Land degradation in the lower catchment of the Crasna river (Central Moldavian Plateau)

Petronela DARIE (CHELARU)[1], Ion IONITA[1]

Abstract. Land degradation has been recognized as an important environmental threat in the Moldavian Plateau of eastern Romania. The cumulated action of natural factors, especially the coupling of the Kersonian sandy-clayey facies and the hilly fragmentation as well as anthropogenic ones resulted in triggering degradation processes, especially soil erosion, gullying and landslides. In addition, another issue of interest is the reservoir sedimentation.

Land with slopes over 5% is subjected to soil erosion with different intensities and it represents the process with the highest extension. Landslides represent the most relevant geomorphological process, affecting particularly the cuesta fronts and amounting up to 34.6 % of the study area. Locally, where in the bedrock appear loose sandy and sandy-loamy layers, numerous valley-bottom gullies and valley-side gullies have developed, some with an impressive growth.

Even if through soil erosion, gullying and landslides are carrying significant quantities of solid material to the base of slopes, the average rate of sedimentation in reservoirs remains relatively low.

Keywords: landslides, soil erosion, gullying, sedimentation.

1. Introduction

Land degradation is defined as "*the total or partial removal of an area from the economic circuit through various geomorphic processes (soil erosion, landslides, sedimentation etc.)*" or as "*the gradual reduction in relief height through the destructive action carried out by external geomorphic agents*" (Băcăuanu et al., 1974).

Among land degradation processes, for the lower catchment of Crasna, of most interest, both in terms of damage and affected areas, are soil erosion, gully erosion, landslides and sedimentation. Since 1960, these processes have attracted the attention of many experts in agronomy, forestry, land improvement, soil science, geography, etc. As a result of the many deployed efforts by the end of 1980s, it was possible to implement different soil conservation practices on half of the land with degradation potential within the study area.

Since 1990, new Land Reforms have been implemented in Romania. The impact of implementing two major provisions of Act No. 18/1991 was very severe on soil conservation and crop yields. One of these stipulates that land re-appropriation has *to be usually applied on the old locations*. In most cases, this means that the layout of plots is orientated up-and-down slope. The second provision refers to '*successors*' rights up to the 4th degree of kinship. Consequently, the rate of land division has sharply increased and today there are over 46 million small individual plots. An added Act (No. 1/2000) focuses on forestland division for private ownership. The major effect of these Acts is the revival of traditional agricultural systems, especially the up-and-down hill farming. Another major problem over the recent decades is that the State ceased the funding of conservation practices and such an investment is not a high priority for landowners. However, the merging of some agricultural land through the establishment of free associations or by taking on leasing can be noticed over the last few years in the study area, and *there* contour farming can be performed again.

Located in the eastern part of Central Moldavian Plateau, the lower catchment of the Crasna river, upstream of the junction with the Lohan river, has 16 491 ha, which represents 31% of the total catchment (Fig. 1). From a territorial-administrative point of view, it is stretching entirely within the Vaslui County, partially overlapping the territories of the Albeşti, Boţeşti, Creţeşti, Munteni de Sus, Munteni de Jos, Olteneşti, Soleşti, Tanacu, Tătărăni villages and Vaslui municipalities.

Erosion revealed sedimentary loose, Kersonian, Meotian and Quaternary formations, namely clay, sand and weakly cemented cineritic sandstones.

Altitudes vary between 84 m at the junction with the Lohan river and 412 m in the northern part of the basin, in the Popeşti Hill. Slopes record average angles of 19.7%, the lowest characterizing the main floodplains and the highest ones the main cuesta fronts.

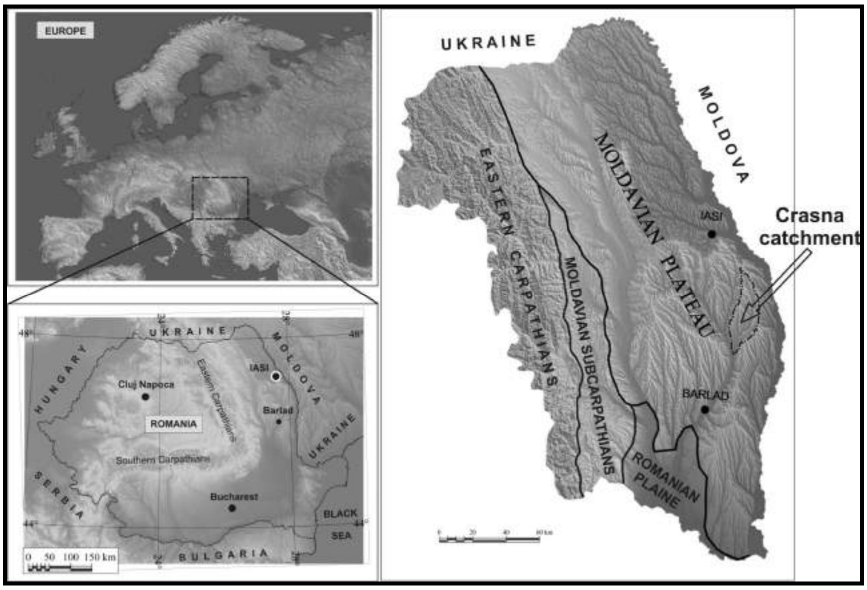

Fig. 1. **Location of the Crasna catchment in the Moldavian Plateau of eastern Romania**

All the specific landforms developed in a hilly-rolling/hilly region developed on a homocline have been identified in the Crasna catchment. The highest extension is represented by the sculptural relief (fluvio-denudational landforms) within a general homoclinal structure (80%), followed by depositional (17%) and structural-lithological landforms (3%).

