GEOMORPHOLOGICAL PROCESSES IN THE STUDINEȚ CATCHMENT (TUTOVA HILLS)

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Abstract. Studineț catchment is situated in the eastern part of Romania (Tutova Hills), having a surface of about 9669 hectares. The land degradation in Studineț catchment is mainly represented by sheet erosion processes, gully erosion and landslides. Gully erosion is the most characteristic geomorphological process, both by the occupied area and by the resulting effects, even if, overall, this process does not exceed the amount of soil losses, caused by sheet erosion The exploitation of GIS techniques and the use of aerial photos allow the diachronic analysis of large land surfaces. Departing from the digital elevation model (DEM) and from derived thematic maps constructed with the help of the TNT mips software, we have conducted a complex analysis of geomorphological processes in relationship with the control factors (rainfalls, slope, fragmentation depth, land use, etc).

Keywords: Studineț catcment, geomorphological processes, gullies, sheet erosion, landslides

Introduction

Studineț catchment is located in the eastern part of Romania (Tutova Hills), having an area of about 9669 hectares. Spread on a North-South priority direction, it is a part of the classic pattern of catchments in region. The maximum amplitude (370 m) ranges between 485.5 m in the northern part of basin, (the Cheii Hill) and 109 m, to the confluence with the Tutova River, in the southern part of region (fig 1).

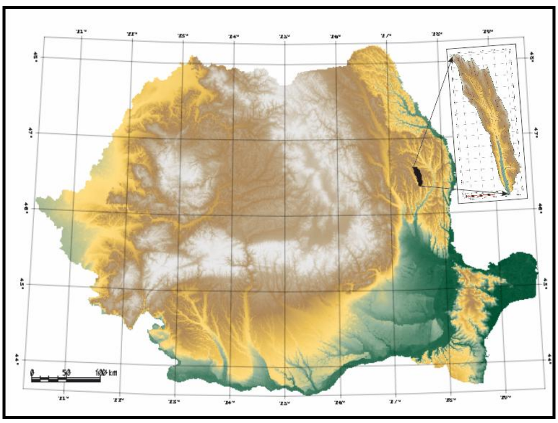

Fig. 1. The geographic location of Studineț catchment

The geological fund is dominated by geological deposits of Khersonian, followed by the Meotian ones which are present especially in the upper part of slopes. Quaternary deposits occupy a relatively restricted surface, being found mainly in lower and middle basin, along the Studineț River. The lithology is represented by sands, loamy sands, sandy-clays and clays, in different sequences. The only clear stratigraphic marker is represented by the cinerites of Nuțasca-Ruseni, whiles the rest of structure is relatively simple and monotonous and difficult to interpret.

Increased fragmentation of the predominantly sculptural landforms influences the dynamics of slope processes. The general monoclinal structure favors the development of cuesta relief (Ioniță, 2000) and thus the appearance of morphological, morphodynamic and land use asymmetries resulting, expressed by: unequal length of slopes, different declivities, distinct dynamics of geomorphological processes, and a differentiated land use on slopes.

Studineț catchment has a defining characteristic: the left side slope, with a general West and South-West aspect, can be unframed in the category of very prominent cuesta forehead (structural asymmetry of the II order), which is highly fragmented by gullies. In fact, many of these ones are much evolved, being subsequent valleys at an advanced stage of evolution (fig. 2). These valleys (Siliştea, Lunca, Valea Lupului) present an asymmetric profile and the overall northern slopes, typical cuesta forehead, are steep, more degraded, while the opposite slopes, with a southern general aspect, are typical reverse of cuesta. Also, the left side of Studineț catchment has a much greater share of the total area of basin – 66.34% (64.15 km^2) – compared with the right slope which is extended only on 32.54 km^2 (33.65%). The latter has a predominantly eastern aspect, occupying the position of a reverse cuesta, less inclined.

Given its position in the eastern part of Romania (on the one hand at the shelter of Carpathians, on the other hand due to its broad openings to the east), Studineț catchment is characterized by a temperate continental climate with obvious nuances of excessiveness. The mean annual temperature ranges between 8.1˚ and 9.6˚C and the mean rainfall is about 566 mm in one year, with a frequent deviation between 450 and 700 mm. Maximum values of rainfall in 24 hours are recorded mostly in the warm half of the year, their average intensity ranging from 0.3 to 0.4 mm/min. Climatic conditions influence the groundwater aquifers that have only minor reserves.

