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ASSESSMENT OF LAND SUSCEPTIBILITY TO HYDRIC EROSION IN SMALL RIVER BASINS FROM CENTRAL PART OF ROMANIA USING GIS APPLICATIONS

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Abstract: Hydric erosion is a geomorphologic process which produces significant damages in agriculture through loss of fertile soil horizons in the southern part of Transylvanian Depression. Integration of the Geographic Informational System (GIS) and RUSLE model was used for achieving research on hydric erosion susceptibility and quantifying erosion rate in Secaşul Mare river basin. The erosion factors are addressed in detail, each factor being than described, assessed and accurately illustrated by applying specific equations and modern analytical tools for evaluation and analysis of them. The article is also investigating the relationship between climate, soil type, slope character, land cover and land use and the erosion rate in two small basins from south-western part of Transylvanian Depression. The results suggest many strong relationships between annual erosion rate (t/ha/year) and geological substrata, length slope and soil character. The greatest differentiations in spatial distribution of erosion rate are given by the land cover management factor. The values obtained for annual erosion rate vary between 0 – 94 t/ha/year. The values of equation factors indicate that this region, by its nature, is vulnerable to erosion. The human impact through inappropriate land use and pressure on lands lead to accelerating the erosion processes. Local scale variability of parental material and soils, morphology and morphometry of landforms, pluvial erosivity and land use are strongly related to the concept of altitudinal zonality and indicate the distribution of high values of annual erosion rate, frequently, in the plateau and submontainous hills. This procedure of integrating GIS with RUSLE model offers the possibility to develop and expand researches on soil erosion in different geographical regions and is an excellent tool for use in regional and local scale studies because of the possibility to obtain a rapid evaluation and visualization of the average erosion rate and land susceptibility to erosion and to compare the results.

Keywords: susceptibility, erosion rate, RUSLE, GIS, Secaşul Mare basin, Transylvanian Depression, Romania.

1. INTRODUCTION

Hydric erosion is a geomorphologic process of grubbing up and removal of soil and slope deposits through mechanical action of rain water and concentrated flows on versants (McCool & Williams, 2008). Pluvial denudation and linear erosion can lead to major imbalances in geomorphologic and pedological systems. These have direct impact in loss of soil fertility and quality of land for a particular use, and can generate a total degradation of land and implicitly of landscape and also economic losses (Van Oost et al., 2000; Valentin et al., 2005). Degraded lands are true "black spots" on the map of a region. On the one hand, these indicate the intensity of natural phenomena and aggressiveness with which they occur, and, on the other hand, the intense exploitation of soil resources and improper use of the land. Acceleration of erosion processes and extension of degraded surface by water erosion are the results of cumulated conditions and actions in time, in which the human influence is major (Lal, 1990; Borselli, 2006).

The people consider the runoff a non dangerous process and ignore its variable character and the rain water action mechanisms. The recent researches reveals that the human impact on slopes amplifies water action due to the unprecedented increasing of pressure on lands through artificialization, compaction and soil sealing, improper agricultural technology, fragmentation, etc. (Jakab et al., 2013; Munafò et al., 2013).

The statistical figures are relevant at international level. European Environment Agency (2012), in the Environmental Status Report for 2010 shows that the degraded areas had increased due to the sealing and erosion of soil. In the European Union, between 2000 and 2006, the soil loss increased on average by 3% compared to the period between 1990 and 2000; at regional level the growth was significant: more than 10 - 14% in regions with humid climate and over 15% in regions with mediterranean climate (Poesen & Hooke, 1997).

In Romania, at 2010 census, the degraded and unproductive surfaces totalized 495 300 ha, or 2.08% of the land fund. Apparently, the figure is not alarming, but it is added to agricultural lands affected by erosion. The statistics for 2010 mentioned works against soil erosion on 2285.1 thousands ha, i.e. 9.6 % of lands fund. The arable land is about 53.6% of the total arranged areas to reduce erosion (i.e. 13% of the total arable land), 22.6% are pastures (i.e. 15.7% of the total grassland), 8.7% are meadows and also 8.7 % are orchards and vineyards (National Statistical Institute – INSSE, on line series). These figures show that agricultural surfaces affected by erosion are much extended and they are added to degraded and unproductive lands.

The concept of soil and land assessment launched by FAO (1985) to "assess the production capacity of an area under the agricultural or forestry use conditions" must be reconsidered in order to prevent land degradation phenomena, to identify the erosion control factors and the appropriate uses to the lands characteristics (Garrigues et al., 2012). In order to have a more accurate estimation of erosion rate and land susceptibility to this process we must consider rainfall aggressiveness assessment, evaluation of soil typology, morphometric and morphogenetic characteristics of landforms, vegetation typology and quality and the use of lands.

In Romania, there have been concerns in the research of soil erosion and land quality assessment within the Institute for Soil and Agrochemical Research Bucharest (ICPA, 1983-1987), directed towards research methodology, factors assessment and soil erosion assessment on agricultural land (Moţoc et al., 1975; Moţoc, 1984; Florea et al., 1986; Moţoc & Sevastel, 2002).

Efforts for inventory, monitoring and reducing the risk to erosion are made also at European and global level. Land degradation and loss of soil quality are topics of EU major projects launched also under the coordination of European Environmental Bureau (EEB), European Society for Soil Conservation (SCES), the European Commission for Environment and Joint Research Center - Soil Action.

Integrated analysis of environmental components involved in erosion and more accurate and efficient evaluation of it can be achieved today through valuation models and GIS techniques for processing and analyzing data. However, a common methodological approach is necessary, based on direct observations, inventory of landforms, appropriate evaluation models. Research needs to take into account the local/regional characteristics of the analyzed area. In this sense, the empirical models Universal Soil Loss Equation - USLE (Wischmeier & Smith, 1978) and the Revised Universal Soil Loss Equation - RUSLE (Renard et al., 1991) are quantitative models that simulate erosion. These are based on equations derived from experiences and field observations and allow long-term assessment of average annual erosion and soil loss. These models have been proposed and used for the first time in the United States for soil erosion forecasting studies conducted by the Department of Agriculture (USDA) and later adapted to erosion forecast studies in Europe and even in Romania.

