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# 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 extention, 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 modelized avalanches, whose avalanche deposit part is divided into 3 zones characterized by different impact pressure (fig.2). The structure of avalanche inventory geodabase was created and subdivided in several feature dataset and raster dataset related to cartography, and into raster dataset related to avalanches, either surveyd or historically detected or modelized, 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.

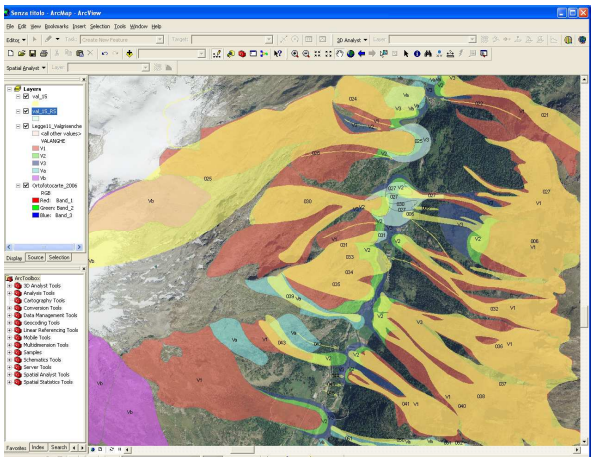

*Fig. 2: feature classes related to surveyed and modelized avalanches*

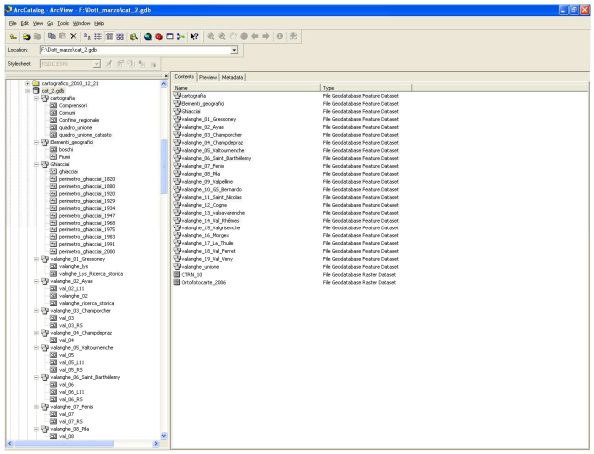

*Fig. 3: part of the "Avalache Inventory Geodatabase"*

## *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 geoprosessed 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.

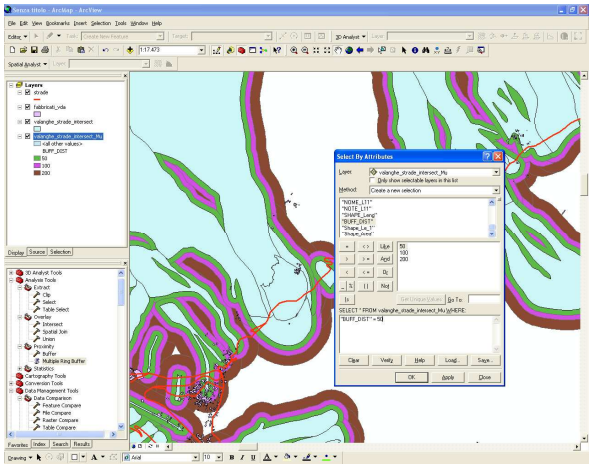

*Fig. 4: a selection query after the Multi Ring Buffer tool geoprocessing*

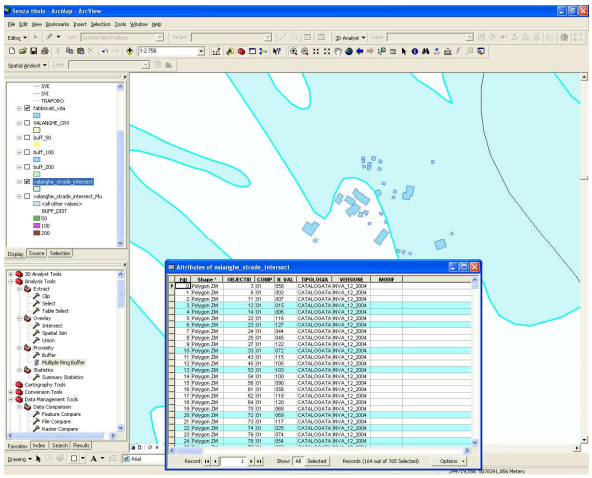

*Fig. 5: 164 avalanches intersect the road system and buildings*

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.

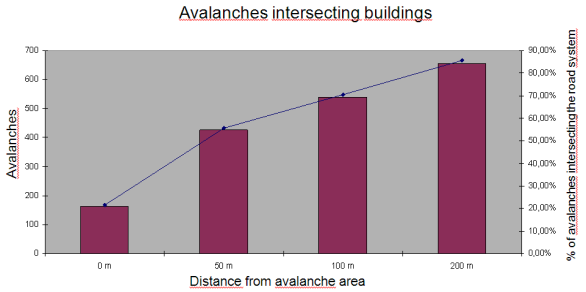


*Fig. 6: Avalanches intersecting buildins*

*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.

