Geomorphologic Considerations on the Dobrotfor Catchment

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Abstract. The Dobrotfor Creek is a right tributary of Zeletin River and its catchment of 87 km^2 is stretching within the central part of the High Tutova Rolling Hills.

The geologic layers brought to the surface by the erosion have been deposited in deltaic facies. They are predominantly sandy–clayey and showing a gentle dipping south-southeastwards of 7-8 m/km. Also, they are Upper Miocene and Pliocene in age and belong to the Chersonian, well outlined in the lower third of the valley sides, to the Meotian with a maximum vertical development and just a few to the Pontian in the south-western corner.

The Dobrotfor valley is, generally, a consequent one and on the background of an intense relief fragmentation, the valleys of some tributaries, however, emphasize the two types of structural asymmetries specific to the Moldavian Plateau.

The natural, geologic, pedo-geomorphologic, climatic, hydrologic circumstances, combined with the influence of the human activity, are in the favor of significant development of the present-day geomorphologic processes.

The analysis of some morphometrical indicators suggests that the susceptibility to the land degradation processes is higher in the northern half and more reduced in the southern part of the Dobrotfor catchment. Under these circumstances, soil erosion, gullying, landslides and sedimentation are representing the major threat to the local environment.

Key-words: structural asymmetries, soil erosion, gullies, landslides.

Introduction

The Tutova Rolling Hills represents a major subunit of the Moldavian Plateau of eastern Romania covering around 3.400 km^2. This area is well-known for its elongated and narrow rolling hills (colinnes) that are southward stretching and separated by parallel valleys. The hydrological regime of the rivers is characterized by big pulses including either lack of streamflow or severe floods. Due to its natural conditions (friable layers, high relief amplitude, rain aggressivness and wooden soils prone to erosion) and non-appropriate human impact, this area is at a high risk of land degradation.

The catchment of Dodrotfor Creek, a right tributary of the Zeletin River, is located in the central part of the Tutova Rolling. Of the total 423 km^2 of Zeletin catchment about 20.6% (87 km^2) is drained by Dobrotfor network.

Presently, significant changes in land management practices resulted from the application of the Land Property Act no.18/1991, namely the marked shifting from contour to up and down hill farming. Thus, on the background of a sandy-clayey lithology, of steep slopes, of some changes on the climatic parameters, and the impact of human activities, a large range of land degradation processes are on the screen, among which the soil erosion and gullying being one of the most important.

The Study Area and Methods

From an administrative point of view, the Dobrotfor catchment is situated in the eastern part of Bacau County and comprises a big part of the Stanişeşti community, in the northern area and Motoşeni community, in the South.

Spindle-like in shape, a classic type for the rivers within the south-western part of the Moldavian Plateau, the Dobrotfor catchment is 32 km long and only 4 km wide in the southern half.

From a geological point of view, the Dobrotfor catchment is superposed upon the Barlad Platform, which is surrounded by two main deep faults, in the North – Falciu-Plopana fault which divides the Moldavia Platform, and in the South – Sf. Gheorghe-Oancea-Adjud fault, where it reaches the Orogen North Dodrogea (*Ionesi*, *L.* 1989). Over the Precambrian or Paleozoic folded structure, rests a thick sedimentary layer, from which the erosion brought into relief layers belonging to the Chersonian, Meotian and Pontian, laid in deltaic facies (Figure 1). The sedimentary layers are set out in a generally monocline structure, showing a gentle dipping of 7-8 m/km to South-South-East (*Jeanrenaud P., 1966, 1971, 1995*).

The Upper Sarmatian (Chersonian) layers are well outlined in the lower third of the hill sides, and the Meotian ones have a maximum development on the vertical. At the beginning, Jeanrenaud P. (1966) has distinguished the following three layers in the

Meotian formation: the lower layer, an intermediary, cineritic layer and the upper sandy and clayey layer. Later on, in 1971, the author previously mentioned, reduces the Meotian layers at two horizons, the cineritic and the upper, respectively. The former lower horizon was included into the Upper Sarmatian (Chersonian).

The typical, cineritic layer of the Meotian formation has a thickness of 30 – 40 m, and it consists of three cineritic banks split by sand, clay and marl deposits. The volcanoes located on the western side of the Eastern Carpathians represented the source of the pyroclastic material, thus some authors as Filipescu M. don't exclude the likely occurrence of extra-Carpathian volcanism. Both types of structures, the Chersonian and the Meotian, are developed in deltaic facies.

Frequently, the outcrops of the Nuțasca-Ruseni andesitic cinerites or cineritic sandstones appear well outlined in the valley-side gullies of the Dobrotfor (Figure 2).

