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GIS-BASED WATER EROSION MODELLING: THE CASE OF HIGH SLOPE WATER CATCHMENT AREA, ROMANIA

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Abstract

This paper shows the results of a series of hydrographic simulations by mathematical modelling of the erosion phenomenon. The main goal is to show the importance of using the GIS technique to analyse the erosion process. Our research uses several well-known mathematical models and GIS software. Mathematical modelling was performed with the USLE model running under Geo-Graph software and the WEPP model running under ArcGIS 9.2 software. The multitude of factors involved in modelling and especially their spatialization is the main argument for choosing these two models. Finally, in order to be able to compare the results, in both cases the erosion simulation was conducted in the same hydrographic area, under the same geographical, climatic, pedological and relief conditions. The research focuses on a location with steep slopes affected by significant soil degradation processes.

This paper used five input parameters in the simulation process using the USLE model: daily weather forecasting, vegetation or food growing management, land and soil topography. The model is based on daily regulates the hydrological state of the tested soils. Since climate change has had a major impact on soil erosion, the WEEP model has proven to be an efficient tool in erosion modelling, as it allows the entry of a large set of climate data. The WEEP model has also been used worldwide due to its ability to accept a multitude of data sets of soil characteristics. In the present case, in our research, the USLE model was used first, being launched before WEEP, as it has been used worldwide, but the results obtained with the WEEP model were good in almost all our simulations. The main results of this phase of our research show that the erosion is significant and exceeds acceptable limits. Therefore, in conclusion, major support practice actions and an appropriate agricultural practice are recommended to mitigate the effects of erosion process.

Key words: GIS, modelling, runoff, soil topography, water erosion

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1. Introduction

Along with other soil degradation processes, erosion contributes to the continuous contraction of the world's agricultural land, while the dramatic increase in population worldwide requires special measures for natural resources preservation. (Burrough, 1988). One third of the ground surface worldwide is in an acute state of degradation. The fertile soil loss rate amounts to 24 billion tons per year. In Romania, this process is intensified by both natural factors (relief, climate) and anthropogenic factors due to negative human action.

In Romania, the annual soil losses due to erosion range from 3.2 to 41.5 t/ha/year, while tolerable losses are as high as 3 to 6 t/ha/year, and about 150 million tons of soil, containing about 1.5 million tons of humus, 0.45 million tons of N, P, K, are lost on the entire agricultural land each year (Biali et al., 2014; Bilasco et al., 2018; Niacsu, 2012).

The risk of erosion can be estimated using an expert system (qualitative) or a model (quantitative)

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approach). Over the last decade, a series of initiatives have been developed to assess the risk of soil erosion at country, European and global levels. The methodologies to assess the risk of erosion are: USLE, CORINE, RIVM, GLASOD, EEAPESERA and others (Biali et al., 2019; Irimus et al., 2017).

As a result of recent studies, the scientific community has developed and extended the concept of DPSIR (Driver, Pressure, State, Impact & Response) for environmental changes (Berghoff et al., 2014). The main purpose of this concept was to transform environmental changes into information that is easily accessible for decision makers (DPSIR used by the European Environment Agency) (Haidu and Costea, 2012).

When it comes to erosion, the concept mentioned above ensures a chain of causes and effects determined by this form of degradation, which obviously also involves society in its entirety. When trying to determine and quantify all these factors on a case-by-case basis, the first step is to try to estimate the risk. The determining forces of erosion are: human population, land development, tourism, agriculture, transport, natural events and climate changes.

The pressure factors are: the degree and type of land coverage and climate changes. The pressure factors act as indicators that provide information regarding the *stage* (degree) of erosion and the *impact* of (direct or indirect) changes determined by erosion on certain systems (e.g. soil characteristics, biodiversity, etc.), to which the society will *respond* with a series of rules, policies or certain behaviours (strategies of conservation) (Biali and Cojocaru, 2018).

Observing and measuring the factors that influence the susceptibility to erosion (the so-called factorial approach) is a way to determine and classify surfaces at risk of erosion. The measurement indicators generally characterize climatic conditions, soil, topography, etc. The positioning of these indicators on the map results in the drawing up of maps presenting the risk of erosion. The accuracy of the data used obviously contributes to achieving quality results, but the advantage of using the GIS technique on large areas consists of integrating these data into different mathematical-hydrological modelling patterns. However, sometimes the algorithms used to integrate these data have some shortcomings and thus simulation errors occur.

Comparisons are therefore necessary. This type of methodology deduces the risk of erosion from the current stage reached by this form of soil degradation in a specific area. Expert-type analyses estimate the risk of erosion directly from field observations and/or satellite images and aerial photography. Characteristics such as: the aerial extension and coverage of gutters, ravines and sediments deposited are parameters that ensure a real indication of the level of erosion, apart from the measurements made at plot-level in order to determine the intensity of erosion (Dumitrescu et al., 2014).

In order to derive erosion risk estimations at a national scale, experts can be consulted through surveys. A quick and easy way to estimate an erosion risk in a particular area may be the expert approach method. In this case, the experts are consulted through surveys.

A computer application creates a database that allows drawing conclusions, especially where there are uncertainties or the results are not clear from the very beginning. Such an approach is exemplified by the GLASOD Global Assessment of Soil Degradation (Fig. 1), of the UNEP project (United Nations Environment Programme).

It is based on the answers to a survey sent to renowned experts in different countries and thus depends largely on a set of expert-type analyses.

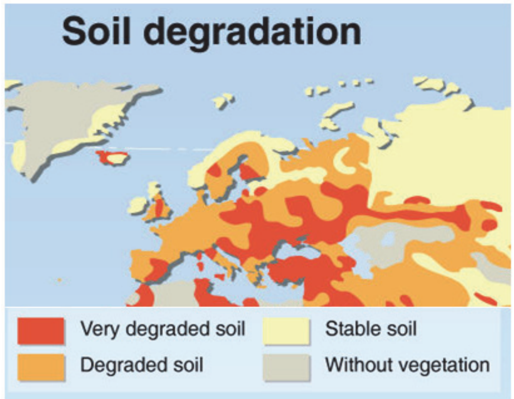


Fig. 1. Water erosion of soils in according to the GLASOD approach Source: United Nations Environmental Programme – GRID (https://seos-project.eu/resources/resources-c01-s01.html)

The GLASOD map can be used by: international decision makers, national decision makers, international programs and conventions, researchers, at national and international level, universities, professors and students, environmental organizations (public awareness), etc. The disadvantages of using the GLASOD map are: small scale, expert assessment (qualitative and potentially subjective), limited number of attributes, only the dominant type of degradation is represented by colour, etc. The data shown in Fig.1 are general but they suggest that Romania is positioned in an area of significant soil erosion.

