.2 billion, these exerted unusual pressure on land use pattern. [12-14] established that the changes of land use pattern positively affected runoff and soil erosion. At present day, in India, 80% people are engaged in agricultural practices. After 1950, in India, total agricultural land increase from about 129 to 156 M ha [12] therefore, soil erosion from agricultural land is maximum [15]. Vohra [16] reported that in India, in every year, 1200 M tons top soil is eroded by water action which coasts Rs. 12,000 crores. Soil loss vulnerability not only affects on economic loss but also impacts on changes of rural livelihoods pattern [17,18], natural resource degradation, increasing sediment deposition [19,20], sustainable development [21] and ecosystem services [22,23]. Kushkarani river basin is highly susceptible to soil erosion because of its fragile laterite soil, uncovered land surface, seasonality of rainfall, coarser sandy soil and presence of ferrous mineral [24].

The objective of this work is to identify soil erosion potential zone and estimation of annual soil loss. Also the potential soil loss is tried to validate with surface lowering rate of the over variant surface. A long lasting debate is existing regarding the methods of compositing and ways of providing weights to the parameters selected for work. This work is also attempted to extract the differences between simple and weighted compositing models; knowledge based and correlation matrix based weighted compositing models. On the basis of that it is tried to establish that whether knowledge based approach of weighting parameters is justified.

2. STUDY AREA

Kushkarani river (length: 35 km) basin, covering an area 132 sq km (see Fig. 1), is a sub basin of Mayurakshi river system located mainly over the western part of Chottonagpur plateau fringe at Birbhum district of West Bengal and Jamtara district of Jharkhand with 23°54’ 36” N. to 24° N. latitudes and 87°14’24” E. to 87°30’ E. longitudes. The total basin area comes under rarh tract topography [25] with laterite soil formation [26] which is mainly received by flowing rivers of Chottonagpur plateau [27-29]. The elevation of this catchment varies from 155 m (at the source region) to 62 m. (at the confluence region). Maximum area of the basin is occupied by undulating topography with an average elevation of 108 metres. Average slope of the basin is 1–4 degree whereas it is <1 degree in the confluence part of the basin measured as per Wentworth’s method [30]. Geologically 90% of the basin area is composed with granitic gneissic rock of Plesitocene age (50 lakh years old) overlain by coarse grain lateritic soil and a few isolated patches covering 08%

and 02% area of the lower catchment is made with older and newer alluvium respectively of Holocene period over granitic basement (Fig. 1) (GSI 1985). The basin falls under the hot and sub-humid monsoonal climatic region. The average annual rainfall is 1444.432 mm. About 82% of total rainfall occurred in monsoon season (June to September). The estimated runoff of this basin area in monsoon time is 693.34 mm. [31] which is also a significant factor for controlling soil erosion potentiality. The mean annual temperature of the region is 26°C. The absolute maximum temperature occurs from March to May (38°C-40°C) and the absolute minimum temperature occurs in December to January (10-16°C). There is variation of soil qualities in different parts of the basin viz. upper catchment is dominated by coarse lateritic soil, and rest part is composed with laterite and relatively old alluvial soil. This type of soil is very susceptible to erosion. Soil erosion rate is very low at lower part of the basin because of sediment deposition. The extreme confluence part of this river is frequently submerged by the transgression of water from the reservoir of Tilpara barrage.

3. MATERIALS AND METHODOLOGY

Identification of potential soil erosion zone and assessment of soil erosion has been accepted as a challenge to researchers since the 1930s' [32]. For estimating soil erosion potentiality several methods and models are originated by the researchers. Among them empirical (statistical/metric), conceptual (semi-empirical) and physical process based (deterministic) models [33] are mainly designed for this purpose. Universal Soil Loss Equation (USLE) [34], Modified Universal Soil Loss Equation (MUSLE) [35-37], a revised version of the empirical-based USLE or Revised Universal Soil Loss Equation (RUSLE) [36,37], RUSLE 1.06 [38], RUSLE1.06c [39], RUSLE2 [40], Water Erosion Prediction Project (WEPP) [41] Revised Universal Soil Loss Equation (RUSLE), Morgan and Morgan–Finney model are also produced for quantitative and qualitative evaluation of soil erosion.

For nearly two decades, a number of multi-criteria evaluation methods have been implemented in the GIS environment for land suitability evaluation, including Weighted Linear Combination (WLC) and its variants [42,43] and the analytic hierarchy process [44,45]. In present day multi criteria models are used for predicting total soil loss with GIS environment.

3.1 Framing of Soil Erosion Potential Models

3.1.1 Correlation based and knowledge based

In this study, two models are used to estimate soil erosion susceptible zone. One is correlation based model and another is knowledge based

