COMPARATIVE ANALYSIS OF THE SOIL EROSION IN HILL BASINS (SĂSĂUŞ AND MISLEA)

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The present study focuses on soil surface erosion and applying the Universal Soil Loss Equation with GIS techniques of spatial analysis on an area of two river basins. The erosion and the processes associated with it are studied with the help of digital terrain data and the USLE and RUSLE models are successfully applied within the area. Soil surface erosion occurs when detachable soils on sufficiently steep slopes are exposed to overland flow and/or the impact of rainfall.

The Universal Soil Loss Equation (USLE) predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices but does not however predict the soil loss resulting from gully erosion. Five major factors are used to calculate the soil loss for a given site. Each factor is the numerical estimation of a specific condition that affects the severity of soil erosion at a particular location.

Key words: *GIS techniques, soil erosion, Universal Soil Loss Equation, Săsăuş River Basin, Mislea River basin.*

Introduction

Addressing and combating soil erosion assessment dates from the third decade of the twentieth century as a reaction against the effects of grubbing and massive deforestation (Iowa State University, 1926). In Europe, only the Austrian and Swedish agriculture has contributed to increase fertility in soils affected by erosion, due to their protective measures, but afterwards entered into decline.

Over time several stages have been revealed in the research models based on physical soil erosion, which allow an adequate and a quantitative estimate, taking into account both erosion and deposition on a regional scale.

During the simple models stage, the obtained results were completed by developing the Universal Soil Loss Equation (USLE), with the contribution of: Cook M. (1936), Zingg M. (1940), Smith R. M. and Whitt (1947), Musgrave W. G. (1947) and Wischmeier W. H. (1955-1958-1972-1976).The development of

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USLE equation was based on a rich database which was statistically processed. Subsequently from USLE several equations were derived, such as: MUSLE, RUSLE etc.

The development stage of empiric mathematical and deterministic models ended up with the elaboration of the following models: RUSLE (1979) that revises the USLE model, ANSWERS (Beasley and others, 1980), EPIC (Williams J. R., 1985), MORGAN (1995), AGNS.

In the stage of deterministic type models, with a physics base, in which the predominance of empirical equations was limited, the following models were noticed: CREAMS (Knisel W. G. and others, 1980 and Foster, 1981), ROSE (1984), LISEM (1984), WEPP (Foster and Lane,1987; Flanagan D., 1991), LANE (1994), EUROSEM (Morgen and others, 1997), EGEM, EROSION-3D, GLEAMS, KINEROS2, MOSES, MWISED, PESERA, SERAE, STREAM, SWAT, WATEM, CAESAR, WILSIM, WATEM, NRCS, etc.

Since the results of the process models WEPP and EUROSEM, weren't always the best compared to USLE or RUSLE, the review and improvement of the existing physical models represent actual lines of interdisciplinary analysis and connecting to experimental data (Morgan and Nearing, 2000).

In Romania, systematic research regarding surface erosion, performed with drainage plots were initiated by Staicu Ir. (1945), followed by Moțoc M. (1956, 1963, 1973, 1979, 1998), Stănescu P. (1979), Ionescu V. (1981), Ene Al. (1987), Savu P. (1980-1985), Ioniță I. (1990-2000), Pujină D. (1991-1998), Popa N. (2000-2009) etc. Along with the standard plot-level experiments (Rădoane N., 1987; Ioniță I., 2000) researches were also carried out on slopes and hydrographical basins, yielding valuable results (Stanescu P., Drăgan Livia, 1970; Moțoc M., Munteanu S., Băloiu V., Stănescu P., Mihai Gh., 1975; R. J. Bally, 1977; Grecu Florina, 1980; Gaşpar., Untaru E., Roman F., Cristescu C., 1982; Băloiu V., Ionescu V., 1986; Munteanu, S.A., Traci, C., Clinciu, I., Lazăr, N., Untaru, E., Gologan, N., 1993; Pujină Liliana, Pujină D., 1991-1998; Grecu Florina, 1996; Clinciu, I., Lazăr, N., 1997; Rădoane, N., 2003) etc.

Important contributions were made by specialists of the National Institute of Meteorology and Hydrology (INMH), especially those related to production and sediment transport in small and large river basins (Diaconu, Stănescu, Roşca, Miță etc.). Deterministic models have been developed (P. Stanciu, Zlate I., 1985) and water balance modeling was performed in experimental pools (M. Adler, 1993).

Studied Areas

The study area focused on Săsăuş and Mislea hydrographic basins (*Fig. 1*). These basins have many similarities in morphology, despite their location in different morpho-structural units. Both basins have approximately the same area (~200km^2), same shape, and order 6 on the Horton-Strahler hierarchy system.

Both basins have a dendritic structure, as evidenced by the existence of tributaries that flow the same direction with the main river; the confluence angles usually less than 90^0 (Coteț P., 1951).

Săsăuş morpho-hydrographic basin is located within the Romanian territory, and lies at the junction of the Hârtibaciu Plateau with the Făgăraş Depression, in the Transylvanian Depression, framed by the geographical coordinates 24°49'23" and 24°32'14" eastern longitude and 45°56'51" and 45°47'54" northern latitude (*Fig. 2*). Săsăuş basin is found in the southern part of Hârtibaciu Plateau, a clearly defined entity and delimited space in the geographical center of Romania. From a morpho-hydrographical point of view, Săsăuş River falls within Pârâul Nou river basin, a direct tributary to Olt River. The total length of the river Săsauş is 27 km, which drains a surface of 85 km^2 from the total study area of 232,21 km^2. The basin is bordered in the north, northwest and west by Hârtibaciu river basin, in the east by Cincu river basin and in the south by Olt river basin. In geological terms the basin area overlaps a Neogene sedimentary package belonging to Sarmatian and Badenian, uncemented rocks (sands and gravels) or weakly cemented rocks (friable sandstone, thin horizons of conglomerates, clays and marls).

