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Estimation of soil loss and sediment yield in small watershed under humid condition of Rajasthan

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Abstract
Present study aimed at estimating soil loss in Kherot watershed of Pratapgarh district, Rajasthan. Soil loss was estimated by using Revised Universal Soil Loss Equation (RUSLE) using Remote Sensing and Geographic Information System (GIS) techniques. GIS-based maps of five RUSLE factors (R, K, LS, C, P) were generated for the study area. Raster maps of the RUSLE factors were multiplied to estimate sediment yield on pixel basis. It was apparent from the study that in the year 2015, 164.0 ha area (72%) was under the very slight erosion class which covered major portion of the study area. Severe, very severe and extremely severe classes covered 19.60 ha area (8.63%). In the year 2017, 172.0 ha area (75.44%) was under the very slight erosion class which covered major portion of the study area. Sever, very severe and extremely severe classes covered 14.30 ha area (6.26%).

Keywords: estimation, sediment yield, small watershed, humid condition, Rajasthan

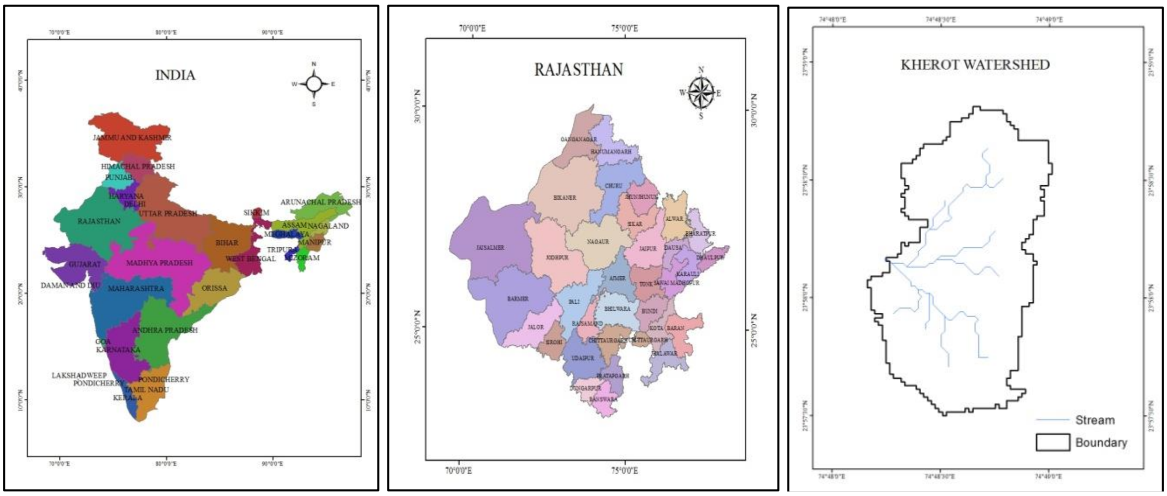
1. Introduction

Soil erosion is a complex dynamic process which involves detachment, transport and subsequently deposition (Jain *et al.* 2001) [9]. It is a naturally occurring process and erodes top soil by the natural physical forces of water, wind or through forces associated with farming activities such as tillage. The removal of fertile soil from the upper layer of soil profile causes loss of soil nutrients which in turn reduces agricultural productivity. Worldwide, more than 50% of pasturelands and about 80% of farming lands suffer from soil erosion. In India it has been estimated that about 5334 m-tons of soil is being detached yearly due to various reasons and about 113.3 m ha of land is subjected to soil erosion due to water (Narayan and Babu 1983) [17]. It has been estimated that 329 M ha, constituting about 53% of the total geographical area of India suffers from deleterious effect of soil erosion with an annual average soil erosion rate of 16 t/h/year (Jain *et al*. 2001) [9]. Although, there are several attempts implemented by Govt. of India in order to control soil erosion and land degradation, lack of accurate information has hindered the process of proper conservation planning and management. The quantification of soil loss and estimation of risk is important for identifying areas exposed to severe erosion and implementation of proper land management program. The field based methods of soil loss quantification is time consuming and lack of sufficient sampling plot may constrain the reliability of actual spatial extent of area under soil erosion. So, monitoring and accurate mapping the spatial pattern of soil loss over a large area is really difficult owing to the time and cost involved in this traditional field based method (Lu *et al*. 2004, Chen *et al*. 2011, Kumar and Kushwaha 2013) [14, 5, 11]. The main problem in relation to the erosion risk models is the validation, because of scarcely available data for comparing the estimates of the models with actual soil losses (Gitas *et al*. 2009, Lazzari *et al*. 2015) [8, 13]. Several models have been developed to estimate erosion risk, in that most commonly used model is USLE. The Universal Soil Loss Equation (USLE) was first developed in 1965 by Wischmeier and Smith of the United States Department of Agriculture as a field scale model. It was later revised in 1997 in an effort to better estimate the values of the various parameters in the USLE and developed RUSLE (Revised Universal Soil Loss Equation) (Renard *et al.* 1997) [18]. The RUSLE incorporates improvements in the factors based on new and better data but keeps the basis of the USLE equation.

