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PEDOLOGICAL AND GEOTEHNICAL ANALYSIS OF LANDSLIDES AREA AT CORNU, PRAHOVA COUNTY

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Abstract

The research performed as part of this topic resulted in a modern methodology for geological risk management triggered by natural and/or anthropic phenomena occurring at Cornu, Prahova county. The methodology was applied in the area and consisted of risk identification, analysis, evaluation and monitoring in order to reduce or limit theit negative impact on the community life, environmental factors and natural habitat.

Keywords: *environmental factors, erosion, geological risk, landslides*

INTRODUCTION

From the administrative viewpoint, the area under study is located at Cornu, the north-western part of Prahova county, about 7 km far from Campina. The place is on the left side of the Prahova river, and can be reached by D.N.1 Ploiesti Brasov, 40 km north of Ploiesti.

Accessibility to the location under study is easy, owing to the well maintained roads. The area belongs to the South Carpathians, morphologically situated in a hilly region.

The area consists in slopes of various expositions and slopes strongly divided by valleys, mostly of torrential nature.

The overall relief aspect is strongly rugged, its elements being dominated by extremely non-uniform slopes. Micro-relief is characterized by the presence of landslides, which provides a precarious equilibrium to the area.

The adjacent slopes are steep and have numerous fault faces which eventually trigger landslides and even collapses on small areas.

On small areas, there are spontaneous bushes which maintain a fragile equilibrium of the small areas with high slippage potential.

In the Land Resources register, the land is recorded as agricultural land (degradation-affected pasture and grassland) and as non-agricultural land (exploitation roads, marshes, bushes and non-yielded land).

The specific degradation processes of the area include landslides, permanent moisture excess and deep erosion.

The area belongs to the Prahova river basin which bounds the western part of the location. The area under study is bounded by the Campinita creek in the North.

MATERIALS AND METHODS

The fieldwork was carried out between 08/11/2010 and 15/11/2010. In general, the geotechnical investigation consisted of advancement of three (3) boreholes, as F1, F2 and F3. The F1 borehole was located outside the slope, on the stable upper land, being used as control; F2 and F3 boreholes were placed within the landslide. The three drillings were performed on a NW– SE alignment.

The boreholes were generally advanced to depths between 4 and 7 m, using a drilling unit equipped with continuous flight augers, soil sampling and soil testing equipment. Within each borehole, disturbed samples were recovered at depth interval of 0,75 m using conventional split spoon sampling equipment. During the drilling, the stratigraphy within each borehole was examined. Observations of the groundwater level were also noted in the open boreholes.

Following the drilling, the boreholes were backfilled with the excavated material.

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Representative samples of the various soil strata encountered at the locations were taken in Soil Science Laboratory of the University of Agricultural Sciences and Veterinary Medicine for further examination. Laboratory testing for this investigation comprised of routine moisture content determination and grain size analysis. Also, we had calculated plasticity, consistency and pore indexes.

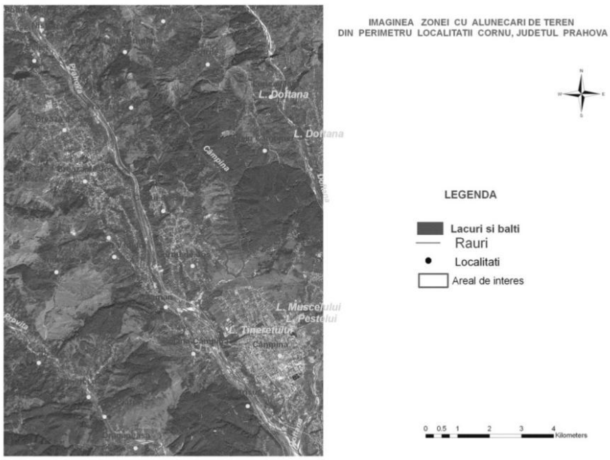

Figure 1. Cornu, Prahova county, orthophotomap

RESULTS AND DISCUSSIONS

METEOCLIMATIC CONSIDERATIONS

Climate is characterized by annual average temperatures of 9^0C. The annual amplitude is 21.5^0C, as January is the coldest month (-1.9^0C) and July the warmest month (19.6^0C).

