Abstract: Water induced soil erosion has always been a matter of concern in watersheds as they increase the soil vulnerability towards erosion. If unchecked, the eroded material reduces the capability of the river to carry the adequate amount of water and increase the amount of sediments in the watershed area. Determining vulnerability of soil to erosion plays a key role in identifying the extent of fragility and helps in making appropriate plans for conservation. Among various methods present to assess soil erosion vulnerability, there is a need to understand the frequently used methods so far and its advancement with time. Various models have been used in past two decades (1991-2019) and the Revised Universal Soil Loss Equation (RUSLE) is the most used model because of its quantitative ability to estimate the average annual soil loss due to erosion in a watershed and its compatibility with the GIS interface. Different approaches like MCDM, SWAT etc. are being utilised to study soil erosion vulnerability of watersheds. This review showed that the frequently used MCDM method is a Compound Factor (CF) method and that RUSLE is a most used quantitative approach. The review identifies 14 different methods which includes 4 methods which provide quantitative estimation while the other 10 methods are used for qualitative assessment of soil erosion vulnerability. Being the most adopted approach, various modifications of different factors of RUSLE introduced by researchers have made it more efficient with time. This review identifies the trend in advancement of various approaches and methods to study soil erosion vulnerability of watersheds around the world and also how various studies are distributed in the Himalayan and non-Himalayan region. The review also provides an understanding of the status of various current approaches to study soil erosion in a watershed and lists the improvements adopted in the frequently used approaches during 1991 and 2019.

Keywords: Soil erosion vulnerability; RUSLE; Watershed; MCDM
INTRODUCTION

Watershed comprises different land uses and water bodies. Vulnerability of watersheds towards soil erosion is triggered by a combination of factors such as steepness of slope, climate, inappropriate land use & land cover patterns (e.g. sparse vegetation) and ecological disasters (e.g. forest fires) (Parveen et al., 2012) and depends on erosivity, erodibility and land use management practices. Soil erosion vulnerability plays a key role in identifying the extent of fragility and making appropriate plans for conservation of a watershed. Soil erosion has both on-site and off-site detrimental impacts and is one of the most critical environmental hazards as it adversely affects both the economy and environment.

To understand soil conservation and ecosystem management mechanisms in a watershed, soil erosion evaluation and mapping of soil loss susceptible area is required (Gelagay and Minale, 2016). There are several methods used to access a soil erosion susceptible region. These methods are based on various parameters like land use, soil quality and topography etc. So far, water quality being a strong indicator (Ghosh et al. 2013) of soil erosion is often neglected in conducting susceptibility studies. The relationship between soil erosion vulnerability and land use allows the identification of more susceptible areas to erosion and the need for implementation of soil management and conservation practices to reduce soil erosion vulnerability. The assessment of the annual soil erosion rate and development of a soil erosion map (Zhou et al., 2014) for a watershed in various studies have provided spatial patterns of classified soil erosion risk zones indicating areas with high, severe and low erosion risk area. Topography plays an important role in controlling soil movement in a watershed and areas mostly covered by high fraction vegetation are at a lower level of soil erosion risk (Prasannakumar et al., 2011). Unsystematic land use pattern has a certain impact on soil and water resulting in its erosion and deteriorating its stream quality. The eroded materials carried down to the lower reaches of the rivers make them incompatible to carry excess amount of water and sediment load during a monsoon period (Ghosh et al., 2013). The protective effect of land cov-
er leads to demotion of vulnerability categories (Stathopoulos et al., 2017).

In watersheds, soil erosion is a matter of concern as it is likely to have an impact on water quality along with soil degradation. Study of soil erosion in various regions has increased in the past decade. A wide variety of methods have been adopted by different researchers to study and model soil erosion. The objectives of this paper are a) to understand advances in the study of soil erosion vulnerability around the globe, b) to identify the most frequently used methods to assess soil erosion vulnerability under different circumstances, in the past two decades, c) to know the proportion of studies conducted in the fragile region of Himalayas and d) to understand how water quality has been included in research related to the assessment of the soil erosion vulnerability factor.

METHODOLOGY

This paper attempts to understand the advancement in use of several models in assessing soil erosion vulnerabilities in the last three decades (1991-2019). Since the Himalayan region is one of the most fragile ecosystems because of its steep slope, poor soil and heavy monsoon rains, it is important to study the fragility of such an ecosystem. In this view, it becomes necessary to be familiar with the frequency of previous studies conducted in this region and the methods employed globally to assess such an ecosystem in order to plan on future strategies. For the selection of related academic papers in past two decades (1991-2019) on related subjects web search engine (Google scholar) and publishers’ websites were used. To obtain papers on soil erosion vulnerability the primary key words used were: soil erosion vulnerability assessment, Himalayan region, RUSLE for the period 1991-2019 in three different sets and combinations. The papers including any qualitative or quantitative method to assess soil erosion vulnerability were selected. These papers come from journals published worldwide to cover the work done across the globe. These studies were further searched on the basis of filter for a decade and were classified into three time periods, namely, 1991-2000, 2001-2010 and 2011-2019. The
papers obtained from both these searches were compared and repetitions were removed. Among the top searches which were directly related to the subject, 130 research papers were selected to further understand the approach used to assess soil erosion vulnerability in the past two decades (1991-2019) and distribution of the studies conducted in the Himalayan and Non-Himalayan region. Further, each study was categorized according to the used methods to identify the most popular methods in the past two decades.

ADVANCEMENT IN VARIOUS APPROACHES FOR ASSESSING SOIL EROSION VULNERABILITY

Various models have been used for assessing soil erosion vulnerability such as Revised Universal Soil Loss Equation (RUSLE), Water Erosion Prediction Project (WEPP), Soil & Water Assessment Tool (SWAT), Erosion Potential Method (EPM), Principal Component Analysis (PCA) and Multi Criteria Decision Method (MCDM)-based qualitative assessment methods like Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Compound Factor (CF), Višekriterijumska Optimizacija i Kompromisno Rešenje (VIKOR), with morphometric, soil and water quality parameters as input. The results showed that RUSLE/USLE models are the most used methods to assess soil erosion vulnerability. Studies related to soil erosion vulnerability using different methods (Figure 1) have increased in each decade since 2000. In models, different parameters like land use and land cover, morphometric parameters, soil quality, and combinations of these parameters have been used to study the soil erosion vulnerability. It is evident from the results that no study among 130 studies has incorporated all three parameters i.e. soil quality, water quality and land use together to study soil erosion vulnerability (Figure 2).

Over the years, the number of studies more than doubled from 2011 to 2019 (155) in comparison to the period 2000-2010 (41) (Figure 1(a)). In the past three decades, the regions of study distribution were mainly non-Himalayan regions (75.38%) and the Himalayan region being one of the most fragile ecosystems accounts for only 24.62 percent of studies. The review also suggested that RUSLE is the most frequently used model having been used in 51.4 percent of the studies (Figure 3), while all other methods together account for 48.6 percent of the studies.

A total of fourteen methods were used so far among which ten methods provide qualitative status of soil erosion vulnerability and four methods (RUSLE, SWAT, EPM and WEPP) provide a quantitative estimation of soil erosion. Both qualitative and quantitative methods involve various parameters like topography, land use, soil quality etc, whereas water quality parameters were not considered as indicators. Methods used to assess soil erosion will be briefly discussed in the following section.

METHODS USED FOR ASSESSING SOIL EROSION VULNERABILITY

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS):

This method was first introduced by Hwang and Yoon (1981) and Ameri et al., 2018 used it to study the soil erosion susceptibility in a watershed (Table 10). This method shares 0.7% of the total studies reviewed being among the least used MCDM methods so far (Figure 3). It is a distance-based method and the main source of calculation is based on a positive ideal solution (PIS) and negative ideal solution (NIS) for identifying decision making alternatives. In the model, the preferred alternative is the one that has the least distance from the positive ideal solution (PIS) and a higher distance from the negative ideal solution (NIS). The results of the two distances are expressed in the form of a closeness coefficient. The highest closeness coefficient indicates the most preferred alternative (Liou and Wang, 1992); (Kannan et al., 2009). In this method, different parameters like morphology, geology, slope; soil quality and land use can be taken depending upon the data availability and behaviour of the parameter. This method has been used less frequently in the past decades (2000-2010) but is a useful method for a qualitative ranking of watersheds with respect to soil erosion (Figure 2 & 3).
VIšekriterijumska optimizacija i kompromisno rešenje (VIKOR):

VIKOR is a very well known MCDM technique which emphasizes the selection and ranking of an alternative set of conflicting criteria (Opricovic and Tzeng, 2004). It was first introduced by (Opricovic and Tzeng, 2004). The VIKOR is a less used method in assessing and ranking sub watersheds (Table 10). In this method, normalized decision matrix based on criteria and their behaviour towards the alternatives and weighted decision matrix is computed. The advantage of this method is that the evaluation of all the criteria does not require expert review; but, raw data can also be used for assigning weights to the criteria. Methods

Figure 1. (a) Year wise increase in research on soil erosion vulnerability (b) Region wise studies conducted on soil erosion vulnerability assessment

Source: Author

Figure 2. Various methods used along the years (1991-2019)

Source: Author
like AHP (Analytical Hierarchy Process) may be used for assigning weights. $S_i$ (Utility index) and $R_i$ (Regret Index) are calculated based on the best and worst value of each function. Further, $Q$ index is calculated and highest ranked alternative would be the best alternative. This method is suggested as best by Ameri et al. 2018 among other MCDM methods whereas overall it is less used by other researchers and shares 0.7% the total studies (Figure 2 & 3).

**Compound Factor (CF)**

This is the most commonly used MCDM methods with a varying number of parameters. This model provides a comparative estimation driven by scientific knowledge and understanding of a qualitative phenomenon (Todorovski and Džeroski, 2006). This is the most used MCDM method so far (9.5%) as shown in Figure 2 & 3 in which the total number of ranks assigned is based on the number of options. In this average of the ranks of all the parameters is designated as a compound value and represents the collective impact of all the parameters (Altâf et al., 2014). This method is flexible with a number of parameters selected for the study and weight assignment and if required can be performed based on expert review. The drawback of this method is that it has no provision for the normalization of variables of different scale and sizes and also, in case of same values, an assignment of the same rank can lead to over or underestimation of the state.

