Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 1, July : 2023

Assessment Of Soil Erosion Risk Within A Small-Watershed Nandivargam, Nandyal District, India. Using Revised Universal Soil Loss Equation (RUSLE): A Remote Sensing & GIS Approach.

Mr. Vidudala Ravi Babu, Civil Engineering. Dept. of S.V.U college of Engineering. S.V. University, Tirupati, Andhra Pradesh, India.
. **Prof. D. V. Satyanarayana Murthy**, Civil Engineering. Dept. of S.V.U college of Engineering. S.V. University, Tirupati, Andhra Pradesh, India.
.

Abstract
This study aims to assess soil erosion risk within the small-watershed of Nandivargam in Nandyal district, India, utilizing the Revised Universal Soil Loss Equation (RUSLE) model along with a remote sensing and Geographic Information System (GIS) approach. The RUSLE model, widely recognized for estimating soil loss and serving as the basis for global soil loss models, has undergone numerous modifications over time. The specific focus of this study is on estimating yearly soil loss in the Nandivargam small-watershed. The researchers utilized GIS and remote sensing technologies, along with the RUSLE model, to accomplish this objective. To do this, they incorporated various GIS data layers, such as rainfall erosivity (R), slope length and steepness (LS), land cover management (C), soil erodibility (K), and conservation practice (P), to analyze their respective impacts on soil loss. The findings of the study revealed an estimated annual potential soil loss of approximately 3974.7 t/yr (240.0244 km^2) within the Nandivargam small-watershed. This information provides valuable insights into the extent of soil erosion in the area and can contribute to the development of effective soil conservation strategies and land management practices to mitigate erosion impacts.

Keywords: Revised Universal Soil Loss Equation (RUSLE), Geographic Information System (GIS), remote sensing (RS), Nandivargam watershed; Soil erosion.

I. Introduction
Soil erosion is one of the major issues with land degradation in agriculture and is now recognised as a serious environmental threat [18]. Soil erosion also contributes to the degradation of land resources globally. A danger to regional water quality and sustainable agricultural output, soil erosion is typically linked to agricultural practices in tropical and semi-arid countries. It causes a reduction in soil fertility and a host of other detrimental effects on the environment. 5334 million tons of soil are reportedly removed from India each year for a variety of causes [16], [17]. In recent years, as part of the environment and land degradation assessment policy for sustainable agriculture and development, soil erosion is increasingly more being diagnosed as a threat that's more serious in mountain regions [14], [2], [1], [4], and [24]. To ensure effective management strategies, a quantitative assessment is essential for determining the scope and severity of soil erosion issues. However, the intricate nature of the variables involved makes it challenging to accurately estimate or predict erosion. Fortunately, recent advancements in spatial information technology have enhanced existing methods and provided efficient approaches for monitoring, analyzing, and managing Earth's resources. By leveraging tools such as digital elevation models (DEMs), along with remote sensing data and geographic information systems (GIS), it is possible to swiftly and comprehensively assess erosion hazards, enabling both rapid and detailed evaluations. [7], [22], [10]. Spatial and quantitative data regarding soil erosion at a small-watershed level play a significant role in the development of plans for soil conservation, erosion control, and overall management of the watershed environment. The outcomes of the estimation of soil loss in the small-watersheds had been done on an experimental foundation in lots of tropical regions the usage of unique techniques of prediction [21], [5], [27]. In this scope of study, the Revised

Universal Soil Loss Equation (RUSLE) was applied within a Geographic Information System (GIS) framework to predict potential annual soil losses in the Nandivargam small-watershed in Nandyal district, India. The utilization of remote sensing and GIS techniques has proven to be invaluable, particularly when evaluating erosion on a larger scale, due to the extensive data requirements and broader area coverage involved. For this reason use of these techniques have been widely adopted and currently there are several studies that show the potential of remote sensing techniques integrated with GIS in soil erosion mapping. The primary aim of this study was to estimate soil loss by employing the Revised Universal Soil Loss Equation (RUSLE) model, utilizing input parameters generated through remote sensing and GIS techniques. These input parameters encompassed factors such as soil erodibility, topography, land use practices, and crop management.

II. Geographical of the Study Area

The study area selected for assessing soil erosion vulnerability is the Nandivargam small-watershed shown in (Fig-01), which is part Nandyal district, India. The study area extends between latitudes 15°22' 30"N to 15°32'30"N and longitudes 78° 7' 30"E to 78°25'0"E, the covering an area of 240.72 km^2. The mean elevation of the study area is 425 meters above mean sea level. It experiences a dry climate with an annual & annual average rainfall of 1273mm and 902mm respectively. The mean minimum and maximum temperatures are 21.9 ºC and 38.5 ºC, respectively. Located in the Kundu river basin, also known as Kunderu, Kumurdruthi, it is a tributary of the Penna River in the Rayalaseema region of India. The Kundu valley, known as Renadu, is associated with the term "Renati Pourusham." The Kundu River's flood plains cover an area of around 6,000 acres (24 km^2). The study area encompasses the Kunderu river valley, situated between the Erramala and Nallamala hills, forming the western and eastern boundaries, respectively. It includes the entire Koilakuntla and parts of Nandikotkur, Nandyal, Allagadda, and Banaganapalle. The Kunderu River, a tributary of the River Penner, flows southward through the central part of the region. The Madduleru and Jurreru rivers in the west, and the Galeru and Vakkileru Rivers in the east, are the main tributaries of the Kunderu River [11]. The region has an average slope ranging between 200 and 300 meters.

