USING GIS FOR AVALANCHE SUSCEPTIBILITY MAPPING IN RODNEI MOUNTAINS

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ABSTRACT. Using GIS for avalanche susceptibility mapping in Rodnei Mountains. This case study combines GIS methods with field work in order to assess the snow avalanche susceptibility in Rodnei Mountains. The database used contains a 10 m resolution DEM, ortophotos and data from field campaigns. Several factors affecting avalanche formation (slope angle, land use, slope curvature, elevation) were calculated in a first phase. Using the bonitation method, each of these factors was taken into consideration depending of its own importance in avalanche formation. As a result of GIS implementation, an avalanche susceptibility map was derived, our focus being on the high zone of Rodnei Mountains. A high avalanche susceptibility was calculated for 50.6 km² of the territory and characterizes steep slopes close to the following peaks: Pietrosul, Puzdrele, Laptele Mare, Gărgălău, Roşu, etc. In order to validate this method, we used 94 avalanche starting zones. After analyzing them in relation to the susceptibility map, we conclude that 89.4% of the avalanche starting zones are situated in areas calculated as being high susceptible in avalanche formation.

Key words: GIS, avalanche, bonitation, susceptibility.

1. Introduction

Avalanches represent a local, dynamic event in snow covered mountainous regions. They result from interactions between climatic factors, local topography and the existing snow pack structure (Hebertson and Jenkins, 2003). They and are not easily predictable and often enough they produce devastating results.

Snow avalanches can be placed into a suite of natural hazards, together with rock avalanches, rockfall, landslides, debris flows, etc. Avalanches can affect the environment, they can cause damages or affect people by causing injuries or death. The strategies used in analysing the avalanches are extremely useful in understanding the process and crucial for predicting the appearance of avalanches so as to reduce the damages they cause.

Generally speaking, it is possible to distinguish between two types of

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avalanche susceptibility maps: (1) susceptibility registration maps containing the maximum boundaries of historically known avalanches, usually drawn for large areas (scale 1:25.000 or 1:10.000) and compiled from literature, documents, and interviews, and by field investigations and interpretation of photographs or ortophotos ; and (2) susceptibility zoning maps (Gruber et al. 1998; Sauermoser 2006), outlining zones with different degrees of hazard (usually high, moderate, and low), with a typical scale of 1:5.000 or 1:2.000 and drawn on the basis of known historic events, geo-morphological investigations, and statistical and/or dynamic computational models. (Barbolini et. al 2009)

In mountain areas that have been inhabited for a long time, information about historical avalanches is usually available. As a consequence, identifying the area affected by major avalanches and roughly delimitating their maximum outline is a quite straightforward procedure. Conversely, in more remote mountain areas, as Rodnei Mountains, systematic data on past snow avalanche activity is generally lacking, and sometimes nonexistent. In these cases, the identification of areas that could potentially be affected by avalanche release and motion is much more difficult and uncertain.

This is the reason why our study uses GIS tools and field campaigns in order to provide a definition of areas potentially affected by avalanches in Rodnei Mountains. We define the zones of potential avalanche release based on the consolidated relations on slope, land use, slope angle, slope curvature and altitude.

2. Study area

Rodnei Mountains (fig. 1) are the highest and the most massive in the Eastern Carpathians in Romania. Their altitude reaches the maximum at 2303 m above sea level in Pietrosul peak.

They represent a tilted horst with a short slope northwards and a higher northern area where snow avalanches are a common phenomenon. They have one of the longest ridges in Romania, measuring more than 50 km from west to east. The studied area is being mainly formed by crystalline schist from Proterozoic and Paleozoic Era and a small amount of volcanic in the southern part.

In what concerns the climate, this mountain area is included in the Eastern European temperate climate, which is characterized by transitional features from oceanic and sub-Baltic humid nuances to excessive ones. Nevertheless specific climatic differences are found according to elevation and aspect. The analysis of temperature variations registered between 1971-2006 at Iezer meteorological station (1785 m) emphasizes a multi-annual average value of 1,26 ºC with variations according to elevation. The annual average precipitation values registered is 1267 mm with a lower extension in the cold season. The annual average of snowfall days is 82 days with a maximum frequency in January (15 days). The highest number of days with snow cover is registered in March (30.7).

