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Forest-avalanche feedbacks under environmental changes in the Swiss Alps

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Snow avalanches, one of the main disturbance factors in Swiss Alps, strongly influence forest dynamics at treelines. At the same time, forests may also locally influence avalanche release probabilities, leading to feedback effects between forests and avalanches. The influence of forests on avalanches is strongest in avalanche release zones, while forests cannot significantly reduce the destructive power of large avalanche events in their flow zones.

Anthropogenic and climatic changes influence not only forest dynamics, but also avalanche release probabilities, both directly via changes in snow and weather properties, and indirectly via changes in the forest and its abilities in preventing avalanche release events. These feedback loops make it difficult to predict how protection forests should be managed in the future. Our goal is to investigate the strength and direction of the feedback effects between avalanche release and forest development, the influence of anthropogenic and climatic changes, and the potential consequences for future land management.

We used the forest-landscape model TreeMig (Lischke et al. 2006), merged with a new avalanche model, to simulate forest and avalanche dynamics in future centuries. The new avalanche model consists of two components, a probabilistic submodel calculating potential avalanche release areas, based on historical avalanche data (Schneebeli et al. 1992), and a flow submodel derived from results of the avalanche flow model RAMMS (Christen and Meyer-Grass 2008). For the avalanche release probability inside forests, the merged forest-avalanche model applies variables commonly used to predict avalanche release outside of forests, namely topography, climate, and snow conditions. Additionally, our model includes crown coverage, stand structure, and gap size, as measures of snow throughfall and snow layer homogeneity. This allows us to assess the impact of forests on avalanche release and to simulate future avalanche events dependent on forest dynamics.

Results of a sensitivity analysis show that feedback effects between forests and avalanches are strong, but depend on local slope steepness and climate. Slope steepness influences the avalanche release probability, while climatic conditions determine how long a forest takes to regain its protective status. The strength of the influence of protection forests on avalanches depends on the forest structure and local conditions such as topography and climate. The influences of disturbances on forests could be both negative, such as increased gap sizes, but also positive, such as increased structural and species diversity. Human land use such as low intensity timber harvesting may reduce avalanche release probability locally in less steep slopes due to increased structural diversity in the forest. In steep areas however, timber harvesting increases avalanche release probability, especially where gaps are created. Abandonment of alpine pastures, which is increasingly common in Swiss Alps, may therefore have both positive (increased forest area) and negative (decreased structural diversity in protection forests) effects on forest-avalanche feedbacks.

Environmental changes will influence the strength and direction of feedback effects differently in different topographic and climatic conditions. We discuss the quantification of the effects of protection forests, their influences on feedback strength, and their potential consequences for future land management planning.

Literature

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