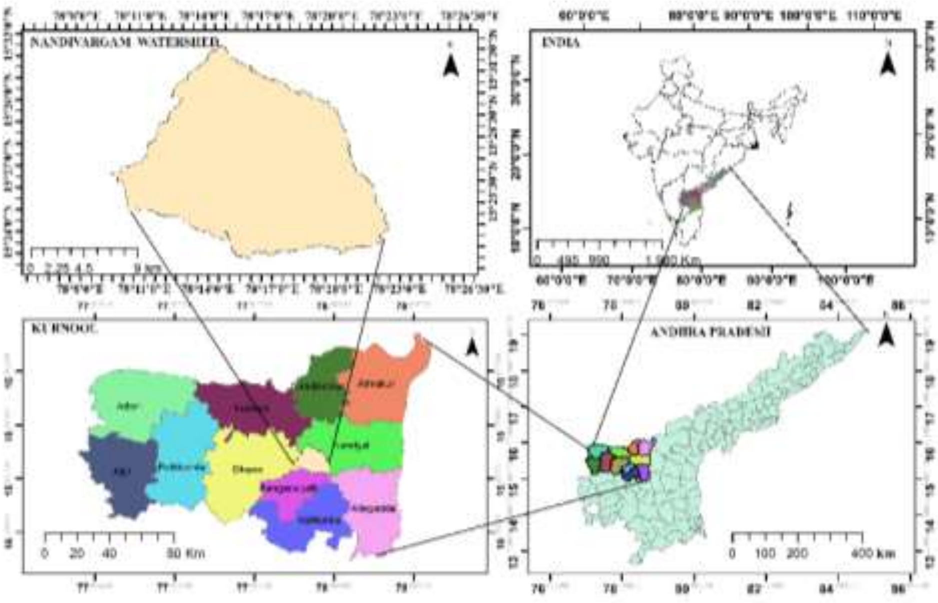

Figure 01: Location map of the study area of

The main objective of this research is to investigate the specific form of land degradation that has occurred within the designated study region. To investigate the changes in vegetation resulting from mining activities within the area, to evaluate the endeavours made by the inhabitants in restoring and reclaiming the mined areas, and to investigate additional modifications induced by mining activities on the physical environment.

III. Materials & Methodology

3.1 Annual soil loss estimation method

The source of organisation of data for study area shown in (Table -01) to estimate the soil erosion in the small- watershed

S.No.	Source	Map	Description
1	Topo-sheet / Spatial Data	Study area boundary	Watershed boundary.
2	Rainfall data (IMD) & Rainfall Erosivity of world	Rainfall data & Erosivity map GloRED	Rainfall map was used to calculate the R-factor
3	Digital soil Map of the World (DSMW)	Soil map	Soil map was used for calculation of K-factor
4	ASTER GDEM	Digital elevation model (DEM)	Digital elevation map (DEM) and LS-factor
5	Satellite imagery -10m Sentinel – 2 LA2 Thematic	Land use / land cover (LULC)	LULC map was used for calculation of P-factor and C-factor

Table 1: Data collected to estimate soil erosion using from source.

3.2. The generation of RUSLE factors through the processing of data.

Data processing and generation of Revised Universal Soil Loss Equation (RUSLE) factors (Fig-02) were carried out using a combination of high-resolution (ASTER) Global Digital Elevation Model (GDEM) data with a 30 m resolution and various techniques for extracting topographic information of hydrological interest directly from the Digital Elevation Model (DEM). These techniques, based on established studies by [8], [12], [15], [13], encompassed the extraction of slope properties, catchment areas, drainage divides, and channel networks. To calculate the soil erodibility (K-factor), the FAO Digital Soil Map of the World (DSMW) was utilized. Rainfall data from the Indian Meteorological Department (IMD) were used to determine the rainfall erosivity (R-factor). Base map delineation of the watershed boundary and processing of Landsat-8 data enabled the acquisition of land use and land cover (LULC) information. The Survey of India (SOI) topographic maps at a scale of 1:50,000 were utilized for the georeferencing of satellite data, ensuring spatial alignment of the satellite imagery. The coverage of the image corresponded to an area of 240.03 Km^2. GIS software version 10.8 was employed for generating the digital coverage of input parameters required for the erosion model. The Revised Universal Soil Loss Equation (RUSLE) was applied to determine the soil loss of the watershed. Certain modifications were made to the parameter estimation process of the RUSLE equation to better align with Indian conditions. The Revised Universal Soil Loss Equation (1) (RUSLE) is as follows:

$$A=R\times K\times LS\times C\times P \quad \text{------------ (1)}$$

Where, A is average annual soil loss ((t ha^{-1} yr^{-1}), R is the Rainfall and Runoff erosivity factor in MJ·mm·ha^{-1} ·h^{-1} ·y^{-1}, K is the soil Erodibility factor (t h MJ^{-1}mm^{-1}. LS is the Slope and Length of Slope Factor; C is the dimensionless Cropping Management (range between 0 and1) Factor; P is the supporting conservation practice factor (range between 0 and1).

