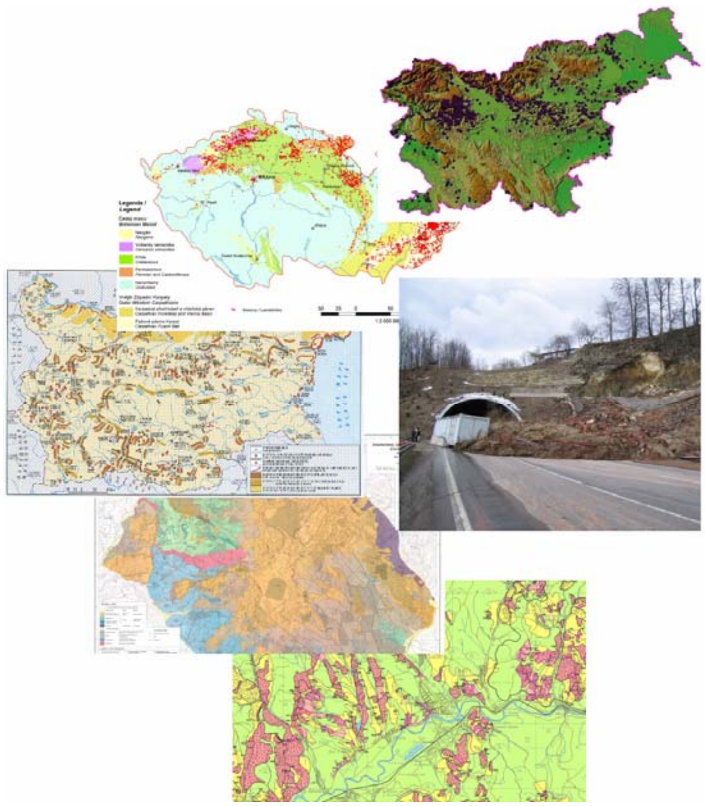
JRC Scientific and Technical Reports

Risk Mapping of Landslides in New Member States

by

Róbert Jelínek, Javier Hervás and Maureen Wood



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1. INTRODUCTION

1.1 Overview: Landslides and Risk Mapping

According to the World Atlas of Natural Hazards (McGuire et al., 2004), landslides are the most frequent and widespread natural hazard on Earth. They can occur on any terrain given the suitable conditions of soil or bedrock, groundwater, and the angle of slope. Landslides commonly occur in conjunction with other natural hazards such as storms, floods, earthquakes, volcanic eruptions or tsunami.

Every year landslide activity causes significant economic loss as well as loss of human life. In the view of PECO country experts (see Figure 1), landslides represent a high risk in Romania, a medium risk in Bulgaria, the Czech Republic, Slovakia and Slovenia, and a low risk in Cyprus, Estonia, Hungary, Lithuania and Poland. For Latvia, the risk associated with landslides is not considered a priority at all.

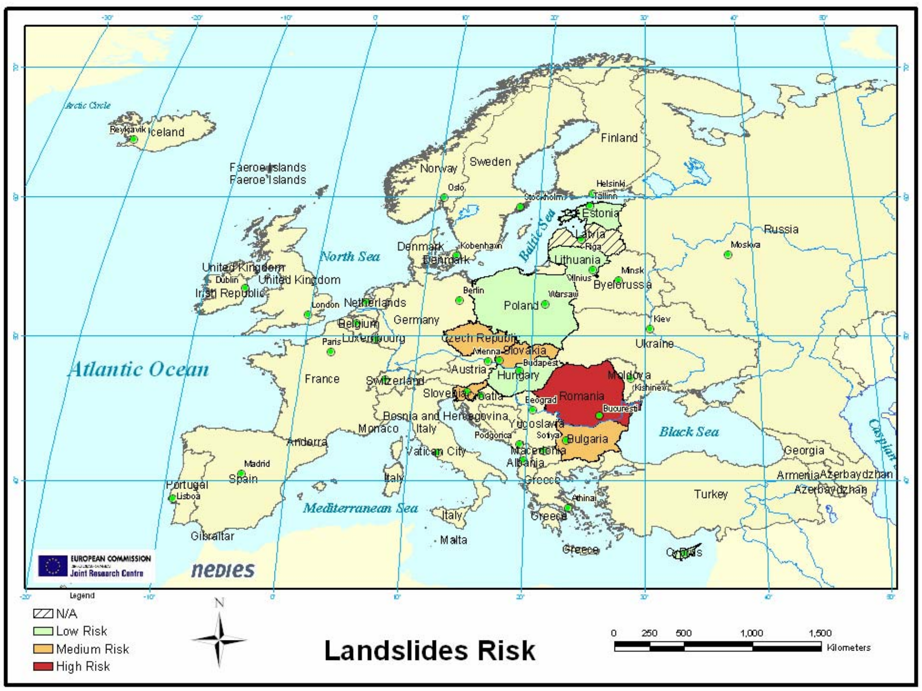

Figure 1: Risk relevance to landslides in the surveyed countries

Many recent landslides have been reported as occurring within the surveyed countries in conjunction with recent major floods, for example, in Romania and Bulgaria in 2005, Romania in 2004, Romania, the Czech Republic and Slovakia in 2002, and Romania and Poland in 2001. Some examples of recent landslide events in the Czech Republic and Slovakia are presented in Figure 2 and Figure 3, respectively.

It is necessary to emphasize that in the survey, the term "landslide" was used in a general sense to describe all types of gravitational slope movements of earth material, such as creep, slides, lateral spreading, flow or fall. The same term is also used to describe specific types of gravitational movement, sliding and its resulting form landslides.

Figure 2: The Hrebec landslide, Czech Republic, March 2006- situation during the first day of the origination (Source: Oldrich Krejci, Czech Geological Survey)

Figure 3: An old road destroyed by landslide close to Harvelka village, northern Slovakia (Photo by R. Jelínek)

Similarly the term "***landslide hazard map"*** was used in two different ways. Firstly, it was used in a broad non-technical sense meaning for all kinds of landslide maps such as inventory maps, susceptibility maps and hazard zonation maps. Secondly, it was also used in reference to local maps that indicate landslide potential or probability within a given area. To provide further clarity, the various types of landslide maps covered by the questionnaire are described in more detail in the following paragraphs.

LANDSLIDE HAZARD MAPS

Landslide maps generally fall into the following categories:

- Landslide inventory maps or landslide location maps
- Landslide susceptibility (or propensity) maps
- Landslide hazard maps

Landslide inventory maps: This type of map shows the locations and/or outlines of landslides. A landslide inventory is a data set that may present a single event, a regional event, or multiple events. Small-scale maps may show only landslide locations whereas large-scale maps may distinguish landslide sources from deposits and classify different kinds of landslides and show other geological or geomorphological data.

Landslide susceptibility maps: These types of maps usually divide the study area into zones according to different degree or level of proneness (susceptibility) to slope movement. Many susceptibility maps use a colour scheme that relates warm colours (red, orange, and yellow) to unstable and marginally unstable areas and cool colours (blue and green) to stable areas.

A landslide hazard map ideally indicates the probability of landslides occurring in a given area at a given time or with a given frequency. A hazard map, however, may be as simple as a map that uses the locations of old landslides to indicate potential instability, or as complex as a quantitative map incorporating probabilities based on variables such as rainfall thresholds, slope angle, soil type, and levels of earthquake shaking. Landslide hazard maps usually divide the study area into zones according to different levels of hazard to slope movement. They can also be called ***landslide hazard zonation maps*** (Varnes et al., 1984).

The other types of maps that include information on landslide types and features together with landforms and processes are ***geomorphological maps*** (and sometimes engineering geological maps). As far as landslide-related information is concerned, these kinds of maps are generally closer to the inventory-type of maps. However, some authors, e.g. Hansen (1984) also refer to geomorphic (or geomorphological) hazard maps when they include landslide hazard levels and other geomorphological features.

