USE OF TREE DAMAGE AND TREE-RING INFORMATION TO UNDERSTAND THE DYNAMICS AND IMPROVE THE CARTOGRAPHY OF CANAL DEL ROC ROIG AVALANCHE PATH (VALL DE NÚRIA)

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ABSTRACT

The map collection "Mapa de Zones d'Allaus" (MZA) (Avalanche Paths Map) 1:25.000 of the Institut Cartografic de Catalunya (ICC) has been made using different information sources: population inquiry, historical research, terrain features and vegetation checking. Other sources of information allow a higher resolution in the cartography, such as the detailed study of the effects on vegetation and tree-ring analysis. In a forested snow avalanche path, a dendrochronological analysis of the trees and other woody species can provide acurate data about frequency, maximum avalanche area, and also aproximate extension of single events. Canal del Roc Roig avalanche path is a lateral gully of Núria river which affects the Núria rack railway at Pla de Sallent site. In this path, a study based on the vegetation and on the morphology and damage of trees (Dept. de Geodinàmica i Geofísica of the Universitat de Barcelona and ICC)[1] and an extensive dendrochronological study of 470 trees have detected several avalanche episodes, some already known, but others not documented, such as the one that occurred in 1930 (ICC and the Dept. d'Ecologia of the Universitat de Barcelona)[2]. The cartography of Canal del Roc Roig avalanche path limits was improved after analysing all the data extracted from the trees affected by avalanches, and valuable information to assess frequency and magnitude of the avalanches that occur has been obtained.

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INTRODUCTION

The study of vegetation and the dendrogeomorphological analysis in forested areas can supply additional and valuable data to improve the cartography of avalanche paths. For land planning and management it is important to know the maximum extent of the largest avalanches and also the frequency and extent of single events. In their anual rings, trees and other woody plants reflect growing conditions and register the events they have undergone through life. Historical data about past avalanches are scarce, but trees old enough can show signals of past avalanche episodes and can be accurately dated. Frequently, forests growing at avalanche altitudes are protection forests, not exploited, so it is easy to find the oldest trees there.

Single avalanche episodes running along an avalanche path do not always follow the same trajectory. Snow cover characteristics, weather conditions and triggering causes may differ from one event to another and therefore the trajectory and extent can be different. In the “Mapa de Zones d’Allaus” (MZA) (Avalanche Paths Map) 1:25.000 (ICC, 2000) the encoded areas encircle the maximum extent that is known or interpreted for every path. The information comes from geomorphologic and slope measurements, recent avalanche events checked in the field and, population enquiries and historical documents which in the best cases, supply data for extraordinary events and define the maximum extent of the avalanche path. To find out the most probable maximum extent of avalanche paths in forested sites, specially where other information sources are missing, a detailed vegetation study followed by dendrochronological research can be very useful.

Trees growing at sites that can be affected by geomorphological processes, such as rock falls, land slides, debris flows and snow avalanches can register these events in their tree rings. The resulting external features can be detected at the field: tilted trees, injured trees with scars and cracks, broken stems and branches, and derived tree shapes: hockey-stick trees, horizontal trunks, candelabra-shaped and multistem trees (Schweingruber, 1996). These morphologies are related to tree ring anatomical features and they can be detected by magnification and dendrochronological analysis at the laboratory. Suspected and non-suspected past events can be assessed after field sampling and search for tree-ring signals and they can be accurately dated by dendrochronological methods (Cook and Kairiukstis, 1990; Holmes, 1983).

In this paper we present the results for Canal del Roc Roig avalanche path, encoded NUR127 in the MZA, located in Vall the Núria (Eastern Pyrenees) which affects the rack railway and the walking path to Núria tourist ressort. In winter 1995-1996 a large quantity of avalanches took place in the Pyrenees, being the most extense and intense avalanche crisis in recent times at this mountain range (García and others, 2000). At Pla de Sallent, Canal del Roc Roig avalanche path runout, the railway was damaged by two consecutive great avalanche events (on February 7-8th and on March 22nd). From the analysis of the vegetation and the wood samples taken from trees growing on this path, these and other past avalanche seasons were detected and mapped.