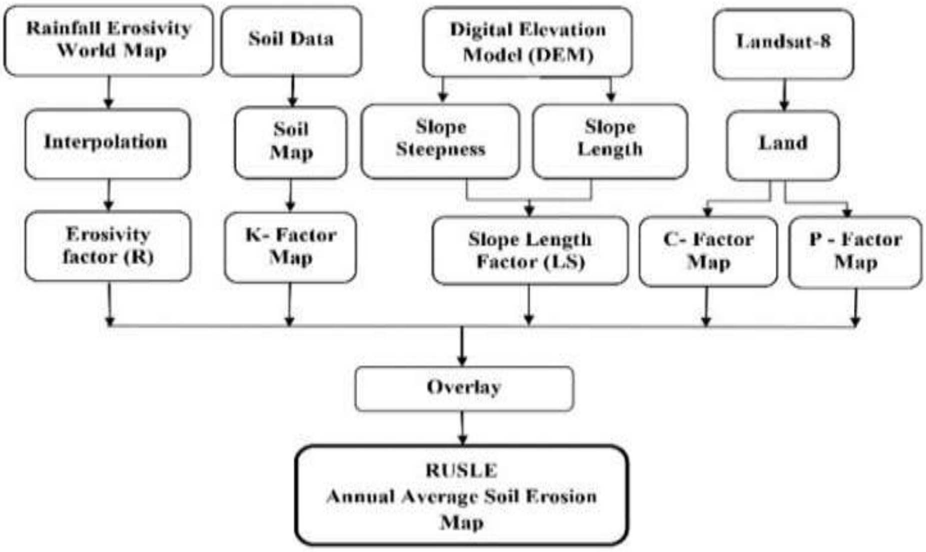

Figure 02: Factors for evaluating erosion in an incorporated integrated assessment framework.

3.2.1. Rainfall erosivity (R):

The rainfall factor, an index unit, is a measure of the erosive force of a specific rainfall. This is determined as a function of the volume, intensity and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period. Raindrop/splash erosion is the dominant type of erosion in barren soil surfaces. Rainfall data of 40 years (1982-2021) collected from Indian Meteorological Department (IMD) were used for calculating R-factor using the following relationship developed by [28] and modified by [3], this modified formula incorporates only annual and monthly precipitation data to calculate the R factor. The Global Rainfall Erosivity Database, named hereafter as GloRED a, contains erosivity values were used for calculating R-factor using the following relationship equation (2) provided below.

$$R = \sum_{i=1}^{12} 1.735 \times 10 \left(1.5 \times log_{10}\left(\frac{p_i^2}{p}\right) - 0.08188\right) \quad \text{-------------- (2)}$$

Here R is the rainfall erosivity factor (MJ mm ha^{-1} h $^{-1}$ yr^{-1}), P_i is the monthly rainfall (mm), and P is the annual rainfall (mm). For the present analysis, R-factor for the Nandivargam small-watershed was computed from available gridded rainfall data, because the watershed has no record of daily rainfall intensity. For assessing the spatial variability in rainfall, the ArcGIS software was utilized employing spatial interpolation techniques. While assessing the R-factor, it was found that, the variation of R-factor among the rain gauge stations were in the limit of ±3. To enhance the reliability of the R-factor value, the spatial distribution of R was computed based on the available rainfall data. The average R value obtained from this calculation was then utilized for further analysis. The highest value (946.743 MJ mm ha^{-1} h^{-1} yr^{-1}) of R-factor was observed and the lowest value (758.87 MJ mm ha^{-1} h^{-1} yr^{-1}) (Fig-03). Factors for evaluating erosion in an incorporated integrated assessment framework.

