“BABEŞ-BOLYAI” UNIVERSITY, CLUJ-NAPOCA
FACULTY OF GEOGRAPHY

THE AVALANCHES FROM RODNEI MOUNTAINS

-PhD THESIS-

Summary

SCIENTIFIC COORDINATOR **PhD CANDIDATE**

prof. univ. dr. VIRGIL SURDEANU **IOANA MARIA SIMEA**

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I. INTRODUCTORY ASPECTS

1.1. Location of the study area

Rodnei Mountains constitutes a great asymmetric horst having the highest altitude from Carpaţii Orientali (Pietrosu peak – 2303 m).

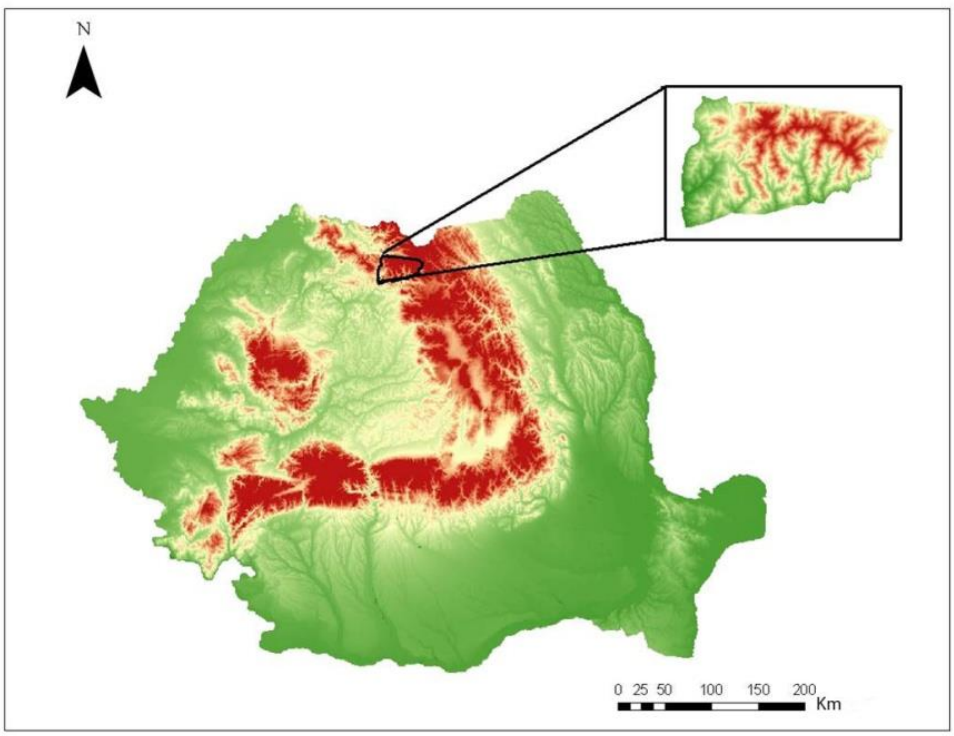

Fig. 1 *Location of Rodnei Mountains*

The north limit with Depresiunea Maramureşului, is represented by a steep tectonic fault named Dragoş Vodă which is east-west oriented. This marks the contact between Rodnei Mountains crystalline rocks and sedimentary - oligocene deposits of the Maramureşului

Depression. West limit is overlapping the margin line of crystalline rocks under flysch rocks, which follows Salauţa valley, then continues on Carelor valley, up to the point that reaches Iza river. South and southeast limits are represented by Someşul Mare valley, and then continue along a fault that has the same direction as Someşul Mare valley. Eastern limit is represented by Rotunda river and the Rotunda mountain pass where the altitude drops to 1271 m. From here, the limit continues on Preluca and Someşul Mare valleys separating the Rodnei Mountains from the Suhard Mountains crystalline.

1.2. A brief history of scientific studies

This study addresses a series of problems related to avalanches from Rodnei Mountains. The first concern regarding avalanches in Romania, took place in inter-war period, by mentioning them in some mountain club publications that were existing by then, as the Romanian Alpine Club or Siebenburgischer Karpatischer Verein.

Along time, there were several preoccupations related to the avalanche favorable weather conditions (Stoenescu, 1956), avalanche couloirs identification and their role in soil erosion (E. Nedelcu, 1962, Valeria Velcea, 1961,Gh. Niculescu, E. Nedelcu, 1961, Gh. Niculescu, 1966, Silvia Iancu, 1970, N. Popescu, M. Ielenicz, 1981, M. Ielenicz, 1984), avalanche classification and the factors that generate them (S. Ciulache, Nicoleta Ionac, 1995, Octavia Bogdan, Elena Niculescu, 1999, Florina Grecu, 1997, F. Moldovan, 2003).

More recently, there is an increased interest in using specialized software, getting information out of satelitary images, topographic maps and orthophotos (C. Flueraru şi colab., 2004; M. Török Oance, 2004) and in dendrogeomorphology, as well (M. Voiculescu, 2010).

Internationally, avalanches have been carefully studied. There were carried out many valuable studies, being tackled different aspects of the phenomenon.

In terms of mapping avalanche couloirs and the study of morphometric parameters which characterize the starting zones there are several important studies belonging to Maksimov (1965), Lachapelle (1968), Martinelli (1974), Lied, Bakkehøi (1980), Salm (1982), Pietri (1993), Hutter (1996), Bartelt et. al (1999), Munter (1999), Maggioni, Gruber (2003).

Avalanches were frequently studied using tree rings by: Schaerer (1972), Butler (1979, 1985), Boucher et al., (2003), Dubé et al. (2004), Butler, Sawyer, (2008), Stoffel et al. (2006a), Mundo et al., (2007), Casteller et al., (2008).

More recently, the computer systems have become indispensable in processing and analyzing data. Among the most important studies in terms of mapping and GIS analysis together with susceptibility and risk maps, we mention Gruber (1995, 2001), Kriz (2001), Barbolini, Keylock (2002), Gruber, Bartlet (2007), Barbolini et. al. (2009).

1.3. Research approach and methodology

Research approach and methodology followed geographical specific techniques and other related sciences. This study was guided after the following methodological aspects:

- the analysis of physical-geographical characteristics of the study area in order to determine the natural framework in which the avalanches occur;
- identification of avalanche couloirs and the factors that generate them;
- spatio-temporal reconstruction of avalanche activity through case studies;
- avalanche susceptibility mapping;

The research activity took place according to the proposed aims and objectives and followed the next steps: documentation stage, field work and laboratory or synthesis stage.

Documentation stage started with consulting bibliography and other sources of information. Obtained data were summarized and a strategy of work was elaborated, which has directed the research process in order to achieve the proposed objectives. In this stage, the first thematic maps were created (land use, soil, etc.) and were used to identify areas affected by avalanches, which were then investigated and monitored.

During the field work stage, assumptions made in the stage of documentation were verified in the field. The research was focused on identifying areas affected by avalanches together with slope, curvature, lithology, etc. Resulted data were processed using GIS applications in order to achieve an accurate quantitative and qualitative evaluation. For the avalanche activity analysis, the dendrogeomorphology method was used.

Laboratory stage had the purpose of processing the complex information accumulated in the first two stages and completing them with new information.

In the last stage, conclusions were drawn by comparing results and data. Information resulting from field and laboratory measurements has been processed using different statistical and mathematical methods in order to obtain land susceptibility to avalanches, but also for making some correlations between them.

Identification of areas affected by avalanches, the frequency and intensity of their activity, and mapping land susceptibility represent the aspects which record the utility and importance of this research.

II. PHYSICAL-GEOGRAPHICAL PREMISES

2.1. Geology

Geology is an important factor that influences the evolution of a territory. The rock hardness degree influences the morphology of an area and rock physical properties (porosity, compactness, permeability, low solubility, etc.) together with the mechanical ones (resistance to perforation) are important, too.

