THE ESTIMATION OF SOIL LOSSES AND THE SEDIMENT YIELD USING THE SATEEC MODEL ON THE SOUTHERN SLOPE OF THE LIPOVEI HILLS

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Key-words: SATEEC, USLE, soil losses, nLS, USPED, sediment yield, Lipovei Hills, Romania.

Abstract. The purpose of this study is to estimate soil losses and the sediment yield using SATEEC (Sediment Assessment Tool for Effective Erosion Control). The SATEEC model uses USLE (Universal Soil Loss Equation) to estimate soil loss, the nLS model for gully head detection, and the USPED model to establish soil erosion and deposition. Therefore, the USLE model shows that classes with very low values of soil loss (0.36 tons/ ha/year) are prevalent throughout 83.71% of the surface. The gully head detection, using the nLS model, showed that a gully with lengths under 9.21 m, are the most recurrent on 98.76% of the studied area. The USPED model indicated that soil erosion is present on 9.63% of the studied area, while deposition is found on 0.65% of the analysed territory. Through the SATEEC erosion modules we found very low values (<7.44 tons/ha/year) of sheet, rill, and gully erosion on 98.63% of the surface of the southern slope of the Lipovei Hills, due to the low slopes on the interfluves and from the plain units.

1. INTRODUCTION

The formation of the soil, the thin, discontinuous and complex stratum located at the surface of the earth's crust, takes time, hundreds and even thousands of years, and takes place under the direct influence of the other elements of the natural environment and, of course, under the influence of socio-economic activities. Soil erosion consists in its degradation by detaching unconsolidated particles from steep slopes devoid of vegetation under the action of atmospheric precipitation, but also as a result of the improper application of agricultural works.

Over time, many mathematical expressions have been developed to quantify and to predict soil erosion, such as USLE (Wischmeier & Smith, 1978), RUSLE (Renard *et al.*, 1991), WEPP (Flanagan & Nearing, 1995), SWAT (Arnold *et al.*, 1998), EUROSEM (Morgan *et al.*, 1998) etc. In Romania, ROMSEM (Moțoc *et al.*, 1973, revised in 1979 and reconfirmed in 2002) is used to estimate surface soil erosion.

Since Universal Soil Loss Equation uses input data that are easy to integrate into Geographical Information Systems, over time, for estimating soil erosion, numerous USLE-based soil erosion models have been developed. Thus, SATEEC (Sediment Assessment Tool for Effective Erosion Control) was developed (Lim *et. al.*, 2003, 2005, 2010). Consequently, SATEEC consists of the integration of factors from the USLE equation to estimate soil loss and the sediment yield. USLE and the newly revised RUSLE only estimate annual soil loss erosion per unit area from rill and inter-rill erosion processes caused by rainfall splash and overland flow, but not from gully and channel erosion. Moreover, this does not take into consideration the runoff process, soil detachment, transport, and deposition (Renard *et al.*, 1994).

In this situation, SATEEC uses the nLS model (McCuen & Spiess, 1995) and the USPED model (Unit Stream Power – based Erosion Deposition) for gully head detection and for the establishment of

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soil erosion and deposition (Mitas, L. & Mitasova, 1998; Mitasova *et al.*, 1996). SATEEC combines soil loss with gully erosion, more precisely, nLS and USPED to estimate sheet, rill, and gully erosion (Kang *et al.*, 2010). Because the SATEEC model is easy to implement, it was successfully used also in Romania, in areas where sheet, rill, and gully erosion occurs, such as in the Prislop Catchment (Damian *et al.*, 2014).

The purpose of this study is to estimate soil losses and the sediment yield using SATEEC (Sediment Assessment Tool for Effective Erosion Control) on the southern slope of the Lipovei Hills.

2. STUDY AREA

The study area is that of the southern slope of the Lipovei Hills and the contact with the Timiș-Bega Plain. This territory is in the western part of Romania and pertains to the Western Hills and the Western Plain (Fig. 1). The territory has a low South – West and North – East general inclination.

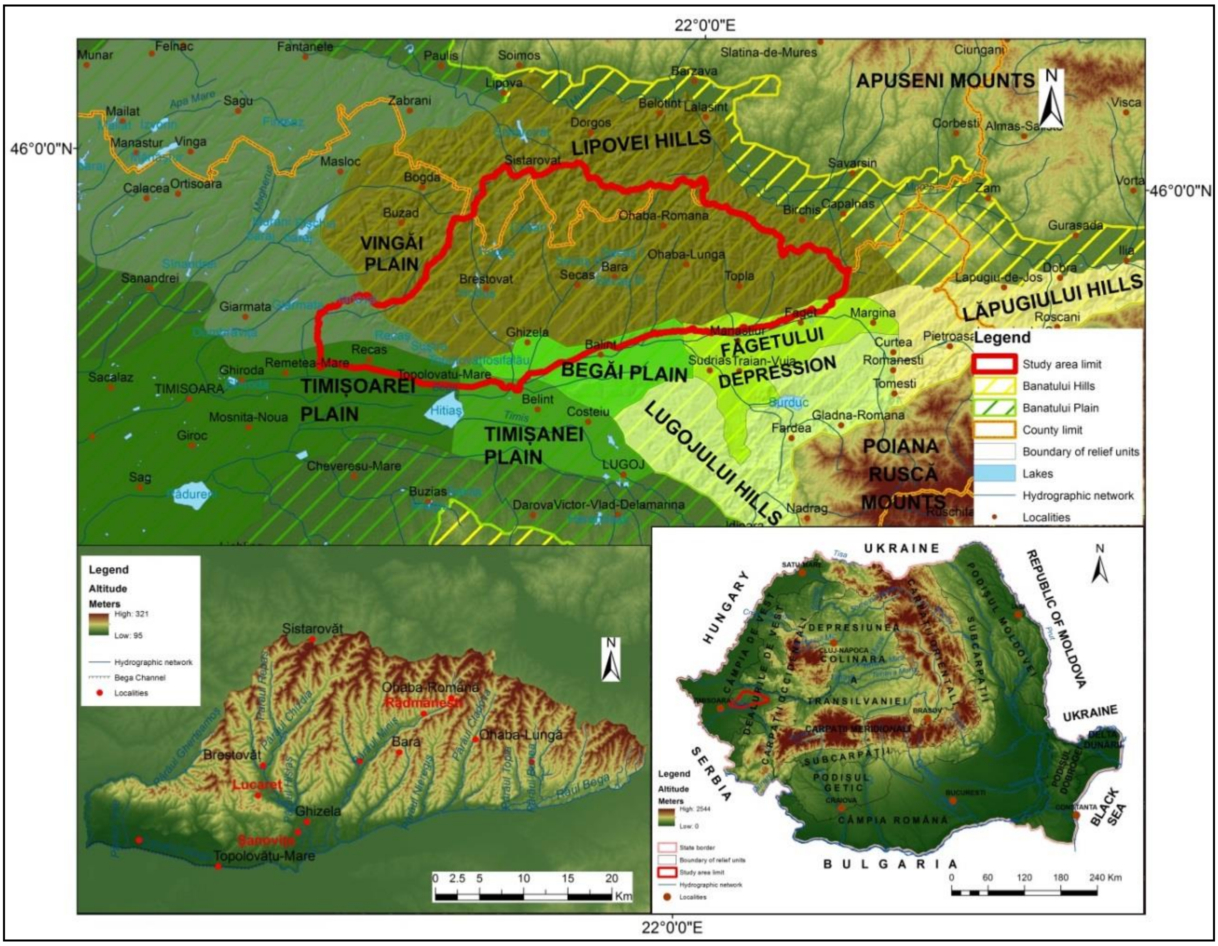

Fig. 1 – Location of the study area in relation to neighbouring relief units.