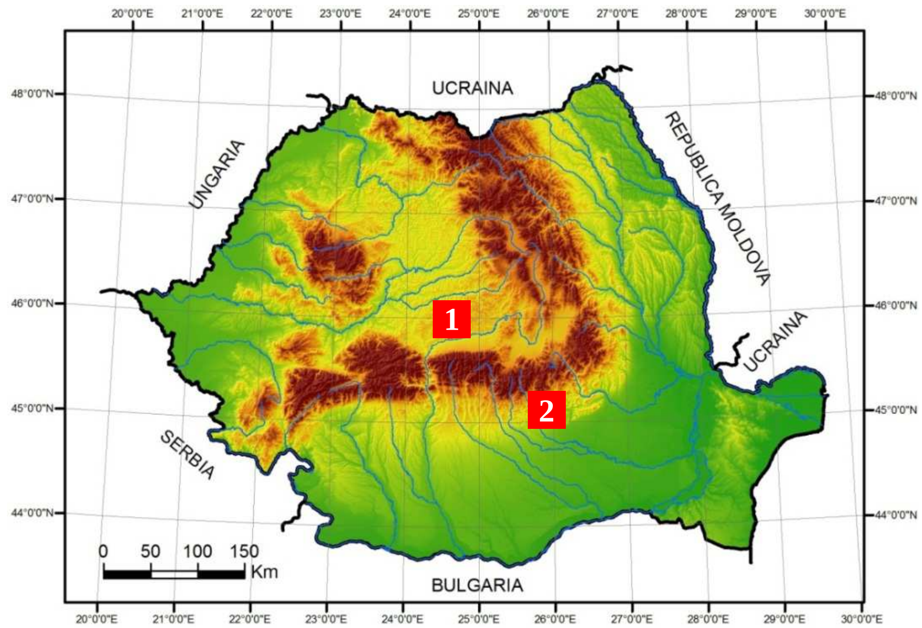

Fig. 1. Geographic location of Săsăuş (1) and Mislea (2) river basins within Romania

Mislea morpho-hydrographic basin is located in the south-eastern part of Romania, at the contact of the Curvature Sub-Carpathians with the Romanian Plain, framed by the geographical coordinates 45°11'25" and 45°03'12" northern latitude, 25°46'19" and 25°59'48" eastern longitude (*Fig. 3*).

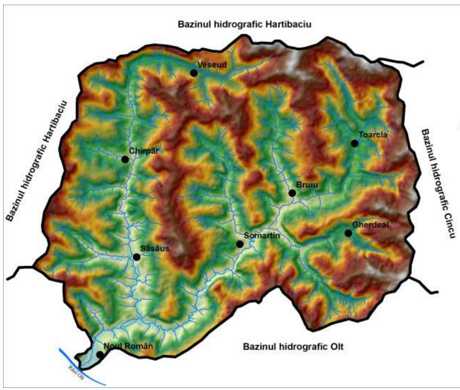

Fig. 2. Săsăuş hydrographic basin, hypsometric map

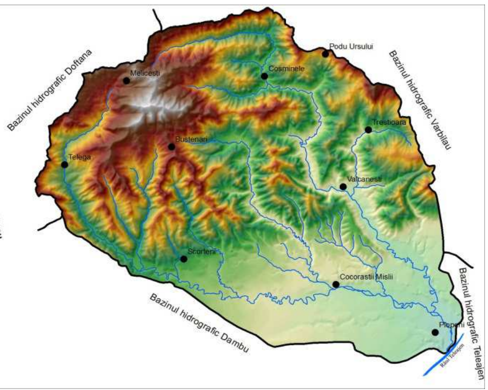

Fig. 3. Misela hydrographic basin, hypsometric map

The basin has a total area of 175 km^2 and is a part of Teleajen river basin. It is bordered in the north and east side by Vărbilău river basin, by Doftana basin in the east and Dâmbu basin in the south. From a geological point of view, Mislea basin overlaps the following structural units: Carpathian Molasses, consisting of sandstones, marls, clays, marl-limestone of Mio-Pliocene age and Tarcău nappe consisting of Oligocene and Eocene age formations (sandstones, shales, marls, breccias).

Techniques and Methods

Ability to erosion of an area broadly depends on two important factors: a) heavy erosivity b) soil erodibility. Currently, the research conducted by INCPA Bucharest (simulation models of water balance in soil, soil loss forecasting models for agricultural use by erosion and landslides) and also the Research and Development Center for Combating Soil Erosion in Perieni – Vaslui County, will improve the ROMSEM model (Romania Soil Erosion Model).

Table 1

Soil Erosion Models Developed in GIS (after Capolongo, Piccaretta, 2007 – with Additions)

USLE *(Universal Soil Loss Equation)*	Wischmeier and Smith, 1965
ROMSEM (Romanian Soil Erosion Model)	Moțoc and others, 1979
CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems)	Knisel, 1980
EPIC (Erosion-Productivity Impact Calculator)	Williams, 1985
AGNPS (Agricultural Non-Point Source Pollution Model)	Young and others, 1989
WEPP (Water Erosion Prediction Project)	Nearing and others, 1989
KINEROS (Kinematic Runoff and Erosion Model)	Woolhiser and others, 1990
EROSION 3D	Schmidt, 1991, 1996
LISEM (Limburg Soil Erosion Model)	De Roo and others, 1996
USPED (Unit Stream Power Erosion Deposition)	Mitasova and others, 1996
RUSLE (*Revised Universal Soil Loss Equation)*	Renard and others, 1997
EUROSEM (European Soil Erosion Model)	Morgan and others, 1998
PESERA (Pan-European Soil Erosion Risk Assessment Project)	Gobin and others, 1999
SWAT (Soil and Water Assessment Tool)	Neitsch and others, 2001

For the development of the soil erosion model, topographic maps at 1:25.000 scale (1980 edition), the Romanian Soil Map at scale 1:200.000 and the Corine Land Cover data set from 2006 were used. For the study area these coefficients were calculated at pixel level, for the 20m resolution model. Implementation scheme of the equation is shown in *Fig. 4*.

