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Impact Assessment of Soil and Water Conservation Measures on Soil Loss in the Tropical Watershed using RS and GIS

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ABSTRACT

Soil erosion is one of the main causes of land resource decline in India, which in turn affects agricultural productivity. With the help of suitable soil and water conservation measures, this problem can easily be overcome. It has been proven that soil and water conservation (SWC) measures make a lasting contribution to the conservation of natural resources. The present study was conducted to highlight the importance of SWC measures for the conservation of soil resources at the watershed scale. Central MPKV Campus Watershed is selected as a study area. It is located in the tropical rain shadow region of Western Ghats, Maharashtra. SWC measures are proposed for the watershed based on the topography and soil characteristics of the area. Soil loss from the watershed before conservation and after conservation measures was estimated using the USLE model combined with RS and GIS techniques. It was found that average annual soil loss rate will be reduce upto 6.51 t/ha/yr from 18.68 t/ha/yr after the implementation of recommended SWC measures in the watershed. Soil loss will be reduced by approximately 65% once recommended SWC measures are implemented. It was found that SWC measures in the watershed not only contribute to the protection of natural resources, but also act as a climate change mitigation measure.

Keywords Soil erosion, USLE model, RS and GIS, Natural resources, Climate change mitigation.

INTRODUCTION

Soil erosion is one of the most serious environmental issues associated with land management around the world. It is an intricate natural process that has been influenced by anthropogenic activities such as land clearing, agricultural practices, surface mining, construction and urbanization. It is estimated that wind and water erosion remove 75 billion tons of soil from land each year (Borrelli *et al.* 2017). Water erosion, accelerated by anthropogenic activities, is the primary process that occurs in humid and tropical

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regions. Severe soil erosion not only threatens the sustainability of agriculture by lowering the soil's water holding capacity and its nutrient and soil organic carbon content (Zhao *et al.* 2016) but also causes adverse effects like off-site reservoir siltation and water pollution. Above-tolerable soil loss has serious consequences for agricultural productivity. The loss of top fertile soil degrades soil quality, reduces agricultural production and poses a serious threat to food security (Gomiero 2016). Long-term measures are needed to reduce fertile soil loss. In this regard soil and water conservation measures are very critical.

A wide range of soil and water conservation technologies are now used around the world to combat soil and water loss, including conservation tillage, bunding, terracing, trenching, hedgerow planting and mulching (Maetens *et al.* 2012, Mason *et al.* 2015, Prosdocimi *et al.* 2016, Taye *et al.* 2013). Soil and water conservation measures can be used effectively to reduce and control soil erosion and sediment mobilization (Maetens *et al*. 2012). The ultimate goal of SWC measures is to achieve the highest sustainable level of production in a given area of land while keeping soil loss below a threshold level that allows the natural rate of soil formation to keep pace with the rate of soil erosion (Wolka 2014). The renewed awareness that soil is critical to both food and fiber production and global ecosystem functioning has sparked interest in controlling soil erosion and maintaining soil quality (Lal 2015).

The watershed is an ideal hydrological unit for management. Therefore, natural resources conservation should be started from watershed level. Limited data is available related to the impact of SWC measures on soil loss in watersheds. Therefore, the present study is conducted with the primary goal of assessing the impact of SWC measures on soil erosion rate at the watershed level. Central Mahatma Phule Krishi Vidyapeeth (MPKV) Campus Watershed was selected for the present study. The study area is located in the rain shadow region of Western Ghats, Maharashtra. Nearly half of the study area is already being treated with various SWC measures. Additional conservation measures are suggested for the watershed to reduce the soil loss caused by water erosion. The rate of soil loss under current conservation measures was compared to the rate of soil loss under recommended conservation measures.

MATERIALS AND METHODS

Study area

The study area is "Central MPKV Campus Watershed" located in Rahuri subdivision of Ahmednagar District in Maharashtra State, India. The study area lies between latitudes $19^0$21.77' N and $19^0$18.73' N and longitudes $74^0$37.79' E and $74^0$36.49' E. The study area covers 1260 ha (12.60 km^2), with elevation ranging from 441 to 542m above mean sea level (Fig. 1). It has an average north-south length of about 6 km and average east-west extension of about 3 km. The study area is in the rain shadow region of the Western Ghats and it has a hot semi-arid climate. The climate is hot all year round and muggy in the pre-monsoon months from March to mid-June. It receives an average of 592 mm of rainfall per year.

