Spatial modelling of soil erosion susceptibility mapping in lower basin of Subarnarekha river (India) based on geospatial techniques

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Abstract This paper applied GIS based Revised Universal Soil Loss Equation (RUSLE), remote sensing and ground based data to develop the soil erosion risk mapping in lower Subarnarekha Watershed in India. The soil erosion input parameters were assessed in different ways: the R factor map was developed from the daily rainfall data and spatial distribution using Ordinary Kriging (OK) interpolation techniques, the K factor map was obtained from the soil map, the C factor map was generated based on a back propagation (BP) neural network model of Landsat ETM+ data with a correlation coefficient (r) of 0.921 to the ground truth collection and LS factor was derived from a digital elevation model (DEM) with a spatial resolution of 30 m. P factor map was generated using standard table proposed by USDA-SCS for conservation practices. By integrating the six factor maps in GIS platform through pixel-based computing, the spatial distribution of soil loss was obtained by the RUSLE model. The spatial distribution of erosion risk classes was 26.2 % (796.97 km²) very low erosion (<5 ton ha⁻¹ year⁻¹), 12.88 % (394.66 km²) low erosion (5–10 ton ha⁻¹ year⁻¹), 20.77 % (636.37 km²) moderate erosion (10–20 ton ha⁻¹ year⁻¹), 20.75 % (635.67 km²) high erosion (20–30 ton ha⁻¹ year⁻¹), and

19.58 % (599.71 km²) very high (>30 ton ha⁻¹ year⁻¹), soil erosion prone zone. The highest volume of very severe soil loss was observed in Keshiary > Dantan-I > Jaleswar > Sankrail blocks. However, the southern part of lower Subarnarekha watershed areas which are in the extremely severe level of soil erosion risk need immediate attention from soil conservation practices.

Keywords RUSLE model · Remote sensing · GIS · BP neural network method · Soil risk · Subarnarekha watershed

Introduction

Soil is a valuable natural resource that performs crucial ecosystem functions, and provides many valuable environmental resources (Kouli et al. 2009). Soil erosion and its impact on ecosystem services receive increasing attention from scientists and policy makers (Bouaziz et al. 2011). To assess the socio-economic and environmental implications of soil erosion and to develop management plans to deal with them, quantitative data on soil erosion rates at regional and global scales are needed (Alexakis et al. 2013). These management plans need to consider on-site and off-site impacts of erosion. On-site impacts refer to soil loss and the decline of soil organic matter content and soil structure, leading to decay in soil fertility and water-holding capacity, and ultimately to a reduced food security and vegetation cover (Pimentel 2006). The off-site effects involve an increased flood risk and reduced lifetime of reservoirs (Sinha and Joshi 2012). Furthermore, dispersal of polluted sediments and soil organic carbon may cause severe contamination of flood plain sand water bodies (Baroudy and Moghanm 2014), and forms a still poorly

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understood part of the global carbon budget (Kuhn et al. 2009).

Soil erosion has been the hindrance of ecological development in the locality, which has instigated extra care of the India Government and researchers (Sharma 2010; Nagaraju et al. 2011; Nasre et al. 2013; Shit et al. 2015). Awkwardly, consistent or economically feasible means of measuring soil erosion is missing in these areas. There is a growing demand for envisaging yearly soil loss from erosion and portraying the geographical distribution of soil erosion to make available a technical basis for soil management planning (Prasannakumar et al. 2012).

RUSLE is a good tool to estimate soil loss on a cell-by-cell basis (Pandey et al. 2007). Prasannakumar et al. (2012) assessed soil erosion risk based on a simplified version of RUSLE using digital elevation model (DEM) data and soil mapping units. The application of remote sensing (RS) and GIS techniques makes soil erosion estimation and its spatial distribution to be determined with reasonable costs and better accuracy in larger areas (Rahman et al. 2009). The RUSLE model has been integrated with geographic information systems (GIS) to estimate soil erosion because GIS technique not only helps user to manipulate and analyze the spatial data easily but also it helps to identify the spatial locations that are sensitive to soil erosion (Pandey et al. 2007; Sharma 2010; Shit et al. 2015).