MATERIALS AND METHODS

Site forest. The forest surrounding Canal del Roc Roig avalanche path is composed of mountain pine (*Pinus uncinata*, Ramond) a subalpine conifer that grows at the highest altitudes in the Pyrenees (up to 2300-2500m a.s.l.). Nowadays, this forest grows from the runout at 1780m to nearly the starting zone at 2200m a.s.l., some scattered trees grow above this timberline. In the past, this forest was not so extended, most probably due to other land uses such as cattle pasture. The central channel is occupied by shrub (*Rhododendron ferrugineum* mainly) and grass communities.

Sampling dessigns. Two different studies were developed at Canal del Roc Roig avalanche path: vegetation study and dendrochronological analysis. The vegetation study consisted on the botanical characterisation of the plant communities (phytocenology) and the typification of the tree shapes (damaged and undisturbed). The dendrochronological study consisted on the analysis of wood samples taken from living and dead trees in search for past avalanche tree-ring signals and its dating.

For the phytocenological study, 10 square plots (measuring 10x10 m^2) were distributed along the altitudinal range of the gully. All the plant species were determined and quantified at each plot. The sampling strategy for the typification of tree shapes consisted on 8 profiles across the avalanche path (at 2185, 2130, 2075, 2000, 1875, 1825, 1800 and 1780 m a.s.l.). Information about tree shape and tree dimensions was registered for every tree in a 4 meter wide band along the transects (Molina, 2003) (Figure 1).

The dendrochronological sampling was also carried out in transects, but scattered trees showing external morphologies possibly related to past avalanches were sampled too. Along the starting zone and the track, 7 transects were established (at: 2165, 2075, 2050, 1980, 1925, 1845 and 1780 m a.s.l.). These crossed the open avalanche area and continued some meters into the forest at both ends. At the runout, 4 longitudinal transects (parallel to the avalanche trajectory) were established to detect possible past avalanche maximum distance (Figure 2). Along the transects, all the trees intercepted in a 2 meters wide band were inspected for external avalanche signals, and, in most cases, wood samples for dendrochronological analysis were taken. Data and samples from 470 trees were collected.

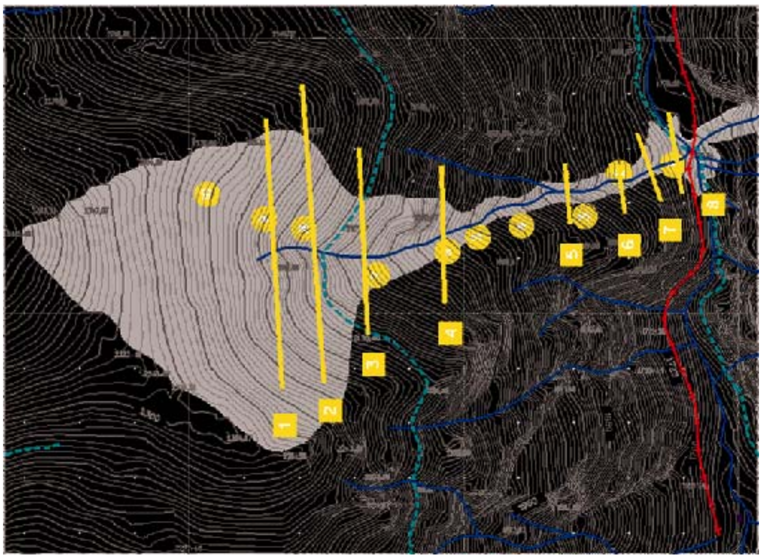

Figure 1. Sampling dessign of the vegetation study. The grey polygon encircles the hydrographical catchment of Canal del Roc Roig torrent. The yellow circles show the location of the 10 phytocenological square plots where all the plant species were determined and quantified.The yellow lines symbolize the 8 profiles across the avalanche path where all the trees in a 4 meters wide band were analysed (Molina, 2003).