According to multi-annual average data, first frost occurs on 6 October, while the last one can occur on 30 April. The average length of no-frost days is 175.

The number of frosty days (below 0^0C) is 115.6 days, while the number of days with highest temperature (over 25^0C) is only 74.7. The number of hot days (temperatures over 30^0C) is 15.7.

The number of cloudy days is 108.4, the cloudiest month being June (14.2 days). Sunshine duration is 2136.4 hours.

Concerning the rainfall, the annual average amount is 779 mm. at the Câmpina station. The rainiest month (June) consists in an average of 80 mm in the plains and about 100 mm in the hilly region. The month of lowest rainfall is February, with an average of 35-50 mm.

The annual average potential evapotranspiration is 640 mm, the highest values being registered in June (112 mm), July (128 mm) and August (114 mm).

Water excess is registered in six months of the year, the annual amount being 140 mm. The months with the highest water excess are January, February and March (over 30 mm each).

Northeastern winds are predominant but the Prahova hilly regions are sheltered, with slight intensifications towards the valleys and lanes.

Based on these overall climatic features, various topoclimates are manifest, determined mainly by the diverse geographical structure. Local temperature inversions in the large valleys and depressions result in early autumn and late spring frosts. Air flow from the mountain to the plain is recorded on the valley bottoms.

The climatic aggressiveness coefficient k is a constant which depends on the geographic position and is used for the prognosis of multi-annual average volume soil losses.

The value of the climatic aggressiveness coefficient corresponding to the location is k

=0.14 (k=0.08-0.16). The number of the pluvial intensity area is z=7 (z=1-19) .

Table 1. Average annual and monthly temperatures and rainfalls registered at Campina meteorological station

Monthly	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
T (^{0}C)	-2.3	-0.5	3.4	9.3	14.4	17.7	19.7	19.1	14.8	9.7	4.8	0.2	9.2
P (min.)	41.2	40.6	38.6	57.9	96.7	115.3	97.1	78.9	58	53.3	54.7	467	779

Table 2. Maximum rainfall layer of different probabilities

Maximum rainfall layer in 24 hours (mm) with ensurance				
0.50%	1%	5%	10%	20%
101	95	80	73	66

PEDOLOGICAL CONSIDERATIONS

Data to obtain

a. Soil genetic type
b. Textures and erosion degrees
c. S factor value
d. Degradation types

Information sources

Data writing method

a. Soil genetic type

The soil of the area is brown forest. It evolves as podzol under the influence of the humid climate.

Bedrock could be of crystalline or sedimentary origin; generally, the formation rocks do not contain carbonates and are relatively permeable.

Rainfalls exceed evapotranspiration, especially in winter and spring, determining a trans-percolation hydric regime resulting in soil salt leaching.

These soils have the following profile:

Ao – El – Eb – Bt – D or C.

Ao horizon – grey brown color, slightly structured.

Bt horizon – different from Ao horizon in color, structure and important clay accumulation; the color gradually lightens to the base, towards the D horizon.

D horizon – rock generally leached by carbonates; carbonates are present in some cases, especially if the initial rock is carbonated.

C horizon – can be absent or occurs at relatively high depths.

The fertility level of the soils decreases as the podzolic and pseudo-gleyey processes intensify. In this case, the soil ability to provide the plant with useful nutrients decreases significantly and the soil conditions (reaction, temperature, aeration) worsen.

Pseudo-rendzinic soils occur together with brown soils. Dark meadow soils also occur in the slight depression or slight slope zones. Proluvial soils are formed at the slope base.

Pseudo-rendzinic soil features:

- Specific horizons – Am – AmD – D
- Clay content – 4-7%
- pH in H_2O, pH = 7.0
- nitrogen, potassium: well-stocked
- $CaCO_3$ content: 3.2 % (AmD), 16.2 % (D)
- fertility: medium.

Dark meadow soil features:

- Specific horizons – Am (W) – Bv (W) – Bv – D
- Clay content – 4-10%
- pH in H_2O, pH = 6÷7
- nitrogen, potassium: well-stocked
- $CaCO_3$ content: -
- Aerial-hydric regime: imperfect (soils used as pastures and grassland).

