Estimation of soil erosion in the Balason River Basin using RUSLE modelling of the Darjeeling Himalayan region, India

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Research Article

Keywords: Soil erosion, GIS, RUSLE, Balason River Basin

Posted Date: June 24th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1766179/v1

Abstract

Globally soil erosion is a frequent concern for the environment, which has an adverse effect on the agricultural outputs as well as the economy. The physical set-up and the development of different land-use practices across the watershed with time have a greater effect on soil degradation. The study has been conducted with employing the RUSLE (Revised Universal Soil Loss Equation) modelling in the Balason River Basin (BRB) (basin area: 367.42 km^2) of the Darjeeling Himalayan region to predict the actual or predicted and potential soil loss with the incorporation of remote sensing (RS) and GIS techniques. The input factors were the rainfall erosivity (R factor), soil erodibility (K factor), slope length and steepness (LS factor), cover and management (c factor), and support practice (P factor). The study depicted the region into five predicted and potential in both soil erosion-wise categorized. The outcome of the work reflects that the actual soil loss in the BRB ranges from 0 to 1054.41 t ha^{-1} $year^{-1}$, while the potential soil loss varies from 0 to 6125.56 t ha^{-1} $year^{-1}$. In the study area, the central and northernmost portions are in the extremely very high potential soil loss zone, while the lower course of this watershed is in the low anticipated soil loss zone. It also proposed scientific soil conservation practices, which are mainly required for the areas with high soil erosion rate. The study will be immensely beneficial in identifying areas of high soil erosion risk, where the government must speed effective preservation procedures.

1. Introduction

Soil erosion occurs when water or wind breaks up soil particles and transports them to a new location. Soil erosion has become a global concern due to both intended and unintended on the economy and society. The land use and land cover processes are gradually degraded as a consequence of soil erosion. Understanding the relationships between LULC, topographical aspects of the landscape, and land use management is critical for applying optimization techniques for effectively reducing soil erosion. Soil erosion's potential as a severe danger to soil sustainability has been recognized in recent decades (Khademalrasoul and Amerikhah 2020). As a result, understanding soil management scenarios and implementing practical conservation strategies can help to protect the soil from erosive forces. However, being the most common kind of soil degradation, soil erosion pretends a constant threat to the soil and degrades its quality. All around the world, the soil is the primary source of production. As a result, evaluating various effective soil erosion factors is critical to selecting and implementing the optimal management techniques.

However, as a predetermined outcome in soil erosion elements, vegetation cover can conserve soil against erosive agents and control soil deterioration (Duchemin and Hogue 2009; Wang et al. 2016). Human involvement, such as constructional activities, land use changes, deforestation, and farming practices, speeds up the rate of soil deterioration. Water erosion affects 1094 million hectares of land worldwide, with 751 million hectares severely damaged, and the world's rivers are expected to transfer 15e30 billion tonnes of silt into the ocean each year (Walling and Webb 1996, Lal 2003). In India, approximately 91 percent of the entire geographical area is subject to possible soil deterioration rates ranging from 5 to 40 tones ha/year, so there is a huge need to adopt a variety of conservation strategies to avoid soil erosion (Sharda et al. 2013). Even if slow and gradual geologic erosion is required for pedogenesis and fast soil erosion should be avoided to avoid negative repercussions for soil fertility, soil quality, and agricultural production (Blanco-Canqui and Lal 2008).

A variety of soil deterioration and sediment transport models have been created to estimate soil loss and sedimentation at various scales (Lorup and Styczen 1990; Avwunudiogba and Hudson 2014). However, a number of factors impact which model is optimal, including the intended goal, catchment characteristics, and input data availability, among others (Ranzi et al. 2012). Due to their simple and resilient model structure and integration with GIS, USLE and RUSLE have gained incredible global acceptance for predicting soil loss at diverse geographical scales (Mallick et al. 2014). Because of its versatility and data availability, RUSLE, designed for land use management by the agriculture department in the US, is widely utilized (Renard et al. 1997, Alewell et al. 2019). The RUSLE model has five input components: R, K, LS, C, and P. The C-factor depicts the influence of vegetation and soil cover among these five input elements (Karaburun 2010). Human activities have a significant impact on the C-factor, which is calculated as the proportion of harvested land soil degradation to the resulting loss from farmed land in the barren environment (Das et al. 2018). The R stands for rainfall erosivity factors, and soil erosion patterns are varied from one place to another because of rainfall erosivity factors variation as it is the primary determinant of vegetation cover (Talchabhadel et al. 2020). Whereas the letter K stands for soil erodibility factors, LS stands for slope angle and angle of inclination. Factors and the letter P stand for the factor of conservational works. The RUSLE model is a versatile tool for management that may be applied at multiple scales, including landscape and watershed. According to the researchers, is it the RUSLE model can anticipate the map about the spatial pattern of erosion and soil loss when paired with a geographical information system (GIS) (Amsalu and Mengaw 2014). As a result, using the GIS technique, this model can be used by managers to build practical conservational strategies for soil loss mapping. The RUSLE model can also be used to detect areas at soil erosion threat and offer spatial distributions of soil loss in various locations within eroding areas (Ashiagbor et al. 2013).

The BRB is very much susceptible to soil erosion. Several works were previously done to intend to show the amount of soil loss in the region, viz., De (1998), Lama (2003), Tamang (2013). De (1998) quantitatively assesses the soil erosion rate of the BRB. Using rainfall, soil, and topographic factor, the highest potential soil loss of the BRB is observed > 8000 t ha^{-1} $year^{-1}$, mainly in the hilly central part. The highest predicted or actual soil loss of the BRB using rainfall, soil, topographic, and biological factors found > 1000 t ha^{-1} $year^{-1}$. Another author Lama (2003), has a detailed analysis on the different aspects of soil erosion in the BRB through the USLE method. The study computed the maximum potential soil loss in the hilly areas around Ambotia is > 10000 t ha^{-1} $year^{-1}$, while the predicted soil loss is > 1000 t ha^{-1} $year^{-1}$. Tamang (2003) focuses on the causes of bank failure of BRB, mainly in the plain areas. The studies also suggest proper land use planning and conservational measures to mitigate the issues related to soil erosion.

The primary goal of this research is to apply the RUSLE model to estimate the actual or predicted and potential soil loss in order to better understand the regional distribution of soil runoff in the area under study.