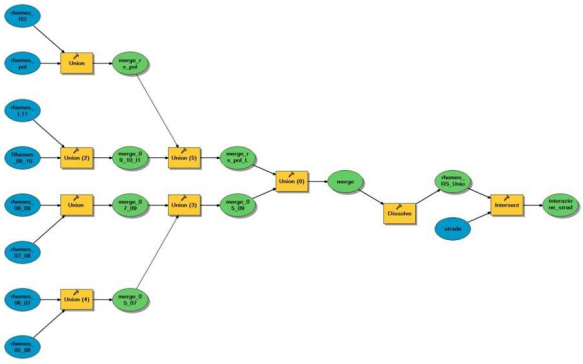

*Fig. 7: Model Builder*

## *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.

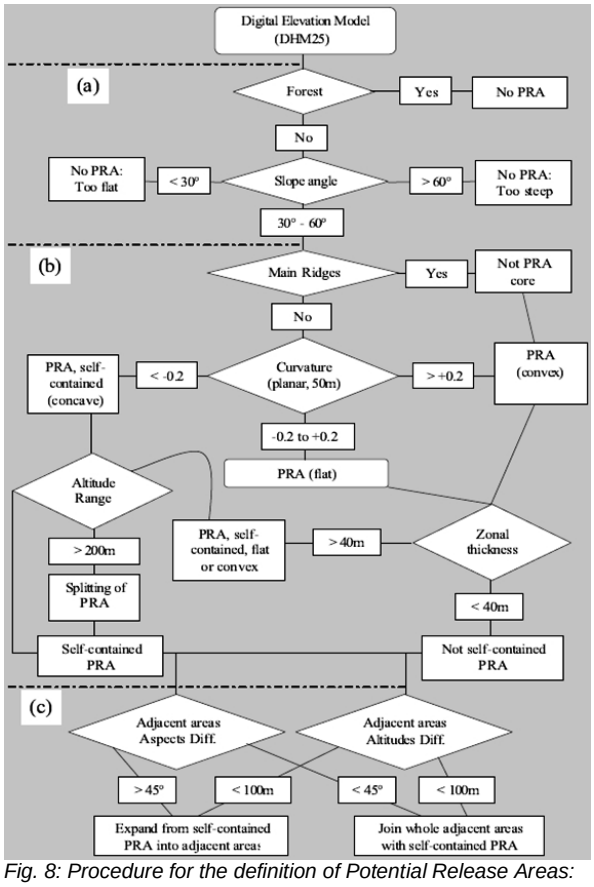


*Fig. 8: Procedure for the definition of Potential Release Areas: (a) Defining potential release areas, (b) Separating potential release areas, (c) Merging and expanding potential release areas (Maggioni M., 2005)*

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 geoprocessed with ArcToolbox tools.

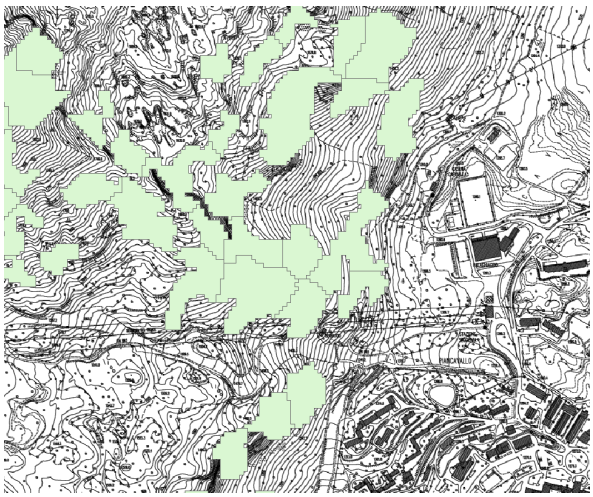

*Fig. 9:* Potential Release Areas of the ski resort of Piancavallo

## 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.

## 7. REFERENCES


Armstrong, B. & Williams, K. (1986). The avalanche book. Golden, Colorado, Fulcrum Inc.

Buisson, L. & Charlier, C. (1989). Avalanche starting-zone analysis by use of a knowledge-based system. Annals of Glaciology 13, 27–30.

Cagnati, A. (2003). Strumenti di Misura e Metodi di Osservazione Nivometeorologici. Aineva

Canadian Avalanche Association (1995). Obeservation Guidelinesand Recording Standards for Weather, Snowpack and Avalanches. CAA, Revelstoke, BC, Canada.

Carter, J. R. (1988). Digital representations of topographic surfaces. Photogrammetric Engineering and Remote Sensing 54, 1577–80.

