PRESENT- DAY LANDSLIDE RISK ASSESSMENT IN MĂHĂCENI TABLELAND

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ABSTRACT. **Present- day landslide risk assessment in Măhăceni Tableland.** Actual landform processes rely on approaches to intensify research into quantitative and experimental geomorphology. Among contemporary modeling landform processes, landslides take an important place in Măhăceni Tableland. Landslide predictability in the actual context of slope dynamics, follows two main aspects: the geomorphologic behaviour (landslide trigger action and evolution) and the social behaviour (human perception on their impact). Landslide risk assessment, follows concepts like: susceptibility, vulnerability, hazard, risk, disaster. In Romania, at present, there is a lack of predicting, preventing, reconstruction and planning actions regarding landslides. Short and middle- time landslide predictability tries to fill up this gap with actions like: identifying areas with high susceptibility to landslides, finding areas with high vulnerability to elements at risk, the construction of landslide risk maps, getting the population to be more conscious of landslide risk. On the other hand, this study tries to get institutionalized actions like: analyzing, predicting, risk management, throughout territorial monitoring.

Key words: predictability, risk assessment, landslides, GIS, Măhăceni Tableland

1. Introduction. Aim of paper

The more efficient the level of resource exploitation, there is a growing anthropic pressure towards the natural environment and thus, an increasing risk. The relationship: natural environment- society, takes a certain response from society (becoming conscious of risk, community attitude towards hazards, etc).

Landslide predictability in the actual context of slope development, follows two main aspects (Fig.1.): the geomorphological behaviour; the trigger action of landslides and landslide- affected areas evolution and the social behaviour; the human perception on landslide damage. It becomes a relevant issue, the assessment of those hazards as regarding the susceptibility of landslide occurrence, the vulnerability of an area which can be subject to those processes.

Risk management assessment follows terms like: susceptibility, vulnerability, hazard, risk, disaster. Landslide prediction as natural hazards is preceded by getting probabilistic information related to the dynamic and spatial extension of the process.

In România, at present, there is a lack of a national integrated system of crisis management and according to OUG (Emergency Decree) No21/2004 for the foundation of the National System for Emergency Situation Management, the intervention, including of international NGO's, related to disaster management, takes place only post- disaster. There is a lack in the prevention, reconstruction and planning aspect. A short and middle- term prediction tries to fill this gap through approaches like: contemporary identification of areas with high rate of phenomenon occurrence, identifying the vulnerability of elements at risk, population consciousness of risk, etc. The first steps in landslide predictability rely on the studying of susceptibility, vulnerability and risk induced by landslides, which point out landslide zonation and potential damage on human settlements, roads, land, etc. On the other hand we can see the effort to get a practical approach and instistutionalize the analysis, prediction and risk management approaches throughout the territorial monitoring process, regarding the interaction: society-natural environment, in the context of sustainable developing.

