# THE NEED OF INTERDISCIPLINARITY APPROACH ON LANDSLIDES RESEARCH IN ROMANIA

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**Abstract**

According to the World Atlas of Natural Hazards (McGuire et al., 2004), the landslides are the most frequent and worldwide developed natural hazard. It can occur on any type of terrain where exist the proper conditions concerning the soil or bedrock, groundwater and slope. The landslides usually occur accompanying the other natural hazards like heavy rainfall, floods and earthquakes. In time, all subgroups of natural hazards (cosmic, geological, hydro-meteorological and biological) have been recorded in Romania. Types of natural hazard are very numerous (over 67). But five from the most important hazards, regarding the number of dead or affected persons, or economic damages, are the earthquakes, floods, droughts, excessive temperatures and landslides (Marinescu et al., 2010).Actually, the landslides affect strong many country's regions. The high frequency of landslides on land have great importance in the evolution and shaping of the landscape. Large areas of agricultural land suffered from landslides which also damaged various buildings both in villages and cities, and destroyed roads, railways, etc. Damage in industrial areas is also important. Landslide terrains could seal some running rivers causing partial or total blocking of leakage. The landslide research involves considerable human and financial efforts. Being on very complex process, its survey implies the using of many scientific disciplines. The need for interdisciplinary approach within the landslides, who to conduct at better knowledge and, finally at more adequate stabilization solutions, is the main objective of this paper.

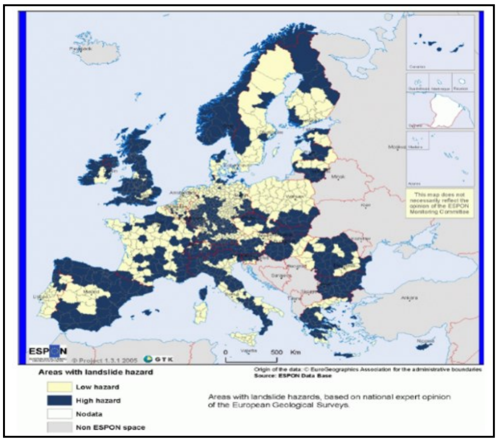
**Keywords:** Landslides, approach methods, mapping, interdisciplinarity, Romania

## Introduction

The processes represent a succession of states, stages, phases and mechanisms generated by factors or agents specific to the slope system or external, which are manifested at a certain moment in time, as a result of a surplus of energy and matter, determining the evolution, transformation or even shifting into another system, in the tendency to reach a level of balance. In the case at hand, what is important is represented by the geomorphologic, hydro-geological and anthropogenic processes. The geomorphologic processes (geomorphic processes) are mechanisms generated by shaping agents (internal or external) which lead to the shaping of the landform thru gravitational processes: landslides, rock-falls, settlings and hydrodynamics: erosions – accumulations, and climatic. Hydrogeological processes: infiltrations, suffusions, pollution and anthropogenic processes: fillings, excavations, slope cu, anthropogenic settlings, terrain overload, lack of drainage, seepage damage.

Romania is one of the countries whose territory is exposed to geomorphologic processes landslide type. The researchers investigate from their perspective, different aspects of landslides, but the landslides are most complex systems with a special dynamic.

Depending on the specific methods to each environmental research areacanbe identified only certain aspects of movement mass or in a wider perspective, of slope system shaped by landslides researched.



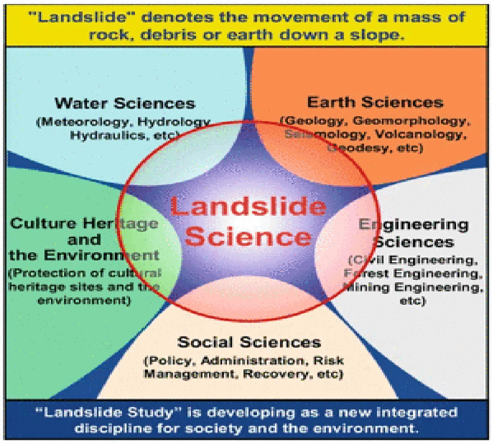




Fig 1 Area with landslide hazard (left), *Source: EPSON (European Spatial Planning Observation Network) project http://www.gtk.fi/projects/espon/Landslides.htm;* Landslide science as a new integrated discipline(right) (Sassa, 2007)

An attempt above landslides interdisciplinarity approach (which he considered as a new scientific discipline) is made by Sassa (2010), indicating five groups of scientific area which do contribute: earth sciences, water sciences, engineering sciences, heritage cultural and environmental, social sciences (fig 1). Many of the disciplines that contribute to landslides study are presented below. The need for interdisciplinary approach within the landslides is the main objective of this paper, because cases were identified in which they were less durable improvement on exposed slopes of sliding, in conditions which were investigated only a few aspects of land or the environment.

Interdisciplinary research lies in the multitude of peculiar aspects of landslides related to the shape, size, intensity of displacement mechanisms, which highlighted the diversity and regionalization of landslides types in Romania. This country has a great diversity of landform units arranged in the form of concentrically tiered steps, the highest steps – the Romanian Carpathians in the center, then the Sub-Carpathians towards the exterior, the plateaus and plains on the periphery of the territory. The Carpathians appear not as a compact structure, but in the shape of an arc (Carpathians Arc), composed of three branches,the Eastern, Southern and Western Carpathians, which comprise within them a great depression area,the Transylvanian Plateau (Andra-Toparceanu, 2015). In the regions with high potential for slipping 50% of the total slope surface is affected by gravitational movement mass (Posea, Popescu, Ielenicz, 1974), some of them old (Pleistocene), others actual.

