

Automatic procedure for landslide hazard mapping through GRASS

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Extended abstract

In the management of landslide problem, the estimated hazard is an important factor for the creation of thematic maps of the general conditions of risk and constitutes an essential element of decision support for both a proper planning of the territory and for the optimization of prevention actions.

With regard to this, GIS can be considered an excellent tool, because it allows a rapid evaluation of the landslide hazard over large areas. During the last two decades many procedures have been developed, having recourse both to deterministic and statistical analysis. The latter is more appropriate for the study of extended and varied zones, but it often requires a rather complex calculation (Carrara et al., 2006; Clerici, 2002; Dai & Lee, 2002; Fock & Rebolledo 2004; Mantovani et al., 2010; Ohlmacher & Davis, 2003; Pauditš & Bednárík, 2002, just to quote the most recent works).

In order to simplify the analysis, the present work proposes a new automatic procedure that, taking into account only easily available data (Landslide Inventory map, DTM, land use map and geological map), allows the creation of landslide hazard maps over large areas using multivariate statistical analysis (Carrara, 1983; Chung et al., 1995). The procedure is devoted to slides and flows (UNESCO WP/WLI 1990, 1991, 1993, 1994; Varnes, 1958). The factors of instability so far considered are slope, lithotype and land use, attributes of proven importance in the genesis process of landslides and often available on extensive areas. The features of the study region are implicitly taken into account using, as test areas of the statistical model, areas pertinent to the region itself and previously subjected to landslides. Alternatively, the procedure can be calibrated in regions which are similar to the analysed one from the morphological, lithological and vegetation cover point of view, and in which landslides occurred.

The procedure, implemented in the GRASS GIS software by a shell script, consists in five steps as follows:

- 1) data acquisition and creation of information layers (slope, land use and lithotype);
- 2) definition and delimitation of the test areas, in which the model will be calibrated;
- 3) automatic creation, within the test areas, of the information layers showing the conditions before-landslide. Since the landslide happens, it modifies the original configuration; hence, the procedure tries to rebuilt it;
- 4) model calibration, which consists in intersecting the information levels inside the test areas and extracting the areal information necessary for calculating the probability P of landslide occurrence for a given vector composed by the analysed instability factors;

5) application of the model to the entire study area providing the landslide hazard map.

The second and third steps remind Clerici (2002) but they are original because new solutions are proposed.

Test areas must include just the cells that previously gave rise to landslides. Usually they are assumed coincident to the areas reported in the Landslide Inventory map. But, such maps does not delimit the accumulation zones, where the displaced material stops and which are substantially not responsible for the phenomenon. In order to exclude such zones from the test areas, a new procedure has been implemented which automatically distinguishes accumulation and depletion zones, individuating the mean contour line of points with vertical curvature close to zero (fig. 1a). If the new slope profile has no flex point, the contour line will be placed at a percent level defined on the basis of the analysis of other landslide areas. In such a way the procedure automatically creates a new landslide map, classified in accumulation and depletion zones (fig. 1b), and the latter zones are assumed as test areas.