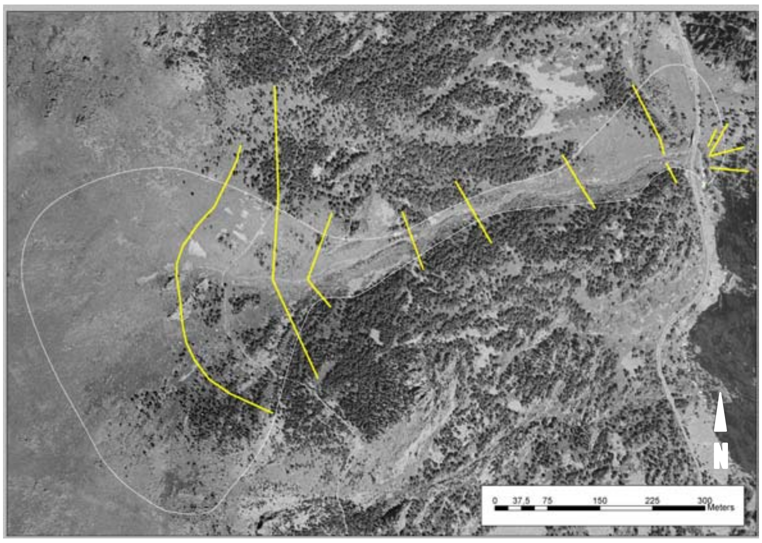

Figure 2. Sampling dessign of the dendrochronological study. The white line is the mapped avalanche path NUR127 as it appears in the MZA (ICC, 2000). Trees were sampled along 11 transects (yellow lines) across the avalanche path at different altitudes.

At Canal del Roc Roig, the dendrochronological study included several steps: establishment of a master chronology, identification of pointer years and search for anatomical disturbance signals in tree rings. The master chronology was built with samples from trees growing in the nearby forest. In this chronology tree rings with special features were identified as pointer years. For instance, the mountain pines at Canal del Roc Roig and close forest had some frequent pointer years: 1963 and 1972 present light rings (related to an early cold weather period during autumn); 1871, 1945, 1997 have frost rings (due to late frost episodes during spring) (Kaennel, 1995). The use of the master chronology and the pointer years is to serve as a reference and allow accurate dating of avalanche events on avalanche path trees. Avalanche disturbed trees present tree ring differences (signals) compared to the master chronology. These are detected through magnification, and dated by comparison to the master chronology. Different anatomical tree ring features include: reaction wood, callus tissue, abrupt growth changes and death of the tree (for further information see: Muntán and others, in press). From every sample, a list of tree ring signals related to the corresponding production year was composed (skeleton plot) (Stokes, 1968). Afterwards, a list with the event years for every tree was built. Those years that showed a comparatively much higher disturbance signal frequency were assigned to avalanche seasons.

Map making. Trees were mapped in the field on detailed orthophotomaps (1:5000 scale). We used the 1997 version, which was made one year after the last exceptional avalanche events in 1996. With some practice, most of the trees sampled could be identified on the orthophoto image. Trees were later mapped using Arc GIS on the georeferenced orthophotomap layer. Those that showed effects of different avalanche episodes were mapped in different views and the next step was drawing a polygon including these affected trees. This allowed to visualize the trajectories followed by the different avalanches and to recognise a minimum area with a high possibility of having been affected by a single avalanche episode. Eventually, the different views were analysed to obtain a unique map which displayed frequency areas affected by avalanches.

RESULTS AND DISCUSSION

As a result of the dendrochronological study, 5 avalanche seasons were detected: 1996, 1991, 1986, 1972 and 1930. The 1996 and 1972 events were already documented being the 1996 avalanches the largest recorded up to the present, but we had no information about the other possible avalanches. From the distribution of the mapped trees with dendrochronological signals in 1930, this avalanche episode might have been larger, its starting zone achieving a wider area than the ones in 1996. No old trees have been found at the runout zone which would have recorded the disturbance, although this could also be a signal that a big disturbance destroyed the forest there in 1930. In search for confirmation, historical documents were found which described the winter season of 1929-1930 as of high avalanche activity at Vall de Núria (Salmerón, 1987; Solà, 1952). Consequently, a first approach to the frequency of the largest avalanches known at Canal del Roc Roig can be ascertained at some 60-70 years of return period.