Taking into account the ENE-WSW orientation of the lower Crasna valley, one of the most representative examples of cuesta landforms occur associated to its subsequent position. Thus, the left valley-side is a vast cuesta front (antidip slope) facing NNW, almost uniform, while the right valley-side exhibits a very broad cuesta backslope (dip slope) looking SSE and deeply incised by reconsequent tributaries. At their turn, the valleys of those tributaries display the structural asymmetry by second degree, where typical are a westward looking cuesta front on the left valley-side and an eastward facing cuesta backslope on the right valley-side (Fig. 2). Those two systems of cuestas are associated with the double dipping of the underlying strata to the south and to the east, and from their combination the general homocline structure is resulting (Ionita, 1998, 2000a).

The study area has a temperate continental climate with shades of excessivity, underlined by high values of thermic amplitude and by a frequency of heavy rainfalls. The average precipitation amounts to 534 mm yr^{-1} and the average annual temperature is 9.7° C at the Vaslui weather station over the period 1961-2008.

In terms of water discharge regime, flash floods triggered by snow-melt and overlapping with certain rains during late winter and early spring are distinguished. Floods induced by heavy rainfall during the warm season are more frequent in May and June, followed by shallow flows over autumn-winter.

The natural vegetation includes species belonging to the silvo-steppe and broadleaf forests but over large areas it was replaced by agricultural crops that fail to provide the same protection to the soil.

Fig. 2. **Cuesta landforms along the reconsequent Burghina Valley. Eastern looking cuesta backslope in the foreground and western looking cuesta front in the background** (October 1st 2011).

By processing information from the soil surveys deployed in the lower catchment of the Crasna, 7 soil classes and 11 soil types could be counted. Widespread surfaces, covering almost half of the area (7 742 ha), belong to the cernisol class. The increased weight of eroded anthrosols and regosols (26%) emphasizes the development and the intensity of the degradation processes.

The human impact is a first-order controlling factor in triggering recent land degradation processes, through deforestation, overgrazing, improper farming etc.

2. Materials and methods

In order to reach the proposed objectives, both traditional research methods (analysis, synthesis, mathematical-statistical processing, field observations and mapping) and modern methods based on the GIS softwares were used. The cartographic material was obtained by using TNTmips v.6.9 software and statistical processing was done using Microsoft Office Excel 2007.

A very important step in the spatial modelling of land degradation consisted in achieving the Digital Elevation Model by vectorizing contour lines on 1:5 000 scale topographic plans. Then, different thematic maps have been released for the complex analysis of land degradation processes, such as the hypsometric, slope angle and slope aspect maps. Also, the following data were of interest:

- The geological map of Central Moldavia between the Prut and the Siret rivers (Jeanrenaud, 1971);
- Climatic data from the Vaslui and Huşi weather stations;
- Hydrologic measurements recorded at the Mânjeşti hydrometric station;
- Soil surveys for the Albeşti, Boțeşti, Crețeşti, Munteni de Sus, Munteni de Jos, Olteneşti, Soleşti, Tanacu, Tătărăni villages and Vaslui municipalities, carried out by O.J.S.P.A. Vaslui since 1980.
- Corine Land Cover maps (2000) and aerial orthophotos from 2005 to identify some features of the geomorphological processes and highlight land use.

The map of soil erosion intensity was made by processing information obtained from soil surveys at a scale of 1:10 000. The distribution of gullies and landslides resulted from bringing together the data collected during field stages and the ones taken from the 2005 orthophotos and the 1:5 000 scale topographical plans.

In order to estimate the average sedimentation rate within reservoirs the Cs-137 technique has been used. The sediment samples were collected at intervals of 50 mm and then analysed at the Institute of Physics and Nuclear Engineering „Horia Hulubei" Măgurele – Bucharest.

3. Results obtained

3.1. Soil erosion

Among the degradation processes, the largest spatial extension is associated with water soil erosion affecting with different intensity the slopes with gradients above 5%. This results in the displacement of soil and/or rock particles by rainsplash and runoff as dispersed and concentrated flow (Moțoc, 1963; Moțoc et al., 1975).

The extent and the intensity of soil erosion are strongly connected to some favourable natural conditions (the prevalence of Kersonian loose sedimentary layers, the large extent of the steep slopes, heavy rainfalls, low density of vegetation, soils with light texture and low organic matter content etc.), as well as an inappropriate land use.

Figure 3 and Table 1 give the image of the spatial distribution and intensity of soil erosion on the agricultural lands of the lower Crasna river catchment.

