Evaluation and estimation of soil erodibility by different techniques and their relationships

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Abstract

Direct measurement of soil erodibility, resistance offered by the soil to both detachment and transport processes, is not only costly but time consuming also. So, efforts have been made to predict it from the soil physical properties. To evaluate soil erodibility under different land uses using natural and simulated rainfall and to estimate soil erodibility by nomographic (Wischmeier *et al.* 1971) and fuzzy logic method (Torri *et al.* 1997), a field experiment was conducted both under natural and simulated rainfall conditions under four land uses viz. barren, cultivated, grassland and forest in the submontaneous tract of Punjab (India). Measured soil erodibility (K) values varied from 0.33 to 0.67 under natural rainfall conditions and from 0.23 to 0.40 under simulated rainfall conditions. Values of the soil erodibility factor estimated by nomograph and FUZKBAS program were very low as compared to the observed values. The trends were also in contrast to these observed values of soil erodibility under simulated and natural rainfall conditions.

Key Words

Soil erosion, soil aggregation, soil texture, rainfall simulator, universal soil loss equation

Introduction

Soil erosion depends not only on rainfall erosivity but also on the soil's resistance to erosion, which is usually measured as the soil erodibility factor K. The measurement of K can be done using Universal Soil Loss Equation (USLE) given by Wischmeier and Smith (1978) by knowing other factors of the equation using natural or simulated rainfall experimentation, but this process is costly and time consuming. Wischmeier *et al*. (1971) gave empirical nomograph for estimating erodibility from basic soil properties. Fuzzy logic based program FUZKBAS was also given by Torri *et al*. (1997) to obtain K values. Present study was planned to study the interrelationship between different methods of estimating soil erodibility.

Methods

Experimental sites

Field experiment was done in ecologically fragile zone of lower Himalayas in North-west India, the Shiwalik system. Four sites of the sub-montaneous region of Punjab i.e. Ballowal Saunkri – I, Ballowal Saunkri – II, Kokowal Majari and Saleran differing in soil texture and other soil properties were selected with four land uses i.e. barren, cultivated, grassland and forest at each location.

Experimental details

To determine soil erodibility, field experiment was conducted at two locations i.e. Ballowal Saunkhri-I and Ballowal Saunkhri-II under natural rainfall conditions and at four locations i.e. Ballowal Saunkhri-I, Ballowal Saunkhri-II, Kokowal Majari and Saleran under simulated rainfall conditions under four land uses with three replications each. Under natural rainfall conditions plots measuring 5 m x 1.5 m were prepared and the average slope of the plots was maintained at 4 percent. For simulated rainfall experiment using micro-sprinkler based rainfall simulator the plot size kept was 2.5 m x 1.0 m with 4 percent slope. Soil erodibility was evaluated using Universal Soil Loss Equation (USLE) as described in Singh and Khera (2009).

Soil analysis

Standards methods were employed to analyze the collected soil samples for water stable aggregates, mean weight diameter, particle size analysis, steady state infiltration rate, saturated hydraulic conductivity and soil organic carbon.

Nomographic estimation of soil erodibility

The modified version of nomographic expression given by Wischmeier *et al.* (1971) for estimating K in SI units (t ha hr / ha MJ mm) as given by Rosewell (1993) was used.

$K = 2.77\ M^{1.14}(10^{-7})(12\text{-}\alpha) + 4.28(10^{-3})(\beta\text{-}2) + 3.29(10^{-3})(\gamma\text{-}3)$

Where, M = (% silt+% Very fine sand).(100-% clay), α = Organic matter (%), β = structure code and γ = permeability rating.

Fuzzy logic based estimation of soil erodibility

Fuzzy logic based program FUZKBAS (Torri *et a.l* 1997) was used to estimate K distribution as a function of the decimal logarithm of the geometric mean particle size (Dg), the clay fraction and organic matter content.

Results

Observed soil erodibility under natural rainfall conditions

Under natural rainfall conditions, soil erodibility values based on EI_{30} index varied from 0.35 to 0.67 (Table 1). The erodibility values were significantly higher at Ballowal Saunkhri-II (0.54) than that at Ballowal Saunkhri-I (0.45), under all land uses. The barren soils were having highest erodibility value (0.62) followed by cultivated (0.55), grassland (0.45) and forest (0.39) soils.

Observed soil erodibility under simulated rainfall conditions

Under simulated rainfall conditions, Ballowal Saunkhri-II location was having highest soil erodibility (0.34) whereas Kokowal Majari was having lowest values of soil erodibility (0.25). Among different land uses, it was observed in the order of barren (0.34) > cultivated (0.30) > grassland (0.29) > forest (0.25) land use (Table 2).

Nomographic estimation of soil erodibility

The soil erodibility factor (K) estimated using nomograph varied from 0.14 to 0.46 (Table 3). As compared to observed K values, the values obtained using nomograph were low. Among different locations, significantly highest K values were obtained for Kokowal Majari (0.43) and lowest for Ballowal Saunkhri-II (0.15).

Fuzzy logic based estimation of soil erodibility

The maximum membership K values were 0.15, 0.14, 0.33 and 0.14 for Ballowal Saunkhri-I, Ballowal Saunkhri-II, Kokowal Majari and Saleran locations (Table 4). Among different land uses the fuzzy logic K values were 0.15, 0.16, 0.20 and 0.25 for barren cultivated, grassland and forest soils respectively.

