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THE ASSESSMENT OF GEOMORPHOLOGICAL CHARACTERISTICS AND THEIR INFLUENCE OVER LAND DEGRADATION PROCESSES WITHIN VALEA NEAGRĂ CATCHMENT AREA

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Abstract: The paper analysis geomorphological conditions in the drainage basin of Valea Neagră river, upstream Dulcești locality, and also the influence of the landforms over the development of main degradation processes: soil erosion, linear erosion and landslides. The area lies on the western edge of the Moldavian Plateau, where the unit confines the Moldavian Subcarpathians. The characteristic landform is the hilly relief, with altitudes ranging between 219 m and 505 m. Geologically, the monoclinic structure of the deposits determined the evolution of cuesta landform that emphasizes the double asymmetrical structure. The relief inversions occured in the territory are the result of a long paleogeomorphologic evolution. In the studied section, the Valea Neagră river valley has a subsequent direction, except from the river section, upstream Hârtop village, where the valley is consequent. Results indicate that unappreciable soil erosion characterizes 73% of the entire area, while the landslides occupy 22% of the territory, being often accompanied by linear erosion forms.

Keywords: *Piedmont Plateau, monoclinic structure, asymmetrical valleys, erosion remnants, soil erosion, landslides*

I. INTRODUCTION

Valea Neagră stream is a right tributary of Siret river, with a channel length around 60 km. The study region encompasses the Valea Neagră catchment, upstream of Dulcești village, Neamț county, and covers an area of 14.165 ha (figure no. 1). The region is located on the western edge of the Moldavian Plateau, partially overlapping Piedmont Plateau and Bozieni Plateau, according to Ungureanu Al. (1993).

The geological stratum is represented by sedimentary rocks, namely clayey-sandy layers of the Bessarabian age (Middle Sarmatian) and on a small area, in the south-western part of the basin, develop the Kersonian (Upper Sarmatian) sandy-clayey layers. These lithological deposits are arranged in a monoclinic structure registering a slight gradient of 7-8 m/km NNW-SSE (Ioniță, 2000a) and are locally covered by Quaternary recent formations. The tectonic relation between the studied area and the Orogen shows that on the west boundary of Valea Neagră catchment, where is the pericarpathian fault, the Superior Bessarabian deposits cover transgressively the folded strata of the subcarpathian Miocene (Saraiman, 1993).

From a geomorphological point of view, the entire area is an asymmetrical valley which emphasizes the first order structural asymmetry, where the left valley-side is a back-slope facing south and the right one is a cuesta front oriented towards north (Băcăuanu and Martiniuc, 1970).

Based on Strahler classification of a river system, Valea Neagră, in the studied section, is a fifth order river network. The long-term evolution of this catchment area is the result of the monoclinic structure, together with the contribution of fluvio-denudational factors and the lithological strata. The highest altitude registers 505 m in Plaiu Stâncii Hill, on the western boundary of the studied area. Close to this point, the geological layers are lifted 65° according to Macarovici (1964). From this area, the altitudes continue to decline progressively eastward to 219 m, in the Valea Neagră floodplain, at Dulcești.

The climate is temperate continental, characterized by a mean annual temperature of 8.4°C and a mean annual precipitation of about 540 mm (Apostol, 2004). Among the most common soil types are the luvosols (forest soils), secondary spatial extent belonging to the phaeozems.

