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The role of slumps in the changing process of soil formation and soil degradation

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Abstract

The effects of slumps on soil erosion and soil formation in a Romanian study area, in the Nyárádmagyarós Basin being part of the Nyárádmenti Hills are investigated in this paper. Field and laboratory measurements revealed that slumps particularly intensified linear erosion along the edges of the area of slumps, furthermore, they contributed to the acceleration of erosion in the neighbouring agricultural areas, as well. Slumps contributed to the diversification of the pedological conditions, however, they decreased agricultural usefulness as soils of poor fertility had been formed (stagni-gleyic phaeozems, calcaric regosols). The great ratio of colluvic calcaric regosol proves the erosion of the surrounding areas while two versions of calcaric regosol reflect the locations of different intensity of areal erosion.

Keywords: slump, dissectivity, soil erosion, soil types, Nyárádmenti Hills

Introduction

Slumps are generally studied by geomorphologists, their effects are great on soil formation and degradation therefore pedological investigations are also reasonable in such areas. In this paper the effects of slumps on soil erosion and soil formation are studied in the area of a piedmont basin (Nyárádmagyarós Basin, Romania) *(Figure 1).*

Slumps, special types of mass movements resembling the characteristic forms of the Transylvanian Mezőség are also typical in the Nyárádmagyarós Basin. The clay-marl-sand stratification of the basin and its piedmont basin character help the formation of these landslide types.

Cholnoky, J. (1926) notes that the Transylvanian Mezőség is the "locus classicus" of "slump" formation. He calls the large surface movements on the horizontally stratified slopes of Miocene marly clay slumps. This type of mass

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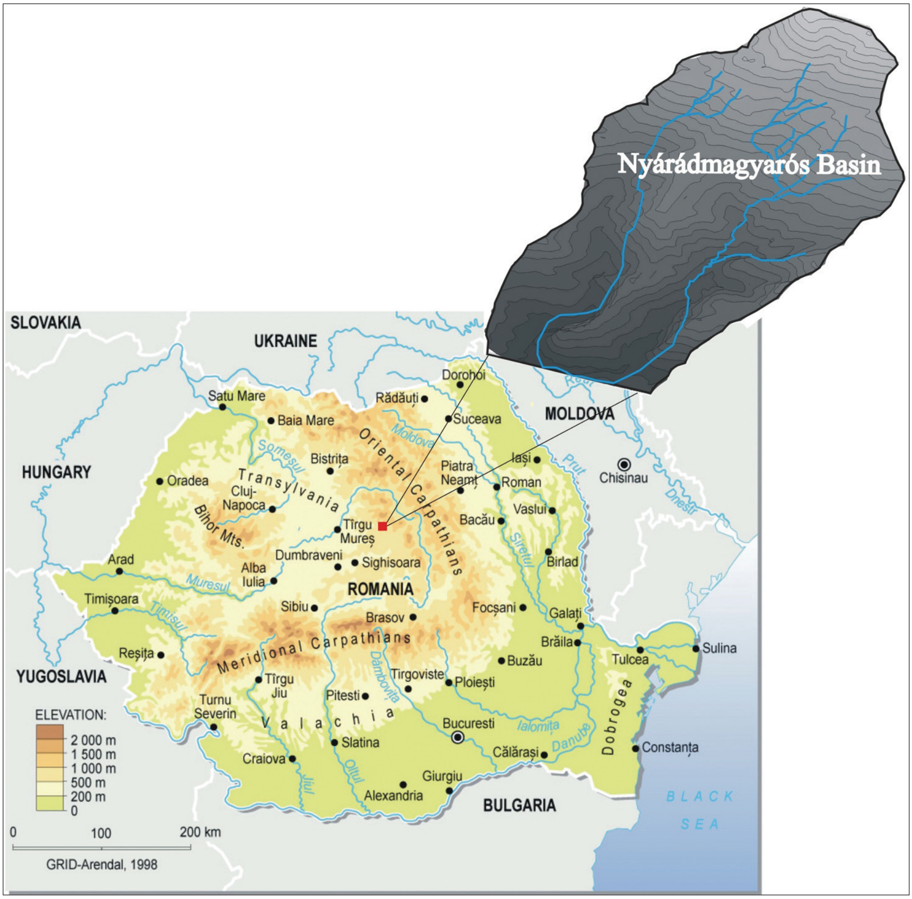

Fig. 1. Location of the Nyárádmagyarós Basin in Romania

movement can be considered as a special form of natural hazard (Szabó, J. et al. 2007). The term slump stands for the deep seated, occasionally rotational surface movements of homogeneous materials (and) with syngenetic slip planes (Sharpe, L.F.S. 1938; Hutchinson, J.N. 1978; Varnes, D.J. 1978; Plummer, Ch.C. and McGeary, D. 1991).

Based on his observations primarily in the Transylvanian Mezőség and on the relevant Romanian literature (e.g. Tövissi, J. 1963; Morariu, T. and Gârbacea, V. 1968), Szabó, J. (1996) thinks that syngenetic slumps "may form not only on slopes of homogeneous material". In his opinion, the landslides formed on the inface slopes which "cross" the anaclinal strata of the asymmetric valleys formed by the non radial dissection (tectonic or erosional) of the monocline structure developed on the edges of the diapirs in the Mezőség occur on non preformed slip planes although the slope is inhomogeneous. Therefore those obsequent landslides are syngenetic.

