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A Scientific Network for Earthquake, Landslide and Flood Hazard Prevention – *SciNet NatHazPrev*

Landslide Susceptibility, Hazard and Risk Assessment in Romania – The State of the Art

Zoia Prefac

Ovidius University of Constanta
Faculty of Natural and Agricultural Sciences
- (Partner no 4)

Presentation content

- Legislative and institutional framework for emergencies and risk management,
- Susceptibility and hazard mapping
- Bibliography and projects contributing to landslide susceptibility and hazard mapping in Romania
- Qualitative and quatitative results on landslides susceptibility/hazard mapping

Laws regarding natural disaster – with special focus on landslide hazard

Low/Governmental Decision (G.D.)/Common order of Ministry (C.O.)	Overview
G.D. No. 438 /06 June 1996	Regulation of organization and functioning of the ***Central Commission for Defense against landslides and earthquake effects***, established by the Minister of Public Works and Planning (now the Ministry of Transport)
C.O. of the Ministry of Public Works and Territorial Planning, of the Chief of Department for Local Public Administration and Ministry of Waters and Environmental Protection No. 62/N-19.0/288-1.955/1998	***delimitation*** of the ***areas prone to natural risks***
Law No. 575 /22.October 2001	• the ***Plan for national territory development*** • the maps and tables attached to the Law are providing ***information about the localities potential affected by*** floods caused by torrents draining or water courses overflowing and ***landslides***.

- In Romania, the lack of a strong legislation at the beginning of the transition period led to accelerating of the deterioration of environmental conditions and an increase of impact of natural hazards on society caused by massive deforestation and destruction of irrigation systems in the plains and tablelands (Bălteanu et al., 2004).

- **Nowadays**, Romania has a **well-defined legal framework**, covering the requirements for protection against natural disasters, according to those at the European level.

- International conventions and other ratified accords and agreements are components of Romanian legislative system and are part of the national policy for disaster risk reduction management.

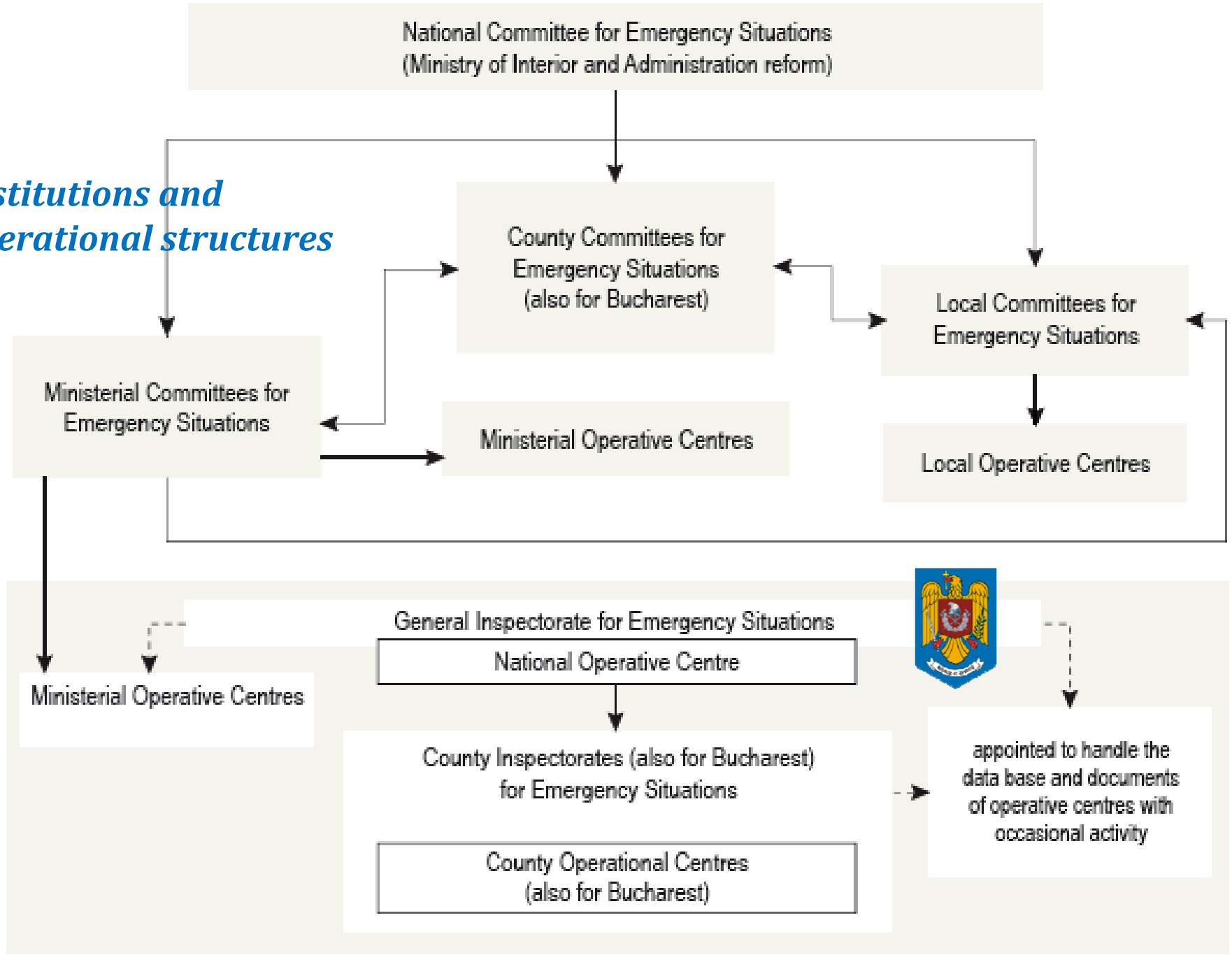
➢ Though, in **the implementation** of the strategy for civil protection and environmental safety are leaking.

➢ For example, the *Law no. 575 of 22 October 2001*, regarding the approval of the *Plan for national territory development – The Fifth Section– Areas of natural hazards*, foresees **risk maps for every locality placed in the natural risk areas**, order to be included in the Plans for General Urbanism (PUG).

➢They are managed by local authorities and because of lack of funds, integrated **risks maps are not finished, but are under development**.

