



# **Estimation of Soil Loss by Revised USLE Model using Geospatial Techniques: A Case Study of Sainj Valley, Northwestern Himalaya, India**

**Dharam Chand <sup>a</sup> and Renu Lata <sup>a\*</sup>**

<sup>a</sup> G.B. Pant National Institute of Himalayan Environment, Mohal Kullu, 175126, India.

## **Authors' contributions**

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

## **Article Information**

DOI: 10.9734/JGEESI/2023/v27i10721

## **Open Peer Review History:**

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/107534>

**Original Research Article**

**Received: 06/08/2023**

**Accepted: 13/10/2023**

**Published: 18/10/2023**

## **ABSTRACT**

Soil erosion is a severe environmental problem. The current study is being conducted in Sainj valley of Himachal Pradesh. An increase in soil erosion rates has significant effects on land degradation, biodiversity loss, productivity and other factors. The Revised Universal Soil Loss Equation (RUSLE) model along with, Geographic Information System (GIS) and Remote Sensing (RS), was used in current study to quantify soil loss in the Sainj valley. Five important parameters like, Rainfall erosivity factor (R), Soil erodibility factor (K), Slope length and steepness (LS), Cropping management factor (C), and support practice factor (P) have been used to estimate the amount of soil loss in the study area. All these maps were created in GIS software using a variety of data preparation methods. The rainfall erosivity factor ranged between 501.19 to 1097.23 mt ha<sup>-1</sup> cm<sup>-1</sup>. Spatial distribution of conservation support practice on soil loss indicated the variability (0–1) where lower value represents the higher conservation practice. The results show that average

\*Corresponding author: E-mail: [renu\\_15@yahoo.co.in](mailto:renu_15@yahoo.co.in); [renunegi15@gmail.com](mailto:renunegi15@gmail.com);

annual predicted soil loss is between 0 to 541.52tons/ha/yr and the predicted Average soil erosion rate was 11.15 tons/ha/Yr. Predicted soil loss was classified into six Erosion intensity classes Negligible (0-5), Low Erosion (5-10), Moderate Erosion (10-25), Moderately high (25-75), High Erosion (75-100), Extremely High Erosion (>100) From soil loss estimation it was observed that 62 % of the area is having very low erosion intensity and 0.37% of the study area having Extremely High erosion intensity. These findings can help the decision makers further in developing a suitable conservation program to prevent soil erosion.

*Keywords: Soil erosion; RUSLE; rainfall erosivity factor; cropping management; support practice factor; erosion intensity.*

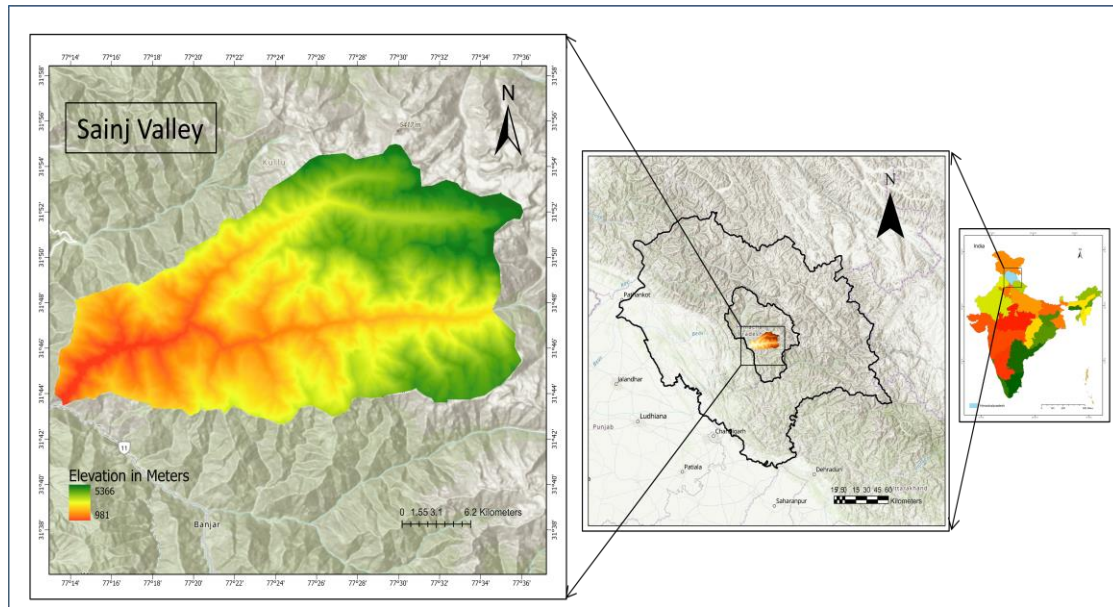
## 1. INTRODUCTION

Soil erosion is a natural process associated with geomorphic processes or agents such as running water, winds etc. Soil erosion is a widespread and serious threat to survival and well being. Since soil formation is a very slow process, once removed completely, soil will take thousand and millions of years to form again and meantime land will be unproductive. In order to assess soil loss and identify watershed areas most likely to experience critical erosion, RS and GIS techniques are used [1]. The biophysical environment which includes soil, climate, terrain, ground cover, and interaction between them, affects how soil erosion occurs. Slope length, aspect and shape of the terrain are significant terrain characteristics influencing the mechanism of soil erosion [2].The evaluation of soil erosion in developing countries is a difficult task primarily because the crucial data are insufficient or occasionally unavailable [3].In study of Admankar and Patil [4] the relationship between C factor and soil loss is Good ( $R^2=0.99$ ). This implies that the influence of crop management factor on soil loss is higher. Lee suggested in their study [5] R factor will be used to identify areas at risk of soil disasters and to establish soil conservation plan. The topsoil is more susceptible to soil erosion due to the frequency of higher intensity rainfall erosivity [6]. Soils in the regions of cultivation are susceptible to erosion because of their low organic matter content and poor soil structure, according to the relationships between soil properties, land-use systems, and erodibility [7]. Important factors affecting soil erosion by water include soil characteristics, heavy rainfall, unusual weather patterns, complex terrain, and land use [8].On these aspects, numerous studies have been carried out globally using the GIS and the USLE and RUSLE approaches [9]. The estimated annual soil loss in Kashmir's Lidder catchment area ranges from 0 to 61 tonnes per hectare. Agricultural areas

experienced the highest average soil loss (26 tones  $ha^{-1} yr^{-1}$ ) whereas forest witnessed the lowest soil loss rates ( $0.99 \text{ tons } ha^{-1} yr^{-1}$ ) [10]. Lower Himalayan regions's Suketi watershed is situated in a region of moderated to high runoff and erosion risk. The study's results will benefit a wide range of stakeholders, which include farmers, water resource manager and decision maker in order to improve management procedures and decision making [11]. In the study of Tariq and Li [12] the finding shows that for the water year 2020, the estimated total annual potential soil loss of 4,67,064.25 tonnes  $ha^{-1}.year^{-1}$  is comparable to the observed sediment loss of 11,631 tonnes  $ha^{-1}.year^{-1}$ . An increase in agricultural area is expected to result in a predicted soil erosion rate of about 164,249 tones  $ha^{-1}.year^{-1}$ . The ability of regions to develop sustainably is severely hampered by soil erosion, which frequently results in land degradation, decreased agriculture production, and environmental deterioration. Major finding of this study demonstrates that machine learning approach's superior capacity for modeling soil erosion and investigating its causes [13].RUSLE, enhanced by GIS and RS, assessed soil loss in Nagavangala watershed, Karnataka, aiding conservation planning. Dominant land uses were cropland (41.81%) and agricultural plantation (41.5%). Average annual soil loss was 9.80 t/ha/year, highest in scrubland (10.58 t/ha/year) and cropland (10.2 t/ha/year). The resulting erosion map guides strategic soil and water conservation efforts for sustainable resource management [14].

