

GIS TOOLS FOR AVALANCHE ASSESSMENT

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ABSTRACT: The use of Gis in avalanche assessment is widely adopted, it performs analysis which help to make decisions in land management.

The aim of this work was to apply different tools, provided by a GIS software, for the study and management of the avalanche risk in the Region of Valle d'Aosta (north-west of Italy) and in the ski resort "Piancavallo" in Friuli Venezia Giulia Region (north-east of Italy). As a goal and also a starting point for further processes, a geodatabase of the Regional Avalanche Inventory was created and divided into several raster datasets, feature datasets and feature classes related to avalanches. Then, within the Interreg project Italy-Switzerland "STRADA", still in progress, strategies for the avalanche hazard mitigation were found, focusing in particular on roads crossed by avalanche paths.

That was reached by assessing a procedure, obtained interpolating (geoprocessing) features related to avalanches, roads and buildings, which provides a useful tool to identify the sites that might be suitable for artificial avalanche triggering. This process could help in avoiding the preventive closure of roads, and such application can be the starting point for more detailed analysis, necessary to provide decision-making to local governments in emergency management. Finally, a methodology, processed from digital terrain models, allowed the identification of the potential release areas in the Piancavallo ski-resort realized through various steps in geoprocessing environment, or through file .aml of Arc Info Workstation.

INTRODUCTION

Main roads closed several times, power and telephone lines interrupted, whole forests uprooted and swept away, entire villages and valleys isolated not only by avalanches but also by the considerable snowfalls.

That's a shocking description of 2008/2009 winter but it's a scenario, that even if with a lower extension, is quite common in the Region of Valle d'Aosta. That's why land managers have to face those emergencies with great energy and with powerful decision-making tools.

This work, developed during the PhD studies, aims to develop a methodology of analysis, integration and processing of spatial data through Geographic Information Systems (GIS), to provide decision making tools useful for technical and economic assessments, for the management of critical situations related to avalanches risk.

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Fig. 1: a buried gallery during winter 2008-2009

Specifically, the work takes into account the avalanche danger, in particular related to the road system, infrastructures and ski-resort. Often routes and valleys are closed for several days, entire villages kept isolated.

Nowadays, the use of non-permanent avalanche control techniques like the artificial avalanche

release is preferable, both for impact and economical reasons. However, the adoption of this type of intervention involves a careful evaluation of the suitable sites to avoid any risk to structures or population.

Another problem is represented by the avalanche risk in the ski resort. In both cases the use of GIS tools for spatial analysis allows to identify sites that may be suitable for artificial avalanche release, or to gather important elements for decision makers.

In the first part of the work a geodatabase of the Regional Avalanche Inventory has been created, then a methodology for detecting the sites suitable for the artificial avalanche release has been carried out. The last part of the work processes a DEM-based procedure for the identification of the potential release areas PRA (Maggioni M., 2005) in a ski resort.

Study areas

The study area, located in the Region of Valle d'Aosta (north-west of Italy) and in the ski resort "Piancavallo" in the Region of Friuli Venezia Giulia (north-east of Italy).

Avalanche Inventory Geodatabase

In order to process all the analysis a file Geodatabase of the Regional Avalanche Inventory of the Region of Valle d'Aosta has been modeled. The Regional Avalanche Inventory was originally divided into several shapefiles principally regarding the avalanches mapped by field surveys and, by historical data and the modeled avalanches, whose avalanche deposit part is divided into 3 zones characterized by different impact pressure (fig.2). The structure of avalanche inventory geodatabase was created and subdivided in several feature dataset and raster dataset related to cartography, and into raster dataset related to avalanches, either surveyed or historically detected or modeled, whose databases contains several informations (fig.3).

At the end of 2010-2011 winter season 1.852 avalanches phenomena recorded affecting the 15% of the regional territory. Since 2005 628 new avalanche phenomena have been surveyed.