2. Location and description of the Study Area

Kherot watershed selected for the study is located in Pratapgarh Tehsil, Pratapgarh District of Rajasthan State, India.

Kherot village is situated 9 km away from Pratapgarh. Pratapgarh is both district and sub-district headquarter of Kherot village. The project area is bounded by 74º48'9.576" to 74º49'0.696"E longitude and 23º57'30.6" to 23º58'48.756" N latitude. The Streams of study area contribute toward Erav river which is the main tributary of Mahi river. The total geographical area of the watershed is 228 ha. The study area falls under agro climatic zone-IV B of Rajasthan i.e., "humid Southern Plains". Pratapgarh is located with an average elevation of 580 meters (1610 feet above mean sea level). Pratapgarh is the second highest place in Rajasthan after Mount Abu. The area of the district is 4449 km^2 and ranks at 30^{th} among other districts of the state. The study area is characterized by sub-tropical dry climate with distinct hot summer, cold winters and rainy monsoon. The maximum temperature ranges between 40 ºC to 43 ºC in May-June and minimum temperature ranges between 6 ºC to 10 ºC in December-January with an average annual rainfall of 856 mm received. The major crops in study area are soybean, maize, and pulses in kharif season and wheat, mustard, gram and few pockets of opium in rabi season.



Location Map of the study area

3. Material and Methods

3.1 Data Collection

Daily rainfall data for the years 2015, 2016 were collected from rain gauge station located in the Kherot watershed, Pratapgarh, Rajasthan. Sediment data was collected from silt observation post installed in the watershed. Remote Sensing data of the study area was obtained from Satellite imagery Resourcesat-2, LISS-III (Date of acquisition: 5 Dec, 2015) from www.bhuvan.nrsc.gov.in. Digital Elevation Model (DEM) of the study area was obtained from satellite data of Cartosat-1, downloaded from www.bhuvan.nrsc.gov.in. The Survey of India topographical sheet (46I/13) on 1:50000 scale was collected from Survey of India. Soil map of the study area was collected from Regional Centre of National Bureau of Soil Survey and Land Use Planning (NBSS and LUP), Udaipur, Rajasthan.

3.2 Revised Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) determines soil loss at any given point as a function of rainfall energy and intensity, slope length, soil erodibility, soil cover, slope gradient, and conservation practices (Wischmeier and Smith 1978) [20]. The RUSLE is a revised form of the Universal Soil Loss Equation which is developed to predict erosion on croplands in the US. The Revised Universal Soil Loss Equation (RUSLE) has the same form as the USLE, but it includes modification for slope length and slope gradient calculations, for more detailed calculations of soil cover and conservation practices (Renard *et al.* 1997) [18]. In this study RUSLE (Revised Universal Soil Loss Equation) model was used to estimate soil loss from catchment. RUSLE model was developed as an equation representing main factors affecting soil erosion, namely climate, soil characteristics, topography, land cover characteristics (Wischmeier 1965). The equation is expressed as:

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

Where A (t/ha/year) is the Computed annual soil loss per unit area, R (MJ-mm/ha-hr-year) is the rainfall erosivity factor in, K (t-ha-hr/ha-MJ-mm) is the soil erodibility factor, L is the slope length factor, S the slope steepness factor, C is the crop management factor, P is the support practice factor.

