MODELING EROSION DEGRADATION ON SLOPING LAND USING GIS

MODELAREA DEGRADARILOR EROZIONALE PE VERSANTI FOLOSIND TEHNICA GIS

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Abstract. *This study presents the GIS techniques referring to the modelling of the process of degradation by erosion of the territory in the hydrological basin of Romania. On a surface of 4697 ha, the relief is strongly fragmented, presenting relief energy of around 395 m with averages slopes over 15%. The slopes are affected by the erosion and by the active sliding. The choice for this hydrographic basin is motivated also by the fact that there was the possibility of the validation of the results obtained by the simulation, comparing them with the measurements of the alluvial deposits in the lakes accumulation situated at the exit of the receiving basin.In our project, the geo-characteristic dates are represented as layers. This facilitated the analysis of the spatial variables and the distribution of the objects on the surfaces studied and the overall analysis of the information obtained, that supposes the simultaneous approach of more layers could be realized using the "overlay" technique. Along the application we used a module of software ArcGIS specialized for the operations with digital maps and of the large databases. The mathematical model used to determine the damage of the soil is based on the RUSLE (Revised Universal Soil Loss Equation) equation under the usual form from Romania. The results are presented in the form of digital thematic maps.*
Key words: modelling, erosion, spatial data, GIS

Rezumat. *În lucrarea de față este prezentat un studiu efectuat prin tehnici GIS, asupra evoluției proceselor de degradare a terenurilor prin eroziune dintr-un bazin de recepție din Romania. Suprafața de studiu este de 3963 ha, relieful este puternic fragmentat, prezentând o energie de relief de cca. 330 m, cu pante medii de peste 15 %.Versanții sunt afectați de eroziune în suprafață, în adâncime şi de alunecări active. Alegerea acestui bazin hidrografic este motivată şi prin faptul că a existat posibilitatea validării rezultatelor obținute prin simulare, comparându-le cu măsurătorile privind depunerile de aluviuni în acumularea situată la ieşirea din bazinul de recepție. În cadrul proiectului nostru, datele georeferențiate sunt reprezentate sub formă de straturi informaționale (layere), fapt ce facilitează analiza variabilelor spațiale şi a distribuției entităților de pe suprafețele luate în studiu, iar analiza globală a informațiilor obținute, ce presupune abordarea concomitentă a mai multor straturi, s-a putut realiza prin tehnica „overlay”. În cadrul aplicației s-au folosit module sub software ArcGIS, destinat operațiunilor de lucru cu hărți digitale şi baze de date consistente. Modelul matematic pentru determinarea pierderilor de sol are la baza ecuația RUSLE (Revised Universal Soil Loss Equation), în forma uzuală din Romania. Rezultatele sunt prezentate sub forma de hărți tematice digitale.*
Cuvinte cheie: modelare, eroziune, date spațiale, GIS

INTRODUCTION

Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, salinization, and soil acidity

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problems. These other forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion.

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks.

Water erosion's complex hierarchy of processes mean that erosion by water operates (and is studied) over a wide range of spatial scales. Rainsplash redistribution and the initiation of microrills and rills occur at a scale of millimetres. Rill erosion on agricultural hillslopes operates at a scale of meters to tens of meters, while gully erosion can occur on a scale of hundreds of meters, or even kilometres. The offsite impacts of erosion can affect very large areas, sometimes hundreds or even thousands of square kilometres.

Soil erosion has a range of environmental impacts, including loss of organic matter and nutrients, reduction of crop productivity, and downstream water quality degradation (Moriasi *et. al*., 2007).

Effective control of soil erosion is a critical component of natural resource management when the aim is to achieve sustainable agriculture and acceptable ecosystem integrity (Mulligan, 2004; Nearing, 2000).

In this context, the implementation of the Geographic / Territorial Information Systems for the above mentioned purpose, in our country, is required and justified not only by economic reasons, but also by the safety and celerity ensured by the provision of required information "in real time".

MATERIALAND METHOD

Negative effects of surface runoff and soil erosion in watersheds can be controlled and mitigated through hydrological models. Moreover, they are suitable to simulate various combinations of different scenarios of land and water management in a watershed and therefore they are useful for comparative analysis of different options and as a guide to what Best Management Practices (BMPs) can be adopted to minimize pollution from point and nonpoint sources (Niacşu, 2012; Patriche *et al.,* 2015)

The erosion prediction in experimental plots and hillslopes or the erosion modelling of small basins at the same analysis scale have been successful using physical models that require a detailed parameters measurement and a considerable quantity of input data in many cases, with the purpose of being used in the planning and management of watersheds (Lal, 2001).

Several mathematical models were developed to estimate the soil loss by surface erosion, as aresult of the action of raindrops and sheet flow. One of the widely known and used model is RUSLE (Revised Universal Soil Loss Equation), developed Renard *et al.* (1997). It estimates soil loss from a hillslope caused by raindrop impact andoverland flow (fig. 1), taking into account factors such as rainfall erosivity, soil type, landscape characteristics, land use (including types of crops) and management practices of agriculture.