Landslide risk maps are however clearly distinguishable from all the above-mentioned maps, since they consider the exposure (or elements at risk) and vulnerability in addition to the susceptibility/hazard.

CAUSES OF LANDSLIDES

According to Griffiths (1999) landslide casual factors can be classified into two groups: (1) preparatory factors and (2) triggering factors. The former make the slope susceptible to movement without actually initiating it, while the latter initiate movement. The trigger is an external stimulus that produces an immediate change in the stress-strain relationships in the slope, resulting in movement. The typical triggers are heavy rainfall or snow melt, earthquake shaking, volcanic eruption, erosion, or human factors. As the main factors that control landsliding, there are (1) geological conditions, (2) groundwater conditions, (3) geomorphological conditions, (4) climatic factors, (5) seismic activity, (6) weathering, and (7) man-made factors.

TYPES OF LANDSLIDES

Landslides can be classified according to variety of factors such as material composition, and type and velocity of movement. The material involved in sliding includes soil, rock, and/or artificial fill. Common types of movement are e.g. creep, sliding, flow and fall (Nemčok 1982) or fall, topple, slides (rotational and translational), lateral spreading and flow (Dikau et al., 1996). In a broad sense according to depth of the shear plane, landslides can be distinguished between shallow landslides (<2 m) and deep-seated landslides (>10 m).

1.2 General Description of the Project

In 2003-2004 the Joint Research Centre performed a survey of mapping practices in eleven (11) countries for eight (8) major natural and technological hazards. This activity was funded as part of the project entitled "Management of Natural and Technological Risks" under the JRC Enlargement action within the Sixth Framework Programme (FP6) for Research and Technological Development (RTD). This project was a continuation of an activity supported by the JRC Enlargement action programme within the Fifth Framework Programme (FP5) RTD aimed at the 10 "PECO" countries.[1] The two activities were designed to support the efforts of new Member States and Candidate Countries in the creation of compatible regional and national central information systems for supporting authorities in the management of risks and emergency situations due to natural and technological hazards. The FP6 project was expanded to include Cyprus.

Under the FP5 project experts from the PECO countries nominated by national authorities agreed on ten priority hazards, including also potential hazards and hazardous activities, as important concerns for the region, as follows (Wood et al. 2003):

Natural hazards	**Technological Hazards**
▪ Floods	▪ Industrial installations
▪ Forest fires	▪ Transport of dangerous goods
▪ Storms	▪ Contaminated lands
▪ Landslides	▪ Pipelines
▪ Earthquakes	▪ Oil-shale mining

[1] PECO countries refer to the 10 Member States in central and Eastern Europe (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia). The acronym is derived from the French translation of "Central and Eastern European Countries" ("Pays de l'Europe Centrale et Occidentale").

The FP6 project aimed to investigate risk mapping practices and policy for priority hazards in these countries. The aim of this activity was to:

- Examine the existing situation in each surveyed country for mapping of priority natural and technological hazards.
- Compare practices used in the different countries for hazard to inform guidelines for establishing compatible national mapping systems.
- Provide a basis for defining a pilot project that would test feasibility of different approaches to harmonizing aspects of mapping practices in regard to specific hazards.

Moreover, it was determined that these objectives could be best fulfilled in a first instance through the administration of a questionnaire on risk mapping practices and policy for priority hazards to the target countries (Di Mauro et al., 2003).

The FP6 project selected eight priority hazards from the FP6 project as the subject of the questionnaire, excluding oil-shale mining and pipelines for practical reasons[2]. The survey and its main results are fully described in the document, "Risk mapping in the New Member States" (Wood & Jelínek, 2007) although this report focuses only on the landslide portion of the questionnaire.

1.3 Survey Methodology and Content

This section describes the survey process including the background as well as practical and technical considerations that determined its focus and approach.

Method for Soliciting and Verifying Questionnaire Responses

Survey responses were collected over the course of a 10-month period between November 2003 and July 2004. The initial survey was sent to project focal points nominated by the countries to respond to the hazard questionnaires. Each country was requested to complete a questionnaire for only those hazards that they had identified in the previous survey as priority hazards (and as mentioned, countries were allowed to modify the previous prioritization for their country if they so desired). For this reason, there is not a complete set of questionnaire responses for any one hazard. The JRC then organized a meeting in each participating country to discuss the answers to the questionnaires with the responding authorities. This meeting offered an opportunity to clarify questions and responses, gain more comprehensive information, and improve consistency between responses across hazards and respondents.

Following the meeting the questionnaire was revised and reviewed and through an iterative exchange between respondents and the JRC, the responses were finalized and accepted as complete.

[2] In the case of oil-shale mining, interest in this hazard was not widespread and it was determined that most respondents would not have a mapping programme aimed at this activity. On the other hand, in many countries the competent authority that manages pipelines and pipeline mapping is quite distinctly apart from those that handle other technological hazards or natural hazards. Therefore, it was considered impractical to include this hazard in the survey based on the additional extra effort that might be required to gain the support and co-operation of these authorities.

Content of the Full Questionnaire

The questionnaire encompassed eight separate sections, each one focused on a particular hazard. Moreover, the same methodology was applied for each hazard. In essence, the questionnaire aimed to identify state-of-the-art mapping practices, priorities, and similarities and differences in data collection and mapping practices for each hazard. Each questionnaire was divided into six sections:

- General description of hazard maps
- Data and data collection
- Identification of elements at risk
- Vulnerability mapping and classification
- Risk mapping
- Final considerations (use and accessibility)

Questions within sections were then individualized for each type of hazard.

Description of the Landslide Section Questionnaire

The analysis of the landslide questionnaire is the subject of this report. Its contents can be summarized as follows:

General description of hazard maps

This section deals with the availability of official landslide hazard maps (i.e. maps made by a government entity, such as a ministry, mapping agency, the army or other) in a particular country. Additionally, the availability of any other types of landslide maps is investigated. Standard map parameters such as coverage, scale, projection, symbols, format, issuing authority, date of origin and the latest updates are also requested.

The second part of this section asks respondents to identify the standard background components of official landslide maps, while in the third part, the respondent is asked to specify how landslide hazards maps or other landslide maps are used, degree of accessibility to such maps to the public and their availability via Internet.

The final part requests information on existing legislation covering landslide mapping practices in the surveyed countries.

Data and data collection

This part of the questionnaire deals with information on landslide hazard data sources and related collection process. The section starts with questions in regard to responsible authorities for collecting information about landslide hazard sources and its related management.

The second part asks for information on official mechanisms for collecting landslide hazard data. The respondents were allowed to specify the type of information collected (e.g. rainfall, seismic data, geological setting, terrain configuration), parameters and units used, and how data are collected. Furthermore, information was also requested about the area covered by the data, the time period covered, the frequency of update and whether the data are maintained in digital or paper form.

This section also asked questions about availability of metadata, the specific way in which data are used in the surveyed countries, and the degree of accessibility of data or constraints on its use.

Identification of elements at risk

This section explores how respondents classify elements ("objects") exposed to landslide hazard and the level of importance assigned to each category (from very low to very high) for the elements selected.

Vulnerability mapping and classification

The first part of this section asks about the availability of official landslide vulnerability maps in the surveyed countries and how different levels and types of vulnerability are classified in the country. Respondents are also asked to indicate whether certain types of damage (e.g., to people, to property) are considered reversible (temporary) or irreversible (persistent) in their country.

Risk mapping

This part of the questionnaire aims to determine whether landslide risk maps, i.e. maps considering hazard, exposure and vulnerability, are produced in the country and, if so, what the standard features of these maps are. It also seeks information on how landslide risk is represented in such maps, public accessibility and how the maps are used.