### 1.1 Study Area

Present study was conducted at Sainj valley in district Kullu of Himachal Pradesh. Sainj is 49 Kilometers far from the district headquarter in Kullu. Sainj valley falls under the left bank of upper Beas river system in the lesser Himalayan alpine zone [15].The Sainj valley comprises of



**Fig. 1. Study area map of Sainj valley**

Area 528.99 Km<sup>2</sup> in size (Fig. 1). Study area lies within the altitudinal range of 981m to 5366m. The study area (528.99 km<sup>2</sup>) located between latitudes 31°43'3" and 31°54'51"N and longitudes 77°13'28" and 77°35'48"E. Sainj experiences 1,387 mm of rainfall annually, with an average annual temperature of 20.6 °C. Sainj valley situated in the Great Himalayan national park's lower ranges. The primary rock types in the study area are granites, colluviums, slate, quartzites, dolomites, alluviums, and glacial deposits. The Sainj river is the main river that flows through the Sainj valley. Sainj river originates from the Raktisar glacier (+5500m) and there after it flows toward the South-west direction to join the Beas River at Larji village. The river Sainj and its tributaries are home to a diverse range of cold water fish, with trout reigning supreme. During the winter season, the region's average annual snowfall is about 345 mm, and it is mostly restricted towards the upper reaches of the Sainj river catchment.

## 2. MATERIALS AND METHODS

The USLE was developed by Weishmeier and Smith [16] and is used in many countries all over the globe. For the estimation of soil erosion by Revised Universal Soil Loss Equation (RUSLE) we have used five parameters which is depicted in (Fig. 2)

The USLE soil loss equation is:

$$A=R*K*LS*C*P$$

In this equation:

- A = Potential Average Annual Soil Loss
- R=Rainfall- Runoff Erosivity Factor
- K= Soil-Erodibility Factor
- L=Slope Length Factor
- S= Slope Gradient Factor
- C= Cropping Management Factor
- P= Support Practice Factor

### 2.1 Rainfall Erosivity

Rainfall and soil erosion are interlinked with each other through the combined effect of detachment of raindrops striking the soil surface and by runoff [17].The primary causes of soil erosion by water in forestland are wildfires and logging [18]. Rainfall erosivity factor (R) is calculated from the Rainfall erosivity equation given by Wischmeier and Smith in 1978 [11]

$$R= 0.5 * P^{1.73}$$

Here R is the Rainfall erosivity Factor and P is the Mean annual rainfall in mm. In Sainj valley values of rainfall ranges from 579.41 to 1268.48mm (Fig. 3). Rainfall data was downloaded from Terra climate lab's website for 2021 year in netcdf file format. Downloaded netcdf was then imported to the Arc GIS pro in raster form (using netcdf to raster tool) then the raster file was converted to point vector file. Furthermore, the point data was used to generate the map for the basin extent using IDW interpolation technique.