Half of the 13 872.5 ha agricultural land is subjected to moderate to excessive soil erosion and that area raises great concern regarding the implementation of soil and water conservation practices at a larger scale than today. The highest intensity of soil erosion characterizes the cuesta front slopes and degraded backslopes, with angles over 25%, while non-appreciable erosion is specific to floodplains, hilltops, structural-lithological plateaus and slightly degraded backslopes (Fig. 4).

Table 1. **Soil erosion intensity on the agricultural land in the lower catchment of the Crasna River**

Soil erosion classes	Surface (ha)	Weight (%)
Excessive	608.3	3.7
Very severe	1 397.2	8.5
Severe	1 883.5	11.4
Moderate	1 196.6	7.3
Slight	2 733.3	16.6
Non-appreciable	5 706.2	34.7
Total	**13 525.1**	**82.1**

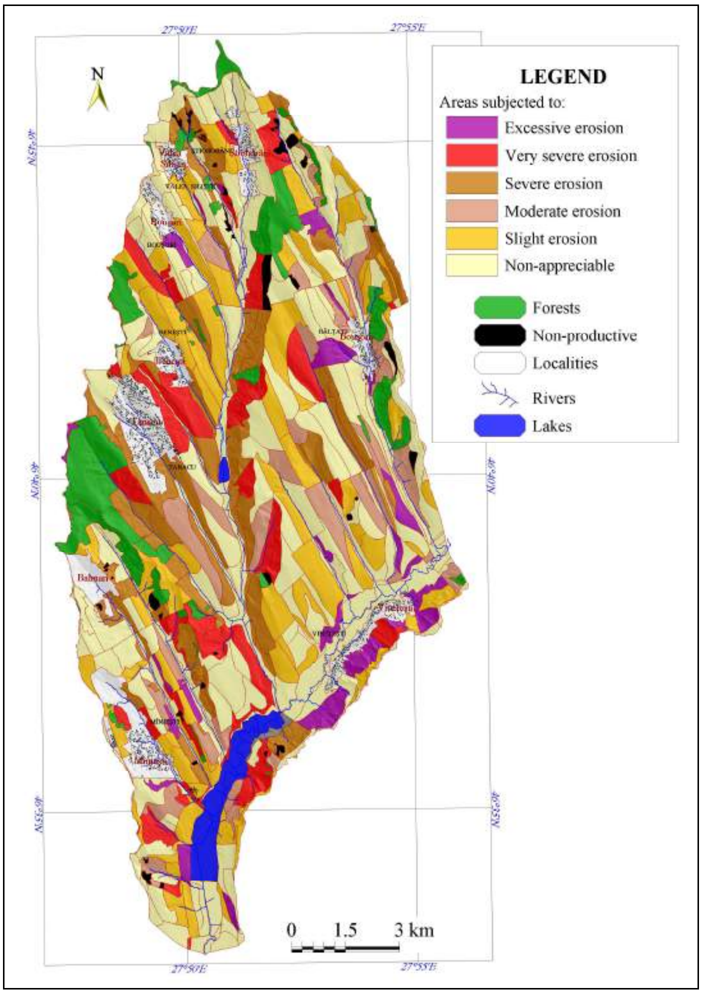

Fig. 3. **The soil erosion intensity on the agricultural land in the lower Crasna catchment**
(based on the processing of pedological surveys from O.J.S.P.A. Vaslui)

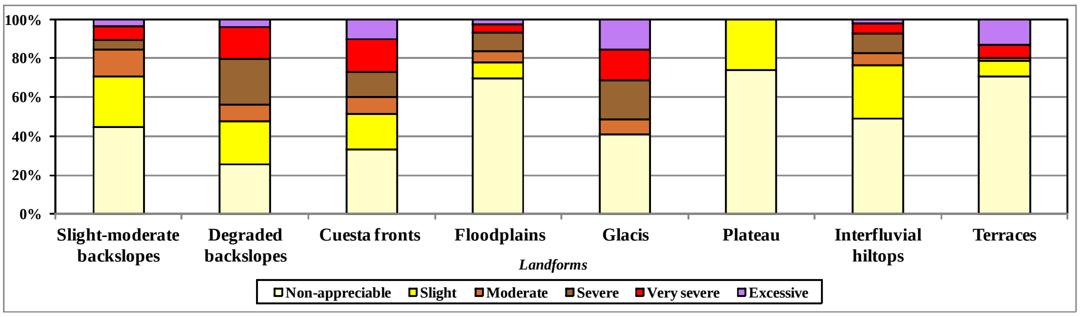

Fig. 4. **The weight of soil erosion intensity classes on agricultural land by landforms**

Soil erosion determines the changing of some physical, chemical and biological properties of soils, thereby reducing soil fertility and crop yields. The most affected soils by erosion are anthrosols, particularly the eroded ones and regosols, at the other end being aluviosols, solonchaks and gleiosols (Fig. 5).

