ERODIBILITY OF AN ANDISOL (HYDRIC FULVUDANDS) IN THE ANDEAN CENTRAL ZONE OF COLOMBIA

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Abstract

The erodibility factor (K) for an andisol (*Hydric Fulvudands*) in the Central Andean Zone of Colombia was determined following the Revised Universal Soil Loss Equation (RUSLE) methodology. The research was carried out in the Tesorito Experimental Farm of University of Caldas (5º01'47''N, 75º26'03''W, 2280 m asl) from August 08/2001 to August 08/2002 on a 55% slope hill. The EI for a given rainstorm was calculated as the product of total storm energy (e) times the maximum 30-min intensity (I_{30}). Storm kinetic energy was calculated by two different methods, e.g. $e = 0.119+0.873 * \log_{10} i$, and $e = 0.29 * [1-0.72 * e^{(-0.05i)}]$ where i is rainfall intensity in mm h^{-1}. During the experimental period, 228 storms occurred with a total rainfall of 1670 mm. 50% of rainfall (115 storms) were considered to be erosive with a maximum I_{30} of 57 mm h^{-1}. The annual EI parameter (R) was 3552.9 $MJ.mm.ha^{-1}.h^{-1}.y^{-1}$ and 3189.7 $MJ.mm.ha^{-1}.h^{-1}$.y-1 for the former and second method respectively. Thus, K factor was 0.039 $Mg.ha.h.ha.^{-1}MJ^{-1}.mm^{-1}y^{-1}$ and 0.038 $Mg.ha.h.ha.^{-1}MJ^{-1}.mm^{-1}y^{-1}$ respectively. The linear regression between R, soil losses and runoff was highly significant (R^2 of 0.82**). The K values were rather high in comparison with Andisols in Central and South America.

Additional Keywords: RUSLE model, rainfall erosivity, steeplands, erodibility, volcanic ash soils

Introduction

Historically erosion research in steeplands has been ignored by the scientific community, in part due to preconceptions created by the Land Use Capability Classification System that considers soils with slope greater than 20% unsuitable for cultivation because of high susceptibility to erosion (Thurow and Smith, 1998). Several empirical relations between slope gradient and soil losses have been proposed for the RUSLE model. The general conclusion is that all of them overestimate soil losses for slopes greater than 20% (Wu and Wan 2001). In fact, the (R)USLE´s topographic factor has not been experimentally determined for slopes greater than 16% - 20% (Hudson 1993; Laflen and Moldenhauer 2003). Therefore, the model does not satisfactorily predict soil losses for steeplands. This work shows advances in the understanding of erodibility of Andisols in steeplands of the Colombian Andes.

Materials and methods

This research work was carried out in Tesorito experimental farm of University of Caldas, Colombia (5º01'47''N, 75º26'03''W, 2280 masl) located in the Central Cordillera of Colombian Andes. Experimental soils are classified as *Hydric Fulvudands* (USDA 1992), derived from thick volcanic ash. Landscape is mountainous with an isomesic temperature regime and mean slope of 55%. Mean annual rainfall is about 2000 mm. Antecedent land use was kikuyu pasture (*Pennisetum clandestinum*) under extensive grazing. Three 3.6 m x 15 m runoff plots were installed in a systematic non random design, 80 m apart from the meteorological station of Tesorito farm, following the recommendations of Obando (2000). The experimental site was maintained under permanent fallow, cultivated along the slope as suggested by Römkens *et al*. (1997). Table 1 shows physical and chemical properties of the experimental soil determined by standard methods (Montenegro and Malagón 1995; IGAC 1990; Pla 1995).