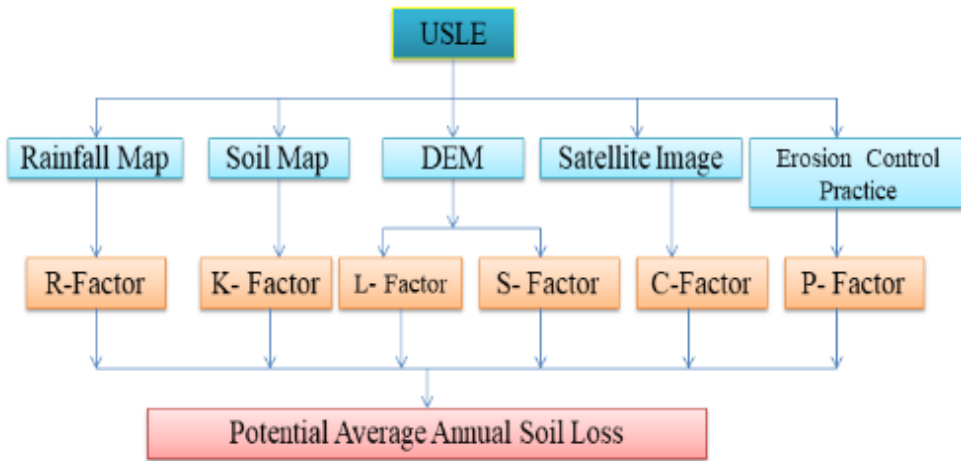


Fig. 2. Flow chart of the study area

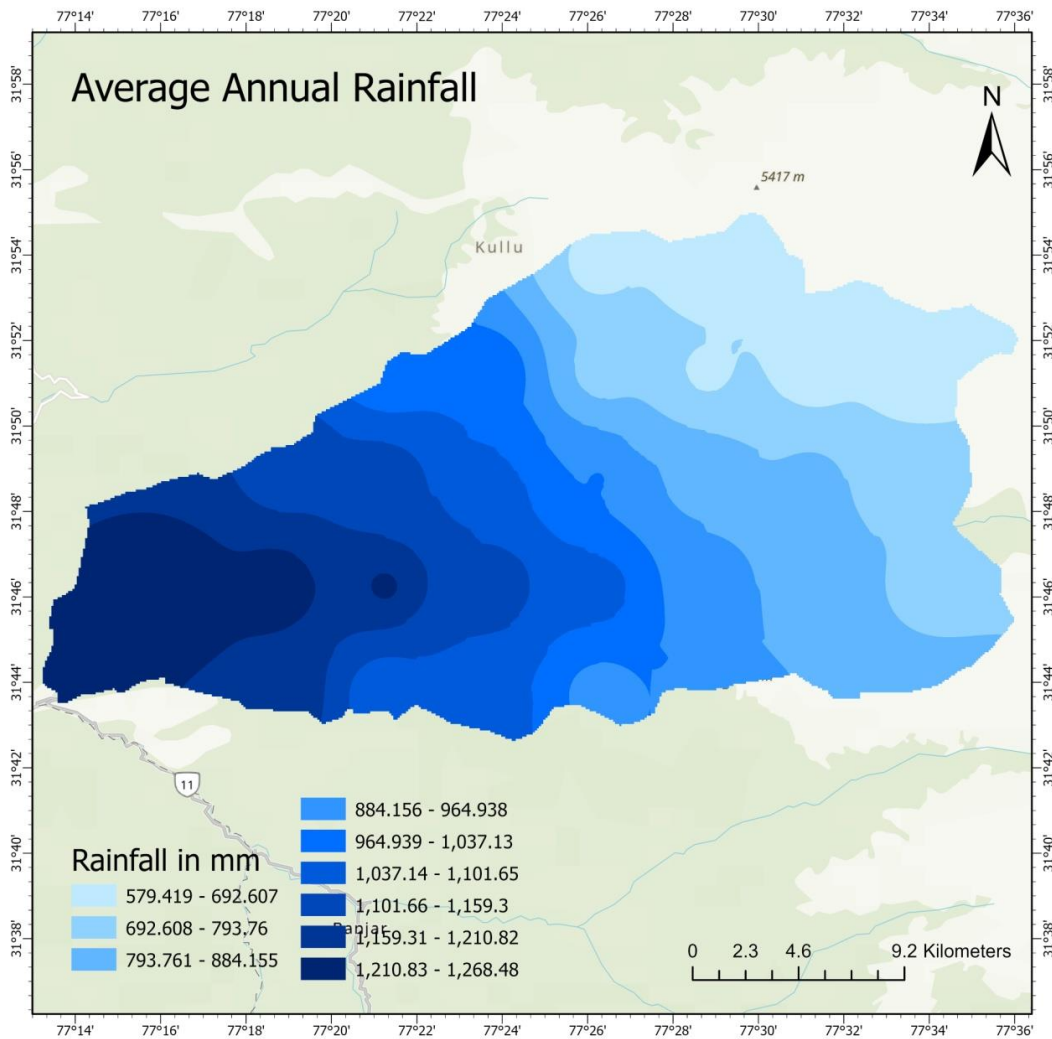


Fig. 3. Annual average rainfall in Sainj

## 2.2 Soil Erodibility Factor

One of the most significant factors required to determine or estimate soil loss globally is soil erodibility, which has been proven to be strongly correlated with the soil loss [19]. Soil erodibility refers to the association between the combined impacts of rainfall, runoff and infiltration on soil loss as well as the effect of soil qualities and soil profile characteristics on soil loss [20]. Based on topographical and lithological properties, soil type differs from one region to another. The Erodibility of soil (K) is an important index; it aids to determine the soil's erodibility. The USLE nomograph was used to estimate the K-Values of various soil types [16]. There are 4 type of soil within the Sainj valley Loamy, Rock outcrop, Glacier and rock crop, Sandy. Soil map shows only 4 soil classes viz Loamy, Rock outcrop, Glacier and rock outcrop, Sandy (Fig. 4) which covers almost 37.57%, 8.12%, 8.54%, 45.74% of the study area respectively (Table 1).

**Table 1. Soil classification in Sainj valley**

Soil Type	Area in Km <sup>2</sup>	% of Area
Loamy	197.12	37.57
Rock outcrop	42.64	8.12
Glacier and Rock outcrop	44.84	8.54
Sandy	239.96	45.74

## 2.3 Topographic Erosivity Factor (LS)

Topographic factors (LS) are gradient slope length factors that include slope length (L) and slope steepness (S) [21]. One of the most important parameter in the RUSLE analysis is the topographic erosivity factor (LS). When the length of slope increases, because of the increased accumulation of surface runoff, soil erosion by water increases. The flow accumulation and slope values are used to calculate the slope gradient and slope length factor. GIS and RS are nowadays generally viewed as essential tools for the natural management studies; therefore almost all researchers use DEM and GIS tools to measure LS in soil erosion studies [22]. The Topographic erosivity factor (LS) map was created using the Arc GIS Pro .LS depend upon Slope and Length of slope of the area is computed from the DEM by the Following formula [23].

$$LS = (\text{Flow accumulation} * \text{Cell values} / 22.13 \text{ m}) * (\text{Sin } \beta / 0.0896)^n$$

The accuracy of estimation is determined by the resolution of the DEM. Topographic factor was calculated in Arc GIS Pro's spatial analyst module using a 30 m resolution SRTM DEM. Terrain of Sainj valley having very dense stream system and therefore "m" and "n" were respectively assigned 0.5 and 1.3 (Table 2) [24].

**Table 2. The variation of m-exponent and S-slope of variation**

m-Value	Slope degree
0.5	>5
0.4	3-5
0.3	1-5
0.2	<1

## 2.4 Cropping management factor (C-Factor)

"C" is the Crop management factor. The majority of researchers reported using these two factors as distinct factors when computing for USLE [25]. Majority of the study area is covered in numerous types of vegetation. The C factor ranges from 0-1 (Bare land). To calculate C factor NDVI of year 2021 has been used which is produced by using Google earth engine. NDVI of 2021 had been generating by using the Sentinel-2 10m for 1 January 2021 to 31 December 2021. NDVI map is the median for all the Tiles of year 2021 by using filtered scene with criteria i.e Cloudy Pixel percentage <=30%. NDVI was computed using equation suggested by Rouse [26] and shown in Fig. 5.

$$NDVI = (NIR - Red) / (NIR + Red)$$

The regression equation [27] was found as

$$C \text{ factor} = 1.02 - 1.21 * NDVI$$

Final C factor map was generated by using this regression equation in Arc GIS Pro software.

## 2.5 Support Practice Factor (P-Factor)

"P" is the erosion control practice or conservation factor. P factor depends upon the soil land use practices and also implementation of any soil erosion protection measures in the area (Such as Afforestation, slope stabilization, vegetative erosion traps etc.). To calculate P-Factor Sentinel- 2, 10m Land use land cover map (2021) has been used which is produced by ESRI, Microsoft and impact observatory (Fig. 6). The typical values of P-Factor (Table 3) based on the land use type and the erosion protection measures [28] presented in Table 3.