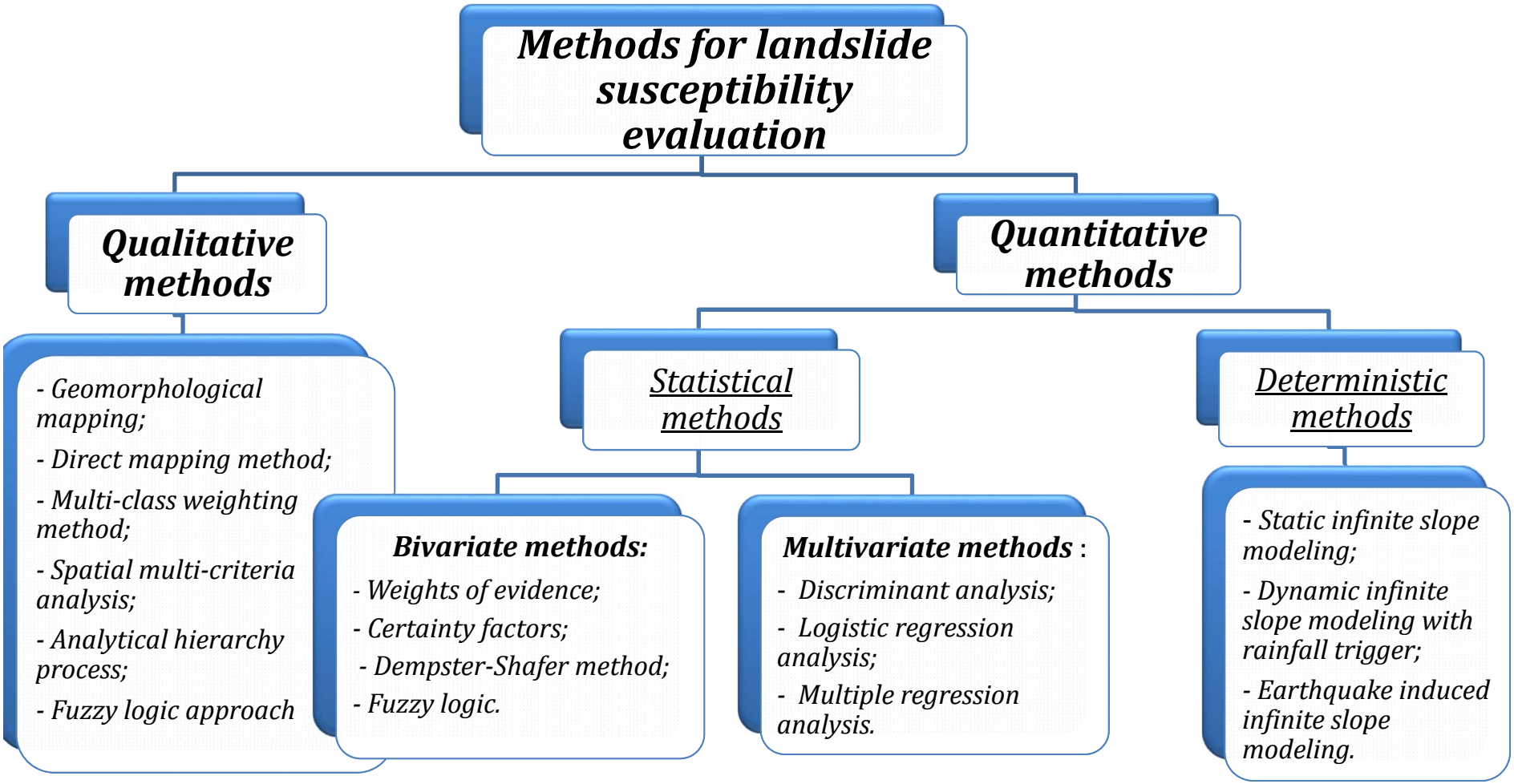
Low/Governmental Decision (G.D.)/Common order of Ministry (C.O.)	Overview
G.D. No. 382/2 April 2003	approves ***methodological norms*** regarding ***minimal demanding*** in content for ***territory planning and urbanism documentation for natural risk areas***.
G.D. No. 447/10 April 2003	***norms regarding elaboration mode and content of the floods and landslides risk maps***
G.D. No. 1 491/9 September 2004	approves the ***framework regulation of the organizational structure, responsibilities, operation and endowment of the committees and emergency operational centers***
C.O. of the Ministry of Public Minister of Transport, Construction and Tourism and the Ministry of Administration and Interior No. 1.995/2005/1.160/2006	the ***Regulation on the prevention and management of specific emergency situations regarding earthquake and/or landslides risks***
G.D. No. 932/7August 2007	approves the ***Methodology regarding state budget financing of natural hazard maps for earthquakes and landslides***

Institutions and operational structures



From *The Structure, Role and Mandate of Civil Protection in Disaster Risk Reduction for South Eastern Europe*

- In the literature the terms of ***susceptibility*** and ***landslide hazard*** are often used as synonyms, although they are different concepts (Guzzetti, 2005).
- ***Landslides susceptibility*** is the probability that a landslide to occur in an area characterized by certain environmental conditions (Brabb, 1984). Is the degree which a surface can be affected by the landslide process.
- In contrast, ***landslide hazard*** is the probability that a landslide of a given magnitude will occur in a given period of time and in a given area. In addition to prediction of where the landslide will occur, landslide hazard forecast "when" or "how frequently" it will produce and "how large" it will be (Guzzetti et al., 2005).
- Thus, susceptibility is the space component of landslide hazard.



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- In Romania, landslides are among the most widespread geomorphological processes in the hilly regions built of Neogene molasse deposits, as well as in the mountainous regions developed on Cretaceous and Paleogene flysch.
- A review of geomorphic literature regarding landslides emphasizes that numerous articles and books addressed this subject, with the aim of classifying, presenting some local cases, or zoning landslides across geomorphic units or all over the country, have started especially since the late '20s (e.g., Mihăilescu, 1926, 1939; Tufescu, 1964, 1966).
- In the recent decades, an issue approached by Ielenicz, 1970; Ichim, 1979; Mac; 1986 and Surdeanu, 1987, was that of detection of areas prone to landslides on the principle of functional analysis of slopes.

- Recent studies in the direction of landslide risk analysis and vulnerability have had: Cioacă et al., 1993, Rădoane et al., 1993, Cioacă, 1996, Surdeanu, 1998, Bălteanu et al., 1989, 2004, 2010, Grecu, 1996, 1997, 2002, Manea, 1998, Armaş et al., 2003, Armaş, 2006, Sandu & Bălteanu, 2005, Prefac et al., 2008.

- During the '90s and early 2000s, in the estimation of landslide susceptibility was used especially qualitative approaches.

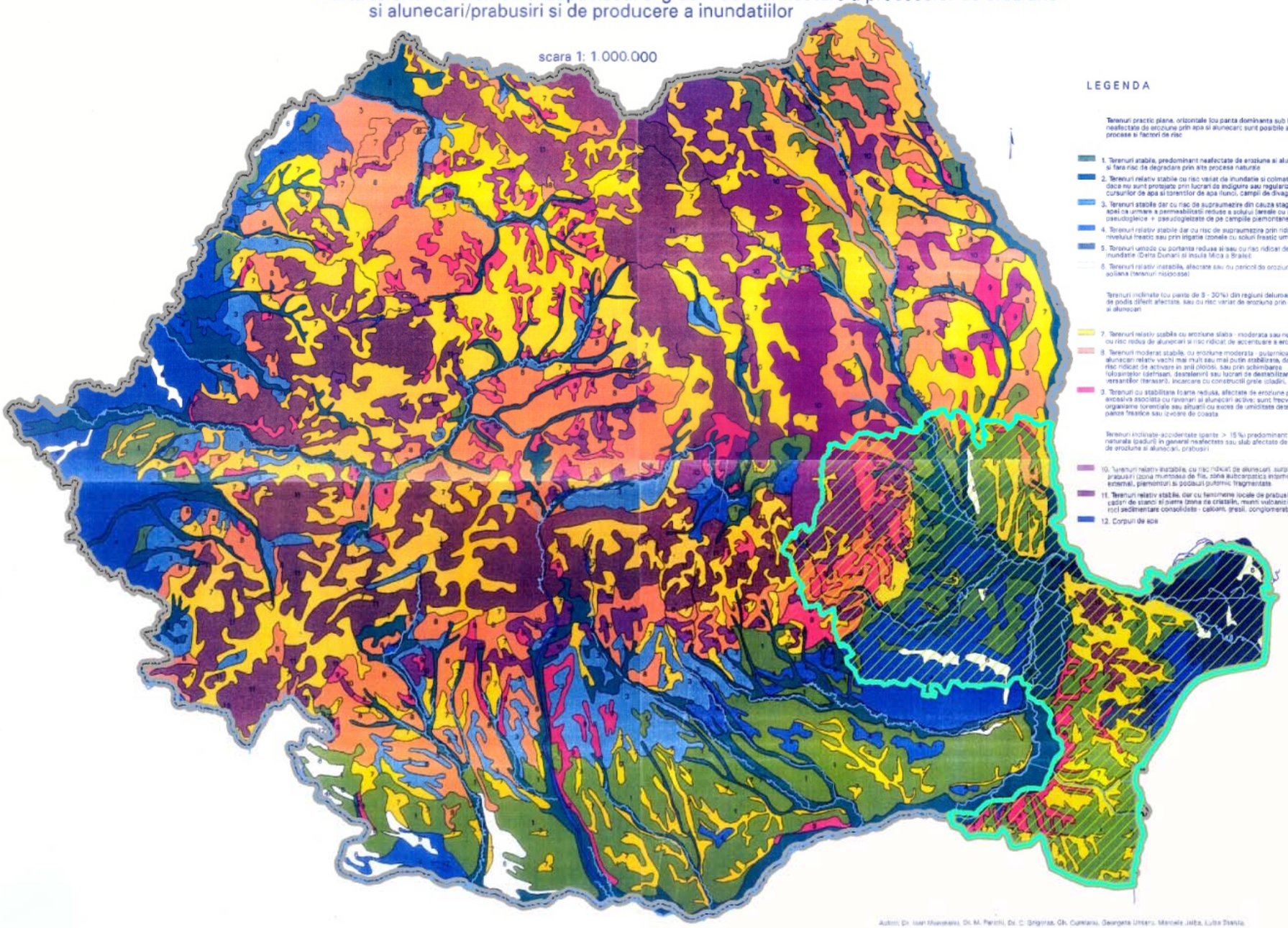
- The number of quantitative ones has risen steeply in the last years (Micu & Bălteanu, 2009; Armaş, 2011, 2012; Constantin et al., 2011; Şandric et al., 2011; Grozavu et al., 2012; Armaş et al., 2013).