3.2.1 Rainfall erosivity factor

Rainfall erosivity factor (R-factor) is the important factor for the estimation of soil loss in the mathematical models i.e. Universal Soil Loss Equation (USLE) and its revised form RUSLE (Kamaludin *et al.* 2013) [10]. In this study rainfall data of two years (2015-2016) of Kherot watershed were used for calculating R-factor. Monthly rainfall data were used to calculate R-factor using the following relationship developed by Wischmeier and Smith (1978) [20]:

$$R = \sum_{i=1}^{12} 1.735 \times 10^{\left(1.3 \log_{10}\left(\frac{P_i^2}{P}\right) - 0.08188\right)}$$

Where R (MJ-mm/ha-hr-yr) is the rainfall erosivity factor, P_i (mm) is the monthly rainfall, P (mm) annual rainfall. Kherot watershed have single raingauge station. Thus, there is single value of calculated R-factor for the entire study area for the individual years.

3.2.2 Soil erodibility factor

The soil erodibility factor (K-factor) is expressed as tons of soil loss per hectare per unit rainfall erosivity index, from a field of 9% slope and 22.13 meters as field length. Soil erodibility factor (K-factor) is a measure of the effect of soil properties on soil erosion. A nomograph developed by Wischmeier *et al.* (1971) [22] used five soils to determine the

K-factor values viz., percent of silt (0.002-0.05 mm), percent of very fine sand (0.05-0.1 mm), percent of sand greater than 0.1 mm, percentage of organic matter content (OM), structure (S) and permeability (P). An analytical relationship for nomograph by Wischmeier *et al*. (1971) [22] is given by the equation:

$$K = \frac{2.1 \times 10^{-4} M^{1.14}(12 - a) + 3.25(b - 2) + 2.5(c - 3)}{100}$$

Where K (t-ha-hr/ha-MJ-mm) is the soil erodibility factor, M is the (% silt + % sand) × (100 - % clay), a is the organic matter content, b is the Structure of the soil, c is the Permeability of the soil.

Soil erodibility factor was calculated using soil map. The soil map of the area was gathered from the regional centre of the national bureau of soil survey and land use planning (NBSS and LUP), Udaipur, Rajasthan. Values of M, a, b and c were assigned to soil map and K-factor was calculated using field calculator in ArcGIS 10.1.

3.2.3 Topographic factor

Length (L) and Steepness (S) of the land slope significantly affect the rate of soil erosion by water. Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well-defined channel which can be a drainage network or channel (Wischmeier and Smith 1978) [20]. The LS factor was generated using the DEM (30 m resolution) that has been collected from www.bhuvan.nrsc.gov.in. From the DEM, the slope was derived using ArcGIS 10.1. The LS-factor was calculated using equation proposed by Moore and Burch 1986 is as follows:

$$LS = \left([\text{flow accumulation}] \times \frac{\text{cell size}}{22.13}\right)^{0.4} \times \left(\frac{\sin \text{slope}}{0.0896}\right)^{1.3}$$

3.2.4 Crop management factor (C-Factor)

Crop management factor defined as the ratio of soil loss from land cropped under specific conditions to the corresponding soil loss from clean-tilled, continuous fallow (Wischmeier and Smith 1978) [20]. The value of C-factor depends on the vegetation cover percentage and growth stage. For a large watershed, it is hardly possible to estimate C-factor using the RUSLE guidelines due to lack of detailed data (Van der Knijff *et al*. 1999). In this study Resourcesat-2, LISS-III satellite imagery (Date of acquisition: 5 Dec, 2015), downloaded from www.bhuvan.nrsc.gov.in was used for the calculation of Cover Management factor. LISS-III images have 5 bands. However, for the calculation of NDVI only 2 bands are required, band 4 (RED) and band 5 (NIR). NDVI was calculated using ArcGIS 10.1. C-factor map was derived by using following equations in ArcGIS using raster calculator.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

$$C = 1.02 - 1.21 \times NDVI$$

3.2.5 Support practice factor (P-Factor)

The support practice factor (P-factor) in RUSLE is the ratio of soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage. This practice effects erosion by modifying the flow pattern, grade or direction of surface runoff and by reducing the amount and rate of runoff (Renard *et al*., 1997) [18]. The values of P-factor ranges from 0 to 1 in which the highest value is assigned to areas with no conservation practices and the minimum values correspond to built-up- land and plantation area with strip and contour cropping. In this study, values of P-factor for the study area were chosen based on land use/land cover practices.

4. Results and Discussion

4.1 Rainfall erosivity factor (R-factor)

The calculated values of rainfall erosivity factor (R-factor) are given in Table 1. The value of R-factor in the year 2016 was found to be 9932.807 MJ-mm/ha-hr-yr when the total rainfall was 1222 mm. The value of R factor in the year 2015 was found to be 8417.359 MJ-mm/ha-hr-yr when the total annual rainfall was 712 mm.

