Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIII, 2024
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

GIS METHODS FOR ESTIMATING SOIL EROSION AND ITS IMPACT ON THE ENVIRONMENT. CASE STUDY: CRIŞUL ALB HYDROGRAPHIC BASIN

Loredana COPĂCEAN[1, 2], Eugen Teodor MAN[1], Sorin HERBAN[1], Luminiţa COJOCARIU[2, 3], Cosmin POPESCU[2]

[1]Politehnica University of Timisoara, 2 Victoriei Square, Timisoara, Romania
[2]University of Life Sciences "King Mihai I" from Timisoara, 119 Calea Aradului, Timisoara, Romania
[3]Agricultural Research and Development Station Lovrin, 200 Principala Street, Lovrin, Romania

Corresponding author email: luminita_cojocariu@usvt.ro

Abstract

In Romania, in recent decades, many facilities to combat soil erosion have been abandoned, which leads to the amplification of the effects of this phenomenon, with repercussions on the environment. In this context, through this study, it is aimed to apply a spatial analysis model to identify areas susceptible to soil erosion, to establish the intensity of this phenomenon, but also to analyze its impact on the environment, at the level of the Crişul Alb basin. GIS technique and Universal Soil Loss Equation (USLE) were used. Through this equation, the following factors, participants /determinants of soil erosion were taken into account: climatic aggressiveness, land topography, soil characteristics, vegetation cover, land improvement measures. The soil erosion map at basin level, was classified into five classes, respectively areas with very low, low, moderate, high and very high susceptibility to soil erosion. The results show that 74% of the territory belongs to the class of susceptibility to very low erosion, and 4% with high and very high erosion rates, these being the main "hot spots" that must be taken into account in the development strategies of the hydrographic basin.

Key words*: GIS models, impact, USLE, watershed.*

INTRODUCTION

Soil erosion is one of the severe land degradation phenomena in many areas of the globe (Kim et al., 2005; Spalevic et al., 2020; Biali & Cojocaru, 2021) and varies depending on natural and/or anthropic factors. Balabathina et al. (2020) consider that approximately 85% of degraded lands globally are due to soil erosion, a phenomenon with significant implications for crop productivity due to soil fertility reduction (Singh & Panda, 2017; Copacean et al., 2019; Popescu et al., 2022; Patriche, 2023), also considered a major environmental issue.
In Romania, approximately 43% of agricultural lands exhibit erosion potential, which takes various forms depending on specific local conditions (Nistor & Nistor, 2002). The critical erosion season is generally from May to August, against a backdrop of heavy, torrential rainfall (Nistor & Nistor, 2002).
At the level of Romania, in the last decades, many of the arrangements for combating soil erosion (originally existing on the surface of 2,231,356 ha) have been abandoned or are in a precarious state, which leads to the amplification of the effects of erosion on other components of the environment, such as groundwater and surface waters, agricultural lands and so on (Mircea, 2011; Man, 2014).
Classical methods for assessing soil loss through erosion at the watershed level are very difficult to implement and apply, requiring financial and time resources and a large volume of data, sometimes unavailable. In this context, various spatial and temporal assessment and computerized modeling techniques can be chosen to evaluate soil loss through erosion at different spatial and temporal scales (Borrelli et al., 2015; Greiner et al., 2017; Todisco et al., 2022).
One of the most well-known and widely used methods for estimating the susceptibility to erosion of a territory is the Universal Soil Loss Equation (USLE) developed by the United States Department of Agriculture (USDA), an

equation revised by RUSLE, with several variants (Foster et al., 2003; Panagos et al., 2015). These methods are easily applied through Geographic Information Systems (GIS) under various conditions and at different spatiotemporal scales, both internationally and in Romania (Diodato & Bellocchi, 2007; Estifanos, 2014; Roşca et al., 2014; Golosov et al., 2017; Asnake & Amare, 2019; Mengie et al., 2019; Niacsu et al., 2021; Patriche, 2023).
In the elaboration of the present study, we have exploited the possibility of applying the USLE model to estimate the average soil erosion in the Crişul Alb watershed, using remote sensing tools and GIS technologies. Therefore, this study aims to apply a spatial analysis model to identify areas susceptible to soil erosion and to determine the intensity of this phenomenon in different subzones of the Crişul Alb river basin.

MATERIALS AND METHODS

1. **Study area**
The study area is represented by the hydrographic basin (H.B.) of the Crişul Alb River (Figure 1), located in western Romania, mostly within the territory of Arad County. The basin area covers 422,798 hectares.

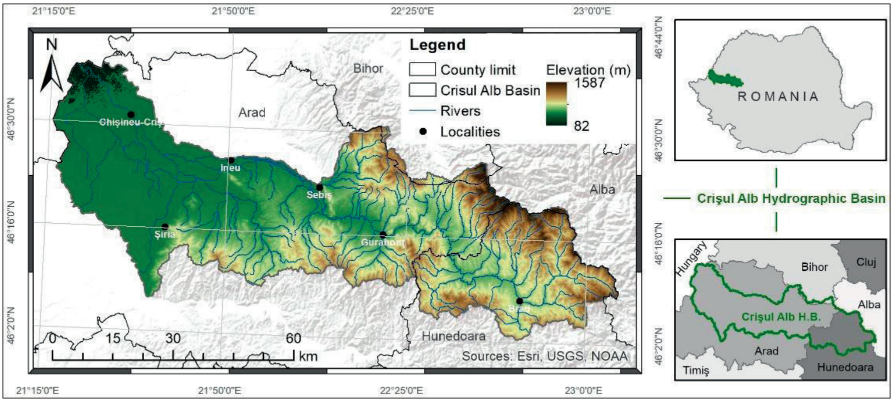

Figure 1. Location of the study area (processing after EEA, 2016; Geospatial, 2022)

