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IMPLEMENTATION OF THE USLE MODEL USING GIS TECHNIQUES. CASE STUDY THE SOMEŞEAN PLATEAU

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Abstract. The soil erosion process is influenced by a series of geomorphological factors like the slope length and the slope steepness, by the climatical and soil characteristics and also by the land cover management. This study proposes a GIS based model for the computation and representation of areas, which are exposed to soil erosion from the Someşean Plateau. In the implementation process of the USLE (Universal Soil Erosion Model) model, we created a vector and raster GIS database covering the studied geographic unit, using specific spatial analysis methods and database interrogations for the quantitative estimation of the eroded soil volume regarding the whole area and also the regional subunits. The validation and emphasize of each USLE factor influence on the soil erosion process was made with the help of profiles and comparative analyses between each other. After we analyzed the results of the model and we compared the results with the existent soil erosion values, at national and local scale, we can say that the results of the USLE model are veridical and that the model can be used with success in the studied area.

Keywords: USLE, Soil, erosion, database, GIS analysis, profile.

1. INTRODUCTION

Taking into consideration the implementation process of Romania's projects initialised for the adheration to the European Union and for the attraction of the proposed structural funds, for the development of the agriculture, it is absolutely necessary the creation of an inventory about the areas exposed to different natural and anthropical processes. It is also important the identification of the causes that are producing them for taking the right decisions about the possible quality improvements of the affected areas.

The study refers to the process of soil erosion frequently encountered in the last years together with the intensive exploitation of the natural resources, primarily the deforestation and the intensive grazing.

In the Romanian dedicated scientific literature, we find different types of computation models for the identification of areas and the quantities of transported eroded soil, the most used being the model Moțoc M. et. al. 1975 and revised until 2002. A series of similar models were developed also in the foreign literature, in 1940 by R.W. Zigg, who found a mathematical relation using as principal factors the slopes length and the inclination grade, continued then with other models developed by Smith 1941, Browning et al. 1947, and Lloyd & Eley 1952.

The model used in this study was first elaborated and published in the year 1965 in the Agriculture Handbook journal Nr. 282, under the name U.S.L.E. (Universal Soil Loss Equation), implemented in the 60's by the Soil Conservation Service named today the Natural Resources Conservation Service. The model underwent numerous modifications, the most important, and most used modified model being the RUSLE (Revised Universal Soil Loss Equation) model proposed by Renard et. al. 1997.

The study proposes to obtain results using the most recent information and a technical GIS base, applied with success by Moore & Wilson 1992, Mitasova et al. 1996, Mitasova et al. 1998, Patriche et. al. 2006, Filip 2008.

1.1. Someşean Plateau

Integrative part of the Transylvanian Plateau, the studied region represents its North – North-Western compartment, and is the most complex and extended unit among the Transylvanian Plateau's three major subdivisions.

The morphostructural complexity of the region is determined by the geologic evolution, manifested through a variety of the dominant sedimentary formations (grit, sand, clay, limestone) disposed over crystalline blocks that appear at different depths. A typical structural relief, with cuesta fronts developed at the level of grit or conglomerate layers in South, tuff in the center or limestone in the North; extended structural plateaus, deep valleys, subsequent depression basins, petrographical relief on limestone; also two erosional surfaces (± 650m, ± 550m).