Table 1: Rainfall Erosivity Factor (R-Factor) values

S. No.	Year	Annual Rainfall (mm)	R-Factor (MJ mm/ha/hr)
1	2015	712	8417.36
2	2016	1222	9932.81

4.2 Soil erodibility factor (K-factor)

The K-factor value was computed from the soil parameters such as percentage sand, silt, clay, organic matter, soil structure and soil permeability. Soil information from the study area was used for calculating K-factor value. In this study area clay, clay loam and loam type soil texture exists. Low K-factor values show low erodibility. The value of K-factor ranged from 0.05 to 0.19 t-hr/MJ-mm in the study area. Agricultural land and pasture land has low K-factor value 0.054 t-hr/MJ-mm. Majority area, i.e. 205.3 ha (90.04%) is having lowest K-factor value. Lowest proportion of the study area i.e. 3.75 ha (1.64%) has highest K-factor value (0.19).

Table 2: Soil Erodibility Factor (K-Factor) values

Sr. No.	K-Factor Value	Area under different K-Factor	
		(ha)	(%)
1	0.05	205.3	90.04
2	0.06	56.18	8.31
3	0.19	3.75	1.64

4.3 Topographic factor (LS-Factor)

L and S factor in combination are called as topographic factor. The LS-factor map indicates that most of the area of the watershed is characterized with the low slope or low value of LS-factor. The area of the LS-factor was classified into five classes. From Table 3 it can be seen that the LS-factor value varies from 0 to greater than 3. The majority of the region about 163.50 ha (71.70%) has LS-factor values between 0 and 0.5 which indicates moderate erosion. LS-factor values ranges from 2.0 to 3.0 occupies the least area about 6.42 ha (2.82%) which indicates that the area is highly vulnerable to erosion.

Table 3: Area covered under Topographic Factor (LS-Factor)

S. No.	LS-Factor Value	Area under different LS Factor	
		(ha)	**(%)**
1	0-0.5	163.50	71.70
2	0.5-1.0	32.60	14.30
3	1.0-2.0	18.00	7.90
4	2.0-3.0	6.42	2.82
5	>3	7.48	3.28

4.4 Crop Management Factor (C Factor)

In the Kherot watershed, four categories of the land use/land cover are prominent which are agricultural land, habitats, wasteland and pasture land. It can be seen from Table 4 that agricultural lands have lowest values of C-factor ranges from 0.33 to 0.45 and covered major portion of the study area about 125.72 ha (55.14%). The C-factor value more than 0.50 covered 46.10 ha area (20.22%) which indicates that this area is succeptible to erosion.

Table 4: Area covered under Crop Management Factor (C-Factor)

S. No.	C-Factor Value	Area under different C-Factor	
		(ha)	(%)
1	0.33-0.45	125.72	55.14
2	0.45-0.50	56.18	24.64
3	>0.50	46.10	20.22

4.5 Support practice factor (P-Factor)
In this study, the values of support practice factor (P-factor) was assigned as per the land cover classes in India given by hann *et al.* (1994). For habitats the P-factor value was assigned as 0 and for pasture land and waste land P-factor value were assigned as 1. Similarly, for agricultural land P-factor value was assigned as 0.3.

Table 5: Area covered under Support Practice Factor (P-Factor)

