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SOIL EROSION AND LANDSLIDES IN IZVORUL MUNTELUI LAKE AREA

EROZIUNEA SOLURILOR ȘI ALUNECĂRI DE TEREN ÎN ZONA LACULUI IZVORU MUNTELUI

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Abstract *The basin of Lake Izvorul Muntelui, is located in the Carpathian Flysch, being limited by the slopes that belong to the Ceahlău, Bistriței, Stânișoarei Mountains. Due to the alternation of detrital deposits with different hardness, the slopes around the lake are affected by various forms of degradation, determined either by gravitational processes, such as; landslides, collapses or solifluxions, or processes and denudational phenomena such as: gutters, ravines, torrents. Of these processes, landslides are predominant, because in the petrographic structure of the flysh there are mainly rocks with advanced plasticity in contact with water, especially clays, marne or marny-clayey shale.*
The most landslides affected localities are: Poiana Teiului, Hangu, Bicaz, where hundreds of such gravitational processes have been identified, the effects of which are the destruction of households, dwellings, household annexes, blocking of communication routes, splitting villages in two parts by the transported and deposited deluvial material, but also the impediment of the traffic on DN 15, its blocking, the interruption of the traffic or its deviation. After the inventory of lands degraded land affected by landslides and the map of soil erosion, a series of amelioration measures were proposedin order to reduce the effects of these geomorphological processes.

Key words: *soil erosion, landslides, degradation, geomorphological process, anthropogenic impact*
Cuvinte cheie: *eroziunea solului, alunecări de teren, degradare, proces geomorfologic, impact antropic*

I. INTRODUCTION

In the area of the Izvorul Muntelui accumulation reservoir, the dynamics of the slopes was made in a long period of time, under the influence of meteoric water infiltrations, deposition and erosion of the superficial layer and the modification of the relief energy. The basin of Lake Izvorul Muntelui falls within a tectonic zone of the Flysch from the Oriental Carpathians, where Tarcău and Ceahlău canvas have the largest extension. The lithological features of the region are given by the alternation of layers with different hardnesses, as well as different plastic properties

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or resistance to the action of external agents. In general, the marl rocks dominate and it is often the phenomenon of diaclase of some rock complexes, as is the case with Hangu layers. The altitude of the relief varies between 400 1528 m, but on surfaces of about 90% the altitude has values below 1300 m.

An important feature of the evolution of the slopes in periglacial conditions is due to the accumulation processes generated by the gully erosion, being represented by the rise of the base of the slopes, up to 10-15 m. (Surdeanu&Catană, 1985). The formation of the dejection cones in the river shedding areas represents the contribution of flowing waters to this process. Sometimes the length of the dejection cones can represent ¼ of the length of the valley, fact observed in the Fărcaşa, Sabaşa and Suha Mare rivers. Some smaller valleys were totally blocked due to pleistocene climatic conditions which did not allow the permanent release of the base of the slopes of the material deposited here after transport (Ichim, 1979). Due to this tendency, many valleys in the region present thalweg formed in devotional deposits, without being deep down to the base rock. The slopes of the Ceahlău Mountains are shaped by numerous landslides on the lake that are not directly felt. Another category of mass movement processes is pseudo-fluctuations of superficial displacements in which there is a combination of flow and sliding movements, while maintaining the continuity of the upper surface (Ichim, 1972).

The slopes shaped by torrential erosion compared to the type previously analyzed, it occupies much smaller surfaces. However, the torrential organisms are the main suppliers of sediment to the lake from the slopes area. Almost all the transversal works on some torrents (Ruginești, Grozăvești) have been overtaken by alluviums, outlet conduits instead of deltaic cones of many meters thick have been formed instead.

The deforested cliffs in the vicinity of the lake have higher inclinations and are covered by a thin deluvial cover, being affected by landslides and collapses. These processes can cause unbalancing of the slopes, a phenomenon that particularly affects smaller mountains. The slopes with lower inclinations are affected by solifluxion and pluviodenudation processes, which can be observed in the valley of Bistricioarei, Schitul and Jgheabului. The linear erosion affects all deforested slopes and is represented by the occurrence of gullies, drains at the shedding of which dejection cones appear (stream of Jgheabului, Schitului).