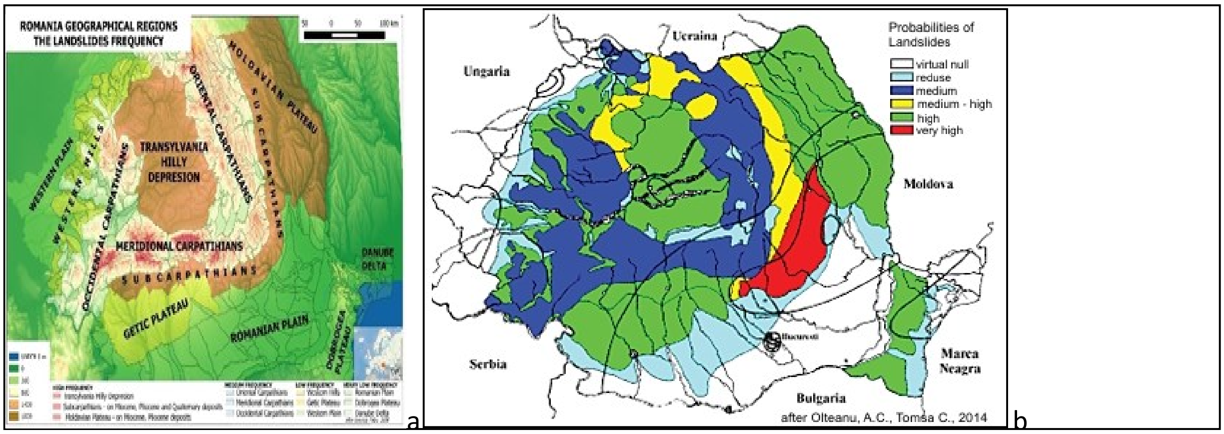


Fig 2. Geographic regionalization after landslide densitiesand frequency map (a) (modified Ielenicz, Patru, 2005) and probabilities of landslides in Romania map (b) (Olteanu, Tomsa, 2014)

The deep landslides are common in Transylvania Hilly Depression with regional name„glimee", triggered in Sarmatian and Pliocene deposits (layer, diapiror dome structure) and extending over large areas, with 5 – 6 km lengths and 2 - 4 km widths: Saschiz (6,15 $km^2$), Movile, Saes (15,50 $km^2$). In Moldovia Plateau region the landslides with a strong structural character have different shapes furrows, lenticular or sliding shaped in "nest", stepped in waves, mixed or complex, earthflow (Bacauanu, 1968).In the Eastern Carpathians flysch and Subcarpathiansa lithological variety of folded structure cause massive landslides, block slides and rockfalls. In the Subcarpathians the most common are linear slides and the earthflow or mudflow (Chirilesti) and furrows.

## The complementarity of methods in landslide science

Every applied methodcan bring new specific knowledge data, contributories at better research of the landslides, finally at better stabilization solutions. The multidisciplinary approach to solve problems connected with landslides is one of the most difficult but it is also the most suitable for planning a correct land use (Squarzoni et al., 2006).

## Remote Sensing and air-photogrammetric methods

Geographical and superficial geological data can be retrieved and processed with the help of aerial photographs, orthophotoplans, satellite images, regarding the landslides micro-morphology, morphological surface roughness, texture, soil moisture or deposits, by their reflectance, type, land cover and phenophases vegetation. Through GIS data about geographical viewed, the measurements and the interpretations geographical data(analyzed vector and raster type) generates new data (Mihai, 2007) that can be combined with surveying and mapping geomorphologic and geological investigations to identify aspects that characterize the slope slide system.

**Topographic measurements**

First base in geomorphologic and geological mapping is composed of topographic maps 1: 25,000 topographic plans or 1:10000 and 1:5000, but landslides are earth or rock mass that slide on slope, accordingly to the move mechanisms product that trigger or reactivate the morphological surfaces and topographical data of land no longer correspond to those recorded on maps and plans edited. Consequently, topographic survey are needed to identify the extent, distances that have moved some volume masses, scale vertical steps or movements of the waves, the relative altitude of micro-depression sliding or lakes slipping, sliding contour and configuration in general and specific sectors in detail.

**Geomorphic indices / parameters geomorphologic methods**

The important parameters analyzed in order to investigate landslides and the type of vulnerability for an efficient technical solution of landslides consequences are the hypsometry or the depth of the fragmentation / the vertical fragmentation of the landform, and slopes / geo-declivity, drainage density / horizontal fragmentation, the landform's curvature etc., which usually have high values in such cases; other geo-morphometric indices: aspect, analytical hill-shading; plan curvature; profile curvature; convergence index;wetness index; LS-factor;potential incoming solar radiation; terrain ruggedness index, etc.

*The vertical fragmentation* expresses the intensity or profundity that the linear or vertical erosion has reached, generated by the flowing water agent and is equivalent with the difference of altitude between the points from within a territory, situated in different positions one in relation to the other (unit of measurement: m/km$^2$).

