# Soil Erosion Computation using RUSLE for Harsul Lake Catchment of Kham River Basin, Aurangabad, India

**Vedant Karhade[1], Shraddha Vangujare[2]**

[1, 2]Government College of Engineering, Aurangabad – 431001, Maharashtra, India

**Abstract:** ***Soil erosion is the widespread concern as it leads to loss of top fertile layer of the soil. Soil erosion is termed as the detachment, transportation and deposition of soil particles by the agents such as water, wind and biota. The main aim of this work is to evaluate the annual soil loss in the catchment of the Harsul Lake in Kham river basin which ultimately contributes to the silt load in the Harsul Lake. The revised universal soil loss equation (RUSLE) in integration with GIS is used to evaluate soil loss by computing and multiplying rainfall erosivity (R-factor), Soil erodiblity (K-factor), Slope length & steepness (LS-factor), Conservation practices (P-factor) and crop management (C-factor). Study reveals that annual average soil loss ranges from 0 to 59.63 ton/ha/year and around 76.65 % of portion of the study area have soil loss less than 5 ton/ha/year. The lower value of average annual soil loss of 2.38 ton/ha/year can be correlated with the effective soil and water conservation (SWC) measures in the study area.***

**Keywords:** Soil erosion, Erosion prediction, RUSLE, GIS, Kham River, India

## 1. Introduction

Soil erosion is process of detachment and transport of the soil particle from its parent material and thus degrading the quality of soil and adversely affecting the productivity of the land [1]. It is a serious concern due to intensification of agriculture, degradation of land and other anthropogenic activities [2]. Soil erosion is naturally occurring process and the agents of soil erosion are water and wind. It is one form of soil degradation along with soil compaction, low organic matter and loss of structure of soil, poor internal drainage, salinization and soil acidity problems. Soil erosion can broadly take place due to water, wind and biotic erosion. The water erosion can further be classified as splash erosion, sheet erosion, rill erosion, gully erosion, ravines erosion, landslides or slip erosion, stream bank erosion. The wind erosion can be further classified as saltation, suspension and surface creep [3]. It is a problem of great concern in India as about 53% of total area is affected by the soil erosion [4]. In India soil erosion is widespread and the major factors contributing to the soil erosion are Over grazing, Faulty practices of farming, Deforestation, Shifting cultivation [5]

Thus to evaluate the soil loss various soil loss models were developed, the development of equations to compute soil erosion started around 1940 in Corn Belt. The equations developed around 1940 and 1956 were referred as slope-practice method. Around 1946 by altering Corn Belt values and adding rainfall factor Musgrave equation was developed and then a widely used empirical model for evaluating soil loss as universal soil loss equation (USLE) was developed by Wishmeier & Smith [6]. Mathematically the USLE is given as A=RKLSCP where A is computed soil loss, R is a rainfall-runoff erosivity factor, K is a soil erodiblity factor, L is the slope length factor, S is the slope steepness factor, C is a cover management factor and P is supporting practice factor. The empirical equation derived from large mass of field data, computes sheets and rill erosion based on four major factors climate erosivity factor (R), Soil erodiblity (K), Topography (LS) and land use management (CP). These same factors are there in the revised universal soil loss equation (RUSLE). Revised universal soil loss equation (RUSLE) is the improvement over USLE in various aspects such as computerizing the algorithms to assist with calculation, New rainfall erosivity term, development of seasonally variable soil erodiblity term, a sub factor approach for calculating the cover management term, New slope length and steepness factor relating the rill to inter rill erosion ratios and new conservation practice factor values for rangelands, strip crop rotation and contour factor values [7]. The studies reveal that the integration of the GIS tool with RUSLE/USLE model is efficient in ascertaining the output parameter as the zones pertaining to higher risk of erosion can be denoted [8]-[9]-[10]

## 2. Objective of Study

The main objective of the present study is to compute the annual soil loss in the study area. The study area being on the u/s side of the Harsul Lake, thus the entire soil loss adds silt load to the Harsul Lake and reduces the water carrying capacity. Hence the computation of the soil loss using the revised universal soil loss equation (RUSLE) in integration with GIS tool is the primary objective of the present study.