The altitudes increase from west to east, but an asymmetry can be noted on the north-south direction, due to the obvious advance of the tributaries from the right of the Bega River to the Mureș River basin divide. This is the result of the ascending movements from the end of the Pannonian and from the Quaternary (Magyar *et al.*, 1999). The lifting movements were accompanied by the descending movements from the Timiș Plain which started in the Badenian, continued in the Sarmatian and in the Pannonian, in a specific spatial arrangement, of “sedimentary bays” on graben structure, and in the western mountain units of the Apuseni and Banat Mountains on horst structure.

The territory covers an area of 978.97 km² and was encased by the neighbouring relief subunits, taking into account the morpho-hydrographic significance of the rivers. As such, in this area, there are two relief steps: the hill step, such as the Lipovei Hills, and the contact step with the neighbouring plains represented by the Vinga, the Timișoara, the Timișana and the Bega Plain.

The Lipovei Hills, a subunit of the Banat Hills, take the shape of an “extended bridge”, which is why they are also called the *Lipovei Plateau* (Badea *et al.*, IV, 1992).

In the territory formed by the southern slope of the Lipovei Hills and by the contact with the Timiș–Bega Plain, the hill step, with an altitude of 120–300 m, occupies an area of 790.42 km², that is, 80.74% of the surface of the studied territory. The Lipovei Hills descend to the west up to the contact with the high Vinga Plain.

In the analysed territory, the plain step, approximately 100 m in altitude, covers an area of 188.55 km², that is, 19.26% of the studied territory’s area. Therefore, the minimum altitude of 95 m is recorded in the southwest of the territory, and the maximum altitude of 318.22 m on Cugla Peak is recorded in the northeast of the territory.

The plain step is crossed by the Bega River and by its right hand-side tributaries, the Gherteamoș, the Chizdia, the Miniș, the Cladova etc. Thus, from the north, the highest part of the studied territory, there are a series of elongated interfluves, sometimes dominated by rounded peaks, separated by the wide valleys, which descend to the Bega River, the part with the lowest altitudes within the studied territory. These tributaries create a dense network of valleys with a 1 km in width, and ensure the deep penetration of the plain into the hill unit in the form of “bays”. The wide valleys influence the transfer of certain surfaces from them to the plain step, but also the disappearance of some of their characteristic elements, such as some terraces. In this situation, the boundary between the southern slope of the Lipovei Hills and the Timiș-Bega Plain is not precisely defined. Thus, the study area extends towards the Bega River.

3. METHODOLOGY

The present study considers the application of the SATEEC model proposed by Lim *et al.* (2003, revised in 2005, and reconfirmed in 2010). In order to apply the SATEEC model, the Corine Land Cover data from the year 2012 were used, which refer to the use of the land on the southern slope of the Lipovei Hills (Fig. 2.a). Thus, the smallest area of 0.03% is occupied by natural grasslands located at an altitude of about 300 meters, inside deciduous broad–leaved forests especially in the northern part of the southern slope of the Lipovei Hills, and which occupies the largest surface (28.61%) of the studied area.

The non-irrigated arable lands are present on around 27.47% of the researched territory’s surface, while pastures make up 21.40% of the study area. On 7.22% of the analysed area, towards the contact with broad-leaved forests located in the northern part of the southern slope of the Lipovei Hills, there is predominantly land occupied mainly by agriculture, with significant areas of natural vegetation. In the plain units, the discontinuous urban fabric can mainly be found on 3.47% of the studied territory. The vineyards are cultivated in the Recaș Hills and take over an expanse of 3.04% within the studied area.

The areas occupied by complex cultivation patterns constitute 2.87% of the analysed territory and are found from the plain unit up to over 200 m in altitude in the central part of the southern slope of the Lipovei Hills, while the fruit trees and berry plantations are also located in the central part of the southern slope of the Lipovei Hills and account for 2.77% of the area.

The transitional woodland-shrub areas (generally deforested) make up 2.35% of the researched surface and are found from the plain unit to the northern part of the southern slope of the Lipovei Hills occupied by broad-leaved forests, intensely affected by the deforestation process.

