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# Raster Grid Based Assessment of Soil Erosion using USLE and Geospatial Technology to Identify Critical Zone: A Case Study of Chaka Watershed, West Bengal, India



**Abstract:** - Soil erosion, an important environmental challenge, exerts a notable influence on land quality and productivity affecting food security at all level from local to global. In India, the prevalence of soil erosion covers about 120.7 hectares area with an average annual soil loss of 16.35 tonnes per hectare (ICAR and NAAS, 2010). Assessment and identification of spatial pattern of soil erosion are essential prerequisites for sustainable management. The estimation of soil loss has been attempted integrating USLE (Universal Soil Loss Estimation) with Geospatial Technology. The present study aims to estimate soil erosion in Chaka Watershed of Purulia district, West Bengal, India. The study also assessed relative influence of factors involved in soil erosion. Six erosion classes were derived for the watershed out of which four classes were identified as critical zones covering about 44.39% area with a soil loss ranging from 10 to more than 80 tonnes  $\text{ha}^{-1} \text{ year}^{-1}$ . The study reveals 19.61% area is under high erosion (10-20 tonnes  $\text{ha}^{-1} \text{ yr}^{-1}$ ), 14.92% area is under very high erosion (20-40 tonnes  $\text{ha}^{-1} \text{ yr}^{-1}$ ), 7.73% is under severe erosion (40-80 tonnes  $\text{ha}^{-1} \text{ yr}^{-1}$ ) and 2.13% area is under very severe erosion (>80 tonnes  $\text{ha}^{-1} \text{ yr}^{-1}$ ). Result of multiple linear Regression analysis shows significance of factors influencing soil erosion. It is revealed that slope length and steepness factor has highest influence followed by cover and management factor, soil erodibility factor, support practice factor and rainfall erosivity factor.

The severity of erosion in conjunction with diverse factors facilitates a comprehensive understanding of spatial distribution of soil erosion within the watershed. This information will be helpful for immediate intervention of the authority with active participation of the stakeholders to implement site-specific programmes and effective soil conservation practices, as well as tailor-made land use plans specifically designed for critical areas prone to severe erosion.

**Keywords:** Soil Erosion, Universal Soil Loss Equation (USLE), Raster GIS, Multiple linear Regression analysis.

## 1. Introduction

Soil erosion emerges as a significant environmental concern, presenting substantial obstacles to the promotion of sustainable land management and agricultural productivity. Influenced by both natural and anthropogenic factors soil loss results in increase of runoff, depletion of nutrient rich top soil, soil productivity, biodiversity and adverse effect on environment [24,38,11,36]. Throughout the world about 85% of land degradation is caused by soil erosion leading to reduction of crop yield up to 17% [33]. In India, 16.35  $\text{t ha}^{-1}$  of soil erosion occurs annually, 29% of soil loss is carried away by the river into the sea and 10% into the reservoirs that lead to reservoir sedimentation [30]. Removal of top soil by soil erosion leads to reduction of fertility while sedimentation in downstream area results in decrease of storage capacity of streams increasing the possibility of flood [49]. Soil detachment predominantly occurs through rainwater erosion (56%) and wind erosion (28%) while physical degradation (12%) and chemical degradation (4%) also contribute to soil erosion in smaller proportions [5]. Water-induced soil erosion occurs in rills, inter-rills, gullies, stream channels, and areas under active construction [51]. Soil characteristics, nature and intensity of rainfall, distinctive climatic conditions, nature of terrain, and land use patterns are important controlling factors of water induced soil erosion [2]. Anthropogenic factors of soil erosion include over farming, intensive grazing, increasing population pressure, expansion of farming, change of landuse, deforestation and desertification, faulty land and water management practice [18,31]. In this regard soil conservation is essential to control soil erosion and improve agricultural productivity for sustainable food security. Consequently, it is crucial to identify erosion-prone areas and quantify erosion within watersheds for efficient watershed management including the implementation of soil conservation strategies.

Many physical, empirical and conceptual model have been employed over the years to estimate soil loss for spatial and temporal analysis. Many tools have been used to assess soil erosion such as Soil and Water Assessment Tool (SWAT), the Water Erosion Prediction Project (WEPP), Universal Soil Loss Equation (USLE) and its improved version the Revised Universal Soil Loss Equation (RUSLE), the European Soil Erosion Model (Euro SEM), Revised Morgan–Morgan–Finney model (RMMF). Among all soil erosion prediction models most widely used is

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USLE [53] which predicts the soil losses from sheet and rill erosion under specified cropping and management system condition, because of its simple means of application. Later its modified version RUSLE [42], developed with similar structure of USLE and containing several improvements with detailed input factors has also become popular. USLE model is widely used for its relative easy application. In spite of limitations of application of USLE it may be considered as a suitable model for the study area as it predicts the long-term average annual rate of erosion based on rainfall pattern, soil type, topography, crop system and management practices. Moreover, application of other complex models could be limited to the lack of input data [37]. During last few decades remote sensing technology and Geographical Information system has been used in integrated manner to estimate soil erosion and its spatial distribution in view of providing information in watershed level for remedial land and water management [3, 19, 16, 35,13, 17, 14]. Number of attempts have been made to estimate soil erosion in watershed level in India using USLE model and geoinformatics [4, 43, 29, 22,36, 40]. To identify critical soil erosion zone area grid cell based studies have been carried out to adopt land management planning and conservation practices (10, 49, 35, 45, 6, 37).

