GEOMORPHIC RESPONSES OF SMALL TORRENT CATCHMENTS AT A REGIONAL SCALE (SOUTHERN FRENCH ALPS)

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INTRODUCTION

Torrents of the Southern French Alps are prone to dramatic debris-flows and flash floods. These extreme events may cause significant economical damages and human deaths. In order to minimize these consequences, it is necessary to improve our ability to map these phenomena. For this purpose we need to integrate the spatial and temporal variability of geomorphic sensitivity in the chain of risk prediction. Therefore a GIS approach is performed to characterize torrent responses at a regional level. The main objective of this study is to produce maps of geomorphic responses for small upland catchments that will be used as a tool for decision support in risk management. The studied area covers 17 000 km² (e.g. the 3 alpine departments of the Provence-Alpes-Côte-d'Azur region in France). This study is a part of the RHYTMME project dedicated to the deployment of an X-band meteorological radar network in the Southern Alps. It is also supported by the Alpine-Space PARAmount project dedicated to the protection of transport infrastructures in the Alps. Regional maps of the geomorphic sensitivity will serve as a pre-warning system for debris flow and flash flood prevention.

DISCRIMINATING FLUVIAL AND DEBRIS-FLOW MOUNTAIN STREAMS

The identification of torrents prone to debris-flow based on GIS-derived morphometric measures has been widely studied with discriminant analysis and logistic regression. Bivariate statistical approaches aim at providing thresholds on morphometric variables to characterize the dominant torrent responses (fluvial vs. debris-flow) whereas distributed approaches allow assessing runout paths and deposition area of debris flows. The latter approaches are not suitable at regional scale since it is not possible to constraint the spatial variability of control parameters. Consequently, we used morphometric criteria and two multivariate statistical models to assess dominant torrent response for the entire study area.
Fan slope and Melton's ruggedness index are reported as the best parameters for discriminating fans dominated by fluvial and debris-flow processes. Different threshold values were proposed by previous authors. Then we compiled data from the literature with our own observations and we defined a discriminating model based on 620 catchments (Fig. 1a.).
The relationship between channel/fan slope and Melton index do not depend on spatial location as no clear spatial pattern appears on the scatter plot. Therefore we considered that the data from literature can be used to define a statistical model to predict catchment responses in the Southern Alps. We tested two bivariate statistical models with the same dataset: a linear discriminant analysis (Fig. 1b.) and a logistic regression (Fig. 1c.). For each model we sampled 1000 times the training and target datasets. We also compared the results of the two models with balanced and unbalanced response groups with sensitivity and specificity indicators (Fig. 1d.).

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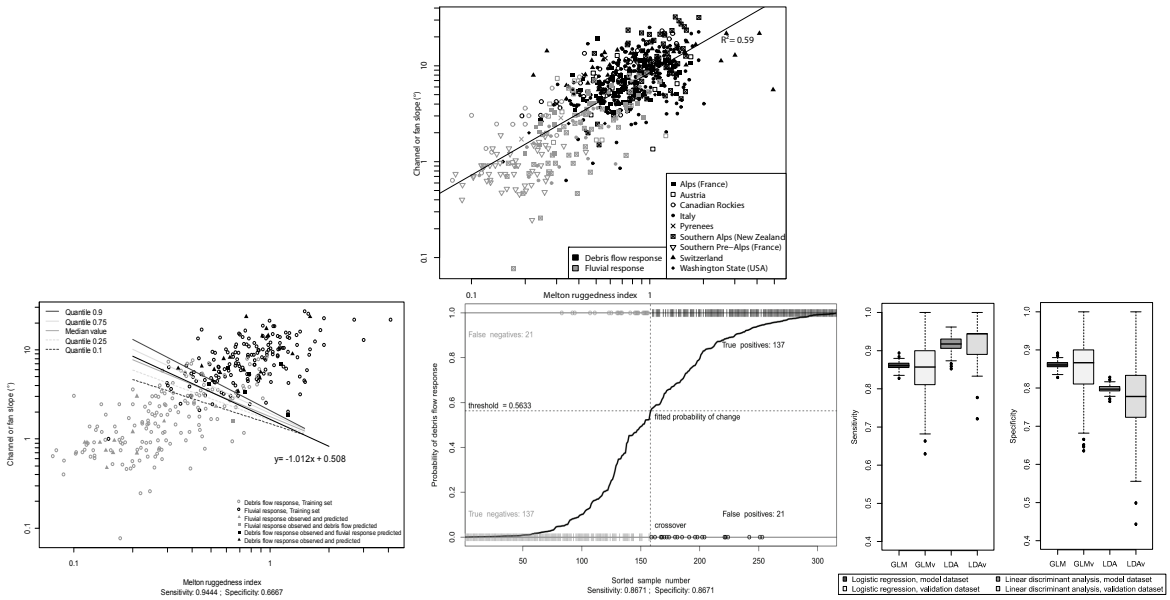

Fig. 1a. Morphometric parameters of catchments, data extracted from literature. Logarithmic scale; b. Example of linear discriminant analysis model construction and prediction based on a random catchment sampling. Logarithmic scale; c. Example of logistic regression model construction and prediction based on a random catchment sampling; **d.** Comparison of sensitivity and specificity of both models (balanced response groups)

The logistic regression method based on balanced response groups showed better results compared with linear discriminant analysis. The median sensitivity and specificity of the 1000 sampling tests are both 0.85, whereas those values are 0.95 and 0.80 for the linear discriminant analysis. By taking unbalanced response groups, we improved both model parameters, with a median sensitivity value of 0.9, and the 90th percentile of specificity of 0.93.

We choose a sampling of unbalanced response groups and implement the logistic regression model on data derived with GIS procedure to identify potential sites of debris-flow impact on transport infrastructures. The basins were delineated by a hydrological analysis of the 25m DEM. Outlets were defined as intersection of the streamlines and the transport infrastructures (BD Topo, IGN®). We decomposed the calculation of the Melton index into a few steps. First, we calculated the maximum elevation of the catchment with a zonal statistic tool. Then, we extracted the elevation at the intersection points. Finally, we extracted the value of drainage area at each intersection point, and computed the relief of the catchments and the Melton index. We considered that the channel slope can be used rather than the fan slope, because it is an indicator of the capacity of the channel to propagate debris-flow (located or not on a fan) and it can be easily extracted automatically from DEM. We calculated the slope of the channels within a buffer of 100 m around the intersection points. The prediction is calculated as a probability to debris-flow response.

We validated the results on a random sample of basins with expert knowledge (field work and erosion control work service database).

CONCLUSION AND PERSPECTIVES

We identifed torrents prone to debris-flow event. To improve the evaluation of debris-flow susceptibility of torrent catchments we need to better localize the sediment sources and to study the geomorphic connectivity between hillslopes and channels. In this purpose automatic object-oriented classification protocols are under development to map erosion on hillslopes and the riverscape features (active channels and vegetation patches) from 50 cm resolution orthophotographs. Other developments concern the assessment of variation of channel slope and profile curvature upstream of the sensitive reaches (intersection points prone to debris-flow).

Keywords: flash floods, debris-flows, macro scale, regionalized models, spatial analysis, GIS