In general, geology affects the morphological features of a territory, which in Rodnei Mountains, due to crystalline rocks form a massive territory which represent a proper place for avalanches to occur. Rodnei Mountains are mostly formed by crystalline rocks and only in a small percentage of sedimentary and eruptive rocks.

2.2. Climatic factor

The climate itself has a causal role in determining avalanche duration, intensity and return period. The most important climatic elements affecting them are: precipitation, temperature, wind and solar radiation. We analyzed data from Iezer meteorological station, situated at an altitude of 1785 m, on the northern slope of Rodnei Mountains.

The quantity and variation of precipitations plays an important role in avalanche formation, due to the snow layer and its quantitative and qualitative features. According to data obtained for the 1979-2007, at the meteorological station Iezer, annual average precipitation quantity is 1208.5 mm.

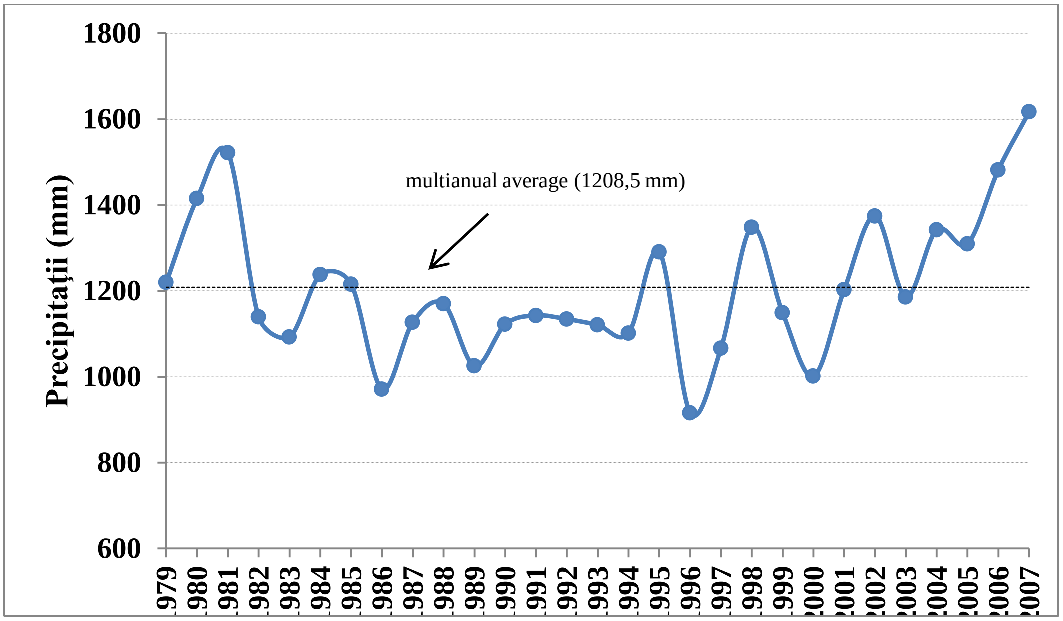

Fig. 2 *Annual averages precipitations at Iezer station (1979-2007) (Source: data processed after ANM archive)*

Air temperature is an important factor as well, influencing characteristics and formation of snow layer.

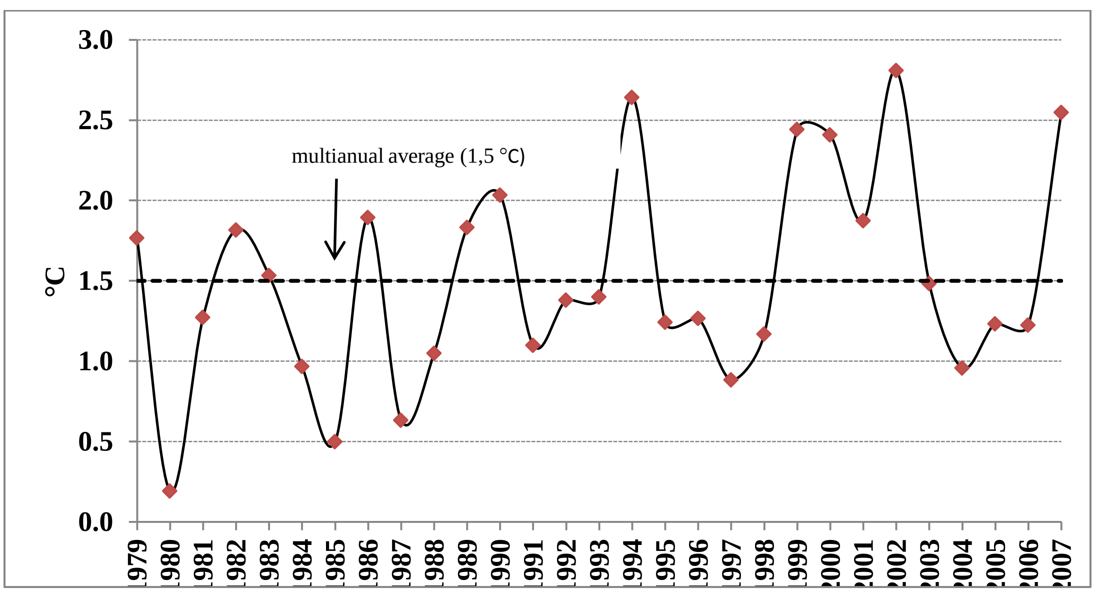

Fig. 3 *Evolution of annual average temperature (1979-2007) (Source: data processed after ANM archive)*

The temperature annual average is 1.5 ºC and yearly average amplitude is 17 ºC.

2.3. Hydrological factor

The hydrological factor influence avalanche formation through the numerous river catchment areas, located above the upper limit of the forest. They tend to develop small valleys that cause the avalanche couloirs formation.

The stream network is organized following two directions: North and South. The characteristics of water courses are related to land features, so rivers on the northern slope are shorter and rushed while those on the southern slope are longer, having larger drainage basins.

We analyzed hydrological data for a 37 years period (1968-2005) for the following rivers: Vişeu (Poiana Borşa station), Iza (Săcel station), Someşu Mare (Nepos station), Cormaia (Sângeorz Băi station), Rebra (Rebrişoara station), Sălăuţa (Romuli and Salva station) and Telcişor (Telciu station).