In this region, magnitude and frequency of the geomorphological processes has been stimulated by the components both of the natural systems and of the human structures. One of the most appropriate indicators of landscape changes and human pressure is the faulty planning of land use. It must be noted the atomization of the arable plots, the frequently up and down-slope farming, and the severe limitation of forestry in the last two centuries. Thus, the human factor becomes a real stimulus in triggering or accelerating some geomorphological processes.

The land degradation in Studineț catchment is mainly represented by sheet erosion processes (with a generalized distribution), gully erosion and landslides. Sheet erosion develops in all places where there is a small slope that can allow water runoff through diffuse processes. The agricultural lands situated on slopes greater than 5%, are the most exposed areas to this process (Hârjoabă, 1968, Moțoc, 1983), which is less noticeable and difficult to be assessed, but which evolves gradually and causes the loss of surface fertile soil horizon.

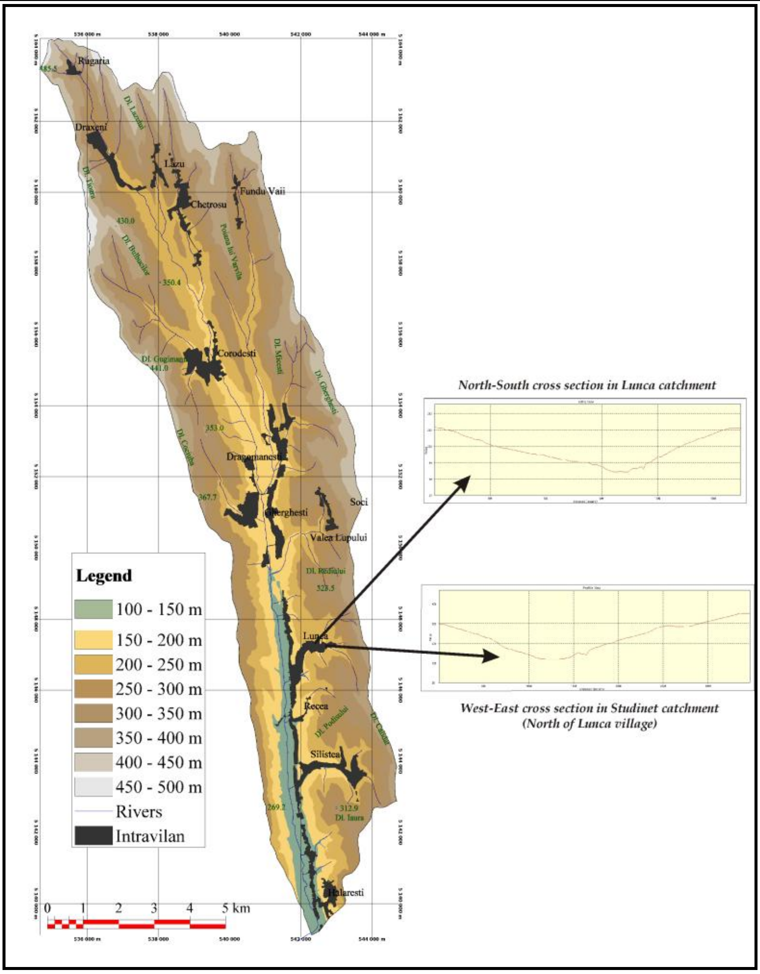

Fig 2. Hypsometric map of the Studineț catchment

Gully erosion is the most characteristic geomorphological process, both by the occupied area and by the resulting effects (consequences of functional, structural, landscape order), even if, overall, this process does not exceed the amount of soil losses, caused by sheet erosion. The development of landslides in the studied area is at a small scale, being especially favored by the Khersonian sandy-clay substrate, intercrossed at the slopes' level.

Materials and methods

A complex database has been created to analyze the current geomorphological processes in the Studineț catchment: topographic maps (1:25000), orthophotoplans, (1:5000, 2005 edition), soil surveys of the rural territories (1:10000) and climate data of the meteorological stations Plopana (1963-1999) and Bârlad (1961-2006). The topographic maps are the property of "Al. I. Cuza" University of Iasi, the orthophotoplans were purchased by CEEX 756/2006, the soil surveys have been provided by OJSPA Vaslui and the climate data by the National Meteorology Administration Bucharest. This material support has been exploited using GIS techniques that have allowed a detailed analysis of the entire catchment. The analysis of geomorphological processes has been made in relation to control factors (topography, rainfall, soil erosion, land use). The starting point was the digital terrain model and the thematic maps, realized using the program TNTmips 7.3., based on statistical information and field observations.