The map of Western Europe presenting the risk of soil erosion is another example of such an expert-type approach. The map was drawn up by various experts who have outlined the areas that affected by erosion processes.

2. Material and methods

2.1. An empirical approach to estimate erosion

The sediment balance is the final product of erosion through the action of water and other agents.

The total volume of eroded material within a hydrographic basin constitutes the gross or total erosion. From this quantity, only a part enters the hydrographic network. A part of the material is deposited at the base of slopes in the form of alluvial cones, or in the major riverbeds in the form of alluvial ridges or fields. The quantity of eroded material transported through the hydrographic network is known as solid runoff.

In order to assess the risk of soil erosion, it is necessary to map and analyze many factors involved in the erosion process: aggressiveness of rainfall, steepness and length of slopes, erodibility of soil, vegetation and agricultural practices. Each factor has a different behavior from one area of the region to the next. A great deal of data to be mapped, stored, structured and processed rationally is thus collected.

The majority of the empirical approaches for estimating the rate of erosion are based on the following methods (Wischmeier and Smith, 1978):

1) The Universal Soil Loss Equation (USLE) or one of its amendments;

2) Sediment production calculation as a function of the receiving surface;

3) Sediment production calculation as a function of runoff characteristics.

The empirical modelling of erosion, in this case, applying the USLE model, implies a series of intrinsic limitations, which derive from the specificity of the model:

- model is only applicable to planar, not linear erosion;
- model was tested on plain and hill regions with slopes of 5 – 25 %;
- relation between kinetic energy and precipitation intensity;
- model is applicable only for calculating the average values of soil losses for time frames over 20 years and is not applicable to unique events;
- neglects some interactions between factors, so it is difficult to distinguish the role of each of them.

The model represents a multiplicative function of six hydrological factors (Eq. 1): climate aggression, soil erodibility, steepness and length of slopes, vegetation coverage and support practices:

$$A = R \cdot K \cdot LS \cdot C \cdot P \tag{1}$$

A–annual rate of soil erosion, ($t \cdot ha^{-1} \cdot year^{-1}$); *R* – rainfall erosivity (energy factor), ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot year^{-1}$); *K*–soil erodibility–depends on soil granulometry, on the quantity of organic matter in soil, soil permeability and structure, ($t \cdot ha^{-1} \cdot h^{-1} \cdot MJ^{-1} \cdot mm^{-1}$); *LS*–relief factor, dependent on the length and inclination of the slopes, dimensionless; *C* - vegetation cover factor, dimensionless; *P* – support practices factor, dimensionless (Wischmeier and Smith, 1978).

Factors R, K and C are usually determined within field research over several years in order to assess annual climate variations, requiring major time and resource investments. Empirical equations are developed using data collected from specific geographical areas, and for this reason, the use of these equations is limited to the given areas. Consequently, several attempts have been made to change or adapt models such as USLE in order to adjust them to other conditions than those of the central and eastern United States, for which they were created. Applying the USLE model required assessing a variety of factors of the equation for the entire surface of the area studied and expressing them in the form of thematic maps. These maps were integrated in Geo-Graph GIS through the process of map digitizing. The polygons obtained for each map have their own attributive databases. The maps were overlapped using Raster Map Calculator in ArcGIS (Niacsu et al., 2015).

Among the six factors, rainfall erosivity and vegetation cover have a great variability during the year. Thus, data regarding rainfall erosivity combined with data regarding the vegetation layer and agricultural practices can be used to research soil erosion at different scales. Intra-annual variations in rainfall erosivity affect agriculture, forestry, water management and ecosystem services. Consequently, neglecting intra-annual variability of rainfall erosivity can lead to inappropriate decision-making (Wischmeier and Smith, 1978).

2.2. Expert systems

An expert system (ES) is a complex app (a software program) that explores a great deal of knowledge in order to draw new conclusions about activities that are difficult to examine, using methods similar to human experts (Popita et al., 2014).

About multi-criteria analysis, applying Geographic Information Systems (GIS) allows to manage information efficiently and to facilitate the integration of multiple layers of data with various analysis procedures. Integrating Risk Analysis, using Geographic Information Systems, with Multi-Criteria Evaluation (MCE) and with Analytic Hierarchy Process (AHP) is probably the most appropriate method to solve complex problems regarding: natural and anthropic risk distribution, land use, spatial planning, etc (Clinciu et al., 2010).

The Weighted Linear Combination (WLC) of map layers within the AHP is a strategy to evaluate multi-criteria decision-making problems. The WLC applies Eq. (2):

$$E = \sum_{i=1}^{n} W_i \cdot V_i \tag{2}$$

where: *Wi* - the importance/relative weight of factors/parameters; *Vi* - the relative weight of parameters i; *n* - number of parameters.

In order to integrate geographic data and preferences/knowledge of decision makers into a single value, the Analytic Hierarchy Process (AHP), developed by (Moore and Wilson, 1992), is used. It is a mathematical instrument used for the systemic analysis of complex decision-making problems. AHP is not a "correct" decision-making instrument in itself; it only allows to find, among a multitude of alternatives, one solution that corresponds, to a large extent, to the way the researcher understands to solve a given problem (Biali et al., 2018; Iacobescu et al., 2012). The program solutions implemented in GIS compare the map layers taking them two by two and determine the weight values of each. In this manner, the decision makers can select the right result by defining a hierarchy for a complex problem.

