ASSESSING SOIL EROSION CAUSED BY RAINDROPS UTILIZING THE INDEX OF EROSION THROUGH PRECIPITATION (R-FACTOR)

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ABSTRACT. – Assessing soil erosion caused by raindrops utilizing the index of erosion through precipitation (R-factor). Soil erosion caused by raindrops is a topic that arouses the interest of researchers at the international level. The negative impact that this meteorological phenomenon has on the edaphic component determines a limited development of the zone or area on which the entire research process takes place. In order to arrive at an analysis consistent with the reality on the ground, many researchers have used an essential indicator, namely, the R-Factor. It highlights the action of the kinetic energy produced by precipitation over a period of time. The purpose of our research is to reveal the degree of soil erosion following raindrops, with the Someșan Plateau situated in North-West Romania as a study area. The spatio-temporal analysis consisted in the processing of the ESDAC (European Soil Data Centre) databases that were outlined following the application of the R-factor indicator, on which we applied GIS techniques, in order to finally obtain cartographic material that reveals on the basis of several analysis indices, the degree of soil erosion in a time interval (1970-2018). The notable results that we obtained after processing the data, outline the fact that during the analyzed period a low amount of precipitation is recorded, an aspect that creates a low degree of erosion. Regarding the probability of producing erosion determined by this meteorological phenomenon, the values obtained are reduced far below the normal values of the analyzed indicators, highlighting that the probability of producing a high-risk erosion in the near future is zero.The results of our research, including the entire cartographic material, will be able to be used by the competent authorities (the town hall of Bălan commune, the county councilas) as a basis for spatial development projects

Keywords: soil erosion, degradation, rain drops, R-factor, indicators, Someșan Plateau, Romania.

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1. INTRODUCTION

The erosivity of the rain is an essential climatic factor in terms of the manner and degree of destructiveness of the soil, even leading to the appearance of gravity processes, whose essential triggering factors are the appearance of water and the high degree of inclination of the slope. Raindrops are an impetus for the degradation processes that take place at ground level, and automatically at the level of all landforms.

Due to the action of precipitation soil erosion is a problem often encountered and addressed nowadays at an international level, being considered to be a necessary aspect to take into account regarding the numerous managerial and economic development projects of an area (Borrelli et.all , 2016). The more eroded the vegetal carpet within which (the edaphic component is the most important factor to consider), the less possible the development of an area, both natural and socio-economic factors being affected.

The research carried out in recent years that addresses this issue, highlights numerous factors that led to the emergence of the soil degradation process, including the impact that raindrops have in the degradation process. The research carried out by Hugh Hammond Bennett (1939) highlights the mode of soil erosion through the prism of agriculture, following the massive and intensive cultivation of extensive areas in the United States. In 1940, Zingg considers that a necessary factor in the erosion process is the presence of aspect`s slope. Although, in his research, he does not take into account in the analysis equation the presence and infiltration of water from precipitation, it is the impetus to specify that the high slope, the presence of a high amount of water in the geological substratum and the permissive lithology, are the main elements in what consists in the production of a landslide.

The realization of numerous specialized works that address this problem, represent essential tools in the conservation and territorial planning processes, both at the local, zonal, regional and national level. The most widely used models used for soil conservation result from the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965, 1978). Within these models are included two other models, the Revised USLE (RUSLE) (Renard el all., 1997) and RUSLE2 (Foster, 2004). They have been adapted and developed in other parts of the world, such as: Germany, China, Russia, etc. (S. Yin et al., 2015).

The models have a common indicator that is essential in ground-level analyses, namely the index of erosion through precipitation (R-factor). This is an essential basic factor in estimating the level of soil erosion as a result of water action resulting from rains or storms (Renard, 1991, Borrelli, 2016). Also, this indicator reveals essential aspects in analyzes of environmental hazards (landslides, etc.) and hydrological processes (floods) (Nazzareno 2004; Capolongo et al. 2008; Nazzareno et al. 2015).

For a good understanding of how to interpret this index, it is essential to specify how it works. Thus, R-factor expresses the mode of action of the total kinetic energy produced by precipitation in a time interval (30 minutes) (KE x I30) (Wischmeier and Smith, 1978). Kinetic energy is taken into account because it is an indicator that suggests how a raindrop infiltrates a soil particle and dislodges it from a larger mass (Nearing and Bradford, 1985, S. Yin, 2015). For a good measurement of this energy and to obtain plausible values, it is necessary to use high-performance instruments. In their absence, methods have been developed through which the kinetic energy can be estimated based on the intensity of precipitation (I), using logarithmic methods, exponential or power functions.

