



# Assessment of Soil Erosion Using Large-scale Soil Information and GIS in Utkal Coastal Plain, Odisha

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## ABSTRACT

The present study was conducted during 2017–2018 to estimate soil loss in the Utkal coastal plain, Odisha, India using the soil loss model, Universal Soil Loss Equation (USLE) integrated with GIS. A 16-soil series (management units) was established with 30 mapping units. Each mapping unit having different characteristics which are integrated and developed soils erosion maps of the area. The five major input parameters used in the study are rainfall erosivity factor (R), soil erodability factor (K), Length slope factor (LS), vegetation cover factor (C) and erosion control factor (P) were collected during field work and analyzed for estimation. The quantitative soil loss ( $t\ ha^{-1}\ year^{-1}$ ) ranges were estimated and classified the coastal plain into different levels of soil erosion severity map was developed. The annual average R factor ranged from 697.48 to 710.16  $mt\ ha^{-1}\ cm^{-1}$ . The K factor was low in loamy sand and sandy loam texture and poor organic matter soils. Topographic factor increases in a range of 0.1 to 5.0 and flow accumulation also increased. P factor is  $<0.25$  in uplands soils and 0.25–0.5 in low land soils. The study area is classified according to Indian condition into different erosion classes such as ( $>5\ t\ ha^{-1}\ year^{-1}$ ) slight, ( $5-10\ t\ ha^{-1}\ year^{-1}$ ) moderate, ( $10-15\ t\ ha^{-1}\ year^{-1}$ ) strong, ( $15-20\ t\ ha^{-1}\ year^{-1}$ ) severe, ( $20-40\ t\ ha^{-1}\ year^{-1}$ ) very severe, and ( $>40\ t\ ha^{-1}\ year^{-1}$ ) extremely severe. The study area 42.68% has moderate erosion risk and 21.96% slight erosion risk of the total area. The results can certainly aid in the implementation of soil management and conservation practices to reduce soil erosion in coastal systems.

**KEYWORDS:** Large scale, remote sensing, soil erosion, utkal coastal plain

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## 1. INTRODUCTION

Soil loss by runoff is a severe ecological problem occupying 56% of the worldwide area. Soil loss is accelerated by human-induced soil degradation (Bai et al., 2008). There are varieties of soil erosion, and rill and inter-rill erosion are the recurrent types of water erosion, involving detachment, transport, and accumulation of soil particles to a new depositional area, deteriorating soil quality as well as diminishing the productivity of vulnerable lands (Fernandez et al., 2003). Despite the fact that soil erosion can be caused by a geomorphologic process, accelerated soil erosion is principally favored by human activities. Rapid population growth, deforestation, unsuitable land cultivation, uncontrolled and overgrazing have resulted in accelerated soil erosion in the world principally in developing tropical countries like India, especially in coastal landscapes. Climate change, slope gradient, and poor cultivation and establishment in the upland situation speed up the intensive rates of soil erosion in several parts of Coastal Odisha (Srinivasan et al., 2021a).

Coastal agriculture occupies a major portion of available farmlands and provides livelihood support for the rural community, but often suffers from natural hazards such as soil erosion, salt stress, and nutrients mining leading to insufficient production in different regions of India and the world (Barman et al., 2021). The coastline of about 445 km has extended from east to south in Odisha state undulated plain. Floods during the monsoon season and soil salinity during the summer season are the major problems in the adjoining coastal area and severe soil erosion in undulated upland soils (Srinivasan et al., 2022).

Large-scale soil mapping at 1:10000 scale accruing of detailed information of each parcel of the farm on cadastral number wise soil information, which provides an accurate and scientific inventory of different soils their kind and nature, and extent of distribution so that one can't predict their characters and potentialities for farm planning of each parcel of land resources (Hegde et al., 2018; Srinivasan et al., 2021b). It also provides adequate information in terms of landform, terraces, vegetation as well as characteristics of different thematic soil layers (viz., texture, depth, organic carbon, stoniness, drainage, acidity, salinity, etc.) which can be utilized for erosion assessment and other planning and development (Srivastava and Saxena, 2004).

In many regions, unchecked soil erosion and associated land degradation have made vast areas economically unproductive. Often, a quantitative assessment through ground truth checking information is ideal for assessing accurate extension of soil erosion problems so that effective management strategies can be resorted to implementing. But, the complexity of the variables makes precise estimation

or prediction of erosion makes difficult. The latest advances in spatial information technology have augmented the existing methods and have provided efficient methods of monitoring, analysis, and management of earth resources. Remote sensing data and GIS can be successfully used to enable rapid as well as a detailed assessment of erosion hazards (Jain et al., 2001; Chatterjee et al., 2014; Bera, 2017; Srinivasan et al., 2019). Soil erosion vulnerability has been assessed using empirical models like the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) helps of Remote Sensing and GIS (Lee, 2004; Fu et al., 2005). The present study was justifying the earlier, small-scale soil mapping may not help in the decision-making by policymakers due to poor connection with ground truth. Therefore, using large-scale (1: 10000 scales) soil information for mapping the severity of soil erosion in any parcel of land is appropriate and accurate for conservation and crop management. Keeping this in view, a case study was attempted in Ganjam block, Odisha part of Utkal plain.