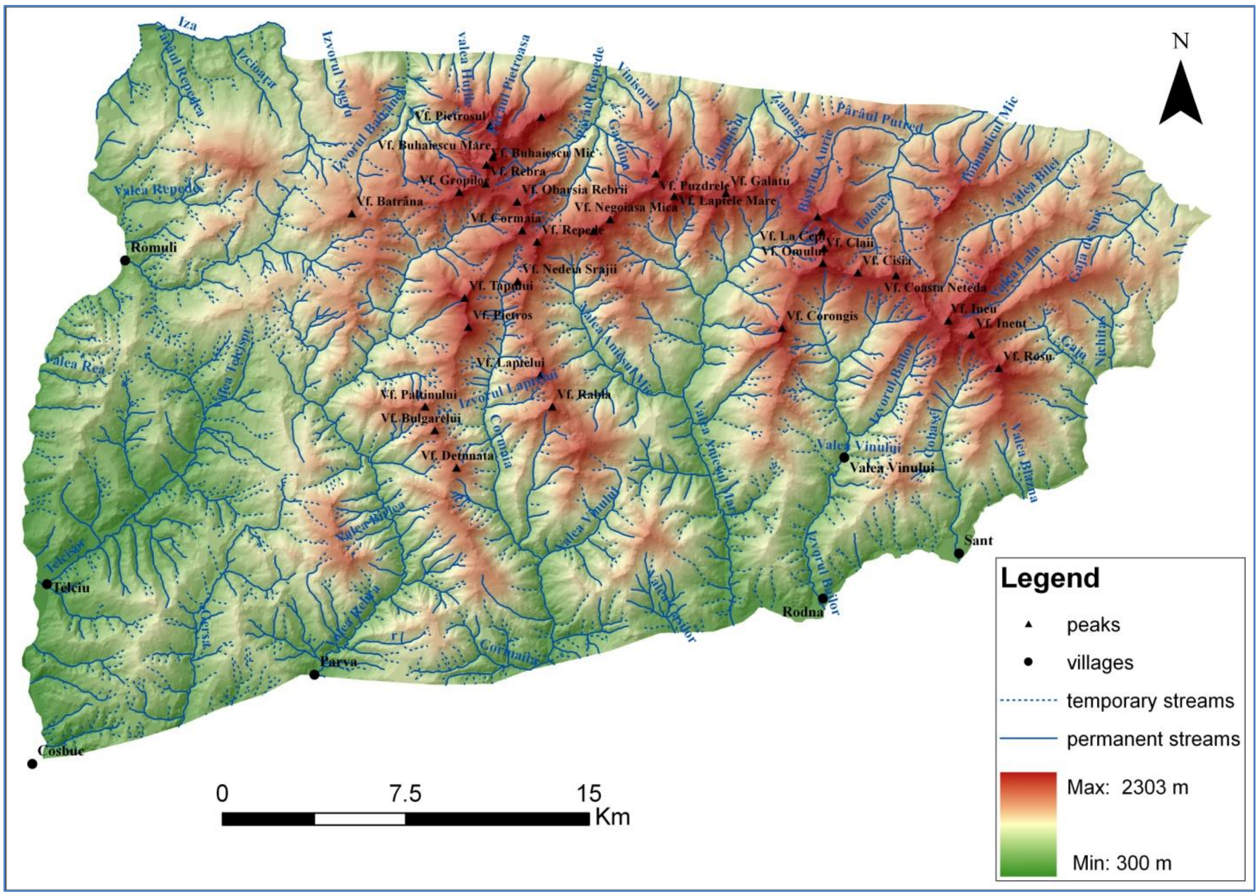

Fig. 4 *Rodnei Mountains – Stream network*

2.4. Biotic factor

It is well known from literature that vegetation has the role to reduce and stabilize geomorphologic processes. The forest range, composition, structure and age have a crucial impact upon avalanche genesis and formation (Gaspar, 1965).

In Rodnei Mountains, vegetation varies with altitude being in close contact with the climatic and soil factors. There are three vegetation floors (Coldea, 1990): forest, subalpine and alpine floor.

Natural vegetation suffered along time many modifications due to human and natural factors. A good part of the shrubs were removed in order to increase pasture land. In many cases, trees from the upper limit of forests were cut down, this fact being favorable to avalanche formation.

There were large-scale avalanches (64.1 hectares) which have destroyed forests on a length of about 3.8 km, as the one from Izvorul Oii under Roşu peak (Fig. 5).

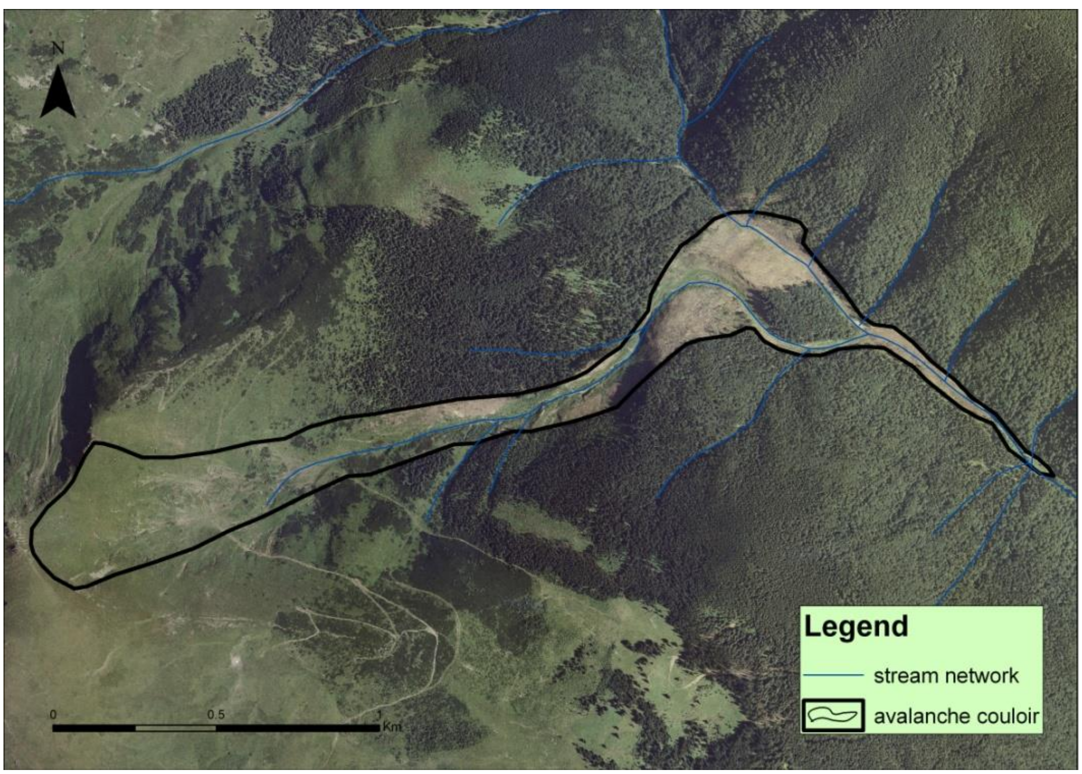

Fig. 5 Avalanche couloir on Izvorul Oii

2.5. Pedological factor

Pedological characteristics are influenced by climate, vegetation and terrain morphology. The conditions of relief, climate and vegetation are responsible for soil characteristics in this area. In Rodnei Mountains there are seven soil classes: protisoils, cernisoils, umbrisols, umbrisoluri, luvisols, spodisols, histisols and 1.17% cliffs.

In terms of erosion, avalanches affect the superficial soil structure and the debris deposits as well (Moţoiu, 2008). In their path, avalanches are gathering all of these materials, together with tree trunks and deposit them in the runout zone. The eroded soil layer comes from the starting or track zone (Gardner, 1983; Jomelli and Bertran, 2001).

Soil erosion has a higher degree in the case of ground avalanches, where the slide plan is located at the ground level. If surface avalanches are predominant, the slide plan is located within the snow layer and then soil is not eroded anymore. Generally in this case, the avalanche track zone is covered by grass and this is often the case in Rodnei Mountains.

2.6. Anthropic activity

The human factor is influencing avalanche formation too, so through its activities represents a disturbing factor. Rodnei Mountain area was populated since ancient times because of the natural resources.

Human villages are situated along main rivers, such as Şanţ situated along Someşul Mare valley, Rodna village situated at the confluence of Izvorul Băilor and Someşul Mare valleys, Parva village situated on Rebra river and Coșbuc, Telciu and Romuli villages are located on Sălăuţa valley.

Avalanches may be caused by man involuntarily: by tourists, sounds, mechanical shocks etc. In Rodnei Mountains several types of tourism are practiced: recreational, cultural, agro-tourism, etc., but only leisure tourism involves the avalanche areas. Because of a beautiful natural landscape, during winter, tourism is intensively practiced, many times even by skiers. Most victims are caught in avalanches due to their fault, because of the additional weight which they exert on the snow layer, which can break a fragile layer inside the snow.

III. AVALANCHES

3.1. General aspects

Avalanches represent an important natural hazard, causing socio-economic damage in all areas in which they occur. They are spectacular as manifestation and may have devastating effects both on environmental and human components.

The origin of word "avalanche", comes after some authors from the french verb "avaler" which means to swallow a slope (Moţoiu, 2008). Other authors (Voiculescu, 2008) say that the word comes from the swiss reto-roman language wehere "avalantse" means sliding down on a slope. The sections of an avalanche path are: starting zone, track and runout zone (fig. 6).

