ESTIMATION OF SOIL LOSSES IN SMALL RIVER CATCHMENTS

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Abstract. *Soil erosion is a key challenge for agriculture. Soil erosion is the phenomenon of removing particles from the upper soil horizon through washing due to runoff water, wind or through farming activities. Soil erosion has three distinct stages – soil detachment, movement and deposition. Topsoil, which is rich in organic matter, with a high rate of fertility, is relocated elsewhere, inside or outside the river catchment; where it is deposited in time or is transported outside the catchment, being able to clog the drainage channels. The most important negative effects of soil erosion are the reduction of cropland productivity and the pollution of adjacent watercourses, wetlands and lakes. Serious soil degradation conditions, like soil compaction, low organic matter, loss of soil structure, poor internal drainage, and salinization and soil acidity problems contributes to the acceleration of the production intensity of the soil erosion phenomenon. This paper presents the evaluation of soil losses volume in a small river catchment, for one year, considering the influence of soil characteristics, length of catchment slopes, the rainfall intensity, vegetation cover factors, conservation practice factors, the catchment area, soil erodibility factor and slope in percent. For calculus is using the SURFER software, for simulate the topography of catchment and calculate the soil losses volume.*

Key words*: estimation, soil erosion, soil loss, hydric erosion.*

INTRODUCTION

In recent decades, with the development of intensive agriculture and climate change, the soil erosion is a key challenge for agriculture. Soil erosion has been considered as the principal cause of soil degradation because soil erosion determines the loss of topsoil and soil organic matter, which are essential for the development of plants. Estimation of soil loss is a significant challenge for soil and water conservation professionals, authorities, policy and decision makers. (PHUONG et al, 2017) The primary causes of accelerated soil erosion are the human activity and related land use change, which has substantial implications for nutrient and carbon cycling, land productivity and on worldwide socio-economic conditions. (EUROPEAN COMMISSION, 2021) The soil erosion causes can be classified and summarized as shown in Figure 1.

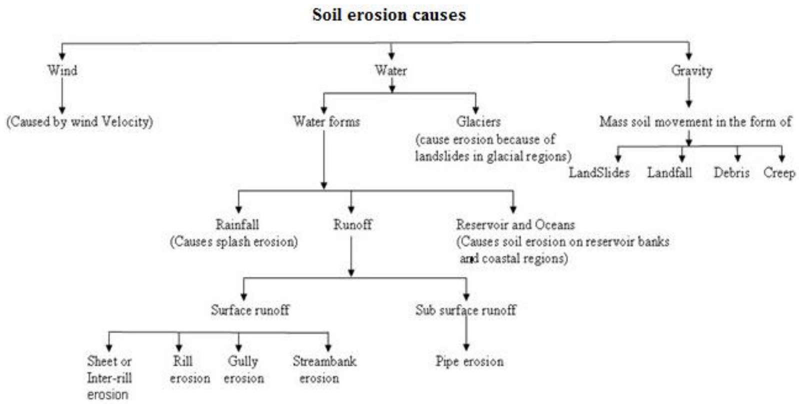

Figure 1. Soil erosion causes, processes and effects (DAS, 2000)

The map of human-induced soil degradation situation is shown in Figure 2.

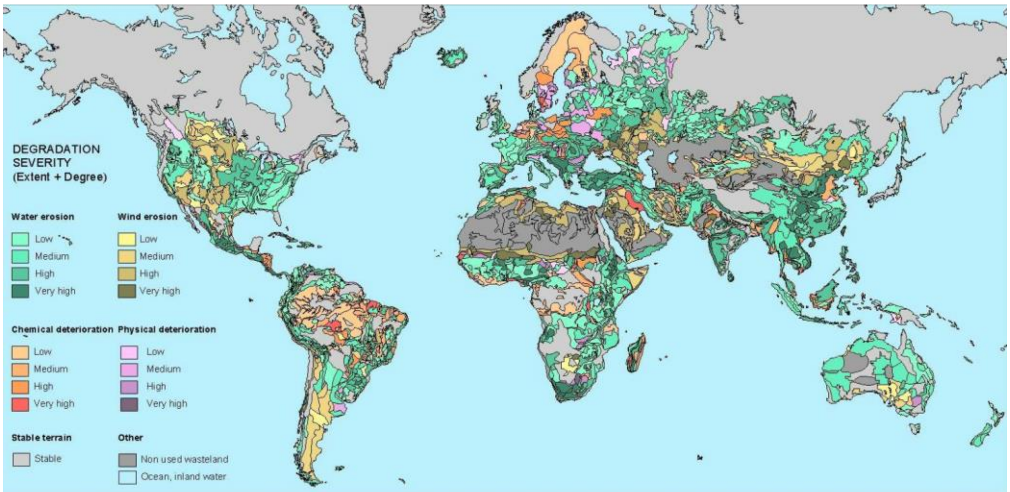

Figure 2. The map of human-induced soil degradation (OLDEMAN et al, 1991)