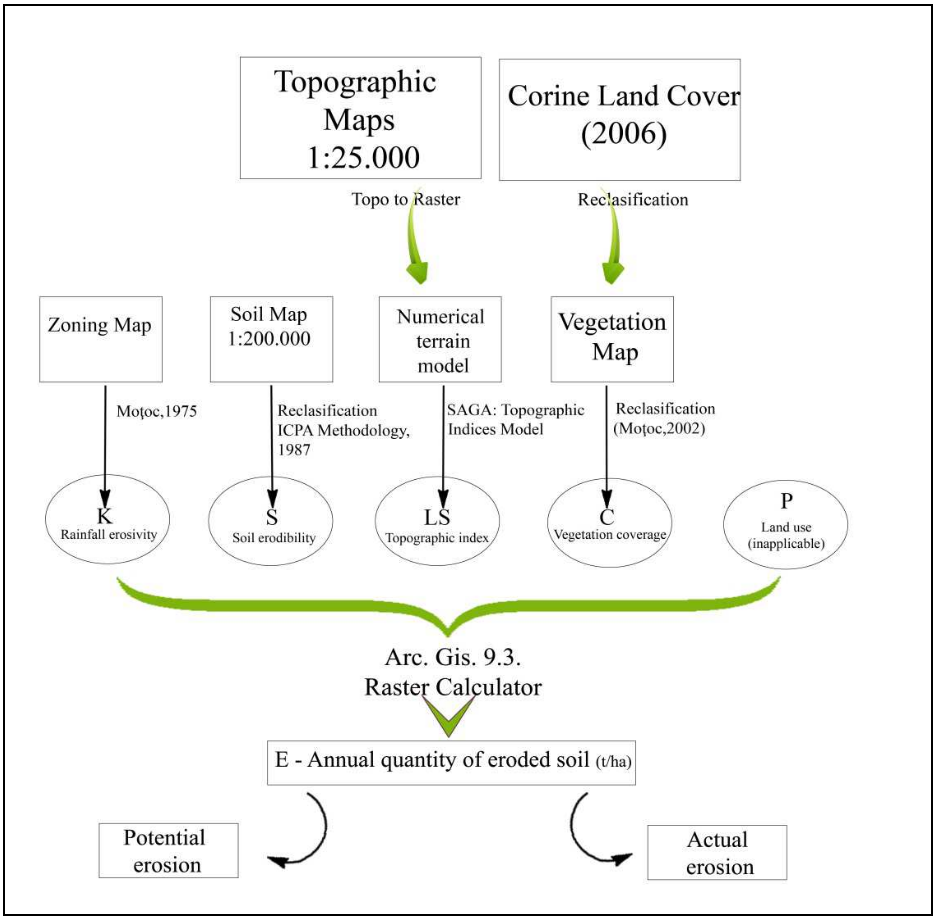

Fig. 4. The elaboration scheme of the erosion model explaining GIS methods (Alexandru, Cătescu, 2012)

Adapting the Universal Soil Loss Equation (USLE) to the specific Romanian conditions, was first attempted by Mircea Moțoc and collaborators in the year 1975. Based on the general equation for assessing potential soil erosion, $Ep = A \cdot L\alpha \cdot I\beta$ (corresponds to the situation when the soil isn't covered with vegetation and anti-soil erosion measures are not taken). Mircea Moțoc developed the actual erosion equation based on the formula presented above, which combines the influence of the slope length (L calculated in meters), slope steepness (I calculated in %) and soil properties in a single parameter:

$$E = K \bullet L^m \bullet I^n \bullet S \bullet C \bullet C_s\,,$$

where: *E* = average annual actual erosion rate(t/ha/year);
K = correction coefficient for rainfall erosivity = 100 Eps • Ap / $L^{0,5} \bullet I^{1,45}$ (erosion of the standard erosion control plots);
Ap = pluvial aggressiveness = $e^{I15} \bullet H^{0,5}$;
L and *I* = length (m) and slope steepness (%);
S = correction coefficient for soil erodibility;
C = correction coefficient for crops effect;
Cs = correction coefficient for the effect of erosion control measurements; m = 0,3; $I^n = 1,36 + 0,97i + 0,381i^2$, where "i" is the average slope.

Rainfall Erosivity (K)

Rainfall erosivity represents the annual sum of the products between the energy of the erosive rainfalls (E) and their maximum 30 minutes intensities:

$$K = \sum_{i=1}^{n} E_i \cdot I30_i$$

where: E_i = the kinetic energy of every rainfall with a duration over 30 minutes during a year (MJ/ha);
$I30_i$ = the maximum intensity of the 30 minute rainfall (mm/h).

For the studied area, the K factor value was taken from the rainfall erosivity zoning map of Romania (Moțoc and others, 1975). This value ranges from 0.12 for the Depression of Transylvania, 0.16 for the Meridional Carpahtians, 0.14 for the Curvature Subcarpathians and 0.13 for the Romanian Plain.

Soil erodibility (S)

This factor was obtained starting from the soil map, taking into account the texture of every soil type, and following the reclassification proposed by ICPA (1987).

In the studied areas, soils fall under four classes of erodibility (*Fig. 5*):

• Erodibility class 1 is the most susceptible to erosion and includes: eroded soils, brown eu-mezobasic soils with sandy-clay texture, clay-loamy and clay textures. Within the Mislea river basin, this class is found especially on the slopes of Mislea, Lupăria, Telega and Cosmina valleys and in the Săsăuş river basin on the slopes of Valea Lungă, Valea Ilimbav, Valea Vizina, Gherdeal and Pârâul Nou Valleys.

- Erodibility class 0,80 is characteristic for brown acid soils with sandy-clay texture and its present only within Mislea River basin on the Măceşu – Plaiul Rotund interfluve.
- Erodibility class 0,70 is representative for reddish-brown luvic soils, clay-illuvial brown soils, black clinohidromorfic soils, pseudorendzines, brown eu-mezobasic soils, brown luvic soils with clayish texture, sandy-clay and clay textures. This type of class is present in both river basins, especially on the slopes of the following valleys: Cosmina, Doftăneț, Poiana Trestiei, Gherdeal, Valea Caprelor, Valea lui Trifan, Veseud.
- Erodibility class 0,60 is the class with the lowest tendency to erosion and includes alluvial soils, brown luvic, alluvial protosoils, albic luvisols, with loam-sandy and loamy texture. These soils are developing on the terraces and floodplains of the Mislea, Cosmina, Săsăuş, Şomartin and Pârâul Nou valleys.

The length (L) and slope steepness (I)

These factors were considered as a single factor ***(LS)*** based on the numerical altitude model, to help simplify the analysis in GIS. LS factor causes the influence of the relief on soil erosion and consists in determining the length (L) and slope steepness (S). For the studied areas, this factor was calculated based on the numerical model at a resolution of 20m altitude, applying the Topographic Indices function in SAGA GIS program (Moore, 2003). This factor estimates the highest values up to 400 and correspondes to the areas with the highest tendency to erosion. The highest values of this indicator are found along river thalwegs, ranging between 200 and 400 with the lowest values found on the interfluves, terraces and floodplains (*Fig. 6*).

The vegetation factor (C)

For the studied areas, the C factor was determined from Corine Land Cover data set (2006) which, after the reclassification, resulted in a number of five classes of vegetation: orchards; pastures, hayfields, grasslands; built area; arable land and forests *(Table 2).*

The corresponding values for factor C, were taken after Moțoc M. (1975), assigned to each class of vegetation and processed in GIS, which led to creating the distribution map of the C factor.

From the analysis of the two maps (*Fig. 7*), it results that the highest value of 0.50 is assigned to orchards, the value of 0.45 corresponds to arable land with a higher proportion in Mislea basin, the value of 0.30 corresponds to pastures, hayfields and grasslands with a higher proportion found in Săsăuş basin, 0.20 value represents the forests and the 0.02 value is attributed to the built perimeter.