Results and discussion

1. Factors of soil erosion control

The main erosional factor are rainfalls, mainly those with torrential character and secondly those of long duration. Heavy rain falls, defined by Yarnell criterion, are recorded especially between May and September (50%), with a maximum frequency in June. Thus, these rainfalls overlap the critical erosion season, between May 15th and 20th of June (Ioniță, 1990, 2007). According to the Methodology of Soil Surveys Elaboration (third volume), Studineț catchment belongs to an area with low erosion in terms of rainfall aggressiveness, although some recent calculations indicate a higher value of this indicator (Stângă, 2009).

Declivity and slope length are very important in the spatial analysis and dynamics of erosion processes. The tilt of terrains influences the erosion processes on slopes, by adjusting both the ratio runoff/seepage and the increasing of pluviodenudation effect. In Studineț catchment, where slopes are the main feature of landscape, the lands with slopes ranging from 5 to 15˚ dominate (60.11%). The inclined slopes have a relatively high percentage (19.71%) are witnessing an increased fragmentation of the landscape and present a high and very high erosion risk. The slightly inclined slopes (3-5°, 26.12%) have a predominantly agricultural use and they are affected mainly by sheet erosion that implies the loosening of fertile horizon, bringing significant damage to crops (Moțoc, 1975). Slope length has a significant contribution to the volume of erosion during heavy rain; in our catchment, slopes of small and medium length are dominant. Thus 53.39% of slopes are below 200 m in length, 42.11% are between 200-600 m, and only 4.51% above the threshold of 600 m. The influence of the two control factors may be expressed by the acceleration of erosion as the slope length increases and reaches its highest values.

The erodibility of soil is another erosion factor. The most exposed to erosion are the forest soils that occupy an appreciable area (preluvosols, 23.59%, and luvosols, 11.31%) and cambic chernozems (3.55%). The extension of regosols and erodisols stands as a testimony to the high level of sheet erosion.

Land use (land cover and land use practices) is the last important factor reflected in the soil erosion amount, but also in the dynamics of gullying and landslides. The overall image of Studineț catchment is filled by the presence of excessively large farm’s number of relatively small size, as a result of improper application of Land Law no.18/1991. In the studied catchment there are a total number of 12,627 plots, with the average size of 0.40 ha, spread over a total area of 3149.48 hectares (32.57%). Agricultural works are carried out individually (subsistence farming), thereby creating an extremely heterogeneous agricultural landscape. Strong fragmentation of land minimizes the economic profitability and emphasizes the dynamics of erosion processes.

Relatively high percentage of woodland (34.35%) makes the Studineț catchment to be one of the most forested drainage basins in the Tutova hills. Since the analysis of land use has been made on the basis of orthophotoplans at the maximum allowed resolution

(0.5x0.5 m), it is not possible to integrate in this article a synthetic image of the drainage basin, but some details can be suggestive (fig 3).