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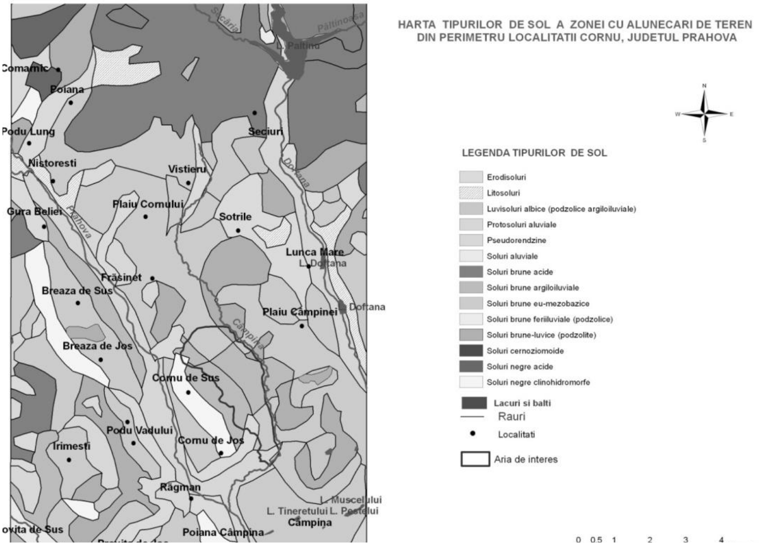

Figure 2. Map of soil geography with soil type distribution at Cornu

b. Textures and erosion degrees

The soils are characterized by medium textures, with favorable chemical features and fertility, rich in clay and nitrogen, with well-stocked phosphorus and middle-stocked potassium.

As part of the area under study, the following soil units are identified:

Table 3. Analytical data – podzolic brown forest soil

Horizon	Ao	El	EB	Bt	D
Depth –cm	0-9	9-27	30-50	63-83	140-160
Clay % <0.002 mm	21.2	24.1	31.4	42.7	35.5
Clay % <0.01 mm	34.4	37.8	44.5	53.3	47.2
Humus (%)	5.24	1.71	1.14	-	-
Ntotal (%)	0.22	0.08	0.08	-	-
Horizon	Ao	El	EB	Bt	D
pH in H_2O	5.16	4.9	5.24	5.48	6.74
Gv (g/cm^3)	1.35	1.50	1.50	-	-
Pt (%)	48	43	44	-	-

U.S. 1 – pseudo-gleyey, brown soil

U.S. 2 – medium pseudo-gleyey, slight podzolic, brown soil

U.S. 3 – pseudo-gleyey, medium podzolic, brown soil

U.S. 4 – skeleton, brown soil

U.S. 5 – medium eroded, brown soil

U.S. 6 – slightly moderate podzolic, brown soil

U.S. 7 – moderately eroded, pseudo-gleyey, slightly moderate podzolic, brown soil

U.S. 8 – pseudo-gleyey, strongly eroded, brown soil

U.S. 9 – moderately eroded, slight skeleton, dark-brown forest soil

U.S. 10 – complex of strongly eroded soils

U.S. 11 – locally strongly-excessively eroded, brown soil

U.S. 12 – moderately eroded, dark-brown soil, with strongly eroded soils in area with stable slips

U.S. 13 – complex of eroded pseudo-rendzinis soils, with excessively eroded soils eroded ones in area with temporary stabilized landslides

U.S. 14 – complex of podzolic brown soils, dark-brown pseudo-gleyey, pseudo-gleyey, moderately and excessively-strongly eroded soils, with quasi-stabilized landslides
U.S. 15 – complex of dark-brown podzolic soils, pseudo-gleyey, excessively-strongly eroded
U.S. 16 – complex of strongly eroded dark-brown soils, with semi-stable slips
U.S. 17 – dark-brown forest soil, slight podzolic one, pseudo-gleyey, medium eroded, with many slightly deep crevasses
U.S. 18 – lands affected by deep erosion (active or under activation crevasses)
U.S. 19 – brown pluvial soil, pseudo-gleyey, slight skeleton into depth
U.S. 20 – complex of colluvial brown soils, eroded, into valley, locally
U.S. 21 – consolidated natural outlets pseudo-gleyey soils
See below the plan including the soil map
Pedologic risk factor, S:
Depending on the soil groups (soil type, texture, erosion degree) found in are under study, the S erosion factor has the following values: 0.8; 1.0; 1.2.