2. Materials And Methods

2.1. Description and location of the study area

The Balason River is one of the important tributary of the Mahananda River in the Darjeeling Himalayan region. The river originated from Lepchajagat in Ghum-Simana ridge and merges with the Mahananda River near Naukaghat in the Jalpaiguri district. It extends between the latitude $26^{0}41'15''$N to $27^{0}01'00''$N and longitude $88^{0}07'00''$E to $88^{0}17'30''$E (Fig. 1). The total length of the river is about 48.40 km (24.27 km in hills and 24.13 km in plains), with covering basin area 367.42 km^2. Geologically, the basin comprises five geological formations, including Darjeeling gneiss, Daling series, Damuda series, lower Siwalik deposits, and recent alluvium deposits, which stretches from north to south. The basin elevation ranges from 112 to 2610 m. Tamang (2013), based on topographical variations, divided the basin into three geomorphic units: rugged middle and upper hill tract (above 800 m), dissected foothill (400–800 m), and southern alluvial fan region (120 to 400 m). Here annual rainfall varies from 2000–5000 mm, and on average, the amount of rainfall is 3359 mm. The four seasons, i.e., winter (December-March), hot weather (April-May), rainy (June-September), and transitional (October-November), have prevailed in the season. In the lower part, a long hot, and humid summer season has been observed (Lama 2003). According to NBSS and LUP, the basin is covered with five groups of soils, i.e., W002, W003, W004, W006, and W009 (Fig. 2). The soil group W002 is the coarse loamy type soil of the Eastern Himalayan hills and side slopes region; whereas, W003 is the fine loamy soil and W004 is the loamy skeletal soil in this region. The soil groups W006 and W009 are both coarse loamy type soil of the Indo-Gangetic alluvial plain region. W002 soil is associated with a strong erosion zone, while W003, W004, and W006 are associated with moderate erosion zone. The BRB has been considered for modelling RUSLE due to: (a) the river basin experiences very intensive and high amount of rainfall during the monsoon time for the South West Monsoon prevailing over the region, (b) the physical set-up of the basin is accelerating to susceptible to soil erosion, (c) different land-use practices have modified the natural environment and enhances the soil degradation. Figure 3 shows different types of soil erosion in the BRB.

2.2. Data collections

The study included using a variety of spatial datasets gathered from various governmental agencies. Table 1 depicts the datasets used for the assessment of soil erosion with their sources.

Table 1
Datasets used for the assessment of soil erosion, their sources and description

Datasets	Descriptions	Sources
Rainfall	Gridded rainfall (0.25 x 0.25) NetCDF File	India Meteorological Department (IMD)
Soil	Digitized from vector layer and converted into raster data with 30m*30m cell size	NBSS & LUP, Indian Council of Agricultural Research, India https://www.nbsslup.in/
DEM	ASTER DEM (30m*30m)	USGS https://earthexplorer.usgs.gov
LULC	Landsat 8 OLI/TIRS, 30m*30m	USGS https://earthexplorer.usgs.gov

2.3. Methods

RUSLE model is an analytical erosion model for calculating estimated mean soil degradation over time (A) due to variety of factors such as runoff, cropping factor, non-cropping region, topographic condition of any region, and soil quality. Here, The RUSLE model was implemented in the GIS platform in this circumstance. To estimate the yearly soil loss of the BRB, the RUSLE model is expressed by an equation (Wischmeier and Smith 1978; Renard et al.1997) as follows:

$$A = [R]*[K]*[LS]*[C]*[P] \quad (1)$$

where, A is considered as average annual soil loss (t ha^{-1} year$^{-1)}$, R represents the rainfall erosivity factors (MJ mm ha^{-1}h^{-1}year^{-1}), K represents soil erodibility factors (t ha^{-1}h^{-1} MJ mm), LS represents slope length and slope steepness factors (dimensionless), C represents cover management factor (dimensionless), P represents conservation practice factor (dimensionless). The flowchart in Fig. 4 depicts the process used to assess RUSLE using a geoinformatics technique.

2.4. Determination of RUSLE parameters

2.4.1. R factor

The factor of rainfall erosivity (R) indicates the influence of torrential rainfall on soil erosion of the region. It specifies the erosivity of rainfall at a certain place depending on its volume and intensity. The influence of raindrops on the substrate must be determined by rainfall erosivity. Furthermore, the R factor describes the relationship between runoff and rainfall of the study area. It expressed in unit as MJ mm ha-1 h-1 (Wischmeier and Smith, 1978). R factor is based on the storm energy (E) of times by the highest half-hour intensity (I30); following such a storm, rill erosion and sedimentation may occur, demonstrating the impact of a significant storm characteristic on soil loss (Renard et al. 1997). In this river basin, to estimate annual soil loss, we use annual rainfall data for not having half-hourly information. One rainfall period was selected for the computation of yearly rainfall erosivity: 2011–2020. The rainfall data has been collected from IMD for different stations. Finally, the IDW Interpolation technique has been adopted for preparing rainfall erosivity map in ArcGIS software. Referenced provides the integrated equation for generating the r factor (Choudhury and Nayak 2003).

$$R = 79 + 0.363 * Xa \quad (2)$$

where, R depicts rainfall erosivity factor, Xa depicts mean yearly rainfall in mm.

2.4.2. K factor

Here, the RUSLE K factor is entirely dependent on the characteristics of the soil. K factor is a metric that measures the susceptibility of ground material to degradation, sediment transportability, and the magnetute and peak doscharge for a given precipitation input under typical conditions. The K factor is an analytical measure of soil erodibility as influenced by inherent soil characteristics (Fu et al. 2006). In a plot of clean bare soil with a 9 percent slope and a length of 22 metres, the K factor is the quantity of soil loss per unit of erosive energy of rainfall (Brady and Weil 2012).

The K factor is calculated based on soil textural information. Soil data was produced using state-level maps given by the NBSS and LUP, the regional centre in Kolkata. The types and textures of the soil have been categorized using the USDA's classification system. Using the soil related data of NBSS and LUP, soil types, texture, organic materials, etc., were detected. Furthermore, erodibility of the soil was calculated in this study using K values from several sources.

2.4.3. LS factor

The LS factor is called the 'gradient factor'. It represents the integrated influence of slope steepness and slope length on soil loss measures. The more steep and longer slopes generate maximum overland flow velocities. Hence the rate of runoff is also higher, which makes a higher potential for soil loss (Haan et al. 1994). LS factor is also a dimensionless factor which is also known as topographic factor. The Arc- GIS' spatial analyst' tool was used to prepare the LS factor map from the SRTM DEM of 30m spatial resolution. In the present study, the flowing equation has been used to estimate the LS factor (Moore and Burch 1986).

$$LS = \left(FlowAccumulation * \frac{cellsize}{22.13}\right)^{0.4} * \left(\frac{\sin[slopegrid * 0.01745]}{0} 0.0896\right)^{1.4} * 1.4 \quad (3)$$

where, LS describes the slope length and steepness component combined, $FlowAccumulation$ describes for a specific cell, the total upslope contributing area, cell size is the size of the grid cell (in the present study area, cell size is 30*30).

2.4.4. C factor

The C factor is the ratio of land degradation from a cropped land in a certain condition to soil loss in a continuous tilled fallow on the same soil and slope. It is mainly dependent on land use (Pandey et al. 2007). After topography, vegetation cover is the second significant element for determining the risk of soil loss. Rainfall is intercepted, infiltration is increased, and rainfall energy is reduced by the ground cover. In this region, land uses are the predominant practices observed in the last fifty years compared to farming. Hence, the C factor was typically weighted dependent on the quick evaluation of vegetation cover rather than a detailed analysis of agricultural cropping patterns.