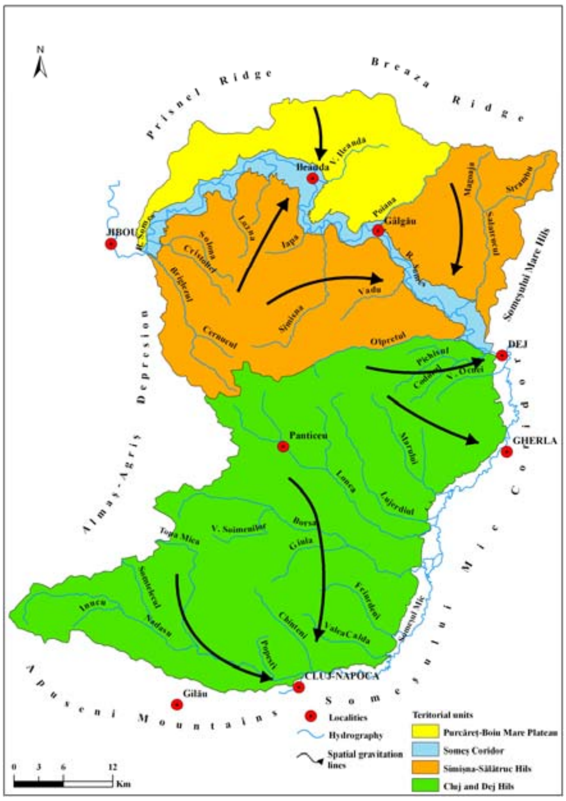

Figure 1. Someşean Plateau. Limits and regional subdivisions (Cocean et. al., 2009)

This particularity is reflected in the configuration and typology of the relief (predominantly structural and lithologic) and in the rivers network organization, drained by the Someş River to the North-West of the country. Additionally, the particularities of the bio-pedo-geographic cover, mirrored in the predominance of the forestry – preserved mainly on the higher hills – and of the luvisoils at different levels of argil-iluviation. Another particularity of the region is the lack of urban structures, which are grouped in the Someşul Mic Valley.

From the regional point of view there are four major subdivisions evidenced, Purcăreț-Boiu Mare Platou, Someş Corridor, Simişna Sălătruc Hills and Cluj and Dej Hills, each being polarised by urban or very developed rural centers (Fig. 1.). The main polarizator centers are the cities Cluj-Napoca, Gherla and Dej for the Clujului and Dejului Hills, and the commune centers of Ileanda and Gâlgău for the Simişna-Sălătruc Hills and the Boiu Mare Plateau.

Regarding the limits of the Someşean Platou (Fig. 1.) we distinguish in the South the Apuseni Mountains, in Vest the Almaş-Agrij Basin, in the North-West part the Prisnel Peak in North the Breaza Peak and in the East the Someşul Mic corridor till Dej continued then by the Someşul Mare Hills.

2. UNIVERSAL SOIL LOSS EQUATION

The estimation of the actual sheet erosion rata was computed with the help of the well-known Universal Soil Loss Equation (USLE) adapted by Moțoc et. al. 1975 after Wischmeier & Smith from 1965. The model uses five major factors in the computation of soil loss for certain area. Every factor is a numerical estimation of a specific condition that affects the soil erosion severity in an area. The erosion values vary concomitantly with the climatic variation, so the values obtained from USLE are more precise, using average long-term values. The formula is:

$$E = K \cdot Ls \cdot S \cdot C \cdot C_S \qquad (1)$$

where, ***E*** is the average annual surface erosion rate in tons/ha/year

K: correction coefficient for climatic (rain) aggressivity which represents the rainfall erodibility index. Although in the original USLE form, this represented the annual sum of the products between the energy of the erosive rainfalls (E) and their maximum 30 minutes intensities (I30). Due to the difficulty of direct calculation of rainfall erodibility - as the rainfalls intensity is not currently recorded at the meteorological stations - indirect estimative methods were elaborated based on statistical relations between the erodibility and other measurable parameters.

Ls : slope length coefficient and slope degree defined as the topographic factor or coefficient which is a function of both the slope and length of the studied area (Kinnell 2005). The longer the slope length the greater is the amount of cumulative runoff. Also the steeper the areas slope, the higher is the velocity of the runoff that contributes to erosion.

S: the correction coefficient for soil erodibility represents the soil or rock resistance to rain and the micro currents generated by the meteorical water flow.

C: correction coefficient for cover-management factor and vegetation characteristics, it is defined as the ratio of soil loss from land with a specific vegetation to the corresponding soil loss from continuous fallow. Its values depend on vegetation cover and management practices, in addition, the growth stage and cover degree at the time when most erosive rains occur.

C_S: correction coefficient, for the effect of erosion control measurements. This is the conservation practice factor. Values are obtained from field experience regarding soil conservation practices tables, where the ratio of soil loss where contouring and contour strip-cropping are practiced to that where they are not.

3. GIS MODEL

At this stage in the study we identify two main fazes: creating and processing the database by attribute interrogation and spatial analysis.

