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ESTIMATION OF SOIL ERODIBILITY FACTOR FOR SOILS OF DEDIAPADA TALUKA OF NARMADA DISTRICT IN GUJARAT

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Abstract: Soils are the main source of essential nutrients, water, oxygen as well as supports plant through the root system. Healthy soils are basis for healthy food production. The services provided by soils are primarily determined by the three core soil properties (texture, mineralogy, and organic matter), which together form the natural capital of soils (Palm *et al.* 2007). Unscientific use and mismanagement has led to soil degradation, it is an important global issue causing adverse impact on agricultural productivity and environmental quality and ultimately affecting quality of human life. Water erosion is the chief contributor of soil degradation worldwide. Soil erodibility factor plays an important role and dominant factor for inter-rill and rill erosion. In the present study, soil erodibility factor was estimated for soil erosion modelling of the study area. Ten representative soil samples from clay soils and eight representative soil samples for clay loam soils of study area were collected from top 15 cm soil layer. International pipette method, Walkley and Black's rapid titration method and Sieve analysis technique was used to ascertain textural properties, organic matter and rock fragment content of soils of the study area. Organic matter content of both the soils was less than 4 % so the erodibility factor would play a major role in erosion. Soil erodibility factor was estimated separately for all soil samples using reclassified and modified formula. The average erodibility estimated for clay loam and clay soil was 0.236 and 0.177 respectively.
Keywords: Soil Textural Analysis, Soil Erodibility, Soil Erosion, Soils of Gujarat

Introduction

Soils could be referred as the earth's fragile skin that anchors all life forms on earth, comprising of countless species that create a dynamic and complex ecosystem and is among the most precious resources to humans. The services provided by soils are primarily determined by the three core soil properties (texture, mineralogy, and organic matter), which together form the natural capital of soils (Palm *et al.* 2007). Soil texture and mineralogy are inherent properties of soil that are initially inherited from the parent materials which change very slowly with time. Soils supplies essential nutrients, water, oxygen and support root system that our food producing plants need to grow and flourish. Healthy soils are basis for healthy food production. FAO estimated that about 33 % of soils are degraded globally which

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needs to be improved upon. Management has become an essential component of strategy for sustenance of ever-increasing population and development pressure (NAAS, 2012). Indiscriminate use and mismanagement has led to soil degradation which is an important global issue causing adverse impact on agricultural productivity and environmental quality and ultimately quality of human life. Water erosion is the chief contributor of soil degradation worldwide (Oldeman, 1992). Soil degradation is a further strong driver of climate change through its current and anticipated effects on land use and management. Among the major causes of soil degradation in India, water erosion is considered to be the most severe one which covers almost 68.39 % of the affected area resulting into the annual soil loss of about 5.3 billion tons through erosion. Restoring eroded soils can enhance biomass production and improve SOC concentration. The total potential of restoring degraded soils in India is 7 to 10 Tg C/y (Lal, 2001). The water erosion could be controlled by watershed development and management programme. The first step of planning for watershed management programme is to identify the magnitude and degree of soil degradation spatially and temporally. Soil erodibility factor play an important role for the inter-rill and rill erosion. In the present study, soil erodibility factor was estimated for soil erosion modelling of study area.

Materials and Methods

Dediapada taluka is situated in the Narmada district in South Gujarat Agro Climatic Zone of Gujarat state at 21° 66' N latitude and 73° 59' E longitude with an elevation of 169 m above mean sea level covering an area of 1026.84 km^2.

Soil Sample Collection

The soil map of study area was collected from Bhaskaracharya Institute for Space Applications and Geo-Informatics (BISAG), Gandhinagar, which shows that the study area has mainly two types of soils i. e. Clay and Clay Loam. The maps show that clay and clay loam soil covers 53.39 percent and 46.61 percent of study area respectively.

To ascertain the soil texture analysis, soil samples from top 15 cm soil layer were collected by V-shape excavation from various land cover categories (agricultural, forest and waste land) of the study area. These soil samples are mixed as per their land cover and finally 10 representative soil samples from clay soils and 8 representative soil samples for clay loam soils for different land cover categories were prepared for laboratory analysis.

Soil Physico-Chemical Properties

The standard procedure was used to estimate the various soil physico-chemical properties of study area. The methods adopted to estimate various soil properties are described in the Table 1.