In this work, the risk of erosion was analyzed for the study area for five data sets at input (Fig. 2). In the first phase, the weights of the layers (factors/criteria) were calculated using AHP, then the map of the potential distribution of the risk was generated using the WLC (Weighted Linear Combination) analysis. For this purpose, the AHP extension for the ArcGIS program was applied for WEPP model (Cochrane and Flanagan, 1999). The WEEP (Water Erosion Prediction Project) model was developed within the USDA/ARS-USA. It was originally presented in 1990 and has evolved continuously. It is a computerized model based on a new technology for predicting soil erosion by water, taking into account the laws of water infiltration and percolation, soil physics, hydraulics and erosion and runoff mechanisms, and the grounds of agricultural plant growing science (Cochrane and Flanagan, 1999).

This model aims to determine the hydrological parameters and the erosion potential of runoff on different areas of a slope, in various conditions of land use and in the presence of a variety of agricultural practices (Biali and Cojocaru, 2020).

The two models (USLE and WEEP) have been tested for a long time in the USA, Europe and Romania and the results confirm that both models are reliable and can be used successfully (Moţoc, 2002; Renard et al., 1997; Wischmeier and Smith, 1978).

The main input/output data of the WEPP model are present in Fig. 2.

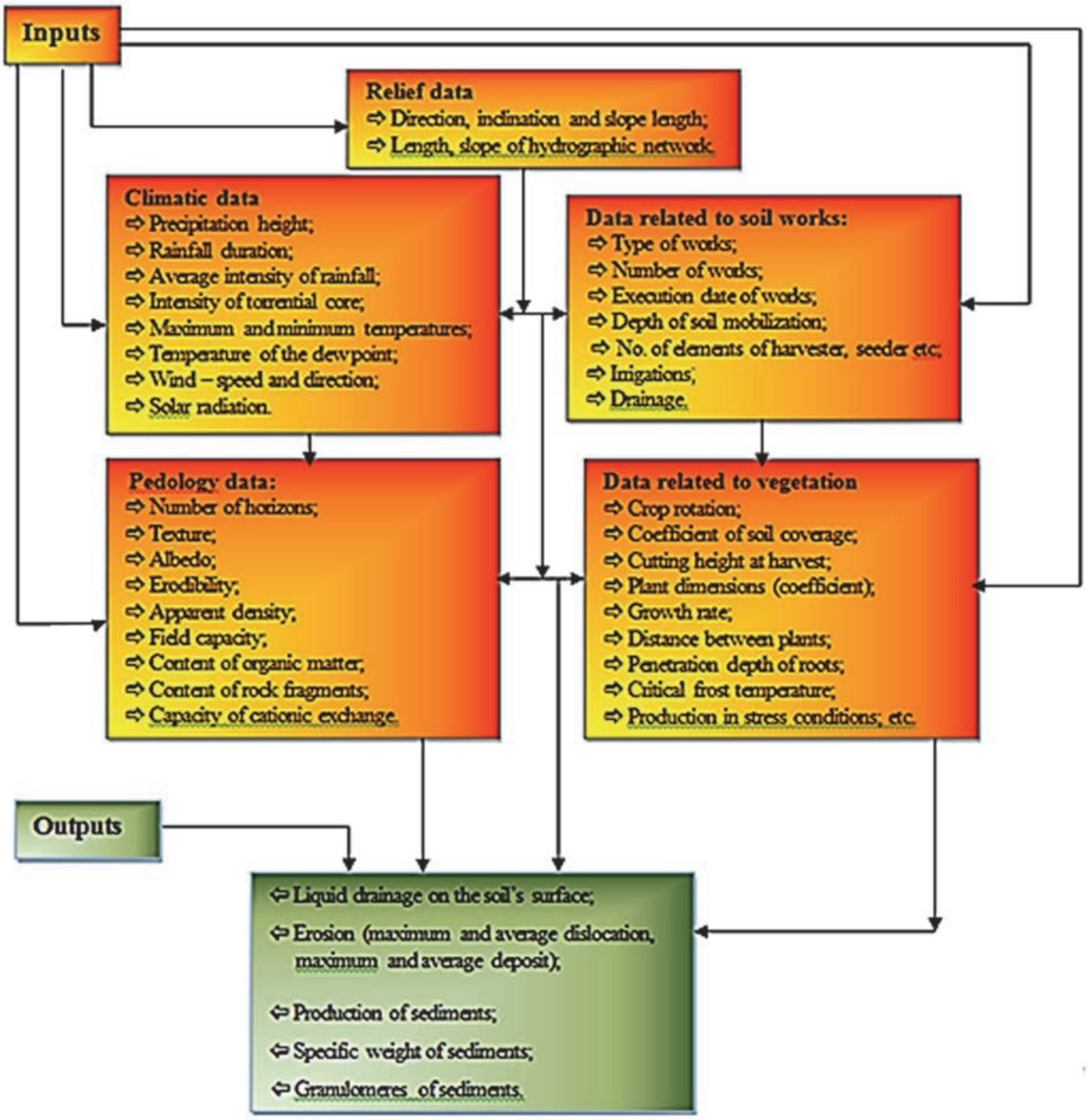


Fig. 2. The main input/output parameters of the WEPP model (Cochrane and Flanagan, 1999)

The WEEP and USLE models are among the most common in the world and they are used to simulate water-caused erosion. The research in this paper simultaneously uses WEEP simulation and the USLE model to make a comparative result analysis. The input parameters are different but erosion quantification by simulation provides the same information.

3. Results and discussion

3.1. Localization of research

Our research location has the following characteristics: the land has an area of 1,107 ha and is located in the Ghilavesti river basin, in the upper Berheci basin, in Tutovei Hills in Bacau County, in the North-Eastern part of Romania (Fig. 3).

This location was chosen for our research first of all due to the relief factor: the relief is very fragmented, with forms of deep erosion, with a relief energy of over 270 m, the average slopes have high values of over 18%. From a climatic point of view, the studied land is located in an area of Romania with high rainfall aggressiveness, where the rainfall aggression coefficient is higher than 0.100. The predominant soils in the studied river basin are chernozems and brown soils, which generally fall into high erodibility categories. The land is mainly arable land and pastures. Some of this land is affected by significant gullying and landslide processes (Biali et al., 2014).