## 3. Methodology

The soil erosion modeling done with RUSLE using GIS, consists of computation of various factors required calculating the annual soil loss. The annual soil loss 'A' is calculated by using RUSLE model i.e. A = R X K X LS X C X P, where A is annual soil loss in (ton/ha/yr). The unit of 'A ' primarily depends on rainfall erosivity factor (R) and soil erodiblity factor (K). Where, L is the slope length factor, S slope steepness factor, C is the crop management factor and P is the conservation practices factor. In RUSLE model to reduce the value of 'A' i.e. to reduce the annual soil loss in the watershed C factor and P factor are primarily responsible as increase in vegetative cover reduces the C factor and increase in conservative measures in the watershed reduces the P factor which ultimately results in reduced value of 'A' There is no such control on the rainfall, soil and topographic features of the watershed. The methodology for assessment of soil erosion is explained in Figure 1.

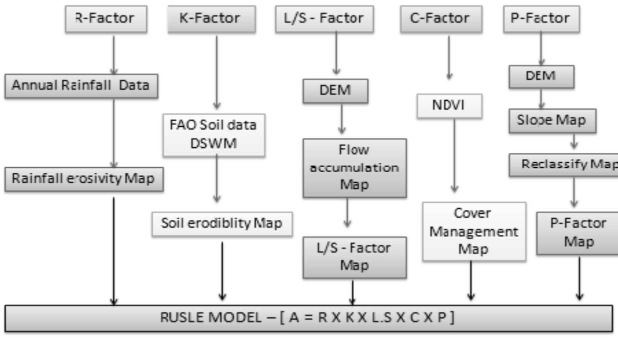


**Figure 1:** Flow chart of Methodology

### 3.1 Study Area

Harsul lake catchment is taken as the study area for present work. This catchment is the part of Kham river basin in Aurangabad district. Harsul lake is on the upstream reach of Kham river basin, and serves as the domestic water supply source for 20 wards of Aurangabad municipal corporation.

The study area is on North-East side of Aurangabad city and lies around 19° 55' 37.7904" latitude and 75° 19' 50.9154" longitude. The study area i.e. the catchment area of Harsul Lake is found to be 6502.9 hectors. This study area is under the Topo sheet no. 47 M/5 Geological survey department of Government of India. The study area is shown in Figure 2.

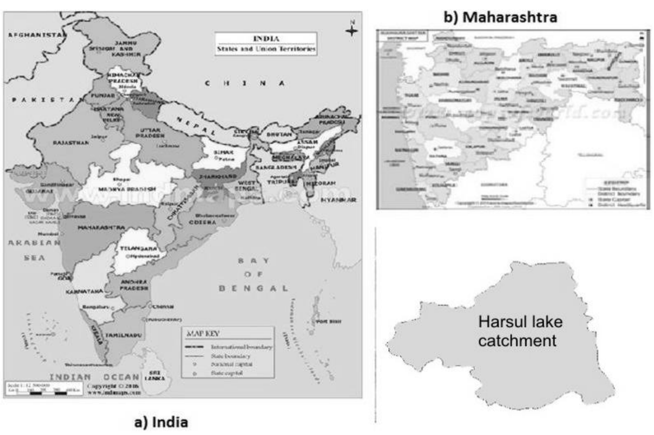


**Figure 2:** Map of the study area

### 3.2 Data collection

The rainfall data from the rain gauges in the vicinity of the study area is taken from the Website of Global weather data[11]. The Topo sheet no. 47 M/5 in which the study area is enclosed is acquired from the water resources department of Maharashtra government. The Digital elevation map (DEM) is acquired from the United States geological survey (USGS) SRTM dataset of 30 meter resolution [12] and the soil data is acquired from the Food and agricultural organization of united nations (FAO)[13].

### 3.3 Model description

The Arc.GIS 10.2.2 software is used for the computation of soil loss in the catchment. The acquired DEM is then clipped for the extent of the study area by extracting the shape of the study area prepared using Goggle earth software. The DEM model is then delineated with the streams and sub-watersheds in the catchment as shown in Figure 3. The three dimensional representation of study area is also prepared as shown in Figure 4.