**Principal component analysis (PCA):**

Principal component analysis (PCA) is a powerful multivariate statistical technique to segregate parameters contributing to observed criteria to assess soil erosion vulnerability in a sub-watershed (Khaledian, 2016). It may be employed to explore the most influential parameters of different criteria like morphometric parameters, soil and land use parameters etc. based on the parameters which are highly correlated with important components. Further, this can be used to rank sub-watersheds to assess soil erosion vulnerability. This method has been used in few studies (1.4%) as shown in Figure 2 & 3 and is flexible for criteria selection, but requires a large number of parameters. Farhan (2017) has suggested that prioritization of watershed based on the Compound Factor is more consistent as compared to the PCA approach.

**FUZZY:**

The Fuzzy method can provide an optimum solution in which the uncertainties associated with evaluating criteria while assessing soil erosion vulnerability status using various multi cri-
teria approaches. The prioritization by the fuzzy analysis technique can be performed using various related criteria like morphometrics, land use etc. or even single criteria with different parameters. According to Chang’s extent analysis of the FAHP method (Chang, 1996), each criteria can be evaluated through the formation of pairwise comparison matrix-based on the fuzzy linguistic scale and weightage could obtained through the normalization of fuzzy measures. The prioritization of each sub-watershed can be carried out on the basis of an FAHP analysis score where the first rank will be assigned to the sub watershed having the highest analysis value which will indicate the most vulnerable zone. Fuzzy techniques are mostly useful for carrying out ranking with overlapping parameters and there is a lot of scope for the application of this method for the ranking of sub watersheds (Table 10). This method is used in 5.4 percent of the studies reviewed (Figure 3).

**Water Erosion Prediction Project (WEPP):**

WEPP (Water Erosion Prediction Project) are process-based models for runoff and soil erosion prediction (Laflen et al., 1997). Similar to the empirical models such as Revised USLE (RUSLE), the models have been widely used to model agricultural land (Renard et al., 1997). WEPP predict soil loss in a range of environments, e.g. rangeland and forest. WEPP model is capable of simulating runoff and sediment yield from the untreated watershed with good accuracy. It can be used to control soil loss and runoff by formulating structure based management strategies for watersheds. The WEPP software includes an erosion prediction model, a climate generator program and a Windows interface (Flanagan et al., 2007). Data required for this model are climate files, soil input and practices and management scenarios. This model requires parameters like the amount & duration of rainfall, maximum & minimum temp., solar radiation, organic carbon, texture and land use management practices in the watershed. This model has been used in only 2.7 percent of the studies (Figure 3 and Table 10), which may be due to its non-GIS interface and specific data requirements.

**Soil and Water Assessment Tool (SWAT)**

The Soil and Water Assessment Tool (SWAT) is a river basin model developed by the United States (US) Department of Agriculture in collaboration with Texas A&M University. SWAT version 2012 has been released in combination with ArcGIS (version 10.4) and ArcSWAT interface. Within the Geographic Information Systems (GIS) environment, SWAT is a distributed modelling as a watershed is delineated into sub-basins and subsequently into hydrologic response units (HRUs), which represent homogeneous combinations of land use, soil types, and slope classes in each sub basin. The physical processes associated with water and sediment movement, crop growth, and nutrient cycling are modelled at the HRU scale to assess the runoff generated from streams (Table 10). SWAT provides two methods for surface runoff estimation. The first one is based on the Soil Conservation Service curve number and the second one estimates runoff height using the Green and Ampt infiltration method. SWAT calculates the surface erosion caused by rainfall and runoff within each HRUs with the Modified Universal Soil Loss Equation (MUSLE) (Equation 2) (Williams, 1975). Soil erosion caused by rainfall and runoff is computed by the Modified Universal Soil Loss Equation (MUSLE).

\[
\text{sed} = 11.8 \times (Q_{surf} \times q_{peak} \times \text{areahru})^{0.56} \times K_{USLE} \times C_{USLE} \times P_{USLE} \times L_{USLE} \times C_{FRG}
\]

Where: sed is the sediment yield on a given day (metric tons); Qsurf is the surface runoff volume (mm H₂O ha⁻¹); qpeak is the peak runoff rate (m³ s⁻¹); areahru is the area of the HRU (ha); K_{USLE} is the USLE soil erodibility factor; C_{USLE} is the USLE cover and management factor; P_{USLE} is the USLE support practice factor; L_{USLE} is the USLE topographic factor, and C_{FRG} is the coarse fragment factor.

This model simulates hypothetical, real and future scenarios and has been proven an effective method of evaluating alternative land use effects on runoff, sediment and pollutant losses. SWAT model is one of the appropriate watershed models for long-term impact analysis. This method is among the most used (4.5%) quantitative methods used worldwide (Figure 2 & 3).
Erosion Potential Method (EPM)

The Gavrilović method (Erosion Potential Method, EPM) is an empirical, semi-quantitative model which has been extensively applied to erosion and torrent-related problems in the Balkan countries. The method encompasses erosion mapping, sediment quantity estimation, and torrent classification. The method does not explore physics of erosion processes and it is difficult to predict it efficiently with minimal data and lack of previous erosion research (Kostadinov et al., 2014). The outputs of this model are based on the multiplication of the model and categorisation of the model parameters such as Average annual temperature, Average slope of the study area, and Drainage density etc. Not all parameters are included in the model through multiplication, e.g., most of these parameters are categorized as high- or medium-sensitivity, whereas those in the multiplication form are classified as very high-sensitivity parameters. This method has been widely used in the European continent making it the second (8.1%) most used quantitative method (Figure 2&3). The following table represents the parameters used in this method by (Gavrilović et al., 2005) and also by other researchers provided in Table 10.

\[ W = T \times H \times F \times \pi \sqrt{Z^3} \]  \hspace{1cm} (1)

Where, \( W \) is the total annual erosion (m³/year), \( T \) is the temperature coefficient, \( H \) is the mean annual precipitation (mm), \( Z \) is the erosion coefficient, and \( F \) is the basin area (km²)

The temperature coefficient (\( T \)) is calculated by Equation (2):

\[ T = \sqrt{t_{10} + 0.1} \]  \hspace{1cm} (2)

The soil erosion coefficient (\( Z \)) can be calculated from the following Equation (3):

\[ Z = Y \times X (\phi + I_{av}) \]  \hspace{1cm} (3)

Where, \( X \) is the soil protection coefficient which reflects the type of landuse, \( Y \) is the coefficient of soil resistance which depends on soil and geology, \( \phi \) is the erosion and stream network developed coefficient that includes the type and extent of erosion, and \( I \) is the average slope(%) of the watershed.

Revised Universal Soil Loss Equation (RUSLE)

Being the most used model, RUSLE has been modified by various researchers retaining the basic soil loss equation (Benavidez et al., 2018). This method has been used in 51.4 percent of the studies is the most promising method for quantitative soil erosion vulnerability assessment. RUSLE is a straightforward and empirically based model that has the ability to predict long term average annual rate of soil erosion on slopes using data on rainfall pattern, soil type, topography, crop system and management practices (Prasannakumar et al., 2011). Although it is an empirical model, it not only predicts erosion rates of ungauged watersheds using knowledge of the watershed characteristics and local hydro climatic conditions, but also presents the spatial heterogeneity of soil erosion that is too feasible with reasonable costs and a better accuracy in larger areas (Angima et al. 2003). RUSLE has been widely used for both agricultural and forest watersheds to predict the average annual soil loss by introducing improved means of computing the soil erosion factors (Wischmeier and Smith, 1978; Renard et al., 1997). Digital elevation model (DEM) along with remote sensing data and GIS can be successfully used to enable rapid as well as detailed assessment of erosion hazards (Jain et al. 2001, Kouli et al. 2009). The emergence of soil erosion models has enabled the study of soil erosion, especially for conservation purposes, in an effective and acceptable level of accuracy. In order to estimate soil erosion and to develop optimal soil erosion management plans USLE/RUSLE has been widely applied worldwide to predict soil loss because of its convenience in application and compatibility with GIS (Millward and Mersey, 1999); (Jain et al., 2001); (Jasrotia and Singh, 2006); (Dabral et al., 2008); (Pandey et al., 2009); (Zhou et al., 2014); (Shivhare et al., 2018). The assessment of the vulnerability of soils to erosion on a large scale, like in basins, can be carried out with the RUSLE model, while its topographic factor is reformulated, improving its representation in the ba-
sin’s scale (Yuksel et al., 2008) (Adediji, 2010) (Ozsoy et al., 2012) (Prasannakumar et al., 2011) (de Oliveira et al., 2014).