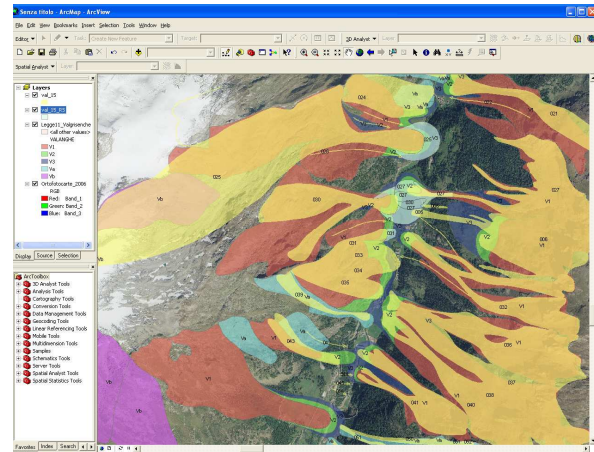


Fig. 2: feature classes related to surveyed and modeled avalanches

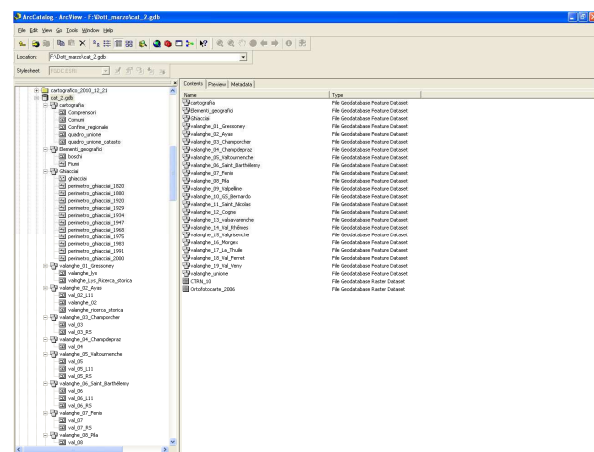


Fig. 3: part of the “Avalache Inventory Geodatabase”

Strada project

The second part of the work regarded the italian-swiss project STRADA, an Italian acronym for: "Climate change adaptation strategies for the management of natural hazards".

To avoid the preventive closure of the valleys affected by avalanches, a first attempt for the detection of the avalanche sites, suitable for the artificial avalanche release, was carried out. The work was processed in the ArcToolbox geoprocessing environment. Road system and infrastructures shapefiles have been modeled in a file geodatabase and geoprocessed several times with the Regional Avalanche Inventory geodatabase features classes. Explosives and gases are usually used for the artificial avalanche release, that's why a security distance between the avalanche release area (or triggering point) and buildings must be considered. So in this experimental procedure the distances of 50, 100

and 200 m from the avalanche area have been chosen using the *Multi Ring Buffer tool*, which allows to preserve the databases of the input feature classes. Summarizing, by different interpolations in *ArcToolbox* and *Selection queries* among the feature classes related to avalanches and to buildings, the avalanches intersecting or close to the road system and buildings have been detected.