Degradation types :
Depending on the soil degradation type and degree, soil units were included into pedo-ameliorative groups.
Group I – non-eroded, pseudo-gleyey soils: U.S. 1, 2, 3, 4, 19, 20 – S = 83 ha
Group II – moderately eroded soils E1: U.S. 5, 6, 7, 9 – S = 156.25 ha
Group III – strongly eroded soils E2: U.S. 8 – S = 56.7 ha
Group IV – excessively eroded soils E3: U.S. 10, 11 – S = 34.6 ha
Group VI – complexes of erosions into area with stable slips: U.S. 14, S = 146.7 ha
Group VII – eroded soil complexes affected by quasi-stabil U.S. 15, 16 – S = 5.7 ha
Group VIII – soils affected by erosions into depth
Sub-group VIII A – natural consolidated outlets, U.S. 21 – S = 2.0 ha
Sub-group VIII B – active and under activation crevasses, U.S. 17, 18 – S = 65.0 ha

The landslide test was performed on a slope of high relief energy, on the right upper side of the ramified ravine. The whole area was affected by first and second-degree landslides which were firstly produced at the contact between the basic rock and the covering delluvial formations, and subsequently in the delluvial deposits.
The ground had an irregular aspect, being partly covered by herbs and partly by thistles and shrubs. The second-degree slips had an obvious ‗crock skin' aspect. The first-degree slips were detrusive and produced starting from the upper part of the slope.
In the F1 drilling area, the land was stable, the first slip occurring at approximately 10.00 m downstream.
In the drilling area and the right flank of the ravine, the first-degree slip had the first severance of about 4.00 m in height, the land being organized into three major terraces. Delapsive slides of low extension subsequently occurred in the ravine flank. Counterslip areas were identified in the bermes, where rainfall water accumulated resulting in vegetation typical for excessively moist areas.

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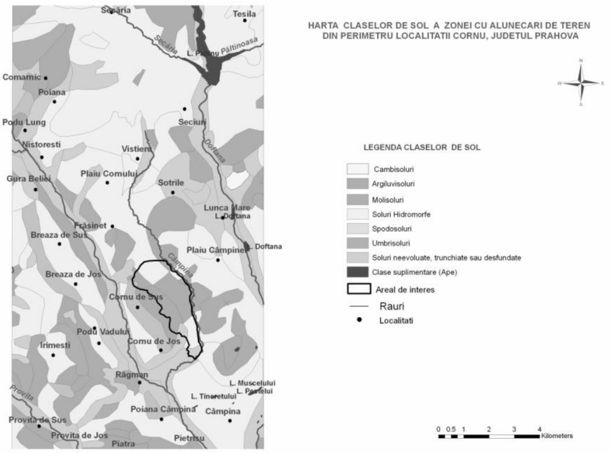

Figure 4. Map of soil classes at Cornu

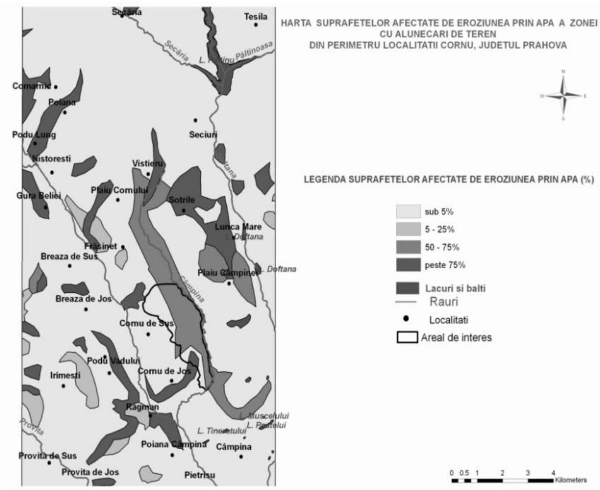

Figure 5. Erosion map of Cornu

Cracks and fissures were identified on the surface of the whole slipped mass. In time, they lead to new phenomena of instability.

Drilling F2 was placed on a first-degree slip while F3 on a semi-stable, second-degree slip.