Majority works on soil erosion estimation and prediction have been done in regional scale, while few attempted on raster grid cell based soil erosion assessment in small watershed with agricultural importance. In Eastern India where the present study area is located soil erosion significantly contributes to soil productivity and agricultural output which motivated the researcher to explore the spatial and quantitative approach of soil erosion. In this context the present study has been structured with few objectives: i) Estimation of average annual soil erosion on 30 meter x 30 meter raster grid cell using USLE model integrated with GIS and remote sensing technology. ii) Identify spatial distribution of average annual soil erosion by classifying the data on grid cell basis. iii) Identification of critical soil erosion zone. iv) Determination of weightage of soil erosion controlling factors by applying statistical measures.

## 2. The Study Area

The Chaka watershed, a part of Kasai catchment is located in Purulia district, West Bengal, India covering the blocks of Purulia I, Puncha, Manbazar I, Barabazar and Arsha. It covers an area of 192.37 sq.km. extending  $23^{\circ}3'N$  to  $23^{\circ}13'12''N$  and  $86^{\circ}19'48''E$  to  $86^{\circ}33'36''E$  (Fig 1).

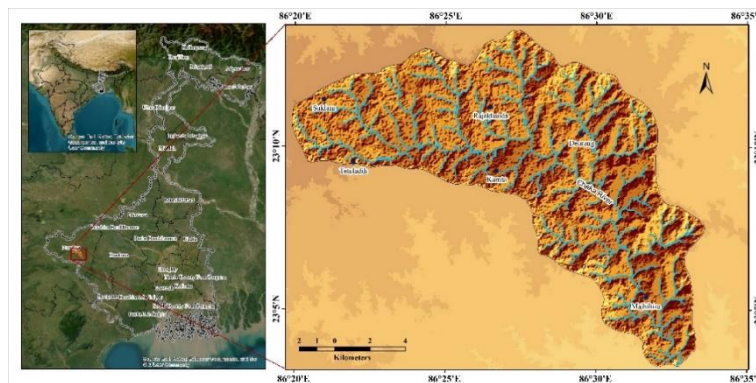


Fig 1: Location of the Study Area

Geologically the watershed embraces the rocks of Chhotanagpur Gneissic Complex of Archaean Age. Almost 90% of the area is composed by granite gneiss, metamorphosed basic rocks, and intrusive granite; while remaining area is covered by mica schist, and hornblende schist. Geomorphologically the watershed is a part of eastward extension of dissected Chhotanagpur Plateau. The maximum and minimum elevations found to be 292 mt. and 159 mt. respectively with average slope varied from  $1^{\circ}$  to  $26^{\circ}$ . The watershed consists of different physiographic units like Plateau slope, Undulating upland, Undulating plain and Valley side slope. It is composed of flat to dissected plateau slope with higher slope in the western part, undulating upland in the north, and undulating plain with low slope component in the eastern and southern part. The watershed morphology including slope and gradient, drainage density significantly contributes to the soil erosion of the watershed. In the study area the main stream is Chaka which flows to the northern part of Jor Nadi, fed by innumerable non perennial tributaries and finally meets Kumari River, the main tributary of Kasai (Fig 2).

