Tree-ring dating of snow-avalanche history in Parâng Mountains (Southern Carpathians, Romania)

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INTRODUCTION

In high mountainous areas worldwide, snow avalanches (SAs) represent one of the main morphodynamic processes which influence the morphology of steep slopes. They usually disturb the forests and represent a significant natural hazard that may endanger the safety of tourists exposed along the hiking trails crossing the avalanche-prone slopes. In the context of the growing tourism activities in the area where tourist become exposed to snow-avalanche hazard, there is need for detailed analysis for documenting the past activity of this geomorphic process, especially in remote areas where historical data are lacking. Such mountainous area without snow-avalanche monitoring and archival records is in Parâng Mountains (Southern Carpathians, Romania). The aim of this study is to reconstruct the past snow-avalnche activity along an avalanche path (see location on Fig. 2.) and together with the previous studies to enrich the existing database created in our laboratory and to contribute to the snow-avalanche hazard assessment in Parâng Mountains.

STUDY AREA

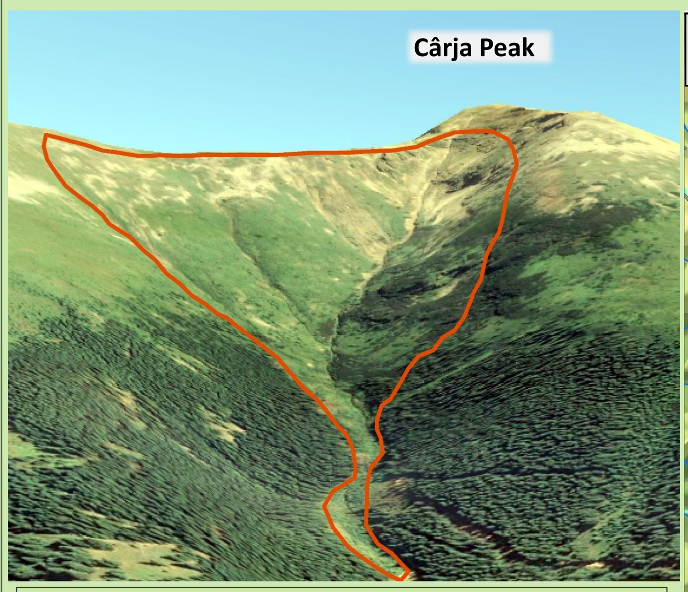

Fig. 1. Image of Cârja avalanche path (source: Google Earth)