This characteristic group of slope mass movements is thoroughly discussed in the Romanian geomorphological literature (Morariu, T. and Gârbacea, V. 1968; Grecu, F. 1985; Jakab, S. 1968; Mac, I. 1997; Surdeanu, V. 1998; Urdea, P. et al. 2008). The publications analyse the initiation conditions and the way of movement of those processes together with their re-occurrence and age. The formation and the erosion of soils are, however, less related to the topic.

The climatic and geomorphological conditions of a region determine the circumstances of slump formation (Lacelle, D., Bjornson, J. and Lauriol, B. 2009). Based on the example given by Burn, C.R. and Friele, P.A. (1988) who besides studying the conditions of slump formation also point to the change of soils on the new surfaces developed as a result of slumps, we try to discover the soil conditions changed as a result of a large slump formed in the area of the Nyárádmagyarós Basin.

Mass movements are not new phenomena in the study area, they were present centuries ago. Most of the hillsides composed of loose clayey and marly sediments in the study area have already experienced slumping or they are currently in movement or exposed to landslides.

Studying slumps in relation to soil erosion was carried out on a relatively large Holocene, already stabilized slump area. The effects of surface dissection due to the formation of the slump, changed slope conditions and soil forming factors are studied in relation to the current condition of the soils of the region.

Field and laboratory analysis of the soils contribute to understanding the influence of changed surface conditions on the formation and deterioration of soils and the extent of the area where slumping affects agricultural land-use.

Material and method

The geomorphological map of the Nyárádmagyarós Basin is based on field survey. The model area studied in details is located in the western part of the map *(Figure 2).*

The grade of dissection was determined by field measurements using a Garmin eTrex Vista GPS and a tape-measure due to the relatively small extent of the study area (126 ha). Data were plotted on a 1:10,000 topographic map with 5 m contour lines applying CorelDraw software. Based on the data and the contour lines, the slope gradient map of the area was constructed, as well.

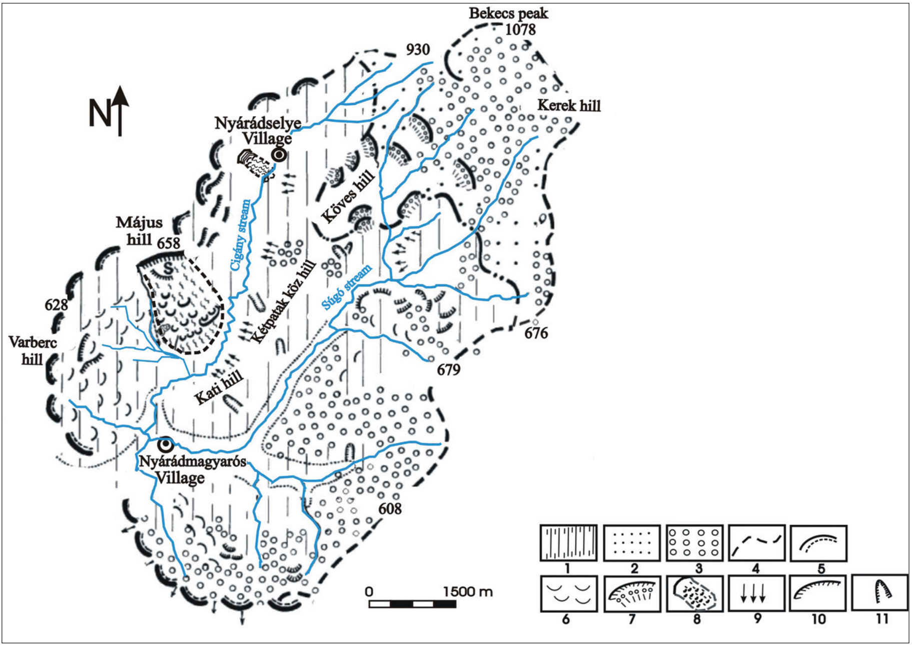

Fig. 2. Geomorphological map of the Nyárádmagyarós Basin. – 1 = Pannonian sediments; 2 = andesite tuffs; 3 = land affected by mass movements; 4 = borderline of the Nyárádmagyarós Basin; 5 = ridges; 6 = translational slides; 7 = step like landslides; 8 = area of the slump at Nyárádmagyarós; 9 = soil flow; 10 = scarps; 11 = erosion trenches

Linear erosional forms on the surface and in the marginal parts of the slump were also measured in order to emphasize the grade of dissection.

Four representative profiles were prepared and described in situ in order to study the soils. Eleven samples were taken from the profiles. Soil type determination was confirmed by drilling at 25 locations using a Prückhauer drilling rod and with the help of 5 control profiles. Soil samples were analysed in the laboratory of the Mures County Office for Pedology and Agrochemistry applying the following methods: pH – potentiometric method; $CaCO_3$ determination – calcimeter with Scheibler's method; humus – Schollenberg's method; nitrogen supply – Kyeldahl's method; phosphorous supply – Egner-Riehm-Domingo method; potassium supply – Egner-Riehm-Domingo method; SB (basoid cation exchange capacity) – Kappen's method; SH (hydrogen ion exchange capacity) – Cernescu's method; grain-size distribution – Kacinski's method. The soil map of the area was constructed based on field and laboratory analyses.

Results

The Nyárádmagyarós Basin is a typical structural basin formed by erosion. The streams running down on the slopes of the Bekecs Hill exposed the monoclinal Pannonian strata in strike orientation forming asymmetric valleys by sliding along the bedding planes.

The Cigány and Súgó streams crossing the basin with NE–SW strike have very variable water levels. Their discharge increases rapidly during spring snowmelt and extended rainfalls and cut into their valley bottoms.