The most frequently used method for obtaining plausible values is the calculation of the R-factor indicator based on a time interval between 1-5 minutes (Williams, R.G., Sheridan, J.M.,1991). This time interval brings many shortcomings or even aspects that do not coincide with reality, due to the limitations of the measuring instruments. Because of this aspect, there are many studies that opt for a time interval of 15 -30 minutes (Renard et al., 1997; Agnese et al., 2006; Yin et all., 2007).

At the international level, in the last two decades, numerous researches have been carried out that address the problem of soil erosion following the impact of raindrops, using the R-factor indicator as a calculation method. It was extracted from a USLE database, being the most commonly used to obtain the numerous indicators needed to obtain a plausible and realistic R-factor value. There are studies that applied the indicator using databases obtained from a single station (Zanchi, 1988; Borrelli et al., 2013), but also research that was carried out referring to a much wider area (e.g. regional level) (Renard and Freimund, 1994; De Santos Loureiro and De Azevedo Coutiho, 2001; Bosco et al., 2015). Research using the time period between 15 -30 minutes (Angulo Martinez et al., 2009; Meusburger et al., 2012) combined this interval with a set of criteria that enter into the analysis of the environment, finally obtaining satisfactory results.

The research that approaches our study area, Someșan Plateau, presents the variety of problems that the relief of this unit raises in terms of the presence of water resources. In 1986, Sorocovschi and Schreiber highlight the morpho-hydro-climatic relationships in the northern area of Transylvania. In 2002, a research was carried out showing the existence of periods of pluviometric excess of the Transylvanian Depression. Croitoru, Eliza (2006) analyzes the excess precipitation within the previous territory, a major relief unit which include our study area. Another analysis is made by Schreiber, W., (2009) who makes numerous remarks and presents the response mode of the existing rocks in the lithological substrate on which the research area is carried out. Sorocovschi, in his work Someșan Plateau. Hydrogeographic study (2020) wants to highlight, through the water component, the set of geographical interactions that outline certain particularities of this area. Likewise, numerous other studies address the issue of soil erosion in

Romania, from different perspectives: precipitation, geomorphological processes, floods, anthropogenic processes, etc. (D., Dumitru, (2021), C., Totolea, (2022), Croitoru, Adina, (2016, 2018), Moldovan, F. et al., (2002), I., Holobâcă (2006, 2007), I. A., Irimuș et all. (2005, 2015).

The main objective of this study is to reveal the degree of soil erosion following the impact of raindrops falling over a period of time. It is a spatio-temporal analysis study, based on the use of the R-factor indicator obtained from the ESDAC (European Soil Data Centre) databases. The entire database was entered into the GIS geo-informational software, where, based on spatio-temporal analysis techniques, we highlighted the existence or lack of the degree of soil erosion that we identified within our research area, in the analyzed time interval.

2. STUDY AREA

Alexandru Savu (1963), in the contents of his doctoral thesis, mentions for the first time the name "Podiș Someșan", a unit that was previously known and researched under the name "Platformă Someșan". Under this name, this Someșan Platform was composed of two sides, the external side and the internal side, sides separated by the Intracarpathian Yoke (Mihăilescu, 1936, 1966, Pop, 2001). The space on the western side of the Jug belongs to the Western Hills, and the space on the western side, namely, the internal side, is known as the Someșan Plateau (Pop, 2001).