Use and accessibility (final considerations)

The final part of the questionnaire includes general questions related to a harmonized approach to define risk maps and asks about potential benefit of those integrated risk maps in the surveyed countries.

2. ANALYSIS OF RESPONSES TO THE LANDSLIDE SURVEY

As is shown in Table 1, six out of the eleven target countries identified landslides as a priority hazard and completed responses to the questionnaire. Estonia, Hungary, Lithuania and Poland did not provide data. Latvia indicated that landslides hazards are generally a low risk and therefore did not provide data either.

Table 1: Respondents and focal points for landslide mapping questionnaire

Country	Address
Bulgaria	Ministry of Regional Development and Public Works ul. "Sv. Kiril i Metodii" No 17-19, Sofia, 1202 Bulgaria www.mrrb.government.bg
Czech Republic	Czech Geological Survey Leitnerova 22, Brno, 658 69 Czech Republic www.geology.cz
Cyprus	Geological Survey Department 1, Lefkonos Str. Nicosia, 1415 Cyprus www.cyprus.gov.cy
Romania	Ministry of Agriculture and Rural Development B-dul Carol I, No. 24, Sector 3, Codul Postal 020921, Oficiul Postal 37 Bucharest, Romania http://mapam.ro/
Slovakia	State Geological Institute of Dionyz Stur Mlynská dolina 1, Bratislava 11, 817 04 Slovakia www.geology.sk
Slovenia	Ministry of the Environment, Spatial Planning and Energy Einspielerjeva 6 Ljubljana, 1000 Slovenia www.mop.gov.si

Half of the respondents were from national geological institutions, two from related ministries and one from academia. Survey responses should be considered in light of the following observations:

- The majority of responses were very comprehensive with many useful comments, therefore the response quality is considered very high.
- Nonetheless, some experts did not answer every question. (When relevant it has been noted in this report when one or more response is lacking for a specific question.)

2.1 Landslide Hazard Maps in Surveyed Countries

Table 2 presents data on the current state of landslide hazard maps and their parameters in the surveyed countries.

Table 2: Availability of landslide hazard maps

Country	Maps Produced Format – Digital (D) or Paper (P)	Coverage/ Scale	Date Created/ Last Updates	Legal Act Foreseeing Landslide Maps
Bulgaria	Landslide inventory maps (D, P)	National: 1:500,000 Not geo-referenced	1999/Not updated	Organization of Territory Act
Czech Republic	Landslide inventory maps (D, P)	National: 1:50,000	1960 - up to date/ updated periodically	No, only a recommendation
	Landslide hazard maps (D, P)	Provincial: 1:10,000	1997-2003/ continuously	
	Maps of stability conditions (D, P)	Provincial: 1:10,000	1997-2003/ continuously	
Cyprus	Detailed landslide inventory maps (P, some D)	Municipalities and small areas 1:10,000 1:5,000	1986-1987/not specified	No, only a code for technical practices
Romania	Detailed landslide maps and Hazard maps to landsliding (P, some D)	National 1:1,000,000 Regional 1:1,000,000 Provincial 1:25,000 Municipal 1:5,000	2001/updated after changes	Law No. 62/N-19.0/288-1.955/1998 and No. 575/2001
Slovakia	Landslide inventory maps Landslide susceptibility maps (P, some D)	National 1:1,000,000 Regional 1:50,000 and 1:10,000 Provincial: 1:10,000	1960 - up to date/ Not updated	No
Slovenia	Landslide inventory maps and unofficial landslide hazards maps (D, P)	National 1:400,000	1995-1997/updated in 2004	The Water Act from August 2002

Types of maps

Official landslide maps (i.e. maps made by a government entity, such as a ministry, a mapping agency, the army or other) are currently available in Bulgaria, the Czech Republic, Romania and Slovakia. In Cyprus and Slovenia no official maps exist at the moment.

- Bulgaria, the Czech Republic, Cyprus, Romania, Slovakia and Slovenia have landslide inventory maps at a scale of 1:1,000,000 up to 1:5,000 (Figures 4, 5 and 6).
- Czech Republic, Romania, Slovakia and Slovenia have landslide hazard or landslide susceptibility maps (Figures 7, 8 and 9).
- The Romanian expert explained that the landslide hazard maps were initially prepared only for small and important areas. Since adopting a new law (No. 575/2001), the maps are required to be prepared in digital format for the entire Romanian territory.

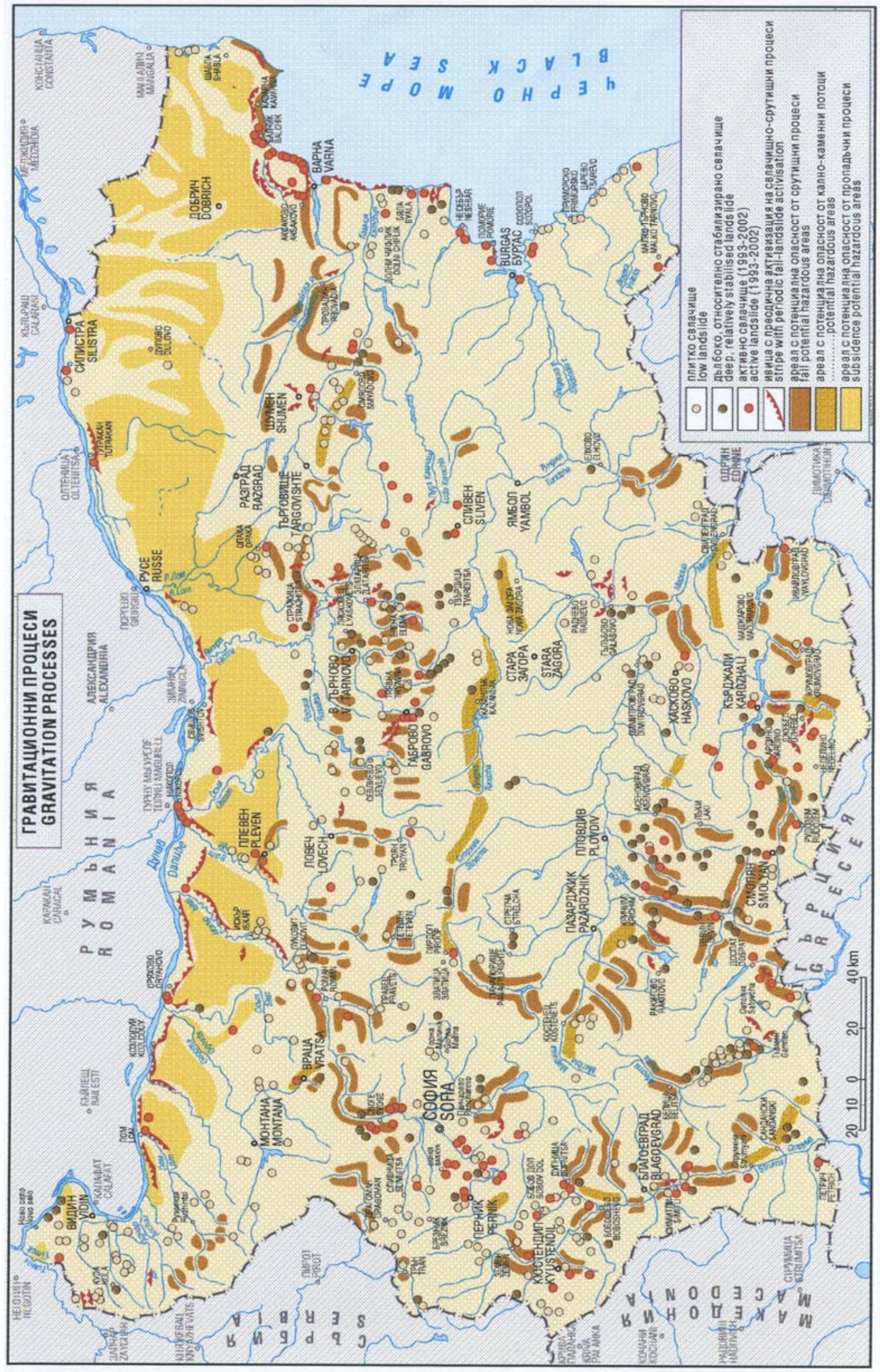

Figure 4: Map of gravitational processes in Bulgaria
(source: George Alexiev, Geography Institute, Bulgarian Academy of Sciences, Sofia)