➢For Romania, over the time, regarding landslide phenomenon, the **spatial distribution of landslides** especially, a few maps were drawn up, at a small scale:

- ✓Map of territorial areas with landslides potential (Tufescu V., 1966)
- ✓Maps of soil stability in Romania (PROED S.A., 1966)
- ✓Romania's land zoning in terms of potential for landslides (Marchidanu E, 1995)
- ✓Territorial map of landslides (UTCB, 1997)
- ✓Macro-zoning map of induced landslides risk in Romania (GEOTEC S.A., 1998).

Harta terenurilor Romaniei dupa riscul si gradul de manifestare a proceselor de eroziune si alunecari/prabusiri si de producere a inundatiilor

scara 1: 1.000.000



LEGENDA

Terenuri practic plane, orizontale (cu panta dominanta sub 8 %) neafectate de eroziune prin apa si alunecari; sunt posibile alte procese si factori de risc

1. Terenuri stabile, predominant neafectate de eroziune si alunecari si fara risc de degradare prin alte procese naturale
2. Terenuri relativ stabile cu risc variat de inundatie si colmatare, daca nu sunt protejate prin lucrari de indiguire sau regularizare a cursurilor de apa si torentilor de apa (lunci, campii de divagare)
3. Terenuri stabile dar cu risc de supraumezire din cauza stagnarii apei ca urmare a permeabilitatii reduse a solului (areale cu soluri pseudogleice + pseudogleizate de pe campiile piemontane si terase)
4. Terenuri relativ stabile dar cu risc de supraumezire prin ridicarea nivelului freatic sau prin irigatie (zonele cu soluri freatic umede)
5. Terenuri umede cu portanta redusa si/sau cu risc ridicat de inundatie (Delta Dunarii si insula Mica a Brailei)
6. Terenuri relativ instabile, afectate sau cu pericol de eroziune eoliana (terenuri nisipoase)

Terenuri inclinate (cu panta de 8 - 30%) din regiuni deluroase si de podis diferit afectate, sau cu risc variat de eroziune prin apa si alunecari

7. Terenuri relativ stabile cu eroziune slaba - moderata sau neapreciabila cu risc redus de alunecari si risc ridicat de accentuare a eroziunii
8. Terenuri moderat stabile, cu eroziune moderata - puternica, cu alunecari relativ vechi mai mult sau mai putin stabilizate, dar cu risc ridicat de activare in anii ploiosi, sau prin schimbarea folosintelor (defrisari, deselenirii sau lucrari de destabilizare a versantilor (taieturi), incarcare cu constructii grele (cladiri, soselei)
9. Terenuri cu stabilitate foarte redusa, afectate de eroziune puternica - excesiva asociata cu ravenari si alunecari active; sunt frecvente organisme torentiale sau situatii cu exces de umiditate determinat de panze freatice sau izvoare de coasta

Terenuri inclinate-accidentate (panta > 15%) predominant sub vegetatie naturala (paduri) in general neafectate sau slab afectate de procese de eroziune si alunecari, prabusiri

10. Terenuri relativ instabile, cu risc ridicat de alunecari, surpari, prabusiri (zona muntoasa de fliș, zona subcarpatica interna si externa), piemonturi si podisuri puternic fragmentate
11. Terenuri relativ stabile, dar cu fenomene locale de prabusiri, caderi de stanci si pietre (zona de cristalin, muntii vulcanici), roci sedimentare consolidate - calcare, gresii, conglomerate)
12. Corpuri de sare

Autori: Dr. Ioan Munteanu, Dr. M. Peticilă, Dr. C. Grigoraș, Gh. Cuteanu, Georgeta Untaru, Marcela Jelea, Lucia Stelia

Prelucrare computerizată: Sorina Dumitru, Victoria Mocanu, Irina Motoi

RESEARCH INSTITUTE FOR SOIL SCIENCE AND AGROCHEMISTRY (ICPA) - ROMANIA

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➢ During the last decade, some research institutes have been involved in several **international projects** having **landslide susceptibility/hazard/risk assessment** as a main goal:

✓*Risk Assessment Methodologies for Soil Threats* - RAMSOIL(2007-2010);

✓*Hazard Risk Mitigation And Emergency Preparedness Project In Romania (2008-2012)*

✓*Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies - SafeLand* (2009-2012);

✓*Changing Hydro-meteorological Risks as Analyzed by a New Generation of European Scientists – CHANGES* (2011-2014).

✓ *Enabling CLimate Information Services for Europe – ECLISE* (2011-2013)

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Risk Assessment Methodologies for Soil Threats - RAMSOIL (2007-2010)

www.ramsoil.eu

✓ The general objective was to provide scientific guidelines on current risk assessment methodologies of soil threats encountered within EU Member States;

✓ The selected soil threats were: erosion, salinisation, organic matter decline, compaction and landslides.

✓ For Romania, NATIONAL RESEARCH AND DEVELOPMENT INSTITUTE FOR SOIL SCIENCE AGRO-CHEMISTRY AND ENVIRONMENT - ICPA Bucureşti has elaborated methodology for estimating the areas with risk for three types (from five) of soil degradation analyzed: compaction, salinisation, erosion.

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Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies - SafeLand (2009-2012).

http://www.safeland-fp7.eu/

- ✓ SafeLand is a Large-scale integrating Collaborative research project funded by The Seventh Framework Programme for research and technological development (FP7) of the European Commission.
- ✓ The project team was composed of 25 institutions from 13 European countries.
- ✓ From Romania, the responsible institution was GEOLOGICAL INSTITUTE OF ROMANIA.

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Changing Hydro-meteorological Risks as Analyzed by a New Generation of European Scientists – CHANGES (2011-2014).

http://www.changes-itn.eu/

- ✓ The main objective of project is how global changes, related to environmental and climate change as well as socio-economical change, will affect the temporal and spatial patterns of hydro-meteorological hazards and associated risks in Europe; how these changes can be assessed, modeled, and incorporated in sustainable risk management strategies, focusing on spatial planning, emergency preparedness and risk communication.
- ✓ CHANGES include 11 partner institutions that host one or more researchers and 6 associate partners that co-supervise research projects, offer internships and participate in CHANGES network events.
- ✓ Romanian partner is the INSTITUTE OF GEOGRAPHY - ROMANIAN ACADEMY.
- ✓ Case study chosen from Romania is Buzău County.

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- A series of normative acts published in several stages, such as:
  - Law 575/2001,
  - Law 124/1995,
  - Government Decision 382 and 447/2003,
  - Common Order of the Ministry of Public Works and Territorial Planning, of the Chief of Department for Local Public Administration and Ministry of Waters and Environmental Protection no. 62/N-19.0/288-1.955/1998, based on the *Writing guide for landslides risk maps to ensure construction durability – Indicative GT-019-98*

set the methodological norms regarding *elaboration way and content of the landslides hazard maps* based on calculating of the average **coefficient of hazard K(m)** .