The Revised Universal Soil Loss Equation (RUSLE) is used to estimate the average annual soil loss in the watershed or basin (Mondal et al., 2016) and further categorise into soil erosion vulnerability classes on the basis of annual soil loss (tonne ha⁻¹ yr⁻¹). In addition to the studies reviewed by Hess et al., 2018, the advances in various improvised methods for calculating factors of RUSLE by various researchers to conduct the study in past years from 1991-2019 has been reviewed in the following section. RUSLE has the following structure by (Renard et al., 1997), which is an empirical formula:

\[ A = R \times K \times L \times S \times C \times P \]  

(1)

Where,

- \( A \) = soil loss (t ha⁻¹ yr⁻¹)
- \( R \) = rainfall erosivity (MJ mm ha⁻¹ h⁻¹ yr⁻¹)
- \( K \) = soil erodibility (t h MJ⁻¹ mm⁻¹)
- \( L \) = topographic factor (dimensionless)
- \( S \) = soil use and management factor (dimensionless)
- \( P \) = soil conservation practice factor (dimensionless)

Table 1. R factor used by various researchers (Source: Author)

| S.No. | Equations | Other studies |
|-------|-----------|--------------|
| 1.    | \( R = 79 + 0.363X \) | (Bhat et al., 2017) (Parveen et al., 2012) (Kumar and Kushwaha, 2013) (Ghosh et al., 2013) (Mahapatra et al., 2018) |
| 2.    | \( R = 0.0483 \times 1.610 \) | (Uddin et al., 2016) |
| 3.    | \( R = 8.12 + 0.562X \) | (Gelagay and Minale, 2016) |
| 4.    | \( R = 1.753 \times 10(1.5 \log \Sigma(Pi2)/P - 0.8188) \) | Wischmeier and Smith (1978) (Tahiri et al., 2016) |
| 5.    | \( \log R = 1.74 \times \log n (Pi2 / P) + 1.29 \) | (Haregeweyn et al., 2017) |

Where, \( X \) is the average annual rainfall in mm and \( P \) is monthly precipitation in mm, while \( P_2 \) is annual precipitation.

Figure 4. Conceptual framework of soil loss analysis by the RUSLE model

Source: (Gelagay and Minale, 2016)
RECENT ADVANCES IN THE ASSESSMENT OF SOIL EROSION VULNERABILITY IN WATERSHEDS

Brief of each factor as follows:

- **Rainfall Erosivity (R)**
  It is one of the factors that used to quantify the soil erosion and it is the potential ability to erode. Rainfall erosivity represents the potential of rain to cause erosion in an exposed and unprotected soil surface, whose physical definition is the product of rainfall kinetic energy and the maximum rainfall intensity in a 30-minute consecutive (EI_{30}) (Zhang et al., 2013).

- **Soil erodibility factor (K):** It is a measure of the erodibility of soil. The soil erodibility factor (K) relates to the rate at which different soils erode. The factor is rated on a scale from 0 to 0.7, with zero indicating soils with the least vulnerability to erosion and those with 0.7 as most vulnerable. According to various researchers the following methods have been adopted to calculate this factor:

| S.No. | Equations | Other studies |
|-------|-----------|---------------|
| 1.    | 100K= 2.1*10^{-4}M_{1.14}(12-a)+3.25*(b-2)+2.5(c-3) | Wischmeier and Smith, 1978 |
| 2.    | K= 2.8*10^{-7}M_{1.14}(12-a)+4.3*10^{-3}(b-2)+3.3*10^{-3}(c-3) | (Renard et al., 1997) (Kumar and Kushwaha, 2013) (Mahapatra et al., 2018) (Gaubi et al., 2017) |
| 3.    | Literature (Based on soil colour) (Table 1) | (Gelagay and Minale, 2016) |
| 4.    | Literature (Based on textural class) (Table 1) | (Parveen et al., 2012) |

Where, $K$=soil erodibility factor, $t$ ha$^{-3}$ MJ$^{-1}$ mm$^{-1}$, $M$=particle size parameter (per cent silt+per cent very fine sand)×(100–per cent clay), $a$=organic matter content (per cent), $b$=soil structure code (very fine granular 1; fine granular 2; medium or coarse granular 3; blocky, platy or massive 4) $c$=soil permeability class (rapid 1; moderate to rapid 2; moderate 3; slow to moderate 4; slow 5; very slow 6)

Table 2. K factor used by various researchers (Source: Author)

| S.No. | Equations | Other studies |
|-------|-----------|---------------|
| 1.    | 100K= 2.1*10^{-4}M_{1.14}(12-a)+3.25*(b-2)+2.5(c-3) | Wischmeier and Smith, 1978 |
| 2.    | K= 2.8*10^{-7}M_{1.14}(12-a)+4.3*10^{-3}(b-2)+3.3*10^{-3}(c-3) | (Renard et al., 1997) (Kumar and Kushwaha, 2013) (Mahapatra et al., 2018) (Gaubi et al., 2017) |
| 3.    | Literature (Based on soil colour) (Table 1) | (Gelagay and Minale, 2016) |
| 4.    | Literature (Based on textural class) (Table 1) | (Parveen et al., 2012) |

**Table 3. Estimated K values for some soils (Source: Author)**

| Based on Soil Colour (Gelagay and Minale, 2016) | Estimated K value [metric tons ha$^{-3}$ MJ$^{-1}$ mm$^{-1}$] |
|-----------------------------------------------|----------------------------------------------------------|
| Soil colour                                    |                                                          |
| Black Andosols,Vertisols                      | 0.15                                                     |
| Brown                                         |                                                          |
| Cambisols, Phaeozems, Re-gosol, Luvisols       | 0.20                                                     |
| Red                                           |                                                          |
| Lixisols, Nitosols, Alisols                   | 0.25                                                     |
| Yellow                                        |                                                          |
| Fluvisols, Xerosols                           | 0.3                                                      |

| Based on Textural class (Parveen et al., 2012) | Estimated K value [metric tons ha$^{-3}$ MJ$^{-1}$ mm$^{-1}$] |
|------------------------------------------------|---------------------------------------------------------------|
| Texture                                        | 0.5   | 2.0   | 4.0   |
| Fine sand                                      | 0.16  | 0.14  | 0.1   |
| Very fine sand                                 | 0.42  | 0.36  | 0.28  |
| Loamy sand                                     | 0.12  | 0.10  | 0.08  |
| Loamy very fine sand                           | 0.44  | 0.38  | 0.30  |
| Sandy loam                                     | 0.27  | 0.24  | 0.19  |
| Very fine sandy loam                           | 0.47  | 0.41  | 0.33  |
| Silt loam                                      | 0.48  | 0.42  | 0.33  |
| Clay loam                                      | 0.28  | 0.25  | 0.21  |
| Silt clay loam                                 | 0.37  | 0.32  | 0.26  |
| Silty Clay                                     | 0.25  | 0.23  | 0.19  |
• **Topographic factor (LS)**
  It is a factor of slope length (L) and slope gradient (S). According to various authors (Table 4) different equations have been used in the model.

Where, λ is the field slope length (m), and m assumes a value between 0.2 and 0.5

sl is slope length of the site (m) and S is the slope factor, A is the upslope contributing factor, B is the slope angle, β® is the land surface slope in degrees, m and n constants equal to 0.6 and 1.3, A® is up-slope contributing area per unit width of cell spacing (m² m⁻¹). The digital elevation model (DEM) can be used to obtain the accumulated flow and slope map.

• **Crop Cover Management Factor (C)**
  Crop cover management factor is the ratio of soil loss from land with specific vegetation to the corresponding soil loss from a continuous fallow land (Wischmeier and Smith, 1978). To derive the crop factor, imagery can be downloaded from relevant websites, and further the C factor value can be derived as per table provided in Table 6.

| Table 4. LS factor used by various researchers (Source: Author) |
|---|
| S.No. | Equation | Other studies |
| 1. | LS = Flow accumulation×cell size22.130.6SinSlope0.08961.3 | (Bhat et al., 2017) (Gelagay and Minale, 2016) |
| 2. | L = (λ/22.13)ᵐ | (Uddin et al., 2016) (Mahapatra et al., 2018) |
| 3. | LS = (Sλ/22.13)ᵐ - (0.065 + 0.045·S + 0.065·S²) | (Tahiri et al., 2016) |
| 4. | LS = (λ/22.13)ᵐ·(65.4sin²β + 4.5sin β + 0.0654) | (Wischmeier and Smith, 1978) |
| 5. | LS = A²22.130.6SinB0.08961.3 | (Parveen et al., 2012) |
| 6. | LS® = (m + 1) [A® / 22.13]ᵐ [sin β® / 0.09]ⁿ | (Gaubi et al., 2017) (Kumar and Kushwaha, 2013) |

| Table 5. C Factor used by various researchers (Source: Author) |
|---|
| S.No. | Equation | Other Studies |
| 1. | Literature (Table 6) | (Kumar and Kushwaha, 2013) (Gelagay and Minale, 2016) |
| 2. | C = 0.431 – 0.805·NDVI | (Uddin et al., 2016) (Parveen et al., 2012) |
| 3. | C = exp -αNDVIβ-NDVI | (Bhat et al., 2017) |

| Table 6. The value of C factor from literature (Source: Author) |
|---|
| Land use land cover | C – Factor | Other Studies |
| Water body | 0 | (Gelagay and Minale 2016) (Kumar and Kushwaha 2013) (Wischmeier and Smith, 1978) |
| Shrub land | 0.014 | (Gelagay and Minale 2016) |
| Grazing land | 0.05 | (Gelagay and Minale 2016) |
| Built up land | 0.024 | (Gelagay and Minale 2016) (Wischmeier and Smith, 1978) |
| | 0.2 | (Wischmeier and Smith, 1978) |
| | 0.5 | (Kumar and Kushwaha 2013) |
| Barren land | 0.6 | (Gelagay and Minale 2016) |
| Agricultural land | 0.58 | (Mahapatra et al. 2018) |
| Forest land | 0.04 | (Gelagay and Minale 2016) |
| Forest and Grasslands | 0.01 | (Mahapatra et al. 2018) |
| Very dense forest | 0.004 | (Kumar and Kushwaha 2013) |
• Conservation Practices Factor (P)

It is the ratio of soil loss with specific support practice to the correspondence soil loss with upslope and downslope cultivation. The value of practice factor will be assigned according to the table given below.