The consequence of soil erosion is the removing of particles from the upper soil horizon through washing due to runoff water from rains and snowmelt, wind or through farming activities. Sloping lands are mostly subject to hydric erosion, and horizontal lands to wind erosion. Soil erosion has three distinct stages – soil detachment, movement through transport by runoff water and deposition. Particles from topsoil, which is rich in organic matter, with a high rate of fertility, is relocated inside or outside the river catchment; where it is deposited in time or is transported outside the catchment, being able to clog the drainage channels. The most important negative effects of soil erosion are the reduction of cropland productivity and the pollution of adjacent watercourses, wetlands and lakes. Serious soil degradation conditions, like soil compaction, low organic matter content, loss/deterioration of soil structure, internal drainage capacity reduction, salinization and soil acidity problems contributes to the acceleration of the production intensity of the soil erosion phenomenon. (WORLD WILDLIFE FUND, 2021)

Hydric erosion of soils is one of the most important problems in Romania, as it is present in different degrees on 6.3 millions ha. This, together with the landslides affecting about 0.7 millions ha cause up to 41.5 t/ha/annually soil losses. Romania has an agricultural area of 13.906 millions hectares. Rural areas in Romania cover 87.1% of the territory, and include 45.1% of the population i.e. 9.7 million inhabitants. Majority of soils are of good quality, but soil erosion, drought, negative balance of water in soil or acidification, alkalinity and compaction affect a lot the fertility. (NEDELCU et al, 2008)

Total erosion on agricultural land in Romania is shown in Figure 3.

Assessing the human influence on the natural flow of water on slopes and in watercourses is very important, given that there are currently rapid environmental changes over large areas, through: complex development of river basins, forest development or massive deforestation, the extension of agricultural crops on practically unused lands, the extension of the dried and irrigated perimeters on an industrial scale, the chemicalization of agriculture, the multiplication and extension of the industrial platforms, the fast pace of urbanization of the localities etc. (MITTAL et al, 2015)

Soil erosion is a very complicated problem as many complex factors affect the rate of erosion and therefore it is difficult to solve. Estimation of soil losses and modeling of hydric soil erosion is important to understanding the processes governing soil erosion, predicting runoff and soil erosion rates, and identifying or choosing adequate measures of erosion control.

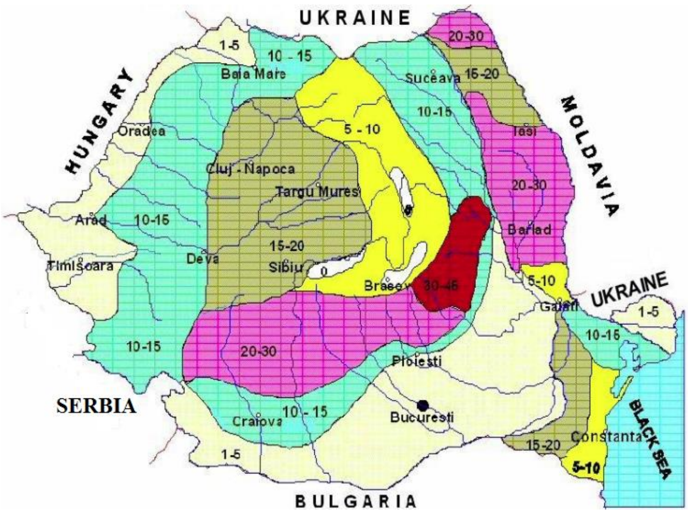

Figure 3. Total erosion on agricultural land in Romania in tonnes/ha/year (MOTOC, 1983)

The current state of theoretical knowledge and mathematical modeling of soil erosion, alluvial transport processes and their effects on the hydrographic space is not very developed, due to the multitude of factors that influence each other, as well as the extraordinary diversity of concrete conditions in nature in which such processes occur.