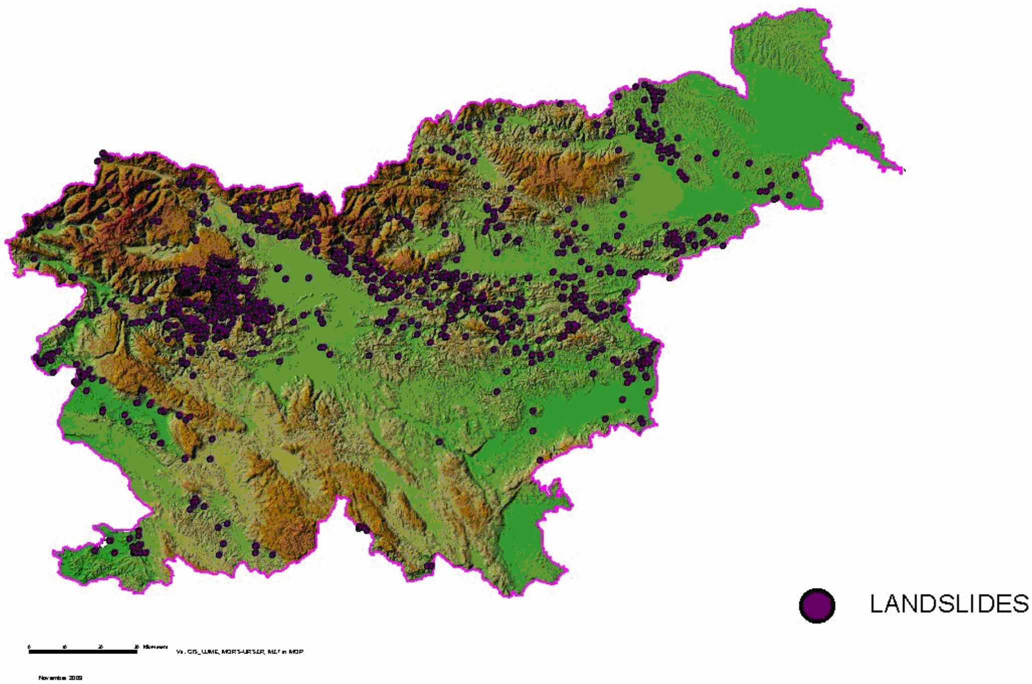

Figure 5: Landslides in Slovenia in 2002
(Source: Ministry of the Environment, Spatial Planning and Energy)

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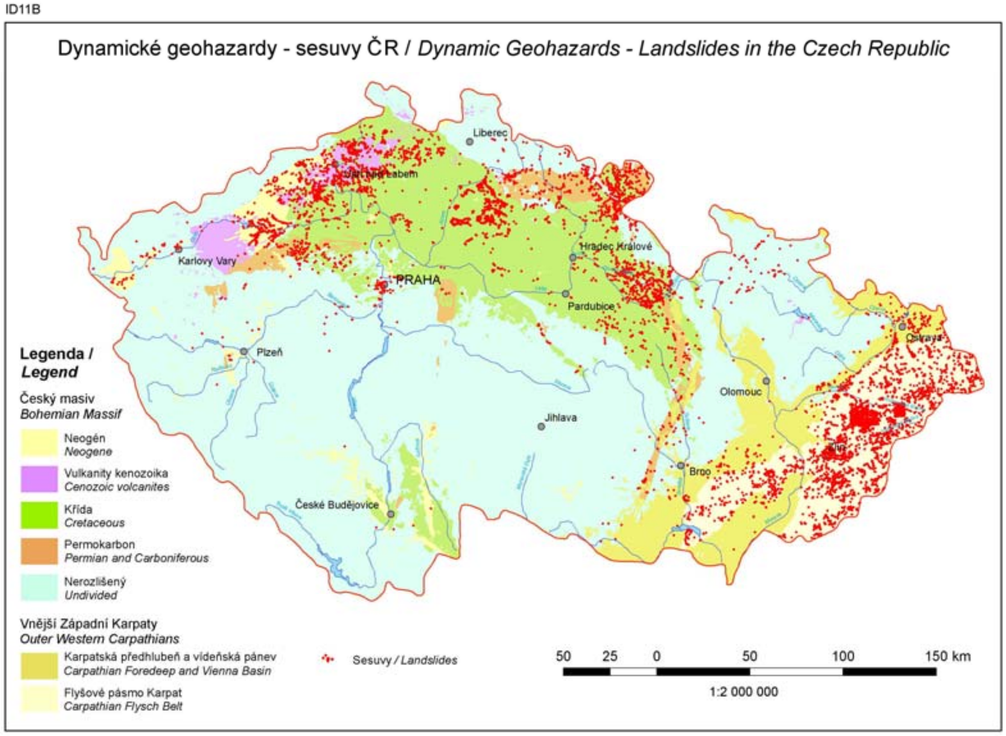

Figure 6: Landslides in the Czech Republic
(Source: Oldrich Krejci, Czech Geological Survey)

- Existing landslides are often included in so-called maps of geofactors in Slovakia or in engineering geological maps. An example of such an engineering geological map from Statos area in Cyprus is illustrated in Figure 10.
- In Slovakia, approximately 15,000 landslides have been inventoried, covering about 3.7 % of the entire country.
- In Slovenia, the official landslide inventory includes about 1,450 landslides.

Scale, coverage, format and projection of maps

- The scales of different landslide maps generally range from a rather small scale of 1:1,000,000 to a large scale of 1:5,000.
- Paper is still the most common format used in the surveyed countries, however paper maps are gradually being replaced with digital versions.
- The majority of the countries' national grid systems are based on the Transverse Mercator projection with their own national coordinate reference system. Some countries use more then one coordinate system. Annoni et al. (2001) recommended for the member states to use the Universal Transverse Mercator (UTM) projection system and the Lambert Conformal projection (LCC) for topographic maps with scales larger than 1:500,000 and cartographic maps with scales equal 1:500,000 or less, respectively.

Data created and last updated

Results indicate that the majority of the respondent countries have quite recent landslide susceptibility/hazard maps created in the 1990's or 2000's, although production of such maps has been in existence for a few decades in some countries. For example, in the Czech Republic and Slovakia the earliest landslide susceptibility maps date from the 1960's. It was noted that maps are updated periodically in the Czech Republic, Romania, Slovakia and Slovenia.

Legislative framework

Respondents were asked to describe any legal instruments that mandate or guide official mapping of landslide hazards. The responses show that a legal framework supports landslide mapping in Bulgaria, Romania and Slovenia. In the Czech Republic and Cyprus, there is a recommendation or code for technical practice, respectively. These instruments generally contain guidance or requirements relative to hazard management, including data and mapping requirements, and a definition and classification system for landslide-prone areas.