The intensity of soil erosion is strongly related to the farming system, namely the traditional up-and-down farming or the contour farming. Of the total of 16 491 ha, agricultural land occupies 13 525 ha (82%), of which 9 072 hectares are arable land. The poorly farmed complex agricultural land, the poor pastures and the abandoned vineyards and orchards are also depicted by the high intensity of soil erosion (Fig. 6).

Data collected in the Tutova Rolling Hills over a 30-year period on the runoff plots located on slightly eroded cambic Chernozems, indicate the following (Ionita, 2000c, Ionita et al., 2006):

- Mean annual precipitation is 504.3 mm and precipitation which causes runoff and erosion occurs during the crop-growing months of May-October.

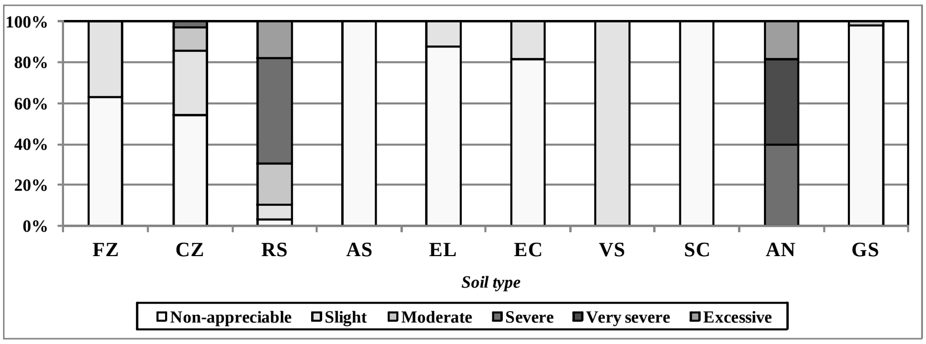

Fig. 5. **The weight of soil erosion intensity classes on agricultural land by soil types**

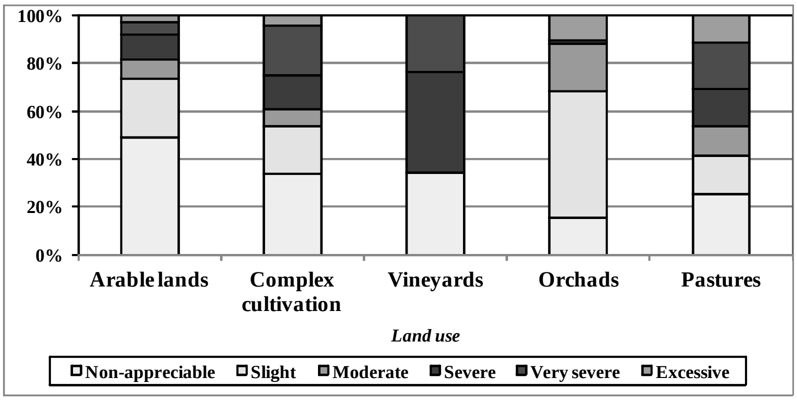

Fig. 6. **The weight of soil erosion intensity classes on agricultural land by land use**

- About 26% (133.5 mm) of annual precipitation induces runoff/erosion on continuous fallow and 18.5% (93.5 mm) on maize.
- Runoff ranges from 36.5 mm under continuous fallow with a peak of 12.0 mm during July, and 17.7 mm under maize with a peak of 6.5 mm during June.
- Mean soil loss is 33.1 t ha^{-1} yr^{-1} for continuous fallow with a peak of 12.8 t ha^{-1}during July, and 7.7 t ha^{-1} yr^{-1} for maize with a peak of 3.7 t ha^{-1} during June.
- The critical soil erosion season is the two months from late May to late July.

Soil losses have doubled on severely eroded forest soils due to their higher erodibility. Data collected from a continuous fallow plot and processed using a 3-year moving average revealed that over the period 1970-1999 there were three peaks. These are placed at 1975, 1988 and 1999 (Motoc et al., 1998; Ionita, 2000c).

3.2. Gully erosion

Gully erosion has a secondary role in the lower catchment of the Crasna, without reaching the magnitude noticed in other subunits of the Barlad Plateau, namely the Falciu Hills and the Tutova Rolling Hills.

By putting together field information with data retrieved from the orthophotos of 2005, 825 gullies were inventoried. These cover 150.4 ha representing 0.9 % of the total area (Fig. 7 and Table 2). Numerically, valley-side gullies prevail in the form of discontinuous gullies, which are either single (isolated) or successive (chain), and generally have small dimensions. Most of them developed due to runoff concentration along previous up-and-down hill roads. The valley-bottom gullies occupy a larger area, of 93.8 ha, and, unlike the first ones, they are more developed.