For determining annual soil loss with the help of Arc GIS tools, downloaded digital elevation model and classified land use and a land cover map, each factor of the RUSLE equation can be generated in the form of a raster image. After combining the entire raster image of five factors using the Arc GIS tool, soil erosion map can be made and annual soil loss can be calculated for each sub-watershed sensing. After calculating annual soil loss, soil erosion vulnerability assessment can be done on the basis of a category defined in literature by different researchers as provided below:

| Dense forest | 0.008 | (Kumar and Kushwaha 2013) |
| Moderately dense forest | 0.08 | (Kumar and Kushwaha 2013) |
| Open forest | 0.4 | (Kumar and Kushwaha 2013) |
| Scrub forest | 0.02 | (Wischmeier and Smith, 1978) |
| Forest plantation | 0.02 | (Kumar and Kushwaha 2013) |
| Orchard | 0.1 | (Kumar and Kushwaha 2013) |
| Dense scrub | 0.05 | (Kumar and Kushwaha 2013) |
| Wasteland with scrub | 0.6 | (Kumar and Kushwaha 2013) |
| Wasteland without scrub | 0.8 | (Wischmeier and Smith, 1978) |
| Degraded forest/wastelands | 0.14 | (Mahapatra et al. 2018) |
| Degraded lands | 0.5 | (Mahapatra et al. 2018) |
| Fallow lands | 1 | (Mahapatra et al. 2018) |

Table 7. The value of factor P (Source: Author)

| Based on contour tillage (Wischmeier and Smith, 1978) | Renard et al., 1997 | Panagos et al. |
|------------------------------------------------------|----------------------|-----------------|
| **Slope %** | **Maximum length** | **P** | **Slope %** | **P** | **Slope** | **P** |
| 1 - 8 | 122 to 61 m | 0.5 | 0-1 | 0.6 | 9-12 | 0.6 |
| 9 - 12 | 36 m | 0.6 | 1-3 | 0.6 | 13-16 | 0.7 |
| 13 - 16 | 24 m | 0.7 | 3-5 | 0.5 | 17-20 | 0.8 |
| 17 - 20 | 18 m | 0.8 | 5-10 | 0.5 | 21-25 | 0.9 |
| 21 - 25 | 15m | 0.9 | 10-15 | 0.7 | >25 | 0.95 |

Gelagay and Minale, 2016

| Land use type | Slope % | P | Land use type | P |
|---------------|---------|----|---------------|----|
| Agriculture land | 0-5 | 0.1 | Dense Vegetation | 1 |
| | 5-10 | 0.12 | Sparse vegetation | 0.8 |
| | 10-20 | 0.14 | Built-up | 1 |
| | 20-30 | 0.19 | Water bodies | 1 |
| | 30-50 | 0.25 | Scrub land | 1 |
| | 50-100 | 0.33 | Agricultural Cropland | 0.5 |
| Other land | All | 1 | Fallow land | 0.9 |
| | | | Bare soil/barren land | 1 |

Naqvi et al., 2013
Apart from the above mentioned methods, researchers have used single components and combination of components such as morphometry, land use, water quality and soil quality of watersheds. Based on these components watersheds have been prioritised using a combined component i.e. land use & water quality; land use and soil quality and a few studies have calculated it based on only one components such as morphometric parameters, land use and land cover (Table 9). A general approach is to assess soil erosion vulnerability using the Revised Universal Soil Loss Equation (RUSLE) model inclusive of land use and by and discretely analyse the effect of land use on water quality. The existing approach (Figure 5) for understanding the influence of land use includes study on soil erosion and water quality separately, which does not establish a relation between soil erosion vulnerability and water quality, although it has been reported by various studies that water quality is a strong indicator of soil erosion. Therefore, an advanced approach is required to manage watershed that could be taken into consideration which could analyse the link between soil erosion vulnerability and its relation with stream quality in a watershed. This advanced approach will provide assistance in developing better watershed management plans (Figure 5).

### Table 8. Categories of soil erosion vulnerability

| Soil Loss (Tons ha\(^{-1}\) yr\(^{-1}\)) | (Beskow et al. 2009) | (Praveen and Kumar, 2012) | (Haregeweyn et al. 2017) | (Mahapatra et al. 2018) |
|----------------------------------------|----------------------|--------------------------|------------------------|------------------------|
| 0-2.5                                  | Slight               | Very Slight              | Slight                 | Very Slight            |
| 2.5-5                                  | Slight to moderate   |                          |                        |                        |
| 5-10                                   | Moderate             | Slight                   | Moderate               | Slight                |
| 10-15                                  | Moderate to High     | Slight                   | High                   | Moderately severe     |
| 15-20                                  | High                 | Moderate                 | High                   |                       |
| 20-25                                  |                      | Very High                | Severe                 |                        |
| 25-30                                  |                      | Very High                |                        |                        |
| 30-40                                  |                      | Severe                   |                        |                        |
| 40-50                                  |                      | Very High                |                        |                        |
| 50-60                                  |                      | Very Severe              |                        |                        |
| 60-70                                  |                      |                          |                        |                        |
| 70-80                                  |                      |                          |                        |                        |
| 80-100                                 |                      |                          |                        |                        |
| >100                                   |                      |                          |                        |                        |