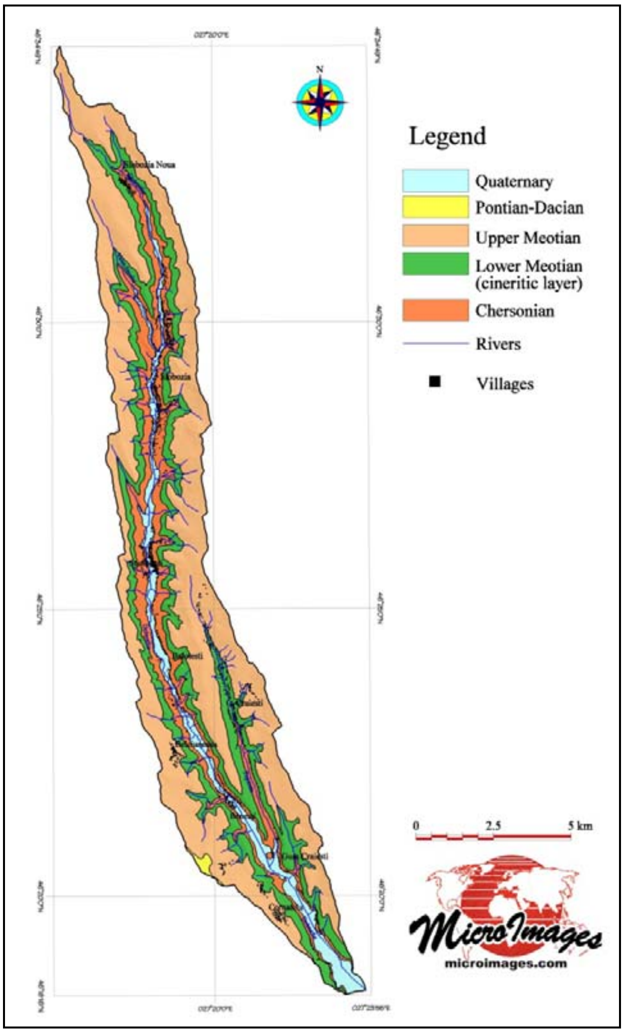

Figure 1 The geological map of the Dobrotfor catchment (processing after Jeanrenaud, 1971)

Figure 2. Cineritic sandstones in the Onofrei gully, north of Stanișești village, on the left valley-side of Dobrotfor

The Pontian layers have reduced incidence, covering only 0.30 km², in the south-western corner of Dobrotfor catchment, on the hilltop between Berheci and Zeletin. Initially, they were more extended, but they have been eroded as the hydrographic network and the relief developed.

Among the geologic units within the Dobrotfor catchment, the biggest share belongs to the Meotian, which averages 75.20% (66.3 km²) from the total area (Figure no.3). That formation is stretching in the middle and upper third of the hillslopes. Thus, the cineritic horizon occupies 22.17 % (19.47 km^2) and the upper horizon has a share of 53.03 % (46.56 km^2).

Beside these older deposits, there are also recent Quaternary formations, such as: eluvia, diluvia, colluvia, proluvia, and alluvia.

Under such conditions, between the Siret and Barlad rivers a typical area has been outlined, the Tutova Rolling Hills, whose main characteristic is depicted by narrow, prolonged interfluves, southward oriented and separated by parallel valleys (*Hârjoabă I., 1968*). In addition, the cuesta relief was notified to have appeared and developed (*Ioniță I.*, 1985, 1998, 2000a).

The climatic factor acts, first of all, through the thermal regime and rainfalls, secondly through the action of the wind. The annual average temperature at the Oncești Weather Station, located on the western side of the Dobrotfor catchment, varies around 9.0° C, with maximum in July and minimum in January. As to the thermal regime, an important role in the development of geomorphologic processes is played by the freezing regime. For the Tutova Rolling Hills area, the average annual number of *freezing days* oscillates between 112 and 127, values that are specific to the Moldavian Plateau.

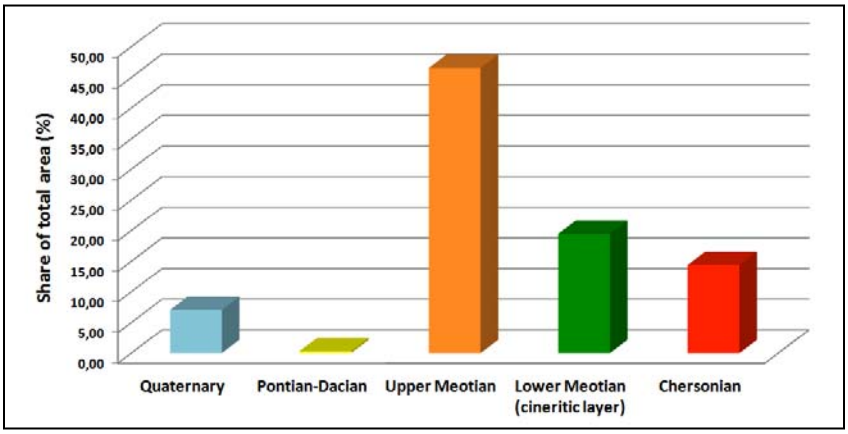

Figure 3. Histogram of the areas covered by different layers

The rainfalls may be considered the most important factor in the climatic control hierarchy of the geomorphologic processes. As to the rainfall distribution in the Tutova Rolling Hills area, we may note that the influence of the altitude is bigger than the influence of the latitude. The average annual precipitation is 529.4 mm at Motoşeni, 551.3 mm at Onceşti and 531 mm at Plopana, with maximum in June for all the three locations and minimum in December for Motoşeni and January for Onceşti and Plopana.