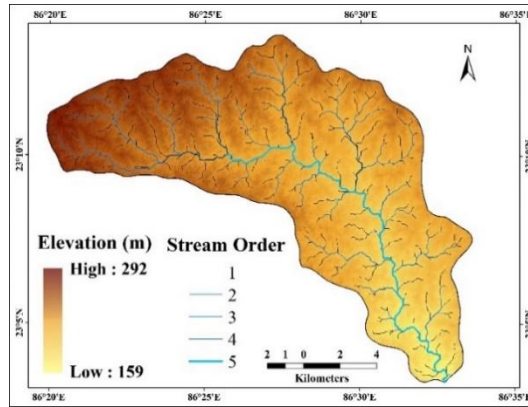


Fig 2: Relief and Drainage Map of Chaka Watershed

The climate of the watershed is hot, dry, sub humid in nature and characterized by hot dry summer, distinct rainy season and cool to cold dry winter. Average summer and winter temperature are 29.8<sup>0</sup>C & 14.3<sup>0</sup>C respectively. The annual rainfall ranges between 1414-1498 mm. According to National bureau of Soil Survey,1996 the area belongs to agro-ecological subregion 12.3 characterised by hot, dry subhumid with Length of Growing Period 150-180 days. The upper part of the watershed is characterized by sandy loam to sandy clay loam soil with high drainage and severe erosion. The soil of middle part is characterized by loam to sandy loam and sandy clay loam with high to very high erosion, while the lower part of the watershed with mainly sandy loam, loam to clay loam soil is dominated by moderate to slight erosion. The soil temperature and moisture regimes are Hyperthermic and Ustic respectively. Major soil series of the watershed are Jambad, Ledabera, Sitalpur, Shimaldanga, Mehi characterized by loam, sandy loam and sandy clay loam. Landuse landcover map (Fig 3) prepared by image classification of Sentinel 2A data (S2A\_MSIL2A\_20231123T045111\_N0509\_R076\_T45QVF\_20231123T075650.SAFE) and subsequent ground verification shows coverage of forest and open forest (7.48%), water body (2%) crop land (52.2%), fallow and barren land (36.65%). Agriculture is the main economic activity dominated by monocrop in monsoon.

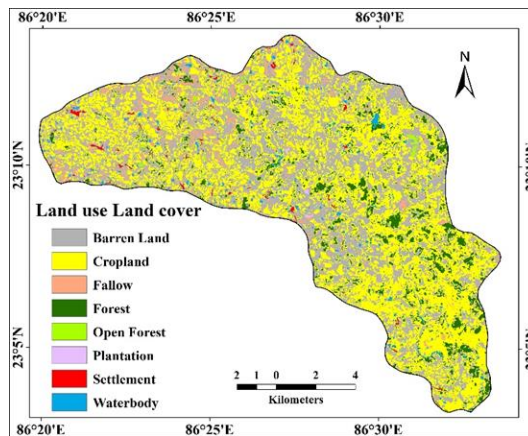


Fig 3: Landuse and Landcover Map of Chaka Watershed

### 3. Database

The USLE model as proposed by Wischmeier and Smith (1978) has been applied for calculating soil erosion of the study area where an empirical equation is expressed as a product of five major erosion controlling factors.

$$A = R \times K \times LS \times C \times P \tag{1}$$

A is the average annual soil loss (tons ha<sup>-1</sup> year<sup>-1</sup>), R is the rainfall erosivity (MJ mm ha<sup>-1</sup> h<sup>-1</sup> year<sup>-1</sup>), K is the soil erodibility factor (ton ha<sup>-1</sup>/MJ mm ha<sup>-1</sup> h<sup>-1</sup>), LS is the topographic factor (dimensionless where L represents the slope length factor and S represents slope steepness factor), C is the land cover management factor (dimensionless), and P is the support practice factor (dimensionless).

For application of the model in the study area to estimate soil erosion, data has been collected from several sources. Daily rainfall data was collected from data base of Indian meteorological Department from 2003-2022. In addition, daily rainfall collected from four rain gauge stations namely Simulia, Rangagora, Tusuma and Kharidwar of Central Water Commission was also used for calculation of R factor. Seventeen soil series has been demarcated from the soil map of NBSS&LUP in 1:50,000 scale and soil samples have been collected from each unit. Soil texture, depth, organic matter, soil structure and permeability have been analysed for quantification of K factor. For calculation of topographic factor (LS) from a flow path based algorithm Digital Elevation Model (DEM) data has been extracted from Shuttle Radar Topography Mission (SRTM) with a spatial resolution of 30 m. Normalized Difference Vegetation Index (NDVI) derived from LANDSAT 8 image (March, 2023, Path140, Row 44, Cloud Cover less 0.5, Sensor Id = "OLI\_TIRS"), has been used for calculation of C Factor in ARC-GIS 10.5 platform. Landuse map prepared from Sentinel image as mentioned earlier has been used in calculating C and P factor. DEM generated slope data and landuse data have been used in determination of P factor.

#### 4. Methodology

The USLE model has been applied in GIS environment to predict soil loss on a cell to cell basis [26, 49]. The raster grid based calculation helps to develop a uniform spatial analysis environment in GIS platform [23, 40, 10, 1]. Grid cell of 30m x 30m has been considered and inputs of all erosion controlling parameters like average annual rainfall, slope, flow accumulation, soil type and its characteristics, landuse have been calculated in raster calculator to determine the soil erosion risk zone. Each factor is calculated on the grid cell bases to identify area with different erosion risk intensity and determine the role of each factor in erosion potentiality.