### Table 9. Summary of the review

| Authors       | Year | Model                   | Country | Region |
|---------------|------|-------------------------|---------|--------|
| 1 B et al.    | 2013 | SWAT, LULC              | India   | NH     |
| 2 Campos Pinto et al. | 2016 | FUZZY, LU & SQ         | Brazil  | NH     |
| 3 Said et. al. | 2018 | Morphometric            | India   | NH     |
| 4 Aher et. al. | 2013 | MCDM, FUZZY, Morphometric | India   | NH     |
| 5 Bhat et. al. | 2017 | RUSLE                   | India   | H      |
| 6 Altaf et. al | 2014 | MCDM, Morphometric, LULC | India   | H      |
| 7 Quiroz Londoño et al. | 2016 | FUZZY, LU & SQ | Argentina | NH |
| 8 Kumar and Kushwaha | 2013 | RUSLE                   | India   | H      |
|   | Authors           | Year | Methods/Techniques                              | Location  | Type  |
|---|------------------|------|-----------------------------------------------|-----------|-------|
| 9 | Ameri et. al.    | 2018 | MCDM, TOPSIS, Morphometric, VIKOR              | Iran      | NH    |
|10 | Shahabi et. al.  | 2015 | FUZZY                                         | Iran      | NH    |
|11 | Mandal and Sharda| 2011 | RUSLE                                         | India     | H     |
|12 | Khaledian et. al.| 2016 | PCA, LULC                                      | Iran      | H     |
|13 | Xavier et. al.   | 2016 | RUSLE                                         | Brazil    | NH    |
|14 | Sharda et. al.   | 2013 | RUSLE                                         | India     | H     |
|15 | Guo et. al.      | 2013 | RUSLE                                         | China     | NH    |
|16 | Hart             | 2006 | LU & WQ                                       | USA       | NH    |
|17 | Stathopoulos et. | 2017 | MCDM                                          | Greece    | NH    |
|18 | Gaubi et. al.    | 2016 | RUSLE                                         | Tunisia    | NH    |
|19 | Gealgay and Minale| 2016 | RUSLE                                         | Ethiopia  | NH    |
|20 | Tahir et. al.    | 2016 | RUSLE                                         | Morocco   | NH    |
|21 | Ghosh et. al.    | 2013 | RUSLE                                         | India     | H     |
|22 | Kinthada et. al. | 2013 | Morphometric                                   | India     | NH    |
|23 | Millward and Mersey| 1999 | RUSLE                                         | Mexico    | NH    |
|24 | Haregeweyn et. al.| 2017 | RUSLE                                         | Ethiopia  | NH    |
|25 | Gaikwad and Bhagat| 2018 | MCDM                                          | India     | NH    |
|26 | Singh et. al.    | 2008 | Morphometric                                   | India     | H     |
|27 | Ahn and Kim      | 2017 | SWAT                                          | South Korea | H |
|28 | Parveen and Kumar| 2012 | RUSLE                                         | India     | NH    |
|29 | Mahapatra et. al.| 2018 | RUSLE                                         | India     | H     |
|30 | Jain et. al.     | 2001 | RUSLE                                         | India     | H     |
|31 | Sharda and Mandal| 2018 | RUSLE                                         | India     | H     |
|32 | Beskow et. al.   | 2009 | RUSLE                                         | Brazil    | NH    |
|33 | Teferi, E. et. al.| 2009 | RUSLE                                         | Ethiopia  | NH    |
|34 | Dabral et. al.   | 2008 | RUSLE                                         | India     | H     |
|35 | Erdogan et. al.  | 2007 | RUSLE                                         | Turkey    | NH    |
|36 | Fistikoglu and Harmancioglu| 2002 | RUSLE | Turkey | NH |
|37 | Fu et. al.       | 2005 | RUSLE                                         | China     | NH    |
|38 | Hui et. al.      | 2010 | RUSLE                                         | China     | H     |
|39 | Jain and Das     | 2010 | RUSLE                                         | India     | NH    |
|40 | Pandey et. al.   | 2009 | RUSLE                                         | India     | H     |
|41 | Yue-qing et al.  | 2014 | RUSLE                                         | China     | NH    |
|42 | Zhang et. al.    | 2009 | RUSLE                                         | USA       | H     |
|43 | Prasannakumar et. al.| 2012 | RUSLE | India | NH |
|44 | Sheikh et. al.   | 2011 | RUSLE                                         | India     | H     |
|45 | Bagyaraj et. sl. | 2014 | Morphometric, LULC                             | India     | NH    |
|46 | Balasubramani et. al.| 2015 | RUSLE                                         | India     | NH    |
|47 | Bhandari et. al. | 2015 | RUSLE                                         | Nepal     | NH    |
|48 | Biswas and Pani  | 2015 | RUSLE                                         | India     | NH    |
|49 | Chatterjee et. al.| 2014 | RUSLE                                         | India     | NH    |
| Page | Title                                                                 | Year | Methodology | Location | Decision Maker |
|------|----------------------------------------------------------------------|------|-------------|----------|----------------|
| 50   | Chowdary et. al.                                                      | 2013 | MCDM        | India    | NH             |
| 51   | Demirci and Karaburam                                                | 2012 | RUSLE       | Turkey   | NH             |
| 52   | Dutta et. al.                                                        | 2015 | RUSLE       | India    | NH             |
| 53   | Rawat et. al.                                                        | 2013 | RUSLE LULC  | India    | H              |
| 54   | Karaburam                                                           | 2010 | RUSLE       | Istanbul | NH             |
| 55   | Ganasari and Ramesh                                                  | 2015 | RUSLE       | India    | NH             |
| 56   | Abdul Rahaman et al.                                                 | 2015 | RUSLE       | India    | NH             |
| 57   | Farhan et. al.                                                       | 2013 | RUSLE       | Jordan   | NH             |
| 58   | Claessens et. al.                                                    | 2008 | RUSLE       | Kenya    | NH             |
| 59   | Patil and Sharma                                                     | 2014 | RUSLE       | Malaysia | NH             |
| 60   | Bhattarai and Dutta                                                  | 2007 | RUSLE       | Thailand | NH             |
| 61   | (Pancholi et al. 2015)                                               | 2015 | RUSLE       | India    | NH             |
| 62   | Kumar et. al.                                                        | 2014 | RUSLE       | India    | H              |
| 63   | Efe et. al.                                                          | 2006 | RUSLE       | Turkey   | NH             |
| 64   | Farhan and Anaba                                                     | 2016 | Morphometric| Jordan   | H              |
| 65   | Kushwaha and Jain                                                    | 2013 | SWAT        | India    | H              |
| 66   | Lee                                                                  | 2003 | RUSLE       | Korea    | H              |
| 67   | Li et. al.                                                           | 2009 | FUZZY       | China    | NH             |
| 68   | Malik and bhatt                                                      | 2014 | MorphometricLULC | India | H             |
| 69   | Markose and Jayappa                                                  | 2016 | RUSLE       | India    | NH             |
| 70   | Ashiagbor et. al.                                                    | 2013 | RUSLE       | Ghana    | NH             |
| 71   | Laahaoi et. al.                                                      | 2015 | RUSLE       | Morocco  | NH             |
| 72   | Nunes et. al.                                                        | 2008 | SWAT        | Portugal | NH             |
| 73   | Oeurng et. al.                                                       | 2011 | SWAT        | France   | NH             |
| 74   | Patil et. al.                                                        | 2015 | RUSLE       | India    | NH             |
| 75   | Prasannakumar et. al.                                                | 2011 | RUSLE       | India    | NH             |
| 76   | Rahman et. al.                                                       | 2009 | MCDM        | China    | NH             |
| 77   | Rawat et. al.                                                        | 2011 | MCDM        | India    | H              |
| 78   | Rozos et. al.                                                        | 2013 | RUSLE       | Greece   | NH             |
| 79   | Setegn et al.                                                        | 2009 | MCDMSWAT    | Ethiopia | NH             |
| 80   | Mutua and Klik                                                       | 2004 | RUSLE       | Kenya    | NH             |
| 81   | Shinde et. al.                                                       | 2011 | RUSLE       | India    | NH             |
| 82   | Singh et. al.                                                        | 2012 | WEPP        | India    | H              |
| 83   | Singh and Panda                                                      | 2017 | RUSLE       | India    | H              |
| 84   | Amsalu and Mengaw                                                    | 2014 | MCDM        | Ethiopia | NH             |
| 85   | Uddin et. al.                                                        | 2016 | RUSLE       | Nepal    | H              |
| 86   | Shalini Tirkey et al.                                                | 2015 | RUSLE       | India    | NH             |
| 87   | Vemu and Pinnamananeneni                                             | 2011 | RUSLE       | India    | NH             |
| 88   | Vijith et. al.                                                       | 2012 | MCDM        | India    | H              |
| 89   | Kalambukattu and Kumar                                               | 2017 | RUSLE       | India    | H              |
| 90   | Singh and Singh                                                      | 2018 | MCDM        | India    | H              |
| 91   | Angima et. al.                                                       | 2003 | RUSLE       | Kenya    | NH             |
| 92   | Farhan et. al.                                                       | 2017 | PCA         | Jordan   | NH             |
|    | Authors and Year | Methodology | Region | Himalayan |
|----|------------------|-------------|--------|-----------|
| 93 | Albaredeyia et al. 2011 | WEPP | Palestinian Territories | NH |
| 94 | Kefi et al. 2011 | RUSLE | Tunisia | NH |
| 95 | Greer et al. 2006 | WEPP | PNW USA | NH |
| 96 | Manyiwa and Dikinya 2013 | RUSLE | Botswana | NH |
| 97 | Naqvi et al. 2012 | RUSLE | India | H |
| 98 | Farhan and Nawaiseh 2015 | RUSLE | Jordan | NH |
| 99 | Pal 2016 | MCDM | India | NH |
| 100 | Landi et al. 2011 | WEPP | Iran | NH |
| 101 | Yacine et al. 2019 | RUSLE | Morocco | NH |
| 102 | Mustefa et al. 2019 | RUSLE | Ethiopia | NH |
| 103 | Mihi et al. 2019 | RUSLE | Algeria | NH |
| 104 | Haidara et al. 2019 | FUZZY | Morocco | NH |
| 105 | Makaya et al. 2019 | FUZZY | South Africa | NH |
| 106 | Panagopoulos et al. 2019 | SWAT | Greece | NH |
| 107 | Richardson and Amankwata 2019 | FUZZY | Mexico | NH |
| 108 | Jazouli et al. 2018 | RUSLE | Morocco | NH |
| 109 | Panagos et al. 2015 | RUSLE | Europe | NH |
| 110 | O.A. 2019 | RUSLE | Nigeria | NH |
| 111 | Hembram et al. 2019 | Morphometric | India | NH |
| 112 | Halefom et al. 2019 | MCDM | Ethiopia | NH |
| 113 | Borrelli et al. 2014 | RUSLE | Italy | NH |
| 114 | Karan et al. 2019 | RUSLE | India | NH |
| 115 | Phan et al. 2019 | RUSLE | Vietnam | NH |
| 116 | Baloshi et al. 2019 | LULC | Albania | NH |
| 117 | Pareta et al. 2019 | Morphometric | India | H |
| 118 | Tadesse et al. 2017 | LULC | Ethiopia | NH |
| 119 | Owusu 2012 | RUSLE | Ghana | NH |
| 120 | Dragićević et al. 2018 | EPM | Croatia | NH |
| 121 | Amini et al. 2010 | EPM | Iran | NH |
| 122 | Blinkov et al. 2013 | EPM | Macedonia, Serbia, and Bulgaria | NH |
| 123 | Amini et al. 2008 | EPM | Iran | NH |
| 124 | Haghizadeh et al. 2009 | EPM | Iran | NH |
| 125 | Yousefi et al. 2014 | EPM | Iran | NH |
| 126 | Spalevic et al. 2016 | EPM | Montenegro | NH |
| 127 | Lense et al. 2019 | EPM | Brazil | NH |
| 128 | Spalevic et al. 2015 | EPM | Montenegro | NH |
| 129 | Kostadinov et al. 2018 | EPM | Serbia | NH |
| 130 | Lovric and Tosi 2018 | EPM | Bosnia and Herzegovina | NH |

**Legend:** H= Himalayan; NH=Non Himalayan
CONCLUSION

There is need to recognise sites which are prone to erosion in watersheds. There are many methods adopted worldwide to implement the best management practices and suggest mitigation measures to overcome problems i.e. flooding landslides and sedimentation. As there is lot of scattered information on methods which are being used to assess soil erosion vulnerability, it is important to understand the methods which are being used and improved with time. The review suggested that so far RUSLE as a quantitative method has been the most widely used method to study soil erosion, yet other methods like MCDM SWAT and FUZZY etc. are also advancing with time. It was also observed that most of the less frequently used methods provide a qualitative output and researchers should encourage the use of such methods to identify erosion prone regions. Because of its compatibility with ArcGIS, RUSLE has emerged as the most accepted quantitative model to estimate soil loss so far. All factors of the RUSLE model have been modified to make it more convenient and user friendly with time, since many studies on water quality and soil erosion vulnerability under different land use have been reported separately using the RUSLE model and water quality analysis. Presently there is a lack of studies which establish the relationship between soil erosion vulnerability and water quality, since water quality acts as an indicator for the prioritization of a watershed. The determination of such relationships could be suggested as an advanced approach. A discrete effect of land use on soil or water quality will not provide adequate information about the characteristics of a watershed. The paper suggested how different methods are frequently being used and how different methods are varying across the Himalayan and non-Himalayan region. There has been a noticeable increase in study related to soil erosion assessment in the past decade. Studies such as this one may have possible effects on the understanding and estimation of the water quality status based on soil erosion conditions in watersheds.

Figure 5: Flow chart showing the existing and advance approaches to the development of watershed management plans
Source: Author
REFERENCES

Abdul, R.S., Aruchamy, S., Jegankumar, R., Abdul, A. S., 2015. Estimation of annual average soil loss, based on Rusle model in kallar watershed, bhavani basin, tamil nadu, India. Ann. Photogramm Remote Sens. Spat. Inf. Sci. 2, 207–214.

Adediji, A., 2010. Assessment of Revised Universal Soil Loss Equation (RUSLE) in Katsina Area, Katsina State of Nigeria using Remote Sensing (RS) and Geographic Information System (GIS). Iran J. Energy Environ,1.

Aher, P.D., Adinarayana, J., Gorantiwar, S.D., 2013. Prioritization of watersheds using multi-criteria evaluation through fuzzy analytical hierarchy process. Agric. Eng. Int. CIGR J. 15,11–18.

Ahn, S.R., Kim, S.J., 2016. Assessment of watershed health, vulnerability and resilience for determining protection and restoration Priorities. Environ. Model Softw.

Amini, S., Rafiei, B., Khodabakhsh, S., Heydari, M., 2010. WEPP and ANNs for simulating soil loss and runoff in a semi-arid Mediterranean region. Environ. Monit. Assess. 180,537–556.

Altas, S., Romshoo, S.A., 2014. Morphometry and land cover based multi-criteria analysis for assessing the soil erosion susceptibility of the western Himalayan watershed. Environ. Monit. Assess. 186, 3891–8412.