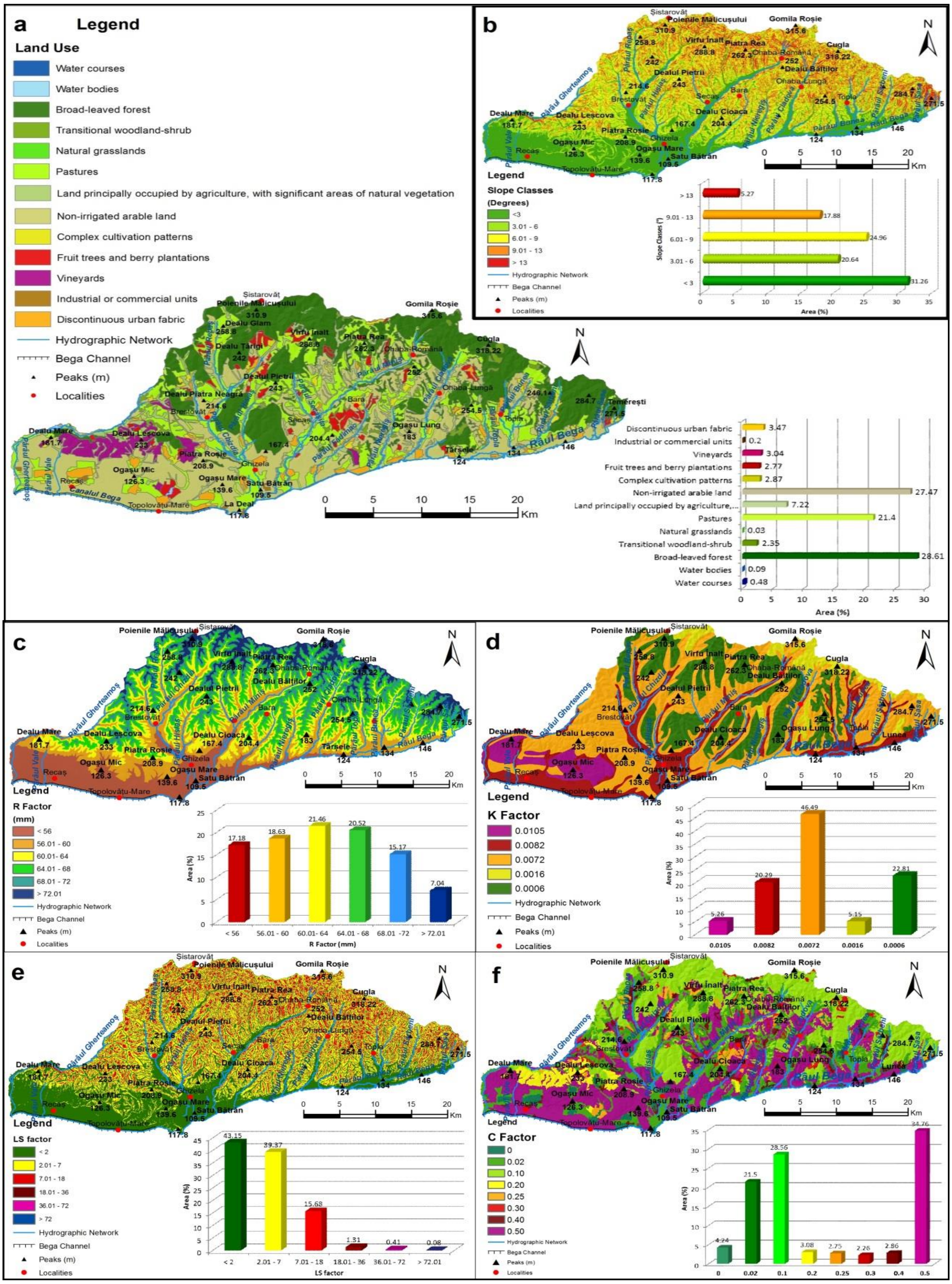

Fig. 2 – The data used to evaluate soil erosion according to the SATEEC model: a. the land use map; b. the slope map; c. the R factor map; d. the K factor map; e. the LS factor; f. the C factor.

Water courses constitute 0.48% of the study area and water bodies represent only 0.09% of the extent of this territory.

The commercial units (Recaş's wineries) or industrial units, such as: the stone quarries from Lucareț-Şanovița, the Ghizela Ecological Depot, the Chizătău ballast located on the Bega terraces, account for 0.20% of the extent of the territory formed by the southern slope of the Lipovei Hills.

Due to the very large surface area of 376.79 km² occupied by arable land, fruit trees and berry plantations, transitional woodland-shrub areas, vineyards and complex cultivation patterns, this territory is susceptible to various forms of erosion. Thus, it is possible to observe the penetration of the arable lands through the valleys up to the high part of the studied territory, at over 300 m in altitude. The presence of pastures can also be noted towards these places, and when contacting broad-leaved forests and pastures, the presence of transition areas with shrubs, which are generally deforested, must be considered. This fact points to the existence of erosion processes on the southern slope of the Lipovei Hills.

The Corine Land Cover data are also used to calculate Manning's n coefficient (Table 1) which indicates a leakage factor depending on the land use. Therefore, Manning's n coefficient is used by the nLS (McCuen, Spiess, 1995) model erosion (formula 1) for gully head detection.

$$\text{Gully head} = \frac{3.3 * n * L}{\sqrt{S}} \tag{1}$$

where: n is the Manning coefficient, L is the length of the runoff in meters and S is the slope (m/m); Manning's n coefficient is a factor that changes the flow depending on how the land is used.

Table 1

Manning's n coefficient for different land uses (Vieux *et al.*, 2004)

Class	Land Use	Manning's n Coefficient
1.	Water area	0,030
2.	Urbanization	0,150
3.	Eroded land	0,035
4.	Marsh	0,050
5.	Grassland	0,100
6.	Forest	0,130
7.	Paddy field	0,050
8.	Cropland	0,035

Thus, to apply the SATEEC model, a Digital Elevation Model of the land with a resolution of 10 m was used. Then, the slope and the USLE equation factors are generated from the Digital Elevation Model. Thus, from DEM, with the help of the *Surface* function, the slope was obtained (Fig. 2.b). The unit of measurement for the slope is expressed in degrees.

The slopes under 3° are prevalent in the plain unit and on the bottom part of the Gherteamoş, Chizdia, Miniş, Fădimac, Nieregiş, Cladova, Topla, Bunea, Sârbeni, etc. valleys, while the slopes greater than 13° are present in the high part of the southern slope of the Lipovei Hills and account for 5.27% of the study area surface.

At the same time, it is necessary to specify the classes of slopes with values between 6.01 and 9°, because they represent 24.96% of the area. Slope classes of 3.01 and 6° correspond to 20.64% of the territory and, last, but not least, those with values between 9.01 and 13° are characteristic for 17.88% of the analysed territory.

From DEM the parameters used by the USLE equation are generated: the R factor, the K factor, the LS factor, and the C factor.

The R factor (Rain Aggression Factor) – (Fig. 2.c) was established with the help of the formula for calculating the Modified Fournier Index (2) proposed by Arnoldus in 1980.

$$F_M = \sum_{i=1}^{12} \frac{Pi^2}{P} \tag{2}$$

where: Pi is the average amount of precipitation for month i (mm) and P is the average annual amount of precipitation (mm).

Following the calculations, it was found that the R factor indicates an increase in rainfall aggression as the altitude increases. As such, the step with altitudes lower than 100 m corresponds to 17.18% of the studied territory's surface, a value of the R factor under 56 mm/year.

The hypsometric step with values between 100 and 150 m, is characterized by values of the R factor between 56.01 and 60 mm/year, that is, 18.63% of the researched area.

R-factor values between 60.01 and 64 mm/year are present on 21.46% of the analysed area and are associated with the step with altitudes between 150 and 200 m.

The steps with altitudes between 200 and 250 m, correspond to R factor values between 64.01 and 68 mm/year, on 20.52% of the studied expanse.

15.17% of the researched area records R factor values between 68.01 and 72 mm/year, which are associated with the hypsometric level between 250 and 300 m.

R factor Values higher than 72.01 mm/year correspond to altitudes higher than 300 m, that is, 7.04% of the extent of the analysed territory.

The K factor (Soil Erodibility Factor) – (Fig. 2.d) indicates a quantitative description of the soil's vulnerability to erosion.

The calculation of the soil erodibility on the southern slope of the Lipovei Hills was performed by means of the mathematical expression (3) proposed by Wischmeier *et al.*, in 1971 and reformulated by Wischmeier and Smith in 1978. This calculation formula contains five characteristics of the soil, namely: texture, organic matter, coarse fragments, structure, and permeability, while among these, the texture of the soil has been identified as influencing the K factor.

$$\text{K} = [(2{,}1 * 10^{-4} * \text{M}^{1{,}14} * (12\text{-MO}) + 3{,}25 * (\text{s-}2) + 2{,}5 * (\text{p-}3))/100] * 0{,}1317 \tag{3}$$

where: MO is organic matter, M is soil texture, s is soil structure and p is soil permeability.

Soil texture (M) is calculated according to formula (4)

$$\text{M} = (\text{mp} + \text{ms}) \times (100 - \text{ma}) \tag{4}$$

where: ma represents the clay content (<0.002 mm), mp represents the dust content (0.002–0.05 mm) and ms represents the very fine sand content (0.05–0.1 mm).

The structure of the soil (s) has been established according to the following classification: 1 (very fine granular structure), 2 (fine granular structure), 3 (medium or coarse granular structure) and 4 (block, slab, or solid structure).

Soil permeability (p) was established according to soil texture (Table 2).

Table 2

Soil permeability classes estimated from major soil textural classes (Panagos *et al.*, 2014)

Permeability class (p)	Texture
1 (fast and very fast)	Sand
2 (moderate fast)	Loamy sand, sandy loam
3 (moderate)	Loam, silty loam
4 (moderate low)	Sandy clay loam, clay loam
5 (slow)	Silty clay loam, sand clay
6 (very slow)	Silty clay, clay

Following the calculations, values of soil erodibility factor (K) between 0.0006 and 0.0105 were obtained, which show the low erosion resistance of the soils in the studied area, and which correspond to the range of general values between 0.002 and 0.69 (Goldman *et al.*, 1986). Thus, the high values of Factor K highlight a high soil erosion and therefore a low resistance to the action of erosion processes, while low Factor K values suggest a low soil erosion, and therefore its high resistance to erosion.

