USING UNIVERSAL SOIL LOSS EQUATION FOR SOIL EROSION ASSESSMENT IN AGRICULTURAL LAND FROM LUGOJ HILLS

Ionuț ZISU
West University of Timișoara, Romania,
Department of Geography,
Email: ionut.zisu@e-uvt.ro

Daniel NĂSUI
Technical University of Cluj-Napoca, Romania,
North University Center of Baia Mare, Faculty of Science,
Email: daniel.nasui@cunbm.utcluj.ro

Abstract. In the last period, a very large variety of soil erosion assessment methods were made. Among these methods, modeling was used most often. Thus, a wide range of soil erosion models was developed and used worldwide. From these, Universal Soil Loss Equation (USLE) represents the most practical method to estimate soil erosion potential. Also, the equation is very easy to be implemented in the geographic information systems (GIS). The average value of annual soil loss on the agricultural land of Lugoj Hills, determined using USLE equation, is approximately 1.12 t/ha/year, which represents a total annual average value of about 51,328 tons.

Keywords: Universal Soil Loss Equation (USLE), GIS, soil erosion, agricultural land, Lugoj Hills.

1. INTRODUCTION

Faeth, P. and Crosson, P. (1994) specify that every year around 10 millions hectares of agricultural land are abandoned worldwide due to the lack of productivity caused by soil erosion.

In Romania, the annual total erosion value is estimated to 126.6 millions tons/year, from which 106.6 millions tons/year (84 % of the total) is recorded on the agricultural land. Agricultural land subjected to water erosion averages 43 % of the total, whereas wind erosion has a potential manifestation on only 1.4 % (Ioniţă et al., 2006).

Soil erosion is characterized not only by the amount of earthy material lost, but also by reducing its fertility due to the removal of the superficial layer, the rich in humus. Removing a centimeter thick soil layer per hectare is equivalent to 130 tons, from which 3 tons represent humus (Surdeanu, V., 1998).

In the last half century, it was realized a very large variety of methods aimed to evaluate soil erosion and to estimate the amount of material dislodged and transported by water, both spatially and temporally. Among these methods, the modeling was used most
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In Romania, the USLE model has been adapted to the climatic conditions of our country by a team of researchers from The National Research and Development Institute for Soil Science Bucharest (ICPA), coordinated by M. Moțoc. Thus, in the 70s of last century, it was created *Romanian Soil Erosion Model* (ROMSEM) (Moțoc et al., 1975; Moțoc, M. and Mircea, S., 2002).

In the last period, these models for soil erosion calculation were integrated in the geographic information systems (GIS), which led to an automatic cartographic representation and with a higher accuracy of land erodibility data.

Among the models listed above, USLE remains the most practical method for estimating soil erosion potential (Dennis, M.F. and Rorke, B.B., 2000), being easy to be implemented in GIS.

The study area is located in Timiș County and belongs to the Western Hills of Romania (fig. 1), measuring a surface of 619.03 km², from which agricultural land represents 74 % (45,828 ha). The rest of the surface is occupied by the broad-leaved forests, built-up perimeters and Surduc Lake.

![Fig. 1. Lugoj Hills geographical position](image-url)
2. MATERIALS AND METHODS

USLE represents a soil erosion estimation model, designed to calculate the quantity of soil removed by sheet and rill erosion, especially, from the surface of agricultural land (Wischmeier, W.H. and Smith, D.D., 1978). As sheet erosion characterizes the most part of the agricultural land in the study area, we consider that the results obtained using USLE method are, mostly, in accordance to the field reality.

Universal Soil Loss Equation (USLE) (1) is an empirical one, designed to compute the average of soil losses from the agricultural land. This equation has been made for estimating the dislocation and removal capability of soil particles from fields with negligible curvature and it has the following formula (Wischmeier, W.H. and Smith, D.D., 1978):

$$A = R \times K \times LS \times C \times P$$

(1)

where:

- $A$ = the soil loss, expressed by the annual average rate of erosion (t/ha/an);
- $R$ = the rainfall erosion factor (MJ mm/h ha/an);
- $K$ = the soil erodibility factor (t ha h/MJ mm);
- $LS$ = the topographical factor (slope-length and slope-steepness) (dimensionless);
- $C$ = the land cover and management factor (dimensionless);
- $P$ = the factor of the works for erosion prevention and control (dimensionless).

3. RESULTS AND DISCUSSION

In order to be integrated into the GIS and to estimate the erosion of large areas, this equation suffered in time a number of modifications regarding the calculation method of the factors, especially for LS one.

