SHEET EROSION ASSESSMENT IN MĂHĂCENI TABLELAND USING THE U.S.L.E. MODEL

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Key words: contemporary landform processes, surface erosion, U.S.L.E., GIS, Măhăceni Tableland.
Cuvinte cheie: procese geomorfologice contemporane, eroziune în suprafaţă, U.S.L.E., SIG, Podişul Măhăceni.

ABSTRACT:

Throughout Măhăceni Tableland, actual erosion processes on slopes, show a strong dynamics and they do realise interrelations and self connections, with a high degree of degradation for some specific areas. Surface erosion is quite active and it carries out some damage potential. The present study shows a way for evaluating the proclivity of steep areas, to contemporary slope erosional processes, using the U.S.L.E. model. The purpose is to realise the sheet erosion map for Măhăceni Tableland.

1. Introduction

In Măhăceni Tableland, actual landform processes, mostly surface erosion processes, have strong dynamics and they have self relationships and mutual conditioning connections, with a high degradation level for certain areas. These processes concern slopes from 11 catchments out of the total of 15 in the study area.

The purpose of the study is to identify the actual areas affected by surface degradation and to realize the quantitative assessment of soil erosion degree, all being expressed within the sheet erosion map for Măhăceni Tableland.

In order to have most realistic results concerning the present-day situation of slope erosion processes and their degradation effects on the parcels from Măhăceni Tableland, the surface erosion values were calculated, using the U.S.L.E. model and finally, the sheet erosion map was constructed for Măhăceni Tableland.

Surface erosion is realized by miscellaneous sheet-flood, set on the whole surface of the slope, with spread, coated and laminar run-off. The form of the slope profile and the coated strata thickness, together with the run-off forces, depend on: precipitation force, water infiltration capacity, sheet-flood length, slope, surface roughness, turbidity degree and run-off type. Surface erosion depends on some factors such as: landform configuration (slope gradient, slope length, slope curvature and slope aspect), climatic characteristics (especially precipitations and thermic regime), lithology, soil type (structure, texture), land cover (with a protective role) and the anthropic factor (which can accelerate or decrease erosion).

The specific mechanism of this geomorphic process is very close to heavy rainfall duration. The negative effects induced by surface erosion, follow: decrease in land cover, evolution of transitional vegetation, development of areas dominated by erosion micro morphology.

2. The study area

The considered area-Măhăceni Tableland lies in the central-north-western part of Romania, as a contact region between Trascău Mountains and The Transylvanian Basin, extended between Trascău Mountains in the west, the Mureş-lower Arieş Way in the east, north and south (figure 1).

Măhăceni Tableland belongs to the hilly contact region on the western border of the Transylvanian Basin, realizing the geotectonic and morphological-structural relation between the orogene structure of Apuseni Mountaions and the basin unit of the Transylvanian Depression.

The northern part of the Alba Iulia- Turda Way, with the great curl of the Arieş river, reveals a hilly region with a peninsular aspect ("The Arieş river peninsula"- V. Mihailescu, 1965), which goes deeply eastward into the Mureş- lower Aries Way. This hilly massif is known in the geographical literature as Măhăceni Tableland or Vințu Piedmont.