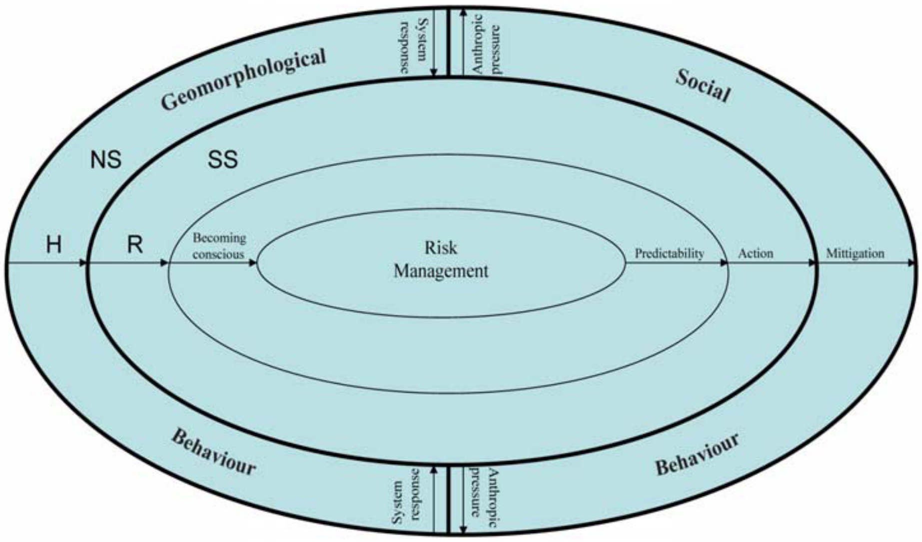

Figure 1. *Becoming conscious of risk in the relationship: natural system- social system. NS= natural system; SS= social system; H= hazard; R= risk*

We consider it beneficial for one to perform studies on vulnerability of the social community, before hazard manifestation and damage. Our approach should follow the following route: firstly, predictability studies, relying on susceptibility, vulnerability and risk and the social behaviour should go according to the obtained results, with the main purpose to reduce hazard damage.

2. Terms and concepts

In this context, we call for susceptibility- the spatial probability of action of one or more natural hazards; it involves combined analysis of factors with a high influence in landslide occurence and evolution, indicating areas with high landslide frequency and vulnerability- as estimated loss level of a space which is exposed to risk, for a given hazard magnitude. It becomes relevant through 2 perspectives: potential damage and social behaviour (the attitude towards hazard occurence, the influence upon human settlements' system, roads, land, etc). Vulnerability indicates a damage potential, so it is a predictive variable *(Iuliana Armaş, 2006).* Vulnerability takes more types: physical, economical, environmental, social, technical and implies the following notions: the intensity of the event and estimated damage level. Landslide vulnerability *(Galli, Guzzetti, 2007),* indicates the probability of loss to a certain element or the damage proportion of an element, in case of a landslide, being expressed on a 0- 1 scale. Vulnerability can be expressed economically (moetary, quantitative) and heutristically (qualitative). Economical vulnerability is expressed according to the element value:- monetary value (good's value, replacement costs); intrinsic value: the goods are considered important and irreplaceable (human life); utilization value of the element (capitalization). Qualitative vulnerability: it describes in qualitative terms (descriptive), the potential or definite damage to elements at risk; in this context, damage bear vulnerability.

Following the natural interaction between natural and social environment, hazards involve the possibility of extreme events which produce damage and may lead to disaster *(UNDRO, 1991; Alexander, 2000).* Hazards are aggressive events and they reveal the probability of occurence in a certain period, of a potentially damaging factor for humans, for their goods and for the environment *(Teodorescu & colab., 2007).* In hazard assessment, one can follow two directions *(Crozier, Glade, 2005):* - the physical process with damaging potential and the threatening state/conditions indicated by the probability of occurence.

Landslide hazard analysis, follows three steps: - anal of all identified landslides for determining their type and behaviour; analysis of impact characteristics; determination of location, magnitude, frequency and spatial extension of potentially damaging landslides.

Risk lies at the intersection of Hazard and Vulnerability. It includes the probability for a certain hazard to produce and carries the level of damage which a certain community considers acceptable in certain conditions of social, economical, political, cultural, technical, and environmental nature (Smith, 2001). Mathematically, risk can be represented by the following relation:

R= HxV (including the cost of elements at risk)

R= Σ(Hx Σ (V x A) (Van Westen, 2004);

where: H= hazard; V= vulnerability; A= the cost of the elements at risk (buildings, people).

Taking into consideration hazard manifestation and consequences, risk assessment may take two directions *(Crozier, Glade, 2005):* - the probability of occurence of a hazard event, the consequences of this occurence and the risk level results by the intersection of hazard with the value of the elements at risk, on the way of thier vulnerability. Therefore, risk lies at the intersection of probability and consequence (lESSLOSS, 2006), respectively, the produce of probability, the cost of the elements at risk and of the vulnerability of the elements at risk.