The relief of the study area is varied, with altitudes ranging from 1587 meters, in the mountainous region, to 82 meters in the plain areas and river valleys. The average altitude of the Crişul Alb H.B. is 323 meters. In terms of land use, the eastern half is predominantly covered by forest areas interspersed with grasslands, while in the western half and in depressions, agricultural lands predominate. The relief units with significant presence in the analyzed territory are: the Bihorului Mountains, the Metaliferi Mountains, the Cigherului Hills, the Brad - Hălmagiu Depression, the Low Plains of the Criş Rivers and the Mureş Plain (Posea & Badea, 1984; Rusu, 2007; Simon et al., 2022).

2. **Materials used**
The study area, respectively the territory of the Crişul Alb basin, was delimited according to the Crişuri Water Basin Administration.
In the case of the present study, the following materials were used:
- climatic data, specifically annual precipitation amounts from the period 2013-2022, recorded at 11 meteorological stations near the area of interest (Climatic databases, 2023; Open Source data): Alba Iulia, Câmpeni (Bistra), Chişineu-Criş, Deva, Gurahonţ, Roşia Montană, Sânnicolau Mare, Sebeş (Alba), Şiria, Ştei (Petru Groza), Vărădia de Mureş. Since the level of precipitation is very variable, from one year to another, in the study we took the multiannual average over ten years;
- pedological data, in vector format (Geospatial, 2022);
- the Digital Elevation Model (DEM), with a spatial resolution of 25 m (EEA, 2016), a hybrid product based on SRTM and ASTER GDEM data; based on the DEM, flow direction and flow accumulation maps, as well as the map of the slopes, were generated;

- Sentinel 2 satellite images, from the year 2021, from the months of March, May, July, October and November (Copernicus Open Hub, 2023); based on them, the NDVI map was generated, with average values, at the level of 2021. The year 2021 was chosen based on the availability of Sentinel images from the selected periods (images without clouds or noise). Based on the working models from the specialized literature, but also the fact that all evolutionary stages of the vegetation were captured, 5 satellite images were used to calculate the average NDVI.

3. **The working methodology**

The Universal Soil Loss Equation (USLE) formulated by Wischmeier and Smith (1978) was used to estimate the annual amount of soil lost through erosion and to generate a map of soil erosion susceptibility in the analyzed territory. This equation involves the product of five factors: Rainfall erosivity factor (R), Soil erodibility factor (K), Topographic Factor (LS), Land cover management factor (C), and Conservation Support Practice Factor (P) (Balabathina et al., 2020; Selmy et al., 2021; Ge et al., 2023). The five USLE factors were spatialized in GIS as raster maps (Figure 2) with a spatial resolution of 25 meters. The spatial resolution at which the results were obtained was conditioned by the available geospatial data, especially DEM.

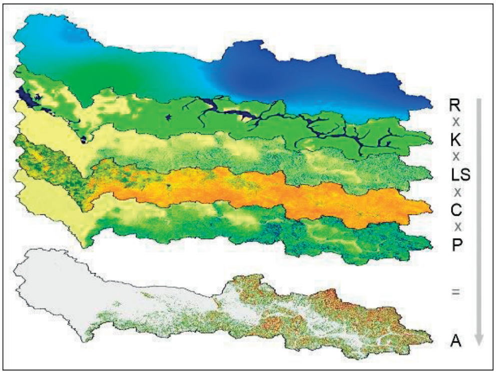

Figure 2. The USLE factors in the Crișul Alb H.B.

The calculation relations from Table 1 were used to determine the USLE factors.

Table 1. Calculation relations of the USLE factors

Factor	Calculation relation		Meaning
Rainfall erosivity factor[1] (MJ mm ha^{-1} h^{-1} $year^{-1}$)	$R = 0.55 \times P - 4.7$	(1)	P - average annual precipitation (mm).
Soil erodibility factor[2] (t ha^{-1} MJ^{-1} mm^{-1})	$100K = 2.1M^{1.14} \times 10^{-4} \times (12 - a) + 3.25 \times (b - 2) + 2.5(c - 3)$	(2)	M - calculated as [very fine sand (%) + silt (%)] × [100 − Clay (%)]; a - soil organic matter (%); b - soil structure code; c - soil profile permeability class.
Topographic Factor[3] (adimensional)	$LS = \left(\frac{FA \times cell\ size}{22.13}\right)^m \times \left(\frac{\sin\ (slope\ angle \times 0.01745)}{0.9}\right)^n$	(3)	FA - flow accumulation; cell size - 25 × 25 m; slope angle – map of slope, in radians; m = 0.5; n = 1.3 - the exponent values
Land cover management factor[4] (adimensional)	$C = exp\left[-\alpha \times \frac{NDVI}{(\beta - NDVI)}\right]$	(4)	NDVI - Near-infrared band; R - Red band; α = 2; β = 1
Conservation Support Practice Factor[5] (adimensional)	$P = 0.2 + 0.03 \times S$	(5)	S - the slope grade (%).
Average annual soil loss (t $ha^{-1}year^{-1}$)[6]	$A = R \times K \times LS \times C \times P$	(6)	