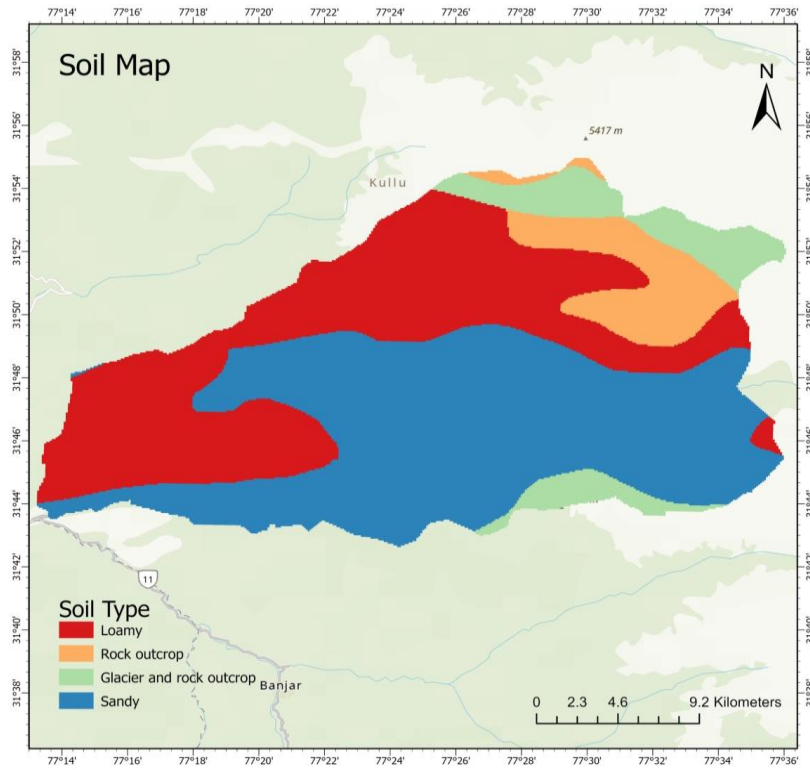


Fig. 4. Soil map of Sainj valley

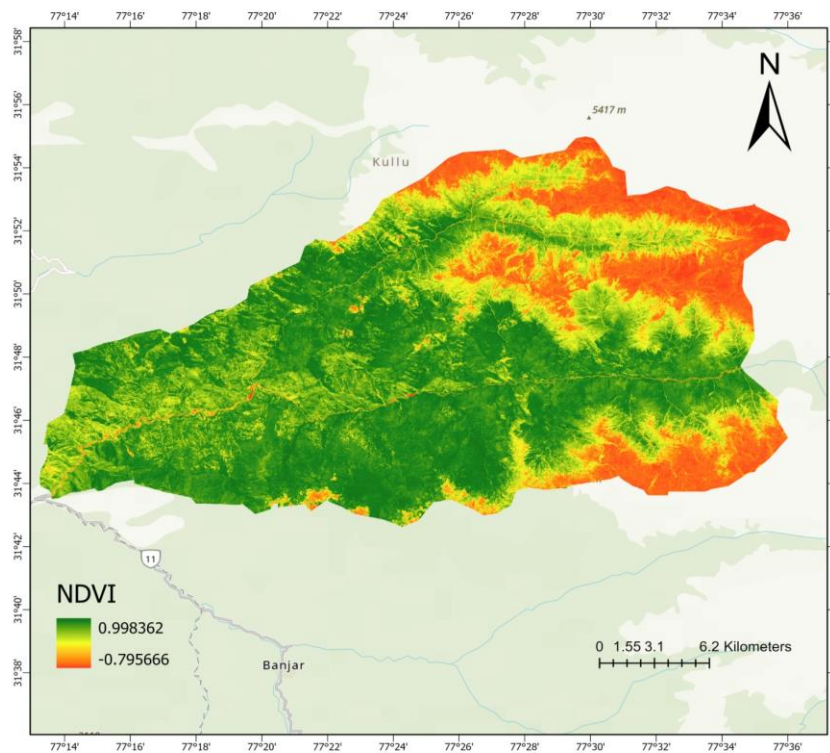
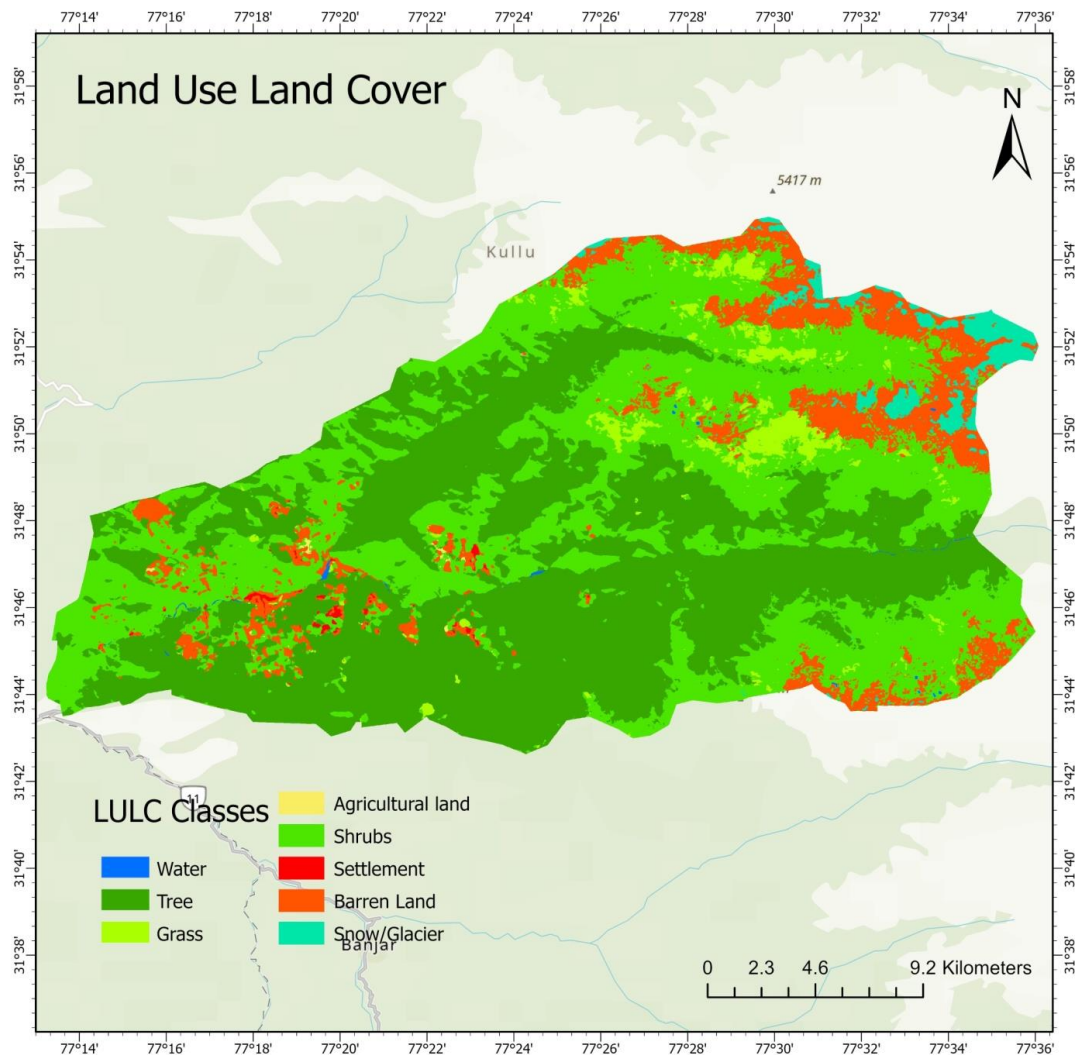


Fig. 5. NDVI Map of Sainj valley (2021)

**Table 3. P-factor values according to the land use type**

Land Use Type	P factor	Area(Km <sup>2</sup> )	% of Area
Water body	0.0	0.52	0.10
Tree	1.0	233.67	44.54
Grassland	0.9	14.85	2.83
Agricultural land	0.5	0.36	0.06
Shrubs	0.8	209.65	39.96
Settlements	0.1	1.11	0.21
Barren land	1	53.32	10.16
Snow/ Glacier	1.0	11.65	2.10



**Fig. 6. Land use/ Land cover Map of Sainj valley**

### 3. RESULTS AND DISCUSSION

#### 3.1 Rainfall Erosivity (R)

Rainfall erosivity is the soil erosion factor that has gained most attention during the last decade and a lot of research has been done to improve

the Erosivity Indexes [29]. For evaluating and controlling soil erosion, the rainfall erosivity map is important [30]. The annual rainfall erosivity factor (R) for the year was found to be in the range of 501.19 to 1097.23 mt ha<sup>-1</sup> cm<sup>-1</sup> signifies the variability in erosive potential, with higher values indicating a greater propensity for soil

erosion due to rainfall. Calculated rainfall erosivity factor for the study area is shown in Fig. 7.

### 3.2 Soil Erodibility (K)

The soil erodibility index or K-factor is described as the rate of soil loss per unit of R. Texture Organic Matter (OM) content, structure and permeability all have an influence in the soil erodibility [31]. The K factor, which determines the rate of soil loss per rainfall erosion index unit is influenced by six factors, including the organic matter content, permeability, and soil structures as well as the primary soil particles (Silt, Sand, clay) [32]. The K-Factor is quantitative criteria used in USLE model; the index can be interpolated to estimate soil erosion [33]. K factor map shows a maximum value of 0.3 and minimum value of 0 (Fig. 8).

### 3.3 Topographic Erosivity Factor (LS-Factor)

The LS factor in the study area was found to be in the range of 0 to 8.57 (Fig. 9). Steep slopes are defined by higher LS factor value [34]. Relative slope and steepness values (L & S) indicate how erodible a parcel of land is. The lowest value of LS factor was found along the Sainj River that flows toward west direction because the slope values are low near the river. The result demonstrates that the slope is very steep and the slope length is short. The LS factor, spanning 0 to 8.57, signifies the impact of slope length and steepness on soil erosion. Higher values indicate more challenging terrain, highlighting areas with increased erosion vulnerability due to topography. This factor causes a high rain flow rate, which causes severe soil erosion.