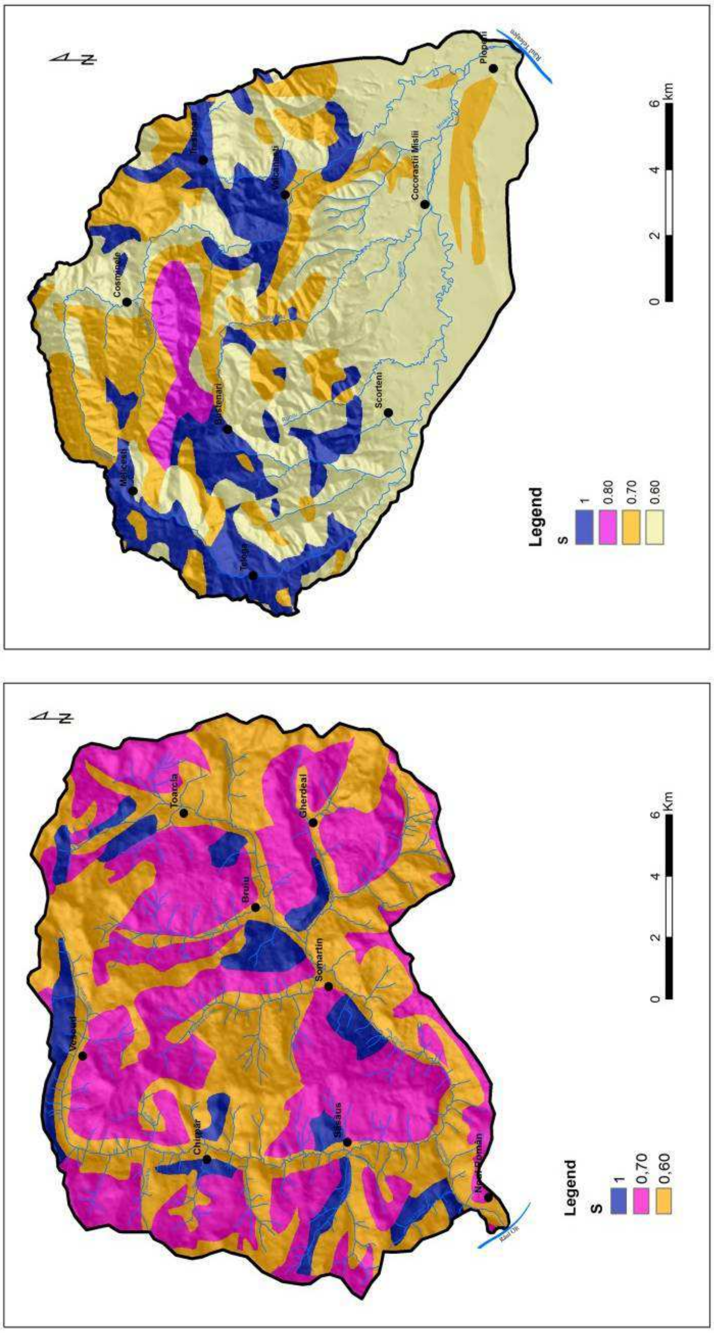

Fig. 5. The distribution of the soil erodibility Factor (S) within Săsăuş and Mislea river basins

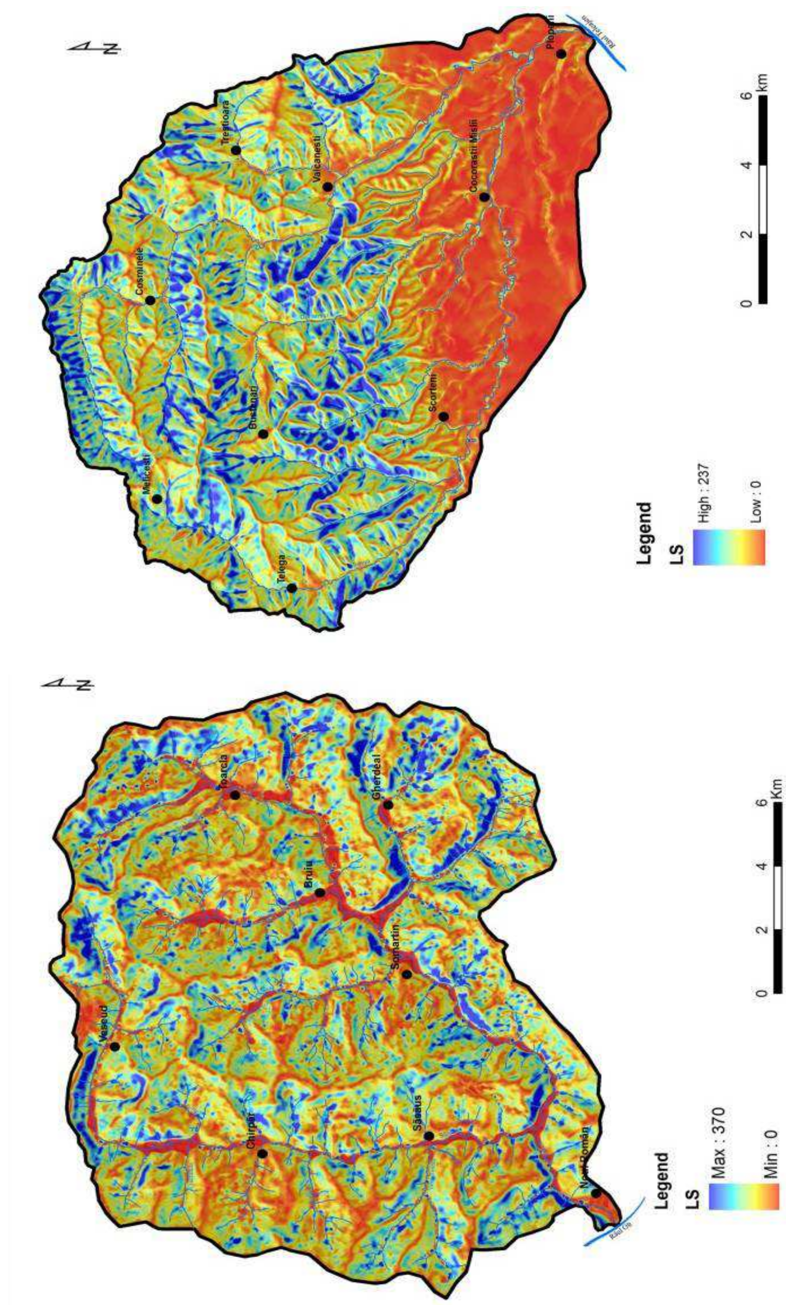

Fig. 6. The distribution of the length and slope steepness Factor (LS) within Săsăuş and Mislea river basins

