

Quantitative assessment of soil erosion using GIS empirical methods in the upper catchment of Bârsa River

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Abstract. The study regards the estimation of soil erosion rate through the application of the USLE/RUSLE equation within GIS in the upper basin of Bârsa River. Our work also compares between treed and deforested nearby areas. The end product is a susceptibility map that can be used as a support to determine the regions that are prone to erosion. This study only addresses rill and inter-rill erosion.

Keywords: *soil erosion, susceptibility, RUSLE equation*

1. INTRODUCTION

The determination of soil loss predisposition within a drainage basin is considered a significant theoretical and practical issue, the knowledge of it creating premises for a better management.

Various approaches can be adopted in soil loss determination. The main methods of risk erosion evaluation are classified as either *expert*-based or *model*-based approaches. (Knijff, et al., 2000).

The expert-based approaches imply the identification of areas with accentuated erosional processes by granting factorial scores. The main limitation in applying this method is linked to the uncertainty in defining the criteria according to which areas are delineated (Yassoglou et al., 1998).

The availability of digital databases eased the development and use of mathematical models for soil loss risk analysis. Another division can be made between empirical and physically-based models. (Grimm et al., 2002).

One of the most used empirical methods is the USLE model (Universal Soil Loss Equation) developed by Wischmeier & Smith in 1978. The USLE model is based on the regression rates of soil erosion analysis for annual determinations. In 1993, the Revised Universal Soil Loss Equation

(Reynard et al., 1997) bettered up the previous one by updating the methods to calculate the terms in the mathematical equation. Although the model has limitations, it is used due to the flexibility and low data demand (Bosco et al., 2015)

In Romania, the Institute for Soil Science and Agrochemistry Research has made studies to calibrate these coefficients to the local and regional environmental conditions found in Romania.

2. METHODS

The quantitative assessment of the soil erosion for the Bârsa River upper catchment has been made using the RUSLE model and by adapting some of the coefficients according to IPCA methodology (Florea et al., 1987). The estimation of the soil erosion rates has been determined for the years 2006 and 2016, aiming to observe the influence of changes in land use and their implications in the quantities of eroded soil from the river basin.

The RUSLE model is designed to predict only rill and inter-rill erosion. Sediment deposition processes or concentrated overland flow erosion are not taken into consideration (Bosco et al., 2015).

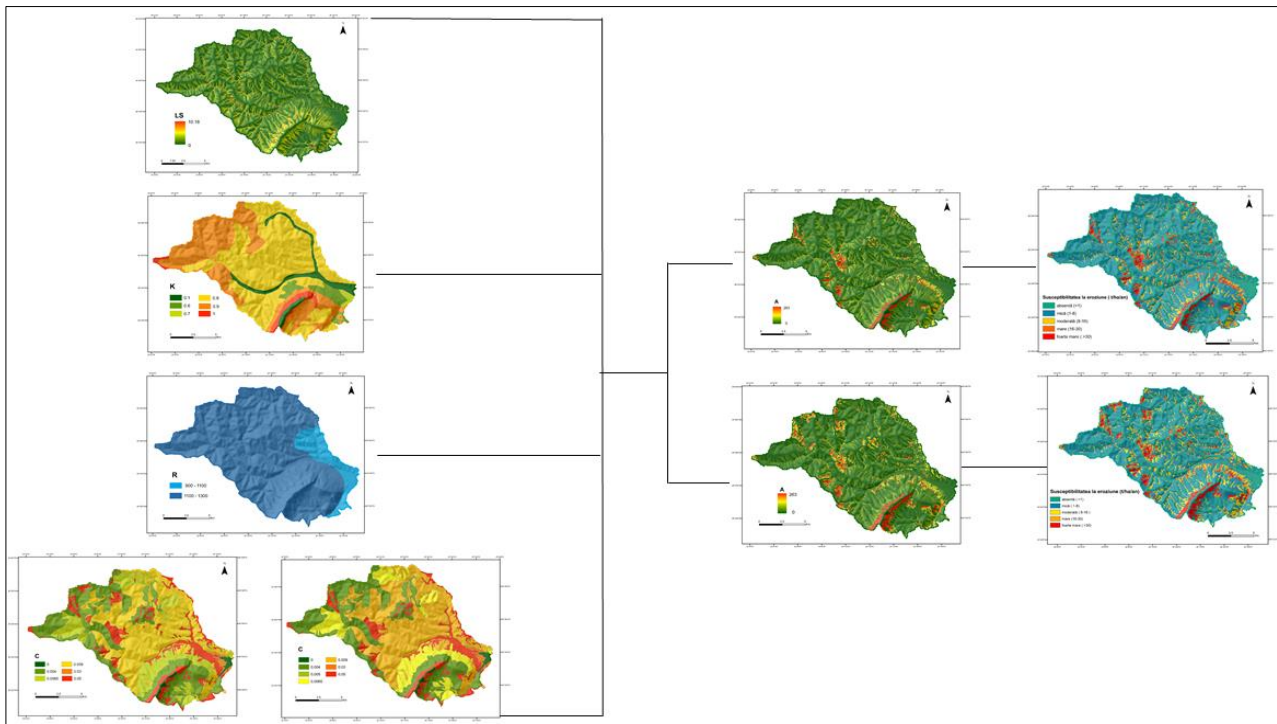


Figure 1. Implementation of RUSLE equation in ArcGis

In the RUSLE model, five factors (LS, C, K, R, and P) are multiplied to compute the annual average soil loss per unit area. Because supporting practices are missing, the correction coefficient for the effect of erosion control measurements (P) is equal to 1.

