MiSRaR

Good Practice

Methodology for landslide risk analysis in the Province of Forlì-Cesena (Italy)

During the second MiSRaR seminar on Risk analysis, the Province of Forlì-Cesena presented a methodology for the analysis of the hydro geological hazard and for the assessment of the risk concerning geological instability suitable for homogeneous territories. The methodology is based on known reference parameters, which allow homogeneous maps for landslide risk to be produced.

Territorial risk assessment, both for natural risks and man-induced risks, is important not only for managing risk mitigation programmes, but also for urban planning, which is a key factor in establishing the measures for reducing the vulnerability of exposed elements.
Italian norms on territorial risks identify two specific scopes: urban planning and emergency planning.
After the tragic event that happened in the Province of Salerno on 5 May 1998, which caused the death of 160 people from Sarno and Quindici, a law was approved that modified Soil Defence by giving the responsibility of drawing up evacuation plans and landslide risk analysis to Basin Authority and Civil Protection.
In the Emilia-Romagna region the bodies and authorities involved in this process are: the Geological and Seismic Service for the Soil, the Basin Technical Service, the Basin Authority, the Regional Authority of Civil Protection and the Province of Forlì-Cesena (Territorial Planning Service and Civil Protection).
Italian laws concerning the competences of those authorities are Law n. 183/1989 (Soil Defence) as far as Basin Plans are concerned, and Law n. 267/1998 (law Sarno) as far as Emergency Plans and landslide risk are concerned. Moreover, Regional Law n.1/2005 creates the Regional Agency of Civil Protection and assigns the competences among the Region, the Provinces and the Municipalities giving the Province the task to write down Provincial Emergency Plans.
The weakness of this legal framework is the lack of funds necessary to create the process of risk analysis and keep it up to date. Unfortunately, in the last few years, resource allocation has been significantly decreased if not totally cut off, which entailed serious problems for updating plans.

Analysis methodology

The methodology for landslide risk analysis divides the activities carried out by the different bodies and authorities into two phases:
1) Identification of the hazard and analytical risk evaluation;
2) Analysis of risk maps and determination of possible scenarios (forecast and prevention programs).
The first phase was carried out by the regional Geological and Seismic Service for the Soil, the Basin Technical Service and the Basin Authority.
The second phase was carried out by the Regional Agency of Civil Protection and the Province of Forlì-Cesena.

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Identification of the hazard and analytical risk assessment

The regional Geological Service detects and maps landslides on the territory and then groups them up according to their activity state and kind.
The detection of geological instabilities is carried out through an orthophotogrammetric survey and a direct survey on site. Sometimes detailed geotechnical and topographic measures are taken in order to better understand the activity state of the landslides.
The first goal achieved by this activity is the Inventory Map of the regional geological instabilities, later merged into the Regional Geological Map, which also includes the information concerning geological formations and tectonic edges.
On the geological Maps, landslides are classified according to activity state (dormant or active) in different colours to better identify them (fig. 1).

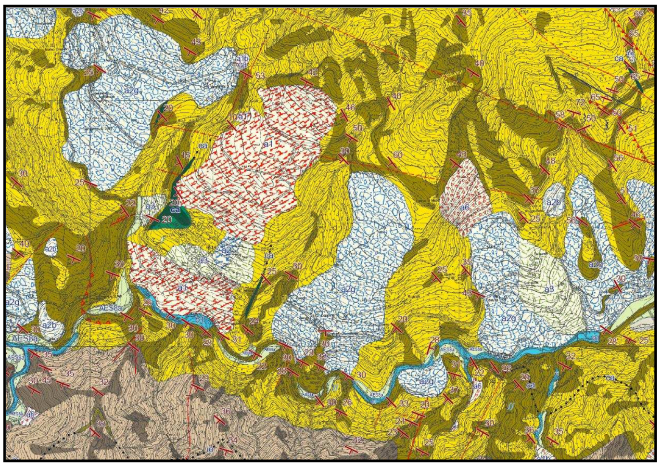

***Fig 1**- Part of a geological map of Emilia-Romagna region.*

During the first step of the risk analysis process, the **hazard** of the geological instabilities is identified based on the **activity state** and the **morphology** of the landslide body (plan metric dimensions). Therefore it is possible to identify the risk sources according to the other elements on the map, which makes it possible to classify the hazard of landslides with the same activity state more precisely. For instance a landslide body with an activity state indicating a rockfall landslide is more dangerous than a debris slide translational landslide.
The elements described are inferable from the regional Geological Map that constitutes the official situation on the territorial geological instability and whose database is publicly available on web-GIS.
Based on the regional Geological Map, the regional Basin Authority carried out the **risk cartography** thanks to a specific analysis methodology of the complementary activities for the drawing up of a Basin Draft Plan.
The risk identification refers to UNESCO's definition (Varnes & IAEG, 1984)

$$R = H \times E \times V$$

Where:

- ✓ **H** (hazard) is the dangerousness considered as the likelihood for a destructive event to happen at a certain time in a certain place;
- ✓ **E** (element) encompasses all the elements exposed to a risk that are present in a certain area, such as population, economic and productive activities, infrastructures, cultural and environmental heritage;
- ✓ **V** (vulnerability) is the vulnerability considered as the extent of damage of a certain exposed element in case of a disaster.

The risk R is the result of the combination of the elements above, and is classified by a progressive number that can indicate the number of casualties, wounded people or damaged goods. In the case of landslide risk, the main exposed elements are buildings and infrastructures.

In order to assess each element of the risk equation an analysis methodology was created that allows the many landslides to be divided into groups based on the extension of the unstable area rather than the activity state.
The concept of Elementary Hydromorphological Unit (U.I.E.) was also introduced, which is a physical amount of territory whose dimensions are determined by the crest lines and the drain net and is characterized by its own hydrological functioning and geomorphologic dynamics.
This approach was possible because the regional rivers basin is almost entirely within the regional borders and is therefore present in the advanced, up-to-date and detailed cartography, which can easily be extended to the little areas outside the region.
The methodology is based on a territorial analysis of elementary basins (U.I.E.) found on the regional Hydro morphological Map. Each U.I.E. is assigned a risk value based on the hazard of the cell (ratio of unstable area to total surface of the area) and the risk-exposed elements present in the cell.
Thanks to the combination of the landslide bodies' map and the U.I.E. map it was possible to determine a landslide index (Li) based on the percentage of landslide surface within a unit compared to the total surface of the unit. The landslide index indicates the landslide hazard within a unit and is divided in the following classes:

P1 = Low (2% < Li < 5%)

P2 = Medium (5% < Li < 10%)

P3 = High (10% < Li < 25%),

P4 = Very high (Li > 25%),

The detection of risk-exposed elements was carried out following the Regional Map of Soil Usage database from which the mapping of buildings and infrastructures present on the area under the jurisdiction of the Basin Authority derived.
The elements included in the map were then classified according to a specific index to which a parameter for determining the value of each category was associated, as shown in the table.

Urban areas	**Value**
Towns/villages	18
Hamlets	8
Isolated households	4
Factories (and craftsmanship laboratories)	8
Small factories (and craftsmanship laborato-	6
Isolated craftsmanship and industrial settlements	5
Houses, tertiary sector, farming settlements	5
Farming and farming products processing	5
Cemeteries	5
Architectonic heritage	7
Minor architectonic heritage	5
Transport infrastructures	
Railways	9
Highways	8
Main roads	8
Strategic roads	7
Service infrastructures	
Waterworks	8
Gas pipes	7
Sewage systems and purification plants	7
Waste disposal plants	6

The total sum of the values of each element of a single U.I.E. determines the overall value of the risk-exposed elements within the unit. The E.H.Us are then divided into two classes based on the value of risk-exposed elements:
- **V.E.1**: total value less than 30
- **V.E.2**: total value equal to or more than 30

By combining the hazard map (P1-P4) and the value map (V.E.1-V.E.2) a Landslide Risk Map was created:

	V.E.1	V.E.2
P1	R1	R3
P2	R1	R3
P3	R2	R4
P4	R2	R4

The risk is divided into 4 classes:

- R1 (moderate risk)
- R2 (medium risk)
- R3 (high risk)
- R4 (very high risk)