Of particular importance are the landslides, natural hazards that will certainly manifest in the future and which will influence the dynamics of protected lake ecosystems. In the area of Izvoru Muntelui lake, about 10 km upstream of the dam, landslides have taken place, a large part of the area overlaps with old areas and reappear mass travel processes.

II. DATA AND METHODS

The entire methodology is based on the data obtained from field observations and maps, those obtained from the literature and the interpretation of topographic maps and statistical documents and data. The purpose of the work is to identify areas subject to erosion and landslides.

The cliff of the relief was calculated on the basis of the topographical map at a scale of 1:25000, taking into account the distance between the curves of the level and the normal equidistance of 5 m and the main 25 m. It was deduced, the cliff in sexagesimale degrees, based on the correspondence between equidistance and degrees. For the purpose of inventorying and analysing landslides, I have studied various scientific papers, local development plans, media sources, various phases and effects, and older and newer photographs. Through field studies, I have made an inventory of the landslides in the area, I have identified the genetic factors of the phenomena, in correlation with the lithological peculiarities of the slopes. Finally, I synthesized and correlated these data, established the link between the frequency and intensity of the landslides and the size of the area affected by these phenomena. In order to assess the risk of landslides triggering or their reactivation, I have analyzed the dynamics of slides' manifestations, geomorphological consequences in slope modeling, economic implications, and impacts on human settlements, measures to rehabilitate affected areas, and establishing strategies to preserve the balance of slopes and to prevent the recurrence of landslides.

III. RESULTS AND DISCUSSIONS

In the hydrographic basin of the Izvorul Muntelui Lake there are processes of land degradation: gravitational (landslides, collapses, solifluxions) but also denudational (ravens, gullies, torrents).

In the basin of the Izvorul Munteului Lake, processes of linear erosion, such as ravens, gullies, torrents, but also crumbling, can be observed. The factors contributing to the occurrence and evolution of these processes are of climatic, lithological, geomorphological, biogeographic, and anthropic kind, of which the most important external agent that accentuates the evolution of this type is precipitations. For the studied area, precipitation is important, considered as torential (Rădoane, 1980) if it exceed 50 mm in 24 hours. Such values were recorded at the Ceahlău-Toaca meteorological station in month of July 2007 (52.9 mm in 24 hours, in month of July 2011 (99.9 mm in 24 hours, in month of June 2016-56 mm in 24 hours, which reveals that there are few such events recorded in the Ceahlău Mountains. A stronger impact is the anthropic intervention by the exploitation works because it favors the phenomenon of drainage and concentrated water leakage both on the trails of wood and along the forest roads where there are frequent gullies. There is less distribution in the ravines, since the linear erosion forms can not be deepened to the specific dimensions of a ravine due to the reduced thickness of the deluviums formed and the hardness of the rocks in the substrate.

The torrential processes are manifested on the steep high slopes and vegetation. The formation of torrents is favored by abundant rainfall during the spring months, especially from May to June, which, together with snow melting, leads to the accumulation of water in the reception basins, the erosion of soils and eluvial deluvial deposits, their transport, and deposition in the form of manure cones. Thus, the torrent reception basins advance regressively towards the interfluves, and also affect the grass surfaces so that the material from the grohotiser blanket, already fixed, is detached. On high cliffs, made up of diluvial deposits less resistant to erosions, it is formed due to the water flowing on the slopes: drains, ravines and gullies, which deepen quickly, reach to the mother rock and then spread through linear erosion processes.