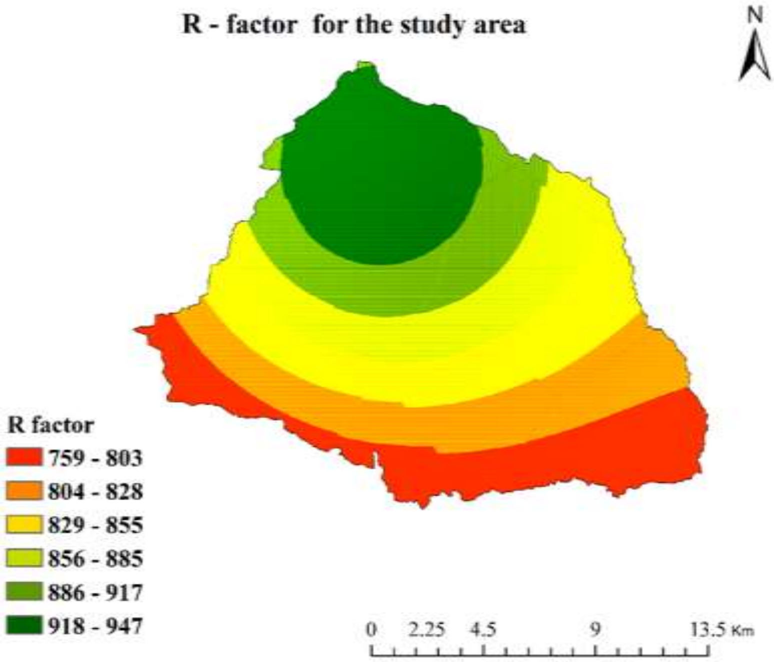

Figure 03: R - Factor for the study area (Rainfall erosivity)

3.4 Soil Erodibility Factor (K)

K is the soil erodibility factor is the average soil loss in tons/hectare for a particular soil in cultivated, continuous fallow with an arbitrarily selected slope length of 22.13 m and slope steepness of 9 %. K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute [23]. The soil erodibility value typically falls within the range of 0 to 1, where 0 represents low sensitivity to erosion for a soil class, while 1 indicates a high susceptibility of the soil class to water erosion (Fig-04). The K factor value was derived by applying a formula adapted from existing published literature, with the FAO systematized digital soil map as follows [26]. The calculation of this factor is made as follows according to [27] equation (3–7).

$$K_{USLE} = K_W = F_{csand} \times F_{cl\text{-}si} \times F_{orgc} \times F_{hisand} \quad \text{----- (3)}$$

$$F_{csand} = \left(0.2 + 0.3 \times \exp\left[-0.256 \times m_s \times \left(\mathbf{1} - \frac{m_{silt}}{\mathbf{100}}\right)\right]\right) \quad \text{----- (4)}$$

$$F_{cl-si} = \left(\frac{m_{silt}}{(m_c + m_{silt})}\right) \quad \text{----- (5)}$$

$$F_{orgc} = \left(1 - \frac{0.25oegC}{orgC+\exp[3.72-2.95\times orgC}\right) \quad \text{----- (6)}$$

$$\mathrm{F_{hisand}} = \left(1 - \frac{0.7\times\left(1-\frac{m_s}{100}\right)}{\left(1-\frac{m_s}{100}\right)+exp[-5.51+22.9\left(1-\frac{m_s}{100}\right)}\right) \quad \text{---- (7)}$$

FAO Digital Soil Map of the World (DSMW) in ESRI shape file format was utilized to create a K factor map. The estimated K values for the different textural groups range from 0.13 t hMJ^{-1} mm^{-1} for sandy clay loam to 0.14 t hMJ^{-1} mm^{-1} sandy clay soil.

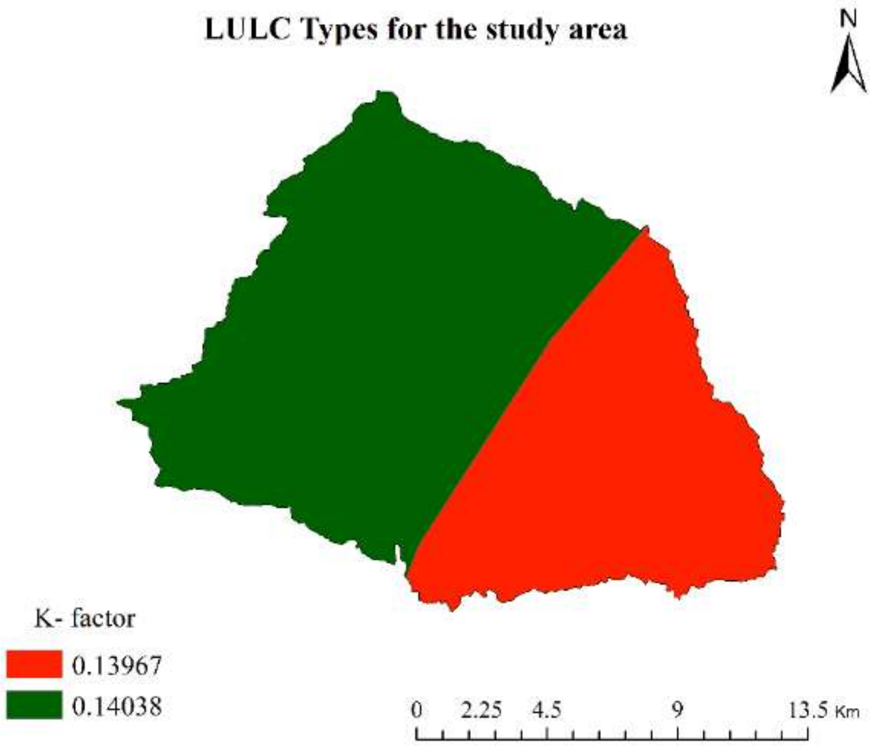

Figure 2: K – Factor for Study Area (Soil Erodibility)