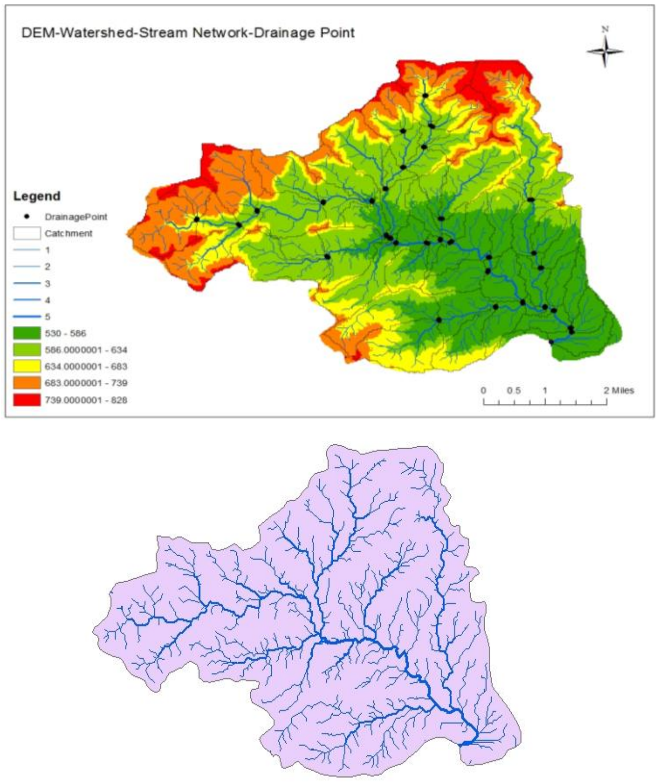


**Figure 3:** Features of study area

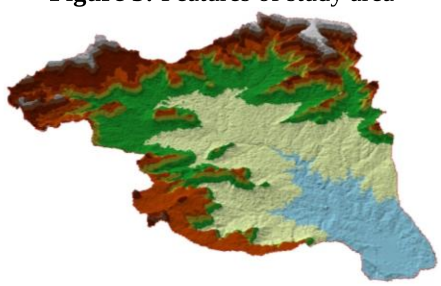

**Figure 4:** Three dimensional representation of study area

The RUSLE model for annual soil loss computation gives the value of annual average soil loss 'A' in ton/ha/year. This value is the product of the multiplication of five factors as R, K, LS, C & P. The methodology for computation each factor is as stated below.

#### 3.3.1 Rainfall erosivity factor (R)

Rainfall erosivity factor is computed using the equation given by Ram babu, Ra = 81.5 + 0.380 Pa & Rs = 71.9 +

ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

0.361 Ps, where, R = Rainfall erosivity index, Pa = Annual rainfall (mm). Ps = Seasonal rainfall (mm), a & s = annual & seasonal parameters. [14]. The unit of R is (in MJ* mm\ha*yr.). The rainfall map of the study area is then prepared by the acquired data as shown in Figure 5.

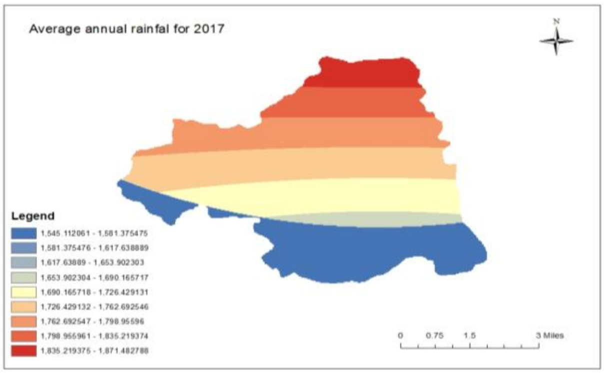


**Figure 5:** Average annual rainfall map

### 3.3.2 Soil erodiblity factor (K)

Soil erodiblity factor is computed using the equation given by Sharpley & Williams, K = A X B X C X D X 0.1317; where,

K = Soil erodiblity factor (tons-year/MJ-mm),
A = [0.2 + 0.3 exp(-0.0256 SAN (1-SIL/100))] ,
B = [SIL / (CLA+SIL)] ³,
C = [1.0 – (0.25 C / C + exp (3.72 – 2.95C))],
D = [1.0 – (0.70 SN1 / SN1 + exp (-5.41 + 22.9 SN1))],
SAN = Percent sand, SIL = Percent Clay,
CLA = Percent Clay, C = Organic carbon content,
SN1 = [1-SAN/100] [15]-[16]. The soil found in the study area of the extracted watershed is Bv12-3b as per FAO soil map shown in Figure 6. The characteristics of Bv12-3b soil type are taken from FAO soil manual.

