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QUANTITATIVE ASSESSMENT OF SOIL EROSION USING GIS EMPIRICAL METHODS. A COMPARATIVE STUDY BETWEEN THE MOTRU MINING AREA AND THE SUCEVIŢA CATCHMENT

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Abstract: ***Quantitative assessment of soil erosion using GIS empirical methods. A comparative study between the Motru mining area and the Suceviţa catchment.*** The geomorphologic process of soil erosion has negative consequences on the soil quality. The anticipation of the erosion release is important for adopting protection measures for the susceptible areas. Through our study, we will make a qualitative estimation of the soil losses in the Motru Mining Area and in the Sucevita Catchment as a consequence of soil erosion. We will apply the classical methodology suggested by the ROMSEM model, USLE type, using the GIS technology. The practical importance of the informatical applications using deterministic models of risk evaluation to soil erosion is argued by the fast operations, the precision of the results obtained and their spatial distribution.

Key words: soil erosion, GIS, ROMSEM method

1. Introduction

As concerning the visual impact soil erosion is a ”discreet” geomorphological process, but it has a widespread spatial distribution. Its negative effects are easy to perceive and they are represented by: sparcely vegetation, the occurence of weed, erosion entities etc.

One of the most facile and precise methods to calculate the quantity of the eroded material is represented by the empirical equations for soil erosion. There were a few methods developed in the last seven decades that aproach this issue. One of the most well-known is USLE (Universal Soil Loss Equation), which was developed in the USA as a tool for determining the loss of soil in cultivated areas, but later on its applicability was extended to areas with other types of landuse as well.

The first model was published in 1940 by A.W. Zingg as an equation that considered slope steepness and slope lenght as determining factors (Zengg, 1940). In the 1950s this equation was improved by reevaluating the mathematical shortcomings of the previously ones. Wischmeier and Smith used for the first time the acronym USLE in Agriculture Handbook No. 282, which was published in 1965. This method evolved in time, having wide applications nowadays. Thus, the same authors published in 1978 the Agriculture Book No. 537, which underlined that USLE represented the first methodology used at the end of the 1970s and early 1980s for determining soil loss.

The USLE method revised as RUSLE (Revised Universal Soil Loss Equation) represented an updating product on the basis of their previous experience. It uses the same empirical principles as the first one, but it was improved as regarding the methods to calculate the terms of the mathematical equations. An important contribution to the new

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method was due to Renard and Foster, who published their work in 1983. They analyze the influence of each erosion factor, but the shortcomings are due to the fact that they used anglo-saxon measurement units, thus being nonfunctional in Europe.

Being widely used for soil loss assessment, this method was adapted to the Romanian conditions by a team of researchers from the Institute of Pedology and Agrochemical Research in Bucharest under the leadership of Mircea Moțoc. The released the first methodl to be used in Romania in 1963. A second version of this method was published in 1973 and followed the model of Wischmeier and Smith (1958). In 1979 the researchers improved the method again and they named it **ROSEM** (Romanian Soil Erosion Model). In 2002 the academician Mircea Moțoc proposed that the version form 1979 of the ROSEM should be used for future evaluations (Moțoc, Sevastel, 2002, p. 15).

2. General characteristics of the case studies.
The Motru mining basin

The Motru Mining Basin is situated in the north-western part of the Getic Plateau, within the limits of the Motru Piedmont, being "housed" by the Jilțului Hills (Fig. 1). The study area is fragmented in an ensemble of long hilly ridges sculptured into monoclinal formations disposed to northwest-southeast, with altitudes that do not exceed 450 m. Lithology is specific to the Carpathian foreland. The petrographical formations were deposited in the Miocene – Holocene, in mainly lacustrine facies under the form of alternating strata of clay, marly clay, sandy clay, and sand, partially covered by Pleistocene gravel and loess-like deposits. The piedmont area was sectioned from north to south by the Motru River, the primary morphology of the piedmont plateau being subsequently modified under the activity of the temporary rivers (Ploştina, Lupoaia, etc.).