The main rivers don't have a regular flow regime during the year, the frequent drying up in summer contrasts with floods resulting from snow melting or heavy rainfalls, but the average water discharge of Dobrotfor river is 0.20 m^3/s. The specific average streamflow is of 1 $l/s/km^2$, the spring streamflow being dominant due to the snow melting and the heavy rainfalls in May and June.

The natural vegetation, especially the forest vegetation, occupies much smaller areas at present than in the past, the ubiquitous presence of the forest soil in various stages of degradation being the proof of that. It occupies 12.92 km^2 (14.72 %) as discontinuous areas, especially in the upper part of the interfluves.

The dominant soils belong to Luvisols (2018.39 ha, 29.32%), Antrisols (1768.89 ha, 25.70%), Protisols (1748.13 ha, 25.40%) şi Cambisols (1176.91 ha, 17.10 %) and very little to Cernisols (102.37 ha, 1.49%), Pelisols (59.64 ha, 0.87%) şi Hidrisols (9.23 ha, 0.13%).

The objective of this paper is to underline the main relief characteristics, through its geological structure and in close connection to the other physical-geographical factors, and to emphasize the impact of the land degradation processes.

In order to make the maps concerning the morphographic and morphometric analysis and all the other thematic maps the TNTMips v. 6.9. programme has been used, achieved by Microimages Inc., Lincoln, NE, USA. The analysis of the morphometric factors and the morphographic aspects are based on achieving the Digital Elevation Model (DEM), obtained by the georeference and the vectorization of the topographic maps in 1:5,000 scale. In order to analyze the state of land degradation the orthophotoplans of the year 2006 and the field survey have been used.

Results and Discussion

The morphometric characteristics of the relief intervene in the rate of land degradation processes through the direct influence on soil erosion, gullying, landslides and sedimentation.

Based on the Digital Elevation Model (DEM) several thematic maps have been delivered, such as those regarding the hypsometry, slope gradient, slope facing, the relief fragmentation map etc.

1. The Hypsometry

Within the study area, the altitudes are decreasing as we're heading towards South, likewise in the entire Tutova Rolling Hills area (Figure 4).

The highest altitude of 555 m is encountered at the Doroşanu Hill, in the northern tip of the Dobrotfor catchment. A close value, of 532 m, occurs at the Panu Hill, west of Panu Village, now called Slobozia Nouă. The lowest altitude of 137 m appears in the Dobrotfor floodplain at the confluence with Zeletin River and, therefore, the maximum relief amplitude is 418 m. Almost 80% from the study area has the altitude between 150-400 m and the medium altitude is 302 m (Figure 5).