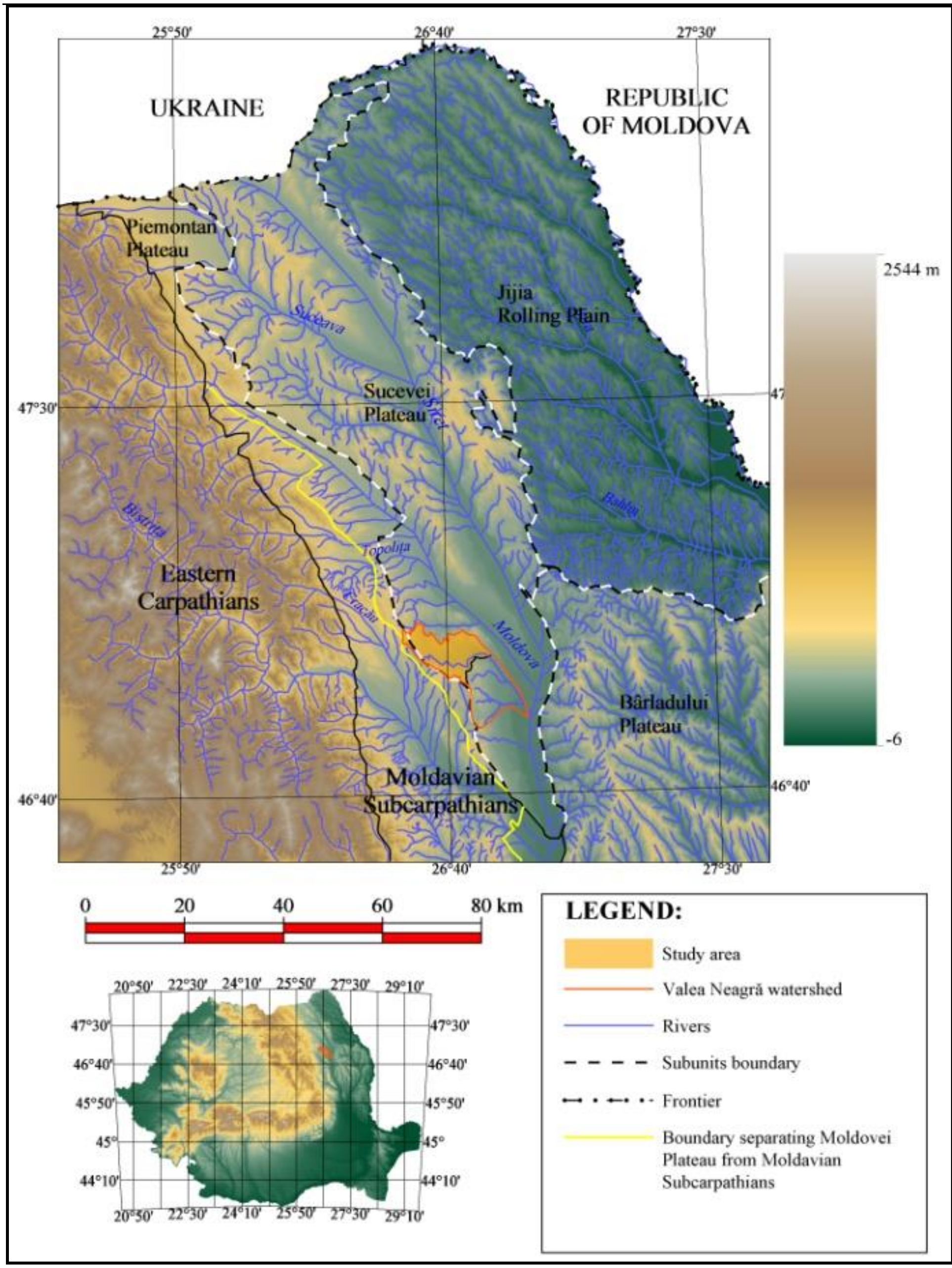

Fig. 1 Geographical position of Valea Neagră upper catchment area

II. MATERIALS AND METHODS

Nowadays, the development of modern GIS techniques has a major influence over the analysis and elaboration of spatial data, hence for obtaining the thematic geographical maps (geological map, geomorphological map, soils distribution map, soil erosion map, landslides distribution map) we used TNT Mips 6.9 software. Based on this program we processed the cartographic materials. For the statistical database we used Microsoft Office Excel 2007. This database contains information about the mean annual temperature, the mean annual precipitations, the surfaces occupied by each soil type, by the landslides, by each type of landform.

The main steps in acquiring the thematic maps were: the georeferencing of the topographic maps, in 1:5000 scale, using the method of corner coordinates and the contour lines vectorization, which are necessary in interpolation of the Digital Elevation Model (DEM). The DEM, which was obtained through Surface Modelling command, was largely utilized for the identification of landslides perimeters. The maps' projection was set to Stereo 70 and the resolution of maps to 5/5 m.

Other important data used for the assessment of the geomorphological conditions:

•Geological map, 1:200.000 scale, number 13, Piatra Neamț, L-35-IX (Romanian Geological Institute, 1968); this material was used in obtaining the geological map for the study area.