However, numerical simulation models that have emerged in recent decades allow some results to be obtained with practical utility. It is known that morphological changes are of interest on a much larger time scale (relative to the scale of the flow process) and have less variability in space and time. In numerical simulation, various semi-empirical formulas can be used, which can be calibrated using measurements, and the results obtained can be analyzed comparatively. All these allow to form a relatively precise image both on the qualitative aspects and on some quantitative elements related to a given study problem.

MATERIAL AND METHODS

The easiest model to use for calculus of soil loss due to surface soil erosion by runoff is Wischmeier formula (1960). (POPOVICI, 1991; BICOV, 1978)

The model equation is:

$$E_s = K_a \cdot K \cdot C \cdot P \cdot L^m \cdot S^n$$

where: E_s – (t/ha.an) annual average soil loss through surface soil erosion; K_a – pluvial aggressivity, with values ranging from 0.08 to 0.16; K – erodibility coefficient of soil, with values ranging from 0.6 to 1.2, obtained according to the erosion grade, soil type and soil texture; C – cropping management factor, with values ranging from 0.001 to 1.6; P – conservation practice factor, with values ranging from 0.15 to 1; L – (m) slope length; S – (%) average slope of land; m – exponent for length, with values ranging from 0.3 to 0.4; n – exponent for slope, with values ranging from 1.35 to 1.45.

Areas of application of this model are:
- small areas, less than 10 km^2 (for satisfactory accuracy);
- the studied surface must be divided into relatively homogeneous surfaces, with the same characteristics; for each of these surfaces the 8 parameters must be determined which intervene in calculations;
- applies to surfaces with a slope of less than 25% and length of slopes $L \leq 400$ m.

For soil loss volume estimation on the entire small river catchment was used SURFER program, developed by Golden Software from USA, a leading provider of scientific graphics software, specializing in the development of software that transforms both simple and complex data into understandable visual tools such as maps, graphs and models.

SURFER is a powerful informatic tool for contouring, gridding, and surface mapping used by scientists, engineers and educators for generate maps quickly and easily. SURFER is a grid-based mapping software that interpolates irregularly spaced XYZ data into a regularly spaced grid. The surfaces are modeled on the basis of topographical coordinates (x, y, z). SURFER map types are: contour; base; post; 3D surface; color relief; classed post; 3D wireframe; peaks and depressions; 1-grid vector; 2-grid vector; watershed; grid value; viewshed; point cloud.

The software needs the discretization of studied area, determination of coordinates x, y and z in the grid node. The form of the land surface between the points of discretization grid is determined by means of the following gridding methods (such as the obtained form of surface to draw near reality): polynomial regression, inverse distance to a power, kriging, minimum curvature, modified Shepard's method, triangulation with line, natural neighbor, nearest neighbor, Spline functions etc.

At the sometime, with the help of SURFER, we can calculate the volume of natural and artificial lakes (reservoirs), based on the knowledge of topography of lakes basins and water level; the volume of soil loss through erosion; we can predict the hillslopes forms after a few years, if the erosion rate is constant. (GOLDEN SOFTWARE, 2014; GOLDEN SOFTWARE, 2021)

Description of studied small river catchment

The studied small river catchment is located in Mănăştiur hydrographical basin – is situated in the depression between Zărandului and Poiana Ruscăi mountains, at the crossover line between Lipova Plateau and Occidental Field. Torrential fluviatile erosion, like hillslope erosion, are the factors that contributed to recording of mainly morphological terracing. The Bega River tributaries (Topla, Padurani and Bunea) have their springs in higher areas and have had the possibilities to fragmentation and modulation of terraces.

In this way was form erosion valleys with more or less inclinated hillslopes, as numerous zones with ravines, isolated appear landslides. Erosion valleys are narrow, temporary with water and silt with fine-medium materials. Terraces corridors are regularly narrow, generally parallels, thanks to parallelism of separation valleys.

The hillslopes have in generally a complex profiles, with slope between 2 – 50 %. Ravines are frequently on hillslopes with high and medium slopes, landslides are isolated, on small areas.

