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Landslide hazard zoning at regional level – Vâlcea County case study

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Abstract. In recent years the severity of the extreme meteorological phenomena significantly increased, i.e. heavy rains which led to historical floods on the most part of the hydrographical basins of Romania, mostly during 2005 and 2010. These abnormal meteorological phenomena reactivated a great number of landslides. Therefore, risk managers, in order to urge the landslide inventory at the whole country level, launched hazard maps in terms of Law no 575/2001 regarding the "Plan of the national territory development, the Fifth section – Areas of natural hazards". This means risk maps of Romania for areas prone to natural hazards (floods, landslides and earthquakes), as well as the exact geographical and administrative localization of these areas, including the indication of the risk level of producing the specific hazards. The present paper presents the methodology of hazard zoning at the local and regional level, including the parameters used to draw down the thematic maps for inventory and representation of the active landslide for the whole territory. As a case study area, Vâlcea County was chosen for the large number of damages due to the landslide effects. Of them, the Ocnele Mari case is noteworthy as a natural reservation of diapire salts massifs, affected by collapse due to salt dissolution by runoff water and overexploitation by water injection.
Key words: landslide, hazards, Vâlcea County.

Rezumat. În ultimii ani, recrudescenţa fenomenelor meteorologice periculoase s-a agravat simţitor, de exemplu precipitaţiile abundente care au determinat inundaţii istorice afectând cea mai mare parte a bazinelor hidrografice din România, în special între 2005 şi 2010. Aceste fenomene meteorologice anormale au reactivat un număr crescut de alunecări de teren. De aceea este necesar, ca personalul de specialitate implicat în activităţi de urgenţă, sa urgenteze inventarierea alunecărilor de teren la nivelul întregii tări, pe suport cartografic, corespunzator specificaţiilor Legii nr. 575/2001, în ceea ce priveşte "Planul de amenajare a teritoriului naţional, secţiunea a V-a, de risc natural". Acestea se referă la necesarul de întocmire de hărţi pentru zonele vulnerabile la hazarde naturale (inundaţii, alunecări şi cutremure), precum localizarea exactă geografică şi administrativă a acestor zone, incluzând indicarea nivelului de risc de producere a hazardului specificat. Lucrarea de faţă prezintă metodologia de zonare a hazardului la nivel local şi regional, incluzând indicatorii utilizaţi pentru întocmirea de hărţi tematice pentru inventarierea şi reprezentarea alunecărilor active la nivelul întregului teritoriu naţional. Ca studiu de caz a fost analizat Judeţul Vâlcea, pentru valoarea crescută a pagubelor produse de efectul alunecărilor de teren. Între cazurile analizate, zona Ocnele Mari se distinge datorită statutului particular de rezervaţie naturală de masive diapire de sare, afectată de sufoziune, datorată dizolvării de catre apa de suprafată meteorică şi de către exploatarea saramurii prin injecţie de apă necontrolată în subteran.
Cuvinte cheie: alunecări de teren, hazarde, judeţul Vâlcea.

Introduction. The spreading of landslides in Romania with severe damages as a result of frequent reactivation due to related geo-hazards factors, i.e. meteorological, hydrological etc. induced the increasing concern of specialists and risk managers on both local and central scale.

A brief assessment of this kind shows that the ground affected by active landslides in Romania covers a surface of 115,000 ha (Balteanu 1999).

The stability of the land depends on permanent and sporadic factors, which influence the development of the landslides. The permanent factors are represented by general geological and geomorphologic conditions. The sporadic factors are represented by the local conditions of landforms, climatic, hydrologic, seismic, forestry, and anthropogenic type.

In Romania, the landslides and other types of land movement or block fallings are connected particularly to slope rock composition and linked to climatic regime. The most frequent types of landslides are associated with the network of erosion of subjacent rock material, and the mudflows with the surface erosion on an advance stage.

Landslide mapping situation in Romania. So far landslide mapping for the Romanian territory has been conducted on small areas, for important objectives and only in the case when the landslide took place in different stages of evolution. The Law no. 575/2001 imposes elaboration of landslide hazard maps in digital format to cover the whole Romanian territory. This program is in the initial phase of development and such maps issued since the beginning of 2004.

The Law regarding the "Plan of the national territory development", the Fifth section – Areas of natural risks" (no. 575/2001) deals with "risk zones", and includes the presentation of the zones prone to floods, landslides and earthquakes. Accordingly it created the legislative frame for the delimitation of the areas prone to natural risks, for prevention and mitigation of the effects, which are produced by the destructive natural phenomenon, like landslides, earthquakes and floods (Official Journal 2001).

