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Original Article

Soil Erosion Estimation in Suciu de Sus Commune, Maramureş County, Romania

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Abstract

The Universal Soil Loss Equation (USLE) is widely used for estimating soil erosion for croplands. Although the methodology is old, improvements to the estimation of the equation factors using GIS techniques are being implemented each year. Using the new ESDB K factor values and a 10 m resolution, I ran the model on a 109.45 km^2 area belonging to Suciu de Sus Commune. The results show low erosion values throughout the study area due mostly to land cover and soil texture.

Keywords: soil, erosion, USLE, GIS, Suciu de Sus.

1. Introduction

The Universal Soil Loss Equation (USLE) is widely used for estimating soil erosion for croplands. Although the methodology is old, improvements to the estimation of the equation factors using GIS techniques are being implemented each year. U

sing the new ESDB [10] K factor values and a 10 m resolution I ran the model on a 109.45 km^2 area belonging to Suciu de Sus Commune.

The analyzed location belongs to the Northern part of the Transylvanian Basin; it is located in its totality in the Southern extremity of Maramureş County. Suciu de Sus Commune measures 109.45 km^2, representing 0.05% of the surface of Romania and 1.74% of Maramureş County (fig. 1).

Figure 1. Location of the study area

2. Material and Method

USLE (Universal Soil Loss Equation) is an empirical equation set for the measurement of average soil loss on agricultural lands.

This equation was developed for the measurement of soil particle detachment from the agricultural lands with negligible curvature and without sediment deposition; it represents the average loss of soil particles in time on a given area. Equation (1) has the form [9]:

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E = R * K * L * S * C * P (1)

Where:

E (tons/ha/year) = average soil loss (erosion);

R (MJ.mm/ha/hour/year) = rainfall intensity factor; K (tons/ha/R) = soil factor; LS (without measure) = topographical factor (the length and angle of the slope); C (without measure) = land use factor;

P (without measure) = soil erosion prevention factor.

For it to be integrated in GIS, and to estimate erosion on wide areas, the equation suffered in time a lot of changes especially for measuring the LS factor. The LS factor indicates that erosion grows with the length and angle of the slope.

The value of the LS factor it is measured with the equation (2) [9]:

LS = (ℓ/22.13) m (65.41 sin2β + 4.56sinβ + 0.065) (2)

Where:

ℓ = length of the slope in meters;

β = angle of the slope in degrees;

m = variable dependent on the slope:

0.5 if the angle of the slope is bigger than 2.860^0; 0.4 for angles of the slopes between 1.720^0 and 2.860^0;

0.3 for angles of the slopes between 1.570^0 and 1.720^0;

0.2 for angles of the slopes smaller than 1.570^0.

LS factor can be derived from the digital elevation model using the method proposed by Moore and Burch (1986) [4], equation (3).

The length of the slope in experimental parcels of the original USLE equation can vary from 10.7m to 91.4 m, thereby, it is recommended using slopes smaller than 122 m, because in natural condition the flow concentrates in gullies after the length of 122 m.

$$LS = \left(\frac{A}{22.13}\right)^{0.4} * \left(\frac{\sin\Delta}{0.0896}\right)^{1.3} \quad (3)$$

Where: A = flow accumulation x raster grid cell size; Δ = slope angle in degrees; 22.13 = parcel length in the standard USLE equation; 0.0896 = 8.96% or 5.14 degrees that represent the slope measurement for the standard parcel in USLE equation.

An easier method in addition to this equation (4) it is proposed by Mitasova (1996) [3]:

$$LS_{(r)} = (m+1)\left[A_{(r)}/a_0\right]^m \left[\sin b_{(r)}/b_0\right]^n \quad (4)$$

Where: LS(r) = LS factor in the r point (x, y); A(r) = aria of accumulation situated above r point; b = the slope in degrees; m(0.6) and n(1.3) = parameters for slopes shorter than 100m and smaller than 14^0; a0 = 22.1 standard parcel length of USLE equation; b0 = 0.09 = 9% = 5.16 = slope measurement for the standard parcel of USLE equation.