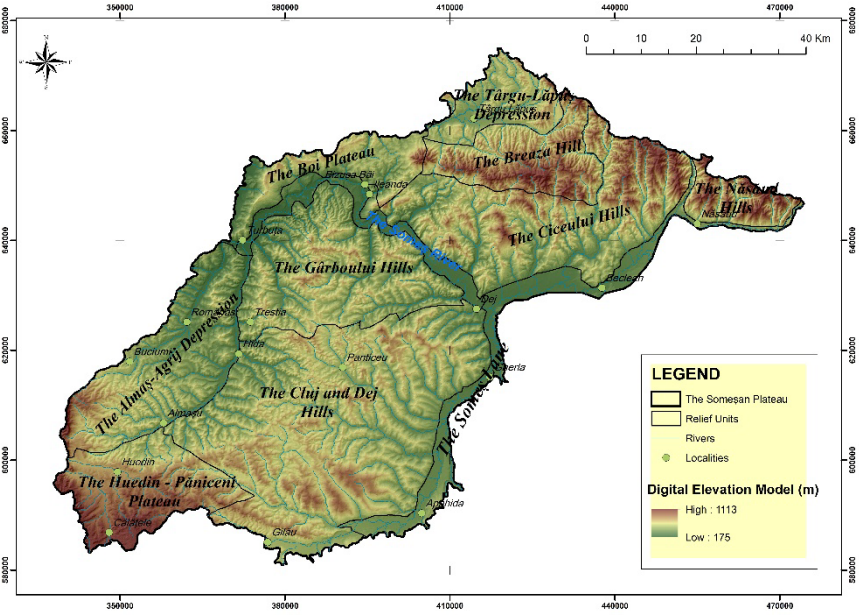

Fig. 1. Study area – The Someșan Plateau

The Someșan Plateau (fig.1) is a hilly unit with a cuesta relief appearance, an appearance given by the presence of concentric cuesta and structural surfaces. Also, within this relief unit, from the point of view of rock types, we are faced with a lithological homogeneity, due to the development mostly on Eocene-Miocene sedimentary formations. Another aspect that characterizes the plateau is the tectonic articulation that highlights the mode of formation, so that the southern area (south of Someș river) dominates Eocene horizons (sandstones and red conglomerates with clayey cement) that end with the presence of coarse limestones and reddish gravels which develops towards the northern part in the form of sandstones, and towards Turbuța village (Sălaj county) in brown marl-limestone and white marl-type limestone (Ilie, 1958).

Due to the parallelogram shape, whose sides have a SW, NE and SE orientation (Savu, 1963), and which includes within it elements specific to the landscape (lithology and structure of the relief, the way of development and appearance of the strata, the valley lanes, the climate that has imprints on the vegetation, on the resulting landforms, but also on the soils) allows the identification of the subdivisions that make up the Someșan Plateau.

The morphometric and morphological peculiarities of the relief, but also the geographical position of the studied unit in Europe and in Romania, contribute to the formation of climatic elements. As for the climate of the Someșan Plateau, it is characterized by mild and wet winters, with precipitation predominantly in the form of rain. The summers in this region are cool, they outline a character of instability. The prevailing winds are from the northwest and west.

The air temperature reaches the highest values (18 -20°C), which are recorded in the Someșului Corridor, but also in the lower territories on the eastern side of the Cluj and Deju Hills. On the hills that reach an altitude higher than 600 m, the average annual temperature reaches 5 – 6°C. As for the average thermal amplitudes, they outline higher values in the south-eastern part of the Someșan Plateau, (22 -23°C) (Croitoru, Adina-Eliza et al., 2002).

The annual amounts of precipitation in relation to the altitudes present different links attributed to the component units of the studied region, and which are differentiated by the value of the pluviometric gradients. The lowest amounts of precipitation (550-600 mm) are recorded in the Cluj Hills. Intermediate amounts (600-650 mm) are recorded in the Dejului and Simișna-Gârbou Hills. The highest values (over 650 mm) appear on the high peaks of the Simișna-Gârbou Hills, but also in the western part of the Someșului Pass (downstream of Răstoci). The highest amount of precipitation in the Someșan Plateau is recorded in June, and the month that reaches the lowest precipitation values is February (Geographia României, III, 1987, Croitoru, Adina – Eliza et al. 2002, Sorocovschi, 2020) .

3. DATA AND METHODS

The methodology used in this study combines a number of analysis techniques, which were used in the processing of ESDAC data. The GIS methodology allowed us to outline a morphometric database for the analysis of the relief inscribed on the sandstones and microconglomerates within the research unit. The morphometry but also the typology of the rocks in the substrate are essential aspects that must be taken into account in the elaboration of this study. Sandstones and conglomerates following the action of external agencies (in this case, precipitation), are prone to the appearance of degradation processes both at the level of the soil and at the level of the relief forms created.

Using the ESDAC (European Soil Data Centre) database, we obtained a database that we will use to identify the degree of soil erosion and automatically at the level of relief forms that raise importance within the study area. The obtained values are measured over a period of 48 years (1970 - 2018), with the specification that the period integrated in the formula for obtaining the R-Factor is carried out over a time interval of 48 years (1970 -2018). The database was subjected to processing based on spatial analysis techniques, through which we were able to identify the areas where the erosion caused by precipitation is absent, is incipient or the degradation it achieves generates numerous geomorphological risks.

The calculation of the monthly values of precipitation and the level of runoff (R-factor) was done according to the instructions contained in the RUSLE manual. To obtain data regarding the mode and level of soil erosion following precipitation, we call for the analysis of some indicators, such as the density, trend, probability and period of erosion, but also the standard error that shows us the deviation that may exist within the process.