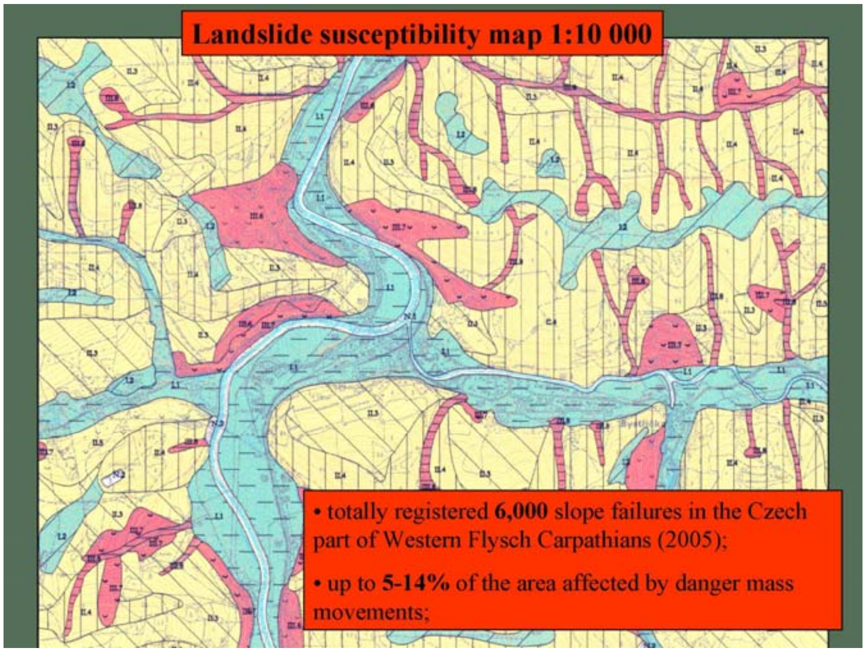

Figure 7: Example of Landslide susceptibility map of Flysch Carpathians, Czech Republic at an original scale of 1:10,000 (Source: Oldrich Krejci, Czech Geological Survey)

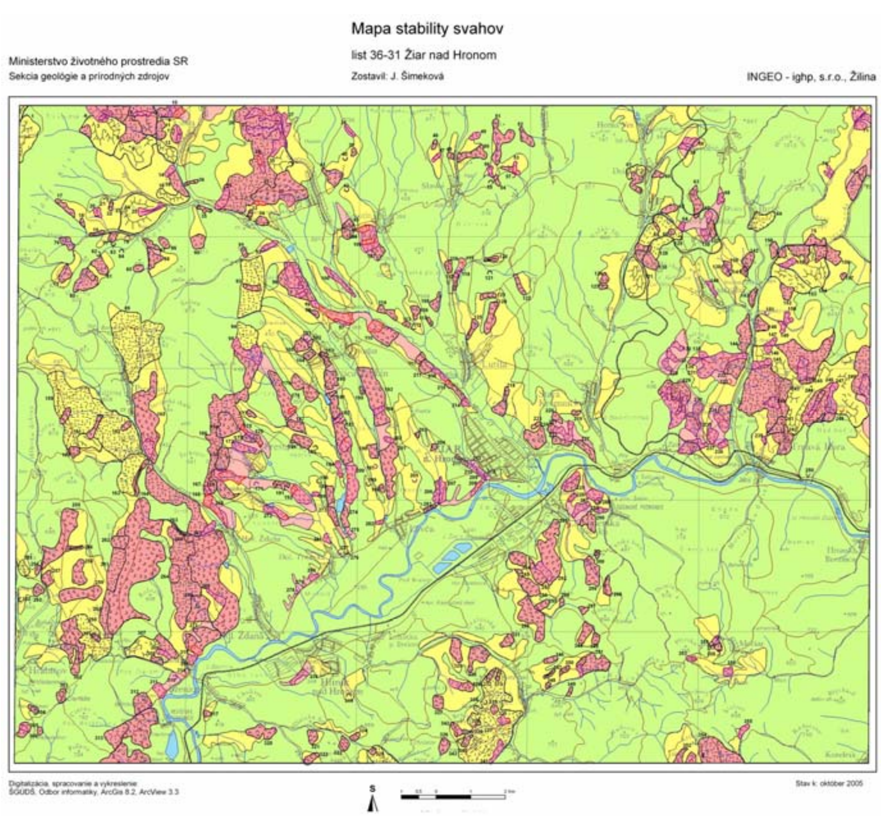

Figure 8: Example of slope stability map of Žiar nad Hronom region, central Slovakia (Source: Peter Wagner, State Geological Institute of Dionyz Stur)

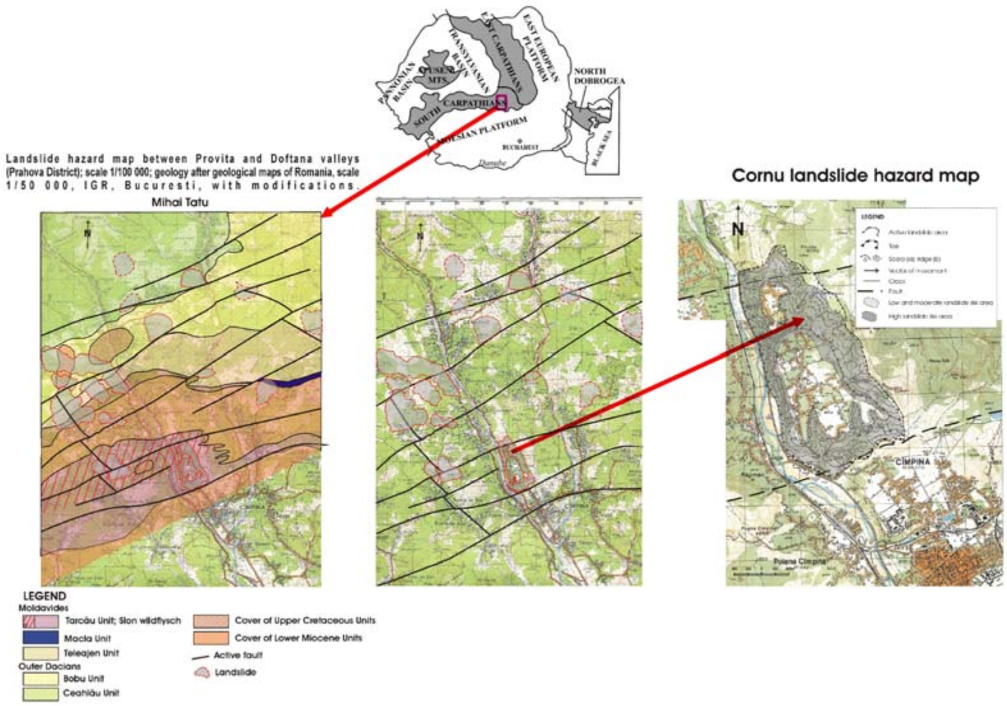

Figure 9: Landslide hazard map of the Prahova district, Romania
(Courtesy of Mihai Tatu, Institute of Geodynamics, Romanian Academy, Bucarest)