## 2. MATERIALS AND METHODS

### 2.1. Study area

A detailed soil survey work was carried out in part of Utkal coastal plain, Ganjam block of Ganjam district, Odisha, India during the year 2017–2018. Study area located part of eastern coastal and lies between 19°22'07" to 19° 32' 24" N and 84° 58'04" to 85° 10'30" E (Figure 1), coming under 18.4 agro-ecological -sub-region (AESR) and covered

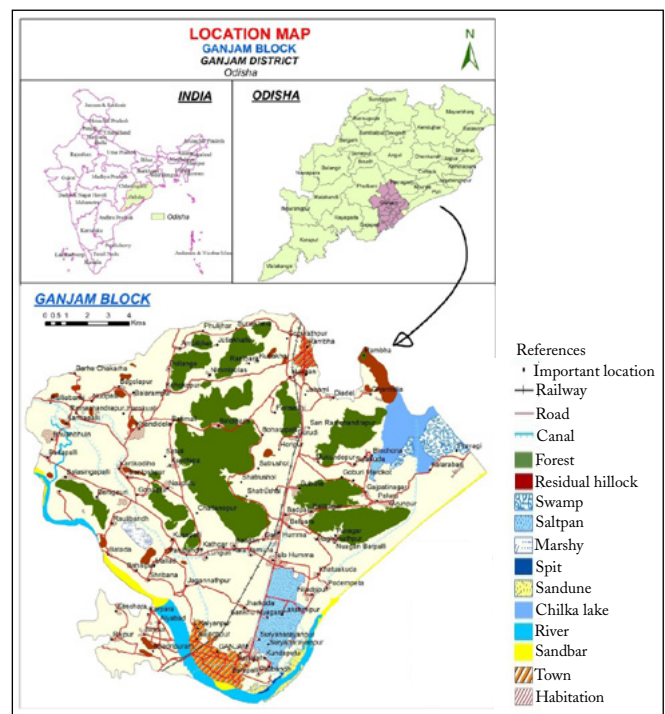


Figure 1: Location map of the study area

216.12 km<sup>2</sup>. The mean annual average rainfall is 750 mm, the maximum received from south-west monsoon, the mean maximum summer temperature is 39°C, and the mean minimum winter temperature is 11.5°C (Figure 2). The soil temperature class is “*hyperthermic*” and the moisture regime is “*ustic*” which is a hot humid plain with an LGP of 180-210 days. The soils are formed different landforms mainly in the deltaic alluvium of Rushikulya rivers, colluvium of Chilka Lake and Fluvio-marine of Bay of Bengal Sea. These lands are being undulated topography, sand bars are running parallel to the Bay Bengal coast and soils are an enrichment of salts. Major land use of the area are rice, pulses, oilseeds, vegetables, cashew and areca nut.

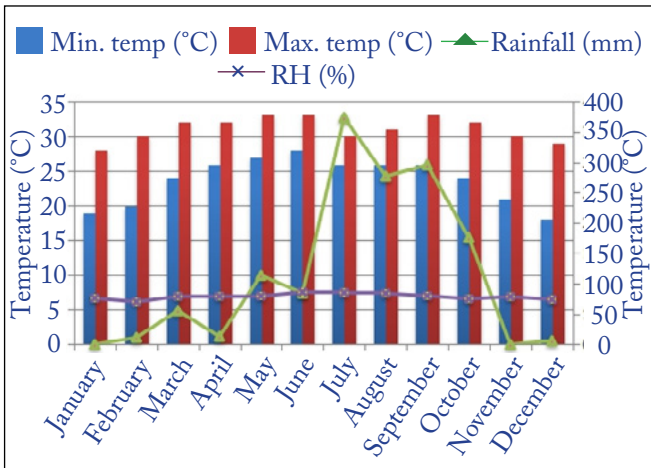


Figure 2: Rainfall and temperature in study area

2.2. Field studies

The detailed soil survey was carried out on a 1:10,000 scale by using a base map prepared from remote sensing satellite data (IRS-P6 LISS IV) in conjunction with village cadastral map and survey of India (SoI) toposheets. An intensive soil profile and auger study was taken in all the landforms and major landuse landcover. Totally forty-six (46) soil profiles and 72 auger samples were studied in this study area. Soil profiles were excavated on each landform for describing morphological characteristics. Major variables in site characteristics were slope, depth, and soil color was examined by standard methods. After the final soil correlation, 16 soil series have been identified and mapped on a 1:10,000 scale with 30 soil mapping units.

2.3. Soil mapping and classification

Soil series were identified based on their differentiating characteristics like depth, texture, slope, erosion, presence of gravel and salinity, etc. After final soil correlation, 16 soil series have been identified on 1:10,000 scale with 30 soil mapping units and mapped using Arc GIS environment (Figure 3). Based on morphological characteristics and soil properties, soils were classified into the family level according to Keys to Soil Taxonomy (Table 1). Major soil

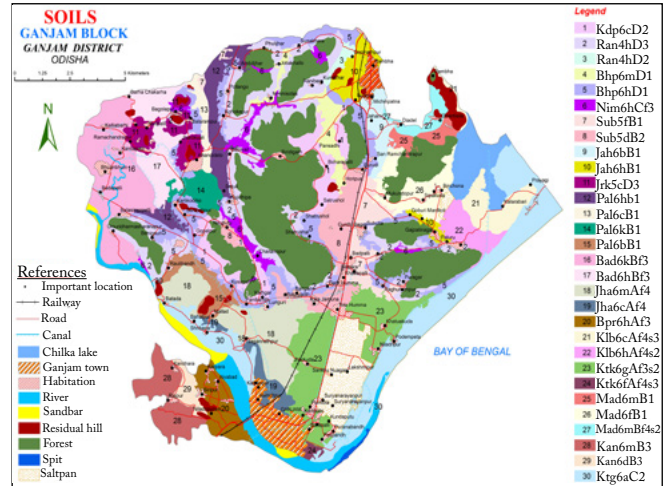


Figure 3: Soil series map of the study area

orders are inceptisol, alfisols, entisols, and vertisols covering in 41.86%, 13.03%, 9.73% and 3.51% areas respectively. Soil series information and different surface thematic maps were used for soil erosion assessment and identification of different erosion severity zones.