The objective of this study is to assess the applicability of GIS based RUSLE model for determination of soil erosion risk zone in lower Subarnarekha River (India) as a case study and discuss measures for soil conservation planning according to their erosion vulnerability in the area.

Material and method

Study area

Subarnarekha river basin is one of the longest flowing inter-state rivers in eastern parts of India, extended 21°30'N to 22°23'N latitude and 86°42'E to 87°30'E longitude (Fig. 1), with an area of approximately 3063.38 km². It is bounded on the north-west by the Chota Nagpur plateau, in the south west by Brahmani basin and in the south-east by the Bay of Bengal. The topography of the study area is characterised by an undulating terrain patterns. Geologically, the region is predominance of igneous and metamorphic rocks since early Paleozoic period (Biswas and Biswas 2015). The middle to lower basin area expressed in a series of residual hills of various origins, escarpments, basins and plateau surface, which actually truncates several geological formations. The main soil types are lateritic and yellow soils (northern part) and coastal soil affected alluvial soil (southern part).

The river in this part including its tributaries runs through the extreme south western part of Paschim Medinipur district of West Bengal and eastern most part of Mayurbhanj and Baleswar district of Orissa. The study area includes the Community Development Blocks (CDB) of Gopiballavpur-I & II, Sankrail, Nayagram, Keshiary and Dantan-I of Paschim Medinipur district, West Bengal and Moroda, Betnoti, and Rasgobindapur; CDB of Mayurbhanj district and Jaleswar, Basta, Bhograi and Baliapal; CDB of Baleswar district of the state of Orissa.

Data used and analysis

The base map was collected from the District land Revenue Office. In the present study Survey of India toposheet were used with a scale of 1:50,000, acquired from Survey of India, Kolkata. A digital elevation model (DEM) was derived from Advanced Space Thermal Emission Radiometer (ASTER). The final DEM was projected into Universal Transverse Mercator (UTM) Projection to overplay other thematic maps. The final DEM map was reclassified into 30 m spatial resolution. Land cover map was derived from Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images having a spatial resolution of 30 m. The satellite was radio metrically and geo-referenced by the imagery providers with a published spatial accuracy of 14 m root-mean-squared error (RMSE) in ERDAS Imagine software v9.0. Supervised classification technique was adopted with maximum likelihood algorithm. The land cover map was used for determining the C-factor and P-factor values. The details of the data are represented in Table 1. A suitable spatial database was created in ArcGIS v10.0 software, providing all soil, elevation, rainfall as well as land-use data, essential for the application of the RUSLE model. Spatial analysis tool was used as a tool to manage data and perform the computations as much as possible in an automated way in order to facilitate repetition of calculation procedures. Calculations were performed on a raster cell basis which has advantages in identifying areas under high erosion risk.

Rainfall erosivity factor (*R*)

R factor is an index of rainfall erosivity, measures the potential ability of the rain to cause erosion. Rainfall data were collected from the Indian Meteorological department (IMD) station, Pune to calculate the rainfall erosivity factor. Rainfall data were collected during the period between 2003 and 2008 from ten IMD stations (Fig. 2). To calculate the R-factor Wischmeier and Smith (1978) and Arnoldus (1980) methods have been followed (Eq. 1):

Fig. 1 Location of the study area (middle and lower part of Subarnarekha river basin)

$$R = \sum_{i=1}^{12} 1.735 \times 10^{[1.5 \log_{10}(p_i^2/p) - 0.08188]}, \quad (1)$$

where, R is the rainfall erosivity factor in $\text{MJ mm ha}^{-1} \text{ h}^{-1} \text{ year}^{-1}$, P_i is the monthly rainfall in mm and P is the annual rainfall in mm.

Topographic factor (LS)

Topographic factors like, slope length (L) and slope steepness (S) was generated in ArcGIS software through Digital Elevation Model (DEM) and ArcGIS Spatial Analyst and Hydrotools extension tools (Moore and Burch 1986).