Resource: [1]Hurni, 1985, cited by Balabathina et al., 2020; [2]Wischmeier et al., 1971, cited by Selmy et al., 2021; [3]Mitasova, 1996, cited by Zisu, 2014; [4]Van der Knijff et al., 2000, cited by Balabathina et al., 2020; [5]Wener approach, cited by Allafta & Opp, 2022; [6]Balabathina et al., 2020; Selmy et al., 2021; Ge et al., 2023

In the initial approach, Wischmeier (1959) calculated the rainfall erosivity index (EI, in MJ/ha) as the product of the total kinetic energy of rain (E, in t/ha) and the maximum intensity of rainfall in 30 minutes (I_{30}, in mm/h) (Zisu, 2014; Balabathina et al., 2020). Considering the lack of climatic data over time, various methods have been developed for determining the R factor

(Choudhury & Nayak, 2003; Fathizad et al., 2014). In this study, the R factor was calculated based on equation (1), and for the spatialization of the results, the Inverse Distance Weighted (IDW) interpolation method was applied (ArcGIS Documentation, 2022).

The K factor, calculated on the basis of equation (2), refers to the soil's susceptibility to erosion, or in other words, it expresses the soil's resistance to erosion, a characteristic given by its physical and chemical properties. In the quantification of the K factor, the texture, structure, permeability and organic matter content of the soil are considered in particular (Balabathina et al., 2020; Selmy et al., 2021; Allafta & Opp, 2022).

The LS factor (equation 3) shows the contribution of topography to soil erosion and represents one of the most complex and difficult-to-estimate factors of the USLE (Ligonja & Shrestha, 2015). Based on this consideration, over time, several algorithms for calculating the LS factor have been developed, which generally involve the slope of the terrain, the flow direction, and flow accumulation (Zhang et al., 2013; Pham et al., 2018).

The C factor expresses the effect of land use and their management on soil erosion (Renard et al., 1997; Balabathina et al., 2020). Parameters that have the highest impact on the C factor are represented, especially by the degree of soil cover with vegetation, the canopy of trees, the roughness of the terrain, and its previous land use (Zisu, 2014; Cojocariu et al., 2024; Măgureanu et al., 2024).

In this study, the C factor was obtained based on the NDVI map, according to relation (4). Although different algorithms for determining the P factor are described in the specialized literature (Foster et al., 2003; Fu et al., 2005; Robert et al., 2012), this is considered one of the "uncertain" factors of USLE, considering given the lack of data on the practices applied in the territory.

Due to this consideration, an algorithm based on slope terrain (equation 5) was chosen for calculating P, highlighting areas at major risk of soil erosion. The five raster images obtained for each factor were multiplied according to equation (6), resulting in the map of soil erosion susceptibility for the analyzed territory (Figure 2).

Soil erosion map was classified, based on the intensity of the phenomenon, into five classes: very low rate (tolerable) below 3 t ha^{-1} $year^{-1}$; low rate between 3.1-10 t ha^{-1} $year^{-1}$; moderate rate between 11-20 t ha^{-1} $year^{-1}$; high rate, between 21-40 t ha^{-1} $year^{-1}$ and very high rate, above 41 t ha^{-1} $year^{-1}$ (Sestras et al., 2023).

RESULTS AND DISCUSSIONS

1. **Rainfall erosivity factor (R)**

Rainfall erosivity (R) refers to the capacity of raindrops to cause erosion by detaching and mobilizing soil particles (Allafta & Opp, 2022). In this study, the map of the R factor (Figure 3) was determined based on the equation proposed by Hurni (1985), as cited by Balabathina et al., 2020.

In the study area, the multi-year average precipitation over the period 2013-2022 is distributed unevenly; precipitation amounts varied between 247 mm (Alba Iulia, 2013) and 1739 mm (Rusca Montană, 2021). Based on the multi-year average precipitation values, the map of the R factor was generated, with minimum values of 275.85 MJ mm ha^{-1} h^{-1} $year^{-1}$, in the southwest, in the lowland area, and maximum values of 571.59 MJ mm ha^{-1} h^{-1} $year^{-1}$, in the central and mountainous areas (Figure 3).

2. **Soil erodibility factor (K)**

The soil erodibility factor (Figure 4) depicts the soil particles' predisposition to detachment and transportation by runoff. The soils in the analyzed area are distributed in accordance with physico-geographical factors: in mountainous and hilly areas, districambosols and luvisols predominate, while in low-lying areas, chernozems, eutricambosols, and alluvial soils prevail.

In the study area, the values of the K factor range between 0.04 t ha^{-1} MJ^{-1} mm^{-1}, for sandy soils and 0.6 t ha^{-1} MJ^{-1} mm^{-1}, for clayey soils (Figure 4).

3. **Topographic Factor (LS)**

The LS factor refers to the impact of topography on erosion processes. In this context, the most important elements are the length and inclination (angle) of the slope (Simon et al., 2020; Allafta & Opp, 2022), the impact of erosion phenomena increasing proportionally with them (Liu et al., 2000; Lastoria et al., 2008).