Ameri, A.A., Cerda, A., 2018. Erodibility prioritization of sub watersheds using morphometric parameters analysis and its mapping: A comparison among TOPSIS, VIKOR, SAW, and CF multi-criteria decision making models. Sci Total Environ. 613–614,1385–1400.

Amini, S., Rafiei, B., Khodabakhsh, S., Heydari, M., 2010. Estimation of erosion and sediment yield of Ekbatan Dam drainage basin with EPM, using GIS. Iran. J. Earth Sci. 2, 173–180.

Amsalu, T., Mengaw, A., 2014. GIS based soil loss estimation using RUSLE model: The case of Jabi Tehinan Woreda, ANRS, Ethiopia, Soil Loss. Nat Resour. 5, 616–626.

Angima, S.D., Stott, D.E., O’Neill, M.K., 2003. Soil erosion prediction using RUSLE for central Kenyan highland conditions. Agric Ecosyst Environ. 97, 295–308.

Ashiagbor, G., Forkuo, E.K., Laari, P., Aabeyir, R., 2013. Modeling soil erosion using RUSLE and RUSLE parameter estimation. Int J Remote Sens Geosci. 2.

B, H.K., Sai, R., Sampath, O., Nagendher, T., 2014. A Review- Impact of land use land cover change and best management practices in a watershed by using swat model. International Journal of Pure & Applied Bioscience. 2, 276–285.

Bagyaraj, M., Ramkumar, T., Venkatramanan, S., 2014. Assessment of soil erosion probability in Kodaikanal, India using GIS and remote sensing. Disaster Adv. 7, 36–49.

Balarasubramani, K., Veena, M., Kumaraswamy, K., Saravanabavan, V., 2015. Estimation of soil erosion in a semi-arid watershed of Tamil Nadu (India) using revised universal soil loss equation (rusle) model through GIS. Model Earth Syst Environ. 1.

Baloshi, V., Gjoka, F., Toromani, E., 2019. Determination of soil loss by erosion in different land covers categories and slope classes in Bovilla. International Journal of Environmental and Ecological Engineering. 13, 57–61.

Benavidez, R., Jackson, B., Maxwell, D., Norton, K., 2018. A review of the (Revised) Universal Soil Loss Equation ((R)USLE): With a view to increasing its global applicability and improving soil loss estimates. Hydrol. Earth Syst. Sci. 22, 6059–6086.

Beskow, S., Mello, C.R., Norton, L.D., 2009. Soil erosion prediction in the Grande River Basin, Brazil using distributed modeling. Catena. 79, 49–59.

Bhandari, K.P., Aryal, J., Darnawasdi, R., 2015. A geospatial approach to assessing soil erosion in a watershed by integrating socio-economic determinants and the RUSLE model. Nat Hazards. 75, 321–342.

Bhat, S.A., Hamid, I., Dar, M.U.D., Rasool, D., Pandit, B.A., Khan, S., 2017. Soil erosion modeling using RUSLE & GIS on micro watershed of J & K. J Pharmacogn Phytochem. 6, 838–842.

Bhattarai, R., Dutta, D., 2007. Estimation of soil erosion and sediment yield using GIS at catchment scale. Water Resour Manag. 21,1635–1647.
Biswas, S.S., Pani, P., 2015. Estimation of soil erosion using RUSLE and GIS techniques: a case study of Barakar River basin, Jharkhand, India. Model Earth Syst Environ. 1, 11–13.

Blinkov, I., Kostadinov, S., Marinov, I.T., 2013. Comparison of erosion and erosion control works in Macedonia, Serbia and Bulgaria. Int. Soil Water Conserv. Res. 1, 15–28.

Borrelli, P., Marker, M., Panagos, P., Schutt, B., 2014. Modeling soil erosion and river sediment yield for an intermountain drainage basin of the Central Apennines, Italy. Catena 114, 45–58.

Campos Pinto, L., de Mello, C.R, Norton, L.D., 2016. Spatial prediction of soil-water transmissivity based on fuzzy logic in a Brazilian headwater watershed. Catena 143, 26–34.

Chang, D.Y., 1996. Applications of the extent analysis method on fuzzy AHP. Eur. J. Oper. Res. 95, 649–655.

Chatterjee, S., Krishna, A.P., Sharma, A.P., 2014. Geospatial assessment of soil erosion vulnerability at watershed level in some sections of the Upper Subarnarekha river basin, Jharkhand, India. Environ Earth Sci. 71, 357–374.

Chowdary, V.M., Chakraborty, D., Jeyaram, A., 2013. Multi-Criteria Decision Making Approach for Watershed Prioritization Using Analytic Hierarchy Process Technique and GIS. Water Resour Manag. 27, 3555–3571.

Claessens, L., Breuge, P.V., Notenbaert, A., 2008. Mapping potential soil erosion in East Africa using the Universal Soil Loss Equation and secondary data. IAHS-AISH Publ. 398–407.

Dabral, P.P., Baithani, N., Pandey, A., 2008. Soil erosion assessment in a hilly catchment of North Eastern India using USLE, GIS and remote sensing. Water Resour Manag. 22, 1783–1798.

De Oliveira, V.A., De Mello, C.R., Duraes, M.F, Da Silva, A.M., 2014. Soil vulnerability to water erosion in the Rio Verde watershed, south of Minas Gerais. Agrotec science. 38, 262–269.

Demirci, A, Karaburun, A., 2012. Estimation of soil erosion using RUSLE in a GIS framework: A case study in the Buyukeymekmece Lake watershed, northwest Turkey. Environ Earth Sci. 66, 903–913.

Dragicevic, N., Karleusa, B., Ozanic, N., 2018. Modification of erosion potential method using climate and land cover parameters. Geomatics, Natural Hazards and Risk, 9(1), 1085-1105.

Dutta, D., Das, S., Kundu, A., Taj, A., 2015. Soil erosion risk assessment in Sanjal watershed, Jharkhand (India) using geo-informatics, RUSLE model and TRMM data. Model Earth Syst Environ. 1, 1–9.

Efteheri, W.B., 2009. Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the chemoga watershed, Blue Nile Basin, Ethiopia. L. Degrad. Dev. 20, 609–622.

Efe, R., Ekinci, D., Curebel, I., 2008. Erosion analysis of Findikli Creek catchment (NW of Turkey) using GIS based on RUSLE (3D) method. Fresenius Environmental Bulletin. 17, 586–576.

Erdogan, E.H., Erpul, G., Bayramin, I., 2007. Use of USLE/GIS methodology for predicting soil loss in a semiarid agricultural watershed. Environ Monit Assess. 131, 153–161.

Farhan, Y., Anaba, O., 2016. A remote sensing and GIS approach for prioritization of wadi shueib mini-watersheds (central Jordan) based on morphometric and soil erosion susceptibility analysis. J. Geogr. Inf. Syst. 08,1–19.

Farhan, Y., Anbar, A., Al-Shaikh, N., Mousa, R., 2017. Prioritization of semi-arid agricultural watershed using morphometric and principal component analysis, remote sensing, and gis techniques, the Zerqa River Watershed, Northern Jordan. Agric Sci. 08,113–148.

Farhan, Y., Nawaiseh, S., 2015. Spatial assessment of soil erosion risk using RUSLE and GIS techniques. Environ Earth Sci. 74,4649–4669.

Farhan, Y., Zregat, D., Farhan, I., 2013. Spatial estimation of soil erosion risk using rusle approach, RS, and GIS techniques: a case study of Kufranja watershed, Northern Jordan. J Water Resour Prot. 05,1247–1261.

Fistikoglu, O., Harmancioglu, N.B., 2002. Integration of GIS with USLE in assessment of soil erosion. Water Resour Manag. 16, 447–467.

Flanagan, D., Gilley, J., Franti, T., 2007. Water Erosion Prediction Project (Wepp). Trans. ASABE. 50, 1603–1612.
RECENT ADVANCES IN THE ASSESSMENT OF SOIL EROSION VULNERABILITY IN WATERSHEDS

Fu, B.J., Zhao, W.W., Chen, L.D., 2005. Assessment of soil erosion at large watershed scale using RUSLE and GIS: A case study in the Loess Plateau of China. L Degrad Dev. 16,73–85.

Gaikwad, R., Bhagat, V., 2018. Multi-criteria watershed prioritization of Kas basin in Maharashtra India: AHP and Influence Approaches. Hydrospatial Anal. 1,41–61.

Ganasri, B.P., Ramesh, H., 2016. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. Geosci Front 7:953–961.

Gaubi, I., Chaabani, A., Ben Mammou A, Hamza, M.H., 2017. A GIS-based soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) (Lebna watershed, Cap Bon, Tunisia). Nat Hazards. 86, 219–239.

Gavrilovic, Z., Stefanovic, M., Milojivic, M., Cotric, J., 2005. “ Erosion Potential Method “ an important support for integrated water resource management. Conference on water observation and information systems for decision support : BALWOIS (Balkan Water Observation and Information System).

Gelagay, H.S., Minale, A.S., 2016. Soil loss estimation using GIS and Remote sensing techniques: A case of Koga watershed, Northwestern Ethiopia. Int Soil Water Conserv Res. 4,126–136.

Ghosh, K., Kumar, S., Bandyopadhyay, S., Saha, S., 2013. Assessment of Soil Loss of the Dhalai River Basin, Tripura, India Using USLE. Int J Geosci 04:11–23.

Greer, R.C., Wu, J.Q., Singh, P., Mc, Cool, D.K., 2006. WEPP:Simulation of observed winter runoff and erosion in the U.S. Pacific Northwest. Vadose Zo J 5, 261.

Guo, J., Niu, T., Pooyan, R., Wang, Fu., Zhao, Z.J., 2015. Assessment of soil erosion susceptibility using empirical modeling. J Meteor. Res., 27(4), 98-109.

Haghizadeh, A., Shui, L.T., Godarzi, E., 2009. Forecasting sediment with erosion potential method with emphasis on land use changes at basin. Electron. J. Geotech. Eng. 14 G.