Data sources

Survey of India topographical map no. 47 I/11 was used to delineate the watershed. Stream network of the watershed was validated upto fourth order stream using toposheet. Toposheet for the study area was obtained from nakshe portal of SOI (Survey of India) (https://onlinemaps.surveyofindia.gov.in/Free Map Specification.aspx). Soil loss from the watershed was estimated using USLE model under two different conditions. One with current conservation measures and another with recommended conservation measures. The USLE model variables are derived from a variety of sources. The annual rainfall data from the Rahuri Meteorology Station were used to calculate the rainfall erosivity factor (R-value). Soil erodibility factor (K value) calculated from field estimates of soil properties such as organic matter, structure, texture and permeability of the study area's soil. The slope length and slope gradient factor (LS value) were calculated using Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) with a resolution of 30 m. The crop management factor (C) and conservation practice factor (P) were calculated using Sentinel-2A imagery and DEM data. The DEM and satellite images were obtained from the United

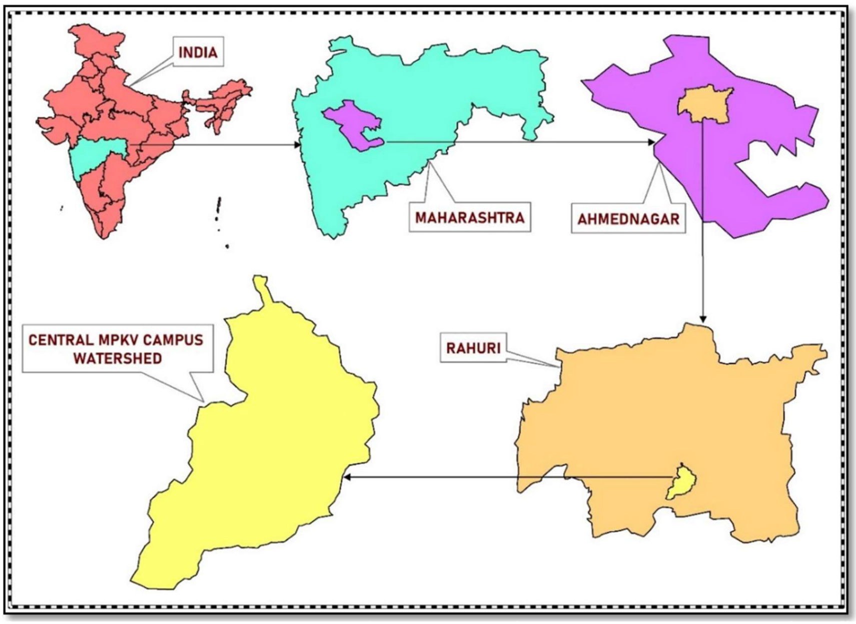

Fig. 1. Location map of study area.

States Geological Survey (USGS) Earth Explore portal (https://earthexplorer.usgs.gov/). The satellite images were obtained for the year 2021. The satellite data was processed in Arc GIS 10.8 software.

Details on derivation of USLE parameters

Rainfall erosivity (R) factor

The amount, duration and intensity of the rainfall strongly influence soil erosion and hence rainfall factor has remained as the most important variable in USLE model. According to Vantas *et al.* (2019), one hundredth of the product of kinetic energy of the storm and the 30-minutes intensity which is expressed as EI30 is the single most reliable estimate of rainfall erosion potential. The annual total of the storm EI value is the rainfall erosion-index. The rainfall erosivity equation developed by Barai *et al.* (2014) for Rahuri subdivision using EI30 method was used to calculate the rainfall erosivity of watershed. Rainfall data from 1995 to 2021 was obtained from the Rahuri Subdivision Meteorological Station and the R-factor for the study was calculated using the following formula:

$$R = 0.0022X^2 + 0.7526X + 152.35 \qquad \ldots(1)$$

Where, R= Annual Erosivity, MJ-mm/ha-hr-yr
X= Annual Rainfall, mm.

Soil erodibility (K) factor

K is the average soil erodibility factor (t-ha-hr/ha-MJ-mm), which is the resistance of the soil to both detachment and transport. Using the grain-size distribution, organic matter content, structure and permeability of the soil, K values can be estimated from the nomograph proposed by Corral-Pazos-de-Provens *et al*. (2022).

Fifty soil samples were collected from the watershed using a 500×500 m grid, with samples taken from the center of each grid for analysis. Soil samples were analyzed according to standard laboratory procedures. The hydrometer method (Beretta *et al.* 2014) was used to analyse particle size distribution, while the wet combustion method of Walkley and Black as described by Jha *et al.* (2014) was used to determine soil organic carbon.

Soil structure was identified in the field using a soil structure assessment kit and soil structure class code was determined. The soil structure class code was determined based on the observed shape and size of the soil structure according to the USLE nomograph (Corral-Pazos-de-Provens *et al.* 2022), while the permeability class code was derived from soil texture classes (Groenendyk *et al*. 2015) encoded based on the textural triangle chart.

The K factor values for watershed were calculated using soil properties such as texture, organic matter, permeability and structure (Panagos *et al.* 2015). The K factor was calculated using (Eq. 2) and mapped by interpolating the values using Arc GIS 10.8 software.

$$\text{K (factor)}= 2.77 \times 10^{-7} (12\text{-OM})\, M^{1.14} + 4.28 \times 10^{-3} (s\text{-}2) + 3.29 \times 10^{-3} (p\text{-}3) \quad \ldots(2)$$

Where,

$$M = [(100\text{-C})\,(L + A_{rmf})] \quad \ldots(3)$$

C is % of clay (<0.002 mm), L is % of silt (0.002–0.05 mm) and A_{rmf} is % of very fine sand (0.05–0.1 mm), OM is the organic matter content (%), p is a code denoting the class of permeability and s is a code for the structure size.