3.1. Database

The creation of the database imposes a specific management, in concordance with the final appointed objective.

Considering the necessities of the presented model (see chapter 2) we created a GIS database complexly structured on vector and raster layers, starting from the primary database (contours, hydrography, soil, land cover management) to the derivate data (soil grid, cover management grid, digital elevation model) and finishing with the modelled database, raster structures (slope length and eroded soil quantities) (Tab. 1.).

Table 1. Database structure.

Nr. crt.	Name	Type	Structure	Attribute	Origin
1	Contour	vector	Line	Altitude	Primary
2	Hydrography	vector	Line	Name, order, direction	Primary
3	Soil	vector	Polygon	Type, texture	Primary
4	Cover management	vector	Polygon	Management type	Primary
5	Soil	raster	Grid	Soil erodibility factor	Derivate
6	Cover management	raster	Grid	Cover management factor	Derivate
7	Climatic aggressivity factor	numeric	-		Derivate
8	D. E. M	raster	Grid	Altitude	Modelled
9	Slope length	raster	Grid	Slope length	Modelled
10	Erosion value	raster	Grid	Soil loss t/ha/year	Modelled

For creating the primary database, we used cartographical materials represented by 1:25000 scale curvature line maps scanned and georeferenced in the Romanian Stereographic 1970 projection, from which we picked by digitization the curvature lines and the hydrographic network, necessary layers in the digital elevation model creation process. For the creation of the digital elevation model, we used the ESRI ARCINFO software's TOPOGRID function, creating with its help a hydrologicaly correct digital elevation model at 20-meter resolution.

In addition, at this stage, we created the vector type layers representing the two base factors (soil and the land cover management) in the process of spatial analysis and the modellation of the soil erosion.

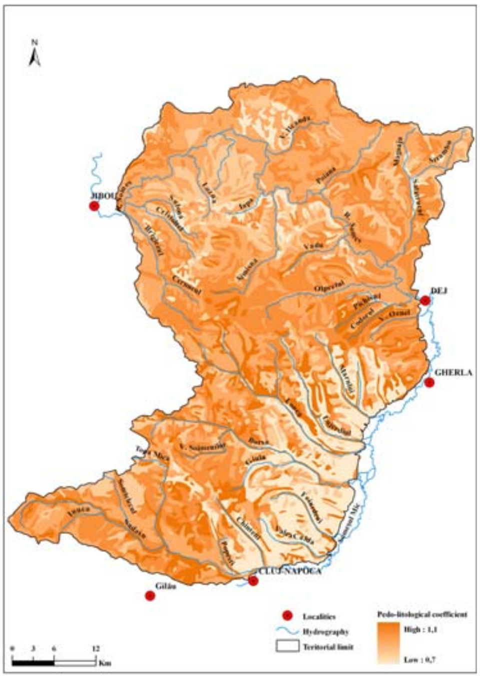

Figure 2. Pedo-litological coefficient

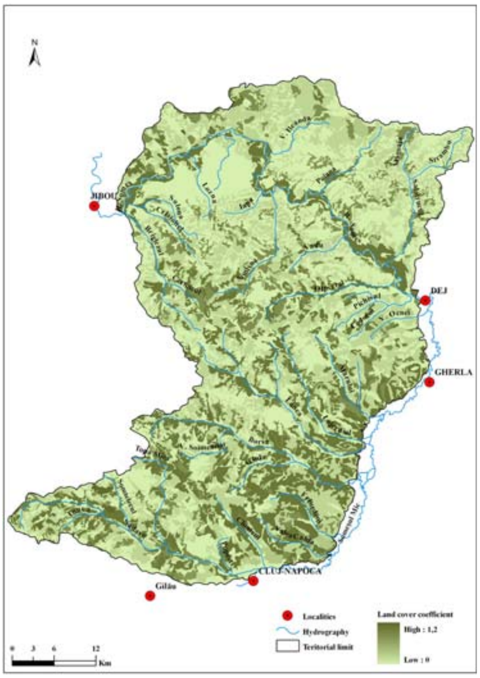

Figure. 3. Land cover management coefficient

The soil database was created by digitizing the 1:200000 scale maps with the SRCS ICPA-1980 (Romanian Soil Classification System) naming and updating them to the new FAO UNESCO SRTS 2003 (Romanian Soil Taxonomy System) denominations. Concomitantly with the creation of the soil layer we identified and introduced as attribute the soil erodibility coefficient dependent to the soil type and texture. The value of these varies between 0.6 and 1.1 (Moțoc et al. 1975, page 50-51) (Fig. 2.).