In the study area, the terrain is complex and varies between 82 and 1587 meters in elevation, and the slope ranges from 0 to 59 degrees. Under these conditions, LS values range from 0 to 16.56 (Figure 5). The minimum LS values are specific to low-lying, plain areas, while the maximum values are found on the slopes of mountainous areas.

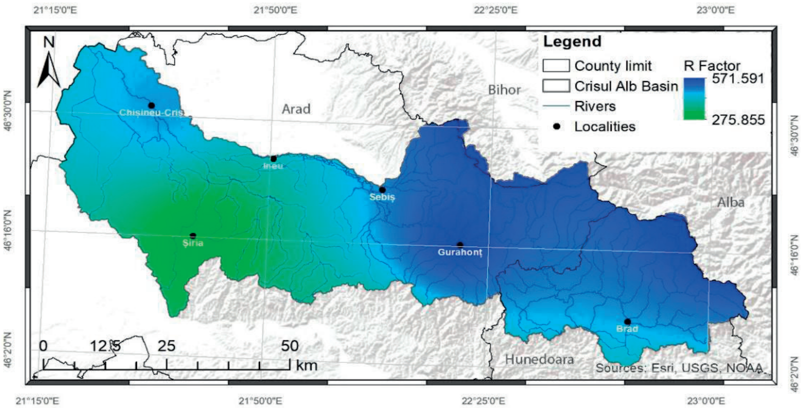

Figure 3. The R factor distribution map (MJ mm ha^{-1} h^{-1} $year^{-1}$) in the study area

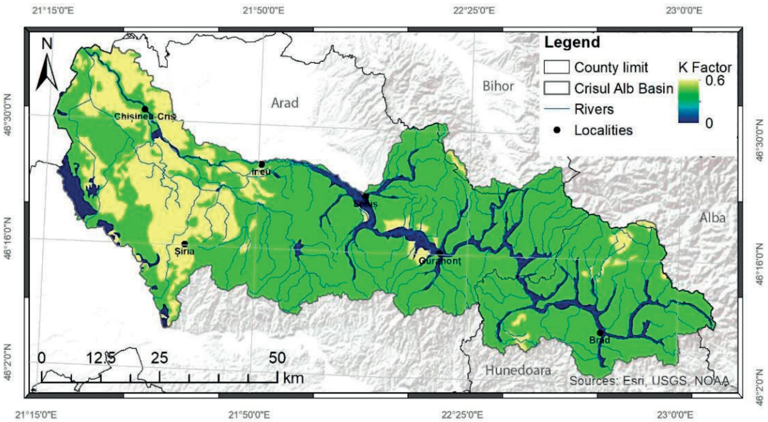

Figure 4. The K factor distribution map (t ha^{-1} MJ^{-1} mm^{-1}) in the study area

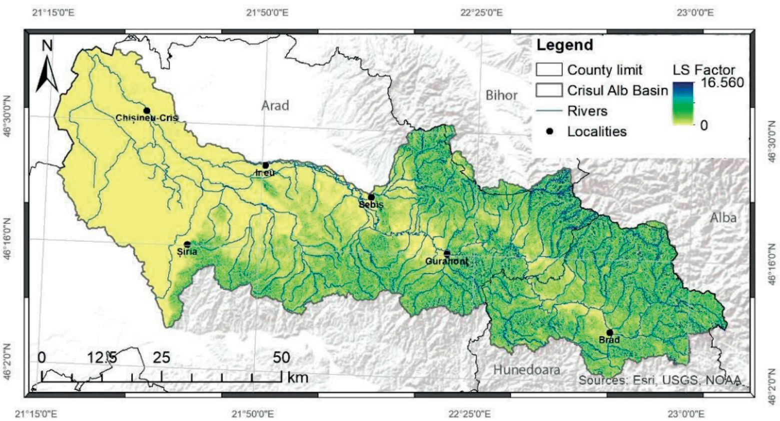

Figure 5. The LS factor distribution map in the study area

4. **Land cover management factor (C)**

In the case of this study, the C factor (Figure 6) was determined based on the NDVI derived from satellite images, a method applied through various algorithms in other studies (Durigon et al., 2014). In the hydrographic basin of the Crișul Alb River, in the year 2021, the average NDVI values ranged from -0.21 to 0.63. The minimum values are specific to areas not covered by vegetation (water bodies, roads, or plowed or harvested agricultural land), while the maximum values characterize forested areas in mountainous regions. The C factor, calculated based on satellite images, ranged from 0.03 to 1.41, in the hydrographic basin of the Crișul Alb River. The maximum values of the C factor correspond to plain areas dominated by agricultural land with a lower degree of soil cover and therefore lower potential protection against erosion.

The C values decrease towards higher altitudes, where forested areas prevail, providing a higher degree of soil erosion protection.

5. **Conservation Support Practice Factor (P)**

The P factor defines the impact of land use and agricultural and non-agricultural practices on soil erosion, thus quantifying the influence of conservation strategies in the emergence and manifestation of erosion processes (Allafta & Opp, 2022).

In the case of the area of interest, P had values ranging from 0.2 to 5.2 (Figure 7).