Slope gradient and length factor (LS)

Slope length and gradient factors also known as topographic factor includes slope length (L) and slope steepness (S) which mainly reflect the effect of surface topography on erosion by water action (Yildirim 2012, Shit *et. al.* 2015). Slope length (L) and slope steepness (S) were derived by using SRTM DEM (30 m resolution) in ArcGIS 10.8 platform. Slope length factor (L) was calculated based on the following equation (Eq. 4) given by Zhang *et al.* (2017), which is :

$$LS = (X/22.1)^m\ (0.065+0.045S+0.0065S^2), \quad (4)$$

$$X = (\text{FLow Accumulation} \times \text{Cell value}) \quad \ldots(5)$$

Where, LS is slope length-steepness factor, X = slope length (m), m = a variable slope-length exponent, and S = slope gradient (%).

Crop management factor (C)

Crop management factor for different land covers was derived from satellite imagery based on land use and land cover maps and their attribute data analysis. The crop management factor is defined as the ratio of soil loss from areas with specific vegetation cover to the corresponding soil loss from fallow land with similar rainfall (Zhao *et al*. 2013). The Sentinel-2A satellite imagery was used to drive land use and land cover (LU/LC) map of watershed. Image classification was performed using supervised digital image classification techniques using ArcGIS 10.8 software. Satellite imagery dated December 16, 2021 was used to create the LU/LC map of the study area.

The maximum likelihood classification method was used to create 100 training signatures for land use classification. For validation, 105 reference points were generated using Google Earth. The study area was classified into seven land use and land cover classes as agriculture, horticulture, barren, natural vegetation, current fallow, settlement and waterbody. The corresponding C factor values were assigned to each land use and land cover classes using Reclassify tools in the ArcGIS 10.8 environment. Finally, C factors raster layer of the watershed was generated by assigning adapted C value for each land use and land cover class. The image classification accuracy was validated through Kappa coefficient and ground truthing.

Conservation practice (P) factor

Conservation practice or erosion management factor is a factor of comparable importance while considering soil loss in any region. The conservation practice factor (P) is the ratio of soil loss expected for a given soil conservation practice to those expected for up and downslope ploughing (Kuok *et al*. 2013). The P value ranges between 0 and 1, with the lower value of P indicating the higher supporting practice and a value 1 indicate an absence of erosion resistant facility. A field survey was conducted to map the P factor raster layer. The area under various soil and water conservation measures in the watershed was mapped using GPS device and Arc GIS software. Corresponding P-factor values were then assigned for the respective conservation measures in the Arc GIS environment. Finally, the watershed's P factors raster layer was created by allocating adapted P factor values for conservation measures.

Soil loss estimation

The average annual soil loss of watershed was calculated on a raster cell basis by interactively multiplying the respective USLE factor values (R, K, LS, C, and P) in the Arc GIS 10.8 environment using the Raster Calculator tool.

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

Where, A is the average annual soil loss (t/ha/yr); R is the rainfall erosivity factor (MJ-mm/ha-hr-yr); K is the soil erodibility factor (t-ha-hr/ha-MJ-mm); LS is the slope length factor (dimensionless); C is the crop management factor (dimensionless); and P is the conservation practice factor (dimensionless).

Site suitability assessment for soil and water conservation measures

The soil conservation measures are required to control soil erosion and runoff in the watershed. The different types of soil and water conservation measures are recommended in the watershed to minimize soil loss and runoff. Climatic conditions, soil characteristics (depth and texture) and topographical characteristics of the region are key parameters considered for deciding areas appropriate for soil and water conservation measures in the watershed. The advanced tool of remote sensing and GIS was used to identify the locations for SWC measures. The different thematic layers such as slope, elevation, contour, stream network, soil type, soil depth and LU/LC were generated in the ArcGIS environment and used to locate the SWC measures in the watershed.

Improved conservation practice (P) factor

Improved conservation practice factor map for watershed was prepared after recommendation of suitable SWC measures in the watershed. The respective P factor value was provided to the recommended conservation measures in the Arc GIS environment and an improved P factor map for the watershed was prepared.

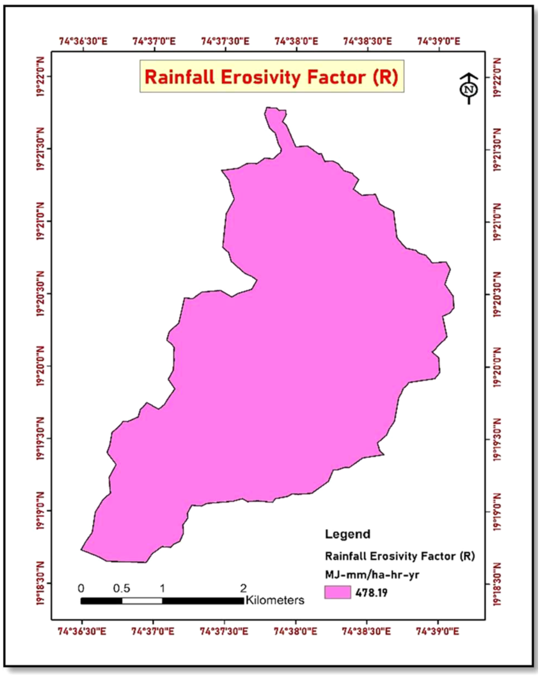

Fig. 2. Rainfall erosivity (R) factor map of watershed.

