Quantitative analysis of the susceptibility of avalanche triggering on the road to Bonaigua pass (Pallars Sobirà county)

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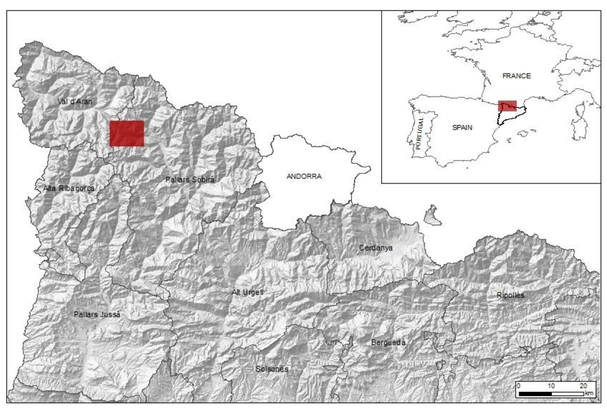
Introduction

The study was based on the analysis and understanding of avalanche terrain. Its aim was to classify the avalanche starting zones according to their susceptibility and to implement the results in areas without observational data. The final goal of the study was to help to improve the knowledge of the susceptibility of avalanche triggering in order to prevent and mitigate the consequences of this phenomenon in infrastructures and roads.

Study area

This study was conducted in the pilot area of the Bonaigua valley (Pallars Sobirà County), located at the northwest corner of the Catalan Pyrenees. Affectation due to avalanches in the road C-28 is a current problem.



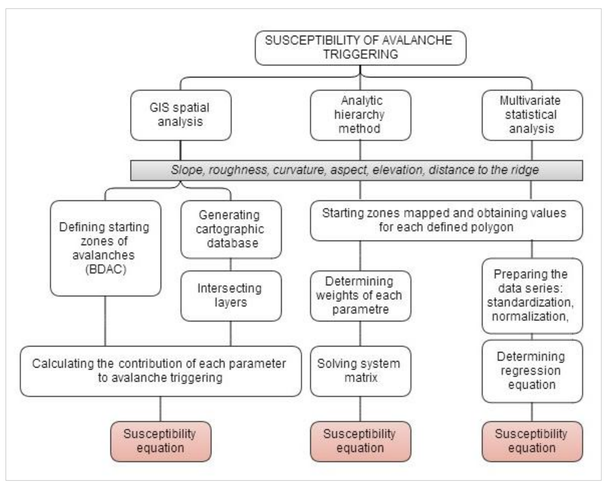
Study area

Avalanches on the road to Bonaigua pass.

