Risk mapping in the Pyrenees area: a case study

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ABSTRACT A risk map of Andorra at 1:25 000 scale is discussed. The map has been carried out based on geomorphological criteria. The risk assessment is considered through risk localization, intensity and reach of phenomena and activity. Four risk classes are defined based on magnitude and activity of processes. The latter are represented as symbols on the zoning map.

INTRODUCTION

A geological risk map of a 100 km² area in Andorra Principality has been carried out at 1:25 000 scale. The area surveyed corresponds to the Gran Valira and the Valira d'Orient valleys. The main part of the area is over 1000 m above the mean sea level and was covered by glaciers until holocene period. Valley bedrock is composed of schists, phyllites, sandstones and limestones from Paleozoic ages which are overlaid by quaternary deposits: till and colluvium. These surficial deposits show signs of recent instability. For instance, a debris avalanche detached from a till destroyed the small village of Fener in 1865 (Thos y Codina 1884) and recently several movements have been triggered by heavy rain periods. The purpose of the map was the analysis of both landslide and flood risks.

METHODOLOGICAL PRINCIPLES

The map is geomorphologically based. The basic criteria was to apply the principle of the actualism as used by Varnes (1984). Only natural phenomena have been considered, that is, no evaluation has been done concerning excavated slopes or foundations. The reason is that stability of cut slopes depends on geometrical characteristics of final slope and on the excavation method. Nevertheless the geological structure of the bedrock and the location of unfavourable joints for cut slopes have been indicated.

RISK ASSESSMENT

Risk assessment it has been considered in four different ways:
(a) risk localization, by means of geomorphological reconnaissance using photointerpretation and field techniques. Ancient scarps, developed scars, landslide deposits and other geomorphological features are used together with historical information.
A landslide inventory was carried out in the study area. From it, threshold stability slope angles have been derived. Using Varnes (1978) terminology:
(i) translational slides (in colluvial soils) occur in slopes over 27°, usually from 32 to 40°.
(ii) rotational slides (in tills) occur in slopes from 35 to 40°
(iii) debris flows occur in slopes over 27° in colluvium and over 35° in tills.
(iv) rock falls occur in rock slopes normally steeper than 40°

(b) Intensity. For landslides, intensity has been related to mobilized volume. For floods, intensity has been derived from main historical floods recorded in the area.

![Diagram](image-url)

**FIG. 1** Rockfall mobility. Plot of mobilized volume versus apparent coefficient of friction (\(\tan \alpha\)) derived from the path of the fallen debris, for several rock falls from Andorra and neighbouring Pyrenean area. Slope characteristics below the rock fall source: (G) grass (R) rock (S) scree deposits (F) Forest (see explanation in the text).

(c) Assessment of areas subjected to hazard. Different landslide types show variations in runout distances
covered by them. The mobility of a landslide may be expressed as the ratio between the maximum vertical drop and the maximum horizontal distance travelled (equivalent coefficient of friction or \( \tan \alpha \), where \( \alpha \) is the angle of the line linking the highest point of the landslide scar and the farthest point of the slide mass). Hsü (1975) in very large rockfalls observed a decrease of \( \tan \alpha \) with the rockfall volume. We have also found a friction reduction with volume for small shallow landslides. Nevertheless, the mobility is also dependent on the type of failure mechanism: rockfall, debris flow or translational slide (Corominas et al. 1988).

These kind of relationship are useful in assessing landslide prone areas. For example, Fig. 1 shows different rockfalls inventoried in the Pyrenees area. No rockfall paths have been found below the dashed line on the left. Above this line, the effect of the slope characteristics below the rockfall source is observable. Rockfalls propagate more easily in bedrock or grass covered slopes (\( \tan \alpha \) lesser than 0.75-0.8) than in scree and forested slopes. Central dashed line delimitate rockfalls paths through grass and bedrock slopes from scree slopes (\( \tan \alpha \) lesser than 0.8-0.85) and these ones from forested slopes. Given a rockfall source site and an expected volume to be mobilized, the downslope area between the source and the arrival point (intersection of a straight line with angle \( \alpha \) and the slope surface) has been designed as a risk area.

(d) Activity. Due to the lack of historical information (only present century floods are known with a minimum data) the activity has been inferred from the last experience of November 1982 floods and landslides and from field geomorphological criteria (open scars, tilted trees, open cracks in buildings).

RISK ZONING

Varnes (1984) distinguished between hazard and risk. A low risk area may be attributed either to a populated area without a threatening hazard or to an important hazard in a non urban area. In order to avoid possible misinterpretations on land use potentiality, an urban use is assumed in the whole studied area. Four risk levels have been defined (Fig. 2) considering the magnitude and activity of phenomena. In each zone the hazardous phenomena are represented by means of symbols which have been overlaid on it.

CONCLUSIONS

This methodology has allowed to develop the risk map in a very short period of time (only five months) with a reasonable degree of accuracy. The data extracted from
landslide inventory referring to the landslide reach may be extrapolated to other risk areas because they are independent from the climate and in a lesser measure from the geological context as well.

REFERENCES