In the study, the LULC map was prepared to obtain the C factor map. Firstly, Landsat 8 satellite image has been collected from USGS, and then five types of LULC classes (Table 2) are identified by using maximum likelihood classification in ArcGIS software. For each LULC type, the C factor value was assigned based on different literatures (Pandey et al. 2007; Prasannakumar et al. 2012; Panagos 2015; Koirala et al. 2019). Higher value has been attributed to LULC classes that is related to being very vulnerable to soil loss and vice versa. The highest value is 1, and the lowest value is 0.

Table 2
C factor value of different LULC categories of the Balason River Basin

LULC categories	C factor values
Vegetations	0.03
Build-up area	0.00
River	0.00
Baren land	0.18
Agricultural land	0.21

2.4.5. P factor

The amounts of soil loss according to diverse ploughed areas is indicated by the support practise factor. Contours, cropping, and terrace are some of the tactics used, and they are all essential factors in erosion management (Koirala et al. 2019). The coefficient of P factor is the ratio of soil loss to the type of soil cultivation when topographic features are taken into account (Renard et al. 1997). It varies from 0 to 1, with 0 indicating an excellent anthropic erosion resistance facility and 1 indicating a non-anthropic erosion resistance facility (Table 3).

Table 3
P factor values for slope as per agricultural practice

Slope (in percentage)	Contouring
0–7	0.55
7-11.3	0.6
11.3–17.6	0.8
17.6–26.8	0.9
26.8>	1.0

3. Results And Discussion

3.1. Spatial pattern of soil erosion factors

The selected soil erosion factors for the RUSLE model have been mapping using the GIS platform. The detailed description of these factors is described below:

3.1.1. R factor

In the BRB, the rainfall erosivity or R factor ranges from 870.30 to 892.77 (Fig. 5). The research adopted rainfall data from IMD data to calculate the average yearly rainfall during a 10-year period (2011–2020). High erosivity is linked to high erosion susceptibility due to high precipitation rates. The entire watershed receives high annual rainfall, which leads to huge soil erosion. The high value of the R factor shows in the lower part of the basin, and the lower value shows in the upper part. Mainly, the northern segments of the basin is covered by mountainous region (Himalayan mountains), which is the main responsible for extreme soil erosion due to the turbulent stream flow that has been observed in this area. But despite being a plain region, there can be found moderate to low soil erosion due to the high amount of annual rainfall in the lower part of the watershed.

3.1.2. K factor

A higher value of 0.31 on the K factor map of the basin indicates that it is more prone to erosion (Fig. 6). In the BRB, this portion of the area is covered by coarse loamy, or loamy skeletal type of soil, which is associated with severe erosion as this type of soil with a gravelly loamy surface is found on steep side slopes as well as low organic matter. Along with a steep slide of the slope, the area also falls under high drainage density. Fine loamy coarse loamy is found in the central part of the watershed, which is also a more erosible region. Instead, the hilly region, the study area heaving plain area, which is mostly associated with moderate to low erosion.

3.1.3. LS factor

The map of the LS factor (Fig. 7) has been used to understand that the higher the LS value, the more likely it is to erode. This factor is basically related to the topographic condition of any region. As the watershed is situated in the Himalayan range, nautically heaving undulation types of landscape. The majority of the basin's territory is characterized by a steep slope or a high LS factor, which facilitates high to moderate soil loss. The LS factor values have been categorized into five categories viz. very low (0-1.95), low (1.95–4.92), moderate (4.92–7.18), high (7.18–9.60), very high (9.60-19.19). Most of the regions of the watershed fall under moderate to very high regions due to the presence of high elevation and steep slopes. In southern portion indicates lower value as it is covered by plain area.

3.1.4. C factor

In the BRB, six categories of land use land cover are identified from the Landsat 8 satellite image viz. vegetations, agricultural lands, build-up area, rivers, and sand depositions (Fig. 8). The highest value is given to the fellow land, and agricultural land as these have a crucial role in soil erosion. Similarly, lower value has been put to the build-up areas and water bodies. Built-up sites may minimize erosion by concretizing the soil, but they also increase erosion by changing the soil texture, organic content, and other factors. As in the present study, area build-up is mainly found in the lower part where the elevation and slope both are low; the value has been given 0.00. Along with build-up area and water bodies, vegetation cover is also considered as lower value. The ability of vegetation cover in hilly places to mitigate soil loss. The shallow to medium depth soil is more prone to erosion in mountainous areas.

3.1.5. P factor

The Support practice factor (P) varies between 0.55 to 1, with a greater value indicating the absence of any support practice, resulting in maximal degradation (Fig. 9). The higher value is found in the northern part of the watershed, and the lower value has in the lower part of the watershed.

3.2. Predicted soil loss

This research develops a precise spatial evaluation of the pattern of erosion risk over the BRB using a proposed model RUSLE based approach. Prior studies adopting the GIS-based RUSLE approach to quantify soil erosion have found that the classification of soil erosion zones is largely reliant on the local topographical nature and the acquired erosion rate value (Karydas et al. 2009; Dabral et al. 2008; Prasannakumar et al. 2011).

Figure 10 represents the final output map, which shows the average yearly predicted soil loss in the BRB. Predicted or actual soil loss in this study was estimated by integrating all RUSLE parameters such as $R \times K \times$ LS × C×P. The predicted soil erosion in this region varies from 0 to 1054.41 t ha^{-1} $year^{-1}$, which is basically considered as moderate to extremally very high soil erosion (Pandey et al. 2007). The actual soil loose of the watershed is also categorized into five categories viz., low (0–24.80 t ha-1 year-1), moderate (24.80–115.77 t ha-1 year-1), high (115.77–268.77 t ha-1 year-1), very high (268.77–479.65 t ha-1 year-1), extremely high (479.65–1054.41 t ha-1 year-1). The area-wise distribution has been shown in Table 4 and Fig. 12 (a). The centre region of the basin, which is somewhat extended towards the north, has the largest expected soil loss. During the field investigation and analysis of satellite data, it is overseeded that a large number of landslides are situated in the upper portion, especially in the central part of the watershed among these landslides. Along with this reason, the central part and northern central part of the basin also heaving steep slopes, coarse textual soil, which are also responsible for accelerating deforestation and exceptionally high soil erosion. The very high sensitivity (268.77–479.65 t ha-1 year-1) encroaches the top part of the foothill zone in an east-west direction and encroaches the northern, north-eastern, western, and a small strip in the middle western. High soil erosion zone (115.77–268.77 t ha-1 year-1) can be found in the northern and north-eastern portions of the state, as well as in the southern part of the state, running east-west across the foothills. Very low soil loss zone (0–24.80 t ha-1 year-1) has been identified in a large area (62.47%) in the southern portion of the watershed, varying the foothills, around Longview and Simulbari. Gently sloping slopes with thick vegetation cover result in reduced soil erosion in the lower part of the BRB.