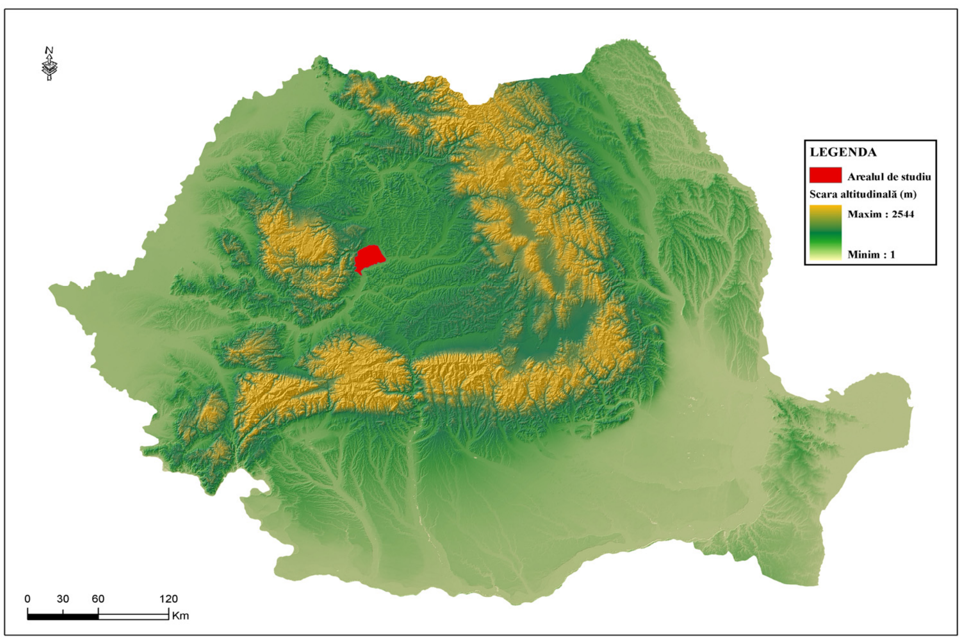

Fig.1. Location of Măhăceni Tableland in România.

Lithostratigraphically, Măhăceni Tableland is a Miocene formation, through which Badenian, Sarmatian and Pannonian structures are aged in almost parallel west-to-east strips. Regarding the structure, Măhăceni Tableland shows a tipically folded morphology, belonging to both: the normal folds and the diaper-deformed folds. The lithology of the study area has a crumbly charcter, sedimentary consisting of: sandstones, sand marls, marls, marl clays, sand clays sands and gravels.

Concerning the climatic regime, Măhăceni Tableland follows the moderate continental- temperate type, with the soft penetration of the Atlantic air mass and the action of the foehn phenomenon on the south-eastern flank of the Apuseni Mountains, manifested by the increase of the annual mean temperature and the decrease of rain quantity.

Climatic observation data from the main meteorological stations in the studied area (Turda station, Luna station, Câmpia Turzii station) between 1974 and 2007, reveal a mean multi-annual temperature of 8.5ºC at Turda station and 9ºC at Câmpia Turzii station, with an annual mean amplitude of 28,5ºC (Turda station). The mean annual precipitations go between 500 and 650mm per year (630mm at Turda station, 539mm at Luna station), the annual evolution is characterized by a maximum of precipitations in the warm period of the year (820 mm in June, for Turda station) and a minimum, in the colder period of the year (144mm in April at Turda station).

3. Sheet Erosion assessment using the U.S.L.E. model for Măhăceni Tableland

Best models for the assessment of soil loss, by the action of rainfall, are the empirical models of surface erosion. The applied practical significance of these informatic applications on basis of deterministic models, concerning surface erosion risk, is remarkable through the precision of the results and their spatial distribution.

In determining the surface erosion vulnerability of the parcels from Măhăceni Tableland, the U.S.L.E. (Universal Soil Loss Equation) model was used. The U.S.L.E. model is the most used in estimating surface erosion and in our country, it has been adapted by a team led by Mircea Moțoc, which proposed in 1979, the ROMSEM (Romanian Soil Erosion Model), the best version for Romania being re-confirmed in 2002 (Moțoc M, Sevastel M., 2002). This mathematic formula is set in the following way:

$$ES=K*L^{m}*i^{n}*S*C*Cs$$

where:

Es- the quantity of sediments generated by sheet erosion estimated as multi-annual average (tons/ha/year)
K- corrective coefficient of the rainfall-runoff erosivity factor
Lm- the slope length factor
i^n - the slope gradient factor
S- corrective coefficient of the soil erodibility factor,
C- corrective coefficient of the crop/cover management factor
CS - corrective coefficient of the support practice factor

The values of the factors within the presented formula, were established within the soil preservation laboratory of I.S.C.I.F., with an application to the pedo-climatic conditions from Romania.