S. No.	P-Factor Value	Area under different P-Factor	
		(ha)	(%)
1	0	3.54	1.55
2	0.3	172.04	75.44
3	1	52.42	23.00

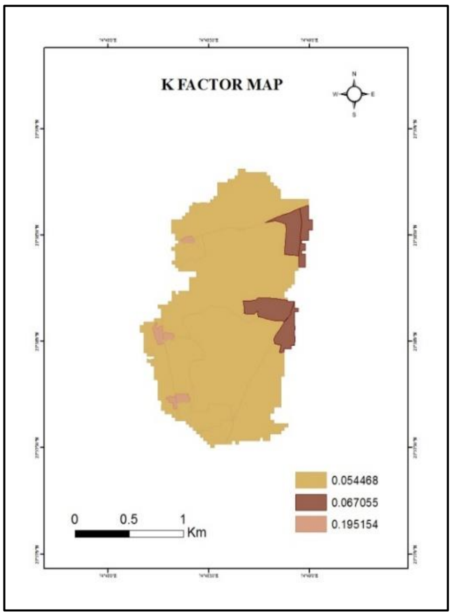
4.6 Estimation of Soil Loss
Annual soil loss was estimated for each pixel (30 m × 30 m). The pixels of the resulted soil loss maps were classified into seven priority classes namely, very slight, slight, moderate, moderately severe, severe, very severe and extremely severe as per guidelines suggested by Shyampura *et al.* (2003). It can be seen from Table 6 that in the year 2015, 164.0 ha area (72%) is under the very slight erosion class which is covering major portion of the study area. Severe, very severe and extremely severe classes cover 19.60 ha area (8.63%). It can be seen from Table 7 that in the year, 172.0 ha area (75.44%) is under the very slight erosion class which is covering major portion of the study area. Sever, very severe and extremely severe classes cover 14.30 ha area (6.26%).

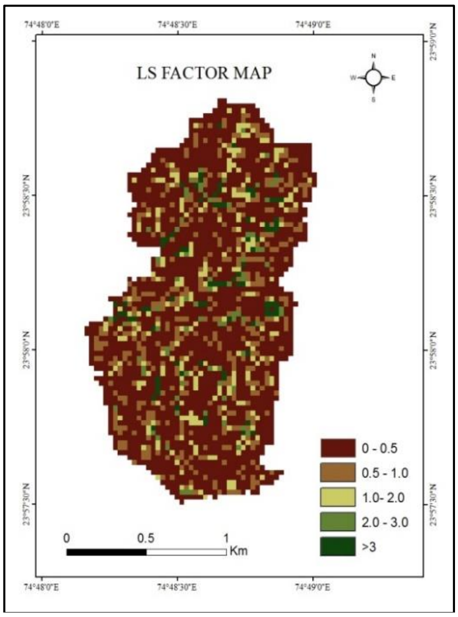
Table 6: Area covered under different Soil Loss rate in the year 2015

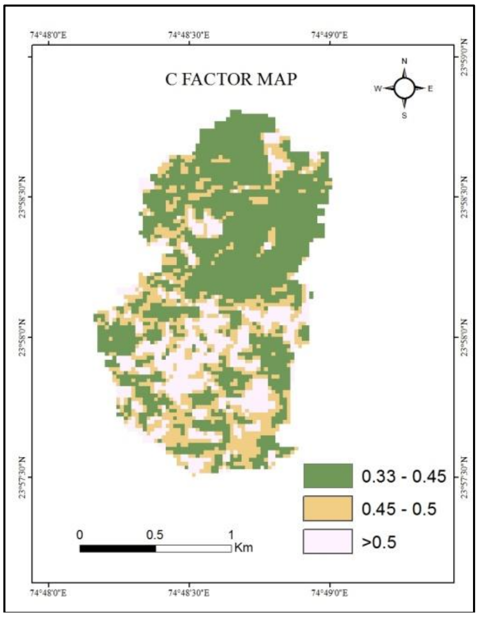
Sr. No.	Soil Loss (t/ha/yr)	Priority Class	Area Covered	
			(ha)	(%)
1	0-5	Very Slight	172.00	75.44
2	5-10	Slight	22.60	10.00
3	10-15	Moderate	12.40	5.43
4	15-20	Moderately Severe	6.70	3.00
5	20-40	Severe	8.30	3.64
6	40-80	Very Severe	4.00	1.75
7	>80	Extremely Severe	2.00	0.87

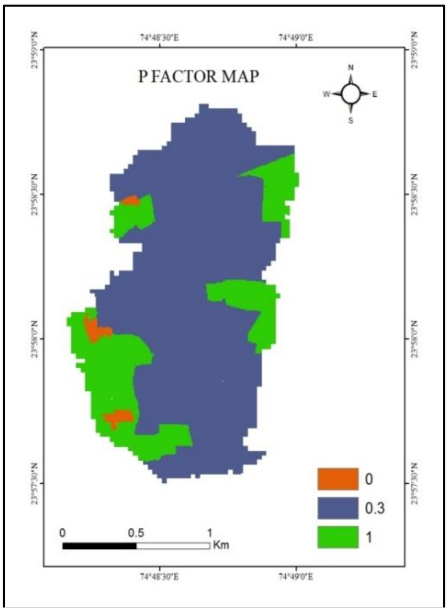
Table 7: Area covered under different Soil Loss rate in the year 2016