Mitasova [3] also proposes an implementation on the formula for this equation in ArcGIS (equation 5).

Pow([flowacc]*resolution/22.1, 0.6) * Pow(Sin([slope]*0.01745)/0.09,1.3)) (5)

Where: flowacc (flow accumulation) = flow accumulation, resulting from the digital elevation model; Slope = resulting from the digital elevation model.

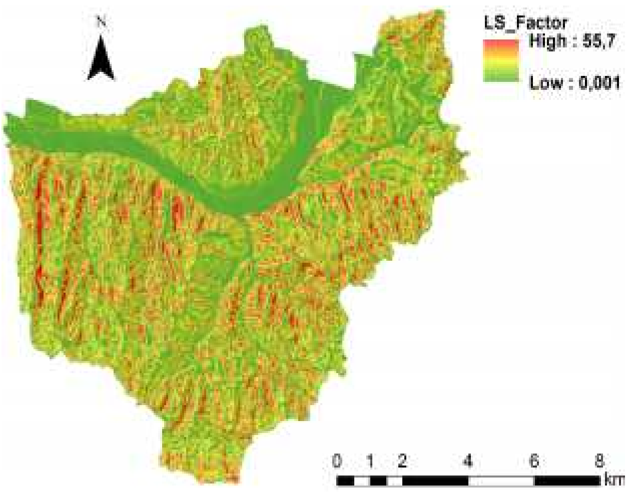

Figure 2. LS Factor map

3. Results and Discussions

For the study area, the LS factor map (fig. 2) indicates low values in the floodplains and higher values on the southern steep slopes. The rainfall intensity factor or climatic aggressiveness factor (**R factor**) is hard to measure on wide spaces using the original formula. Using a large number of data on the intensity of the storms from 37 sites from the Eastern U.S., Wischmeier and Smith (1958) [7] found that the product between the kinetic energy from the storm, E, and the maximum intensity of rainfall in 30 minutes, I30, represents the best correlation between the loss of soil and the other 19 features of measured rainfall. Therefore, Wischmeier and Smith (1978) [9] defined R factor as the average annual rainfall that came from storms EI30, exception only to those rainfalls that give below the quantity of 12.7 mm.

The E portion of these values represents the rainfall energy, and the I30 potion represents the maximum 30 min flow during the storm.

A number of changes have been brought along the time to this method. For estimating the pluvial aggressiveness on the soils in the Suciu Commune, I have used the Modified Fournier index (F_M) proposed by Arnoldus (1980) [1] in equation (6):

$$F_M = \sum_{i=1}^{12} \frac{Pi^2}{P} \quad (6)$$

Where: Pi = average rainfall for the i month (mm); P = annual average rainfall.Precipitation data was extracted from the set of monthly maps for the 1950 – 2000 interval measured by Hijmans *et. al.,* (2005) [2] that are available on http://www.worldclim.org [11].

The R factor map (fig. 3) follows the altimetry repartition of pluvial aggressiveness, with high values in Breaza Hill and low values in the floodplain.

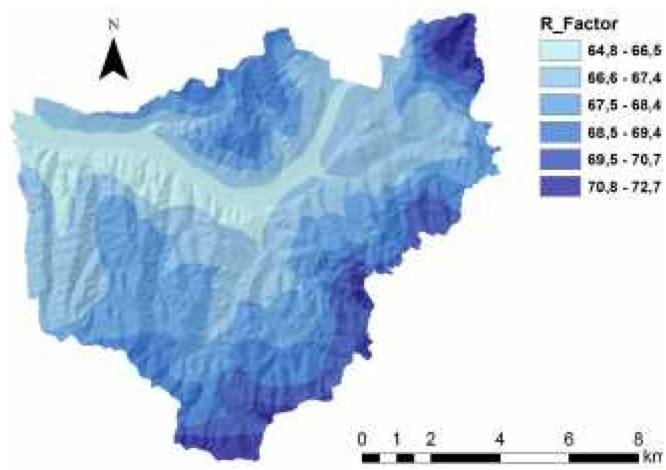

Figure 3. R factor map

K factor, in the original USLE equation it is determined in the fields. The direct measurements of the K factor are not feasible from o financial point of view. The nomograph proposed by Wischmeier *et. al.* (1971) [8] it is mostly used for soil erosion measurements. An approximate algebraic expression it is proposed by Wischmeier and Smith (1978) [9] in this nomograph that includes five soil parameters (texture, organic matter, coarse fragments, structure and permeability) in equation 7:

K = [(2.1 x 10-4 M1.14 (12 – MO) + 3.25(s – 2) + 2.5(p – 3)) / 100] x 0.1317 (7)

Where: MO = organic matter; M = textural factor, M = (m_p + m_s) x (100 – m_a), where: m_a = clay fraction content (< 0.002 mm); m_p = silt fraction content (0.002 – 0.05 mm); m_s = very fine sand content (0.05 – 0.1 mm); s = structural class of soils (s = 1: very fine granular structure, s = 2: fine granular structure, s = 3: average or coarse granular structure, s = 4: block structure.); P = permeability class (p = 1: very fast … p = 6: very slow).

After classifying K factor values proposed by Panagos *et. al.* (2014) [5], on the Suciu Commune area I have found the next type of textures (Table 1).

Table 1. K factor values given by soil textures

Texture	K factor
Loamy	0.0395
Clay Loam	0.0402
Clay Loam – Clay	0.0349
Sandy Loam	0.0171
Sandy Loam – Clay	0.0233
Loamy Sand	0.0060

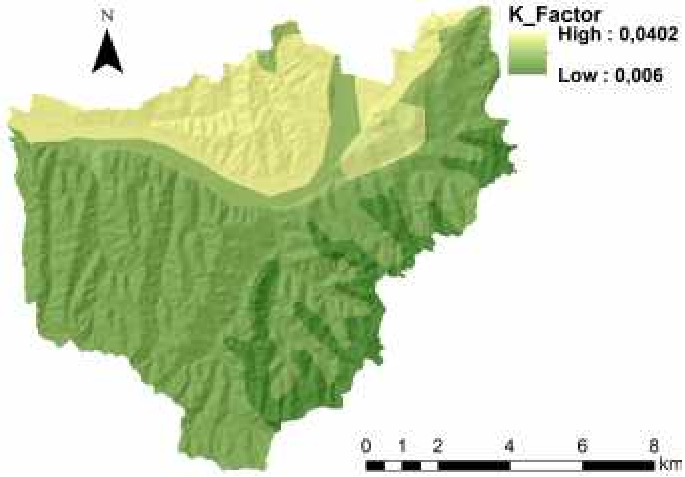

Figure 4. K Factor map

The K factor map (fig. 4) shows relatively reduced variations of resistance to soil erosion (0.006 – 0.0402), given maybe by the low silt fraction of the soil texture in the southern part of the Suciu Commune.

The **C factor** is probably the most important USLE factor because it represents the easiest modifiable condition for reducing erosion [6].

C factor values can vary from almost nearly 0 (if it is a protected soil) to 1.5 if it is a plowed soil that shows gullies.

Factors that influences the soil use values are given by the degree of soil surface covered with vegetation, canopy trees, and the height of which the rain drops are falling, root extension and the previous soil usage [6].

Table 2. C factor value given by soil usage

Soil usage	C factor
Built area	0
Areas covered by water	0
Grasslands, meadows	0.02
Forests	0.1
Vineyards	0.2
Orchards	0.25
Transitional areas with shrubs	0.3
Areas with complex cultures	0.4
Arable lands	0.4