**Factor R** expresses the rainfalls intensity and it represents the local value of rainfall erosion index, derived by Wischmeier, W.H. (1959) according to the following formula:

$$EI = E \times I_{30}$$

(2)

where:

- $EI$ = the rainfall erosion index (MJ/ha);
- $E$ = the total kinetic energy of the rainfall (t/ha);
- $I_{30}$ = the maximum intensity of rain in 30 minutes (mm/h).

As factor $R$ is difficult to be calculated on the large territories using the original formula, over time a number of changes were made to its method of determination. The values of the coefficients expressing rainwater erosion are calculated based on some mathematical relations using various climate data.

Rainwater aggression exerted on the soils from Lugoj Hills has been assessed on the basis of Modified Fournier index ($F_M$) (Arnoldus, 1980), determined by the following equation:
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\[ F_M = \sum_{i=1}^{12} \frac{P_i^2}{P} \]

(3)

where:

\( P_i \) = the average amount of rainfall for the month \( i \) (mm);
\( P \) = the annual average amount of rainfall (mm).

The rainfall data necessary for factor \( R \) determination have been extracted from the set of values globally calculated for the period between 1950-2000 by Hijmans et al. (2005) and available for free on the site [http://www.worldclim.org](http://www.worldclim.org). The map representing factor \( R \) of USLE equation (fig. 2) shows the altimetric distribution of pluvial aggressiveness, with high values for the regions on the contact with Poiana Ruscă Mountains and low values in meadow lowlands.

![Map of factor R of USLE equation calculated for Lugoj Hills’ area](image)

Fig. 2. The map of factor \( R \) of USLE equation calculated for Lugoj Hills’ area

The most accurate method for determining the values of factor \( K \) is to perform measurements directly on the field. But as the direct determination is not financially feasible, when we refer to large areas, the soil-erodibility nomograph made by Wischmeier et al. (1971) is the most used to calculate the values of this process. Within this nomograph there are included 5 soil parameters: texture, organic material content, soil coarse quantity, structure and permeability.
The values of factor $K$ for the agricultural land of the study area are presented in table 1. They are determined according to the classification made by Panagos et al. (2014) depending on the soil texture type.

Figure 3 shows the map of factor $K$, calculated for the research area. There it can be noticed a relatively low variation of soil erosion susceptibility exercised by precipitation and water runoff on slopes, the values being between 0.006 and 0.0513. This fact is due to the high homogeneity of soil granulometry composition. The biggest values appear in soils with high compaction. The soils with a high total porosity present an increased water infiltration capacity, which determines the reduction of the erodibility.

Table 1. *Factor $K$ values according to the soil texture*

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Factor $K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loamy sand</td>
<td>0.0060</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0.0171</td>
</tr>
<tr>
<td>Silty sandy loam</td>
<td>0.0513</td>
</tr>
<tr>
<td>Sandy clay loam</td>
<td>0.0263</td>
</tr>
<tr>
<td>Loam</td>
<td>0.0395</td>
</tr>
<tr>
<td>Silt loam</td>
<td>0.0513</td>
</tr>
<tr>
<td>Clay loam</td>
<td>0.0402</td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>0.0428</td>
</tr>
<tr>
<td>Silty clay</td>
<td>0.0349</td>
</tr>
</tbody>
</table>

Fig. 3. *The map of factor $K$ of USLE equation calculated for Lugoj Hills’ area*
**Factor LS** is a coefficient resulting from the combination of two parameters: slopes length and slopes inclination degree. It indicates the soil erosion intensification with increasing the length of the slope and its angle.

Mitášová et al. (1996) have developed the following equation to calculate this indicator:

\[ LS(r) = (m+1) \left[ \frac{A(r)}{a_0} \right]^m \left[ \sin \left( \frac{b(r)}{b_0} \right) \right]^n \]  (4)

where:

- \( LS(r) \) = the factor LS in point \( r \) (x, y);
- \( A(r) \) = the accumulation area located above the point \( r \);
- \( b = \) the slope, expressed in degrees;
- \( m (0.6) \) and \( n (1.3) \) = the parameters for slopes less than 100 m and 14\(^\circ\).
- \( a_0 = 22.1 \) the length of standard parcel from USLE equation;
- \( b_0 = 0.09 = 9\% = 5.16^\circ \) = calculation slope for standard parcel from USLE equation.