Basically, this parameter highlights the limits from which the landform energy intervenes in the landform's breaking of the balance; to the same extent, it is responsible in relation to the lithostructural nature for the triggering and maintenance of the morphodynamics, and for the intensity of the geomorphological processes (Grigore, 1979).

*The slope / geo-declivity* is a geometrical notion pertaining to topographical surfaces and the parameter that quantitatively expresses the value of the angle created by the morphological surface with the horizontal axis of the place: it represents the potential factor upon which the genesis, dynamics and evolution of geomorphological processes all depends,[º, % or

‰). The relationship between density drainage, vertical fragmentation depth and geo-declivity projecting surface morphology, the last parameter is the potential factor of which depend triggering, dynamics and evolution of geomorphological processes (Grigore, 1979). Certain values of the slopes are considered as critical thresholds for certain processes, including the sliding type. In the above example can be remarked favoring sliding, Momaia, AG. , by the 7 - 20º range values slopes (Fig 3, b).

*Density drainage* parameter reveals the discontinuity degree of morphological surfaces, into horizontal plan, modeling as a result of external agents (Grigore, 1979). Horizontal fragmentation consists, in fact in alternating valleys and interfluves spaces, and its value can be calculated by total length of the river system per unit of measurement [km / km$^2$]

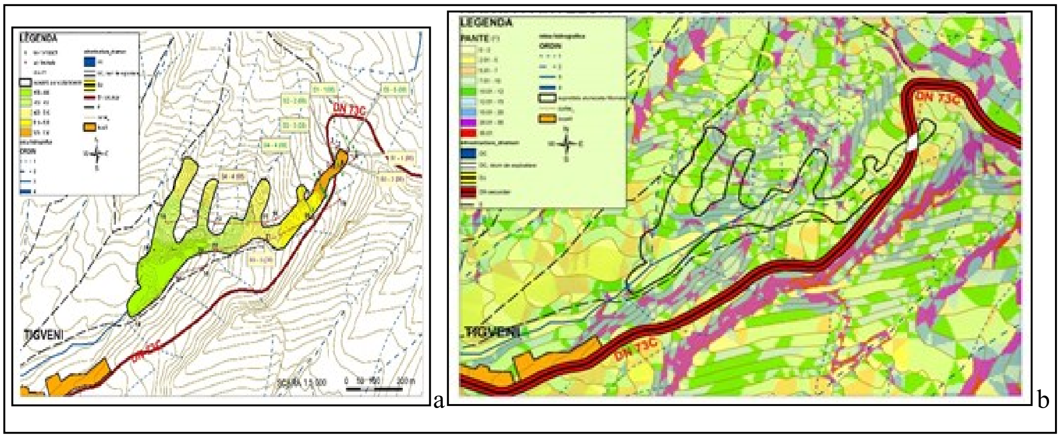



Fig 3. Hypsometry (a) and slope maps (b) of Momaia landslides (Andra, Mafteiu, 2007, 2008)

Geomorphological processes like landslides are in relationship with the degree of density drainage, being favored by its high values, while revealing dynamic intense hydrodynamic processes including them on the hydrogeological processes. Density drainage map may underliethe morphological surfaces forecasting with intense morphodynamics(fig 4.b). Geomorphological maps are transmitters of information about the form, origin, relative age and distribution of landforms together with their formative processes, rock type and surface materials (Brunsden et al., 1975). The geomorphological mappings are based on topographic maps of scale 1:25000, topographical plans of scale 1:10000 and orthophotoplans. They aimed to highlight the specific features of the landforms and their dynamics.

The geomorphologic mapping can be divided into the following stages:

a.Acquisition and pre-processing of maps: consulting and mapping landform features and processes based on topographic maps at 1:25 000 scale and 1:10 000, 1:5.000, 1:2000 scale plans or historical maps.

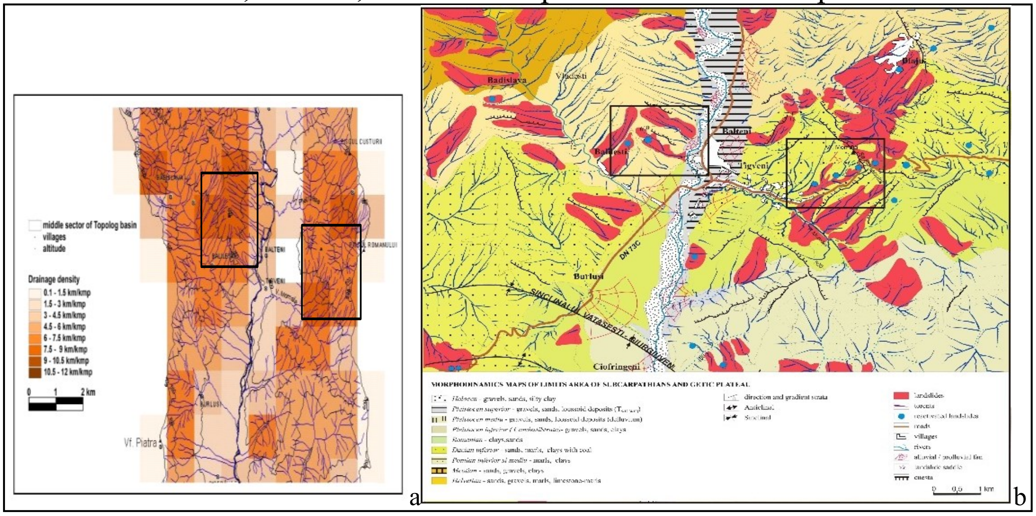



Fig.4.The relationship between drainage density, (a) (Andra, 2009) and the morphodynamic of slopeand density of landslides (map) of middle sector of Topolog basin (b) (Andra, Mafteiu, 2007)

b.Field investigation topo- and geomorphological survey, filling up of perception questionnaires about slides rockfalls and site degradation, morphodynamics monitoring, mapping of human impact.