3.2. Modelling erosion by USLE with Geo-Graph GIS

The USLE model has been modified and adapted according to the specific factors that trigger and maintain the erosion process on the Romanian territory. This model was developed by researchers from the Institute of Pedology and Agrochemical Research in Bucharest (Moţoc, 2002).

3.2.1. Rainfall aggressiveness (pluvial erosion - R)

Rainfall characteristics (R on Eq. 1) such as: frequency, duration, quantity, intensity and kinetic energy play important roles in soil erosion by water.

The R factor in the general formula USLE is recognized as being one of the most adequate parameters to predict the erosive potential of raindrops and of the potential capacity of transporting rainfall runoff, respectively. At the regional level, data on climate erosion can be used as an indicator of the potential risk of erosion. The R factor does not take into account soil losses due to melting snow, ice or to the action of the wind.

Often, the only data freely available on rainfall are the monthly and annual averages. Some authors (Ioniță et al., 2014) have developed alternative formulas that only involve monthly and/or annual average rainfall in the calculation to determine the R factor. The calculation relation R (Eq. 3) is entered in the calculation module r.usler.

$$R = \sum_{i=1}^{n} r_i \qquad (3)$$

For data on rainfall, the raster of the average annual rainfall level was used. Using the *r.usler* module, R factor maps were calculated (Fig. 4).

Runoff concentration values represent the "receiving basin" from which liquid and solid runoff is accumulated (Fig. 5). Therefore, the higher the value of a cell, the more it is assumed that a larger amount of water and sediment, respectively, will pass through it. The flow direction is calculated using two models: the MFD (Multiple Flow Direction) and / or SFD (Single Flow Direction).

3.2.2. Soil erodibility (K)

It is the factor of soil erodibility - namely of its capacity to withstand/undergo erosion. K factor sizes vary between 0.1-0.9. As the value of parameter K increases, the infiltration decreases and the risk of soil erosion increases. It is obtained based on the intrinsic properties of soils, such as texture, structure, organic matter content and measures soil resistance to erosion. It represents the erosion rate determined experimentally under standard conditions.

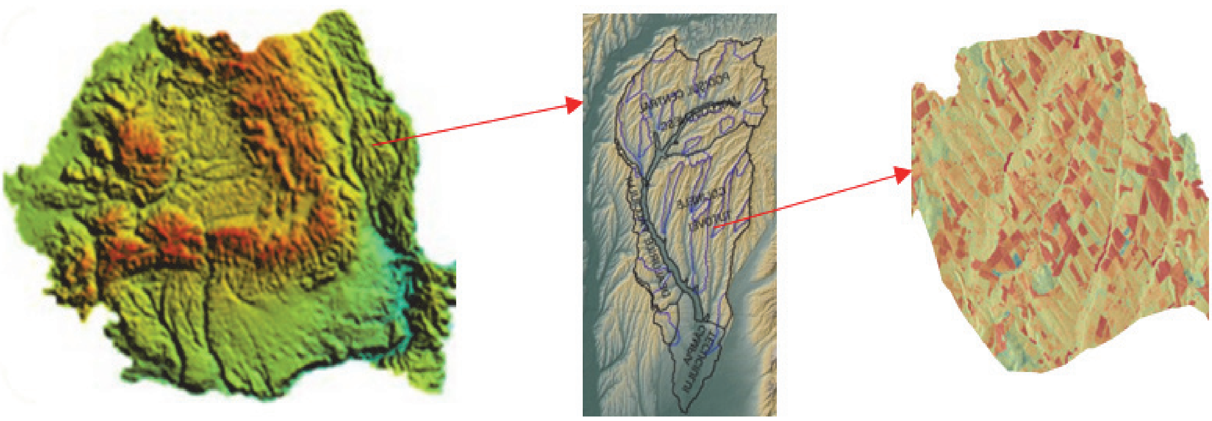


Fig. 3. Location of the study area (Ghilavesti catchment)

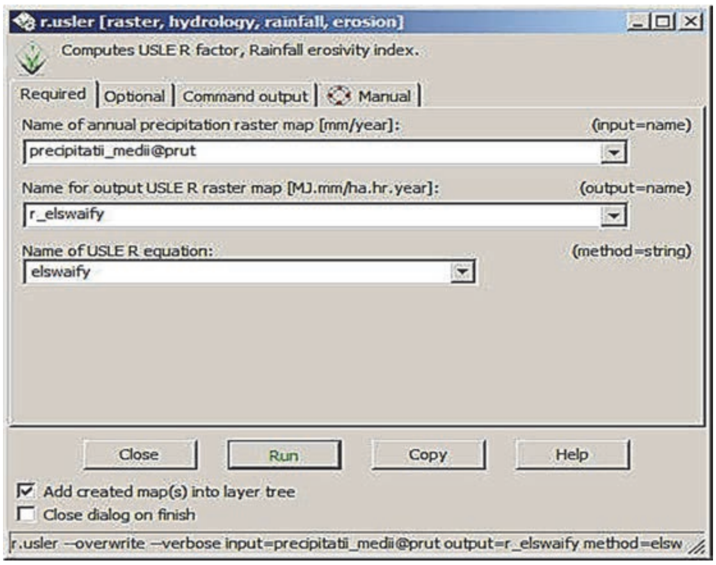
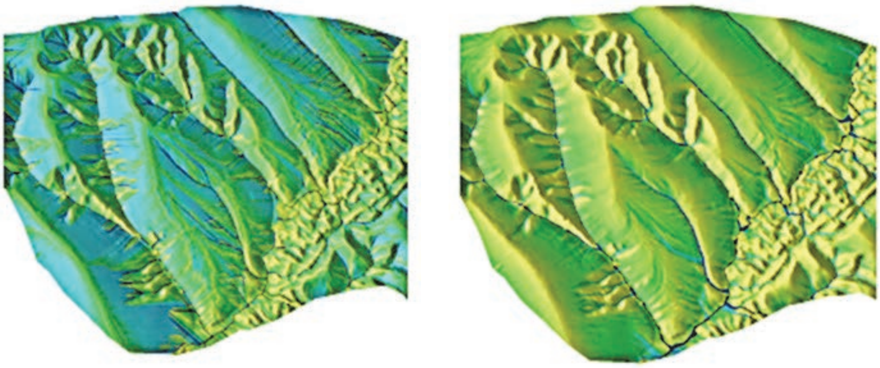


Fig. 4. Graphical interface of the *r.usler* module



(a) (b)

Fig. 5. Runoff accumulation: (a) multiple flow direction; (b) single flow direction

Repeating the experiments under different soil conditions has led to the development of an equation (Eq. 3) to calculate soil erodibility:

$$K = \frac{2.1 \cdot M^{1.14} \cdot 10^{-4}(12-a) + 3.25(b-2) + 2.5(c-3)}{100} \quad (3)$$

where: M-(sand + dust) (100 - clay); a-share of organic matter (%); b-soil structure code; c-soil permeability code.