Erosion and torrent accumulation processes are of a temporary nature with maximum intensity, when the maximum leakage is due to snow melting and torrential rains. In an experiment conducted by (Bojoi, 1979) in the case of a torrential rain that lasted two hours and 30 minutes at the bottom of the Bistrita valley downstream of the lake, 47 mm of alluviums accumulated, and in the Oanţu River, 74.8 mm of alluviums, due to the existence of a deforested slope belonging to the Stânşoarei mountains in the case of the Oanţu River, and of a forested one in the case of Bistriţa, both slopes being made of Hangu layers. The depth erosion in this case was similar, generating mass movement processes along the drainage channel and generating manure cones whose shape suggests critical moments of the flash flood. Such phenomena are more frequent in the valleys reception basins. The Izvorul Muntelui water storage may play an important role in the flood regime, because by retention of water, the effect of the flash floods is diminished unless, owing to human exploitation errors, naturally occurring flash floods can be amplified by superimposed discharged flows. The Izvorul Muntelui lake, reduces the peak of the flash flood, in the case of maximum flows because the lake can accommodate the volumes of 4 large flash floods: having a total volume of 1211 mil. Cubic meters (Neamţ Water Management System). This way, the lake ensures the diminution of the effects of the flood waves, and protects all localities downstream to the Pângăraţi Lake area from floods. The flash floods evacuation is achieved both centrally, depending on the capacity of the turbines and by the dam drainage system.

The precipitation falls in large quantities and therefore acts on the relief, by surface scrubbing, erosion, and soil erosion. The results of this form of erosion are observed by uneven ground, non-soil and alluvial soil deposits affected by gelivation (Grecu&Pallmentola, 2003). These processes precede the torrential erosion and can also be triggered by intensive grazing, the movement of sheep flocks or the removal of dwarf mountain pine for the extension of pastures and meadows.

Under the conditions of the rainy season it is found that the land most exposed to degradation by mass movement processes is found in the area of the roads built on the diluavial slopes. The breaking of the natural balance of the cliffs of these slopes in the conditions of thick diluavial covers (the areas along the Poiana Teiului-Bicaz roads, Poiana Teiului-Pipirig Borca-Mălini; some forest roads: on the upper valley of the Hangu river, the area of Bucşoaia village) has created the most suitable places of landslides reactivation. It is necessary to consider that one of the features of the slopes is the large thickness of the diluvials and the great discontinuity of their spreading on the slopes. The mass of old debris, even when it is not possible to talk about the reactivation of landslides, is within a

„hidden" dynamic in the phenomenon of creep: stable landslides are potential areas of large scale processes. The gully erosion has varied over time in both intensity as well as erosion and accumulation regime. Until historical times, which also marks the beginning of deforestation, the chemical erosion was more pronounced, while mechanical erosion became dominant after man's intervention through deforestation. According to his researches (Rădoane, 2002), on grass portions of 460 m altitude on a slope of 26 degrees inclination, the erosion threshold was caused by rainfall ranging between 3.8 and 4 mm. In the case of a grass and not mowed land, while the same values kept on a mowed land resulted in a 26-fold higher threshold.

The landslides have the highest frequency due to the petrographic composition of the flysch from the clays, marne, marne - clay shale, advanced plasticizing rocks in contact with water (Stănescu et al., 1980). The gravitational processes are still present upstream from Poiana Teiului and continues up to Izvorul Muntelui, being easily seen on the left slope of the Bistriţa valley. The torrents also present on the steeper slopes are activated by torrential rains orby the sudden melting of snow and develop a specific erosion due to the reduced hardness of the rocks and the lack of forest vegetation (Barbu et al., 1981).

Slopes with lower inclinations are affected by processes of solifluxion and pluviodenudation, processes that can be observed in the valleys: Bistricioarei, Schitului and Jgheabului.

In Poiana Teiului locality, 975 landslides were identified, 160 of which affected the dwellings. Other localities currently affected by landslides are: Bicaz, Păstrăveni, Făuneni, Hangu and Cuejdel, located on the slopes limiting DN 15.

The Hangu commune has an intensely affected area of denudational processes and landslides that affect both the carriageway and the protection works of the DN 15 as well as the civil constructions and agricultural fields. In this area, the landslides are activated and reactivated also due to existence of the reception basins of the streams: Vârlam, Buba, Buti, Huidumani and Grozăveşti.