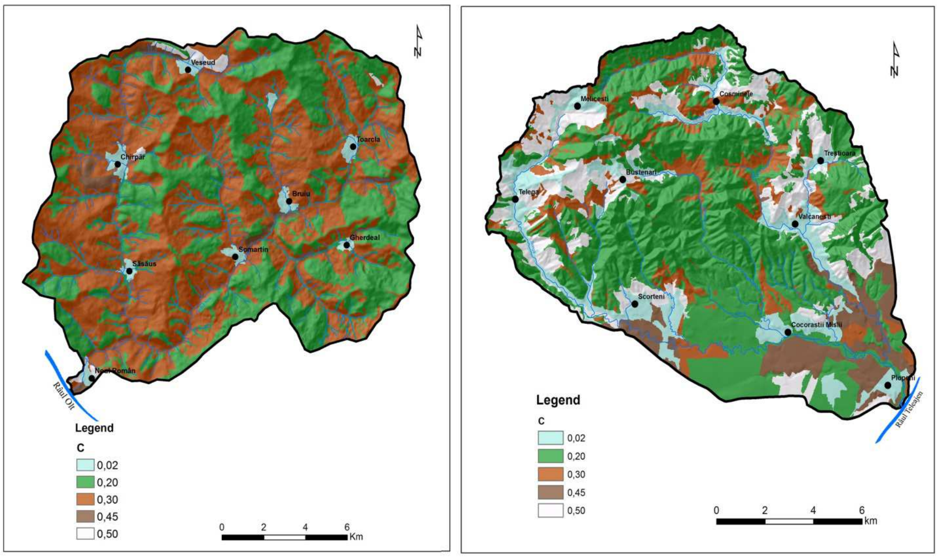

Fig. 7. The distribution of the vegetation coverage Factor (C) within Săsăuş and Mislea River basins

The Correction Coefficient for the Effect of Erosion Control Measurements (P/Cs)

This factor was not considered due to limited applicability and lack of data.

Results and Discussions

Maps of actual and potential erosion (*Fig. 8* and *Fig. 9*) resulted from the combination of rasters corresponding factors K, LS, S and C, respectively K, LS and S factors. From the analysis of the obtained maps the following observations emerged: the actual erosion model estimates an annual quantity of eroded soil ranging from 0 to 8.4 t/ha/year (Săsăuş Basin), and 0 to 13.5 t/ha/year (Mislea Basin). Most of Săsăuş Basin falls within the ranges of 0-1 t/ha/year, while the share of Mislea Basin erosion is given by the intervals 0-2 t/ha/year. The lowest erosion values (0-1 t/ha/an) can be found particularly in areas covered with forests and along the main river valleys of Săsăuş and Pârâul Nou.