Haidara, I., Tahri, M., Maan, M., Hakdaoui, M., 2019. Efficiency of Fuzzy Analytic Hierarchy Process to detect soil erosion vulnerability. Geoderma 354, 113853.

Halefom, A., Teshome, A., Sisay, E., 2019. GIS-based MCDA model to assess erosion sensitivity in Gumara watershed, Blue Nile, Basin Ethiopia. Asian J. Appl. Sci. 12, 61–70.

Haregeweyn, N., Tsunekawa, A., Poesen, J., 2017. Comprehensive assessment of soil erosion risk for better land use planning in river basins: Case study of the Upper Blue Nile River. Sci Total Environ. 574,95–108.

Hart, H.M., 2006. Effect of land use on total suspended solids and turbidity in the Little River Watershed, Blount County, Tennessee. Masters Thesis, University of Tennessee - Knoxville. 144.

Hembram, T.K., Paul, G.C., Saha, S., 2019. Comparative analysis between morphometry and geo-environmental factor based soil erosion risk assessment using weight of evidence model: a Study on Jainti River Basin, Eastern India. Environ. Process. 6, 883–913.

Hui, L., Xiaoling, C., Lim, K.J., 2010. Assessment of soil erosion and sediment yield in Liao watershed, Jiangxi Province, China, Using USLE, GIS, and RS. J Earth Sci. 21,941–953.

Jain, M.K., Das, D., 2010. Estimation of sediment yield and areas of soil erosion and deposition for watershed prioritization using GIS and remote sensing. Water Resour Manag. 24, 2091–2112.

Jain, S.K., Kumar, S., Varghese, J., 2001. Estimation of soil erosion for a Himalayan watershed using GIS technique. SpringerLink. 51,29–37.

Jasrotia, A.S., Singh, R., 2006. Modeling runoff and soil erosion in a catchment area, using the GIS, in the Himalayan region, India. Environ Geol. 51,29–37.

Jazouli, A. E., Barakat, A., Khellouk, R., Rais, J., Baghdadi, M. E., 2019. Remote sensing and GIS techniques for prediction of land use land cover change effects on soil erosion in the high basin of the Oum Er Rbia River (Morocco). Remote Sens. Appl. Soc. Environ. 13, 361–374.

Kalambukattu, J., Kumar, S., 2017. Modelling soil erosion risk in a mountainous watershed of Mid-Himalaya by integrating RUSLE model with GIS. Eurasian J Soil Sci. 6,92–92.

Kannan, G., Pokharel, S., Kumar, P.S., 2009. A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider. Resour. Conserv. Recycl. 54, 28–36.
Karaburun, A., 2010. Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed. Ozean J Appl Sci. 3, 77–85.

Karan, S.K., Ghosh, S., Samadder, S.R., 2019. Identification of spatially distributed hotspots for soil loss and erosion potential in mining areas of Upper Damodar Basin – India. Catena 182, 104-144.

Kefi, M., Yoshino, K., Setiawan, Y., 2011. Assessment of the effects of vegetation on soil erosion risk by water: A case of study of the Batta watershed in Tunisia. Environ Earth Sci. 64,707–719.

Khaledian, Y., Kiani, F., Ebrahimi, S., 2017. Assessment and Monitoring of Soil Degradation during Land Use Change Using Multivariate Analysis. L Degrad Dev. 28,128–141.

Kinhada, N.R., Gurram, M.K., Eedara, A., Velaga, V.R., 2013. Remote sensing and GIS in the geomorphometric analysis of micro-watersheds for hydrological Scenario assessment and characterization - A study on Sarada river basin , Visakhapatnam district ,India. Int J geomatics Geosci. 4,195–212.

Kostadinov, S., Braunović, S., Dragićević, S., Zlatić, M., Dragović, N., Rakonjac, N., 2018. Effects of erosion control works: Case study- Grdelica Gorge, the South Morava River (Serbia). Water (Switzerland) 10, 1–19.

Kostadinov, S., Miodrag, Z., Dragovic, N., Gavrilovic, Z., 2014. Serbia and Montenegro, in: The Central and Eastern Europe Handbook. pp. 92–103.

Kouli, M., Soupios, P., Vallianatos, F., 2009. Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. Environ Geol. 57, 483–497.

Kumar, A., Devi, M., Deshmukh, B., 2014. Integrated Remote Sensing and Geographic Information System Based RUSLE Modelling for Estimation of Soil Loss in Western Himalaya, India. Water Resour Manag. 28,3307–3317.

Kumar, S., Kushwaha, S.P.S., 2013. Modelling soil erosion risk based on RUSLE-3D using GIS in a Shivalik sub-watershed. J Earth Syst Sci. 122, 389–398.

Kushwaha, A., Jain, M.K., 2013. Hydrological Simulation in a forest dominated watershed in Himalayan region using SWAT Model. Water Resour Manag 27, 3005–3023.

Laflen, J.M., Elliot, W.J., Flanagan, D.C., Meyer, C.R., Nearing, M.A., 1997. WEPP-Predicting water erosion using a process-based model. J. soil water Conserv. 96–102.

Lahlaoi, H., Rhinane, H., Hilali, A., 2015. Potential erosion risk calculation using remote sensing and GIS in Oued El Maleh Watershed, Morocco. J Geogr Inf Syst 07,128–139.

Landi, A., Barzegar, A.R., Sayadi, J., Khademalrasoul, A., 2011. Assessment of soil loss using WEPP Model and Geographic Information System. J Spat Hydrol. 11, 40–51.

Lee, S., 2004. Soil erosion assessment and its verification using the Universal Soil Loss Equation and Geographic Information System: A case study at Boun, Korea. Environ Geol. 45, 457–465.

Lee, S.W., Hwang, S.J., Lee, S.B., 2009. Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics. Landsc Urban Plan. 92, 80–89.

Lense, G.H.E., Parreiras, T.C., Moreira, R.S., Avanzi, J.C., Minicato, R.L., 2019. Estimates of soil losses by the erosion potential method in tropical latosols. Cienc. e Agrotecnologia. 43.

Li, L., Shi, Z.H., Yin, W., 2009. A fuzzy analytic hierarchy process (FAHP) approach to eco-environmental vulnerability assessment for the danjiangkou reservoir area, China. Ecol Model. 220, 3439–3447.

Liou, T.S., Wang, M.J.J., 1992. Fuzzy weighted average: An improved algorithm. Fuzzy Sets Syst. 49, 307–315.

Lovric, N., Tasic, R., 2018. Assessment of soil erosion and sediment yield using erosion potential method: case study - Vrbas river basin (B&H). Bull. Serbian Geogr. Soc. 98, 1–14.

Maalim, F.K., Melesse, A.M., Belmont, P., Gran, K.B., 2013. Modeling the impact of land use changes on runoff and sediment yield in the le sueur watershed, minnesota using GeoWEPP. Catena. 107,35–45.

Mahapatra, S.K., Reddy, G.P., Nagdev, R., 2018. Assessment of soil erosion in the fragile Himalayan ecosystem of Uttarakhand, India using USLE and GIS for sustainable productivity, Curr Sci. 115,108–121.

Makaya, N., Dube, T., Seutloali, K., Shoko, C., Mutanga, O., Masocha, M., 2019. Geospatial assessment of soil erosion vulnerability in the upper uMgeni catchment in KwaZulu Natal, South Africa. Phys. Chem. Earth. 112, 50–57.
Malik, M.I., Bhat, M.S., 2014. Integrated approach for prioritizing watersheds for management: A study of Lidder Catchment of Kashmir Himalayas. Environ Manag. 54, 1267–1287.

Mandal, D., Sharda, V.N., 2013. Appraisal of soil erosion risk in the eastern himalayan region of India for soil conservation planning. L Degrad Dev. 24,430–437.

Manyiwa, T., Dikinya, O., 2013. Using universal soil loss equation and soil erodibility factor to assess soil erosion in Tshesebe village, North east Botswana. African J Agric Res. 8,4170–4178.

Markose, V.J., Jayappa, K.S., 2016. Soil loss estimation and prioritization of sub-watersheds of Kali River basin, Karnataka, India, using RUSLE and GIS. Environ Monit Assess.188.

Mihi, A., Benarfa, N., Arar, A., 2019. Assessing and mapping water erosion-prone areas in northeastern Algeria using analytic hierarchy process, USLE/RUSLE equation, GIS, and remote sensing. Appl. Geomatics. 12,179–191.

Millward, A.A., Mersey, J.E. 1999. Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. Catena. 38,109–129.

Mondal, A., Khare, D., Kundu, S., 2016. A comparative study of soil erosion modelling by MMF, USLE and RUSLE. Geocarto Int. 33, 89–103.

Mustefa, M., Fufa, F., Takala, W., 2019. GIS estimation of annual average soil loss rate from hangar river watershed using rusle. J. Water Clim. Chang. 11, 529–539.

Mutua, B.M., Klik, A., 2004. Soil erosion management at a large catchment scale using the RUSLE-GIS: the case of Masinga catchment, Kenya.

Naqvi, H.R., Mallick, J., Devi, L.M., Siddiqui, M.A., 2013. Multi-temporal annual soil loss risk mapping employing Revised Universal Soil Loss Equation (RUSLE) model in Nun Nadi Watershed, Uttrakhand (India). Arab J Geosci. 6, 4045–4056.

Nunes, J.P., Seixas, J., Pacheco, N.R., 2008. Vulnerability of water resources, vegetation productivity and soil erosion to climate change in Mediterranean watersheds. Hydrol. Process. 22, 3115–3134.

O.A., O.-O., 2019. Erosion mapping using revised universal soil loss equation model and geographic information system: A case study of okittipupa, nigeria. Euro. J of Eng. and Tech. 7 (4), 73–80.

Oeurng. C., Sauvage, S., Sanchez-Perez, J.M., 2011. Assessment of hydrology, sediment and particulate organic carbon yield in a large agricultural catchment using the SWAT model. J Hydrol. 401,145–153.

