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Research Article

Quantifying Soil Erosion in Drought-Impacted Central Odisha, India, through Geospatial Mapping with RUSLE

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Soil degradation in Odisha poses a significant conservation concern for the local environment. The present research focused on a region in central Odisha State, India, affected by drought conditions. Several models have emerged to assess soil loss, with the Revised Universal Soil Loss Equation (RUSLE) standing out as the most suitable option. The erosion computation process entails utilizing the digital elevation model (DEM), Landsat-9 imagery, and soil data from several sources accessible in different forms and scales. The present analysis took into account various elements, namely, crop management factor (C), practice management factor (P), slope length factor (LS), steepness factor of the slope (S), and rainfall factor (R). Multiplying these factors yielded the average rate of soil erosion. Areas with a high slope length factor, such as those in Kandhamal, Kalahandi, and Nuapada, have a high erosion rate. The study reveals that 57% of the land in the study area experiences very low to moderate soil erosion at a rate of 2–10 tons per hectare per year, while 43% faces moderately to very severe erosion at a rate of 10–25 tons per hectare per year. Erosion hotspots, covering 32,205 square kilometers, are mainly identified in agricultural and forested hilly areas where slopes exceed 10°, such as those in Kandhamal, Kalahandi, and Nuapada, which have a high erosion rate. These districts are especially vulnerable to soil loss and resulting climate action (Sustainable Development Goals-13) because of frequent and severe rainfall, shifting agricultural practices, a thin surface soil covering, natural erosion, and barren hills. The research emphasizes the urgent need for implementing conservation and management measures to protect high-risk areas from further degradation. In conclusion, the study underscores the effectiveness of the RUSLE-GIS model in conducting quantitative and spatial assessments of soil erosion on a river watershed scale. The model is deemed crucial in formulating conservation strategies to address the identified erosion issues in the tropical highlands of the area.

1. Introduction

Decision-makers should better understand the impact of soil erosion because it impedes the achievement of several sustainable development goals (SDG), including SDGs 2 and 15 (sustaining life on land), SDG 11 (achieving sustainable cities and communities), SDG 1 (reducing poverty), and SDG 6 (ensuring safe drinking water and proper sanitation) [1]. The phenomenon of soil erosion caused by water, as emphasized in previous studies [2, 3], is a significant environmental concern leading to land degradation. According to previous studies [4–7], soil erosion has been identified as an essential factor contributing to the loss of rich topsoil and the degradation of farmed land. Moreover, it has been discovered in several research studies [8–10] that the materials transported during erosion could contaminate water bodies located downstream. As cited by the source cited as [11], natural soil erosion encompasses the processes of detachment, transportation, and deposition of soil particles due to gravitational forces, water flow, and wind.

Conversely, as mentioned by the source [12], human activities encompass practices such as intensive farming, inadequate land management, deforestation, and agriculture on steep inclines. The amount of soil loss is influenced by several factors, as indicated by previous studies [13, 14]. These factors encompass rainfall characteristics such as quantity and intensity, anthropogenic activities, soil qualities, and landscape characteristics.

Natural soil erosion occurs when water and wind erode the topmost layer that covers the soil, causing cause damage [15, 16]. Fertile soil is removed, and sediments build up due to this process [17]. The production loss is substantial for the highest portion of the soil, which is both the most fertile and susceptible to erosion. According to recent research, the cycling of both carbon and nutrients impacts how soil is mobilized and deposited [18, 19]. The long-term impact is considered when evaluating soil and field capabilities, and attribute photos are included in possible land-use maps [20–22]. According to RUSLE is widely used globally to assess long-term rates of inter-rill and erosion of rills in field or farm-size units under multiple management schemes. It is highly correlated with site circumstances impacted by management strategies [23, 24]. July through September is when the risk of soil degradation is highest. Using an H-type flume, the average yearly flood level throughout the marsh is determined to be 2.3 cm [25, 26].

Nevertheless, soil erosion is a notable concern that affects various aspects such as recreational activities, water quality, sedimentation in lakes and rivers, farmland, soil fertility, excessive siltation [27–31], and excessive silting [29]. Researchers employ diverse soil erosion methods for calculating soil erosion and watershed sediment outcomes, ranging from simple empirical approaches to more complex physical-based models [32].

The Revised Universal Soil Loss Equation (RUSLE), established by [33], is widely utilized as an empirical method for calculating soil loss, specifically in rill and inter-rill erosion situations. The RUSLE model distinguishes itself from others due to its simplicity, adaptability, cost-effectiveness, and efficiency. As evidenced by previous studies [2, 34], it is possible to obtain all the necessary variables for the Revised Universal Soil Loss Equation (RUSLE) model from a total of four datasets, namely, land use/land cover (lu/lc), slope, soil, and rainfall. Scholars such as [35, 36] have conducted investigations on the integration of RUSLE with geographic information system (GIS) and remote-sensing methodologies. And they have identified that these methodologies are enhacing the precision and accuracy of the soil degrdation assessment.