Soil loss after SWC measure was estimated considering recommended SWC measures are implemented in the watershed. An improved conservation practice factor map was prepared by considering recommended SWC measures are implemented. All other layer of the USLE model were kept constant, only P factor layer was replaced with the improved P factor layer and soil loss was estimated. Change in the soil loss rate before and after the implementation of SWC measures in the watershed was analyzed.

RESULTS AND DISCUSSION

Rainfall erosivity (*R*) factor

The average annual rainfall in the study area was 592.19 mm. The result showed that the average *R*-factor value in the study area was 478.19 MJ-mm/ha-hr-yr (Fig. 2). The lower the R-value, the lesser will be

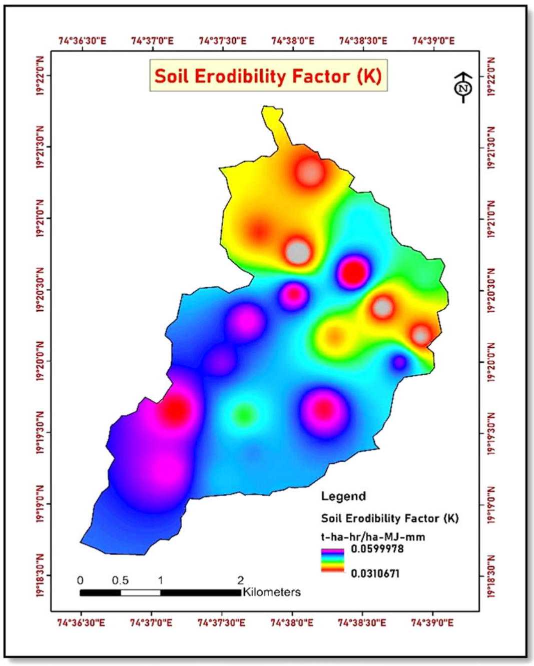

Fig. 3. Soil erodibility (K) factor map of watershed.

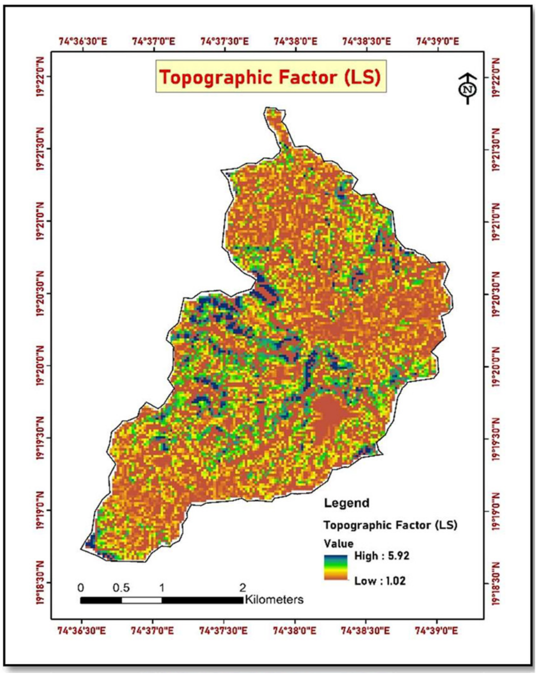

Fig. 4. Topographic factor (LS) map of watershed.

the ability of rainfall to erode the soil (Asmamaw and Mohammed 2019) and the lower the rainfall intensity in the study area (Devatha *et al.* 2015).

Soil erodibility (K) factor

The soil erodibility value illustrates the susceptibility of soil types to erosion, which is influenced by the kinetic power of rain and surface runoff (Khairunnisa *et al.* 2020). The structural stability and water infiltration capacity of the soil affect the value of the *K* factor (Devatha *et al.* 2015). Soil structure in the watershed is coarse grained, with moderate to rapid permeability. The greater the soil erodibility, the higher will be the soil erosion, and vice versa. Soil erodibility in this watershed ranged from 0.0310 to 0.0599 t-ha-hr/ha-MJ-mm (Fig. 3). The watershed has three main types of soils: Sandy clay loam, sandy loam and clay loam. Among the different soil types found within the watershed, sandy loam has the highest erodibility and clay loam has the lowest. The clay loam soil was predominantly found in the lower reaches of the watershed while sandy soil was found in the upper reaches. Therefore, soil erodibility values were lower in the lower reaches of the watershed while high soil erodibility values were observed in the upper reaches of the watershed. Soil organic carbon content in the watershed ranged from 0.32 to 0.84%. The forest land has the higher organic carbon while the barren land has less. The areas with low soil organic carbon values are more prone to erosion than the areas with higher organic carbon values. The soil type wise average K factor values are given in (Table 1).

Table 1. Soil type wise soil erodibility (K) factor values (t-ha-hr/ha-MJ-mm).