Table 1 Details of data used in this study

Data type	Source	Year	Spatial resolution	Parameter extracted/purpose
Topographical sheet	Survey of India, Kolkata	1979	Scale = 1:50,000	Base map preparation
Satellite image	LANDSAT ETM+	2008	30 m	Vegetation cover (C factor)
Google Earth image	Google Inc.	2014–2015	0.5 m	Cross check C parameter
Rainfall data	IMD (Pune)	2003–2008	10 meteorological stations	Rainfall erosivity factor (R factor)
Soil map	NBSS & LUP, Kolkata	–	–	Soil texture and K factor
DEM (digital elevation model)	ASTER DEM	–	30 m	Topographic factor (LS)
Field survey	22 soil samples with GPS	2014–2015	–	Field check for verification of land use and land degradation area and C factor

ETM+ enhanced thematic mapper+, IMD Indian meteorological Department, NBSS & LUP National Bureau of Soil Science Land Use Planning, ASTER DEM Advanced Space Thermal Emission Radiometer Digital Elevation Model

Fig. 2 Temporal rainfall distribution pattern of study area

Slope length factor (L)

The L -factor was calculated based on the relationship developed by McCool et al. (1987). The equation follows as:

$$L = \left(\frac{\lambda}{22.13} \right)^m, \quad (2)$$

where, L is the slope length factor; λ is the field slope length (m); m is the dimensionless exponent that depends on slope steepness.

Slope steepness factor (S)

The S -factor was calculated based on the relationship given by McCool et al. (1987) for slope longer than 4 m as:

$$S = 10.8 \sin \theta + 0.03 \quad \text{if } \theta \leq 5^\circ \quad (3.1)$$

$$S = 16.8 \sin \theta - 0.5 \quad \text{if } \theta > 5^\circ \quad (3.2)$$

$$S = 21.91 \sin \theta - 0.96 \quad \text{if } \theta \leq 10^\circ \quad (3.3)$$

where S is the slope steepness factor and θ is the slope angle in degree. The slope steepness factor is dimensionless. LS factor was derived with the help of Arc Info GIS. The spatial distribution of these factors so derived is shown in Fig. 6. Topographic factor was found to be in the range of 0.0–12.0.

Soil erodibility factor (K)

The soil erodibility factor (K) represents both susceptibility of soil erosion and the amount and rate of runoff measured under standard plot condition. Soil erodibility factor (K) in

RUSLE model was estimated by Wischmeier et al. (1971) model. Soil texture is classified based on United States Department of Agriculture (USDA) techniques. Soil maps (Spatial resolution 30 m) were collected from National Bureau of Soil & Land use Planning (NBSS & LUP, Regional Centre Kolkata). A digital database of soil map was generated through heads-up digitizing method and reclassified into 30 m pixel size.

Vegetation cover (C factor)

The cover management factor (C) is a decisive factor to the erosion because it is a willingly managed condition to shrink erosion (Renard et al. 1997; Chatterjee et al. 2013). Soil erosion decreases exponentially with intensification in vegetation cover (Jiang et al. 2015; Shit et al. 2013). Plant cover reduces soil erosion by intercepting raindrops, enhancing infiltration, slowing down the movement of runoff (Wang et al. 2003, 2011). The crop management factor (C) is the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow. In the present study, the factor C was calculated from the predominant crops using the back propagation (BP) neural network (Chen et al. 2008, 2010).

Numerous researchers built up the relationship between vegetation index and the vegetation cover, and obtained satisfied results (Chen et al. 2011a; Dutta et al. 2015; Mokarram et al. 2015). In present work, two vegetation indices and their different combinations were taken as input layer to test the neural network, which were Normalized difference vegetation index (NDVI), soil adjust vegetation index (SAVI).