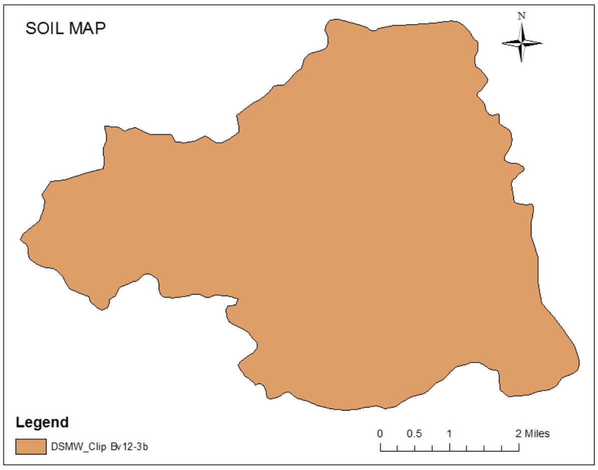


**Figure 6:** Soil map for study area from FAO data

### 3.3.3 Slope length & steepness factor (LS)

The slope length & steepness factor is computed from DEM. The DEM is processed to derive flow accumulation and slope maps. Then the LS factor is calculated using the raster calculator tool in Arc.GIS 10.2.2 by using stated equation, LS = [Flow accumulation X Grid Size / 22.13]$^{0.6}$ X [sin (slope) X 0.01745 / 0.0896]$^{1.3}$ and LS factor map is prepared. The LS factor is dimensionless.

### 3.3.4 Crop management factor (C)

The land use land cover map of the study area is prepared using the unsupervised classification technique and the LULC is classified into five classes as water, settlement, forest cover, agricultural and fallow land. The classification of the land consist 203.76 ha is under water, 1177 ha of area is under settlements, 1253 ha area is under forest, 2265 ha of area is under agriculture and 1600 ha area under barren land. The values of C factor are then assigned and C factor map is prepared. The LULC map of the study area is as shown in Figure 7.

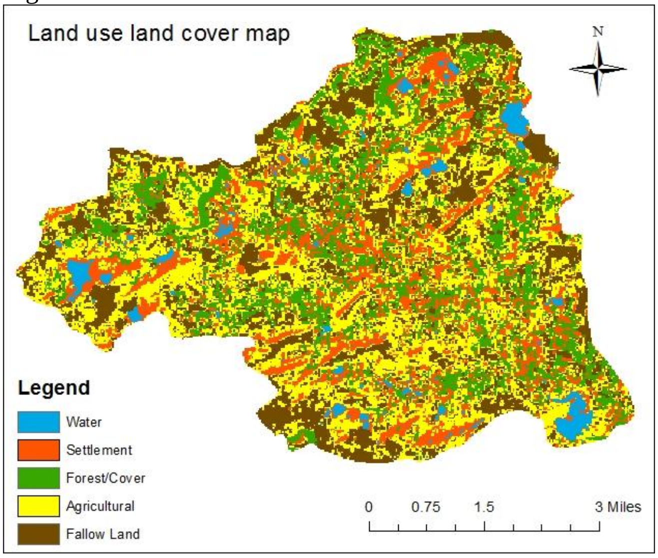


**Figure 7:** Land use land cover map

### 3.3.5 Conservation practice factor (P)

Conservation support practices include contour cropping, contour bunding, cropping and terrace as some of the methods. The value of conservation practices are taken according to Shin [17]. The P factor map is derived by reclassifying the derived slope map with values given by Shin in Table 1.