Colbeck, S., Akitaya, E., Armstrong, R., Gubler, H., Lefeuille, J., Lied, K., McLung D., & Morris, E. (1993). The International Classification for Seasonal Snow on the Ground. International Association of Scientific Hydrology.

Coppock, J. T. & Rhind, D. W. (1991). The history of GIS. In D. J. Maguire, M. F. Goodchild, & D. W. Rhind (Eds.), Geographic Information Systems: principles and applications, Volume 1, Chapter 2, pp. 21–43. London: Longman.

Evans, I. S. (1980). An integrated system of terrain analysis and slope mapping. Zeitschrift f¨ur Geomorphologie Supplement Band 36, 274–95. 132

Florinsky, I. V. (1998). Accuracy of local topographic variables derived from digital elevation models. International Journal of Geographical Information Science 12 (1), 47–61.

Gleason, J. A. (1995). Terrain parameters of avalanche starting zones and their effect on avalanche frequency. In Proceedings of the International Snow Science Workshop, Snowbird, Utah, U.S.A.,30 October - 3 November 1994, pp. 393–404. Int. Snow Sci. Workshop 1994 Organ Comm., Snowbird, Utah. 133

Goetz, D (2011) - LES AVALANCHES. Stage Moyenne Montagne, Cen, Météo-France.

Maggioni, M. (2005) ”Avalanche Release Areas and Their Influence on Uncertainty in Avalanche Hazard Mapping”. Tesi di dottorato SLF Davos. Zurigo

Maggioni, M. & Gruber, U. (2003). The influence of topographic parameters on avalanche release dimension and frequency. Cold Regions Science and Technology 37, 407–419.

Maguire, D. J. & Dangermond, J. (1991). The functionality of GIS. In D. J. Maguire, M. F. Goodchild, & D. W. Rhind (Eds.), Geographic Information Systems: principles and applications, Volume 1, Chapter 21, pp. 319–335. London: Longman.

Maguire, D. J. & Raper, J. F. (1990). An overview of GIS functionality. In Proceedings of the Design Models and Functionality Conference, Leicester, pp. 10pp. Midlands Regional Reseach Laboratory.

McClung, D. M. (2001). Characteristics of terrain, snow supply and forest cover for avalanche initiation by logging. Annals of Glaciology 32, 223–229.

McClung, D. M. & Schaerer, P. A. (1993). The Avalanche Handbook. The Mountaineers, Seattle, WA.

Moore, I. D., Turner, A. K., Wilson, J. P., Jenson, S. K., & Band, L. E. (1993). Gis and land surface-subsurface modeling. In M. F. Goodchild, B. O. Parks, & L. T. Steyaert (Eds.), Enviromental Modeling with GIS, pp. 196–230. New York: Oxford University Press.

Munter,W. (1997). 3x3 Lawinen – Entscheiden in kritischen Situationen. Agentur Pohl & Schellhamer.

Peucker, T. K., Fowler, R. J., Little, J. J., & Mark, D. M. (1978). The triangulated

irregular network. In Proceedings of the ASP Digital Terrain Models
(DTM) Symposium, Falls Church Virginia, pp. 516–40. American Society of
Photogrammetry.

Schweizer, J. & Jamieson, J. B. (2001). Snow cover properties for skier triggering
of avalanches. Cold Regions Science and Technology 33, 207–221.

Schweizer, J., Jamieson, J. B., & Schneebeli, M. (2003). Snow avalanche formation.
Review of Geophysics 41 (4), 1016.

Segor, V. (editor), 2012. Rendiconto Nivometeorologico - Inverno 2008-2009, Regione Autonoma Valle d'Aosta - Direzione assetto idrogeologico dei bacini montani - Ufficio neve e valanghe, Quart

Sitko, R., Identification, classification and assessment of forest function with the use of geoinformatics. PhD Thesis, Technical University in Zvolen, 2008.

Smith, M. J. & McClung, D. M. (1997). Avalanche frequency and terrain characteristics at Rogers' Pass, British Columbia, Canada. Journal of Glaciology 43 (143), 165–171.

Toppe, R., Terrain models: a tool for natural hazard mapping. In: Salm, B., Gubler, H.(Eds.),
Avalanche Formation, Movements and Effects (Proceedings of the Davos Symposium, September
1986). International Association of Hydrological Sciences (IAHS), Wallingford, UK, 1987.

UNESCO (1981). Avalanche Atlas. Illustrated International Avalanche Classification.
Paris.

USDA (1961). Snow Avalanches, Volume USDA Handbook No. 194. Washington:
U.S. Government Printing Office.

VIENNAU A. (2001): Using ArcCatalog, ESRI

Wilson, J. P. & Gallant, J. C. (2000). Digital Terrain Analysis. In J. P.
Wilson & J. C. Gallant (Eds.), Terrain Analysis: Principles and Applications,
Chapter 1, pp. 1–27. John Wiley & Sons, Inc.

Wood, J. (1996). The geomorphological characterisation of digital elevation
models. Ph. D. thesis, Department of Geography - University of Leicester