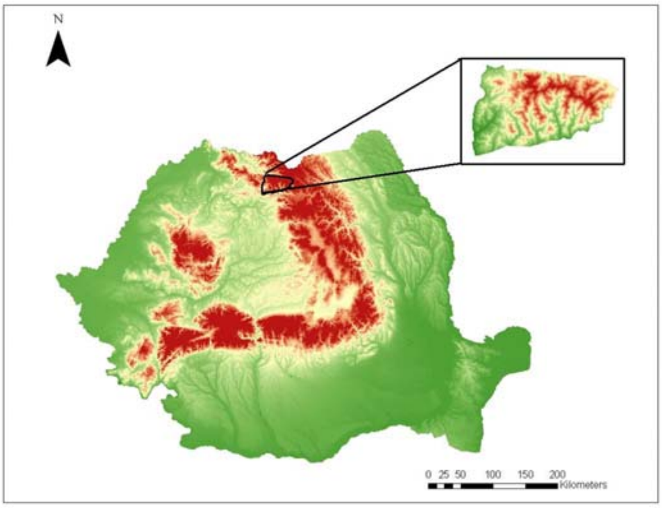

Fig. 1 Location of the studied area.

3. Methodology

In this study we took into consideration several factors which can influence the avalanche occurrence: slope angle, land use, elevation, plan and profile slope curvature. Each of these factors was subdivided into different classes according to its influence upon avalanche formation.

Input data were composed of derived digitization of 1:25000 topographic maps using GIS techniques. Delimitation of avalanche release areas was done using the measurements obtained during the numerous field campaigns together with the information extracted from ortophotos and from forest range's documents.

Slope angle is recognized as the most important topographical parameter for avalanche formation. The assumption made is that avalanches can initiate on slopes with an inclination between 28° and 50° (McClung and Schaerer 2006). Below 28°, the gravitational force is weak, spring wet avalanches being distinguished here, whereas on slopes steeper than 50° releases are limited to frequent small avalanches. Land use is a key factor in the anchorage of the snow cover to the ground. Therefore, regions covered by forest are excluded from the potential release areas. Boulders, shrubs, and trees add to slope roughness and therefore provide more stability than grass or smooth rock. The terrain curvature is a determining factor in what concerns the delimitation of avalanche release areas. Slope shape contributes to the frictional forces that hold the snowpack in place. Gleason (1995) and McClung (2001) found that avalanches are more frequent in starting zones with concave plan curvature.

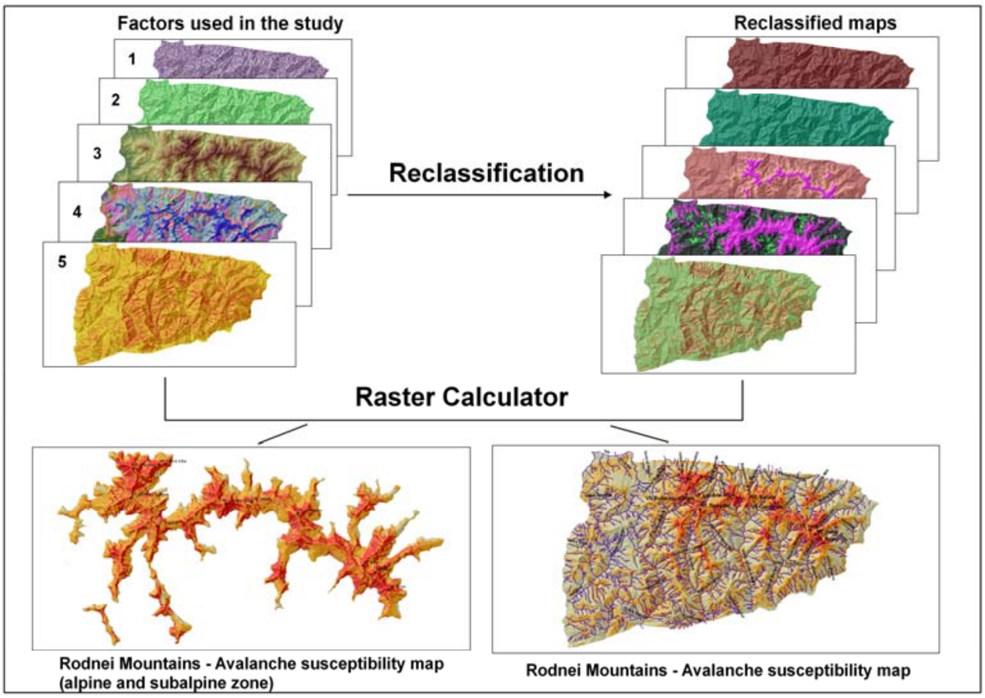

Fig. 2 The methodology used in avalanche susceptibility mapping (1-plan slope curvature, 2-profile slope curvature, 3-elevation, 4-land use, 5-slope angle).