These versions were used in Europe by the researchers in studies on the soil loss through erosion especially in mediterranean environment (Bianchi et al., 2001; Bianchi & Catani, 2005; Novara et al., 2011; Baskan et al., 2010; Perović et al., 2012). Also, USLE/RUSLE models had applied in Romania to assess soil erosion in very vulnerable relief units to erosion like Someş Plateau (Bilaşco et al., 2009), Moldavian Plateau (Patriche, 2004) and Apuseni Mountains (Ştefănescu et al., 2011).

Since these studies did not include the south of the Transylvanian Depression, a morphological and structural contact area affected by active water erosion processes, we considered appropriate to apply the RUSLE model to assess the erosion in this region. Because of heterogeneous character of study area, the evaluation of erosion rate was done on small inferior basins of Secaşul Mare river basin which extend both in the mountains and in the plateau.

2. AREA OF INTEREST

Secaşul Mare river basin is located in the south of the Transylvanian Depression. It's right tributary of the Sebeş River and has a basin area of 567 km^2. Secaşul Mare River drains the submountainous Apold Depression. Tributaries position is almost symmetrical on both sides of the collector. The left tributaries are more numerous

(Apold, Dobârca, Pustia, Gârbova, Câlnic, Răhău, Caselor Valley), have an elongated shape and have their sources in the Cindrel Mountains (Rod, Gârbova) or sub-mountainous hills. The right tributaries are fewer as number (Gusu, Sângătin, Boz, Daia), but well developed in width and extend entirely in Secaşe Plateau.

Choosing the inferior order river basins (source area and Gârbova river basin) for case study was done based on different relief units appurtenance, geological characteristics, morphometric and morphological criteria (Fig. 1). Linked to this, the extension of the degraded areas by erosion, intensity of process and also the economic specific of rural settlements in those basins (reflected in land use), were taken into account.

The source area of Secaşul Mare Basin has a surface of approximately 37.18 km^2 and is entirely developed in the Secaşelor Plateau, on a difference of level of about 249 m. Maximum altitude is reached on the eastern watershed, in Măgura Copaciului Hill (579 m) and the minimum height is about 330 m in the meadow of Secaşul Mare River, downstream Ludoş. In this basin 8 degraded areas by erosion have been identified, totalling an area of 19.73 km^2, i.e. 53.06% of the basin. Geological substrate is composed of clay deposits, in which sands horizons alternating with clays and marls can be identified. The landforms are adapted to the monoclinic structure, with cuesta fronts and structural surfaces. Dominant modelling processes are runoff and gullying, with the development of complex ravines in the source area. Frequent associated processes are splash and sheet erosion, landslides and collapses. The dominant soils are regosols, erodosoils, typical and gleyic phaeozems, preluvisols and complexes of soils resulting from the association of them, with loamy, clayey-loamy, loam-clayey, loamy-sandy-clayey texture. Southern exposure of basin, protected position towards the influence of western air mass and Főehn influence (associated with geological substrata and soil characteristics) lead to hydro-climatic stress evidenced by strong evaporation (average annual temperature is about 9 to 9.5° C), disaggregation by insolation, compaction during drought and dryness periods alternating with rapid saturation of clays in rainy periods (annual average of rainfall about 400-500 mm/year). In these conditions the superficial flow and especially the linear erosion is facilitated. Through corroboration of geological, climatic and morphodynamic factors, a relief with precarious balance resulting.