NDVI is the combination of the highest and minimum absorption and reflectance regions of chlorophyll content. It can, however, saturate in dense vegetation conditions when leaf area index (LAI) becomes high (Rouse et al. 1973).

$$NDVI = \frac{NIR - R}{NIR + R} \quad (4)$$

SAVI suppresses the effects of soil pixels. It uses a canopy background adjustment factor, L , which is a function of vegetation density and often requires prior knowledge of vegetation amounts (Huete 1988). This index is best used in areas with relatively sparse vegetation where soil is visible through the canopy.

$$SAVI = \frac{NIR - R}{NIR + R + L} (1 + L)$$

Finally, the network topology structure is shown in Fig. 3. The number of nodes in hidden layer is six, and the NDVI and SAVI images are taken as the input values, and

Fig. 3 Structure of the BP neural network used for C factor map evaluation (NDVI normalized difference vegetation index, SAVI soil adjust vegetation index)

the C factors of lower Subarnarekha watershed are the output layer. As a consequence of the Stone Weierstrass theorem, all three-layer (one hidden layer) feed-forward neural networks the neurons of which use arbitrary activation functions are capable of approaching any measurable function from one finite dimensional space to any desired degree of accuracy (Homik et al. 1989).

Conservation practice factor (P)

Conservation practice factor (P) is the ratio of soil loss after a specific support practice to the corresponding soil loss after up and down cultivation. The P value will be obtained from the standard table proposed by USDA-SCS (1972), and Rao (1981). The lower the P value, the more effective the conservation practices. The values for P-factor were assigned to be 0.28 for area under paddy cultivation and 1.0 for other area (Table 2).

Table 2 Crop management factor for different land use/land cover classes

Land use/land cover	P-factor
Water body	0.28
Waste land with/without scrub	0.33
Dense forest	0.004
Degraded forest	0.008
Open forest	0.008
Settlement	1.0
Paddy/crop cultivated	0.28
Agricultural fallow	0.18

Source: USDA-SCS (1972), Rao (1981)

Model description

A static prescriptive model—RUSLE—was adopted to evaluate soil erosion, as it is one of the smallest amount data challenging erosion models and it has been useful extensively at different scales. RUSLE model stated as a function of six erosion factors followed by Renard et al. (1997) (Eq. 5)

$$A = R * K * L * S * C * P, \quad (5)$$

where A is the gross amount of soil erosion in cell i ($t \text{ ha}^{-1} \text{ year}^{-1}$); R is the rainfall erosivity factor ($\text{MJ mm ha}^{-1} \text{ h}^{-1} \text{ year}^{-1}$); K_i is the soil erodibility factor in cell i ($\text{MT ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1}$); LS_i is the slope steepness and length factor for cell i (dimensionless); C_i is the cover management factor i (dimensionless) and P_i is the supporting practice factor for cell i (dimensionless). RUSLE model is applied in GIS in order to provide spatial distribution of soil erosion and identify the areas particularly affected by erosion risk. The proposed methodology of soil erosion model is shown in Fig. 4.

Result and discussion

RUSLE factors

R factor signifies the erosivity happening from rainfall and runoff at a particular location (Pan and Wen 2014; Chen et al. 2011b). The estimated R factor is portrayed in Fig. 5b. The rainfall erosivity factors (R) for the years 2003–2008 were observed to be in the range of $78.7\text{--}608.6 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ year}^{-1}$, respectively. The average R factor was observed to be $316.8 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ year}^{-1}$. The spatial distribution of

R factor has been obtained using Ordinary Kriging interpolation method in ArcGIS software. In the study area, maximum rainfall was recorded in the eastern part and minimum rainfall was recorded in the north-west corner.

The P factor is the proportion of soil erosion with a particular sustenance practice to the equivalent loss with upslope and down slope tillage (Van der Knijff et al. 2000). Figure 5c represented the LULC characteristics of the study area. The study area has been categorized into ten LULC classes, namely dense forest, mixed forest, degraded forest, land under miscellaneous tree crop, fallow land, crop land, agricultural fallow, sandy area and moist land. Most of the area in the study site covered with the crop land. Forest areas (e.g., dense, degraded and mixed forest) were covered in the eastern part of the study site. Very less percent of area were enclosed by fallow land in the study area and sandy areas were found on the river bed. P-factor map was prepared from land use/cover map, using the values represented in Table 2.