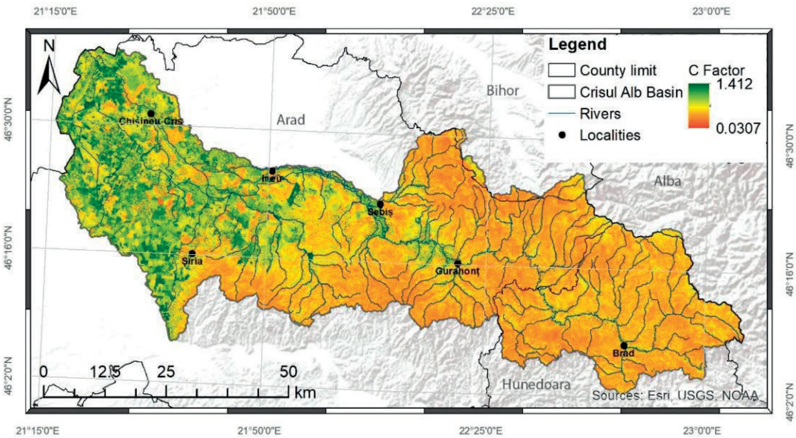

Figure 6. The C factor distribution map in the study area

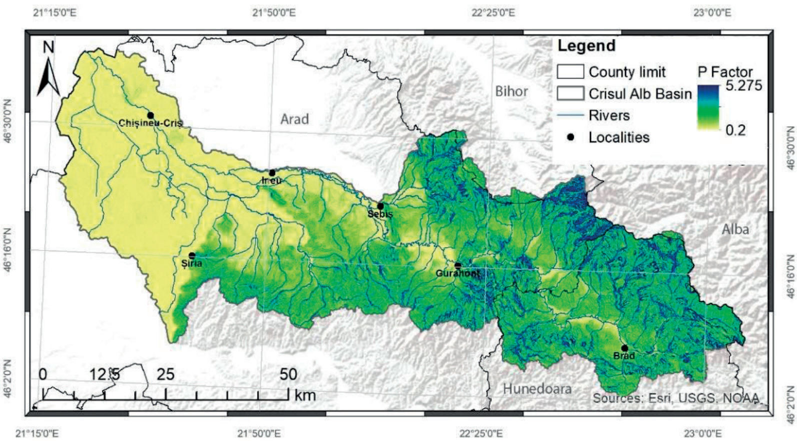

Figure 7. The P factor distribution map in the study area

Assessing the vulnerability of the territory to soil erosion

At the level of the study area, the soil erosion rate falls between 0 - >41 t ha^{-1} year^{-1}.

Based on the severity level, the soil erosion map of the Crișul Alb watershed has been divided into five classes: very low rate (tolerable) of less than 3 t ha^{-1} year^{-1}; low rate between 3.1-10 t ha^{-1} year^{-1}; moderate rate between 11-20 t ha^{-1} year^{-1}; high rate, between 21-40 t ha^{-1} year^{-1} and very high rate of over 41 t ha^{-1} year^{-1} (Sestras et al., 2023).

From Figure 8 and Table 2, it can be observed that 74% of the territory falls into the class of very low susceptibility to soil erosion (below 3 t ha^{-1} year^{-1}), which are areas located in low-lying plains, river valleys, and depressions, at the base of slopes. In the class with a low rate (3.1-10 t ha^{-1} year^{-1}), 14% of the land is classified; 7% have been classified with moderate rates, while 4% have high (21-40 t ha^{-1} year^{-1}) and very high erosion rates (over 41 t ha^{-1} year^{-1}).

High rates of soil loss through erosion generally characterize areas with high amounts of precipitation, with clay soils and high values of slopes, in premontane and mountainous areas.

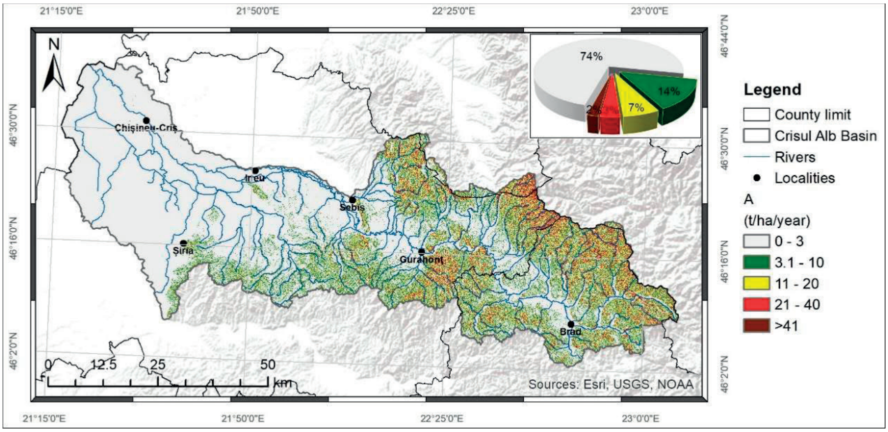

Figure 8 Soil erosion susceptibility map (t ha^{-1} year^{-1}), of the Crișul Alb H

Table 2 Erosion modeling by severity classes (erosion rates), at the sub-basin level