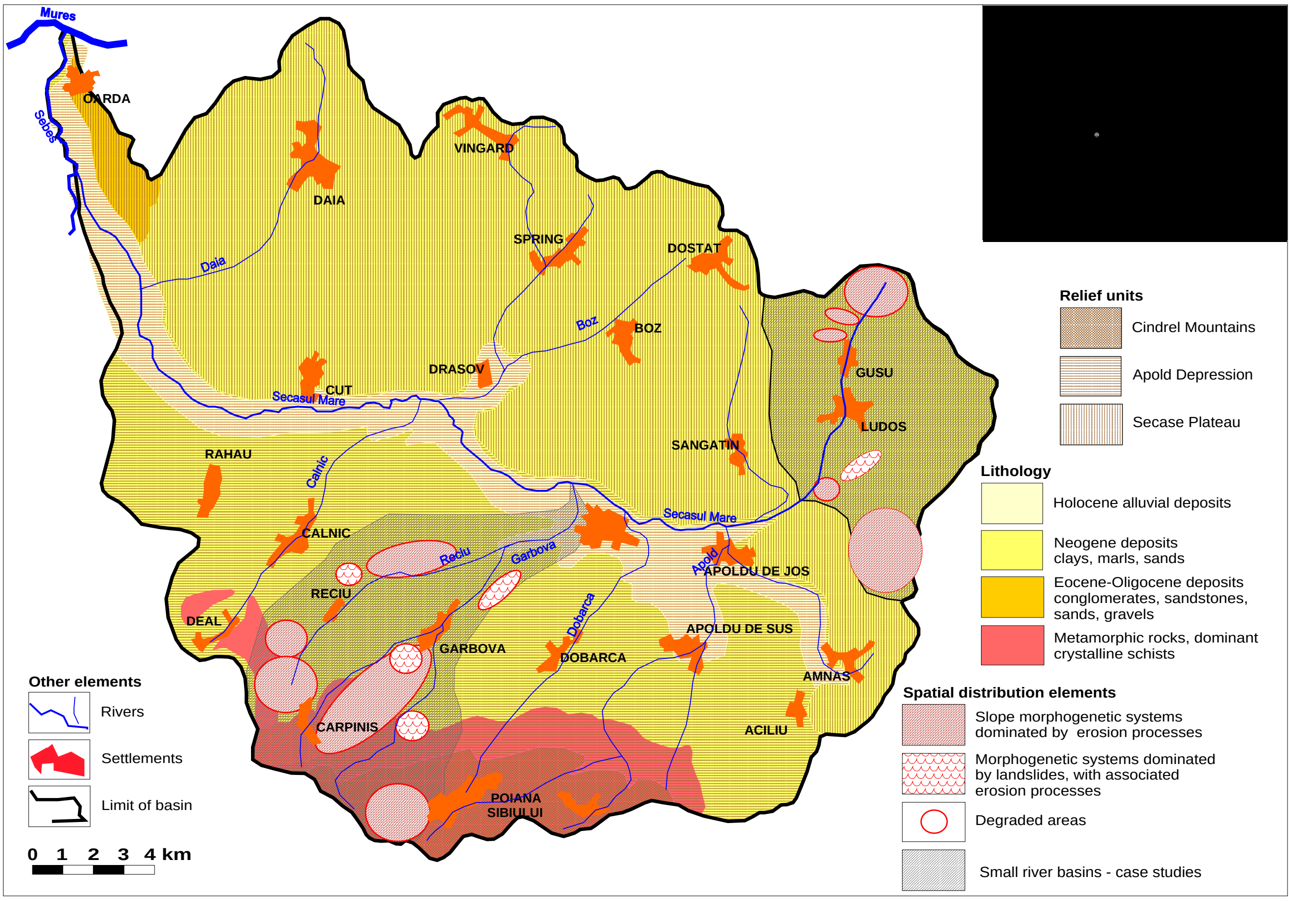

Figure 1. Secaşul Mare basin and small inferior order basin – location, geological and geomorphologic features

Anthropogenic influence by agricultural use has changed the morphogenetic conditions and has intensified the erosion. Prevailing pastures on which uncontrolled grazing is practicing and hoeing crops are made on slopes (>10°) and on small plots, agricultural techniques being applied along the slope. Lack of land improvement efforts and abandonment of agriculture terracing activities, besides overgrazing, are the main anthropogenic causes of land degradation by erosion.

Gârbova basin has a surfaces of 64.6 km^2 and is developed on the left side of the Secaşul Mare River, on 678 m difference of level. The maximum altitude (968 m) is reached at the origin, which located in Jina, in the lower mountain level of the Cindrelului Mountains (Fig.1). The minimum altitude, of 290 m, is recorded at the confluence with the Secaşul Mare River in the Apold Depression.

The morphological and structural contact between the Cindrel Mountains and the Transylvanian Depression is reflected in the weight of degraded areas and intensity of erosion processes. In this small basin a number of 7 areas degraded by erosion have been identified, which totalized 16.13 km^2, i.e. 24.96 % of the basin surface. In the southern part of the basin, the geological substrata is composed of metamorphic rocks covered by piedmontane sands and gravels in mountain area and Miocene – Pliocene sedimentary deposits (sands, clays, marls and loam) with crystalline nuclei in submountainous hills (Geological map). In the northern part of the basin, Sarmatian and Pontian sedimentary deposits and Pleistocene terraces deposits, composed of small gravels, sands, clays and marls, are dominant.

The complex versants are predominating, with accentuated declivity in the southern half of basin and the small and moderate slopes in the northern part. The terraces and the fluvial plain of Secaşul Mare river are well developed and fragmented by the Gârbova River, tributary of 1st order. In the southern part, on metamorphic rocks, districambosoils, luvosoils and skeletal soils are developed, while on the deluvial deposits of northern part preluvosols, regosols and even phaeozems (on fluvial terraces) or complexes of these kind of soils prevail. As a result of geological, climatic, edaphic and anthropogenic factors association, the lands are moderate and highly eroded. Torrential erosion, ravening and runoff are dominant, whereas the solifluxion and medium deep landslides are associated processes. The impermeability of the crystalline schists and of clays from sedimentary deposits, alongside the sharp slopes and high relief energy, are the main passive factors of erosion in this basin (Costea, 2013).

Also, the erosion is intensified by climatic condition of the basin. The altitudinal development and the opened position towards western humid air mass, determine variations of temperature (smaller temperature in the southern part 7 – 8 ^{o}C and higher in the north 8.5 - 9^{o}C), of precipitations (abundant in south 900 – 750 mm/year, reduced in north 600 - 550 mm/year) and higher humidity in air and soil. Withal, the Gârbova basin is heavily modified by human through intensive and mechanized agricultural holdings in lowland area on larger surfaces (plant culture - straw, hoeing, sunflower), through the practice of viticulture and fruit growing in the submountainous hills and intensive grazing and logging in the hilly and mountainous area.

3. MATERIALS AND METHODS

Research methodology is based on both field observations and the application of modern analytical tools and evaluation, respectively using of Landsat ETM satellite images and digital techniques for mapping and analysis of geographic information (GIS). Erosion risk assessment was performed by quantifying soil loss (t/ha/year) using empirical model RUSLE (Revised Universal Soil Loss Equation - Renard et al., 1991, 1994).

For this application we used GIS software package ArcGIS, version 9.2., produced by ESRI (Environmental Systems Research Institute, USA). Applying the RUSLE model gave us the possibility to use more easily accessible data and by quantifying the average rate of erosion gives an overview of long-term erosion risk. Erosion susceptibility assessment and visualization followed distinct phases depending on the used data (primary data, derived data) and the succession of their introduction in soil loss equation. Also, some of the equation terms were evaluated according to the regional and local conditions in which the basin under study is located.

Creation of Digital Elevation Model was based on georeferenced topographic maps, scale 1: 25000 with 5 m equidistance. By digitizing the level curves and quotas have been created a vector layers which were subsequently converted to raster layers using ArcToolbox module. The DEM, obtained with a resolution of 10 m, was subsequently used as a basis for quantifying and automatic obtaining, at the same resolution, the maps of the RUSLE equation factors in digital format.