➢For drawing the map of landslide hazard are required the following steps:

❑dividing the territory for which the hazard map is elaborated in bounded polygonal surfaces to represent as homogeneous lithologic and structural deposits ;

❑estimating the weights and geographical distribution of "risk coefficients" K(a-h) depending on the criterion presented in Table 1;

❑ calculating the average hazard coefficient K(m) corresponding to each analyzed polygonal surface by using a specified formula (1); :

❑determining the degree of potential (low , medium, high) associated with a certain probability of landslides occurrence (practically zero, low, medium , medium -high , high and very high) .

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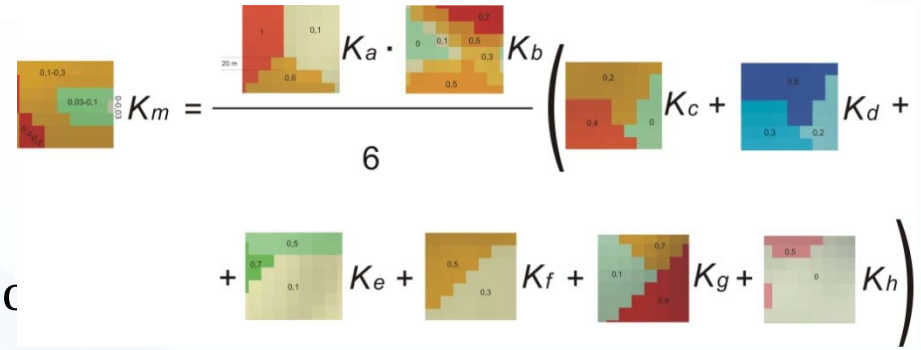
$$K_{(m)} = \sqrt{\frac{K_a \times K_b}{6}\left(K_c + K_d + K_e + K_f + K_g + K_h\right)} \quad (1)$$



Where:

K_a = lithologic criterion;
K_b = geomorphological criteric
K_c = structural criterion;
K_d = hydrological and climatic criterion;
K_e = hydrogeological criterion;
K_f = seismic criterion;
K_g = forest cover criterion;
K_h = anthropogenous criterion,

expressed through a scale from 0 to 1

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➢ Among the landslide affecting factors, **lithology** and **geomorphology** are considered the most important.

➢ Depending on the K(m) coefficient's value, are establish landslide occurrence potential:

- ❑ low potential, K(m) < 0.1
- ❑ medium potential, K(m) = 0.1 to 0.3
- ❑ medium-high potential, K(m) = 0.3 to 0.5
- ❑ high potential, , K(m) = 0.5 to 0.8
- ❑ high-very high potential, K(m) are above 0.8.

Legend:

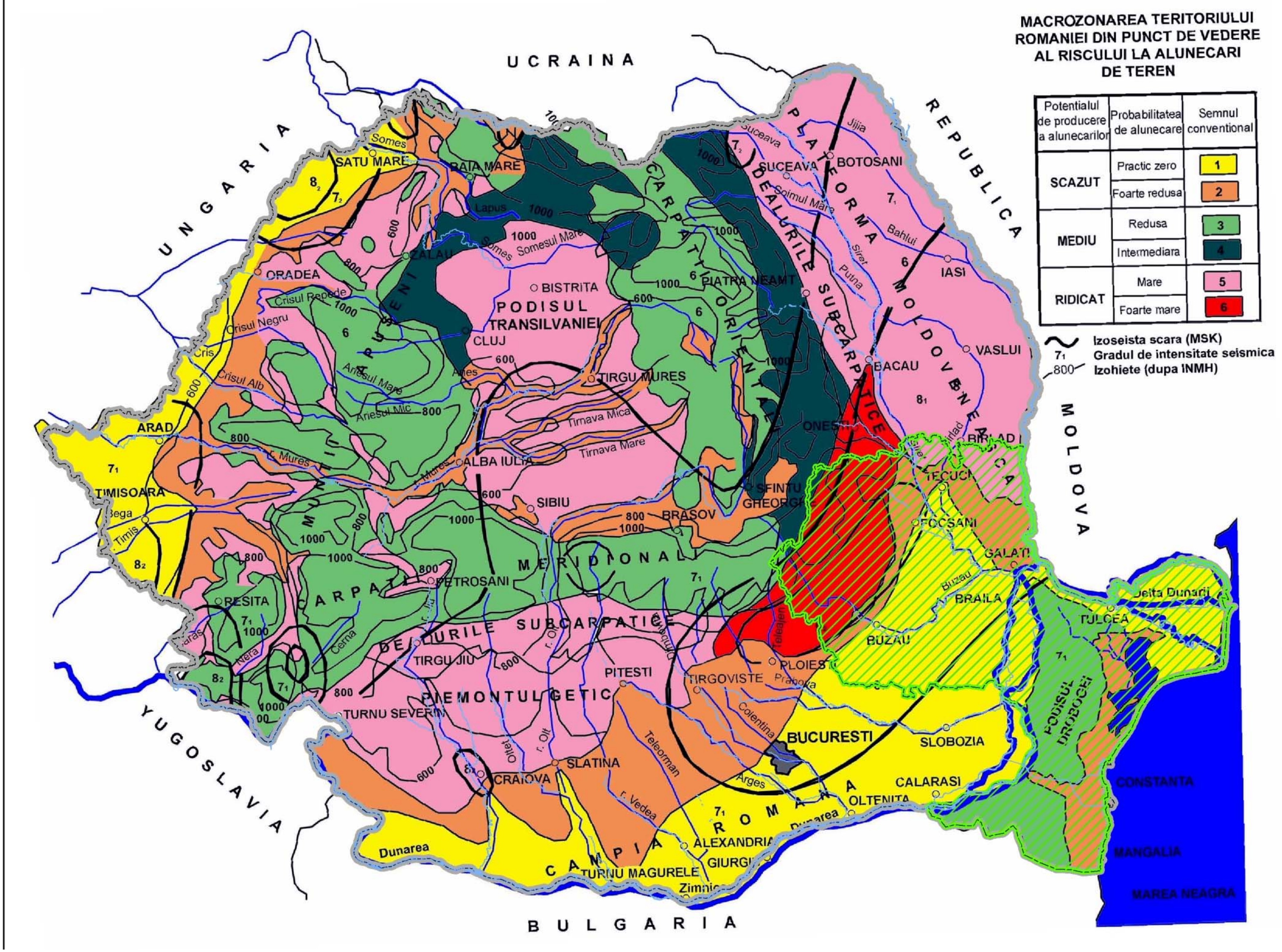
Table 1. Rating -Criterion for landslide potential and probability occurrence assessment

Crt. No.	Symbol	Criterion	Landslide occurrence potential (p)					
			Low		**Medium**		**High**	
			Landslide probability occurrence (p) and the corresponding risk coefficient (K)					
			Practically zero	**Low**	**Medium**	**Medium-high**	**High**	**Very high**
			0	**< 0,1**	**0,1-0,3**	**0,31-0,5**	**0,51-0,8**	**> 0,8**
0	1	2	3	4	5	6	7	8
1	a	Lithologic	Solid, massive, compacted or fissured unweathered rocks		Sedimentary rocks of overlaying formations (deluvial, coluvial and proluvial deposits) and pelitic stratified rocks (clay slate, marls, calcareous marl, chalk); metamorphic rocks (especially epizone and less mesozone schists, highly weathered and exfoliated); some weathered igneous rocks		Detrital sedimentary rocks (unconsolidated – saturated, plastic clays, with high expansive and contractile capacity); montmorillonitic clays; small or medium grain sized loose silt and sand; salt breccia	
2	b	Geomor-phologic	Plain relief (hydrographic network integrates mature valleys)		Hilly relief representative for piedmont and plateau areas, edged by medium height slopes with, generally, medium and high declivity		Hilly and mountainous relief, highly fragmented by a dense network of young valleys (most of them, subsequent valleys) with steep and height slopes	
3	c	Structural	Massive igneous rocks; stratified sedimentary rocks with horizontal bedding; metamorphic rocks with horizontal schistosity planes		Most of folded and faulted geological structures affected by cleavage and fissuring; diapir structures; overthrust sheet forehead		Geological structures representative for geosynclines areas in flysch facies and molasse formations from marginal depressions; stratified geological structures highly folded and dislocated, affected by a dense cleavage, fissuring and stratification network	