However, Odisha lacks sufficient recognition of sites that exhibit heightened vulnerability to soil erosion. Researchers such as [37, 38] have shown that many soil erosion models incorporate medium-to-fine resolution remote-sensing data. The importance of geographic information systems (GIS) in the analysis, processing, and mapping of input and output data variables related to the revised universal soil loss equation (RUSLE) has been highlighted in studies undertaken by researchers [35, 39]. The RUSLE technique and the GIS methodology will be used to estimate the quantity of soil loss in Chilika Lake as a study area [40] and the research area as a coastal part of Odisha [7]. The present research is needed as the primary aim of this study is to identify and visually depict the average soil erosion rate in various districts of the Indian state of Odisha. To achieve this objective, the researchers employed the RUSLE model. By individually examining each erosion component, the study enables a thorough assessment of the region's topographical characteristics. Integrating RUSLE with GIS allows the prediction of potential soil erosion patterns in the chosen study area. While this approach is widely adopted globally, its application within the context of Odisha has been limited. The main objectives of the present study are to utilize the RUSLE model, remote-sensing data, and GIS tools to estimate the yearly soil erosion in drought-impacted central Odisha, India. The specific objectives of the present study is to apply the Revised Universal Soil Loss Equation (RUSLE) model and analyze the relevant erosion factors (C, P, L, S, R) to determine the average rate of soil erosion in the specific area of central Odisha (Bolangir, Baragarh, Nuapada, Kalahandi, and Kandhamal), to assess the extent and severity of soil degradation in the specified regions of Odisha, particularly in drought-affected areas, and to provide recommendations for conservation and management measures to mitigate soil erosion in high-risk areas within the study region, emphasizing the importance of addressing this significant environmental issue.

2. Materials and Methods

2.1. Study Area. The Odisha State Disaster Management Authority identified the following districts as drought-affected (Bolangir, Baragarh, Nuapada, Kalahandi, and Kandhamal) in central Odisha, situated along the Mahanadi River. These districts fall within the geographic coordinates of 19°10′04″N to 21°50′00″N latitude and 82°20′00″E to 84°40′00″E longitude (Figure 1), covering a total area of 32328.5 square kilometers. Based on the climate data from NASA's POWER database, the research area is characterized by a subtropical climate, where temperatures range from a maximum of 43°C to a minimum of 5°C. The designated geographic area spans 108 to 1,324 meters above mean sea level. Annual precipitation in this region varies, averaging around 1400 mm, with the highest rainfall typically occurring between June and September. Despite its geographic location and weather patterns, the research site is considered an arid region. The middle Mahanadi River is a prominent feature, traversing a significant portion of the area. Therefore, it becomes imperative to identify areas prone to soil loss and quantify erosion caused by water. Practical conservation efforts necessitate utilizing specialized tools with the Revised Universal Soil Loss Equation (RUSLE) concept. Three primary soil varieties dominate this region: red, gravelly red, and yellow soils. Additionally, one can find loam and laterite soils downstream from the river in the central part of Odisha. Understanding the distribution and characteristics of these soils is crucial for implementing appropriate conservation strategies and land use planning in the areas where geographical regions are feasible. The RUSLE model has been employed in various case research studies

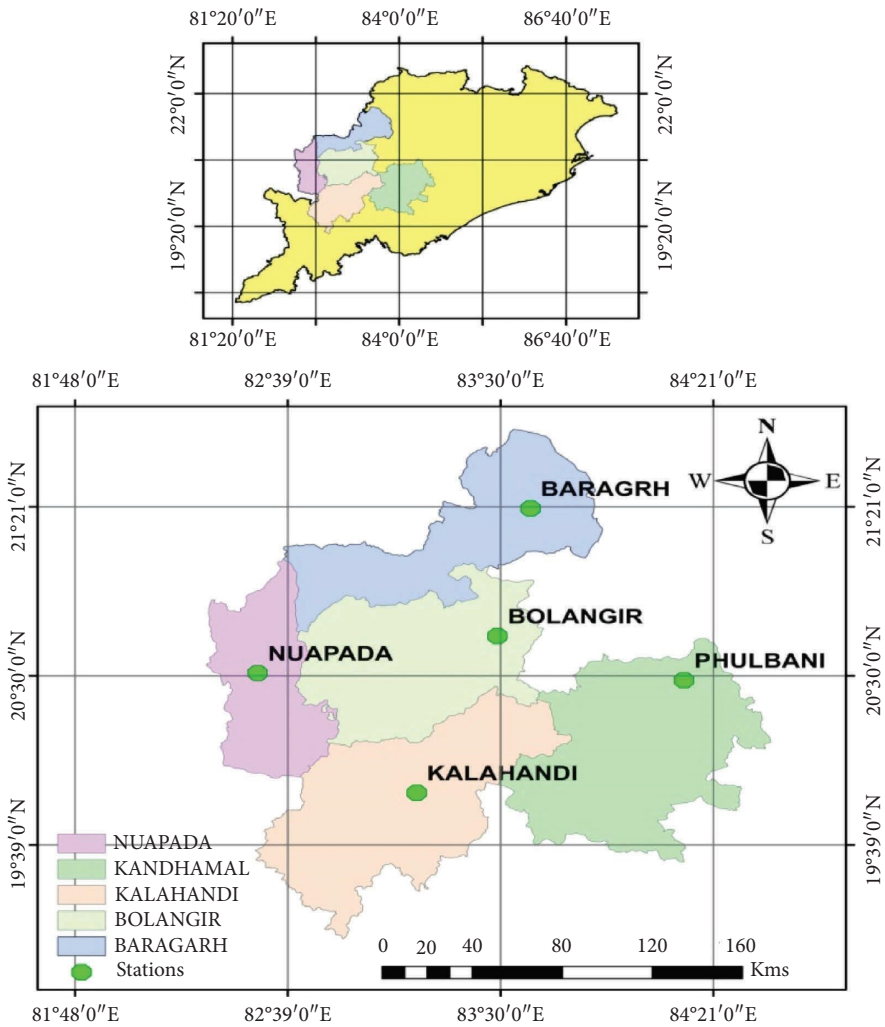

Figure 1: Study area map.