##### A. Rainfall erosivity factor (R)

Rainfall erosivity expresses the erosive power of rainfall that leads to soil loss. Rainfall erosivity factor is a measure of long-term annual average erosivity, calculated considering individual total storm kinetic energy (E) in MJ ha<sup>-1</sup> and the maximum 30 min intensity (I<sub>30</sub>) in mm h<sup>-1</sup> [41]. R value is significantly influenced by the pattern, volume, intensity, and duration of rainfall whether for single or a series of storms. R factor values can be obtained from isoerodent maps, tables, or calculated from historical data [42]. Calculation of R factor using storm kinetic energy requires lots of data which is not available for the watershed. Modified methods have been used by researchers using long-term interval rainfall data [15, 44]. EI<sub>30</sub> values has been computed in case of India from linear relationship using data from multiple rain gauge stations [47]. This equation has also been used in study of nearby Kharkai river, basin, Jharkhand, India [7]. The relationship [36] derived for R is as follows:

$$R = 79 + 0.363 RN \quad \text{-----} \quad (2)$$

where RN = average annual rainfall (mm). R factor has been calculated using equation (2) for all stations and in ARCGIS10.5 raster map has been generated using inverse distance weighted (IDW) interpolation method.

##### B. Soil Erodibility Factor (K)

Soil erodibility factor (K), expresses the rate of susceptibility to detachment and movement of soil particles in response to rate of runoff volume of a particular storm event and considered as rate of soil loss per erosion index unit [53]. It is a function of inherent soil properties related to soil profile parameters [9]. Soil parameters influencing K factor like soil texture (sand, silt and clay composition), organic matter content, soil structure class, soil permeability were analysed for assessment of soil erodibility [53]. Collection of such data also requires detailed field survey and analysis. Soil series has been demarcated in the study area from soil map of NBSS&LUP in 1:50,000 scale and soil samples were collected from 17 soil series and depth, texture composition, organic matter percentage, structure class, permeability class were analyzed in laboratory for K factor calculation with the following formula [53]:

$$K = [2.1 \times 10^{-4} M^{1.14} (12 - OM) + 3.25(S - 2) + 2.5(P - 3)] / 759 \quad \text{---} \quad (3)$$

where M = grain size parameter that is the product of the silt content (%) (particles of 0.002 to 0.1 mm in diameter) with (100% clay). OM = the organic content (%) of soil. S = soil-structure class code and P = profile-permeability class code. Integrating Equation (3) and GIS, digital map of soil properties was generated using the inverse distance weighted (IDW) interpolation method. Afterwards, using reclassification tool of spatial analyst extension in ARCGIS 10.5, K factor map was generated implementing the input values in 30m x 30m grid cell within the

watershed. In India, Naqvi, H. R., Devi, L. M., & Siddiqui, M. A. 2012 [32] used this model in Nun river watershed, Dehradun, Uttarakhand. Kartic, K. M., Annadurai, R., & Ravichandran, T. 2014, [20] used it for Kothagiri Taluk, Nilgiri, north-west part of the Tamil Nadu. Pal and Shit, 2017 [34] used it for Jaipanda watershed, Bankura, West Bengal, a nearer location to the study area.

**C. Slope Length and Steepness Factor (LS)**

This factor, also referred as topographic factor expresses the influence of slope length and gradient on soil erosion. It is defined as the ratio of soil loss per unit area from a field slope to soil loss from a 22.13 m length of uniform 9% slope [53]. With increase of slope length (L), the total soil loss per unit increases, due to progressive accumulation of runoff in downslope and increase of slope steepness(S) triggers to increase in velocity and kinetic energy of runoff leading to higher amount of soil loss [53]. In original USLE calculation LS factor was considered as one dimensional estimating average erosion per unit area while in later stage numerous methods were applied to calculate the LS factor considering it two dimensional, three dimensional and complex terrain over the past few decades. Considering relief as three dimensional Moore and Wilson, 1992 [28] suggested the following equation for calculating LS factor which can be adopted.

$$LS = (A_s / 22.13)^m * (\sin \beta / 0.0896)^n \quad \text{-----}(4)$$

where  $A_s$  is the upslope contributing area per unit width (m),  $\beta$  is steepest slope angle (radian), and m and n are slope length exponent and slope steepness exponent respectively. Integrating RS & GIS many researchers have used DEM to measure LS factor for estimation of soil erosion.  $A_s$  can be calculated based on the multiple direction flow algorithm [12] using raster calculator tool in ArcGIS. The range of exponents for  $m= 0.2-0.6$  and  $n=1.0 - 1.3$ , where lower values are used for estimating sheet flow and higher values for estimating rill flow. The values 22.13 m (72.6 ft.) and 0.09 rad (5.14°) are the length and slope of the standard USLE plot, respectively [39]. In present study, the LS-factor was computed using the ArcGIS raster calculator tool [27] using the following equation:

$$LS = \left( \frac{FA * cell\ size}{22.13} \right)^m \times \left( \frac{\sin(slope\ angle)}{0.01745} \right)^n \quad \text{--- (5)}$$

where FA is the flow accumulation, cell size is the size of DEM data (30×30 m), slope angle in radians, and  $m=0.5$  (0.4–0.7) and  $n=1.3$  (1.0–1.4) are the exponent values considered for area effected by rill and gully erosion [27]. Flow accumulation of each cell has been calculated using ARC Hydro tools.