In 2005 there was a landslide on an old deluvium, which led to a road compaction on a length of 80 m, accompanied by a fracture of the carriageway. In the same year in the reception basin of the Grozăveşti brook, a secondary detour was set in motion, causing the compaction of the road embankment also due to the lack of measures to stabilize the torrent of the talweg and the lack of consolidation works for the billows. The stability of the DN 15 road was affected by valley landslides in the area of Grozăveşti locality, where mounds and lenses of 3-8 m diluviums, affected the stability of the road and were located on both sides of it.

The Huidumani stream has a representative river basinfor denudational processes (Martelloni et al., 2012) within the area of different ages, predominantly mass movements. The Buti brook crosses the road 12 m below the road surface through a concrete tunnel, due to which the phenomenon of compressing the road on 50 m by 0.7 m vertically, occurs. The traffic on DN 15 is blocked due to a drift and muddy flowing from the deluvium belonging to the Buba creek, which has developed a sliding valley below Buba's edge. Since 2011, drainage, consolidation of the slope has been carried out in order to stabilize and reduce the effects of geomorphological processes, without being enough.

Landslides in the village of Izvorul Muntelui

In 2010, due to heavy rainfall in June-July, a landslide was triggered, after which about one hectare of wooded land began to descend on the slope from an altitude of 40 m in an area close to the Izvorul Muntelui brook. The area is located in the vicinity of the dam, and the landslides cause triggers, the formation of lakes in the Nămuca area, whose water infiltrates into the clayey rock layer. This landslide resulted in the coverage of five households in the Izvorul Muntelui village, dividing the locality in two, a situation similar to the 2005 landslide, from the Izvorul Alb village when the slipping body covered 13 households and blocked the national road DN15.

The Izvorul Alba locality has been repeatedly affected by landslides. The locals tell that in 1914, due to a landslide, appeared a small sized lake. In 2006, all 129 households in the village suffered from repeated landslides. The triggering factors are both the nature of the substrate as well as the cliff of the relief and the climatic characteristics.

The village of *Izvorul Alb* is located at the foot of the Ceahlău Mountains (Diaconu&Săndulache, 2008) at the base of the slope made-up of layers layers of shale, clayey rocks, of albian vranconian age, belonging to the flysch, grouped under the name of Ceahlău layers (Albota, 1992). This lithological facies favored the emergence of a deluvial body whose thickness varies between 2.5-6 m, located on the right slope of the Izvorul Alb valley. The left slope of the valley is affected by stabilized landslides that can be reactivated under favorable conditions. Climatic characteristics, and in particular variation in intensity and volume of precipitation, contribute to the movement of the deluvial body, partially or totally, as well as to its expansion into the surface. In years with abundant precipitations exceeding 900 mm per year, the accumulation of water in the bodies of the deluvius is favored, especially in the conditions of lack of natural drainage on the slopes in the area of the village. In the eastern extremity of the deluvium area, there is a torrent, thanks to which the drainage of the waters facilitates the sliding. Another factor contributing to the sliding evolution is the morphometry of the area, because the slope cliff is 10-15% and in the upper part it reaches 25-30% of the slope with a concave shape. In addition to the natural conditions, anthropogenic intervention has also contributed to the development of the slopes, which affected both slopes by: deforestation of the forest, deterioration of the Izvorul Alb river basin arrangement, concreting of the minor bed, regularization of the course, these works being carried out at the same time with the Izvorul Muntelui accumulation lake.