**Table 1:** Conservation practice values

| Slope % | Contouring | Strip cropping | Terracing |
|---|---|---|---|
| 0.0 - 7.0 | 0.55 | 0.27 | 0.10 |
| 7.0 - 11.3 | 0.60 | 0.30 | 0.12 |
| 11.3 - 17.6 | 0.80 | 0.40 | 0.16 |
| 17.6 - 26.8 | 0.90 | 0.45 | 0.18 |
| 26.8 > | 1.00 | 0.50 | 0.20 |

## 4. Results & Discussion

The rainfall erosivity factor varies in range of 668 to 792 (MJ* mm\ha*yr.) as shown in Figure 8. The value of soil erodiblity factor is 0.023501 tons-year/MJ-mm. The detailed calculations for the K factor are shown in Table 2.The slope length and steepness factor is in the range of 0 to 11.5 % for the study area as shown in Figure 9. The value of crop management factor is range of 0.01 to 1 as shown in Figure 10. The value of conservation practices factor varies in range of 0.55 to 0.60 as shown in Figure 11.

The product of the values of the five factors gives the value of annual average soil loss in ton/ha/year. The factorial maps depicting RKLSCP individually are multiplied in the Arc. Toolbox raster calculator and the value of annual average soil loss is obtained ranging from 0 to 59.63 ton/ha/year. It is observed that around 76.65 % portion of the study area have soil loss less than 5 ton/ha/year. The mean value of average annual soil loss is 2.38 ton/ha/year. The average annual soil loss map is shown in Figure 12. There are various soil and water conservation (SWC) measures in the study area which primarily includes the both ridge line treatment and drainage line treatments, including contour trenches, contour bunds, gabion bunds, cement bunds and de-silting of storage/percolation tanks on the u/s of the Harsul lake which are effective in controlling the rate of soil erosion in the study area.

**Table 2:** Soil erodiblity factor calculations

| | |
|---|---|
| sand % topsoil | 23.3 |
| silt % topsoil | 26 |
| clay % topsoil | 50.7 |
| OC % topsoil | 1.1 |
| A | 0.39 |
| B | 0.72 |
| C | 0.75 |
| D | 0.83 |
| **K-Factor** | **0.023501** |