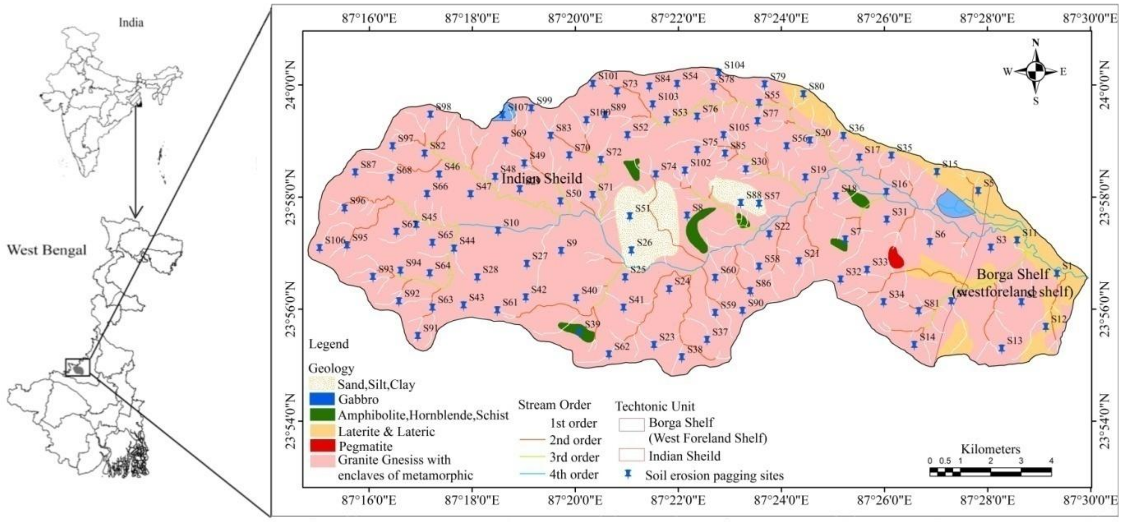


Fig. 1. Study area map showing major geological formations, stream networks and geotectonic units

model using Weighted Linear Combination (WLC) method. Here, 17 parameters mentioned in Table 1 are used for constructing those two models. Spatial analyst tool in Arc GIS software and ERDAS Imagine Software are used for generating the spatial data layers and the models. Every parameters are classified into ten equal classes and then ranking them at 10 point scale, higher rank suggests greater soil erosion potentiality. Table 2 shows the ranking scale and logic behind the rank. PCA analysis is carried out in Arc Gis for correlation based weighting the parameters. Compositing of the parameters is done following equation 1.

$$WLC = \sum_{j=1}^{n} aijwj \tag{1}$$

Where, aij = ith rank of jth attribute; wj = weightage of jth attribute.

Along with correlation based weighting of the parameters, knowledge based weighting of the parameters are drawn following Islam and Sado [46], Sanyal and Lu [47], Drobne and Lisec [48], Mandal and Pal [49] and Pal [15]. In this work total weight is consider as 1 and it is distributed among the parameters based on their prospective influence on soil erosion potentiality. Table 2 shows the knowledge based weights of selected parameters. Soil erosion is maximum at the adjacent area of the streams [50-55] therefore, 0.22 weights are allotted for 1st and 2nd order stream distance map. Slope is one of the dominant parameters for controlling soil erosion [56-58,32] that's why 0.2 weight is assigned. High intensity of rainfall increases soil erosion rate [56,32] so weight is considered as 0.12.

3.1.2 Method for estimating soil loss

For estimating the soil loss Revised Universal Soil Loss Equation (RUSLE) [37] is used.

$$A = LS*R*K*C*P \tag{2}$$

Where,

A = annual soil loss (tons/ha/year)
LS = slope length factor
R = rainfall erosivity factor (MJ mm ha-1 ha-1 yr^{-1})
K = soil erodibility factor (metric tons ha-1 MJ -1 mm-1)
C = land cover and management factor dimensionless, ranging between 0 and 1)
P = conservation practice factor (dimensionless, range between 0 and 1)

In the present study, annual soil loss rates based on RUSLE is computed using Arc GIS 9.3 and ERDAS Imagine 9.2 softwares. Required factors and their ways of computations are described in the following sections.

Table 1. Selected parameters and their respective sources

Parameters	Sources
All order Drainage frequency, 1st order Drainage frequency, 2nd order drainage Frequency, All order Drainage density, 1st order Drainage frequency, 2nd order Drainage frequency, Drainage texture, Slope.	Toposheet, Survey of India (1968-69) and Google Earth Image (2015)
Land use land cover (LULC)	Sensor: Landsat 8 (OLI), Feb., 2014 (Path/Row:139/43; Band used: G, R, NIR; Spatial resolution: 30m.
Soil Texture/ soil type	Soil texture map prepared by NIC Birbhum District Centre (2015)
1st and 2nd order stream distance map, Hydraulic gradient	Prepared from toposheet and Google earth image and SRTM data (USGS)
Elevation	Derived from SRTM data (USGS)
Rainfall	Directorate of Agriculture West Bengal
NDVI, Ferrous mineral	prepared from Landsat images as mentioned earlier using ERDAS Imagine 9.2
Geology	GSI (1985)

Table 2. Parameters and their scaling, logic behind scaling, correlation based weight and knowledge based weight to the parameters

Parameters	Scaling	Logic behind	Total Correlation score	Correlation based weight	Knowledge based weight
Elevation	10 rank at highest elevation	High elevation is prone to greater gravity force	3.53	0.65	0.03
NDVI	10 rank at sparse vegetation	Sparse vegetation protects soil with very least manner.	2.75	0.51	0.03
LULC	10 rank at bare land	Bare ground exposes land directly to sun rays and rain	3.28	0.60	0.05
Geology	8 rank at laterite	High silica and ferrous content causes high erodibility	2.48	0.46	0.03
Ferrous mineral	10 rank at maximum presence of ferrous mineral	High ferrous content means greater probability of oxidation weathering and soil fragility	3.96	0.73	0.05
Rainfall	10 rank at highest amount of rainfall	High rainfall intensity strongly hits land	3.43	0.63	0.12
1st & 2nd order stream distance	10 rank at adjacent to stream	1st and 2nd order streams are located at the steep and elevated areas and frequency of them are maximum	3.75	0.69	0.22
1st order drainage density	10 rank at highest drainage density	More drainage density indicates more spatial association of erosion agent as well as high soil rate of erosion.	4.81	0.89	0.04
2nd order drainage density			3.22	0.59	0.02
Total drainage density			5.32	0.98	0.02
1st order drainage frequency	10 rank at highest drainage frequency	High drainage frequency enhances soil erosion; these are located in higher elevation and slope process as well as fluvial process due their presence is high	4.94	0.91	0.06
2nd order drainage frequency			4.69	0.87	0.02
Total drainage frequency			5.43	1	0.02
Soil texture	10 rank at coarse texture	Coarser soil reduces soil coherence causes erosion	1.63	0.30	0.05
Hydraulic gradient (HG)	10 rank at highest hydraulic gradient	Greater HG causes dominant chance of soil removal	1.82	0.34	0.03