Soil type	Minimum	Maximum	Mean	Coefficient of variation
Sandy clay loam	0.031	0.052	0.044	15.64
Sandy loam	0.052	0.060	0.056	4.48
Clay loam	0.029	0.033	0.031	6.08

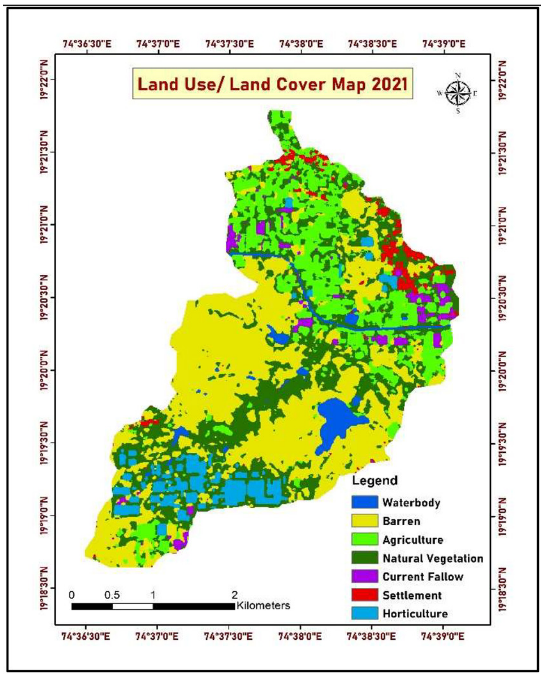

Fig. 5. Land Use/Land Cover Map of Watershed.

Topography factor (*LS*)

The LS factor varied from 1.02 in the plains to 5.92 in the highlands (Fig. 4). The slope of the watershed ranges from 0 to 30.23%, with a mean slope of 4.17%. Around 90% of the watershed had a slope of 0-9%, with the remaining 10% having a slope steeper than 9%. The majority of the watershed, 90%, has a moderate slope range, indicating moderate soil erosion potential, while the remaining 10% has a high erosion potential. The highlands have a higher potential of runoff generation and a large amount of sediment is transported along with runoff, resulting in severe soil erosion.

Crop management factor (C)

The crop management factor is the ratio of soil loss from specific vegetation cover to soil loss from fallow land with the same rainfall (Zhao *et al.* 2013). Land use land cover map was prepared for the watershed (Fig. 5). Through supervised image classification seven land cover classes in the watershed were identified as agriculture, horticulture, barren, natural vegetation, current fallow, settlement, and waterbody (Table 2). The overall accuracy of image classification and Kappa coefficient for watershed was 88% and 0.78, respectively.

Table 2. Area coverage by different land use/ land cover classes.

Sl. No.	Land cover class	Year 2021	
		Area (ha)	Area (%)
1	Waterbody	41.48	3.29
2	Barren land	478.17	37.95
3	Agriculture	230.1	18.26
4	Natural vegetation	304.97	24.20
5	Current fallow	40.49	3.21
6	Settlement	72.82	5.78
7	Horticulture	91.97	7.30

Barren land was observed to be the dominant land cover class in the watershed, followed by natural vegetation. The C-factor is less significant when the land use and land cover area includes a maximum percentage of natural vegetation and plantation crops (Fig. 6). The value of C factor ranges from ‘0’ in water bodies to nearly ‘1’ in barren land (Ganasri and Ramesh 2016). C factor values in the study area

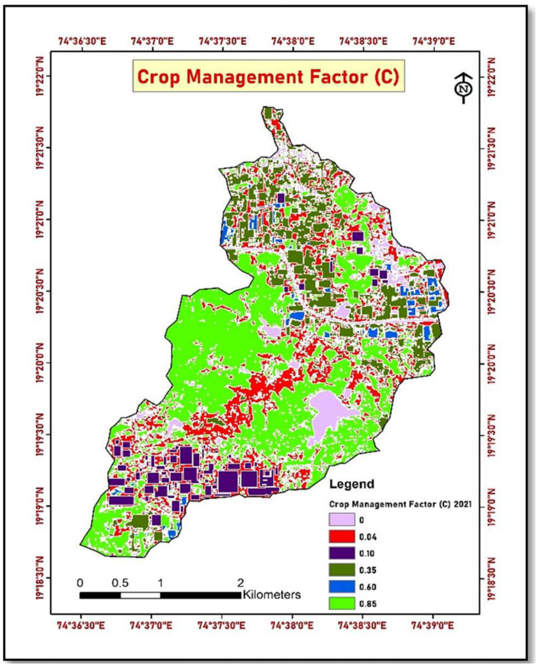

Fig. 6. Crop management (C) factor map of watershed.

Table 3. Crop management (C) factor for different land cover classes.

Sl. No.	Land use/land cover	C value
1	Forest (Rasool *et al.* 2014)	0.04
2	Barren land (Rasool *et al.* 2014)	0.84
3	Settlement (Rasool *et al.* 2014)	0
4	Horticultural crops (Pal and Samanta 2011)	0.1
5	Agriculture land (Pancholi *et al.* 2015)	0.45
6	Waterbody (Pancholi *et al.* 2015)	0
7	Current fallow (Pancholi *et al.* 2015)	0.6

vary from 0 to 0.85.