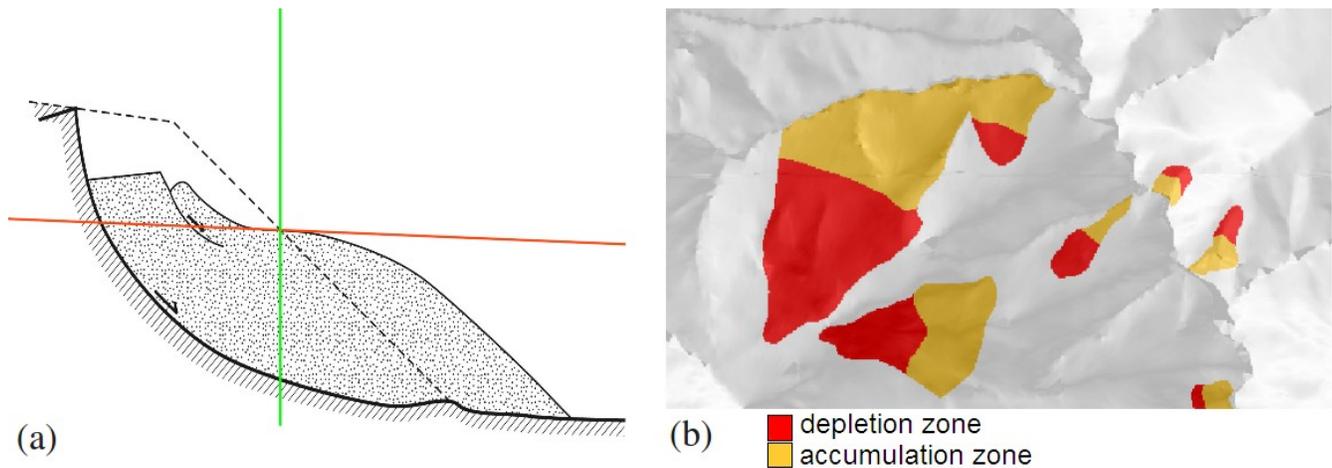


Figure 1. Division of a landslide in accumulation and depletion zones: (a) sketch of a ground profile, where the red line represents the ideal tangent line in the flex point of the slipped surface; (b) results of the proposed procedure.

The second peculiar aspect of the present procedure is related to the reconstruction of the triggering factors. In fact, the landslide modifies slope, lithology and land use of the test area. Hence, the original values are estimated applying Voronoi tessellation as follows:

- as far as lithology is concerned, data are extended from the upper part of the accumulation zone, where the displaced material (probably collaborating to the landslide genesis) stops (fig. 2a);
- as far as slope and land use are concerned, the data are extended from the boundary area of the depletion zone, assuming such zone representative of the original condition (fig. 2b).

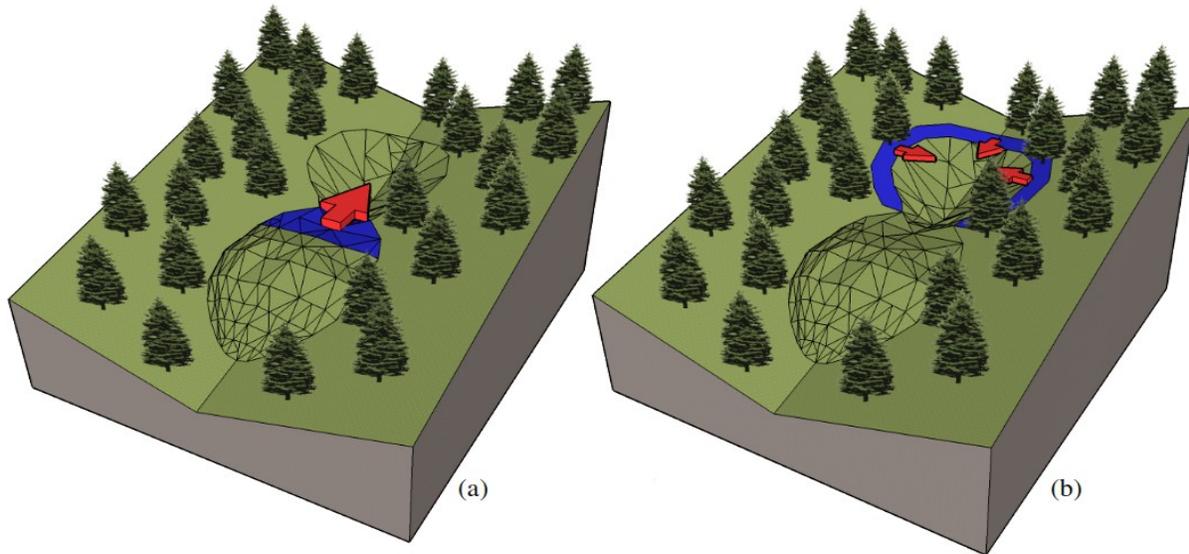


Figure 2. Sketch of the reconstruction process of the original information levels inside the test areas: lithotype (a), slope and land use (b).

The main key points of the proposed procedure are:

- the capability of analysing large areas quickly and easily also by not expert GIS users (in fact no complex statistical calculations outside GIS are required and the analysis is completely automatic);
- the possibility of being applied to any area, whose features are implicitly taken into account exclusively by the thematic maps, without the necessity of other input parameters (consequently results are not influenced by the user).