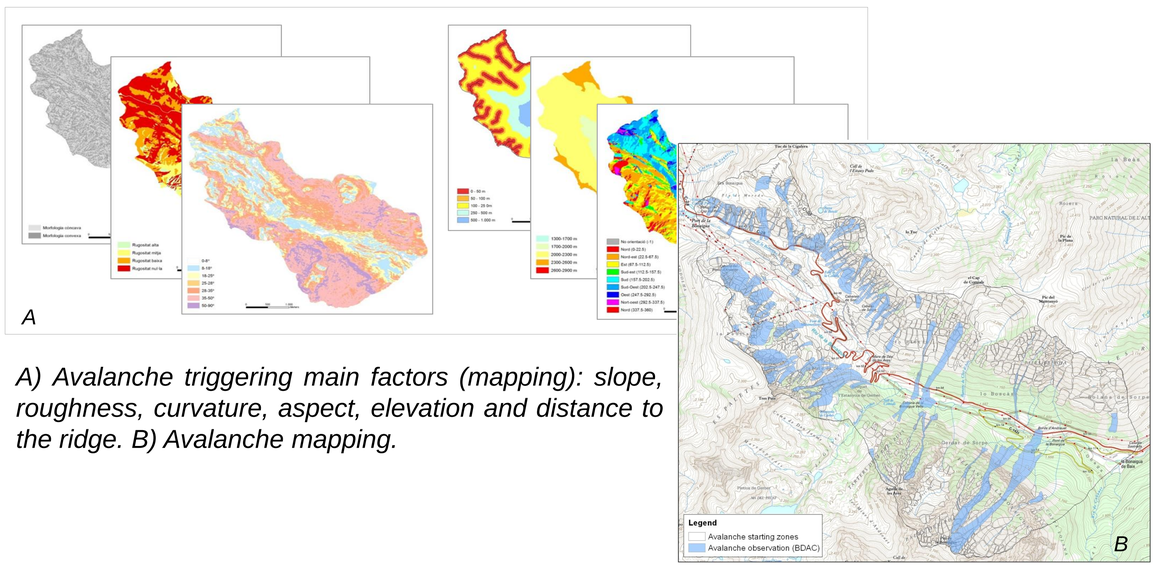
Methodology

This work focused on the application and comparison of three methods to determine quantitatively the susceptibility of avalanche triggering on the road to Bonaigua pass. As main factors of avalanche triggering ***slope***, ***roughness***, ***curvature***, ***aspect***, ***elevation*** and ***distance to the ridge*** were considered.

Methodology



Geographic Information Systems (GIS) spatial analysis



A) Avalanche triggering main factors (mapping): slope, roughness, curvature, aspect, elevation and distance to the ridge. B) Avalanche mapping.

Processing of the data was based on the spatial relationship between the total extent of the study area and the extent of the starting zones obtained from avalanche observation data (Avalanche Database of Catalonia, BDAC). This data was used to calculate the degree of influence of each factor to the avalanche release.

$$S_{parameter} = 100*[\text{affected area}_{class}/\text{total area}_{class}]$$

$$(S) = [S_{slope}] + [S_{roughness}] + [S_{curvature}] + [S_{aspect}] + [S_{elevation}] + [S_{dist.ridge}]$$

Multivariate statistical analysis

Multivariate statistical analysis was applied to obtain the equation of the regression model. The weight of different terrain parameters was obtained according to avalanche release susceptibility based on observation data.

$$(S) = -0{,}142 + (0{,}157*[\text{curvature}]) + (0{,}098*[\text{elevation}]) + (0{,}114*[\text{aspect}]) + (0{,}108*[\text{slope}]) + (0{,}029*[\text{roughness}])$$

Analytic hierarchy method

The analytic hierarchy process (Saaty, 1980) is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute.

Terrain parameters	Slope	Roughness	Curvature	Dist. ridge	Elevation	Aspect
Slope	1	3	4	4	6	7
Roughness	1/3	1	3	3	5	6
Curvature	1/4	1/3	1	1	3	4
Dist. ridge	1/4	1/3	1	1	3	4
Elevation	1/6	1/5	1/3	1/3	1	2
Aspect	1/7	1/6	1/4	1/4	1/2	1