The soil-forming rock in the study area is clay marl which is a clay containing large quantity of carbonic lime. The permeability of this formation is poor as it contains a large amount of swelling smectite type clay minerals which can retain an excessive amount of water. The soil is saturated by water percolating parallel to the surface until late spring. Those characteristics enable the development of such enormous mass movements like the slump at Nyárádmogyorós in certain hydroclimatic conditions.

The Cigány stream was shifted to southeast due to the formation of the slump at Nyárádmagyarós *(Figure 3)* resulting in the occurrence of a steep slope on the left side composed by the slopes of the Köves Hill, the 530 m high Leány Hill extending towards southwest and the 570 m high Kati Hill.

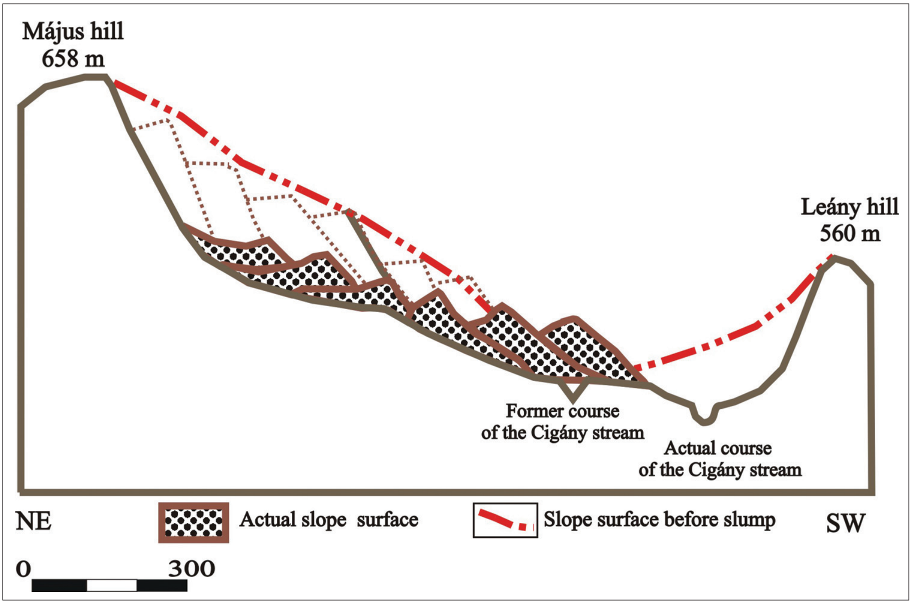

Fig. 3. Sketch of the slope of the Cigány stream prior to the slump

The slope on the right hand side is much gentler, it is the gentle continuation of the cuesta ridge formed along the Várbérc and the Május-tető, sloping towards east, southeast. Its shape is determined by the dip direction of the bedding planes. Its average slope is 10–14° which is roughly the same as the deposition angle of the strata.

On that side the ridge connecting the Május-tető (658 m), Vár-bérc (580 m) and the southern 520 m high points from North to South is a semi-circular form. The area of the slump at Nyárádmagyarós is located in the south-eastern continuation of that semi-circle. The area of slumps at Nyárádmagyarós can be divided into two groups considering the formation and the distribution of slump forms *(Figure 4).*

– the area of the so called twin slumps showing the parallel setting of slump heaps in the three lower belts and

– the upper, younger forms orientated irregularly in the area of the „brother slumps" (Tövissi, J. 1958).

The slump at Nyárádmagyarós is located on the eastern, northeastern limb of the gas dome at Nyárádszereda. Here the average dip of the bedding planes is 9–11° towards the northeast. The infaces are not exposed at the scarp. The scarp is not even located at the infaces. The orientation of the slump is perpendicular to that section of the scarp and has an angle of about 35° with the strike of the strata. Thus the scarp occurred not on the side of the strata but along a line that has an angle of 35° with the dip direction. The slump appeared along a line that has an angle of 35° with the strike of the strata.

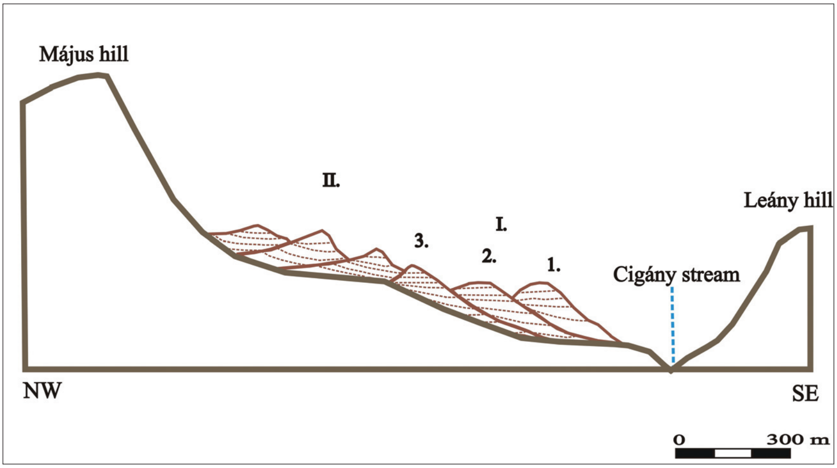

Fig. 4. Distribution of the moved masses on the slope (distorted slope conditions). – I = lower belt: parallel distribution of 1, 2 and 3 slump-head rows ("twin slumps"); II = upper belt: irregular distribution of the slump-blocks ("brother slumps")

No analyses were performed to determine the age of the slump (pollen analysis) in the area, however, the soil conditions and the geomorphological characteristics of the slump suggest a post-glacial (Holocene) age for the formation of the slump.