Table 4
Distribution of area of different predicted soil erosion classe

Soil erosion class	**Predicted soil erosion (t ha^{-1} year-^{1})**	**Area (sq.km)**	**Area (in percentage)**
Low	0–24.80	228.98	62.47
Moderate	24.80–115.77	127.49	32.78
High	115.77–268.77	6.28	1.69
Very high	268–479.65	2.87	0.76
Extremely very high	479.65–1054.41	1.80	2.30

3.3. Potential soil loss

The potential loss of soil has occurred from the coupling of physical variables such as climate, soil, and topography without the engagement of the moral dimension or natural vegetative cover (Requier 1978). Hence, the potential soil erosion map depicts projected soil erosion without taking into account cover management and support practice considerations. The potential soil loss in BRB ranges from 0–6125.56 t ha-1 year-1 (Fig. 11). Potential soil loss in this region has been categorized into five categories viz. low (0–408.37 t ha-1 year-1), moderate (408.37–1105.00 t ha-1 year-1), high (1105.00–1777.61 t ha-1 year-1), very high (1777.61–2594.35 t ha-1 year-1), extremely very high (2594.35–6101.54 t ha-1 year-1), as illustrated in Table 5 and Fig. 12 (b). This very high potential erosivity is caused by a number of conditions, including a big gradient, significant rainfall, low organic matter content, and coarse soil texture. The central portion and the northern most portion of the watershed fall under the extremely very high potential soil loss zone for heaving such type of reason. Surrounding all sides of extremely very high zone, high and moderate soil loss zone have been found. Low predicted soil loss zone (0–408.37 t ha-1 year-1) is identified in the lower course of the BRB due to low gradient, fine loamy type of soil, lower intensity of rainfall from the upper portion of the study area.

Table 5
Distribution of area of different potential soil erosion classes

Soil erosion class	Potential soil erosion ($t\ ha^{-1}\ year^{-1}$)	Area (in sq.km)	Area (in percentage)
Low	0–408.37	153.89	41.93
Moderate	408.37–1105.00	77.07	20.99
High	1105.00–1777.61	73.53	20.34
Very high	1777.61–2594.35	45.53	12.04
Extremely very high	2594.35–6101.54	17.40	4.70

4. Proposed Conservation Measures Of Soil Erosion

Soil conservation is the process of preventing the rate of soil erosion due to erosion or diminished productivity misuse and abuse, alkalinity, deterioration of water quality, or other organic soil degradation (Mekonnen et al. 2015). The evaluation of soil conservation facilities is essential in preventing land degradation and ensuring environmental resource security (Navarro-Hevia et al. 2016) and would provide supporting evidence for geographical soil health and soil erosion remediation (Borrelli et al. 2017; Ma et al. 2020).

Soil conservation measures are aimed with the goal of keeping soil erosion to a minimum limit. A maximum allowable annual loss of 1.3 kg.m2 is widely recognized, while amounts as minimal as 0.2 to 0.5 kg.m2 are occasionally proposed for a sensitive area (Hudson 1971). The BRB land degradation evaluation shows that the soil seems to be very vulnerable to erosion. When external conditions are favourable, extremely high rates of land degradation or soil erosion occur. The varying degrees of soil erosion in the basin have been grouped into five categories based on this soil loss tolerance limit, and relevant mitigation strategies have been provided for each classification. In Table 6, a detailed description of the several soil conservations measures has been demonstrated. The proper and scientific soil conservation practices are mainly required for the areas with high and very high soil erosion classes (i.e., Class-IV and Class-V), while minimum conservation measures are needed for low and medium soil erosion classes (i.e., Class-I and Class-II).

Table 6
Proposal of different conservation measures of soil erosion of the Balason River Basin based on Dey (1998) and Lama (2003

Major soil erosion class	Rate or soil erosion (t ha^{-1} $year^{-1}$)	Level of conservation measures	Proposed conservation measures
Class-I	< 7	Negligible	In this soil erosion class, minimum or no needs of proper conservation measures, but crop managements like cover crop, crop rotation, and strip cropping is recommended for some exceptional areas.
Class-II	7-100	Moderate	In this soil erosion class moderate conservation practices are required like cover crops, diversion channel, bench terracing, application of mulching organic matter.
Class-III	100–750	High	In high soil erosion zone immediate conservation measures are required. Hence, application of cover crop, bench terracing, storm water removal system, slop stabilization is recommended.
Class-IV	750–1500	Very high	In this category, soil conservation practices are need to preciously applicable. The recommended practices are plantation of fast-growing plants, mulching, bench terracing, geo-wire, proper water ways, stabilization of slope.
Class-V	> 1500	Immediate	In exceptional high soil erosion zone, there need to adopt some immediate action plans. Agricultural and deforestation are need to prohibited in this zone. Along with, the region should be kept under natural cover.

5. Conclusions

Land degradation is a global problem in the current situation that has a significant impact on agricultural regions. RUSLE model was used to calculate the yearly soil erosion rate and actual soil erosion potential of the BRB utilizing databases available in the GIS platform. Rainfall erosivity, soil erodibility, topography, cover, and support practices are the five elements that influence land degradation by water. The outcomes of the study show that different land use practices across the watershed have a major impact on soil loss. Natural forest cover, for example, had negligible soil losses, but regions with high levels of human interference had substantial erosion and sedimentation. The results also reveal that a landscape with a lot of precipitation and steep terrain can cause soil erosion, which makes the soil more vulnerable to degradation. The entire river basin is suffering moderate to very high soil loss. The outcome result of predicted soil loss of the watershed has been found 0–1054.41 t ha^{-1} $year^{-1,}$ and potential erosion of soil is also considered, which is ranges 0–6101.54 t ha^{-1} $year^{-1}$.

The BRB is a site that attracts settlement because it is a pristine field of natural resources with scenic beauty and a healthy atmosphere. The loosening of the compactness of the soil in the study area has been attributed to the gradual deterioration of the forest cover along with growing human pressure. The outcome is so negative that Basin's ecological balance has been severely disrupted. The study's significance comes from the ability to provide a spatial variability of soil loss in the BRB that can be used in protection and maintenance management phases at the systemic level by land utilization regulators and strategy.

Declarations

Acknowledgements

The authors would like to express cordial thanks to the Department of Geography and Applied Geography, University of North Bengal, for support in the research. The authors extend sincere thanks to the IMD, NBSS & LUP, and USGS for providing the necessary data. The authors also would like to thank Prof. Deepak Kumar Mandal and Dr. Jayanta Das for their support.

Authors' contributions

Dipesh Roy: Conceptualization, Methodology, Visualization, Data Analysis, Investigation, Validation, Original Draft Preparation, Review and Editing.

Rajib Mitra: Conceptualization, Methodology, Visualization, Data Analysis, Investigation, Validation, Original Draft Preparation, Review and Editing, Project Administration and Supervision.

Availability of data and materials

The data that helps the results of this study are available on various websites. The gridded rainfall (0.25 x 0.25) data was collected from India Meteorological Department (IMD) portal, soil map was used from NBSS & LUP, Indian Council of Agricultural Research portal (https://www.nbsslup.in/), ASTER DEM (30m*30m) and Landsat 8 OLI/TIRS (30m*30m) data were obtained from United States Geological Survey (USGS) portal (https://earthexplorer. usgs.gov).