c.From data interpretation, mapping the geomorphological attributes, processes and their evaluation will be made morphometrical, morphographical, superficial deposits and morphodynamical maps and also geomorphological cross sections (profiles).

d.The mentioned source data will be combined in an ArcGIS / QGIS, Saga GIS project, and interpretation data will be made in separate layers.

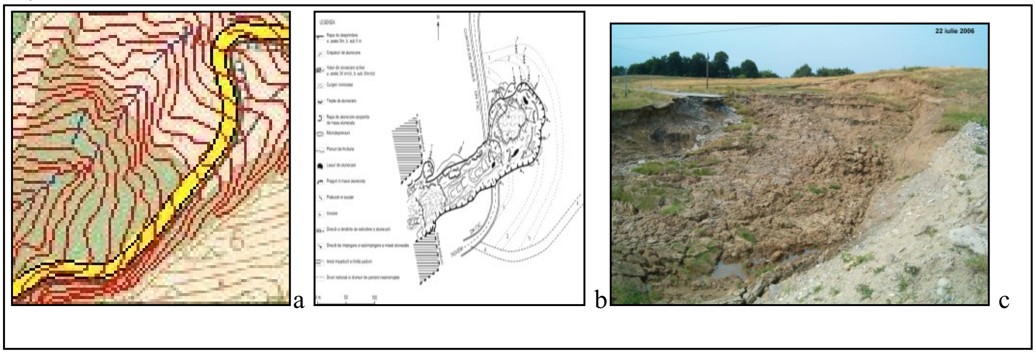



Fig.5 Topographical a) and geomorphological maps b) of a landslide upper sector from Subcarpathians, and foto c) (Andra, Mafteiu, 2007)

The results are one or more geomorphological map(s) that can be integrated with information from other disciplines (geological data and maps from historical studies, archeological surveys, social attributes and will be used for further vulnerability and hazard analyses). The gravitational and hydrodynamic processes on the slope (landslides, mudflow, earthflow,debrisflow, rockfalls) are generated as a result of the geomorphological conditions (of geo-declivity, fragmentation), geological, hydrogeological, bio-geographical (land cover, deforestation) meteorological. It should be notedthat the same processescan also beprepared andtriggereddue toanthropogenicintervention. The incidence of gravitational processes is wherever lithology imposes weak resistances to mechanical forces, either through the structure or physical properties of rocks, or through the degree of decay or moistening. Furthermore, the processes can also be triggered in superficial deposits and fillings. From this point, we are reminded again about the inherence of the anthropogenic intervention and impact on the morphological surfaces. The landslide processes have preliminary causes, largely natural, imposed by the lithostructural characteristics, the slope gradient, precipitations, lines of springs. To these, in most cases, we can also add the anthropogenic factors that fulfill the role of trigger factors for the landslides: water seepage, the raising of the ground water level, the absence of measures for the control and accumulation of water, traffic, the existence of overloads on the land (buried bodies like walls) which allow differentiated movements of the terrain (Andra, 2007). Geomorphological mapping consists in representation of landforms (their genesis, type, size, etc.) and processes in their spatiality and even identify their relative age, representing thus a cartographic document on which can make forecasts on morphodynamics.

**Meteorological contribution**

In Romania it was estimated that the overall trend is lowering (-10%) of the annual quantities of rainfall (1901-2010), with an increase in their intensity, due to an increase in mean annual temperature valuables in the decade from 2000 to 2010 with 0.4- 0.5ºC, over each decade from the period 1961-2010 (Sandu, 2013). Estimating climate change
predicted for 2021 – 2050, the average annual rainfall in Romania, reported the range 1961 - 2010 is – 20 %. In these hypothetical conditions, rainfall intensity will increase, because it induces the idea of possible reactivation or new triggers of mass movements in the comingyears. Annually, the most landslides occur in periods of maximum rain like springand also when the snow melts or in summer period during the rapid rainfall.More important is to identify the conditions of rainfall events thresholds responsible forlandslides (Mellilo et al., 2014)

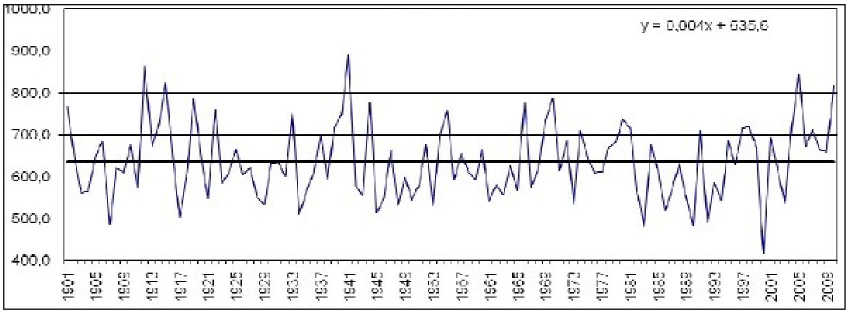



Fig. 6. Evolution of annual among rainfalls (mm) in Romania, 1901 – 2010 (Sandu, 2013)

