SCHOOL OF DOCTORAL STUDIES IN ENVIRONMENTAL ENGINEERING - XVIII Cycle

Marco Bezzi

Integrated Analysis of Natural Hazards in Mountain Areas

Abstract of the doctoral thesis

Supervisor: **Prof. Maria Giulia Cantiani**

Snow avalanches and debris flows are significant recurrent natural hazards in many mountainous regions of the world. Every year avalanches and debris flows cause much loss-of-life and damage to infrastructures and buildings. Possibilities that avalanche and debris flow frequencies may recently have increased are still a matter of public debate. To investigate this hypothesis, proxy data of past avalanches and debris flows are needed. Unfortunately, such information is currently available for only a few sites, and even at these sites written records cover only a very limited time span. Proxy data of these land-forming events, particularly in remote regions where no records are available, would therefore be of considerable practical value.

Tree rings analysis has been shown to be a helpful tool for avalanche and debris flow dating. However, although previous studies have provided interesting results, there is a lack of methodological information on the best choice of tree ring indicators and the most appropriate statistical techniques to use when analysing trees injured by avalanches or debris flows. This research aims (i) to improve knowledge on growth-disturbance indicators for reconstruction of avalanche and debris flow frequencies and (ii) to investigate new approaches for data analysis. The possibility of dendro-geomorphological applications for landslide analysis in tropical environments is also considered.

This research was financed by the Italian National Institute for Mountain Research (IMONT). Study areas for debris flow and avalanche analysis were selected in Trentino Alto Adige (Italy) and, for landslide analysis, in the Cuzco region (Peru). Field data for the work on avalanche and debris flow events were collected from different subalpine sites in the Alps. Approximately 850 cores from different tree species were collected and approximately 60 000 tree-rings were examined for growth anomalies caused by these events, with anomalous indicators including compression wood, abrupt growth reductions and releases, traumatic resin ducts and scars. Data were statistically analysed to find the most reliable tree ring indicator for the frequency reconstruction of avalanche and debris flow phenomena. *Firstly*, the percent presence of each indicator was analysed. S*econdly*, a nonparametric statistical test was applied to the data set. And t*hirdly*, a new methodology was applied to the data to investigate fluctuations in the frequency of the phenomena, through comparison of different combinations of the selected indicators. The analysis of growth disturbances over time made possible the reconstruction of the frequency of avalanche and debris flow activity over the last 50 years and, in some areas, over the last century. A detailed analysis of one of the avalanche tracks provided interesting results as regards the reconstruction of avalanche dynamics and a mathematical model validation. Analysis of scars on buried stems of *Pinus Sylvestris* also provided interesting results in terms of debris-

flow-volume estimations. Concerning landslide analysis, tree rings were collected from the margins of the Hiram Bingham access road to Machu Picchu, Peru. Although no evidence of past landslides was provided from tree ring analysis, due to difficulties in finding species with reliable annual growth rings, *Alnus acuminata* revealed a potential for dendrochronological analysis at this latitude and altitude (13° S and 2000- 2500 m) and trunk-tilt analysis suggested areas most at risk from landslides. This research confirms the potential of dendrochronological reconstruction of past geomorphological events and demonstrates the technique's greater precision compared with other available methodologies currently applied.