POTENTIAL OF AUTOMATED AVALANCHE DYNAMIC SIMULATIONS FOR LARGE SCALE HAZARD INDICATION MAPPING IN ITALY: A FIRST TEST APPLICATION IN AOSTA VALLEY

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ABSTRACT: The different hazard levels in avalanche hazard maps are defined on the basis of the impact pressures of the design avalanche with a specific return period. Avalanche dynamics models are needed to define such limits. For a single path, the definition of the potential release area (PRA) of the design avalanche and the other model input parameters is generally made on an expert-based assessment. For large areas, such expert-based approach is too time consuming and therefore not feasible.
A procedure to automatically produce avalanche hazard indication maps is here applied in a test site in Aosta Valley in the Western Italian Alps. The large scale hazard mapping (LSHM) procedure is described in Bühler et al. (2018). In this work, we present the comparison of the results of the LSHM procedure with the already existing avalanche hazard maps in the upper Gressoney's Valley, in order to verify the potential of such automatic procedure.
We made a first run of the procedure completely automatically. Then, we performed a second run, after a manual expert-based selection of the automatically identified PRAs. To summarize, the main differences between the limits of the hazard zones in the official hazard maps and the results of the procedure arose mainly from the definition of the PRAs and of the forested areas.
In conclusion, the automatic procedure generally produced hazard zones in good agreement with those in the official maps. This case study illustrates the high potential of the automatic, not time-consuming, procedure for large areas.

KEYWORDS: avalanche simulations, hazard indication maps, automatic procedure, large areas

1. INTRODUCTION

Avalanche hazard maps are efficient protection measures which allow the identification of areas at different hazard levels and a consequent choice of the optimal land use planning. The hazard levels are defined on the basis of the impact pressures of the design avalanche with a specific return period. In Aosta Valley for ex. the red, yellow and green zones are defined as those areas where the impact pressure of a 100y return period avalanche is higher than 3, between 3 and 0.5, and below 0.5 t/m^2, respectively (L.R. 11/98 RAVA). Avalanche dynamics models are needed to define such limits. For a single path, the definition of the potential release area (PRA) of the design avalanche and the other model input parameters is generally made on an expert-based assessment. For large areas, such expert-based approach is too time consuming and therefore not feasible.

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Different works were made in the past to create automatic GIS-based procedures to define potential release areas (e.g. Bühler et al., 2013; Chueca Cía et al., 2014; Maggioni and Gruber, 2003).
Only more recently, automatic procedures which combine the PRA definition with the related avalanche dynamics have been created, in order to define the area of influence of the avalanches. Barbolini et al. (2011) proposed a procedure to realize maps on a large undocumented areas with the indication of the runout distances of avalanches which release from areas automatically defined on the basis of topographic features gathered from a DEM. Very recently, Bühler et al. (2018) developed a procedure to automatically produce avalanche hazard indication maps (Large Scale Hazard Maps - LSHM procedure) for large areas.
In this work, we applied the procedure by Bühler et al. (2018) in a well-documented test site in Aosta Valley in the Western Italian Alps and present the comparison of the results with the already existing avalanche hazard maps (L.R. 11/98 RAVA), in order to verify the potential of such automatic procedure.

2. STUDY AREA

The test area is the upper Gressoney's Valley in Aosta Valley (NW Italian Alps) (Fig. 1). It is about

110 km^2 with altitudes between 1000 and 3000 m a.s.l.; as the longitudinal axis of the valley is North-South, the main aspects are in the Eastern and Western sectors. In the area about 263 avalanche paths exist. Some of them (51 avalanches) are included within a special territorial management document (*PAV, Piano delle attività in materia Valanghiva*); to those paths we paid more attention in the analysis of the results.

