EGU2020-8922, updated on 05 Jan 2021
https://doi.org/10.5194/egusphere-egu2020-8922
EGU General Assembly 2020

Potential avalanche release in windthrow areas: the effect of snow height and terrain roughness

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Windthrow is an important disturbance agent in forest ecosystems and is expected to become more frequent and severe under climate change. Windthrow creates large amounts of surface roughness from downed trees, root plates and stumps. In mountain forests, these elements increase the surface roughness and provide a considerable protective effect against snow avalanches during the first years following a disturbance event. However, if large volumes of snow covers the surface roughness elements, a windthrow area may become prone to avalanche release. Snow accumulation produces terrain smoothing, which is an important factor in avalanche formation.

To assess the effect of snow accumulation on surface roughness in windthrow areas, we quantified terrain smoothing using a vector ruggedness measure and corresponding snow heights, based on digital surface models from summer and winter terrain produced from repetitive UAV flights. Additionally, the snowpack structure was examined using a digital snow micro penetrometer (SMP) to quantify the heterogeneity of snow stratigraphy and to monitor a possible development of weak snow layers over distances greater than 10-20 m, which may contribute to slab avalanche formation. Four study plots were selected to characterize different conditions: i) undisturbed forest, windthrow area with ii) high and iii) low surface roughness, and iv) an open meadow control plot. We then quantified how surface roughness is smoothed depending on the snow height, and at the same time characterized the snowpack structure and the extent of potential weak layers.

We found that increasing snow height leads to decreasing surface roughness, which can produce local release areas. We expect that with continuous increase of snow height, these release areas expand in size; however, further analyses of the snowpack structure will provide deeper insights in potential weak layer formation. Critical conditions for avalanche releases in windthrow areas may thus be defined based on scenarios for snow height and close-range sensing-based roughness data.