Disaster is the result of the action of a hazard, which affect people, their goods and/or the environment, as a result of the action of a natural/anthropic hazard (UNISDR, 2004). Disaster is therefore, a function of the risk process, resulted from combining hazards, the vulnerability conditions and insufficient capacity or means to reduce negative consequences of risk.

Predictability involves the activities of prediction, detection and hazard monitoring. It can take the form of “ex- ante” and “ex-post” action, as a result of hazard manifestation. Within risk management, the maximum efficiency is revealed by predictability, as a first step in determining the hazard manifestation and consequences on a short and middle-term period. Thus, potential damage can be considerably reduced and social behaviour takes the proper direction.

3. A model of actual landslide predictability for Măhăceni Tableland

Măhăceni Tableland lies in the central- north- westernern part of the country, as a contact area between Trascău Mountains and The Transylvanian Plateau, limited by Trascău Mountains at vest and by the Mures- Lower Aries corridor, on the east, north and south. The northern part of the Alba Iulia- Turda corridor reveals a hilly region with a peninsular aspect, which gets to the west into the Mures- Lower Aries corridor, an area defined in the geographical literature as Măhăceni Tableland or Vintu Piedmont.

Litostratigraphically, Măhăceni Tableland is a Miocene formation, in which Badenian and Sarmatian structures lay in relative parallel stripes. Tectonically, the region reveals Badenian anticlines (the most important being Mahaceni Anticline, consisting of: marls, sand marls and sands), separated by Sarmatian synclines.

The climatic data from the main metheorological stations in the study area (Turda, Campia Turzii, Viisoara) in the interval 1966-2002, reveal a multiannual mean temperature of 8,5ºC (Turda station), 9ºC (Campia Turzii), and an annual mean amplitude temperature of 28,5ºC (Turda ststion). Mean annual precipitations go in the interval: 500-650mm/year (630mm/year at Turda station; 539mm/year for Luna station), the annual evolution showing a maximum in the warm period of the year (820mm in june, Turda station) and a minimumin the cold season (144mm in april).

In Mahaceni Tableland, landslides have a high spreading rate, many of them being active and a great number of the existing ones, can reactivate. Their negative effect revertebrates on: buildings, roads, land. Within short- time and mid-time prediction of the negative effects on the human community, we followed two main elements at risk: human settlements and roads.

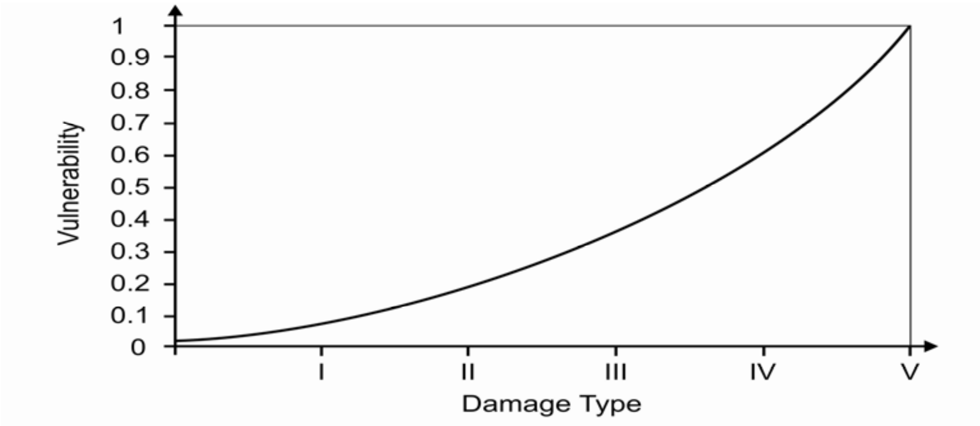

Figure 2. *Landslide vulnerability for houses in Măhăceni Tableland, for damage type (modified after Leone et. al., 1996 and Glade, 2003).*

I- (V=0.01-0.1): superficial damage (cracks in lateral walls); stability not affected. II- (V=0.2-0.3): big cracks in lateral walls; stability not affected; repairs not urgent. III- (V=0.4-0.6): strong deformations, big cracks in the walls; cracks in supporting structures; stability affected; doors and windows unusable; evacuation necessary. IV- (V=0.7-0.8): structural breaks (laeral walls broken, breaks in wall suture points, ground breaks); partially destroyed; evacuation necessary; reconstruction of destructed parts needed. V- (V=0.9-1): partly or totally destructed; evacuation necessary; complete reconstruction needed.