Based on the common Order of Ministry of Agriculture, Forests, Waters and Environment and Ministry of Transportation, Constructions and Tourism regarding the delimitation of the areas prone to natural risks (no. 62/N-19.0/288-1.955/1998), flooding risk areas from Romania are established in terms on rivers and torrents overflowing and land sliding and upon lessons learnt from previous disasters (Official Journal 1998).

The General Urban Planning (PUG's), which is managed by local authorities, have to indicate specific areas exposed to natural risks, such us floods, landslides and earthquakes, wherein is forbidden to build, excepting the works that limit the effects of a potential natural disaster. Mainly due to high impact, the landslide maps are very important for the accuracy of scientific research, regarding prevention measures for stopping the solid material removal or the reactivation potential, which provide in turn protective measures for the stakeholders interested in the safety of their units and facilities.

According with the Law of Cadastre, no. 7/1996 (completed in 2004 by Governmental Emergency Order no. 41) the public can consult the specialized cadastre maps (such us for landslides hazard) excepting the case of strategic units. Of course, general information is made public to inform population about hazards existence in their living area.

Regarding the representation of the landslide maps, the level of hazard may be rated qualitatively, for at least three different levels (low, medium and high):

- Phase 1 – qualitative – maps of landslide hazards at scales 1:50.000 ÷ 1:10.000
- Phase 2 – detailed maps of landslides hazard, in areas of high probability of occurrence of landslides in the presence of vulnerable elements that would allow to estimate the risk; scales: 1:5000 ÷ 1:1000 (Fig. 2).

It has to be specified that in the Urban and Territorial Planning Plans, managed by the local authorities, the information regarding the natural hazards are represented in detail at scales between 1:5,000 and 1:500, depending on the size of the locality. Taking into account that natural hazards have generally a regional extension, an approach at the level of the county, which contains the all data from the local level is imposed.

- Phase 3 - in the emergency and response Plans of the Civil Protection/Emergency Situations, in case of disasters, at the county level, maps at the scales 1:25,000 and 1:50,000 are to be used. For representations at the national level, maps at scales 1:1,000,000, 1:500,000 and 1:200,000 are used. Those scales are chosen according to the surface of Romania, which is 238,000 square km (Fig. 1a).

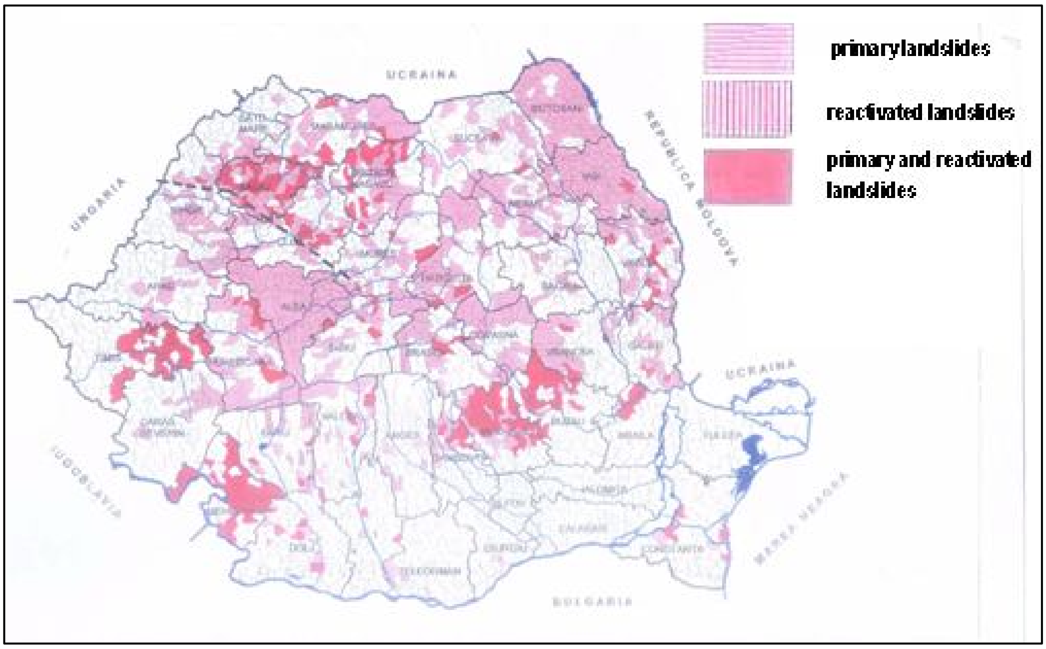

Figure 1a. Landslide types zoning at the administrative level in Romania.