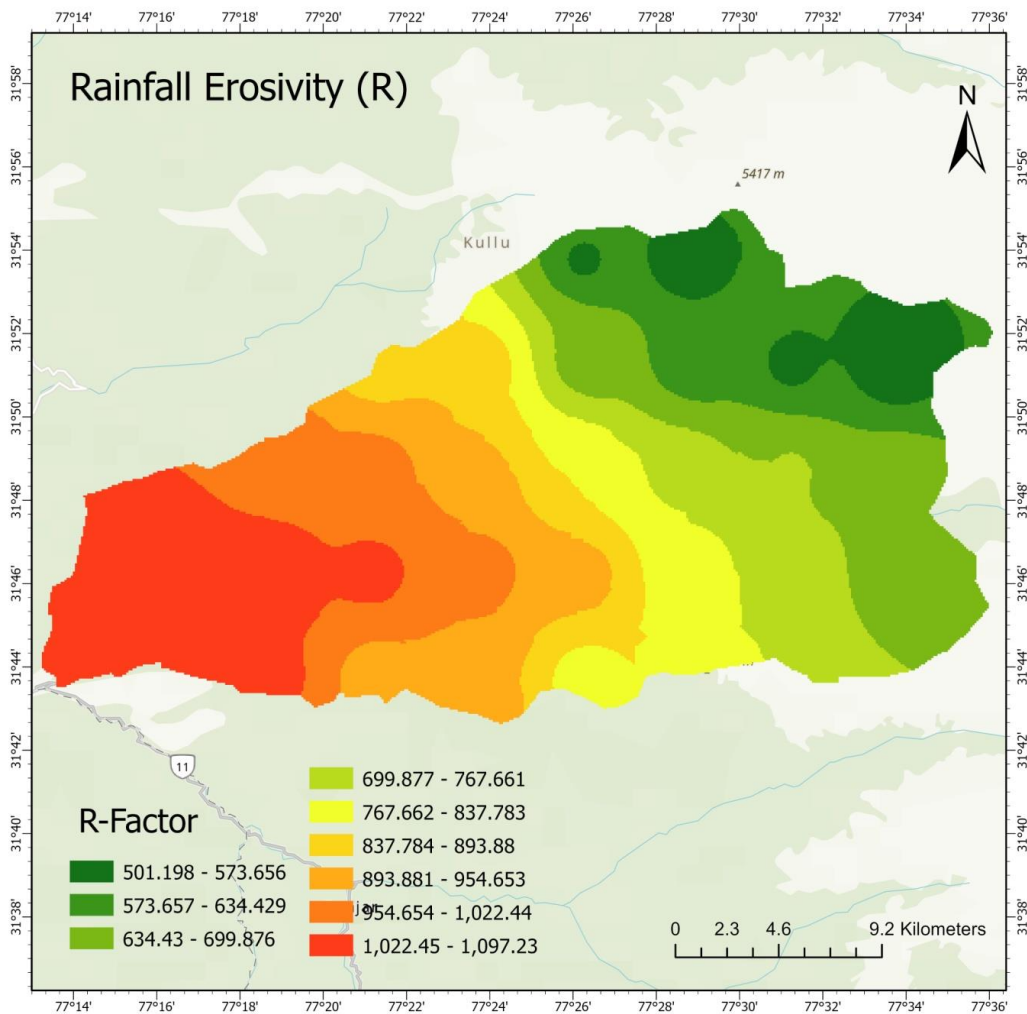
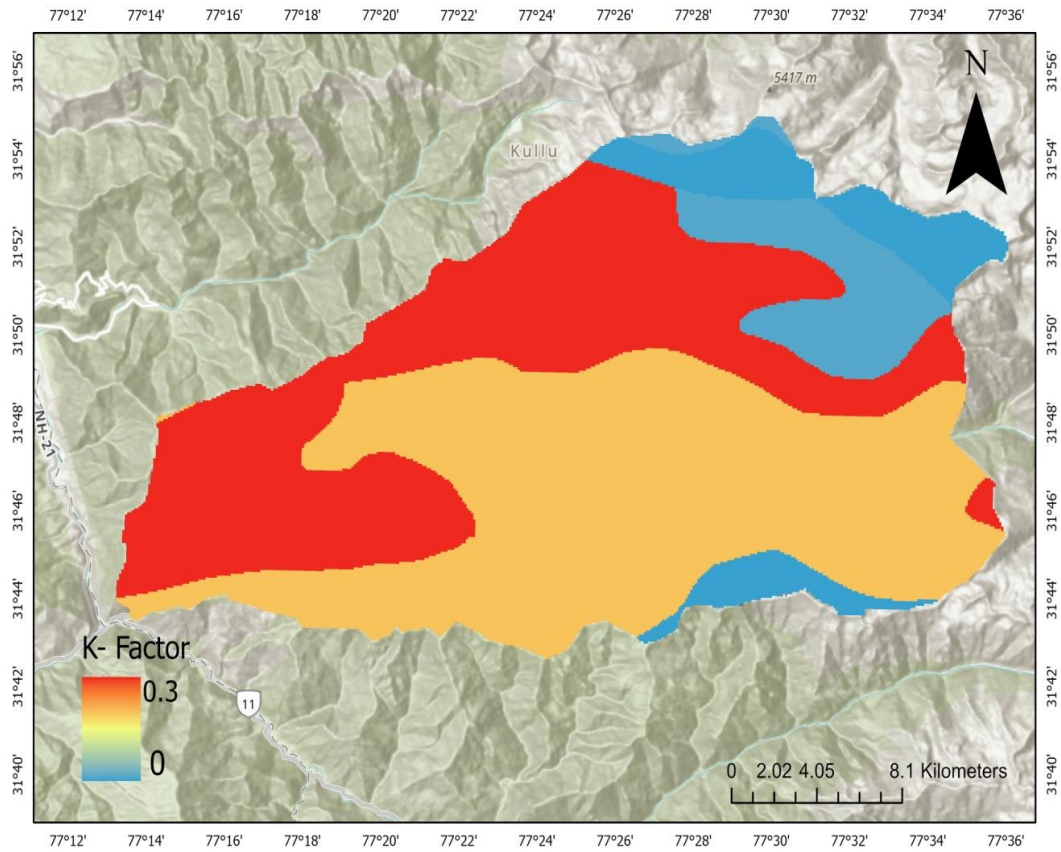


Fig. 7. R- Factor map of Sainj valley





**Fig. 8. Soil Erodibility map of Sainj valley**

**Table 4. P factor classification according to the Area**

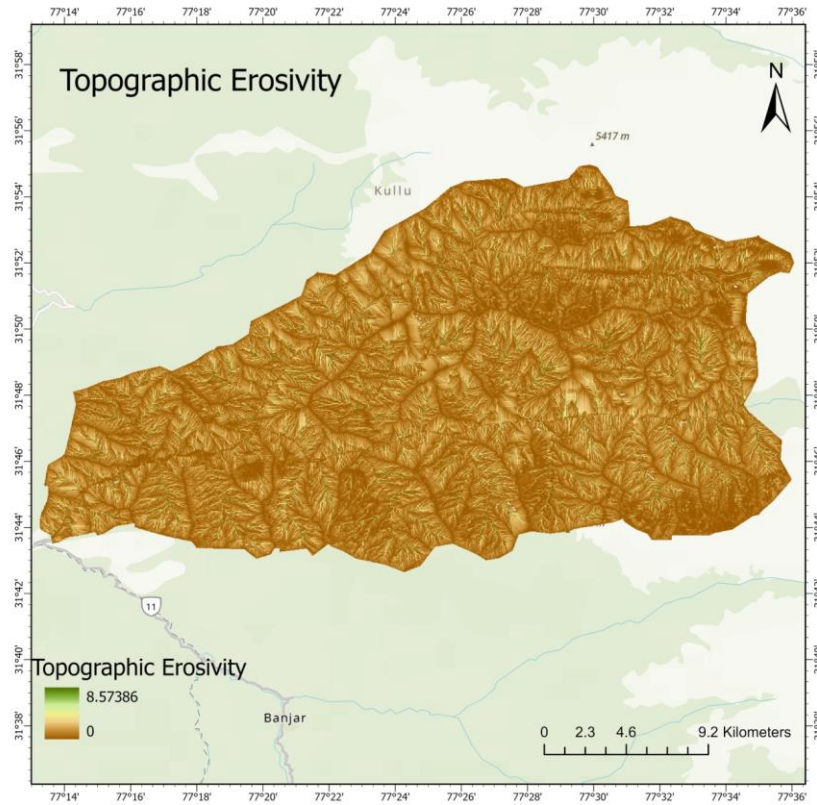
P Factor	Area in Km <sup>2</sup>	% of Area
0	0.49	0.09
0.1	1.18	0.22
0.5	0.39	0.07
0.8	211.19	39.92
0.9	14.93	2.82
1	300.78	59.85