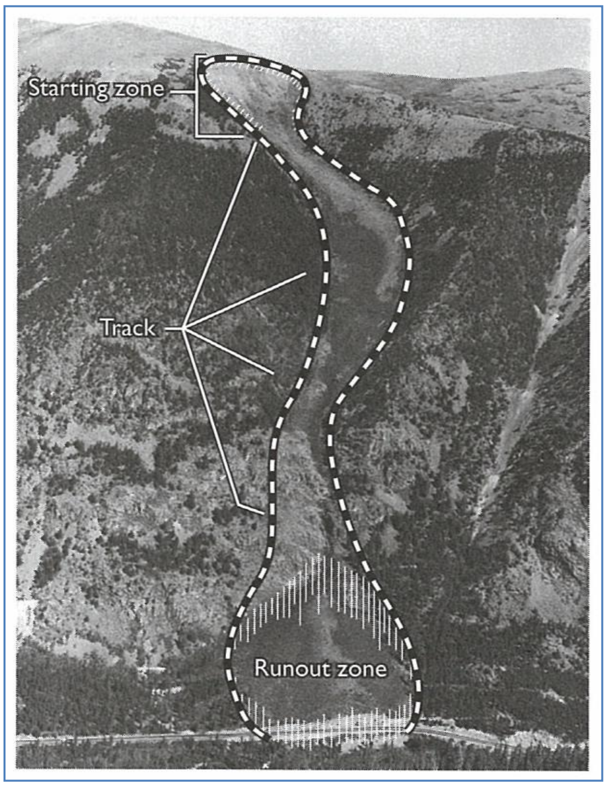

Fig. 6 *Sections of an avalanche path (McClung, Schaerer, 2006)*

3.2. Avalanche classification

Along the time, avalanche classification passed through various stages, so that almost every scientist involved in this field proposed a classification system. At the International Congress IUGG from Torornto in 1957, de Quervain made an inventory of existing classifications.

He reminds some of the first classifications, Ratzel (1889) which has made a difference between dust avalanches (staublawinen) and ground avalanches (grindlawinen). Then in 1888, Coaz proposed three types of avalanches: dust avalanches, ground avalanches and glacier avalanches. In 1891, Pollak distinguished between pure dust avalanches, common dust avalanches, mass avalanches and surface layer avalanches.

In our country, one of the first classifications belongs to Topor, 1957 who divides avalanches in five categories:

- dust avalanches which occur during winter time when high precipitation are covering an old layer of snow;
- ground avalanches, which occur in warm periods of winter or spring, when the snow starts melting or when is raining;
- avalanches formed by blocks which are formed on slopes with small inclinations and are caused by the different snow layers that are not properly linked;
- snow balls avalanches, which occur usually in spring or summer when ice is melting;
- cornice avalanches which are formed in winter or spring when the rock is heated, and the entire suspended platform breaks up with noise;

Other criteria used in avalanche classifications (Voiculescu, 2002; Maria Moţoiu, 2008) are: release type, movement type, location of the slide layer, avalanche couloir shape, snow moisture.

3.3. Avalanche factors

There are several factors that contribute to avalanche formation. These factors can be divided into: preparation factors, potential factors and starting factors (Grecu, 1997; Voiculescu, 2002, Moţoiu, 2008).

The preparation factors are also divided into natural and anthropic factors. Potential factors are represented by snow layer characteristics. Starting factors influence the avalanche proportions, frequency and manifestation mode. They can be split into: morphometric factors, climatic factors, biotic and accidental factors.

3.4. Morphometric characteristics of avalanche couloirs

In order to identify avalanche couloirs we used measurements gathered along numerous field campaigns, and also information extracted from orthophotos and forest administration documents. According to all of these, we were able to identify 47 avalanche couloirs that have track and runout zones situated below the upper limit of forest vegetation (fig. 7).

Among the 47 avalanche couloirs that we analyzed, only one exceeds the length of 3000 m and has the highest difference in altitude of 1246 m. This couloir has been formed due to a large avalanche from 2005 winter. Since then, the frequency of avalanches has increased in this area, a large avalanche being registered in 2009 winter.

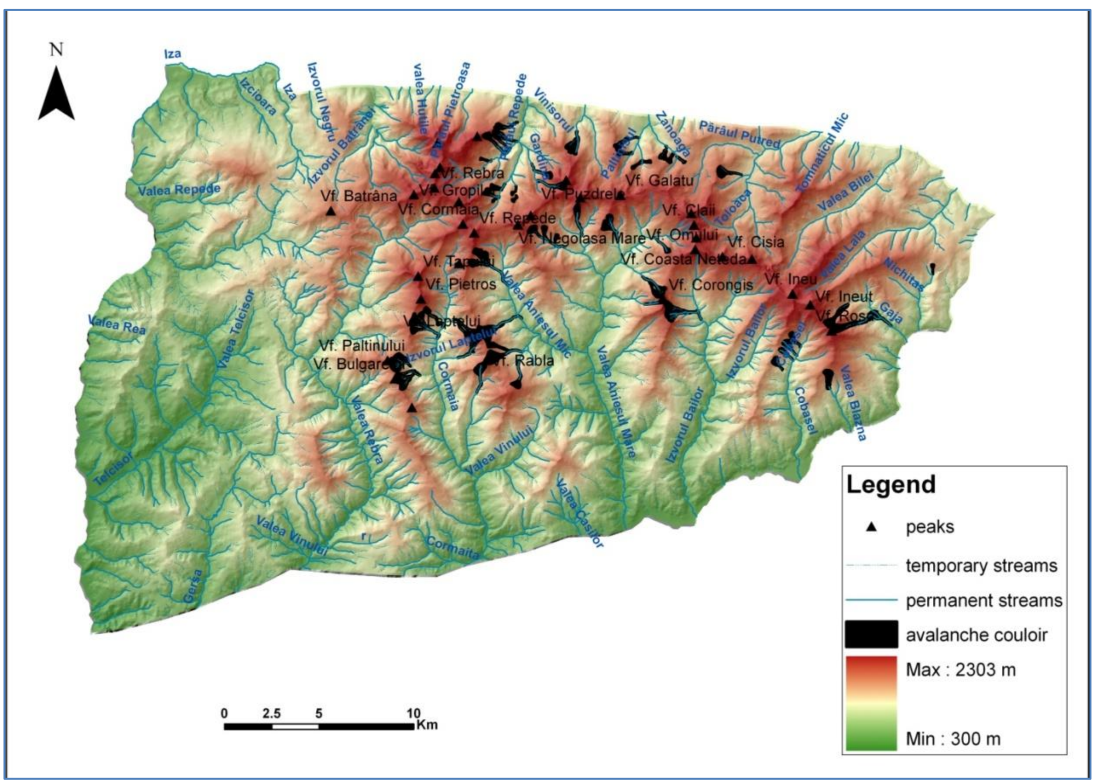

Fig. 7 – Rodnei Mountains – Avalanche couloirs

IV. DENDROGEOMOPRHOLOGY IN AVALANCHE RESEARCH. CASE STUDIES

4.1. General aspects

Along time, there were several references to the tree ring growth that they hide series of useful information for various sciences, but systematically study starts only at the beginning of XXth century in U. S.A. where Andrew Ellicot Douglass, tries to find the link between solar activity and climate using tree rings.

The term "dendrocronology" comes from Greek: dendron-tree, chronos-time and logos-science. According to Shroder (1980), dendrocronology is a general science that deals with dating tree rings and analyses environmental information associated with these increases.

4.2. Tree reactions to avalanches in Rodnei Mountains

Dendrogeomorphology is based on the concept "process-event-answer" defined by Shroder 1978. The process refers in this case to any geomorphologic process: avalanches, rockfalls, debris flows, etc. In case of an "event", the geomorphologic process will affect the tree, which will respond with a growth "answer".

Fig. 8 *Morphology of the tilted tree (A), excentric tree rings (B), reaction wood (C) - Picea abies (Rodnei Mountains – Cobăşel Valley)*

In Rodnei Mountains during the analysis of areas affected by avalanches, there were identified tilted trees, decapitated tress and trees presenting scares (fig. 8).