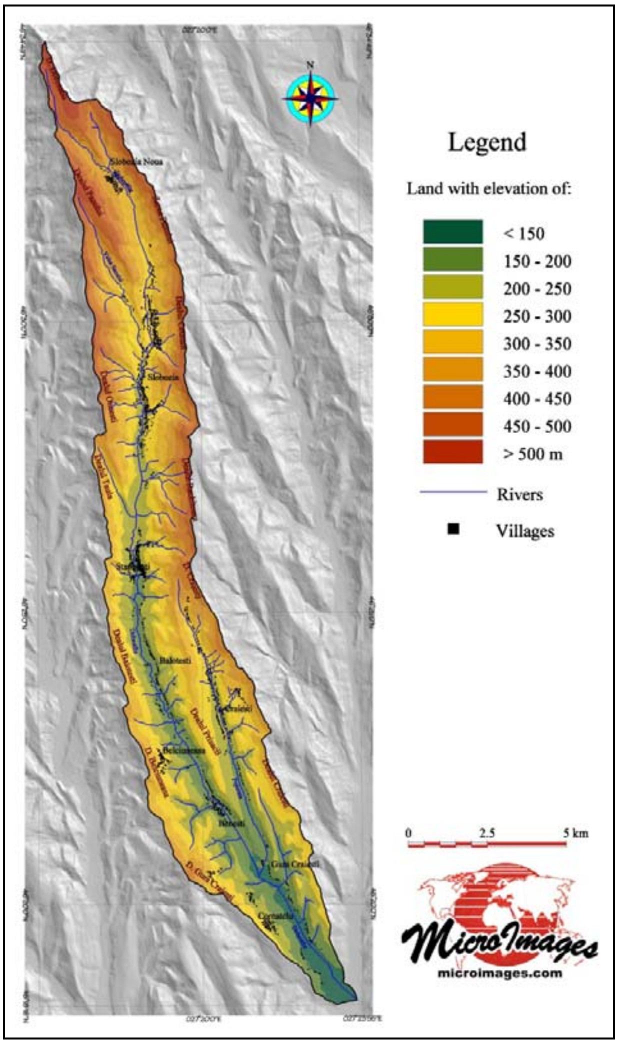

Figure 4. Hypsometric map of the Dobrotfor catchment

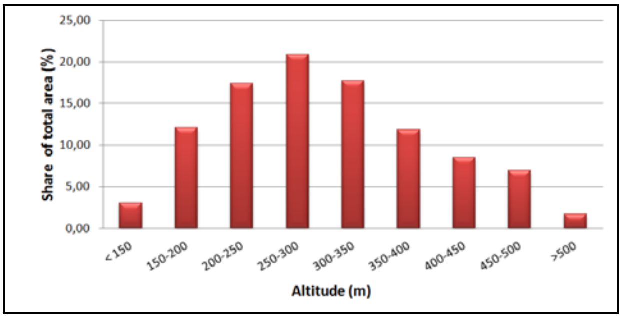

Figure 5. Hystogram of the areas by altitudinal classes

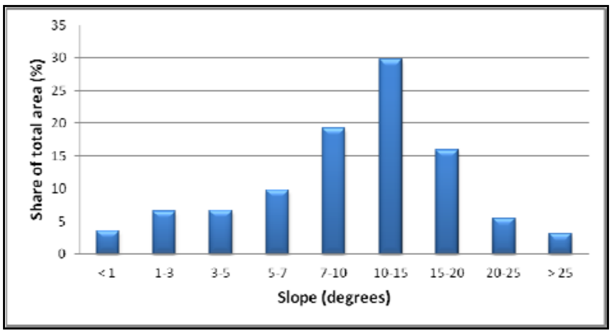

Figure 6. Hystogram of the areas by slope classes

2. The geodeclivity

This feature is very important as the soil and water conservation is concerned because it influences the distribution, intensity and specific of the present-day geomorphologic processes. The average value of slopes is 11.2º and the peak value reaches 50º. Two thirds of the Dobrotfor catchment are covered by field with the slopes between 7-20º (Figure 6).

The slopes with smaller values than 3º are found especially in the Dobrotfor floodplain, but also on some hilltops in the North, as at Panului Hill, Dorosanu Hill or on the hilltop between Dobrotfor and Pojorâta.

The slopes between 3º and 5º are found especially on the glacises located at the contact between the floodplains and the hill slopes. The poorly-moderate sloping field of 5º-10º usually occupies the back-slope of cuestas**.** The field with slope over 15º is found on the cuesta escarpments which are facing to the west or to the north (e. g., the left hillside of Dobrotfor valley near Beneşti village). Other deluvial very steep slopes appear also on the front of cuestas being associated to cornices or in the drainage basin of tributaries.

3. Slope orientation

Figure 7 shows us on one hand the weak presence of the northern and north-western facing slopes, with direct implication on the classic Moldavian cuestas whose escarpment is always looking to the north, north-west and on the other hand, the development of the cuestas with the western front and eastern back-slope.

Northern facing cuesta escarpments are linked to the valleys of the tributaries by first or second order as in the south-western part of the Dobrotfor catchment and very rarely on the valley associated to the upper river orders.

For the consequent/re-consiquent valleys**,** which have the main drain direction on NNW-SSE, we can notice the high percentage of E and NE orientation, well outlined on their right slope. Thus, the eastern facinf slopes, the back-slopes of cuesta, represent the most typical example being the right side of the Pojorâta Valley. Instead, the left side of these valleys has a predominantly SW orientation as in Sacului Valley and Darie's Valley.

Generally, the *eastern looking slopes* (23.85 %) have the greatest development, and they are followed by the western facing ones (20.21 %), this fact being mainly due to the southward flow direction of Dobrotfor river (Figure 7). The slopes with eastern orientation dominate the right side of the northern half of the Dobrotfor catchment or Pojorâta Valley, and the western slopes are prevailing in the central part of the study area.

The distribution of north-western slopes depends upon the orientation of the valleys, and they are more present in the SSW and NW of the Dobrotfor catchment, where the valleys have NW - SE orientation.