### 3.4 Cropping Management Factor (C factor)

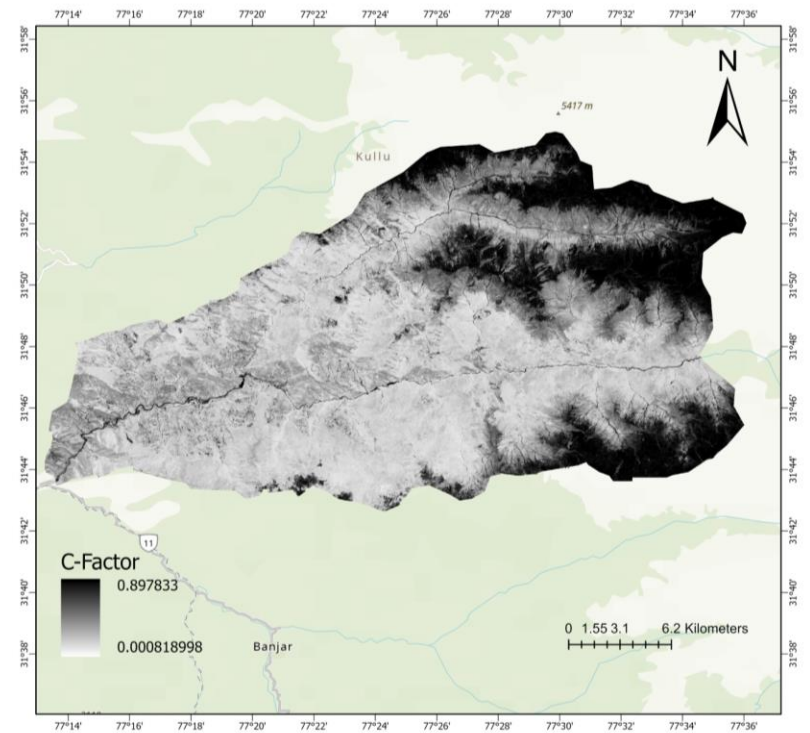
C- Factor was derived from the NDVI. NDVI is a crucial factor because it indicates the type of soil layer cover. Large scale soil erosion can be predicted and evaluated in a significant way due to the C-Factor [35]. The C factor values in the study area vary from 0.0008 to 0.8978 (Fig. 10). In the study area, higher values in the C-factor represents rocky area or barren land while lower values in the C-factor represents vegetation cover [36]. Lower values suggest effective soil conservation practices, while higher values imply increased erosion susceptibility.

### 3.5 Support Practice Factor (P)

P factor can differ according to the farming practices and level of conservation practices adopted particularly in the agricultural land. To create the Support practice factor, P values was assigned to the Land use land cover map of the area using Reclassify tool in Arc GIS. Distribution of Conservation support practice on soil loss ranges from 0 to 1 (Table 4). Resultant map was classified into 6 support practice classes 0, 0.1, 0.5, 0.8, 0.9, 1 (Fig. 11). The higher P-values indicate the lack of available soil conservation measures, while the lower P values indicate the higher conservation practice on the soil [36].



**Fig. 9. Topography Erosivity map of Sainj valley**



**Fig. 10. Crop management factor for Sainj valley**

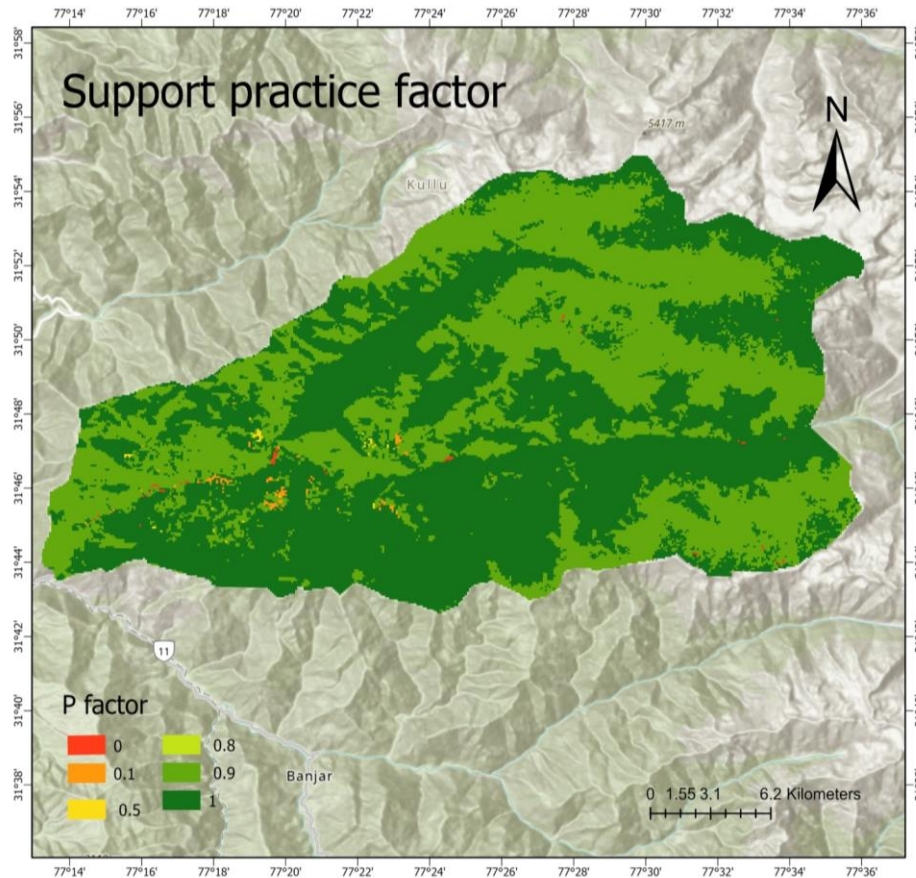


Fig. 11. Map showing spatial variability of Support practice factor

### 3.6 Average Annual Soil Loss (A)

Annual average soil erosion potential (A) has been computed by multiplying the developed raster data from each factor of RUSLE analysis. The resultant “A” factor map shows the average annual soil loss potential of the Sainj valley. Average annual predicted soil loss ranges between 0 to 541.52 tons  $ha^{-1}yr^{-1}$  (Fig. 10). Highest values of estimated soil erosion potential are 541.52 tons  $ha^{-1}yr^{-1}$ . The resultant map is classified into six classes viz. Negligible erosion (0-5 tons  $ha^{-1}yr^{-1}$ ), Low erosion (5-10 tons  $ha^{-1}yr^{-1}$ ), Moderate erosion (10-25 tons  $ha^{-1}yr^{-1}$ ), Moderately high erosion (25-75 tons  $ha^{-1}yr^{-1}$ ), High Erosion (75-100 tons  $ha^{-1}yr^{-1}$ ), Extremely high erosion (>100 tons  $ha^{-1}yr^{-1}$ ) classes (Table 5). Mean annual soil loss for the entire study area is 11.15 tons  $ha^{-1}yr^{-1}$ . In Sainj valley soil erosion rates ranged from 0-5 tons/ha/yr accounts for 39.72% of the total area, whereas soil erosion rates greater than 100 tons/ha/yr accounts for 0.37% of the total area.) (Table 5).