Figure 5d shows the digitized soil map of the Subarnarekha lower catchment. Details such as fraction of sand, silt, clay and organic matter and other related parameter information for different mapping units were taken from NBSS & LUP for Subarnarekha sub-catchment. The corresponding K values for the soil types were identified from the soil erodibility monograph (USDA 1978). Fine-loamy, coarse-loamy, fine and coarse-loamy texture having a higher value of K is more vulnerable to erosion (Baroudy and Moghanm 2014; Biswas and Pani 2015). Soil with loose texture along with low organic matter is highly susceptible to erosion. The soil of the study area is characterized by Alfisols (coastal alluvium, coastal sands), ultisols (laterite), entisols (older alluvium, red gravelly) and aridisols (saline). Most of the central and northern part covered with older alluvial soil. Coastal alluvium and

Fig. 4 Assessment of soil erosion model

Fig. 5 Spatial distribution of the soil erosion factors, **a** DEM, **b** R-factor, **c** land use/land cover, **d** soil type, **e** C factor and **f** topographical factor (LS factor)

coastal sands were found in the southern part of the study site. Western part and small pockets of north-east of the study area were enveloped by the laterite soils. In the north-west, very small percent area covered with red gravelly soil. Soil erodibility factor vacillated from 0.23 to 0.37. Alluvial soils utilized in cultivated production have greater erodibility values. They are denoted by reference groups of ultisol and entisol. The clay cover favours moderate leaching and infiltration process and is associated with high soil loss from the surface (Brady and Weil 2012).

The C factor is employed to imitate the consequence of harvesting and management practices on soil loss in cultivated lands and the possessions of vegetation covers on dropping the soil loss in forested regions (Renard et al. 1991, 1997). C factor estimated from land use characteristics that are persistent for comparatively large areas, and do not sufficiently replicate the dissimilarity in vegetation that exists within large geographic areas (Wang et al. 2007; Alexakis et al. 2013; Pan and Wen 2014). Inaccuracies in image classification are also presented in the C-factor map (Alejandro and Omasa 2007). Therefore, in this study, the factor C was estimated from the principal crops using the back proliferation neural network (Chen et al. 2008, 2010). The estimated C factor is represented in Fig. 5e. The small patches of higher value (>8.0) were recorded in western and southern part of the study site. The lower value of C (<3.0) were recorded in the central and northern corner of the study area. The geographical distribution of the RMSE indicates that comparatively higher values can be noted in areas of bare soils, while low values are perceived in vegetated areas. However, the average RMSE for the entire image is <0.05 , thus it can be presumed that the designated end-members were valid and adequate. The correlation coefficient (r) between the fields estimated vegetation cover and the BP neural network is ($r = 0.921$, $P < 0.005$). The C factor map obtained using the BP neural network is illustrated in Fig. 6.

For LS calculations, the slope length and slope steepness can be used (Chen et al. 2011b). The percent of slope was determined from ASTER DEM, while a grid size of 30 m was used as field slope length (λ). The DEM map shown maximum elevation in the western part of basin area; while the eastern part is comprises of low elevation and slope (Fig. 5a). Length factor (L) and the steepness factor (S) were derived from the DEM. LS factor is intended by multiplying the L and S factors together (Desmet and Govers 1996). The map acquired displayed that LS values are directly connected with the topography. LS values were greater in the mountains area than other place in lower basin of Subarnarekha (Fig. 5f). LS have a range between 0.25 and 34.3 (5f). The eastern and southern part covered with the less LS value, whereas north-west corner enveloped with maximum LS value.

Fig. 6 Field measured C factor versus BP neural network-derived C factor

RUSLE factors of the lower basin of Subarnarekha were denoted by raster layers in the ArcGIS software v9.0. All these raster layers were integrated together to assess the average soil loss using spatial analyst tool. The estimated outcome of this analysis was then categorized into five erosion classes: very low ($<5 \text{ ton ha}^{-1} \text{ year}^{-1}$), low ($5\text{--}10 \text{ ton ha}^{-1} \text{ year}^{-1}$), moderate ($10\text{--}20 \text{ ton ha}^{-1} \text{ year}^{-1}$), severe ($20\text{--}30 \text{ ton ha}^{-1} \text{ year}^{-1}$) and very severe ($>30 \text{ ton ha}^{-1} \text{ year}^{-1}$). In the soil erosion map of the study area (Fig. 7), very severe erosion of soil loss was portrayed in the eastern part of the study area. Severe erosion were found in the south, and some small pockets in northern and central part of the lower basin, while very low erosion were observed in the western part of the study site.