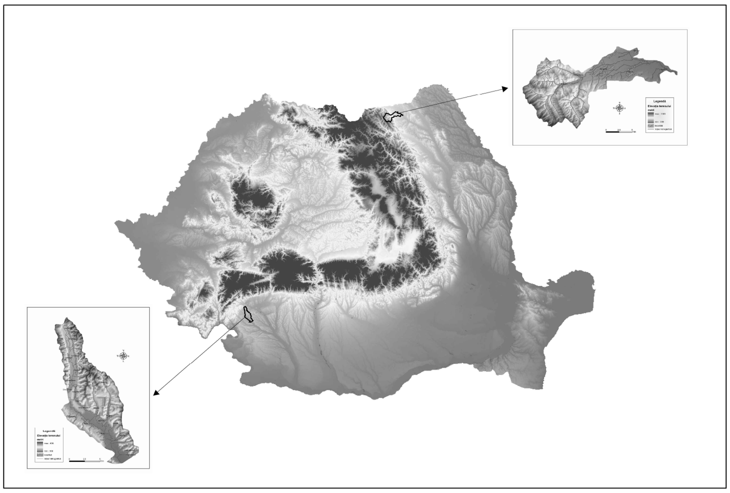

Fig.1. Geographical position of the study areas

The analysis of the temperature values between 1961 and 2000 indicates a multi-annual mean temperature ranging between 9.2°C (at Polovragi meteorological station, in the northern part of the area) and 11.6°C (at Drobeta Turnu Severin meteorological station, in the south-western part). The influence of the sub-Mediterranean climate determines heavier precipitations than usually, the highest values being registered in the northern part, in the vicinity of the Sub-Carpathian sector. The multi-annual average precipitation between 1961 and 2000 ranges between 602.2 mm at the Bâcleşu meteorological station (in the eastern part) and 882.5 mm at the Apa Neagră meteorological station (in the north-western part).

The lignite deposits from the Pliocene sedimentary deposits (lower Dacian and Romanian) are present as a productive complex composed of 17 strata (I-XVII) exploited after 1960 by underground pit mining and in the 1970s, by open-pit mining.

The Sucevița catchment

This catchment is situated in the north-western part of Romania at the contact between the Obcinele Bucovinei and the Suceava Tableland (fig. 1). There are two sectors to be identified within its limits: a mountainous sector that drains the eastern slopes of the Obcina Mare (it is constituted by sandstones and conglomerates and it was formed because of the breaks in the Paleocene flysch) and a hilly area, namely the Rădăuți Depression, which was formed on a platform area with low altitudes, plane landforms and "lazy" rivers. The piedmont sector is sculptured in Sarmatian deposits consisting in a sequence of clays, sandy clays, sand and pebbles with many layers of sandstone and political limestone, as well as Quaternary deposits of pebbles and sand.

As regarding its climate, this area has an eastern European continental temperate climate, with some transition characteristics from humid Atlantic and Baltic to excessive continental ones. There can be also identified the influences of the foehn effects form the eastern slopes of the Carpathians (Obcinele Bucovinei). The analysis of the temperature values between 1995-2000 shows that there is a mean annual value of 7.4 ºC (Rădăuți), but it ranges between 4.2 – 5.5 ºC in the mountain area. The annual mean precipitation values increas from west to east, from 803.6 mm (Sucevița, 1979-2000) to 624.8 mm in the low sectors of the Rădăuți Depression (Rădăuți, 1955-2004).

3. Using the GIS techniques to evaluate soil erosion. Application of the ROSEM method.

The most appropriate method to evaluate soil loss in Romania is the one used by Moțoc et al. (1979) and reinforced by Moțoc and Sevastel (2002). Thus, the final version of this method is represented by the following equation:

$$Es = K \cdot L^{m} \cdot i^{n} \cdot S \cdot C \cdot C_S$$

where:

- **Es**- the multiannual sediment amount due to erosion (t/ha/year);
- **K**- the rainfall-runoff erosivity factor;
- **L^m**- the slope length factor;
- **i**- the slope steepness factor;
- **S**- the soil erodibility factor;
- **C**- the cover-management factor;
- **C_S**- the supporting practices factor.

The values corresponding to the above mentioned factors were determined by the I.S.C.I.F., Soil Conservation Institute in Bucharest, accordingly to the soil and climate peculiarities of Romania.