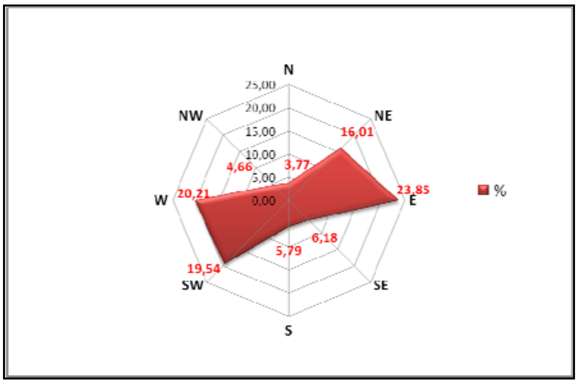

Figure 7. Orientation of the slopes in the Dobrotfor catchment

4. The main genetic landforms

4.1. Structural lithologic topography

Since the main geologic check-layer in the Barlad Plateau, the Repedea oolithic limestone of Middle Sarmatian in age, is under the floodplain level within the Tutova Rolling Hills, this type of relief is very poorly represented. It appears, however, in the restricted areas, as small *structural plateaus* depending on the outcropping of Nuțasca-Ruseni andesitic cinerites/cineritic sandstones. These rocks are more resistant at erosion than the sandy-clayey prevailing layers, but they are crumbly, and they rarely appear as erosion remnants in the local landscape. Thus, some small plateaus of local importance are mentioned, such as those at Mosia Panului Hill, westward of Slobozia Nouă village, at Sacului Hill situated between Dobrotfor and Pârâul Sec, at Crăieşti Hill, Curtea Veche Hill west of Stănişeşti village (Figure 8).

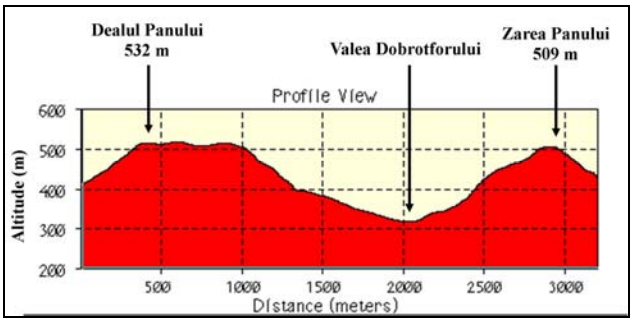

Figure 8. Cross-section through the upper Dobrotfor valley, south of Slobozia Nouă (Panu) village

On the other hand, other types of valleys developed within the geological monoclinal structure, specific to the Moldavian Plateau, are of interest.

Consequent valleys are those whose direction corresponds to the dipping of the layers, so that they comprise all the valleys with north-south orientation. Here are typical almost the entire Dobrotfor Valley and the reconsequent valleys as well, which are younger and located on a derived lower surface.

The cross-section of these valleys is slightly asymmetrical, due to the influence of the secondary digging eastwards of layers by 3 m/km. It is dependent upon the neo-tectonic uplifting of the Moldavian Platform/Plateau at the contact with the Carpathian Orogen. Such valleys, as Pojorata, Gura Crăieşti, Darie Valley are typical to the second order structural asymmetry reported by Ioniță I. (1985, 1998, 2000a).

Subsequent valleys are displayed approximately transversely to the general tilt of the layers, so they are west-east or east-west oriented and they are characterized by a classic asymmetrical cross-section. They are slightly outlined within the Dobrotfor catchment, appear mainly as torrential small valleys, and this actually underlines the youth relief in the Tutova Rolling Hills (*Hârjoabă I., 1968*).

Obsequent valleys are oriented in a direction opposite to the dip of the local strata and they are depicted by a low incidence in the Dobrotfor catchment as Râpa Analoagelor, south-east of the Slobozia village.

4.2. Sculptural (fluvio-denudational) landforms in monoclinal general structure

This type of relief is prevailing in the study area and it is represented by both the hilltops and the deluvial slopes.

The main *top of hills* impose themselves as relief, first of all by their parallelism, a characteristic due to the predominance of the consequent valleys in the Tutova Rolling Hills (*Hârjoabă I., 1968*). They are very elongated, have the longitudinal profile lines slightly wavy and the flanks are sometimes steep, and the local people call them "*horizons*" like for Panului Horizon, Slobozia Horizon, Crăieşti Horizon etc.

At the first sight we can distinguish two major interfluve hilltops, namely those which form at the same time the eastern and western watersheds of the Dobrotfor catchment. They are parallel on the north-south direction in the north part and north-west - south-east in the south.

The main hilltop Dobrotfor - Berheci has a length of 37.9 km and it is stretching southwards from Dorosanu Hill until the Gura Crăiesti Hill, and further is changing the direction to south-east (Figure 9). Due to the geologic specific features, and especially due to the faster and more pronounced relief evolution in the northern and higher part of the Tutova Rolling Hills, the interfluve hilltops are more dissected and they often show some saddles which separate „hillocks" like the one in Gura Crăieşti Hill (428 m).

The hilltop Dobrotfor – Zeletin, of 36.9 km length, is smoother than previous and its altitude decreases gradually southwards, with few exceptions.

The average altitude of the first interfluve hilltop is of 390 m, while Dobrotfor –Zeletin hilltop is higher and showing an average altitude of 422m.

Inside the Dobrotfor catchment, a series of secondary hilltops are outlined, and the Dobrotfor – Pojorâta hilltop is imposing itself. This hilltop is 11.53 km long, smooth, with altitude that decreases gradually from the north (455 m) to the south (146 m), but the average height is 290 m.