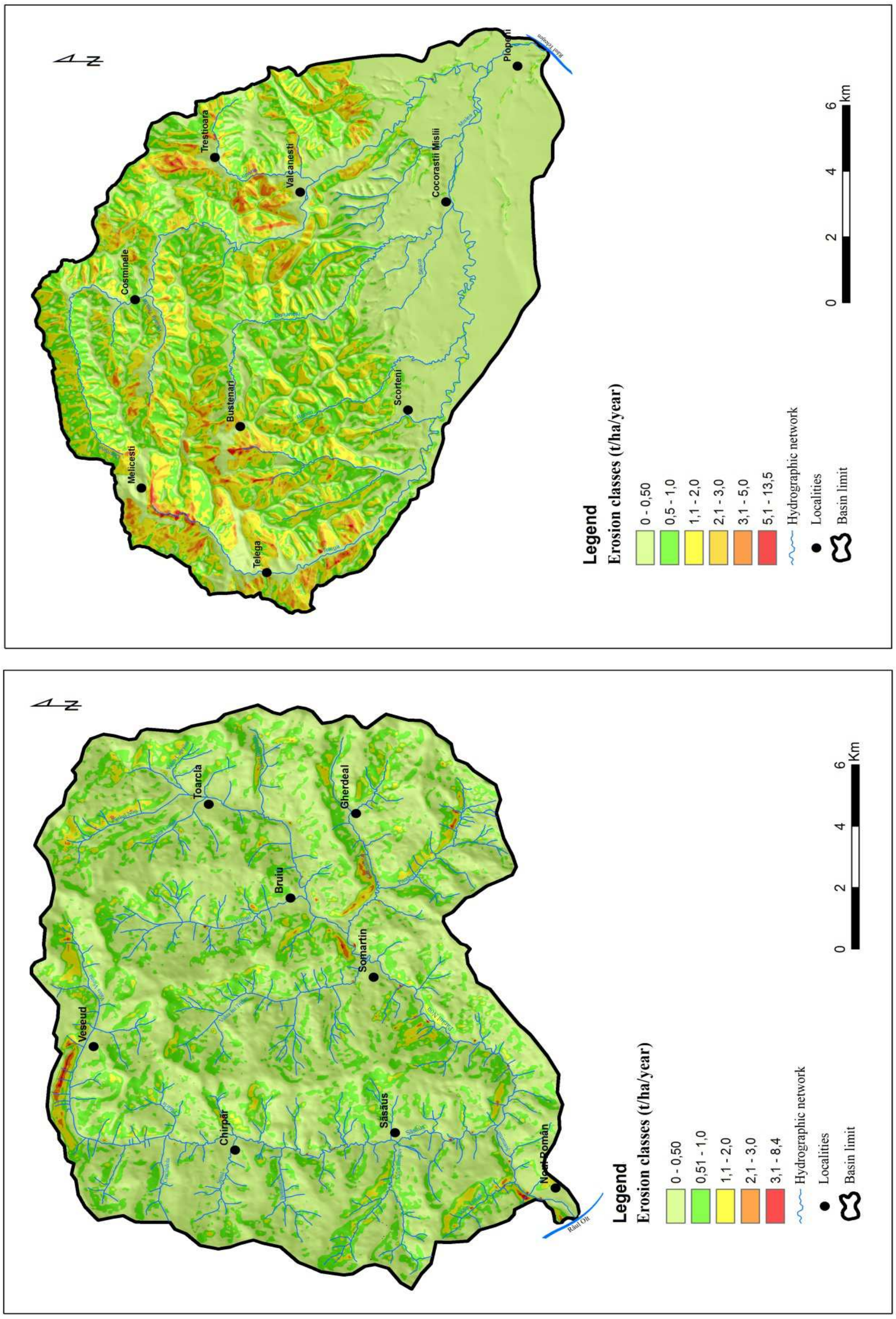

Fig. 8. Actual Erosion within Săsăuş and Mislea River Basins

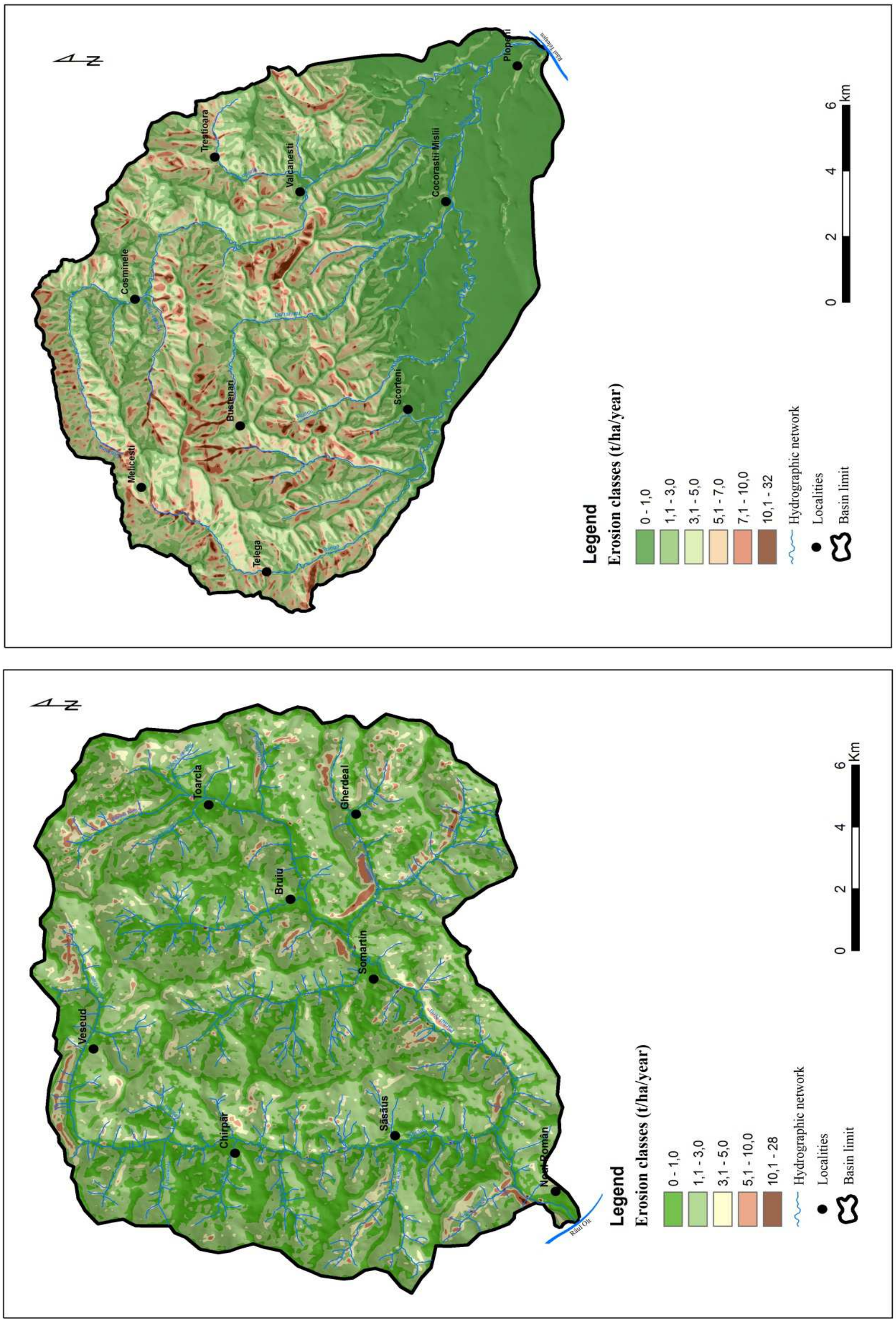

Fig. 9. Potential Erosion within Săsăuş and Mislea River Basins

Regarding Mislea Basin, the lowest values have a significant predominance in its southern region and along Mislea, Seaca Cosmina and Doftănețu Valleys.

Within both basins the following differences are noticed: the highest values of actual erosion within Mislea Basin correspond to torrential river basins with steep slopes and on the slopes of Cosmina and Telega valleys. Meanwhile, within Săsăuş basin, the highest values are distributed in compact areas in the southern part of the basin, along the Pârâul Nou, Valea Lungă, Gherdeal Valleys and in the northern region of Vizina Valley.

The highest values of the erosion correspond to the surfaces occupied by herbaceous vegetation (pastures, hayfields, grasslands) and orchards, overlapped on beds of clay, sandy-argillaceous texture soils and on very steep slopes. Following a scenario of potential erosion, where the vegetation factor (C) was removed, erosion values have resulted within the ranges of 0-28 t/ha/year for Săsăuş basin and 0-32 t/ha/year for Mislea basin. The lowest values generally correspond to those obtained in the case of actual erosion in both basins.

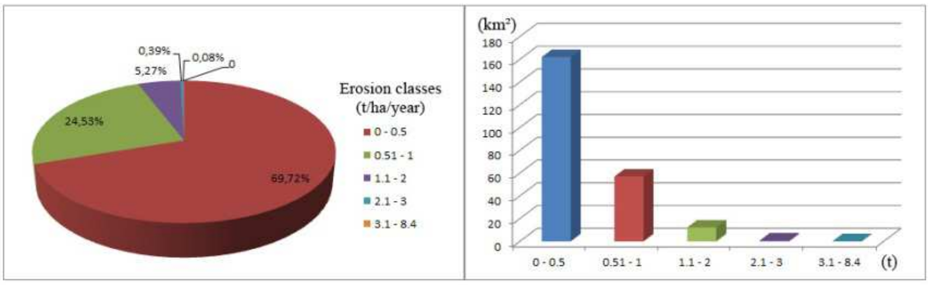

Fig. 10. The Cyclogram and Histogram of the Actual Erosion within Săsăuş River Basin

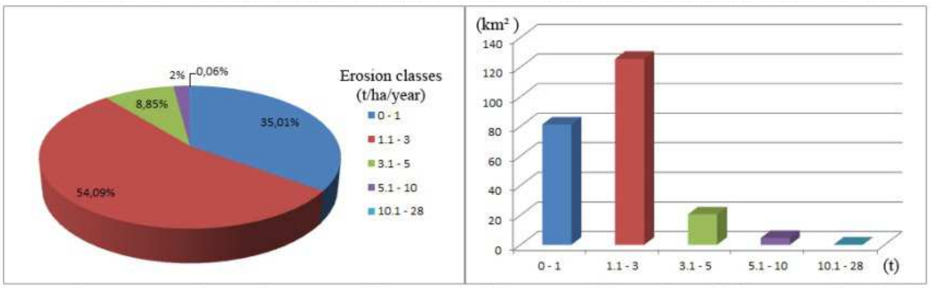

Fig. 11. The Cyclogram and Histogram of the Potential Erosion within Săsăuş River Basin