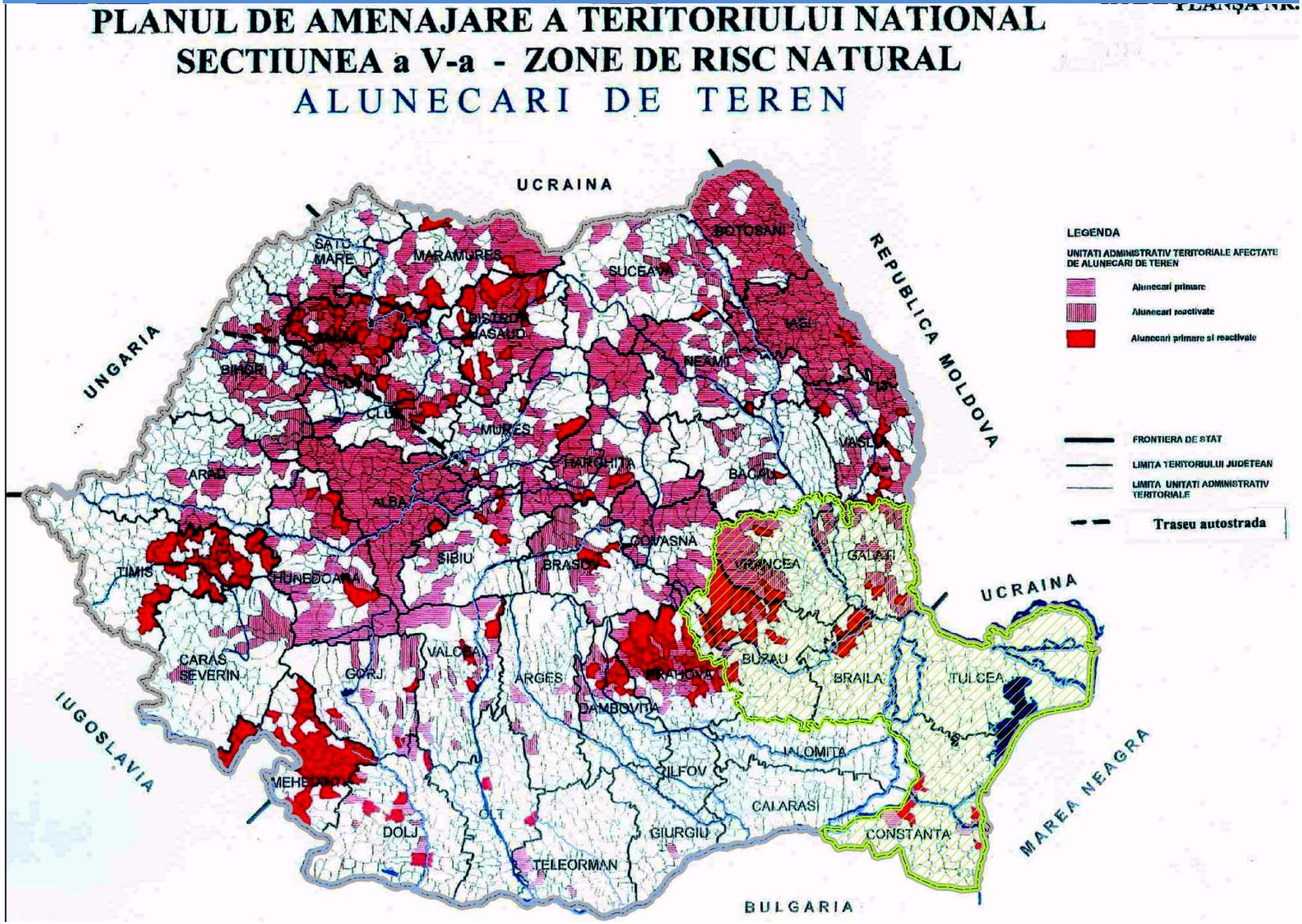
Crt. No.	Symbol	Criterion	Landslide occurrence potential (p)					
			Low		Medium		High	
			Landslide probability occurrence (p) and the corresponding risk coefficient (K)					
			Practically zero	Low	Medium	Medium-high	High	Very high
			0	< 0,1	0,1-0,3	0,31-0,5	0,51-0,8	> 0,8
0	1	2	3	4	5	6	7	8
4	d	Hydrologic and climatic	Generally dry areas with reduced average annual rainfall; the debit flow is strictly conditioned on the precipitation amount; on the river bed, deposition exceeds erosion (lateral erosion only on floods)		Moderate amount of rainfall; the hydrographic network is composed by mature primary valleys, meanwhile, the tributaries are young valleys. During floods, lateral and linear erosion along with important transport and solid discharge are being observed		Long slow rainfall conducive to water infiltration; heavy rainfall with important overflows and solid discharge transport; predominant process: linear erosion	
5	e	Hydrogeo-logic	Ground water flow at low hydraulic gradients; filtration forces are negligible; confined ground water at great depths		Moderate hydraulic gradients; the equilibrium state of the slope responds to the filtration forces values; phreatic water is situated above 5 m depth		Ground water flow at high hydraulic gradients; water sources are located at the base of the slopes; ground water flow direction is outwards; filtration forces can act as a landslide trigger	
6	f	Seismic	Seismic intensity on M.S.K* scale < 6th degree		6 – 7th degree of seismic intensity		Seismic intensity on M.S.K scale > 7th degree	
7	g	Forestry	Timbering covering > 80%; extended deciduous forests		Timbering covering between 20% – 80%; deciduous and coniferous forests of various age and width		Timbering covering < 20%	
8	h	Anthropic	No important constructions on the slopes; water reservoirs are absent		A number of construction works (road platforms and railroads, coast channels, quarries etc) with limited extension with adequate slope protective measures		Overloaded slopes (dense water supply network and sewerage, roads, railroads, coast channels, quarries, dumps etc; water reservoirs.	

*Medvedev – Sponheuer – Karnik seismic intensity scale (MSK 64)

Macro-zoning map of induced landslides risk in Romania



Map of landslides types - Romania



COMMENTS:

- In the absence of chronological information on the occurrence of landslides, spatial-temporal probabilities cannot be calculated and consequently predictions must be restricted to the spatial distribution of future landslides; that is susceptibility (Bălteanu et al., 2010).
- There is no information regarding the differentiation between landslide types in the present methodology.

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ADVANTAGES:

- gives an overview relatively suggestive of areas with different landslide potential;
- integrates data generally easier to find;
- can be used in case of lack information about the existence of landslides (obtained from inventory using different sources).

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Hazard Risk Mitigation And Emergency Preparedness Project In Romania (2008-2012)

➢World Bank Project on natural disasters study in Romania, coordinated by RMSI (Risk Management Solutions India).

➢**Main goals:**

- execution of geological and geotechnical studies on two pilot areas for the design and implementation of an "in situ" monitoring system (including installation of monitoring equipment);
- data collection and processing for elaboration of a model for landslides anticipation;
- elaboration of a monitoring manual including elements of an early warning system;
- design and implementation of a training program for local authorities.

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- More recent, Bălteanu et al., in 2010, have developed a landslide susceptibility model for the whole country applying a scoring system to a set of conditioning factors based on expert judgement (heuristic model).
- This research was carried out due to a World Bank project on losses and insurance costs relating to disasters in Romania, and aims to provide a unitary basis for addressing landslide susceptibility in the country.

- It takes into account the most important triggering factors, as well as settlements and infrastructure affected by landslides.
- It also forms the basis for elaboration of a landslide-hazard risk map in an attempt to quantify all potential losses related to this process.