Competing interests

The authors declare that they have no competing interests.

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Figures

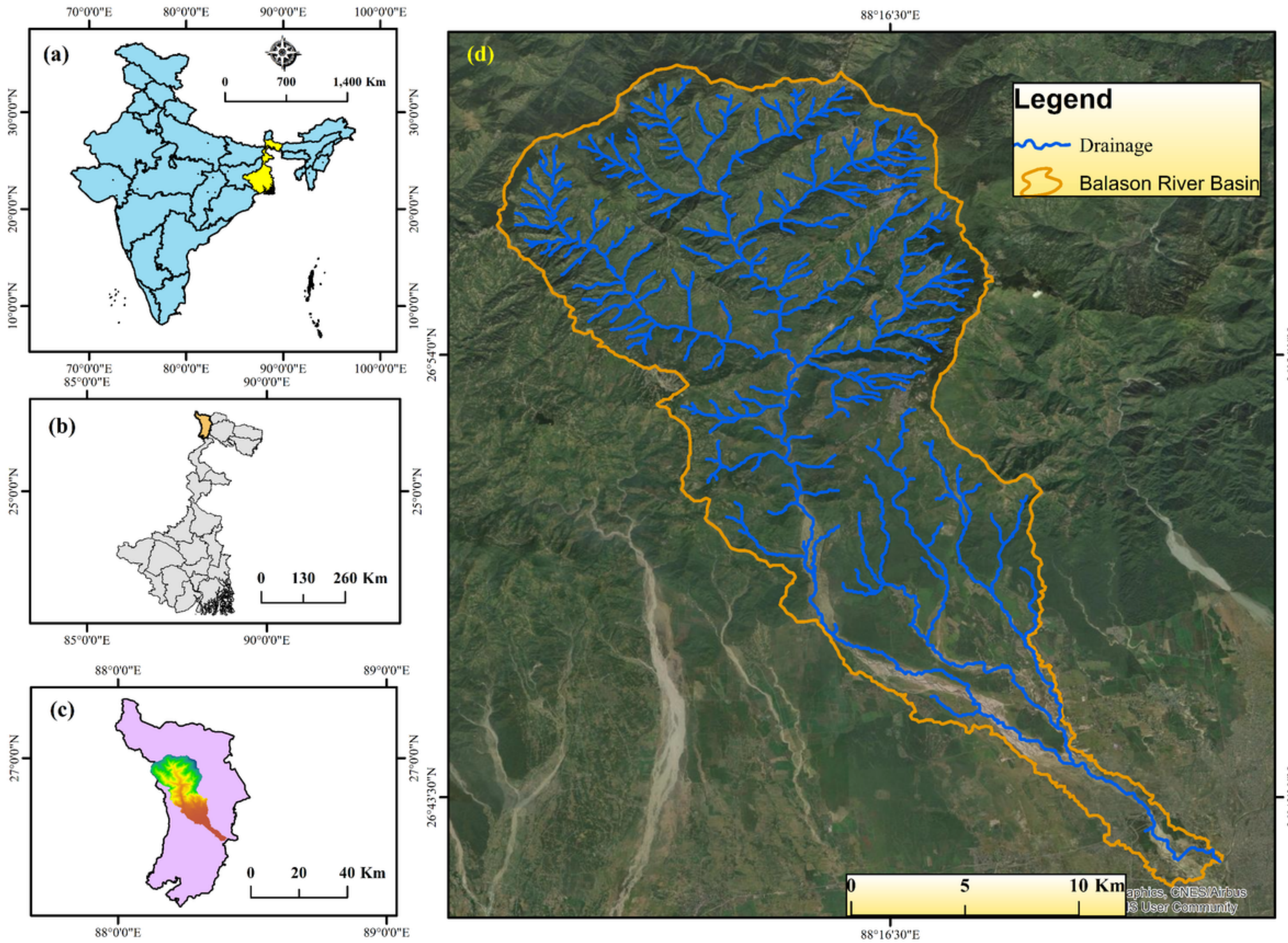

Figure 1

Location map of the study area (a) India, (b) West Bengal, (c) Darjeeling district and (d) Balason River Basin