The model was developed by applying statistical methods on data obtained through experimental measurements and indicates, with a good precision, the areas with potential gully processes. The equation for calculating the mean annual rate of soil erosion is the following:

$$A=R\cdot K\cdot L\cdot S\cdot C\cdot P$$

where,

A– the average annual soil loss (t $acre^{-1}yr^{-1}$);

R- the rainfall erosivity factor, evaluated as a product of the total storm kinetic energy (E) and the maximum 30-min intensity (I_{30});

K –the soil erodability factor;
L –the slope length factor;
S –the slope gradient factor;
C –the vegetation and crop management factor;
P–the support practices factor.

A new version, RUSLE (Revised Universal Soil Loss Equation), was developed by Renard et al.(1997); it keeps the USLE form (developed by Wischmeier & Smith in 1977), being improved the methods for calculating the terms of the mathematical equation.

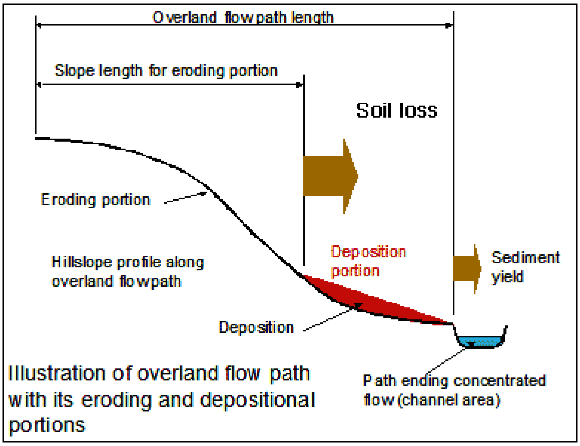


Fig. 1 Overland flow path

The recent methodology for applying the RUSLE or USLE models requires the use of the GIS techniques (etc.).

The importance of the GIS techniques integration to quantify the surface erosion risk is determined by the speed of the performing operations, the accuracy of the results and the possibility of their spatial representation (Biali and Cojocaru, 2015).

The water catchment area subject to research is called Gaiceana, is part of the higher water catchment area of Berheci river and is located in the East side of Romania, in Bacau county (fig. 2).

The reception area is of 4697.5 ha, with a highly fragmented relief, hilly type and average slopes of more than 17 %. Absolute altitudes ranging between 545.5 m and 150 m in the dam accumulation, resulting an energy relief 395.5 m. The slopes are affected by surface erosion, deep and. The sloping land was affected by sheet erosion, gully erosion and by active landslides. Dominant soils are chernozems and brown soils, and the most extended uses are: arable land – 36.31 %, pasture land – 18.89 % and forest - 47.15 %.

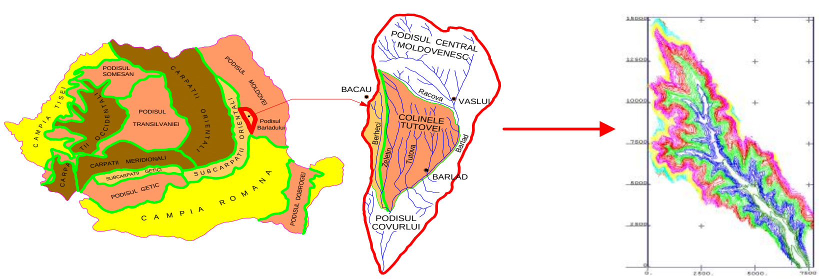


Fig. 2 Location of the study area (Gaiceana catchment)

RESULTSAND DISCUSSIONS

The georeferential data are represented in the GIS project as information *layers*, which enables the analysis of spatial variables and distribution of parameters on the surfaces studied. The global analysis of information obtained which implies simultaneous analysis of several information layers, was performed by the so-called "overlay" technique.

Such technique is based on overlapping or combination of several layers (following specific algorithms, set by the GIS developer), thus obtaining new layers (including new attributes and graphics). The "overlay" technique enables to perform multiple spatial analyses and refer to spatial entities and related databases included in a non-limited number of layers.

Graphical input data are supplied from the site plans on the scale of 1:5000 or orthophotoplans. Descriptive (non-graphical) input data are provided based on analogy with similar documentations and using data collected on site.

The first step in this project was Digital Elevation Models (DEM's) represented an important step within GIS project, and generated (fig. 3.) three information layers included in the computation algorithm of erosion-related soil loss. The Numerical Land Model was obtained by means of interpolation, based on "*weighted average method*" for local interpolation.Based on the map with level curves, the obtained Digital Elevation Model (DEM) provided fundamental layers for the GIS project, such as:Layer 1- Hypsometric map (fig. 3) ,Layer 2-Flowing direction map, Layer 2-Gradient map (fig. 4). Based on the status layouts of uses (cover) on sloping land, types of soil and types of land improvement coverage, the spatial topology methods generated the following information layers:Layer 5- Land coverage and agricultural management, Layer 6 - Soil erodibility factor, Layer7- Effect of soil protection and preservation actions and works.