conducted in the region to predict soil erosion. These studies include the Dikrong River Basin Case Study in Ratlam District, central India [41], Arkosa watershed in the West Bengal Bankura District [42], Arunachal Pradesh [43], the Muhuri River Basin [44], the Dahlia River Basin of Tripura [29], the Panchnoi River Basin [45], Sadiya in Assam [46], and the altered land use of Rib hoi district in Meghalaya [47]. Multiple studies [48–50] utilized RUSLE and sedimentation rate estimation models within different Indian watersheds. The authors of [51] focused on enhancing precision in soil erosion estimation by integrating PSInSAR data with RUSLE, presenting a novel model to improve accuracy. The authors of [52] conducted a comprehensive review aimed at enhancing the global applicability and accuracy of the (Revised) Universal Soil Loss Equation (R) USLE for estimating soil loss. Studies by [53, 54] and others concentrate on specific regions, such as diverse agroecological areas, humid Eastern Himalayan watersheds, and plateau fringe regions. They employed RUSLE, GIS, and high-resolution satellite imagery to assess soil erosion dynamics in response to changing land use patterns and diverse climates.

2.2. Data Description and Sources. Figure 2 shows the overall methodology of the present study, and Table 1 displays the different forms of information and satellite images used in the current investigation. The technique involves integrating various thematic layers into a GIS environment, together with a DEM map, LULC map, precipitation map, and soil map.

NASA provided rainfall data from 1990 to 2021 and an accessible map illustrating the rainfall distribution. It is crucial to present the data in an interoperable format, with GeoTIFF being the most widely used option. The rainfall distribution was accurately visualized in ArcGIS using appropriate symbology. The dataset utilized in this study was sourced from the Food and Agriculture Organisation (FAO) soil map dataset, initially created at a scale of 1 : 25,000. Suitable symbology was employed to represent the soil textural classifications in ArcGIS. For the Land Use/Land Cover analysis, in this study, the United States Geological Survey (USGS) used Landsat-9 satellite images for the year 2021. Land use and land cover classes were generated using supervised classification techniques applied to the acquired images.

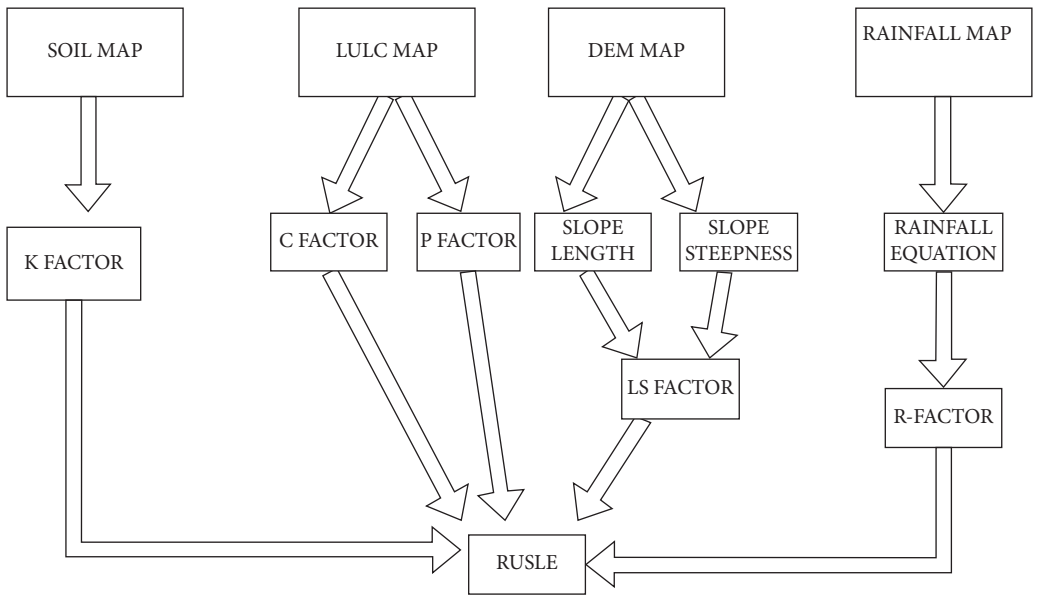

Figure 2: Flowchart for evaluation of soil erosion.

Table 1: Data and its sources.

Input data	Scale	Uses
Rainfall, temp. (Source: POWER NASA)	1990–2021	Rainfall distribution map
Soil data (Source: Food and Agriculture Organisation (FAO))	1 : 25000	Soil textural map
Landsat-9 (Source: United States Geological Survey (USGS), 2021)	30 m spatial resolution	Land use/land cover mapping
DEM (Source: United States Geological Survey (USGS), 2021)	30 m spatial resolution	Slope map and flow accumulation map

Slope maps were derived from USGS digital elevation model (DEM) data, which has a spatial resolution of 30 meters. Slope values were calculated by importing the digital elevation model (DEM) data into ArcGIS and using the "Slope" tool from the Spatial Analyst toolkit. The flow direction characteristics of the flow accumulation layer were also determined using the "Flow Direction" tool in the Spatial Analyst toolbox. The same digital elevation model (DEM) data generated the slope map. The "Flow Accumulation" tool calculates flow accumulation at each pixel.