2.4. Data sources used

2.4.1. Rainfall erosivity (R) factor

Average rainfall data obtained from IMD last 25 years and processed in ArcGIS software and the R factor was obtained using the equation by Wischmeier and Smith, 1978).

$$R = \sum 1.735 \times 10 (1.5 \log (p_i / 2 p) - 0.8188) \dots \dots \dots (eq-1)$$

Where R is the rainfall erosivity, P<sub>i</sub> is the monthly amounts of precipitation and p is annual precipitation. Very few variations in the R factor ranges from 679 m to 710 m.

2.4.2. Soil erodibility factor (K)

Detailed soil resource mapping (1:10000 scale) texture data was utilized to derive the soil erodibility (K) factor. Soil erodibility factor, K, was computed based on texture and soil organic matter content and given by Wischmeier and Smith, 1971).

$$100K = 2.1(M)^{1.14} 10^{-4} (12-a) + 3.25(b-2) + 2.5(c-3) \dots \dots \dots (eq-2)$$

Higher values are associated with silt soils owing to their higher runoff. The values ranged from 0.1 to 0.3 where 0.1 indicates low or almost no erosion and 0.3 indicates soils more prone to erosion.

2.4.3. Topographic erosivity factor (LS)

Slope length (L) and slope gradient (S) in a landscape of the area was used for assessment of erosion. Greater accumulation runoff on longer slopes increases the detachment and transport capacities of the runoff.

$$LS = A = ((3.28/100)\lambda)^{0.5} (0.76 + 0.53S + 0.076S^2) \dots \dots \dots (eq-3)$$

Where λ is slope length and S is slope gradient in percent.

Table 1: Major soil series and phase level description in Ganjam block				
Series name	Phases	Soil landform relationship	Area (ha)	% Of TGA
Kumaradapalli	Kdp6cD2	Very deep, well drained, yellowish red to dark red, sandy clay loam texture in series control section (31–155 cm) on moderately sloping (1–3%) foothill with sandy loam surface texture and moderate erosion. (Fine, mixed, hyperthermic, Typic Rhodustalfs)	671	2.73
Ranibara	Ran4hD3	Moderately deep, well drained, dark reddish brown, sandy clay loam texture in series control section ((18–95 cm) on moderately sloping (3–5%) foothill with sandy clay loam surface texture and severe erosion. (Loamy -Skeletal, mixed, hyperthermic, Typic Haplustalfs)	1511	6.14
	Ran4aD2	Same as above with deep, sandy surface texture and moderate erosion.	75	0.31
Bahadapalli	Bhp6mD1	Very deep, somewhat poorly drained, brown to yellowish brown, clay texture in series control section (16–156 cm) on 1–3% slope with clay surface texture and slight erosion. (Fine, Oxyaquic mixed, hyperthermic, Haplustepts)	344	1.40
	Bhp6hD1	Same as above with sandy clay loam surface texture and slight erosion.	1394	5.67
Nimisula	Nim6hCf3	Very deep, somewhat poorly drained, brown to dark yellowish brown, sandy clay texture in series control section (25–151 cm) on 0–1% slope with sandy clay loam surface texture and frequent flooding (Fine, mixed, hyperthermic, Typic Haplustepts).	330	1.34
Subulia	Sub5fB1	Deep, moderately well drained, dark grayish brown to brown, clay texture in series control section (16–150 cm) on 1–3% slope with clay loam surface texture and slight erosion (Fine, mixed, hyperthermic, Vertic Haplustepts).	461	1.87
	Sub5dB2	Same as above with loam surface texture and moderate erosion.	729	2.96
Jahami	Jah6bB1	Very deep, well drained, brown to dark reddish brown, clay texture in series control section (43–157 cm) on 1–3% slope with loamy sand surface texture and slight erosion (Coarse-loamy over clay, mixed, hyperthermic, Typic Paleustalfs).	265	1.08
	Jah6hB1	Same as above with sandy clay loam surface texture and slight erosion.	343	1.40
Jharokuali	Jrk5cD3	Deep, well drained, strong brown to dark reddish brown, gravelly sandy clay texture in series control section (0–110 cm) on 3–5% slope with sandy loam surface texture and severe erosion (Loamy-skeletal, mixed, hyperthermic, Typic Rhodustalfs).	337	1.37
Palanga	Pal6hB1	Very deep, moderately well drained, dark grayish brown to light olive brown, sandy clay texture in series control section (0–78 cm) on 1–3% slope with sandy clay loam surface texture and slight erosion (Fine, mixed, hyperthermic, Fluventic Haplustepts).	553	2.25
	Pal6cB1	Same as above with sandy loam surface texture and slight erosion.	167	0.68
	Pal6kB1	Same as above with silty clay loam surface texture and slight erosion.	244	0.99
	Pal6bB1	Same as above with loamy sand surface texture and slight erosion.	262	1.06
Badachokada	Bad6kBf3	Very deep, well drained, grayish brown to dark grayish brown, silty clay texture in series control section (0–158 cm) on 0–1% slope with silty clay surface texture and frequent flooding (Fine, mixed, hyperthermic, Typic Endoaquepts).	1230	5.00
	Bad6hBf3	Same as above with sandy clay loam surface texture and frequent flooding.	624	2.54
Jharkuda	Jha6mAf4	Very deep, somewhat poorly drained, brown to gray, clay texture in series control section (0–110 cm) on 0–1% slope with clay surface texture and very frequent flooding (Fine, mixed, hyperthermic, Typic Haplustepts).	1024	4.16

Table 1: Continue...