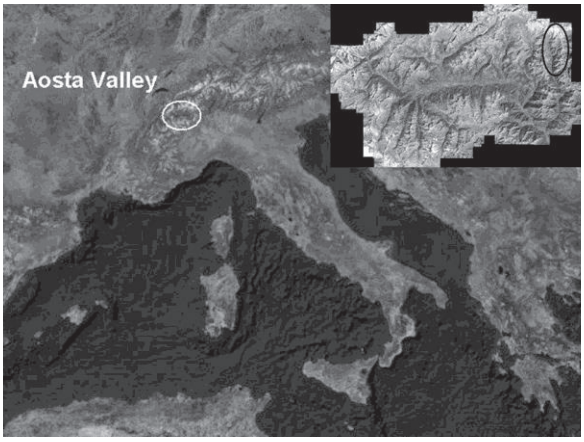

Figure 1: Location of the study area. In the inset the upper Gressoney's Valley is shown in black.

3. METHODS

The large scale hazard mapping (LSHM) procedure is described in details in Bühler et al. (2018). It is mainly based on the following steps: 1. automatic definition of the PRAs starting from the DEM and considering the presence of forest; 2. determination of the fracture depth for each PRA; 3. choice of the model friction parameters; 4. run of the avalanche dynamic simulations with RAMMS::LSHM; 5. classification of the three different hazard level zones on the basis of the modelled impact pressure.

We made a first run of the procedure completely automatically. Then, we performed a second run, after a manual expert-based selection of the automatically identified PRAs.

The necessary input data for the LSHM procedure are the following:

- the digital elevation model of the area: the official DEM of the Aosta Valley at 2 m resolution (LIDAR) was used; it was resampled to 5 m to delineate the PRA and to 10 m to perform the simulations with RAMMS;
- fracture depth for each PRA: Barbolini et al. (2007) analyzed historical snow depth data, to determine the snow depth increase in three days (DH3gg - value associated to the avalanche fracture depth, see SLF, 1999) at different altitudes for different return periods (here we considered T = 100 y);
- model friction parameters μ and ξ: according to the morphology of the avalanche path, to the presence of forest, to the avalanche release volume and to the return period (here T = 100 y), RAMMS computes for each cell of the DEM the values for μ and ξ.

Basically, for each defined PRA the procedure assigned a DH3gg which is then corrected with the mean slope angle of the PRA (inclination factor (f(θ) in SLF, 1999) and with an increment related to the additional load due to snowdrift. As we are considering extreme events (T = 100 y) we assumed that in all PRAs there was an additional load due to snowdrift of 30 cm. Having defined the release area and the fracture depth, the release volume of each avalanche could be computed and the related volume-dependent friction parameters were chosen, according also to the above mentioned avalanche features. RAMMS::LSHM was then applied and the impact pressures computed, which were classified in the three classes established in L.R. 11/98 RAVA.

Finally, we compared the results of the automatic procedure (the different avalanche pressure zones) with the existing hazard levels defined in the L.R. 11/98 RAVA. The evaluation of the results was done simply visually, comparing the limits of the different hazard zones; no statistical or quantitative methods were applied.

4. RESULTS AND DISCUSSION

We report in figures 2-4 the results of the automatic procedure for the PRA definition and the related hazard levels (according to L.R. 11/98 RAVA) for an avalanche path in the study area taken as example.

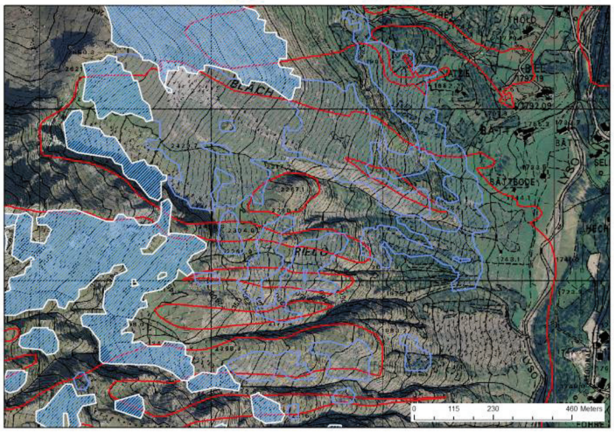

Fig. 2. Automatically defined PRAs in an avalanche path taken as example in the study area: outlined in white the PRAs manually selected for the second run of the procedure (see text). The red polygons show the outline of the avalanches from the Regional Avalanche Cadastre.