- Was used a Landslide Susceptibility Index (LSI) method based on quantitatively defined weighted values.
- Expert analysis, combined with a long history of landslide mapping and assessment and field experiments, play an important role in this method.
- The expert judgement involved a large number of studies and assessments undertaken at different scales, and geomorphological mapping of Romanian territory at the scale of 1:200,000.

Triggering Factors

- In computing a GIS landslide-susceptibility map of Romania six major triggering factors were considered:
  - ✓lithology,
  - ✓height difference,
  - ✓slope angle,
  - ✓land use,
  - ✓rainfall
  - ✓seismicity.
- Each factor was classified under sub-classes carrying a rating from 0 to 10 according to its relevance for landslide susceptibility.
- Further, each factor was considered to have a differential influence on such susceptibility, named ‘assigned weight’.

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- The results were compared with different assessments from several countries.
- To validate the methodology, besides expert judgement, repeated geomorphic mapping over a long period, as well as field observations and measurements in the most affected regions, were used.

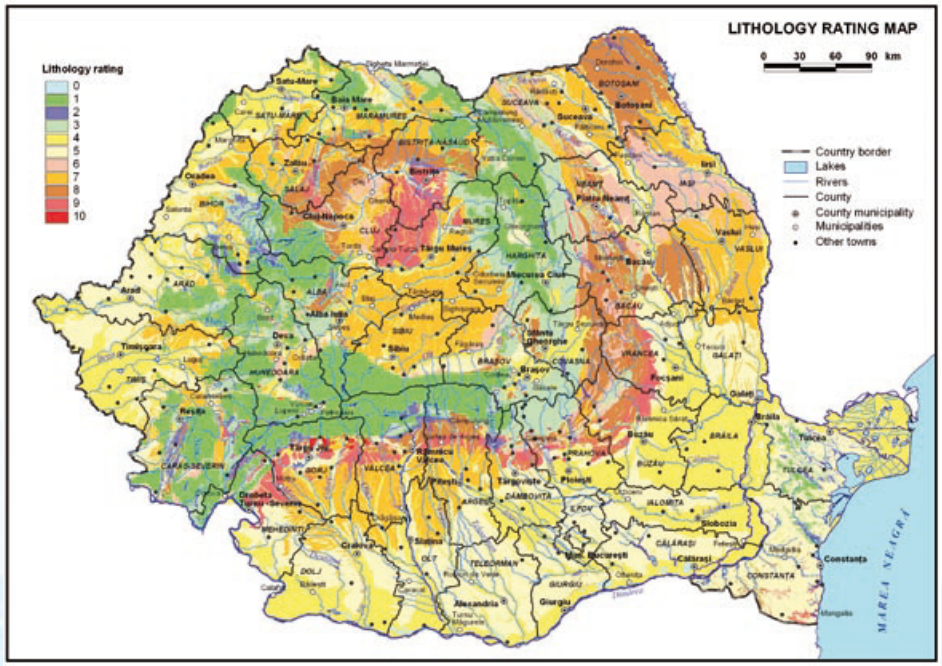

Figure shows an example of a lithology rating map based on 1:200,000 scale map elaborated by the Institute of Geology, Romania.

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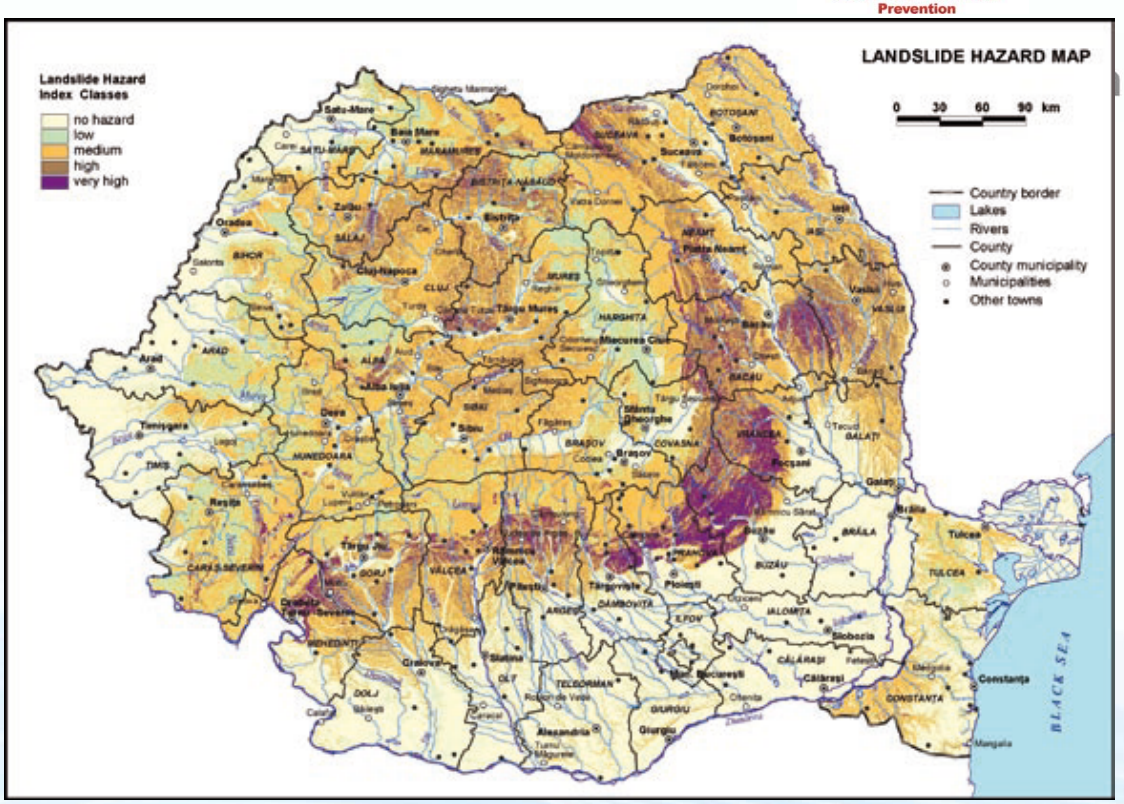

Susceptibility Classes

➢The LSI was further classified under five hazard classes; each category based on correlation of expert judgement and existing geomorphological maps of the whole of Romania.

➢The established classes are:

- ✓ 'no susceptibility', represents around 39% of Romania (plains and low hills),
- ✓'low', 10%,
- ✓ 'medium', 38.3%,
- ✓'high' and 'very high' susceptibility, classes around 10% (mostly in the Subcarpathian region).

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IncREO - Increasing Resilience through Earth Observation

http://www.increo-fp7.eu/

(Jan. '13 – Dec. '14).

- The objective of the work package which includes Romanian Space Agency –ROSA, is to assess and map in a detailed manner the risk and vulnerability of areas in Romania highly prone to landslides in the Buzau County.