On the other hand, the results of the vegetation study arouse the suspicion that an adjacent area, not included in the avalanche path map NUR127, could be affected by avalanche phenomena too, near the starting zone at the hydrographical left hand side. A special vegetal community (*Hieracio-Festucetum airoidis* Br.-Bl. 1948) linked to long innivation periods growing between 2.300 and 2.400m a.s.l. suggested overaccumulation of snow at this point (plot number 10 in Fig. 1). Moereover, the tree shape study showed that there was a high concentration of disturbed trees below plot 10 at the 2180 m profile. After the dendrochronological study, these trees revealed abundant disturbation tree ring signals related to avalanche events (for further information see Molina and others, in press). Thus the mapped avalanche area could be enlarged at the starting zone.

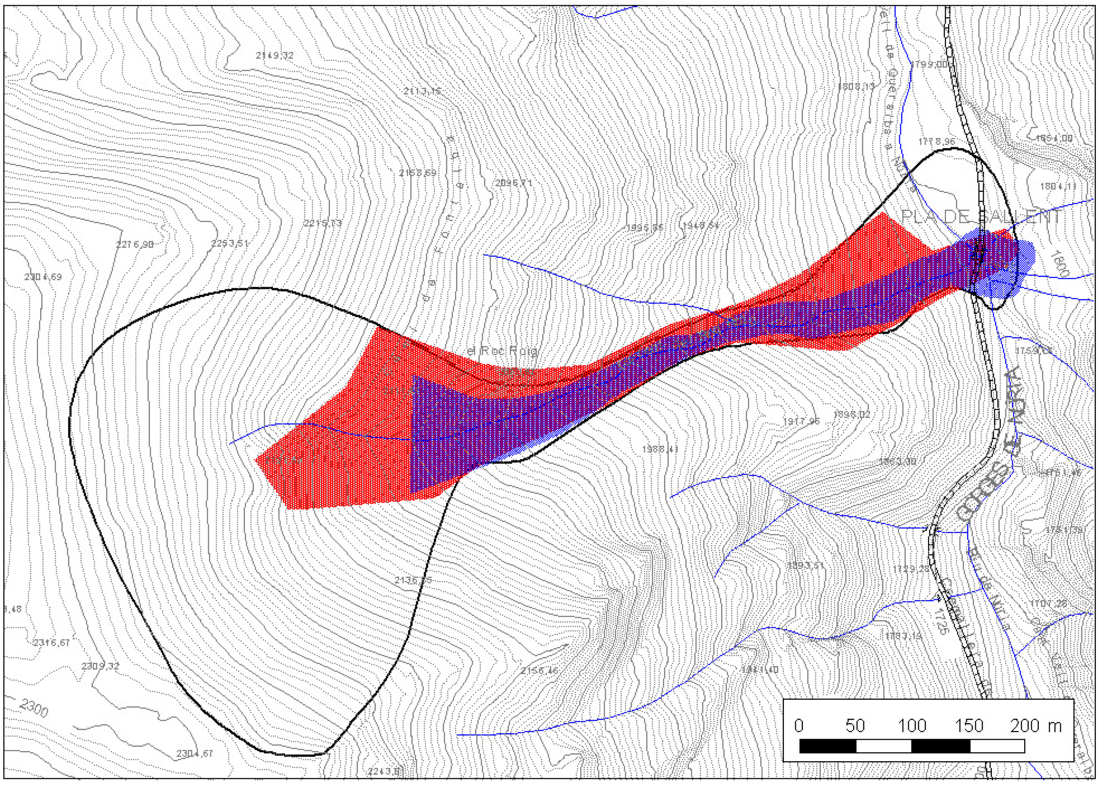

Figure 3. The 1996 avalanche events mapped through field observation (in blue) shortly after avalanche release during winter and, from the dendrochronological analysis (in red) of affected trees.

The trajectories followed by single avalanche episodes can be more accurately defined with dendrochronological data as it is shown in Figure 3. For instance, the mapped trajectory of February 8th, 1996 avalanche (in blue), cartographed shortly after the event, was improved with the dendrochronological results. At the starting zone, it was proved that the avalanche had been released at a higher altitude. On this particular occasion, we know it was a mixed avalanche (powder and flowing). Usually, when mapping a powder avalanche shortly after it has come down, it is not easy to recognise the limits of the avalanche deposit. The dendrochronological results of trees sampled at the track and runout confirmed that the avalanche effects had reached a wider area.