In order to develop the K factor map, data from the soil map at a scale of 1:10,000 were used. Vector data were converted to raster format in order to be able to be used as input data for the *r.uslek* module, implemented in GIS, used to calculate the soil erosion factor (K) in USLE (Fig. 6). The module input includes the soil texture (psand, pclay, psilt/dust) and organic matter content (pomat) rasters. The input data was the percentage of dust, not silt. These data are available from previous research (Biali et al., 2018; Niacsu et al., 2015). The output raster represented by the soil erodibility factor (K) is determined by running the *r.uslek* module. The spatialization of this parameter (K) is shown in Fig. 7.

3.2.3. Relief factor (LS)

The length of the slope determines the concentration of water - between the two being a direct link (the longer the slope, the more water is concentrated at its base). Furthermore, the steeper the slope, the higher the erosion. The combination of the S and L factors represents the topographic factor (LS). It can be calculated according to the formula of (Eq. 4):

$$LS = \left(\frac{\lambda^t}{22.13}\right) \cdot \left(65.41 \cdot \sin^2 \beta + 4.56 \cdot \sin \beta + 0.0654\right) \quad (4)$$

where: λ - horizontal projection of slope length (m); t - constant depending on the size of the slope (equal to 0.5 for s>5%, 0.4 for 3% < s ≤ 5%, 0.3 for 1% < s ≤ 3%, and 0.2 for s ≤ 1%); β - slope in degrees.

The methods (conventionally called *r.flow*) applied to calculate the LS factor in GIS consists of the following stages:

- using the order *r.flow,* the runoff concentration raster is calculated (*flowacc*)
- using the order *r.slope.aspect,* the slope is calculated (slope)
- using the instrument *r.mapcalc*, the LS factor

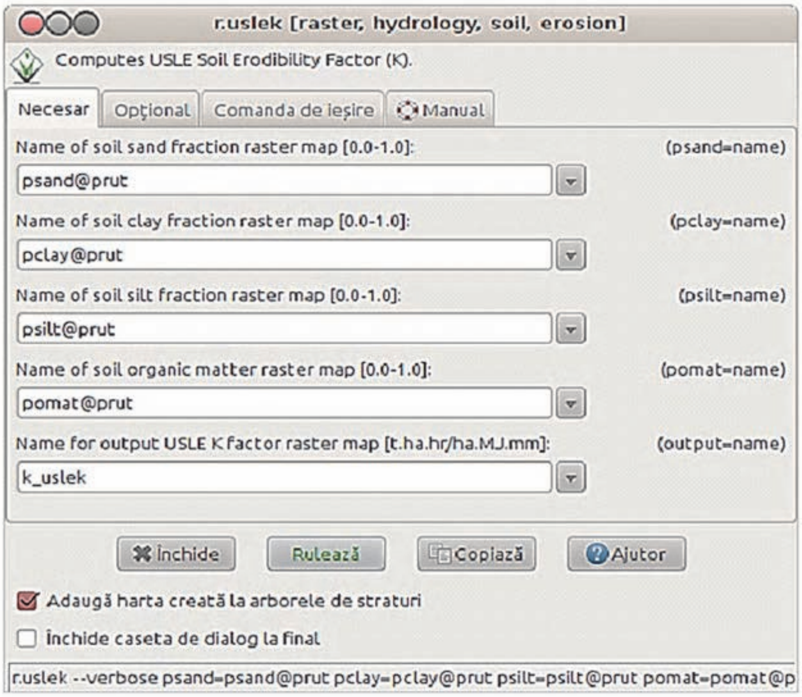


Fig. 6. Graphical interface of the *r.uslek* model

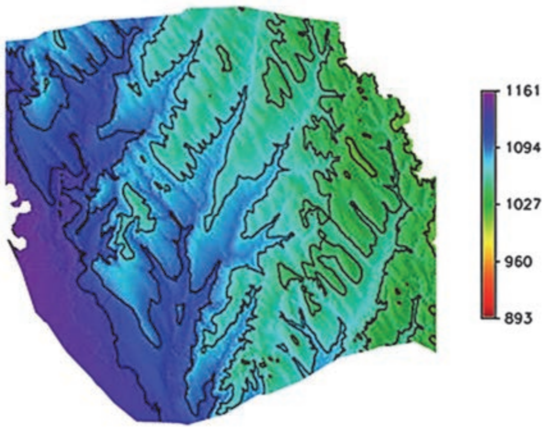


Fig. 7. Soil erodibility (factor K)

The *r.watershed* module in GIS provides a more efficient method to determine the LS factor. It analyses elevation for the purpose of calculating basic hydrological parameters and USLE factors. Thus, raster maps of runoff accumulation, drainage direction, watercourses and hydrographic basins, as well as LS and S factors from the USLE model can be calculated. The LS factor is obtained as a product of two components: the length factor (Fig. 8) and the slope inclination factor (Fig. 9).

Figs. 10-11 present the distributions of LS factor values (ls.r.watershed) within the area studied. First of all, a different structural model of the spatial distribution for the two runoff calculation methods (MFD and SFD) can be noticed. The MFD model results in a more complicated structure, which highlights the drainage pathways, thus serving as an efficient method to determine erosion areas and deposits, respectively, as well as to highlight potential surfaces exposed to linear erosion.