2.3. Data Analysis for Soil Degradation Modeling

2.3.1. RUSLE Model. In the latter part of 1992, the RUSLE tool was made available for general use. A mathematical model known as the Revised Universal Soil Loss Equation (RUSLE) is well-recognized in soil science and agriculture. USLE (Universal Soil Loss Equation) is an earlier version of the soil loss equation. While RUSLE includes refinements and updates, USLE is still used in some applications. The RUSLE is just one of these methods, and its popularity is due to several reasons. It is relatively user-friendly. It allows for evaluating erosion risk over extensive regions and a comprehensive model that considers factors influencing soil erosion, including rainfall, soil properties, topography, land cover, and management practices. A version of the RUSLE model incorporating various critical elements contributing to erosion within a geographic information system (GIS) is commonly used. This version calculates the mean annual soil loss using the following equation [55–57]:

$$A = R * K * L * S * P * C, \tag{1}$$

where A = mean soil loss annually (Mg ha^{-1}·yr^{-1}), R = erosivity factor due to rainfall (MJmmha^{-1}·h^{-1}·yr^{-1}), K = soil erodibility factor (Mgha^{-1}·MJ^{-1}·mm^{-1}), P = conservation practices factor, C = cover management factor, L = slope length factor, and S = steepness factor' S, C, P, and L parameter have unit less.

2.3.2. Rainfall-Runoff Erosivity Factor (R). The rainfall-runoff erosivity factor (R) measures how likely rain and surface overland flow will disintegrate the surface. It directly forecasts the overland flow rate from that precipitation event [58]. For this investigation, the R factor was estimated using average annual precipitation data for the 21 years from 1990 to 2021. Equation (2) [3, 33] was used to estimate the relationship between yearly precipitation and the R factor.

$$R\left(\frac{\text{MJmm}}{\text{ha}}\frac{\text{hr}}{\text{year}}\right) = 79 + .0.363 * P\,(\text{mm}), \tag{2}$$

where P = mean rainfall annually.

2.3.3. Soil Erodiblity Factor and Soil Soil Erosion (K). The soil erodibility factor (K) is used to quantify soil erosion due to precipitation runoff. Other crucial criteria, such as porosity, organic carbon content, soil moisture levels, and

soil texture, significantly influence this factor. As a result of the combined attributes of these traits, the soil is highly vulnerable to erosion caused by rainwater runoff, making soil erodibility a pivotal element in evaluating and addressing soil erosion. The soil erodibility factor value was derived for this investigation and verified through the results of various soil textures extracted from available research [45, 46]. Equation (3) was utilized for this study to measure the K value.

$$K_{\text{RUSLE}} = f_{c\_\text{sand}} * f_{\text{org}\_c} * f_{\text{cl-si}} * f_{\text{hi\_sand}}, \tag{3}$$

where $f_{\text{c\_sand}}$ = factor for soils with high coarse-sand contents, $f_{\text{cl-si}}$ = factor for soils with high clay-to-silt ratios, $f_{\text{org}-c}$ = factor for soils with high organic carbon content, and $f_{\text{hi\_sand}}$ = factor for soils with extremely high sand contents. If $f_{\text{c\_sand}}$ sand concentration is coarser, then the value of k is more; $f_{\text{cl-si}}$ for more silt clay ratio lowers the soil erodibility factor; $f_{\text{org-c}}$ for more the carbon content in soil lesser k value; and $f_{\text{hi-sand}}$ for lower value of k in soils with exceptionally high sand content. Equations (4)–(7) were used to calculate % of sand, silt, clay, and organic carbon content.

$$f_{c\_\text{sand}} = 0.2 + 0.3\exp\left[-0.256 * m_s\left(\frac{1 - m_{\text{silt}}}{100}\right)\right], \tag{4}$$

$$f_{\text{org}\_c} = 1 - \left[0.0256 * \frac{\text{orgC}}{\text{orgC} + \exp}\,(3.72 - 2.95 * \text{orgC}), \tag{5}$$

$$f_{\text{cl\_si}} = \left(\frac{m_{\text{silt}}}{m_c + m_{\text{silt}}}\right)^{0.3}, \tag{6}$$

$$f_{\text{hi\_sand}} = 1 - \left[0.7\frac{(1 - m_s/100)}{\{(1 - m_s/100) + \exp(-5.51 + 22.9(1 - m_s/100))\}}\right], \tag{7}$$

where m_c is the % of clay (0.002 mm diameter), m_s is the % of sands (0.06–2.00 mm diameter), m_{silt} is the % of silt (0.002–0.06 mm diameter), and org_C is the % of organic carbon.

2.3.4. Slope Length and Slope Steepness (LS-Factor). It is the distance between the site of natural drainage origin and the location downslope where sedimentation starts or runoff becomes marked in a specific path. The term "slope steepness" (S) indicates the slope's inclination angle, expressed in degrees or percentages. Soil erosion is more if the land is steep. Steep slope and slope inclination enhance the risk for soil erosion because they result in greater overland flows, which affect more erosion. The LS factor was calculated [47] by combining equation (8) with DEM (SRTM).

$$LS = \left(\frac{\text{flow accumulation} * \text{cell size}}{22.13}\right)^2 * \left(\frac{\sin(\text{slope} * 3.14/180)}{0.0896}\right)^{1.3}, \tag{8}$$

where pixel size x flow accumulation and Θ = slope angle in %. With the help of the Arc GIS 10.8 model, the [59] formula was adapted to estimate the LS element in this paper by utilizing spatial analysis tools.