*The rainfall-runoff erosivity factor (**K**)* represents the erosivity value induced by precipitations, respectively, the soil loss due to rainfall aggressiveness. Research made by P. Stănescu (cit. Dîrja, 2000), have contributed to establishing the structure of the rainfall-runoff aggressiveness factor, expressed as a produce of rainfall quantity and the heavy rainfall nucleus with a 15-minutes duration, which represents the time of water concentration within the runoff parcels for the formation of rills. The rainfall-runoff factor has specific differential values in Romania, the regional distribution of this factor being subject to the different physical-geographical conditions. The values of this corrective factor have been adapted from the hydrologic regional distribution of The National Institute of Meteorology and Hydrology. The exact determination of this coefficient goes according to the 1969 map edited by P. Stănescu & contributors (cit. Dîrja, M., 2000). The corresponding value for Măhăceni Tableland is 0,130.

*The slope length factor (**Lm**)*

The morphologic components which mostly participate within the erosion process are: slope gradient, slope length and slope aspect. The relationship between erosion, slope gradient and slope length, has been established for flat uniform slopes, erosion decreasing according to the convex degree and decreasing with the concave degree. Slope length mostly controls runoff volume during heavy rainfall. Erosion increases, along with slope length growth, due to the accumulation of continuous growing water quantity, during heavy rainfall. Slope length effect is estimated using a function of the type L^m, where m=0,3 or m=0,4. The m value is estimated at the value of 0,4 for slope length over 100m and the 0,3 value is used for slope length up to 100m. With the help of GIS, the critical slope length, for which sheet erosion is significant, was calculated, using the 10m resolution DEM and the established values for the m coefficient. The corresponding value was introduced in the formula proposed by Desmet and Govers (1996):

$$\{[(\text{flow accumulation}) \bullet \text{cell size}]/(22,1)\}^{0,3}$$

This factor stands for a rate of soil loss, in any given situation on a “standard” slope with a 9% steepness and a 21m length. The result of these operations is reflected in the spatial distribution of the slope length factor.

The slope gradient factor (i^n)

Slope steepness has a substantial contribution to the transport of the sediments resulted from the pluvial water runoff, sheet-flood and as a result from the soil cover practice. Within the Romanian geographic literature, the slope gradient factor is calculated by the formula:

i^n= 1,36+0,97i+0,38i², where i= tanα (Moțoc, M., Sevastel M., 2002).

*The soil erodibility factor(**S**)*

Erodibility is the attribute of the surface, which enables the erosion process initiation. The surface cover, generally consisting of slightly cohesive materials (soil and surface deposits), enables high susceptibility to sheet erosion. In estimating the soil erodibility factor using U.S.L.E., the intrinsic soil properties were considered (texture, humus content, permeability and hidrical stability of the structure). Erodibility classes are set according to the genetic type of the surface cover (soil or rock), erosion level and texture.

*The crop/cover management factor(**C**)*

Land cover is the main factor controlling the erosion process. The crop/cover management factor is subject to the influence of plant associations' type, on the erosional process.

In Romania, the land cover protection ability was measured by the runoff plots, the eroded soil quantity on the land covered with different species or vegetal associations was reported to the quantity of eroded soil on land with no plant cover or with a weak protective crop type. Thus, the crop/cover management factor (the natural vegetation and crop structure) are recommended coefficients.

The crop/cover management factor was calculated using GIS, according to the Corine database. Thus, the land cover map was constructed and the values of the C factor were introduced with GIS. This factor shows lowest values in urban and afforested areas and in opposition there go the values for agricultural or degraded areas.

*The support practice factor (**Cs**)*

Te results from field experiments in Romania, regarding the anti-erosion efficiency of frequently used methods for soil conservation, have set up the basis for the calculation of the support practice factor (anti-erosion protection actions). For the areas with soil erosion control (vegetation/cover and hydric improvement actions), the anti-erosion influence is determined. By default of these measures, the practice factor's value is 1.

In order to calculate the estimated sheet erosion value, within the presented calculation relation, the determined values of the factors were introduced, thus being set the balanced mean of sheet erosion value, for each homogenous landform unit.

4. Results

In general, the accepted sheet erosion mean value is 3tones/hectar/year (t/ha/an). The obtained values show that 3,7% of the total study area is affected by erosion values over 3 t/ha/year (table no. 1).