Table 2. **The area under gullies within the lower Crasna catchment**

Gully type	Number	Total area (ha)	Mean area of one gully (ha)	Weight	
				of the total gullied area (%)	of the total catchment (%)
Valley-side gullies	51	56.7	1.1	37.7	0.3
Valley-bottom gullies	774	93.8	0.1	62.3	0.6
Total	**825**	**150.4**	**0.2**	**100.0**	**0.9**

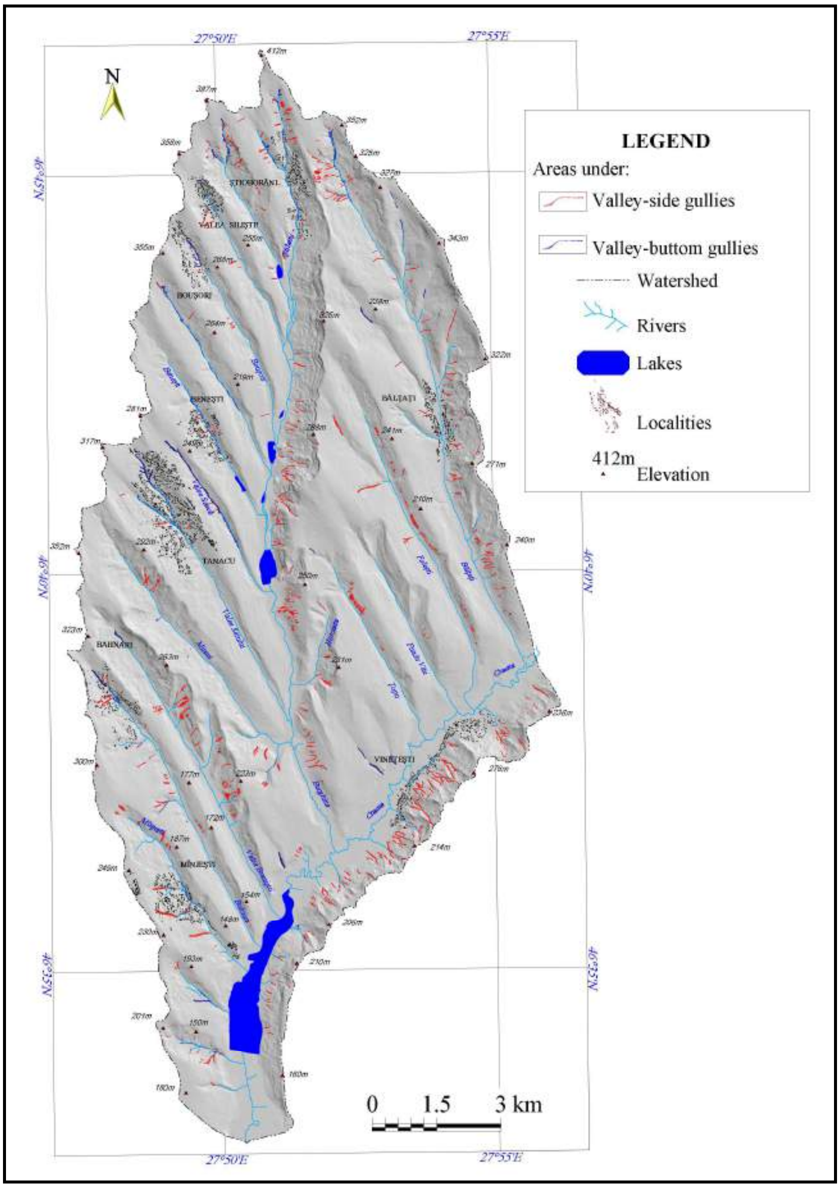

Fig. 7. **Distribution of gullies within the lower Crasna catchment**

The most significant areas affected by gullying are found on the cuesta fronts and on the highly degraded backslopes, while on hilltops, structural-lithological plateaus and terraces, gullies are very poorly represented (Fig. 8).

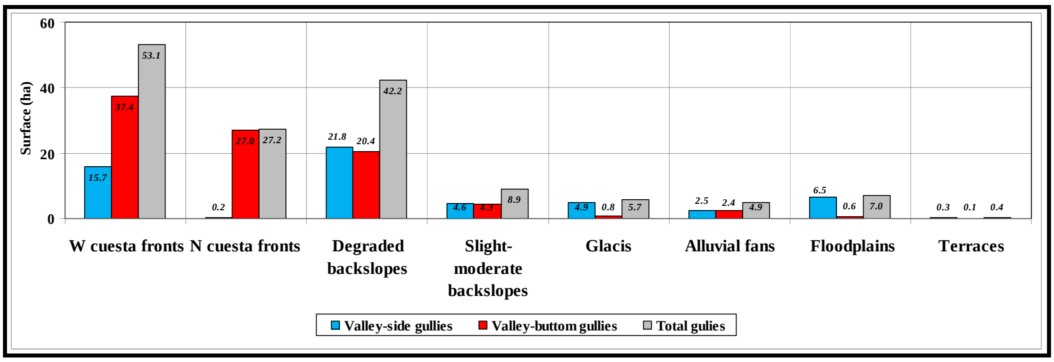

Fig. 8. **The histogram of surfaces under gullying for each landform**

Gullying is a serious problem of contemporary society causing significant damage to agriculture and to socio-economical objectives. For this reason, by 1990 a lot of land reclamation works have been deployed in the area, especially concrete dam structures which are currently in an advanced degradation stage and the setting of false acacia plantations.