2.3.5. Crop Management Factor (C). In this study, the C factor indicates the level of soil protection. A C factor of 0 represents soil that is well protected, while a C factor of 1 indicates soil that is constantly fallow or less protected. The C factor was determined using a Landsat-9 satellite image. The image was obtained from the Earth Explorer website in June 2021 and has a spatial resolution of 30 meters. Clear weather conditions were present when the image was captured. Based on the data obtained from the satellite image, the Normalized Difference Vegetation Index (NDVI) was calculated using the following equation:

$$\text{NDVI} = \frac{\text{band 5} - \text{band 4}}{\text{band 5} + \text{band 4}}. \tag{9}$$

Band 4 covers the visible red zone in Landsat photos, while band 5 reflects the NIR area. NDVI values can vary between −1.0 and +1.0, with higher values denoting green vegetation and lower values indicating bare land or no vegetation. Surface waters are likewise reflected by negative

NDVI values [60, 61]. Equation (10) was used to calculate the C value of the present study.

$$C = 0.431 - 0.805 * \text{NDVI}. \quad (10)$$

2.3.6. Conservation Practice Factor (P). The slope-parallel tillage loss compared to the equivalent loss with a particular agricultural conservation practice is represented through the P factor, and its value lies between 0 and 1, 0, meaning good artificial erosion protection capability, and 1, indicating an absence of such a facility [40]. Because it is impossible to identify any control practices measures, the p factor for the entire region has been considered in the current investigation. P factor values were calculated in vector form based on land use and then transformed to raster form for use with other factors.

3. Results

3.1. Rainfall Erosivity Factor (R). Rainfall data are interpolated through the inverse distance weighted (IDW) technique, giving a significant rather than kriging method. Table 2 shows the study's annual average precipitation and R factor value. The value of the rainfall erosivity index slightly decreases for Kalahandi and Nuapada districts. The R factor ranged between 80.29 and 80.46 MJmm/ha/hr/year. The monsoonal effect is higher in the eastern (Kandhamal, Baragarh, and Bolangir) than in the southwestern (Kalahandi and Nuapada). Figure 3(a) shows a rainfall distribution map, and Figure 3(b) shows rainfall erosivity factor maps of the study area.

3.2. Soil Erodibility Factor (K). From the Food Agricultural Organization (FAO), four types of topsoil were found in the area under study; the proportion of sand, clay, silt, and organic carbon (Figure 4) used in computing the K-factor is given as follows. Results of k ranged from 0.155 to 0.115 t·hr·ha/MJ/mm. A higher value of K represents Hill, and the plain surface indicates the lower value of k. Table 3 shows the soil erodibility factor values, and Table 4 shows the soil structure class of the study area.

3.3. Slope Length and Slope Steepness (LS Factors). It depends on the slope's length and angle of inclination. Different LS factor values are redistributed in the study area depending on regional or microphysiographic differences. The research area's higher regions have the most outstanding value, while the lower and middle zones have moderate to low values. The slope results ranged from 0 to 89°; in Figure 5, mountainous regions, exceptionally slope (≥17°), be identified. The volume and probability of soil loss in the hilly areas and the greater slope and steeper terrain may be amplified.

3.4. Crop Management Factor (C). Six categories of land use/cover within the area also have their soil degradation analyzed. The research area experienced 34% eroding in forests and grasslands, approximately 10% soil loss in hilly forests, 24% soil weathering in hilly farming zones, and almost 23% erosion in terai cropland. The findings also demonstrate how vulnerable soil erosion is, particularly tough and high gradients, minimal vegetative envelopes, and intensive farming methods. In the results, the authors of [62] noted that developed fields experienced higher erosion rates than natural grasslands and forests. C values were allocated using the source [63] as shown in Table 5. The C factor has a range of values from 0 to about 1. Maximum values indicate negligible cover effects, resulting in soil loss comparable to tilled bare fallow conditions, whereas lower values signify a highly effective cover that effectively mitigates erosion. More susceptibility to soil degradation is responsible for a higher c value since those measured to bland are not protected like the hilly site. The c value is low in the region adjoining the river in water. Even inside the jungle, degraded vegetation had greater C values than regions with extensive cover of trees, indicating poor crop management. LULC map (Figure 6) was used to calculate C factor values. Table 5 shows the C factor values.

3.5. Conservation Practice Factor (P). The P values are in the range between 0.55 and 0.9. In the mountainous regions, the terai lands, protected by dense vegetation, created the greatest P values (0.9), whereas grassland and terai-farmed areas produced the lowest (0.55). The intermediate P value (0.8) was observed in hilly agricultural land. Where soil conservation techniques such as terrace, contour, and check dams can be used in irrigated lands, the P value was low. On the other hand, regions without the use of conservation techniques to control runoff flow showed a higher P value. Figure 7 shows the P factor map of the study area.

3.6. Soil Erosion Hotspots. From equation (1), $A = R * K * L * S * P * C$, this five parameter (RUSLE model) was implemented to determine soil_erosion_rate, and its value ranged from less than 2 to 26 tone/ha/yr, highlighted differently below (Figure 8). However, the typical calculated t-value in the Odisha regions of Kandhamala and Kalahandi is 26 tone/ha/yr. To evaluate the significance of soil management, areas in research that experience a rate of soil erosion of more than 10 tons/ha annually were chosen and designated as high erosion hotspots. Thus, hotspots for soil erosion were found in a region of 13848.15 square km (43%), whereas a land area of 18624.86 sq.km (57%) was within the threshold values (Table 6). Hotspots for erosion were primarily found in agricultural and forested hillsides with greater slopes (≥10°).