4.3. Avalanche activity analysis in Cobăşel Valley using tree rings. A case study.

Avalanches are a threat, because of their capacity of both material and human destruction. Information on the past avalanche activity or a analysis of areas affected by avalanches is missing for Rodnei Mountains. The aim of this case study is to perform a spatio-temporal reconstruction of avalanche activity in Cobăşel Valley.

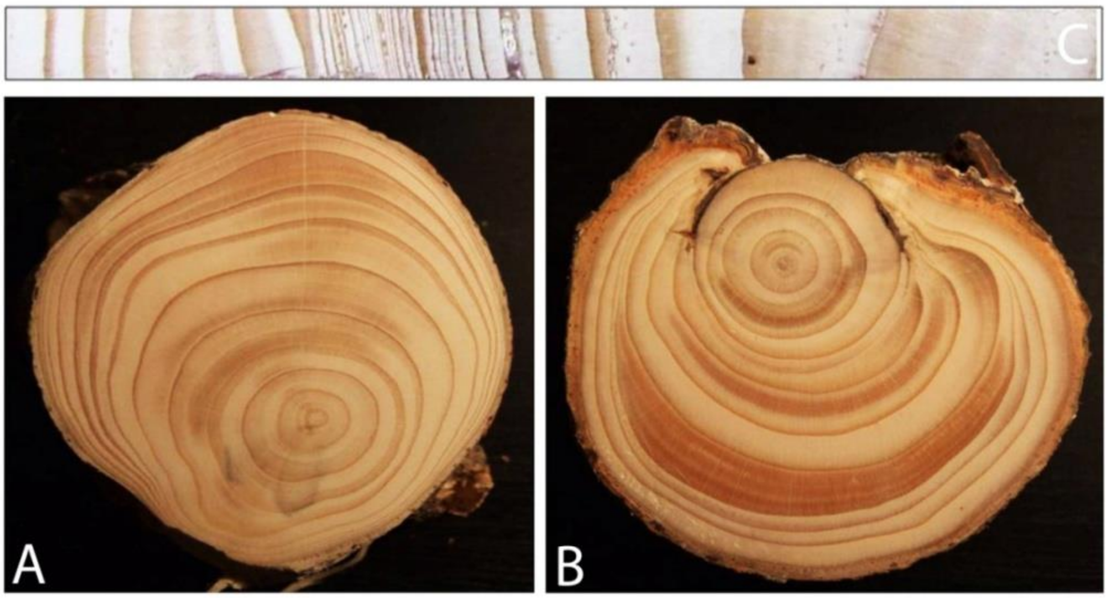

Fig. 9 *Taken samples*

We selected 84 *Picea Abies* trees which were visibly affected by avalanches and we extracted two cores/tree. In total we used 164 samples (159 cores and 5 discs) (fig. 9). The analysis of the 84 trees, made possible the identification of 19 events between 1961 and 2010. The highest frequency took place in decades VII, IX and XX. The events from 1961, 1964, 1979, 1986 and 2006 had the highest intensity, recorded in the number of trees affected by avalanches compared with those who were alive at that moment (fig. 10).

The return period (3,58 years) was calculated by dividing the observation total number of years (49) to the number of identified events (19). The probability of producing an avalanche in a year in Cobăşel valley is 27.94%.

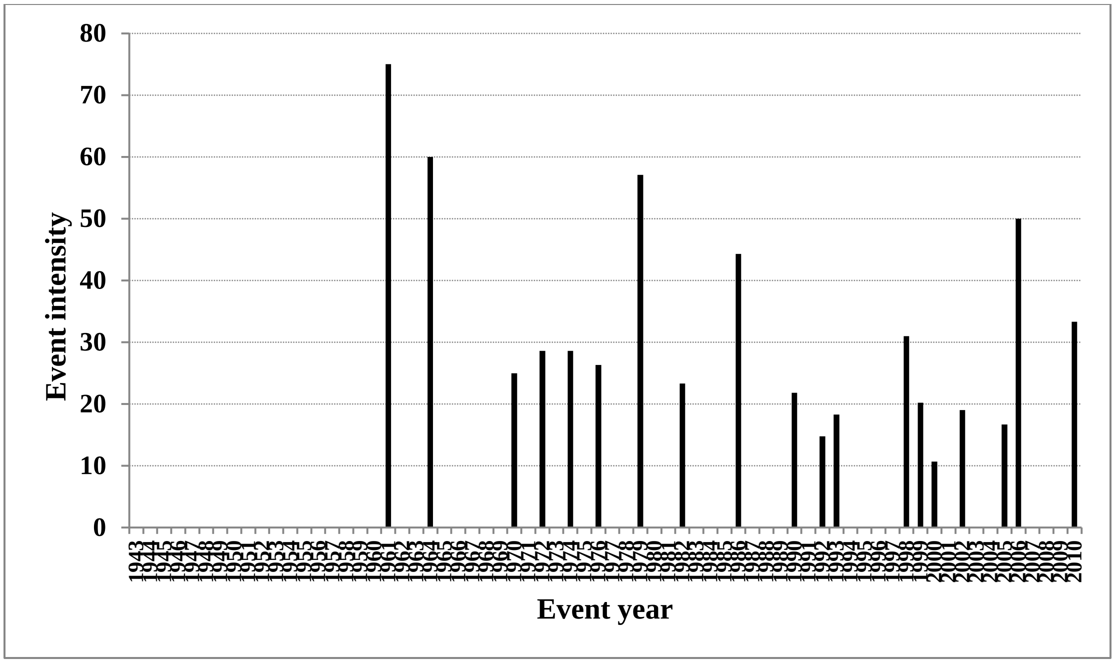

Fig 10 *The frequency of the dated events in terms of their intensity*

4.4. Spatio-temporal reconstruction of avalanche activity below Piatra Albă peak. A case study.

The study area is located in the northern part of Rodnei Mountains, on the left slope of the Buhăescu valley near its confluence with Repede river, under Piatra Albă peak. The affected area has about 14 ha and a slope inclination average of 32°.

Forest vegetation is mainly compound by conifers (*Picea abies*) at the top of the avalanche path and by conifers and deciduous trees in the track and runout zone. In the upper part of the couloir, there is an old hunting path, currently not used.

In total, a number of 75 trees (*Picea abies*) have been selected (fig. 11), and 152 samples taken (142 cores and 10 discs). By analyzing them it was possible to identify 21 avalanches that occurred between 1894 and 2010 (fig. 12).

The average age of the selected trees is 41.15 years, the oldest tree analyzed was shown to be 117 years old and the youngest one, 9 years old. At the top of the avalanche path, the trees are less than 40 years old, due to the high frequency of avalanches. On the other side, at the bottom the living trees are older, since the avalanche has a lower intensity when reaching this area.

The expansion of each event dated can be identified using the tree positions that were alive at that moment. In fig. 13, it can be observed the spatial reconstruction for avalanches that occurred in 1970, 1975, 1979 and 1990.