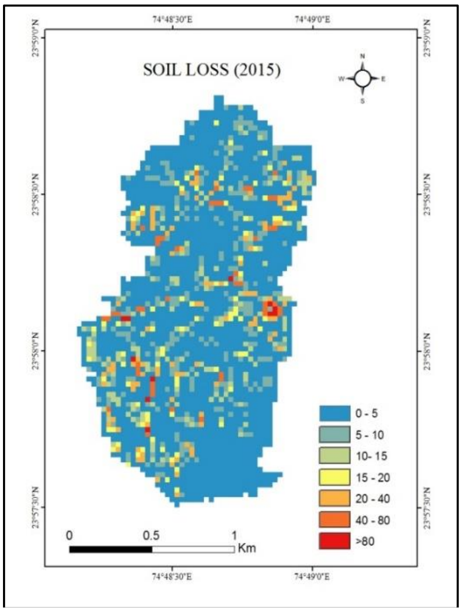
Sr. No.	Soil Loss (t/ha/yr)	Priority Class	Area Covered	
			(ha)	(%)
1	0-5	Very Slight	164.00	72.00
2	5-10	Slight	24.03	10.60
3	10-15	Moderate	13.22	5.80
4	15-20	Moderately Severe	7.15	3.13
5	20-40	Severe	12.00	5.26
6	40-80	Very Severe	5.40	2.37
7	>80	Extremely Severe	2.20	1.00

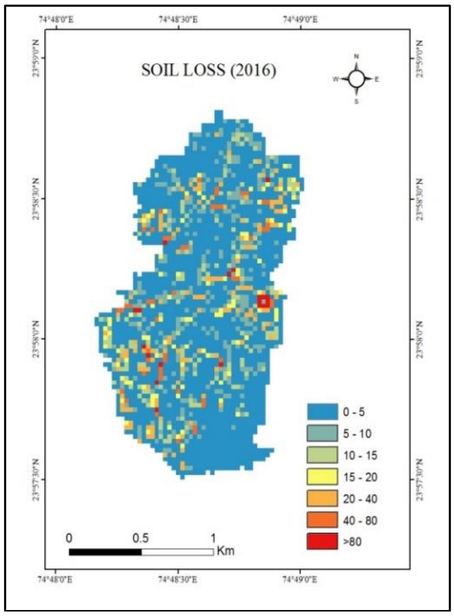












5. Summary and Conclusion

For this study, Soil Loss was estimated using Revised Universal Soil Loss Equation (RUSLE), governed by major five parameters i.e. rainfall erosivity factor (R-factor), soil erodibility factor (K-factor), topographic factor (LS-factor), crop management factor (C-factor) and support practice factor (P-factor). Rainfall erosivity factor for the year 2015 was found to be 8417.36 MJ-mm/ha-hr-yr and for the year 2016 was found to be 9932.81 MJ-mm/ha-hr-yr. The LS-factor value varies from 0 to greater than 3. The majority of the region about 163.50 ha (71.70%) has LS-factor values between 0 and 0.5 which indicates moderate erosion. LS-factor values ranges from 2.0 to 3.0 occupies the least area about 6.42 ha (2.82%) which indicates that the area is highly vulnerable to erosion. Crop management factor used to represent the ratio of soil loss for a given cropping usually ranges from 0 and 1. For Kherot watershed, it has been found in the range of 0.33 to >0.50 depending on the NDVI. In this study the values of conservation practice factor (P factor) was assigned according to the land cover classes in india given by hann *et al.* (1994). For habitats the P-factor value was assigned as 0 and for wasteland and pasture land P-factor values were assigned as 1. Similarly, for agricultural land P-factor value was assigned as 0.3. The average annual soil loss was computed by multiplying the developed raster files for each RUSLE factors. It is apparent that in the year 2015, 164.0 ha area (72%) is under the very slight erosion class which is covering major portion of the study area. Severe, very severe and extremely severe classes cover 19.60 ha area (8.63%). In the year 2016, 172.0 ha area (75.44%) was under the very slight erosion class which was covered major portion of the study area. Sever, very severe and extremely severe classes cover 14.30 ha area (6.26%).