The C factor values of respective land cover class are given in Table 3. The average value of crop management factors in the watershed was 0.27. The barren land had a maximum C factor value (0.85), indicating that area prone to higher erosion. It encompasses the majority of the land use area (38%) in the watershed.

Conservation practice factor (P)

The conservation practice (P) factor, also known as the erosion control practice factor, is the ratio of soil loss associated with a specific conservation practice, such as contouring, strip cropping, or terracing, to the corresponding loss caused by up and downslope cultivation (Kuok *et al.* 2013). After conducting the field survey, it was found that almost half of the watershed was treated with various soil and water conservation measures. The SWC measures implemented in the watershed include both land area measures as well as drainage line measures. In drainage line measures loose boulder structure and earthen nala bunds are constructed while in land area treatments compartment bunding and deep continuous contour trenches are constructed. The respective P factor value of the conservation measure was assigned to the respective area, with one value assigned to the untreated area. The conservation measures constructed in the watershed and their P factor values are given in the (Table 4). The P factor layers before conservation measures is given in Fig. 7.

Table 4. Conservation practice (P) factor.

Sl. No.	Conservation measure	Area (ha)	P factor
1	Deep continuous contour trench	495	0.15
2	Compartment bunding	50	0.03

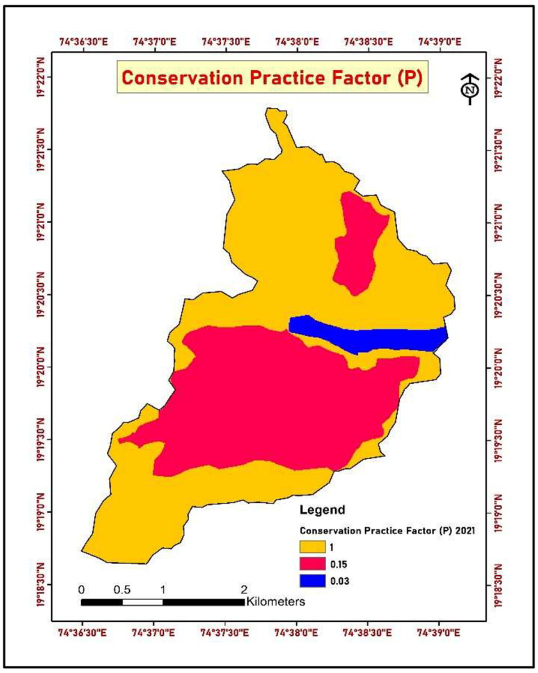

Fig. 7. Before conservation measures conservation practice (P) factor map of watershed.

Soil loss from the watershed before conservation measures

The average annual rate of soil loss in the watershed was varied from 0 t/ha/yr in the plains to 78.23 t/ha/yr in the hilly terrains with a mean of 18.68 t/ha/yr. The rate of soil loss in the watershed was 70 % above the tolerable limit of 11 t/ha/yr for dry region (Ostovari *et al.* 2020). The maximum soil loss occurs in hilly terrains and mainstream, possibly due to high LS factor values and steep slope gradients greater than 25%. Areas with little vegetation cover and without

Table 5. Area under different soil erosion classes before and after conservation measures.

Soil erosion class	Soil loss (t/ha/yr)	Before conservation measures area (ha)	After conservation measures area (ha)
Slight	< 5	365.27	630.25
Moderate	5 to 10	161.54	543.31
Moderately severe	10 to 20	216.51	86.44
Severe	20 to 40	397.13	-
Very severe	>40	119.54	-

any conservation measures are also responsible for high rates of soil erosion. Annual soil loss estimated from the watershed was 23119.36 tonnes. The risk classification of erosion rate was divided into five classes as shown in (Table 5 and Fig. 8). The result showed that nearly 28.99% of the area is characterized by slight erosion rate (0–5 t/ha/year) and such areas can be considered as areas with low risk of erosion. The remaining areas are classified as moderate (5–10 t/ha/year) erosion risk area (12.82%), moderately severe (10–20 t/ha/year) erosion risk area (17.18%); severe (20–40 t/ha/year) erosion risk area (31.52%) and extremely severe (>40 t/ha/year) erosion risk area (9.49%). Almost 60% of the watershed area suffer from the serious problem of severe soil erosion. Therefore, additional SWC measures are suggested in the watershed to minimize soil loss from the watershed.

Recommended soil and water conservation measures

The additional SWC measures are suggested in the watershed to reduce soil loss and runoff from the watershed. The SWC measure in the watershed are suggested based on the slope, elevation, drainage morphology, soil characteristics and topography of the area. The different thematic layers of topography and soil characteristics were prepared in the Arc GIS environment and overlay analysis was carried out to identify site suitability for SWC measures. The conservation measures suggested in the watershed includes both drainage line treatments and land area treatments. Loose boulder structures (184), earthen nala bunds (50), cement nala bunds (3), KT weirs (2), percolation tank (3) and check dams (4) have been proposed for drainage lines and compartment bunds (354 ha), contour bunds (192 ha), DCCT (584 ha) and bench terraces (130 ha) have been proposed on land areas. A total of 246 drainage line structures are suggested and land area treatments are suggested on 1260 ha of land. The details of SWC measures suggested in the watershed is given in Tables 6-7 and Figs. 9-10.