The land cover management was created by derivating the CORINE 2000 database, introducing as attribute the land cover management coefficient by management type and cultures (Moțoc et al. 1975, page 53.), these values vary between 0.001 and 1.2 (Fig. 3.).

Because the whole database spatial analysis is grid type, we converted the soil and land cover management vectors to grid, by interrogating the attributes representing the specific coefficients for the two factors. The resulting grid had he same resolution as the digital elevation model for the accuracy of the final results.

The climatic aggressivity coefficient was introduced in the final equation in a numeric form, because it is unitary on the entire study area, the assigned value being 0,120 (see Stănescu et al. 1969).

3.2. Spatial analysis

The model finalization supposes the computation of the slope length and the spatial analysis, which integrates the whole database created previously. The slope length was created using the spatial analysis equation proposed by Mitasova et. al. 1996 and implemented in Esri ArcGis in the form:

$$POW([accumulation]\cdot 20/22.1,0.6)\cdot POW(\sin([slope]\cdot 0.017)/0.09,1.3) \qquad (2)$$

where: *[accumulation]* – runoff accumulation
20 – grid resolution
0.6, 1.3, 22.1, 0.017 – experimental coefficients (see Moore I.D., Wilson J.P, 1992)
[slope] – terrain slope

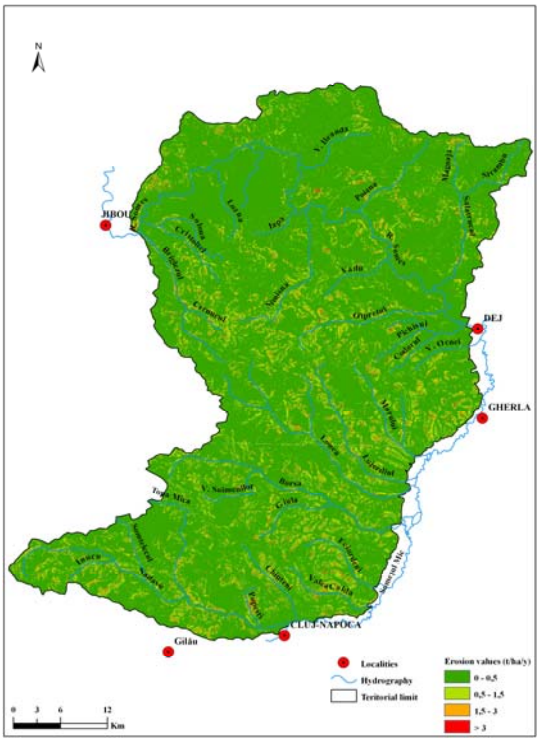

Figure 4. Soil erosion rate

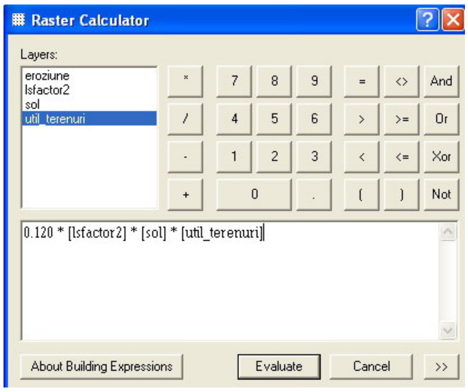

Figure 5. Raster Calculator window

The annual average erosion rate (Fig. 4.) was computed conform the 1. formulae, using the Esri ArcGis geo-informational software (Fig. 5.).

The spatial analysis module “Spatial Analyst”, with the Raster Calculator function permits the integration of mathematic equations in GIS environment.

For the computation and evaluation of the average soil erosion rate, we used the above-mentioned function, by introducing the mathematic identificator of “multiplying”, and so obtaining the Someşean Plateau erosion values, which were between 0 and 37.35 t/ha/year.