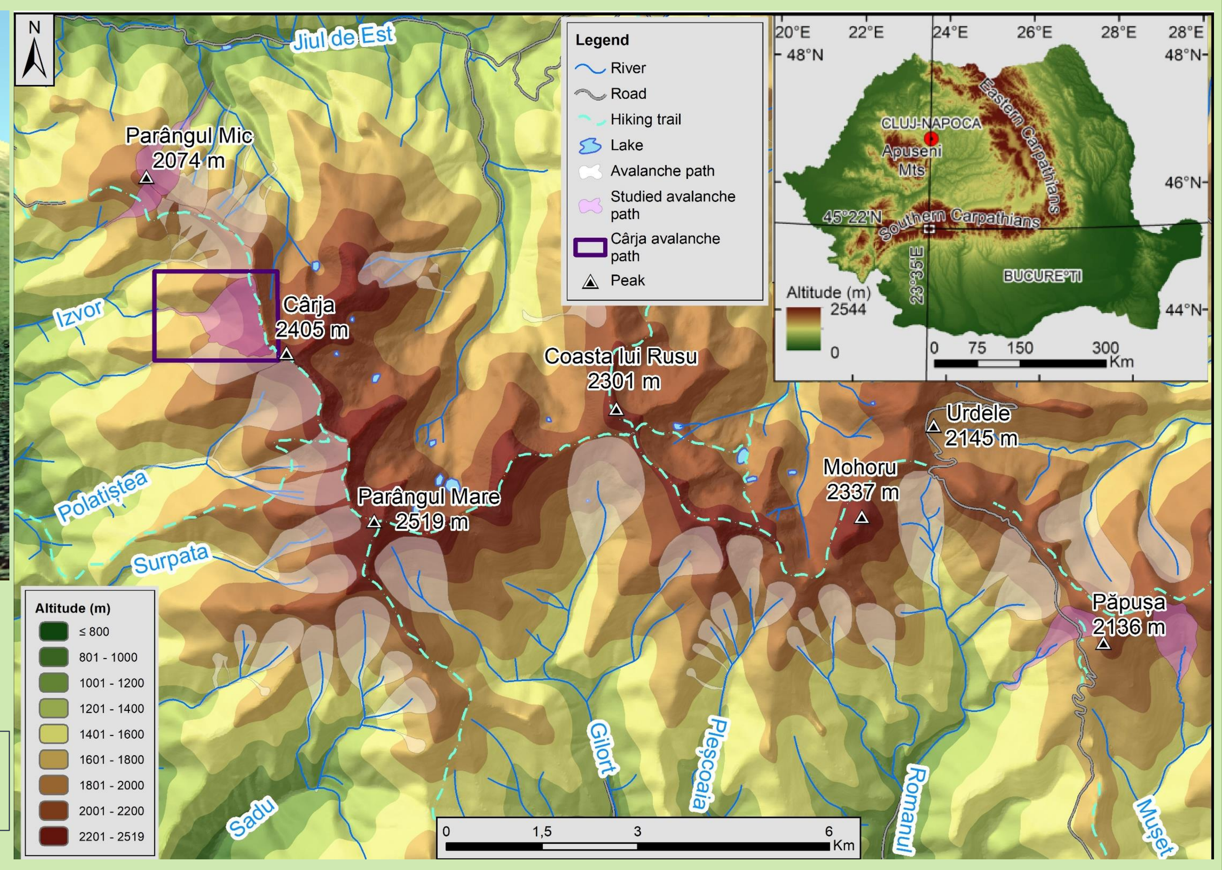

Fig. 2. Location of the investigated avalanche path

- In Parâng Mts. starting areas of SAs are mainly located above 2000 m, on steep slopes over 25°.
- Usually the starting areas are located on slopes southwest, south and south-east oriented due to the favourable topo-climatic conditions (high insolation, increased air temperature).
- Basing on tree-ring reconstruction of snow avalanche and the meteorological data provided by the Parâng meteorological station, Pop et. al. (2018) drawn the main conditions that cause the trigger of avalanches in this area: stormy winds in December, the diurnal variations of temperature in March and high quantity of precipitation in April.
- There is a ski resort in the north-western of Parâng Mts., close to Parângul Mic Peak, therefore tourism activity is frequent in this area during all seasons.
- The studied avalanche path is situated below Cârja Peak (2405 m) and it is crossed by two hiking trails (an official trail and an unofficial trail).

METHODOLOGY

Increment cores and discs collected from 57 disturbed spruce *(Picea abies (L.) Karst.)* have been analysed using standard dendrogeomorphological procedures. Growth disturbances e.g. scars, traumatic resin ducts (TRD), compression wood (CW) and growth suppression (GS) identified within tree-rings served to reconstruct SA activity.