## Bio-geographic aspects

The bio-geographic agent and so much more the anthropogenic one have favored the release of the process, taking into account the deforestation, so that the landslides mass intercept the whole quantity of fallen precipitations. On the other hand, the different land cover and constructions are favoring factors of triggering and reactivation of landslides. Superficial erosion is the first installed one after deforestation, and combine with linear erosion effects which prepares the slip. The role of research on the land-use and land-cover is to identify the coverage degree, different vegetation associations, degree of

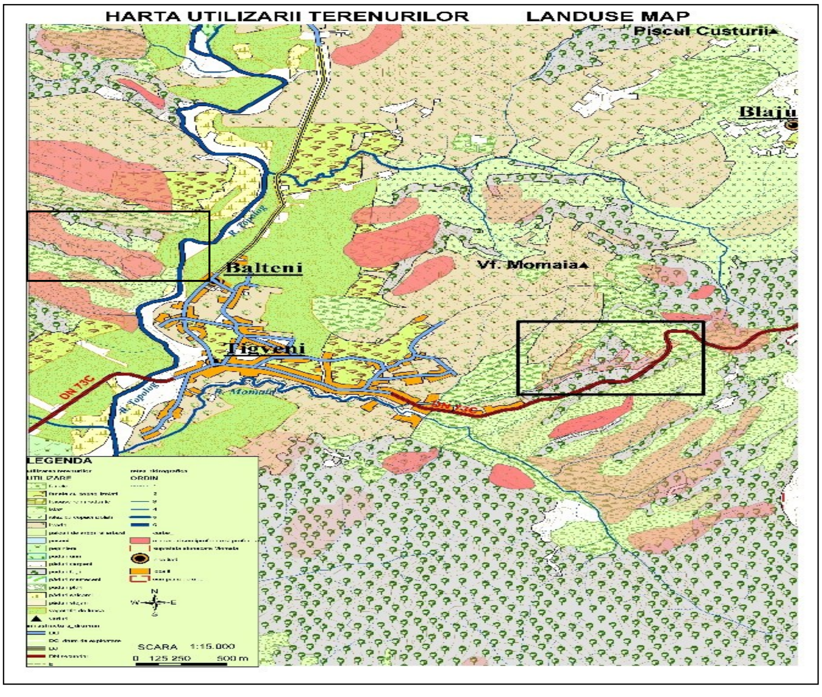
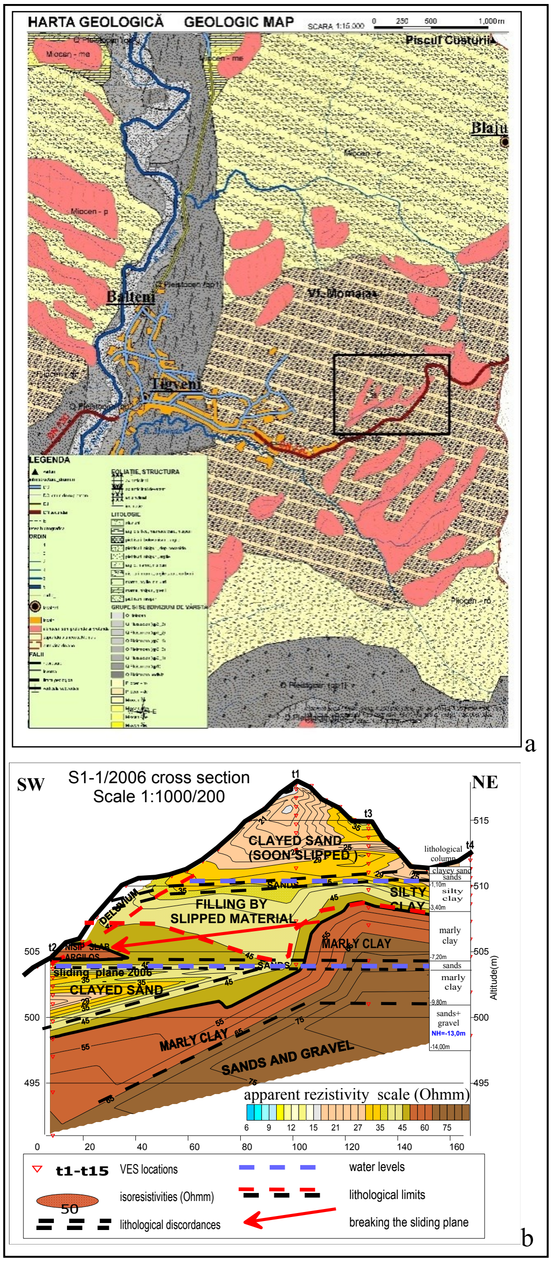



Fig.7. Land-use map and large landslides in contact area of GeticSubcarpathians and Getic Plateau (Andra, Mafteiu, 2008)

artificiality factor, type and surface area built. Such areas can be identified and potential production slips and any types of material damage in case of onset or reactivation.