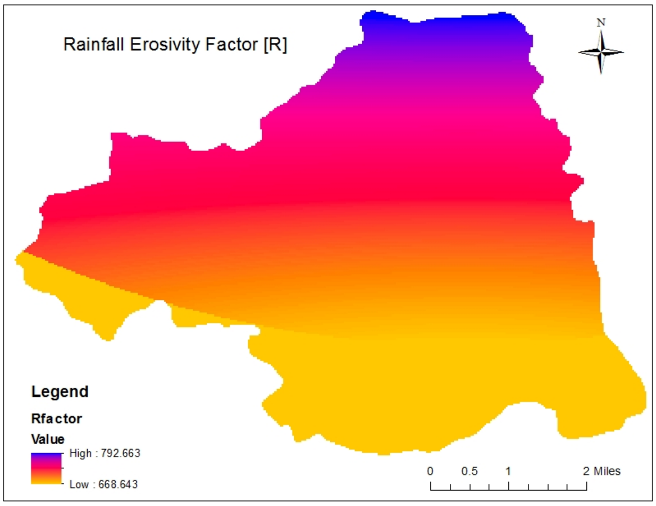


**Figure 8:** Rainfall erosivity factor map

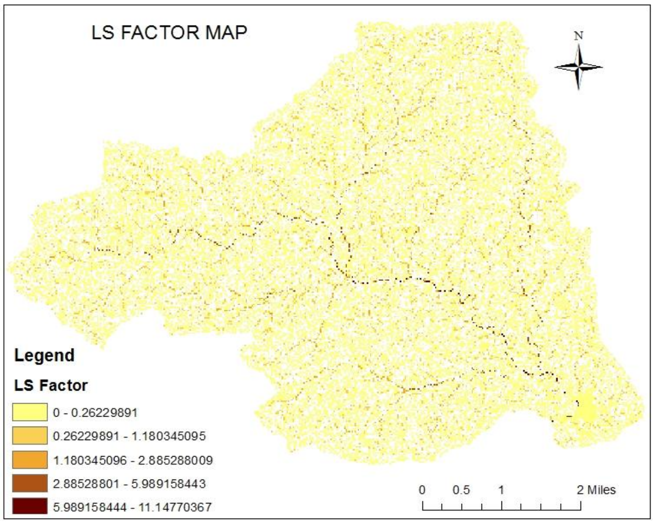


**Figure 9:** Slope length & steepness factor map

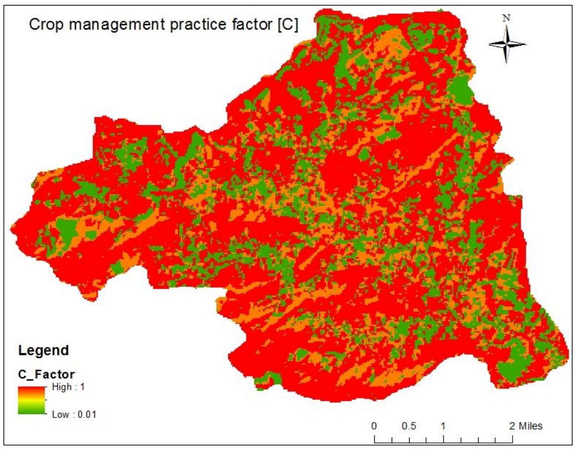


**Figure 10:** Crop management practice factor map

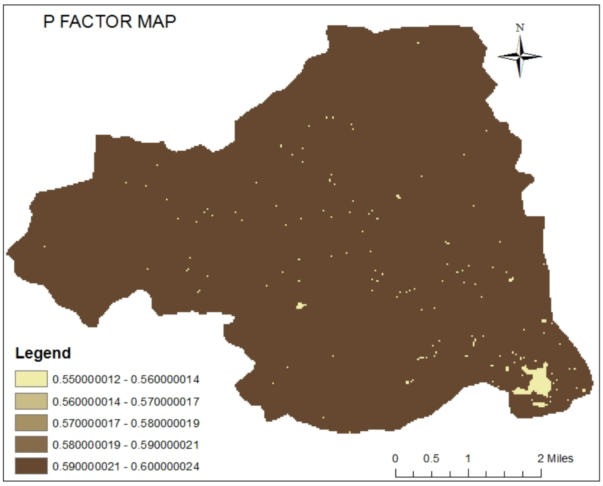


**Figure 11:** Conservation practices factor map

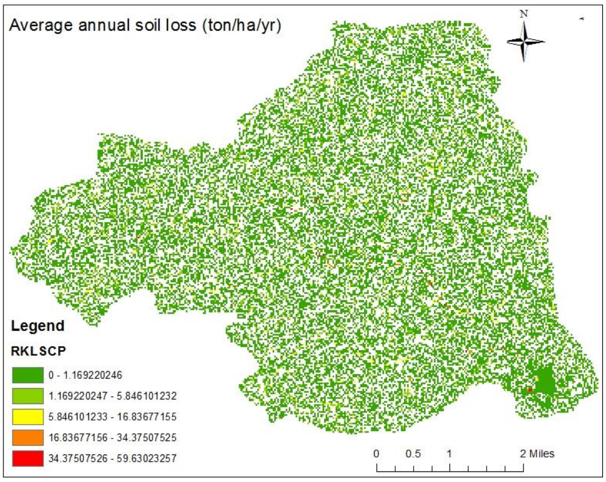


**Figure 12:** Average annual soil loss map

## 5. Conclusion

The evaluation of soil loss is tedious and time consuming by the conventionally available methods. It is easy to evaluate the soil erosion losses by integrating the RUSLE with the GIS platform. In present study out of total area of 6502.9 ha, around 4900 ha of land have soil loss less than 5 ton/ha/year. This can be correlated with the execution of soil and water conservation measures in the study area as well as this value may vary with the change in the methodology of the study. In this study K factor is computed using Sharpley & Williams equation, R factor computed using Ram babu's equation, P factor computed based on the values given by Shin, Thus, if we change the methodology i.e. if we use different equations for the computation of the soil loss the annual average soil loss may vary and that may be taken as the scope of the future study to analyze the difference in the values by altering various equations for evaluating the factors in RUSLE. Similarly, the value of the RUSLE model can be compared with result of the SWAT to check the accuracy of the work.

