



# Soil Erosion Estimation of Mohmand Dam Watershed Using Geo-spatial Techniques in KPK, Pakistan

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**Abstract** Soil degradation is a significant global problem for multiple infrastructures with negative commercial and ecological influences. The loss of productive soil is frequently triggered by surficial land depletion, farming escalation, erosion, and poor anthropogenic land-use practices. In watershed analyses, estimating soil erosion is useful for future planning and development. It is also important in designing hydropower projects as it yields sedimentation influx in the dam reservoirs. The manual assessment of soil loss is always challenging due to serious safety issues and limited resources; therefore, Geographical Information System and Remote sensing techniques are considered the best tools for this purpose. Current research applies an empirical method, namely the Revised Universal Soil Loss Equation model, to compute the Mohmand Dam watershed soil loss represented by  $A$  in tonnes per hectare per year. The parameters of the RUSLE model are empirically calculated using a raster calculator, and the final map shows an aggregated impact on soil loss. The study revealed that the maximum annual soil loss of the study area was approximately 30–1913 tonnes

$\text{h}^{-1} \text{ year}^{-1}$  which covers only 1.5% of the total watershed area. However, the frequent erosion values lie between 0 and 10 tonnes  $\text{h}^{-1} \text{ year}^{-1}$ . The soil loss is almost negligible in 75% of the Watershed, less than 5 tons  $\text{h}^{-1} \text{ year}^{-1}$ . This comprises about 11179.22 sq. km or 2,762,440 acres area of the Watershed. This study revealed that the area is not hazardously prone to soil erosion with a low sedimentation rate indicating a prolonged storing capacity.

**Keywords** GIS · Remote sensing · RUSLE · Soil erosion · Watershed analysis

## 1 Introduction

Soil loss is a significant environmental problem because soil supports life on Earth. It is because of the degradation of productive soil, which is frequently triggered by erosion and poor land-use practices. Large areas of the Asia–Pacific region suffer from soil erosion (Saha 2018). It is significant in agriculture as it reduces farming production (Agarwal et al. 2016). Soil loss modeling provides a quantifiable and reliable assessment of sediment rate (Ganasri and Ramesh 2016). Globally soil erosion is measured by manual or remote techniques. It can be estimated by models integrated with GIS and RS (Biswas 2012). Each model has its specifications and application range with the specific input information. Various approaches and models, like the Universal

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Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE), can be used. These equations are now modified as RUSLE1 and RUSLE2 (Ali et al. 2018). Practical methods vary according to the type of soil erosion, the zone being measured, and the availability of resources for measuring soil erosion. There are some limitations of these practical techniques like challenging to discriminate between types of erosion, plots of various sizes and designs, large civil structures according to the catchment area and runoff volume, devices to trap eroded sediment, no redistribution data within the site, large field force, 24/7 duty staff at the experimental site and a long period of observation (Zerihun et al. 2018). Relevant and numerical data on soil erosion is helpful to watershed planning, soil preservation, and conservational management (Jain et al. 2001; Bhat et al. 2017).

The Watershed is a hydrological and significant socio-economic unit that provides natural life support. Soil conservation strategies in watersheds are usually planned according to the severity of the problem. They can be determined by considering several important factors, such as annual soil loss and quantitative scale hydrological and hydrogeological measurements. Appropriate management programs are essential for sustainable development (Kalambukattu & Kumar 2017). In the current research, the GIS and RS techniques were implemented in the Mohmand watershed. The estimation of soil erosion is challenging to conduct manually due to serious safety issues. As the GIS and RS techniques are fast and reliable, they were considered best for soil erosion modeling of a watershed in the current research. The Erosion model is computed using the global mapper, ERDAS Imagine, and GIS&RS techniques. GIS applications facilitate visualizing changes in the landscape development for soil erosion and generate input values for individual parameters. The final model will assess the annual soil loss of the research area.

## 2 Study Area

According to the climatic point of view, the Mohmand watershed varies from sub-humid to erratic climate. In some areas, the climate ranges from sub-tropical to temperate. Geographical factor, especially

altitude's influence on the local climate, is significant. Rains are primarily impactful due to strong monsoon spells; varies from 300 to 1000 mm. Thirty percent of yearly rainfall in the basin is received from the monsoon season. The study area is semi-arid, based on available data and associated weather observations. During winter, precipitation is frequent at low concentrations and for longer periods. The mean temperature remains between 18 and 23 °C. The Swat River comprises perennial streams produced by snowfall and rainfall. It has considerable surface runoff and occurs mainly in the middle and lower basins due to the rainy season in the monsoon (WAPDA Report 2018). This study is very important in watershed analyses and the water storage capacity of a dam reservoir. In Pakistan, it is always considered that the higher sedimentation rate will reduce the storing capacity, as happened in Tarbela and Mangla Dam reservoirs. The pre-determination of the sedimentation rate will only indicate the dam's life but can also increase the suitability of water supply problems to the nearby areas by providing the karaze system and canals for agricultural use.

Mohmand watershed is selected as the study area for this research which geographically lies at 34° 21' 11.49" N, 71° 31' 58.72" E latitude and longitude. The construction of the project is proposed on the Swat River. Munda Headworks has located 5 km from Mohammed Agency, Khayber Pakhtanhaw (KPK). The dam lies at the Swat River Basin, 48 km from Peshawar, at the Mohmand Agency in KPK. The dam's reservoir extends to the top of the province (Fig. 1), with the reservoir length being 56 km. This area comprises barren and rugged hills (Figs. 1, 2). Mohmand Dam Hydro Power Project is a multipurpose facility with 800 MW of hydropower generation, flood control, and 6773 hectares of irrigated agricultural development (WAPDA Report 2018). The proposed reservoir characterization is that the probable maximum flood is 27,427 cusecs. The minimum water storage level is 510 (m AMSL). The Mohmand dam is previously known as the Munda dam. The dam type will be a concrete-faced rockfill dam. The height of the dam will be 213 m. The cultivable command area of the dam will be 16,737 acres. The expected completion period is 6 years, and the estimated cost is 2.6 bn USD (WAPDA Report 2018).