In terms of projects implemented or under implementation, maps expressing zoning the natural risk (floods, severe storms, earthquakes, landslides, forest fires) and technological hazards (industrial accidents, transportation of dangerous goods, contaminated lands) are priority targets. They have to meet the EU request regarding disaster prevention, combating and mitigation at national and trans-boundary level.

Romanian methodology for landslide representation. The quantification of risk associated landslides requires the use of a unified system of procedure, for better correlation of the characteristics of varied locations and their potential hazards. In order to manage such risks the local and regional administration has to assure proper socio-economic activity, implementing adequate measures to reduce the risks of an accident. The nature of required assessment will vary, based on the degree of potential risk and their potential environmental impact. A useful tool for local and regional administration must be the use of a common methodology based on quantification of the risk components, with a specific standard system of criteria, indices, and notes.

Risk is defined as the probability of an event multiplied by an evaluation of the adverse consequences if such an event occurs (vulnerability):

$$\text{Risk} = \text{Probability x Vulnerability}$$

The Risk values could be substituted by an averaged hazard coefficient for landslides, based on a matrix evaluation, as follows:

$$K(m) = \sqrt{\frac{\mathrm{K(a)} \times \mathrm{K(b)}}{6} \times [\mathrm{K(c)} + \mathrm{K(d)} + \mathrm{K(e)} + \mathrm{K(f)} + \mathrm{K(g)} + \mathrm{K(h)}]}$$

Where the Ka-h indexes are described in Table no. 1 for the vulnerability map (Fig. 1b).

Table 1

Landslide risk evaluation criteria for the Romanian territory

No. crt.	*symbol*	*Classification criteria*	*Landslide potential (p)*					
			low		*Medium*		*Increased*	
			Landslide potential (p) and correspondent risk coefficient					
			zero	*reduced*	*medium*	*medium-high*	*high*	*very high*
			0	*<0.10*	*0.10-0.30*	*0.31-0.50*	*0.51-0.80*	*>0.80*
1	**Ka**	Lythologic	Massive rocks, compact or fissured.		The majority of the sedimentary rocks which belongs to recent cover formations (i.e. delluvium, colluvium and prolluvium deposits) and soft/altered bedrocks semi-rocks category (stratified pelitic rocks, clay schists, marls and limestones, altered epizonal schists and/or igneous rocks.		Not lithfied detrital sediments, i.e. saturated and soft clays, montmorillonite clays, dusts and fine-medium size sands, salt breccia etc.	
2	**Kb**	Geomorpho-logic	Horizontal relief plan, affected by incipient erosion, mature valleys of the hydrographical network.		Hills associated with piedmont and plateau areas, fragmented by hydrographical networks with advanced evolution stage, surrounded by versants with medium elevation and low to medium slopes.		Relief characteristic of hill and mountains area, highly affected by recent valleys with high versants parallel with the layering.	
3	**Kc**	Structural	Massive bodies of igneous origins, horizontally stratified sedimentary rocks, metamorphic rocks with horizontal schistosity.		Main geological structures are folded, faulted and fissured; salt piercing domes; front of thrust nappes.		Geo-synclines with flysch formations and marginal depressions with molasses; Strongly deformed structures, i.e. faulted, folded, traversed by fissure stockwork.	
4	**Kd**	Hydrologic and climatic	Arid areas, with reduced annual precipitations. The flow discharged on the hills and mountains river		Medium precipitation. The main hydrograhic networks reached the maturity stage whereas their tributaries are still in incipient evolution		Calm long lasting precipitation, with increased probabilities of water infiltration through rocks. During showers runoff increases with	

			beds are generally controlled by precipitation from these areas. Sedimentation on river beds whereas lateral erosions restricted to high-floods events.	stage. During the high-floods both vertical and lateral erosion occur. Significant transportation and deposition of solid debris.	transportation of solid material. Vertical erosion prevails.
5	**Ke**	Hydro-geology	Flow of the ground water at very low gradients. The filtration forces are negligible. The hydrostatical level of the ground water is at the relatively high deep.	Flow of the groundwater takes place at moderate gradients. The filtration forces could influence the versants stability. The hydrostatical level of the ground water is less than 5 m deep.	Flow of the groundwater takes place at high gradients. Frequent springs occur at the base of the versants. The filtration forces could produce versants instability and triggering of landslides.
6	**Kf**	Seismic characteristics	Seismic intensity of MSK scale lower than 6.	Seismic intensity of MSK scale between 6-7.	Seismic intensity of MSK scale greater than 7.
7	**Kg**	Forestry	Degree of covering with forest more than 80%. Deciduous forests with large trees.	Degree of covering between 20% ÷80%. Mixed conifer and deciduous forests with trees of various size and age.	Degree of covering with forest less than 80%.
8	**Kh**	Human impact (anthropogenic)	No major buildings on slopes and artificial water reservoirs on slopes.	Construction works (roads and railways, tunnels, quarries) of limited extension with protective works of the versants are found on the slopes.	Versants affected by dense water and sewage pipelines, roads, railways, tunnels, quarries, overloaded by waste dumps, heavy constructions. The accumulation lakes are present, moistening the lower part of the slope.