Series Name	Phases	Soil landform relationship	Area (ha)	% Of TGA
Biripur	Jha6cAf4	Same as above with sandy loam surface texture and very frequent flooding.	215	0.87
	Bpr6hAf3	Very deep, moderately well drained, very dark grayish brown to yellowish brown, sandy loam texture in series control section (18–154 cm) on 0–1% slope with sandy clay loam surface texture and frequent flooding (Coarse-loamy, mixed, hyperthermic, Typic Ustorthents).	388	1.58
Kalarbari	Klb6cAf4s3	Very deep, somewhat poorly drained, grey, sandy clay loam texture in series control section (16–156 cm) on 0–1% slope with sandy loam surface texture and strong salinity and very frequent flooding (Fine-Loamy, mixed, hyperthermic, Typic Halaquepts).	437	1.78
	Klb6hAf4s2	Same as above with sandy clay loam surface texture and moderate salinity and very frequent flooding.	315	1.28
Khatuakuda	Ktk6gAf3s2	Very deep, somewhat poorly drained, brown to dark gray, sandy clay texture in series control section (20–73 cm) on 0–1% slope with silty clay loam surface texture and moderate salinity and frequent flooding (Fine, mixed, hyperthermic, Vertic Halaquepts).	1249	5.08
	Ktk6fAf4s3	Same as above with clay loam surface texture and strong salinity and very frequent flooding.	39	0.16
Madhuchua	Mad6mB1	Very deep, moderately well drained, very dark grayish brown to dark grayish brown, fine texture in series control section (0–157 cm) on 1–3% slope with clay surface texture and slight erosion (Very fine, mixed, hyperthermic, Typic Endoaquepts).	166	0.67
	Mad6fB1	Same as above with clay loam surface texture and slight erosion.	532	2.16
	Mad6mBf4s2	Same as above with clay surface texture and moderately salinlty and very frequent flooding.	167	0.68
Kanchara	Kan6mB3	Very deep, moderately well drained, dark grey to very dark grayish brown, silty clay texture in series control section (0–159 cm) on 0–1% slope with silty clay surface texture and frequent flooding (Fine, mixed, hyperthermic, Vertic Endoaquepts).	525	2.14
	Kan6dB3	Same as above with loamy surface texture and frequent occurs of flooding.	156	0.63
Kantiagada	Ktg6aC2	Very deep, somewhat excessive drained, dark grayish brown, sandy texture in series control section (0–154 cm) on 3–5% slope with sandy surface texture and moderate wind erosion (Sandy, mixed, hyperthermic, Typic Ustipsamments).	2006	8.15
		Soil total	16760	68.13
		Miscellaneous	7840	31.87
		Total	24600	100.0

#### 2.4.4. Crop management factor (C)

It is the ratio of soil loss from the area under specified cover and management to that from an identical area in tilled continuous fallow (unit plot). By using the field observation different crops like paddy and pulses (0.22), vegetables (0.30), cashew (0.15), and areca nut (0.70) and values are taken standard classification method used in India (Srinivasan et al., 2016; Srinivasan et al., 2017). C factor value was allocated to each of the land use classes that are proposed by Hurni (1985).

#### 2.4.5. Conservation supporting practice factor (P)

P is the erosion control practices or soil conservation practices factor. It is the ratio of soil loss under a support practice like contouring, strip cropping, or terracing to that under straight row farming up and down the slope. To restrict the influence of erosion intensive rain, the crop management practices are to be supported by different conservation practices through land management. The P factor values for major conservation practices adopted in coastal plain land are used for erosion assessment.

### 2.5. USLE parameter estimation

The USLE model assists in predicting the soil loss mainly from inter-rill or rill erosion from fields or farm units as a result of changes in management practices for the long term. The model was developed to predict long-term annual average losses of soil and the best suited at local or regional scales to assess soil erosion practically. This model for estimating soil erosion and loss could aid in formulating appropriate soil conservation and management plans.

The equation USLE (Renard et al., 1997) for computing average annual soil loss is given as

$$A=R \times K \times LS \times C \times P$$

where A is the average annual soil loss ( $t\ ha^{-1}$ ) for a period selected for average annual rainfall; R is the rainfall erosivity factor ( $MJ\ mm\ ha^{-1}\ h^{-1}\ year^{-1}$ ); K is the soil erodibility factor ( $t\ ha\ h\ MJ^{-1}\ ha^{-1}\ mm^{-1}$ ); L is the slope length and S slope steepness factor; C is the cover and management factor, and P is the conservation support practices factor. LS, C, and P values are dimensionless. All these factors were mapped in a raster GIS environment (Millward and Mersey, 1999).