Consequently, the very high K factor value of 0.0105 shows the very low resistance of the soil to erosion due to agricultural works being intensively carried out, making up 5.26% of the researched territory, and being found in the hill units.

This factor's high value of 0.0082 is present on 20.29% of the analysed area and indicates a low resistance of the soil to erosion, including the created valleys, and, at the same time, affected by the flow of running water during the rainy periods of the year: the Bega, the Gherteamoș, the Chizdia, the Miniș, the Fădimac, the Nieregiș, the Cladova, the Topla, the Bunea, the Sârbeni, the Șasa and so on.

On 46.49% of the study area, the 0.0072 average K factor value is the most prevalent, and signals the average resistance of the soil to erosion, being characteristic for the hill units on the southern slope of the Lipovei Hills.

The low K factor value of 0.0016 is found on 5.15% of the researched area and shows the high resistance of soil to erosion due to the protection offered by broad-leaved forests, corresponding to the hill units in the northern part of the southern slope of the Lipovei Hills.

The K factor value of 0.0006 is present on 22.81% of the studied territory, which suggests the very high resistance of soil to erosion, also due to the protection offered by broad-leaved forests and is specific to the hill units.

The LS factor (the topographic factor) – (Fig. 2.e) shows that soil erosion increases with slope length and angle. The LS topographic factor can be calculated using the mathematical expression (5) proposed by Moore and Burch in 1985.

$$LS = \left(\frac{A}{22.13}\right)^{0.6} * \left(\frac{sin\Delta}{0.0896}\right)^{1.3} \tag{5}$$

The mathematical expression (6)put forward by Mitasova in 1996 was used to determine the LS factor in ArcGis, within the studied area.

Power (flowaccum*10/22.13,0.6) * Power(sin(slope*0.01745)/0.0896,1.3) (6)

where: flowaccum is the raster of the flow accumulation, the value 10 is the resolution of the DEM, the value 22.13 is the standard length of the plot, and the value 0.6 is used to determine the average length of the slope, the slope is the raster for the slope of the land expressed in degrees, the value 0.01745 is an experimental coefficient proposed by Moore and Wilson, in 1992. Then, the value 0.0896 represents the standard calculation of slope for a plot and the value 1.3 is used to calculate the slope average.

Regarding the share of LS factor values within the studied area, the classes with values under 2 make up 43.15% of its surface and are found in the plain units, as well as on the valleys created by the Bega, the Ghereteamoș, the Chizdia, the Miniș, the Fădimac, the Nieregiș, the Cladova, the Topla, the Bunea, the Sârbeni, the Șasa etc.

The classes with LS factor values between 2.01 and 7 are present on 39.37% of the analysed area and characterise the hilly units on the southern slope of the Lipovei Hills.

On 15.68% of the researched area there are the classes with LS factor values between 7.01 and 18, which are also specific for the hilly units on the southern slope of the Lipovei Hills. Then, the LS factor values between 18.01 and 36 are found on 1.31% of the surface.

The LS factor values between 36.01 and 72 are on 0.41% of the researched area, while the highest LS factor values of over 72.01 constitute only 0.08% of the surface of the studied area and are also specific to the hilly units on the southern slope of the Lipovei Hills.

Factor C (land use factor) – (Fig. 2.f) is viewed as the most important USLE factor, as it shows how the land is used. The factor C values can be different from 0, when the soil is very well protected by the vegetal layer, to the value of 1.5, in the case of bare soils.

To establish the factor C values on the southern slope of the Lipovei Hills, the Corine Land Cover data from 2012 were used, to which were assigned values according to the information in specialty literature (Table 3).

Table 3

The factor C values depending on land use (Stewart *et al.*, 1975, Novotny and Chesters, 1981)

Nr. crt.	Land Use	C Factor
1.	Industrial or commercial units	0
2.	Water courses, water bodies	0
3.	Natural grasslands, pastures	0,02
4.	Broad – leaved forests	0,1
5.	Vineyards	0,2
6.	Fruit trees and berry plantations	0,25
7.	Transitional woodland-shrub areas (generally deforested)	0,3
8.	Complex cultivation patterns	0,4
9.	Non-irrigated arable lands	0,5

Therefore, the factor C 0 value represents 4.24% of the extent of the studied territory and indicates the protection of the soil against erosion on the surface of the built spaces and water accumulations.

The factor C 0.02 value associated with natural grasslands and pastures is present on 21.50% of the researched area and displays the vulnerability of the soil to erosion due to the local dense and small vegetation affected by overgrazing.

On 28.58% of the analysed area, the factor C 0.1 value given to broad-leaved forests is prevalent, which means that the soil is protected against rain erosion due to a large vegetal layer.

The factor C 0.2 value corresponds to 3.08% of the surface of the studied territory, the areas are taken up by vineyards, and points to a protection against soil erosion.

The factor C 0.25 value given to the fruit trees and berry plantations makes up 2.76% of the studied territory and signals the increase in soil vulnerability to erosion through the anthropogenic influence on the land use on the southern slope of the Lipovei Hills.

The factor C 0.3 value is present in 2.26% of the researched area and is linked to the transitional woodland-shrub areas (generally deforested), suggesting that the soil is poorly protected against erosion due to deforestation.

On 2.86% of the analysed area there is the factor C 0.4 value associated with areas with complex cultivation patterns, which shows that the soil is poorly protected against erosion due to agricultural work carried out in these places.

The factor C 0.5 value attributed to the non-irrigated arable lands predominates on 34.76% of the study area, expresses a great vulnerability to soil erosion, also due to the agricultural works carried out for the destruction of weeds, using large equipment, such as: ploughing, weeding and hoeing, but also through the use of herbicides, which, over time, lead to a loss in its quality.

Factor P (factor of soil erosion prevention works) has average values between 0.97 and 0.99 for the Western Region of Romania (Panagos, 2015), but because within the studied territory no measures are known to reduce soil erosion, this factor received the value 1.

The USLE model, or the calculation of the average soil loss, involves performing the multiplication operation of the 5 factors described (climatic aggression factor – R, soil factor – K, topographic factor – LS, land use factor – C and the factor of prevention works). Soil erosion – P received the value 1) using the function Arc Toolbox – Spatial Analyst Tools – Map Algebra – Raster computer in ArcGIS.

The USPED model (Mitas, L. & Mitasova, 1998; Mitasova *et al.*, 1996) deems soil erosion and deposition as dependent on traction force (formula 7). Complex soil erosion takes into account both surface washing, and torrentiality.

$$T = R*K*C*P*A^{m}*(\sin b)^{n} \tag{7}$$

where T is the tractive force, R, K, C, P are the USLE coefficients, A is the area in square kilometres, and m and b are the coefficients for the different types of soil erosion.

Negative values obtained by applying the USPED model indicate deposition, while positive values obtained through this model indicate soil erosion.

By including these modules in SATEEC, by combining the nLS model with the USPED model, the sheet, rill, and gully map was obtained (Kang *et al.*, 2010).

4. RESULTS AND DISCUSSIONS

USLE is a field-scale model used to estimate soil erosion by sheet and rill erosion, therefore excluding gully erosion, which is the main form of soil erosion occurring in a watershed (Damian *et al.*, 2014).

