RESEARCH ARTICLE

COMPARATIVE STUDY OF ESTIMATION OF SOIL ERODIBILITY FACTOR FOR THE LOWER TRANSACT OF RANIKHOLA WATERSHED OF EAST SIKKIM

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Abstract: Soil erosion is a two phase process consisting of the detachment of individual particles from soil mass and their transport by erosive agents such as running water and wind. When sufficient energy is no longer available to transport the particles, a third phase (deposition) occurs. The amount of erosion from raindrops has been linked to the rainfall characteristics such as the rainfall intensity, drop diameter, impact velocity and rainfall kinetic energy. The size, distribution and shape of rain drops influence the energy, amount and erosivity of rainstorm. On the other hand, the soil properties, particles size distribution and organic matter content determine whether soil can be detached and transported. Soils with faster infiltration rates, higher levels of organic matter and improved structure have a greater resistance to erosion. Hence soil erodibility is another important parameter in the estimation of soil erosion. In the present study the main objective was to determine the soil erodibility indices of Ranikhola watershed area so that the values of the soil erodibility index can be established for future works. Runoff Plot method and Soil Physical Properties Analysis method was used for determination of 'K' factor in transact of Ranikhola watershed (Sikkim). The range of 'K' factor in study area varied from 0.0086 to 0.034 with an average value of 0.025 (t ha h/ha mm MJ) by Runoff Plot method. Using Soil Physical Properties Analysis method, the 'K' values were found in between 0.051 to 0.073 with an average value of 0·064 (t ha h/ha mm MJ). From the study it was concluded that the study areas falls under low erodibility (K) class. Among the both methods, the runoff plot methods were under estimated than the other method. Soil textural analyses revealed all the important soil components affecting directly soil inherent properties to resist erosion or to become susceptible to erosion, hence the 'K' values as obtained from Soil Physical Properties Analysis method was considered appropriate for the lower transact of Ranikhola watershed.

Keywords: Soil Erodibility, USLE, Runoff plot, Sikkim

INTRODUCTION

Soil erosion is the most widespread form of soil degradation worldwide (Bridges and Oldeman, 1999). Soil erosion by water involves the interaction of a complex set of physical and chemical processes governed by many factors; soil erodibility describes the degree to which the soil surface is susceptible to soil erosion. Universal Soil Loss Equation (USLE) is one of such empirical equation which is used extensively to estimate the soil loss from a given watershed (Wischmeier and Smith, 1965). Soil erodibility is an important parameter for estimating soil loss and implementing soil conservation practices (Wang et al., 2014). Soil erodibility has been found to be influenced by soil properties such as particle size distribution, structural stability, soil organic matter content, soil chemistry and clay mineralogy and water transmission characteristics (Lal, 1994). Therefore, a common way to investigate soil erodibility would be to produce soil-property maps based on a vast number of traditional field soil samplings and property analyses. Soil erodibility also can be evaluated by using runoff plots. Naturally experimental plots have become one of the most important methods of data gathering in surface runoff and soil erosion studies. Basic data for developing most empirical models such as USLE, MUSLE and RUSLE were originated from natural plots. This is because soil erosion is a function of many factors as stated in the universal soil loss equation (USLE).

$$A = R\ K\ LS\ C\ P \qquad (1)$$

Where, these factors include rainfall factor (R), soil erodibility factor (K), slope length (LS), crop factor (C) and control practice factor (P) and annual average soil loss (A).

The formulation of proper soil management for sustainable development requires an explicit inventory and rating of vulnerable areas. This information is very useful in the decision making context to avoid land degradation in erosion risk areas, or, alternatively, to recommend soil conservation measures to reduce soil loss if developments continue.

In this study, a transact of Ranikhola watershed in high rainfall areas of Sikkim, which is located near Ranipool, East Sikkim district has been taken for estimating soil erodibility (K) factor. Both the methods *i.e.* by soil physical properties analysis and by runoff plot were used to determine the soil erodibility indices of Ranikhola watershed area so that the values of the soil erodibility index can be established for future works.

MATERIALS AND METHODS

Description of study area

Study area comprises the Ranikhola watershed located in the district of East-Sikkim. Ranikhola watershed lies between latitude 27°13'N to 27°24'N and longitude 88°29'E to 88°43' E and the total geographical area is 254·5 square kilometers. In the present study, however, a transact of the watershed as shown in the Fig. 2.1 was considered. The

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topography of this area is hilly and it is a part of eastern Himalayan region as per the classification of agro climatic zone (Planning Commission, 1989) and the elevation ranges from 600 m to 5000 meters above MSL. The average annual rainfall is 2525 mm consisting of 135 rainy days in a year. The major drainage in the study area is provided through the Ranikhola River.