While the probability of the disaster in generally known, the potential consequences of a disaster can be difficult to quantify and this involves many unknown factors. Therefore, special attention has to be given to assessing vulnerability.

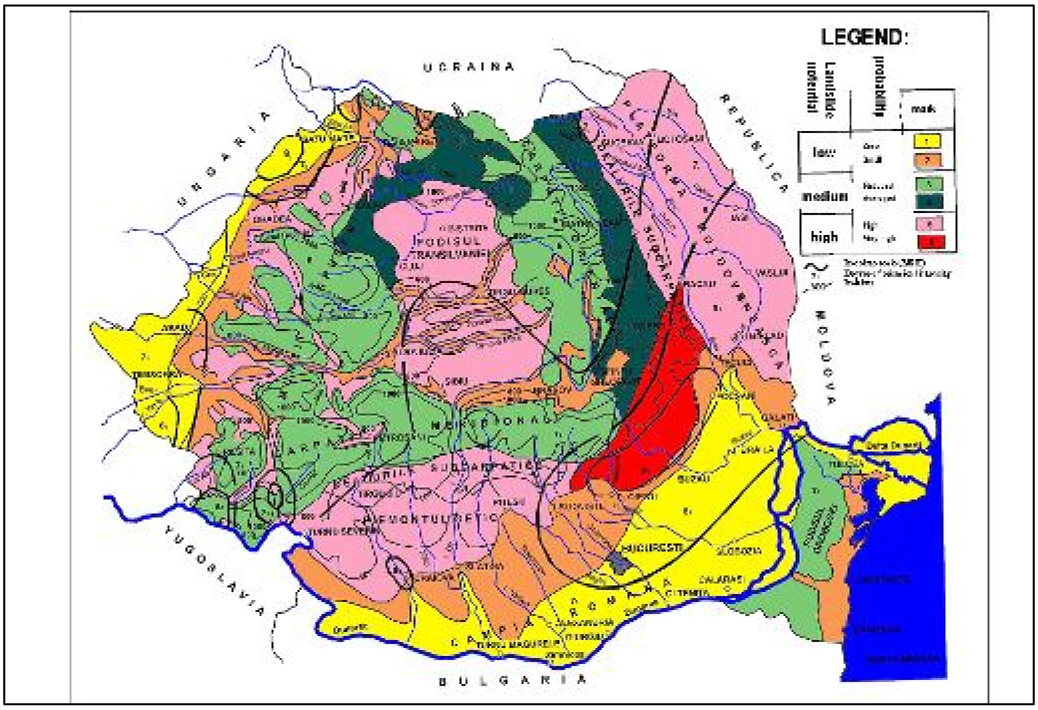

Figure 1b. Territorial micro-zoning of the landslide risk in Romania.

Natural hazards that could affect earth stability (such as floods, earthquake, landslides, and freeze-thaw) can be compared at the national level (see Table no. 1). This approach can lead to establish a priority of needs and measures to be used by local or national authorities involved in natural or anthropogenic risk management. In addition, GIS maps may expose the potential adverse effects of landslides which can trigger multiple-disasters (NATECH – technological disasters triggered by natural causes). So far, this type of disaster has been scarcely investigated in Romania. Even the use of multiple-hazard recognition is relatively recent in Romania, representing a new trend of research, with significant applied implications.

Landslide hazard occurrences in the Vâlcea County. Vâlcea County is one of the most affected counties in the county, by actual dinamic geological effects, especially landslides (Mesescu et al 2009) (Fig. 2).

Atlhough the number of the cities and villages, affected by landslides are not so numerous than other counties, even as a extention of the landslides affecting individual villages, the degraded surfaces are larger, with profound social-economical implications. Economical development of the county industry during the last decades, led to a severe impact on the landscape, regardless the land stability. The affected landscape can be visualised especially in the urban aggregates, where the sewage and rainwater collection network is not enough developed, coupled with the extension of the roads and rail roads network of the coal and salt mining in the region (e.g. Berbeşti, Ocnele Mari). These industrialized areas were affected by large amount of soil excavations, as well as deforestation and hydro-energetic/power plant developments on Olt river (water reservoirs), and represent anthropic factors triggering the natural hazard, especially landslides (Petrescu et al 2008) (Fig. 3).