4. RESULTS

By analyzing the modelled database representing the average soil erosion values we could draw conclusions and extract quantitative information about the entire studied area and as well about each regional subdivision, using once more the Esri ArcGis geo-informatic software by interrogating the database.

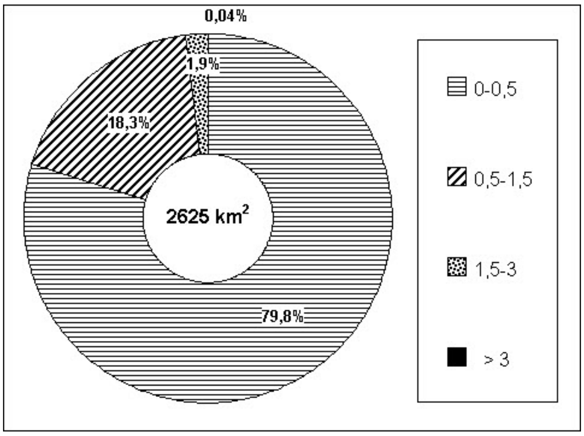

Figure 6. Studied area erodibility values

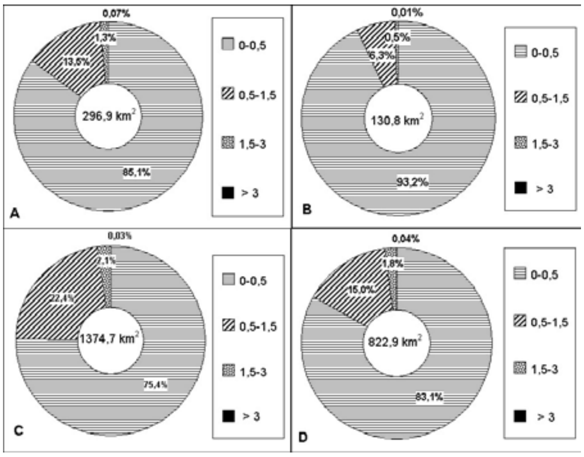

Figure 7. Someşean Plateau regional subdivisions erodibility values (A-Purcareț-Boiu Mare Plateau, B-Somes corridor, C- Clujului and Dejului Hills, D-Simişna-Sălătruc Hills)

Regarding the entire area of the Someşean Plateau (2625 km^2) we can observe (Fig. 6.) that the most part has small erosion values, between the 0 and 0.5 t/ha/year covering 79.8 % from the entire area, followed by the second category with 18.5 % and with erosion values between 0.5 and 1.5 t/ha/year. Higher values are insignificant only reaching 1.9 % from the entire area. The small erosion values are explained by the characteristic relief of the Someşean Plateau, which is mainly hilly with small grade slopes and grasslands, also by the high extension of the agricultural areas in mixture with natural ones, by the meadows and by the well preserved forest clusters.

The same situation can be found also in case of the regional subdivisions (Fig. 7. A, C, D) distinguishing soil erosion values between 0 and 3 t/ha/year. A particular situation appears in the Someş Corridor (Fig. 7. B) where the soil erosion values were very small, integrated between 0 – 1,5 t/ha/year interval. This can be explained by the doll uniformity of the relief, the preponderant agricultural areas, the large water accumulations in the Someş Valley, the very wide minor water bed on some portions of the valley and not least the existence in this regional subdivision of numerous anthropized areas (localities, industrial areas-afferent to Dej City and Ileanda commune – transportation network etc.).

4.1 Case study

To exemplify and evidence the preponderant influence of some factors over the quantity of soil erosion, we picked and implemented a case study, materialized in a transversal profile on the Someş Mare River on the direction North-West, with the starting point at the Braşeului Hills, between the Rus and Glod localities (Fig. 8.).

The case study area wasn't picked by chance, for its identification we accounted all the basic features of the Someşean Plateau, which is characterized, as we mentioned earlier, by hills and a characteristic wide corridor valley. In the exemplification process we used the Esri ArcGIS geo-informational software, with the profile creating option on raster type layers, which represent the base variables for the erosion computation formulae.