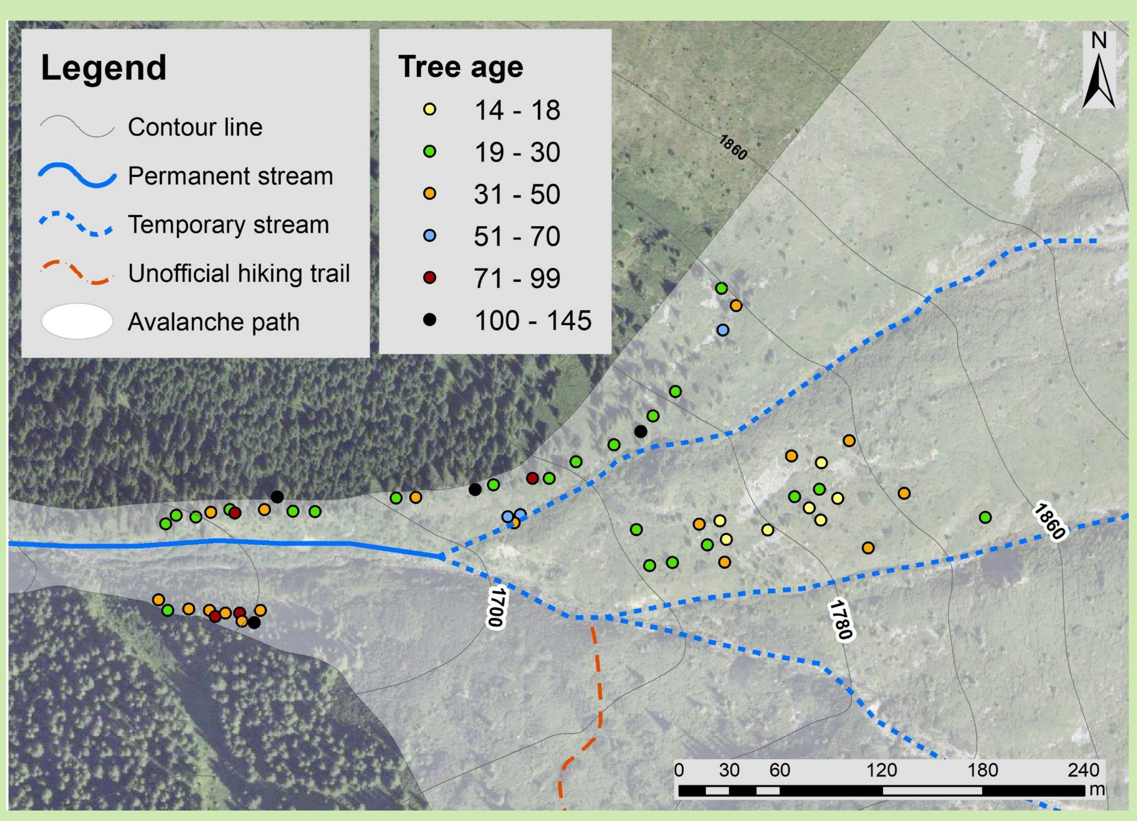

Fig. 3. Location and age of the sampled trees

Growth disturbances (GDs) by intensity classes as suggested by Stoffel & Corona (2014):

- **Intensity 5**: scars (SC), strong traumatic resin ducts (TRD)
- **Intensity 4**: moderate TRD, strong compression wood (CW), strong growth suppression (GS)
- **Intensity 3**: moderate CW and moderate GS

An **Avalanche Activity Index (AAI)** was calculated using the following formula :

AAI = (∑in= 1Rt / ∑in= 1At) ×100 (Shroder, 1978)

(R) - number of trees showing growth disturbances in the event year **(t)**;
(A) - total number of sampled trees alive in the year **(t)**.

Criteria for identifying SA events:
a) At least 10 trees alive available in a particular year, among them a minimum of 3 trees showing severe and modarate growth disturbances
b) An Avalanche Activity Index (AAI) value above 10%

The **Weighted index** (Kogelnig-Meyer et al., 2011) was used to compare the intensity of the avalanche events:

$$W_{it} = \left[\left(\sum_{i=1}^{n} T_5 \times 5\right) + \left(\sum_{i=1}^{n} T_4 \times 4\right) + \left(\sum_{i=1}^{n} T_3 \times 3\right)\right] \times \frac{\sum_{i=1}^{n} R_t}{\sum_{i=1}^{n} A_t}$$

Where ***T5*** is the number of trees with GD intensity 5, multiplied by a factor 5; ***T4*** is the number of trees with GD intensity 4, multiplied by a factor 4; ***T3*** is the number of trees with GD intensity 3, multiplied by a factor 3; ***R*** is the number of trees showing GDs in the year **(t)** and **A** is the total number of sampled trees alive in the year **(t)**.