RUSLE is defined as:

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

- A: is the average annual erosion rate (t/ha an);
- R: is the rainfall erosivity;
- K: is the soil erodibility;
- LS: is the slope length influence;
- C: is the correction coefficient for the effect of vegetation;
- P: is the correction coefficient for the effect of erosion control measurements.

The implementation of the equation is presented in Figure 1.

The input parameters are represented by the STRM at a resolution of 90 m, the soil map (soil type and texture) at 1:200,000, the land use according to CLC 2006 and Google Earth Maps 2016. The spatial information was computed with the ArcMap 10.1 software.

Slope Length Factor (LS)

The LS factor represents the product of the slope length (L) and slope steepness (S) in order to

represent the specific effects of topography on soil erosion.

The original USLE is only effective at predicting soil loss for slopes with a low gradient (Remortel et al., 2001), but RUSLE has been adopted to a wide range of slope gradients (McCool et al., 1989).

We chose to use the Unit Stream Power Erosion and Deposition Model for calculating the LS factor because it can be implemented by using ArcMap tools. The topographic calculations are shown separately:

$$L = (m + 1) \left(\frac{\lambda_A}{22.1} \right)^m$$

L = the slope length factor at some point on the landscape

λ_A = the area of upland flow

m = adjustable value depending on the soil's susceptibility to erosion

22.1 = the unit plot length.

$$S = \left(\frac{\sin(0.01745 \times \theta_{deg})}{0.09} \right)^n$$

θ = the slope in degrees

0.09 = slope gradient constant

n = adjustable value depending on the soil's susceptibility to erosion

The values of the exponents $m=0.4$ and $n=1.4$ are typical for low susceptibility to rill erosion (Pelton et al., 2016). Because slope values have to be converted in radians for the sin calculation, they are multiplied by the constant 0.01745.

Soil erodibility Factor (K)

The soil erodibility factor is a quantitative description of the susceptibility of soil particles to split and be transported by rainfall and runoff (McCloy, 1995). Our dataset only includes information on soil type and soil texture (clay, silt, fine sand and sand). Because most calculating relations require structural and permeability information, we have used the erodibility values as specified by the *ICPA* standards (1987).

Cover management factor (C)

The C factor represents the effect of surface cover and roughness on soil erosion (Cogo et al., 1984). Vegetation directly influences the impact and intensity of rainfall, the resistance to water flow and the amount of water available for transporting the sediments (Rousseva, 2003). As the surface cover is less exposed to erosion, the C factor value approaches zero. The C-factor was defined for each CORINE Land Cover class according to literature values (Lee, 2006).

Rainfall erosivity factor (R)

Statistical studies conducted by the American Meteorological Society indicated that the annual rainfall-runoff erosivity factor (R) is closely related to the maximum amount of rainfall in 6 hours with 50 percent probability of occurrence (Păcurar, 2001). To estimate it, Wischmeier proposed the relation $R = 27.38 (I_{6h}, 50\%)^{2.17}$, where $I_{6h}, 50\%$ is in inch. A similar relation has been established by Moțoc and Stănescu to evaluate rainfall-runoff erosivity for Romania: $R = 0.0426 (I_{6h}, 50\%)^{2.17}$, with $I_{6h}, 50\%$ being measured in mm. It has to be mentioned that R coefficient values (calculated above) are expressed in US customary units, therefore it is necessary to transform them in SI units ($\text{MJ mm/ha-1 h-1 an-1}$) multiplying by 17.02.

Considering that the upper catchment of Bârsa River, part of the zone 19 that corresponds to the mountain area, the average intensity for the maximum of 6 hours rainfall and 50% probability of occurrence is given by STAS 9470-73- at 17 l/s ha (0.1 mm/min) resulting in a quantum of 36.72 mm. Applying the relations above, results a value for R factor of 1803.88 $\text{MJ mm ha-1 h-1 year-1}$, when using the relation proposed by Moțoc.

3. RESULTS

The estimation of the erosion risk resulted from multiplying the four grids corresponding to LS, K, C and R factors.