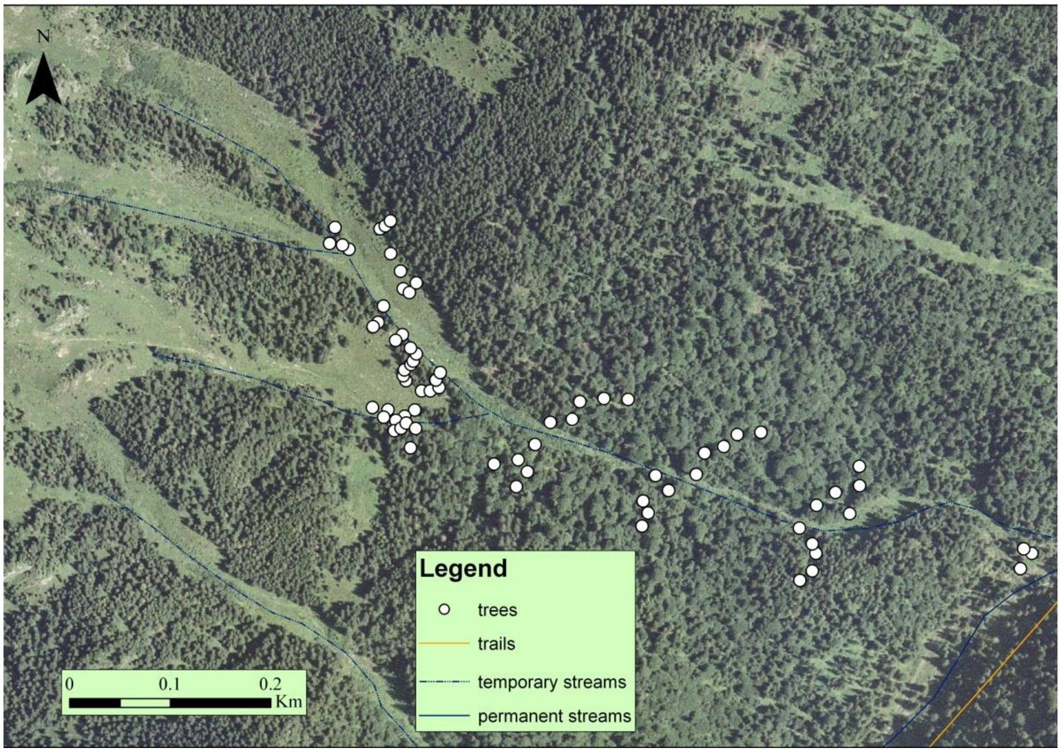

Fig. 11 *Location of the selected trees – Buhăescu Valley, Rodnei Mountains*

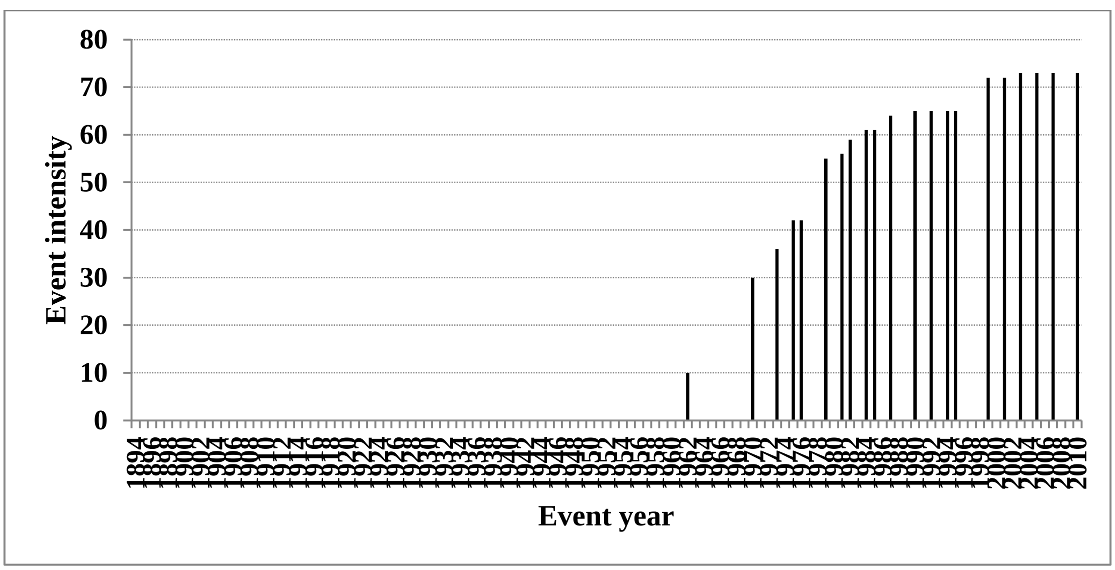

Fig 12 *The frequency of the dated events in terms of their intensity*

The return period (5,52 years) was calculated by dividing the observation total number of years (116) to the number of identified events (21). The probability of producing an avalanche in a year is 18.10 %.

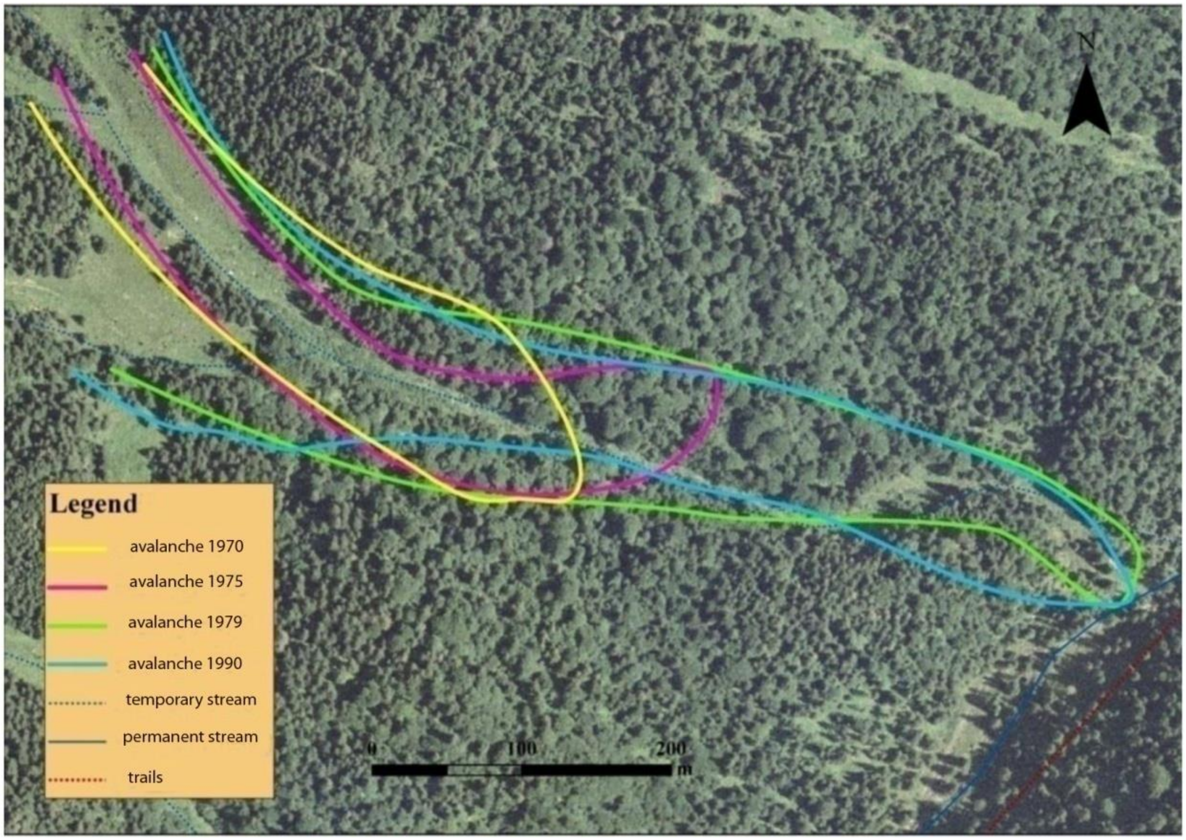

Fig. 13 *Spatial extention of avalanches next to Piatra Albă peak – Rodnei mountains*

Tabel 1 *Avalanche return period and probability of occurence in a year next to Piatra Albă peak*

No. of years	Avalanche no.	Return period (years)	Probability of occurence
116	21	5.52	18.10%

V. AVALANCHE SUSCEPTIBILITY MAPPING

For avalanche susceptibility mapping, different data and information related to avalanche frequency is used (Gruber, 2001). For a proper analysis, data about avalanches that occurred in the past are needed. For many mountains area in our country, including Rodnei Mountains, such information is not accurate and complete. In these cases, primary concepts of avalanche susceptibility mapping include the spatial distribution of responsible factors with the processes that cause snow instabilit. Strategies in this analysis must be made in order to understand the process and to predict the occurrence of new events and also to reduce the damages they produce.