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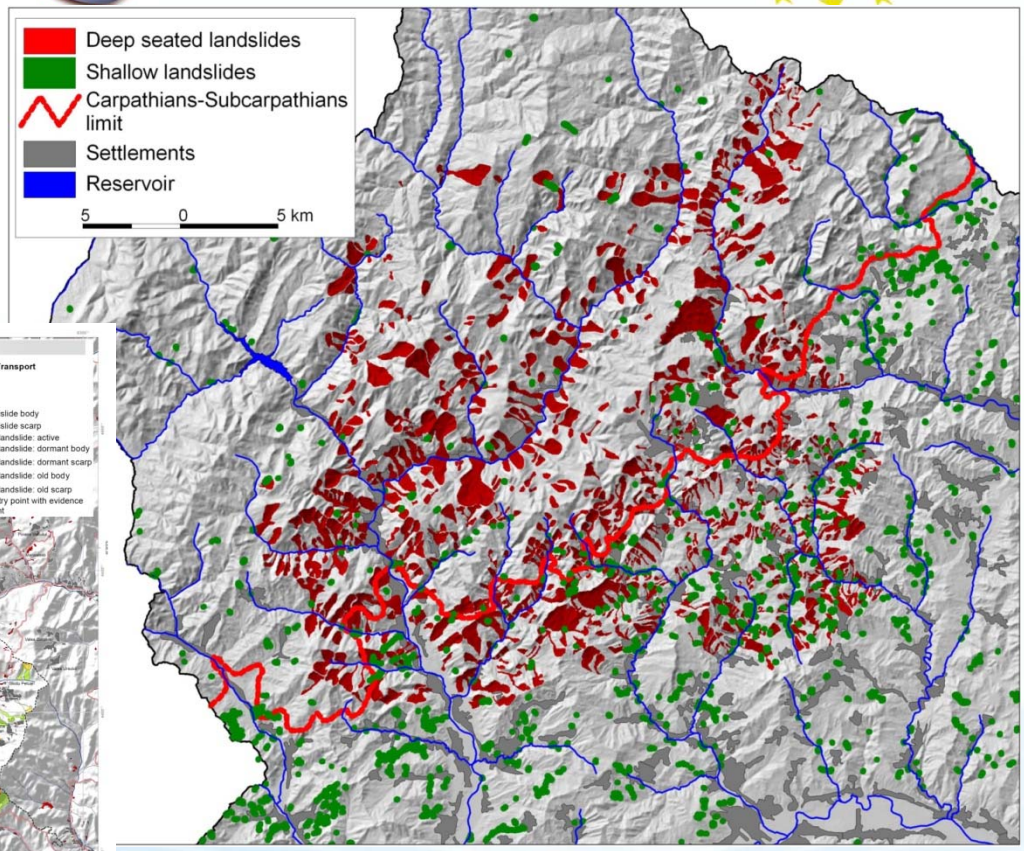
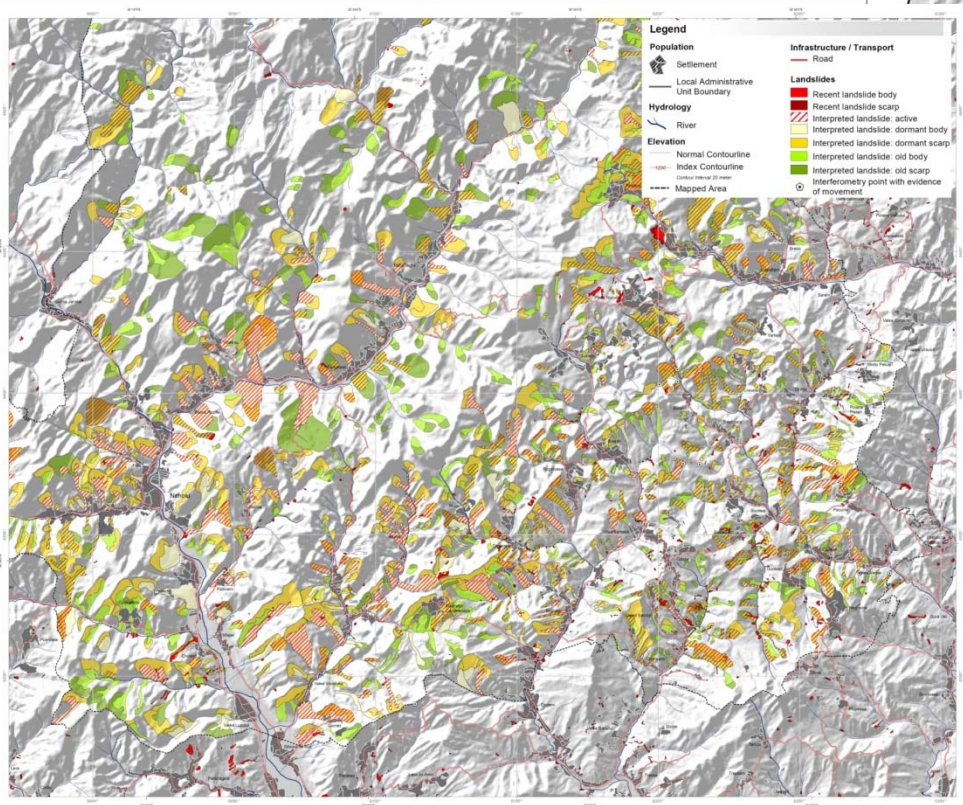
CHANGES FP7, IncREO FP7

- ✓ **Inventar**
- ✓ **Fotointrepretare stereografica digitala (2005, 2008)*(Micu et al. 2014):***
- ✓ **1028 alunecari profunde; 800 km^2**





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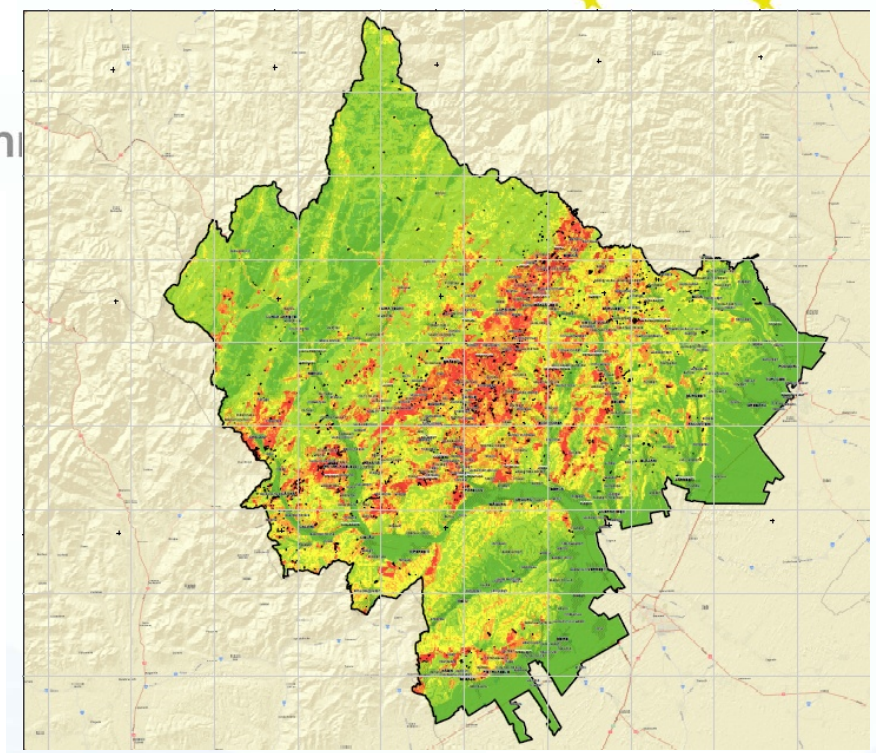
➢The map shows the landslide susceptibility of Buzau County, Romania.

➢For assessing the susceptibility of landslide prone areas a quantitative inventory-based probabilistic method with the approach of **"Weight of Evidence" (WofE)** was chosen.

➢The following inputs were used:

- ✓Landslide inventory (kindly provided by the **FP7 CHANGES project**),
- ✓DEM (slope, aspect, relative relief),
- ✓ geology,
- ✓land use,
- ✓max. rainfall in 72 h,
- ✓distance to drainage network.