A first application was performed with reference to a region close to Genoa, Italy, with an extension of 70 km². Such area is subject to many landslides and characterized by low urbanization, so that the natural land behaviour can be better analysed. The results of the procedure (obtained by a 10 minutes computation) are represented in figure 3. The hazard map reports three classes: low ($P < 5\%$), medium ($5\% < P < 10\%$) and high ($P > 10\%$).

Such results were validated by technical inspection in situ, finding evidence of ground movements in areas classified at high hazard and not included in the Landslide Inventory map (figures. 4, 5).

In the near future, a wider validation of the procedure will be performed. Moreover, slope, lithotype and land use will be integrated by others instability factors in order to better catch the triggering of the phenomenon. In particular, the hydrological aspects could provide also a temporal assessment of the hazard.

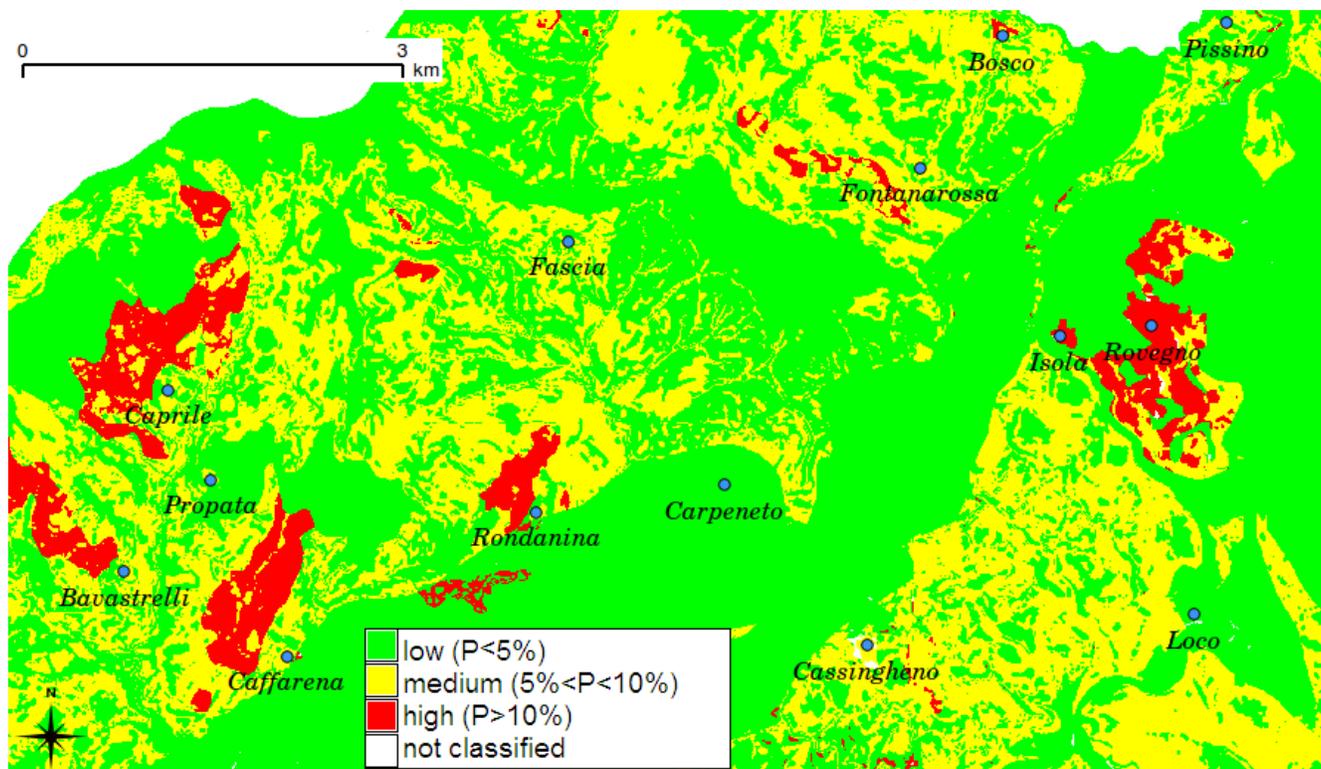


Figure 3. Landslide hazard map obtained for the study area.