## 3. RESULTS AND DISCUSSION

### 3.1. Rainfall erosivity factor (R)

R factor is calculated based on IMD data over 25 years of the study area from equation 1 and these values are interpolated spatially through GIS technique and R factor map is generated is shown in figure 4. The annual average rainfall erosivity factor (R) was found to be in the range of 697.48 to 710.16  $mt\ ha^{-1}\ cm^{-1}$ . Studies revealed that the soil erosion rate in the catchment is more sensitive to rainfall. The daily rainfall is a better indicator of variation in the rate of soil erosion to characterize the seasonal distribution of sediment yield (Jain et al., 2001; Dabral et al., 2008). While the advantages of using annual rainfall include its

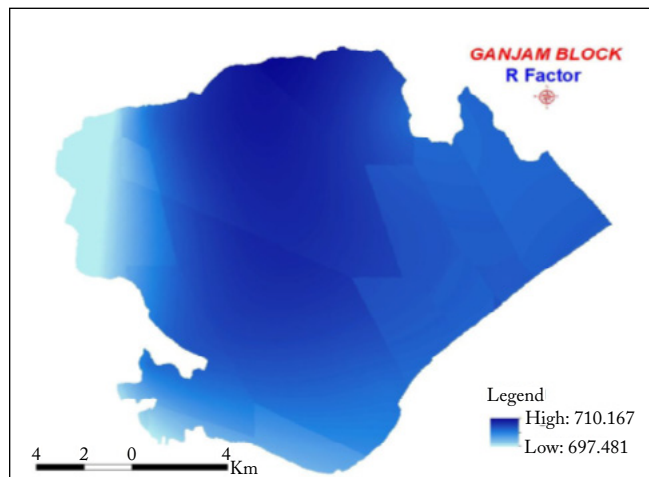


Figure 4: Rainfall (R) factor

ready availability, ease of computation, and greater regional consistency of the exponent (Shinde et al., 2010). Therefore, in the present analysis, average annual (obtained by total rainfall divided by the total number of rainy days) rainfall was used for R factor calculation.

### 3.2. Soil erodibility factor (K)

The soil-erodibility factor (K) is represented by the susceptibility of the soil for erosion, conveyance of the detached soil, and runoff resulted from rainfall. Chance of detachment of soil particles depends upon the structure, infiltration, optimum moisture content, water retentions, presence of cations, texture, and composition using equation 2. Soil erodability (K) of the study area was calculated using the relationship between soil texture class and organic matter content proposed by Stone and Hillborn (2000) and also Wischmeire et al. (1971). The soil erodability factor values are assigned to different texture classes using the GIS technique. The spatial distribution of surface soil K values of the study area has shown in Figure 5. From the study (K factor map) it has been found that less than 0.1 was sandbar near to coastal and 0.1 to 0.2 was moderately coarse texture in the eastern part of the block and 0.2 to 0.3 was central and western part covering fine textures and more than 0.3 was southeast position covered with clay textures. Soil erodibility of near to the sea (sandbar) is comparatively low because soils texture is coarse were generally loamy sand to sandy

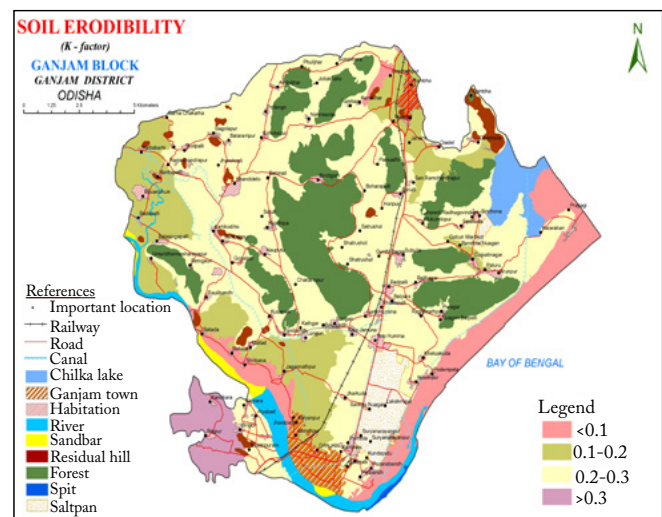


Figure 5: Soil erodibility (K) factor

Table 2: Soil erodibility K values

K value	Area (ha)	TGA %
<0.1	2081	12.42
0.1 - 0.2	3243	19.35
0.2 - 0.3	10755	64.17
>0.3	682	4.07

loam texture in nature and organic matter content was very low, which make more susceptible to erosion around 64% from the total area (Table 2). The percentages of organic matter in soil drop erodibility, decline susceptibility of soil detachment, but enhances infiltration rates, hence the runoff by reducing erosion.

3.3. Topographic factor (LS)

The topographic factor represents the influence of slope length (L) and slope steepness (S) on the erosion process. LS factor was calculated by considering the flow accumulation and slope in percentage as an input and using equation 3. From the analysis, it is observed that the value of the topographic factor increases in a range of 0.1 to 5.0 as the flow accumulation and slope increase. Slope percentage and gradient were observed for each mapping unit and calculated LS factor, the steeper the slope more will be the loss. the study area, the maximum slope is observed to be 0.5 to 1.5-5%. It's considered a a very gently sloping area as from slope classes and LS factor map is generated and shown in Figure 6. It was found that the maximum slope varied in undulated hillock or hills side slope and foothills. Analysis of the topographic factor is very important in USLE application since this parameter characterizes surface runoff speed and quantity of sedimentation (Table 3). Relationship of soil slope on topography established in different conditions by Ozsoy et al. (2012).