Figure 2

Soil map of the Balason River Basin

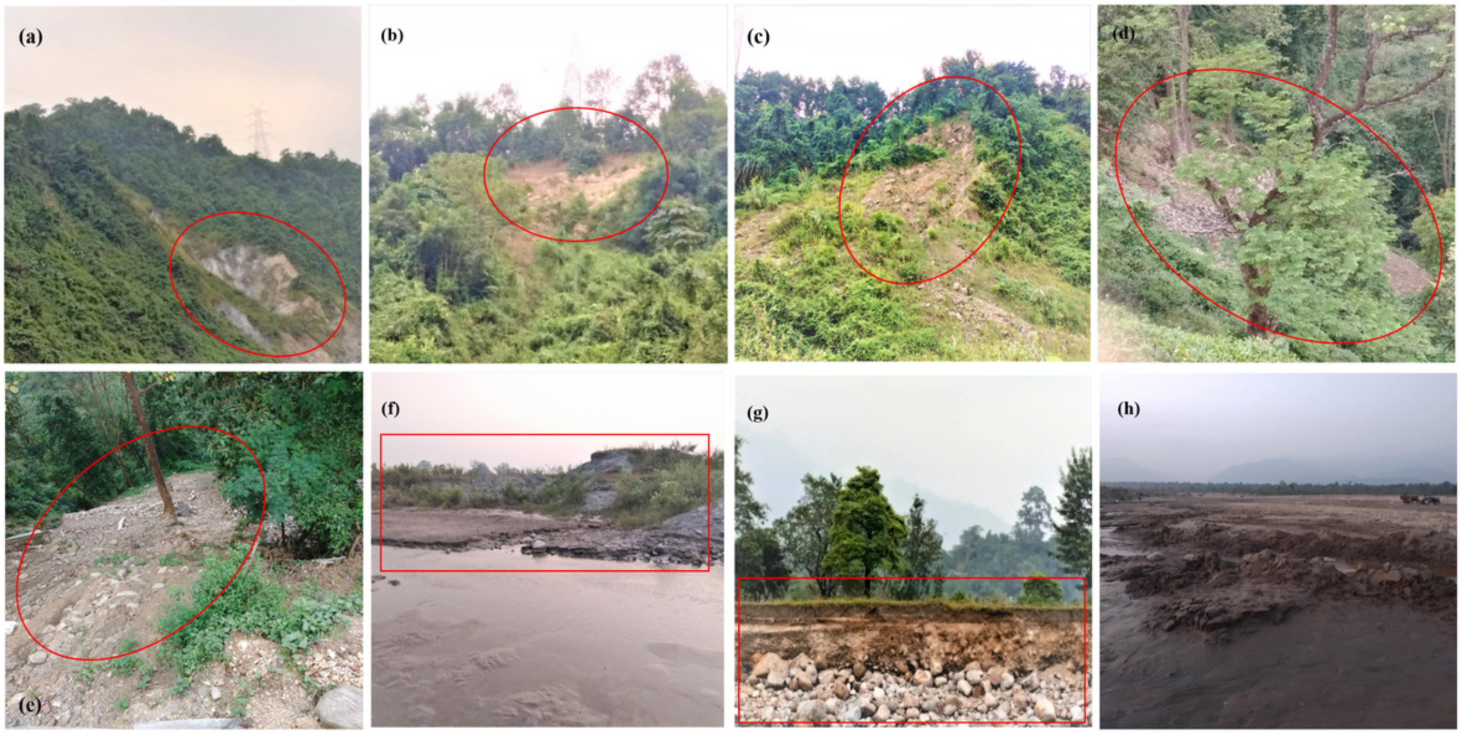

Figure 3

Examples of soil erosion in Balason River Basin (a), (b), (c) landslide erosion, (d), (e) sheet erosion in the hilly areas, (f), (g) bank erosion, and (h) soil erosion due to river bed materials extraction activity in the plain region