Concerning soil loss per year on a mass basis approximately 40 % of the total soil loss originates from severe and very severe erosion category. Therefore, importance must be given to defense of forest and afforestation of fallow lands to lessen erosivity effects on soil loss. Remaining 20.77 % of the total soil loss originates from moderate erosion rate category, while around 38.90 % of total soil loss derives from very low and low erosion rate categories. Lower part of the basin area is located in uniform plains, where the soil loss by water is not vigorous, but maximum percentage of these areas is situated in areas with severe erosion potential, where the unsuitable agriculture practices or crop rotation consequence in accelerated soil erosion.

Assessment of soil erosion risk zone and management strategies

Soil erosion susceptibility map of the study area is illustrated in Fig. 7. The index value of proneness ranges from less than 5 to more than $30 \text{ ton ha}^{-1} \text{ year}^{-1}$. Based on the

Fig. 7 Soil loss in the study area evaluated by the RUSLE method **Table 3** Block wise soil erosion risk of the lower basin of Subarnarekha river

Block	Total area (km ²)	Very low		Low		Moderate		Severe		Very severe	
		km ²	%	km ²	%	km ²	%	km ²	%	km ²	%
Gopiballavpur-I	275.83	74.61	27.05	61.01	22.12	47.72	17.30	56.68	20.55	35.80	12.98
Gopiballavpur-II	192.17	55.29	28.77	22.39	11.65	48.73	25.36	30.75	16.00	35.01	18.22
Nayagram	501.44	100.54	20.05	61.18	12.20	184.98	36.89	71.56	14.27	83.19	16.59
Sankrail	276.80	65.19	23.55	24.50	8.85	42.74	15.44	63.17	22.82	81.21	29.34
Keshiary	292.09	61.02	20.89	21.79	7.46	30.82	10.55	77.26	26.45	101.21	34.65
Dantan-I	257.05	31.15	12.12	26.06	10.14	54.55	21.22	66.09	25.71	79.20	30.81
Muruda	143.91	35.47	24.65	25.41	17.66	21.07	14.64	33.56	23.32	28.39	19.73
Betnoti	204.00	66.50	32.60	30.80	15.10	35.86	17.58	43.00	21.08	27.83	13.64
Rasgobindapur	126.53	57.89	45.75	13.26	10.48	15.53	12.27	16.98	13.42	22.88	18.08
Jaleswar	219.12	39.92	18.22	27.74	12.66	21.43	9.78	62.34	28.45	67.69	30.89
Basta	204.81	55.24	26.97	17.86	8.72	21.24	10.37	87.15	42.55	23.33	11.39
Baliapal	156.41	79.97	51.13	32.20	20.59	29.22	18.68	8.16	5.22	6.85	4.38
Bhograi	213.22	74.18	34.79	30.45	14.28	82.49	38.69	18.98	8.90	7.12	3.34
Total	3063.38	796.97	26.02	394.66	12.88	636.37	20.77	635.67	20.75	599.71	19.58

erosion intensity, the study area has been divided into five categories: very low (less than 5 ton ha⁻¹ year⁻¹), low (5–10 ton ha⁻¹ year⁻¹), moderate (10–20 ton ha⁻¹ year⁻¹), high (20–30 ton ha⁻¹ year⁻¹) and very high (more than 30 ton ha⁻¹ year⁻¹). The result presented in Table 3 showed that about 26.2 % (796.97 km²) of the study was classified as very low potential erosion, 12.88 % (394.66 km²) as low

potential, 20.77 % (636.37 km²) as moderate potential, 20.75 % (635.67 km²) as high potential and 19.58 % (599.71 km²) very high potential soil erosion proneness zone.