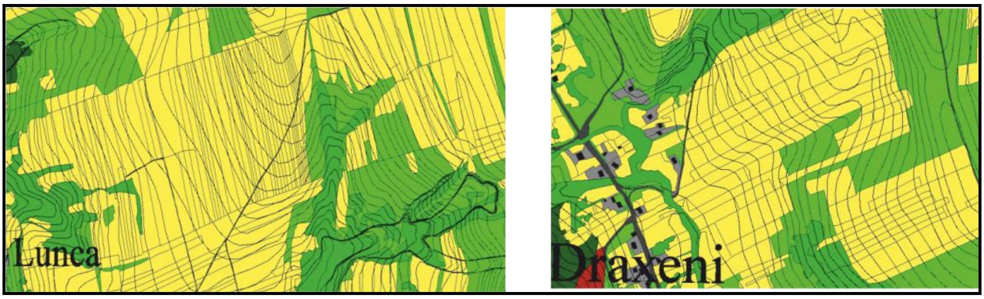

Fig 3. Land use in Studinet catchment

2. Current geomorphological processes
2.1. Gully erosion

The most characteristic geomorphologic process in Studineț catchment is the gully erosion, resulting in a serious range of consequences on large areas, even if, overall, this process does not exceed the amount of sheet erosion. Based on the orthophotoplans (2005) there were identified 329 forms of gully erosion (fig.no.7), with the indication that there were selected only those gullies whose active surface, exceeds 50 m^2. In relation to the total area of catchment, the density of gullies is 3.40 gullies/km^2, their average size being between 0.16 ha and 4.5 ha. (fig. 4). The largest gullies present the features of torrential valleys, which can be classified as first-order valleys (the Horton Strahler ranking system). Among them must be included: Siliştea (10.73 ha), Valea Lupului (10.46 ha), Lunca (8 ha), Corodeşti V (5.86 ha, 2.9 ha) Draxeni (5.40 ha). Many of these largest gullies develop around and within residential areas and they are positioned as follows: eastward Dragomăneşti village (5.3 ha, 3.63 ha, 3.49 ha, 2.41 ha), westward Dragomăneşti village (2.42 ha), southward Draxeni village (4.89 ha) northward Hălăreşti village (3.8 ha), Recea (3.14 ha), Lazu (3.14 ha).

Fig 4. Large-dimension gully: Siliştea catchment

The distribution of gullies on altitude and slope categories (fig 5) provides a very expressive overview image. The altitudes in Studineț catchment range between 108.9 m - 485.5 m, but the largest weight of gullies areas (85.46%) correspond to altitudes between 150-350 m (altitude that define only slopes).

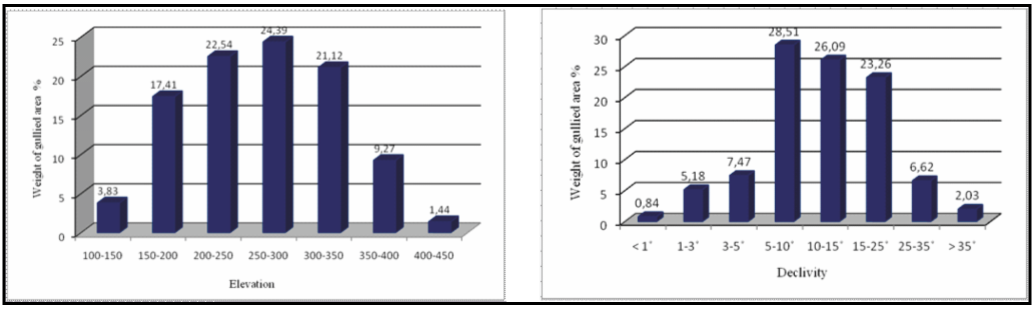

Fig 5. Altitudinal distribution of gullies on altitude (elevation) and slope categories (declivity)

This high percentage /density of gullied areas overlaps almost completely to the left side of basin, which occupies the leading position of a cuesta forehead, characterized by high values and great lengths of slopes. The low values of only 3.83% of the total weight of gullied surfaces, typical to altitudes of 100-150 m, can be explained by their overlapping the area of Studineț River's floodplain. Also, low values correspond to altitudes of 350-450 m (10.71%), which is due to the overlapping of these areas with interfluvial tops with low declivity. It must be noted that above altitudes of 350 m, lands under forestry are well represented.

Another basic parameter in development and evolution of torrential organisms is the slope. The analysis of the chart (Fig. no. 5) on the distribution of gullied areas on slope categories shows the dominance of gullied surfaces between values of 5-25%, totaling a percentage of 77.86%. Low percentage values of gullied surfaces (8.65%), corresponding to the categories of slope with values of over 25˚, are explained by the presence of wooded areas. With a major influence even from the first forms of concentrated runoff on slopes, the high values of declivity cause an acceleration of rill and gully erosion, while lower values favor a lateral extension of the torrential bodies.

The distribution of gullies on classes of the depth of fragmentation (fig 6) shows a high proportion of these surfaces in the range of 80-100 m (41.93%), followed by the interval 100-120 m (21.95%).

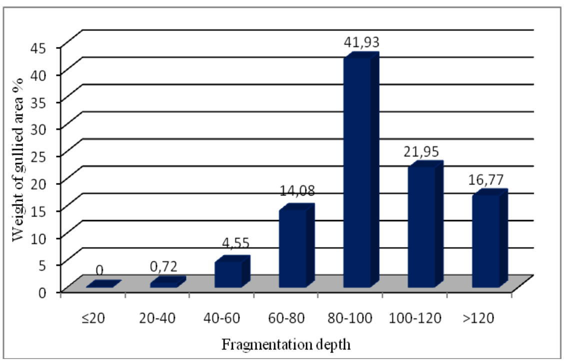

Fig.no.6. Distribution of gullies on representative classes of depth

From the morphogenetic point of view, the maximum relief energy, characterizing the cuesta foreheads, determine appearance and development of active gullies. The torrential basins initially develop on the line of the highest slope, evolving at a fast pace, with a trend of gradual adaptation to the monoclinal structure, either under the form of obsequent valleys or under the form of reconsequent valleys (Stângă, 2009). Some access or exploitation roads in the basin's area make their presence felt by the crucial role they have in the formation of gullies on slopes, given the failure of their tracking system on the direction of the greatest slope before 1945 or by their redrawing after 1991, completely ignoring the existing anti-erosion facilities.