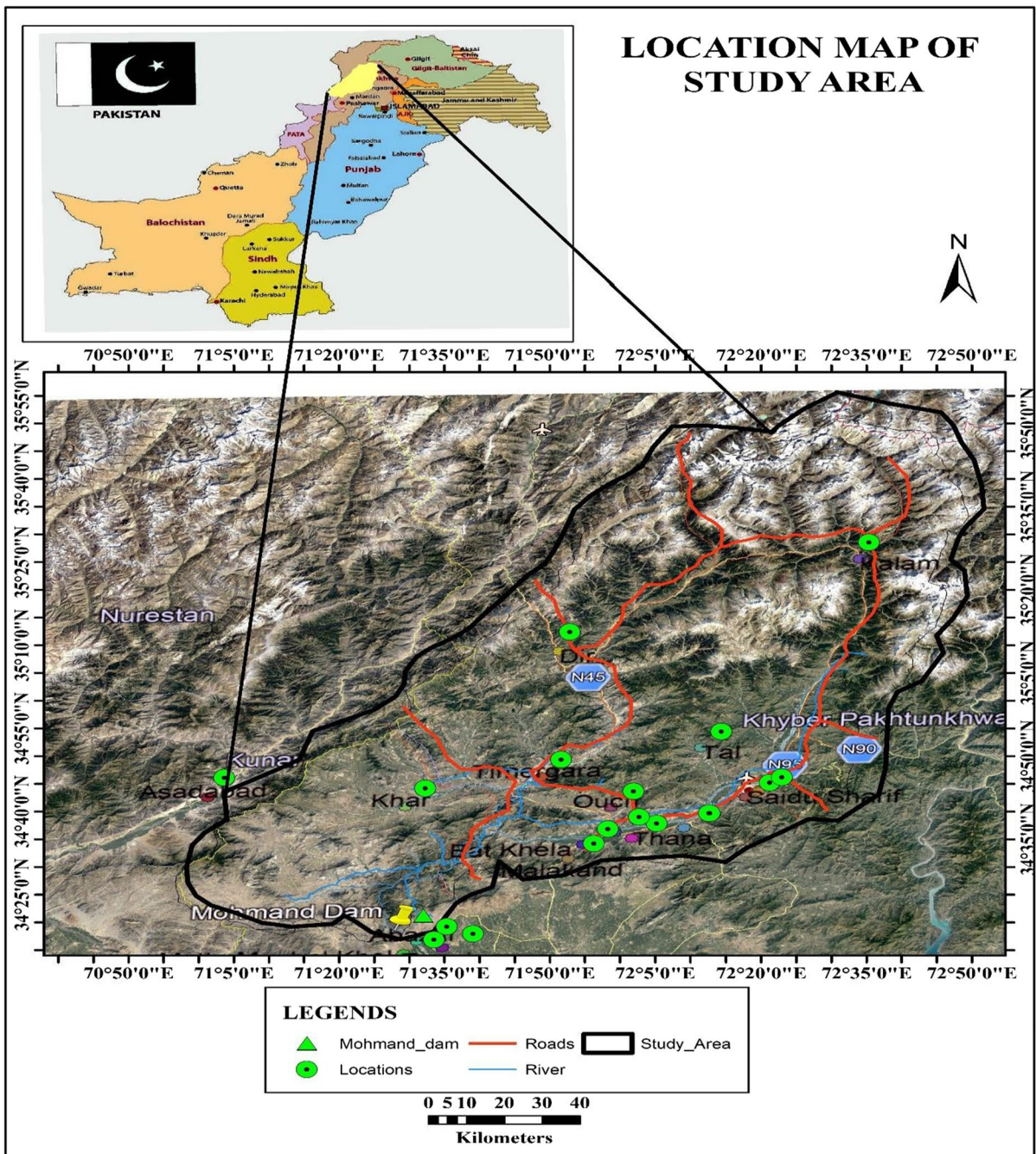


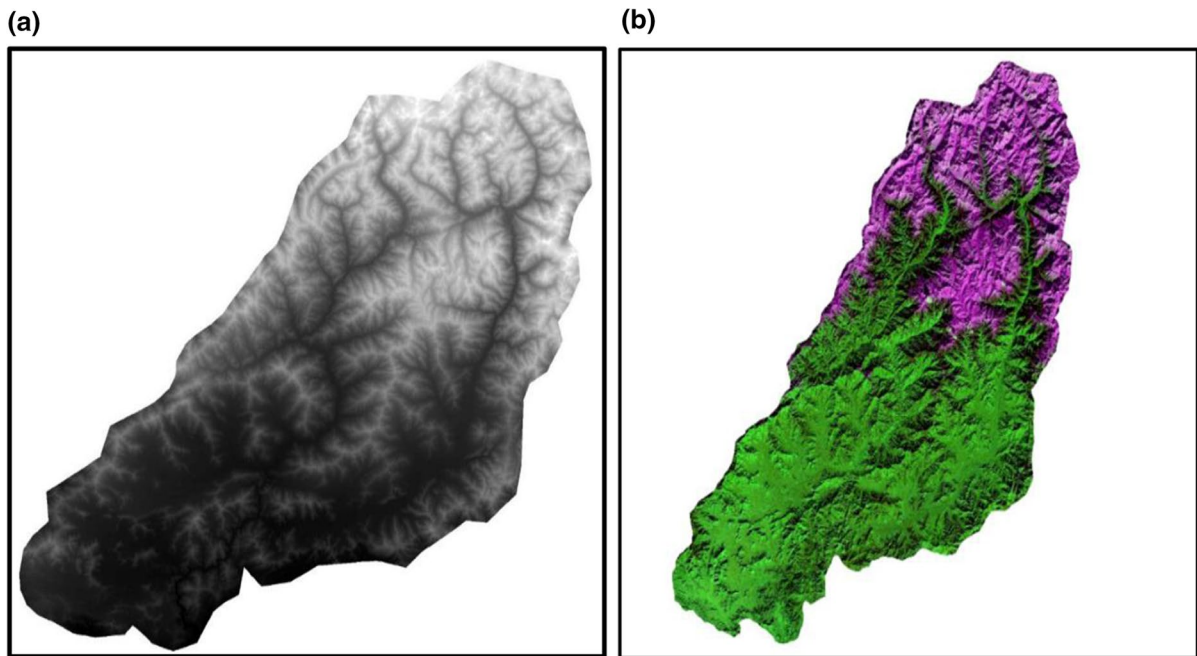
Fig. 1 study area map of Mohmand Watershed

### 3 Methods and Materials

Soil erosion assessment of the Mohmand dam watershed was calculated by demarcating the watershed area using DEM (Digital elevation model) and GIS

incorporated with Arc hydro extension. The physical characterization of a watershed for the RUSLE model included the computation of different parametric maps such as rainfall/runoff erosivity (R-factor), soil erodibility (K-factor) map, slope length and steepness





**Fig. 2** Study Area of Mohmand Watershed. **a** DEM (Digital Elevation Model, 30 m). **b** Sentinel satellite image of study area

(LS-factor) map, (LULC) or land cover management (C-factor) map, land practice as P-factor) map, mean annual soil erosion/loss (A/E) map, and finally, classify the area based on yearly average soil erosion range negligible to very severe.