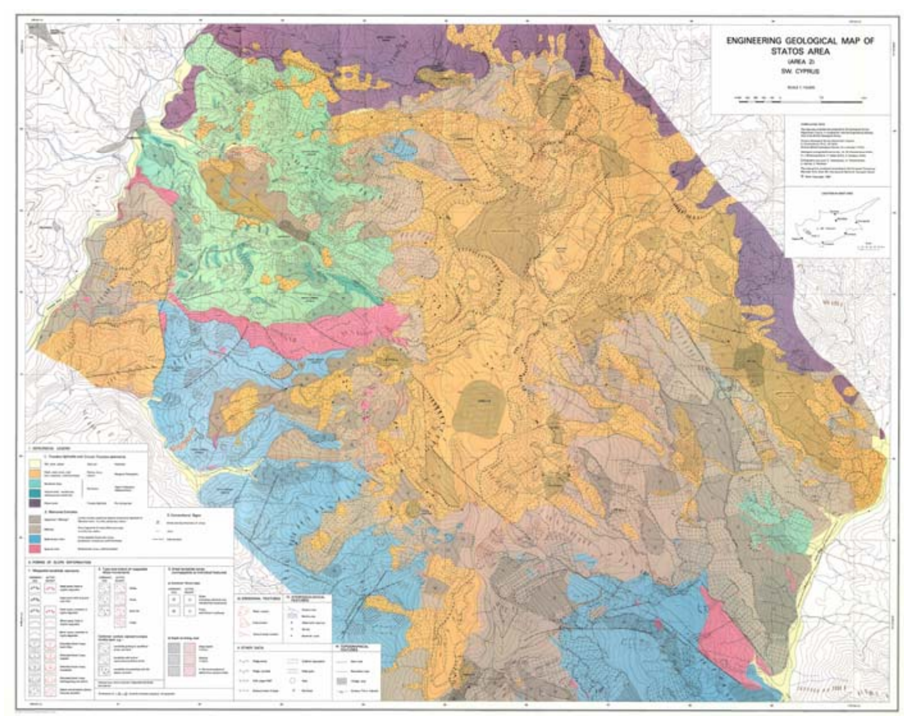

Figure 10: Engineering geological map of Statos area, Cyprus
(Source: Geological Survey Department)

Map features or symbols and background information on landslide hazard maps

As can be seen in Table 3, five countries responded comprehensively to the question related to map features and background information used in landslide hazard maps. Typical map features or symbols displayed usually consist of colour, point, polylines and polygons, which usually express location of a specific landslide and its activity. The background information is generally similar across the countries, consisting of topography, roads, railways, hydrological features (river network, water bodies, catchments, waterworks, etc.) and administrative boundaries.

Table 3: Map features and background information used in landslide hazard maps

Country	Standard Landslide Map Features or Symbols
Bulgaria	**Background:** Topography, roads, railways
Czech Republic	**Landslide-related:** localization of small phenomena, boundaries between stable, unstable and other areas, quasi-homogeneous zones of certain specific level of landslide susceptibility/hazard **Colour:** blue- hydrogeological phenomena; green- jeopardized objects; red- instability zones, amber- zones conditionally exploitable **Background:** Topography, bedrock (only in combination with the official geological map of the Czech Republic in the scale 1:25,000 or 1:50,000), hydrological catchments (only erosional processes and wet areas), water bodies, administrative boundaries (in scale 1:50,000 only), population (villages and towns), roads, railways
Cyprus	**Landslide related:** Some engineering geological maps include landslide types along with landslide geomorphological features and outlines. There are no official landslide hazard symbols **Background:** topography, bedrock, water bodies, administrative boundaries, roads, springs, rivers
Romania	**Landslide-related:** Degree of risk, monitoring stations, measurements wells, landslide front, landslide movement speed and direction **Background:** Topography, hydrological catchments, land use, water bodies, administrative boundaries, population, roads, railways
Slovakia	**Landslide-related:** localization of landslide areas (small phenomena as dots, relatively large landslides as polygons), degree of activity (stable, potentially unstable, unstable) **Background:** Topography, water bodies, administrative boundaries, population, roads, railways
Slovenia	**Landslide-related:** localization of landslide areas (points on the maps with some attributes), potential landslides are not included **Background:** Topography, hydrological catchments, water bodies, administrative boundaries, population (number of inhabitants for each building), roads, railways, waterworks, gas-lines

Use of landslide hazard maps and their degree of accessibility

Landslide hazard maps (in a broad sense) in the surveyed countries are used for a variety of purposes. As can be seen from Table 4, all of these countries use landslide hazard maps for scientific research. In the majority of the countries, information from landslide hazard maps is used to help national authorities in land use and emergency planning, communication amongst decision-makers and to the public, and to target allocation of resources. The Czech Republic and Romania also use landslide hazard maps for military purposes. Landslide hazard maps are accessible to the public in every country, except for Romania where the maps are restricted.

Table 4: Use of landslide hazard maps and their degree of accessibility

Use of Landslide Hazard Map	Bulgaria	Czech Republic	Cyprus	Romania	Slovakia	Slovenia
Targeted Information Communication to the Public	No	Public	No	Restricted	No	No
Targeted Information Communication amongst Decision-makers	No	Public	Public	Restricted	Accessible	No
Land Use/Spatial Planning	No	Public	Public	Restricted	Accessible	Accessible
Territorial Management	Accessible	Public	No	No data	Accessible	No
Emergency Response Plans for Civil Protection	Accessible	Public	No	Restricted	No	Accessible
Targeted Allocation of Resources	Accessible	Public	No	Restricted	Accessible	No
Scientific Research	Accessible	Public	Public	Restricted	Accessible	Accessible
Military Purposes	No	Public	No	Restricted	No	No
Visualization of Information only	No	No	No	Restricted	Accessible	No

Legend: “No” = landslide hazard maps not typically used for this purpose

2.2 Landslide Hazard Data

A basic requirement for preparing a landslide hazard map is to have extensive background data on geological, geomorphological and hydrogeological conditions and land cover/use data of the area. Indeed, it is also important to understand the whole landslide phenomenon, particularly its triggering mechanism, history and development. This section is therefore dedicated to landslide hazard data sources and related collection process.

According to the survey, all of the countries prone to landslides have authorities responsible for collecting information on this phenomenon. Most of the countries also have an official process for collecting landslide data (except of Cyprus and Slovenia). Table 5 shows the types of information collected to characterise landslide hazard in the surveyed countries.

Table 5: Landslide hazard data information

Country	Climatology & Meteorology	Seismology	Geological Setting and Conditions	Terrain Configuration	Format Area coverage Georeference Metadata standard
Bulgaria	Precipitation, other	Unspecified parameter	Lithology, stratigraphy, pore water pressure, other	Soil humidity, other	Paper National, regional, municipal Geo-ref: No Metadata: No
Czech Republic	Official data from Czech Hydrometeorological Institute	Official data from Geophysical Institute	Lithology, faulting	DEM in 1:10,000	Digital & paper National, regional Geo-ref: Yes Metadata used
Cyprus	Not collected	Intensity, ground acceleration	Lithology, faulting, weathering, jointing consolidation	Slope angle, slope aspect, length of slope	Paper Coverage: All levels Geo-ref: Yes Metadata: No
Romania	Precipitation, temperature, pressure, solar degree, air relative humidity, snow depth, snow density, water equivalent of the snow layer	Intensity, ground acceleration, magnitude, other	Lithology, stratigraphy, pore water pressure, ground water level	Vegetation type, slope angle, soil temperature, soil humidity	Digital & paper Coverage: All levels Geo-ref: Yes Metadata: No
Slovakia	Precipitation, temperature, pressure	Not collected	Lithology, stratigraphy, faulting	Slope angle, slope aspect, length of slope, vegetation type	Digital & paper National, regional Geo-ref: Yes Metadata used
Slovenia	Not collected	Not collected	Not collected	Not collected	Metadata used

Climatology and Meteorology

Climatological conditions, such as heavy rainfall, snowfall or temperature anomalies (sudden snow melting) are often a major cause of landslides. Special care must be taken during long periods of precipitation, in particular to understanding how the rainfall influences activation of individual landslides. An intensive rainfall such as those induced by tropical cyclones usually causes rapid shallow landslides, while deep-seated and slow landslides are stimulated by successive rainfalls or sustained snow melting.

The potential relation between climatological parameters and landslide occurrence is an important task in landslide analysis. According to the survey, most common landslide related meteorological parameters are precipitation and temperature (except in Cyprus).