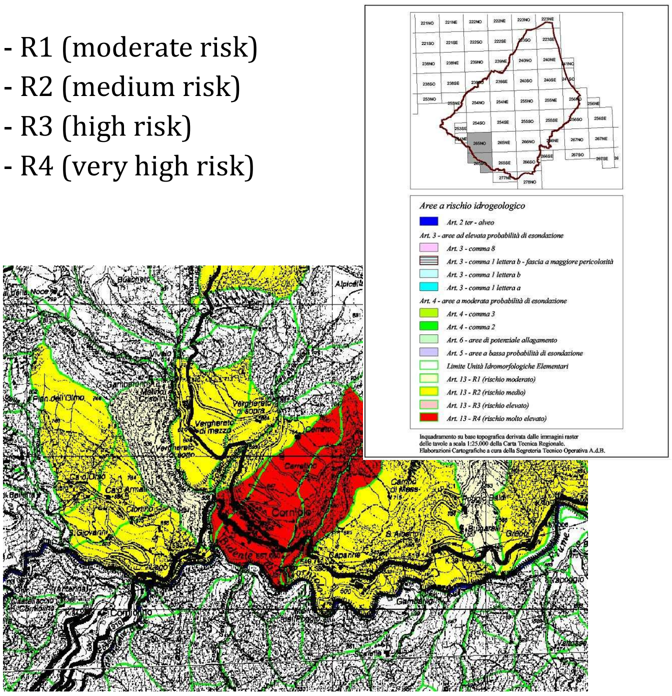

Fig. 2 *- Part of a hydro-geological table from the Hydro-geological Structure Plan (PAI)*

Then, each R3 and R4 unit was deeply analyzed to define the borders of the landslide body, in order to try to find two different areas (area 1 and area 2) subject to the PAI norms.
The Technical Norms of the Plan establish the constraints for the usage of the soil within area 1 (stricter) and area 2 (less strict).
For all R3 and R4 landslides a census table was filled in. The table includes the history of the landslide, the technical details, the geological analyses carried out to understand the geological instability, an estimate of the costs for the stabilization works that are necessary to mitigate the landslide risk, and an approximate cost-benefit analysis.

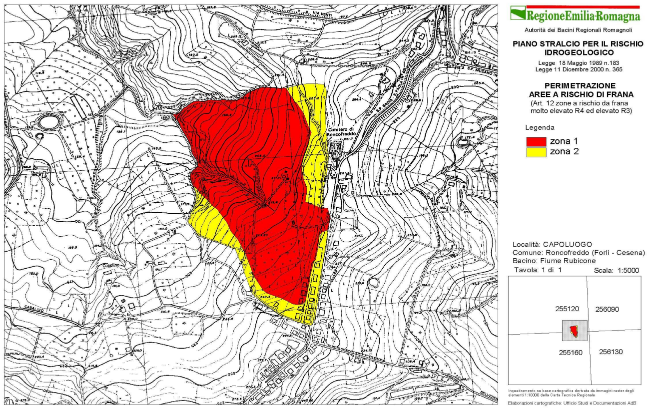

Fig 3*- Borders of areas subject to landslide risk (red = area 1, yellow = area 2)*

Analysis of risk maps and determination of possible scenarios

During the second analysis phase, the details provided by the Civil Protection's analysis activities were combined with the map of landslide risk drawn by the Basin Authority. More precisely, the analysis of landslide risk by the Basin Authority was integrated with the vulnerable elements and strategic infrastructures. These data, which are very useful for the emergency planning, allowed the map of landslide risk to have a more operative application. Based on the norms by the Civil Protection, analysis tools for identifying safety measures for the territory and the population were developed.

Methodology evaluation

Landslide risk classification through the analysis of exposed elements and the territorial vulnerability is a crucial tool for forecast and prevention activities, emergency planning, risk management as well as for alerting the population and defining safety and evacuation plans in case of a disaster. The use of databases connected to soil usage maps and up-to-date geological maps eases the improvement of the analysis methodology as far as both the definition of exposed elements (census of population, households, factories processing dangerous substances, strategic infrastructures) and the vulnerability evaluation are concerned.

Lesson learnt

The major disadvantages of this landslide risk analysis methodology derive from the use of U.I.E. to deal with the numerous landslides present on the territory and to gather the essential information. This approach leaves out all the landslide features determining hazard except for morphology and dimensions.
The methodology described does not consider the kind of landslide (falls, slides, flows) or their activity state (dormant, active), nor does it assess the likelihood of the event to occur again (and the time-span).
In this risk analysis methodology, also the estimate of the vulnerability of the exposed elements (built-up areas, transfer and service infrastructures) was considered based only on the U.I.E. and therefore the percentage of the likely damage based on the specific dangerousness of the landslide was not calculated.