Figure 4

Methodological flow chart of the RUSLE model in Balason River Basin

Figure 5

Rainfall erosivity factor (R) map of the Balason River basin

Figure 6

Soil erodibility factor (K) map of the Balason River Basin

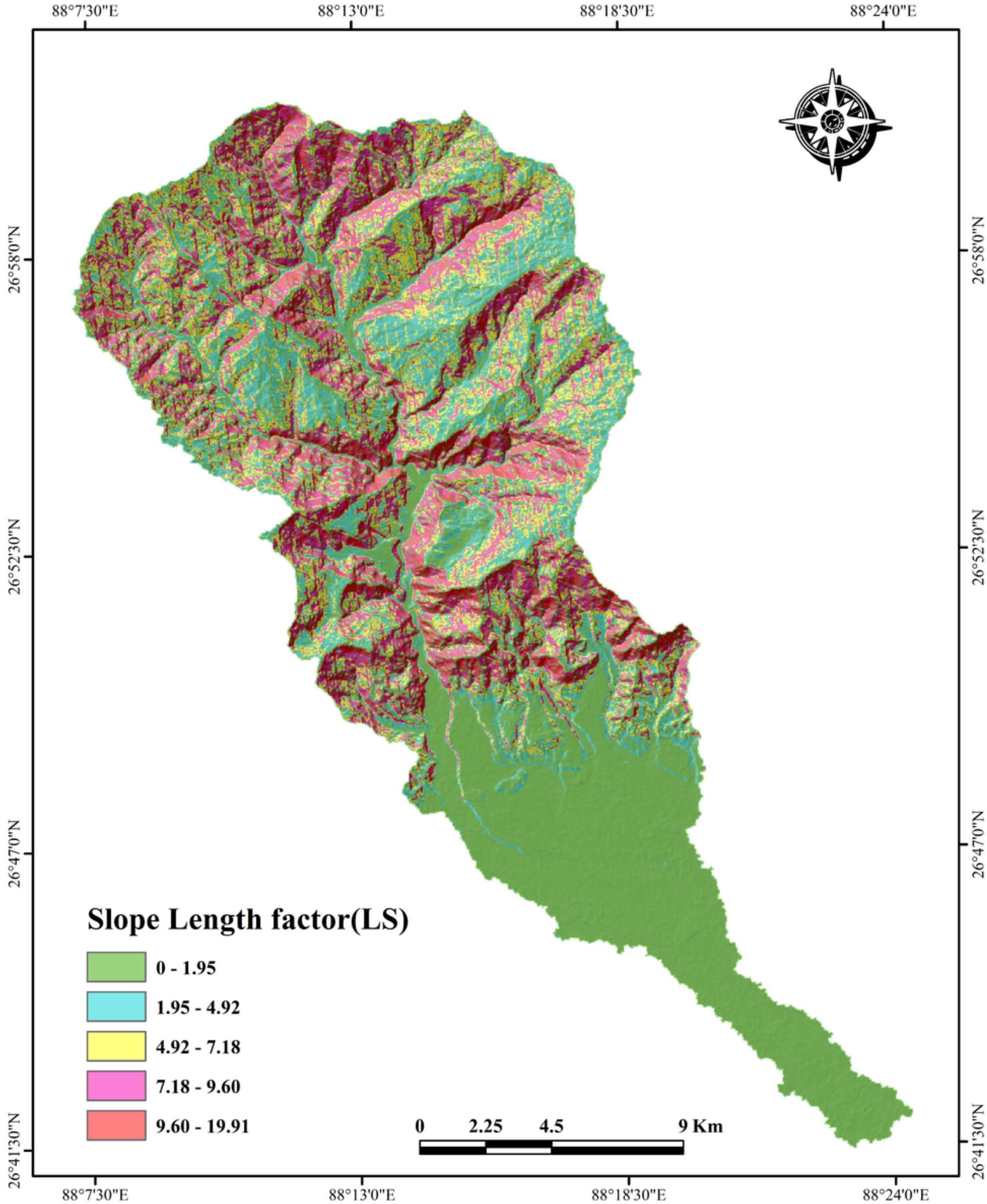

Figure 7

Slope length factor (LS) map of the Balason River Basin

Figure 8

Cover and management factor (C) map of the Balason River Basin

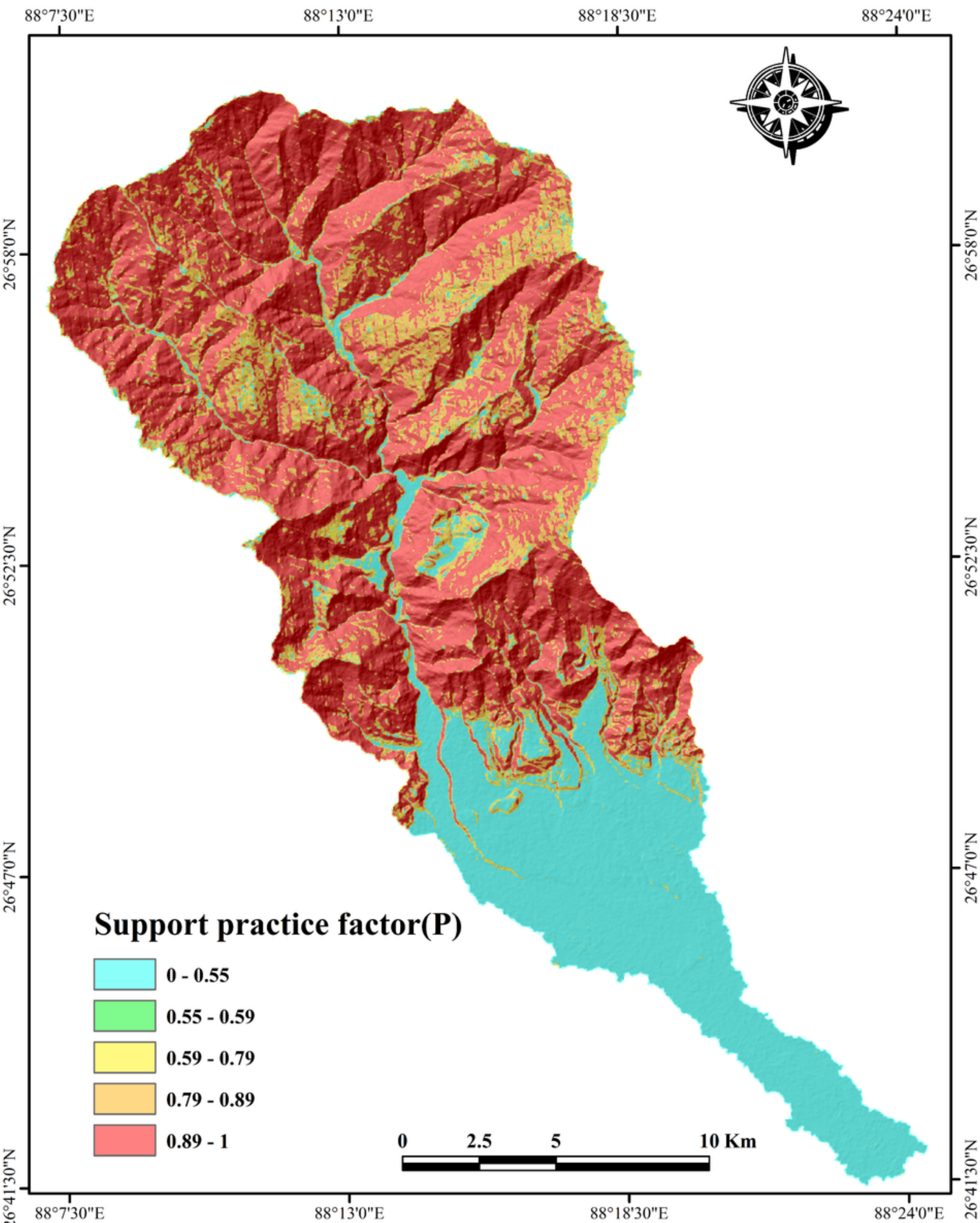