3.5 Slope length and steepness factor (LS):

Slope Length and Steepness Factor (LS) LS-factor symbolizes the impact of slope length (L) and its steepness (S) on the soil erosion. The LS-factor in the Revised Universal Soil Loss Equation (RUSLE) represents the ratio of soil loss on a specific slope length and steepness to the overall soil loss [19], [25]. In this study, we used a digital elevation model (DEM) with 30 m resolution obtained from the Advanced Space borne Thermal Emission and Reflection Radiometer Global. Digital Elevation Model ASTER-GDEM was utilized within the ArcGIS 10.8, compute the LS-factor in the model maker. The LS-factor was calculated using equation (8) as follows:

$$\mathrm{LS} = \left[\frac{Flow\ accumulation\times Cell\ size}{22.13}\right]^{0.4}\times\left[\frac{(sinslope)}{0.0896}\right]^{1.3} \quad \text{----- (9)}$$

Where flow accumulation denotes the accumulated upslope contributing area for a given cell and was derived from DEM having cell size 30 m and sin slope is nothing but sin of slope angle in degrees. LS = combined slope length and slope steepness factor, cell size = size of grid cell (for this study 30 m) and sin slope = slope degree value in sin. The LS factor value in the study area varies from 0 to 155 (Fig-05). The Majority of the study area has LS value ranges between 0 and 15.2.

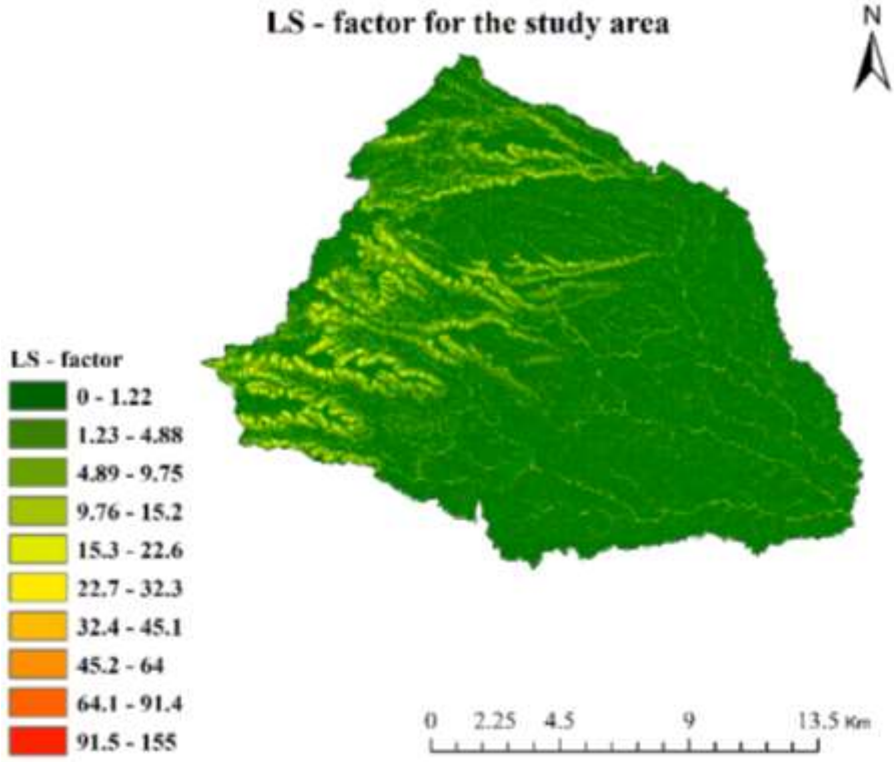

Figure 05: LS- Factor for the study area (Slope length)

3.6 Cropping Management Factor (C)

The C-factor is the most significant parameter for crop management but is not present for all Indian crops. Thus, C-factor founded [9], was used to estimate the rate of soil erosion in agricultural fields. The ground covered by vegetation canopy reduces the rate of soil erosion in the forested area. According to [6], crop cover is a potent tool for reducing the direct effect of rainfall on soil erosion, and he suggested that through the use of appropriate land reclamation techniques, bare land should be turned into agricultural land or a forest plantation. The values of the C-factor depend on seasonal changes as it varies with different parameters, such as crop types, rainfall, agriculture practice, etc. The C-factor was calculated based on the study area's LULC classification (Table-02). The overall accuracy of the classification Nandivargam watershed was classified into five LULC classes: built-up area, forest area, water body, agriculture lands, and land with and without scrubs, (Fig-06). Landsat 8 image was classified using supervised classification technique in GIS 10.8 software. The supervised classification technique requires ground truth information for each LULC.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 1, July : 2023