3.1. The rainfall-runoff erosivity factor (K). This factor shows the amount of soil loss due to runoff erosion, namely the ratio between the soil loss amounts and the agresivity of rainfall. The research conducted by Stănescu in 1969 established the formula to calculate this factor as the product between the rainfall amount and intensity of a 15 minute rainfall, which represents the time that water needs to gain a concentrated flow.

The rainfall-runoff factor has particular values for Romania according to the different types of landscape. The values for this factor are those used in the hydrological regionalization by the National Meteorological and Hydrological Institute.

In our study the rainfall-runoff factor has the following values: K=0.100 for the piedmont areas of the Sucevița catchment; K=0.150 for the mountain areas of the same sector and K=0.140 for the Motru mining basin.

3.2. The slope length factor – L^m. The morphological aspects that influence erosion are slope steepness, slope length and slope aspect. The relation between erosion, slope and slope length was determined on straight uniform slopes. In this case erosion increases along with the degree of convexity and it decreases if concave slopes occur.

The influence of slope lenght is determined with a L^m function, where m=0.3 m (slope lenght is less than 100 m) and m=0.4 m (when slope lenght is greater than 100 m). The ranges of the slope lenght are presented in Moțoc and Sevastel (2002, p. 45).

When using the GIS techniques, slope lenght is determined according to a 10 m resolution DEM (Digital Elevation Model), using the ***m*** values mentioned above. The corresponding value is used in the equation of Desmet and Govers (1996):

$$\{[(\text{flow accumulation}) * \text{resolution}]/(22.1)^{0.3}\}$$

This factor represents a ratio for the loss of soil on a standard slope (9%, 22.1 m long). The result of this operations is represented by the spatialization of the slope lenght factor.

3.3. The slope steepness factor – i^n. Slope is a determining factor for the transport of the sediments resulting from splash and sheet erosion, as well as from agricultural practices. The slope values in the study area range between 0-34° for the Sucevița catchment and between 0-24° for the Motru mining basin. The slope coefficient is usually calculated on homogenous landscape sectors, being expressed as percentage (%).

The Romanian scientific literature mentions the following formula to calculate slope steepness:

$$i^n=1,36+ 0,97i +0,138i^2$$

where: **i** = α tangent (Moțoc, Sevastel, 2002, p. 37).

This equation is then intorduced in GIS, resulting in a map of slope steepness.

3.4. The soil erodibility factor – S. The upper strata of the ground are very susceptible to all types of soil erosion because they consist of weakly cohesive materials (soil and superficial deposits).

The intrinsic properties of the soil (texture, humus content, permeability and hydric stability of the structure) are taken into consideration when performing the assesment of soil erodibility using the USLE method. Nowadays, the method used in Romania to determine the S factor is based on the Indicator no. 186 extracted from the ”Methodology to elaborate pedologic studies” (I.C.P.A., 1987). This indicator establishes the erodability classes according to the genetic type of the soil, its erosion status and texture.

In order to represent it graphically analog data need to be converted into digital data. The next step is to select the coefficients established by I.C.P.A. the values of the I-186 coefficient are to be found in tables (Dârja et al., 2002 table 13, pages 50-51; Moțoc, Sevastel, 2002 - table 3, pages de 39-40; Moțoc et. al, 1975 - table 2.5, page 61 etc.). For the areas considered in this study the value of the S factor ranges between 0.8-1.1.

3.5. The cover-management factor – C. Vegetation represents the main factor that controls erosion. The C factor shows the influence of different types of vegetation upon erosion processes.

The evaluation of this factor used to be done in Romania using runoff parcels. Thus, the amount of eroded material under different types of vegetation was compared to that coming from parcels sparcely vegetated or without any vegetation. In this case, there are some correction factors according to the land use (natural vegetation or cultivated land). The value of these coefficients can be found in many studies (Dârja et al., 2002, table 14, page 53; Moțoc, Sevastel, 2002, table 6, page 43 etc.).

In our case, the delimitation of parcels was done using the GIS techniques from orthophotos taken in 2006, references, topographic maps (1:25.000), Landsat ETM satellite images (2001) and CORINE Landcover (1992, 2000). First, the vegetation map was produced, then the values of the cover-management factor for each vegetation type were implemented in the GIS software.