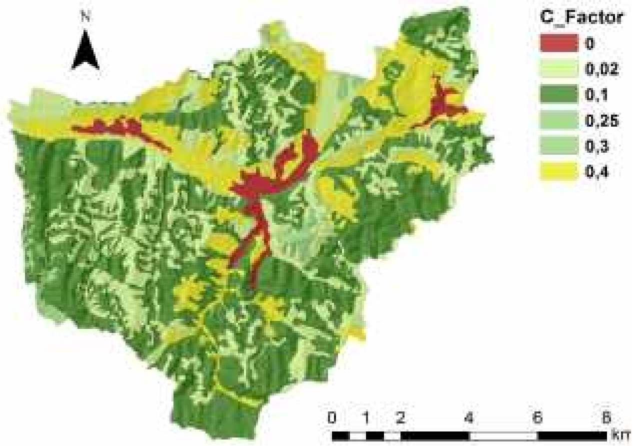

Figure 5. C Factor map

As shown in table 2 and figure 5, the distribution of the C factor values indicates an overall high resistance to erosion due to the extensive forest cover. The highest values (shown in yellow color) represent arable land, which is the most susceptible to soil erosion.

Of all the factors that are in the USLE equation, P factor is the most uncertain [6]. When a soil is situated on a slope and it is up for cultivating, in general in agriculture it is proposed that it is necessary to take measures like offset or plowing along contours for reducing the quantity of soil transported during a heavy rain 9]. Because the data on Suciu Commune is not available, I have chosen to use a constant value on the entire Commune, and that is equal with 1.Applying the USLE equation (1) in ArcGIS 10.1, the 6 grid maps with a 10m resolution are being multiplied, using the raster calculator function (8).

$$LS * R * K * C * 1 \quad (8)$$

The resulting map (fig. 6) represents the average soil loss in the Suciu Commune calculated at a 10m resolution. Low values of erosion (< 3 t/ha/year) appear on 70% of the area due mainly to low K and C factor values. High values (>10 t/ha/year) affect arable land situated on slopes with high C factor. Values between 3 and 10 t/ha/year are found in 23% of the studied area.

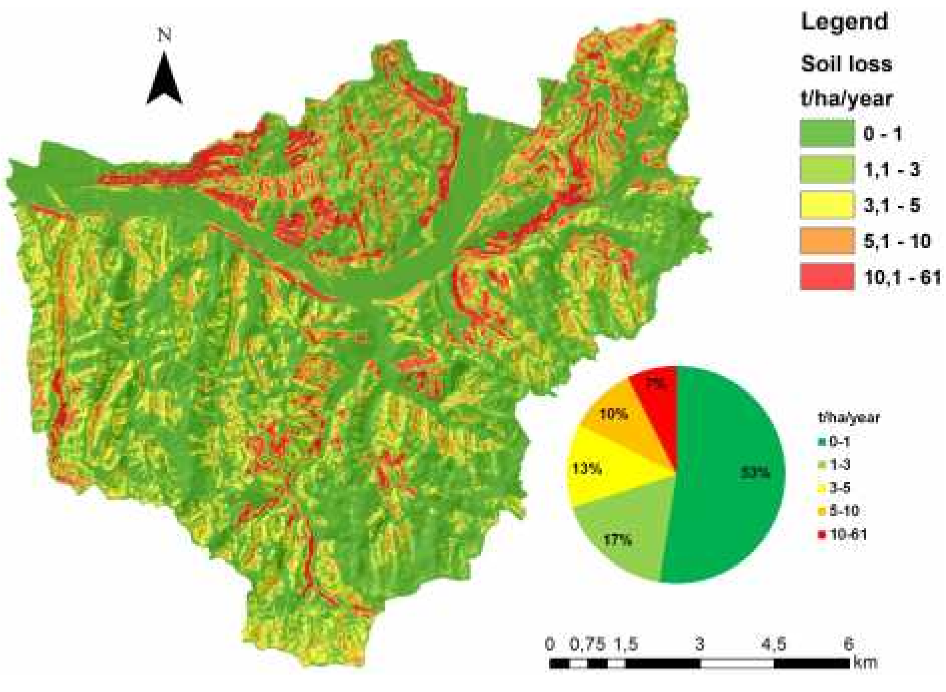

Figure 6. The average soil loss map in Suciu de Sus Commune

4. Conclusions

USLE is a model that helps estimate soil erosion, projected for calculating soil loss from surface flow, run-off and rill erosion. Although it can be used for estimating erosion on non-agricultural lands, the model doesn't calculate neither the sedimentation rate nor the fluvial or gully erosion [9].

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