Overlapping the vector layers of villages with the vector layers of gullies, there have been identified 45 gullies within the rural building area. A good example is the Lunca village, located in homonymous basin (417 ha). This torrential valley has an ample development conditioned by its location on a typical cuesta front, whose fragmentation depth exceeds 350 m. The circularity of the basin, expressed as a form ratio of 0.41, determines the rapid concentration of water, ensuring maximum flows that allows the accelerated deepening of the gullies' banks.

The changing of the degraded lands use has led to an emphasized dynamics of the banks of gullies. The risk associated with the progressive advancement of gullies is amplified by the exposure level and the very high vulnerability of households (located at a small distance from the banks of gullies, 10-15 m) and roads (3-5 m). In Lunca catchment, the emergent changes have been dramatic both in terms of area and perimeter of gullies and in terms of landslides. The extension of the perimeters affected by gullies has been done mostly on the lateral through bank processes - collapse and landslides.

2.2. Landslides

Landslides are punctual events, controlled by the intensity, duration and size of triggering mechanisms and by the local morphological, lithological, hydrological, structural conditions and of land use (Galli and Guzzetti, 2007). In terms of geomorphology, landslides are processes that shape the slopes under the action of gravity. Generally, all deposits characterized by fine textures and contractile clay minerals could be affected by landslides due to the existence of a sliding surface, in the conditions of the soaking of deluvium (Surdeanu, 1998). In Studineț catchment there have been identified 51 landslides (fig.no.13), totaling an area of 81.4 ha (0.84% of basin's area). The lithological conditions have an important role by the presence of a stratigraphic alternating at the superior part, (on interstreams) with thick layers of sandy or sandy-dusty deposits that allow water infiltration and presence of clay deposits under these layers.

Khersonian deposits, represented by intercalations of clays, sandy clays, sands and loamy sands, with few rough intercalations occupy the most part of Studineț catchment (53.97%). In these deposits are concentrated 78.43% of landslides and 76.78% of the total area occupied them.

Taking into account the lithological characteristics and the weight of landslides on geological deposit, three classes of susceptibility were established by assigning to each geological deposit an influence factor (F_i), as a product of absolute frequencies of landslides (number and area), calculated for each type of deposits (Stângă, 2009).

$$If = \frac{Psa \cdot Fca}{S^2}$$

F_i - influence factor;
P_{sa} - weight of area occupied by landslide (%);
F_{ca} - frequency of landslides (%);
S - analyzed area.