The first step in creating and validating a susceptibility map is the creation of a spatial database for avalanches, which for this study was composed of two parts: one containing an inventory of avalanche starting zones and the other one that contains their topographic characteristics. A susceptibility map divides the slope in categories ranging from stable to unstable. It shows the locations where avalanches might occur.

A detailed study upon the topography was realized in order to determine the characteristics of starting zones. Avalanches can be encountered on slopes with different topographic characteristics, except the forested land where forest vegetation prevents the avalanche formation. Trees intercept direct or reflected solar radiation, controlling the air and snow temperature and the crowns of trees detain between 50% and 90% of the snowfall.

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.

All the resulted data were integrated in GIS (fig. 14), by using the bonitation method, so we were able to generate an avalanche susceptibility map. Because the starting zones are situated above tree limit we took into consideration only alpine and subalpine areas. In order to obtain relevant results, the values were divided into 3 classes of susceptibility: low, medium and high.

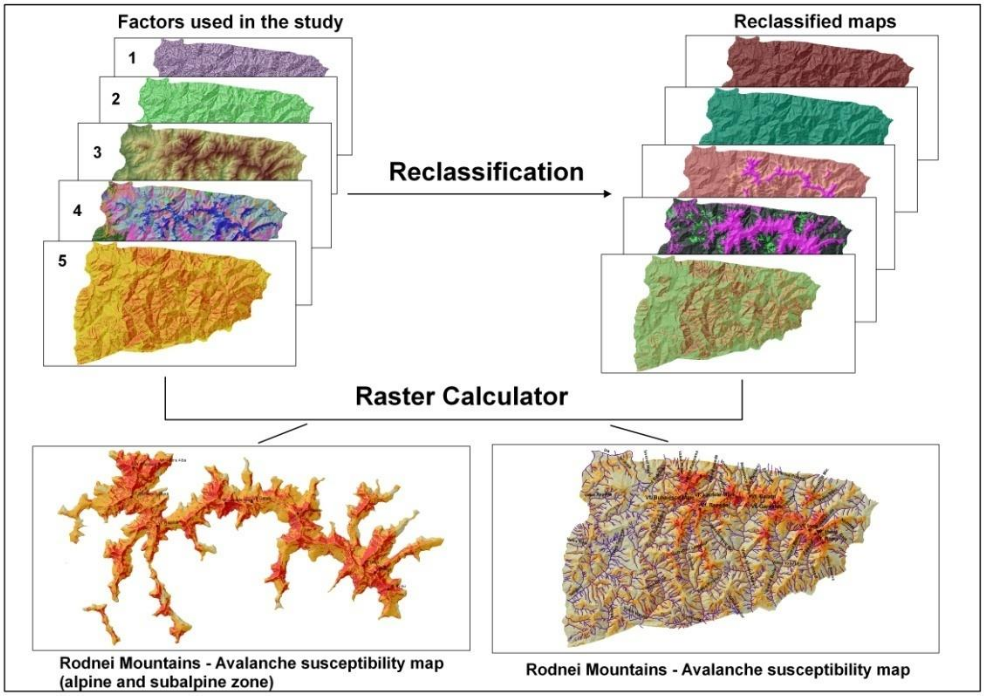

***Fig. 14** The methodology used in avalanche susceptibility mapping (1-plan slope curvature, 2-profile slope curvature, 3-elevation, 4-land use, 5-slope angle).*

From the total of aproximately 140 km², the results showed a high susceptibility to avalanches for 50,6 km², a medium one for 79,9 km² and a low one for 9,6 km². By analyzing the avalanche susceptibility map (fig. 15), 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.

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.

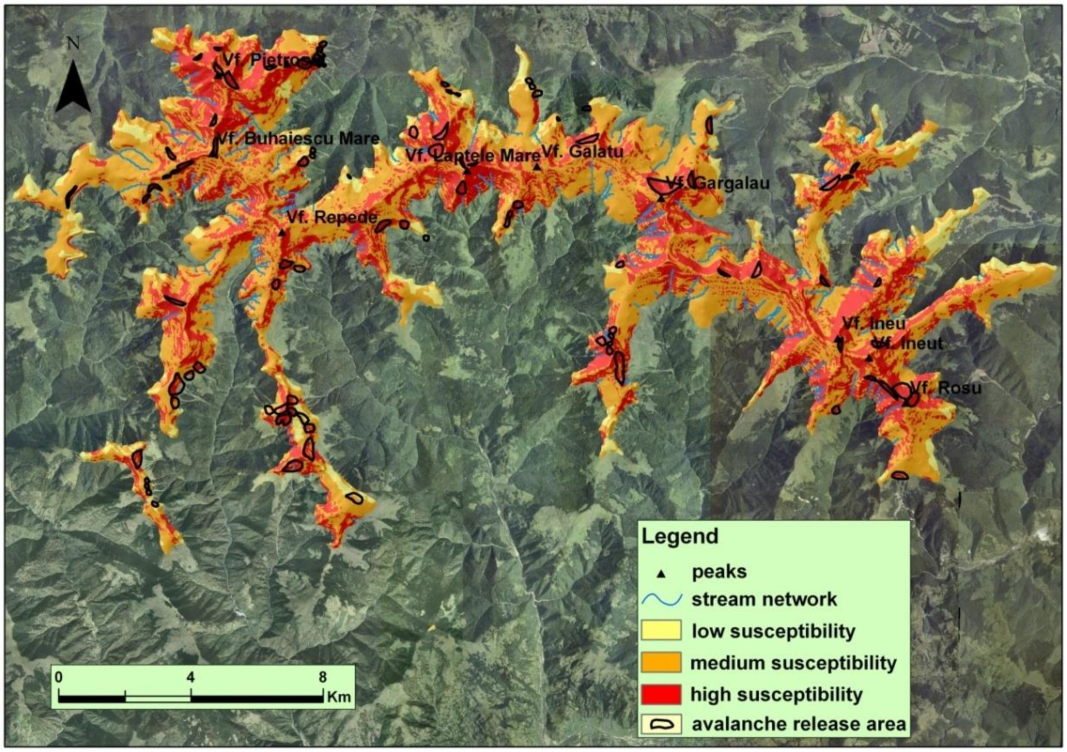

Fig. 15 *Rodnei Mountains – Avalanche susceptibility map*

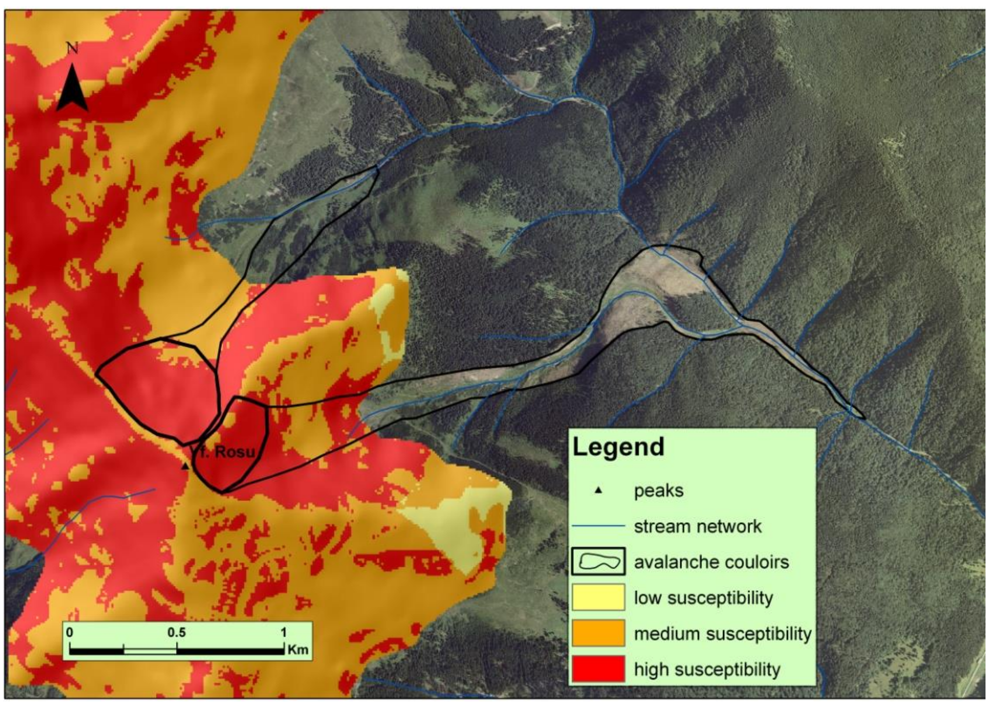

Fig. 16 *Avalanche couloirs and starting yones below Roşu peak*

Touristic trails during winter in Rodnei Mountains

Avalanche susceptibility map for Rodnei Mountains is useful, for a proper evaluation of the areas favorable to avalanche formation. This could be useful in winter time, especially because there is a high interest in tourism and in off-piste winter sports.

