Quantification of energy absorption capacity of trees in combination with rockfall trajectory analysis using numerical simulations.

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To fully understand the protection effect of the forest, the single tree behaviour must be accurately known. However, trees are complex biomechanical systems especially regarding their interactions with rock boulders. A single tree dissipates energy during a rock impact in several different ways: rotation and translation of the root system, deformation and oscillation of the tree stem and local penetration of the rock at the impact location (Foetzki et al. 2004; Brauner et al. 2005; Dorren & Berger 2005). The main objectives of this work are therefore to assess and predict the protection capacity of a forest stand against rockfalls using the simulated behaviour of a single tree. A Finite Element model usable for practitioners was developed that can be used to predict the rock-tree interaction during a rock impact for a Norway spruce (Picea abies (L.) Karst.) tree.

Important phenomena observed in the field are taken into account to implement a realistic numerical model of the rock-tree impact. For example, the rotation and translation of the root-soil system, the penetration of the rock into the tree stem and the failure of the wood material in the impact zone (Figure 1).

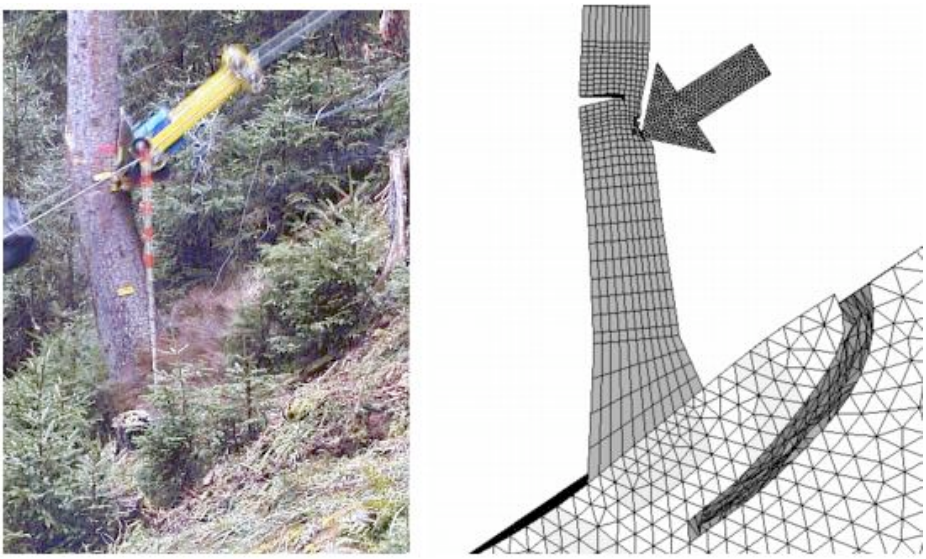

Figure 1: Representation of the full-scale impact tests and the numerical singletree model. The picture from the video camera (left) shows the deformation after t~50 ms and the one obtained from the numerical simulation (right) the deformations after t=40 ms.

To calibrate and validate the numerical model well controlled full-scale impact tests were done, giving accurate boundary conditions for the rock such as impact velocity, impact mass and impact angle (Figure 1). These tests were performed with an energy that is lower than the required energy for a rock to cut through the tree stem. Full-scale rockfall experiments performed on a natural slope were therefore used to validate the energy absorption capacity for higher energy levels(Dorren and Berger 2005). Comparing the simulated behaviour of a single tree, with the observed behaviour in nature, we concluded that the numerical model could be used to predict the energy absorption capacity of a single tree. Performing parameter studies using the numerical model and assuming that the tree was impacted by a spherical rock, it was possible to predict the maximum energy absorption capacity Emax of a single tree as a function of diameter at breast height and impact height, eccentricity and impact angle. Solely using DBH to define Emax, as earlier proposed, is not sufficient because its value depends upon all the above-mentioned factors. Simulating a hollow tree, symbolizing the damage in the tree stem, it is concluded that a damaged tree has a large protection effect against a falling rock. A significant decrease in Emax was seen first when 50% of the diameter was removed.

With the results obtained from the numerical model, an increased understanding of the rock-tree interaction is obtained. The four regression models, relating E_{max} to DBH and the position of the flying rock can be used to model the forest protection function in a very realistic way. Implementing these data into a rockfall trajectory code, which can consider different forest management decisions and the forest growth, the long-term protection function of a forest stand can be studied. With such a combined simulation tool, the possibility exists to study different forest management strategies for a certain forest stand and thus, obtain the most optimal forest protection to a minimized cost. Furthermore, the suggested tool also enables the practitioners to determine when a certain management strategy starts to have a positive or a negative influence on the protection effect. Thus, also the optimal timing for a certain management can be computed.

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