Soil Erodibility Factor

Soil Erodibility factor (K), is the rate of susceptibility of soil particles to erosion per unit of rainfall erosivity factor for a specified soil on a unit plot having a 9 % uniform slope and a slope length of 22.13 meters over a continuously clean fallow land with up and down slope farming. The soil erodibility depends on sand, silt, clay contents, organic matter content and rock fragment content of soil. A nomograph as shown in Fig.3.2 (Wischmeier et al., 1971) or the classical formula as presented in eq. 1 could be used to determine the value of soil erodibility K factor.

$$K = 2.77 \times 10^{-6} \times M^{1.14} (12-a) + 0.043 (b-2) + 0.033 (c-3) \quad (1)$$

Where,

K = the soil erodibility factor (mt·hr. MJ^{-1} mm^{-1} per unit R),

M = particle size parameter (% silt + % very fine sand) x (100-clay)

a = Organic matter content (%)

b = Soil structure code (1-very fine granular, 2-fine granular, 3-medium or coarse granular, 4-blocky, platy or massive)

c = soil permeability class (1-rapid, 2-moderate to rapid, 3-moderate, 4-slow to moderate, 5-slow, 6- very slow)

This equation could be used only for the soils having greater than 70 percent silt, less than 4 percent organic content and less than 1.5 percent rock fragment. The equation does not fully reproduce the nomograph (Wischmeier and Smith, 1978), hence, it has been reclassified and modified by Auerswald et al. (2014) based on silt content, organic matter content and rock fragment percent of soil sample as presented in equation no. 5 to 12. The rock fragment cover percentage of the soil was not measured directly but was assumed equal to the percentage of rock fragment in this study (McCormack et al., 1984).

Plate 1: Soil Textural Analysis through International Pipette Method

For silt + very fine sand < 70 percent,

$K_1 = 2.77 \times 10^{-6} \times M^{1.14}$ (2)

For silt + very fine sand > 70 percent,

$K_1 = 1.75 \times 10^{-6} \times M^{1.14} + 0.0024$ (% silt + % very fine sand) + 0.16 (3)

For organic matter < 4 percent,

$K_2 = 100 - \text{clay}$ (4)

For organic matter > 4 percent,

$K_2 = 0.8$ (5)

For $K_1 * K_2 > 0.2$,

$K_3 = 2.77 \times 10^{-6} \times M^{1.14} (12-a) + 0.043 (b-2) + 0.033 (c-3)$ (6)

For $K_1 * K_2 < 0.2$,

$K_3 = 0.091-0.34* K1 * K2 +1.79 * (K1 * K2)^2 + 0.24 * K1 * K2 * b + 0.033 (c-3)$ (7)

For rock fragment < 1.5 percent,

Soil Erodibility factor K = K3 (8)

For rock fragment > 1.5 percent,

Soil Erodibility factor K = K3 * [1.1- {exp (-0.024 x F_{rk}) – 0.06}] (9)

Where, F_{rk} = Rock fragment content (%)

Results and Discussion

Table 2 shows the textural soil properties of the study area. The clay loam soils have course, fine, silt and clay values ranged from 8.05 to 28.73, 20.81 to 34.03, 13.33 to 27.58 and 29.00

to 39.66 % with average values of 16.77, 28.08, 20.06 and 35.09 % respectively while the clay soils have course, fine, silt and clay values ranging from 3.57 to 19.83, 15.06 to 27.38, 13.20 to 23.72 and 40.92 to 61.05 % with average value of 10.54, 22.51, 17.56 and 49.38 respectively. It is evident that in both the soils, clay content is less than 50 % so it doesn't come under heavy clayey classification.

The rock fragment values ranges from 2.65 to 23.55 % with average value of 12.82 % for clay loam soils while it ranges from 4.41 to 31.02 % with average value of 13.69 % for clay soils.

The organic carbon and organic matter content derived by Walky & Black method of collected 18 soil sample is given in the table 3. In clay soils, organic matter ranges from 0.85 to 1.67 with an average value of 1.50 while in clay loam soils, organic matter ranges from 0.92 to 2.04 with an average value of 1.47. Since organic matter content of both the soils is less than 4 % so the erodibility factor will play a major role in erosion.

Soil Structure and Permeability

Soil structure class was decided based on the particle properties of soil samples. The soils have fine granular particles therefore soil structure code of 2 has been used to estimate soil erodibility factor.

The soil hydraulic conductivity was estimated by using soil texture triangle hydraulic properties calculator (*http://www.afrc.uamont.edu/ficklinr/soils/soiltexture.htm*). The hydraulic conductivity for clay and clay loam soils was estimated as 1.5 and 3.2 mm/hr respectively therefore permeability code of 5 for clay loam and 4 for clay soil was used to estimate soil erodibility factor.