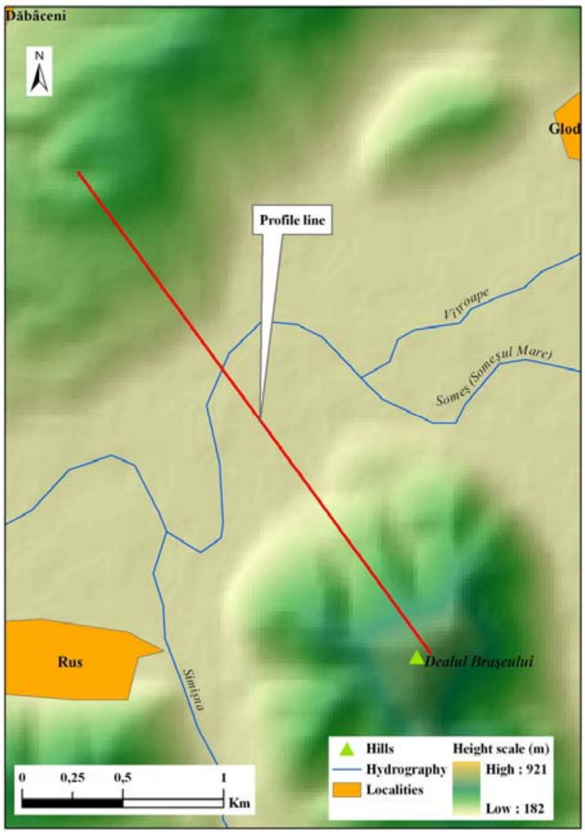

Figure 8. Profile line for the raster database

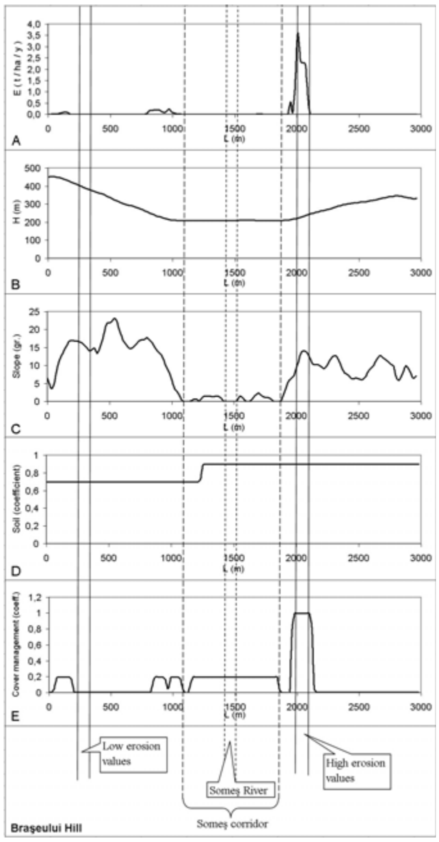

Figure. 9. Profile graphs used in the analysis

By analyzing the 9-th figure we can affirm that the high erosion areas in the Someşean Plateau (Fig. 9. A) are in direct concordance with the high slope values and the variation of these values in a small metrical interval, never the less collaborated with a high land cover management coefficient value (Fig. 9. E) and a significant soil modeled coefficient (Fig. 9. D). Regarding the small values of the erosion, these are identified by similar slope values, high soil coefficient values and very small land cover management coefficients.

5. CONCLUSIONS

The main conclusion is that for the Someşean Plateau the defining factor which influences the areas and quantities of minimal and maximal soil erosion is the type of land cover management. We remark also the fact that the highest and the smallest soil erosion values are approximately on the same metrical surface altitudinal variation.

It is important to mention the fact that in the Someş Corridor the soil erosion quantity is approximately equal to zero even if the land cover management and soil coefficient values are relatively high (0.2 respectively 0.8), the Someş major river bed and the small slope values (0-2°) playing a definite role in the soil erosion process of the area.

Analyzing the entire model, the relatively simple methodology, the database consistence, the comparability of the results with the existent soil erosion values at national and local scale, we can say that the result of the USLE model are veridical and that the model can be used with success in the studied area.

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