Table 1. Physical and chemical properties of the experimental soil (mean of three replications)

pH	4.86	Weigh diameter of water stable aggregates (mm)	2.23
Organic matter (%)	10.3	Bulk density ($Mg.m^{-3}$)	0.99
Nitrogen (%)	0.53	Hydraulic Conductivity 3 cm depth (cm. h^{-1})	1.28
Phosphorous (mg. Kg^{-1})	10.54	Hydraulic conductivity 6 cm depth (cm. h^{-1})	0.17
Aluminum (cmol.Kg^{-1})	86.39	Resistance to cone penetration (RMP) 5 cm depth (MPa)	0.43
Calcium (mg. Kg^{-1})	3.04	Resistance to cone penetration (RMP) 10 cm depth (MPa)	0.68
Potasium (mg. Kg^{-1})	0.24	Resistance to cone penetration (RMP) 15 cm depth (MPa)	0.92
Magnesium (mg. Kg^{-1})	1.80	Resistance to cone penetration (RMP) 20 cm depth (MPa)	0.91
Sand (%)	71.31	Resistance to cone penetration (RMP) 30 cm depth (MPa)	0.88
Silt (%)	16.25	Resistance to cone penetration (RMP) 50 cm depth (MPa)	1.06
Clay (%)	12.44		

Erosivity index (EI) was calculated as follows: (Foster *et al*.1981)

$$EI = (\sum_{i=1}^{n}(e*\Delta h)_i) * I_{30} \qquad (1)$$

where EI is the unit erosivity index (MJ mm ha^{-1} h^{-1}), I_{30} is the highest intensity in 30 minutes (mm h^{-1}), e is the kinetic energy (MJ $ha^{-1}mm^{-1}$) for segment i of uniform slope (mm), Δh is the water amount for segment i of uniform slope (mm), and n is the number of segments in a unit storm. e was calculated by two methods e.g. $e = 0.119+0.873 * \log_{10} i$ (Foster *et al,*1981) and $e = 0.29 * [1-0.72 * e^{(-0.05i)}]$ (Brown and Foster 1987), where i is rainfall intensity in mm h^{-1}. The annual rainfall erosivity index (R) was calculated as

$$R = \sum_{i=1}^{n} EI_i \qquad (2)$$

where EI is the erosivity index for the storm i in MJ mm $ha^{-1}h^{-1}y^{-1}$ and n is the number of storms in a year period. The erodibility index (K) was determined as $K = A * R^{-1}$ (Wishmeier and Smith 1978), where K is the erodibility index (Mg $ha^{-1}MJ^{-1}mm^{-1}$), A is annual mass of soil losses (Mg $ha^{-1}y^{-1}$) and R is the erosivity index calculated by equation (2).

Results and Discussion

Table 2 shows monthly values of rainfall, erosivity index (EI), runoff and soil losses. The value of R calculated by the methods of Foster *et al.* (1981) and Brown and Foster (1987) was 3553 MJ mm $ha^{-1}h^{-1}y^{-1}$ and 3190 MJ mm $ha^{-1}h^{-1}y^{-1}$ respectively. Dvorakova (2002) calculated R for five locations abstracting several years of rainfall- intensity data of Colombian Andean Central Zone, omitting rain showers less than 12.5 mm from the erosion index computations (Wishmeier and Smith 1978). She found percentages of erosive storms ranging from 2.3% to 13.2%. Therefore, it is likely that the value of 12.5 mm underestimate the R parameter for such a zone. In fact, in the experimental site, significant soil losses occurred with rainfall intensity less than 25 mm.h^{-1}, the threshold value used the method of Wishmeier and Smith (1978). However the one-year experimental R value calculated by Foster *et al.*(1981) is considered rather low in comparison with those reported by Dvorokova which ranged between 2046 MJ mm ha^{-1} h^{-1} y^{-1} and 21959 MJ mm ha^{-1} h^{-1} y^{-1}.

Tabla 2. Precipitation, erosivity, runoff and soil losses

Month	1[3]	2	3	4	5	6	7	8	9	10	11	12
Precipitation (mm)	66.93	72.3	231.1	235.6	133.4	70.9	52.3	228.8	214.2	307.3	38.9	17.4
EI[1] (MJ.mm.ha^{-1}.h^{-1})	146.8	77.2	271.6	387.4	236.7	105.8	97.1	457	851.2	831.8	74.5	15.9
%EI[1]	4.13	2.17	7.64	10.90	6.66	2.98	2.73	12.86	23.96	23.41	2.10	0.45
EI[2] (MJ.mm.ha^{-1}.h^{-1})	129.1	63.2	233	335.1	195.8	91.3	91.4	406.9	779	793.3	57.7	13.9
%EI[2]	4.05	1.98	7.31	10.51	6.14	2.86	2.86	12.76	24.42	24.87	1.81	0.44
Soil Losses (Mg.ha^{-1})	0.23	0.18	0.21	1.82	16.10	0.24	3.70	34.85	34.82	33.06	0.04	0.10
Runoff (mm)	0.09	0.18	1.16	6.69	11.78	0.35	2.67	11.02	16.00	90.45	0.00	0.00