Table 6. Newly suggested drainage line treatments in the watershed.

Drainage line treatments	Total quantity
Earthen nala bund	50
Cement nala bund	3
Percolation tank	3
Check dam	4
Loose boulder structure	184
KT weir	2

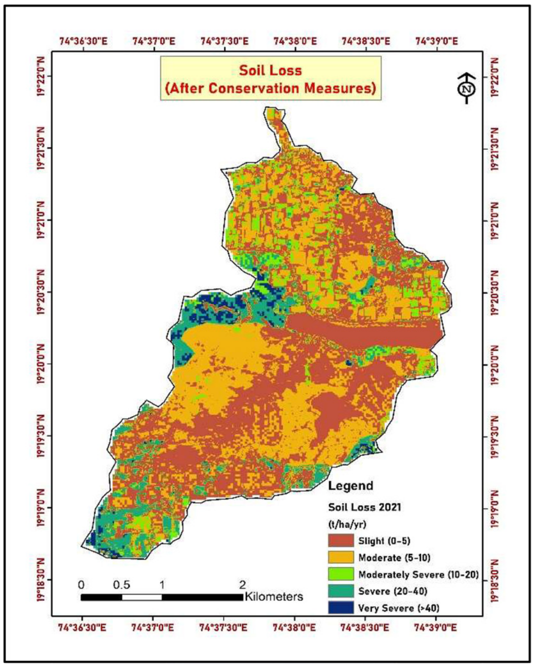

Fig. 8. Soil loss from watershed before conservation easures recommended soil and water conservation measures.

Improved conservation practice factor

An improved P factor map for the watershed was prepared by considering additional conservation measures suggested in the watershed. The improved P factor for the watershed ranges from 0.03 to 0.2 (Table 8). The lower value (0.03) was assigned to compartment bunding and the higher value (0.2) to the contour bunding. This improved P factor layer (Fig. 11) was used to estimate soil loss after conservation

Table 7. Newly suggested land area treatments in the watershed.

Land area treatments	Suggested area (ha)
Compartment bunding	354
Contour bunding	192
Deep CCT	584
Bench terraces	130

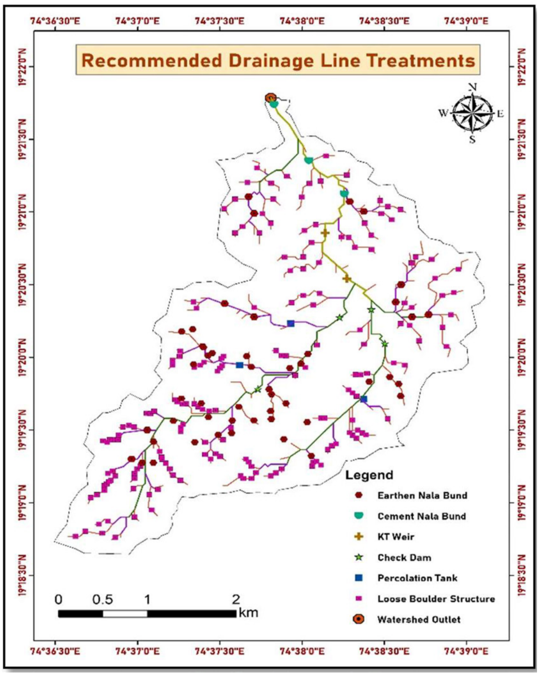

Fig. 9. Recommended drainage line treatments in the watershed.

measures.

Soil loss from watershed after implementation of recommended conservation measures

Soil loss after conservation measures was estimated similar to the soil loss before conservation measures. All parameters of the USLE model prior to the conservation measures were kept constant, with the exception of the P factor. In the revised soil loss after conservation measures, P factor was replaced with an improved P factor. The average annual soil loss after implementation of conservation measures will range from 0 to 18.46 t/ha/yr with a mean value of 6.51 t/ha/yr (Table 5 and Fig. 12). This is almost half the tolerable soil loss limit. Annual soil loss after conservation measures estimated from the watershed will

Table 8. Improved conservation practice (P) factor.

Sl. No.	Conservation measure	Area (ha)	P factor
1	Deep continuous contour trench	584	0.15
2	Compartment bunding	354	0.03
3	Contour bunding	192	0.20
4	Bench terraces	130	0.10

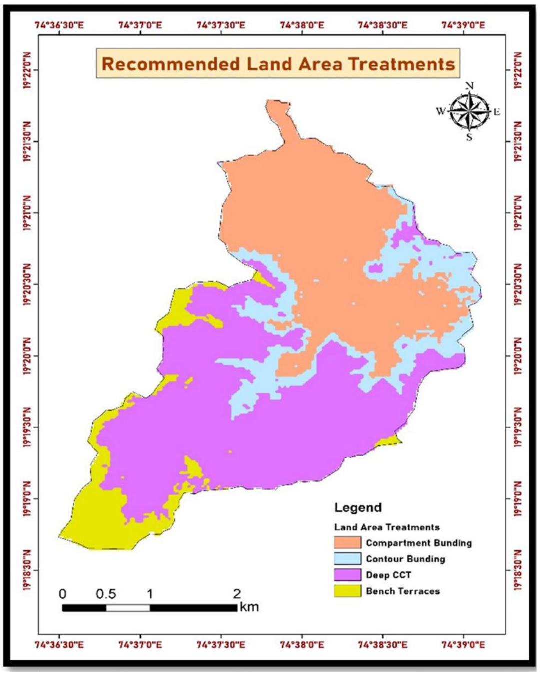

Fig. 10. Recommended land area treatments in the watershed.