As to gully development in the Barlad Plateau, the long term findings obtained by Ionita (1998, 2000b, 2007) and Ionita et al., (2006) are as follows:

- Gully erosion rates have decreased since 1960, but still remain at high levels.
- The mean annual regime of gullying over the period 1981-1996 exhibited pulsatory activity.
- During this 16-year monitoring period, 57% of total gullying occurred during the cold season (late winter), with the remainder occurring during the warm season.
- The critical period for gullying is during the four months between 15-20 March and 15-20 July.

3.3. Landslides

Landslides are the most representative degradation process, holding a critical role in land morphogenesis in the lower catchment of the Crasna river. The considerable development and the extent of landslides in the study area are the result of several factors. The category of potential factors includes the alternation of permeable and impermeable layers and the pre-existing landscape characteristics (slope, relief amplitude). Among the preparatory factors rainfall distribution and deforestation are to be mentioned. Important triggering factors are groundwater fluctuation, freeze-thaw cycles, slope angle changes by undercutting, some earthquakes, overloading of slopes with constructions, etc.

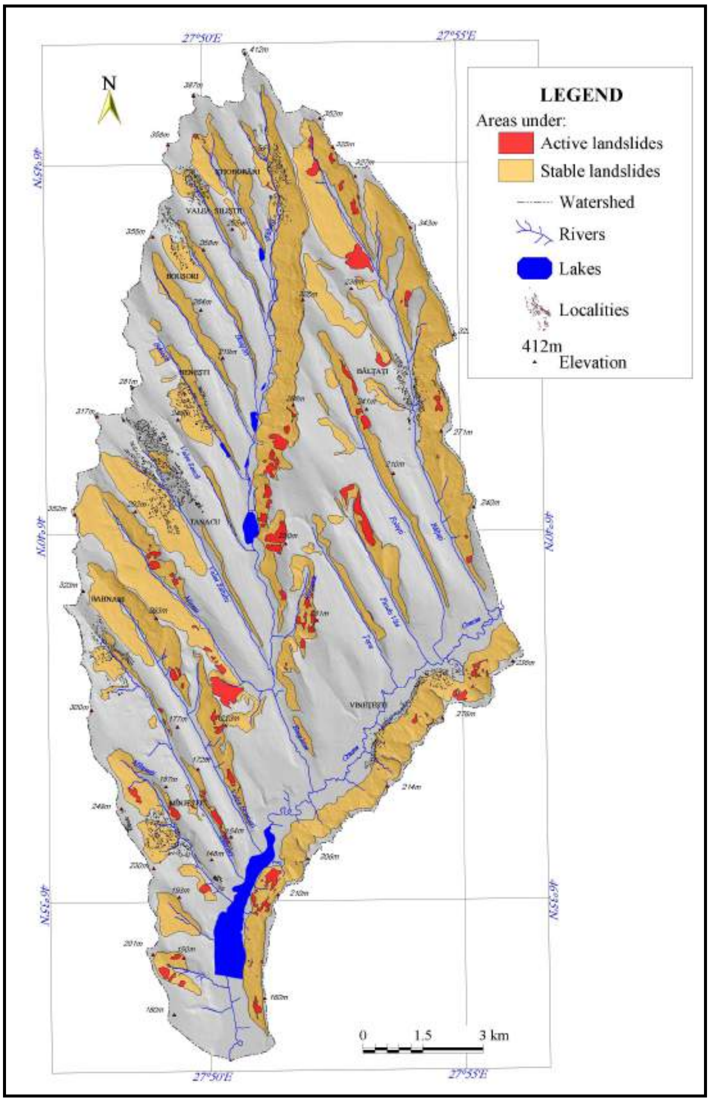

Fig. 9. **Distribution of landslides within the lower Crasna catchment**

Table 3. **The surfaces under landslides in the lower Crasna catchment**

Landslide type	Total area (ha)	Average weight (%)	
		of the total catchment area	of the area under landslides
Active	980.9	5.9	17.2
Stable	4 720.8	28.6	82.8
Total	**5 701.7**	**34.6**	**100.0**

Figure 9 and Table 3 show the distribution of landslides within the lower Crasna catchment, where these are extending on 5 701.7 ha representing 34.6% of the total area. Most of the landslides are stabilized, while those active occupy small areas, and have developed by reactivation of the old ones. The recent peak of landslides' reactivation was triggered by the higher amount of precipitation occurred over the 1968-1973 period.

The most sensitive slopes to landslides are found where the elevation varies between 150-250 m, and the slope angle is above 25% (Fig. 10). By far, the northern and western looking cuesta fronts are subjected to moderate to deep-seated landslides covering about 4 165.5 ha (73% of the total area under landslides); the most affected are the Crasna, Burghina and Bălțați cuesta fronts (Fig. 11). They also develop on highly degraded backslopes.

Morphologically, many landslides in the study area are mixed, usually as step-like and waves-like landslides but the most typical are landslide amphitheatres, locally called *hartop* (Fig. 12).