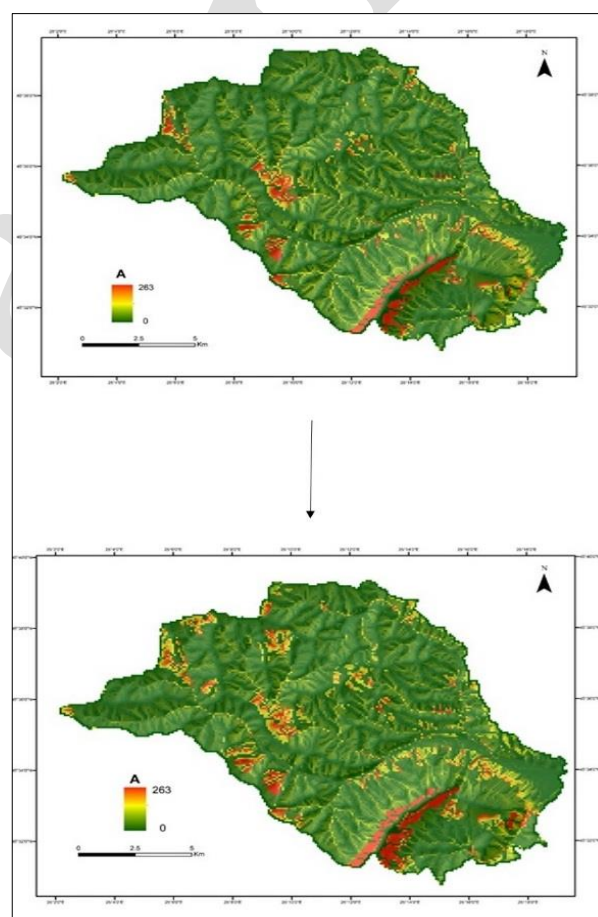


Figure 2. Approximated soil loss (t/ha/yr) in 2006 and 2016

To be noted that LS, K and R factors don't variate for the given period.

The analysis of both maps (fig. 2) leads to the following observations:

- The estimated annual quantity of soil loss varies between 0 – 263 t/ha.

- Values higher than 100 t/ha have an insignificant weight.
- Most of the surfaces have a value in range of 0 – 25 t/ha which corresponds to wooded areas.
- The main areas susceptible to erosion are covered with herbaceous vegetation, or are rocky areas and steep valley thalwegs that appear as lines of concentration for the eroded soil, thus representing linear erosion channels.
- The areas located under the main ridge highlight the scale of linear erosion in subalpine torrential catchments, where the slope is the primary influencing factor.

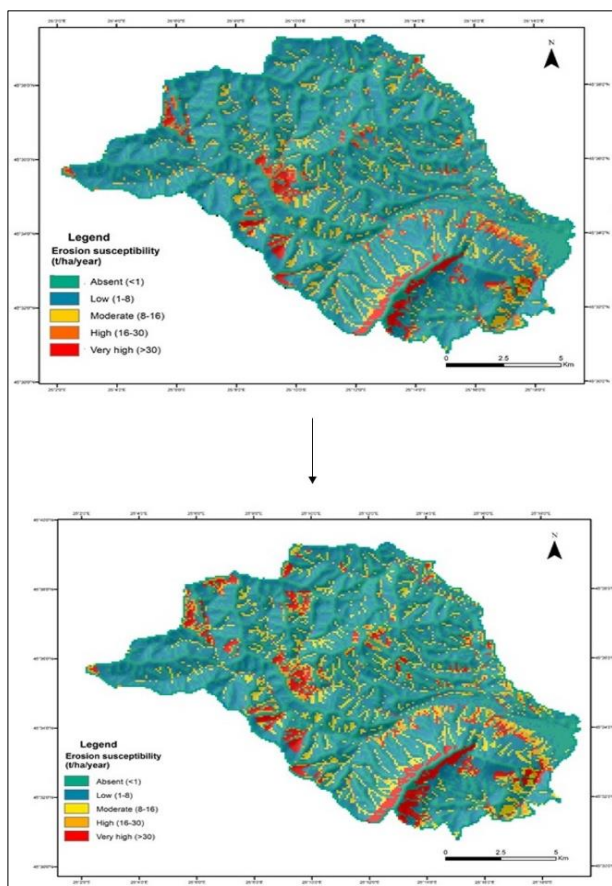


Figure 3. Soil erosion susceptibility in 2006 and 2016

In both years, 2006 and 2016, the highest susceptibility shown in Fig. 3 corresponds to alpine and subalpine areas, where sheet washing is the main process. The valleys appear as areas with moderate soil loss owing to stream erosion.

Between 2006 and 2016, 583.8 hectares were deforested, which corresponds to 5% of the total catchment area. These land use modifications triggered changes in the spatial distribution of soil

loss susceptibility classes, which can be observed in the two maps above.

4. CONCLUSION

The spatial distribution of the estimated erosion emphasizes the importance of cover management practices. Irrational deforestation favours the appearance of soil loss on land with high slope gradients, where values can be 10 times higher than those in adjacent wooded areas.

Even though we did not have measurements of erosion to validate the results, by comparing our outcomes with others studies the results are much alike.

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