Deluvial slopes represent the most representative landform in the Dobrotfor catchment and it has the greatest share among the existing relief forms. Slopes frequently play role of either the cuesta escarpment or cuesta back-slope within the Bârladului Plateau. For a better understanding of the cuesta relief in the Moldavian Plateau *Ioniță I.* (1985, 1992, 1998, 2000) recommends to be taken into account two dipping planes of the outcropping layers, namely: a major one North-South of 6-7 m/km, who is responsible for the fisrt order structural asymmetry and a secondary one, West-East of 3 m/km, which is specific to the second order structural asymmetry. By combining the two dipping planes of the strata, a general monocline structure of de 7 – 8 m/km southwards is resulting.

The most obvious example in this respect is represented by the consequent Pojorata , which is described by its typical asymmetric cross-section and thus emphasizes the second order structural asymmetry. Its right valley-side is a cuesta back-slope eastern facing, whilst the left hill-side is a western looking cuesta escarpment.

The lack of typical subsequent valleys explains the weak development of the first order asymmetry. We can mention only a series of small torrential valleys, orientated West- East or East-West, which show cuesta escarpments (small apophyses) northern looking. The Alunis Valley near Stănisesti village or Bărbălău Valley near Benesti village are few examples of this valley type. Due to the intensity of the degradation processes, the cuesta back-slope in these valleys is severe deraded too, and it doesn't play the role of classic cuesta reverse.

Generally, the cuesta back-slopes are subjected to soil erosion, usually of moderately-strong intensity, to gullying or landslides. In many cases, cuesta back-slopes present a narrow basal border, usually with 10 to 20 m amplitude increasing upstream, and the geomorphologic processes are often similar to those on the cuesta escarpment. Often, based on the petrographical facies, some morphological discontinuities coincide with local cineritic sandstones. That is why it is estimated that the border at the basis of the cuesta reverse is firstly due to the Würmian deepening of the rivers, which was moderate in the middle courses and stronger in the upper courses of the valleys (*Ioniță I., 1985, 1998, 2000a*). A typical example for the differential evolution of the cross-section is illustrated by Pojorâta Valley.

It is important to learn that, due to the very high values of the relief fragmentation and the intensity of the present-day geomorphologic processes, the second order structural asymmetry is much more blurred. Initially, the consistent valley of Dobrotfor was installed on the Berheci cuesta backslope, and at least the middle and upper catchment exposed an asymmetric cross-section: the right valley-side as cuesta back-slope eastern facing and the left one with as western looking cuestã escarpment. Subsequently, the reverse was heavily ddegraded and, therefore, its actual cross-section is a symmetric one. So that, the second order asymmetry is encountered on the younger valleys of the tributaries, like Pojotâta Valley. Usually, the cuesta escarpments are subjected to severe gullying, landslides and soil erosion.

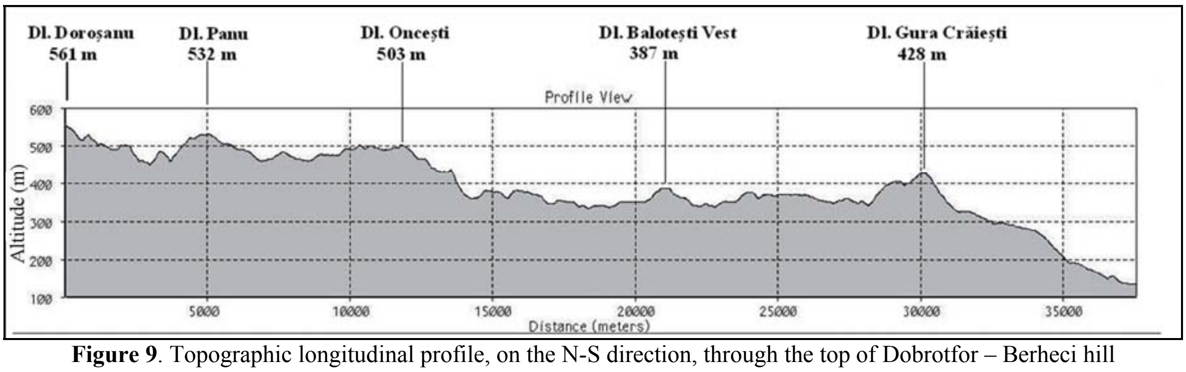

Figure 9. Topographic longitudinal profile, on the N-S direction, through the top of Dobrotfor – Berheci hill

In general, the soil erosion is ubiquitous and according to *Ioniță I. (2000c, 2007)* the critical season of this process covers two months from mid-May to mid-July. On the slightly eroded cambic chernozems, the annual soil loss averaged 7.74 t/ha for corn and 33.10 t/ha for continuous fallow. Moreover, under the forestry soils, strongly-excessive eroded, with small cohesion, slightly structured, the soil loss doubles *(Ioniță I., 2000c)*. Since wooden soils (luvosols) are dominant in the Dobrotfor cathment, it is estimated that the average annual soil loss 15-16 t/ha under row growing crops.