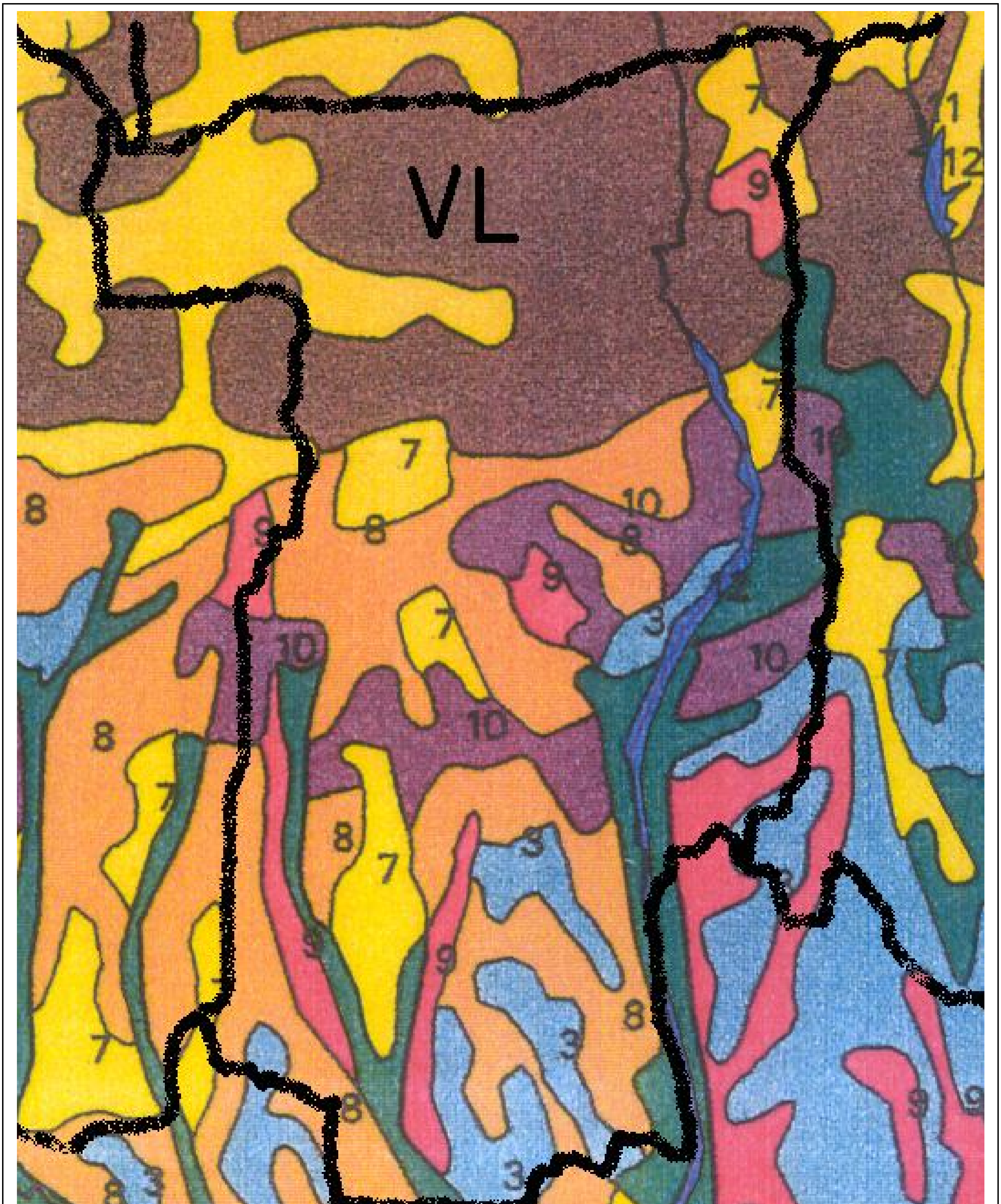

Figure 2. Micro-zoning of the landslide risk in Vâlcea (VL) County.

Legend:

Lands practically flat, horizontal (the slope lower than 8 %) unaffected by erosion by water and landslides; are possible other processes and risk factors.

2 - Relatively stable lands, but with variable risk of flooding and sediment settling.

3 - Relatively stable lands, but with risk of excessive humidification because of water stagnation because of reduced soil (areas with pseudo-glazed soils) on the piedmont planes lands and terraces.