Sub-basin	Classes of erosion susceptibility (t ha^{-1} year^{-1})					Sub-basin	Classes of erosion susceptibility (t ha^{-1} year^{-1})				
	0-3	3.1-10	11-20	21-40	>41		0-3	3.1-10	11-20	21-40	>41
Crisul Alb	78	11	6	4	2	Topasca	92	7	1	0	0
Valea Satului	40	27	18	11	5	Chisindia	60	28	9	3	1
Birtin	50	27	14	7	2	Cleja	92	6	1	0	0
Vata	52	27	13	6	1	Sebis	60	20	12	6	2
Obarsa	70	18	7	4	1	Hodis	93	6	0	0	0
Pravaleni	51	27	14	7	2	Potoc	97	3	0	0	0
Ociu	84	13	3	1	0	Trei Holamburi	99	1	0	0	0
Banesti	44	22	16	12	7	Gut	97	3	1	0	0
Leasa	89	11	1	0	0	Cigher	87	11	2	0	0
Valea de la Lazuri	55	17	11	10	7	Luncoiu	61	24	10	4	1
Valea Mare	41	30	17	9	3	Valea Noua Chiser	100	0	0	0	0
Tacasele	69	20	7	3	1	Canalul Morilor	100	0	0	0	0
Artan	38	26	20	12	4	Brad	57	27	11	5	1
Gruiet	59	25	10	4	1	Junc	52	25	14	7	2
Sighisoara	48	28	15	8	2	Ribita	40	24	18	12	6
Zimbru	61	25	9	4	1	Tebea	58	26	11	5	1
Mustesti	77	18	4	1	0	Baldovin	63	24	9	3	1
Fenis	80	16	3	1	0	Valea Laptelui	35	25	19	13	7
Crocna	64	21	9	5	1	Plai	31	24	22	14	9
Bodesti	72	20	6	2	0	Bucuresci	52	27	13	6	2
Dumbravita	69	17	9	4	1						
Craicova	77	13	7	3	1	**Total**	315417	58786	27446	14628	5811
Almas	67	26	6	1	0	**% of total**	74	14	6	3	1

The soil erosion susceptibility map (Figure 8) illustrates that the spatial distribution of annual average soil loss in the analyzed hydrographic basin was variable, with minimum values in the western half, corresponding to the plains and low hills, and maximum values in the eastern half, in the highland areas.
The precision and accuracy of the results is conditioned by the average resolution of the data used. This aspect is also a limitation in using the data for large-scale analyses. However, such studies are accepted in the specialized literature and practices in the field, given the fact that they provide an overview of the phenomena in the territory.

CONCLUSIONS

In this study, USLE, the empirical soil erosion estimation method, was used, implemented through GIS tools and remote sensing data. By applying this method, accessible from the point of view of the involved data and working methods, both the quantitative evaluation of the average annual soil losses and the classification of the area of interest, according to the risk of soil erosion, was achieved.
The research results in the hydrographic basin of Crișul Alb have revealed a significant spatial variability in the soil erosion potential, influenced by intrinsic and extrinsic factors. Estimated soil loss varies from 0 t ha^{-1} $year^{-1}$, in low-slope plain areas to over 41 t ha^{-1} $year^{-1}$, in mountainous areas with steep slopes or in degraded and unvegetated lands.

Attention is drawn to areas where the erosion rate is high and very high (approximately 4% of the territory), which should be considered a priority for implementing soil erosion control measures (excess moisture removal, slope stabilization, proper agricultural management, and so on).
The results regarding the identification and classification of erosion-prone areas support the development of H.B. management plans aimed at soil conservation.
The spatial distribution of erosion rates, according to the severity of the phenomenon, along with other individual factors, helps in understanding the primary processes that cause and sustain erosion and can provide support in recommending measures for preventing and controlling soil erosion.

REFERENCES

Allafta, H., & Opp, C. (2022). Soil Erosion Assessment Using the RUSLE Model, Remote Sensing, and GIS in the Shatt Al-Arab Basin (Iraq-Iran). *Appl. Sci., 12*, 7776. https://doi.org/10.3390/app12157776.
ArcGIS Documentation. (2022). https://desktop.arcgis.com/en/documentation/ (accessed on 25.10.2022).
Arhiva Administraţiei Bazinale de Apă Crişuri, 2023.
Asnake, Y., & Amare, B. (2019). Soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshillo Catchment of the Blue Nile Basin, Ethiopia. *Environ. Syst. Res., 8*, 17.
Balabathina, V.N., Raju, R.P., Mulualem, W., & Tadele, G. (2020). Estimation of soil loss using remote sensing and GIS-based universal soil loss equation in northern catchment of Lake Tana Sub-basin, Upper Blue Nile Basin, Northwest Ethiopia. *Environ. Syst. Res., 9,* 35. https://doi.org/10.1186/s40068-020-00203-3.
Biali, G. & Cojocaru, P. (2021). The influence of gis technology in reclamation solutions for sloping land affected by erosion. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, X*, 293-300, Print ISSN 2285-6064.
Borrelli, P., Märker, M., & Schütt, B. (2015). Modelling post-tree-harvesting soil erosion and sediment deposition potential in the Turano River basin (Italian Central Apennine). *Land Degrad. Dev, 26*, 356–366.
Choudhury, M.K., & Nayak, T. (2003). Estimation of soil erosion in Sagar Lake catchment of Central India. In *Proceedings of the International Conference on Water and Environment*, Bhopal, India, 15–18 December; pp. 387–392.
Climatic Database. (2023) https://rp5.ru/Weather_in_Romania.
Cojocariu, L.L., Copăcean, L., Ursu, A., Sărăţeanu, V., Popescu, C.A., Horablaga, M.N., Bordean, D.-M., Horablaga, A., & Bostan, C. (2024). Assessment of the Impact of Population Reduction on Grasslands with a New "Tool": A Case Study on the "Mountainous Banat" Area of Romania. *Land, 13*, 134. https://doi.org/10.3390/land13020134.
Copăcean, L., Zisu, I., Mazăre, V., & Cojocariu, L. (2019). Analysis of land use changes and their influence on soil features. Case study: Secaș village, Timiș County (Romania). *PESD, 13*(2), Doi: 10.2478/pesd-2019-0032.
Copernicus Open Access Hub. (2023). Available online: https://scihub.copernicus.eu/dhus/#/home (accessed on 11.01.2023).
Diodato, N., & Bellocchi, G. (2007). Estimating monthly R factor USLE climate input in a Mediterranean region using limited data. *J. Hydrol., 345*, 224–236.
Durigon, V.L., Carvalho, D.F., Antunes, M.A.H., Oliveira, P.T.S., & Fernandes, M.M. (2014). NDVI time series for monitoring RUSLE cover management