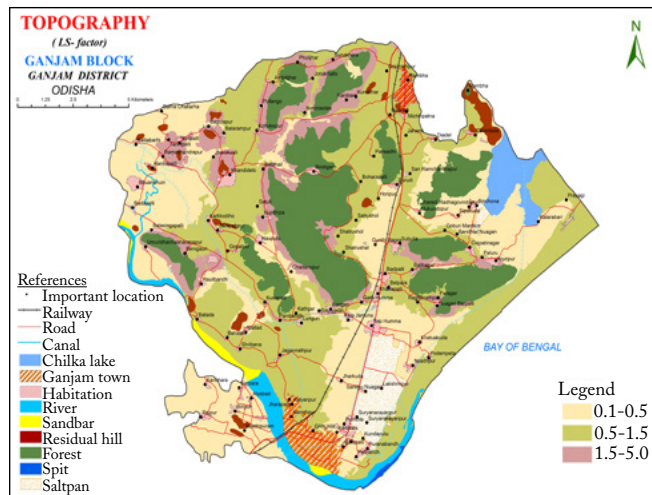


Figure 6: Slope length and steepness factor (LS)

Table 3: Slope length and grade and LS values

LS value	Area (ha)	TGA %
0.1-0.5	6983	28.39
0.5-1.5	7929	32.23
1.5-5.0	1848	7.51

3.4. Crop management factor (C)

Land use and land cover is a better understanding of the

land utilization aspects of cropping patterns, fallow land, forest, wasteland and surface water bodies, which are vital for developmental planning and erosion studies. Current land use and landcover recorded during the fieldwork, the major area is covering paddy followed by pulses and groundnut in low land condition, whereas uplands are vegetables and sorghum. The lower position of hills/foothills and part of side slopes are cashew and mango. Parrel to Bay of Bengal Sea, Sandbar is cultivated cashew and eucalyptus. Based on standardized values 0.25 to 0.50 are given to major paddy growing regions covering around 73% of TGA, and 0.5 to 1.0 is upland cashew and mango covering 27% (Table 4). Using land use-land cover map and C factor map was prepared in Figure 7. C factor map shows that the study area consists of a high percentage of vegetation cover which will reduce soil erosion (Renard et al., 2011). Soil loss is very sensitive to land cover in addition to relief (Chatterjee et al., 2014). In the present study, almost 30 % of the area is

Table 4: Current land use/ land cover and C values

LULC	C value	Area (ha)	TGA %
Crop land	0.25 - 0.5	12235	73.00
Plantation	0.5 - 1.0	4525	27.00

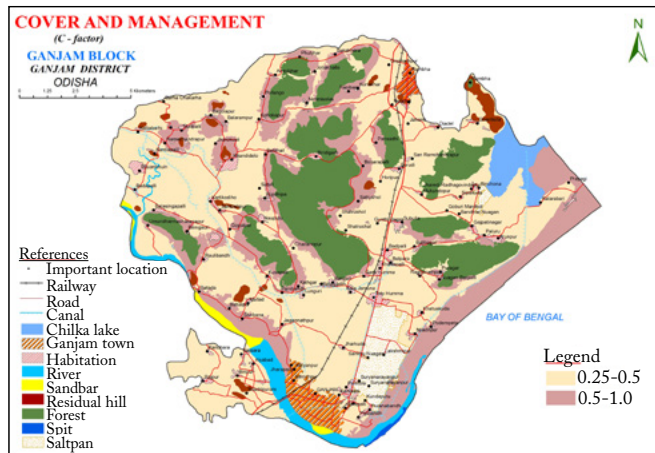


Figure 7: Cover management (C) factor

under forest. C factor is less significant when land use and the land cover area comprise the maximum percentage of natural vegetation and plantation crops. The value of which ranges from '0' in water bodies to slightly greater than '1' in barren land (Toy et al., 2002).

3.5. Support practice factor (P)

The support practice factor (P) is the ratio of soil loss in a normal condition to soil loss due to ploughing in undulating terrain. P values can be reduced by contouring, vegetative strips, strengthening the soil bunds, diversions, sediment basins, and channel of an eroding area can also reduce P-Value. Foothills and uplands are lesser P values (<0.25) and other plain lands are 0.25 to 0.5 respectively (Table 5).

Table 5: Soil slope and corresponding P values

Slope	SWC	P Value	Area (ha)	TGA %
Nearly Level (0-1%)	Strengthening of existing bunds	<0.25	4525	27.00
Very gently sloping (1-3%)	Trench cum bunding	0.25 - 0.5	12235	73.00

The value of the P-factor is 0.25 for the upland and 0.50 for lower land with gentle slope and cultivation of paddy and pulses (Figure 8). It is the ratio of soil loss with specific support practice to the corresponding loss with up and slope tillage. The factor is an expression of the effect of specific conservation practices in the soil such as contouring, strip cropping, and terracing farming. These practices affect erosion by modifying the flow pattern, grade, or direction of the surface runoff and by reducing the amount and rate of runoff.