Lands inclined (the slope between 8÷30%) from hilly and plateau areas, affected in different ranges by erosion, and different risk of erosion by waters and landslides.

7 - Relatively stable lands, with unspecified or light-moderate erosion with reduced risk of landslides, but with increased risk of increasing erosion.

8 - Moderately stable lands, affected by moderate - excessive erosion, with relatively old landslides, more or less stabilized, but increased risk of reactivation during rainy periods, or by changing the land development (deforestation, agricultural works) or activities leading to slope destabilization by terracing, or exceeding loading with heavy constructions (buildings roads).

9 – Very low stable lands, affected by excessive erosion, associated with gullies and active landslides; Are present torrential organisms or situations with humidity excess, caused by shallow ground water table and slope springs.

Lands abruptly inclined (the slope higher than 15%) predominantly covered by natural vegetation (forests) generally unaffected or slightly affected by erosion processes and landslides and collapses.

10 – Relatively unstable lands, with increased risk of landslide, crumbling, collapsing (mountain areas of flisch, internal or external sub-Carpathian area), affected by excessive erosion, and associated by gullies and active landslides; strongly fragmented piedmont planes lands and plateaus.

11 - Relatively stable lands, but with local rocks and stones fallings phenomena (specific for crystalline rock areas, volcanic rocks, consolidated sedimentary rocks – limestone, sandstones, conglomerates).

12 - water bodies.

Figure 3. The landslide occurrence affecting surface infrastructure, power lines and roads, example of the Lăpuşata commune (6 November 2004), Vâlcea County.

Extensive salt mining represents another factor of risk, due to over-exploitation. Ocnele Mari case is noteworthy as a natural reservation of Miocene diapire salts massifs, affected by collapse due to salt dissolution by runoff water and intensive water injection (Petrescu et al 2008; Mesescu et al 2009) (Fig. 4).

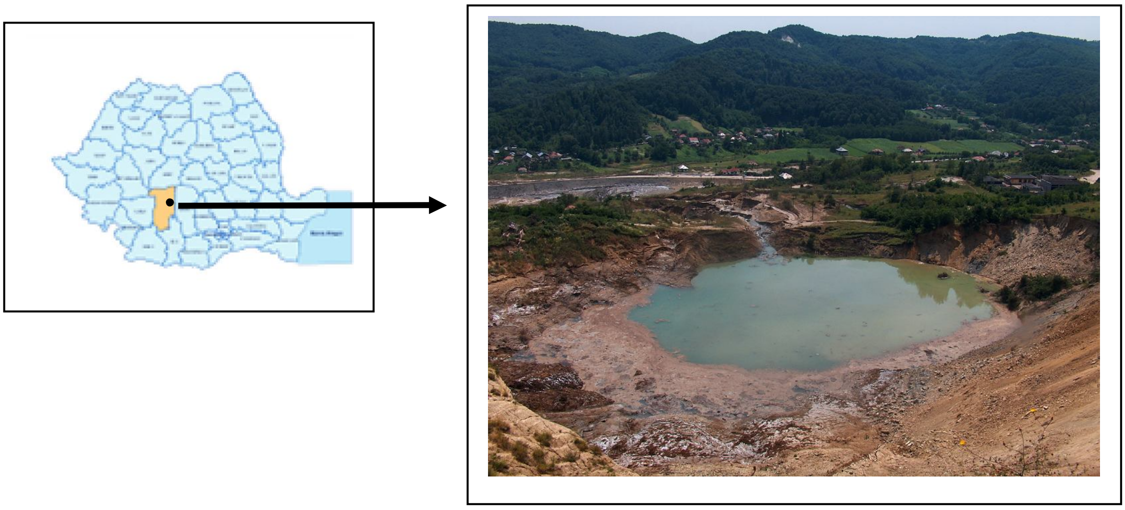

Figure 4. Location of the Ocnele Mari landslide caused by salt mining by water injection - Vâlcea County.