[1]Method 1; [2]Method 2;[3]August 8/2000 – September 8/2001

Total soil losses were 125.35 Mg ha^{-1} y^{-1}. Soil losses were best estimated by method 2, as the equation $\tilde{A} = 1.39 * \%EI$ ($R^2 = 0.82^{**}$) where $\tilde{A}$ is estimated soil losses (Mg. ha^{-1}) and %EI is the monthly percentage of R. A combination of both methods best estimated surface runoff according with the equation $\tilde{Q} = 29.67 * \%EI_{(2)} - 29.47 * \%EI_{(1)}$ $R^2 = 0.82^{**}$) where $\tilde{Q}$ is estimated surface runoff (mm), and sub indexes $_{(1)}$ and $_{(2)}$ indicate the corresponding percentage of EI for method 1 and 2 respectively. Erodibility index, K, was 0.039 Mg ha h ha^{-1} MJ^{-1}. mm^{-1} and 0.038 Mg ha h ha^{-1} MJ^{-1} mm^{-1} calculated by methods of Foster *et al.* (1981) and Brown y Foster (1987) respectively. In both cases K is higher than K values reported by Rivera (1998) and Rodríguez *et al.* (2002) for andisols of Colombian coffee zone with 70% slope and Canary Islands with 24% slope. Evans cited by Morgan (1990) prefers to examine erodibility in terms of the clay content, indicating that soils with a restricted clay fraction, between 9 and 30 per cent, are most susceptible to erosion. The use of the clay content as an indicator of erodibility is theoretically more satisfying because the clay particles combine with organic matter to soil form aggregates or clods and it is the stability of these which determines the resistance of the soil.

Gonzáles (1983) quoted by Rivera (1999) points out that the higher the structural stability the lower erodibility. According with experimental data of table 1, the effect of soil organic matter is not clear, but the high sand content (70.31%) and the low weigh diameter of water stable aggregates (2.23 mm) definitely influenced the erodibility index. Shoji *et al.*(1993) point out that in general Andisols show a strong resistance to water erosion, and associate this property to the high content of macropores, high permeability and high resistance of aggregates to dispersion. These properties give Andisols a high ability to accept great amounts of rainfall before runoff occurs (Shoji *et al.*, 1993). Surface runoff was 140.43 mm. Consequently, runoff coefficient, expressed as a percentage of total rainfall was 8.41%, which is rather low in comparison with values reported by Rodriguez *et al.* (2002) and Khamsouk *et al.* (2002) in Andisols with lower slopes. Although the physical process of sol water sorption is more related to differences in matric potential, Khamsouk *et al.* (2002) postulate that the higher the slope the smaller the runoff becase of the effect of gravity attraction that rapidly increments water infiltration. Consequently, in steep slopes, interrill erosion by rainfall splash is likely to be more important than surface runoff. In fact this effect has been demonstrated by Carmone e Isaza (2002) and van Dijk (2002).

Conclusions

The EI parameter of the RUSLE model significantly explained ($R^2 = 0.82^{**}$) soil losses and surface runoff in the experimental site. The method of Brown and Foster (1987) showed a better adjustment to estimate soil losses and surface runoff, which allow to corroborate the recommendation of Renard *et al.* (1997) in terms of using this method to calculate EI. The K value for the experimental Andisols resulted higher than those reported to other Andisols in Central and South America. The R value calculated for the experimental period was rather low in comparison with those reported to regional scale. Thus, it is necessary to found threshold values of erosive rain showers for specific conditions of Andisols in tropical steeplands. The present threshold value of 12.5 mm, adequate to specific conditions of low slope fields of North America is likely to be low for tropical steeplands. In fact, in the experimental site occurred erosive storms with values of rain much lower than 12.5 mm. It is needed to find pedotransfer functions that allow estimation of K from soil attributes, particularly from those associated to acceptance of water, particle size distribution and resistance of soil aggregates to dispersion.

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