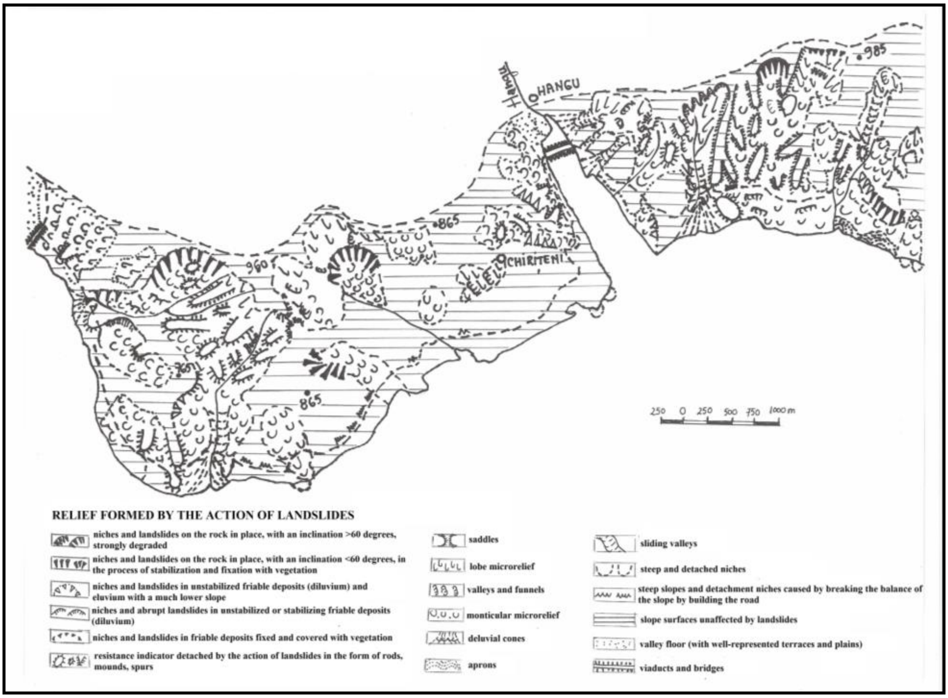

Fig. 1. Landslides map in the Lake Izvorul Muntelui area (left slope: Largu-Buhalnița Sector)

Landslides in Hangu commune

On the territory of the Hangu commune there are the layers made of marl, calcareous sandstone, clayey and gresy limestone, marble and marlin, representing a predominantly limestone flysch of senonian age (upper Cretaceous). The cliffs that favor the landslides in the Hangu area are between 20-30%, and communication routes, constructions, plantations and orchards within the commune are susceptible to 70% to be afected by slides. According to ISU NEAMŢ data, the potential for slides production in Hangu is medium, both in terms of primary and reactive types of slide. On the surface occupied by Hangu layers were recorded 125 landslides, amounting to 48.6 sqkm.

The first landslide occurred in 1997 in the village of Rugineşti in Hangu commune, the slip body having about 6 ha affected the 4 households families. According to a press release issued by the Prefect Institution of Neamţ County on November 22, 2007, a landslide has been reactivated due to heavy rainfall, with a length of 250 m, a depth of 3-5 m and a width of 50 m, the slip body affecting the house and household annexes of a family in the village of Grozăveşti, Hangu commune also affecting a section of DN 15 where cracks and fissures appeared, requiring consolidation works. In 2016 a landslide was triggered by infrastructure works to regulate a torrent, which affected two households. In the same locality the asphalting works of the communal road triggered a slip that affected four households.

Fig. 2. Landslide near Borsec

The landslide since 2010, located near the Izvorul Muntelui stream, triggered at an altitude of 40 m, in the vicinity of the dam falls, according to the depth of the sliding surface criterion, in the category of surface landslides after the sliding speed is a rapid sliding after the distance the displacement falls into the category of slopes proper after the sliding slope evolution is a detrusive sliding - progressive in relation to the stratification of the slope is a consistent slip and by age it is a current sliding.

The landslide in the village of Izvorul Alb located upstream of the Izvorul Muntelui along the valley of the same name is located on the right slope of the Izvorul Alb valley and falls from the point of view of the depth of the sliding surface in the category of shallow landslides after the sliding speed is a slow sliding after the travel distance is a sliding after the direction of displacement of the accumulation is: *delastic, regressive* after the position of the sliding surface, compared to the stratification is consistent and after the old age is present, no other manifestations in the respective area.

