Landslides: Evaluation and Stabilization, Lacerda, Ehrlich, Fontoura & Sayão (eds)
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Current practices and assessment tools of landslide vulnerability in mountainous basins – identification of exposed elements with a semi-automatic procedure

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ABSTRACT: Vulnerability assessment poses the problem of understanding the interaction between the landslide phenomenon and the endangered element. Over the last decade, several approaches have been developed; some of them are difficult to apply in practice, mainly because of the absence of valuable data on the historical damages. This paper proposes a semi-automatic procedure, based on GIS technology and statistical analysis, to locate exposed elements and to identify homogeneous vulnerable zones. Exploratory results are presented and compared to an expert analysis performed on a landslide-prone catchment of Southeast France.

1 INTRODUCTION

Vulnerability assessment is a key aspect of anchoring mitigation of landslide impacts to present development planning. Several methods of vulnerability assessment have been developed over the past several decades, especially for earthquakes and floods. These approaches provide a core set of best practices for use in studies of landslide risk mitigation.

On the one hand, landslide vulnerability assessment results to a census of exposed elements and stakes in a given area and to the evaluation of empirical indexes. This *qualitative approach* is used in practice in France for the realisation of the '*Plan de Prévention des Risques*' (MATE/METL 1999), or in Switzerland for the '*Carte des Dangers Naturels*' (BUWAL/BWW/BRP 1997). On the other hand, landslide vulnerability assessment results in a *quantitative evaluation* through the use of damage functions and the definition of impacts for each type of landslides. In this approach, mainly used in theory for research, analysis may result in sophisticated and complex methods using extended databases and multi-criteria modelling (Mejia-Navarro & Garcia 1996).

Looking at more significant parameters to introduce in landslides prevention studies, an 'in-between' structured approach to landslide vulnerability assessment (called *semi-quantitative approach*) is being developed in the EU-funded project *ALARM 'Assessment of Landslide Risk and Mitigation in Mountains Area'* (Silvano 2002). This is motivated mainly because the qualitative approach of MATE/METL (1999), based on the interpretation of aerial photographs, is difficult to apply on large areas; the conceptual method of Léone et al. (1996) is also difficult to use in practice because of the lack of valuable data.

On the basis of both landslides inventory maps and landslides hazard maps, the main idea of the proposed approach is to identify vulnerable zones through the automatic aggregation of endangered elements possessing identical attributes. To be used in practice, the methodology utilizes commercial existing spatial databases, the processing of aerial and satellite imagery, and GIS technology. The methodology is being developed for landslide risk assessment at large scales (1:5000 to 1:10,000).

In this paper, the methodology for the identification of the endangered built-up elements and for the aggregation of homogeneous vulnerable urban fabrics is presented. In a first step, several definitions of landslide vulnerability are reviewed. Then the question related to the identification of the exposed elements is stressed, and the methodology is presented. Finally, results of the semi-automatic procedure is compared to an expert analysis performed on a landslide-prone catchment in Southeast France.

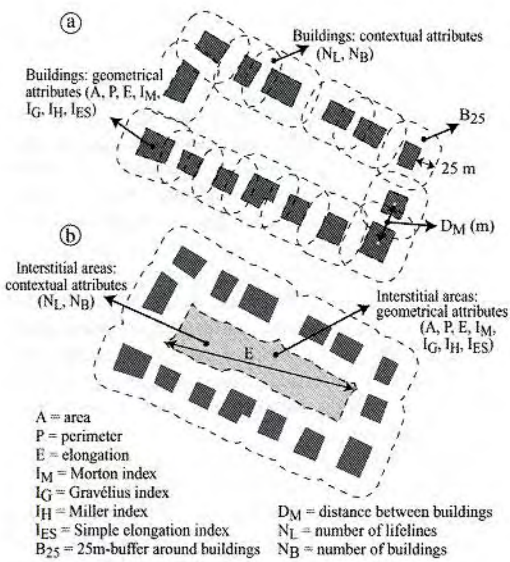

Figure 2. Geometrical and contextual attributes of each elements. (a): Building criteria; (b): Interstitial area criteria.

buffer of 25 m is taken into account. The geometrical and contextual characteristics of the interstitial areas are thus derived from the aggregation of the buffer zones (Fig. 2b). A Correlation Analysis (CA) and a Hierarchical Ascending Classification (HAC) have been used to analyse the descriptive dataset.HAC has been carried out to identify a statistical *a posteriori* classification of the built-up elements to be compared with an*a priori* expert typology.