•Topographic plans, 1:5000 scale, National Agency for Cadastre and Land Registration – N.A.C.L.R. Neamț county, 1980;

•Climate data from Piatra Neamț and Roman meteorological stations, covering the period 1899 – 2002 for the mean annual temperature at Piatra Neamț and 1896 – 1985 for the same parameter at Roman. Concerning the mean annual precipitations, we used data only from Piatra Neamț station, between 1896 - 1996 (Apostol L., 2004);

•Pedological studies for Ștefan cel Mare (1983), Bârgăuani (1983), Făurei (1983), Dulcești (1999), Ruginoasa (1999) and Dragomirești (1999) communes, in 1:10.000 scale (Pedology and Agrochemistry County Offices – P.A.C.O. Neamț county). Considering that these pedological studies have been drawn before year 2000, we had to correlate the soils names from Romanian System of Soils Classification (R.S.S.C.), 1980, with Romanian System of Soils Taxonomy (R.S.S.T.), 2012 edition, and after that with WRB-SR 1998 (Munteanu and Florea, 2012). The data contained by the pedological studies were used to acquire the soil erosion map.

•Aerial ortophotos from 2007 (N.A.C.L.R. Neamț county), with a 0.5/0.5 m resolution, to identify land degradation processes, such as gullies and landslides.

Based on the data mentioned above we obtained a series of layers in TNT Mips 6.9, each of one corresponding to a thematic map. Many of these layers are vectors but some have been converted to raster, in order to show the relations between geomorphological conditions and land degradation processes. For this step we largely used the GeoTool Box command in TNT Mips 6.9.

Amongst the classic methods, specific to geographical researches, we largely used the analysis, the synthesis, the comparison method, the mathematical-statistical method, mapping method and, of course, the compulsory phase of field surveys.

III. RESULTS AND DISCUSSIONS

III.1. Geological factor

The drainage area of Valea Neagră river represents a subsequent valley, a type frequently developed on the western edge of Moldavian Plateau, its geomorphological evolution being linked with Siret valley evolution, which flows from north to south.

Geologically, the sedimentary strata of the study area belong to the Bessarabian and Kersonian age (Middle and Upper Sarmatian), plus the recent deposits of quaternary age towards east and north. The Bessarabian geological layers have the largest extent (93,4%), the Kersonian occupies small areas in the SSW part of the territory and the Pleistocene deposits appear discontinuously (figure no. 2). According to the geological map, L-35-IX, there are no Holocene or loess deposits across the studied area.

The Văleni Sands, reported by Macarovici (1964), are considered an intermediary depositional level between Middle and Upper Sarmatian and have been identified on the hilltops of the Valea Neagră left slope. Litologically, this sub-stage is consisted of sandy-shales layers, above which we find fossiliferous sands with fine sandstones intercalations. Specific investigations deployed by Ionesi and Ciobanu (1978) and Saraiman (1976) demonstrate that in Stan's Hill (350 m) outcrops, eastwards of Budești village, the macro- and microfauna belong to the Upper Bessarabian age. In 2009, Țabără, Chirilă and Paraschiv, based on the paleovegetation identified in the same outcrop, assign the deposits to the same age.

On the south-western boundary, the Kersonian outcrops in some small perimeters (87 ha) where the layers have a relative high content of sands, associated with interbedding of sandstones and gravel/pebble (Martiniuc,1948). The sedimentation during the Kersonian occured in a brackish water environment according to Ionesi (1988).

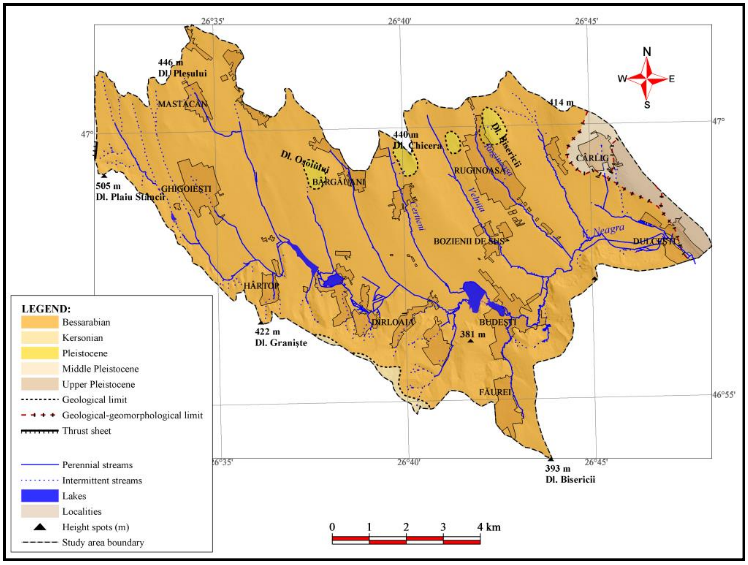

Fig. 2 Geological map within Valea Neagră catchment area, upstream Dulcești
(Source: Romania Geological Institute, 1:200.000 scale)

The sedimentary cover is represented by clays, sands, interbedded with sandstone and limestone strata. Ionesi (1988) states that these deposits are arranged in a cross-bedding structure, characteristic for fluvial-deltaic sediments (figure no. 3).