Also, in the area of Izvorul Alb but on the left slope the valley there is a slip considered to be stabilized falling within the category of shallow landslides and in the category of very slow slides according to the speed of the slides after the travel distance of the sliding slippage body detrusive by the direction of evolution on the slope of the consecutive ones after the position on the stratification of the slope and the old landslides according to their age. The sliding on November 22, 2007 from Hangu commune, the Grozăvești village, is part of the deep slides according to the depth of the sliding surface criterion is a very fast sliding after the sliding speed a sliding after the distance on which the accumulation of slip is a detrusive-progressive sliding according to the direction of evolution and consistently according to the lithological structure and by age is an actual sliding.

Table. no. 1. Areas affected by landslides in the Lake Izvorul Muntelui area

No.	Surface degraded by landslides	Thickness of the diluvium	The volume of the diluvium (cubic m)	The main features	How to use the land
1	2,400	6	4,400	Clay with rugged fragments	Meadows
2	1,200	1.2	1,040	Clay-sandy with rare rugged fragments	Pastures and meadows
3	240	0.7	210	Clay-sandy with rugged fragments of less than 10 cm	Pastures and meadows
4	1,100	0.8	394	Clay-sandy with rugged fragments of less than 15 cm	Grubbed area transformed into pasture
5	360	1.4	400	Fine clay-sandy	Within the village limits
6	11,000	2.5	24,400	Sandy-clayey with rare rugged fragments	Within the village limits (road area)
7	840	1.5	1,000	Sandy-clayey	Within the village limits

According to the ICPA 1987 map, the following types of soils have been identified.

1. BO/10-Brown-acid soils and lithosols
2. LS / Litosols - weak erosion
3. BM/5 - Eu-mesobasic brown soils and lithosols
4. BM5- Eu-mesobasic brown soils and lithosols
5. BM/A- Eu-mesobasic brown soils on recent fluvial deposits.
6. BM/An- Andic eu-mesobasic brown soils - weak erosion
7. BM/an/1- Andic eu-mesobasic brown soils and brown-luvic soils - weak erosion.

These 7 soils of category BO /10 fall into the category of acidic brown soils and lithosols and fall into the category of weak erosion and can be observed on the map in 20 areas. The soils in the BM/5 category are brown eumezobasic soils and lithosols, distributed only in 5 areas on the map, which supports the claim that soil erosion in this category is weak. The andomic eumosobasic brown soils, marked on the map with the BM/Year symbol, as well as the Andes and Brown-lucius Eumezobasic Soils marked on the map with BM/year/1, occupy smaller areas than previously mentioned. If the evolution trend of the erosion processes in this area continues, the increasing erosion degree will determine the passage of the 29 areas from the erosion stage to the moderate erosion stage. At present the share of soils affected by moderate erosion is reduced, with only 5 areas with typical brown soils and brown soils, marked with BM/I/5a, whose tendency the conditions of acceleration of erosion are the transition from the moderate erosion stage to the strong erosion stage. The soils marked on the BM/1 map are eumezobasic brown soils eroded and erodisols, totaling 15 strong erosion soils. There are also erosion-free soils marked with the following symbols: 9-BM- eumezobasic brown soils 10-PB/4 Brown-feriluvial, podzolic soils 11- PB/3 feriluvial brown soils: a) under the meadows b) under the forest) 12- PD/1 Podzols 13 PB/3 - Feriluvial brown soils and lithosols a) under the meadows b) under the forest).