Erosion processes emphasized on hillslopes with exposition to south, south –east and south-west these processes are increase in intensity thanks to land use for agriculture, beside to land use for pasture or hay field. To appearance of soil deep erosion contributes also the irrational human intervention (emphasized deforestation and unjustified soil turning). (OSPA, 1982)

In Figure 4 can be seen the situation plan of studied catchment and in Figure 5 is shown the small river catchment with contour lines. (GOOGLE EARTH, 2021)

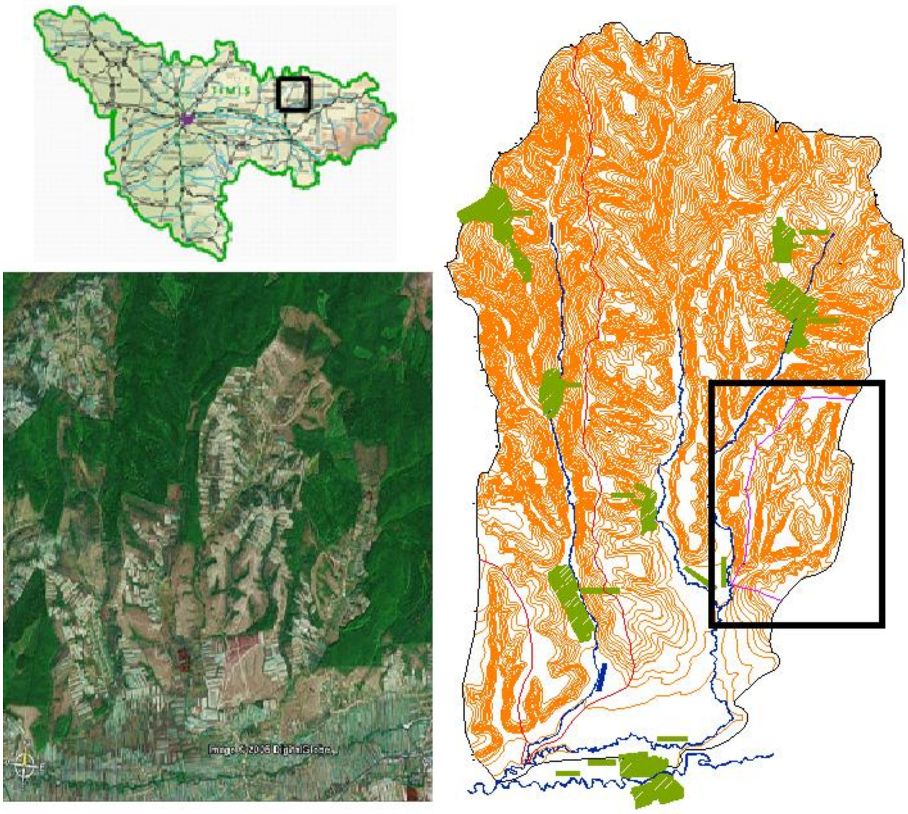

Figure 4. The situation plan

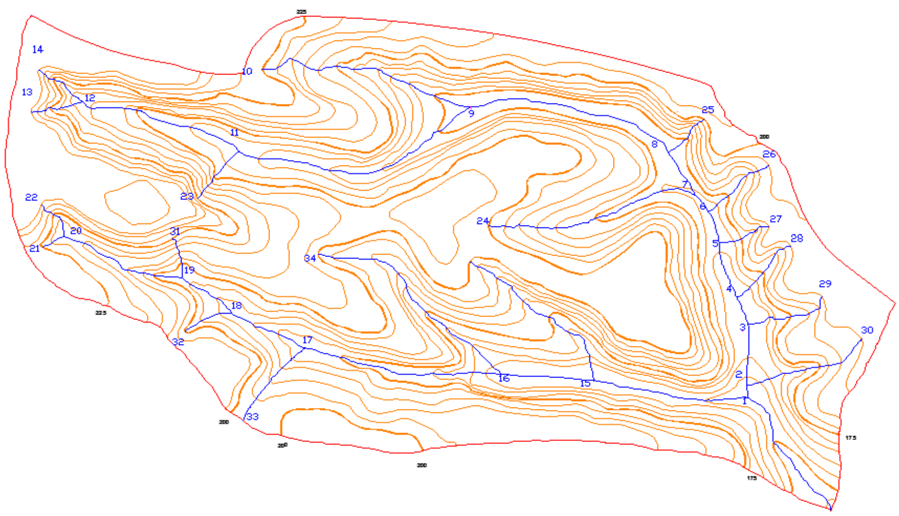

Figure 5. The small river catchment with contour lines

Calculus stages of soil loss volume estimation:

1. Demarcation of entire studied hydrographic basin with identification of valeys (Figure 5).
2. Delimitation of small hydrographic basins corresponding for each valley (Figure 6).
3. Determination of input data for SURFER (domain discretisation – point coordinates, levels etc.) (Figures 7, 8, 9, 10 and 11).