➢It is assumed that the landslide inventory is complete



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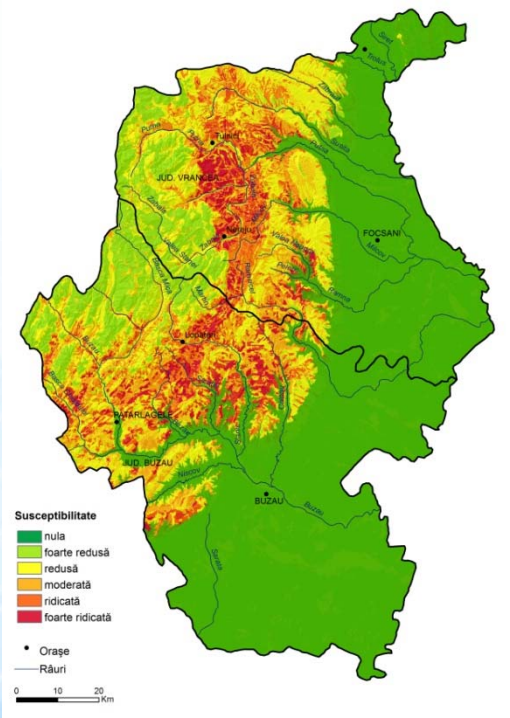
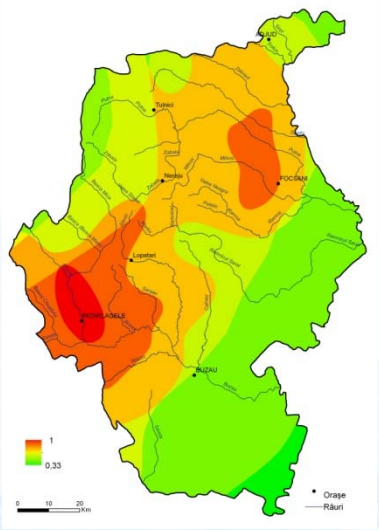
• **Logistic Regression** (*altitudinea; declivitatea suprafetelor; expozitia suprafetelor; curbura totala a suprafetelor; curbura in plan a suprafetelor; curbura in profil a suprafetelor; formatiunile litologice; grupele hidrologice de sol; acoperirea terenurilor.*)

Common borders. Common solutions.

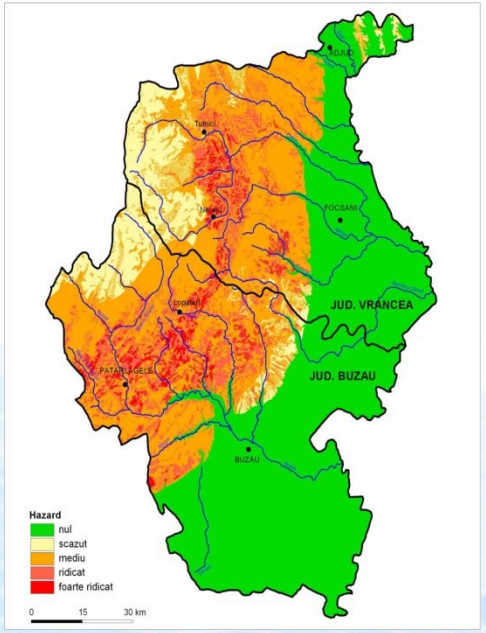
Harta de susceptibilitate la alunecari de teren (logistic regression)



Indice compozit al factorilor declansatori (pp. max in 72h si PGA)



Harta de hazard relativ la alunecari de teren



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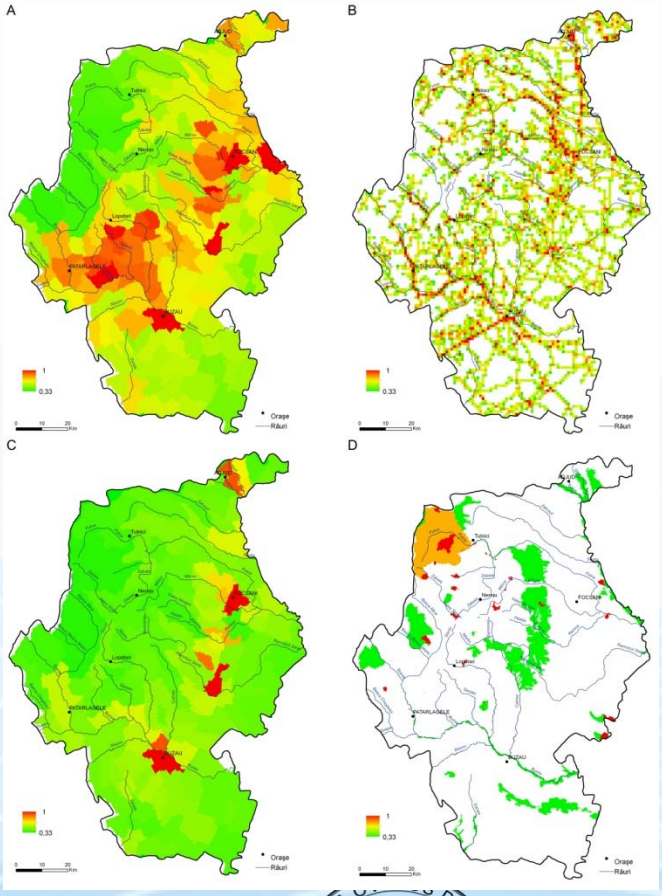
Black Sea CROSS BORDER COOPERATION

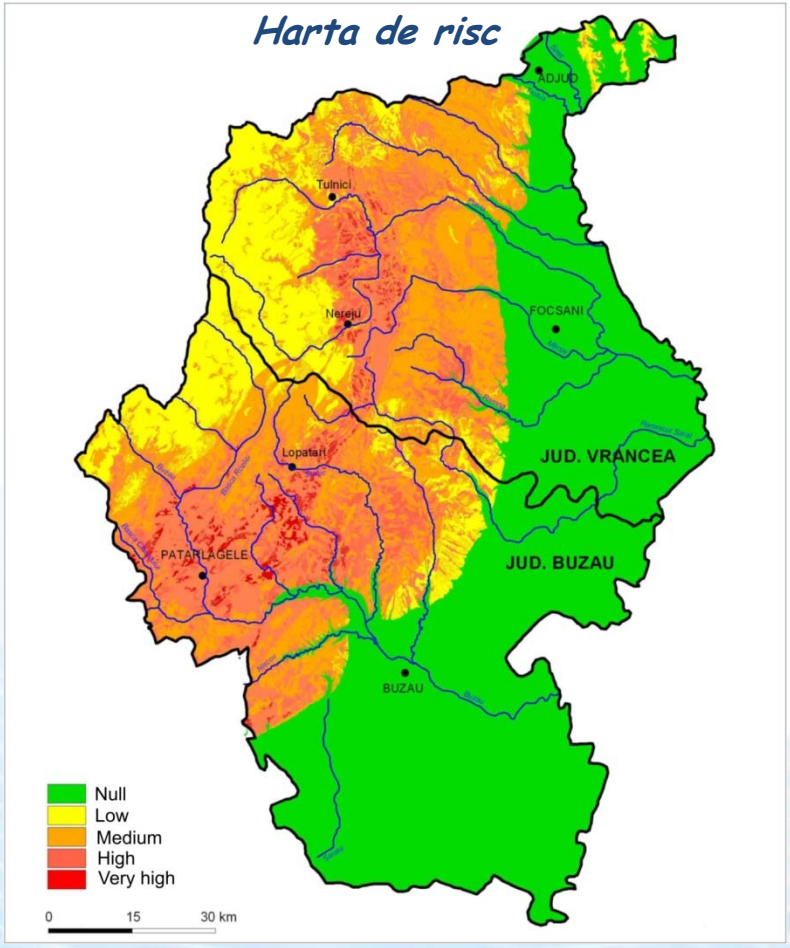
Vulnerabilitate: fizica, sociala, de mediu

Common borders.



FP7 ECLISE

Harta de risc



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CONCLUSIONS

Common borders. Common solutions.

- The methodology provided by the Ministry of Local Public Administration in 1998, 2001 and 2003 it is subjective and difficult to apply (Șandric et al., 2011), due to the uncertainties and different interpretations of the specialists that may occur in assigning weights to various landslide controlling factors in assessing susceptibility.
- Presently, there is no coherence and cohesion in decisions and actions taken by the research institutes and government institutions involved, at local or regional scale in systematic investigation, or a strategy for inventorying and monitoring of landslide affected areas, at national scale.
- Moreover, although a general trend of unification between the Romanian and the international terminology regarding landslide susceptibility, hazard and risk has been observed in recent years, the present methodological requirements underlying the legal framework are not updated.