Gullying represents the most typical process in the study area, which *Hârjoabă I. (1968)* summarizes as "*one of the most important geomorphologic phenomena in the Tutova Rolling Hills, assuming the most important role the current development of this region*." Moreover, successive long term measurements allowed *Ioniță I. (1998, 2000b, 2007)* to get a series of findings, namely:

- The annual gullying regime has pulses, with large variations;
- The critical gullying season covers four months, between mid-March to mid- July;
- Cold season, especially freeze- thaw cycles at the end of winter, plays an important role in the gully development been responsible for 57% of the changes occurring in the gully;
- The average gully-head retreat was about 1.0 m/yr for the discontinuous gullies and increased to 12.5 m/yr for continuous gullies during 1960-1990.

The discontinuous gullies are more frequent in the Dobrotfor catchment and they have moderate dimensions when are situated on slopes, while the bigger gullies were subjected to land reclamations, like dam structures or forestry plantations, deployed before 1990 (Figures 10).

By using topographic maps in the 1:5000 scale, the orthophotoplans done in 2006 and the field surveying it was possible to identify a number of 285 gullies and to estimate that the area covered by gullies is 3,76 km^2, which represents 4.28 % of the total (Figure 11).

The slopes subjected to landslides have a considerable spreading of 45.32 km^2 (51.61 %). At present, most landslides have a high degree of stability, mainly due to forest plantations but also due to the drier period of time after 1982. As *Hârjoabă I. (1968)* stated that the incision through gullying is an important factor in triggering landslides and the majority of landslides in the basin are "*almost exclusively connected with the development of the gullying*". The slopes strongly affected by this process are located mainly in the northern half of the catchment and in the south-western part as well (Figure 12).

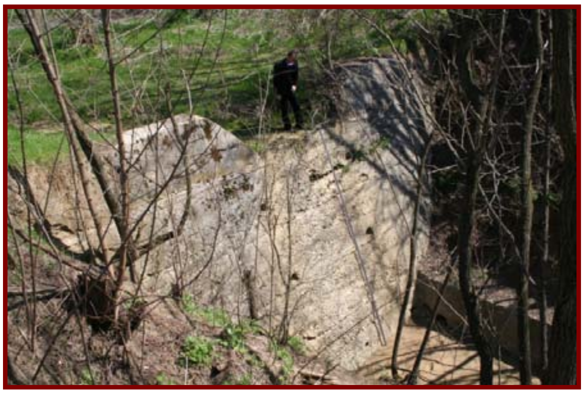

Figure 10. Dam structure built in the Gura Poacei gully (April 21, 2011)

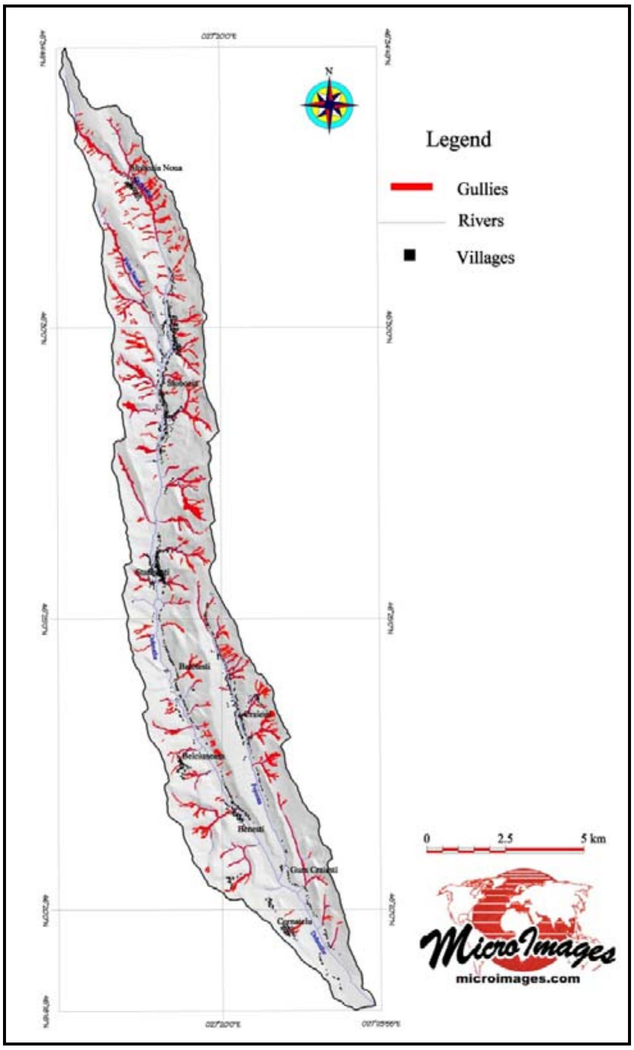

Figure 11. Map showing the distribution of the gullies within the Dobrotfor catchment