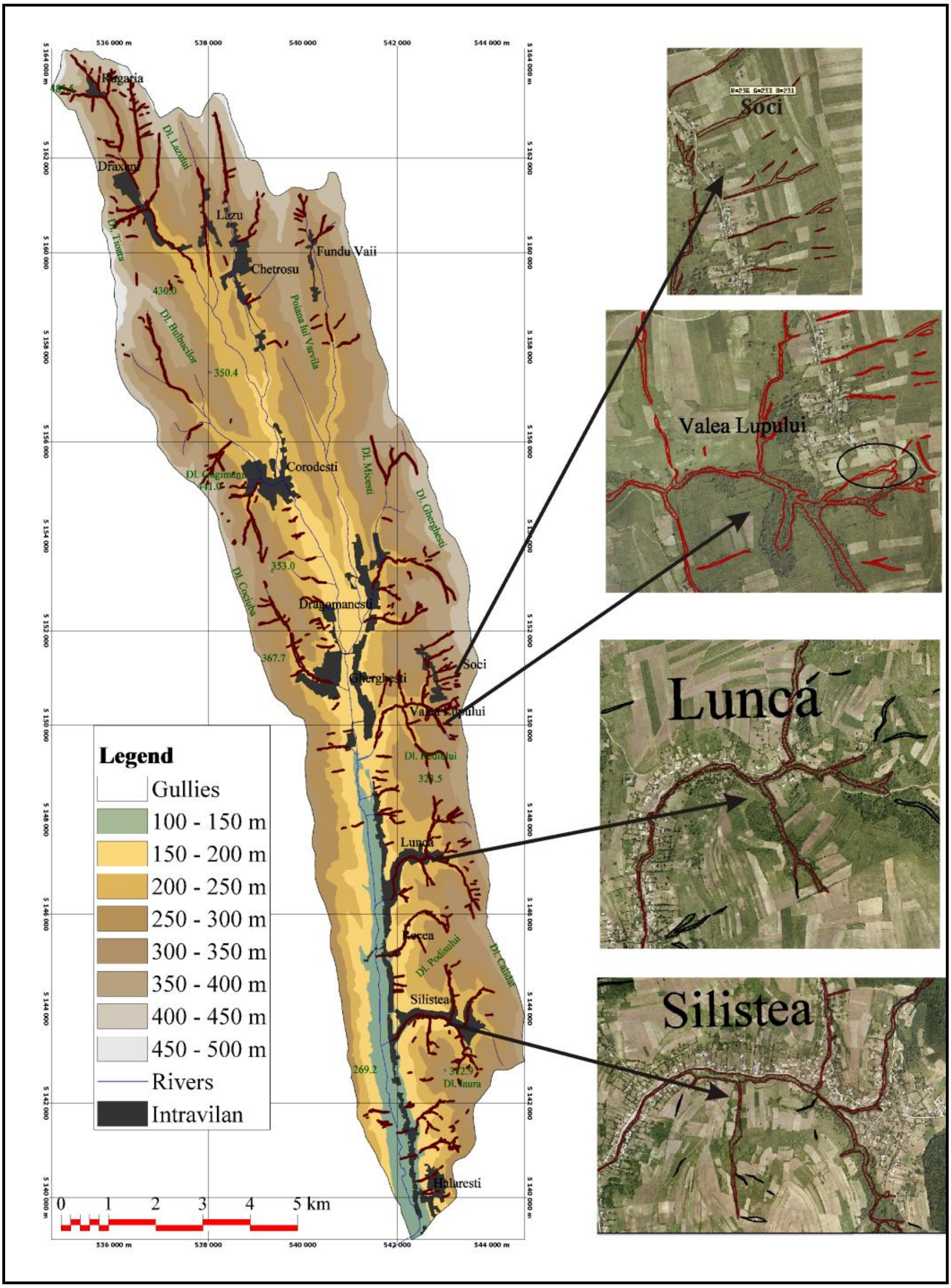

Fig 7 . Distribution of gullies in Studineț catchment

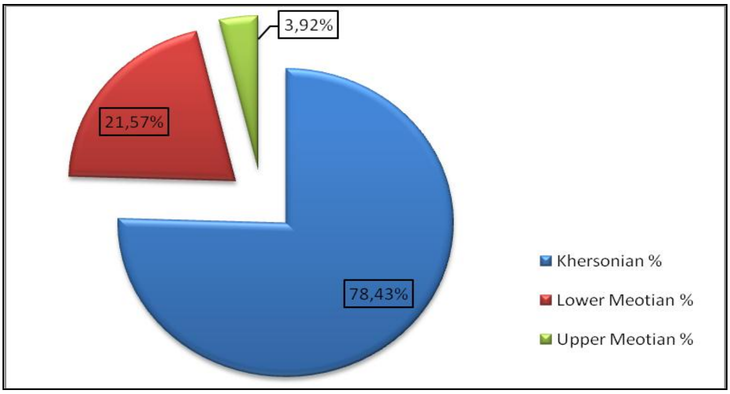

Fig 8 Weight of landslides on geologic deposits

The altitude is an indirect control factor for landslides through geomorphological parameters such as slope or fragmentation depth. Thus, the highest susceptibility for the development and evolution of landslides is between altitudes of 150-250 m, values that broadly correspond to slopes (fig. no 10). The analysis of the influence factor on slope classes shows that the triggering and evolution susceptibility of landslides has the highest value on slopes between 25 -35 ° (fig.no.10). This aspect, in order to be coherent it has been correlated with the reduced surface that these slopes classes have in the drainage basin's area (1.51%). For this reason the possibility of landslides extend to the entire area owned by these categories of slopes. The high susceptibility of triggering landslides is directly linked to the high fragmentation of the relief, the maximum frequency of these processes is between the 80-120 m vertical deviation (fig 9).