Avalanches are usually more likely at higher elevations because there is more snow and wind than at lower elevations, and there are fewer trees, bushes and logs to anchor the snowpack. Due to the fact that in Rodnei Mountains, timberline is situated approximately at 1600 m, we focused our study on the alpine and subalpine part.

All the resulted data were integrated in GIS (fig. 2), by using the bonitation method, so we were able to generate an avalanche susceptibility map. In order to obtain relevant results, the values were divided into 3 classes of susceptibility: low, medium and high.

4 . Results and validation

By analyzing the avalanche susceptibility map (fig. 3), we can assert that 36.1% of the studied area is characterized by high slope susceptibility in what avalanches are concerned. These areas are situated on steep slopes close to the following peaks: Pietrosul, Puzdrele, Laptele Mare, Gărgălău, Roşu, etc.

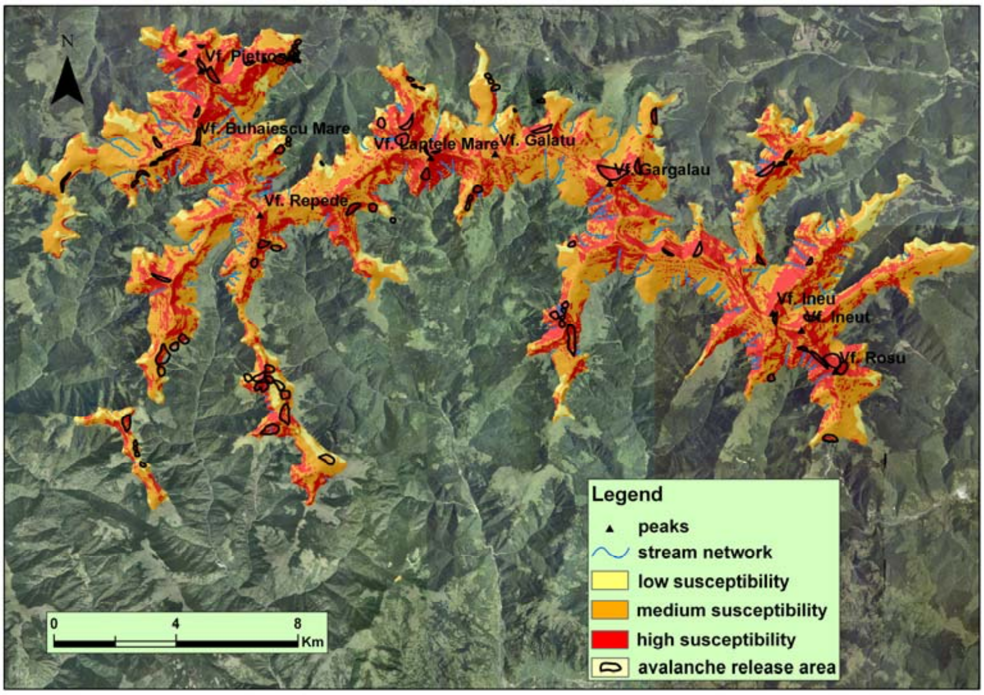

Fig. 3 Rodnei Mountains – Avalanche susceptibility map

Table 1. Classes of avalanche susceptibility for Rodnei Mountains

Susceptibility class	**Area(km²)**	**% of area**	**% of total avalanche release areas**
High susceptibility	50.6	36.1	89.4
Medium susceptibility	79.9	57	10.6
Low susceptibility	9.6	6.9	0
Total	**140.1**	**100**	**100**

Medium slope susceptibility was calculated for 57% of the area and is to be found in the western part of Rodnei Mountains, on Piciorul Pleşcuţei and between

Galaţu and Gărgălău peaks. Only 6,9% of the total area is characterized by low slope susceptibility.

In order to validate this method, we used 94 known avalanche release areas from Rodnei Mountains. Validation was performed by comparing the location of the avalanche release area with the generated susceptibility map.

The results shown that the high resulted susceptibility, can explain 89.4% of the avalanche release areas. The rest of 10,6 % are situated in the area calculated to have a medium susceptibility to avalanche formation.

According to these results we consider the model we used, a valid one.

Acknowledgements

The authors wish to thank for the financial support provided from programs co-financed by The SECTORAL OPERATIONAL PROGRAMME HUMAN RESOURCES DEVELOPMENT, Contract POSDRU 6/1.5/S/3 – „Doctoral studies: through science towards society".

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