Digital Elevation Model (30 m) and the sentinel satellite images are downloaded from USGS, Earth Explorer site, and mosaiced (Fig. 2a, b). A geological map of the area under consideration from GSP, a Soil map of the Mohmand watershed from the Soil Survey of Pakistan, and Rainfall data from ESDAC (European soil data center) were collected. GIS Arc map, Global mapper, ERDAS Imagine, Arc hydro extension incorporated with GIS and Google Earth software for data processing.

### 3.1 Demarcation of the Watershed

A DEM of 30 m was downloaded from the USGS site to demarcate the boundary of the watershed of the study area. A mosaic of DEM in ERDAS Imagine was added in GIS (Arc map) software (Fig. 2a) by using the arc toolbox spatial analyst tool. The hydrology tool is applied to delineate the watershed, so the arc map equally treats all the study areas without

any sink. For this purpose, the fill tool was applied to the mosaiced DEM, and then flow accumulation, direction, and other watershed characteristics were computed. Then a pour point was snapped so that the Watershed could be delineated with some reference points, and finally, run the watershed tool to demarcate the Watershed's boundary. After watershed delineation, a map was generated, grid system and scale were assigned to the map (Fig. 3).

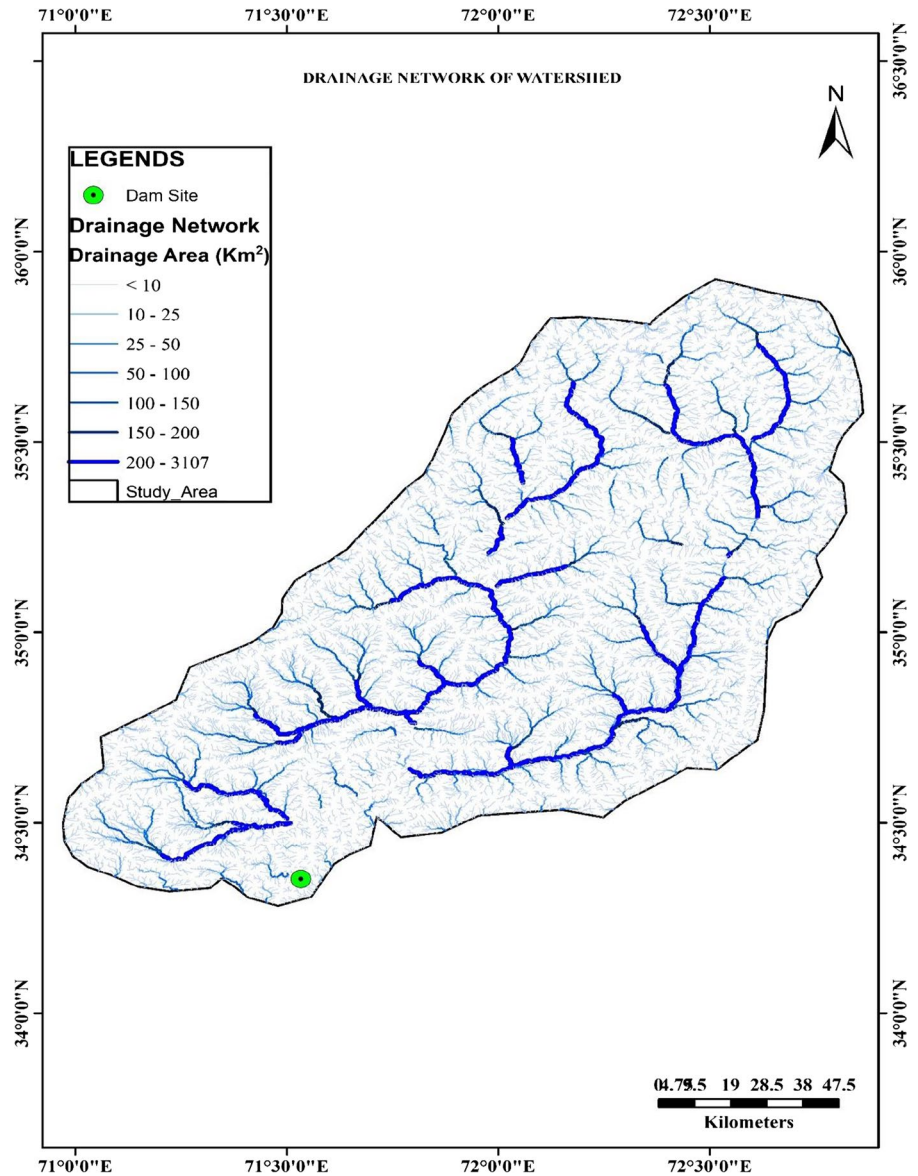
It is important to mention here that a DEM (30 m) is acquired with characteristics of Earth Explorer of 1-s arc and one-degree contour maps. The other option is also available, like 2 s of arc, 7.5 min, and 15 min, but in this study, the DEM with 1 s of arc was used (Fig. 3).