Most part of the study area (92%), shows values of sheet erosion, under 2t/ha/year, and for 4% out of the total area, values of 2-3t/ha/year were found. Still, for specific small areas, high values for sheet erosion were found in the following catchments: Bădeni, Mirăslău, Cicău, Ciugud, Aiud, Unirea and Feldioara (figure 3).

For catchments located over Unirea Valley, there are situations of older land clearings, especially fruit-tree plantations, thus leaving a territory vulnerable to erosion processes.

Table 1. Sheet erosion values for Măhăceni Tableland.

Erodibility class	Surface (ha)	Percent from total area (%)
<1 t/ha/year	34031,22	80,7
1-2 t/ha/year	4849,75	11,5
2-3 t/ha/year	1704,44	4,0
3-4 t/ha/year	767,71	1,8
4-5 t/ha/year	391,82	0,9
>5 t/ha/year	422,65	1,0
Total	42167,57	100,0

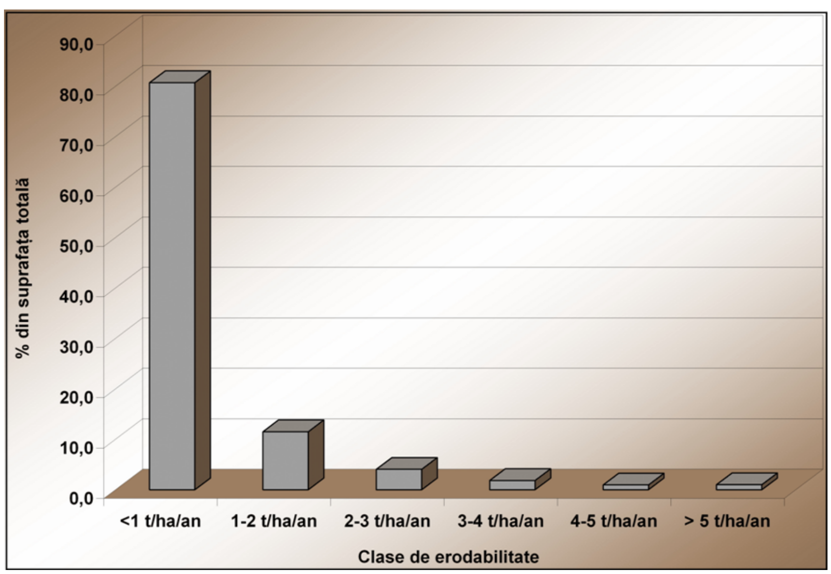

Fig.2. Erodibility classes weight out of the total surface of the total surface of Măhăceni Tableland.