Seismology

Earthquakes are another natural phenomenon that can often trigger a landslide. According to Chowdhury (1978), acceleration of earthquake acting on a slope induces a temporary change of stress, which can break the equilibrium. External impact from seismic activity results in increased shear stresses and also reduces shear strength by increasing pore water pressure. Therefore, measurement of earthquake parameters, particularly in seismically active areas, is very important for landslide prediction. Among the surveyed countries, Bulgaria, Cyprus, the Czech Republic and Romania collect seismic data. The most common parameters for which data are collected are intensity and ground acceleration. According to the Czech experts, the relation between occurrence of large landslides and seismological events in the Western Carpathians has not been confirmed.

Geological Setting and Conditions

The geological basis of a study area is highly important to understanding potential slope developments and movement. Traditionally, identification of significant geological features, the position of all the important soil and rock layers with their properties, the weathering process, and seismic activity should be defined and carefully analysed. Lithological data are collected in all of the surveyed countries. Data on weathering are collected in Cyprus.

As mentioned previously, landslides are often associated with earthquakes, which usually occur along faults. Fault data are collecting in the Czech Republic, Cyprus and Slovakia.

Other important parameter related to landslide activity includes pore water pressure. Groundwater level rising after heavy rain increases pore water pressure within a slope and consequent reduction of shear strength can often lead to a landslide. Measurements of pore water pressure are performed in Bulgaria and Romania.

Terrain Configuration

A key data element in landslide hazard assessment is information related to terrain configuration such as slope angle, slope aspect, and slope length, which can be easily derived from digital elevation models (DEM). Therefore, it is assumed that these data are also available in all countries with suitable DEM. Data on soil humidity are collected in Bulgaria and Romania; and data on vegetation type in Romania and Slovakia.

Additional observations

- The Czech Republic, Cyprus, Romania and Slovakia generally have geo-referenced information.
- Metadata, although of different types, are standardly used in the Czech Republic (ORACLE- MGE system), Slovakia (ESRI system) and Slovenia (cen/tc287). The advantage of using a metadata standard is that data sets will interoperate with other sets that use the same standard.
- The Czech Republic, Romania and Slovakia keep data in either digital or paper format; Bulgaria and Cyprus maintain data only in paper form.

- A landslide monitoring system has been developed in some countries, for example:
  - In Cyprus, inclinometric measurements are used in small areas affected by landslides.
  - In the Czech Republic, about 50 selected sites have been automatically monitored using geodetic, hydrogeological or geophysical methods.
  - A real-time monitoring and warning system similar to that of the Czech Republic has been applied in Slovakia.

Use of landslide hazard data

Landslide hazard data have a specific use in all of the surveyed countries, except Slovenia. The majority of countries use the hazard data for scientific analysis, targeted information communication among decision-makers (except in Slovakia), land use and spatial planning (except in Bulgaria) and emergency response plans for civil protection (except in Slovakia). Detailed information related to the use of landslide hazard data in the surveyed countries is summarized in Table 6.

Table 6: Use of landslide hazard data and their degree of accessibility

Use of Landslide map/degree of accessibility	Bulgaria	Czech Republic	Cyprus	Romania	Slovakia	Slovenia
Targeted Information Communication to the Public	Yes/ns	Yes/Public	No	Yes/ Restricted	No	n/a
Targeted Information Communication amongst Decision-makers	Yes/ns	Yes/Public	Yes/Public	Yes/ restricted	No	n/a
Land Use/Spatial Planning	No	Yes/Public	Yes/Public	Yes/ restricted	Yes/ns	n/a
Territorial Management	Yes/ns	Yes/Public	No	No data	No	n/a
Emergency Response Plans for Civil Protection	Yes/ns	Yes/Public	Yes/ns	Yes/ restricted	No	n/a
Targeted Allocation of Resources	Yes/ns	Yes/ns	No	Yes/ restricted	No	n/a
Scientific Research	Yes/ns	Yes/Public	Yes/Public	Yes/ restricted	Yes/ns	n/a
Military Purposes	No	Yes/Public	No	Yes/ restricted	No	n/a
Visualisation of Information only	No	No	No	Yes/ restricted	Yes/ns	n/a

Legend: ns- not specified, n/a- not applicable

The access to landslide hazard data in Romania is permitted only to authorized personnel or competent authority representatives. For the other countries, the data are available to the public.

Experts were also asked if the information available is sufficient for defining a national landslide hazard map. All of the respondents replied positively, except Cyprus and Slovenia. In particular, Cypriot experts stated that the information available does not cover the whole country.

2.3 Landslide Vulnerability Maps

Landslide vulnerability is a fundamental component in the evaluation of landslide risks. Respondents were asked to identify objects considered important vulnerable elements for landslide hazards. In general, the interpretation of responses does not distinguish between the importance of the element (to the economy, to society) or exposure. The responses are simply an indication of how such objects are prioritised for mapping and also other prevention and response activities in relation to landslides.

Results indicate that only a few countries have begun significant work in this area and that by and large most remain open to looking at different approaches and methodologies. Most notably, vulnerability maps are not common in the surveyed countries. According to the survey, only Bulgaria and Slovakia have official landslide vulnerability maps. In particular, there are three degrees of vulnerability levels in Slovakia. Bulgaria is the only country with an official classification system identifying types of objects considered potentially vulnerable to landslide hazards.

Level of importance of the elements at risk exposed to landslide hazards

Respondents were also asked to indicate how various categories of typically vulnerable objects are prioritised for landslide risk management in their countries, on a scale of very low to very high. The following Table 7 presents the summary of the results obtained.

Table 7: Level of importance of the elements at risk exposed to landslide hazard

Country	Humans as Indivi-duals	Humans as Social Targets	Infrastruc-ture	Cultural Heritage	Private Property	Natural Resour-ces	Ecology
Bulgaria	M	M	VH	M	M	M	VH
Czech Republic	M	M	H	L	H	L	H
Cyprus	VL	VL	VL / L	VL	VL / L	VL	VL
Romania	H	VH	H	H	H	M	M
Slovakia	VL	VL	M	L	M	M	L
Slovenia	VH	H	M	H	L	H	M

Legend: VH: Very high; H: High; M: Medium; L: Low; VL: Very low

The results indicate that most countries assign infrastructure the highest exposure to landslide hazard, while cultural heritage and natural resources the lowest. Humans as individuals, humans as social targets, infrastructure and ecology are ranked as elements at very high risk when exposed to landslides by at least one country. For the countries like Romania and Slovenia, human as individuals and human as social targets have at least high level of importance or very high.

An overall perspective on how individual countries view certain vulnerable objects is presented in Figure 11. This figure indicates that Romania, Bulgaria and Slovenia are the countries that allocate the total highest level of importance of risks to landslides. On the other hand, Cyprus is the country with a low and very low level risk in relation to the elements in question.