Fig. 3 Cross-bedding structure of Bessarabian sandy-layers. Detail from an outcrop within Budești valley, right tributary of Valea Neagră

III.2. Genetic relief types and the main landforms

Geological conditions, the morphographic and morphometric characteristics determined the classification of landforms using three main relief types: structural, sculptural and depositional (figure no. 4).

Structural relief is represented in our area by the valley types, developed as a result of monoclinic structure. The structural plateaus, once still extended in territory, had been destroyed by denudational processes (Lupașcu, 1996). Moreover, after frequent field trips we have not identified these landforms in the study area.

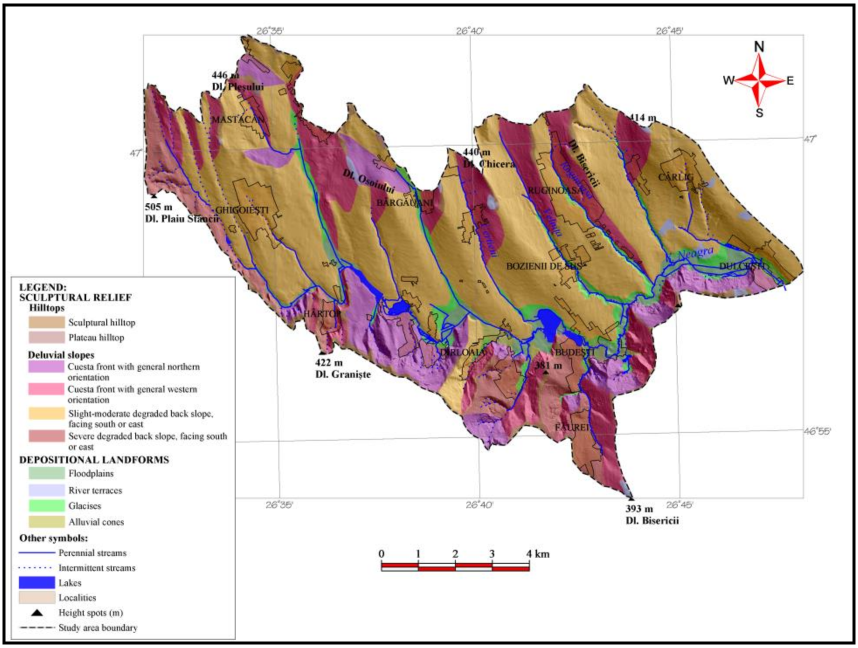

Fig. 4 Geomorphologic map within Valea Neagră catchment, upstream Dulcești

The main types of valleys influenced by the monoclinic structure are: subsequent, obsequent and reconsequent valleys. These categories had been established based on the rapport between the river flow direction and the dipping of the geological strata, outcropped due to erosion. Although the Valea Neagră river valley, upstream of Dulcești, is a subsequent valley, the section between villages of Hârtop and Deleni, has a NNW-SSE orientation, therefore in this section the valley is consequent. Downstream of Hârtop the direction of the river alternates from typical subsequent to a few subsequent sectors and also obsequent sections.

The right hillside of Valea Neagră (upstream of Hârtop), a cuesta back slope oriented towards east, has a low mean relief energy, namely 50 m, and registers an atypical percentage of 38% from the total catchment area corresponding the consequent sector. David (1932) states that where in the present-day flows Valea Neagră, in the paleogeographic past of the region, was the course of the Cracău river. The evolution of Bistrița valley and its lower base level led to the development of some left tributaries, with faster regressive evolution, that determined the beheading of Cracău course. As a result, Valea Neagră stream has continued to flow on the same direction but, upstream of Hârtop village, in its effort of taking the most efficient route, the valley followed the orientation of the geological layers, becoming consequent.

From Dulcești to Deleni, the Valea Neagră valley has a length of about 32 km. The left hillside represents a cuesta back slope, generally oriented towards south, and occupies an area of 10.142 ha (71.6% of the study area). The right one constitutes a cuesta front, generally facing north, with an extent of 4023 ha (28.4%) (figure no. 5).