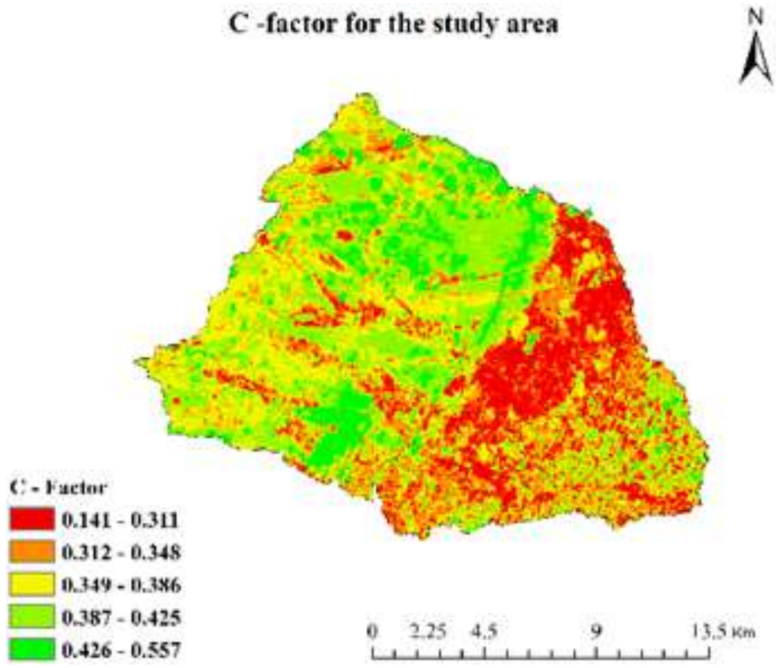

Figure 06: C- Factor for the study area

3.7 Conservation Practice Factor (P)

The P factor represents the ratio of soil loss with a specific support practice to the corresponding soil loss without support measures, specifically considering tillage practices on upslope and downslope areas [20].

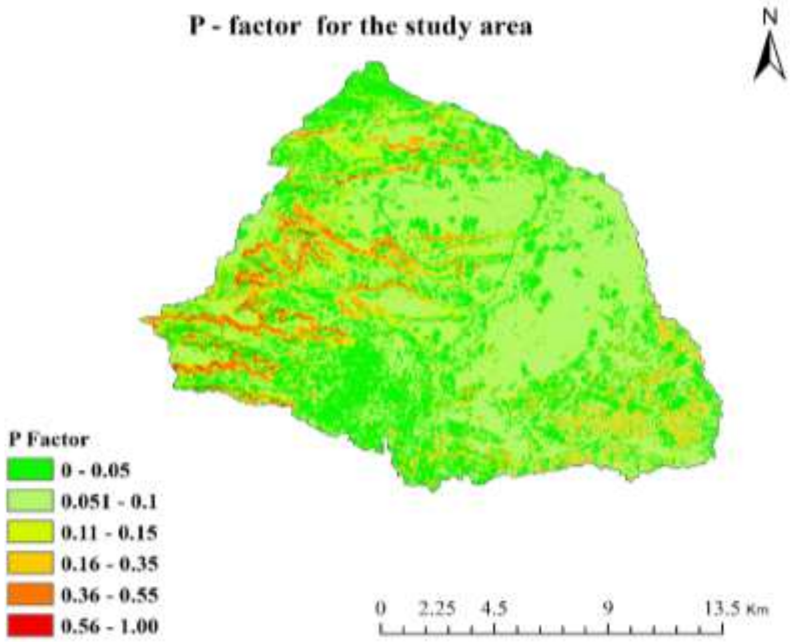

Figure 07: P- Factor for the study area (Conservation Practice)

Typically, the conservation practice factor adjusts the estimation of the Revised Universal Soil Loss Equation (RUSLE) to account for management and tillage practices that protect the soil from erosion. The P factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil. The value of P factor ranges from 0 to 1, the value approaching to 0 indicates good conservation practice and the value approaching to 1 indicates poor conservation practice. In this study, the P factor map was generated based on land use/land cover and support factors. The values of the P factor range from 0.05 to 1, as depicted in (Fig-07). Higher values are assigned to areas where no conservation practices are implemented, while lower values correspond to built-up areas and plantations employing strip and contour cropping techniques.

4. Results and Discussion:

Average Annual Soil Loss the data layers (Maps) extracted for the R, K, LS, C, and P factors of the RUSLE model was performed using Equation (1) within the raster calculator option of the ArcGIS spatial analyst. This process allowed for the quantification, evaluation, and generation of maps depicting soil erosion risk and severity within the Nandivargam Small-watershed. The estimated (A) values obtained indicate the rate of sediment yield, with higher values representing a higher rate and lower values indicating a lower rate. Based on the analysis, the Nandivargam small-watershed was classified into five soil erosion risk categories, as shown in (Fig-08). The distribution and proportion of soil erosion risk classes are presented in (Table 3). The minimum and maximum soil losses were found to be approximately 31.17 $t \cdot ha^{-1} \cdot y^{-1}$ and 3974.7 $t \cdot ha^{-1} \cdot y^{-1}$, respectively. Approximately 94.11% (226.544 km^2) of the watershed falls within the range of 0 $t \cdot ha^{-1} \cdot y^{-1}$ and 31.17 $t \cdot ha^{-1} \cdot y^{-1}$, indicating varying degrees of soil erosion within the study area. The results presented in show that about 94.11% of the study area is classified as medium potential erosion risk (31.17t h^{-1} y^{-1}) erosion risk levels. The spatial pattern of classified soil erosion risk zones indicates that the areas with high and severe erosion risk are located (Table-04).