A different composition surface layer is created by combining all of the preceding levels (Figure 8). Using the composite layer could forecast the mean soil loss annually for the research area. Table 6 shows the different categories of soil erosion. The lowest and highest figures for soil loss are 2 tones/ha/yr and 26 tones/ha/yr, respectively. The largest

Table 2: Annual average precipitation and R factor for the present study.

Station name	Latitude	Longitude	T_{max} (°C)	T_{min} (°C)	Average precipitation mm	Rainfall erosivity factor (R)
Kalahandi	19.91	83.16	31.84	20.53	1295.78	549.37
Bolangir	20.70	83.49	31.73	20.63	1401.78	587.84
Baragarh	21.34	83.62	32.29	20.62	1384.07	581.42
Nuapada	20.72	82.49	31.89	20.23	1313.41	555.77
Kandhamal	20.48	84.23	31.20	20.27	1469.65	612.48

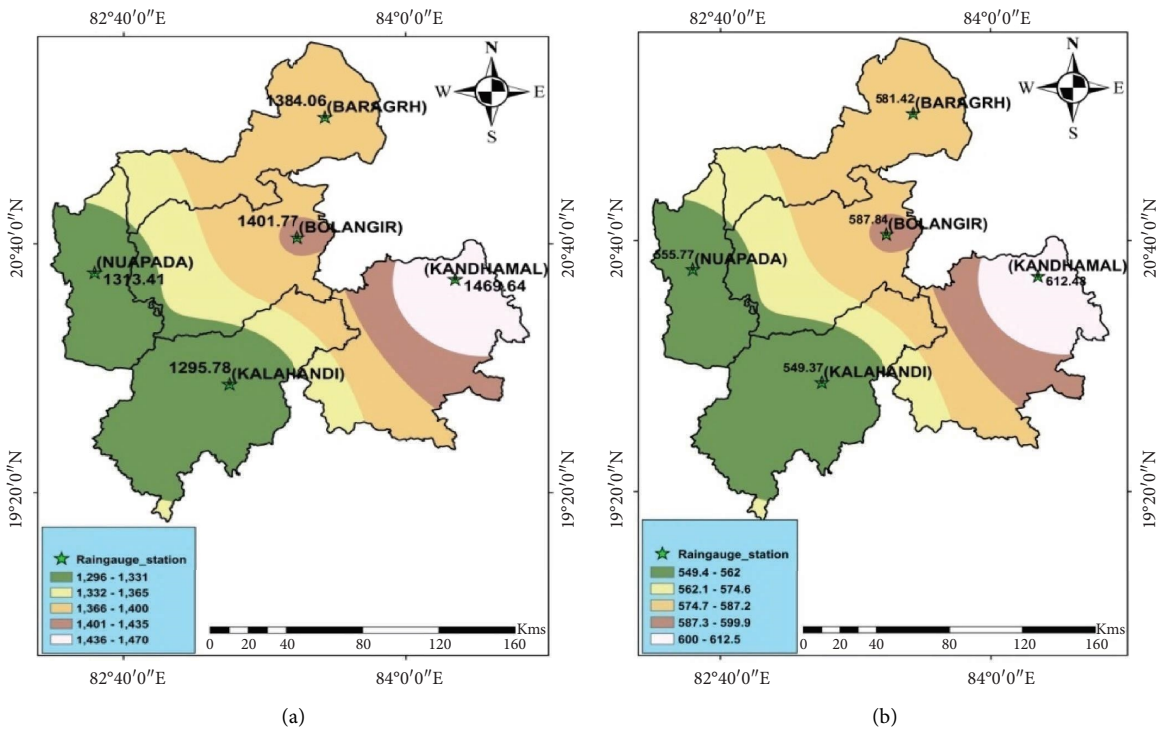

Figure 3: (a) Rainfall distribution map (unit-mm). (b) Rainfall erosivity factor map (unit-MJmm/ha/hr/year).

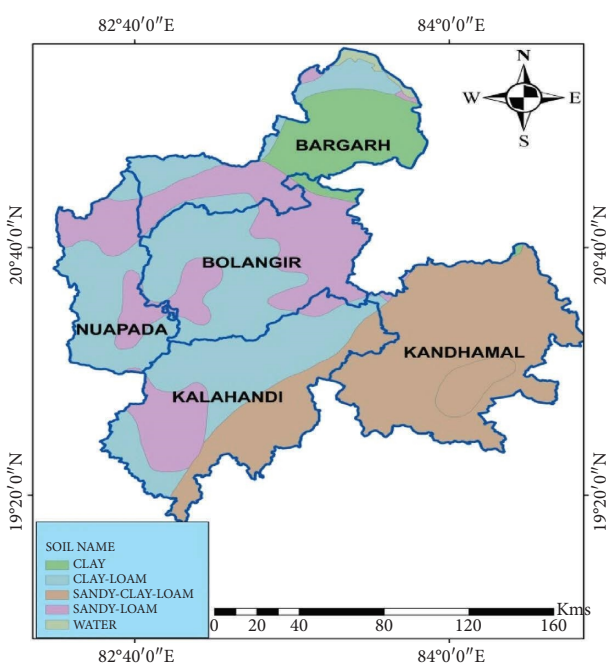

Figure 4: Different soil maps of the research area.

Table 3: Soil erodibility factor for five districts, Odisha.