Block wise soil loss was estimated in the lower basin of Subarnarekha river (Table 3). The highest volume of very severe soil loss was observed in Keshiary > Dantan-I >

Table 4 Soil erosion vulnerability zone and soil conservation priority (modified shit et al. 2015)

Erosion Risk Zone	Range of erosion ($\text{t ha}^{-1} \text{ year}^{-1}$)	Block	Soil conservation priorities
Very low	<5	Baliapal, Rasgobindapur	Much less priority for soil conservation. Planning should be taken for restoring degraded vegetation and restoration
Low	5–10	Betnoti	Less propriety for soil conservation. Proper land-use planning is needed such as suitable cropping pattern for agricultural land
Moderate	10–20	Gopiballavpur-II, Nayagram, Bhograi	Medium priority for soil conservation. Strictly maintain suitable cropping pattern and crop rotation practice
Severe	20–30	Basta, Muruda, Gopiballavpur-I	High priority for soil conservation. Community based soil erosion management program should be introduced and lower cost erosion control techniques should be applied
Very severe	>30	Jaleswar, Dantan-I, Keshiary, Sankrail	Special soil and water conservation measure required. To control and protect areas from severe soil erosion, preference should be given to agronomic measures of soil conservation, such as conservation tillage, in conservation planning

Jaleswar > Sankrail. The lowest extent of very severe soil loss was perceived in Bhograi < Baliapal < Basta < Gopiballavpur-I < Betnoti. The maximum volume of severe soil loss was found in Basta (42.55 %) and the minimum volume was documented in Baliapal (5.22 %). The highest amount of moderate soil loss estimated blocks were Bhograi > Nayagram > Gopiballavpur-II, while the lowest volume estimated blocks were Jaleswar < Basta < Keshiary. Very low amount of soil loss estimated block were Dantan-I < Jaleswar < Nayagram in the lower basin of Subarnarekha. However, the overall very severe soil loss estimated as 599.71 km² (19.58 %) and 26.02 % (796.97 km²) was documented as low soil estimation. In the study area, the moderate and severe soil loss were calculated as 636.37 km² (20.77 %) and 635.67 km² (20.75 %) respectively.

The outcome of the study designates the priority areas where various soil conservation measures should be implemented. Actually, most property-owners have numerous smaller not contiguous farms which typically do not have uniform shape. Farmers in this region habitually put on traditional tillage practices because of lesser operational costs and it is not predictable they will move to management tillage in the future. Table 4 is representing the general soil erosion management strategies of the study area. Therefore, information derived in this study essential to practice prudently used for local level soil preservation planning. The location of each sample site was recorded through Global Positioning System (GPS) and also investigates to understand the soil erosion processes and management practices with discuss the local farmers (Fig. 8).

Conclusion

The globally used RUSLE model was adopted under a lower basin of Subarnarekha river as simulating the existing data with remote sensing images in a GIS. Approximately 40 % of the river basin was observed to be under severe and very severe erosion rates, while about 38.9 % of the basin is very low to low prone to erosion risk. The lower basin is relatively big and characterized by spatial heterogeneity of erosion factors. In these regards, the usefulness of RUSLE model together with geospatial technology is of ample significance for a primary mapping of soil erosion rate. With a strong correlation of 0.921, the technique deals a consistent assessment of the C factor on a pixel-by-pixel basis, which is valuable for spatial modeling of soil loss through the RUSLE model. Using the BP neural network, the values of C factor can be simply assessed by satellite data with its geographical distribution.

Soil erosion is major problem in lower basin of Subarnarekha for several decades. Present study delivers methodologies for gathering representative data required for the RUSLE and determines its expediency for envisaging soil loss and soil management planning. The fore told extent of soil loss and its geographical allocation can deliver a basis for wide spread conservation and ecological land use for the basin. The areas with very severe and severe soil erosion permit distinctive precedence for the execution of control. Methodology followed in this study would aid enrich fragmentation of erosion patches, and finally lessening or resolve the soil erosion problem. Conversely, a more precise on ground data could be

Fig. 8 Soil erosion and conservation process at Sankril block and Gopiballavpur block **a** lateritic bare soil surface erosion prone area, **b** lateritic soil (Murom) excavation due to human activities, **c** soil samples, **d** discuss the soil erosion process and conservation techniques with local people, **f** plantation of soil conservation wing, Department of Agriculture, Government of West Bengal, **g** gully erosion and **h** rill erosion process

prerequisite in comprehensive studies directing at the assessment of dissimilar extenuation measures and assessment of various management circumstances under concrete and upcoming land use and predictable climate change.

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