This equation is based on the multiplication factors, by the following expression (1):

$$(1) \qquad A = R \cdot K \cdot LS \cdot C \cdot P$$

- Rainfall erosivity (R) was directly introduced into the erosion equation as numeric primary data. For rainfall erosivity the coefficient proposed by Moţoc et al., (1975) for the Transylvanian Depression of 0.12 was used. The team of researchers in erosion of Soil and Agrochemical Research Institute (ICPA), headed by Moţoc, states that for Romania the best indicator of rainfall aggressiveness is the one that takes into account the average intensity of rain in 15 minutes. The calculation of the mentioned coefficient (0.12) was made by considering the heavy rains, the torrential rains whose nuclei per 15 minutes have the intensity of at least 0.6 mm/min. This coefficient was calculated based on long strings of data from meteorological stations, representative for this geographical region of Romania. Because of the cost and difficulty of obtaining climate data, this indicator is used even today by Romanian researchers in studies of rainfall aggressiveness (Mureşan & Pleşa, 1992; Patriche, 2004; Patriche et al., 2006; Bilaşco et al., 2009; Stângă, 2011).

- The erodibility (K) assessment was based on soils systematic analysis according to the Romanian System of Soil Taxonomy (SRTS 2003) elaborated by ICPA Bucharest after World Reference Base for Soil Resources (FAO) requirements. Primary data were obtained from soil map, scale 1: 200000 (Orăştie sheet, ICPA, 1988) by digitizing soil types and update the old classes from Romanian System of Soil Classification (SRCS 1980) according SRTS 2003 (Florea & Munteanu, 2003). In the vector layer attribute table achieved for each soil type a correction factor for erodibility (K) was assigned, according to erodibility classes established by SRTS 2003 and subsequent amendments (2011). This attribute was used for vector layer (soil map) transformation in raster layer (soil erodibility map), using the tools of ArcToolbox. K varies between 0.6 and 1.2 depending on the morphogenetic characteristics, morphological and physical-chemical properties of soils. Very low erodibility ($K < 0.6$) have the soils with higher cohesivity, a very good structure, well developed profile with obvious horizons and upper horizon thickness more than 35 cm. Very high erodibility ($K > 1.1$) have the very weak cohesiveness soils, without structure (Carnicelli, 1999; Bryan, 2000; Mulqueen et al., 2006).

-Length slope factor (LS) was determined based on digital elevation model with a resolution of 10 m by applying the following equation (2) (Moore & Burch, 1986; Mitasova et al., 1996; Desmet & Govers, 1996; Mitasova & Mitas, 2001):

$$(2) \; LS(r) = [F(r) / a_0]^m \cdot [\sin S(r) / S_0]^n$$

where:

F = flow accumulation grid, i.e. runoff accumulation, calculated according to the digital elevation model resolution;

S = slope, expressed in degrees;

a_0 = the length of standard parcel on which observations were made and underlying the USLE model (22.1 m) (Wischmeier & Smith, 1978);

S_0 = the slope of standard parcel (0.09 or 9 %);

m = values between 0.4 – 0.6 according to the dominant flux;

n = values between 1 – 1.4 according to the dominant flux;

To obtain the LS factor intermediate phases using Spatial Analyst module of ArcMap were necessary. There are obtained derived data such as slope and flow accumulation grid. The above equation was applied in our study for each cell in raster format (x, y) and shows the length of the route followed by hydric flow on a slope of any point to the nearest point in which the slope change causes accumulation, stagnation or divergence of flow (Desmet & Govers 1996; Liu et al., 2009). This equation has been applied in other studies on erosion in Romania, but at much lower resolutions (100 m, 250 m) (Patriche, 2004; Patriche et al., 2006; Goţiu & Surdeanu, 2008; Bilaşco et al., 2009). Using the resolution of 10 m gives greater accuracy and precision in assessing RUSLE equation factors and hence to quantify the average rate of erosion.

- Land cover management factor (C) was determined based on the NDVI (Normalised Difference Vegetation Index) by using Landsat ETM satellite images (2008) and GIS software that processed radiometric information in different spectral bands (Xie et al., 2008; Karaburun, 2010).
To differentiate biomass and reveal the degree of land cover infrared bands were used. Also, to assess the type of coverage and land use the visible spectrum were used. NDVI mapping is an intermediate step and a prerequisite for the determination of factor C by the algorithm (3) proposed by de Jong & Van Joolingen (1998):

$$(3) \; C = 0.431 - 0.805 NDVI$$

NDVI is a dimensionless index, which takes values between -1 and +1 depending on the differentiated response of vegetation to spectral elaboration of satellite images.

This algorithm was used also by Patriche et al., (2006) in studies of small watersheds in Curvature Sub-Carpathians. Of course, this manner of factor C evaluation has a drawback - namely to give a situation at a certain time (the moment surprised on the satellite images). But at the same time has an advantage, namely automatic and accurate processing and errors eliminating related to observer subjectivity in assessing the effect of vegetation type and coverage in erosion and providing a value (Wischmeier & Smith, 1978, Moţoc & Sevastel, 2002).

- The factor for erosion control measures, practices and conservation planning (P factor) was evaluated based on field observations, which indicate the existence of two contrary realities. On the one hand, the old forms of erosion have been stabilized by anti-erosion measures, through fixation with herbaceous, forest or shrubs vegetation, which had the desired effect and were integrated into the landscape of analyzed basins as types of coverage. These measures have been already quantified by NDVI and entered into the equation by land cover factor (C).

The second situation is the total lack of protection measures for recent forms and the abandonment of arrangement and land reclamation works. Dispersion in surface, density and complementarily of these two cases led to the difficulty of assigning values for this factor. Consequently, we used the P factor value of 1, which introduced as primary numerical data in RUSLE equation does not change the result of multiplying of examined above factors (Bilaşco et al., 2009).

4. RESULTS AND DISCUTIONS

4.1. Annual average amount of eroded soil

Applying the RUSLE equation to quantify the erosion and integration of this model with GIS techniques has allowed obtaining the map of annual erosion average rate for the small basins taken as case study (Fig. 2, Fig. 3).