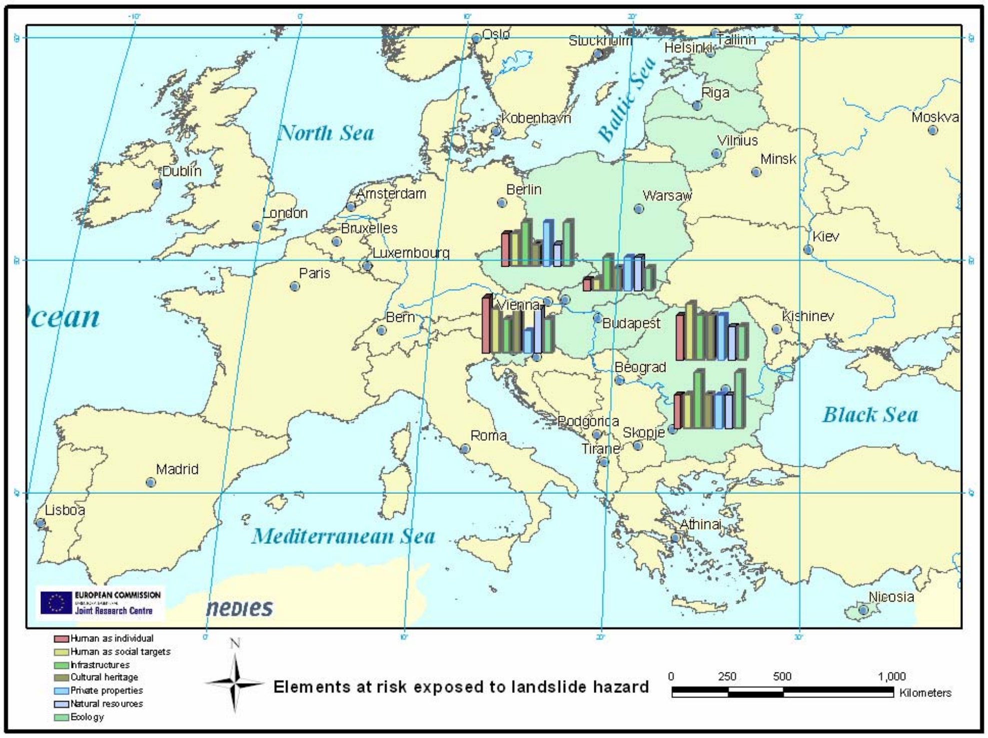

Figure 11: Elements at risk to landslide hazard

Classification of damages

Vulnerability in the proposed questionnaire was further investigated in terms of reversible (temporal) and irreversible (persistent) damage. The distinction between reversible and irreversible effects is usually used in connection with hazards from industrial installations accidents and earthquakes. The terms are not as consistently used in reference to landslides. Only three countries, Bulgaria, Cyprus and Romania, indicated that potential damage resulting from landslides was officially classified as reversible or irreversible, as shown in Table 8.

Table 8: Classification of damages as reversible and irreversible for elements at risk in Bulgaria, Cyprus and Romania

Country	Reversible Damage	Irreversible
Bulgaria	**Human:** Injury **Infrastructure:** Severe damage, economic loss, public service interruption **Cultural heritage:** Economic loss, accessibility **Private property:** Economic loss **Natural resources:** Economic loss	**Human:** Death **Infrastructure:** Destruction, uneconomical recovery **Cultural heritage:** Economy **Private property:** Economic loss **Natural resources:** Economy
Cyprus	**Human:** Economic loss **Infrastructure:** Severe damage, loss of functionality, economic loss, public service interruption **Cultural heritage:** Economic loss **Private property:** Economic loss	**Infrastructure:** Uneconomical recovery **Private property:** Economic loss
Romania	**Human:** Injury, acute effect, epidemic, economic loss **Infrastructure:** Severe damage, loss of functionality, economic loss, public service interruption **Cultural heritage:** Economic loss, accessibility **Private property:** Economic loss, loss of functionality **Natural resources:** Economic loss, loss of resource **Ecology:** Loss of biodiversity	**Human:** Death **Ecology:** Loss of biodiversity

According to the responses of the surveyed countries, the landslides pose serious problems to human, infrastructures, culture heritage and private property.

2.4 Landslide Risk Maps

Similar to vulnerability, the questionnaire also sought to understand how countries were approaching risk mapping, and whether in fact, it was of interest to them. The current situation indicates that landslide risk maps are currently not available in the surveyed countries. However some examples of risk maps exit even if they are not official. In the Czech Republic, each municipality has access to risk maps of its territory produced by the civil protection authorities. For example, the Bulgarian expert responded to the questionnaire indicating that landslide risk maps existed. However, in the follow-up interview with Bulgarian experts, it became clear that there were actually “non-official” landslide risk maps produced, e.g. by universities or research organizations. Nonetheless, relevant information about the risk is available for the entire country. All the countries expressed their intention and need to create landslide risk maps in future years. In addition, all of the experts from the PECO countries answered positively to the question concerning their interest in a harmonised approach to risk mapping of landslide and were particularly interested in maps that could integrate landslide risks with other important manmade or natural risks in a particular region. Furthermore, the definition of a common harmonised approach could allow their experts to gain valuable experience and reduce the time and economic resources required for a similar national effort. A common methodology and symbols could also make maps of landslide risk in the different countries compatible. Aspects such as land use, infrastructure, new buildings, population, sensitive environmental areas, properties, cultural heritage, number of zones in different risk classes, plus their boundaries and symbols would also be valuable to harmonise.

3. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following points summarise key findings from the survey of PECO country practices related to landslide mapping. Landslides are generally considered as low to moderate hazard for all of the countries surveyed, except of Romania where they represent high hazard**.** Notably, six out of eleven countries provided information on landslide mapping, namely Bulgaria, the Czech Republic, Cyprus, Romania, Slovakia and Slovenia. Latvia was not prone to landslides. Estonia, Hungary, Lithuania and Poland did not provide data.

- Landslide hazard maps in a general sense are currently available in all of the surveyed countries. Those maps are usually landslide inventory maps.
- National authorities responsible for collecting information on the landslide hazard exist in all of the surveyed countries.
- Landslide hazard maps and data are generally available to the public in the majority of countries (except Romania).
- Most of the surveyed countries have an official process for collecting landslide data (except Cyprus and Slovenia).
- Most commonly collected landslide data relate to the following parameters: precipitation (in all of the countries), seismology (Bulgaria, Cyprus, the Czech Republic and Romania) and geological features (all countries).
- Geo-referenced information with associated metadata is available in the Czech Republic, Cyprus, Romania and Slovakia.
- Bulgaria and Slovakia indicated that official landslide vulnerability maps are available in their countries.
- At least one respondent ranked humans as individuals, humans as social targets, infrastructure and ecology as elements at very high risk when exposed to landslides.
- Romania, Bulgaria and Slovenia assigned the highest level of risk to landslides. Cyprus considered vulnerable elements to be generally at low risk.
- Cyprus, Bulgaria and Romania reported having an official classification of potential damages as reversible or irreversible.
- None of the surveyed countries is currently producing official landslide risk maps. However some unofficial risk maps have been reported from Bulgaria and the Czech Republic.

Recommendations

Based on these conclusions, the following recommendations can be stated:

- A potential opportunity exists to design and implement new mapping tools for visualising and managing landslide hazards. Landslides are an important hazard for at least 6 of the surveyed countries.
- As a first step, it could be valuable to examine different landslide hazard mapping practices in selected regions of the surveyed countries and make comparisons.
- Identification of a common approach to classifying vulnerability to landslides is another area that could be explored on a collaborative basis. In general, the countries appear to remain quite open to different approaches to classifying vulnerability.
- It could also be useful to develop common approaches to mapping landslide risks to meet the needs of the INSPIRE initiative (http://www.ec-gis.org/inspire/) aimed at harmonising and improving quality and accessibility of spatial information at European level.

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Abstract

In 2003 the Joint Research Centre conducted a survey of mapping practices in eleven (11) new Member States (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia) for eight (8) major natural and technological hazards such as floods, forest fires, storms, landslides, earthquakes, industrial installations, transport of dangerous goods and contaminated lands. This activity was funded as part of the project entitled "Management of Natural and Technological Risks".

One fundamental project objective was to examine the existing situation in each of the surveyed countries, and compare different mapping approaches in order to define guidelines for establishing compatible risk mapping systems, in particular multi-hazard risk mapping. This report describes the results of the landslides section of the risk mapping activity. Responses to the survey provide important information about the current status of landslide hazards and risk mapping in different countries and advantages and obstacles to developing a common methodology for multi-hazard risk mapping including this hazard in each country.

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