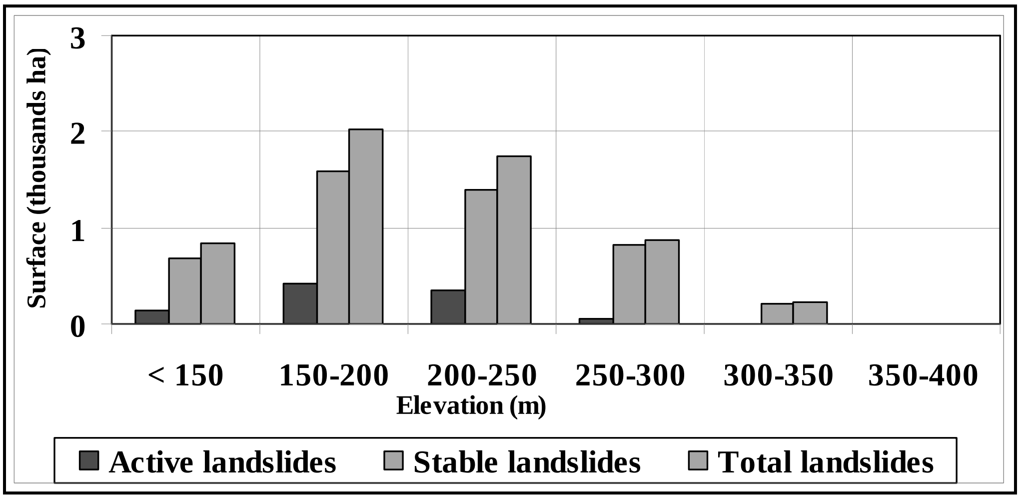

Fig. 10. **The histogram of areas under landslides by elevation classes**

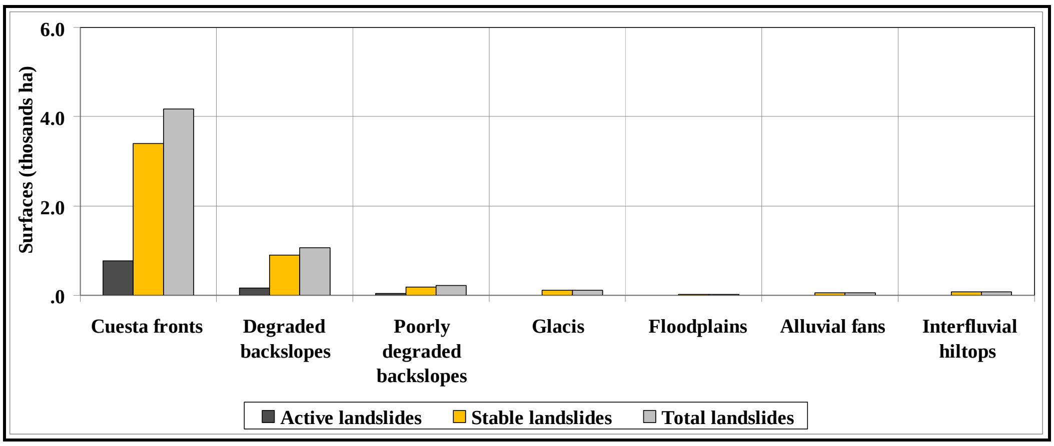

Fig. 11. **The histogram of surfaces affected by landslides for each landform**

Fig. 12. **Simple landslide *hartop*** (amphitheatre) **on the left valley-side of the Crasna at SSW of Vinetesti. In the background the Lohan Valley appears** (October 3rd 2013).

3.4. Sedimentation

From the soil detached through water erosion, gullying and landslides, small amounts either leave the catchment or are partly deposited on slopes, while another part reaches the floodplains, causing their aggradation and reservoir siltation.

By taking advantage of the Cs-137 technique as a tracer, it was possible to date the particular sediment levels associated to the Cernobil nuclear accident from April 26, 1986 or to the peak of the nuclear bomb testing in 1963. Then the rates of deposition for different periods of time were accurately calculated.

The Cs-137 depth profile in the Ţopu reservoir, built in a small catchment of 1.192 ha associated to a right tributary of the Crasna river, shows us an average sedimentation rate of 1.7 cm yr^{-1} between 1963-2011 (48 years). However, the average rate of sedimentation of 2.4 cm/year over the period 1963-1986 was double if compared with one of the 1986-2011 period (Fig. 13). The relatively high value of the sedimentation rate before 1986 resulted from the higher amount of precipitation between 1968 and 1973. Then, the sedimentation rate started to decrease due to the influence of implementing soil erosion control practices (Ionita et al., 2000 and 2007).