The tributaries of the Valea Neagră are either reconsequent, generally the left tributaries (Brițcani stream, Velnița, Certieni, Bahna Mare, Bahna Râmnicului, Ruginoasa, Siliștea), either obsequent, being developed on the cuesta front of the main river (Budești stream, Vlădiceni stream).

As we mentioned before, the cuesta back slope has a large extent that enabled the development of a reconsequent hydrographic network with considerable length, namely a mean value of about 5.4 km. The transversal topographic profile of these valleys is generally asymmetrical and the relief energy of the hillsides decreases as the streams approach the confluence with Valea Neagră. On the other side, the obsequent tributaries have shorter lengths, amounting an average value of 2.3 km.

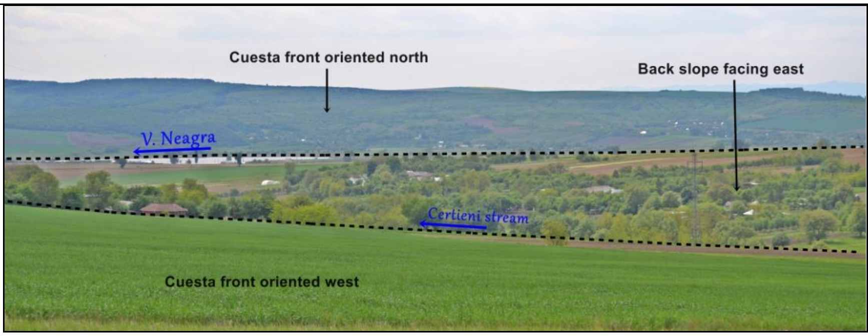

Fig. 5 Cuesta front of Valea Neagră, generally oriented northward, in the background, and cuesta front and back slope of reconsequent tributary Certieni stream, in the foreground

Across Moldavian Platform the rarity of symmetrical valleys is clarified by Ioniță (2000a) who affirms that the double stratigraphic slope, first one N-S, of 6 to 7 m/km, and the second one W-E, of 3 m/km, plays a major role in the evolution of transversal profile.

The largest part of the study territory belongs to the erosional landform (89.5%) comprising an area of 12672.6 ha and a variety of landforms such as: hilltops, plateau-hilltops, cuesta fronts generally oriented towards north or west and back slopes, facing south or east. According to their land degradation condition, the back slopes, both south and east oriented, have been divided in two categories: slight-moderate degraded back slopes and high degraded back slopes. This classification has been evaluated based on the maps of soil erosion intensity, of gullies and landslides distribution. The main cuesta backslope has a mean length of 3 km and comprises mainly slopes that register a low land degradation condition. This is also the case of the reconsequent valleys. On the other side, obsequent valleys encompass hillsides which are in an advanced state of degradation.

The hilltops aspect that confine the Valea Neagră upper watershed is mainly elongated but sinuous, due to the regresive evolution of streams. These landforms encompass oblong, flattened hilltops, accompanied by plateau-hilltops, saddles and feature erosion remnants („piedmont caps”), remainders of the former Sarmatic Piedmont (figure no. 6). In terms of altitude, the left drainage divide has a mean altitude of 371 m, while the right drainage divide is higher and registers 391 m.

Fig. 6 Chicera Hill (440 m), in the background, which represents a sarmatic erosion remnant and a river terrace level of Valea Neagră

In the local morphology, deluvial slopes bring the dominant mark being closely related to cuestas relief and as a result, these landforms play the role of cuesta fronts or back slopes. Ioniță (2000a) distinguishes two types of structural asymmetry, that are the consequence of rivers evolution in a „double system of stratigraphic slopes". The first-order structural asymmetry corresponds to the main leaning of the lithological strata, north-south, including all the subsequent valleys, and determines the shaping of cuesta fronts with northern, north-western or north-eastern aspect and back slopes that generally face south. For the west-est dipping of the geological layers, we have the second-order structural asymmetry, highlighted by the reconsequent and obsequent valleys. These valleys comprise cuesta fronts oriented generally towards west and back slopes with eastern exposure.

Another type of landform developed within the catchment of Valea Neagră river is the depositional landform, which includes: floodplains, river terraces, alluvial fans, glacis.