Mitigation measures of the landslides in Vâlcea County. In order to prevent and mitigate the effects of natural disasters, such as landslides and floods, measures to minimize the socio-economic impact are to be taken and have to include:

- Delimitation of all the areas where building is prohibited, in the documentation of urbanism and planning (cf. PUG above, Fig 5);

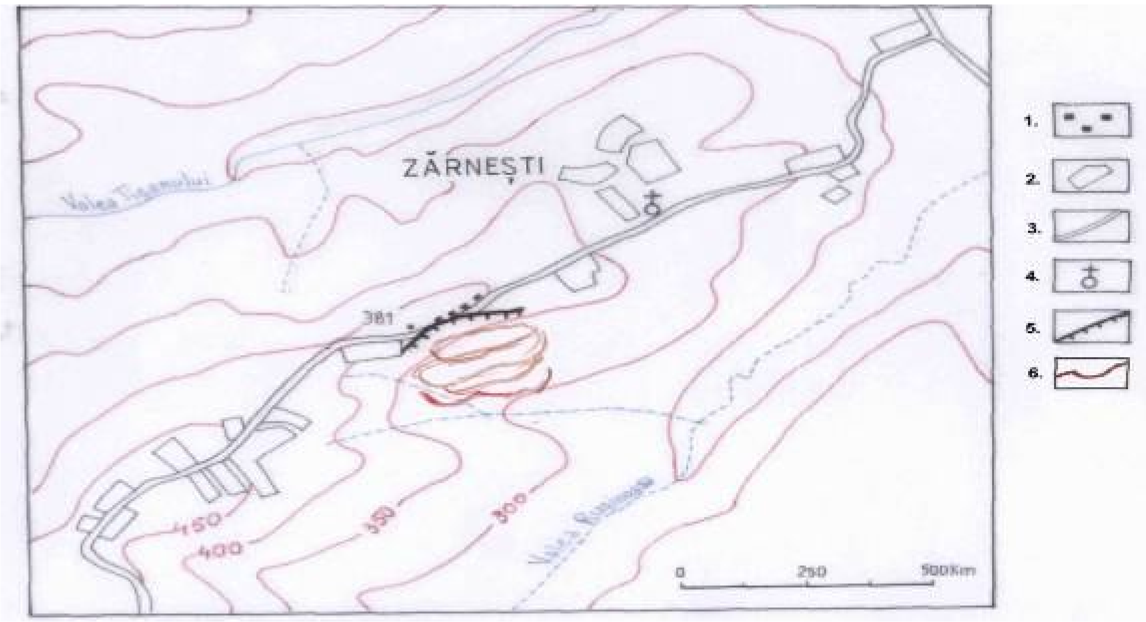

Figure 5. Schematic landslide representation used by emergency services – case of Lăpuşata commune – Zărneşti village – Vâlcea County, 6 November 2004; 1. affected households; 2. village; 3. communal road; 4. church; 5. rupture zone; 6. landslide body.

- Obligation to conduct geological surveys, including laboratory and in situ geotechnical tests, in order to know the properties of the soil and bedrock of the populated areas and those with a socio-economic activity;
- Implementation of special building rules, which have to take into account the existence of natural hazards in the area (Balteanu 1979);

Measures for prevention and reduction of natural risks have also to be implemented. They have to consist of the following:
- Maintenance of the facilities for protection and mitigation of natural disasters;
- Control of the degree of land occupation and the completion of the specific land use and building plans;
- Information of the population regarding the potential risks specific to their respective inhabited area;
- Systematic forecast of heavy rains since intense rainfall is one of the major landslide triggering and reactivation factors.

The main non structural measures in prevention the landslides, are the following:
- the promotion of the field studies, based on laboratory research;
- an improved knowledge of the real situation from the point of view of stability and the characteristics of the usual ground parameters in the areas where it is intended to design and execute any type of works.

These can lead to a reduction of the landslides occurrence, and minimization of the material damages and avoidance of human losses (Mara et al 2003).

It has to be specified that in Romania, the technical coordination of the activity for the protection against the disasters related to the water factor, is accomplished by the National Water Administration A.N-A.R, through directions organized by hydrographical basins, based on the operation. At the level of a hydrographical basin, are used guidelines in case of floods and based of the Defense Plans against the floods and ice blockages. The total length of the watercourses managed by A.N-A.R is approximately 78,905 km, which are included in the Protection Plans against the floods and ice blockages.

Indemnity issues of the affected peoples by landslides. Generally, any damage assessment is made in order to ensure compensation to the affected persons (and according with the law of the National System of Emergency Situations, the main aim of the defence activity after a disaster took place is to diminish the effects and to recover the damages). It has to be specified that the insurance companies had so far a weak involvement in the activities for preventing and reducing the effects produced by the landslides in high risk areas in Romania. The insurance companies were not unwilled to insure goods and properties located in landslides-prone areas. The only financial resources for minimizing the damages caused by the landslide and/or floods were the funds allocated by the State budget and external credits. Recently, in 2005, the Government took the initiative to launch a project of a normative act for the Obligatory Insurance of properties against natural disasters (including landslides) and fires. The new law of Obligatory Insurance entered in force during 2010.