Soil erosion, or average soil loss expressed in tons/ha/year for the southern slope of the Lipovei Hills (Fig. 3) has values from 0 to 23.22 tons/ha/year.

The classes with very low values of soil erosion between 0 and 0.36 tons/ha/year are prevalent on 83.71% of the studied territory's area, due to the reduced slopes on the interfluves, from the plain units (Timișoara, Timișana, Bega Plains) and from the valleys of temporary and permanent watercourses, such as: the Gherteamoșul, the Chizdia, the Miniș, the Cladova, etc.

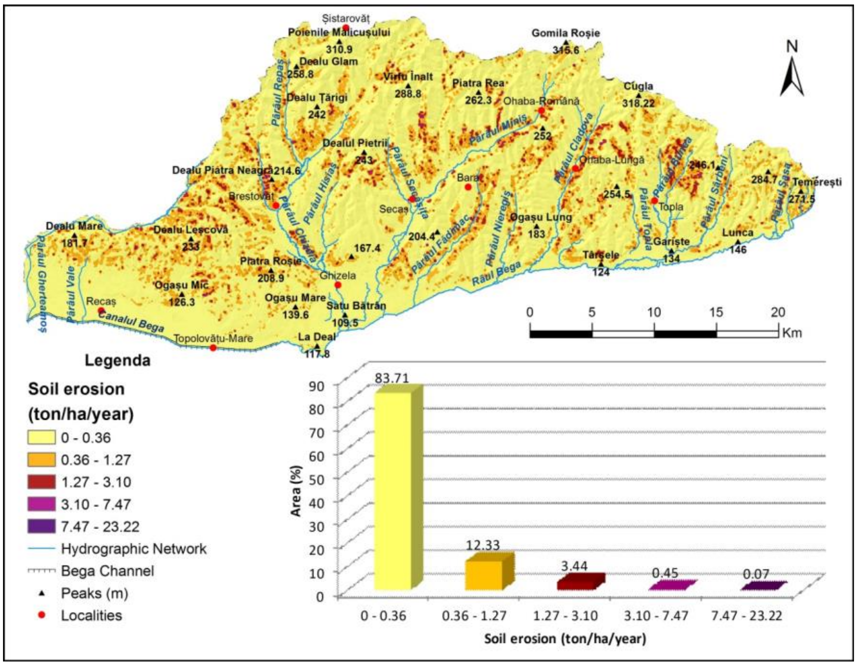

Fig. 3 – The soil erosion map – USLE model.

The classes with low values of soil erosion between 0.36 and 1.27 tons/ha/year and between 1.27 and 3.10 tons/ha/year, make up 12.33% and respectively about 3.44% of the researched area and are found on the slopes of hilly units located on the southern slope of Lipovei Hills.

Approximately 0.45% of the researched area has high values of soil erosion – between 3.10 and 7.47 tons/ha/year, while the value classes with very high values of soil erosion between 7.47 and 23.22 tons/ha/year are present in only 0.07% of the study area. Both classes of values are specific to the hilly units on the southern slope of the Lipovei Hills.

Manning's n coefficient indicates a leakage factor depending on the land use (Fig. 4). As such, Manning's n coefficient value of 0.030 attributed to the water area makes up only 0.57% of the surface of the studied territory.

On 27.47% of the researched area Manning's n coefficient has a value of 0.035 associated with cropland and 15.90% of the surface has a value of Manning's n coefficient of 0.050 specific for the paddy field. For 21.43% of the study area Manning's n coefficient has a value of 0.100 attributed to the grassland. Manning's n coefficient value of 0.130 associated with forests is most encountered in 30.96% of the research area, while the value of 0.150 of Manning's n coefficient corresponds to urbanization and represents 3.67% of the studied territory's area.

The gully head detection on the southern slope of the Lipovei Hills was done by entering the necessary data in the gully head equation (1) using the nLS model (Fig. 5). Thus, the gully head with lengths under 9.21 m, that is, erosion rills, is prevalent in 98.76% of the study area. The gully head with short lengths between 9.21 and 64.44 m represents 1.14% of the researched area and 0.09% of the area is characterised by a gully head with average lengths between 64.44 and 211.73 m, made up of gullies and ravines.

Then, the gully head with long lengths between 211.73 and 524.71 m is on 0.01% of the analysed area and, finally, the values of the gully head with very long lengths between 524.71 and 2347. 37 m represent only 0.02% of the surface.

After the extraction of the gully head from the nLS map, it was found that it is present on 1.28% of the surface (Fig. 6).

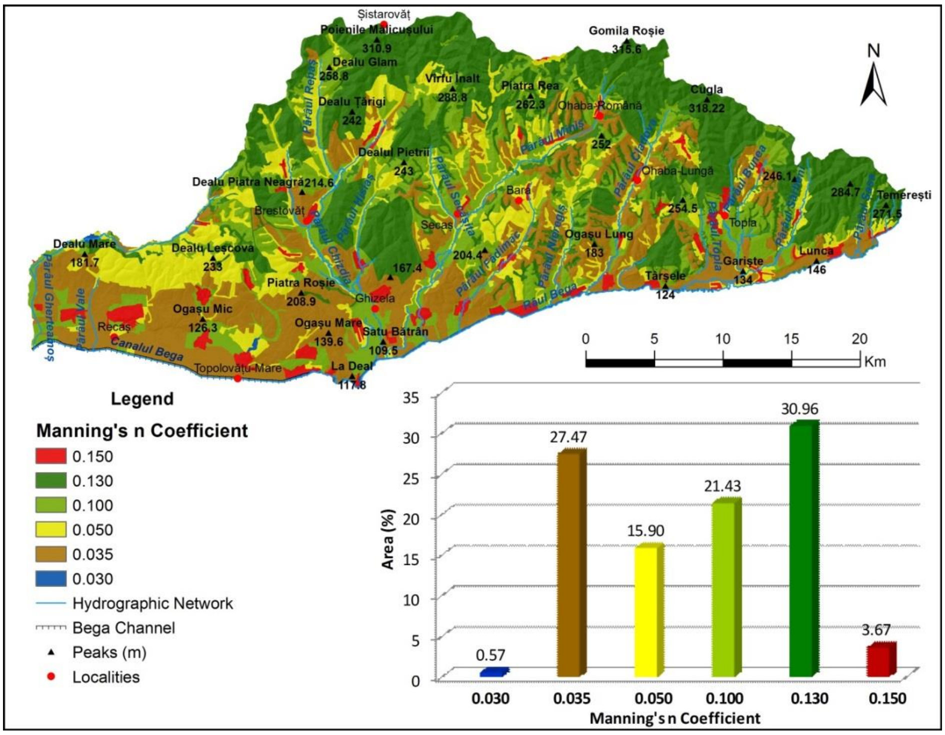

Fig. 4 – The map of Manning's n coefficient on the southern slope of the Lipovei Hills.