Generaly speaking, in Rodnei Mountains, areas requiring special attention are:

- Iezer - Pietrosul peak, where one must not follow the summer route, the most secure alternative being from Iezer meteorological station to Piatra Albă peak;
- the ridge between the peaks Buhăescu Mare, Buhăiescu Mic, Rebra, Cormaia, Repede, which in winter time must be followed by crossing the peaks;
- peaks Negoiasa Mare and Negoiasa Mică, which in winter can be crossed or one can pass on north side, going low enough to avoid area with high avalanche risk;
- peak Laptele Mare, which in wintertime must be climbed and not passed on touristic trail;

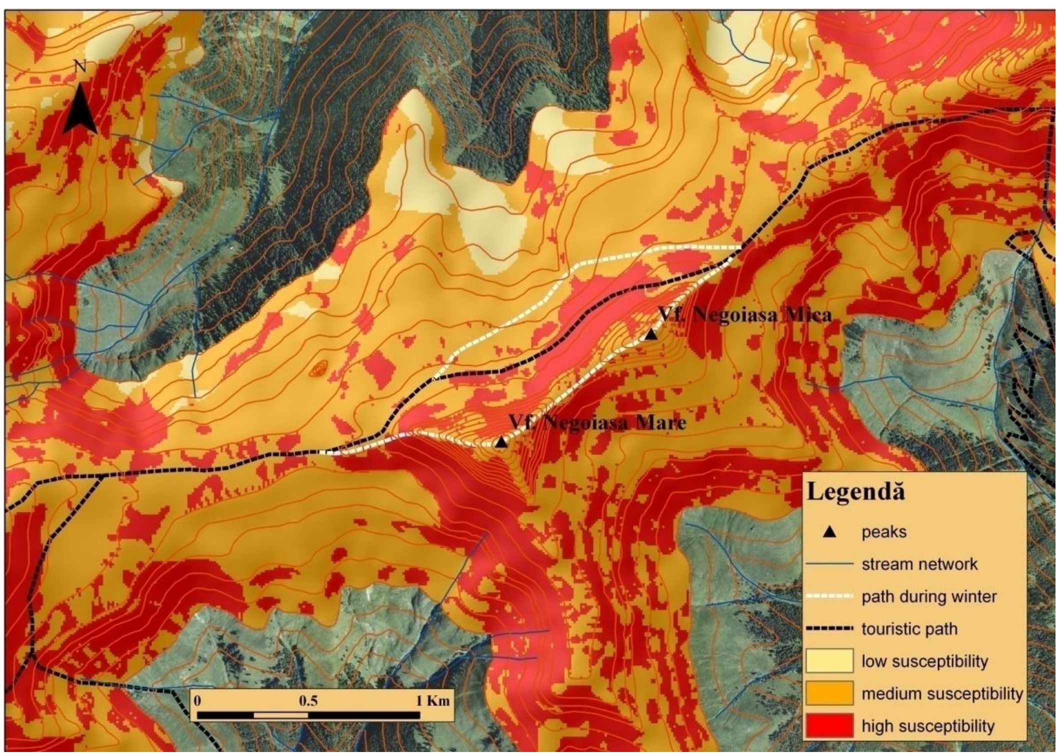

Fig. 17 *Alternative routes during winter between Negoiasa Mare peak and Negoiasa Mică peak, Rodnei Mountains*

In addition to these, there are situations when choosing a route must be made on the spot. In these cases, there are no general valid rules, but there are solutions we can use to organize information that we have and use them to make the proper choice (Tremper, 2008).

ALPRUT method is defined by McCammon, 2002 (quoted by Tremper, 2008) after he analized the avalanche impact upon victims, on north-american continent. He reached the conclusion that, over 93% of avalanches produced when 3 or more factors where present. In this way he created a question list, useful in case we need to chose a trail in winter time (tabel 2).

When the answer is affirmative to three or four questions, a decision requires caution. If five or more factors are present, a different route should be chosen or taken into consideration.

Tabel 2 *ALPRUT method (McCammon*, 2002 *quoted by Tremper, 2008)*

ALPRUT method
Has there been avalanches activity in the past 48 hours?
Has there been loading of new or wind-blown snow in the past 48 hours?
It is an obvious avalanche path?
Does the avalanche path terminate in a gully, trees, cliff or crevasses?
Is the avalanche hazard rated considerable or higher?
Did you notice collapsing or cracking of the snow?
Has there been a rapid or prolonged thaw of the snowpack?

A good decision is vital when hiking or practicing winter-sports in safe conditions in mountains areas. Through a proper organization of the available information, unpleasant situations can be avoided.

CONCLUSIONS

The subject of this research was chosen based on the fact that avalanches are a process frequently encountered but less studied in Rodnei Mountains. No other studies were made in the past having the purpose of study avalanches but only general geographical aspects.

The main objective of this study was to identify the areas affected by avalanches, to analyze their frequency and intensity and to create a susceptibility map to avalanches. This study is the result of numerous field campaigns that were very useful in understanding the avalanche formation, spread and evolution.

The morphology of this territory is the result of geology so the crystalline rocks that prevails, are mainly responsible for the massiveness of Rodnei Mountains which creates a proper environment for avalanche formation.

The climatic factors that characterize this area and also are generating the material that slides on slopes are: precipitations, snow layer, temperature, wind and solar radiation.

The biotic factors, more exactly the vegetation type and afforestation degree have an important role in generating and slowing down avalanches. In the last 31 years 187,6 ha of forest were destroyed by avalanches. The forest represents a great indicator that can provide information about avalanches through tree rings.

Morphology of river catchments situated above tree limit determines the creation of avalanche couloirs along them.

One of the avalanche generating factors is the man who through his activities represents a disturbing factor. By land clearing and shrub cutting there are created favorable conditions for avalanche formation.

Avalanche couloirs were identified using measurements gathered along numerous field campaigns, and also information extracted from orthophotos and forest administration documents. According to all of these, we were able to identify 47 avalanche couloirs that have track and runout zones situated below the upper limit of forest vegetation and affect approximately 980 ha. These are situated mainly in the alpine and subalpine zones of Rodnei Mountains.

For reconstructing past avalanche activity we used the dendrogeomorphology that made possible the analysis of spatio-temporal extension of dated events. We were able to identify 40 events that were produced starting to year 1894. All of these data together with the avalanche return period and probability of occurrence that were calculated are important in winter sports and tourism that are practiced in Rodnei Mountains.

Avalanche susceptibility mapping was performed for Rodnei Mountains because of a high natural and touristic potential of this area. By analyzing the avalanche susceptibility map, we can assert that 50.6 km² out of 140 km² are characterized by high slope susceptibility. These areas are situated on steep slopes close to the following peaks: Pietrosul, Puzdrele, Laptele Mare, Gărgălău, Roşu, etc

The method used for susceptibility mapping was validated by using a number of 98 starting zones. 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.

The avalanches in Rodnei Mountains have a complex formation and this research was useful in understanding it. The results of this study, mainly the spatio-temporal reconstruction of avalanche activity and the mapping of avalanche susceptibility can be used to save human lives and foresee damages.

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