### 3.2 Physical Characterization of RUSLE Model in Mohmand Watershed

#### 3.2.1 Rainfall Erosivity Factor (*R-factor*)

The R-factor in the RUSLE model depicts the two essential features of climatic data, i.e., quantification of rainfall in a specific area and its intensity extended over time. The erosion due to the rainfall fluctuates

**Fig. 3** Demarcation of Mohmand Watershed



momentously. R-factor may vary between different regions. The area with a low slope degree has a lower shear R-value suggesting that the water depositions increase in flat areas; thus, this protects the upper layer of soil from rainfall. More value of R factors indicates more significant climate erosion (Farhan et al. 2013). R signifies the climatic factor defining the possible erosional forces of the rainwater, and it is a considerably contributed parameter in the RUSLE model. R values are typically derived from continuing specific weather information as a product of total hurricane influences (Fu et al. 2005). The present studies'

precipitation data were obtained from ESDAC (European Soil Data Center) European Commission, Joint Research Center (Panagos et al. 2012) was used in a raster format.

### 3.2.2 Soil Erodibility Factor (K-Factor)

The soil erodibility factor was calculated under standard conditions referring to soil sensitivity to shear and runoff rates. That K-factor signifies the association between yearly mean soil loss, hydraulic developments, and the transportation of sediments under

normal soil circumstances (Fu et al. 2005). The infiltration rate is associated with annual soil loss and the hydraulic processes during the precipitation. It is the soil disintegration and transport of soil particles (grains or fragments) measured under standard conditions; it depends on the amount and expanse of runoff for specified precipitation data. K-factor varies between 0 and 1. The soil will have more erodibility if there are more fractions of sand (Gelagay and Minale 2016). The soils that resist erosion have small K values, ranging from 0.05 to 0.15, like sandy soils, with a K value ranging from 0.05 to 0.2, although these soils are easily degraded due to less durability of soil (Belayneh et al. 2019). Medium-grained soils have moderate K values, ranging from 0.25 to 0.4, like silt loam soils, as they are discreetly affected. Soils with high silt content are highly depleted. The surface of the soil breaks apart easily and has a high rate of runoff. The K value for these soils is larger than 0.4 (Blanco and Letelier 2017; Bhat et al. 2017). In the current research, the soil map and geological map of the research area are incorporated to compute the k-factor. The value of k is used from the literature and reclassified in the soil map according to the standard values (Table 1).

### 3.2.3 Slope Length/Slope Steepness (LS-Factor)

L-factor represents the slope length that characterizes the consequence of gradient/slope distance. It is the distance from the land flow source to the deposition point along its path length. L estimates the consequence of slope length on the slope, and S computes

the consequence of slope constancy on slope inclination. The LS factor in the RUSLE gives the proportion of total soil loss under specified circumstances according to slope length and steepness. The effect of soil erosion rate, slope length, and slope LS factor outlines the behavior of local landscape structure. DEM with 30 m was applied to analyze the LS factor. As the length of the slope increases, the unit increase leads to annual soil loss, resulting in more accumulation of runoff on the bottom slope (Abadi et al. 2016). The slope with higher shear strength represents stability against erosion. There will be more soil erosion if the slope is unstable with the increase in length. This can be influenced and controlled by the slope gradient, vegetation cover density, and soil texture (El Jazouli et al. 2017; Wang et al. 2018) (Eqs. 1 and 2.)

$$LS = \text{Power}(\text{Flow Accumulation}'' \times 30/22.1, 0.4) \times \text{Power}(\sin(\text{Slopedem}'' \times 0.01745)/0.09, 1.4) \times 1.4 \quad (1)$$

$$LS = (\text{Raster class of } LS/100) \quad (2)$$

### 3.2.4 Land Use/Land Cover or Land Cover Management (C-Factor)

The C factor represents the consequence of crop and land management on erosion rates. It's the most frequently used to link the comparative influences of land use possibilities on preservation strategies. The C-Factor Management Strategy describes how the mean soil loss affects and how the soil is dispersed

**Table 1** K\_Factor values (Source: Blanco and Letelier 2017)

Soil and rock types	K_Factor
Loamy and clayey are mainly non-calcareous soils of alluvium or loess	
Plain/terraces	0.3
Mountains: mainly loamy shallow soils and some rock outcrops	0.18
Valleys: mainly loamy non-calcareous soils	
Mountains: rock outcrops and loamy, very shallow soils	0.35
Valleys: mainly loamy soils	
Mountains: mainly loamy shallow soils and rock outcrops	0.6
Valleys: manly loamy soils	
Mountains: rock outcrops and loamy, very shallow soils	0.4
Valleys: mainly loamy soils	
Mountains: rock outcrops with some loamy, very shallow soils	0.3
Valleys: mainly loamy soils	

through construction, yield crop rotation, or further managing plans during potential damage. It is the subsequent key factor after topography in controlling soil erosion (Saha et al. 2018). It describes soil safety by type of land cover and thickness. It ranges from 1 in the severe to 1/1000 in bare soil, 1/100 in grassland and undercover plants, and 1–9/10 in root and tuber crops (Moses 2017). A feature used in the RUSLE model to understand how the percentage of C-factor affects the soil cover erosion. Surface covers may include rock fragments, living trees, cryptograms, and plant remains (Chen et al. 2019). A protected vegetation layer helps stabilize the soil, preventing soil degradation. Areas with less vegetation have a higher C value, so areas with mature vegetation cover are prone to soil loss (Farhan et al. 2013). The supervised classification calculates the land cover in the current research. The signatures are created for a different land cover type by drawing polygons and land use and merging the polygons with the same land cover. Then assign the values to LU/LC from the literature (Table 2).

### 3.2.5 Land Support Practice (P-Factor)

The fractional relationships among the soil loss, strip-cropping, and elevation behavior of up and down slopes are directly proportional (Chen et al. 2019). The preservation activity factor in the RUSLE model depicts the effectiveness of these activities that lessen the precipitation runoff rate, consequently decreasing erosion. The relation of soil loss is associated with slope cultivation with specific support practice

on cropland (Bouguerra et al. 2017). This includes a variety of farm management practices: strip cropping, contouring, then pruning. The p-factor map is computed by calculating the slope in percent rise and assigning the values accordingly mentioned in (Table 3) (Shin 1999). P-factor distinguishes between cultivated and open land (Lamyaa et al. 2018). It is often based on the support procedure performed, while the support operation in the Cropland option is part of the annual maintenance exercise (Belayneh et al. 2019). It is again computed through the spatial analyst tool and reclassified for reclassification of the slope percent(%). According to (Shin 1999), a reclassified slope file is created. Then from the conversion tool, it was converted into a feature class to raster using P-factor as an input value from the literature.