## References

[1] G. Ashiagbor, E. K. Forkuo, P. Laari, and R. Aabeyir, "Modeling soil erosion using rusle and rusle Parameter Estimation for," vol. 2, no. 4, 2013.
[2] B. P. Ganasri and H. Ramesh, "Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin," Geosci. Front., vol. 7, no. 6, pp. 953–961, 2016, doi: 10.1016/j.gsf.2015.10.007.
[3] S. G. Telkar and N. S. Pote, "Soil Erosion: Types and Their Mechanism Soil Erosion," Biomol. Reports, no. May, pp. 1–5, 2018, [Online]. Available: https://www.researchgate.net/publication/325300770_Soil_Erosion_Types_and_Their_Mechanism (accessed 14 November, 2019).
[4] D. V. V. Narayana and R. Babu, "Estimation of soil erosion in India," J. Irrig. Drain. Eng., vol. 109, no. 4, pp. 419–434, 1983, doi: 10.1061/(ASCE)0733-9437(1983)109:4(419).
[5] J. Saroha and B. R. A. College, "Soil Erosion : Causes , Extent and Management in," vol. 5, no. 4, pp. 1321–1330, 2017.
[6] Wishmeier & Smith, Predicting rainfall erosion losses, vol. 26, no. 12. 1978.
[7] G. Renard, Kenneth, F. R. George, A. G. A. Weesies, and P. J. P, "Revised universal soil loss equation (Rusle)," J. soil water Conserv., pp. 607–608, 1991, doi: 10.1007/springerreference_77104.
[8] M. Jabbar, "Application of gis to estimate soil erosion using rusle," Geo-Spatial Inf. Sci., vol. 6, no. 1, pp. 34–37, 2003, doi: 10.1007/BF02826699.
[9] Abhishek sinha and D G Regulwar, "Soil Erosion Mapping of Katteri Watershed using Universal Soil Loss Equation and Geographic Information System," Int. J. Sci. Res., vol. 58, no. 4, pp. 418–421, 2013.
[10] D. Dutta, S. Das, A. Kundu, and A. Taj, "Soil erosion risk assessment in Sanjal watershed, Jharkhand (India) using geo-informatics, RUSLE model and TRMM data," Model. Earth Syst. Environ., vol. 1, no. 4, pp. 1–9, 2015, doi: 10.1007/s40808-015-0034-1.
[11] "Global Weather Data for SWAT." https://globalweather.tamu.edu/request/view/5110 (accessed May 07, 2020).
[12] "USGS EROS Archive - Digital Elevation - Shuttle Radar Topography Mission (SRTM) Non-Void Filled." https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-shuttle-radar-topography-mission-srtm-non?qt-science_center_objects=0#qt-science_center_objects (accessed May 07, 2020).
[13] "Harmonized world soil database v1.2 | FAO SOILS PORTAL | Food and Agriculture Organization of the United Nations." http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/ (accessed May 07, 2020).
[14] K. Ram Babu, B L Dhyani, "Assessment of erodibility status and refined iso-erodent map of India," Indian J. Soil Cons, vol. 32, no. 3, pp. 171–177, 2004.
[15] J. A. A. Anache, C. G. V. Bacchi, E. Panachuki, and T. Alves Sobrinho, "Assessment of methods for predicting soil erodibility in soil loss modeling," Geociencias, vol. 34, no. 1, pp. 32–40, 2015.
[16] A. N. Sharpley and J. R. Williams, "EPIC: The erosion-productivity impact calculator," U.S. Dep. Agric. Tech. Bull., no. 1768, p. 235, 1990, [Online]. Available: http://agris.fao.org/agris-search/search.do?recordID=US9403696.
[17] Ashaq Sheikh Sarvesh Palria & Akhtar Alam, "Integration of GIS & USLE fro soil loss estimation in Himalayan watershed," Recent Res. Sci. Technol., vol. 3, no. 3, pp. 51–57, 2011.