### 3.7 Discussion

Sainj valley is a High altitude valley in Himachal Pradesh's district Kullu. The valley's rainfall ranges from 579.419 to 1268.48mm. The study area ranges in elevation from 981 m to 5366 m above mean sea level. Based on the calculations and remote sensing data, the average value of rainfall erosivity factor-R ranges from 501.19 to 1097.23  $mt\ ha^{-1}\ cm^{-1}$  indicates varying degree of erosive potential, with higher values signifying more erosive rainfall patterns. The LS factor incorporates slope length and steepness, influencing the potential for erosion. The range of LS factor (0 to 8.57) indicates diverse terrain and topographical conditions, impacting erosion susceptibility. Steeper slopes and longer lengths increase erosion risk. LS have the strongest effect on erosion; when the soil loss rate is high, LS values is also strong. The soil erodibility factor (K) varies between 0 to 0.3. There are two major types of soil in the study area: Loamy and Sandy. C factor has a discernible impact on the A- factor which is the Potential annual soil loss.

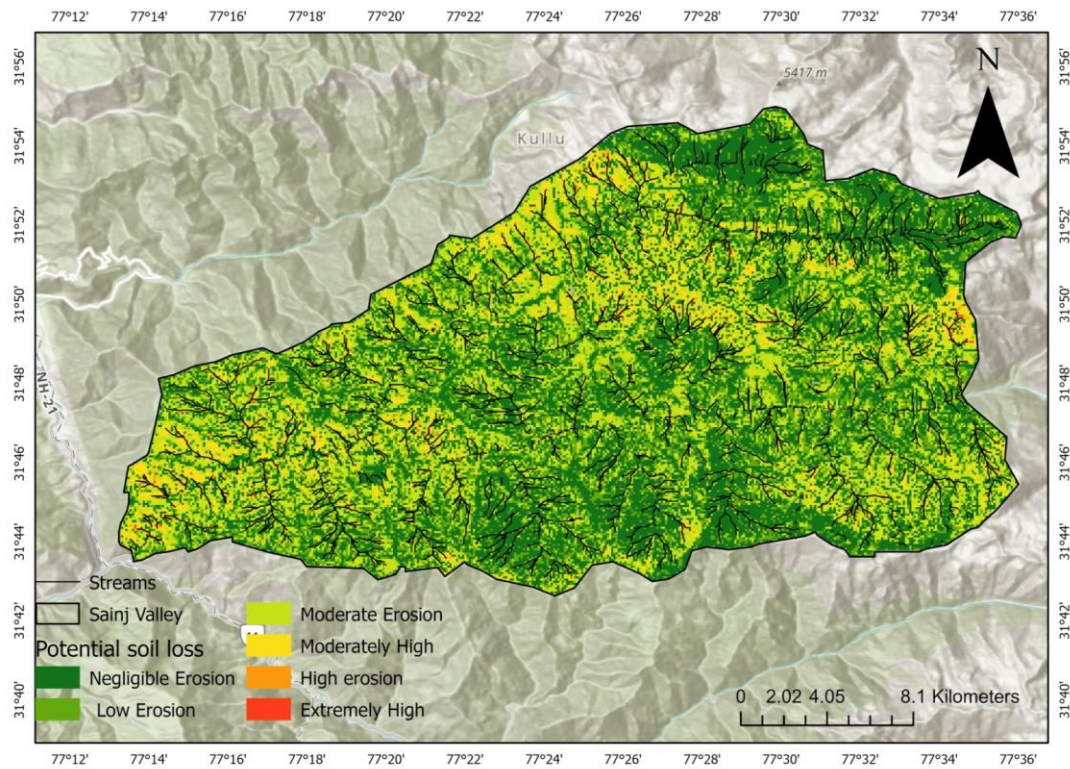


Fig. 12. Potential soil loss (tons/ ha/ yr) in the Sainj valley

Table 5. Soil loss classification according to the Area

Erosion intensity classes	Soil Loss(tons ha <sup>-1</sup> year <sup>-1</sup> )	Area (Km <sup>2</sup> )	% of Area
Negligible Erosion	0-5	210.15	39.72
Low Erosion	5-10	120.04	22.68
Moderate erosion	10-25	141.59	26.76
Moderately high Erosion	25-75	52.72	9.96
High Erosion	75-100	2.50	0.47
Extremely High	>100	1.99	0.37

Lower C- Factor results in lower soil erosion values. "Negligible Erosion" class, constituting 39.72% of the area, signifies areas with minimal soil loss, requiring basic conservation practices. The "Low Erosion" class (22.68%) indicates slightly higher erosion levels, necessitating proactive erosion prevention strategies. The "Moderate Erosion" class (26.76%) represents a significant erosion rate, highlighting the importance of targeted erosion control measures to mitigate soil loss. Moving to higher categories, the "Moderately High Erosion" class (9.96%) calls for immediate and intensive erosion control efforts, while the "High Erosion" class (0.47%) represents areas facing severe erosion, demanding urgent and robust erosion control strategies to prevent irreparable damage. The range of the predicted annual soil loss

is 0 to 541.52 tons ha<sup>-1</sup>yr<sup>-1</sup>. This study describes the predicted amount of soil loss and its spatial distribution in the valley, which is useful when planning and implementing conservation program to reduce soil loss from the valley.

#### 4. CONCLUSION

Soil is the major land degradation process. The study was done to address and quantify the soil loss problem in Sainj valley of Himachal Pradesh. The areas having steep slopes are more vulnerable to soil erosion. Soil erodibility increases with increase in slope and predicted average soil erosion rate in the study area is 11.15 tons/ha/yr. RS and GIS are the most effective tools for analyzing spatial distributed information in a vast area now. The all RUSLE

parameters R, K, LS, C and P factors maps were combined together for creating the annual soil loss map of Sainj valley. This RUSLE is very helpful for estimating the rate of erosion as well as to identify the erosion prone areas in the Valley. According to the findings, the maximum annual soil loss estimated using RUSLE is Sainj valley is 541.52 tons/ha/yr. According to Soil risk classes it is observed that 0.84% area is at risk under High and Extremely high erosion classes. However there is a need to have the direct field measurements of soil erosion in the watershed to confirm and validate the results of USLE prediction. Therefore future works are required for monitoring and sediment load in the rivers and measurement sediment deposition in river and other water bodies that exists in the valley

### ACKNOWLEDGEMENTS

The authors are grateful to the Director, G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora, Uttarakhand for providing the necessary facilities. Authors acknowledge with thanks to Himachal Pradesh Power Corporation Limited for the financial support to carry out the present work.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

### REFERENCES

1. Pandey A, Chowdary VM, Mal BC. Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing, *Water Resources Management*. 2006;21(4):729–746. Available: <https://doi.org/10.1007/s11269-006-9061-z>
2. Ganasri B, Ramesh H. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. *Geoscience Frontiers*. 2016;7(6):953–961. Available: <https://doi.org/10.1016/j.gsf.2015.10.007>
3. Nayak T, Choudhary M, Sahu H, NIH Digital Repository: Assessment of Soil Erosion Based on USLE Model and Application of GIS; 2015. Available: <http://117.252.14.250:8080/jspui/handle/123456789/5989>