At the same time, Mitášová et al. (1996) propose also a formula (5) for implementing this equation in ArcGIS software by which the map of factor LS can be obtained (fig. 4).

\[ \text{Pow}(\text{flowacc}) \times \text{resolution} / 22.1, 0.6) \times \text{Pow}(\text{Sin}(\text{slope}) \times 0.01745) / 0.09, 1.3)) \]  (5)

where:

- \( \text{flowacc} \) (flow accumulation) = the flow accumulation, derived from DEM;
- \( \text{slope} = \) the slope in degrees, derived from DEM.
The map of factor LS (fig. 4) reveals high values for more elevated areas, situated on the contact with the mountain part, but also on some steeper slopes from the eastern side, where the relief is highly fragmented. The low values characterize, especially, the major riverbeds of the main rivers in the area.

**Factor C** is probably the most important in USLE equation because it represents the conditions that can be most easily modified for reducing soil erosion. The parameters with the highest impact for the coefficient of factor C are represented, especially, by the vegetation coverage degree of the soil, the trees canopy, the land roughness and the previous mode of land use (Renard et al., 1997).

The values of factor C can vary from 0, if the soil is very well protected, to 1, for the recently plowed fields. The coefficients of factor C adapted for Lugoj Hills are presented in table 2, and figure 5 shows the map of factor C of USLE equation determined for the study area.
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Table 2. The values of factor C adapted for Lugoj Hills

<table>
<thead>
<tr>
<th>Land use management</th>
<th>Factor C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable land</td>
<td>0.35</td>
</tr>
<tr>
<td>Forest</td>
<td>0.02</td>
</tr>
<tr>
<td>Pastures</td>
<td>0.02</td>
</tr>
<tr>
<td>Hayfields</td>
<td>0.02</td>
</tr>
<tr>
<td>Predominantly agricultural land mixed with natural vegetation</td>
<td>0.40</td>
</tr>
<tr>
<td>Transition areas with shrubs</td>
<td>0.70</td>
</tr>
<tr>
<td>Complex crops areas</td>
<td>0.40</td>
</tr>
<tr>
<td>Orchards</td>
<td>0.1</td>
</tr>
<tr>
<td>Vineyards</td>
<td>0.65</td>
</tr>
<tr>
<td>Built-up space</td>
<td>0</td>
</tr>
<tr>
<td>Water accumulation</td>
<td>0</td>
</tr>
</tbody>
</table>

(after Young, A., 1989)

Fig. 5. The map of factor C of USLE equation calculated for Lugoj Hills’ area

Factor P is the most uncertain of the all factors used to calculate the USLE equation (Renard et al., 1997). As the data showing the land improvements made within the study relief unit are quite old and unreliable, it was chosen to use a constant value equal to 1 for the entire area.
The USLE equation (6) implemented in ArcGIS 9.3 software supposes the multiplication of the five involved factors, at the level of each grid cell with 30 m spatial resolution, using Raster calculator tool:

\[
\text{USLE} = R \times K \times \text{LS} \times C \times 1
\]  

(6)

According to the map made on the base of the USLE equation (fig. 1.) the average value of annual soil loss on the agricultural land of Lugoj Hills, determined by sheet erosion, is approximately 1.12 t/ha/year, which represents a total average value of about 51,328 tons. The obtained values were distributed in 3 classes of annual average soil loss on the following considerations: the losses of up to 3 t/ha/year are negligible, the losses between 3 and 7 t/ha/year are considered substantial, assuming certain measures to prevent soil erosion, and the losses of over 7 t/ha/year require measures to combat soil erosion.

Fig. 6. The map of annual average soil loss on the agricultural land of Lugoj Hills due to sheet erosion
4. CONCLUSIONS

The major part of the agricultural land in the study area (90.45 %) has small annual average of soil loss. This is mainly due to the small geo-declivity of the researched area. Important soil loss, between 3-7 t/ha/year, are registered on a small surface of only 5.59 % of the total agricultural land, and major loss, above the value of 7 t/ha/year are registered on just 3.96 % of the total agricultural surface. The highest values are registered on the frequently ploughed fields, with slopes higher than 5 %. An example is represented by the arable fields located between the settlements Păru-Nevrincea (in the north-west of Lugoj Hills), and also by those between Coșteiu-Lugoj and Lugoj-Tapia (in the south-west of Lugoj Hills) (fig. 6).

In the conclusion of the above presented, it can be affirmed that the agricultural land from Lugoj Hills area is affected in quite low proportion by the soil erosion processes. The most intensely manifestation is that of sheet erosion. Nonetheless, due to the extremely slow process of pedogenesis, for recovering the soil on a surface affected by erosion, from which at least 1 t/ha/year of material was lost, it is necessary a time span of 50-100 years (van der Knijff et al., 2000).

REFERENCES


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