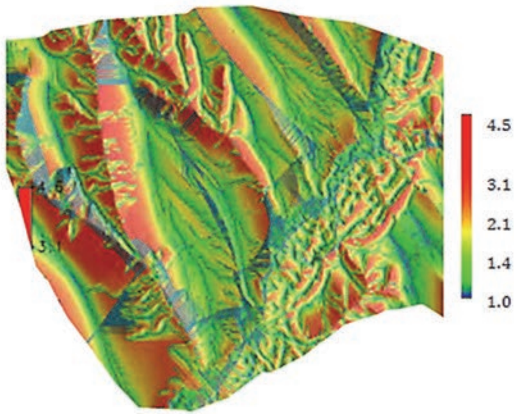


Fig. 8. Slope length factor

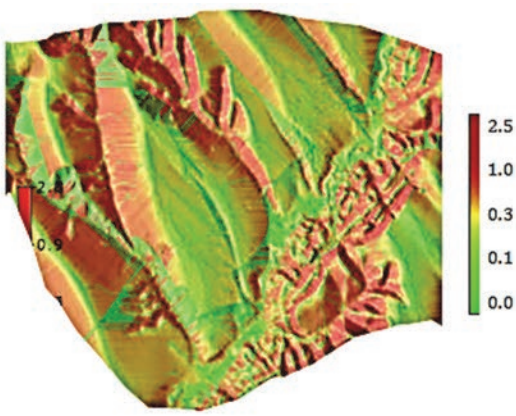


Fig. 9. Slope inclination factor

Moreover, as regards the two methods (SFD and MFD), the statistical analysis shows higher average values for SFD (0.63-0.7) than for MFD (0.29-0.32). Thus, using two methods can result in fairly different results, leading to the overestimation or underestimation of soil losses up to twice as much.

The distribution of LS values is presented in Fig. 9, which also shows the presence of higher values in case of using the SFD method.

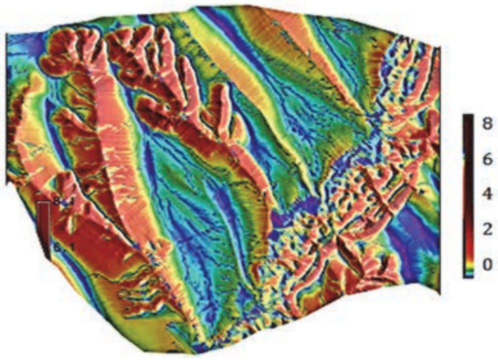


Fig. 10. LS factor (MFD)

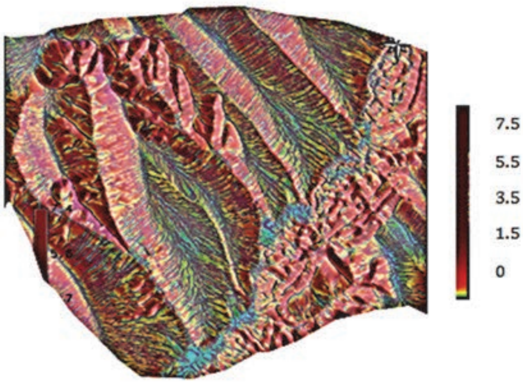


Fig. 11. LS factor (SFD)

3.2.4. Vegetation and management cover (Factor C)

One of the most important factors in the USLE (and RUSLE) equation is the vegetation and management cover factor (C) representing the effect of vegetation and of agricultural practices on soil erosion rates. It also shows the manner in which the erosive potential will be distributed throughout the year, in different agricultural, construction, etc. phases. Factor C represents the influence of vegetation on soil erosion and can take values between 0 - in forests, where due to compact vegetation, erosion is reduced to zero and 1 - in areas uncovered by vegetation, where erosion takes place without the moderating effect of vegetation.

The vegetal layer protects the soil by dissipating the energy of raindrops. Thus, soil erosion can be limited through adequate management techniques. In both models, USLE, the factor C is calculated from empirical equations containing field measurements (Eq.5):

$$C = 1.02 - 1.21 \cdot NDVI \quad (5)$$

NDVI - Normalized Difference Vegetation Index. The spatialization of this parameter (C) is shown in Fig.12.

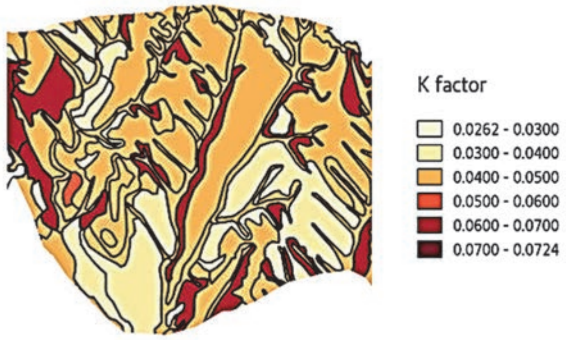


Fig. 12. Vegetation and management cover (factor C)

3.2.5. Support practices (P)

Ploughing and orienting agricultural plots parallel to contours, cultures in alternating strips or on terraces, reforestation, creating mounts and rock ridges are the most effective practices for conserving soil. P factor values are lower than or equal to 1. Value 1 is assigned to lands where no support practices are taken. For the purpose of generating the map layer of the P factor we have used the crop cover/use Map. The database with map attributes in vector format was filled in with the correspondences from interval values 0.05-1.0 (Biali, 2018) for the categories of vegetation cover/use, after which the vector layer of the map was converted to raster format.

3.2.6. Potential annual soil loss (A potential)

Soil loss maps (Figs.13-14) have been generated as a product of map layers representing the factors in the USLE model. Thus, we have generated potential soil loss maps under given conditions of rainfall, soil and relief and estimated soil loss, also taking into account the conditions of vegetation cover/use (Table 1).