4. Amdankar MN, Patil GK. Estimation of soil Erosion using USLE and GIS, *International Journal of Recent technology and Engineering (IJRTE)*. 2019;8(2):3936-3939 Available: <http://doi.org/13.35940/ijrte.b1646.078219>
5. Lee J, Lee S, Hong J, D Lee, Bae JH, Yang JE, Kim J, Lim KJ. Evaluation of Rainfall Erosivity Factor Estimation Using Machine and Deep Learning Models. *Water*. 2021;13(3):382. Available: <https://doi.org/10.3390/w13030382>
6. Shi ZH, Yan FL, Lu Li Li ZX, Cai CF. Interrill erosion from disturbed and undisturbed samples in relation to topsoil aggregate stability in red soils from subtropical China, *CATENA*. 2010;81(3): 240–248. Available: <https://doi.org/10.1016/j.catena.2010.04.007>
7. Saha R, Mishra VK, Khan SK. Soil Erodibility Characteristics Under Modified Land-Use Systems as Against Shifting Cultivation in Hilly Ecosystems of Meghalaya, India, *Journal of Sustainable Forestry*. 2011;30(4):301–312. Available: <https://doi.org/10.1080/10549811.2011.531992>
8. ECA J, An assessment of the dominant soil degradation processes in the Ethiopian highlands: their impacts and hazards; 1984.
9. Bera A. Assessment of soil loss by universal soil loss equation (USLE) model using GIS techniques: a case study of Gumti River Basin, Tripura, India, *Modeling Earth Systems and Environment*. 2017;3(1). Available: <https://doi.org/10.1007/s40808-017-0289-9>
10. Sheikh AH, Palria S, Alam A, Integration of gis and universal soil loss equation (usle) for soil loss estimation in a himalayan watershed, *Recent Research in Science and Technology*. 2011;3:51-57.
11. Singh O, Singh J. soil erosion susceptibility assessment of the lower Himachal Himalayan watershed, *J Geol Soc India*. 2018;92:157–165. Available: <https://doi.org/10.1007/s12594-018-0975-x>
12. Li P, Tariq A, Li Q, Ghaffar B, Farhan M, Jamil A, Soufan W, Sabagh AE, Freeshah M. Soil erosion assessment by RUSLE model using remote sensing and GIS in an

- arid zone, International Journal of Digital Earth. 2023;16 (1). Available:<https://doi.org/10.1080/17538947.2023.2243916>
13. Ge Y, Zhao L, Chen J, Li X, Li H, Wang Z, Ren Y. Study on soil erosion driving forces by using (R)USLE framework and machine learning: A Case Study in Southwest China, Land. 2023;12 (639). Available:<https://doi.org/10.3390/land12030639>
  14. Subramanyan A, Dharmaraj R, Gurumurthy KT, Sampangi S, Srinivasaiah YKH. Assessment of land degradation due to soil erosion based on current land use/landcover pattern using RS and GIS techniques. Arabain Journal of Geosciences. 2023;16(7). Available:<https://doi.org/10.1007/s12517-023-11534-7>
  15. Singh O, Sharma CM, Sarangi A, Singh P. Spatial and temporal variability of sediment and dissolved loads from two alpine watersheds of the Lesser Himalayas, CATENA. 2008;76(1):27–35. Available:<https://doi.org/10.1016/j.catena.2008.08.003>
  16. Wischmeier WH, Smith DD. Predicting Rainfall Erosion Loss: A Guide to Conservation Planning, Agricultural Handbook, No. 537, US Department of Agriculture, Agricultural Research Service, Washington; 1978.
  17. Mkhonta MM. Use of Remote Sensing and Geographical Information System (GIS) on Soil Erosion Assessment in the Gwayimane and Mahhuku Catchment Areas with Special Attention on Soil Erodibility (K-Factor), ITC, Enschede; 2000.
  18. Borrelli P, Panagos P, Langhammer J, Apostol B, Schutt B. Assessment of the cover changes and the soil loss potential in European forestland: First approach to derive indicators to capture the ecological impacts on soil-related forest ecosystems, Ecological Indicators. 2016;60:1208–1220. Available:<https://doi.org/10.1016/j.ecolind.2015.08.053>
  19. Tejada MM, Gonzalez J. The relationships between erodibility and erosion in a soil treated with two organic amendments, Soil and Tillage Research. 2006;91(1–2):186–198. Available:<https://doi.org/10.1016/j.still.2005.12.003>
  20. Renard GK, States U, Service RA. Predicting Soil Erosion by Water: a Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE); 2022. Available:<https://handle.nal.usda.gov/10113/11126>
  21. Panagos P, Borrelli P, Meusburger K. A New European Slope Length and Steepness Factor (LS-Factor) for Modeling Soil Erosion by Water. MDPI; 2015. Available:<https://www.mdpi.com/2076-3263/5/2/117>
  22. Remotel DRV, Hamilton ME, Hickey RJ. Estimating the LS Factor for RUSLE through Iterative Slope Length Processing of Digital Elevation Data within Arclinfo Grid. Cartography. 2001;30(1):27–35. Available:<https://doi.org/10.1080/00690805.2001.9714133>
  23. Moore ID, Burch GJ. Modelling Erosion and Deposition: Topographic Effects, Transactions of the ASAE, 1986;29(6):1624–1630. Available:<https://doi.org/10.13031/2013.30363>
  24. Liu YB, Nearing AM, Shi JP, Jia WZ. Slope Length Effects on Soil Loss for Steep Slopes, Soil Science Society of America Journal. 2000;64(5):1759–1763. Available:<https://doi.org/10.2136/sssaj2000.6451759x>
  25. Bahadur CK. Mapping soil erosion susceptibility using remote sensing and GIS: a case of the Upper Nam Watershed, Nan Province, Thailand, Environmental Geology. 2008;57(3):695–705. Available:<https://doi.org/10.1007/s00254-008-1348-3>
  26. Rouse WJ, Haas HR, Deering WD, Schell AJ, Harlan CJ. Monitoring the Vernal Advancement and Retrogradation (Green Wave Effect) of Natural Vegetation; 1973.
  27. Karaburun A. Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed; 2010.
  28. USDA. Rainfall Erosion Losses from Cropland East of the Rocky Mountain. Handbook no. 282. US Department of Agriculture, Washington, DC; 1981.
  29. Beguería S, Notivolí RS, Burguera MT. Computation of rainfall erosivity from daily precipitation amounts. Science of the Total Environment. 2018;637–638:359–373. Available:<https://doi.org/10.1016/j.scitotenv.2018.04.400>

30. Lee HM, Lin HH. Evaluation of annual rainfall erosivity index based on daily, monthly, and annual precipitation data of rainfall station network in southern Taiwan, International Journal of Distributed Sensor Networks. 2015;11(6):214708. Available:<https://doi.org/10.1155/2015/214708>
31. Ray R, Mukhopadhyay K, Biswas P. Soil aggregation and its relationship with physic-chemical properties under various land use systems. Indian Journal of Soil Conservation. 2006;34(1):28-32. Available:<https://eurekamag.com/research/012/820/012820143.php>
32. Imani R, Ghasemieh H, Mirzavand M, Publishing SR. Determining and mapping soil erodibility factor (Case Study: Yamchi Watershed in Northwest of Iran); 2014. Available:<https://doi.org/10.4236/ojss.2014.45020>
33. Olaniya M, Bora PK, Das S, Chanu PH. Soil erodibility indices under different land uses in Ri-Bhoi district of Meghalaya (India). Scientific Reports. 2020;10(1). Available:<https://doi.org/10.1038/s41598-020-72070-y>
34. Prasannakumar V, Vijith H, Abinod S, Geetha N. 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, Geoscience Frontiers. 2012;3(2):209–215. Available:<https://doi.org/10.1016/j.gsf.2011.11.003>
35. Zhao W, Fu B, Qiu Y. An upscaling method for cover-management factor and its application in the loess plateau of China. International Journal of Environmental Research and Public Health. 2013;10(10):4752–4766. Available:<https://doi.org/10.3390/ijerph10104752>.
36. Das B, Bordoloi R, Thungon LT, Paul A, Pandey PK, Mishra M, Tripathi OP. An integrated approach of GIS, RUSLE and AHP to model soil erosion in West Kameng watershed, Arunachal Pradesh, Journal of Earth System Science. 2020;129(1). Available:<https://doi.org/10.1007/s12040-020-1356-6>

© 2023 Chand and Lata; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*

*The peer review history for this paper can be accessed here:*

<https://www.sdiarticle5.com/review-history/107534>