Parameters	Scaling	Logic behind	Total Correlation score	Correlation based weight	Knowledge based weight
Slope	10 rank at steep slope	Greater slope promotes high gravity	3.81	0.70	0.2
Drainage texture	10 rank at highest drainage texture	Fine texture indicates low spacing of drainage and it directly affects soil erosion	5.36	0.99	0.01

LS or slope length factor

Renard et al. [37] used LS factor in USLE to account the effect of topography on soil erosion. The topographic factor mainly depends on steepness factor (S) and slope length factors (L) [54]. A group of researcher applied grid based DEM method for determined LS factor. To generate slope length factor and slope steepness factor 30 metre resolution DEM is used. Flow accumulation map and percentage slope map has been prepared from DEM by ARC-GIS software. Ganasri and Ramesh [59] framing the following equation (equation no 3) for LS calculation.

LS =

$$\left[\frac{QaM}{22.13}\right]^{y} *(0.065+0.045*Sg+0.0065*Sg^{2}) \qquad (3)$$

Where

Qa = Flow accumulation grid**; Sg =** Slope in percentage**; M =** Grid size (x*y)**; Y =** Dimensionless assume value 0.2 -0.5

R or rainfall erodibility factor

Soil erosion is more sensitive to rainfall in a catchment [60]. R value is strongly affected by rainfall intensity, duration and amount of the precipitation [58]. In this study, 34 years annual average rainfall data is used. Wischmeier and Smith [61] developed the following equation for measuring rainfall erodibility factor.

R=

$$\sum_{1}^{12} 1.735*10^{(1.5\log_{10}(pi/p)-0.08188)} \qquad (4)$$

Where

Pi= Monthly rainfall in mm; P= Annual rainfall in mm.

K or soil erosivity factors

K factor or soil erosivity factor describes the impact of soil properties and soil profile characteristics on soil erosion potentiality [36]. Soil erodibility depends on soil properties such as parent materials, texture, structure, organic matters, permeability, porosity, catena etc. [62]. In the present study K value is demarcated on the basis of soil texture. Table 3 shows the K value of different soil texture. K factor map (Fig. 4) is generated on the basis of K value.

Table 3. K value based on the soil texture

Soil type	K values
Sand	0.02
Clay	0.22
Clay loam	0.3
Sandy loam	0.13
Loam	0.33

Source: Adapted from Robert & Hilborn (2000)

C or Land cover and land management factor

Land covers and land management factor(C) mainly measured by cropping and management practices of land and it effects on soil erosion rate. Vegetation canopy and ground covers are reduced the soil erosion rate [36]. C factor is not available for most of the crop in India. Therefore, C factor propounded by USDA (1972), RAO (1981) are used to show the significant effect of crop management practices on soil erosion rate in agricultural land. Table 4 shows the C factor values of different land used classes.

P or conservation practice factor

P factor is known as conservation practice or conservation support factor in a particular land use pattern. Rahaman et al. [63] Ganasri and Ramesh [59] are identified in their study that practice factor minimized the volume and rate of runoff as well as soil erosion. It also effects on up and down slope cultivation [61,36,64]. In the present study P value range from 0 to 1 (see

Table 4), here minimum value indicates good conservation practice with built up land and forest cover area and the maximum value indicates there is no conservation practice or poor conservation practice.

Table 4. Table shows the C and P factor value

Land use classes	C value	P value
Settlement	1.0	1.0
Vacant land	1.0	1.0
Quarry/Brick Kilns	1.0	1.0
Cropland	0.28	0.28
Plantation	0.28	0.28
Dense forest	0.004	0.28
Open forest	0.008	1.0
Degraded forest	0.008	1.0
Land with scrub	0.7	1.0
Marshy land	0	1.0
Water bodies	0	1.0
Fallow land	1.0	0.28

Source: Rao (1981)

3.1.3 Methods for validation

Correlation among three models have been done using Pearson's correlation coefficient .Surface lowing rate has been calculated for validating soil erosion models. Pegging operation, since 2012-2016 on 107 sites (see Fig. 1) are observed for calculating surface lowering rate.

4. RESULTS AND ANALYSIS

4.1 Spatial Character of the Individual Data Layers

Spatial data layers (Figs. 7 to 23) are constructed for preparing soil erosion model, 17 spatial data layers are used for this purpose. For detecting dominant parameters, correlation matrix among all the 17 parameters have been carried out and found that drainge texture, drainage frequency and drainage density are dominant parameters toward measuring soil erosion (see Table 1).