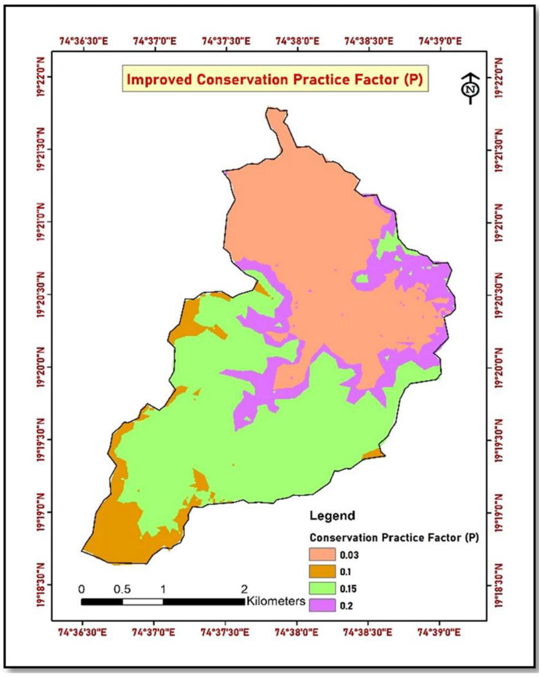

Fig. 11. Improved conservation practice (P) factor map of watershed.

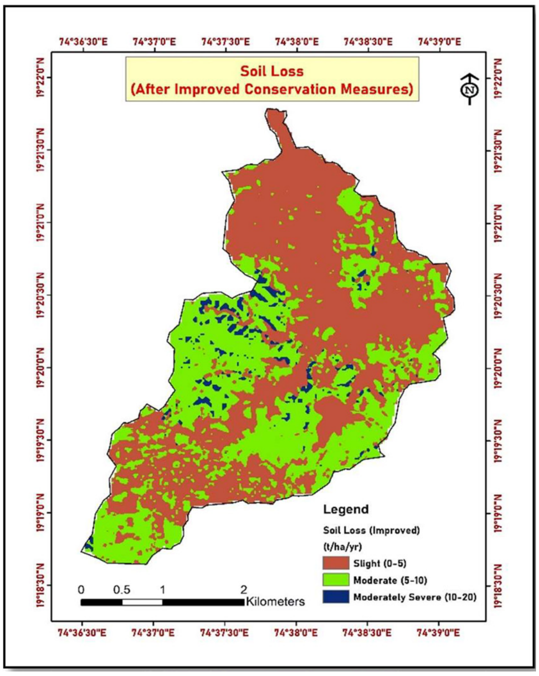

Fig. 12. After conservation measures soil loss map of watershed.

be 8072.4 tonnes. Soil loss from the watershed after the implementation of conservation measures will get reduced upto 65%. It was classified into three classes ranging from slight to moderately severe. Nearly 50.08% of the watershed area will fall under slight risk of erosion (0-5 t/ha/yr). The remaining areas was classified as moderate (5–10 t/ha/year) erosion risk area (43.10%) and moderately severe (10–20 t/ha/year) erosion risk area (6.83%). The area under severe and very severe erosion class will be completely eliminated after the implementation of recommended conservation measures in the watershed. It proves the significance of SWC measures in combating natural resources losses from the watershed. The soil loss from the watershed can be drastically reduced by scientifically appropriate implementation of conservation measures in the watershed. The reduced soil loss as a result of SWC measures can act as a climate change mitigation measure as it reduces the carbon emissions associated with the soil loss.

CONCLUSION

The study was conducted to assess the impact of SWC measures on soil loss in the watershed. The USLE model in combination with the RS and GIS technique were used to estimate soil loss from the watershed. Soil loss from the watershed before conservation measures was found to be 18.68 t/ha/year. This soil loss was well above the threshold of 11 t/ha/year. Therefore, additional SWC measures for the watershed have been proposed. It includes both drainage line treatment and land area treatment. A total of 246 sites for drainage line treatments and land area treatments are proposed on 1260 ha of land. Loose rock structures, earthen nala bunds, cement nala bunds, KT weirs, percolation tank and check dams have been proposed in the treatment of drainage lines and compartment bunds, contour bunds, DCCT and bench terraces have been proposed in the treatment of land areas. Implementation of the recommended conservation measures in the watershed will reduce soil loss by 65% upto 6.51 t/ha/year. It has been found that SWC measures, when implemented scientifically, can reverse the degraded land and limit further damage to land resources. SWC measures together with agroforestry practices can act as climate change mitigation measures.

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