**D. Cover and Management Factor (C)**

Cover and management factor indicates the influence of cropping and management practice on soil loss [53, 42]. Vegetation cover and crop cover influence runoff and erosion rate as they dissipate kinetic energy of rain drops before reaching the soil surface. With proper management of crop cover, tillage and vegetation soil erosion can be controlled. Generally, the C-factor ranges between 1 and 0. C equal to 1 indicates lack of cover whereas C near zero shows very strong cover and well-protected soil. In the present study Normalized Difference Vegetation Index (NDVI) obtained from satellite image interpretation. NDVI shows positive relation with the amount of green biomass and indicates differences in green vegetation coverage [52].

$$NDVI = \left( \frac{NIR-RED}{NIR+RED} \right) \quad \text{-----}(6)$$

Several studies has been established relationship between NDVI and C factor [52,19,8]. In the study, relation established by Karaburun, A, 2010 [19] has been for calculation of C factor.

$$C\ factor = 1.02 - 1.21 * NDVI \quad \text{-----}(7)$$

C Factor map has been generated using conditional expression in Raster calculator in ARCGIS 10.5.

**E. Support Practice Factor (P)**

Support practice factor expresses influence of landuse or farming system on soil erosion [39]. It reflects the potential erosion by water runoff through implementing the effects of contouring, strip cropping, terraced contour

farming and so on [53]. P value equal to 1 indicates no erosion control management. Some researchers suggested that the P-value depends on the slope inclination [46], while others used farming practices on the slope to calculate P values [50]. For this LULC map has been generated (Fig 3) and P factor value has been assigned (Table 1) integrating landuse type and DEM derived slope map in raster using spatial analyst tool in ARCGIS 10.5 as recommended by Shin,1999 [46].

Table 1 : P-factor according to land use class and slope gradients (Shin 1999)

Landuse Group	Slope				
	0°–5°	5°–8°	8°–10°	10°–15°	>15°
Dense forest, Grassland	1.0	1.0	1.0	1.0	1.0
Plantation forest, Shrub land, Perennial and Cash crops	0.55	0.6	0.8	0.9	1.0
Seasonal and yearly crops (Pulses), Crop fields Tef, Barley, Wheat, Rice, Maize, Sorghum, Corn, etc.)	0°–5°	5°–8°	8°–10°	10°–15°	>15°
Built-up area, Bare rock, Bare soil	0.003	0.003	0.003	0.003	0.003

**F. Identification of Soil Erosion Risk Zone**

All factors (R, K, LS, C, P) contributing soil loss in USLE model were quantified and derived as raster layers in 30 m x 30 m grid and the layers are overlaid and values are multiplied using raster calculator to obtain spatial distribution of average annual soil loss in the watershed. The grid cells are further divided into six erosion prone zones to identify soil erosion risk zone in the study area following the guideline suitable for Indian conditions [42, 35].

**G. Statistical Analysis**

A statistical analysis has been performed using descriptive statistics and log linear regression analysis in SPSS 27.0.1 to determine the weightage of input factors of USLE influencing soil loss in the watershed. For the study 200 point data has been selected by random sampling method from soil erosion risk map depicting A factor. Values of soil loss (A factor) and all independent factors (R, K, LS, C, P) have been superimposed and transferred using the following logarithmic equation.

$$\ln(A) = \ln(R * K * LS * C * P)$$

$$= \ln(R) + \ln(K) + \ln(LS) + \ln(C) + \ln(P) \quad \text{-----(8)}$$

Where ‘ln’ is natural logarithm of soil loss. Multi linear regression can be applied to determine effect of input factors on soil erosion rate and the relationship can be expressed as follows:

$$\ln(A) = \beta_0 + \beta_i * \ln(X_i) + \beta_j * \ln(X_j) + \beta_k * \ln(X_k) \quad \text{-----(9)}$$

Where ln(X<sub>i</sub>) is the natural logarithm of value of ith input factor, and β<sub>i</sub> is the estimated regression coefficient that quantifies the relation between the factor X<sub>i</sub> and A. The β<sub>0</sub> value is a standardized coefficient value of different units of the input factors (25,21, 39,1]. The significance level as mentioned in equation (8) must be less than 0.05 (with 95% confidence) and an absence of multicollinearity (Variance Inflation Factor, VIF < 10). Following the above principle multicollinearity of the data has been judged in SPSS 27.0.1.