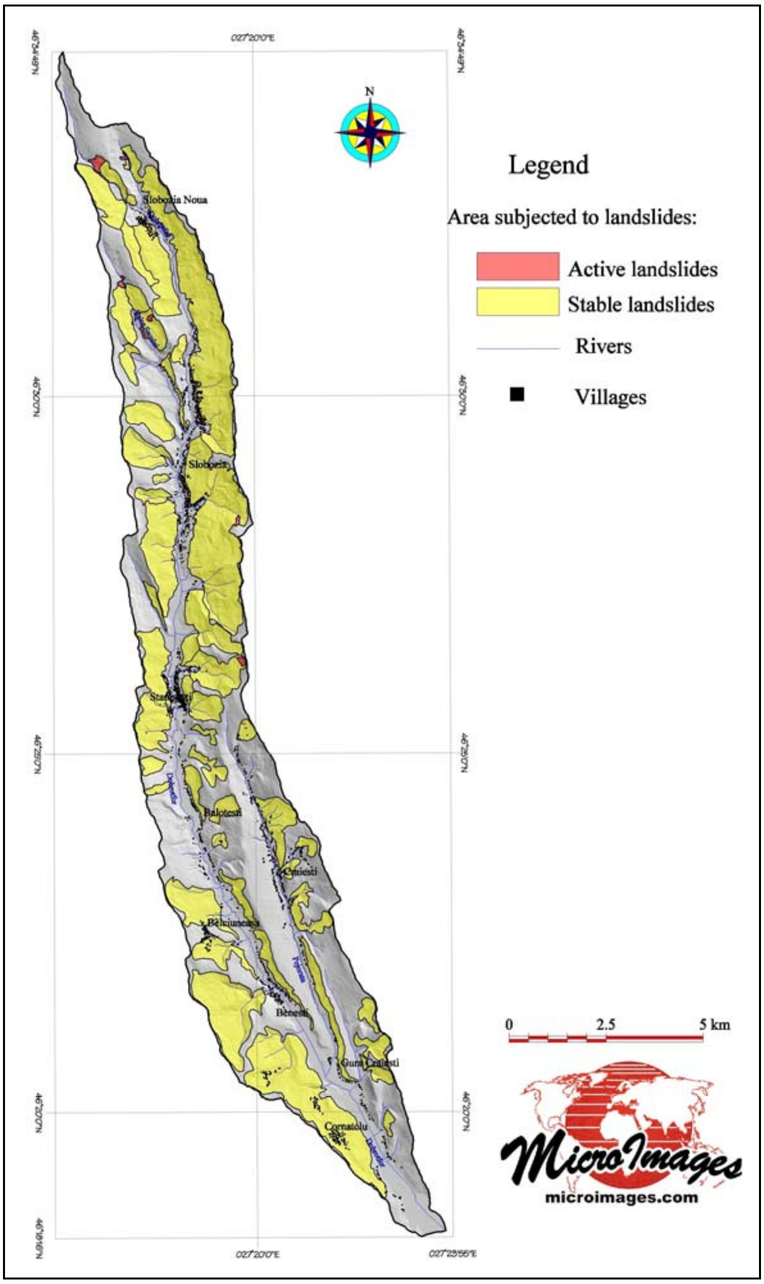

Figure 12. Distribution of the landslides in the Dobrotfor catchment

The active landslides have a reduced incidence of only 1.24 km^2 (0.27 %), most of them being actually reactivations of the old landslides.

In certain sectors, following heavy rainfalls, it is obvious a significant aggradation in the floodplains, phenomenon reported since 1950 by Filipescu M. as "*premature aging of the hydrographic network*". Besides rainfall pattern, the main causes of this process are related to the steepness of slopes, the poor development of the vegetation cover, the non-adequate land use, especially the up and down hill farming, and the low longitudinal slope of the floodplains.

Glacises have a noticeable spreading, forming connection areas between the hillslopes and the floodplains of the Dobrotfor or Pojorâta rivers. Colluvial or colluvio-proluvial in nature, their presence is given by the predominantly sandy strata, by the steep slopes etc.

The fluvial terraces have a very limited distribution, under the form of small fragments towards the confluence of Dobrotfor with Zeletin, and this is due to the petrographic composition, predominantly sandy, but also due to the current intense geomorphologic processes (*Hârjoabă I., 1968*). The left side terrace of Dobrotfor near Gura Crăieşti village with a relative altitude of 2.5 to 3 m is more clearly outlined.

Conclusion

The Dobrotfor Basin can be integrated in the typical morphology of the Tutova Rolling Hills. Due to the relatively fast evolution of the rivers and the pronounced fragmentation of the relief, the second order structural asymmetry is much more blurred.

The land degradation by the present-day geomorphologic processes are ubiquitous, noting that the most characteristic processes are soil erosion, gully erosion and lanslides. The area covered by gullies is 3.76 km^2, which represents 4.28 % of the total. Landslides are especially triggered by previous gullying and half of the entire Dobrotfor catchment is subjected to landslides. Most of them are old landslides and now they show almost stable because of both the drier period of time since 1982 and the impact of the conservation practices deployed by 1990.

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