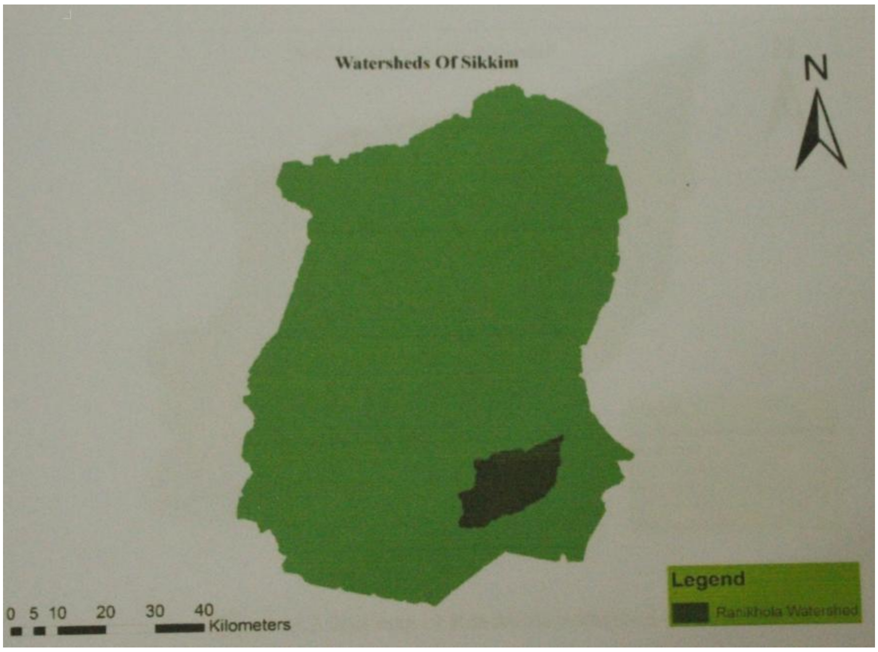

Fig: 1. Study area

Determination of Soil Erodibility Index

Two different methods namely as, a) Runoff Plot method and b) Soil Physical Properties Analyses method were used for determination of soil erodibility factor in Ranikhola watershed of East-Sikkim.

Runoff Plot method

Plot lay out:

Three plots having an equal size of 4.05m ×1m (4.05 m^2 equal to $1/1000^{th}$ of 1 acre) with the natural uniform slope of 16.73% was prepared. The original plot size was 22.13m × 1.83 m (equal to $1/100^{th}$ of 1 acre, Wischmeier and Smith, 1978).

Fig. 2. Runoff plot

Plots were cleaned from the vegetation and were tilled along the slope and bunds were made on all the sides. The bunds were covered with tin and polythene sheet. An outlet made from polythene sheet was fixed to channelize the flow of runoff from plots to the plastic bucket of 20 litres capacity fixed on the lower end of each plot.

Sampling of Soil from Runoff Plot

After each rainstorm, depth of runoff in drums was measured using measuring cylinder and one litres of water sample was taken for determination of soil loss. Drums were emptied and cleaned after each rainstorm manually and plots tilled and cultivated again. The observations were recorded for 8 rainstorms during the month of August, 2015. The duration of rainstorm varied from 1 to 1·5 hours and the intensity varied from 10·74 to 14·92 mm/h. The field experiment was conducted under natural rainfall condition in Ranikhola watershed (Sikkim).

Observation of Storms:

After collecting the samples, these were filtered through the filter paper of 42 no. grade and the soil was separated from the water. Then the soil was kept in oven at 105℃ for 24 hours and then weights of samples (soil) were noted down.

Calculation of K

The soil erodibility factor (K) was calculated by using USLE (Wischmeier and Smith, 1978) formula,

$A = R\ K\ L\ S\ C\ P$ (2)

Where, average annual soil loss (A), rainfall factor (R), soil erodibility factor (K), topography factor (LS), crop factor (C) and control practice factor (P).

$LS = (l/22{\cdot}13)^m \times (0{\cdot}065 + 0{\cdot}045s + 0{\cdot}0065s^2)$ (3)

Where:

l = slope length; s = slope gradient;

m = an exponent depending on the slope.

Current recommendation for 'm' is:

m = 0·5 if s >5%,

m = 0·4 if s ≤5% to >3%,

m = 0·3 if s ≤ 3% to > 1%,

m =0·2 if s ≤1%.