Figure 9

Support practice factor (P) map of the Balason River Basin

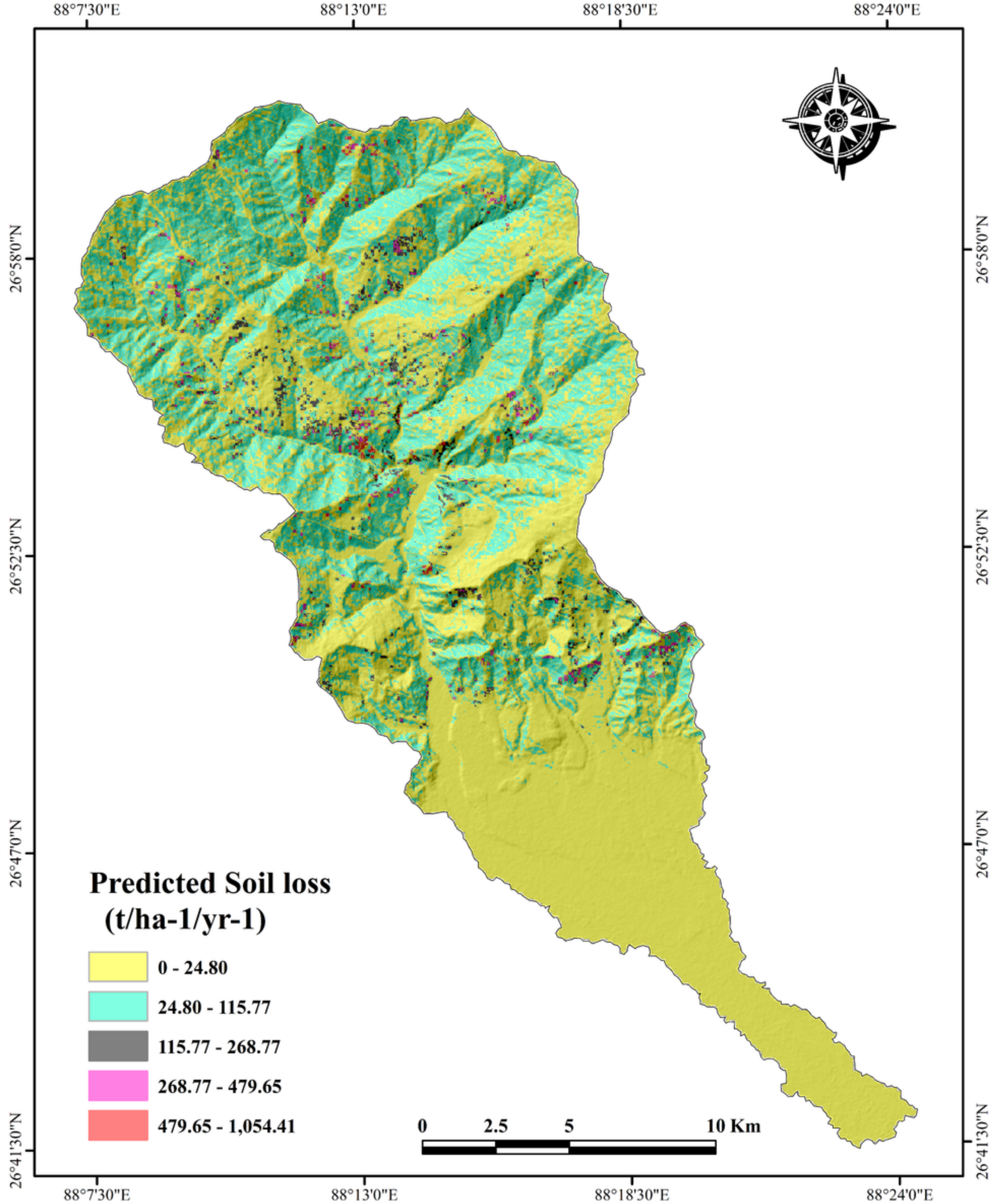

Figure 10

Predicted soil loss map of the Balason River Basin

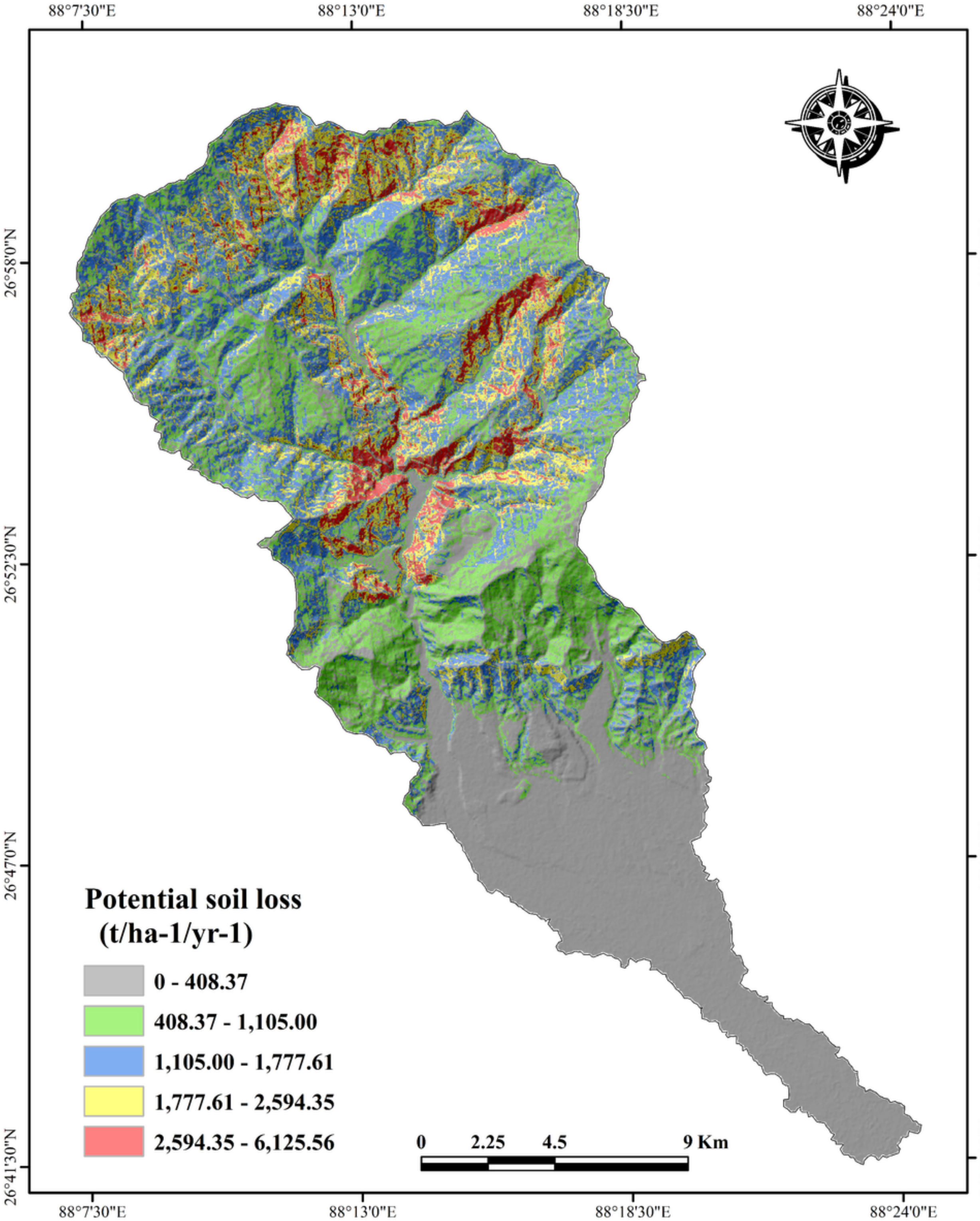

Figure 11

Potential soil loss map of the Balason River Basin

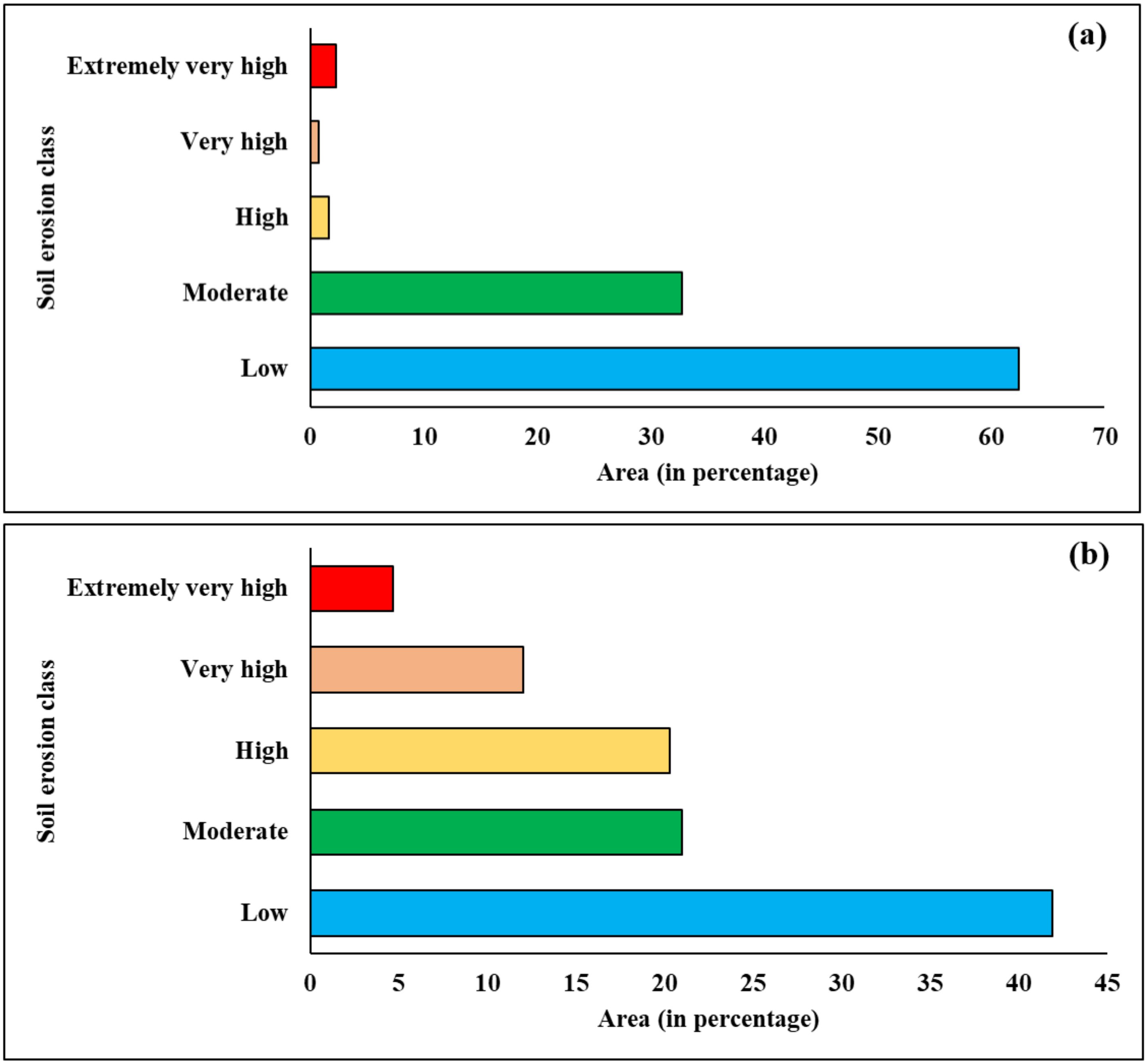

Figure 12

Area-wise distribution of (a) Predicted soil erosion classes and (b) Potential soil erosion classes