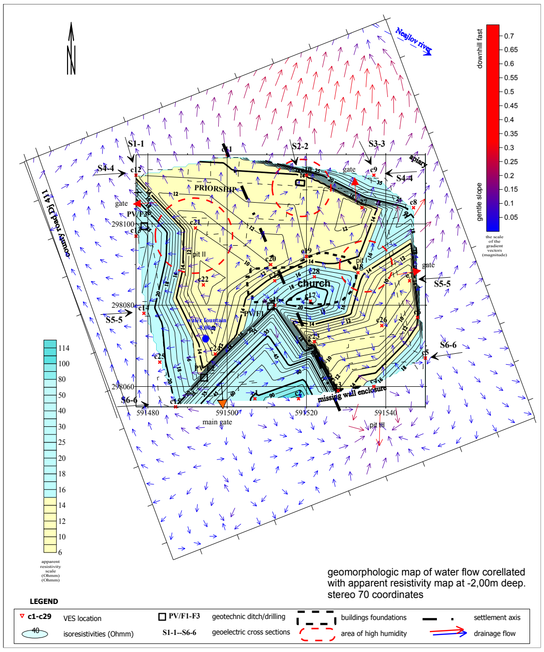
## 1.6.Geological methods and results




Geological settings, in surface and in depth reveal the lithological and structural peculiarity of landslides. Mapping rock strata, types of natural deposits and fillings, thickness and spatial variation, the method is interposed between morphological surface mapping and geotechnical data analysis and geophysical research.

The lithology causes in the same extend the type of slip and specific mechanisms of sliding. Lithological strata tilt is one factor that separates different categories of landslides or may accelerate the slide process.. Slips are consistent with the structure consistent lithology (Subcarpathians, Getic and Moldavia Plateau) tending to extend laterally along the line of springs.

Fig 8. Geological map and variation of landslides frequency, a) and break lithological strata and their consequences, b). (Andra, 2009, Andra-Toparceanu, Mafteiu, 2015)




Slips developed subsequent layer perpendicular to the surface and in conditions of favorable hydro-geological parameters they either can have a tendency to stretch and asymmetric upstream side or often can be reactivated in case of cracks lithology less resistant layers (Balteni) (Fig 8b.). The obsequent landslides develop on the heads of lithological strata and have more roughness morphology.

## 1.1. Hydro-geological parameters and methods

Groundwater levels, by their action manifested in various forms (infiltration, seepage, dissolution, capillarity or hydrodynamic - suffusion, hydraulic fracture) prepare and triggers, sometimes reactivate most landslides, especially in geographical units developed on sedimentary rocks. Thus, for non-cohesive sedimentary rocks, their action is manifested by variation of pore water pressure, pressure filtration, suffusion process, modification of physical and mechanical properties, reducing pore water mineralization and nefarious raising their level. (Florea, 1978), or even liquefaction. Mapping springs, groundwater levels and vacuum

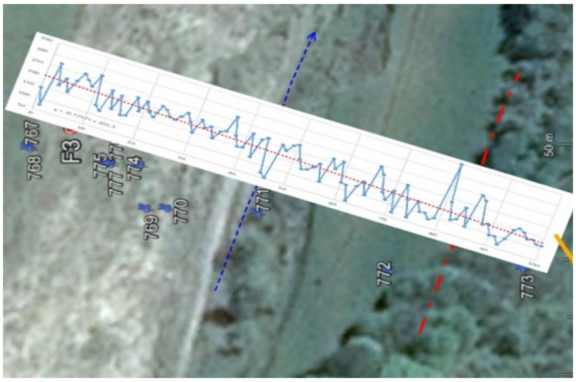
Fig.9.The infiltration direction of the groundwater flow, indicated by arrows are based on results of detailed topographic measurements, hydrogeological and geophysical survey (Andra, Mafteiu, 2009, 2014).

free level of overload conditions, execution of boreholes and installation of measuring instruments even identify groundwater flow gradients can be major survey hydro-geological practices and methods. Because hydro-geological measurements are local or pointed, hydro-geological methods efficiently combine with geophysical methods

## 1.2. Geophysical methods and their relevance

Geophysical methods are increasingly being applied to geotechnical investigations in landslides research, as they can identify material properties and their boundaries, as well as variations in space and time of relatively large volumes of soil. Another advantage is that many of these methods are non-intrusive. The combination of several methods and the verification of their results by sampling and correlating with geotechnical methods are advisable in order to improve the reliability of geophysical investigations. In this case are commonly used the following geophysical methods; combined resistivity and time domain induced polarization (IP) two-dimensional imaging (CVES), seismic refraction plus multi-channel analysis of surface waves (MASW).(Parrales, 2003)

Sliding mass has different physical and mechanical properties of the bedrock in which, the nature, the resistance, the relationship moisture - plasticity, the degree of fissuring, etc. Highlighting these differences through different methods is an important way for understanding and tracking landslides. Geophysical measurements can outline the area with landslides and cause mass thickness and shape of the plane sliding slip. Useful results on the thickness of the aquifer, groundwater flow direction, coefficient and rate of filtration, humidity variation in mass sliding, slipping and changes the dynamic elastic properties of rocks near the sliding plane can be obtained also by geophysical methods (Radulescu, 2008).