The floodplains cover an area of 743.6 ha (5.2%) and the largest extension belongs to the main river plain, which in some sections reaches almost 1 km width. The floodplain is often asymmetrical with dominant development on one side but there are sections where it occupies both sides of the river. Noticeable enlargements of the main valley floodplain occur in the junction areas.

Left tributaries have also shaped over time floodplains, but of smaller widths. In this case, a low longitudinal slope of the channel favoured the formation of the floodplain. On the contrary, for the obsequent tributaries, the areas occupied by river plains are reduced, mainly because the river rapidly cut deeper and formed a narrow V-shaped valley.

Regarding the river terraces, which mark the previous level of floodplain, the researches deployed in the region indicate levels of Siret and Valea Neagră terraces. According to Băcăuanu and Martiniuc (1970) during its homoclinal evolution, Siret river followed the west-est dipping of the geologic strata and left behind terrace levels in Pădurea Corhanei Hill (414 m) and Bisericii Hill (393 m). Based on the scientific data, we consider these levels corresponding the superior terrace T VII, with a relative altitude of 200-210 m. Further, based on bibliographic sources, on D.E.M. and on field surveys, we come with the hypothesis that Siret river formed in studied region, other two level terraces, namely: T V (130 -140 m rel. alt.), south-east of Cârlig village, at 335 m, and T IV (about 100 m rel. alt.) in Cetățuia Hill (308 m) and north of Dulcești, around 300 m. Unfortunately, no gravels stratum, that could confirm the existence of a terrace level, outcrops in the mentioned perimeters.

As concerns the river terraces of Valea Neagră, the superior ones develop on the hilltops of left valley-side, emphasizing a relief inversion (Băcăuanu and Martiniuc, 1970). These levels have been identified by the previously mentioned authors in Chicera Hill (440 m), Mănăstirii Hill (420 m), Mastacăn Hill (442 m), Osoiului Hill (412 m). Considering that Valea Neagră, as Moldova river, is a tributary of Siret, we parallelized the main valley terrace levels with the ones of Moldova, that are already well-known (figure no. 7). Therefore, the levels from Chicera Hill and Mănăstirii Hill represent remnants of the superior terrace, T VI (160-170 m), while in Mastacăn Hill and Osoiului Hill the mentioned surfaces belong to T V(110-120 m).

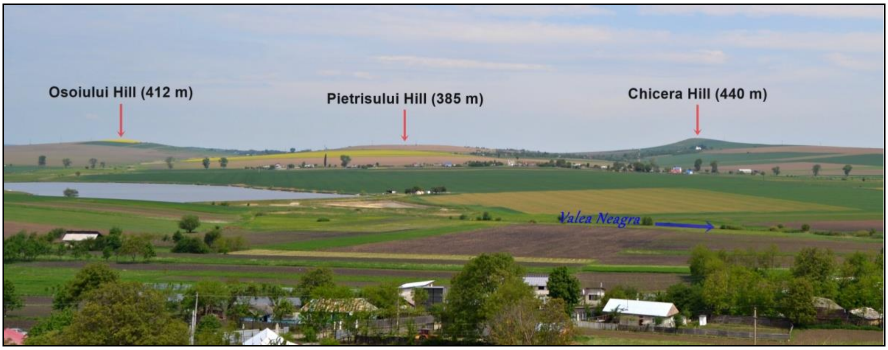

Fig. 7 River terraces levels of Valea Neagră: T V(110 m), T VI (160-170 m)

Also, we presume that other terrace levels appear in Pietrișului Hill (380 m), Poiana Mare Hill (393 m) that most probably are remainders of the superior terraces. As regards inferior terraces, Băcăuanu and Martiniuc (1970) consider their development along the national road Piatra Neamț-Roman. Based on this appraisal and on the terrain topography, we think these terrace levels situate west of Dulcești, at 258 m, and respectively 240 m, absolute altitude.

III.3. Land degradation processes

The main component of the geosphere that takes the negative effects of the geomorphologic processes is the soil. That is why the landforms assessment is always accompanied by an evaluation of soil types. The present-day geomorphologic processes that occur in the studied area and this paper proposes to analyze are: sheet erosion, linear erosion and landslides.

Sheet erosion

Almost 80% of the entire study region represents agricultural land, namely 11316.2 ha. Concerning the soils distribution, the results indicate that the highest percentage belongs to the luvisol type (54%), second extension having phaeozems, respectively 26.9%.