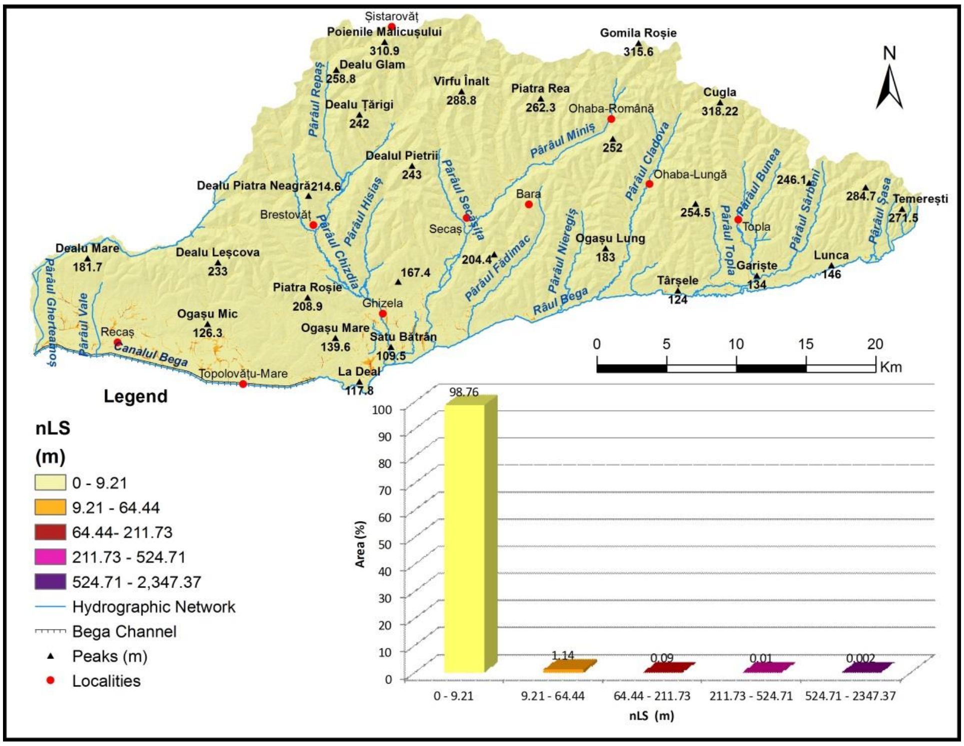

Fig. 5 – The map of the nLS model on the southern slope of the Lipovei Hills.

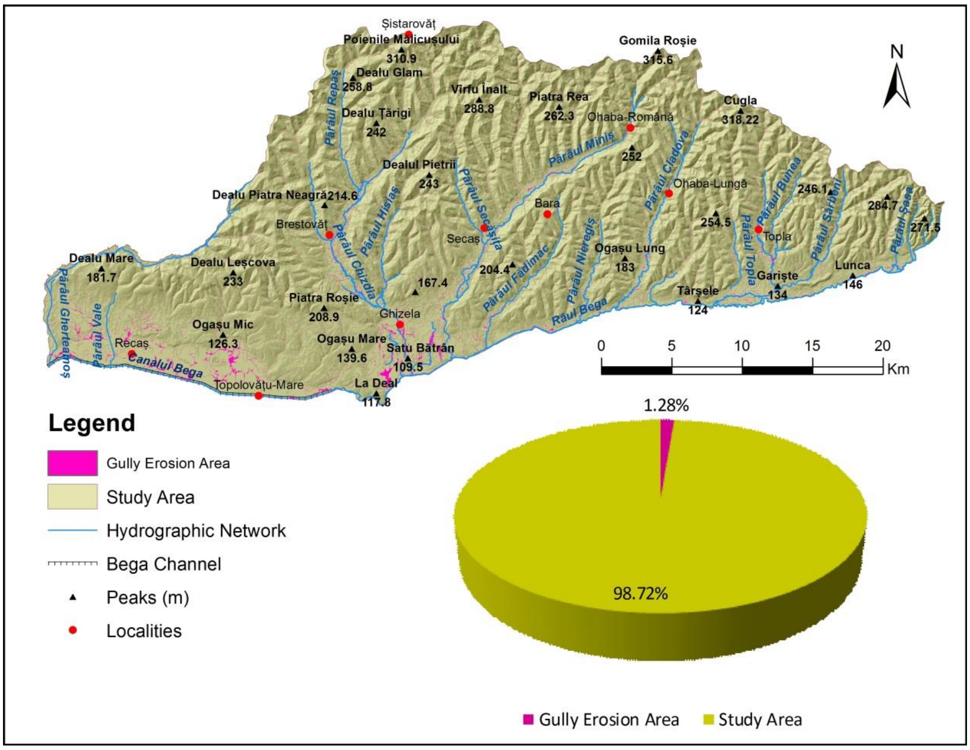

Fig. 6 – The gully head map.

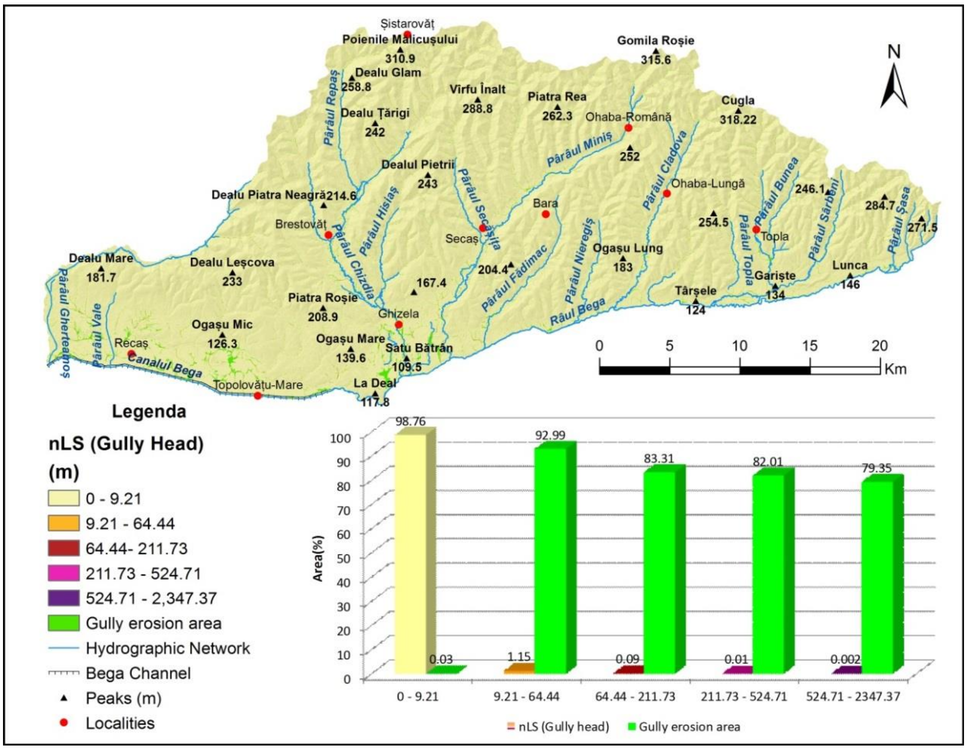

Fig. 7 – The map of the gully head – the nLS model in relation to the identified gully erosion areas.

Regarding the gully head detection (nLS model) in relation to the identified gully erosion areas (Fig. 7), it was found that the gully head is present on 0.03% of the surface of the gully erosion area with values under 9.21 m.

The gully head is found on 92.99% of the gully erosion area with values between 9.21 and 64.44 m. Additionally, the gully head represents 83.31% of the surface of the gully head erosion area with values between 64.44 and 211.73 m. Moreover, the gully head is on 82.01% of the surface of the class with values between 211.73 and 524.71 m and, finally, the gully head is present on 79.35% of the extent of the gully head area with values in excess of 524.71 m.