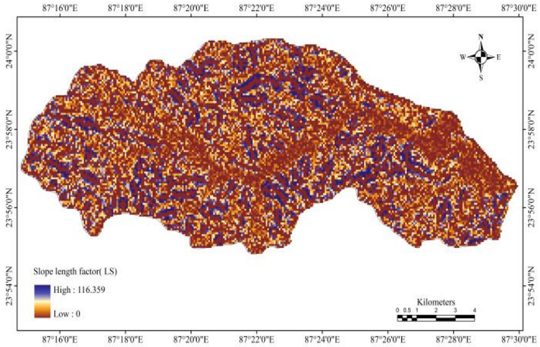


Fig. 2. Spatial pattern of slope length factor

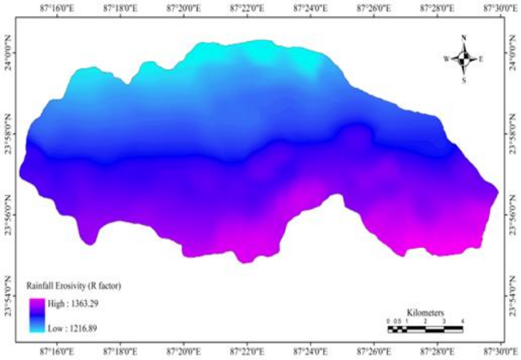


Fig. 3. Spatial pattern of rainfall erodibility factor

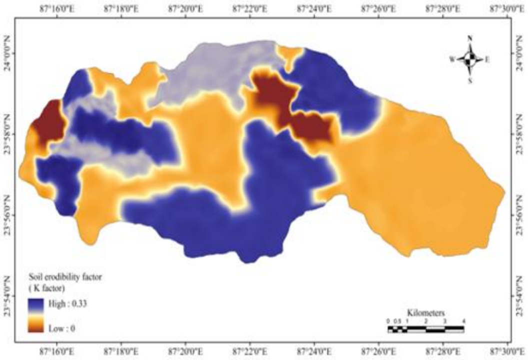


Fig. 4. K factor

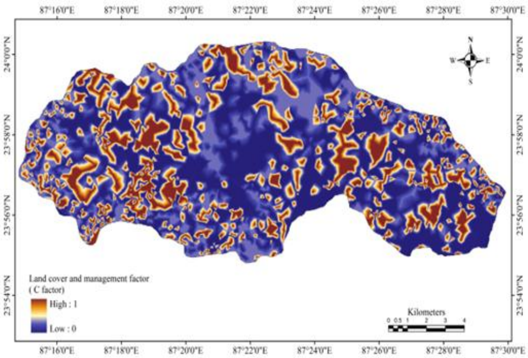


Fig. 5. Land management factor in spatial scale

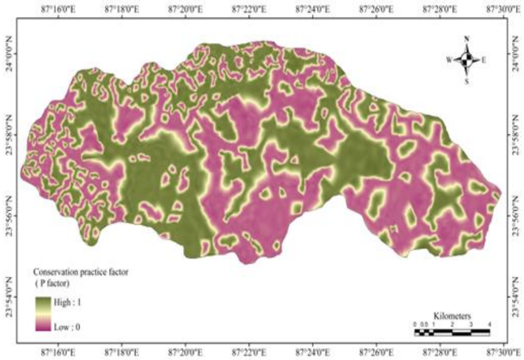


Fig. 6. Conservation practice factor

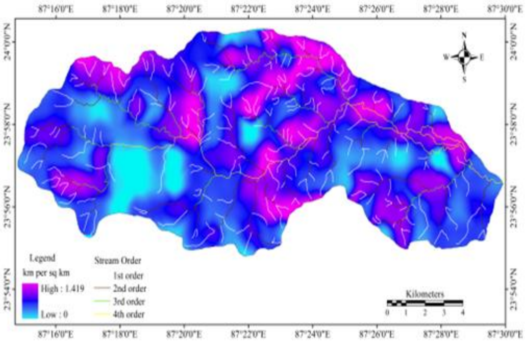


Fig. 7. Drainage density

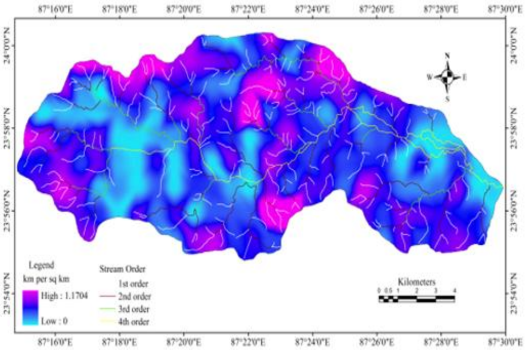


Fig. 8. 1st order drainage density

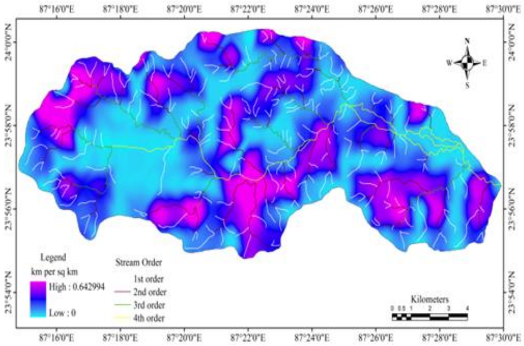


Fig. 9. 2nd order drainage density

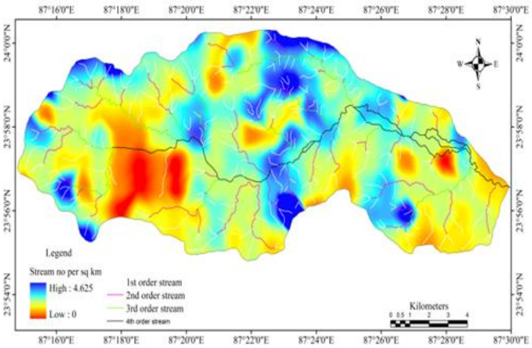


Fig. 10. Drainage frequency

Tables 5-6 shows area and percentage of area under different soil erosion potential zones.