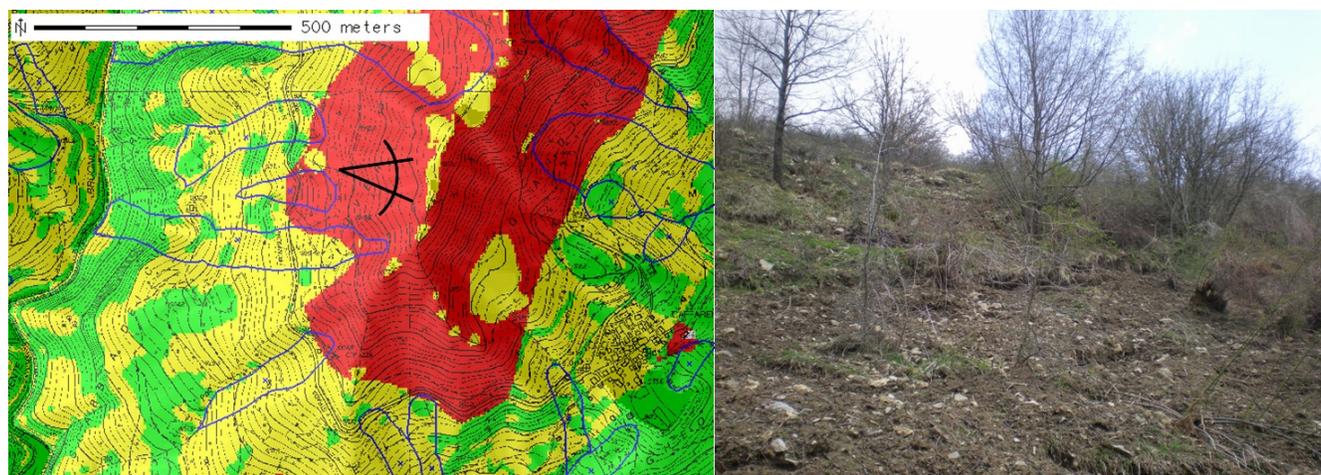


Figure 4. Evidence of ground movements in a high hazard area (Landslide Inventory map in blue).

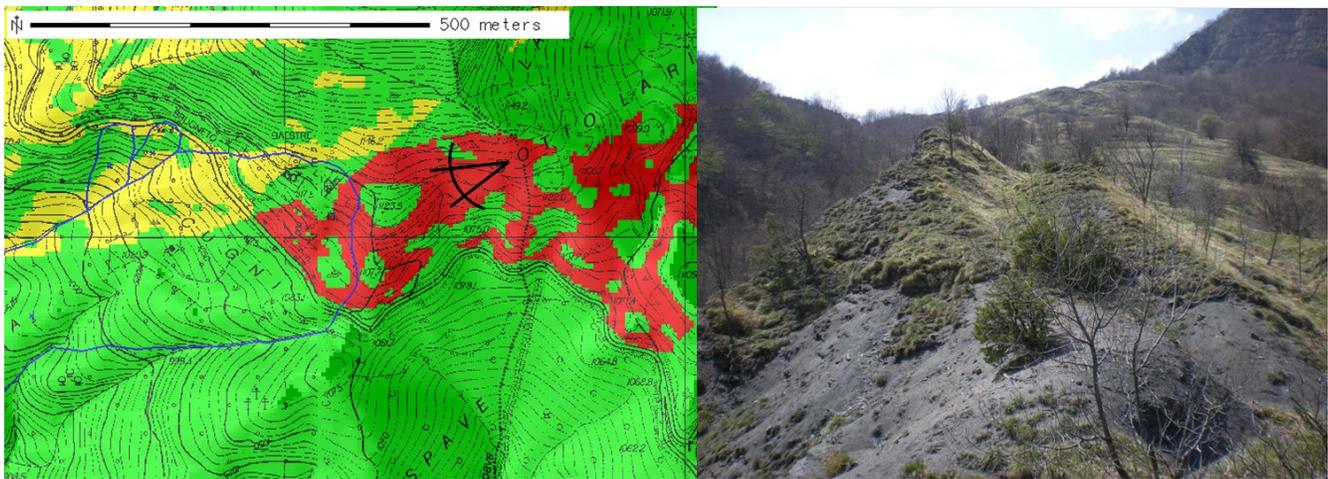


Figure 5. Evidence of ground movements in a high hazard area (Landslide Inventory map in blue).

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