**5. Result And Discussion**

As the average annual soil erosion in USLE model depends on several independent inputs, the results should be analysed in detail. The average annual rainfall erosivity factor, R has been found in a range of 592.31 to 622.80 MJ mm ha<sup>-1</sup>h<sup>-1</sup> year<sup>-1</sup>. The R value (Fig 4a) is observed highest (614.4- 622.8 MJ mm ha<sup>-1</sup> h<sup>-1</sup> year<sup>-1</sup>) in the southern part of the watershed, moderate value (605.4 - 614.4 MJ mm ha<sup>-1</sup> h<sup>-1</sup> year<sup>-1</sup>) and low in the upper catchment area (592.3 – 605.4 MJ mm ha<sup>-1</sup> h<sup>-1</sup> year<sup>-1</sup>) which is very much consistent with annual average rainfall of the watershed. In the watershed K factor ranges from 0.29 to 0.65 ton ha<sup>-1</sup>/MJ mm ha<sup>-1</sup> h<sup>-1</sup> . Loam and Sandy clay loam having higher proportion of fine sand and silt are more susceptible to erosion (Table 2). K factor value <0.38 covers 8.67% area, 0.38 to 0.5 covers 33.62% area, 0.5 to 0.57 occupies 24.86% area, 0.57 to .62 occupies 24.65% area and >.62 occupies 8.19% area (Fig 4b).

Table 2 : Soil Erodibility Factor (K) of Chaka Watershed

Soil Class	Texture	K Value (ton ha <sup>-1</sup> /MJ mm ha <sup>-1</sup> h <sup>-1</sup> )	% of Area
Hyperthermic Typic Haplustepts	Clay loam	0.38	3.48
Hyperthermic Typic HaplustalFs	Sandy clay loam	0.49	1.94
Hyperthermic Ultic HaplustalFs	Sandy loam	0.65	0.54
Hyperthermic Typic EndoaqualFs	Loam	0.64	6.71
Hyperthermic Typic Haplustepts	Sandy clay loam	0.48	16.95
Hyperthermic Aquic Haplustepts	Sandy loam to sandy clay loam	0.61	12.12
Hyperthermic Typic RhodustalFs	Sandy loam	0.60	8.90
Hyperthermic Typic Haplustepts	Sandy clay loam	0.53	2.13
Hyperthermic Typic Haplustepts	Sandy clay loam	0.29	4.72
Hyperthermic Typic Ustorthents	Sandy loam	0.56	8.71
Hyperthermic Typic HaplustalFs	Loam	0.54	9.44
Hyperthermic Lithic Haplustepts	Loam to clay loam	0.52	1.34
Hyperthermic Typic Haplustepts	Sandy clay loam	0.50	4.95
Hyperthermic Typic HaplustalFs	Sandy loam	0.62	3.76
Hyperthermic Typic HaplustalFs	Sandy loam	0.57	3.37
Hyperthermic Typic Haplustepts	Sandy clay loam	0.50	9.95
Hyperthermic Lithic RhodustalFs	Sandy loam	0.64	0.98

The study area being an eastern extension of Chotanagpur plateau the terrain is dissected and complicated. DEM data shows 58% area occupies elevation more than 200m which mainly occurs in the northern and middle part of the watershed. LS factor in the watershed varies from .07 to 5.66 (Table 3 & Fig 4c) and major area of 32.04% of land shows value of LS factor less than 0.31, which indicates higher slope leading to higher runoff and high soil loss (39).

Table 3: Slope Length and Steepness Factor (LS) in Chaka Watershed

LS Factor	% of area
<0.31	32.04
.31-.58	20.94
.58-.97	14.07
.97- 1.54	4.72
>1.54	28.23

The derived data using NDVI shows that Crop coverage and management factor (C) ranges from .01 to 0.3 (Table 4 & Fig 4e). 22.77 % of area is under C factor value of 0.07 which reveals lower amount of land is cover protected while 57.05% area has C factor value above 0.13 which indicates higher erosion potentiality in this area. Higher value of C factor coincides with barren land and fallow.

Table 4: Cover and Management Factor (C) of Chaka Watershed

C Factor	% of Area
<0.07	22.77
.07 -0 .13	20.18
0.13- 0.25	26.71
> 0.25	30.34

Support practice depends on landuse type, slope of land and different farming pattern. Considering the landuse type and slope as mentioned in table 1 [46] P factor has been calculated for Chaka watershed which ranges from 0.5 to 0.9 (Table 5 and Fig 4f). P value 1.0 represents no conservation practice. In the study area moderate degree of conservation has been applied to 60.52% area which mainly covers crop land with strip and contour farming. 20.77% area of the watershed is under low conservation and support practice.