factor in a tropical watershed. *Int. J. Remote Sens., 35*(2), 441–453.

Estifanos, A. (2014). Assessment of Micro-Watershed Vulnerability for Soil Erosion in Ribb Watershed using GIS and Remote Sensing. MSc Thesis. Mekelle University, Ethiopia.

European Environment Agency (EEA). (2016). Digital Elevation Model (DEM), https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem (accessed on 13.12.2016).

Fathizad, H., Karimi, H., & Alibakhshi, S.M. (2014). The estimation of erosion and sediment by using the RUSLE model and RS and GIS techniques (Case study: Arid and semi-arid regions of Doviraj, Ilam province, Iran). *Int. J. Agric. Crop Sci., 7*, 304–314.

Foster, G.R., Toy, T.J., & Renard, K.G. (2003). Comparison of the USLE, RUSLE1.06c, and RUSLE2 for application to highly disturbed lands. In *Proceedings of the First Interagency Conference on Research in the Watersheds*, Benson, AZ, USA, 27–30 October; pp. 154–160.

Fu, B.J., Zhao, W.W., Chen, L.D., Zhang, Q.J., Lü, Y.H., Gulinck, H., & Poesen, J. (2005). Assessment of soil erosion at largewatershed scale using rusle and GIS: A case study in the Loess Plateau of China. *Land Degrad. Dev., 16*, 73–85.

Ge, Y., Zhao, L., Chen, J., Li, X., Li, H., Wang, Z., & Ren, Y. (2023). Study on Soil Erosion Driving Forces by Using (R)USLE Framework and Machine Learning: A Case Study in Southwest China. *Land, 12*, 639. https://doi.org/10.3390/land12030639.

Geospatial. (2022). România: seturi de date vectoriale generale – http://geo-spatial.org/vechi/download/romania-seturi-vectoriale (accessed on 10.01.2022).

Golosov, V., Gusarov, A., Litvin, L., Yermolaev, O., Chizhikova, N., Safina, G., & Kiryukhina, Z. (2017). Evaluation of soil erosion rates in the southern half of the Russian Plain: Methodology and initial results. *Proc. Int. Assoc. Hydrol. Sci., 375*, 23.

Greiner, L., Keller, A., Grêt-Regamey, A., & Papritz, A. (2017). Soil function assessment: review of methods for quantifying the ontributions of soils to ecosystem services. *Land Use Policy, 69*, 224-237. https://doi.org/10.1016/j.landusepol.2017.06.025.

Kim, J.B., Saunders, P., John, T.F. (2005). Rapid assessment of soil erosion in the Rio Lempa Basin, Central America, using the universal soil loss equation and geographic information systems. *Environ. Manage., 36*(6), 872–885.

Lastoria, B., Miserocchi, F., Lanciani, A., & Monacelli, G. (2008). An estimated erosion map for the Aterno-Pescara river Basin. Eur. *Water, 21/22*, 29–39.

Ligonja, P.J., & Shrestha, R.P. (2015). Soil erosion assessment in Kondoaeroded area in Tanzania using Universal Soil Loss Equation, geographic information systems and socioeconomic approach. *Land Degrad. Dev., 26*, 367–379.

Liu, B.Y., Nearing, M.A., Shi, P.J., & Jia, Z.W. (2000). Slope length effects on soil loss for steep slopes. *Soil Sci. Soc. Am. J., 64*, 1759–1763.

Măgureanu, M., Sfîrcoci, M., Copacean, L., & Cojocariu, L. (2024). Monitoring the vegetation coverage of the grasslands in the Poiana Ruscă Mountains using different remote sensing indices. *Present Environment and Sustainable Development, 17*, 189-199. 10.47743/pesd2023172014.

Man, E.T. (2014). *Drenaje*, Vol. I., Editura Orizonturi universitare, Timişoara, Romania.

Mengie, B., Teshome, Y., & Dereje, T. (2019). Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques. *Environ Syst. Res., 8,* 20.

Mircea, S. (2011). *Impactul ravenarii asupra mediului in B.H. Slanic/Buzau*, Editura BREN, Bucuresti, Romania.