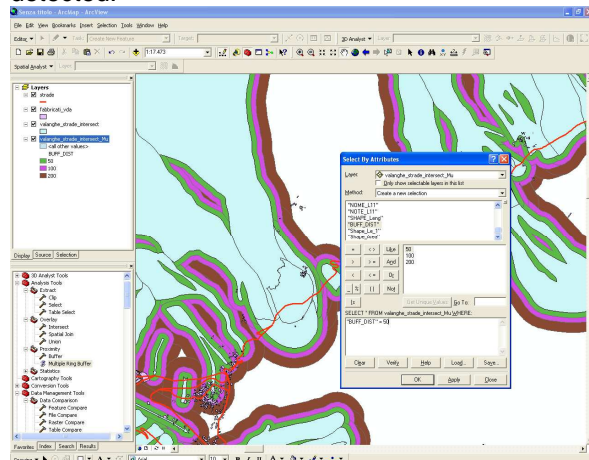


Fig. 4: a selection query after the Multi Ring Buffer tool geoprocessing

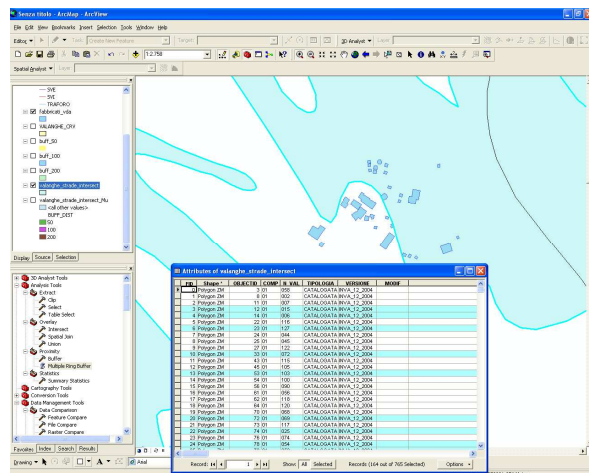


Fig. 5: 164 avalanches intersect the road system and buildings

Among 765 avalanche feature classes analyzed:

- 164 avalanches intersect the road system and buildings
- 426 avalanches intersect the road system and buildings within a distance of 50 m
- 539 avalanches intersect the road system and buildings within a distance of 100 m

- 655 avalanches intersect the road system and buildings within a distance of 200 m

This procedure provides a first assessment of sites suitable for artificial avalanche release; nevertheless, further *in situ* evaluation is needed to check the real possibility of intervention. Moreover it provides basis quantitative assessment and decision-making tools to local government in emergencies management.

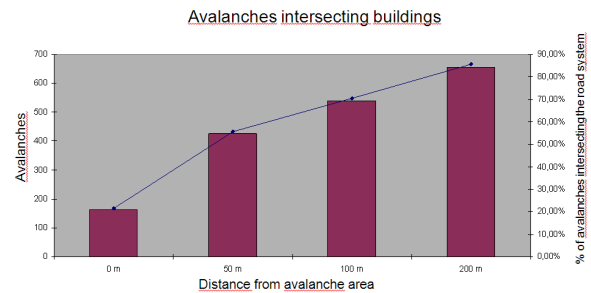


Fig. 6: Avalanches intersecting buildings

Model builder has been used for the modelization of the interaction between the road system and the avalanche phenomena of the Region of Valle d'Aosta.

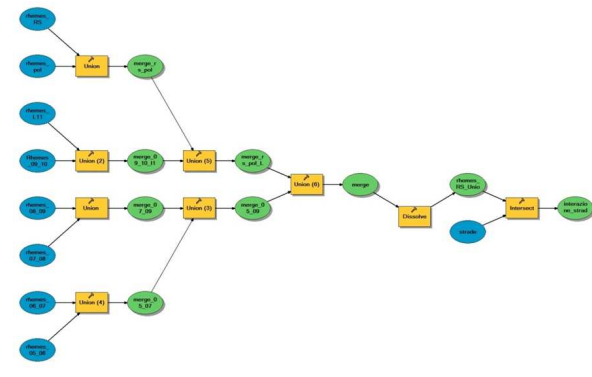


Fig. 7: Model Builder

Pra

The last part of this work has tested a procedure developed by Maggioni M. (2005) for the definition of P.R.A.: "Potential Release Areas" for the ski resort "Piancavallo" in the Region of Friuli Venezia Giulia (north-east of Italy). This rule-based method, processed by ArcInfo Workstation, leads to the definition of the potential release areas from digital elevation models.

The rules are based on expert considerations about topographical parameters influencing

avalanche release, and on past studies of avalanche release. The criteria used in the different steps are the following: forest cover, slope angle, curvature, main ridges, size, aspect, altitude range and aspect and altitude difference.