To summarize, the main differences between the official hazard maps and the results of the procedure arose mainly from the definition of the PRAs and of the forested areas.

The automatic PRAs were generally larger than what experts would choose and often some PRAs were identified lower down the avalanche paths. In fact, in the second run, the manual selection of the PRAs, deleting for ex. such lower PRAs, generally improved the results producing a better agreement with the established hazard levels (see the example in figures 2-4).

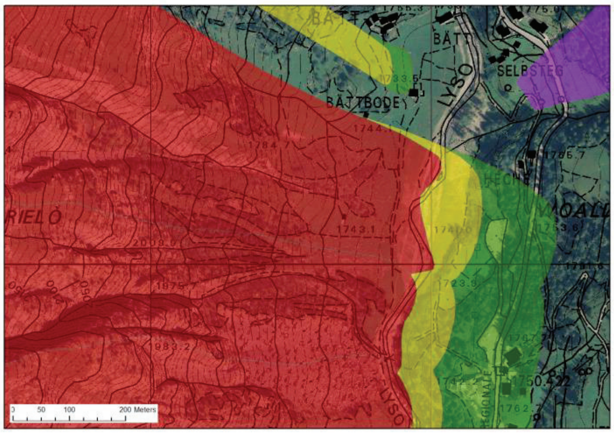

Fig. 3. Avalanche hazard zones defined in L.R. 11/98 RAVA.

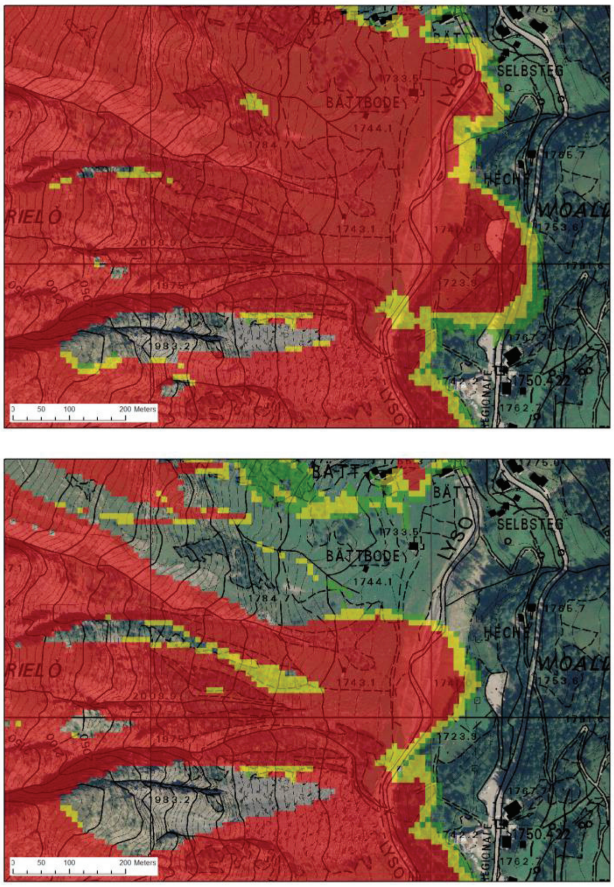

Fig. 4. Avalanche hazard zones defined by a completely automatic procedure (above) and after a manual selection of the PRAs (below).

Our results show that some margins of improvement are present. For example, a parameter related to the position of the PRA along the avalanche path could be introduced, in order to automatically delete those PRAs which are not high up but lower down along the avalanche path.

Also the definition of the forested areas is important, as the presence (or not) of forest is a key factor in the definition of the PRAs. An improvement in this sense might be done including some forest parameters (such as forest density and canopy cover, where present) in the procedure, in order to be able to consider PRAs within sparse, not dense forest. In fact, avalanche release in forest is possible if some parameters does not give it a protective function (e.g. Schneebeli and Bebi, 2004). Viglietti et al. (2010) found that 8% of the avalanches in the Regional Avalanche Cadastre of Aosta Valley (Italy) released in forested areas.