Simultaneous with the formation of the slump, the slope conditions of the area suffered from a drastic change resulting in a highly increased exposition to new erosion effects (denudation, linear erosion, etc.).

The grade of the dissection is determined by a 40–70 m thick sedimentary rock and soil mixture deposited along a 1,100 m wide scarp. The distance between the youngest scarp and the lowest point of the slump toe is 1,343.8 m. The average slope is 11.3 %. This angle is regarded to be the average slope of the original surface (prior to the formation of the mass movement).The material broke up due to slumping and the newly formed positive and negative forms were further changed by the erosion of external forces.

Currently, the slumped area of 126 ha is characterized by 17 sharp positive forms (hummocks) and the depressions (hollows) between them *(Figure 5).*

The ridges formed as a result of the slump were also disjointed separating into heaps elongated orderly or transversally. Their areas are not large but their effects in deteriorating the agricultural potential of the area are significant. Although the total area of the hummocks is only 11.61 ha, the area which is not good for agricultural activity due to dissection is much larger *(Table 1).*

Table 1. The size of hummocks

Nr.	Area, ha	The relative height of hummocks,* m	Surface of the hummocks,** %
1.	0.09	4.30	0.07
2.	0.14	3.80	0.11
3.	0.18	12.70	0.14
4.	0.28	14.00	0.22
5.	0.34	17.80	0.27
6.	2.09	13.70	1.66
7.	0.26	2.90	0.21
8.	0.28	13.40	0.22
9.	0.57	6.70	0.45
10.	0.51	7.00	0.40
11.	1.53	13.50	1.21
12.	0.27	2.70	0.06
13.	0.10	2.00	0.08
14.	0.56	18.00	0.44
15.	2.32	27.50	1.84
16.	0.67	8.00	0.53
17.	1.52	7.40	1.21
Together	*11.61*	*10.32 (average)*	*9.21*

*According to actual ground. **According to the entire slumped area.

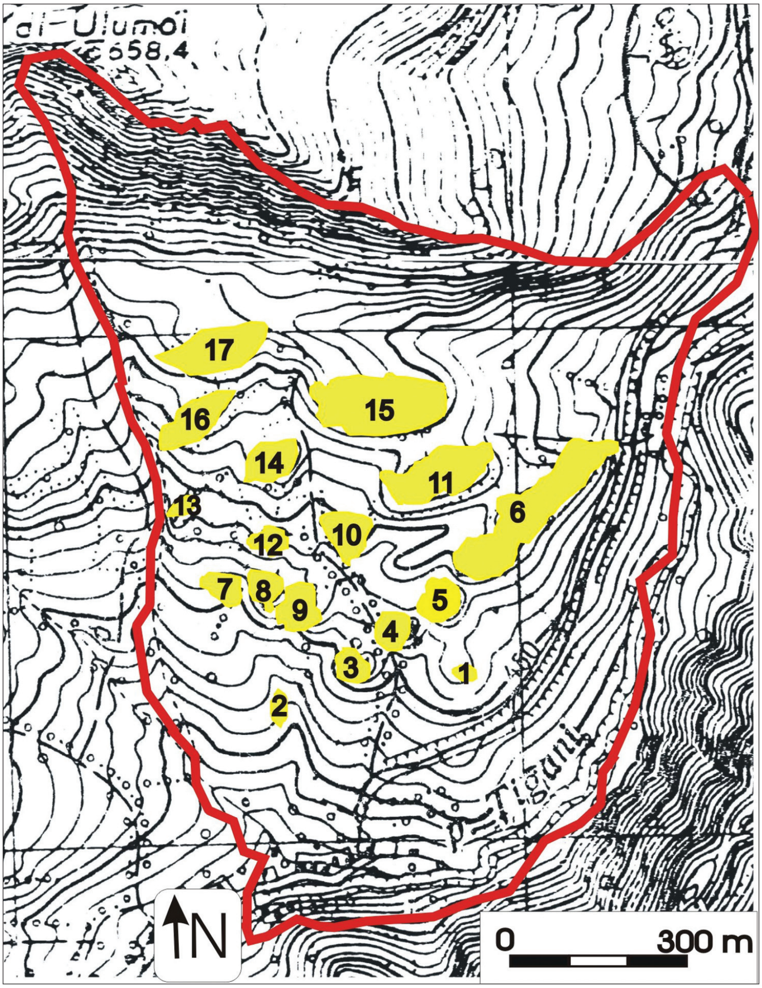

Fig. 5. Dissected and rounded hummocks of the slump surface. (For 1–17 see *Table 1*.)

The figures of *Table 1* show that the sizes of the hummocks vary in a wide range depending on the time of their formations, their locations on the slope and their dissections as a result of their slides. Slumping took place in several phases resulting in one or more slid ridges. This periodicity determined the erosion and the change of the soils and the formation of new soils, as well. Only small patches in the area of the slump have remained to preserve the characteristic soil type of the former surface in an unchanged way/condition.

Considering the occurrence ratio *(Figure 6)* and the spatial distribution *(Figure 7)* of slope gradients, 47% of the area is covered by steep slopes (steeper than 12%) due to dissection. Those steep slopes are considerably exposed to areal erosion.

