A SPATIAL DECISION SUPPORT SYSTEM TO ASSESS DEBRIS-FLOW HAZARD AND RISK

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INTRODUCTION

The mapping of the geo-hydrological hazard plays a fundamental role in sustainable land use planning. An accurate analysis of the debris flow hazard classes is an expensive and time consuming task. Spatial decision support systems (SDSS) can be developed to aid decisions about where detailed investigations should be carried out, and, in particular, where the need is urgent. The techniques for this initial assessment must be easily and quickly applicable to regional scale. Furthermore, they should require an available set of input data. We present our pilot study applied in the low part of Valsugana Valley in Autonomous Province of Trento, Northern Italy. Field recognition is made to validate the results obtained from proposed hazard and risk assessment.

METHODS

The method presented in this study involves several steps to define for each watershed an overall debris-flow hazard index (ODH). The first step is to delineate from a HR-DTM (high resolution digital terrain model) watersheds that are potentially susceptible to debris flows on the base of basin surface ($< 10\text{-}15\ km^2$) and the proximity to urbanized area. The second is to choose the factors that are believed to be critical to the occurrence of debris flow. The third step is to obtain data for each factor (and for each watershed) by GIS analysis. The fourth step is to calculate for each factor a quantitative measure of debris flow potential expressed as debris flow hazard (DH).

Tab. 1 Considered factors for debris flow hazard

Type	Factor	Description
Topographic and geomorphologic conditions	Melton index	Relationship between area and elevation difference in the basin.
	Gravelius index	Relation between the perimeter of the watershed and that of a circle having a surface equal to that of a watershed.
	Profile curvature index	Profile curvature derived from DTM (8 x 8 m).
Geological conditions	Erodibility index	Determined by classification of geo-lithological maps.
	Active landslide index	Determined through the Italian landslide inventory (IFFI).
	Tectonic fault index	Transform fault density.
Hydrological conditions	Curve Number index	Derived from SCS-CN map of the hydrologic model used by the Torrent Control Service of the Autonomous Province of Trento.
	Debris flow initiation index	Potential initiation sites of debris flows identified by a relationship between local slope and contributing area.
Meteorological conditions	Rainfall index (60-min and TR200)	Rainfall depth distributed map of a 60-min event with 200 years return period.
Land-use conditions	Hydraulic interference index of vegetation	Index that considers the woody material recruitment in the river network proximity (partially inspired by the study of Mazzorana et al., 2009).

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	Hydraulic interference index of the streets	Derived from the intersection between the synthetic river network and the street network.

The factors described in Table 1 have different units and are measured on different scales. For the overall hazard assessment, it has been used an empirical approach, in which the relationships of the factors with the debris flow potential are all mapped into an hazard measure on an ordinal scale, as proposed by Ling et al. (2002). The ODH index is calculated by taking a summation of all hazard factors (DH).

The decisions about where detailed investigations should be carried out and where the need is urgent are based on a debris flow risk assessment. Risk is a result of the hazard, value, and vulnerability of the elements at risk. For a regional scale analysis it is not possible to consider vulnerability, so for this study it is taken equal to one for all the elements. Value is derived from planned land-use layer, in according to the general plan of water resources (PGUAP) of the Province of Trento. In order to consider the elements at risk, an area of relevance to the rivers is calculated using the debris fan inventory and the propagation model of mass proposed by Gruber et al. (2008). Each area of relevance is joined to the relative basin unique identifier in order to compute the risk.

CONCLUSIONS

In the low part of Valsugana Valley it has been recognized 724 basins potentially susceptible to debris flows with a surface between about 0.1 and 12 km^2 (mean surface = 0.6 km^2). The overall debris-flow hazard index calculated for these watersheds has values between 5 and 17 (first tertile = 10, median = 11, mean = 11.12, second tertile = 12.5). These values have been grouped into three classes: low hazard if ODH <= 10 (first tertile), moderate hazard if 10 < ODH <= 12, high hazard if ODH > 12 (second tertile). Using these thresholds derived by tertiles, we have found 250 basins in the low hazard class, 256 in the moderate hazard class and 218 in the high hazard class.

The land use value has been divided into four classes on the base of the quartiles and then it has been crossed to ODH index using the Buwal matrix in order to obtain the risk index value. In the investigated area 266 basins are in the moderate risk class, 192 in the mean risk class, 123 in the high risk class and 143 in the very high risk class.

The results of the study have been verified on the base of the field knowledge and experience of some technicians of the Torrent Control Service. In most cases the risk index is consistent with the assessments made by the technicians and in few cases seems to be overestimated. In particular some basins located in the Sella Valley show a higher risk than that estimated by field observation. This result seems to be caused by an high value reported in the planned land-use layer due to some small mountain hut used by the local population in the free time. The results can be considered satisfactory for regional and sub-regional scale analysis. It is important to remind that the proposed method classifies the entire population of analyzed basins on the base of the ordered distribution of the values calculated for each factor and for the land use value. So this approach let us to obtain a relative risk classification on the base of the population of analyzed basins.

A comparison with experts is essential because it is difficult, in terms of economic resources involved, to carry out a detailed analysis on a wide area in order to examine the results.

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