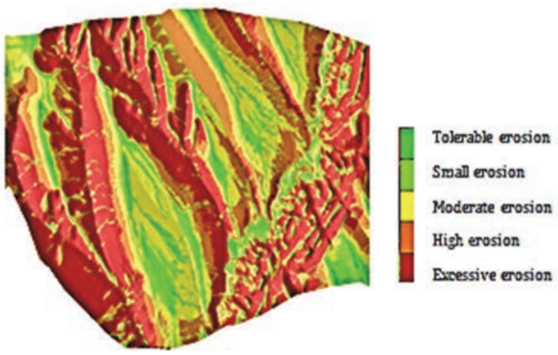


Fig. 13. Potential annual soil loss (MFD)

Potential soil erosion calculated according to the commands used in GIS, (Eq. 6), as a product of rainfall erosivity factors (R), soil erodibility factor (K) and relief factor (LS).

r.mapcalc = r.regresie@prm · k_SI@prm · length.slope.
.mfd.@prm" (6)

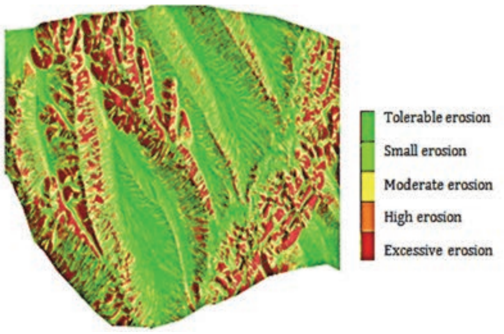


Fig. 14. Potential annual soil loss (SDF)

We have ranked erosion in 5 erosion classes based on our modelling results and SQL query analyses in the output database. The results are shown in Tables 2. We notice a high proportion of high and very high-risk classes for erosion in the case of estimation using the SFD method, compared to the MFD method, where a high proportion is recorded in low-risk classes (Table 2). Soil losses that do not exceed 4-6 ($t \cdot ha^{-1} \cdot year^{-1}$) and that occur over a 50-100 year range can be recovered if the soil has the capacity to recover. Soil losses of more than 10 (t/ha/year) can be irreversible if adequate soil protection actions are not taken.

3.3. Modelling erosion by WEPP with ArcGIS

With WEEP model was used to process sets of spatial and georeferenced data, and some essential parameters in soil losses due to erosion could be determined. The database that we have created allows different variants of erosion process simulation. ArcGIS 9.2 analysis provides a wider range of data on the phenomenon depending on the influence of each parameter. Thus, factors such as soil erodibility, rain aggression factor, positive effects of crops and agricultural practices on land, etc. can be assessed. (Biali et al., 2014).

By comparing the Geo-Graph results using USLE and the GIS analysis results, we noted that the maps looked the same, but the percentages were different (Figs. 16-19).

Table 1. Soil loss tolerance classes (Moţoc, 2002)

Soil erosion class	***Soil erosion type***	***Soil loss*** ($t \cdot ha^{-1} \cdot year^{-1}$)
1	Very small (tolerable)	< 4
2	Small	4.1 – 9.5
3	Moderate	9.5 – 20.0
4	High	20.0 – 40.5
5	Excessive	> 41

Table 2. Proportion of potential erosion classes in the study area

Soil erosion class	***Risk class*** ($t \cdot ha^{-1} \cdot year^{-1}$)	***SFD model***	***MFD model***
1	Unappreciable erosion (<4)	11.04%	9.25%
2	Weak erosion (4-10)	12.27%	13.28%
3	Moderate erosion (10-20)	23.25%	32.61%
4	High erosion (20-40)	31.02%	24.42%
5	Very high/excessive erosion (>40)	22.41%	20.41%

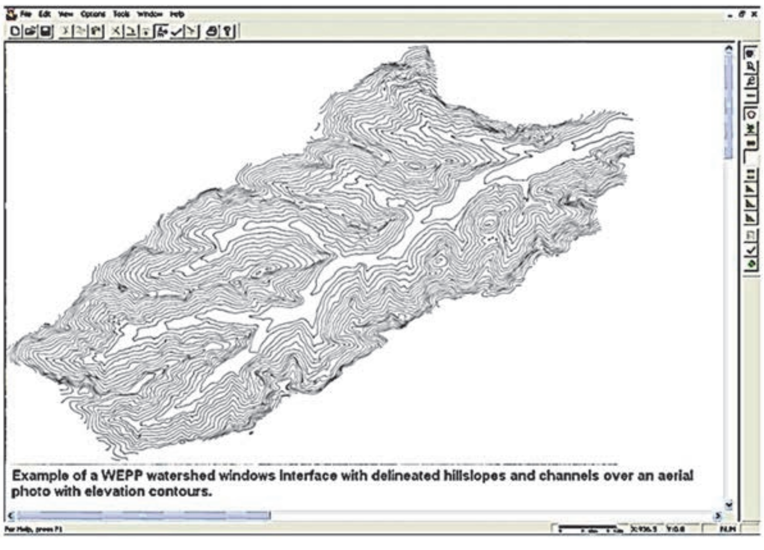


Fig. 15. WEPP watershed window in area studied

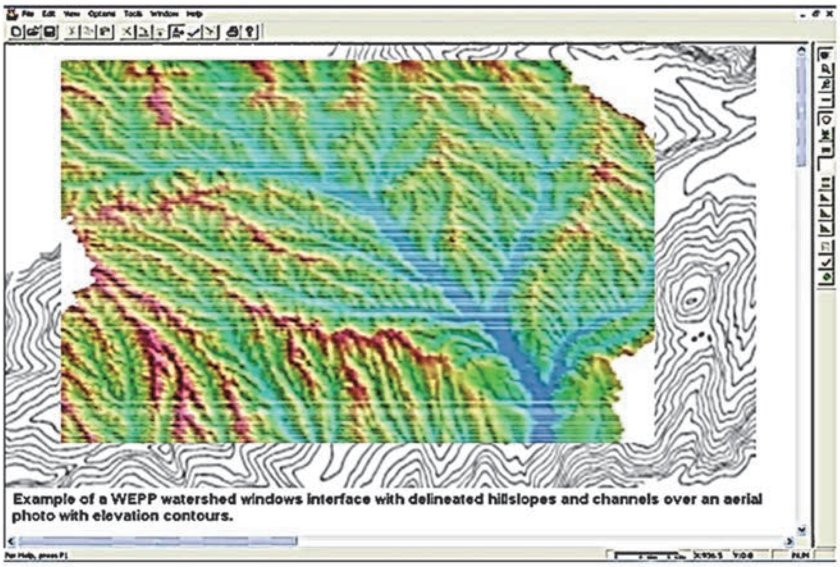


Fig. 16. Slope map (with ArcGIS)