The map of soil erosion and deposition obtained by using the USPED model (Fig. 8) is useful on surfaces where the gully head predominates. Thus, soil erosion is present at the base of the slopes, on the valleys created by the flowing waters and predominates in the Timișoara, Timișana and Bega Plains, making up 9.63% of the studied area, while deposition is also found at the base of the slopes and in Timișoara, Timișana and Bega Plains, comprising only 0.65% of the analysed area.

The gully erosion map (Fig. 9) is useful on surfaces characterized by surface erosion. As such, soil erosion is present on 11.08% of the study area, including interfluves and hilly units on the southern slope of the Lipova Hills. Deposition occurs on only 0.26% of the researched sector.

Regarding the development of soil erosion and deposition in gully erosion (Fig. 10), it was found that the deposition processes are specific for 4.03% of the gully in the analysed area and the soil erosion processes comprise 15.06% of the torrents located in study area.

The soil loss (sheet, rill, and gully erosion) (Fig. 11) was calculated by combining the results obtained in the case of the USLE application with the results obtained by applying the nLS model necessary to calculate the gully erosion. Therefore, on the southern slope of the Lipovei Hills, the cumulative soil erosion has very low values (<7.44 tons/ha/year) on 98.63% of the studied area.

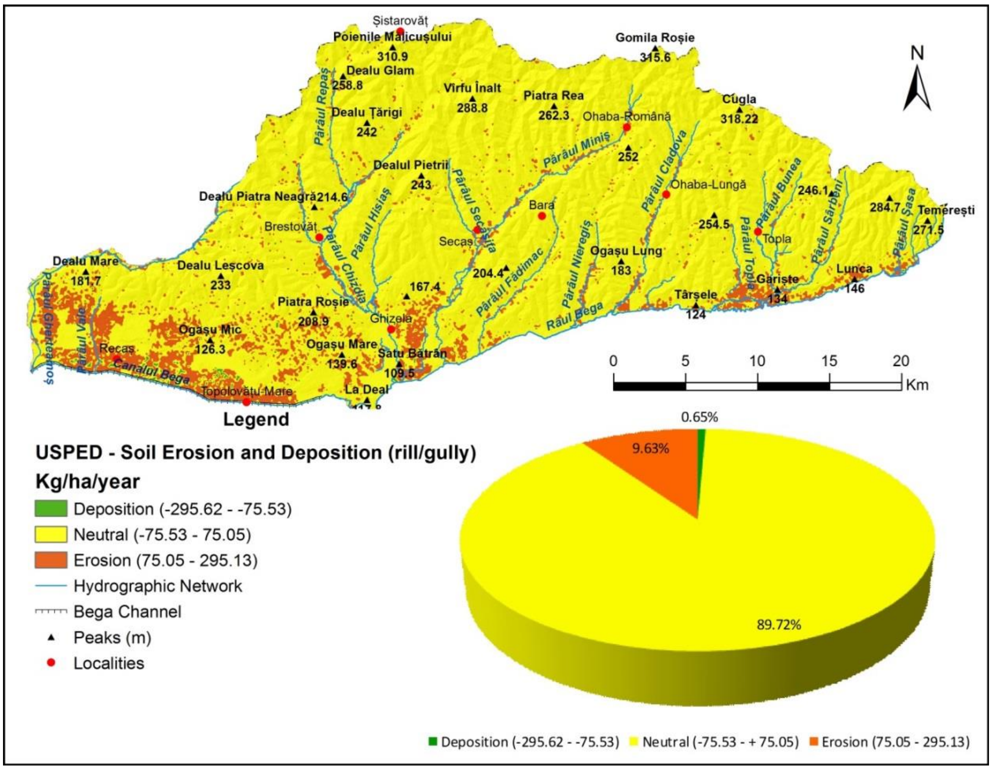

Fig. 8 – The map of soil erosion and deposition on the southern slope of the Lipovei Hills according to the USPED model.

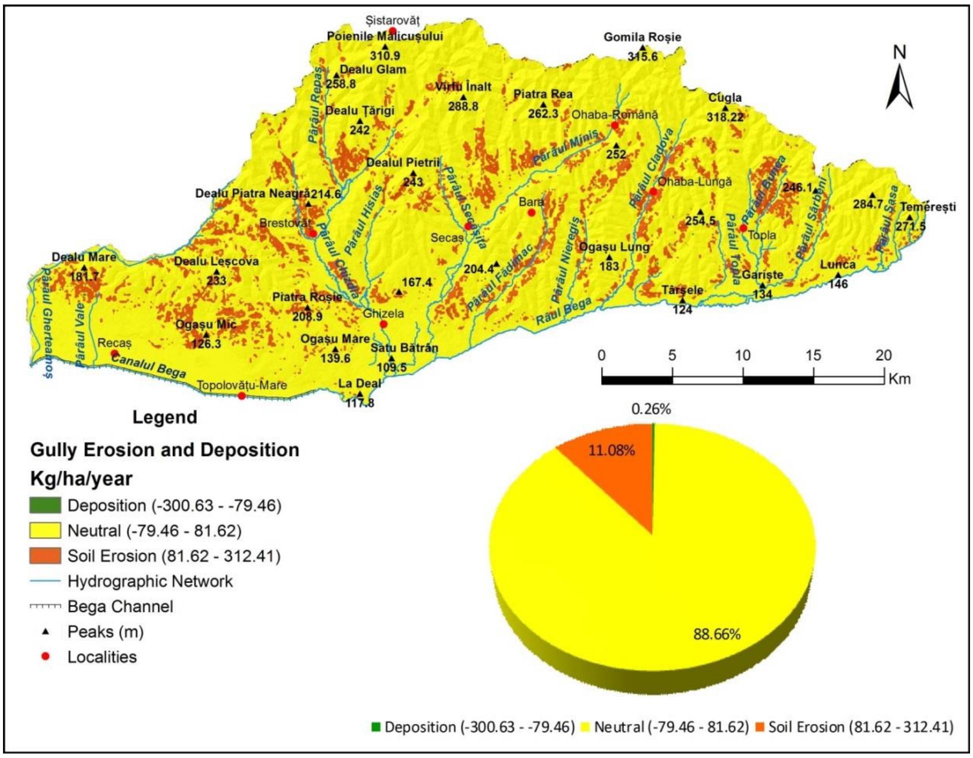

Fig. 9 –The gully erosion map on the southern slope of the Lipovei Hills.