*negative anomalies = water infiltration; positive anomalies = water accumulation zone; - - >drainage channel; . fault*

Fig.10.Self-potential effect of water movement in a landslide, Balteni, Subcarpathians, (Andra-Toparceanu et al. 2015)

Using also *IP and seismic measurements* one and two dimensional shear wave velocities profiles can be efficiently estimated by this method. These data are useful for landslide hazards analysis in terms of ground response prediction at ground surface and soil column. Two seismic methods could be applied, seismic refraction and the multi channel analysis of surface waves (MASW) method. These tests are performed exactly over the same line where resistivity profiling is carried out. A 24-channel Geode seismograph with 4.5 Hz - geophones is used. The effect of water movement appears also in Self-potential measurements, from source (negative anomalies) to the accumulation zone (positive anomalies). Ex. Balteni self-potential profile, where is the accumulation of the water towards the fault from SV.

### 1.3. Geotechnical methods

Geotechnical mapping of landslides is done for determination of its elements, in order to gather the necessary information in order to take measures to stabilization.

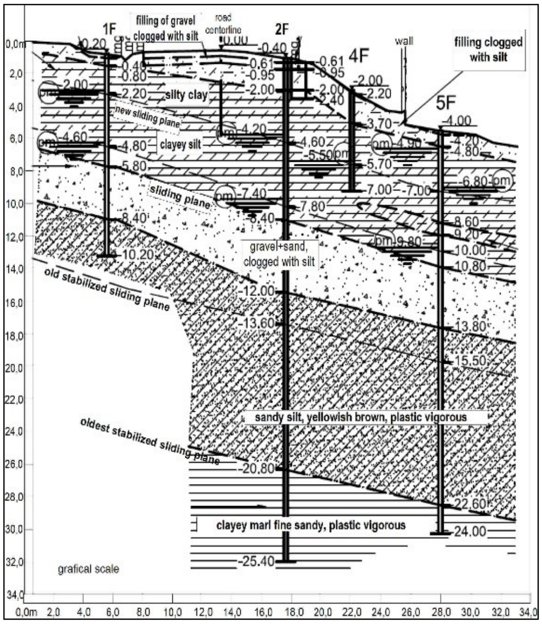



Fig. 11. Geotechnical cross-section on landslide (national road DN 10) (1F – 5F = drills)

Mapping is done through both representation on the map of mudslides and knowing all that is generate (geological formations present, lithology, tectonics, groundwater, etc.) and provides information (front of detachment, sliding terrace, sliding table, the presence of cracks, the edges of the base and sliding, sliding) on their (Florea, 1978). If in the area are numerous outcrops, the following can be solved: estimating depth of surface slip, deciphering regional and local distribution of the sliding, the database valuable insights into setting of exposure and erosion of slip processe, establishing the causes of landslides, estimate the degree of rock alteration and alteration possibility etc.

If mapping for knowledge is made usually from sliding scales 1:10.000 or 1:5.000, measures to stabilize the sliding must benefit from a mapping at scales 1:2.000 scale 1:500 or 1:100.Geotechnical boreholes with continuous coring allow the interception of instability surfaces, water tables, faults, fissures, friction planes etc. Disturbed and undisturbed samples are taken from the boreholes for laboratory analyses. Based on data obtained from the investigation program (boreholes and field observations) and laboratory results will be realized geological – technical profiles with drawing of potential surfaces of failure (see figure.11). Based on these and making use of geotechnical parameters there are performed the stability calculus. The final result of a geotechnical research is represented by the assessment of factors that led to instability phenomena together with recommendations and design of some appropriate solutions to stabilize the affected area.

## Discussions

The interdisciplinary research of landslides is imposed by heterogeneous properties (geological, hydro=geological, geo=morphological and bio-pedo-geographical) of this system. Therefore, we believe that each method adds information about morpho-dynamic system and it is essential to use specific results of each scientific field in the context of implementation of the other.