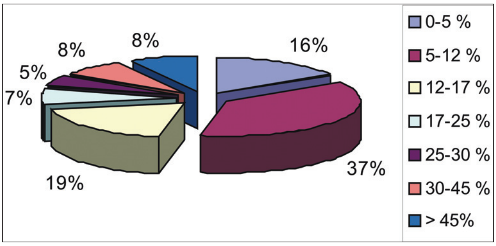

Fig. 6. Percentage of slope gradient categories

Studying the areal soil erosion of the wider environment of the study area, slopes of 8–10% are exposed to areal sheetwash in a smaller extent based on the thickness of the soil horizons. If the effects of weakened soil structure, disrupted vegetation, changed soil moisture conditions and the newly formed linear erosion forms formed as a result of the slumping are considered, it can be stated that the ratio of the area threatened by further erosion effects far exceeds 47%.

Extended steep surfaces were formed on the scarp, in the area of the landslides hummocks, in the foreground of the landslide toe. The originally even, 12–17% steep slope became an area of numerous 65–85% steep hummocks, narrow ridges and dissected talus blocks.

The vegetation cover changed in the slumped area as the ratio of bare surfaces increased and the plant associations changed due to the altered inclination. On the scarp and on the face of the slumped rock and soil blocks, especially on the southern slopes poorly supplied by nutrients, first drought tolerant, thin grassland appeared then bushy vegetation. In the case of the landslide toe, the sliding mass continues its way generally on the gentler foothill. Sliding blocks are piled up into transversal ridges or in different forms of humps. Transversal ruptures run parallel to the ridges.

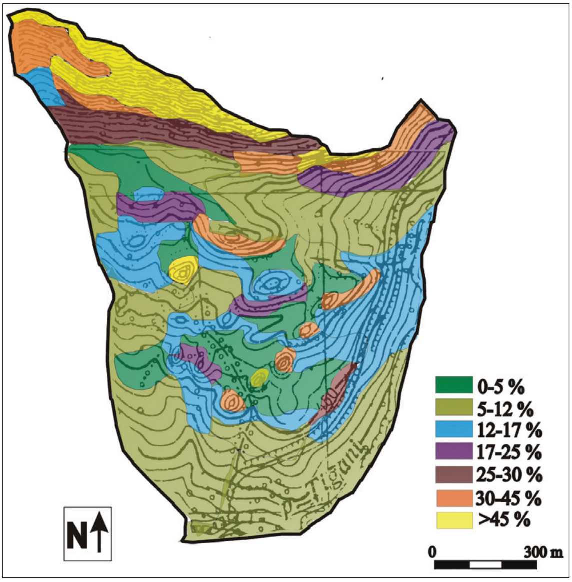

Fig. 7. Slope gradient map of the model area

The internal part of the landslide and the toe even if it is not dissected markedly suffers from significant damage in the internal structure, its mass is separated from its surroundings and the effects of linear erosion are intensified, especially in its marginal parts *(Figure 8).*

The total length of the erosion trenches and valleys framing the landslide and discharging the excess water from between the slide humps is 5,077.8 m, their average depth is 2.6 m *(Table 2).*

As erosion valleys incise and the local base level subsides new slope conditions form and new areas become deteriorated experiencing embankment falls and mudslides. The erosion of neighbouring arable lands has been changed by the downcutting of the erosion valley forming the western edge of the slump. A new linear erosion network has developed thus the erosion effect of the slump not only the slumped slope itself but the wider vicinity of the slump, as well.

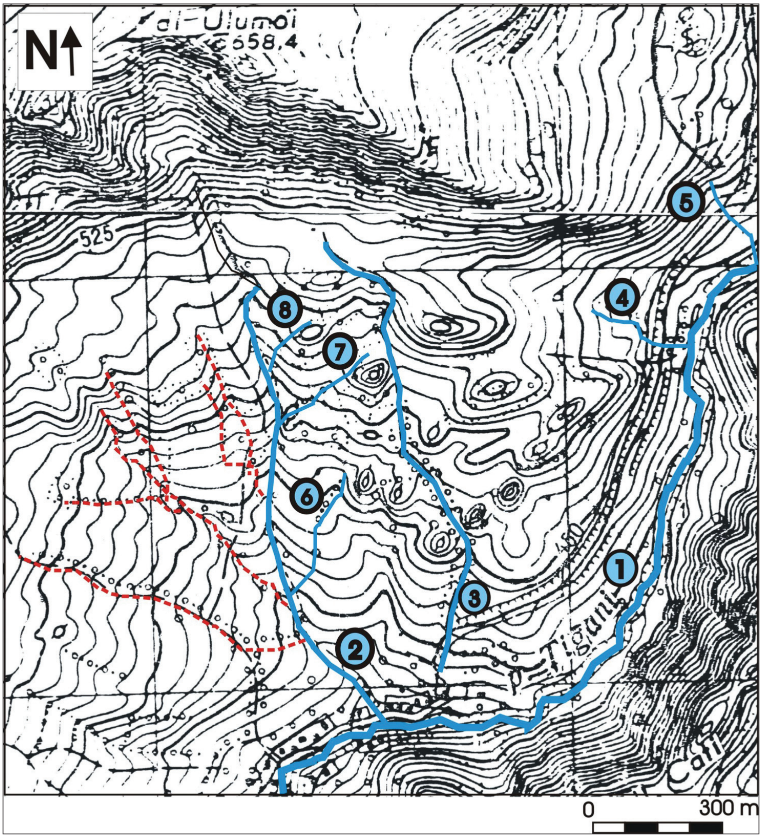

Fig. 8. Linear erosion forms bordering the slump (and developed on it) (see *Table* 2)

Table 2. The size of erosion trenches and valleys

Nr.	Valley classes	Length, m	Average	Maximum	Average	Maximum
			depth		steepness	
			m		%	
1.	1	1,611.4	3.7	6.5	11.61	14.60
2.	2	1,402.2	6.4	15.6	9.50	22.50
3.	2	919.8	1.5	2.7	8.90	14.50
4.	2	299.0	1.7	2.2	10.70	17.30
5.	2	228.1	2.1	4.5	14.60	19.40
6.	3	335.9	1.2	1.8	11.40	22.60
7.	3	184.0	2.4	2.9	9.23	10.30
8.	3	97.4	2.0	2.5	13.70	15.80

Studying the soils of the slumped area

Regarding the current stage of soil formation in the study area, we can state that the soils formed in the depressions between the slumped blocks are relatively young, they have no accumulation (B) horizons. In those areas, however, soil formation is significantly influenced by the $CaCO_3$-rich sediment supply arriving continuously from the elevated steep surfaces.