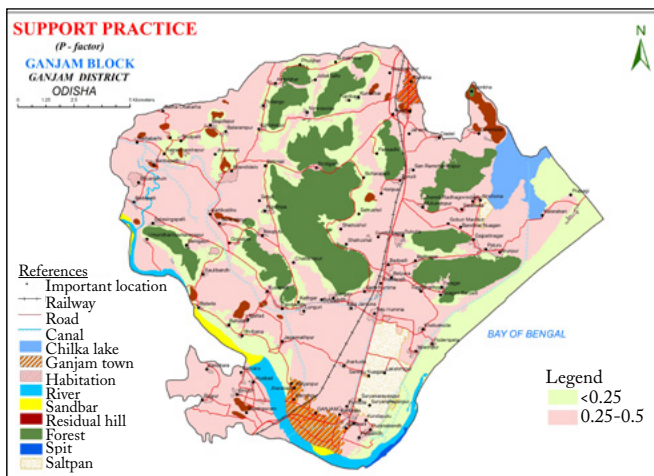


Figure 8: Conservation practices (P) factor

### 3.6. Potential annual soil erosion estimation

The average annual soil erosion potential (A) has been computed by multiplying the developed data from each factor ( $A=R K L S C P$ ) of USLE analysis. The final 'A' factor map displays the average annual soil loss potential of the Utkal plain of Odisha is shown in Figure 9. Results shows that the study area has a gentle slope so the erosion loss is obtained with a low rate and it is within acceptable limit. The GIS analysis has been carried out for USLE to estimate annual soil loss on soil map and mapping unit-based assessed soil erosion in the study area. The potential soil loss in the study area has been categorized into seven types *viz.*, slight, moderate, strong, severe, and very severe erosion based on the rate of erosion ( $t ha^{-1} year^{-1}$ ), i.e., More erosion corresponds to very high erosion and least rate of erosion corresponds to low erosion (Table 6). It is observed that few parts of the study area have higher values of soil loss, which may be due to the steep slope and poor vegetation. It is observed that most of the study area around 42.68% comes under the moderate erosion category due to undulated topography in isolated hills and foothills. Very

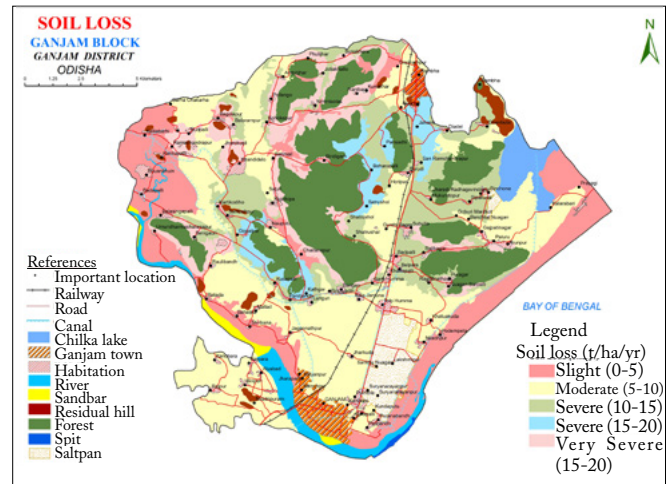


Figure 9: Soil erosion map with different classes

Table 6: Extent of soil loss in the study area

Soil loss	Area (ha)	TGA %
Very Severe ( $20 - 40 t ha^{-1} year^{-1}$ )	1848	11.03
Severe ( $15 - 20 t ha^{-1} year^{-1}$ )	936	5.58
Strong ( $10 - 15 t ha^{-1} year^{-1}$ )	3142	18.75
Moderate ( $5 - 10 t ha^{-1} year^{-1}$ )	7153	42.68
Slight ( $< 5 t ha^{-1} year^{-1}$ )	3680	21.96

high erosion occurs in a few regions where the steep slope with barren land exists. Soil erosion rate was predicted moderately to strong ( $5-10$  to  $10-15 t ha^{-1} year^{-1}$ ) for upland agriculture, which needs proper soil conservation measures to reduce erosion. The very severe ( $20-40 t ha^{-1} year^{-1}$ ) soil erosion was found in hills side slopes, foothills, barren and fallow land. The coastal areas are classified as moderate to strong erosion class covered 61.43% of the study area. Micro-level development should be taken up in the coastal areas to reduce erosion at low cost by constructing structures like check dams, terracing, rainwater harvesting, contour bunds, rock dams, and diversion structures with a proper catchment treatment plan which will enhance the groundwater recharge by increasing infiltration rate, by efficient management of the runoff, conserving the natural resources (Mishra and Das, 2017).

## 4. CONCLUSION

Large-scale soil information is a very crucial for erosion assessment. This paper demonstrates the application of a detailed soil information integrated with soil erosion



models such as USLE with GIS to estimate soil erosion in the Utkal coastal plain. Result revealed that maximum areas covered under moderate and strong, soil loss area around 42.68% and 18.75%, respectively, others are low. The average annual soil loss map is very helpful to predicting soil conservation measures checking the soil loss effectively.