RUSLE2 (The Revised Universal Soil Loss Equation version 2 (RUSLE2) (USDA-Agricultural Research Service, 2013) introduces erosion density (ED) through which a much more plausible R-factor value can be obtained. The indicator is the result of the ratio between the erosion caused by heavy rains and normal precipitations, registering variations during a year, being taken monthly data from the same location. In order to obtain a real value of this density, it is necessary to note the aspects that refer to the energy produced by precipitation in a certain area within a unit of time (eg 15 -30 minutes) (MJ ha-1 , min -1) (Nearing and Bradford, 1985, Panagos, P., 2015). The values we obtain are multiplied by the average depth unit of precipitation (mm) within a period of time (monthly, annually). Thus the average erosion for a certain period of time can be obtained.

ED =R/P, where R represents the average rainfall erosivity over a year, and P is the average annual rainfall.

The use of this index brings several advantages for the preparation of maps aimed at the degree of erosion following rain activity within an area. An important benefit is outlined by the fact that the erosion density within a territory can be

determined over a shorter time interval (weekly, monthly) or even for a longer period (yearly), depending on what we want to highlight.

Also, the lack of data will not influence the obtaining of eloquent results, which is why the fact that null values can be obtained within a small area of the researched area, does not make the research lose its credibility. Another advantage has emerged from the fact that it is possible to obtain useful data that can show changes even in a shorter period (10-15 years).

We can conclude that, using this index, we obtain credible data even if we carry out research carried out over a shorter period of time (10 years), highlighting data that highlight the changes that occurred during this time, even if in certain time intervals, from various reasons, we register small errors at the level of the captured database.

In order to carry out research of the best possible quality, it is necessary that, in addition to the current data that we obtain, we make interpretations of the existing data in the past. Considering this fact, we will call on existing data over a 48-year timeframe spanning the period 1970-2018.

The reconstruction of the past in terms of the degree of soil erosion following the action of precipitation is based on the use of a dataset Rainfall Erosivity Database at European Scale (REDES), as well as Uncertainties in Ensembles of Regional Reanalyses (UERRA). Following the analysis performed on these sets, we will be able to highlight the changes that occur over time in terms of soil level erosion, given by the analyzed climatic factors. The use and processing of the mentioned data sets led to the appearance of the European-wide map showing erosion trends determined by precipitation, results that were successfully validated (Bezak, N et. al, 2020), from which we cut out our analysis area, the Someșan Plateau.

In terms of obtaining the trends of rainfall erosion over time within a more or less extensive territory, a database obtained over certain periods of time is used. In the framework of this research, we will use a set of data that appeared over a decade of 48 years, more precisely, 1970 -2018. Also, to outline these trends it is necessary to use another index, the Mann - Kendall index which presents the probability of degradation and follows how the trends evolve, if they register an increase or decrease, and if they present significant or insignificant records. The highest value of this indicator and which shows us the existence of a degradation is 1.96 or above. The information obtained placed below this value, being negative or positive, does not present a high degree of degradation. Also, this indicator is closely related to the degree of inclination (slope) of the relief unit. The formula that is the basis for obtaining this indicator is:

$$S = \sum \sum \operatorname{sgn}(x_j - x_i) \quad n \qquad [1]$$

$$j=i+1 \quad n-1 \qquad [2]$$

$$i=1 \quad (1) \qquad [3]$$

where, n represents a number of data points, and xi and xj are the data values within time series i and j (Mann 1945; Kendall 1975, Yue and Hashino 2003; Duhan and Pandey 2013).

In terms of standard error, this statistical indicator shows the deviation that can occur in a statistical analysis process using a database. The spatial interpolation model, in addition to obtaining the R-factor, also provides information about the standard error, through which we can reveal whether or not there is uncertainty in the prediction of the data obtained by the analysis.

4. RESULTS

Following the analysis carried out at the level of the indicators used to obtain the degree of soil erosion, also using GIS methods, we obtained a set of cartographic materials that show us the evolution and effects occurring at the level of the territory of analysis.

The period on the basis of which the database used to carry out the evaluation analysis of the erosion fence through the prism of the R-Factor indicator was obtained, is 48 years, included in the time interval 1970-2018. A major advantage that the use of this method with the related databases offered us, is outlined by the fact that the database arsenic was obtained by means of instruments for recording the amount of precipitation that falls daily. These instruments are much more numerous, unlike those that only record the amount of precipitation that hits the ground only in a certain time interval.

First, our research is based on the analysis carried out on the data covering the time period of 48 years (fig.2), in order to be able to form a conclusion regarding the level of action of precipitation over time within this area.

Thus, following the processing of the databases through the GIS software, we can observe that within the Someșan Plateau the amount of precipitation that falls in the analyzed time interval is reduced as a whole, 1970 – 676.6 mm; 1980 - 746.8 mm; 1990 -664.1 mm; 2000 -664.1 mm; 2010 -732.4 mm; 2018 – 656.0 mm. The period that outlines the lowest value is the interval 1990 and 2000, when the same minimum values of the amount of precipitation are recorded, being mainly identified in the central part of the unit. The highest value obtained is between 1970 and 1980 mm, mostly recorded in the southwestern area of the unit, the high area of the Huedin Plateau.