6. References

1. Angima SD, Stott DE, O'neill MK, Ong CK, Weesies GA. Soil erosion prediction using RUSLE for central Kenyan highland conditions. Agriculture, Ecosystems and Environment. 2003; 97:295-308.
2. Adediji A, Tukur AM, Adepoju KA. Assessment of revised universal soil loss equation (RUSLE) in Katsina area, Katsina state of Nigeria using remote sensing (RS) and geographic information system (GIS). Iranica Journal of Energy and Environment. 2010; 1:255-264.
3. Arya SL, Samra JS. Revisiting Watershed Management Institutions in Haryana Shivalik, India. Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh. 2001, 92-93.
4. Bhattarai R, Dutta D. Estimation of soil erosion and sediment yield using GIS at catchment scale. Water Resources Management. 2007; 21:1635-1647.
5. Chen T, Niu RQ, Li PX, Zhang LP, Du B. Regional soil erosion risk mapping using RUSLE, GIS, and remote sensing: a case study in Miyun Watershed, North China. Environmental Earth Sciences. 2011; **63**:533-541.
6. Dabral PP, Baithuri N, Pandey A. Soil erosion assessment in a hilly catchment of North Eastern India using USLE, GIS and remote sensing. Water Resources Management. 2008; 22:1783-1798.
7. Ganasri BP, Ramesh H. Assessment of soil erosion by RUSLE model using remote sensing and GIS- A case study of Nethravathi Basin. Geoscience Frontiers. 2016; 7:953-961.
8. Gitas IZ, Douros K, Minakou C, Silleos GN, Karydas CG. Multi-temporal soil erosion risk assessment in N. Chalkidiki using a modified USLE raster model. European Association of Remote Sensing Laboratories eProceedings. 2009; 8:40-52.
9. Jain SK, Kumar S, Varghese J. Estimation of soil erosion for a Himalayan watershed using GIS technique. Water Resources Management. 2001; 15:41-54.
10. Kamaludin H, Lihan T, Ali Rahman Z, Mustapha MA, Idris WMR, Rahim SA. Integration of remote sensing, RUSLE and GIS to model potential soil loss and sediment yield (SY). Hydrology and Earth System Sciences Discussions. 2013; 10:4567-4596.
11. Kumar S, Kushwaha SPS. Modelling soil erosion risk based on RUSLE-3D using GIS in a Shivalik sub-watershed. Journal of Earth System Science. 2013; 122:389-398.
12. Lal R. Soil degradative effects of slope length and tillage methods on alfisols in western Nigeria. I. Runoff, erosion and crop response. Land Degradation and Development. 1997; 8:201-219.
13. Lazzari M, Gioia D, Piccarreta M, Danese M, Lanorte A. Sediment yield and erosion rate estimation in the mountain catchments of the Camastra artificial reservoir

(Southern Italy): a comparison between different empirical methods. *Catena*. 2015; 127:323-339.
14. Lu D, Li G, Valladares GS, Batistella M. Mapping soil erosion risk in Rondonia, Brazilian Amazonia: using RUSLE, remote sensing and GIS. Land degradation and development. 2004; 15:499-512.
15. Merz R, Bloschl G. A regional analysis of event runoff coefficients with respect to climate and catchment characteristics in Austria. Water Resources Research. 2009; 45:1-19.
16. Moore ID, Burch GJ. Physical basis of the length-slope factor in the Universal Soil Loss Equation. Soil Science Society of America Journal. 1986; 50:1294-1298.
17. Narayana DV, Babu R. Estimation of soil erosion in India. Journal of Irrigation and Drainage Engineering. 1983; 109:419-434.
18. Renard KG, Foster GR, Weesies GA, McCool DK, Yoder DC. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture, Agriculture Handbook, 1997, 314-415.
19. Renschler CS, Harbor J. Soil erosion assessment tools from point to regional scales- The role of geomorphologists in land management research and implementation. Geomorphology. 2002; 47:189-209.
20. Smith DD, Wischmeier WH. Predicting Rainfall Erosion Losses- A Guide to Conservation Planning. United States Department of Agriculture, Agriculture Handbook, 1978, 282-367.
21. Wischmeier WH, Smith DD. Rainfall-erosion losses from cropland east of the Rocky Montains, guide for selection of practices for soil and water conservation. United States Department of Agriculture, Agriculture Handbook, 1965, 47-48.
22. Wischmeier WH, Johnson CB, Cross BV. A soil erodibility nomograph for farmland and construction sites. Journal of Soil and Water Conservation. 1971; 26:189-193.