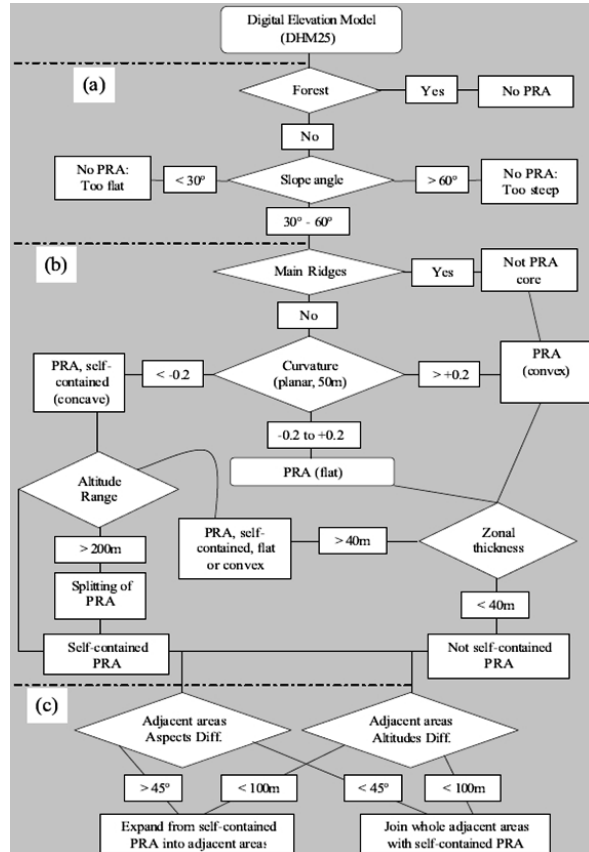


Fig. 8: Procedure for the definition of Potential Release Areas: (a) Defining potential release areas, (b) Separating potential release areas, (c) Merging and expanding potential release areas (Maggioni M., 2005)

The original input is the TIN of the area of interest, converted into a 5 m DEM, with the 3D Analyst "Covert Tin to Raster" command. Some steps of the procedure were performed working with raster data and some others working with vector data, depending on the current need. The output is a raster where all the cells, defined as belonging to any identified PRA, take the identity value of that PRA and the remaining space is set null. Then, this raster file is transformed to a vector file with polygon topology to analyze the results and to perform further analysis.

This study aims to develop a consistent and reproducible method to identify potential avalanche release areas on the basis of more topographical parameters, such as for example slope together with curvature and aspect. The combination of GIS

techniques with an elevation model (DEM) is the most important characteristic in making this method a reproducible tool which can be used in different areas, provided a DEM is available.

All the steps are based on automatic procedures using macro language AML (ArcMacro Language) of the GIS software ArcInfo [ESRI, 2001] so that they can be easily transferred to other areas. Some steps have also been geoprocesed with ArcToolbox tools.

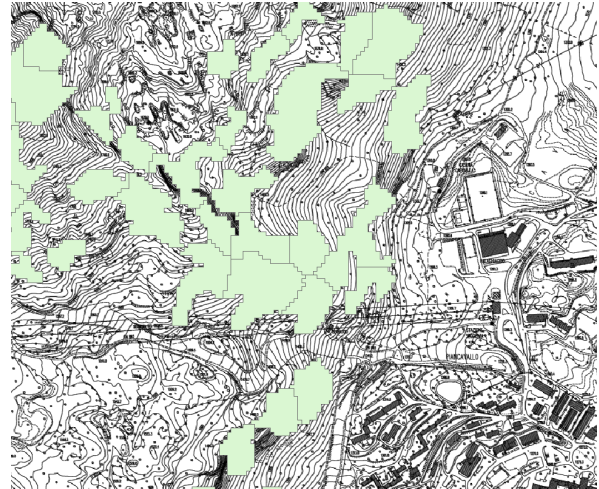


Fig. 9: Potential Release Areas of the ski resort of Piancavallo

CONCLUSION

The aim of the work was the use of Gis tools for the study and management of avalanches, and also for the definition of the potential avalanche sites, where historical informations are missing.

The first aim was to collect all the databases of the Regional Avalanche Cadaster and modeling a file Geodatabase for further implementations and processing. Within the project STRADA the interpolation of different feature classes related to the road system, avalanches paths, buildings and general infrastructures has defined the critical sites, potentially suitable for the artificial avalanche release. Thus represents the starting point for further analysis and for giving decision making tools to the local government during emergencies. That procedure may be an important tool for avoiding the closure of roads and valleys, with good implications for the local economy.

Finally a rule-based method has led to the definition of the potential release areas of a Ski resort of Piancavallo. The procedure has been applied to a DEM and processed either in the geoprocessing environment of *ArcToolbox* and by file .aml with *ArcInfo Workstation*.

Further analysis, processed by avalanche dynamics models on the detected P.R.A., will lead to the definition of potential artificial avalanche release on the ski slopes.

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