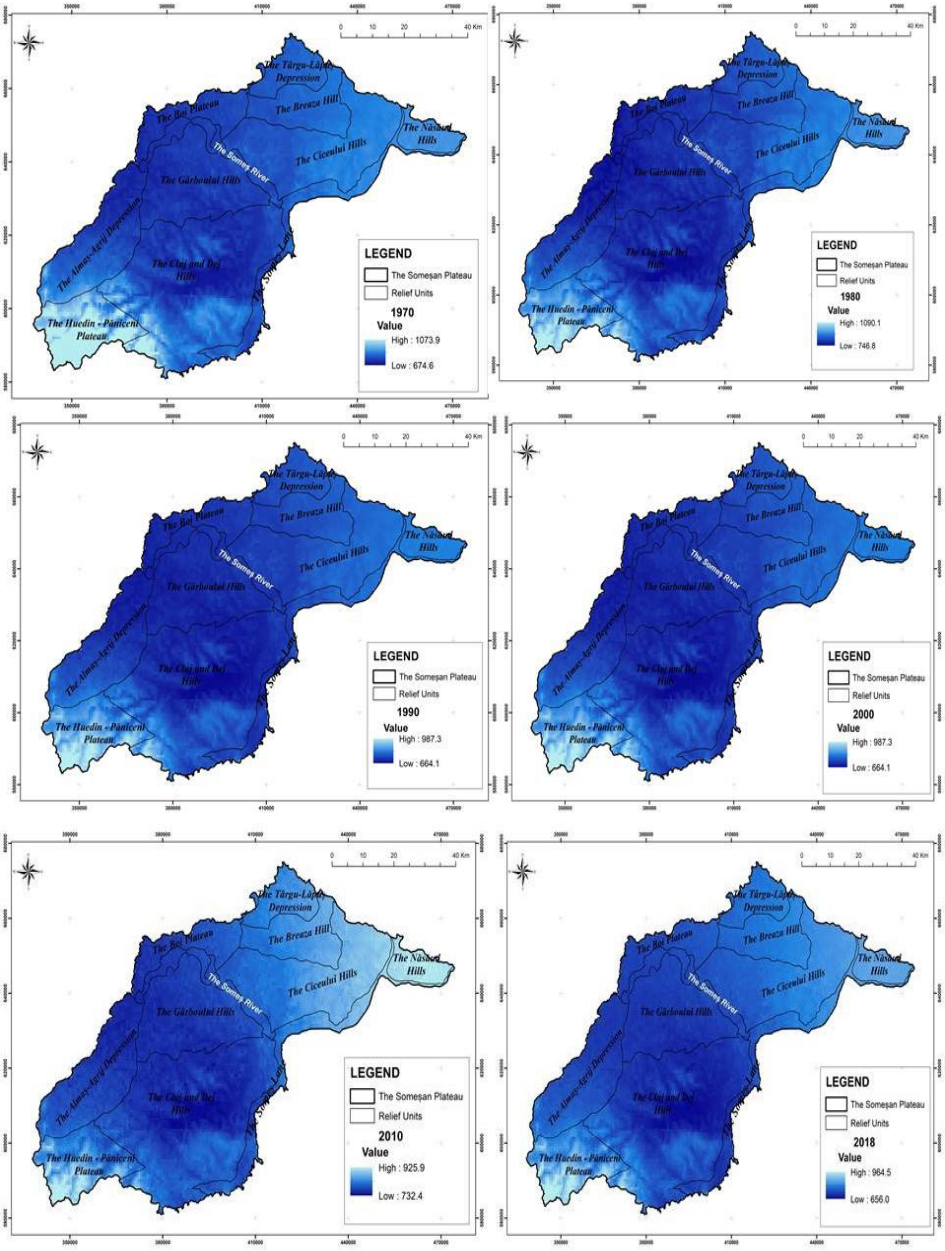

Fig .2. The amount of precipitation recorded over a period of 48 years

Analyzing the production trend (fig.3) of a massive erosion of the area following the action of precipitation, it highlights the tendency of decrease, increase or stagnation of water obtained as a result of precipitation. This indicator is considered together with the Mann-Kendall indicator, with the mention that the trend is expressed in percentages, and the latter represents the average probability.