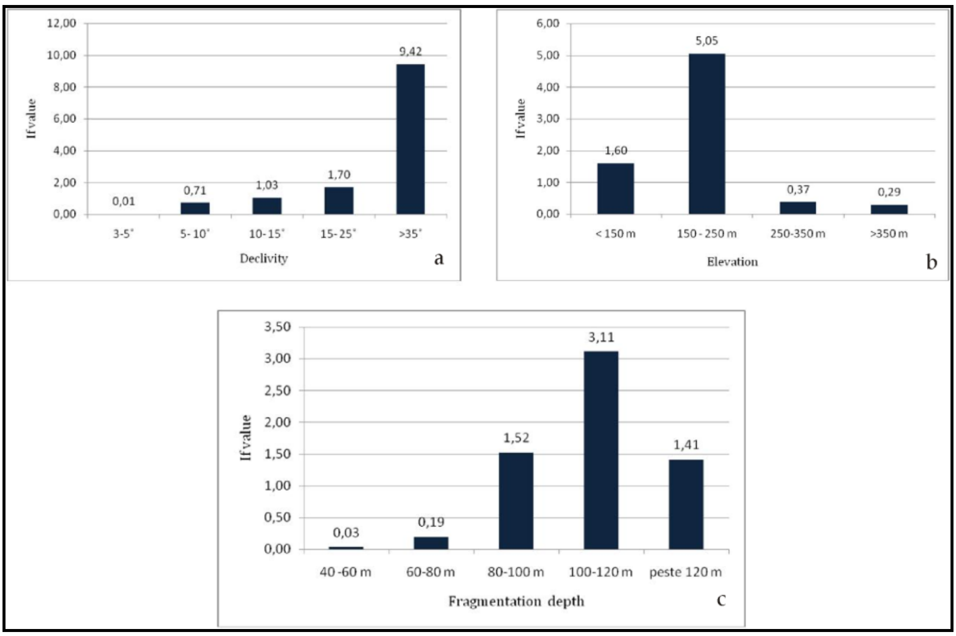

Fig. no. 9 Influence factor of elevation (a), declivity (b) and fragmentation depth (c)

Among the 51 landslides, 15 of them could be directly connected to gullying processes, being caused either by the process of undermining of gullies banks or by high erosion in the gullies peak. In this way, the permanent deepening of gullies emphasizes the probability of mobilizing deluvium.

Rainfalls play as well an important role in triggering or reactivating mass movements. The morphodynamic response of some deluvium in the Moldavian Plateau acts in two characteristic situations. Firstly, it could be caused by long-term rainfall that exceeded 50 mm in March, under the conditions of excess moisture and a lower consumption of water. The second situation is due to rainfall over 100 mm in July, due to a mild water deficit and a high consumption by evapotranspiration (Pujină, 1997).

Depending on the rainfall features in the warm half of the year (Pujină, 2003), geomorphologic activity of slopes was grouped into five significant classes. Thus, we can separate the years characterized by a morphodynamic calm as well as those with strong morphodynamic activity - in this case causing partial and general reactivation of landslides but average depth landslides as well (3-5m).

Table 1 The slope geomorphodynamic activity depending on warm semester rainfall at Plopana and Bârlad meteorological stations.

Class		**A_0**	**A_1**	**A_2**	**A_3**	**A_4**
$P_{i(IV-Ix)}/P_{med(IV-IX)}$		< 1,20	1,20-1,40	1,41-1,60	1,61-1,80	> 1,80
Category		Athmospheric calm	Low morphodynamic activity	Average morphodynamic activity	High morphodynamic activity	Severe morphodynamic activity
Frecv. %	Bârlad	85,1	8,5	4,3	2,1	0
	Plopana	79,5	10,3	5,1	2,6	2,5
	Average	82,3	9,4	4,7	2,35	2,5

Data source: National Meteorological Administration Bucharest

Analyzing these data, it appears that, in accordance with this criterion, most years are characterized by morphodynamic calm (82.3%) and only in 2.45% of cases a strong or severe morphodynamic activity was recorded (tab. no .1).

The decrease of forested areas resulted in a significant increase in the degree of terrain susceptibility to landslides, susceptibility that is facilitated by favorable lithology, long-term rainfall, inappropriate land use, as well as the specific morphometric characteristics of the research area. The Chetrosu landslide is the largest in Studineț catchment. Its surface has doubled in the last 25 years, but it is semi-stabilized at present (Hurjui, 2008).