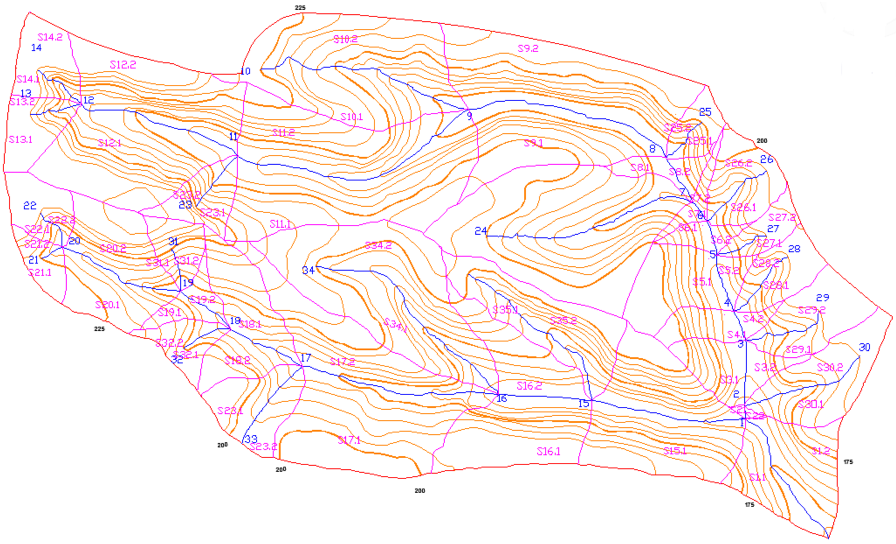

Figure 6. Delimitation of small hydrographic basins corresponding for each valley