Actual landslide prediction has two main components: the geomorphological behaviour (landslide occurence and evolution) and the social behaviour (the consequences on human communities by revealing landslide vulnerability and risk of the main elements at risk: human settlements and roads).

The approach followed the evaluation of landslide susceptibility, vulnerability and risk for localities and roads.

In the first phase, a landslide data base was created (new and stable landslide inventory using a Magellan explorist 600 GPS). Furthermore, the data was transformed in GIS and the landslide susceptibility map was constructed, according to eight major factors in landslide occurence (slope gradient, slope aspect, lithology, slope curvature, distance from drainage, land use, elevation, fragmentation depth). In describing landslide vulnerability for human settlements (buildings) and roads, we followed some major parameters like: the distance of the elements at risk from the source area, damage type, building structure, landslide type and intensity (Fig.2 and 3.).

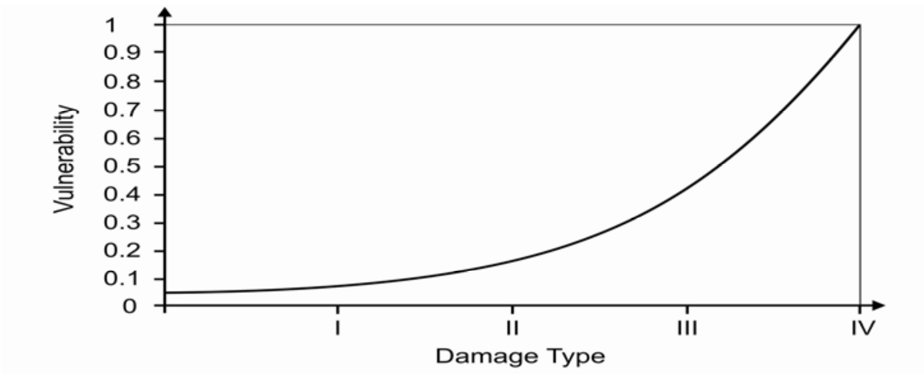

Figure 3. *Landslide vulnerability for roads in Măhăceni Tableland, for damage type (modified after Leone et. al., 1996 and Glade, 2003).*

I- (V=0.05- 0.3):slight damage of road; II- (V=0.3-0.6): damage of roadway, reparation using 10m³ material; III- (V=0.6-0.8):damage of roadway, reparation using 100m³ material; IV- (V=0.8-1): destruction of roadway.

We constructed the landslide vulnerability map, considering the distance from the landslides as a major factor in determining the vulnerability level, this level decreasing along with the increasing distance for the source area. A buffer was established at 50m so that the vulnerability level decreases from very high to very low, every 50m and over 250m distance, the impact is considered to be insignificant, because the magnitude of the process is very low.

