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# Improving the flash flood frequency analysis applying dendrogeomorphological evidences

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Flash floods are one of the natural hazards that cause major damages worldwide. Especially in Mediterranean areas they provoke high economic losses every year. In mountain areas with high stream gradients, floods events are characterized by extremely high flow and debris transport rates.
Flash flood analysis in mountain areas presents specific scientific challenges. On one hand, there is a lack of information on precipitation and discharge due to a lack of spatially well distributed gauge stations with long records. On the other hand, gauge stations may not record correctly during extreme events when they are damaged or the discharge exceeds the recordable level. In this case, no systematic data allows improvement of the understanding of the spatial and temporal occurrence of the process. Since historic documentation is normally scarce or even completely missing in mountain areas, tree-ring analysis can provide an alternative approach.
Flash floods may influence trees in different ways: (1) tilting of the stem through the unilateral pressure of the flowing mass or individual boulders; (2) root exposure through erosion of the banks; (3) injuries and scars caused by boulders and wood transported in the flow; (4) decapitation of the stem and resulting candelabra growth through the severe impact of boulders; (5) stem burial through deposition of material. The trees react to these disturbances with specific growth changes such as abrupt change of the yearly increment and anatomical changes like reaction wood or callus tissue.
In this study, we sampled 90 cross sections and 265 increment cores of trees heavily affected by past flash floods in order to date past events and to reconstruct recurrence intervals in two torrent channels located in the Spanish Central System.

The first study site is located along the Pelayo River, a torrent in natural conditions. Based on the external disturbances of trees and their geomorphological position, 114 Pinus pinaster (Ait.) influenced by flash flood events were sampled using an increment borer. For each tree sampled, additional information were recorded including the geographical position (GPS measure), the geomorphological situation based on a detailed geomorphological map, the social position within neighbouring trees, a description of the external disturbances and information on tree diameter, tree height and the position of the cores extracted. 265 cores were collected.
In the laboratory, the 265 samples were analyzed using the standard methods: surface preparation, counting of tree rings as well as measuring of ring widths using a digital LINTAB positioning table and TSAP 4.6 software. Increment curves of the disturbed trees were then crossdated with a reference chronology in order to correct faulty tree-ring series derived from disturbed samples and to determine initiation of abrupt growth suppression or release. The age of the trees in this field site is between 50 and 100 years old. In the field most of the trees were tilted (93 %) and showed exposed roots (64 %). In the laboratory, growth suppressions were detected in 165 samples. Based on the number of trees showing disturbances, the intensity of the disturbance and the spatial distribution of the trees in the field, seven well represented events were dated for the last 50 years: 2005, 2000, 1996, 1976, 1973, 1966 and 1963.

The second field site was a reach of 2 km length along the Arenal River, where the stream is channelized. Here stumps from previously felled trees could be analyzed directly in the field. 100 Alnus glutinosa (L.) Gaertn. and Fraxinus angustifolia (Vahl.) cross sections were investigated in order to date internal wounds. Different carpenter tools, sanding paper and magnifying glasses were used to count tree rings and to date the wounds in the

field. In addition to the dating in the field, 22 cross sections were sampled and analyzed in the laboratory using the standard methods.
The age of the trees ranges between 30 and 50 years. Based on the injuries dated in the field and in the laboratory, and based on the location of the trees, 8 main events were dated for the last 30 years: 2005, 2003, 2000, 1998, 1997, 1995, 1993 and 1978.

Additional results are in progress, such as the amount of rainfall responsible for the triggering of the events, estimation of the magnitude, and the influence of the channelization in the case of the Arenal River.
The strength of Dendrogeomorphology in flood analysis has been demonstrated, especially in areas where the lack of historical documents, rainfall and flow data limits the use of traditional methods.