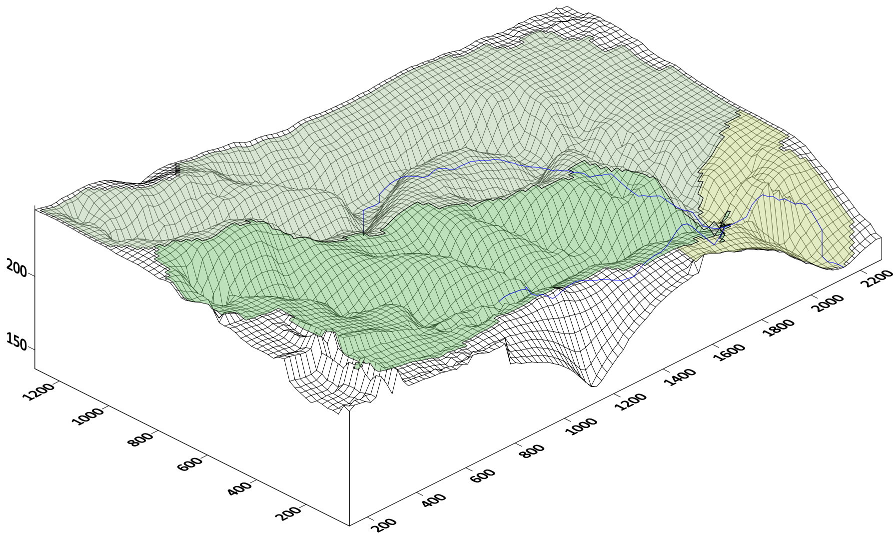

Figure 7. Domain discretization and catchment delimitation 3D in SURFER

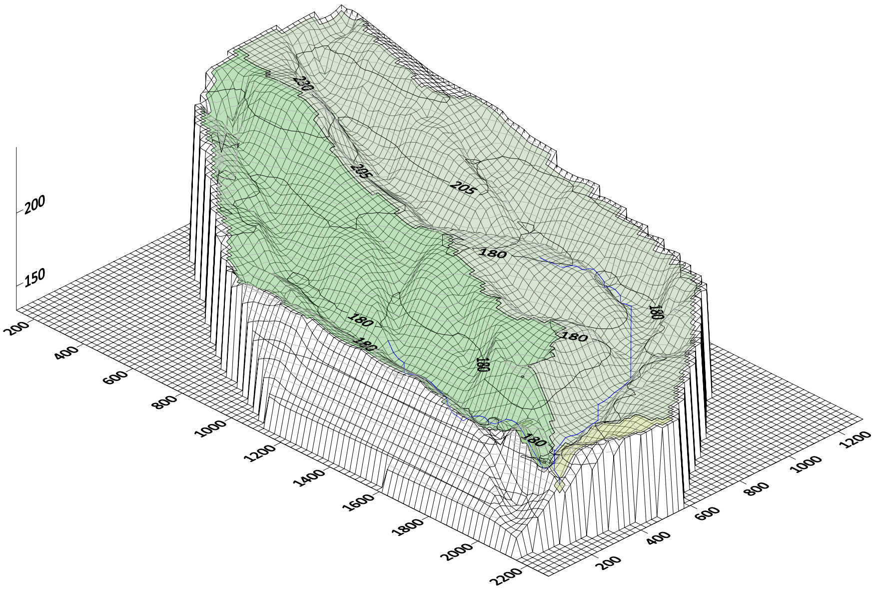

Figure 8. Domain boundary 3D in SURFER

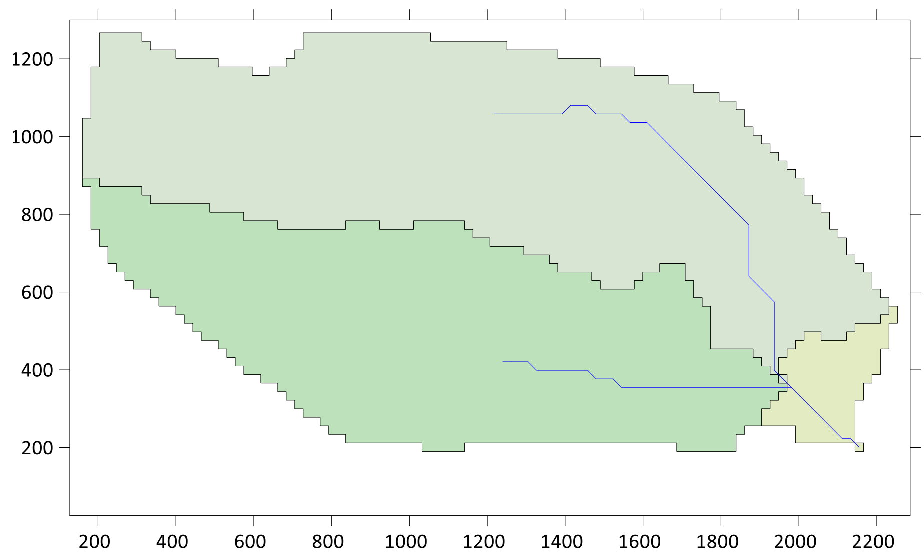

Figure 9. Catchment area plan in SURFER

4. Calculus of eroded soil depth from hillslopes, due to surface hydric erosion (for each hillslopes, with Wischmeier formula). This stage consist in determination / establishment all of parameters which determine the solid flow. (BICOV et al, 1988)