### 3.2.6 Annual Average Soil Loss

The following equation calculates the mean Annual Soil Loss

$$A = R \times K \times LS \times C \times P \tag{3}$$

The raster layers of these factors/parameters are added in a new MXD arc GIS file. Then from the spatial analyst tool, map algebra for the raster calculator was used to multiply all these factors for mean annual soil in  $\text{ton h}^{-1} \text{ year}^{-1}$ .

## 3.3 Soil Erosion Risk Modelling

The area is classified based on the mean annual soil loss computed by the RUSLE model. For the computation of annual soil loss, the data is reclassified as negligible, slight, low, moderate, high, very high, severe, and severe erosion classes (Table 4). Then convert these classes into raster data sets for the map.

**Table 2** C\_Factor values (Source: Chen et al. 2019)

LU/LC	C_Factor
Alpine grassland	0.1
Bare rocks	0
Cropped area	0.2
Settlement/built-up area	0
Shrubs/grasses	0.1
Snow/glaciers	0
Water bodies	0
Dry temperate	0.1
Moist temperate	0.1
Subtropical chir pines	0.1
Subtropical broad leaf	0.1

**Table 3** Support practice factor (P) (Source: Shin 1999 and Biswas 2012)

Slope%	P-factor
0.0–7.0	0.55
7.0–11.3	0.6
11.3–17.6	0.8
17.6–26.8	0.9
26.8 >	1

**Table 4** Soil Erosion classes

Sr. No	Soil erosion risk classes	
	Class	Description
1	<5	Negligible
2	5–8	Slight
3	8–10	Low
4	10–15	Moderate
5	15–20	High
6	20–25	Very high
7	25–30	Severe
8	>30	Very severe

The Watershed is divided into eight classes, respectively, as mentioned above (Fig. 4).

## 4 Results and Discussions

### 4.1 RUSLE Model Parameters Analysis for Soil Loss

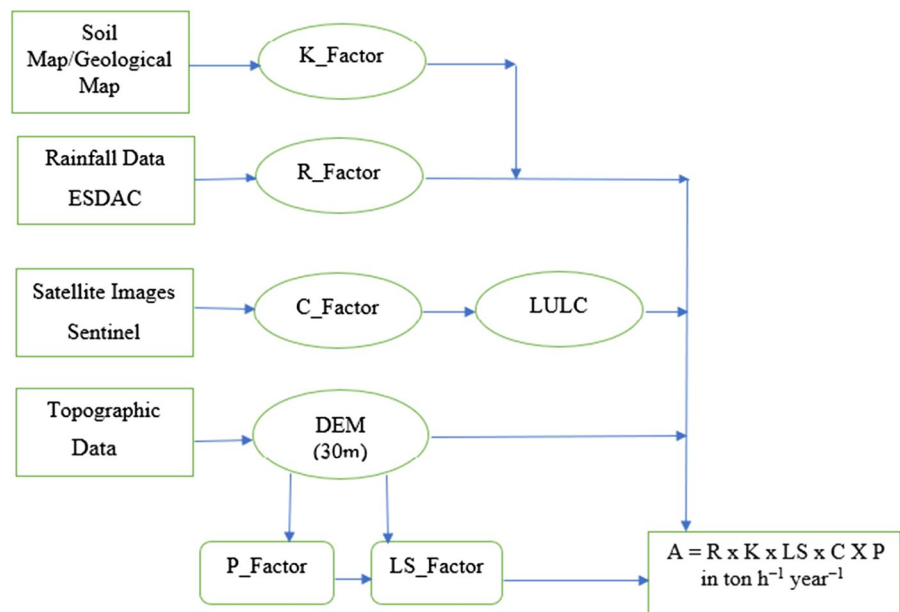
R-Factor is calculated in  $\text{MJ mm ha}^{-1} \text{h}^{-1} \text{year}^{-1}$ , which gives the approximated rate of surface runoff associated with climatic precipitation. The maximum R-value in the study area ranges from 3100 to 5200  $\text{MJ mm ha}^{-1} \text{h}^{-1} \text{year}^{-1}$  in the southeastern part of the Watershed. The moderate value of R ranges from 1100 to 1700  $\text{Mj ha}^{-1} \text{h}^{-1} \text{year}^{-1}$  in the

northeastern and southwestern part of the Watershed, respectively (Fig. 5b). This shows that there will be more soil erosion induced by rainfall in the southeastern part of the Watershed and the rate of soil erosion is moderate in the northeastern and southwestern regions (Table 5).

K-factor is calculated in  $\text{ton h MJ}^{-1} \text{mm}^{-1}$ . It is computed by the area's soil map and geological map. The map shows 0 values for glaciers in the northern part of the Watershed. The maximum value of the k factor is 0.6 (Fig. 5c) in the southern and some western parts of the Watershed, where most people live and practice different activities like construction, roads, cropping, etc. The value of k in the central part of the Watershed is less than in the southern and western parts (Blanco and Letelier 2017).

LS is a combined slope length and steepness factor and is considered the topographic factor. The slope angle and length of a specific area influence the rate of soil erosion and increase with the steepness of the slope, which triggers surface runoff. To calculate the automated LS\_factor in the RUSLE model, DEM is used as input data. LS factor map generated based on the equation stated above. It mainly reflects the consequence of the surface landscape on erosion by water. If the slope is steeper, the erosion rate will be high. The minimum value of LS is 0, and the highest value is 3 (Fig. 5d) (Abadi et al. 2016; El Jazouli et al. 2017; Wang et al. 2018).

**Fig. 4** Methods and Materials





C-factor is a dimensionless factor that can reduce soil erosion depending on the vegetation cover pattern of the area under consideration. It manages the surface conditions of soil; therefore, it is the user parameter in the RUSLE model. The LULC map is reclassified in Alpine Grassland, Bare Rocks, Cropped Area, Settlement/Built-up Area, Shrubs/Grasses, Snow/Glaciers, Water Bodies, Dry Temperate, Moist Temperate, Subtropical Chir Pines, and Subtropical Broad Leaf by using supervised classification (Fig. 6) C factor values are allotted to each polygon of the Watershed from literature (Chen et al. 2019). The maximum value of C is 0.2 for the cropped area, and the minimum is 0 for bare rock built-up, glaciers, and water bodies, respectively (Fig. 5e).