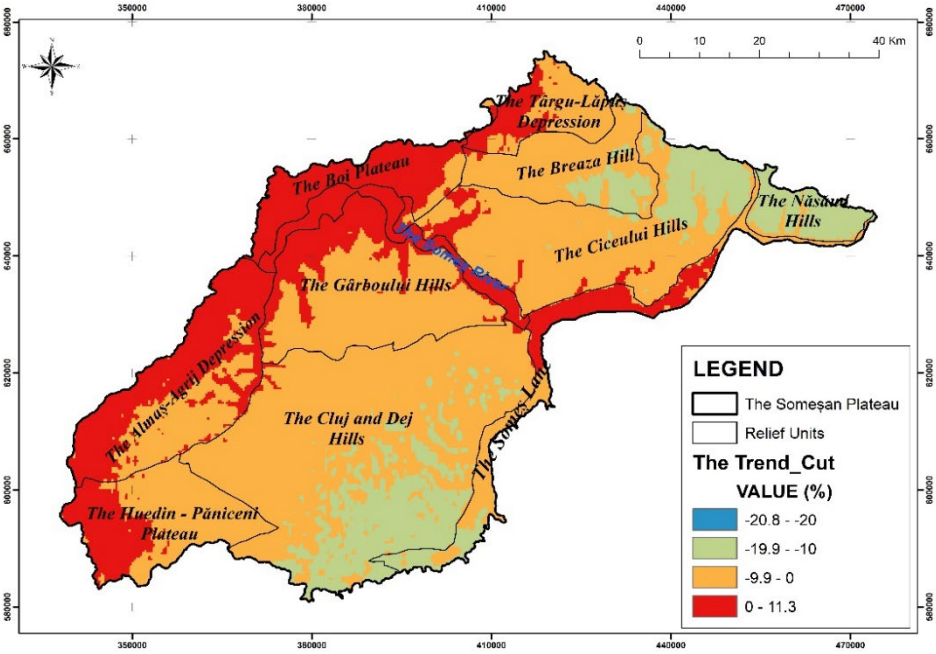

Fig. 3. Erosion trend expressed as a percentage (Trend-cut)

In the context of the scenario in which the tendency to produce erosion through precipitation is described, we obtained the minimum value within a range of -20.8% - -20%, with no visible areas showing this reduced value, unlike the maximum value recorded , which is contained in a percentage range of 0 -11.3%, carried out in the western area of the Almaș-Agrij Depression, the Boiului Plateau, the south-western part of the Târgu-Lăpuș Depression, as well as the Someșului Lane area, where quantities are recorded higher precipitations throughout the year, The prevailing interval is between -9.9% -0%, in the slope areas with an inclination of 5.1° - 35°.

Referring to the Mann – Kendall indicator which is widely used for analyzing the probability of the average that the trend can have over a period of time. The existence of percentages showing the veracity of the data is classified on a scale between 90%, 95% and 99%. 90% presents a certain verisimilitude of the results, having a maximum data value of 1.64, 95% is more eloquent than the

previous percentage, outlining a maximum value of 1.96, and the last gap, namely 99% highlights a probability of production, with the maximum value of 2.57.

The analysis of the meteorological phenomenon that leads to soil degradation (rain), taking into account the time interval in which it occurs, the area in which it acts, the level of action within the analysis unit, shows reduced values well below the probability percentage of 90 %, obtaining values much reduced compared to the value that this percentage presents as a maximum value, namely 1.64.