And, 'C' & 'P' are taken 1.

Soil Physical Properties Analyses method

In this study, 20 samples of surface soil (0-15 cm) were collected from different places (location is given in table, 3.3 and Fig 3.3) of Ranikhola watershed. Using USDA method were determined the percentage of silt, sand and clay and used STFR meter for determine percentage of organic matter content. Soil erodibility factor (K) determined by using USLE monograph (Wischmeier et al. 1971).

$K = [2{\cdot}73 \times 10^{-4} M^{1{\cdot}14} (12 - OM) + 3{\cdot}25 \times (S - 2) + 2{\cdot}5 (P - 3)] / 759$ (4)

Where, K is soil erodibility factor ($t{\cdot}ha{\cdot}h{\cdot}ha^{-1}{\cdot}Mj^{-1}{\cdot}mm^{-1}$) and M is texture from the first 15 cm of soil surface. OM is % of organic matter content that was determined by STFR method.

$M = [(100 - Ac) \times (Si + Armf)]$ (5)

Where, Ac is % of clay (<0·002 mm), Si is % of silt (0·002 - 0·05 mm) and Armf is % of very fine sand (0·05 - 0·1mm).

S is the structural class of soil (Wischmeier *et al.*, 1971).

Table 1. Structural class of soil.

Structural class	Range	Aggregates size(dia.),mm
1	Very fine granular	1 to 2
2	Fine granular	2 to 3
3	Medium or coarse granular	3 to 5
4	Blocky, platy, or massive	Usually construction sites

And **P** is the permeability class index

Table 2. Permeability class index (Wischmeier *et al.*, 1971)

Class	Range (mm/hr)	
1	150	Rapid
2	50 to 150	Moderate rapid
3	12 to 50	Moderate
4	5 to 15	Slow to moderate
5	1 to 5	Slow
6	>1	Very slow

RESULTS AND DISCUSSION

As previously discus the study was done by using two methods namely a) Runoff Plot method and b) Soil Physical Properties Analyses method

Runoff plot methods

R-values:

The rainfall erosivity factor (R) was calculated by using EI_{30} method (Wischmeier and Smith, 1978). The R factor was varies with storm by storm, with the assumptions that 60% of the storm rainfall of storm duration about 1 hour occur within 30 minutes, I_{30}values were calculated for different storms. The assumption was considered based on the observation of actual pattern of storm occurred in Ranikhola watershed area during the period of study. The values of 'R' obtained with the assumption are given in Table 3.1.

Table 3. R-values with obtained from 60% storm rainfall occurred in 30 minutes

Date	Intensity (mm/hr)	I_{30}	E= (e × *p*)	R = $(E*I_{30})/100$
02/08/2015	15.67	18.80	3.50	0.66
05/08/2015	14.42	17.30	3.97	0.69
10/08/2015	13.33	15.99	3.62	0.58
11/08/2015	13.79	16.50	3.16	0.53
12/08/2015	14.25	17.10	3.76	0.64

21/08/2015	12.79	15.35	2.90	0.44
27/08/2015	14.92	17.90	5.77	1.03
29/08/2015	12.84	15.41	3.32	0.51

The storm rainfall recorded in the study area by installing one non-recording type of rain gauge. This was nevertheless expected due to the fact that in the project area the total rainfall collected in the non-recording type of rain gauge and 60% of the rainfall was used to calculate the intensity, which might not be happening in reality during the storms.

The topographic (LS) factor of the study area was found 1.09 whereas the crop management factor (C) and the supporting conservation practice Factor (P) were took 1, because the vegetation were removed and tillage was done in the runoff plots and there was no conservation practices situated.

Soil Erodibility Index

The soil erodibility index was calculated plot wise and storm wise. It was found that storm wise values of erodibility factors in the erosion plot area was varying from 0.0086 to 0.034 with an average value of 0.025 (t ha h/ha mm MJ). The K factor from different at different storm was given in table 3.2.