4 TEST SITE

The test site is located in the Barcelonnette area, an enclosed basin (200 km^2) situated around 100 km north of Nice (France). Approximately 6,000 people are living permanently in the basin, but in relation to skiing and leisure activities population could reach more than 15,000 people in winter and summer. The Barcelonnette basin is known for its susceptibility to erosion and mass-movement processes (Maquaire et al. 2003). Various factors including lithology, tectonics, climate and the evolving landuse have given rise to frequent and active slope movements like shallow rotational/translationnal slides and flow-like landslides (earthflows, debris flows).

On the north-facing hillslope, the Sauze torrential catchment covers a surface of 4.8 km^2, sloping from 1140 m to 2685 m in altitude for a length of 5.8 km (Fig. 3a). The geological setting is made of weathered black marls covered partially by morainic deposits. On the hillslopes, 10% of the surface is affected by mass-movements, among them 75% are active landslides, more or less directly disturbing human settlements (Fig. 3a). Moreover, the inhabited torrential fan is exposed to the spreading of muddy debris-flows that may be released from an active earthflow located in the upstream part of the basin (Malet et al. 2003).

The catchment is characterised by a discontinuous urban fabric. According to urban planners knowledge, two main inhabited areas can be distinguished:

- the *Sauze ski-resort* in the middle and upper part of the catchment (Fig. 3b);
- the *La Chaup housing* located on the alluvial fan (Fig. 3c).

5 PRELIMINARY RESULTS

This section discusses the results obtained and evaluates the accuracy of the semi-automatic procedure. The 'vulnerable zones' are compared to the zones that an expert knowledge may identify (French '*Plan de Prévention des Risques*' methodology).

5.1 *Identification of the discriminant attributes*

Statistical analysis realized on the 529 identified exposed elements of the test site confirms that the area (A) is the first discriminant criteria. Combined with a shape index which takes into account the elongation (E) (such as the Morton index, I_M), discrimination of the elements is more accurate. Indeed, the HAC with only these two attributes allows to classify correctly 84 % of elements (according to the expert zonation). Adding a third criteria, such as the number of buildings in the 25 m buffer zone (N_B), allows to classify properly 91% of elements. Finally, a combination of all the criteria results in a percentage of correct classification of nearly 94%.

5.2 *Application and validation of the methodology*

Figure 3 outlines two snapshots of the test site. These two small zones are classified as discontinuous housing by the expert knowledge, characterized mainly by small housing blocks (of less than 4 floors) for the *Sauze ski resort* (Fig. 3d) and by individual houses for the *La Chaup* housing (Fig. 3e). The semi-automatic procedure with the HAC based on 3 criteria allows to identify fairly well the same zones (Fig. 3f, 3g). Differences result mainly in a lack of information on specific urban functions (industrial, commercial or leisure activities) that an expert integrates directly in his judgment.

Despite these differences, with more than 90% of the exposed elements corresponding to the expert