Maps analysis reveals that the average erosion varies between 0 and 94 t/ha/year, with an obvious asymmetric disposition of values on intervals and a large share of small intervals, as suggested the reduced value of the standard deviation (Table 1). Average values of the average rate of erosion vary from 0.236 t/ha/year to 0.330 t/ha/year. Estimation of annual amount of eroded soil is good, taking into account the use of predominantly arable land, pastures and hayfields. Spatial distribution of the average erosion rate values indicates some significant issues as follows. Erosion is low and very low (less than 1 t/ha/year) mostly in the depressionary area and moderate to large in submountainous hills and plateau areas. The weight of values between 1 - 5 t/ha/year is higher in the plateau (73.4%) compared to the depression area (24.2%).

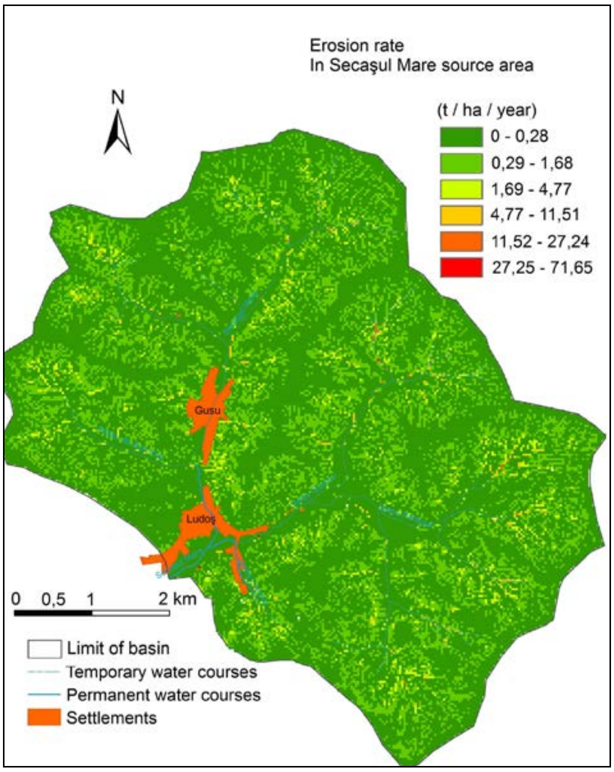

Figure 2. Erosion rate in Secaşului Mare basin – case study on source area - small inferior order basin

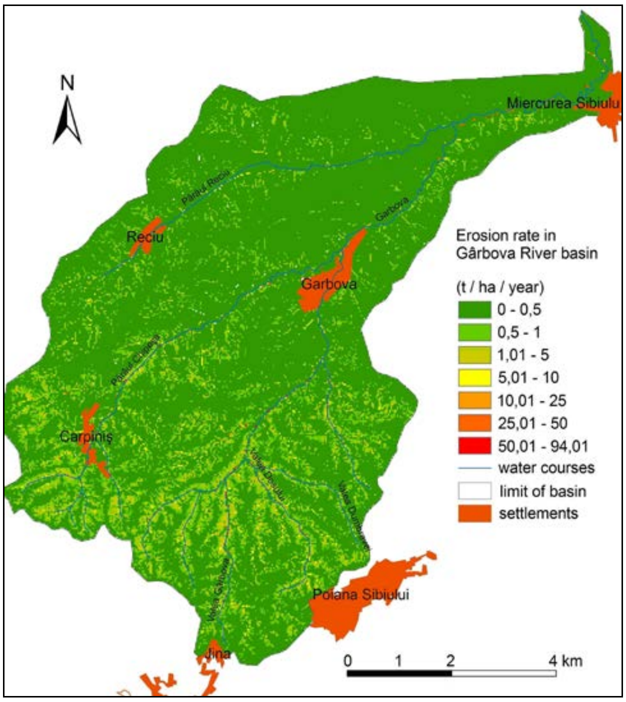

Figure 3. Erosion rate in Secaşului Mare basin – case study on Gârbova basin, first-order tributary

Table 1. Statistical data on erosion (t/ha/year) assessed by RUSLE algorithm

Statistical indicators	Inferior order basin	
	source basin	Gârbova
Minimum value	0	0
Maximum value	71.61	94.01
Average value	0.236	0.330
Standard deviation	0.92	2.22

The weight of values between 5 - 10 t/ha/year is higher in the sub-mountainous hills (11.2%) compared to the plateau (5.6%). The main cause of these differences is the steeper slope in the submountainous hills and the higher length of the route followed by concentrated fluid flow compared to the plateau.

The small values of erosion rate are spread on the main summits (Amnaş and Secaşelor levelling surfaces in the plateau, Gornoviţa surface in the Cindrelului Mountains, which falling partly within Gârbova Basin) and also on the secondary divergent summits in both plateau and sub-mountainous hills. In both basins, the bridges of terraces and floodplains have the lowest values of the average rate of erosion.

The moderate values are concentrated on torrential basins, both in the origin area and upon the terraces foreheads and are disposed along the entire length of the slope. High rates of erosion are present in the middle/lower third of slopes and are the results of deep erosion caused by cumulating of flow and the increase of runoff energy on concave slopes.

The extreme values are present in highly degraded areas by rill and inter-rill erosion and on the surfaces where the erosion processes (like runoff, gullying) are associated with landslides, on the plateau cuesta fronts, on the contact glacis and Gârbova hillsides. In all these cases, the elementary drainage channels are alignments of concentration of the rain water and eroded soil, being subject to linear erosion and deepening.

In the Gârbova basin the high and extreme values of the erosion average rate have a punctual local distribution along the collector channel and along its tributaries, regardless of altitude (Gârbova, Dosului and Chipeşa valleys in the upper sector or along Gârbova River in the vicinity of the Miercurea Sibiului settlement). This indicates, on one hand, the role of slope in the flow concentration and stream energy directing on the drain channel or on the banks, and on the other hand reflects the water level oscillations caused by the torrential rainfall.

The local distribution of high and extreme values is valid also for the plateau area, but the values are encountered in points or areas of torrential convergence and at the bottom of cuesta fronts. Since the Gârbova basin is more heterogeneous in terms of petrography, geomorphology, soil and land use, a detailed analysis on two cross sections on the West – East direction was conducted (Fig. 4, Fig. 5).