Texture classes	f_{csand}	f_{cl-si}	f_{org_C}	f_{hi_sand}	K-factor
Sandy-clay-loam	0.201	0.721	0.762	1.00	0.115
Clay-loam	0.203	0.723	0.981	0.981	0.142
Sandy-loam	0.202	0.755	0.992	0.895	0.133
Sandy-clay-loam	0.201	0.723	0.985	0.967	0.147
Clay	0.220	0.712	0.971	1.001	0.155
Water	0.201	0.841	0.864	0.992	0.141

Table 4: Soil structure class of study area.

SNUM	Texture classes	Hydrological soil group	Soil unit symbol	Sand % topsoil	Silt % topsoil	Clay % topsoil	OC % topsoil
3642	Sandy-clay-loam	D	AO	53.6	15.8	30.6	2.25
3770	Clay-loam	C	LC	64.3	12.2	23.5	0.63
3791	Sandy-loam	C	LF	74.6	9.6	15.9	0.39
3830	Sandy-clay-loam	C	NE	68.4	10.5	21.2	0.6
3864	Clay	D	VC	22.4	24.5	53	0.69
6997	Water	D	W	61.4	21.9	16.7	1.25

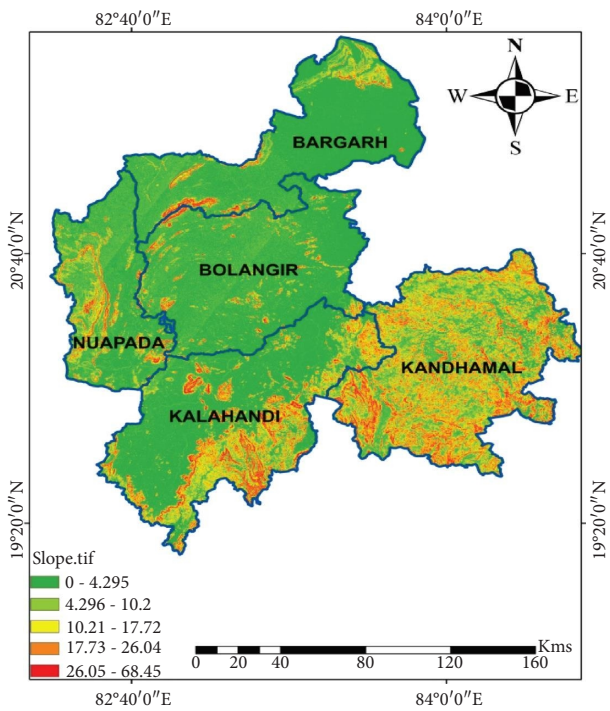

Figure 5: Slope (degree) map of the study area.

Table 5: C value based on LULC.

Type of LULC	C value
Dense forest	0.06
Open/Degraded forest	0.05
Grassland	0.15
Agricultural land	0.094
Water bodies	0
Follow and wasteland	0.638
Built-up area	0.008

soil deficit zone was in the upper areas due to their higher slope and undulation. The factor of land use and coverage is primarily to blame because of this.

4. Discussions

The annual erosion rate varied from less than 2 to 26 tons per hectare. The average rate in regions such as Odisha's Kandhamala and Kalahandi is 26 tons per acre annually. We

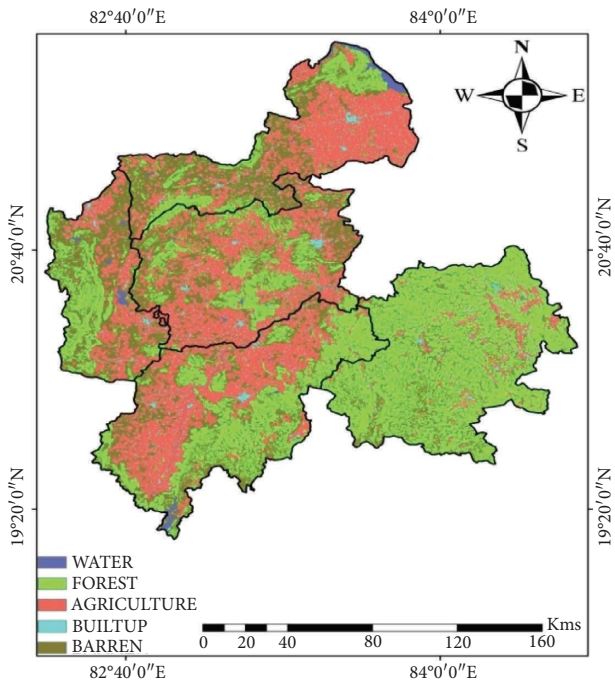

Figure 6: LULC map.

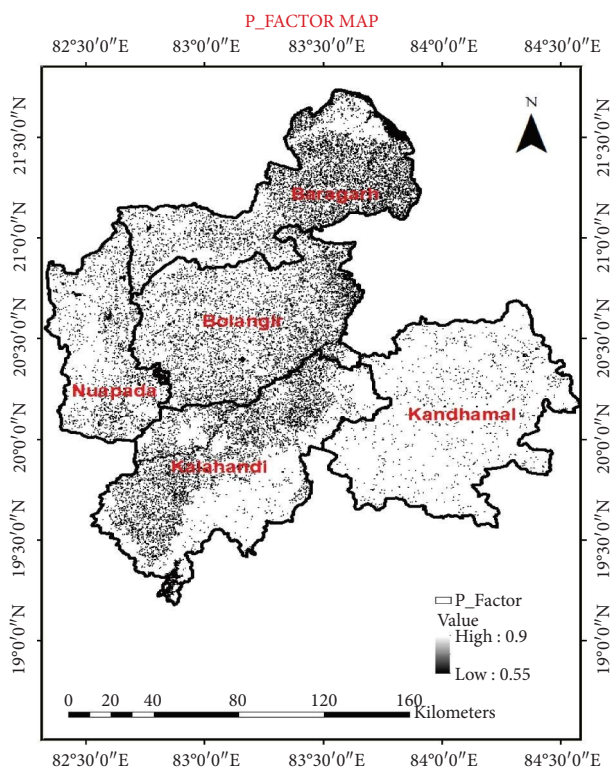

Figure 7: Conservation practice factor for the study area.