The formation of the slump alters the structure of the removed talus and soil; their horizons are mixed. The altered characteristics of the removed material affect the morphological soil conditions of the soils formed on them together with all characteristics associated with them (water, air and heat budget, organic matter content etc.).

As a result of dissection, the structure of the soil is deteriorated (structure disintegration, the lack of structure), the inner cohesion conditions are changed, soils are mixed, various masses are accumulated or replaced. Mixing of the soil horizons causes changes in the physical-chemical properties of the soils and this way their productivity is also reduced. Based on the field sampling and the laboratory analysis of the samples, 4 soil types have been identified *(Figure 9)* in the area of 126 ha. The high number of soil types in the relatively small area reflects high dissection, i.e. that high grade of dissection was probably the cause of such a variable soil cover.

Considering the ratio of the soil types *(Figure 10)*, calcareous colluvic soils with poor humus content and deep humus layer cover most of the surface.

Colluvic calcaric regosol is the characteristic soil type on 48% of the slumped area. This type can be found mainly in the extended depression in the foreground of the main scarp and on the gentle sloping edges of the former slump toe *(Figure 10)*. The great ratio of colluvic calcaric regosol indicates a

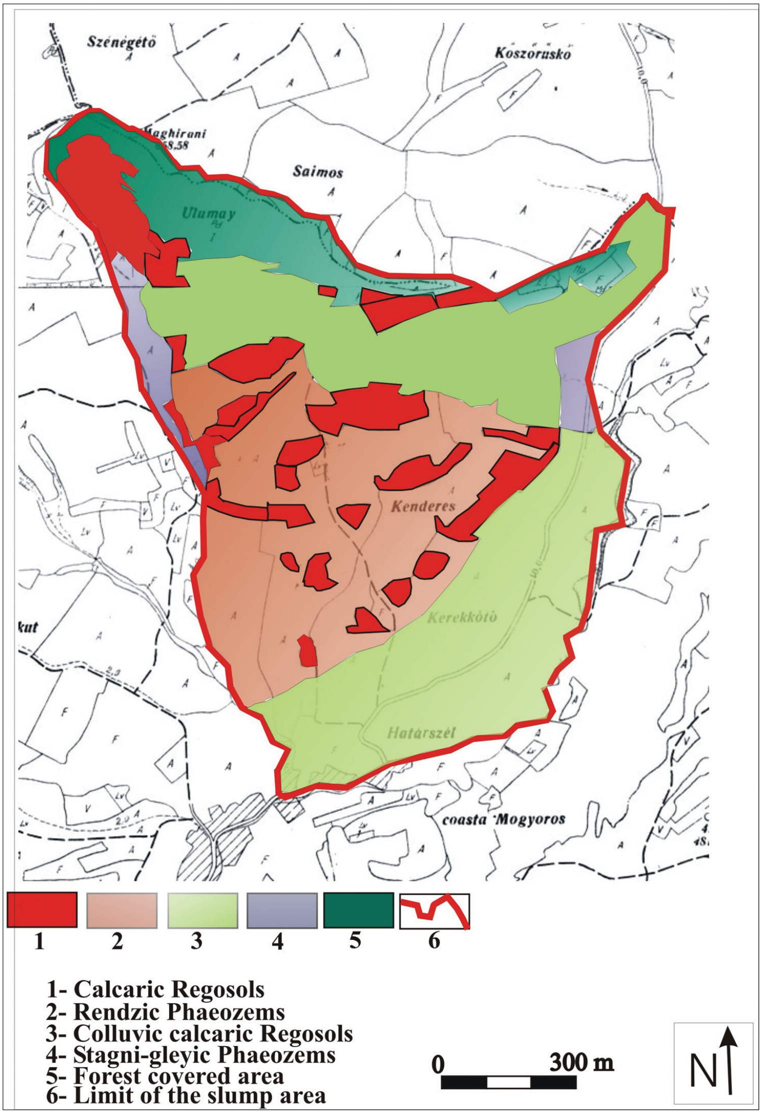

Fig. 9. Soil type map (soils in the areas covered by forest have not been studied)

significant erosion of the neighbouring areas. The material washed from the surrounding highs was accumulated in the lower flat parts or in the depressions of the area and soil formation which started as erosion processes became slower.

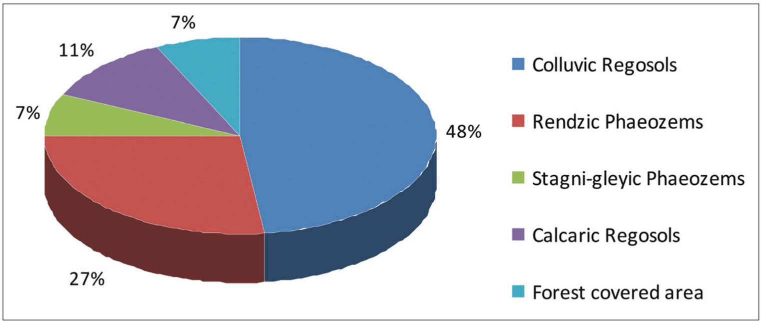

Fig. 10. Soil type ratio of the research area. (Soils in the areas covered by forest have not been studied.)