Based on 17 selected parameters as mentioned above, both simple and weighted composite models are prepared. Fig. 24a and b represent the soil erosion potential model in continuous and classified forms respectively based on simple compositing. Table 5 shows the total area and percentage of the under simple linear composite. Out of the total area 10.89% area dominated very high soil erosion susceptibility (208-247). On the other hand, Fig. 25a and b respectively illustrate continuous and classified models of soil erosion based on weighted linear combination. The WLC scores in the composite models indicate soil erosion potentiality. Table 6 shows proportion of area under different WLC score. Out of total basin area, 12.82% area registers very high soil erosion susceptibility followed by 19.21% area with high potentiality (138.42-168.47). Mainly, the upper catchment specially the head reach of the small rills and gully dominated areas are highly potential for eroding soil (Fig. 25a and b). Coarse soil with high content of silica and ferrous, relatively steeper slope and high frequency and density of 1st and 2nd order streams are principally responsible for such high rate soil erosion susceptibility. Relatively, low land at the confluence segment accounts less soil erosion as usually.

Knowledge based weighted composite model

Fig. 26 shows the soil erosion potential model based on knowledge based weighting of the 17 parameters. Weights to the respective parameters are assigned in Table 1 mentioning the logic lying behind. Fig. 26a and b respectively

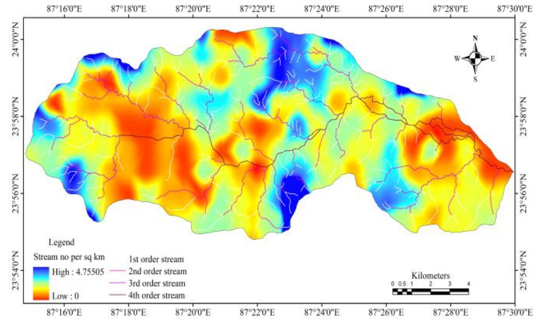


Fig. 11. 1st order Drainage frequency

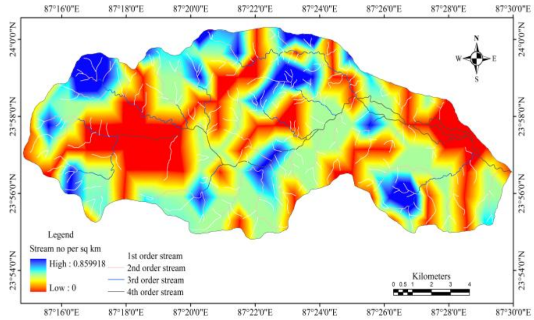


Fig. 12. 2nd order Drainage frequency

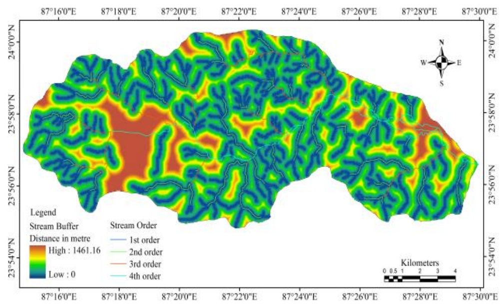


Fig. 13. 1st and 2nd order stream line buffer

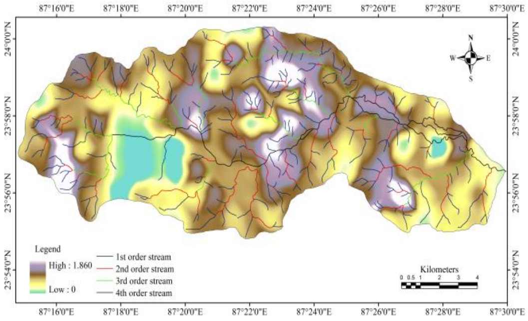


Fig. 14. Drainage texture

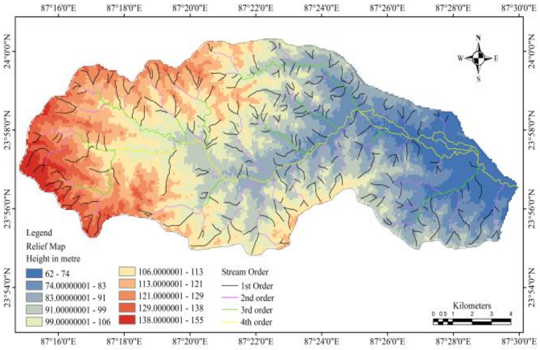


Fig. 15. Relief

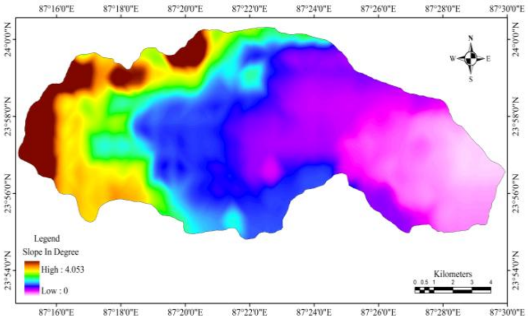


Fig. 16.Slope

represent continuous and classified soil erosion potential models. Table 7 shows that 11.49% of area under very high soil erosion potential (score 9.83-11.75) followed by 20.33% high soil erosion potential (score 8.63-9.83) and most part of these zones are found in the upper catchment.

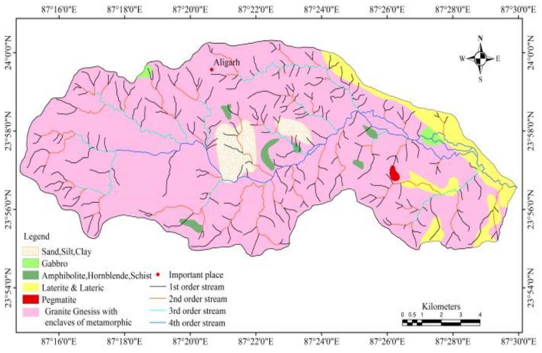


Fig. 17. Geology

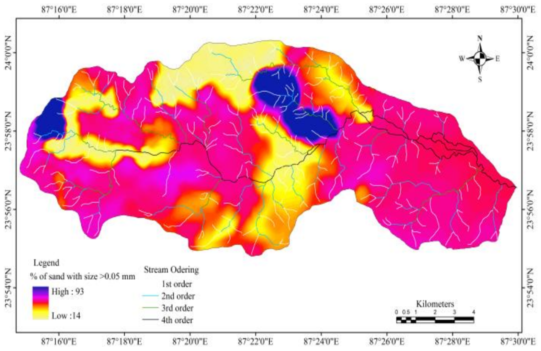


Fig. 18. Soil texture (proportion of sand)