The two profiles are altimetric differentiated, one being mapped out in the sub-mountainous hills (Fig. 4) and the other in the lower basin on terraces and the common meadow of Secaşul Mare and Gârbova rivers (Fig. 5).

In the following, the role of RUSLE equation factors in determining the average rate of erosion is presented. The importance of each factor emerges from the transverse profile analysis plotted on the maps of slope, slope length, erodibility, and land cover management and on the average rate of erosion map.

The relationship between the average rate of erosion and the altitude is an indirect one, through the differentiation of bio-pedo-climatic conditions. However, at altitudes above 500 m the highest values are meeting, while at altitudes of 300 – 400 m the average erosion rate is low and very low (1.5 – 1 - 0 t/ha/year). This values distribution is due to the different rain aggressiveness, moderately to high in the upper part of the basin and low to moderate in the lower part of the basin (Costea, 2012).

As previously mentioned the slope is a very important morphodynamic indicator, because it determines the concentration of fluid flow on slope and increase the power of erosion (fluid flow energy). Slopes range from 3 - 5° and 35 - 50 - 60° in sub-mountainous hills and 0 - 3° and 10 - 20° in the depression area. The relationship between slope and erosion is established by the LS factor from the RUSLE equation. Higher variation of slopes in sub-mountainous hills and complex type of the slopes is reflected in the LS factor wide variation in the profile (100-300).

In the lower sector the size of LS factor is smaller and thus its amplitude on profile (20-40). The profiles indicate the direct and close connection between LS and the average rate of erosion, the topographic factor increase or decrease causing increase or decrease in energy of fluid flow and stream power. Maximum values are found on the hills slopes, on the mountain - depression contact glacis (200-300) and on the terrace foreheads (20-40). Minimum values of LS are found in meadows, on terraces bridges and interfluvial summits. The erodibility distribution on these two profiles indicates a strong direct link between the genetic type of soil (Bryan, 2000), its characteristics (texture, structure, and permeability) and the average rate of erosion.

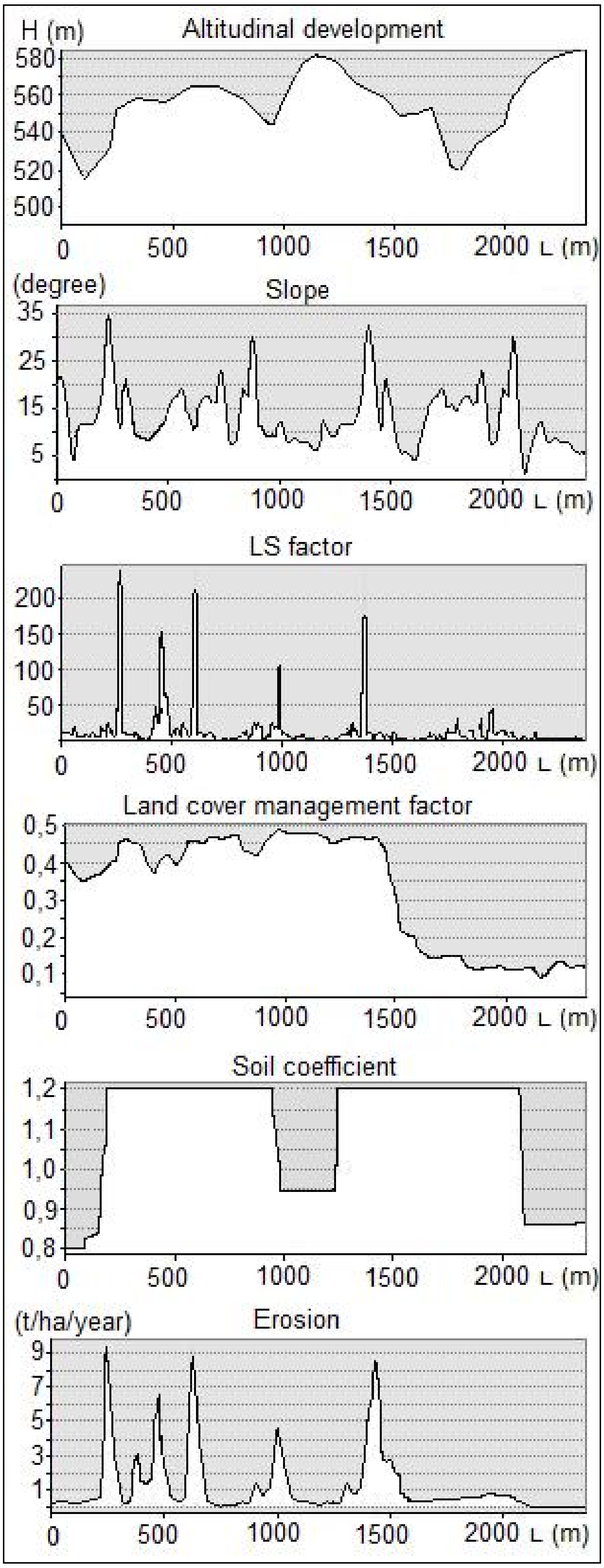

Figure 4. Cross sections on the RUSLE equation factors maps in the upper basin of the Gârbova River