The P-factor map was also computed using the land use landcover map of the Watershed. The values of the P-factor were allocated to the different features constructed on the base of soil conservation practice. The present study shows that land support activities are mainly practiced in the southern, southeastern, and southwestern areas of the watershed. In the northern part, the value of P is less because there are primarily glaciers, less populated, and high elevation. (Shin 1999; Biswas 2012). The minimum value of P is 0.55 for maximum land practicing areas, and the maximum is 1 for less land practicing areas, respectively (Fig. 5f).

Soil loss is calculated in  $\text{ton h}^{-1} \text{year}^{-1}$ . RUSLE is a model applied to produce the possible soil loss map by using the multiplication operation on these RUSLE parameters in a raster calculator. The maximum annual soil loss ranges from 30 to 1913 tonnes  $\text{h}^{-1} \text{year}^{-1}$  comprising only 1.5% area of the watershed (Fig. 7). Frequent values lie between 0 and 10 tonnes/h/ year. The soil loss is almost negligible in 75% of the Watershed, less than 5 tonnes  $\text{h}^{-1} \text{year}^{-1}$ . This comprises about 11179.22 sq. km or 2,762,440 acres of the Watershed (Fig. 8a, b). This is because the area mainly consists of hard rocks and thick vegetation cover, so soil loss is not a big problem in the project area.

#### 4.2 Soil Erosion Risk Classes of Mohmand Watershed

The Mohmand watershed is divided into eight classes to evaluate the soil erosion risk of the study

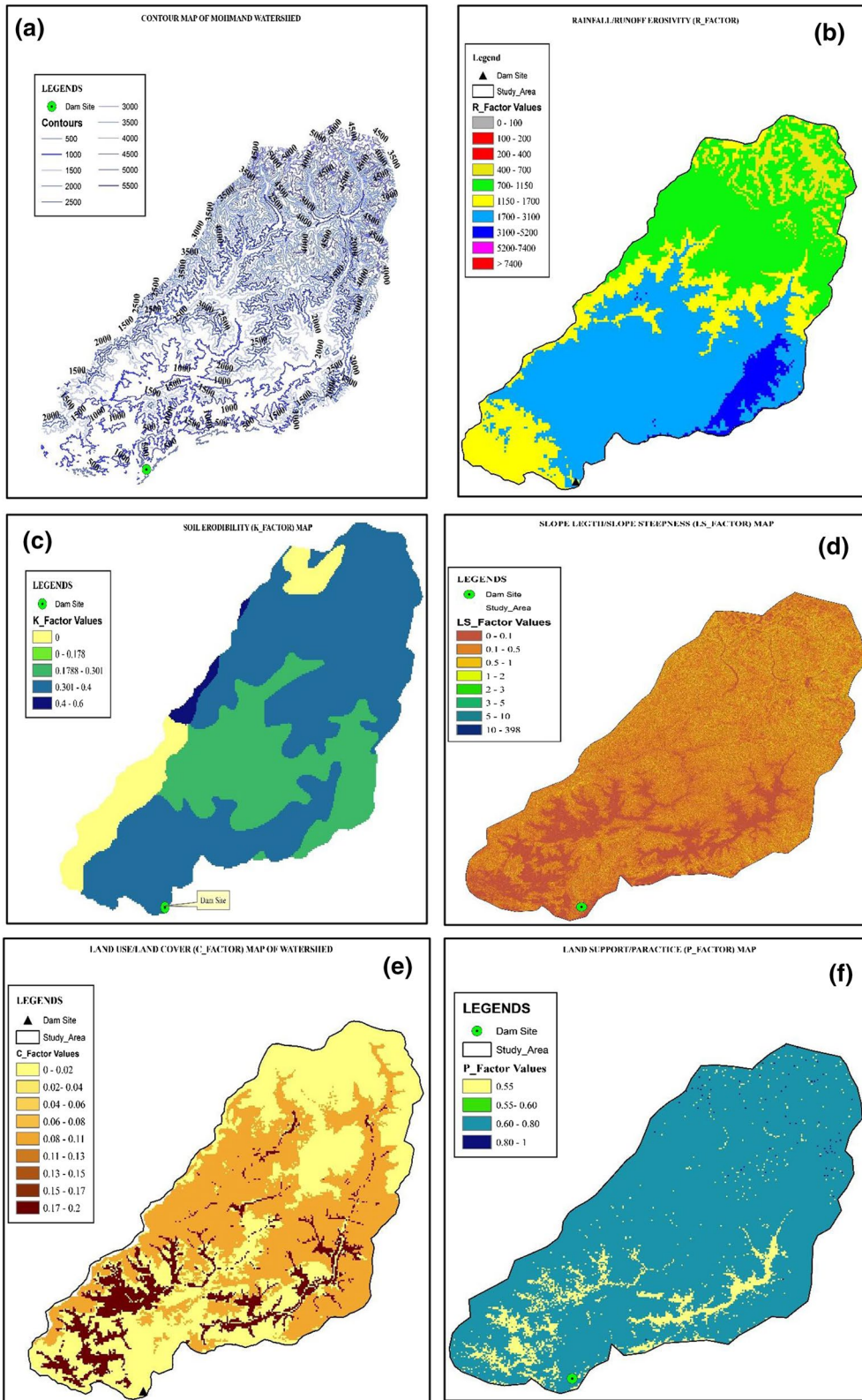
area. The area lies in a negligible to a moderate class of erosion (Figs. 7, 8a, b).