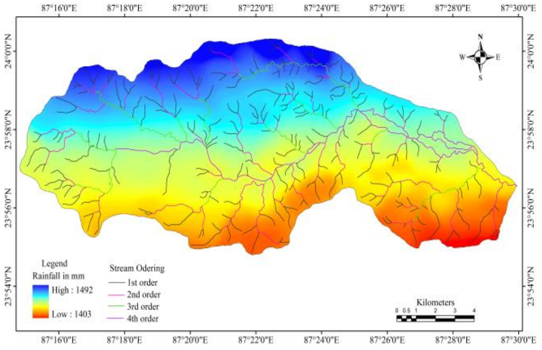


Fig. 19. Annual average rainfall

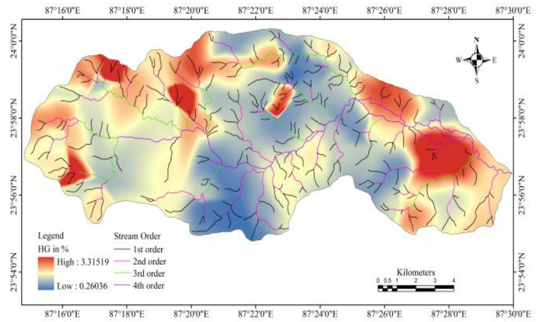


Fig. 20. Hydraulic gradients

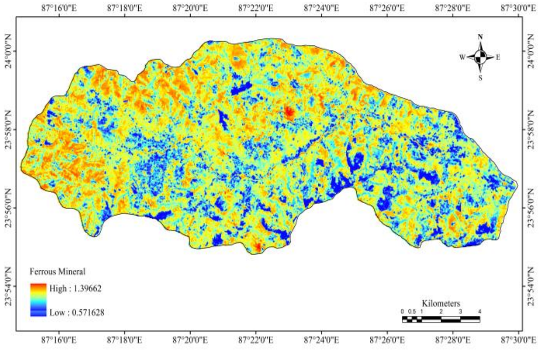


Fig. 21. Ferrous mineral

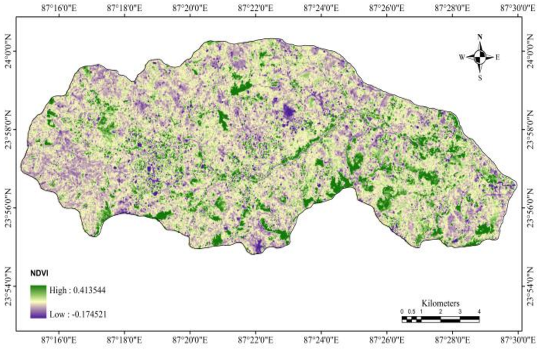


Fig. 22. NDVI

Table 5. Area and percentage of area of different soil erosional category based on LC

Soil erosion status	Classified LC score	Area extent (sq.km)	% to total area
Very low	112 - 149	23.59	13.72
Low	149 - 168	50.09	29.12
Moderate	168 - 186	48.91	28.44
High	186 - 208	30.68	17.84
Very High	208 - 247	18.73	10.89

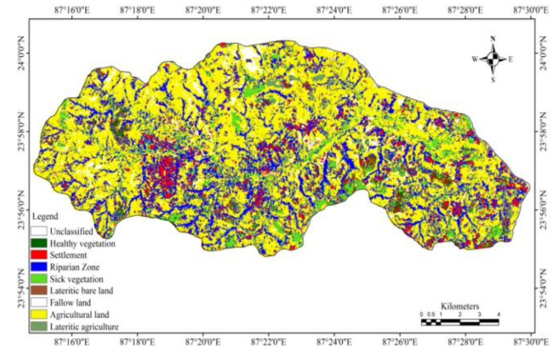
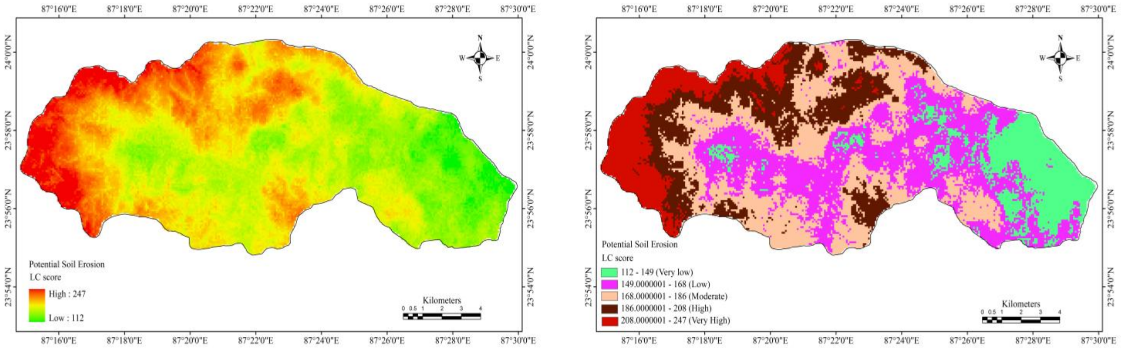
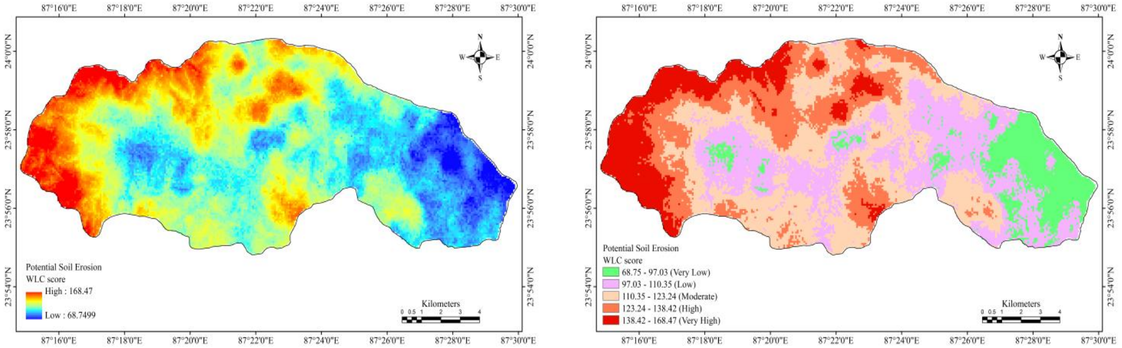