## 5. REFERENCES

- Bai, Z.G., Dent, D.L., Olsson, L., Schaepman, M.E., 2008. Proxy global assessment of land degradation. *Soil Use and Management* 24(3), 223–234.
- Barman, A., Sheoran, P., Yadav, R.K., Abhishek, R., Sharma, R., Prajapat, K., Singh, R.K., Kumar, S., 2021. Soil spatial variability characterization: Delineating index-based management zones in salt-affected agroecosystem of India. *Journal of Environmental Management* 296, 113243. <https://doi.org/10.1016/j.jenvman.2021.113243>.
- Bera, A., 2017. Estimation of soil loss by USLE model using GIS and remote sensing techniques: A case study of Muhuri river basin, Tripura, India. *Eurasian Journal of Soil Science* 6(3), 206–215.
- Chatterjee, S., Krishna, A.P., Sharma, A.P., 2014. Geospatial assessment of soil erosion vulnerability at watershed level in some sections of the upper Subarnarekha river basin, Jharkhand, India. *Environmental Earth Sciences* 71(1), 357–374.
- Dabral, P.P., Baithuri, N., Pandey, A., 2008. Soil erosion assessment in a hilly catchment of north Eastern India using USLE, GIS and remote sensing. *Water Resources Management* 22(12), 1783–1798.
- Fernandez, C., Wu, J.Q., McCool, D.K., Stockle, C.O., 2003. Estimating water erosion and sediment yield with GIS, RUSLE, and SEDD. *Journal of Soil and Water Conservation* 58(3), 128–136.
- Fu, B.J., Zhao, W.W., Chen, L.D., Zhang, Q.J., Lu, Y.H., Gulinck, H., Poesen, J., 2005. Assessment of soil erosion at large watershed scale using RUSLE and GIS: A case study in the loess plateau of China. *Land Degradation and Development* 16(1), 73–85.
- Hegde, R., Niranjana, K.V., Srinivas, S., Danorkar, B.A., Singh, S.K., 2018. Site-specific land resource inventory for scientific planning of sujala watersheds in Karnataka. *Current Science* 115(4), 644–652.
- Hurni, H., 1985. Erosion-productivity conservation systems in Ethiopia. *Proceedings of 4<sup>th</sup> international conference on soil conservation*, Maracay, Venezuela, 3–9 November 1985, 654–674.
- Jain, S.K., Kumar, S., Varghese, J., 2001. Estimation of soil erosion for a Himalayan watershed using GIS technique. *Water Resources Management* 15(1), 41–54.
- Lee, S., 2004. Soil erosion assessment and its verification using the universal soil loss equation and geographic information system: A case study at Boun, Korea. *Environmental Geology* 45, 457–465.
- Millward, A.A., Mersey, J.E., 1999. Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. *Catena* 38, 109–129.
- Mishra, S.P., Das, K., 2017. Management of soil losses in South Mahanadi delta, India. *International Journal of Earth Sciences and Engineering* 10(2), 222–232.
- Ozsoy, G., Aksoy, E., Dirim, M.S., Tumsavas, Z., 2012. Determination of soil erosion risk in the Mustafakemalpasa river Basin, Turkey, using the revised universal soil loss equation, geographic information system and remote sensing. *Environmental Management* 50(4), 679–694.
- Renard, K.G., Foster, G.A., Weesies, D.A., Mccool, D.K., Yoder, D.C., 1997. *Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE) (agriculture handbook No. 703)*. Washington, DC: USDA.
- Renard, K.G., Yoder, D.C., Lightle, D.T., Dabney, S.M., 2011. Universal soil loss equation and revised universal soil loss equation. In: Morgan, R.P.C., Nearing, M.A. (Eds.), *Handbook of erosion modeling*. Blackwell Publishing Ltd. Oxford, England, 137–167.
- Shinde, V., Tiwari, K.N., Singh, M., Anjushree, 2010. Prioritization of micro watersheds on the basis of soil erosion hazard using remote sensing and geographic information system. *International Journal of Water Resources and Environmental Engineering* 2(3), 130–136.
- Srinivasan, R., Karthika, K.S., Amar Suputhra, S., Chandrakala, M., Hegde, R., 2021b. Mapping of soil erosion and probability zones using remote sensing and GIS in arid part of South Deccan Plateau, India. *Journal of the Indian Society of Remote Sensing* 49(10), 2407–2423. [doi.org/10.1007/s12524-021-01396-5](https://doi.org/10.1007/s12524-021-01396-5).
- Srinivasan, R., Nayak, D.C., Gobinath, R., Kumar, S.N., Nageswara Rao, D.V.K., Singh, S.K., 2021a. Consequential rice crop response to resultant soil properties in a toposequence in eastern coastal plain of Odisha, India. *Modeling Earth Systems and Environment*. <https://doi.org/10.1007/s40808-021-01216-2>.
- Srinivasan, R., Shashikumar, B.N., Singh, S.K., 2022. Mapping of soil nutrient variability and delineating site-specific management zones using fuzzy clustering analysis in eastern coastal region, India. *Journal of the Indian Society of Remote Sensing* 49, 2407–2423. [doi.org/10.1007/s12524-021-01396-5](https://doi.org/10.1007/s12524-021-01396-5).
- Srinivasan, R., Singh, S.K., Nayak, D.C., Dharumarajan,



- S., 2017. Assessment of soil properties and nutrients status in three horticultural land use system of coastal Odisha, India. *International Journal of Bio-resource and Stress Management* 8(1), 033–040.
- Srinivasan, R., Singh, S.K., Nayak, D.C., Hegde, R., Ramesh, M., 2019. Estimation of soil loss by USLE model using remote sensing and GIS techniques - A case study of coastal Odisha, India. *Eurasian Journal of Soil Science* 8(4), 321–328.
- Srinivasan, R., Singh, S.K., Nayak, D.C., Naidu, L.G.K., 2016. Characterization, classification and evaluation of cashew growing soils in coastal Odisha for sustainable production. *Agropedology* 26(2), 178–188.
- Srivastava, R., Saxena, A.K., 2004. Technique of large-scale soil mapping in basaltic terrain using satellite remote sensing data. *International Journal of Remote Sensing* 25, 679–688.
- Stone, R.P., Hilborn, D., 2000. Universal soil loss equation (USLE), factsheet, Ontario Ministry of Agriculture, Food and Rural Affairs, Ontario. doi: 10.1016/j.apro.2015.02.185
- Toy, T.J., Foster, G.R., Renard, K.G., 2002. Soil erosion: processes, prediction, measurement, and control. John Wiley & Sons. New York, USA., 338.
- Wischmeier, W.H., Johnson, C.B., Cross, B.V., 1971. A soil erodibility nomograph for farmland and construction sites. *Journal of Soil Water Conservation* 26, 189–193.
- Wischmeier, W.H., Smith, D.D., 1978. Predicting rainfall erosion losses. A guide to conservation planning. The USDA Agricultural Handbook No. 537, Maryland.