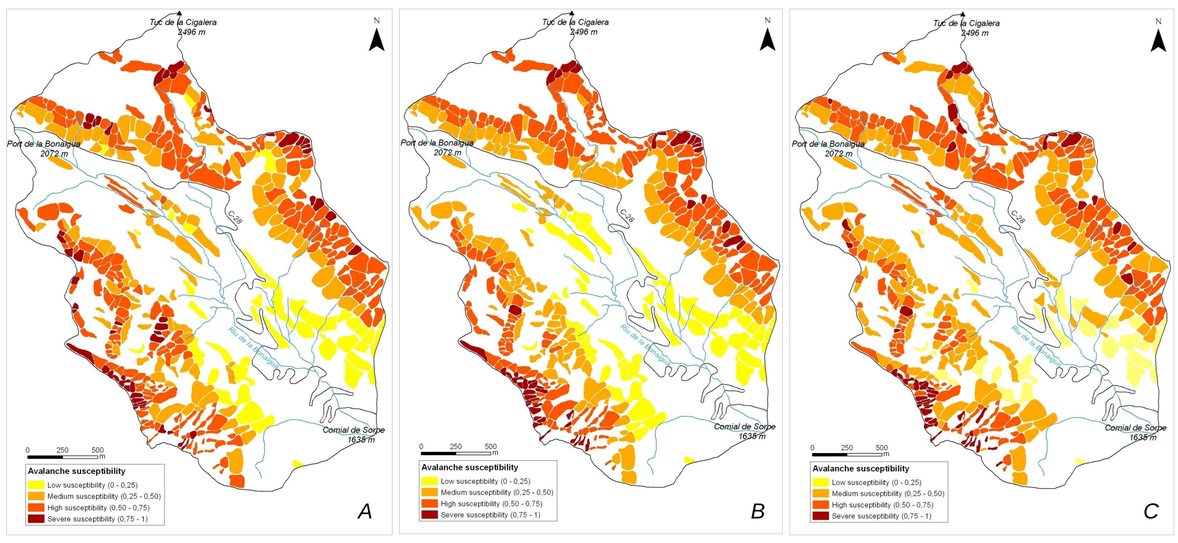
$RI = 0.032$

$$W = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} + \frac{a_{12}}{\sum a_{i2}} + \cdots + \frac{a_{1n}}{\sum a_{in}} \\ \frac{a_{21}}{\sum a_{i1}} + \frac{a_{22}}{\sum a_{i2}} + \cdots + \frac{a_{2n}}{\sum a_{in}} \\ \frac{a_{n1}}{\sum a_{i1}} + \frac{a_{n2}}{\sum a_{i2}} + \cdots + \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} = \begin{bmatrix} w_1 \\ w_2 \\ w_n \end{bmatrix}$$

The alternatives on the left were compared with those on top with respect to relative preference for susceptibility of avalanche triggering.

$$(S) = 0{,}42\ (\text{slope}) + 0{,}25\ (\text{roughness}) + 0{,}12\ (\text{dist. ridge}) + 0{,}05\ (\text{elevation}) + 0{,}04\ (\text{aspect})$$

Results



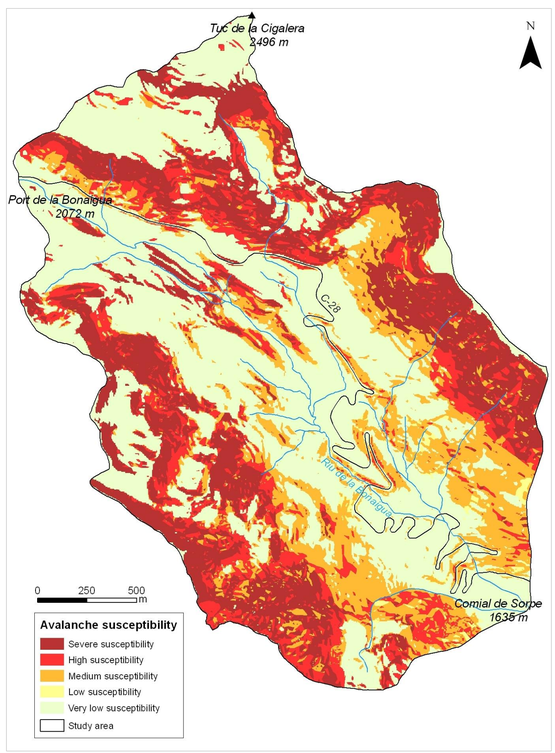
Avalanche susceptibility maps obtained by: A) GIS spatial analysis. B) multivariate statistical analysis. C) analytic hierarchy method

Comparison of methods		Correlation coefficient (R^2)
GIS spatial analysis	Analytic hierarchy method	R2 = 0,74289
GIS spatial analysis	Multivariate statistical analysis	R2 = 0,81595
Analytic hierarchy method	Multivariate statistical analysis	R2 = 0,83318

Correlation coefficient obtained by comparison of methods

The most important adjustment was between susceptibility values obtained by analytic hierarchy method and multivariate statistical analysis.

Conclusions



Example of the avalanche susceptibility map applying GIS spatial analysis to all the study area.

- The results show how the values obtained from the three methods have a high correlation.
- In spite of the degree of subjectivity introduced in the process of the analytic hierarchy method the results have a good fit with the results of the other two methods.
- The GIS analysis and the multivariate statistical analysis require to use observational data, while it is not required when applying the hierarchy method.
- The methods applied allow to perform avalanche triggering susceptibility maps for large areas, from few or none observational data, in order to identify hazardous areas for risk planning.

References

Saaty, T.L. (1980) *The Analytic Hierarchy Process, New York: McGraw Hill. International,* Translated to Russian, Portuguese, and Chinese, Revised editions, Paperback *(1996, 2000),* Pittsburgh: RWS Publications.