Table 4. 'K' value by USLE with 60% storm rainfall data

Date	Plot	soil loss (A)	Avg (A)	Erosivity (R)	Topography	Erodibility (K)	Average (K)	Avg (K)
		(t/ha/h)	(t/ha/h)		factor (LS)		(t ha h/ha mm MJ)	
02-08-2015	1	0.031		0.658	1.089	0.043		
	2	0.024		0.658	1.089	0.034	0.0343	
	3	0.018		0.658	1.089	0.026		
05-08-2015	1	0.0065		0.686	1.089	0.009		
	2	0.0051		0.686	1.089	0.007	0.0086	
	3	0.0075		0.686	1.089	0.012		
10-08-2015	1	0.024		0.578	1.089	0.038		
	2	0.014		0.578	1.089	0.022	0.034	
	3	0.028	0.0175	0.578	1.089	0.044		0.025
11-08-2015	1	0.013		0.522	1.089	0.023		
	2	0.013		0.522	1.089	0.022	0.022	
	3	0.013		0.522	1.089	0.022		
12-08-2015	1	0.018		0.642	1.089	0.026		
	2	0.012		0.642	1.089	0.017	0.019	
	3	0.012		0.642	1.089	0.017		
21-08-2015	1	0.015		0.439	1.089	0.031		
	2	0.014		0.439	1.089	0.029		
	3	0.014		0.439	1.089	0.029	0.03	
27-08-2015	1	0.022		1.033	1.089	0.019		
	2	0.025		1.033	1.089	0.022	0.026	
	3	0.042		1.033	1.089	0.037		
29-08-2015	1	0.023		0.512	1.089	0.041		
	2	0.016		0.512	1.089	0.029	0.032	
	3	0.012		0.512	1.089	0.025		

The K-values as obtained with the help of Eq. No. (4) in material and methods are presented in Table 3.3.

The soil textural analyses revealed that the soils of Ranikhola watershed are sandy to sandy loam with the silt content ranging from 21% to 48.66%, clay content ranging from 13.16% to 21.83% and very low organic matter content ranging from 0.24% to 0.41%. The component of very find was also higher which is ranging from 19.61 to 32.48. As such the soil is very susceptible to erosion due to higher amount of very fine sand and silt content. Based on the Eq. No. (4) the 'K' values are found which are ranging from 0.051 to 0.073 with an average value of 0·064.

Table 5. 'K' values obtained from soil textural data.

% of silt	% of clay	% OM	% of very fine sand	K Factor	Average k
36·29	16·20	0·28	26·99	0·0647	
37·01	16·20	0·31	26·58	0·0649	
37·01	16·20	0·33	26·58	0·0647	
38·68	16·20	0·32	25·63	0·0652	
42·00	17·55	0·30	22·98	0·0653	
33·67	13·83	0·28	29·82	0·0667	
35·33	13·83	0·29	28·88	0·0675	
31·61	16·83	0·28	29·26	0·0617	0·064
34·00	16·83	0·41	27·93	0·0622	
30·67	20·16	0·24	27·93	0·0572	
45·67	13·16	0·30	23·39	0·0732	
39·33	13·16	0·26	26·99	0·0704	
40·33	13·83	0·32	26·04	0·0696	
45·33	16·83	0·37	21·50	0·0674	
48·66	16·83	0·25	19·60	0·0694	
46·66	13·83	0·29	22·44	0·0727	
27·00	18·49	0·37	30·97	0·0573	
21·00	21·83	0·31	32·48	0·0510	
30·67	20·16	0·38	27·93	0·0567	
29·00	18·49	0·33	29·83	0·0583	

Where, 'K' in t ha h/ha mm MJ

The K-values as obtained from the soil physical data are found to be higher than the values obtained with USLE (from actual rainfall data).

The soil textural analyses of the surface soil collected from the lower transact of Ranikhola watershed yielded values of all the components of soil responsible for soil aggregation and soil susceptibility to erosion. The analysis was also done on control conditions and hence the 'K'-values obtained from soil textural analyze were considered to be the true value of soil erodibiltiy in Ranikhola watershed of East-Sikkim district.

CONCLUSION

Soil erodibility factor (K) is strongly correlated with soil loss and known as a key factor in soil erosion prediction. Runoff Plot method and Soil Physical Properties Analysis method was used for determination of 'K' factor in transact of Ranikhola watershed (Sikkim). The range of 'K' factor in study area varied from 0.0086 to 0.034 with an average value of 0.025 by Runoff Plot method. Using Soil Physical Properties Analysis method, the 'K' values were found in between 0.051 to 0.073 with an average value of 0·064. In the erosion plot methods, the 'R' value of Universal Soil Loss Equation was determined with the rainfall intensity collected at the experimental plots. From the study it can conclude that the study area is comes under low erodibility (K) class. Among the both methods, the runoff plot methods were under estimated than the other method. Soil textural analyses revealed all the important soil components affecting directly soil inherent properties to resist erosion or to become susceptible to erosion, hence the 'K' values as obtained from Soil Physical Properties Analysis method was considered appropriate for the lower transact of Ranikhola watershed.

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