In the Săsăuş river basin, the highest values are found in areas consistent with those of the actual erosion, obviously with almost a triple amount compared to the initial value (Valea Lungă, Pandea, Gherdeal, Pârâul Nou, Valea Vizina between 3-28 t/ha/year). Mislea hydrographical basin has a higher degree of potential erosion compared to Săsăuş, with 32 t/ha/year as a maximum value. The highest values can be found in the whole northern half of the basin, focusing on the slopes of Telega, Runcu, Doftăneţu, Poiana Trestia and Lupăria. Considering the classification of ICPA for susceptibility classes it is noticed that following the correlation with the amount of eroded soil, Săsăuş river basin falls within the classes <1 t/ha/year and 1-8 t/ha/year, with a small or sometimes absent susceptibility to erosion.

Regarding Mislea basin, the situation is similar, but due to a higher amount of eroded soil (up to 13.5 t/ha/year), we also take into account a moderate susceptibility class (8-16 t/ha/year). Thus, for both basins one cannot speak of increased erosion, as its maximum values do not exceed 8 and 13.5 t/ha/year, so the development of a susceptibility map is not relevant.

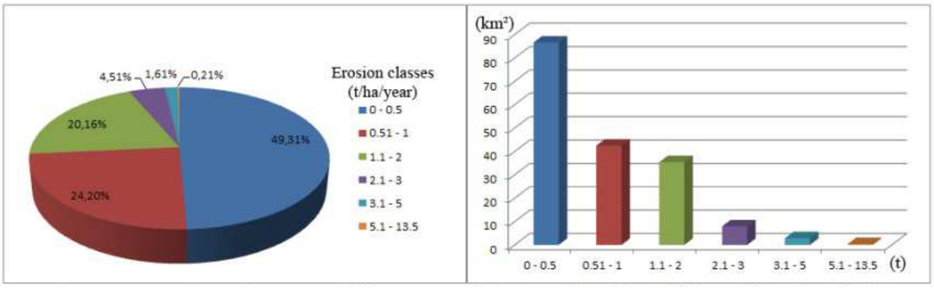

Fig. 12. The Cyclogram and Histogram of the Actual Erosion within Mislea River Basin

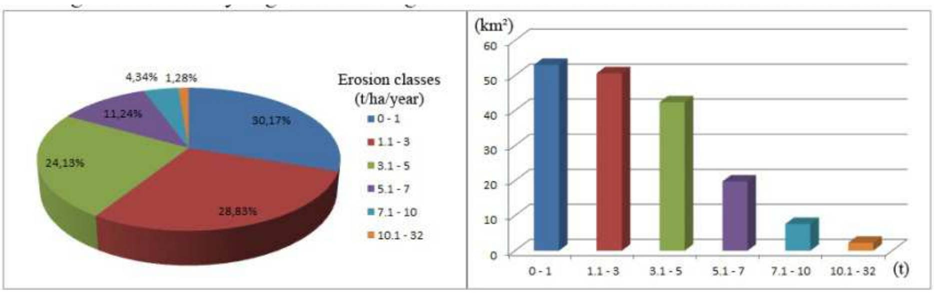

Fig. 13. The Cyclogram and Histogram of the Potential Erosion within Mislea River Basin

Conclusions

The method used was successfully applied, reflecting the reality on the field. This allows the assessment of the degree of surface erosion within the two analyzed basins and the design of protective measures for areas affected by high erosion. After the analysis of the two basins the average of the surface erosion per year which resulted is of 0.6 t/ha.

This result concludes that the basins under study do not fit within a high risk erosion situation. Taking into account different scenarios for the level of vegetation coverage or land use, we can assess the effects of erosion on the landscape and propose strategies to combat erosion. Through the use of GIS techniques in this study, erosion is highlighted by obtaining maps of actual and potential erosion. Regarding these possibilities, we can carry out monitoring and maintenance on the slopes soil quality, which would allow for appropriate protection measures to be taken.

REFERENCES

BALLY, R. J. (1977), *Alunecările şi stabilitatea versanţilor agricoli*, Editura Ceres, Bucureşti.

BĂLOIU, V., IONESCU, V. (1986), *Apărarea terenurilor agricole agricole împotriva eroziunii, alunecărilor şi inundaţiilor*, Editura Ceres, Bucureşti.

BILAŞCO, Ş., HORVATH, C., COCEAN, P., SOROCOVSCHI, V., ONCU, M. (2009), "Implementation of the USLE Model Using GIS Techniques. Case Study the Someşan Plateau", *Carpathian Journal of Earth and Environmental Sciences*, vol. 4, no. 2.

CAPOLONGO, D., PENNETTA, L., PICCARRETA, M., FALLACARA, G., BOENZI, F. (2007), *Spatial and temporal variations in soil erosion and deposition due to land-levelling in a semi-arid area of Basilicata (Southern Italy)*, Wiley InterScience.

CERNESCU, N., FLOREA, N. şi colab. (1964-1994), *Harta solurilor României*, scara 1:200.000. Institutul Geologic – Institutul de Cercetări pentru Pedologie şi agrochimie, Bucureşti;

COTEŢ, P. (1954), "Probleme în legătură cu geomorfologia pantelor", extras din *Revista Universităţii C. I. Parhon*, pp. 184-201.

CLINCIU, I., LAZĂR, N. (1997), *Lucrări de amenajare a bazinelor hidrografice torenţiale*, Editura Didactică şi Pedagogică, Bucureşti, p. 164.

DÂRJA, M., BUDIU, V., TRIPON D., PĂCURAR I., NEAG V. (2002), *Eroziunea hidrică şi impactul asupra mediului*, Editura Risoprint, Cluj-Napoca, p. 100.

DESMET, P. J. J., GOVERS, G. (1996), "A GIS Procedure for Automatically Calculating the USLE LS Factor on Topographically Complex Landscape Units", *Journal of Soil and Water Cons*, vol. 51, pp. 427-433.

EVANS, K. G., LOCH, R. J. (1996), "Using the RUSLE to Identify Factors Controlling Erosion Rates of Mine Soils", *Journal of Land Degradation and Rehabilitation*, vol. 7, Edited by John Wiley & Sons.