## 5 Conclusions

DEM (Digital Elevation Model) based delineation of the Mohmand watershed demarcates the total area and perimeter of the Watershed up to 16,780 sq. km and 586.16 km, respectively. The study area follows the drainage pattern of the Watershed formed by the streams, river, and nallas in a pattern. The watershed drainage depicts the topographic region where a stream receives runoff, throughflow, and surface water flow. Computation of various RUSLE model parameters reflects Rainfall/Runoff Erosivity Factor (R), soil erodibility factor (K), Land use/Land cover factor (C), slope length/slope steepness factor (LS), and support practice factor (P) as 100–7400 in ( $\text{MJ mm ha}^{-1} \text{h}^{-1} \text{year}^{-1}$ ), 0–0.6 in ( $\text{ton h MJ}^{-1} \text{mm}^{-1}$ ), 0–0.2 (dimensionless), 0–398 (dimensionless) and 0.55–1 (dimensionless) respectively. The empirical results of the RUSLE model show the maximum yearly soil loss up to 30–1913 in  $\text{ton/h/year}$  in 1.5% area of the watershed, suggesting that the Mohmand watershed reservoir is not prone to hazardous soil erosion. Soil erosion values vary between 0 to 10- $\text{ton h}^{-1} \text{year}^{-1}$ . Soil erosion is almost negligible in 75% area of the Watershed, with less than 5 tonnes  $\text{h}^{-1} \text{year}^{-1}$  and comprising an area of about 11179.22 sq. km or 2,762,440 acres. This study revealed that this area is not hazardously prone to soil erosion with a low sedimentation rate indicating a prolonged storing capacity.

## 6 Recommendations

Watershed understudies cover a vast area divided into sub-basins for individual soil loss analysis. Considering this work as a pioneer study, various approaches and models to estimate the soil erosion of a specific area can be used like the Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE); these equations are now modified as RUSLE1 and RUSLE2. Some other models integrated with GIS and RS can also be used for this purpose, such as Water Erosion Prediction Project (WEPP), Soil Erosion Model for Mediterranean Regions

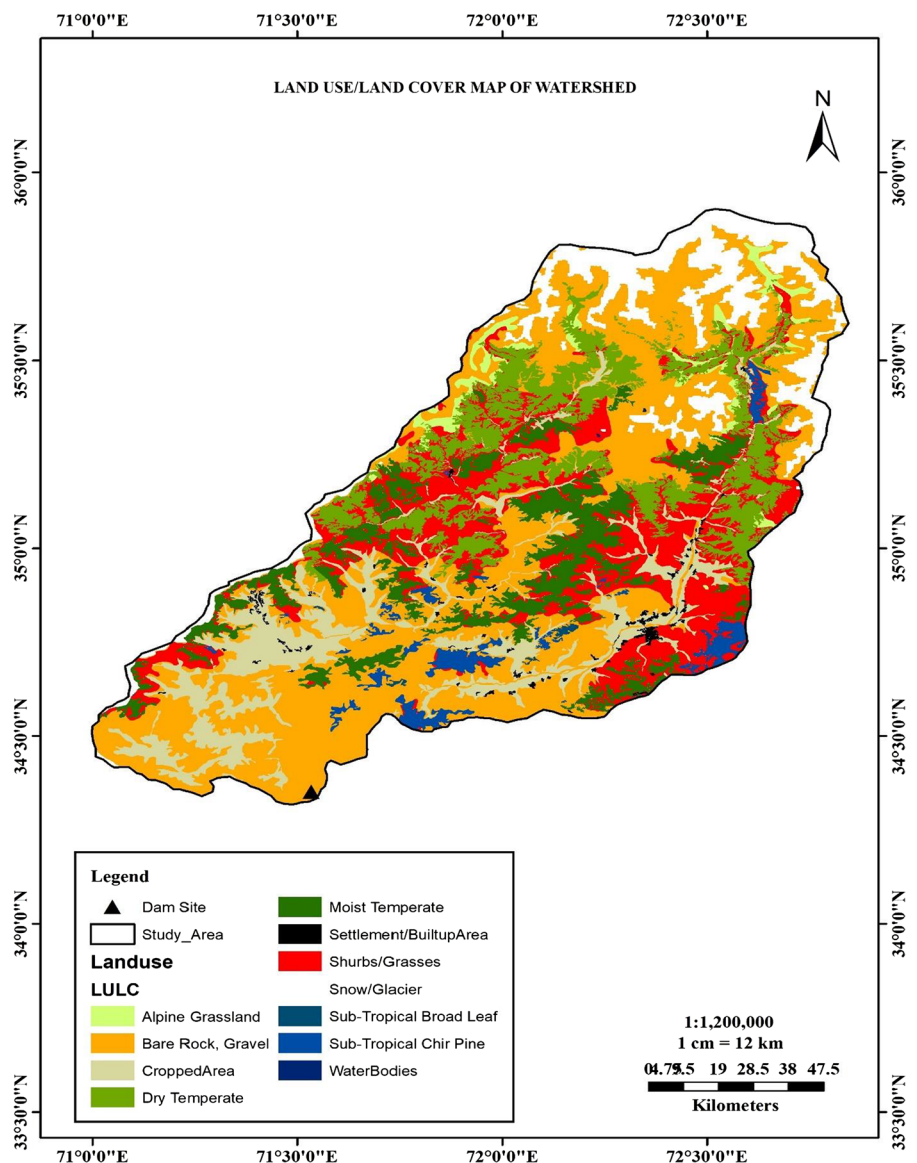


◀**Fig. 5** a, b Contour and rainfall/runoff erosivity (R-factor) map of Mohmmmand Watershed. c, d Soil Erodibility (K-factor) and Slope length/slope steepness (LS-factor) Map of Mohmmmand Watershed. e, f Land use (LU)/Land cover (LC) C-factor and Land Support/Practice (P-factor) Map of the Watershed