Interrelationship among soil erodibility values determined using different methods

Measured soil erodibility varies from 0.35 to 0.67 for natural rainfall conditions and from 0.23 to 0.40 for simulated rainfall conditions and it was in the order of Kokowal majari < Ballowal Saunkhri-I = Saleran < Ballowal Saunkhri - II. Among different land uses, measured soil erodibility both under natural and simulated rainfall conditions was in the order of barren > cultivated > grassland > forest soils. Soil erodibility estimated using nomograph was Ballowal saunkhri – II < Saleran < Ballowal Saunkhri – I < Kokowal Majari, which was in contrast to the observed values of soil erodibility (Figure 1).

Values of the erodibility factor estimated by FUZKBAS program were very low (0.10 to 0.36) as compared to the observed values. These were also in contrast to the observed values of soil erodibility, which were 0.31, 0.34, 0.25 and 0.31 for Ballowal Saunkhri-I, Ballowal Saunkhri-II, Kokowal Majari and Saleran locations under simulated rainfall conditions. The highest values were obtained for Kokowal Majari using FUZKBAS whereas observed values for this location were lowest. This model gave highest values of soil erodibility under forest land use in contrast to observed K values under natural and simulated rainfall conditions. The correlation coefficient between observed K and nomograph K was -0.59, for observed K and FUZKBAS K it was -0.73 and for nomograph K and FUZKBAS K it was 0.92.

Table 1. Soil erodibility factor K (customary units) at two locations under four land uses for natural rainfall conditions.

Location	Barren	Cultivated	Grassland	Forest	Mean
Ballowal Saunkhri – I	0.56	0.49	0.41	0.35	0.45
Ballowal Saunkhri – II	0.67	0.60	0.48	0.42	0.54
Mean	0.62	0.55	0.45	0.39	
CD (0.05) Location = 0.01, Land use = 0.02, Location X Land use = 0.02					

K in SI units = K in customary units x 0.1317

Table 2. Soil erodibility factor K (customary units) under four land uses under simulated rainfall conditions.

Location	Barren	Cultivated	Grassland	Forest	Mean
Ballowal Saunkhri-I	0.39	0.28	0.30	0.26	0.31
Ballowal Saunkhri-II	0.40	0.36	0.33	0.27	0.34
Kokowal Majari	0.27	0.25	0.24	0.23	0.25
Saleran	0.33	0.31	0.30	0.26	0.31
Mean	0.34	0.30	0.29	0.25	
CD (0.05) Location = 0.02, Land use = 0.02, Location X Land Use = 0.03					

K in SI units = K in customary units x 0.1317

Table 3. Nomographic estimation of soil erodibility factor K (customary units) at four locations under four land uses.

Location	Barren	Cultivated	Grassland	Forest	Mean
Ballowal Saunkhri – I	0.20	0.34	0.24	0.17	0.24
Ballowal Saunkhri – II	0.14	0.13	0.20	0.14	0.15
Kokowal Majari	0.46	0.43	0.43	0.38	0.43
Saleran	0.20	0.21	0.15	0.17	0.18
Mean	0.26	0.29	0.25	0.20	
CD (0.05) Location = 0.03, Land use = 0.03, Location x Land Use = 0.06					

K in SI units = K in customary units x 0.1317

Table 4. Fuzzy logic based estimation of soil erodibility factor K at four locations under four land uses.

Location	Barren	Cultivated	Grassland	Forest	Mean
Ballowal Saunkhri – I	0.10	0.12	0.10	0.27	0.15
Ballowal Saunkhri – II	0.10	0.10	0.22	0.13	0.14
Kokowal Majari	0.30	0.30	0.36	0.34	0.33
Saleran	0.10	0.10	0.10	0.27	0.14
Mean	0.15	0.16	0.20	0.25	
CD (0.05) Location = 0.003, Land use = 0.004, Location x Land Use = 0.006					

K in SI units = K in customary units x 0.1317

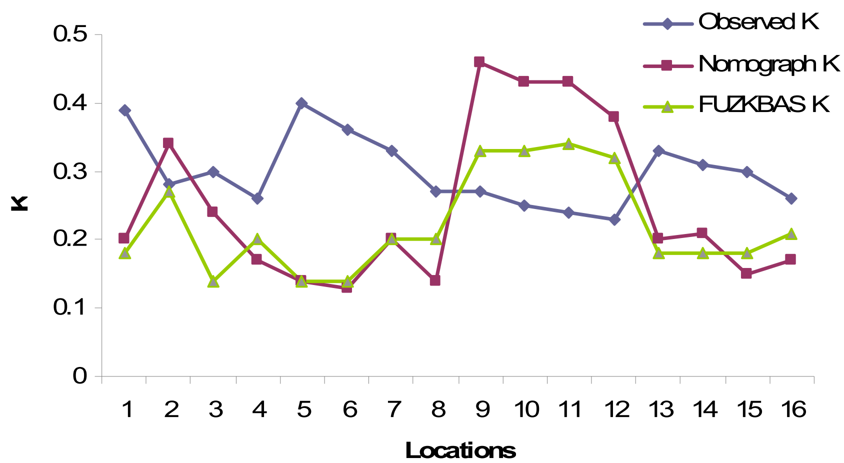

Figure 1. Soil erodibility values determined using different methods.

Conclusion

The nomograph and fuzzy logic method estimation of soil erodibility are not applicable under studied conditions. The reason may be that these methods are based on the data sets or experiments which were not conducted under Indian conditions and being empirical in nature these cannot be extrapolated to other locations. Nomographic method can be modified to use it under Indian conditions (Singh and Khera 2009).

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