GAŞPAR, R., UNTARU, E., ROMAN, F., CRISTESCU, C., (1982) *Cercetări hidrologice în bazinele hidrografice torenţiale mici*, M.E.F.M.C., I.C.A.S., Bucureşti.

GRECU, FLORINA (1980), *Modelul morfometric al lungimii reţelei de râuri din Bazinul Hârtibaciu*, SCGGG – Geogr, XXXVIII, nr. 2, Bucureşti.

GRECU, FLORINA (1992), *Bazinul Hârtibaciului. Elemente de morfohidrografie*, Editura Academiei, Bucureşti.

GRECU, FLORINA (1996), "Expunerea la risc a terenurilor deluroase", în *Lucrările celei de-a doua conferinţe regionale de Geografie*, Timişoara, p. 18-24.

GRECU, FLORINA (1997), *Fenomene naturale de risc (geologice şi geomorfologice)*, Editura Universităţii din Bucureşti.

GRECU, FLORINA (2006), *Hazarde şi riscuri naturale*, Editura Universitară, Bucureşti.

IONIȚĂ, I., OUATU, O. (1985), “Contribuții la studiul eroziunii solurilor din Colinele Tutovei”, *Rev. Cercet. Agron*, vol. 3 (71), Iași.

IONIȚĂ, I. (2000),*Formarea şi evoluția ravenelor din Podişul Bârladului”*, Edit. Corson, Iași;

KRASILNIKOV, P., IBANEZ, J. J. M., ARNOLD, R., SHOBA, S. (2009), *A Handbook of Soil Terminology, Correlation and Classification*, Routledge Publishing.

MITASOVA, H., HOFIERKA, J., ZLOCHA, M., IVERSON, L. R. (1996), “Modeling Topographic Potential for Erosion and Deposition Using GIS”, *Int. Journal of Geographical Information Science*, 10(5), 629-641.

MITASOVA, H., MITAS, L., BROWN, W. M., JOHNSTON, D. (1998), “Multidimensional Soil Erosion/Deposition Modeling and Visualization Using GIS”, *Final Report for USA CERL*., University of Illinois, Urbana-Champaign. p. 24.

MITASOVA, H., MITAS, L. (1999), *GIS-Based Erosion and Deposition Modeling for Complex Terrain*, online tutorial.

MORGAN, R. P. C., NEARING, M. (2011), *Handbook of Erosion Modelling,* John Wiley & Sons.

MOORE, I. D., GRAYSON, R. B., LADSON, A. R. (1991), “Digital Terrain Modelling: A Review of Hydrological, Geomorphological, and Biological Applications”, *Hydrological Processes 5*, no. 1: 3-30.

MOORE, I. D., WILSON, J. P. (1992), “Length-Slope Factors for the Revised Universal Soil Loss Equation: Simplified Method of estimation”, *Journal of Soil and Water Conservation*, vol. 47 (5), pp. 423-428.

MOȚOC, M., MUNTEANU, S., BĂLOIU, V., STĂNESCU, P., MIHAI, G. (1975), *Eroziunea solului şi metodele de combatere*, Editura Ceres, Bucureşti.

MOȚOC, M., MIRCEA, S. (2002), *Evaluarea factorilor care determină riscul eroziunii hidrice în suprafață*, Editura BREN, Bucureşti.

MUNTEANU, S. A., CLINCIU, I. (1982), *Amenajarea bazinelor hidrografice torențiale. Partea a II-a, Studiul torenților şi al amenajării lor*, Universitatea din Brașov.

MUNTEANU, S. A., TRACI, C., CLINCIU, I., LAZĂR, N., UNTARU, E., GOLOGAN, N. (1993), *Amenajarea bazinelor hidrografice torențiale prin lucrări silvice şi hidrotehnice*, vol. II, Editura Academiei Române.

PATRICHE, C. V., CĂPĂȚÂNĂ, V., STOICA, D. L. (2006), “Aspects Regarding Soil Erosion Spatial Modeling Using the USLE/RUSLE within GIS”, *Geographia Technica 2*.

PUJINA, D., PUJINA, LILIANA (1998), “Variabilitatea şi intensitatea actuală a proceselor de alunecare din Podişul Central Moldovenesc”, *Lucrări Ştiințifice,* vol. 40, U.A.M.V. Iaşi, pag. 184-191.

PUJINA, D. (1985), “Amenajarea versanților afectați de alunecări de teren”, *Revista Cercetări Geomorfologice pentru Lucrările de Îmbunătățiri funciare*, Universitatea Bucureşti, Institutul de Geografie Bucureşti, ISPIF Bucureşti, pp. 103-118.

RĂDOANE, N. (1987), *Geomorfologia bazinelor hidrografice mici*, Editura Universității „Ștefan cel Mare” Suceava.

RĂDOANE, MARIA (1999), *Ravenele. Forme, procese şi evoluție*, Presa Universității Clujeană, Cluj-Napoca.

RENARD, K. G., FOSTER, G.R., WEESIES, G. A., MCCOOL, D. K., YODER, D. C., (1997), “Predicting Soil Erosion by Water – A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)”, U.S. Dept. of Agric., *Agr. Handbook*, no. 703.

STANCIU, P., ZLATE-PODANI, I. (1987), “A Study of Hydrological Regimes in Experimental Basins in Relation to Cultivation Practices”, *IAHS Publ.*, no. 164.

STĂNESCU, P., TALOIESCU, I., GRĂGAN, L. (1969), “Contribuții în studierea unor indicatori de evaluare a erozivității pluviale”, *Anuarul I.C.P.A.*, vol. 11 (XXXVI), Bucureşti.

STĂNESCU, P., DRĂGAN, LIVIA (1970), “Zonarea erozivității pluviale”, *An. I.C.I.F.P., s. Pedol.*, vol. III (XXXVII), Bucureşti.

WISCHEMEIER, W. H., SMITH, D. D. (1978), "Predicting Rain Fall Erosion Losses – A Guide to Conservation Planning", Department of Agriculture, *Handbook*, no. 537, US Dept Agric., Washington, DC., p. 63.

WISCHEMEIER, W. H., SMITH, D. D. (1965), "Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains. Guide for Selection Practices for Soil Land Water Conservations", US Department of Agriculture in cooperation with Purdue Agricultural Experiment Station, *Agriculture Handbook*, no. 282, pp. 47.

ZINGG, A. V. (1940), *Degree and Leght of Land Slope as It Affects Soil Loss Inrunoff*, Agr. Ing., no. 21.

Harta topografică a României (1980), ediția a II-a, scara 1:25.000, Direcția Topografică Militară.

*** (1986), *Metodologia elaborării studiilor pedologice*. ICPA.

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