How to use land

Depending on the destination, the land is divided into 5 major categories in accordance with Article 2 of Law 18/199. From these categories in the hydrographic basin of Izvorul Muntelui are lands with agricultural destination (including arable lands, lands occupied with pastures and meadows, lands under landscaping, land improvements and technological and agricultural exploitation roads.) The second well represented category in the hydrographic basin of Izvorul Muntelui is the one of the forestry land, which includes wooded or afforested land, as well as non-productive land included in the forest landscaping. The third category is the land in the localities of the localities situated within their borders buildings such as agricultural or forest land are located in the construction sector, and the last category is land with special destination under roads and railways, hydrotechnical constructions, nature reserves (Secu, Ceahlău or other energy or gas transport constructions). In the hydrographic basin of Lake Izvorul Muntelui were identified 15 areas with erosion-free soils, which are part of the feriluvial brown soils and podzols for which there is the possibility to pass to a low degree of erosion or even to a moderate erosion.

Water from torrential rain or long rains as well as from snow melting is the main erosion agent on the cliff lands of the Izvorul Muntelui basin. Surface spills affect both vegetation-free and vegetation-ridden lands because some of the precipitation water is retained by the forest coronation, and part is retained by the litter infiltrated into the soil, while the surplus is sinks to the surface. The process is accelerated by deforestation on steep slopes when increasing the flow of surface leakage at the expense of infiltration water (Smith, 1996). Increasing the surface water flow determines the gully erosion, the formation of ravine and gullies systems that accelerate the erosion of the slopes. Thus we can distinguish a shallow erosion, which is also supported by the anthropic activity, materialized by the appearance of derains with depths of 15-20 cm and widths of 30 - 40 cm that can be seen on the slopes of the Vârlam, Buba, Huidumani and Grozăveşti valleys belonging to Hangu commune from an administrative point of view and have caused various damages to the road from DN 15. Landslides in the area have a progressive character due to the large extension of the flysch area. Moderate and strong erosion is observable on slopes of 30-40 degrees inclination covered by meadows and on slopes with cliffs of 20-30 degrees covered by pastures.

Fig 3. Road affected by erosion in Tulgheş

Fig 4. Erodisols with very strong erosion, deep erosion, gully

Fig. 5. Gullies, developed on a slope affected by landslides

In order to reduce the erosion of the land and especially of the soils in the studied area, it is recommended to use techniques that serve to maintain the soil structure by methods such as: cultivation of land, adding synthetic products for soil improvement. In order to reduce the energy of the erosion agent, damming geotechnical methods (Borşaru et al., 1975) are also recommended, making a drainage network in order to redirect the water away from the erosion areas. Other methods that can be used are: the agronomic ones for cultivating a vegetal carpet of plant root retention in order to avoid the erosion exposure of a loose soil. The portions of DN 15 were affected by the degradation processes of the slopes by bumps (as in the case of the western section of the Buti brook), blocking the adobe roadway (the part below the Bubei edge in the north-western part of the Buba basin), as well as the appearance of fracturing settlement, (in the area of Grozăveşti locality.) In order to remedy these effects of the degradation processes of the DN 15, measures are needed to stabilize the thalweg of the torrents, especially those that cross the road, the consolidation of the ramps (by supporting walls), drainage works and superficial water run-off works in order to restore terraces and consolidate the slopes.

IV. CONCLUSIONS

The degradation of the lands in the hydrographic basin of Lake Izvorul Muntelui is manifested both on the slopes' litology through gravitational geomorphological processes, predominantly of which are: landslides, but also by mechanical denudational processes such as gullies, ravines, torrents. Mechanical processes can also affect the soil in the area studied through deep-seated transport and deposition process, which can continue until complete removal of the soil layer. In the studied area predominates slopes with average inclinations of 15-30 degrees, so the lands affected by landslides and gully erosion forms represent 12% of the surface of the basin. The lands forested with feriluvial brown soils, acid-brown soils, podzolic, representing 56% of the surface of the basin, are not affected by erosion. Soils affected by weak erosion locarted under grassland and meadows are part of category of brown-acid brown eumezobasic and lithosol soils as well as of brown-luvic soils, representing about 21% of the studied area. The smallest balances are found in soils with moderate erosion from category of brown luvic soils and brown eumezobasic soils representing 6% of the studied perimeter, while only 5% is the weight of soils with hard erosion of the erodated brown eumezobasic type and erodisols.

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