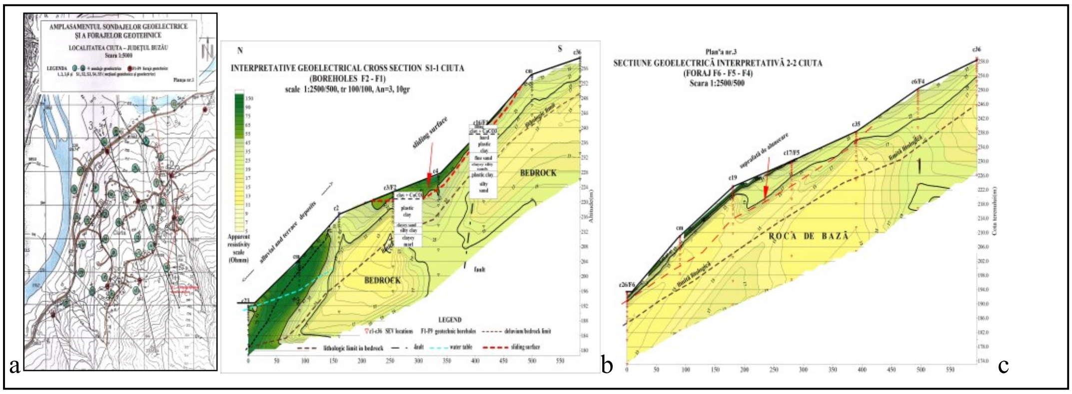
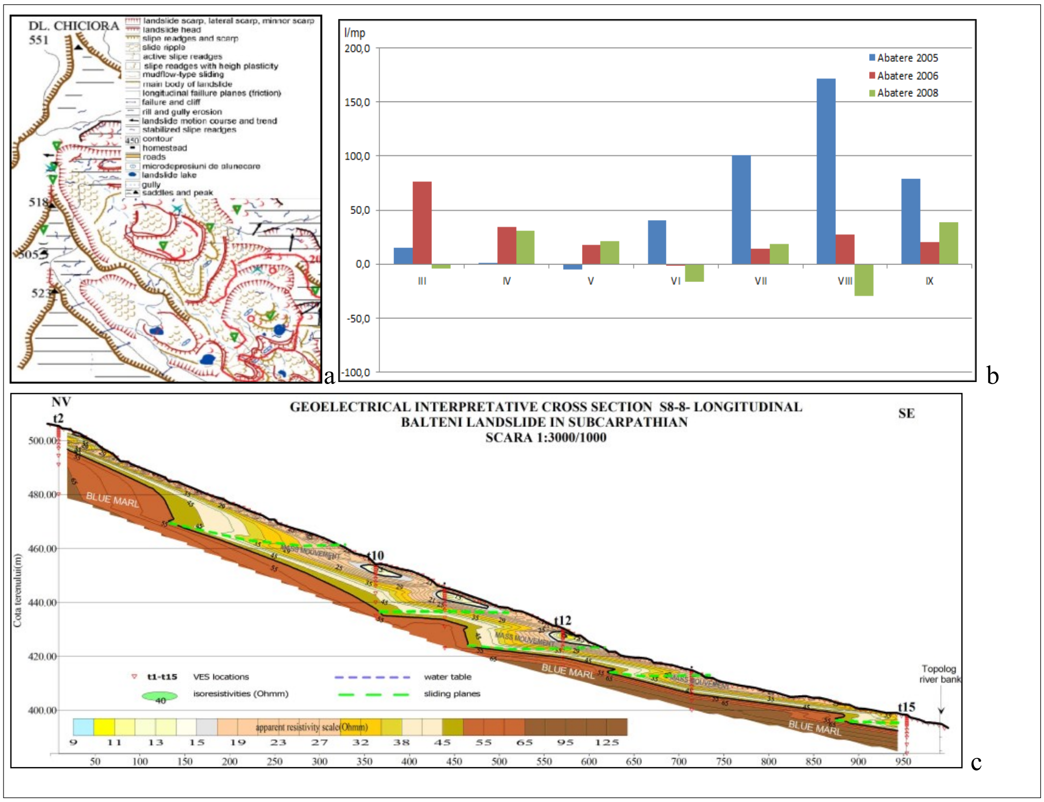



Fig.12 Topographical plan a) and geophysical cross section set on topographical profile b)and geophysical cross section set on geo-morphological direction c), Ciuta landslide

Technical measures for land rehabilitation, to repair roads damaged by landslides or other types of construction must take into account the geographical and geological information regarding landslides, but also the surrounding area. Using different methods (in the case bellow geophysics, geotechnical and topographical) generates at first view relevant results for a landslide (Ciuta landslide), but finds a more thorough analysis that went topographical profile of a secondary interfluve and broke into another slip (so profile indicates two systems of sliding and not just one). Revealing morphology imposed by the slide process, showing its boundaries and its dynamics sectors is thus required, using geo-morphological profiles (and geo=morphological maps) showing the landslide micro=morphology imposed by the manifestation and evolution process to achieve of geophysical cross-sections, geological and geotechnical profiles. In case the geological data, geophysical and geotechnical with the topographical, geo-morphological, climatic, aerial survey, bio-geographic are concomitant imbricated, the landslides are usually well understood. However, there may be some issues that cannot be understood only by aplying certain methods.

Fig.13. Interdisciplinary research for a landslide from Sub-Carpathians: a) from topographical measurements, remote sensing and mapping, result a very detailed geo-morphological map; b) statistic rainfall data, c) geophysical and geotechnical profiles(Andra-Toparceanu et al. 2015)




For example, a landslides monitored since 2006 slipping relatively independent of rainfall variation, even that other factors remain somewhat constant. Detailed morphology of landslide and adjacent areas showed morphological aspects (rupture of slope erosion witnesses, small saddles) which determined the need of SP survey (Fig. 10, 13). The results of these measurements revealed local faults in bedrock sliding and on sliding limit, which have an important role in the circulation of groundwater and springs.

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## Conclusion

The landslide, being on very complex process, its survey implies the using of many scientific disciplines. The multidisciplinary approach to solve

problems connected with landslides is one of the most difficult but it is also the most suitable for planning a correct land use.
The need for interdisciplinary approach results from many cases in which they were less durable improvement on exposed slopes of sliding, in conditions which were investigated only a few aspects of land or the environment. Every applied and analyzed method **(**remote sensing and air-photogrammetric, topographic, geomorphologic, meteorological, bio-geographic, geological, hydro-geological, geophysical, geotechnical**)** can bring new specific knowledge data, contributories at better research of the landslides, finally at better stabilization solutions.

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