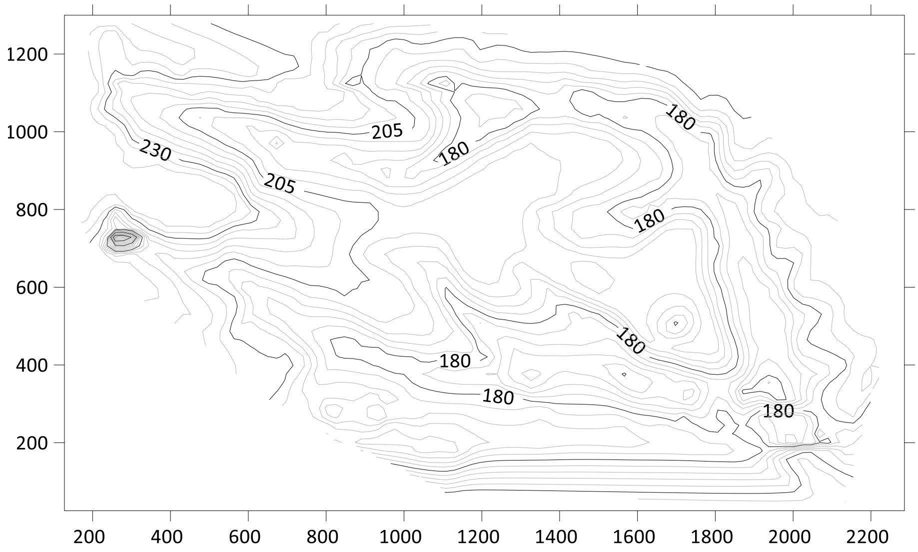

Figure 10. Contour levels in SURFER

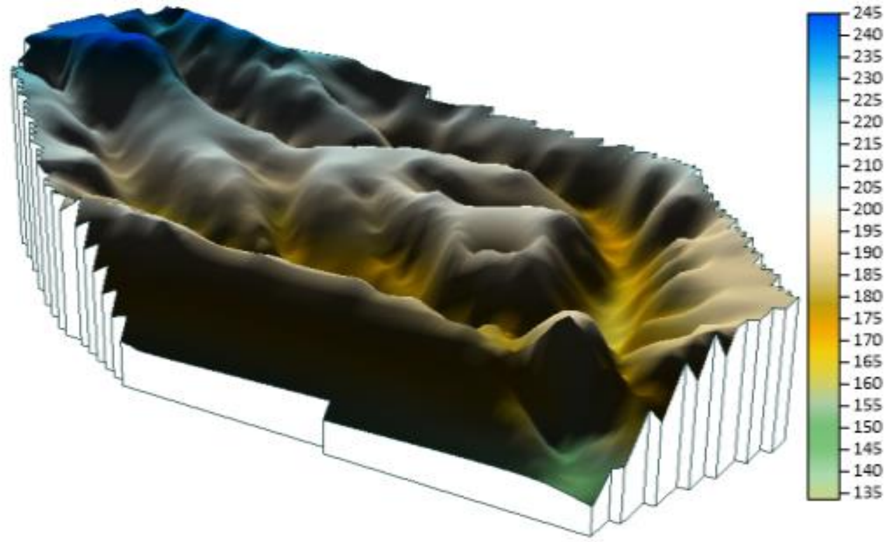

Figure 11. Color map 3D in SURFER

5. Calculus of solid flow volumes from hillslopes (during 1 and 10 years) with SURFER program run, in the following variants of arrangements (measures):
- inexistent soil erosion control practice and erosion diminution works;
- agricultural works executed after level curves direction;
- achievement of inclined earth channels for overland flow collection and elimination from hillslopes.

RESULTS AND DISCUSSION

Following the application of the Wischmeier formula and the simulation with the SURFER program, the lost volumes of soil from the small river catchment resulted in the 3 variants, for 1 year and 10 years, shown in Table 1.

Table 1

Solid flow volume

Variants / Indicators	Inexistent soil erosion control practice and erosion diminution works		Agricultural works executed after level curves direction		Earth channels	
	1 year	10 years	1 year	10 years	1 year	10 years
Solid flow volume (m^3)	4670.475	46704.750	4053.031	40401.735	810.412	8078.405

The differences in percentages can be seen in Table 2.

Table 2

Soil losses volumes differences in percentages

Variants	1 year	10 years
Inexistent soil erosion control practice and erosion diminution works	4670.475 m^3	46704.750 m^3
Agricultural worksexecuted after level curves direction	- 13.22 %	- 13.49 %
Earth channels	- 82.65 %	- 82.70 %

It is observed that the most effective measures for reducing soil losses by washing the surfaces of the hillslopes by surface runoff are the hydrotechnical works.

CONCLUSIONS

Through described method can estimate of soil losses in small river catchments, in different scenarios of land management. The advantage of modeling methods is that they can adapt relatively quickly to different land management scenarios. Their disadvantage is that they require extensive hydrological, pedological and mapping studies, to obtain results as close as possible to reality.

On the ground of obtained results can establish land management, with take in consideration the present situation and perspectives of zones and to fall in with the interest all of important factors (human factor, environment, economic factor etc.). Also, the specialists can establish the economical and technically efficient solid flow control measures and works (agrotechnical, forest, hydrotechnical measures; structural and non – structural measures).

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