Fig. 23. Land use and land cover Soil erosion potential models



(a) (b)

Fig. 24. (a) Simple composite potential soil erosion (b) Simple classified potential soil erosion

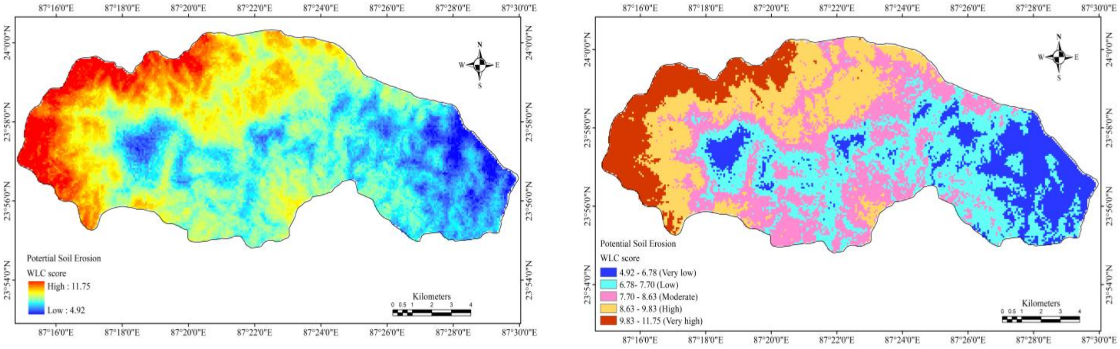


(a) (b)

Fig. 25. (a) Weighted continuous soil erosion model (b) Weighted classified soil erosion model

Table 6. Area and percentage of area of different soil erosional category based on WLC

Soil erosion status	Classified WLC score	Area extent (sq.km)	% to total area
Very low	68.75 - 97.03	19.47	11.32
Low	97.03 - 110.35	44.84	26.07
Moderate	110.35 - 123.24	52.59	30.58
High	123.24 - 138.42	33.05	19.21
Very High	138.42 - 168.47	22.06	12.82

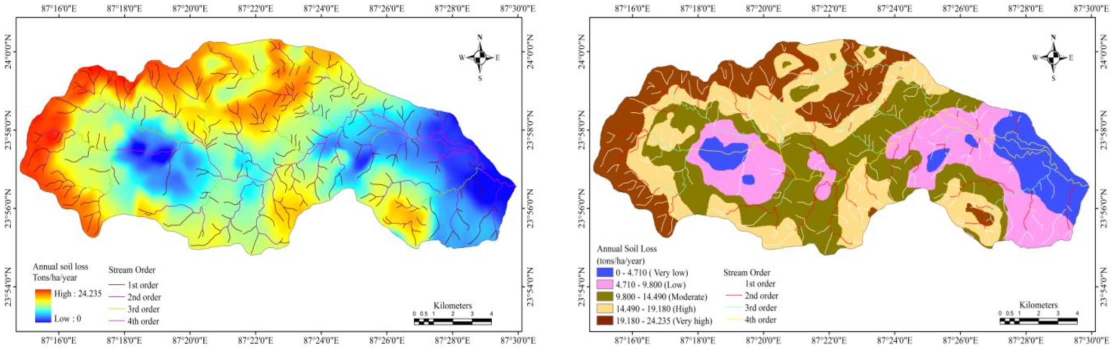


(a) **(b)**

Fig. 26. Knowledge based weighted composite model (a) continuous (b) classified

Table 7. Area and percentage of area under different knowledge based soil erosion classes

Soil erosion status	Classified score	Area extent (sq.km)	% of total area
Very low	4.92 - 6.78	25.06	14.57
Low	6.78 - 7.70	47.76	27.77
Moderate	7.70- 8.63	44.45	25.84
High	8.63 - 9.83	34.96	20.33
Very High	9.83 - 11.75	19.77	11.49
Total		172	100



(a) **(b)**

Fig. 27. (a) Annual soil loss (b) Classified map of annual soil loss

Table 8. Area under annual soil loss on the basis RUSLE method

Soil erosion status	Soil loss (tons/ha/year)	Area extent (sq.km)	% to total area	Total soil loss Tons/year
Very low	0-4.71	16.22	9.43	1621.39
Low	4.71-9.80	33.69	19.59	3369.23
Moderate	9.80-14.49	46.90	27.27	4690.21
High	14.49-19.18	45.10	26.22	4510.34
Very High	19.18-24.24	30.09	17.49	3008.81
Total		172	100	17199.98