Soil Erodibility Factor Estimation

The soil erodibility depends on the silt content, organic matter content and rock fragment content. All the analyzed soil samples have greater than 70 percent silt with less than 4 percent organic matters hence, eq. 2 and 5 were used to compute the values K_1 and K_2.

As given in Table 4, 11 soil samples, (viz. sample no.-1 to 5, 7, 8, 9, 11 and 13) have the value of $K_1.K_2$ greater than 0.2 therefore eq. 6 was used to estimate the K factor, while, for other soil samples, (viz. sample no.-6, 10, 12, 15, 16, 17 and 18), eq. 7 was used for the estimation of K factor.

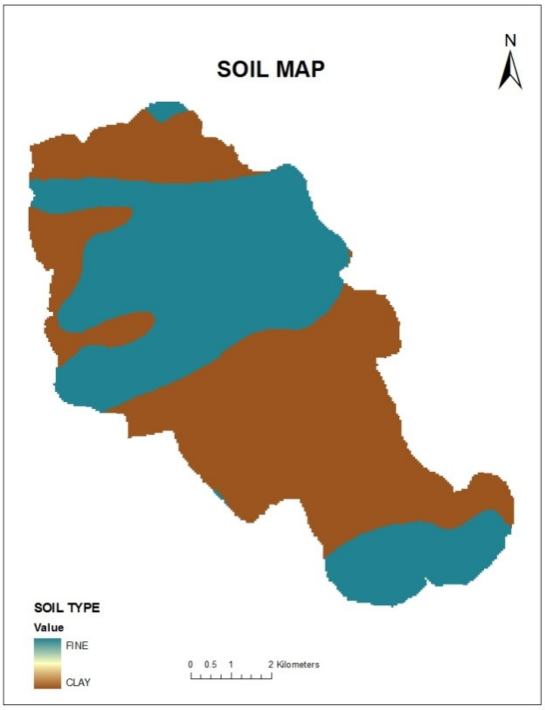

Fig. 1: Soils map

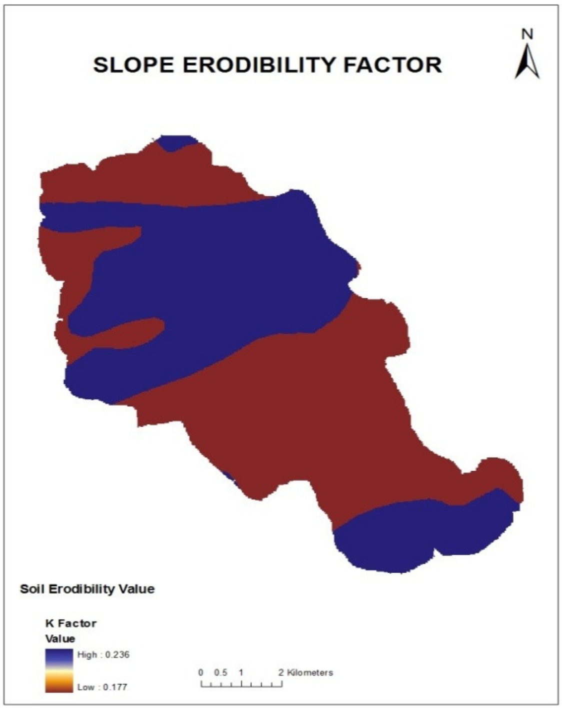

Fig. 2: Soil erodibility map

Table 4 showing soil erodibility factor of different samples, the average erodibility of clay loam and clay soil was 0.236 and 0.177 respectively; the higher value in clay loam soils makes it more susceptible for erosion.

Fig. 1 and Fig. 2 depict soil map and soil erodibility map of the study area. The map shows that clay soil is more (53.39 %) than clay loam (46.61 %) soil, which is also reflected by the area of erodibility map in Fig.2. Further, erodibility value of clay soil is also higher than clay loam soil. The erodibility values so determined play the major role in soil erosion in the study area.

Conclusion

53.36 percent area having soil erodibility factor of 0.236 while 46.61 percent area having soil erodibility factor of 0.177 of the study area. It could be concluded that more area are covered with higher value of soil erodibility factor increase the erosion rate of study area because of less area have lower value of soil erodibility in the study area.