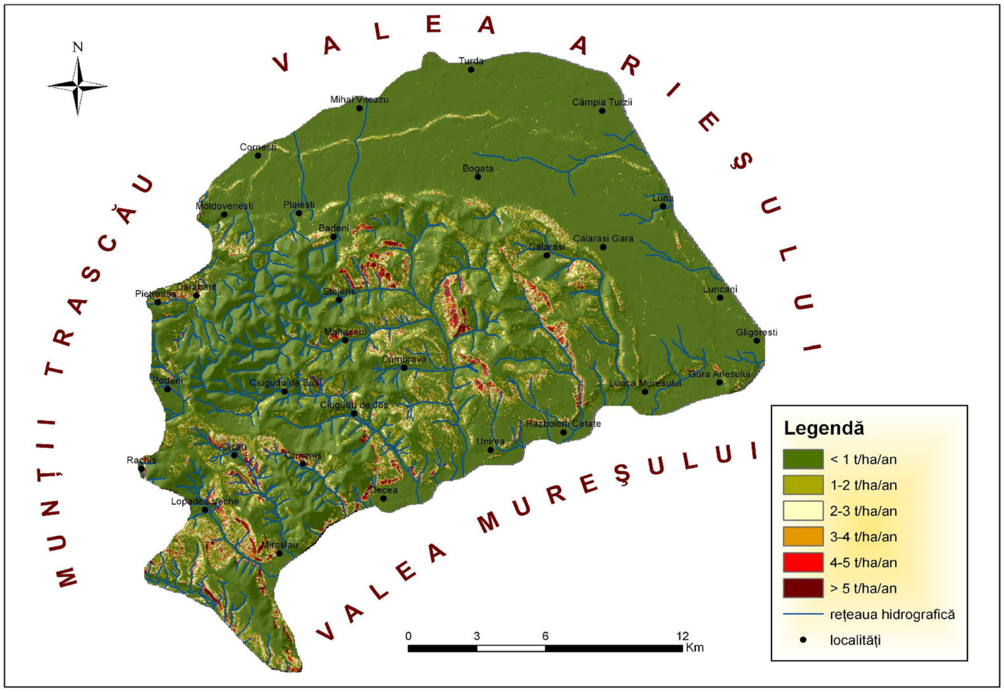

Fig. 3. Sheet erosion map for Măhăceni Tableland using the U.S.L.E. model.

Eastwards from Unirea Valley, there are wider surfaces with high sheet erosion values, which mostly affect pastures. Here one can find a typical over feeding area. The most effective mitigation measures against sheet erosion could be re-planting of fruit trees in areas where they were cleared, especially after 1990, thus contributing to the soil protection with the tree cover.

5. Conclusions

In Măhăceni Tableland, actual landform processes, mostly surface erosion processes, have strong dynamics and they have self relationships and mutual conditioning connections, with a high degradation level for certain areas. These processes concern slopes from 11 catchments out of the total of 15 in the study area.

The purpose of the study is to identify the actual areas with areas affected by surface erosion and to realize the quantitative assessment of soil erosion degree.

Using GIS, the soil erosion values were calculated, using the U.S.L.E. model and finally, the sheet erosion map was constructed for Măhăceni Tableland. If considering that out of the total area of Măhăceni Tableland, arable parcels are dominant (52,34%), followed by pastures (24,12%), and also, a low vegetation cover extent (table 2) due to massive forest clearing since historical times, one can find the proper natural conditions for sheet erosion development. Thus, rainfall-runoff finds the best erosion conditions especially on steeper slopes, with a strong soil erosion and a rapid evolution of the specific surface erosion products (rill-wash, gullies, torrents).

Table 2. Land use classes for Măhăceni Tableland.

Utilizarea terenului	*Suprafaţă (ha)*	*Pondere (%)*
Zone construite	405,93	9,62
Arabil neirigat	2207,68	52,34
Livezi	48,48	1,15
Păşuni	1017,24	24,12
Păduri de foioase	448,72	10,64
Păduri de conifere	0,35	0,01
Păduri mixte	8,92	0,21
Vegetație arbustivă de tranziție	79,20	1,88
Terenuri mlăştinoase	1,36	0,03

The actual pastures' condition indicate the fact that these are subject to over feeding, which enables high linear erosion, especially on slopes steeper than 6º, leading to rill-washing, gulying, etc. On the other hand, one can see the importance of land cover, especially trees, as a safety element against contemporary erosion processes.

In this situation, according as parcels in Măhăceni Tableland become more and more affected by degradation on different levels, there is a strong need to identify areas with high surface erosion potential, as a first step in evaluating land quality and setting the proper mitigation and control measures against land degradation.

The suitable biologic mittigation and control actions, rely on tree plantations, which have beneficial effects: they retain a great amount of rainfall water, within canopy and litter, thus reducing water supply; they realize a strong drainage through the high soil water consumption, which is eliminated by perspiration: they strengthen soil and land surface cohesion, through the rich roots of trees and shrubs, which form a thick and continuous net, on a 0,5-1m depth and over. Best results show the following tree species: acacia, cherry tree, black pine, ash tree, common maple, tartar maple, cornel tree, smoke tree, lilac, white willow, black alder, hornbeam, way thorn, cornel tree.

Sheet erosion is quite active in Măhăceni Tableland, with an actual damage potential over the parcel within the study area. The present study represents a model of evaluating land vulnerability to contemporary surface erosion processes, using the USLE model, in order to construct the sheet erosion map for Măhăceni Tableland.

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