Table 3. Classification of soil loss of sub - watershed according to area of Nandivargam

Soil Loss ($t \cdot ha^{-1} \cdot y^{-1}$)	**Area (km^2)**	**Area (%)**
0 - 31.17	226.54	94.11
31.18 - 124.7	9.008	3.74
124.71 - 249.39	4.149	1.72
249.4 - 405.26	0.090	0.038
> 405.27	0.002	0.02
Total	**240.72**	**100**

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 1, July : 2023

Table 4. Classification of erosion risk

Erosion Rick Class	Soil loss ($t.ha^{-1}.y^{-1}$)
Medium	0-31.12
High	31.18-124.70
Very High	124.71 - 249.39
Very High	249.4 - 405.26
Very High	>405.27

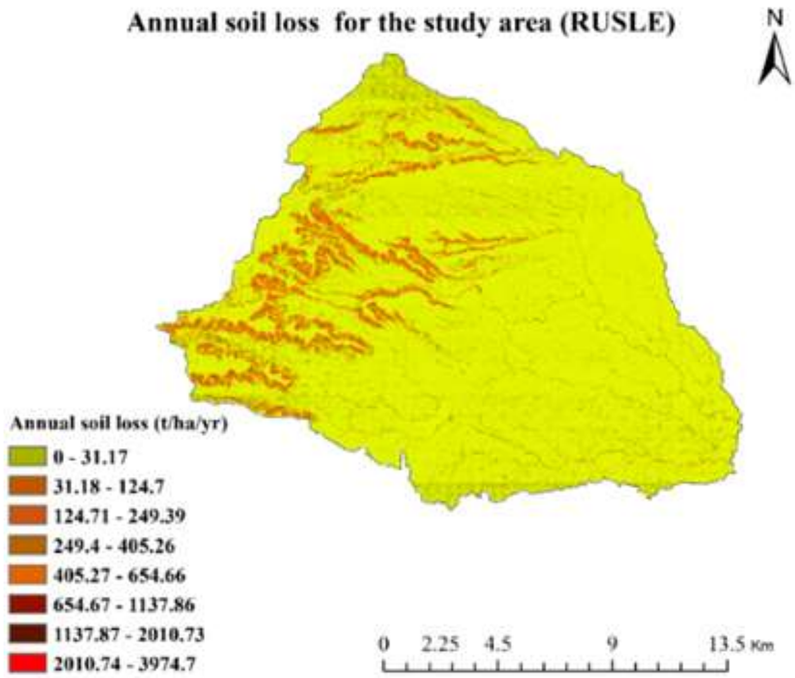

Figure 08: Soil erosion

5. Conclusion:

This study successfully utilized the Revised Universal Soil Loss Equation (RUSLE) and GIS to assess soil erosion in the Nandivargam small-watershed. Key factors driving erosion were identified as steep slopes, slope morphology, soil erodibility, and plant cover. Rainfall and runoff played significant roles in soil detachment and erosion. To mitigate soil loss and restore the watershed's functionality, comprehensive measures are required. GIS effectively managed and analyzed land degradation data, providing a comprehensive understanding of erosion processes. Medium land degradation affected 94.11% (226.54 km^2) of the study area due to rainfall, while mining activities degraded 5.89% (14.18 km^2). Mining led to land disturbance, pits, overburden dumps, altered drainage, and waterway obstruction. Deforestation, gully erosion, and drainage alteration were observed, reflecting the community's response to economic expansion and environmental challenges. This highlights the interconnectedness between human activities and soil degradation, emphasizing the importance of sustainable land management. The study demonstrates the effectiveness of GIS in simulating and mapping soil erosion, supporting decision-making and erosion control strategies. To address soil erosion in the Nandivargam small-watershed, the following measures are recommended: prioritize soil conservation in erosion-prone areas through measures like terraces, contour plowing, and vegetative strategies such as cover crops and grass strips; improve plant cover through reforestation, afforestation, and sustainable agricultural practices; encourage responsible mining techniques that minimize land disturbance, ensure proper waste disposal, and rehabilitate mined areas; implement effective water management practices, including drainage systems, retention ponds, and sedimentation prevention measures; conduct educational programs, workshops, and outreach activities to raise awareness and involve communities in soil conservation; establish a monitoring system to assess the effectiveness of measures and track changes in soil erosion patterns; foster collaboration among government agencies, local communities, researchers, and NGOs to achieve coordinated erosion control efforts.

Abbreviations:

GIS: Geographic Information System; IMD: Indian Meteorological Department; LULC: Land use/land cover; RS: Remote Sensing; RUSLE: Revised Universal Soil Loss Equation; t.ha.h/ha.MJ.mm: ton hectare hour / hectare mega joule millimetre; GDEM: Global Digital Elevation Model.