The results showed that the lowest values are to be found in urban and forrest areas, while the highest ones belong to agricultural lands as well as to eroded and mining areas.

3.6. The supporting practices factor – C_s. The results of the field experiments conducted in Romania for soil conservation represented the basis for determining the correction coefficient according to the anti-erosional practices used.

Some studies focused upon anti-erosional efficiency (by phyto and hydrological methods) on areas where soil conservation works were applied (Dârja et al., 2002, table 15, page 54). When such practises are missing, the values of the C_s factor is 1.

4. Results and discussion

In order to compute the estimated value for soil erosion the determined values of the factors were intorduced in the equation and the mean value for soil erosion on each homogenous landscape unit.

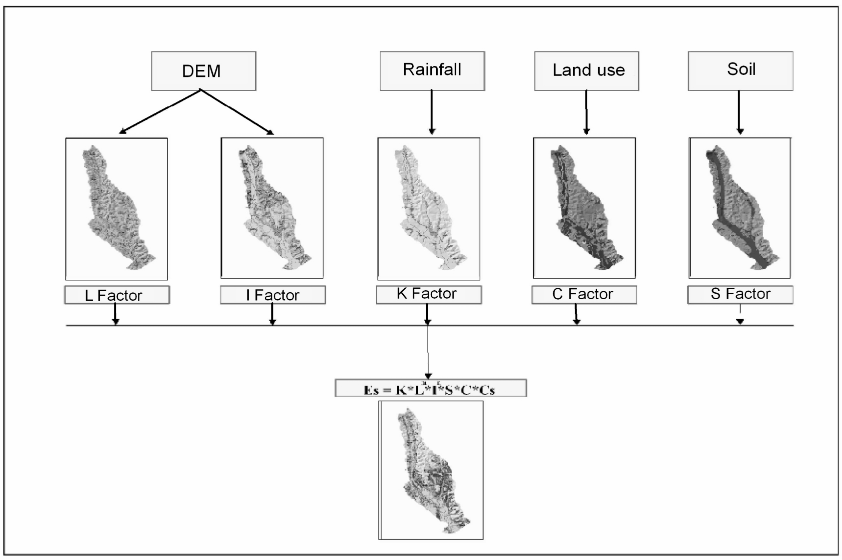

Fig. 2. The raster modelling process of erosion according to the ROMSEM (USLE) method

The general accepted value for soil erosion is 3 t/ha/year. In our case, the values show high discrepancies between the two study areas. Thus, for the Suceviţa catchment in only 4.4% of the territory erosion exceeds 3 t/ha/year, while the Motru mining area eroded lands represent 19.3% of the total surface.

Values of the surface erosion **Table 1**

Soil erosion	**Motru area**		**Suceviţa catchment**	
	Area (km²)	**%**	**Area (km²)**	**%**
0-1 t/ha/an	97.8	65.2	184.8	90.51
1-2 t/ha/an	14.6	9.7	7.2	3.51
2-3 t/ha/an	8.8	5.8	3.3	1.61
3-4 t/ha/an	6.0	4.0	1.8	0.90
4-5 t/ha/an	4.5	3.0	1.1	0.56
>5 t/ha/an	18.4	12.3	5.9	2.89
Total	**150**	**100**	**204**	**100**

The results show that in the ***Motru area*** the mean annual rate of erosion is 1.78 t/ha/year, thus the total amount of the eroded material is 26700 t on a total surface of 150 km^2. The highest values (>5 t.ha/year) are recorded in the neighbourhood of some mining areas (Leurda, Ploştina, Lupoaia, Roşiuţa), as well as on the waste dumps (Valea Mînăstirii). The lowest values (< 1 t/ha/year) represent 65.2% of this territory, being mostly found on the wooded slopes in the north of this study area.