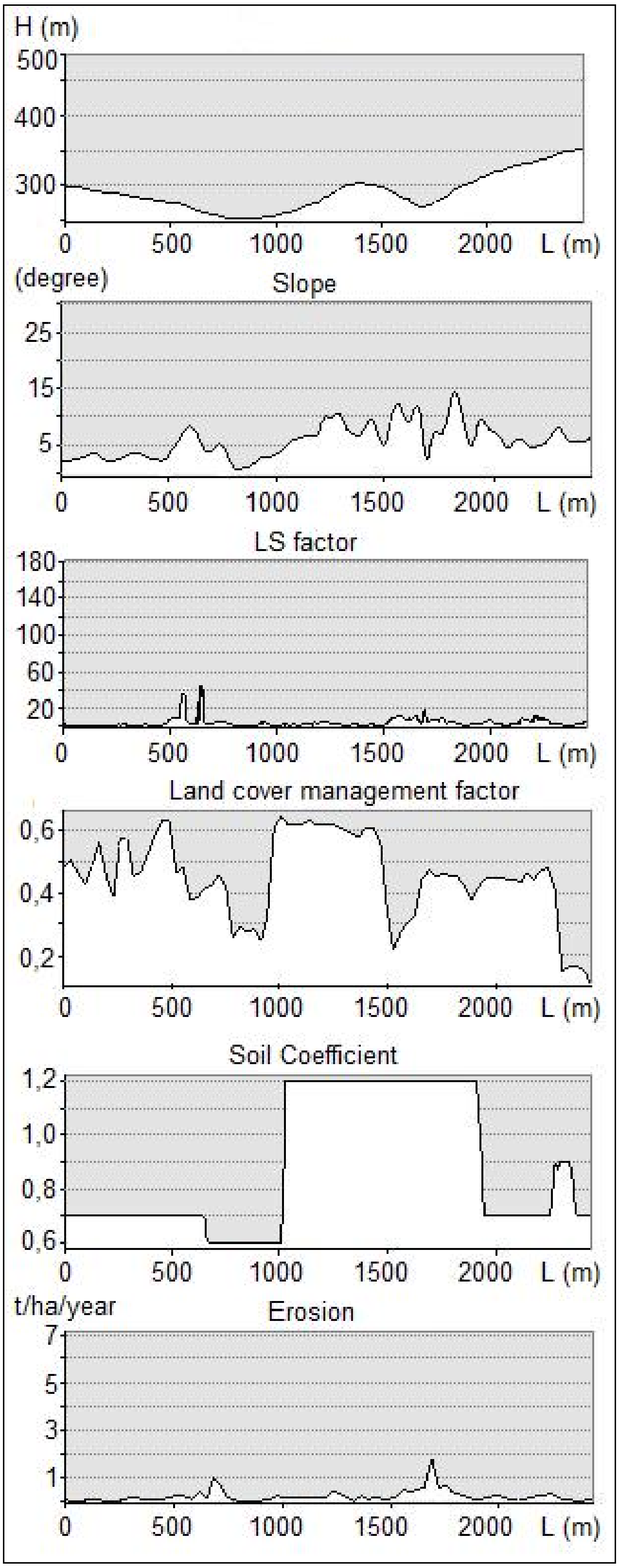

Figure 5. Cross sections on the RUSLE equation factors maps in the lower basin (right) of the Gârbova River

Erodibility is high on regosols, erodisoils, skeletal soils, moderately and strongly eroded luvisols and preluvisols (1 – 1.2), both in the high and low side of the basin. In the sub-mountainous hills, the high erodibility is due to the underdevelopment of soil profile, steep slopes and impermeability of hard rock bed of crystalline substrate which favors the runoff and rill erosion and also the subsurface erosion at the contact between crystalline rocks and slope deposits.

Reduced erodability appears on alluvisols (0.6), phaeozems (0.7 - 0.8), districambisols, eutricambosoils (0.7 to 0.9). In the lower basin, the clay component dominance of superficial deposits and pelitic parental material on which the soils are formed maintain erosion through impermeability and compaction. In the rainy periods, the saturate clay deposits favouring the surface water drainage. In dry periods, loamy - clay texture and evaporation lead to soil sealing through compactation, with negative effects on the quality and density of vegetation. The type and extent of vegetation cover and land use influence directly the erosion (Moţoc, 1984). High values of the erosion rate record on sloping land, used as pasture or arable land on which the agricultural activities are carried along the slope. In the case of pastures, these are subject to degradation by overgrazing, which leads to interruption of vegetation cover, development of runoff channels, gully and ravines on animal paths and changing of physical and chemical characteristics of the soil (enrichment in nitrites, compaction or removal of the upper fertile horizon).

Also, the quality of vegetal cover decreases by excessive consumption, treading and enrichment in ruderal species (which leads to decrease the protection of soil). A very good protection is provided by forests in the upper basin and by dense and compact grassy carpet in the meadows of Gârbova, Chipeşa, Reciu. In this area it is recorded that the lowest values of the coefficient C. Moderate values are found in areas with vineyards and orchards use, and also on agricultural lands worked along the level curves or situated on very slightly inclined terrace bridges (Costea, 2013).

4.2. Susceptibility of lands to erosion

Based on the quantitative determination of soil erosion by applying the RUSLE equation, a qualitative assessment of the susceptibility of land to erosion (Fig. 6, Fig. 7) using the classification of ICPA (1986) was then made. This implies, in the morphologic, pedological and climatic conditions of our country, the grouping of the average erosion rates in susceptibility classes. These are as follows: very low susceptibility (<1 t/ha/year), reduced susceptibility (1 - 8 t/ha/year), moderate susceptibility (8 - 16 t/ha/year), high susceptibility (16 - 30 t/ha/year) and very high susceptibility (> 30 t/ha/year).

The analysis of erosion susceptibility maps for the two small basins taken as case studies reveal the following:

- Low and very low susceptibility to erosion presents riverbanks and terraces bridges and weak inclined interfluvial surfaces, where the vegetation cover is compact, either as forests, riverside coppices, grassy vegetation or agricultural crops (cereals) that provide good protection of soil.