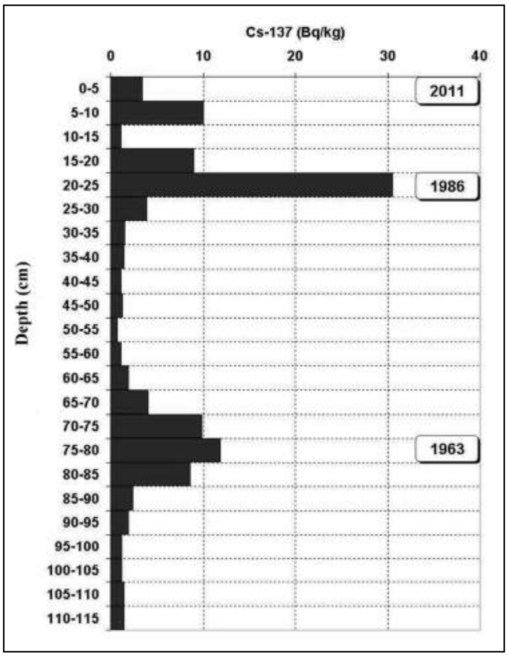

Fig. 13. **Distribution of the Cs-137 in the Ţopu reservoir** (October 2th 2011)

4. Conclusions

1. The main controlling factors, natural and human, have induced significant land degradation within the hilly area of the Crasna catchment.

2. The change of the natural vegetation cover and improper farming decisively contributed to a high risk of soil erosion in more than half of the agricultural land.

3. Landslides represent the most typical degradation process and cover 5 702 ha representing 35% of the total area.

4. The recent reservoir sedimentation rate exhibits low-moderate values.

Acknowledgements

This work was supported by a grant of the Romanian National Authority for Scientific Research, CNDI– UEFISCDI, project number PN-II-PT-PCCA-2011-3.2-0975.

REFERENCES

BĂCĂUANU V., DONISĂ I., HÂRJOABĂ I., (1974), *Dicţionar geomorfologic, cu termeni corespondenţi în limbile franceză, germană, engleza şi rusă,* Edit. Ştiinţifică, Bucureşti.

IONIŢĂ I., (1998), *Studiul geomorfologic al degradărilor de teren din bazinul mijlociu al Bârladului*, Manuscript PhD thesis, "Al. I. Cuza" University, Iaşi.

IONITA I., (2000a), *Relieful de cueste din Podişul Moldovei*, Edit. Corson, Iaşi, 108 p.

IONITA I., (2000b), *Formarea şi evoluţia ravenelor din Podişul Bârladului*, Edit. Corson, Iaşi.

IONITA I., (2000c), *Geomorfologie aplicată. Procese de degradare a regiunilor deluroase*, Edit. Universităţii "Al.I.Cuza," Iaşi.

IONITA I., (2007), *Sezonul critic de eroziune în Podişul Bârladului*, Workshopul "Impactul riscurilor hidro-climatice şi pedo-geomorfologice asupra mediului în bazinul Bârladului", Special Issue, Edit. Univ. "Al. I. Cuza" Iaşi, ISBN 978- 973-703-294-2.

IONITA I., MARGINEANU R., HURJUI C., (2000), “Assessment of reservoir sedimentation rates from 137-Cs measurements in the Moldavian Plateau”. Acta Geologica Hispanica, Queralt I., Zapata F., Garcia A. (eds.) Special Issue *Assessment of Soil Erosion and Sedimentation through the Use of 137-Cs and Related Techniques*,” **35(3-4)**, Barcelona, Spain: 357-367

IONITA I., RĂDOANE M., MIRCEA S., (2006), “Ch. 1.15 Romania”, in Boardman J., Poesen J. (eds) *Soil Erosion in Europe*, John Wiley, ISBN: 978-0-470-85910-0, Chichester, UK: 155-166.

IONITA I., MĂRGINEANU R., (2007), „Consideraţii privind ritmul de sedimentare în acumulările din Podişul Bârladului”, Workshopul *Impactul riscurilor hidro-climatice şi pedo-geomorfologice asupra mediului în bazinul Bârladului*”, Special Issue, Edit. Univ. “Al. I. Cuza” Iaşi, ISBN 978-973-703-294-2.

JEANRENAUD P., (1971), „Harta geologică a Moldovei centrale dintre Siret şi Prut”, *ASUCI-Geol.*, **XVII**, Iași.

MOȚOC M., (1963), *Eroziunea solului pe terenurile agricole şi combaterea ei*, Edit. Agro-silvică, București.

MOȚOC M ., MUNTEANU S., BĂLOIU V., STĂNESCU P., MIHAI GH., (1975), *Eroziunea solului şi metodele de combatere*, Edit. Ceres , București.

MOȚOC M., IONIȚĂ I., NISTOR D., (1998), “Erosion and climatic risk at the wheat and maize crops in the Moldavian Plateau”, *Romanian Journal of Hydrology & Water Resources*, **5(1-2)**, NIMH, Bucharest.

***, (1980-2011), *Soil surveys for Albeşti, Boțeşti, Crețeşti, Munteni de Sus, Munteni de Jos, Olteneşti, Soleşti, Tanacu, Tătărăni and Vaslui municipality*, O.J.S.P.A. Vaslui.

***, (1977), *Topographic plans in scale 1:5 000*, Edit. by Institute of Geodesy, Cartography and Territorial Organisation, O.C.P.I. Vaslui.

[1]**„Al. I. Cuza” University of Iaşi, Faculty of Geography and Geology**
petronela_darie@yahoo.com