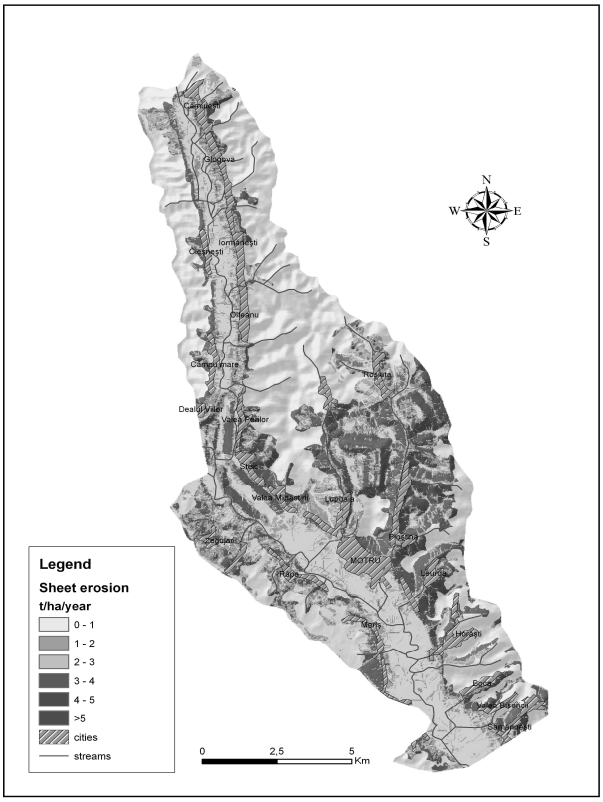

Fig. 3. Motru area – sheet erosion

The ***Suceviţa catchment*** is a natural area with little human influences. Thus, the mean erosion value is 0.64 t/ha/year, which leads to an average amount of 12800 t of eroded material on an area of 204.2 km^2. The highest values of erosion (> 5 t/ha/year) are located on the mountain slopes (Suceviţa, Voievodeasa, Margina), as well as in the hilly areas used for agriculture (Horodnic, Volovăţ, Burla). This is due to the former deforestation practices, the land being used for agriculture or as grasslands. Low values of erosion (<1 t/ha/year) are found on 90.5% of the study area because in the northern part most of it is wooded (55.9%), and the rest corresponds to the Rădăuţi Depression with agricultural lands, which are almost flat (0-2°).

The results that were obtain using the USLE method can be used to estimate the influence of land use upon erosion, as well as for identifying the susceptibility to erosion. The strategies that are used for soil conservation must focus upon the changes of the values of the factors that are taken into consideration in soil loss evaluation.

Unfortunatelly people cannot change two of the factors that influence erosion (the rainfall-runoff and the soil erodibility factors), but all the others can successfully managed. Thus, in order to reduce the lenght and the steepness of the slope people can cut terraces along the slope, althought they need some investments. The best methods are the selection of the type of landuse and the agricultural practices to be implemented, but also the forestation of the unstable slopes for a better soil protection. All of these induce a high improvement on soil loss management.

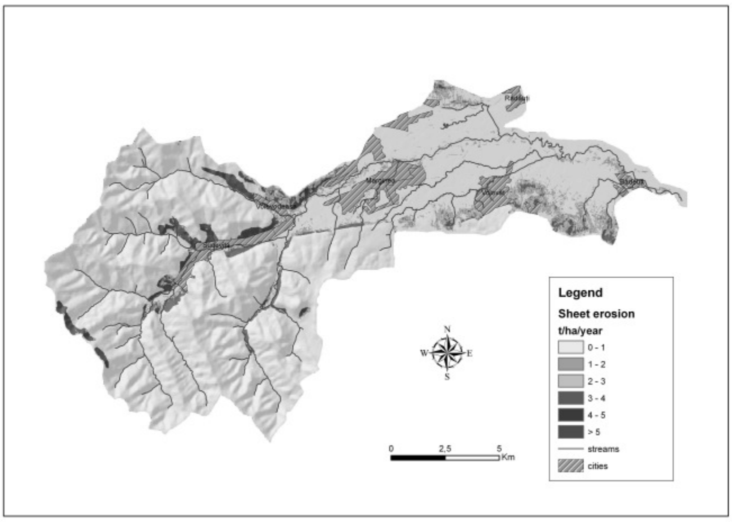

Fig. 4. Sucevita catchment-sheet erosion

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