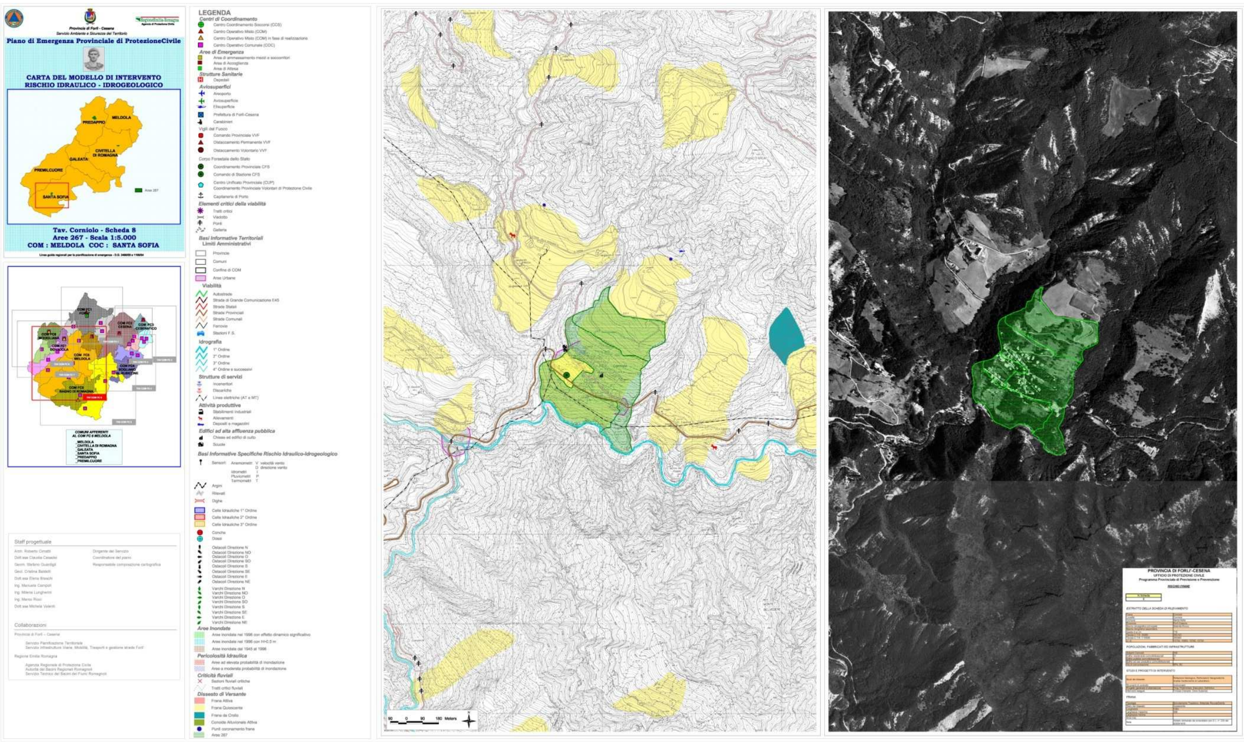

Fig. 4 *- Civil Protection's Forecast and Prevention Program Map*

The MiSRaR project

The MiSRaR project is about Mitigation of Spatial Relevant Risks in European Regions and Towns. The project is a cooperation between seven partners in six EU member states:

- *the Safety Region South-Holland South, The Netherlands (lead partner)*
- *the city of Tallinn, Estonia*
- *the region of Epirus, Greece*
- *the province of Forlì-Cesena, Italy*
- *the municipality of Aveiro, Portugal*
- *the municipality of Mirandela, Portugal*
- *the Euro Perspectives Foundation (EPF), Bulgaria.*

The goal of the project is to exchange knowledge and experiences on risk mitigation in spatial policies. The project will result in a handbook in which the lessons on the mitigation process are described and the good practices from the partners are presented. The Risk Assessment and Mapping Guidelines for Disaster Management of the European Commission will be implemented in the handbook. The MiSRaR project is cofinanced by the European Regional Development Fund and made possible by the INTERREG IVC programme.

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