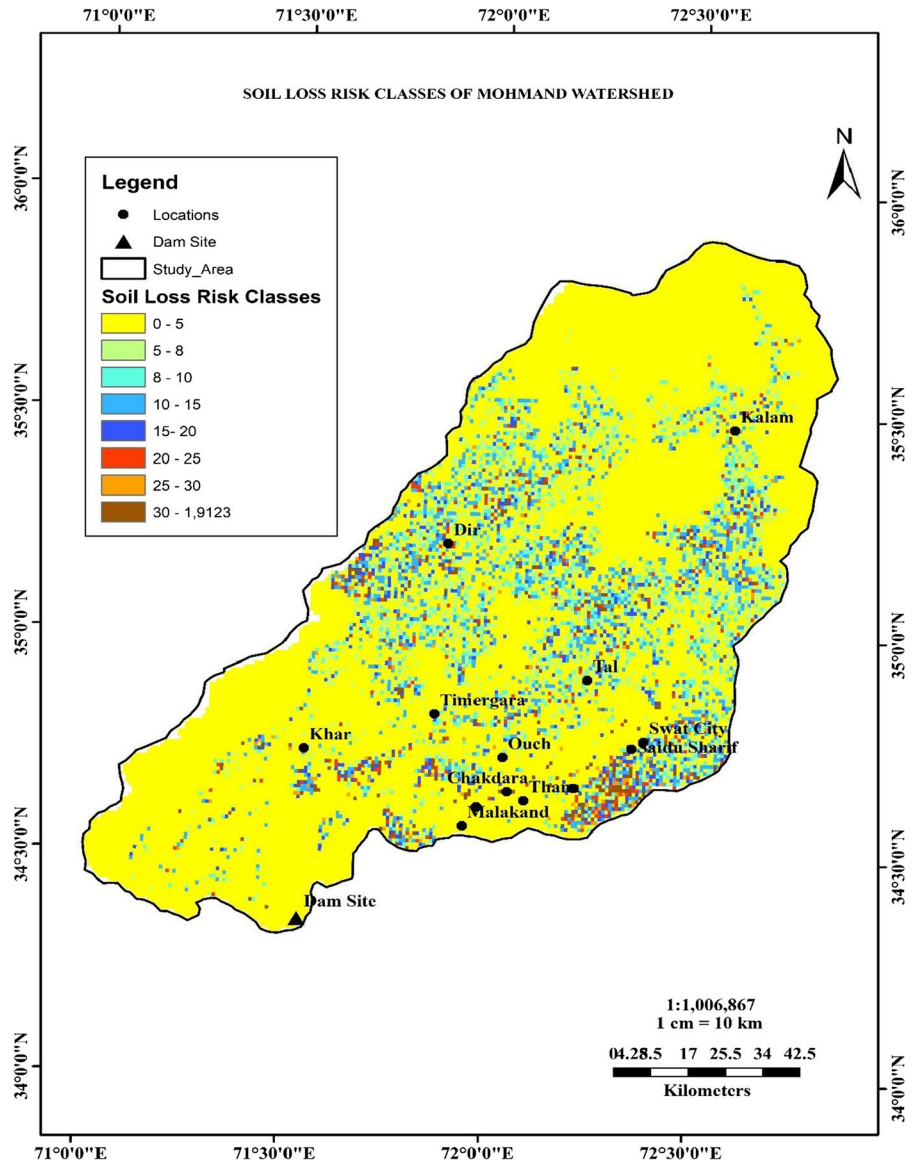
(SEMMED), Areal Non-Point Source Watershed Environment Response Simulation (ANSWERS), Limburg Soil Erosion Model (LISEM) European Soil Erosion Model (EUROSEM) Soil And Water Assessment Tool (SWAT) and Agricultural Non-point

Source Pollution Model (AGNPS). This model can be applied to more alternate management practices, such as the effect of soil stabilization, contour bounding, etc. The model can be helpful in corresponding river basins in the Himalayan region, ensuring proper calibration and validation. Another factor for soil is called the “T-value,” which is “tolerable soil loss.” It is usually not used directly in the RUSLE equation but is often used with RUSLE in addition to conservation planning. Soil loss tolerance (T) means how much soil can withstand maximum soil loss per ton of

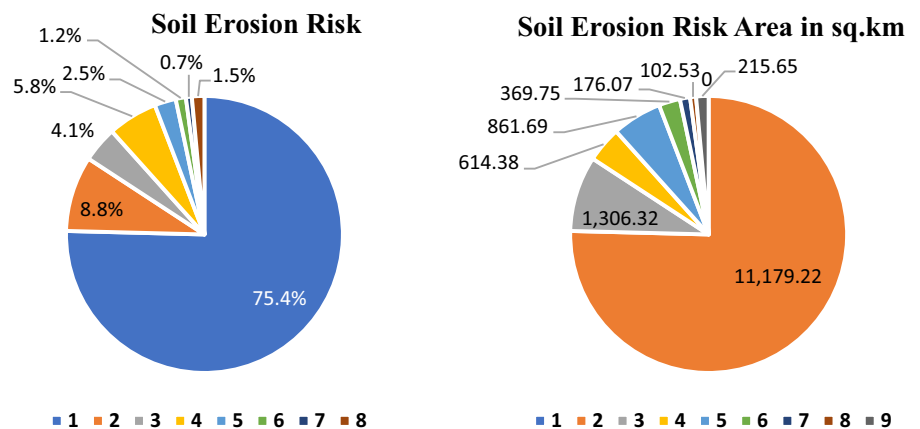
**Fig. 6** LU/LC map of Mohmmmand Watershed



**Fig. 7** Soil loss risk classes of Mohmand watershed



**Fig. 8 a** Percentage of soil erosion risk and **Figure, b** soil erosion risk area in Sq. km





**Table 5** Soil erosion risk classes of mohmmmand watershed

Sr. No	Soil erosion risk classes			Area	
	Class	Description	Km <sup>2</sup>	Acres	Percentage
1	<5	Negligible	11179.22	2,762,440	75.4
2	5–8	Slight	1306.32	322,798	8.8
3	8–10	Low	614.38	151,816	4.1
4	10–15	Moderate	861.69	212,929	5.8
5	15–20	High	369.75	91,368	2.5
6	20–25	Very high	176.07	43,507	1.2
7	25–30	Severe	102.53	25,337	0.7
8	> 30	Very severe	215.65	53,288	1.5
Grand total			14825.61	3,663,482	–

acreage per year and maintain high crop productivity levels economically and indefinitely.

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**Data Availability** Enquiries about data availability should be directed to the authors.

**Declarations**

**Conflict of interest** There are no conflict of interest.

**Appendix**

See Table 6.

**Table 6** RUSLE parameters

Sr. No	Parameters	Description
1	A	Mean annual soil loss (ton ha <sup>-1</sup> year <sup>-1</sup> )
2	R	Rainfall/runoff erosivity factor (MJ mm ha <sup>-1</sup> year <sup>-1</sup> )
3	K	Soil erodibility factor (ton ha MJ <sup>-1</sup> mm <sup>-1</sup> )
4	LS	Slope length/slope steepness factor (dimensionless)
5	C	Cover factor (dimensionless)
6	P	Support practice factor (dimensionless)

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