Fig. 4. Trees disturbed by mechanincal impact of SAs: (a) Tilted tree, (b) Injured tree with open wound, (c) Decapitated tree

Fig. 5. Examples of tree-growth anomalies caused by mechanical impact of avalanches and considered for event reconstruction: (a) Traumatic rows of resin ducts (TRD), (b) Scars (SC), (c) Growth suppression (GS), and (d) Compression wood (CW)

RESULTS AND CONCLUSIONS

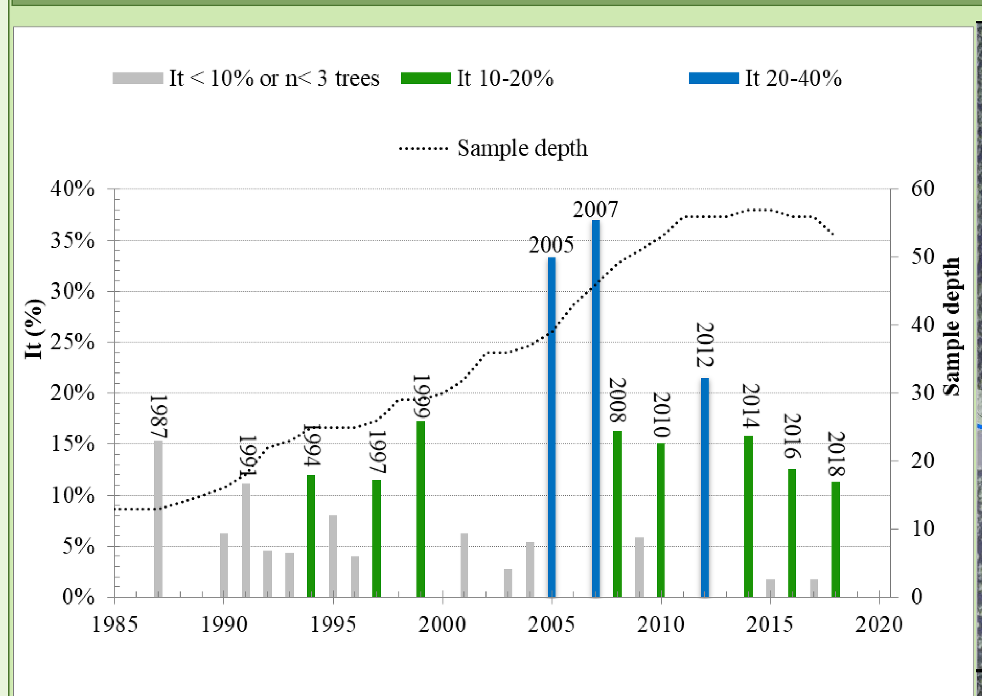

Fig. 6. Reconstructed SA event years

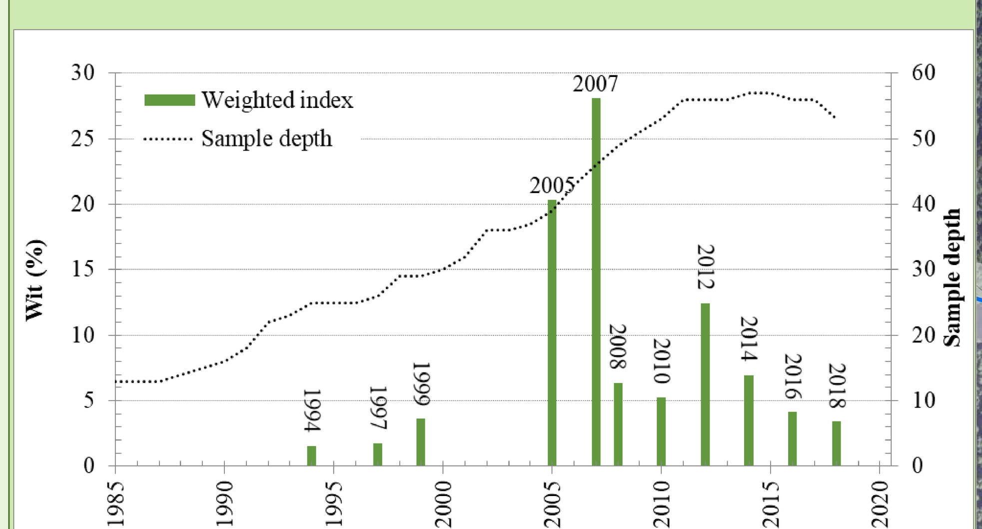

Fig. 7. Intensity of growth disturbances (weighted index) for SA reconstructed events