Reference

[1] A.S. Jasrotia, R. Singh (2006). Modeling runoff and soil erosion in a catchment area, using the GIS, in the Himalayan region, India. *Environmental Geology, 51 (2006), pp. 29-37*

[2] Angima SD, Stott DE, O'Neill MK, Ong CK, Weesies GA (2003) Soil erosion prediction using RUSLE for central Kenyan highland conditions. *Agric Ecosyst Environ 97(1–3):295–308*

[3] Arnoldus, H.M.J., 1980. An approximation of the rainfall factor in the Universal Soil Loss Equation. In: De Boodt, M., Gabriels, D. (Eds.), Assessment of Erosion. Wiley, Chichester, UK, pp. 127-132

[4] 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, 1783–1798.

[5] Douglas IAN (2006) the local drivers of land degradation in South-East Asia. *Geogr Res 44(2):123–134*

[6] Jabbar, M.T. Application of GIS to estimate soil erosion using RUSLE. *Geo-Spat. Inf. Sci. 2003, 6, 34–37.*

[7] Jain, S.K., Kumar, S., Varghese, J., 2001. Estimation of soil erosion for a Himalayan watershed using GIS technique. *Water Resources Management 15, 41-54.*

[8] Jenson, S.K. and Domingue, J.O., 1988. Extracting topographic structure from digital elevation data for geographic information system analysis. *Photogrammetric engineering and remote sensing*, *54*(11), pp.1593-1600

[9] Karaburun A (2010) Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed. *Ozean J Appl Sci 3(1):77–85*

[10] Kouli, M., Soupios, P., Vallianatos, F., 2009. Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS frame-work, Chania, Northwestern Crete, Greece. *Environmental Geology 57, 483-497.*

[11] Kurnool District Census Handbook, Series -29, *Census of India 2011, Andhra Pradesh.*

[12] Mark, D.M. (1984). Automatic Detection of Drainage Networks from Digital Elevation Models. *Cartographica, 21(2/3): 168-178.*

[13] Martz, L.W. and Garbrecht, J., 1999. An outlet breaching algorithm for the treatment of closed depressions in a raster DEM. *Computers & Geosciences*, *25*(7), pp.835-844.

[14] Millward, A.A., Mersey, J.E., 1999. Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. *CATENA 38 (2), 109 – 129*

[15] MOORE, I.D., GRAYSON, R.B. and LANDSON, A.R., 1991, Digital terrain modeling: a review of hydrologic, geomorphologic, and biological applications. *Hydrologic Processes, 5, pp. 3–30.*

[16] Narayana, D.V. and Babu, R., 1985. Closure to “Estimation of Soil Erosion in India” by Dhruva VV Narayana and Ram Babu (December, 1983). Journal of Irrigation and Drainage Engineering, 111(4), pp.408-410.

[17] Pandey, Ashish, V. M. Chowdary, and B. C. Mal. "Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing.*" Water resources management 21 (2007): 729-746.*

[18] Prasannakumar V, Vijith H, Abinod S, Geetha N (2012) Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using revised universal soil loss equation (RUSLE) and geo-information technology. Geosci Front 3(2):209–215.

[19] Remortel, R. D. V., Hamilton, M. E., & Hickey, R. J. (2001). Estimating the LS factor for RUSLE through iterative slope length processing of digital elevation data within arclnfo grid. Journal of Cartography, 30(1), 27–35.

[20] Renard KG, Foster GR, Weesies GA, McCool DK, Yoder DC (1997) Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture *Handbook No. 703, USDA-ARS*

[21] Shrestha DP (1997) Assessment of soil erosion in the Nepalese Himalaya: a case study in Likhu Khola Valley, Middle Mountain Region. *Land Husband 2(1):59–80*

[22] Srinivas CV, Maji AK, Reddy GPO, Chary GR. Assessment of soil erosion using remote sensing and GIS in Nagpur district, Maharashtra for prioritisation and delineation of conservation units. *Journal Indian Society of Remote Sensing. 2002; 30(4):197-212.*

[23] Stone RP, Hilborn D (2012) Universal soil loss equation (USLE) factsheet. Ministry of Agriculture, *Food and Rural Affairs, Ontario*

[24] Thomas, J., Joseph, S., and Thrivikramji, K.P., 2017. Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS. Geoscience Frontiers. *doi:10.1016/j.gsf.2017.05.011*

[25] Tung Gia Pham, Jan Degener, Martin Kappas (2018), integrated universal soil loss equation (USLE) and Geographical Information System (GIS) for soil erosion estimation in A Sap basin: *Central Vietnam, International Soil and Water Conservation Research, Volume 6, Issue 2, 2018, Pages 99-110, ISSN 2095-6339*

[26]United States Department of Agriculture. EPIC-Erosion/productivity Impact Calculator 1. Model Documentation; Technical Bulletin Number 1768; *United States Department of Agriculture: Washington, DC, USA, 1990.*

[27] Williams JR (1995) Chapter 25. The EPIC Model. In: Computer models of watershed hydrology. Water Resources Publications. Highlands Ranch. pp 909–1000

[28] Wischmeier, W. H., Smith, D. D., 1978. Predicting rainfall erosion losses, a guide to conservation planning. Agric. *Handbook. No. 537, US Department of Agriculture, Washington, DC.*