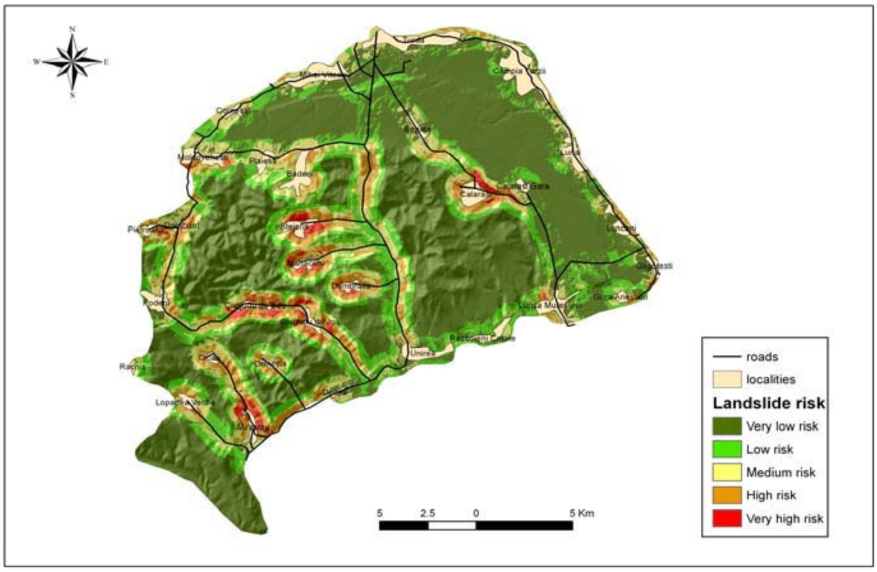

Figure 4. *Landslide risk map for human settlements and roads in Măhăceni Tableland*

In a final phase, on the basis of susceptibility and vulnerability values, we constructed in GIS, the landslide risk map in Măhăceni Tableland, for human settlements and roads, following the relationship:
R= HxV *(UNISDR, 2004*).

4. Results

In Măhăceni Tableland, landslides produce short and middle-term damage to human settlements and roads (Fig .4.). In the study area (421.61 km²), 17.4% represent areas with high landslide susceptibility level, covering 73.38 km². Approximately 10% represent areas with high risk to landslides (42.12 km², out of which: 35.62 km² with high risk and 6.5 km² with very high risk). The highest risk level for localities is found in the case of 8 localities: Stejeriş, Măhăceni, Dumbrava, Ciugudu de Sus, Ciugudu de Jos, Mirăslău, Calaraşi, Ormeniş. Landslides have damaged 35 houses (and a cemetery) so far, out of which 7 were totally destroyed and evacuated and the rest have cracks and wall deformations (Table 1.) which can be recovered, but on landslide reactivation situations, they can be seriously damaged.

Tabel 1. Localities with high risk to landslides in Mahaceni Tableland

Locality affected by landslides	**Stejeriş**	**Măhăceni**	**Dumbrava**	**Mirăslău**	**Călăraşi**	**Ormeniş**
No. Of affected houses	3	11+1 cemetery	10	3	7	1
Cracks	3	8	8	3	5	1
Destroyed houses	-	3	2	-	2	-
Construction materials	Bricks; Stone foundation	Bricks; Stone fundation	Bricks; Stone fundation	Bricks; Concrete fundation	Bricks; concrete fundation	Bricks; Stone fundation

Regarding the road network, the highest landslide risk is to the European road E81 (for a length of almost 1.26 km) and 2 county roads (approximately 1.4 km)- the estimated cost for rehabilitation in case of landslides is about 360000€ (DRDP Cluj, 2008).

5. Conclusions

One can see the lack at community level, of proper information and a low interest shown by the population towards those hazards and the damage they can produce. Thus we find situations like: building new houses in areas with active landslides and high landslide vulnerability, sand excavations in areas with very high landslide vulnerability which leads to slope destabilization and landslide initiation. The local authorities lack a landslide predictability study and identification of areas with high landslide risk. Landslide prediction on a short and mid- term period has the following purpose: decreasing potential material and human damage in case a hazard occurs, the decrease of repairing costs and of risk level, getting correct opinions towards those hazards, with the result of a proper social behaviour (consolidation of affected areas with high landslide risk, avoiding exploitation and construction works in areas with high landslide vulnerability, ensuring land in those areas, etc). Prediction of natural hazards states as a first action before construction and facility works (communication network, buildings, etc). Actual landslide predictability offers useful information regarding contemporary dynamics of landslides.

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