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Table 1: Analytical methods employed to determine soil physico-chemical properties

Sr. No.	Soil Physical Properties	Method and Techniques
1.	Soil texture	International pipette method (Jackson, 1973)
2.	Organic carbon	Wet oxidation followed by Walkley and Black's rapid titration method (Jackson, 1973)
3.	Rock fragment content	Sieve analysis technique (Jackson, 1973)
4.	Soil permeability	Soil texture triangle hydraulic properties calculator
5.	Soil structure	Computed based on soil particle size

Table 2: Textural properties of soils of the selected sub-watershed

Soil Type	Soil Sample No.	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Rock Fragment (%)
Clay Loam soil	1	23.48	27.12	20.40	29.00	11.30
	2	21.79	28.61	19.30	30.30	23.55
	3	12.91	32.80	19.64	34.64	2.65
	4	6.99	30.05	27.58	35.38	11.07
	5	8.05	34.03	21.16	36.76	10.41
	6	28.73	20.81	13.33	37.13	19.57
	7	16.81	27.36	18.02	37.82	11.37
	8	15.42	23.87	21.06	39.66	12.62
	Average	**16.77**	**28.08**	**20.06**	**35.09**	**12.82**
Clay Soil	9	12.06	23.29	23.72	40.92	31.02
	10	19.83	23.57	14.20	42.40	8.99
	11	10.42	26.87	17.46	45.26	12.79
	12	14.03	27.38	13.20	45.40	8.72
	13	8.35	24.43	20.71	46.51	14.18
	14	7.85	27.44	17.86	46.86	17.96
	15	12.05	23.19	17.38	47.38	18.58
	16	7.26	18.33	16.61	57.81	4.41
	17	10.04	15.06	14.65	60.26	7.59
	18	3.57	15.53	19.85	61.05	12.61
	Average	**10.54**	**22.51**	**17.56**	**49.38**	**13.69**

Table 3: Average organic matter of soil samples

Soil Type	Soil Sample	Replication - 1		Replication - 2		Average Organic Matter (%)
		Organic Carbon	Organic Matter (%)	Organic Carbon	Organic Matter (%)	
Clay Loam Soil	1	1.70	2.92	1.85	3.18	3.05
	2	0.87	1.50	0.84	1.45	1.47
	3	0.98	1.69	0.98	1.69	1.69
	4	1.04	1.78	1.04	1.78	1.78
	5	0.60	1.03	0.60	1.03	1.03

	6	0.38	0.66	0.44	0.75	0.70
	7	0.48	0.83	0.51	0.88	0.85
	8	0.81	1.40	0.80	1.37	1.38
	Average					**1.50**
Clay Soil	9	1.22	2.11	1.14	1.97	2.04
	10	0.48	0.83	0.59	1.01	0.92
	11	0.99	1.71	0.90	1.55	1.63
	12	0.77	1.32	0.77	1.32	1.32
	13	0.88	1.51	0.92	1.58	1.55
	14	0.67	1.15	0.68	1.16	1.16
	15	1.10	1.89	1.11	1.91	1.90
	16	0.56	0.97	0.71	1.22	1.09
	17	1.13	1.94	1.10	1.89	1.91
	18	0.71	1.22	0.68	1.16	1.19
	Average					**1.47**

Table 4: Soil erodibility factors of soil samples of selected sub-watershed

Soil Type	**Soil Sample**	**K_1**	**K_2**	**K_1 x K_2**	**K_3**	**Rock Fragment (%)**	**K**	**Average K**
Clay Loam Soil	1	0.029	8.95	0.261	0.29	11.30	0.23	0.236
	2	0.029	10.53	0.303	0.34	23.55	0.19	
	3	0.030	10.31	0.306	0.34	2.65	0.33	
	4	0.033	10.22	0.333	0.37	11.07	0.28	
	5	0.030	10.97	0.332	0.37	10.41	0.29	
	6	0.017	11.30	0.197	0.22	19.57	0.14	
	7	0.024	11.15	0.265	0.30	11.37	0.23	
	8	0.023	10.62	0.241	0.27	12.62	0.20	
Clay Soil	9	0.023	9.96	0.233	0.30	31.02	0.14	0.177
	10	0.018	11.08	0.196	0.25	8.99	0.21	
	11	0.020	10.37	0.208	0.27	12.79	0.20	
	12	0.018	10.68	0.193	0.25	8.72	0.21	
	13	0.020	10.45	0.208	0.27	14.18	0.20	
	14	0.020	10.84	0.215	0.28	17.96	0.18	
	15	0.017	10.10	0.175	0.24	18.58	0.15	
	16	0.011	10.91	0.124	0.20	4.41	0.19	
	17	0.009	10.09	0.089	0.18	7.59	0.16	
	18	0.011	10.81	0.114	0.20	12.61	0.15	