4.2 Estimation of Soil Loss

The annual soil loss rate is determined by the RUSLE method in Arc GIS 9.3. Fig. 27(a) and (b) respectively show the continuous and classified annual soil loss rate map. Table 8 accounts the area under different zones of soil erosion and their relative proportion. Annual soil loss ranges from 0 to 24.24 tons /ha/year. About 17.49% area records very high soil erosion rate (19.18-24.24 tons/ha/year) with annual soil loss 4690.21 tons/year followed by 27.27% area with high soil erosion rate (9.80-14.49). Average soil erosion rate for this basin is 3440 tons/year and total estimated annual soil loss from this basin is 17199.98 tons/year. Soil erosion rate is high in the upper catchment specifically in the 1st and 2nd orders tips. As per the study of Sarkar et al. [65] high erodibility of lateritic soil, bare soil cover due to deforestation, more erosivity of the monsoonal rainfall, low clay with less moisture and organic matter content of the soil, the region is prone to soil erosion. Moreover, sparseness of vegetation coverage over, greater slope and association of numerous lower order streams cumulatively strengthen surface runoff and erosion power in this counterpart. Thick loose secondary lateritic deposit entrained from Chattanagpur plateau is highly friable in nature and therefore highly erodible [26]. Lateritic soil is naturally fragile because of its inherent constraints of acidity, nutrient loss, chemical impairment, crusting, water erosion and poor water holding capacity as these are highly weathered and leached soil and enriched with oxides of iron and aluminum in tropics [28,29] and therefore the region with deep lateritic content instigates more erosion. Chemical analysis of laterite samples of this area indicates that Fe_2O_3 varies antipathetically with Al_2O_3 and the ratio of Fe_2O_3 and Al_2O_3 is 1:0.2–1:2.01. Ti2O3 has a slight good and direct relationship with Fe_2O_3. The presence of anatese probably accounts for appreciable amount of TiO_3 (1.5–5.0%) in this laterite. Such chemical composition with least biomass availability in soil is in fact highly erosive. Kar and Bandopadhyay [66], Bandopadhyay [67], Jha and Kapat [29], Pal [15] condemned strong riling and gulling activities in the upper reach of the basins in the Chottanagpur plateau fringe area as a major vector soil loss. High seasonal variability of rainfall and temperature enhances weathering rate in the Laterite soil [15].

For predicting soil erosion potentiality, three soil erosion models have been prepared as described in earlier section. As per objective, to know how they are associated, simple Pearson's correlation coefficient is drawn among all and the result is shown in Table 9. From this result it is observed that all the models are highly correlated and therefore, any one of them can be applied for predicting soil erosion. Knowledge based weighted soil erosion model is strongly and significantly correlated with RUSLE and matrix weighted soil erosion model. So, if knowledge base is strong enough for distributing weight to the employed indicators, knowledge weighting can be freely adopted.

Validation of soil erosion models

For validating the potential soil erosion models and soil loss status, surface lowering rate from 107 sites of the study area is measured since 2012 to 2016 through pegging operations. Average surface lowering rate in different soil erosion potential zones is calculated for comparing whether surface lowering rate is high in the maximum soil erosion potential zones. Table 10 depicts surface lowering rate in different soil erosion potential zones. Average surface lowering rate for this basin is 0.86 mm./year. High rate of surface lowering rate (1.73 mm./y) is registered in very high soil erosion potential zones and this rate is decreased toward low to very low soil erosion potential zones. In addition, it is to be mentioned that not only high surface lowering rate is recorded in the high and very high potential soil erosion zones but variation of surface lowering rate is also high (CV=83.42% to 123.65%) in these zones.

Table 9. Pearson correlation among weighted potential soil erosion model, RUSLE model and logic based model

	1. Annual soil loss model	2. Weighet potential soil loss model	3.Logic based weighted soil loss model
1.Annual soil loss model	1.00	0.85261	0.81683
2.weighet potential soil loss model	0.85261	1.00	0.94747
3.logic based weighted soil loss model	0.81683	0.94747	1.00

Table 10. Surface lowering status in different potential soil erosion zones

Soil erosion status	Range of surface lowering rate and average (mm./y)	CV (%)	Sample frequency
Very low	0-0.53 (0.24)	54.32%	10
Low	0.25-0.88 (0.47)	69.23%	22
Moderate	0.51-0.96 (0.73)	63.41%	26
High	0.67-1.54 (1.16)	83.42%	31
Very High	0.78-2.34 (1.73)	123.65%	18

**Value within parenthesis indicates average surface lowering rate*

5. CONCLUSION

The spatial information from the parameters and models has been utilized for estimation for annual soil loss and prioritizing areas for soil and water conservation measures. From the analysis, it is evident that out of total area of the basin 17-22% area is highly susceptible for soil loss and average soil erosion rate in this zone is 21.32 tonnes/ha/year. Upper catchment of the basin lies under this zone where, frequency and density of 1st and 2nd orders streams are very high, coarse textured laterite soil predominates and degree of slope is to some extent high. Considering the susceptibility of erosion, management practice can be taken. This area is rapidly deforested and it will enhance the intensity of soil erosion in coming days. So, forest management would be good step for decelerating soil erosion. Some of the gully head bunds were constructed over the highly erosive rills and gullies in the upper catchment but over time these are overloaded and lost their capacity to control soil erosion further. Micro scale check dams can to some extent check soil erosion. Afforestation, agro-forestry, agri-horticulture interventions are suggested for management of natural resources and sustainable development, soil moisture conservation, water resources development, improving the crop productivity and preservation of ecodiversity. It is established fact that how soil erosion can reduce fertile top soil and bring crop failure. People in most part of the basin area are dependent on agriculture and therefore this soil erosion issue is interlinked with livelihood challenges. So, further investigation is to be made addressing livelihood opportunities and challenges.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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