Conclusions

In Studineț catchment, the scale and the frequency of geomorphic processes has been stimulated by natural and anthropogenic components, especially the inappropriate land use. Thus, human factor becomes a real simulator in the development of geomorphological processes. Land degradation in Studineț catchment is mainly a result of sheet erosion (with a generalized distribution), gully erosion and landslides.

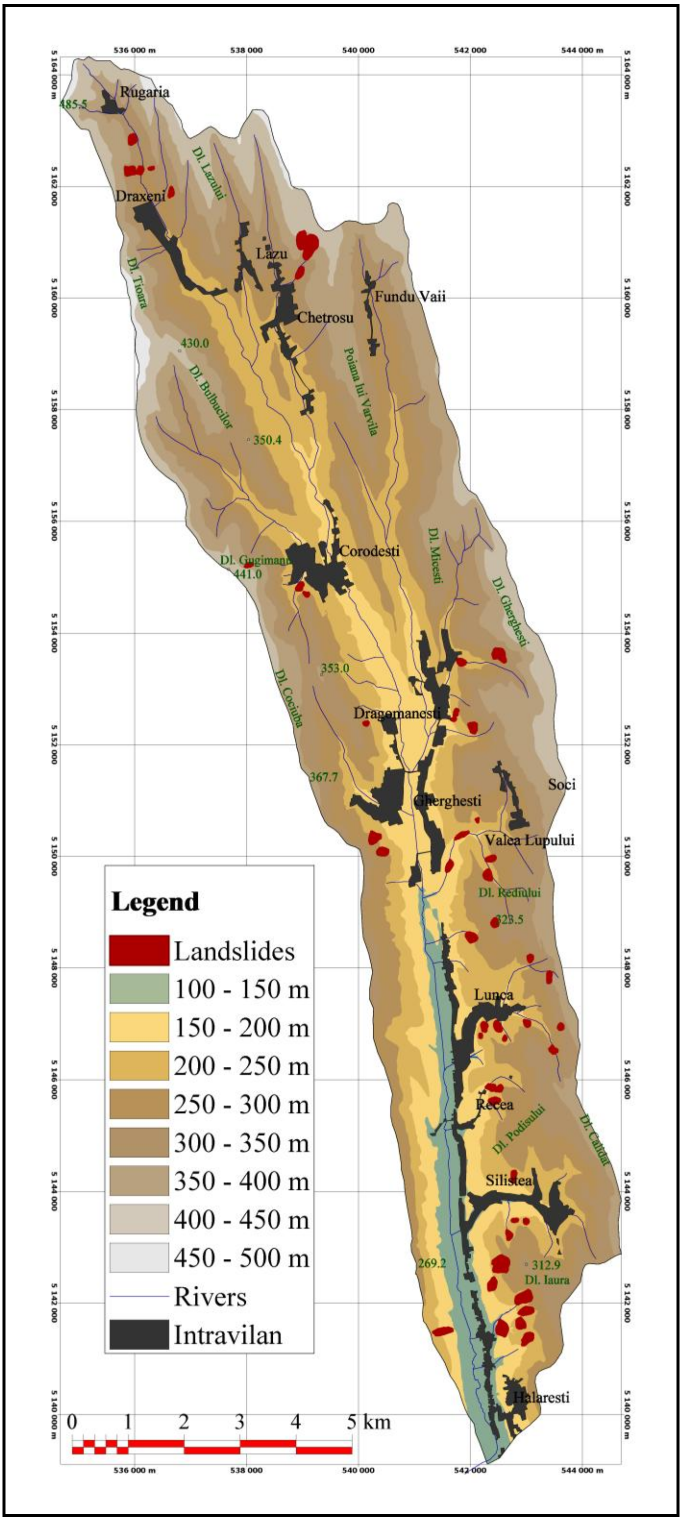

Fig. 10 Distribution of landslides in Studineț catchment

The gully erosion is the most characteristic geomorphological process of Studineț drainage basin, both by its surface and the resulted effect. The greatest gullies in the studied catchment have the appearance of valleys with a torrential character, which can be treated as first-rank valleys (the Horton-Strahler ranking system) Siliştea, Valea Lupului, Lunca etc. From the morphogenetic point of view, the maximum fragmentation depth that characterizes the cuesta fronts from the basin determines the appearance and the development of active torrential organisms. The development of landslides in the studied area is narrower, being favored especially by the sandy-clay substrate of Kersonian, which is intercrossed at the slopes' level.

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