Based on the pedological studies from P.A.C.O. Neamț county, we drew the soil erosion intensity map (figure no. 8). Out of 11316.2 ha agricultural land, the largest extention is held by terrains with unappreciable erosion (72.9%), followed at significant distance by moderately eroded soils (15.5%) and very severe eroded (6.3%). At the opposite pole, rank the severe eroded soils (4.9%) and excessively eroded (0.4%).

In relation with the landforms, the soil erosion intensity occurs differentially (figure no. 9). The most affected are the cuesta fronts oriented westward and northward and some highly degraded back slopes, but also some areas overlapping river terraces, situated on the tops of the left hillside. A lower intensity is registered across the slight-moderate degraded backslopes, floodplains, glacises, hilltops, alluvial fans. Even though the pedological studies date before 2000, we consider that the information contained, related to the soil erosion intensity, is not very precise. Based on the field surveys we think that on some areas with unappreciable soil erosion, the result is underestimated.

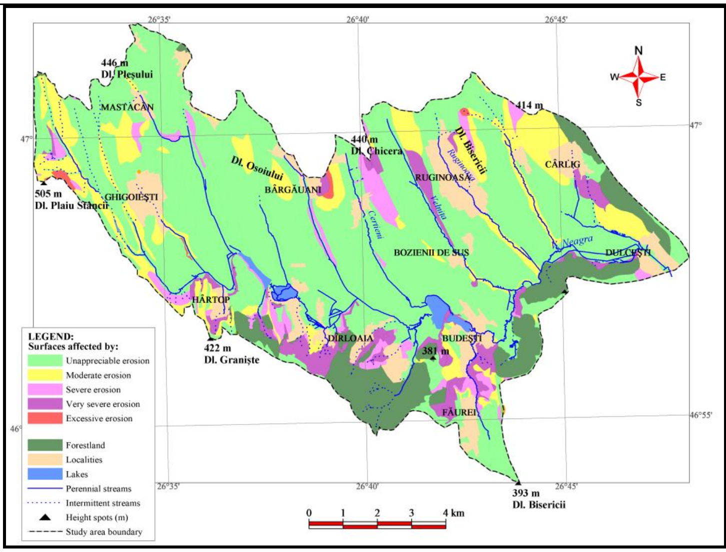

Fig. 8 Soil erosion intensity map within Valea Neagră catchment area, upstream Dulcești (drawn based on the pedological surveys of P.A.CO. Neamț)

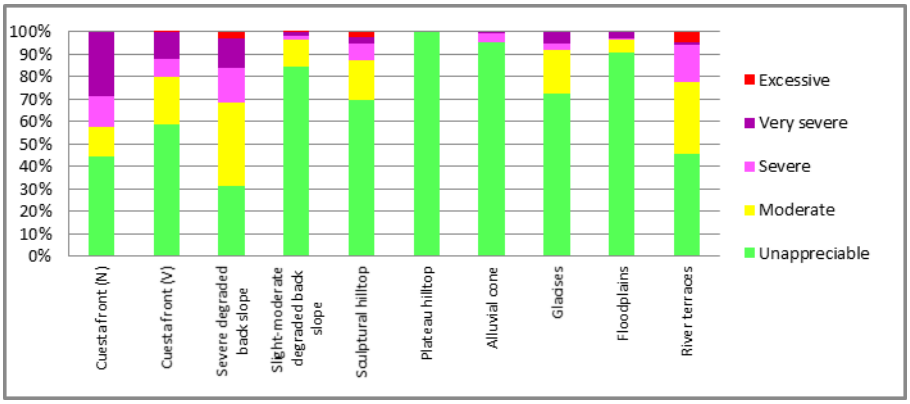

Fig. 9 The distribution of soil erosion intensity classes versus landforms within Valea Neagră catchment area, upstream Dulcești

Landslides

In the Valea Neagră catchment area, upstream Dulcești, a particular importance have the landslides. These land degradation processes are representative through their size, extension, dynamics. The area covered by landslides has 3132,8 ha, corresponding to 22,1% of the total research area (figure no. 10).

Most of the perimeters frame stabilized landslides but there are some areas where the process is still active. This fact is proved by the existence of fissures in the deluvial deposits, the gravitational or lateral movement of these crevices over time or by the difficulty in developing another vegetation cover. In terms of deluvial deposit depth, most landslides are shallow. Still, there are some perimeters where develop deep-seated landslide, like the ones near Vlădiceni village, or under forests that cover the cuesta front of the main river.