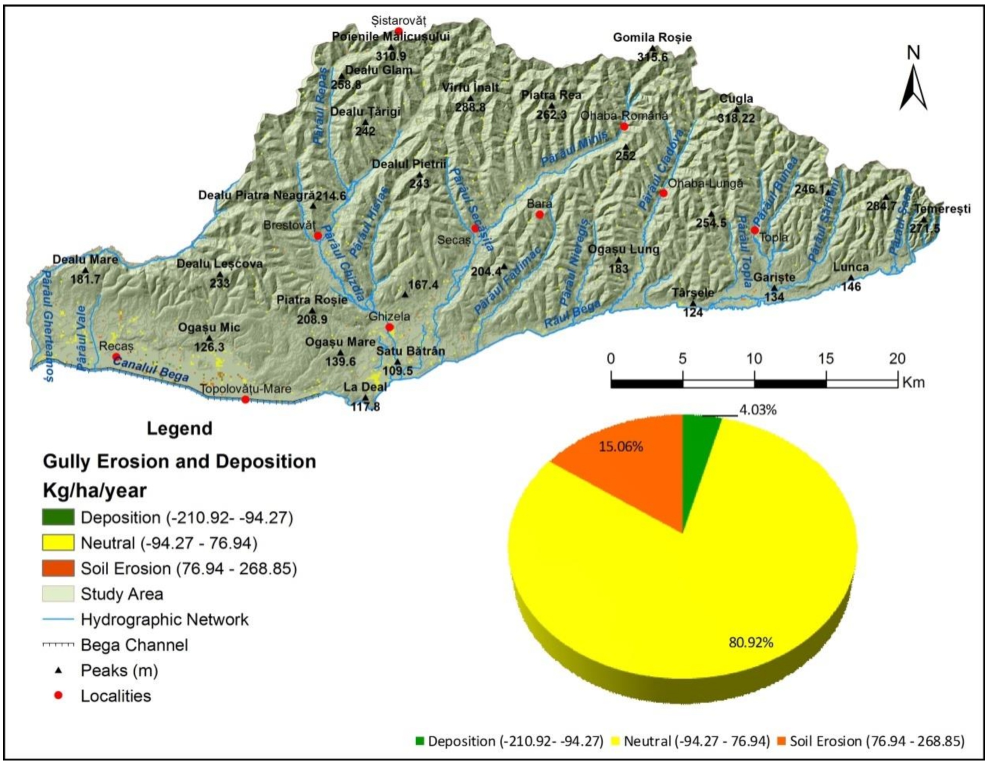

Fig. 10 – The gully erosion map.

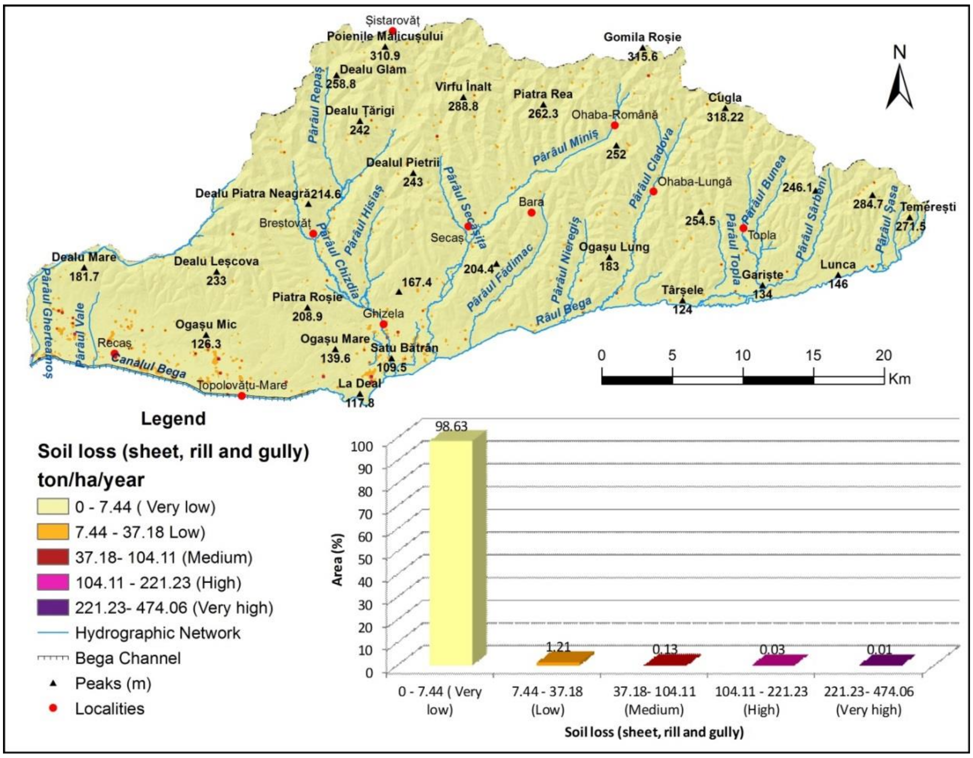

Fig. 11 – The sheet, rill, and gully erosion map.

The low values of the cumulated soil erosion between 7.44 and 37.18 tons/ha/year predominate in the Timișoara, Timișana and Bega Plains, making up 1.21% of the analysed area, and are followed by the average values of the cumulative erosion of soil between 37.18 and 104.11 tons/ha/year which are present on 0.13% of the researched area.

A rate of 0.03% of the study area has high values of cumulative soil erosion between 104.11 tons/ha/year and 221.23 tons/ha/year and, finally, very high values of cumulative soil conditions erosion between 221.23 and 474.06 tons/ha/year, which represent 0.01% of the researched territory's surface.

5. CONCLUSIONS

Due to the very large surface area of 376.79 km² occupied by arable land, fruit trees and berry plantations, transitional woodland-shrub areas (generally deforested), vineyards and complex cultivation patterns, this territory is susceptible to various forms of erosion. Thus, it is possible to observe the penetration of arable lands through the valleys up to the higher section of the studied territory, at over 300 m in altitude. The presence of pastures can also be noted towards these sectors, and at the contact between broad-leaved forests and pastures, the presence of transition areas with shrubs, which are generally deforested, must be taken into account. This suggests the existence of erosion processes on the southern slope of the Lipovei Hills.

The enhanced SATEEC erosion modules can be successfully implemented for areas where sheet, rill, and gully erosion occurs. Thus, the gully head detection on the southern slope of the Lipovei Hills, using the nLS model, was performed by entering the necessary data in the gully head equation (1), and showed that torrential erosion with lengths under 9.21 m, meaning erosion rills, predominates on 98.76% of the study area. After the extraction of torrents from the nLS map, it was found that they are present on 1.28% of the surface area.

The map of soil erosion and deposition obtained by using the USPED model is useful on surfaces where the gully head predominates. Thus, soil erosion is present at the base of the slopes, on the valleys created by the flowing waters, and predominates in the Timișoara, Timișana and Bega Plains, making up 9.63% of the studied area, while deposition is also found at the base of the slopes and in Timișoara, Timișana Bega Plains, comprising only 0.65% of the analysed area.

The gully erosion map is useful on surfaces characterized by surface erosion. As such, surface erosion is present on 11.08% of the study area, including interfluves and hilly units on the southern slope of the Lipovei Hills. The superficial accumulation takes place on only 0.26% of the researched sector.

Regarding the development of soil erosion and deposition in torrential channels, it was found that the deposition processes are specific for 4.03% of the torrents in the analysed area and the erosion soil processes comprise 15.06% of the torrents located in study area.

The sheet, rill, and gully erosion map was established by combining the results obtained in the case of the USLE application with the results obtained by applying the nLS model necessary to calculate the torrential erosion. Therefore, on the southern slope of the Lipovei Hills and the contact area with the Timiș-Bega Plain, cumulative soil erosion has very low values (<7.44 tons/ha/year) on 98.63% of the studied area.

Cumulative soil erosion is suitable for areas occupied by agricultural land, in the case of the USLE model, and, in the case of the nLS model, for areas with a high slope of the land where the highest values of erosion are marked along torrential channels.

SATEEC is useful in areas where water flow capacity is torrential due to its slope, as it estimates a much higher annual erosion rate than USLE and identifies forms of torrential erosion on high slopes. The obtained results allow us to conclude that the application of this model to piedmont regions such as Lipovei Hills is a valid option.

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