Another aspect related to the correct definition of the forested areas is that it is the basis for the choice of the friction parameter ξ in the dynamical modelling with RAMMS. For example, figures 6-7 shows the results of the automatic procedure for an avalanche which, according to the land use map, run within a forest (Fig. 5). Though, in reality, the forest along the track is sparse and very much disturbed by avalanches and practically not influencing their dynamics. In such case, the automatic procedure produced hazard zones smaller than the ones in L.R. 11/98 RAVA.

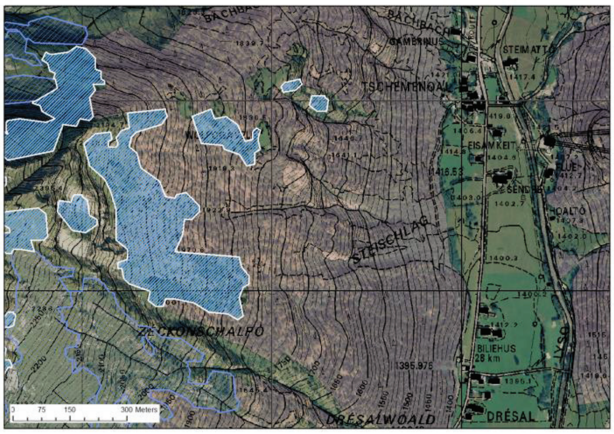

Fig. 5. Steischlag avalanche path: outlined in white the PRAs and in rose the forested area from the land use map.

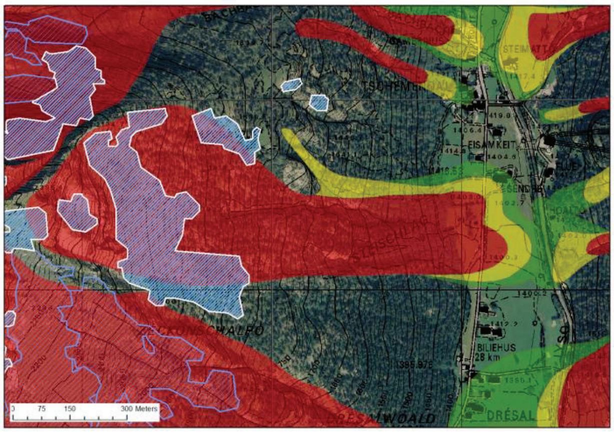

Fig. 6. Steischlag avalanche path: avalanche hazard zones defined in L.R. 11/98 RAVA.

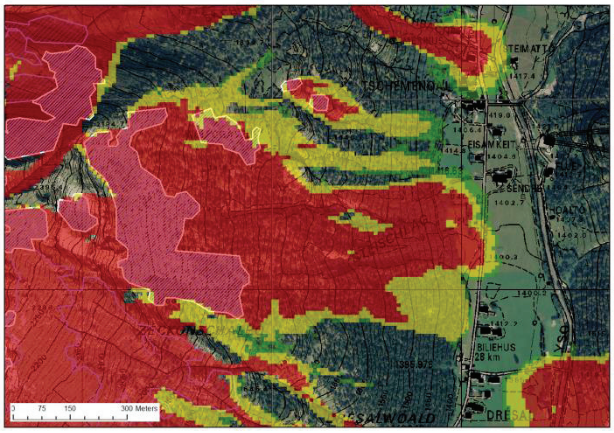

Fig. 7. Steischlag avalanche path: avalanche hazard zones defined by the automatic procedure.

5. CONCLUSIONS

Our results show that the automatic procedure generally produced hazard zones in good agreement with those in the official L.R. 11/98 RAVA. If not, in general, the automatic procedure produced hazard zones larger than those in the official AHM. Therefore, we can say that for unknown areas this might be a useful, defensive tool to give a first indication of the potential avalanche hazard. As this procedure is automated, the results are reproducible and based on the input data chosen, objective. In conclusions, this case study illustrates the high potential of the automatic, not time-consuming, procedure for large areas, especially if with few historical avalanche data.

6. AKNOWLEDGEMENTS

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