Niacsu, L., Ionita, I., Samoila, C., Grigoras, G., & Blebea-Apostu, A.M. (2021). Land Degradation and Soil Conservation Measures in the Moldavian Plateau, Eastern Romania: A Case Study from the Racova Catchment. *Water, 13*, 2877. https://doi.org/10.3390/w13202877.

Nistor, D., & Nistor, D. (2002). Land Degradation by Erosion and Its Control in Romania, *12th ISCO Conference, Beijing*, https://topsoil.nserl.purdue.edu/isco/isco12/VolumeII/LandDegradationbyErosion.pdf

Panagos, P., Ballabio, C., Borrelli, P., Meusburger, K., Klik, A., Rousseva, S., Tadić, M.P., Michaelides, S., Hrabalíková, M., Olsen, P., Aalto, J., Lakatos, M., Rymszewicz, A., Dumitrescu, A., Beguería, S., & Alewell, C. (2015). Rainfall erosivity in Europe. *Sci. Total Environ., 511*, 801–814.

Patriche, C. (2023). Applying RUSLE for soil erosion estimation in Romania under current and future climate scenarios. *Geoderma Regional, 34,* e00687. 10.1016/j.geodrs.2023.e00687.

Pham, T.G., Nguyen, H.T., & Kappas, M. (2018). Assessment of soil quality indicators under different agricultural land use and topographic aspects in Central Vietnam. *Int Soil Water Conserv. Res., 6*(4), 280–288.

Popescu, E., Nenciu, F., Vladut, V. (2022). A new strategic approach used for the regeneration of soil fertility, in order to improve the productivity in ecological systems. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, XI, 277-284*, Print ISSN 2285-6064.

Posea, G., & Badea, L. (1984). *România. Unităţile de relief (Regionarea geomorfologică)*. Ed. Ştiinţifică şi Enciclopedică, Bucureşti, Romania.

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).* In USDA Agricultural Handbook; U.S. Department of Agriculture: Washington, DC, USA; No. 703.

Robert, P., Stone, P., & Don, H. (2012). Universal Soil Loss Equation (USLE); Ministry of Agriculture, Food and Rural Affairs: Ontario, ON, Canada. Available online:

http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm (accessed on 20.012024).

Roșca, S., Bilașco, Ș., Petrea, D., Vescan, I., Fodorean, I., & Filip, S. (2014). Application of soil loss scenarios using the ROMSEM model depending on maximum land use pretability classes. A case study. *Studia UBB Geographia, 59*, 101-116.

Rusu, R. (2007). *Organizarea spaţiului geografic în Banat*, Ed. Mirton, Timişoara, Romania.

Selmy, S.A.H., Abd Al-Aziz, S.H., Jiménez-Ballesta, R., García-Navarro, F.J., & Fadl, M.E. (2021). Modeling and Assessing Potential Soil Erosion Hazards Using USLE and Wind Erosion Models in Integration with GIS Techniques: Dakhla Oasis, Egypt. *Agriculture, 11,* 1124.

Sestras, P., Mircea, S., Rosca, S., Bilasco, S., Salagean, T., Dragomir, L., Herbei, M., Bruma, S., Sabou, C., Marković, R., & Kader, S. (2023). GIS based soil erosion assessment using the USLE model for efficient land management: A case study in an area with diverse pedo-geomorphological and bioclimatic characteristics. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 51*, 10.15835/nbha51313263.

Simon, M., Copăcean, L., & Cojocariu, L. (2022). Techniques for identification, mapping and analysis of grasslands. Case study: Arad county. *PESD, 16*(2), 39-49. https://doi.org/10.47743/pesd2022162004.

Simon, M., Popescu, C.A., Copăcean, L., & Cojocariu, L. (2020). Complex model based on UAV technology for investigating pastoral space. *PESD, 14*(2), 139 – 150. https://doi.org/10.15551/pesd2020142011.

Singh, G., & Panda, R.K. (2017). Grid-cell-based assessment of soil erosion potential for identification of critical erosion-prone areas using USLE, GIS and remote sensing: a case study in the Kapgari watershed, India. *Int Soil Water Conserv. Res., 5*(3), 202–211.

Spalevic, V., Barovic, G., Vujacic, D., Curovic, M., Behzadfar, M., Djurovic, N., & Billi, P. (2020). The impact of land use changes on soil erosion in the river basin of Miocki Potok, Montenegro. *Water, 12*(11), 2973. https://doi.org/10.3390/w12112973.

Todisco, F., Vergni, L., Ortenzi, S., & Di Matteo, L. (2022). Soil Loss Estimation Coupling a Modified USLE Model with a Runoff Correction Factor Based on Rainfall and Satellite Soil Moisture Data. *Water, 14*, 2081. https://doi.org/10.3390/w14132081.

Wischmeier, W.H., & Smith, D.D. (1978). *Predicting rainfall erosion losses- a guide to conservation planning.* Agriculture Handbook No. 537, Department of Agriculture, US

Zhang, H., Yang, Q., Li, R., Liu, Q., Moore, D., He, P., Ritsema, C.J., & Geissen, V. (2013). Extension of a GIS procedure for calculating the RUSLE equation LS factor. *J. Comput. Geosci., 52*, 177–188.

Zisu, I. (2014). *Studiu pedogeografic al Dealurilor Lugojului cu privire specială asupra calităţii terenurilor Agricole*. Teză de doctorat, Universitatea de Vest Timişoara. Romania.