The horizons of colluvic regosol have no genetic connection as they are not the result of in situ soil formation, they were formed by the accumulation and the mixing of the soil and rock particles washed from the surrounding highs.

The materials of those soil types are originated from the immediate surroundings, their compositions depend on the materials of the soils in the higher areas. In the case of the slumped area at Nyárádmagyarós, the high landforms, the hummocks are greatly eroded in the vicinity of those soils and soil erosion reached the parent rock on the extended surfaces. The materials eroded by water are accumulated in the gentler parts of the slopes and in the valleys in a thickness of 160–200 cm. The thickness of the humus materials can reach 1.2 m, as well.

Their morphological characters are influenced by the rate and the volume of sediment transport and the properties of the transported materials. The structure of the cultivated A horizon is mixed while at greater depths the material is middle-sized and coarse crumbly and blocky. On the structural elements of the Ao_2 horizon, carbonate forms washed in from the upper horizons can be observed. The deteriorated structure and the clayey slope material result in poor water budget.

The nutrient supply of the soil depends on the humus content of the deposited sediments. Since the positive forms eroded significantly have poor nutrient content, the nitrogen supply and the phosphorous supply of the colluvic regosols of the region are also very poor *(Table 3).*

The depressions between the hummocks, the former hollow surfaces are now cultivated by agriculture due to the prolonged erosion of the positive forms. It would be difficult to reconstruct the location of the small drainless lakes (hollow lakes) as they were completely filled, partly as a result of erosion and partly as a consequence of human activity.

Table 3. Laboratory analysis results of colluvic calcaric regosol

Horizon	Depth, cm	pH	$CaCO_3$ %	Humus, %	N %	P_2O_5 Mg/100g	K_2O Mg/100g	Texture			
								Coarse sand	Fine sand	Silt	Clay
Aa	0–20	7.85	8.0	1.93	0.125	1.4	12.0	4.4	36.5	32.4	26.8
Ao_1	20–37	8.01	9.7	1.02	0.067	0.8	7.5	5.8	36.2	29.5	28.4
Ao_2	37–120	8.04	11.2	0.83	0.057	0.5	7.1	5.0	33.2	27.9	33.7

Table 4. Laboratory analysis results of rendzic phaeozem with medium humus content and moderately deep humus layer

Horizon	Depth, cm	pH	$CaCO_3$ %	Humus, %	N %	P_2O_5 mg/100g	K_2O mg/100g	Texture			
								Coarse sand	Fine sand	Silt	Clay
Aa	0–26	7.75	0.5	3.20	0.151	1.8	8.6	8.0	26.2	28.1	37.5
A/Cw	26–64	8.03	8.1	1.79	0.080	0.1	8.0	1.2	24.4	36.0	38.5
Cw	64–120	8.11	13.6	–	–	–	–	0.4	20.6	38.4	40.8

The characteristic soils of the former hollow areas are the rendzic phaeozems with medium humus content and moderately deep humus horizons. Their humus content and the thickness of the humus horizons are determined by the original humus content of the depositing sediment. The former presence of the hollow lakes is indicated by traces of gleys in the C horizons of the rendzic phaeozems. Due to the loose, sedimentary soil forming rocks containing carbonic lime, 26 cm deep humus horizon with granular structure was formed containing 3.2 percent organic matter *(Table 4).*

The process of leaching is apparent indicated by the significant decrease of the carbonic lime content of the topsoil compared to that of the soil forming rock. Its humus horizon has a short transition zone towards the soil forming rock.

Since soil denudation erodes the surface continuously and quickly, soil formation appears only in the form of humus formation. Relatively significant vertical extent of the humus layer and the transitional layer suggest decreasing intensity of erosion processes and intensifying humus formation processes. The water supply and the nutrient supply of the covering 27% of the study area are poor and moderate respectively.

The black, leached stagni-gleyic phaeozems (Hanggley-Schwarzboden) covering only a small surface in the study area are regarded to be the most developed soil types which were least affected by the slope debris. It covers 7% of the study area. It is located in the vicinity of the youngest scarp.

Although their formation requires the re-deposition of slope sediments, in our opinion, this re-deposition was areal and took place prior to the slumping based on the thickness of the humus layer. The particles eroded from the surface of the brown forest soils in the more uplifted areas accumulate in the gentler parts and in the negative forms of the slope and significant humus formation takes place in them with the transformation of the remnants of the rich vegetation in the appropriate climatic conditions.

The soil forming rock in the study area is clay marl which is a clay containing large quantity of carbonic lime. The permeability of that formation is poor containing large amount of swelling smectite type clay minerals which can retain excessive amount of water.

Its profile is very deep, horizon C appears generally at around 2 metres. Its humus layer is situated way below horizon A. Its Am horizon containing uniformly high ratio of humus can be divided into two parts *(Table 5).*

The traces of water effect cannot be observed or only in insignificant scale in the upper 0–54 cm. The frequent and tiny iron peas in the lower part indicate marked occurrence of meadow processes. The texture of the stagni-gleyic phaeozem is adobe or clayey adobe. Its upper layer is small or medium grained while its accumulation level is coarse polyhedral. The accumulation layer can be divided into two parts. The upper part is darker, saturated by humus with many iron freckles and iron peas, the lower one is free of the traces of water effect.