The factors leading to slip production were linked to the high energy of the slope, the petrographic nature of the delluvials in relation to both the marl rock and infiltration water at the contact between the cover formation and the basic rock. The same causes led to the formation of the previously mentioned crevasse which, although presently consolidated by gabions, it is under evolution, with an unfavorable impact on the overall stability.

From the base to the upper part of the slope, a cobblestone road was identified, sustained by earthwork and consolidation by wattle fences. The works were partially compromised due to water infiltration, previous slips and the petrographical nature of the delluvials.

The work depth was conditioned by the interferance with the slope plan and basic rock.

The unitary profiles of the drillings present land stratification and the physical-mechanical features of the interfering land.

The F2 borehole was especially equipped for slope measurements.

Based on the results obtained from the F1, F2 and F3 boreholes, the following stratification is presented:

-*F1 borehole*:

0.00 – 2.70 m clay, yellow-brown at the base, plastic-consistent hard, with grey interferings in upper part;

2.70 – 3.50 m dusty clay, yellow, plastically hard, with small gravel and angular elements of shale rocks;

3.50 – 4.70 m clayey sand, brown, with small-big gravel at the base, with angular elements of shale rocks;

4.70 – 7.00 m gravel, with clay-dusty sand binder, with boulders at the base.No water.

- *F2 borehole*:

0.00 – 2.20 m clay, yellow-brown at the base, plastically hard, with rare small gravel in the base;

2.20 – 3.10 m clay, grey-brown, plastically hard, stratified, with brown clay interfering with vegetal residues and gravel in the base;

3.10 – 4.00 m marl clay, grey, hard.

NH_s = 3.10 m (infiltration)

- *F3 borehole*:

0.00 – 1.40 m clay, yellow-brown, plastically hard;

1.40 – 3.80 m clay, grey, yellow in the upper part, hard;

3.80 – 4.00 m marl clay, grey, hard.

NH_s = 2.30 m (infiltration).

As noticed, the F2 and F3 boreholes emphaisezed two land categories:

- lands belonging to the moving earth;
- lands placed under the slope plan, unaffected by the movement.

The landslide is basically represented by superficial delluvial deposits and the stable land is represented by the basic marl rock, the slip occurring at the contact between the two formations.

The table below presents the main features of the lands located over and below the slip plan, expressed as extreme values:

Table 4. Lands over and below the slip plan

Geotechnical feature of lands from F2 and F3 boreholes	**Lands – over slip plan**$^{*)}$	**Lands – below slip plan**$^{*)}$
Plasticity index, **Ip**	35.7 – 43.3	36.8 – 42.3
Moisture, **w (%)**	14.3 – 24.8	13.0 – 16.1
Consistency index, **Ic**	0.81 - >1	>1
Volume weight, **γ(kN/m³)**	19.7 - 21.3	19.7
Porosity, **n(%)**	27.8 – 41.8	41.8
Pore index,**e**	0.38 – 0.72	0.72
Saturation degree, **Sr**	0.92 – 1	0.92
Internal fricton angle , ϕ_{uu}**(kPa)**	28^o – 36^o30‘	12^0 45‘
Cohesion, c_{uu}**(kPa)**	79 - 112	42.00

**) The position of the slip plan was orientative; it could not be directly established by slope measurements, but only estimated based on the land nature and modification of the geomechanical features in certain depths.*

CONCLUSIONS

In the F1 drilling area, the land was stable, the first slip occurring at about 10 meters downstream.

In the area of the drillings and the right side of the ravine, the first-degree slips have the first detachment step of 4 meters in height, the land being organized on three major terraces. On their background, delapsive reduced slips took place in the ravine side. At the bermes level, counterslip areas were identified, where rainfall water accumulated leading to vegetation specific to humid areas.

Cracks and fissures were identified on the whole cover of the slip mass which, in time, results in new instability phenomena.

One can ascertain that the F2 drilling was placed on a first-degree slip, while the F2 drilling was placed on a semi-stable, second-degree slip.
The samples taken from the drillings, which led to the establishment of the physical-mechanical properties of the land, corresponded to the direction of land movement on the slope.
At the date of drilling, underground water was found in two drillings, F2 and F3, at 3.10 m and 2.3 m depth, respectively. Water occurred as infiltration, probably on the slip direction. Underground water was not found in the F1 drilling.

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