The relief influences the distribution of landslides across study area (figure no. 11). Therefore, the extension of the landslides by landforms indicate that cuesta fronts, both oriented north and west, severely degraded back slopes, held the largest surface with landslides. Partly affected by landslides, which are usually stabilized, are the glacis, slightly degraded back slopes and river terraces.

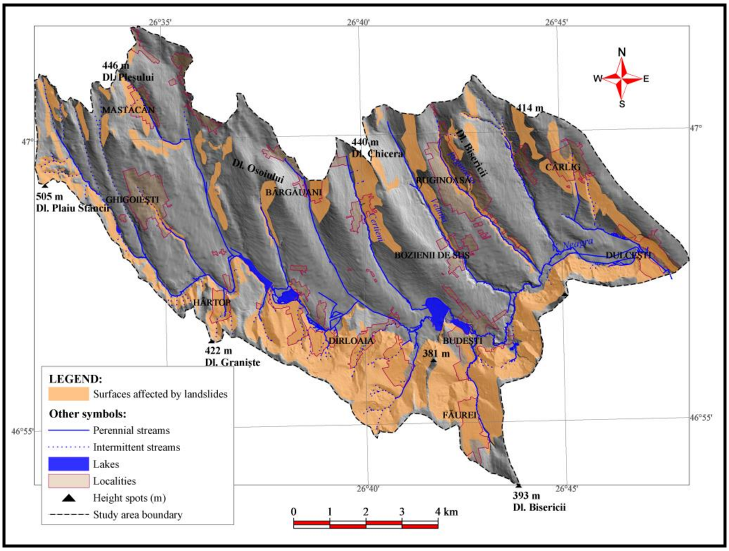

Fig. 10 The map distribution of landslides within Valea Neagră catchment area, upstream Dulcești

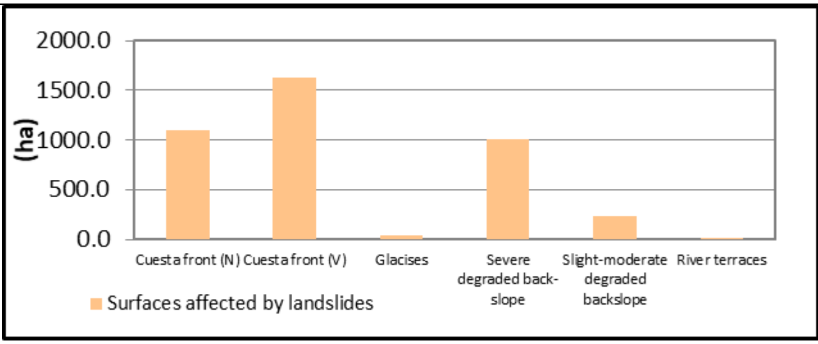

Fig. 11 The distribution of landslides by landform type

Gully erosion

Linear erosion, another important land degradation process, develops mostly alongside landslides, that often constitute the triggering factor. The main and most imposing form of linear erosion is represented by the gully. The morphology of the slopes plays a significant role in the gullies development and dynamics (Nakileza, 2013; Topșa and Niacșu, 2012). The area occupied by gullies is around 17.6 ha which means 0.12% of the total studied area. In relation with the landforms, the majority of gullies appear on the cuesta fronts and on the back slopes of the obsequent valleys.

IV.CONCLUSIONS

The landforms within Valea Neagră catchment, upstream Dulcești, represent an aggregate of hills, that localy have a piedmont aspect, developed in a monoclinic structure, specific for the Moldavian Plateau. The direction of the streams flow emphasize the double structural asymmetry, where the hillsides represents cuesta fronts or back slopes. The relief type with the largest extension is the sculptural one, secondary spatial extent having the depositional relief. Paleogeomorphologic evolution of the area determined in territory the appearance of relief inversions, where the superior river terraces develop on hilltops.

The relation established between geomorphological conditions and the intensity and distribution of land degradation processes indicates that the most affected areas are represented by the cuesta fronts, both oriented north and west, and by the severe degraded backslopes. Severe, very severe and excessive soil erosion register a percentage of 11.6% out of total and terrains affected by these intensities need special consideration. Landslides occupy 22% of the entire area but most of the perimeters are stabilized. Nonetheless, there are spots were this phenomenon has to be monitored. Gullies are the least present process and usually accompany the landslides.

The study shows once again that the presence of cuestas relief is a triggering factor in the development of land degradation processes and although these phenomena are not very intense and spread in our territory, is still necessary to be observed constantly.

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