Opricovic, S., Tzeng, G.H., 2004. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. Eur. J. Oper. Res. 156, 445–455.

Owusu, G., 2012. A GIS-based estimation of soil loss in the Densu basin in Ghana. West African J. Appl. Ecol. 20, 41–51.

Ozsoy, G., Aksoy, E., Dirim, M.S., Tumsavas, Z., 2012. Determination of soil erosion risk in the Mustafakemalpasa river basin, Turkey, using the revised universal soil loss equation, geographic information system, and remote sensing. Environ Manage. 50, 679–694.

Pal, S., 2016. Identification of soil erosion vulnerable areas in Chandrabhaga river basin: a multi-criteria decision approach. Model Earth Syst Environ. 2,1–11.

Panagopoulos, Y., Dimitriou, E., Skoulidakis, N., 2019. Vulnerability of a Northeast Mediterranean Island to Soil Loss. Can Grazing Management Mitigate Erosion? Water.11, 1491.

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., Alewell, C., 2015. The new assessment of soil loss by water erosion in Europe. Environ. Sci. Policy. 54, 438–447.

Pancholi, V.H., Lodha, P.P., Prakash, I., 2015. Estimation of soil erosion for Vishwamitri River watershed of using Universal Soil Loss Equation and GIS. Am. J. Water Sci. Eng. 1, 7–14.

Pandey, A., Mathur, A., Mishra, S.K., Mal, B.C., 2009. Soil erosion modeling of a Himalayan watershed using RS and GIS. Environ Earth Sci. 59,399–410.

Pareta, K., Jakobsen, F., Joshi, M., 2019. Morphological characteristics and vulnerability assessment of Alaknanda, Bhagirathi, Mandakini. Am. J. of Geophy., Geochem. and Geo. 5, 49–68.

Parveen, R., Kumar, U., Singh, V.K., 2012. Geomorphometric Characterization of Upper South Koel Basin, Jharkhand: A Remote Sensing &amp; GIS Approach. J. Water Resour. Prot. 04, 1042–1050.
Patil, R.J., Sharma, S.K., 2014. Remote Sensing and GIS based modeling of crop/cover management factor (C) of USLE in Shakker river watershed. Int. J. Adv. Agric. Environ. Eng. 1.

Phan, B.H., Nguyen,V., Pham, H., Le Xuan, T., Le Sy, C., Nguyen, H., 2019. Integrated Geographical Information System (GIS) and remote sensing for soil erosion assessment by using Universal Soil Loss Equation (USLE): Case Study in Son La Province. Vnu J. Sci. Earth Environ. Sci. 35, 42–52.

Prasannakumar, V., Shiny, R., Geetha, N., Vijith, H., 2011. Spatial prediction of soil erosion risk by remote sensing, GIS and RUSLE approach: A case study of Siruvani river watershed in Attapady valley, Kerala, India. Environ Earth Sci. 64, 965–972.

Prasannakumar, V., Vijith, H., Abinod, S., Geetha, N., 2012. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. Geosci Front. 3, 209-215.

Quiroz Londono, O.M., Romanelli, A., Lima, M.L., Massone, H.E., Martinez, D.E., 2016. Fuzzy logic-based assessment for mapping potential infiltration areas in low-gradient watersheds. J. Environ. Manage. 176, 101–111.

Rahman, M.R., Shi, Z.H., Chongfa, C., 2009. Soil erosion hazard evaluation-An integrated use of remote sensing, GIS and statistical approaches with biophysical parameters towards management strategies. Ecol. Modell. 220, 1724–1734.

Rawat, J.S., Joshi, R.C., Mesia, M., 2013. Estimation of erosivity index and soil loss under different land uses in the tropical foothills of Eastern Himalaya (India). Trop. Ecol. 54, 47–58.

Rawat, P.K., Tiwari, P.C., Pant, C.C., 2011. Modelling of stream run-off and sediment output for erosion hazard assessment in Lesser Himalaya: Need for sustainable land use plan using remote sensing and GIS: A case study. Nat. Hazards. 59, 1277–1297.

Renard, K.G., Foster, G.R., Weesies G.A., 1997. Predicting Soil Erosion by Water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). USDA Agricultural Handbook No. 703, 404.

Richardson, C.P., Amankwatia, K., 2019. Assessing Watershed Vulnerability in Bernalillo County, New Mexico Using GIS-Based Fuzzy Inference. J. Water Resour. Prot. 11, 99–121.

Rozos, D., Skilodimou, H.D., Loupasakis, C., Bathrellos, G.D., 2013. Application of the revised universal soil loss equation model on landslide prevention. An example from N. Euboea (Evia) Island, Greece. Environ. Earth. Sci. 70, 3255–3266.

Setegn, S.G., Srinivasan, R., Dargahi, B., Assefa M. Melesse, 2009. Spatial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia Shimelis. Hydrol. Process. 23, 3738–3750.

Shalini Tirkey, A., Pandey, A.C., Nathawat, M.S., 2015. Use of Satellite Data, GIS and RUSLE for Estimation of Average Annual Soil Loss in Daltonganj Watershed of Jharkhand (India). J. Remote Sens. Technol. 20–30.

Shivhare, N., Dixit, P.K.S., Dwivedi, S.B., 2018. A comparison of SWAT model calibration techniques for hydrological modeling in the Ganga River Watershed. Engineering. 4, 643–652.

Spalevic, V., Railic, B., Djekovic, V., Andjelkovic, A., Curovic, M., 2014. Calculation of soil erosion intensity and runoff of the Lapnjak watershed, Polimlje, Montenegro. Agric. For. 60, 261–271.

Spalevic, V., Vujacic, D., Barovic, G., Simunic, I., Moteva, M., Tanaskovikj, V., 2016. Soil erosion evaluation in the Rastocki Potok Watershed of Montenegro using the Erosion Potential Method. J. Agric. Food Environ. Sci. 69, 32–40.

Stathopoulos, N., Lykoudi, E., Vasileiou, E., Rozos, D., Dimitrakopoulos, D., 2017. Erosion vulnerability assessment of Sperchios River Basin, in East Central Greece—A GIS Based Analysis. Open J. Geol. 07, 621–646.

Tadesse, L., Suryabhagavan, K.V., Sridhar, G., Legesse, G., 2017. Land use and land cover changes and Soil erosion in Yezat Watershed, North Western Ethiopia. Int. Soil Water Conserv. Res. 5, 85–94.

Tahiri, M., Tabyaoui, H., Tahiri, A., 2016. Modelling Soil Erosion and Sedimentation in the Oued Haricha Sub-Basin (Tahaddart Watershed, Western Rif, Morocco): Risk Assessment. J. Geosci. Environ. Prot. 04,107–119.
Todorovski, L., Dzeroski, S., 2006. Integrating knowledge-driven and data-driven approaches to modeling. Ecol. Modell. 194, 3–13.
Tran, C.P., Bode, R.W., Smith, A.J., Kleppel, G.S., 2010. Land-use proximity as a basis for assessing stream water quality in New York State (USA). Ecol. Indic. 10, 727–733.
Uddin, K., Murthy, M.S.R., Wahid, S.M., Matin, M.A., 2016. Estimation of soil erosion dynamics in the Koshi Basin using GIS and remote sensing to assess priority areas for conservation. PLoS One. 11.
Vemu, S., Pinnamaneni, U.B., 2011. Estimation of spatial patterns of soil erosion using remote sensing and GIS: A case study of Indravati catchment. Nat. Hazards. 59,1299–1315.
Vijith, H., Suma, M., Rekha, V.B., 2012. An assessment of soil erosion probability and erosion rate in a tropical mountainous watershed using remote sensing and GIS. Arab J. Geosci. 5,797–805.
Bewket, W., 2009. Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the chemoga watershed, Blue Nile Basin, Ethiopia. L. Degrad. Dev. 20, 609–622.
Wischmeier, W.H. & Smith, D.D. (1978) Predicting rainfall-erosion losses – a guide to conservation farming. USDA Agricultural Handbook No. 537.
Xavier, A.P.C., Silva, R.M., Silva, A.M., Santos, C.A.G., 2016. Mapping soil erosion vulnerability using remote sensing and gis : a case study of mamuaba watershed , paraiba state. Revista Brasileira de Cartografi a, Rio de Janeiro, N. 68:9, 1677–1688.
Yacine, E.A., Essahlaoui, A., Oudija, F., Mimich, K., Nassiri, L., 2019. Assessment of soil erosion by (RUSLE) using remote sensing and GIS case of watershed of Beht in upstream of Ouljat Sultan dam (Morocco). ARPN J. Eng. Appl. Sci. 14, 1765–1776.
Yousefi, S., Kivarnz, N., Ramezani, B., Rasoolzadeh, N., Naderi, N., Mirzaee, S., 2014. An Estimation of Sediment by Using Erosion Potential Method and Geographic Information Systems in Chamgardalan Watershed: A Case Study of Ilam Province, Iran. Geodyn. Res. 2,5.
Yue-qing, X., Jian, P., Xiao-mei, S., 2014. Retraction Note: Assessment of soil erosion using RUSLE and GIS: A case study of the Maotiao River watershed, Guizhou Province, China. Environ. Earth Sci. 72, 2217.
Yuksel, A., Gundogan, R., Akay, A.E., 2008. Using the remote sensing and GIS technology for erosion risk mapping of Kartalkaya Dam watershed in Kahramanmaras, Turkey. Sensors. 8, 4851–4865.
Zhang, H., Yang, Q., Li, R., Liu, Q., Moore, D., He, P., Ritsema, C.J., Geissen, V., 2013. Extension of a GIS procedure for calculating the RUSLE equation LS factor. Comput. Geosci. 52, 177–188.
Zhou, Q., Yang, S., Zhao, C., 2014. A soil erosion assessment of the Upper Mekong River in Yunnan Province, China. Mt. Res. Dev. 34, 36–47.