A well known example of landslide damages covered by the State Budget is the case of Panga Nord coal mining tailing waste deposit landslide, which affected on 9.02.2007, the village Mateeşti, covering several houses without insurance coverage (Fig. 6). This way the acute problem of indemnity for affected people by floods, earthquakes and landslides will be solved.

Figure 6. A faster recovery of the landslide affected areas is possible upon insurance – example of the Panga Nord coal mining tailing waste deposit landslide, Vâlcea County.

Prevention measures for minimizing the landslide vulnerability. Due to increasing risk of extreme meteorological events recorded all over the world in connection with climatic variations of the last decade, increased risks stemming from geo-hazards have been occurring in Romania, on particular settings that combine slope elements and subjacent geology of specific areas (Mara et al 2003). Therefore it is possible that some areas will become more prone to landslides, for instance where slopes are covered by porous soil and rocks and falling rain can saturate it very quickly. If the areas prone to landslide will be inventoried, further information to plan and avoid the danger areas, or put in place protection systems if economically viable, will increase the early warning capability for the people protection, limiting the possible disaster effects.

On the zones vulnerable at landslide near the transportation routes, supplementary works for limitation of the consequences of the landslide effects (soil erosion protection works by reforestation, torrents regulation protection works etc.) are of high necessity.

The vulnerability reduction of the areas prone to landslides, especially the slopes zones, located in the vicinity of socio-economical activities, such as transportation routes, inhabited areas, plants, etc., is recommended by structural measures. These measures should include reforestation, which can improve the slope stability, through restricted investments compared to other correction procedures (diverting the roads, expensive consolidation works, such as supplementary embankments, slope angle reduction, etc.), In the case of the landslide Mateeşti, which affected a nearby water course, endangering a large part of the village to be flooded by blocking the valley (Fig. 7), similar structural measures should have been promoted in order to prevent the land instability.

Figure 7. Reforestation may be more reliable than other engineering works – e.g. Panga Nord coal mining tailing waste deposit landslide, Vâlcea County.

As mentioned before, an intense rainfall represents a major landslide factor, and must be duly forecasted.

Field studies and the laboratory research for assessing the real situation of land stability, and furthermore the mapping of the hazard vulnerability in the areas of intense socio-economical activity, especially inhabited centers, can reduce the impact of the landslides and, consequently, they are fully recommended.

Informing population about areas prone to landslide hazard. Technical information of the inhabitants regarding the potential risk areas, the imminence of the landslides phenomena, their effects and the measures taken, is essential for complete and successful action plans for mitigation of the adverse situations due to landslides nearby inhabited areas.

An efficient preparedness measure depends on warnings issued by the authorities related to the evolution of the adverse hydro-meteorological phenomena, which often constitute the triggering factor for the landslide phenomena.

In order to ensure the mitigation of the disaster effects during the response phase, the endowment at the level of the crisis unit from each municipality is necessary. It may be found as a special building fond designed for natural calamities or man-made catastrophes in order to assure the accommodation of the homeless people affected by the disasters (including landslide), from the inhabited areas.

The prompt information of the population regarding the possible effect of the natural hazards in specific areas, due to the persistence of dangerous hydro-meteorological phenomena, or regarding the presence of other triggering factors of natural hazards, leads to a more precautionary behavior of the population, and to minimization of the consequences in case of a natural disaster, particularly a landslide.

Conclusions. The inventory of the areas potentially affected by hazards, performed during the initiative to build up a complete data base of landslide maps both at the regional and local level, will support the local development. It allows the promotion of projects about protection of both population and economic sites, to comply with the increased safety requirements. Based on the future natural hazard maps, made using the above proposed methodology, once available at local authorities, the insurance companies, able to consult unitary information regarding hazard occurrences at the level of a county, will have to reorient their development strategies, establishing categories of premiums according to the risk level of each region, assuring a better management of the funds for the compensation of the affected persons by disasters. Once the database for natural hazard area for all counties will be operational, it's expected the financial resources of the State will be efficiently distributed as supplementary measures for preventing disasters. Because of recently law of "obligatory insurance", once all property owners will insure their houses, following a disaster, will not be necessarily to use the State funds for direct compensation of the affected persons, as in the past. In this way the State compensation funds will be completely replaced by the newly put in place insured mechanism. A common methodology for accomplishing multi-disasters maps, to be implemented at the level of the local community, will allow the unitary representation of the probability of producing different disasters types and related effects. This information will be available for all factors involved in the activity of prevention and mitigation of the disaster effects at the local, county or regional level. Using a common methodology, harmonized for EU requests, a better cooperation at the European level, leading to a unitary approach in the frame of common projects is to be promoted.

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