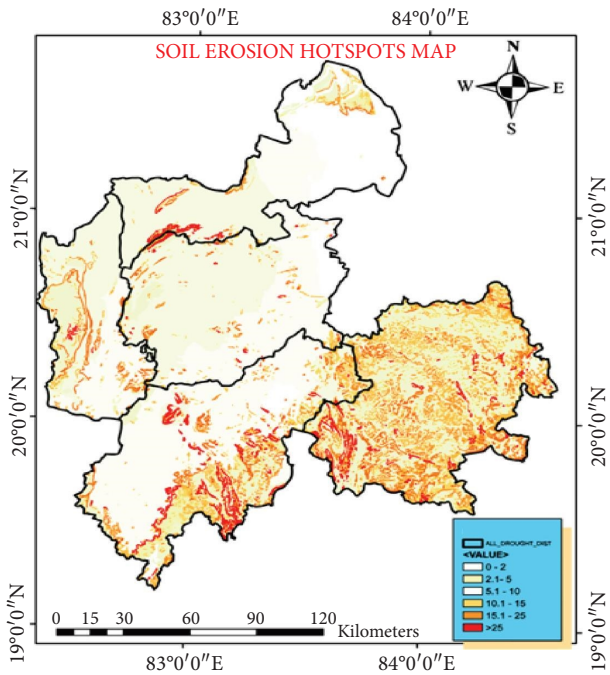

Figure 8: Soil erosion hotspots of the research area.

Table 6: Different categories of soil erosion values.

Soil loss rate ($t \cdot ha^{-1} \cdot yr^{-1}$)	Area (Square_km)	Covered area (%)	Erosion category
<2	10949.7	34	Very low
2–5	3864.6	12	Low
5–10	3542.55	11	Moderate
10–15	2898.45	9	High
15–25	7729.2	24	Severe
>25	3220.5	10	Very severe

referred to these places as high erosion hotspots because we studied locations where soil erosion exceeds 10 tons per hectare annually. These hotspots were found in almost 43% of the territory, or 13,848.15 square km, whereas tolerable values were found in 57% of the area (18,624.86 sq.km). Most hotspots were found on steep slopes (more than or equal to 10 degrees) with forests and agricultural areas. When we merged all the data, we could forecast the average annual soil loss for the entire region. Table 6 lists the various types of soil erosion. Two tons per hectare per year is the lowest, and 26 tons per hectare per year is the greatest. The greatest soil loss was seen in the areas with the steepest slopes, particularly in the upper sections. The primary reason for this is how the land is covered and exploited. In different areas, we have specific plans to control soil erosion based on how severe the erosion is. In places where erosion is "Low," we use methods such as growing special grasses and building structures to prevent erosion. In areas with "Moderate" erosion, we encourage practices like covering the soil with mulch on farms. We have stricter rules for places with "High" erosion, like changing crops on farms and fixing damaged forests to act as natural shields. In the most severe case, the "Very High" erosion zone, we need a comprehensive plan with multiple steps, including changing crops, using mulch, planting more trees, and restoring forests (Table 7). These plans aim to protect the soil, reduce erosion, and promote good land management practices based on the specific erosion risks in each area.

Table 7: Predicted soil erosion and management strategies.

Soil erosion zone	Predicted soil erosion value ($mg \cdot ha^{-1} \cdot y^{-1}$)	Management strategies	
		Nonstructural	Structural
Low	<14	Plantation of soil erosion controlling grasses like fallow and wastelands	Site-specific structures like check dams and gabion structures should be placed in areas with greater slopes
Moderate	14–28	Mulching in the agricultural field	Diversion channels and interception ditches will be constructed in the low-slope areas
High	28–56	Crop rotation in the agricultural field and restoration of degraded forest	
Very high	>56	Crop rotation, mulching, forestation, and restoration of forest	

5. Conclusions

Soil erosion is a big problem worldwide, especially for farmers. This research is crucial because it tells us where soil erosion is happening in the central part of Odisha. Experts and policymakers can use this information to plan how to handle the soil. The study uses RUSLE in ArcGIS to help make these maps. The five things that influence soil erosion by water are the shape of the land, what covers the soil, methods to support the land, how much rain falls, and the type of soil. The area is divided into six risk levels, each with a different priority. Priority 1 is for places with a high risk of losing a lot of soil. There are parts of Odisha's Bargarh and the Bolangir district where soil erosion is less common. There is a range of soil loss susceptibility in Odisha's Kandhamal and certain areas of Kalahandi district, from moderate to extremely high M. About 34% of the land has the least erosion, with rates from 0 to 5 tons per hectare per year. The study shows that 43% of the region needs actions to prevent soil damage. Barren lands lose soil the fastest, followed by farms, shrubs, grasslands, and woods. Places with steep slopes (more than 10 degrees) have the highest erosion rates. Using satellite data and computer analysis, a RUSLE model helps us determine where erosion is likely in a state like Odisha, where we do not have long-term records of erosion risks and slope steepness.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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