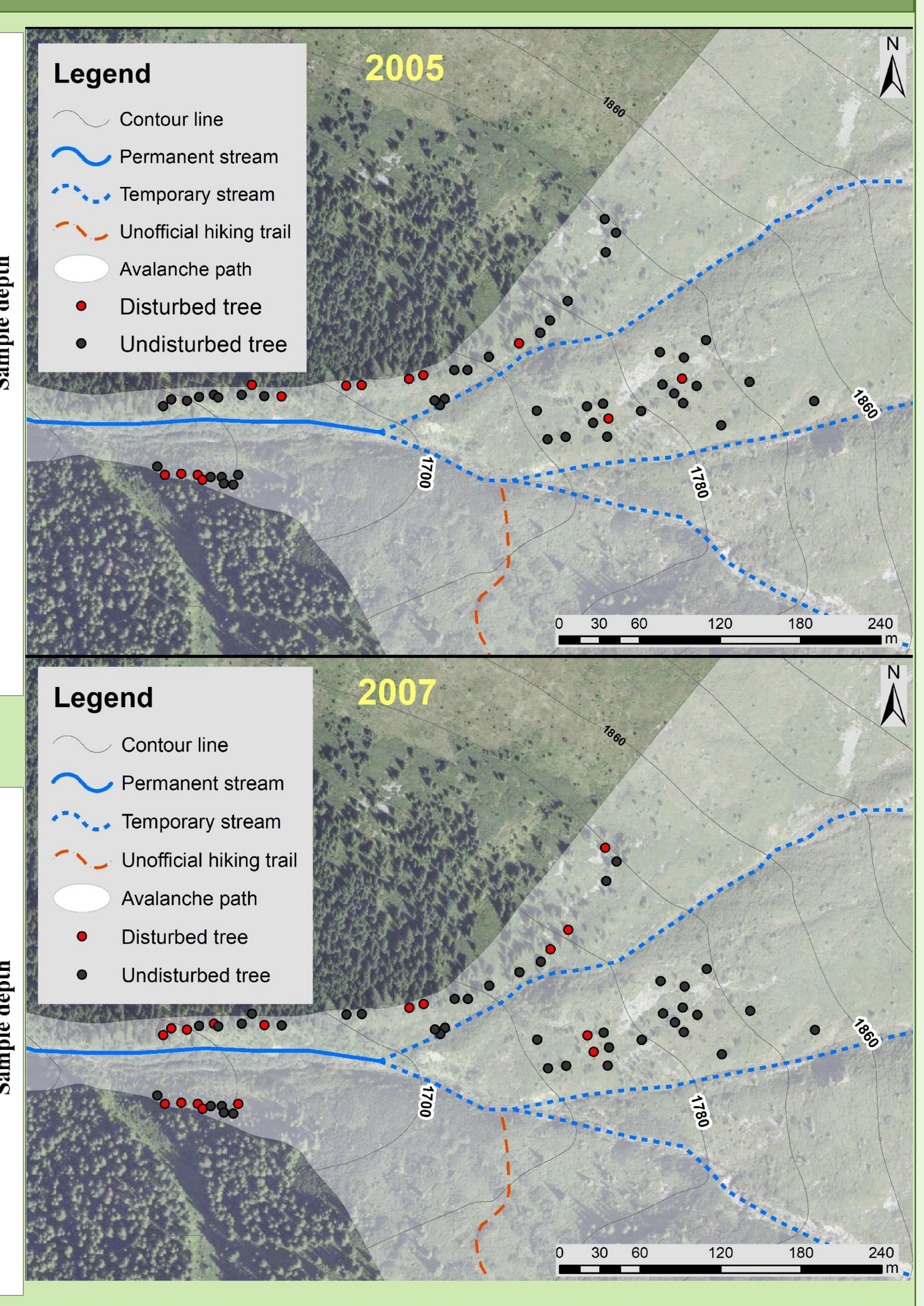

Fig. 8. Spatial distribution of affected trees for 2005 and 2007 reconstructed events

In this study, 11 SA events were reconstructed using dendrogeomorphological techniques. Because the majority of sampled trees reach less than 50 years, the reconstructed SA chronology is limited to the last few decades. There are many event years with less than 3 severe or moderate GDs and/or AAI< 10%, and for these reasons these event years can only be considered as possible snow-avalanche events. A larger sample collection which includes additional samples from trees distributed along the entire avalanche path would improve the results of the study by enlarging the snow-avalanche chronology.

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