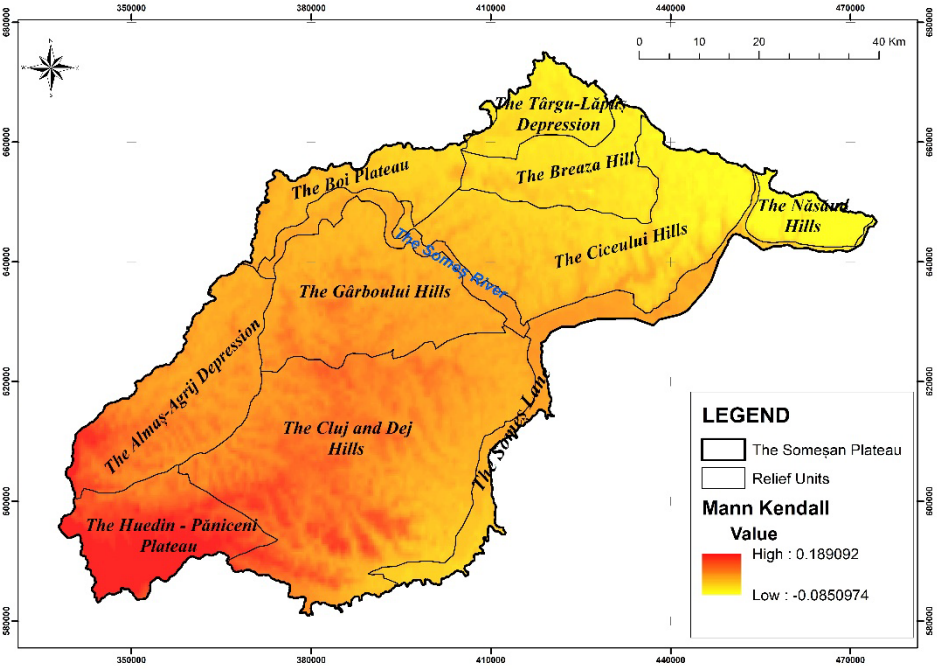

Fig. 4. The probability provided by the Mann-Kendall indicator

The values we obtained at the level of our study area (fig.4) has a range between 0.18 and -0.08, which highlights that the erosion by means of raindrops tracked during a time interval of 48 years is very low. Analyzing the values, the highest values are obtained in the southern part of the Almaș-Agrij Depression, a large part of the Huedin-Păniceni Depression, as well as small areas within the Cluj and Dejului Hills. The numerical data obtained from the use of GIS software through the processing of databases at the European level were reduced or even null. Compared to the values recorded by this indicator in an area where soil erosion is of little interest, the results we obtained reveal that in our study area the percentage of 90% is not reached, based on the level of high soil degradation.

Regarding the erosion density (fig.5), another indicator that needs to be analyzed in terms of soil erosion following the action of precipitation, obtained the highest value of 1.33 and is recorded in the southern part of the Cluj and Dej Hills, the western face of the Almaș-Agrij Depression, areas where these plateau units are in contact with the mountain ranges. The central part of the unit records an erosivity value of 1.05-1.19, and the lowest value (0.8-1.04) is mainly in the area of the Târgu-Lăpuș Depression, Culmea Brezei, Dealurile Ciceului.

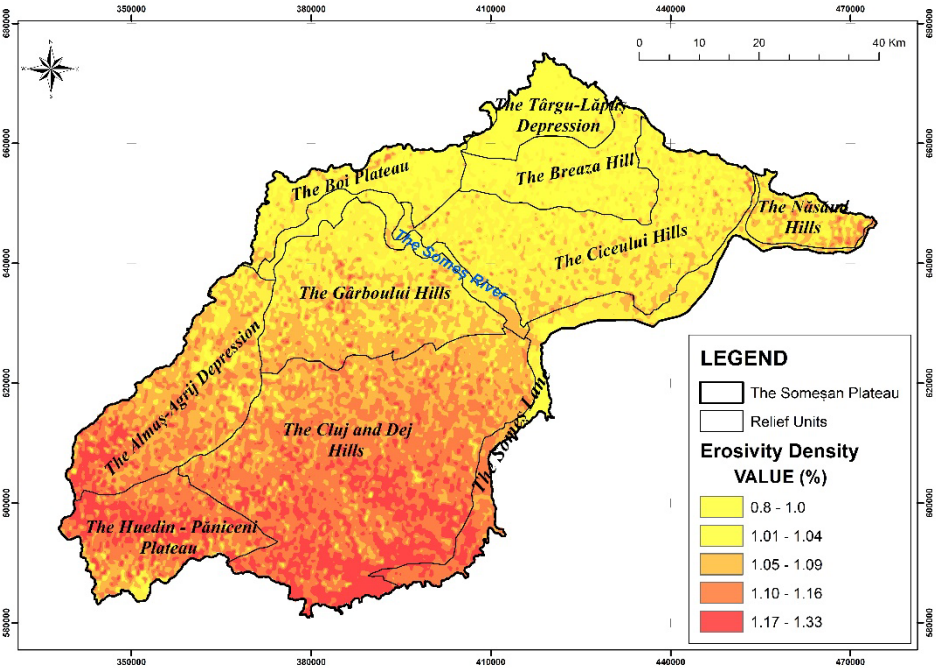

Fig. 5. Erosivity Density

An indicator that is superfluous to be analyzed within this research process is the standard error that highlights the fact that any study presents a 99% probability, and that 1% is outlined by the problems that the measuring devices could register, database processing through GIS software. Obtaining a high value of this indicator highlights the fact that the arsenal of data used presents a small deviation from normal.