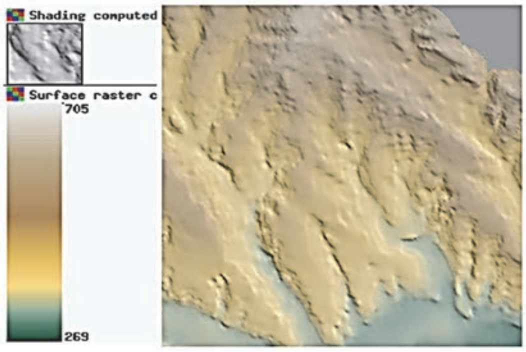


Fig. 17. Hypsometric map (with ArcGIS)

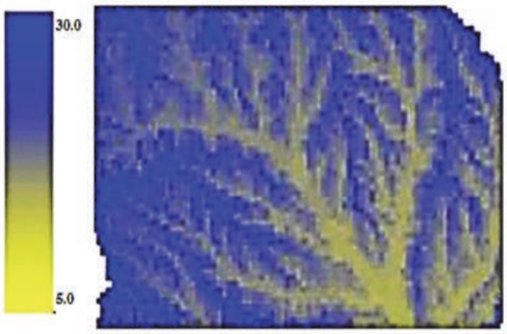


Fig. 18. Runoff concentration (with ArcGIS)

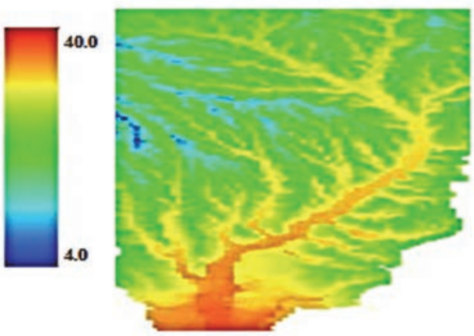


Fig. 19. Annual soil loss map (with ArcGIS)

The results obtained by both methods are similar, as it was predictable the MFD method is closer to the modelling in WEPP. By erosional modelling (both methods), the territory studied falls into the following erosion risk classes: class 1 (unappreciable erosion) - 7.15%; class 2 (weak erosion) - 11.10%; class 3 (moderate erosion) - 31.16%; class 4 (high/severe erosion) - 25.1% and class 5 (very high /excessive erosion) – 25.8%.

The results from both simulations (with USLE and WEEP) show that the erosion is high to excessive. The percentages in Tables 2-3 confirm the vulnerability of the researched area to the degradation processes (Fig. 20).

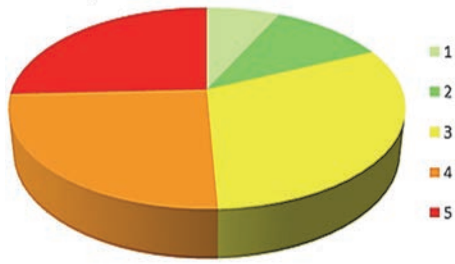


Fig. 20. Diagram of average erosion with the both models (USLE and WEEP)

Table 3. Soil loss tolerance classes in modelling with WEPP

Soil erosion class	***Risk class (Soil loss) (t·ha^{-1}·year^{-1})***	***Percentages of the studied area***
1	Unappreciable erosion (<)4	5.05%
2	Weak erosion (4-10)	8.17%
3	Moderate erosion (10-20)	29.71%
4	High erosion (20-40)	25.78%
5	Very high/excessive erosion (>40)	31.30%

4. Conclusions

1. The novelty of our research consists of the fact that the data sets and databases created may be used in mathematical GIS modelling. This makes it possible to monitor erosion in the same river basin at different times and it allows the detection of changes/modifications in that territory. Based on these changes, methods of agricultural land management may be proposed consisting of anti-erosion practices and works.

2. Hydrological erosion modelling is a greatly researched issued. Currently, researchers have succeeded in diversifying the models of erosion, all based on: various algorithms (empirical, physical), approaches (qualitative, quantitative), characteristics (soil losses, alluvium accumulation) and factors (rainfall, relief, soil, vegetation, land use) of the erosional process, spatial (plot, slope, basin) and temporal scales (single event, average) and forms of erosion (laminar, runoff, ravine, on the bank).

3. The relatively large variability of climatic conditions results in a fairly wide range of rainfall erosion values in the study area, values ranging between 893.4 and 1161.5, at an average of 1058.2 (MJ mm ha^{-1} h^{-1} $year^{-1}$)

4. Relief factor (LS) estimation is of major importance in calculating soil loss; the estimation method used having a primary role as regards the result, which can change even twice. Thus, the SFD method provides results ranging between 0.63 and 0.7, and the MFD method – of only 0.29-0.32. Thus, selecting different algorithms for runoff does not only determine the amplitude of the resulting values but also the model of the spatial distribution of relief factor values.

5. Crop/vegetation and management factors (C) and support practices (P) are real estimation issues, requiring the mapping of vegetation cover/use and support practices arrangements. In this regards, using remote-sensing techniques and photointerpretation of satellite images and aerial photographs, using LiDAR data to create highly accurate numerical models of lands become irreplaceable.

6. Under the conditions in Romania, the soil lost by erosion is recovered through a natural process of pedo-genesis at a rate of 4-7 ($t \cdot ha^{-1} \cdot year^{-1}$). Thus, the studied area presents a major danger of water erosive degradation, it can be saved only by suitable appropriate agrotechnical practices and support practices.

7. In the context of natural and social-economic conditions from Romania, the use of GIS for the analysis and prognosis of land erosion and other associated processes represents a very modern requirement, taking into account the economic grounds and the speed of obtaining the information required for taking the appropriate decisions of improving the situation, in real time.

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