Table 5 : Support Practice Factor (P)

P Factor	% of area
<0.58	60.52
0.58-0.66	18.71
0.66-0.74	8.63
0.74-0.82	6.02
>0.82	6.12

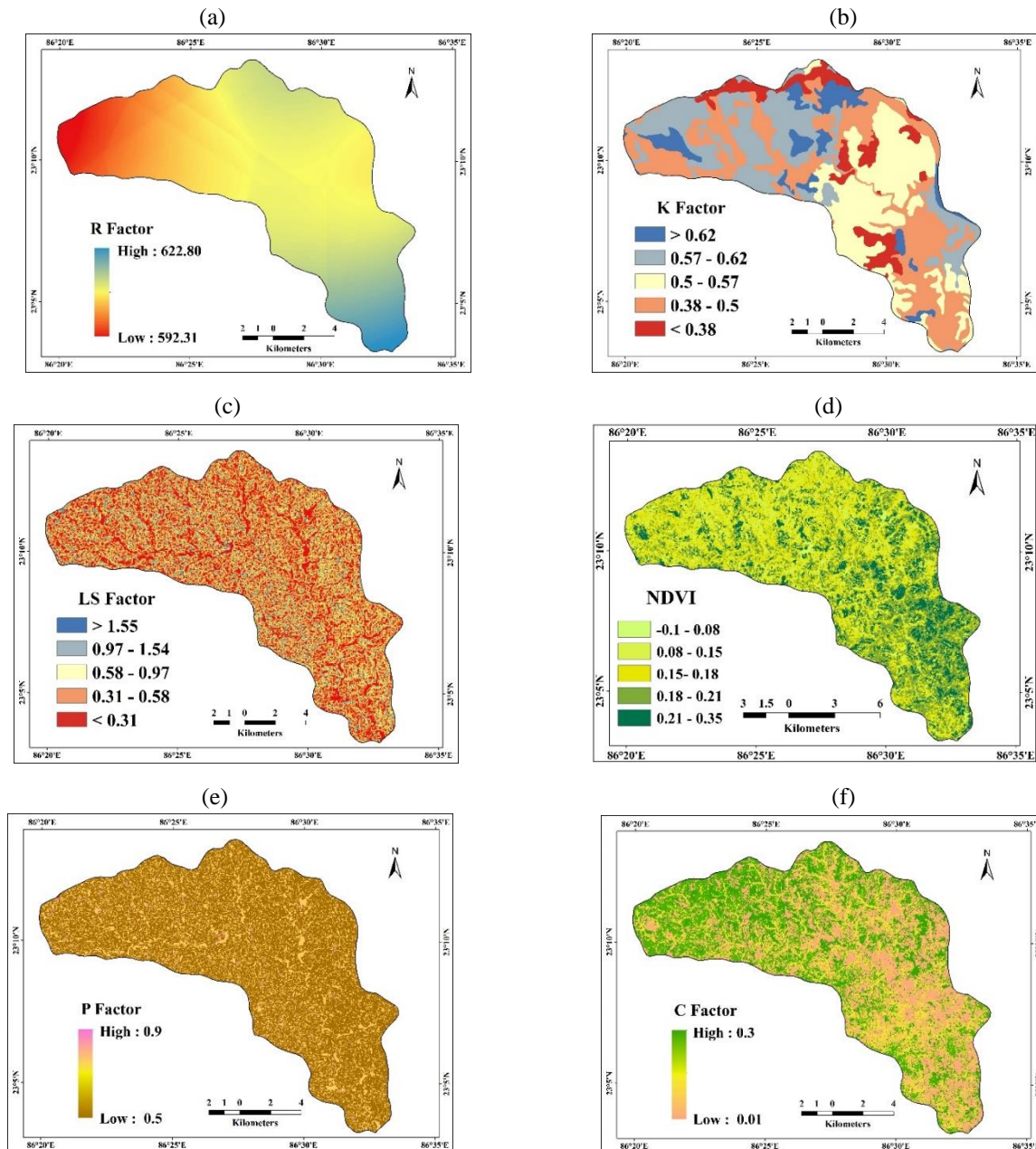


Fig 4 : (a) Rainfall Erosivity Factor, (b) Soil erosivity Factor, (c) Slope Length and Steepness Factor(d) NDVI of Chaka Watershed, (e) Cover and Management Factor, (f) Support Practice Factor

**A. Mapping of Soil Erosion Risk Zone**

A soil loss map has been generated by multiplying all input raster (R, K, LS, C, P) in GIS platform to calculate average annual soil erosion in the watershed. Six erosion potential zone (Table 6 & Fig 5) have been derived according to their severity as: slight (0-5 tonnes/hac./yr.), moderate (5-10 tonnes/hac./yr.), high (10-20 tonnes/hac./yr.), very high (20-40 tonnes/hac./yr.), severe (40-80 tonnes/hac./yr.), very severe (>80 tonnes/hac./yr.). Major part of the watershed is showing slight to moderate erosion covering about 53.61% area. Critical soil erosion risk zone covers 34.53% area with high to very high erosion of 20 to 80 tonnes/hac/yr. But the alarming zone with severe to very severe erosion of 40 to more than 80 tonnes/hac/yr accounts about 9.86 % of the total area of the watershed.