By integrating the above mentioned seven layers inGIS with RUSLE model we obtained the information layer of the erosion risk -Layer 8 (fig. 5). Therefore, both the thematic layers included in the mathematic model and the water erosion calculation for the basin researched were completed up to the cell level.

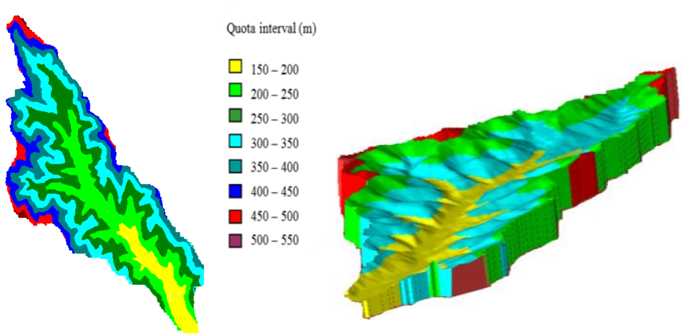


Fig. 3 Digital Elevation Models for Gaiceana catchment

Using DEM it was possible to determine the land declivity gradient, a very important factor in erosion modeling (fig.4). Using RUSLE model with ArcView results water erosion in the studied basin (fig.5).

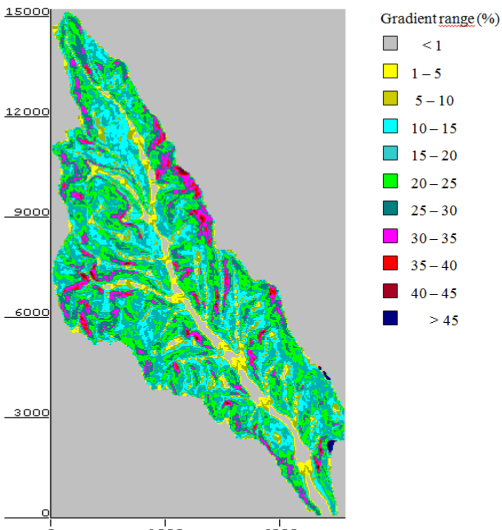


Fig. 4 Relief declivity map

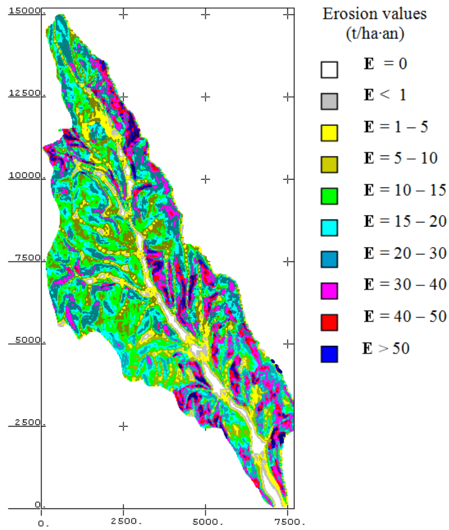
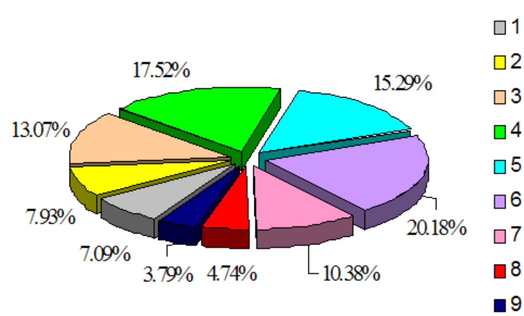


Fig. 5 Water erosion in Gaiceanabasin

Table 2

Distribution of water erosion and potential erosion in Gaiceana basin

Code		Erosion values (t/ha·an)	Surface (ha)	% of the total surface
1		< 1	333.00	7.09
2		1 – 5	372.44	7.93
3		5 – 10	614.00	13.07
4		10 – 15	823.19	17.52
5		15 – 20	718.38	15.29
6		20 – 30	915.56	20.18
7		30 – 40	487.63	10.38
8		40 – 50	222.56	4.74
9		> 50	178.25	3.79
Total			4697.50	100.00



CONCLUSIONS

1. The researches for this study set out the geo-spatial data flow from acquisition to obtaining the graphical and alphanumeric information related to erosion risk in a hydrographic basin of Romania. A digital elevation

model (DEM) was developed based on a rigorous mapping database.

2. This paper proves the computation accuracy of water erosion. Compared to classic procedures (where the computation areas are larger and with variable size), in this case the determination of water erosion takes place at elementary surface level (pixel / cell). Another great benefit of GIS technique consists of the possibility to incorporate/enter all factors (natural and anthropic) at cell level. The computerized data processing that characterizes the factors which determine the initiation and maintenance of water erosion process generate multiple possibilities of erosion simulation on sloping land.

3. After researches it was found that over 80% of the surface of the basin is affected by water erosion to different degrees according to table 2.

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