Its water budget has disadvantageous and preferable properties, as well. It has low permeability, its dead-water content is high and its water retaining capacity is very good which can be very useful in years of drought. Its characteristic property is saturation with water running within the soil parallel to the surface until late spring. Snowmelt following the cold season characterised by precipitation surplus and abundant rains in spring all intensify the slump triggering property of the stagni-gleyic phaeozem.

Table 5. Laboratory analysis results of the stagni-gleyic phaeozem

Horizon	Depth, cm	pH	pH/ KCl	Humus, %	N %	P_2O_5 mg/100g	K_2O mg/100g	V	SH	Texture			
										Coarse sand	Fine sand	Silt	Clay
Aa	0–22	6.4	4.95	2.95	0.157	0.6	13.5	88.2	2.6	4.7	30.1	31.1	34.1
Am	22–54	6.5	5.20	3.02	0.127	0.2	8.0	85.2	3.4	3.3	28.5	31.9	36.2
A/Bw	54–67	–	–	–	–	–	–	–	–	–	–	–	–
Btw	67–180	6.8	5.50	1.57	0.081	0.2	10.0	91.0	2.2	3.0	24.1	29.2	43.7

Table. 6. Laboratory analysis results of the calcaric regosol

Horizon	Depth, cm	pH	$CaCO_3$ %	Humus, %	N %	P_2O_5 mg/100g	K_2O mg/100g	Texture			
								Coarse sand	Fine sand	Silt	Clay
Ba	0–18	7.51	15.5	1.75	0.122	2.2	11.5	13.1	52.2	14.3	20.4
B	18–40	7.90	16.0	0.77	0.055	1.1	9.4	6.9	40.5	21.6	31.0

Its humus content in the upper layers is almost 3% *(Table 5)*. It is well supplied by nutrients but those are released more difficultly in wetter than normal years. Its base saturation is over 80 % while its pH value is over 6. The soil is very sensitive to the cultivation period as the optimal cultivation period is very short when cultivation is possible in reasonable quality. The preferable productivity of the soil is striking in dry years following a dry autumn. This soil type resists long summer drought the most.

One of the most important soil types of the study area is calcaric regosol despite its small spatial ratio as its presence reflects the locations of areal erosion well. That soil type develops on the steep slopes of the hummocks and the scarp.

Since the soil forms on the exposed loose sedimentary rocks, the process of soil formation is impeded by neither the lack of weatherable material nor the transportation of the little weathered material away, but the rapid and constant denudation of the surface. The continuous effects of soil formation and biological processes for a longer term are blocked by erosion processes. Humus development is present only at a shallow depth in the soil profile.

The transformation of the soil forming rock at greater depth is not possible, because soil denudation carries away the already transformed material and new material is continuously supplied for the soil forming processes. The soil layer, i.e. the humus layer does not exceed the thickness of the cultivated layer in actively cultivated areas *(Table 6).*

At places the soil forming rock is exposed from under the completely denuded soil, however, the development of the bare rock into new soil is impeded by continuous erosion. That soil is denuded in such extent by erosion or deteriorated so much due to human activities that the characteristics and the diagnostic signs of the original soil cannot be identified.

Its humus layer does not reach a thickness more than 20 cm at places, its organic matter supply is ensured by the poor herbaceous, bushy and occasionally – in the area of the scarp – arborescent vegetation, however, it never accumulates as it is continuously washed away due to the steep slopes. There are spatial differences in (case of) that soil type caused by the different intensity of erosion, as well. Along the main scarp and on the slope-ward side of the hummocks where the angle of slopes exceed 25% the complete denudation of the soil can frequently be detected resulting in bare lands (completely denuded soils) which cannot be utilized in any way. Those lands make up 6% of the total area. Most of those lands cannot be utilized not even as hayfields, nor as grazing lands. Further degradation of their surface could be reduced by planting arborescent vegetation.

On the gentler slopes of the hummocks degradation is of smaller grade. In those areas earthy, bare soils are formed as well, however, thin humus layers of 15–25 cm thickness can be observed. The rock near the surface is soft, covered by the network of plant roots therefore reasonable quantity of crop of soil protecting plants can frequently be harvested from them applying nutrient supply of appropriate quantity and quality. Such lands are often drawn into agricultural cultivation. It is recommended, however, to grow perennial vegetation which improves the soil, i.e. mainly forage plants or to utilize such areas for grazing.

Conclusions

Based on the investigation of the morphology of the slumped area, it can be stated that variable relief conditions were produced by the mass movement(s) with steep slopes which increased potentially the risk of both linear and areal erosions. The fact that linear erosion was intensified at the edges of the slumped area extending over the agricultural areas beside the slumped area was proved based on maps and analyses, as well. Based on the quality of the soils of the study area, it can be stated that although high ratio of the area is characterised by the accumulation of material washed from the positive landforms of the area, soils with thin humus layers, small humus content and poor nutrient supply can be found on those lands due to the quantity and continuity of erosion together with the quality of the washed material. Although the productivity of those soils could be improved by nutrient supply reduction. The halting of further erosional effects is a long-term and expensive task.

The dissected area together with the depressions between the hummocks and the former hollow surfaces are unsuitable for mechanized cultivation. The economic justification of their cultivation is weak.

Blocking the advancement of linear erosion forms could be achieved by breaking their longitudinal profile by cross barriers impeding in this way the further incision of the erosion trenches and the development of new trenches and valleys.

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