Table 6: Soil Erosion Rate in Chaka Watershed

Level	Soil Loss (tonnes hac <sup>-1</sup> yr <sup>-1</sup> )	% of Total Area
Slight	0-5	40.91
Moderate	5-10	12.7
High	10-20	19.61
Very High	20-40	14.92
Severe	40-80	7.73
Very Severe	>80	2.13
Water	-	2

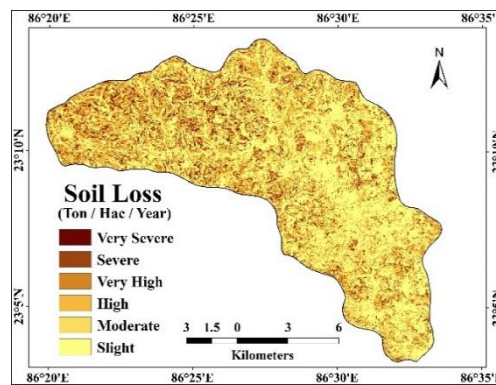


Fig 5 : Soil Erosion Map of Chaka Watershed

**B. Result of Statistical Analysis**

Result of log linear regression analysis shows average annual soil loss (A) is significantly correlated with independent input factors (P<0.041 and VIF<10). Table 7 shows standardized estimated beta (β) coefficient ranges from 0.112 to 0.619 which has been used in multiple linear regression (equation 9) for estimation of average annual rate of soil erosion, A [39,1].

$$\ln(A) = 0.112 * \ln(R) + 0.195 * \ln(K) + 0.619 * \ln(LS) + 0.585 * \ln(C) + 0.178 * \ln(P) \quad \text{-----(10)}$$

The equation shows that LS factor (β =0.619) is highest influencing factor in the watershed followed by C factor (β =0.585), K factor (β =0.195), P factor (β =0.178), and R factor (β = 0.112).

**Table 7 Standardized Coefficient (β) for Factors in USLE Model**

Independent Variable	Standardized Coefficient (β)	Sig <sup>a</sup>	VIF
In(R)	0.112	0.041	1.058
In(K)	0.195	0.005	1.019
In(LS)	0.619	0.005	1.016
In (C)	0.585	0.005	1.045
In(P)	0.178	0.029	1.027

<sup>a</sup> Level of significance @0.05(95%)

## 6. Conclusion

Soil erosion of Chaka watershed has been estimated using raster on 30m x 30m grid cell and RS based on USLE model. 53.61% of total area is covered by slight to moderate erosion rate with 13.2% of total soil loss of the watershed, while about 34.53% area is considered here as critical zone with soil loss of 10-40 tonnes/hac/yr. which consists of 46.95% of total soil loss. Area under severe and very severe soil loss identified as alarming zone with more than 40 tonnes/hac/yr. covers only 9.86% of area but contributes 39.85% of total soil loss of the watershed. It reveals that smaller area contributes larger amount of soil loss which should be given priority for planning and management. Findings of raster grid cell based study using USLE will lead to quantify the soil loss more precisely to frame guidelines for conservation strategies to identify critical and alarming erosion zone. Multiple regression analysis shows highest influence of slope length and steepness factor followed by cover and management factor, soil erodibility factor, support practice factor and rainfall erosivity factor. The study exhibits higher slope, barren and fallow land contribute more soil loss in the watershed. More than 76% area is under mono cropping dominated by kharif crops grown in monsoon season. This single cropping area also contributes higher amount of soil loss. The spatial distribution shows higher amount of soil loss in the upper part of the watershed having higher slope and higher percentage of barren land and fallow land. Some conservation techniques can be adopted to restrict soil erosion affected by slope and steepness and cover factor. Cover crops are very helpful to restrict soil loss in higher slope. Mono cropping dominated with rice is practiced everywhere. To increase crop cover in dry season alternative crops may be selected like pulses (khesari, kalai, khesari moong), oilseed like sesame depending on moisture availability. Winter vegetable may be recommended in the lower part of watershed with higher soil moisture. Strip cultivation may be recommended with a combination of cereal and pulse using alternative strip in the same field. It can be attempted in low moisture condition as two types of crops utilize water from different root zone level. Modern low tillage techniques (mini till, strip till and no till) can be used to restrict displacement of top soil particle in the high slope area. Plantation occupies less than 1% of land which can be increased by planting Kusum, Ber tree for lac cultivation and Asan, arjun can be planted for sericulture and tasar silk production. It can also boost up the local economy. Soil erosion being a natural process cannot be stopped completely, but only can be restricted by adopting proper slope and landuse management, implementing suitable cover and support practice strategies.

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