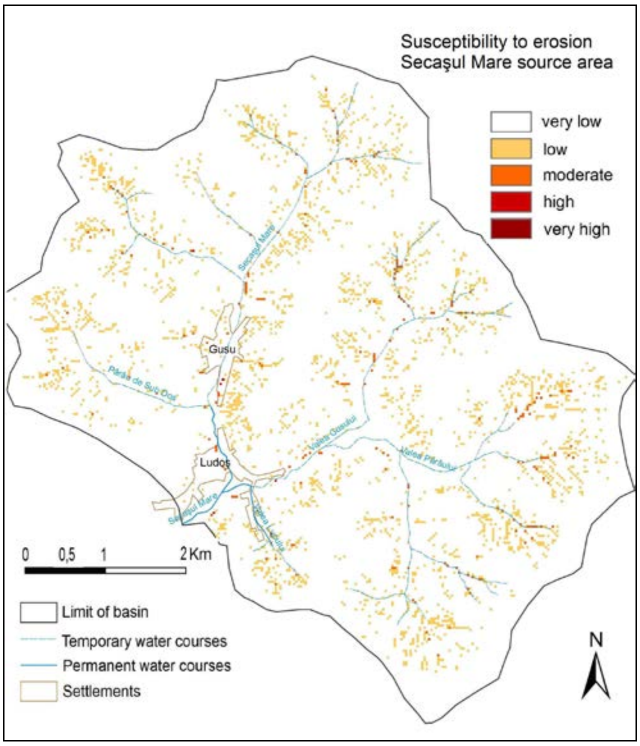

Figure 6. Susceptibility to erosion in source area basin

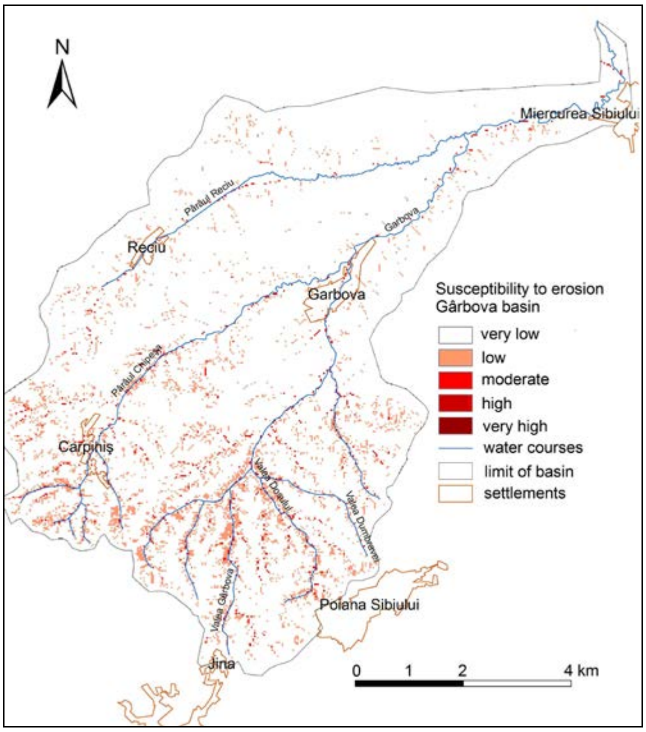

Figure 7. Susceptibility to erosion in Gârbova basin

- Moderate to high susceptibility shows the plateau slopes throughout their length, terraces foreheads in the depression area and submountainous hills slopes in their lower half. On these surfaces old forms of rill and inter-rill erosion, partially stabilized but with reactivation potential can be identified. These processes are not completely extinguished and can recur at the top or sides of ravines and gullies, on their ramifications, even if initially they were stabilized. The pastoral activity and ploughing along the slope, the creating of local roads between parcels are factors in determining recrudescence of processes. The supply areas of elementary channel are heavily affected by splash erosion, sheet erosion and solifluxion, because of overgrazing.

- High and very high susceptibility to erosion presents the slope areas affected in the past by such processes which could not be stabilized and that were still active at the time of observation. The versants are steep slopes, vegetation cover is lacking, the forms (runoff channels, ravines, gullies) are deep in the alteration crust and parental rock and show obvious signs of deepening, extending the length and ramification, which leads to an increase of the length of drainage channel and the supply surface and thus to increase the energy of fluid flow. High and very high susceptibility is specific to the torrential catchment surface in the plateau and submountainous hills and terraces foreheads, respectively to the strongly fragmented areas regardless of altitude. Soils are devoid of cohesiveness, poorly structured or without structure, and the upper horizon was partially or totally removed, no longer able to ensure the conditions for vegetation cover.

5. CONCLUSIONS

Our approach in assessing erosion by estimating annual average rate (t/ha/year) reveals that the geomorphological system is susceptible to this process. The susceptibility to erosion in the Secaşul Mare basin has, first of all, natural causes: the geological substrate, the landforms morphometry (fragmentation and slope) the physical and chemical characteristics of soils, especially the soil texture (loamy, clayey, clayey-loamy loam, sandy-clayey) and the climate conditions (torrential rainfall).

Against this background, the influence of land use in erosion is evident. Soil losses are minimal in the dense pastures and forest areas and progressively increasing on the cultivated areas, on pastures heavily exploited by grazing and on lands where the land reclamation activities are missing or were abandoned. Ploughing along the slope, excessive land fragmentation in small parcels, local roads between plots, the overgrazing and changing the sheepfolds location on the slopes are the main anthropogenic causes of land degradation by water erosion.

Knowledge of the erosive processes features, erosion assessment and mapping are very important tools in the management measures applying and territorial planning. For this purpose, the geomorphologist plays a very important role and he must be part of the research team (Renschler & Harbor, 2002).

Digital techniques for mapping and analysis of geographic information (GIS) and integration of them with the RUSLE model offer the possibility of a real assessment of annual average erosion and land susceptibility to erosion based on easily available data. If there are successive satellite images, then the dynamics in time and space of erosion phenomena and C factor can be analyzed.

This evaluation methodology can be successfully applied to regional levels and enable the comparison of results of researches conducted in different regions and also the creation of databases at national or even European level. This requires the operation with a modern but standardized methodology so that it highlights the main issues and supports the measures of land management. We note, in this regard, that our results for the southern part of Secaşe Plateau, Apold Depression and Cindrel Mountains are comparable to the results obtained in our country by Bilaşco et al., (2009) for the Someş Plateau, Patriche (2004) and Patriche et al., (2006) for Moldavian Plateau and Călimani Mountains.

Also, inter-institutional collaboration, involving of INCPA in the efforts to establish general considerations at national level and proposing realistic models for land management can be important steps in the integration and coordination of researches on erosion control. These must be integrated to the European level under the initiative of the EEA by Joint Research Center and FAO through the Regional Soil Partnerships.

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