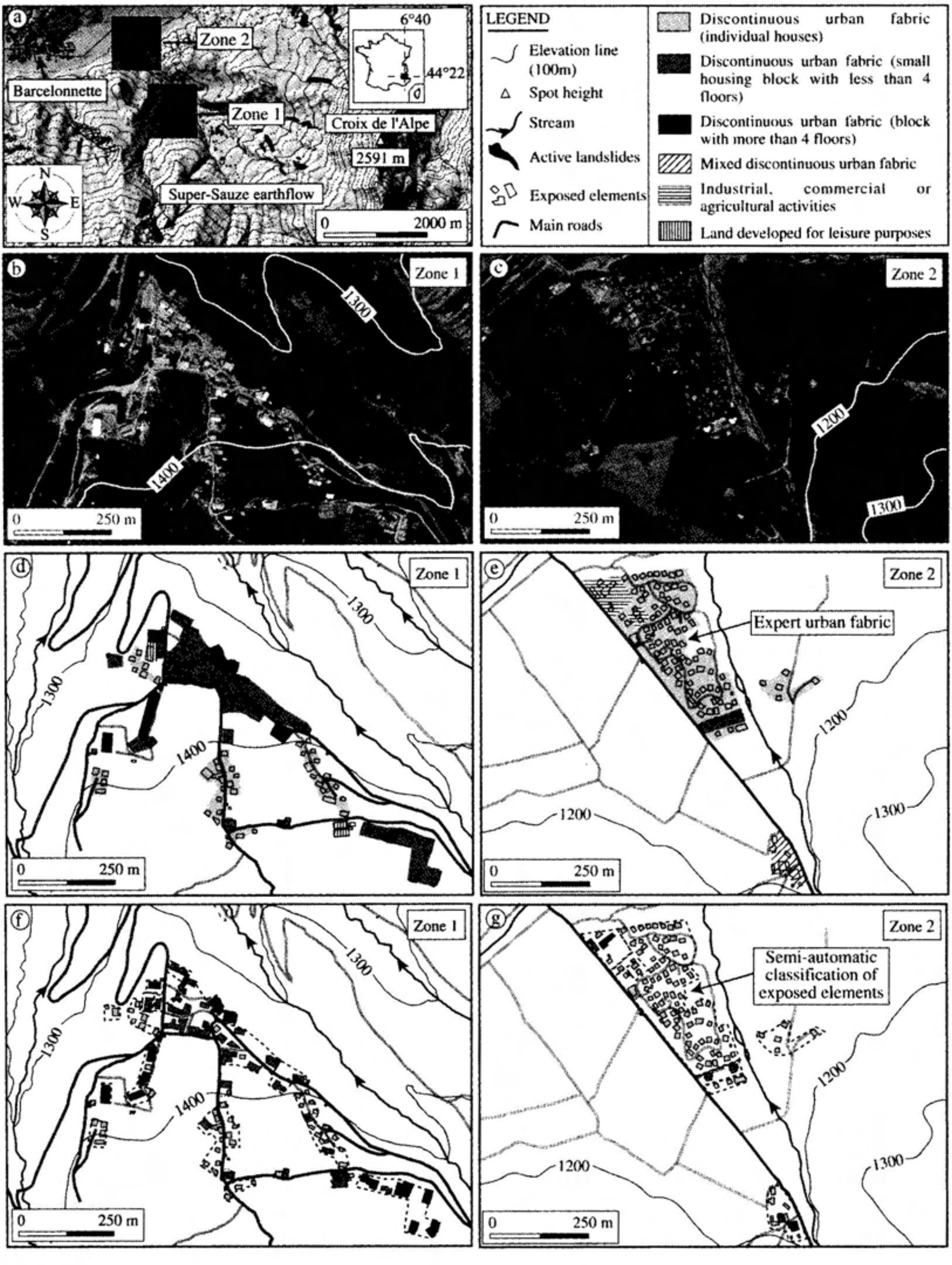

Figure 3. *A priori* expert zonation *vs a posteriori* semi-automatic zonation. Application to the Sauze ski resort and the La Chaup residential housing. (a): Location of the test site; (b): Orthophotograph of the Sauze ski resort; (c): Orthophotograph of La Chaup residential housing; (d): Expert zonation of the Sauze ski resort; (e): Expert zonation of La Chaup residential housing ; (f): Semi-automatic zonation of the Sauze ski resort; (g): Semi-automatic zonation of La Chaup residential housing.

analysis, the semi-automatic classification appears as an efficient tool to help the expert in charge of the zonation. To ameliorate the classification, others criteria derived from imagery (such as the landcover or the distance to the roads) could be integrated. If the results appear encouraging to identify discontinuous urban fabric, a question arises for other types of urban fabric, especially for denser ones. Validation of the methodology is in progress on the city of Barcelonnette.

6 CONCLUSIONS

A semi-automatic procedure based on imagery, statistical analysis and GIS technology has been developed to locate exposed elements and identify homonogenous vulnerable zones. Compared to an expert analysis, the method appears as an efficient tool to help the risk manager. The second step of the methodology, which concerns the ranking of the vulnerable zones by expert weighting, has to be evaluated. The automatic ranking in three vulnerability classes (low, medium, high) is based on additional criteria (number of inhabitants, type of buildings, type of activities, landuse, lifelines). The evaluation is in progress.

Nevertheless, results have to be moderated. Indeed, the method has been tested only on one specific built-up environment (ski resort) with specific activities and exposed elements. A comparison with the other test sites of the *ALARM* project (Silvano, 2001) should allow to validate the procedure.

ACKNOWLEDGEMENTS

This research was supported by the European Union, through the research program ALARM (Assessment of Landslide Risk and Mitigation in Mountains Area). Contract EVG1-2001-00018, 2002-2004. Coordinator: S. Silvano (CNR-IRPI, Padova). Contribution EOST 2004.04-UMR7516.

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