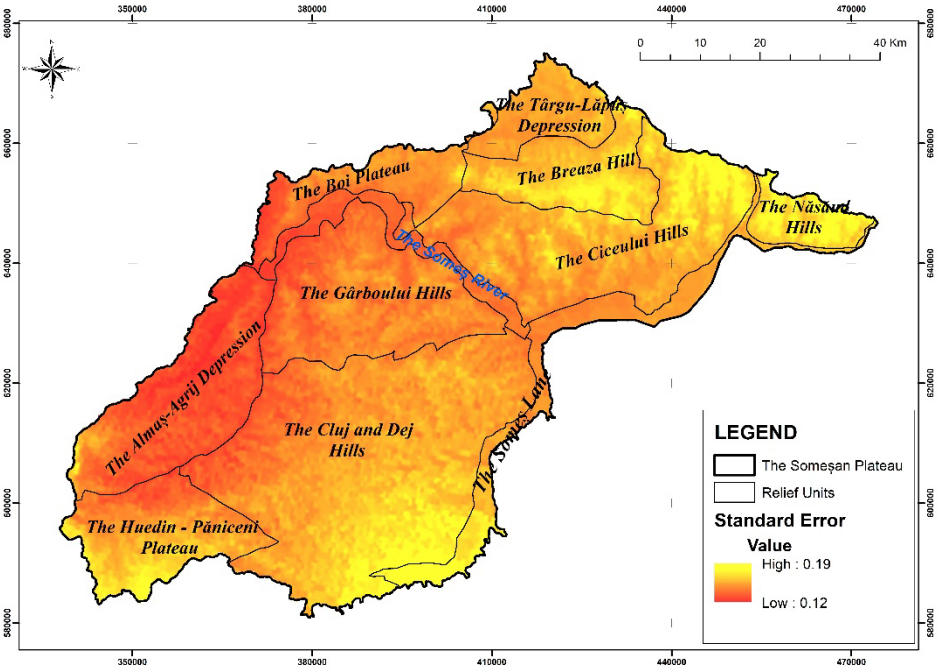

Fig. 6. Standard Error

The databases used in our research recorded a total standard error of 0.19, the maximum value, present mainly in the west of the plateau, and the lowest value of 0.12 in the south of the Huedin-Păniceni Depression, the Someșului Corridor and certain areas in the area of the Năsăud Hills and the peak of Breza.

Because the area on which the entire research process was done is small in size, the results we obtained are not satisfactory. The time analyzed is short, not being sufficient to express a significant degradation at the soil level following the amounts of precipitation.

5. DISCUSSION

The USLE database presents six factors, specifying that two of these factors address aspects related to the level of erosion and degree of erodibility. The level of erosivity is outlined by the energy that has been integrated into the formula alongside the intensity based on a 30-minute time interval. Thus, the obtained erosion data are entered by the factor aimed at erodibility, so that in the end it provides the data related to the level at which the erosion is placed.

All these data are closely related to the morphometric aspects of the relief, namely the degree of inclination of the slope, the orientation of the slopes, but also

to the aspects that refer to the composition of the geological substrate. In the case of our area, the Someșan Plateau has a development on a substrate made up mostly of sandstones, conglomerates and clays, which are prone to the action of climatic factors, but also to the action of geomorphological factors that lead to the emergence of risk processes, leading to a high erosion of relief forms that make up the natural framework.

We believe that while this research may not yield remarkable results concerning soil erosion caused by precipitation, its primary limitation lies in the analyzed time period. The reduced timeframe, specifically chosen for our analysis and emphasis, can be beneficial for relevant authorities. For instance, the study can contribute to various development plans in Sălaj county, particularly for tourist objectives linked to the addressed relief type. The Dragons Garden, a noteworthy geomorphosite within the Someșan Plateau, serves as a tourist attraction, prompting the need for development plans that consider the geological substratum requirements.

In the previously mentioned, the town hall of the commune of Bălan can be a potential beneficiary of this study, placing it as a starting point in the development plans of the Dragons Garden objective, giving more attention to the areas prone to the appearance of risks at the level of the forms that currently present high degree of degradation (e.g. lookout points, landforms- ,,dragons”).

CONCLUSIONS

The use of the ESDAC (European Soil Data Centre) databases were the cornerstones of this research, as we benefited from essential factors that were included in the analysis process, such as the density, trend, probability and occurrence of erosion, as well as standard error, which were processed with the help of GIS software.

The factors analyzed are closely related to the morphometric aspects of the relief, but also to the details that refer to the composition of the lithological substrate, highlighting the presence or absence of risk geomorphological processes.

The analysis carried out on the indicators used shows low values (the amount of precipitation falling in the time period 2070-2018), data located far below the probability percentage of the respective indicator (Trend, Man Kendall), so we believe that, following the analysis of these factors at the level of the study area, there is no significant evolution in the analyzed time period. Also, they do not reveal the occurrence of massive soil degradations, the geomorphological processes of severe risk are missing, being of the opinion that in order to capture these previously mentioned aspects, it is impetuous to carry out a research over a longer period of time.

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