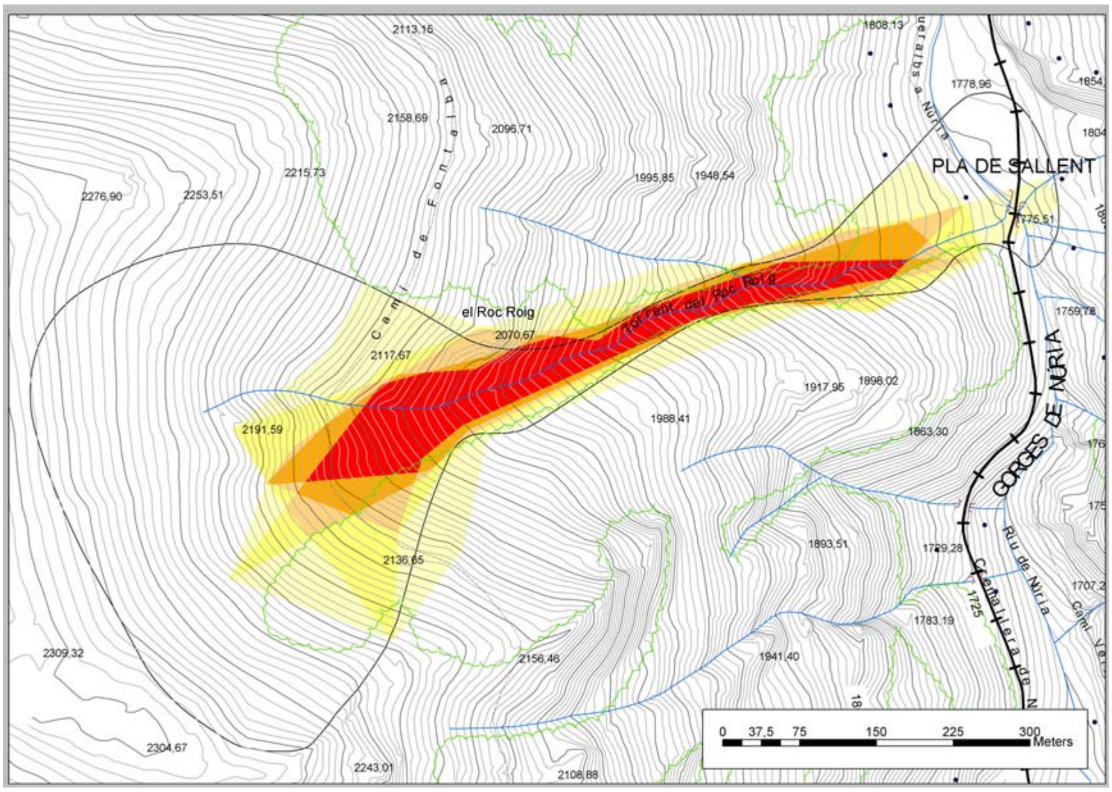

Figure 4. Avalanche frequency map obtained from the superposition of mapped trajectories of the 5 different avalanches found out after dendrochronological analysis. In red the highest avalanche frequency area. In yellow, the areas not so frequently affected by avalanches.

As it has been said above, the trajectories followed by the single avalanches are different from one another. When the mapped polygons of all the detected avalanches obtained from the dendrochronological analysis are put together a frequency map can be delivered (Figure 4). Obviously, the central canal is affected with the highest frequency of disturbances. The outstanding feature belongs to the areas affected by less frequent avalanches, which had not been detected by other means.

CONCLUSIONS

The determination of the maximum extent of avalanche damage is of great interest for land use and planning in alpine mountain regions. Dendrochronological analysis together with vegetation studies permit a better characterisation of frequency and extent in a given avalanche path. Both techniques are complementary to historical documents. Tree-ring data allow to reconstruct trajectories and widths along the track and so, magnitudes of the avalanches. By superposition of the different reconstructed avalanches it is possible to compare runouts, and therefore, to estimate avalanche frequencies. As a consequence, avalanche mapping can be improved. In addition, extent and return period are important inputs for avalanche dynamics modelling, which is an essential tool to predict avalanche behaviour and achieve a better understanding of the whole avalanche path dynamics.

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