Assessment of protective effect of wind-disturbed forest against snow avalanches

BFW AUSTRIAN RESEARCH CENTRE FOR FORESTS

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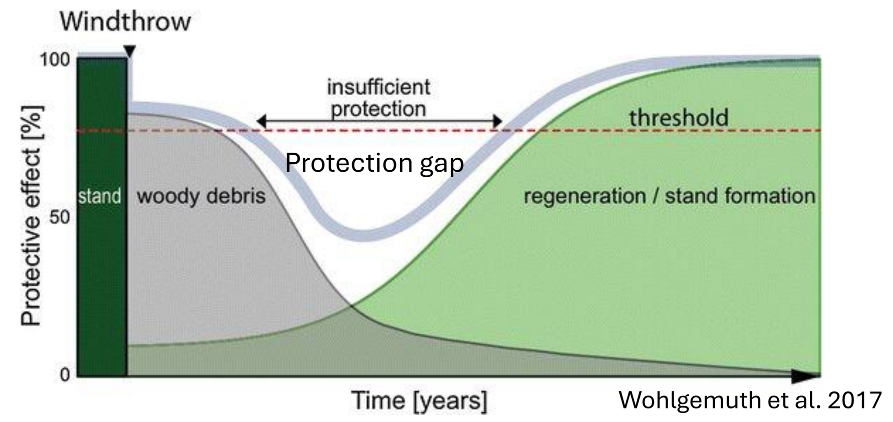
Introduction

- Mountain forests are crucial for snow avalanche protection
- Windthrow is the main disturbance in protective forests with increasing frequency and severity due to climate change
- Studies show that wind-disturbed forests can still provide high protection due to their roughness, but it decreases due to decomposition processes

- **Key facts from storm Vaia (WLV 2020):**
  - In Austria 4300 ha (43 km^2) and in Italy around 40.000 ha (400 km^2) of the mountain forest were damaged
  - 61% of the disturbed area in Tyrol (Austria) was protective forest

- **Clearing led to high costs and the temporarily loss of the protective effect**
- **Installing technical protection measures was often required**
- **Swiss guidelines recommend leaving deadwood in protective forests as long as the effective deadwood height is not exceeded by more than 1 meter during a 30-year snow depth event.**

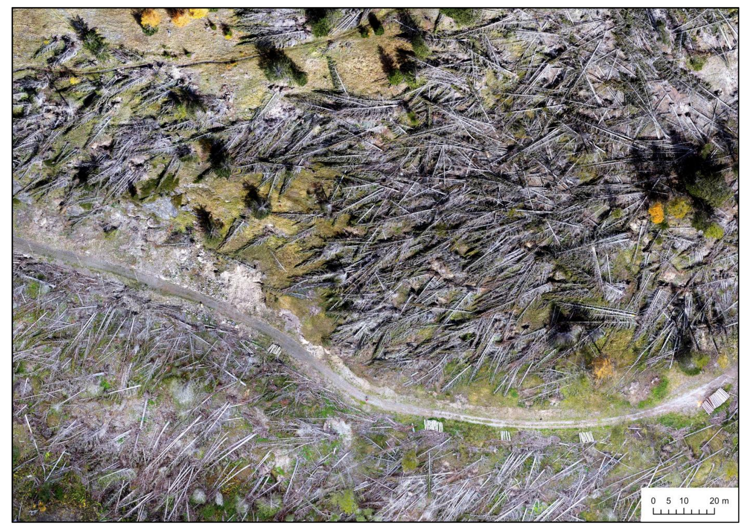
But: How to assess the effective deadwood height in such an area?



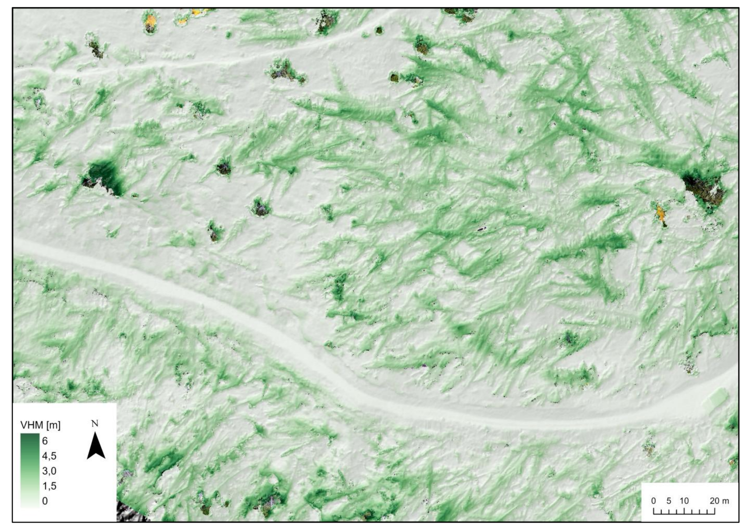
- **An objective, easy-to-apply framework for assessing the protective effect of wind-disturbed forest is needed**

Methods

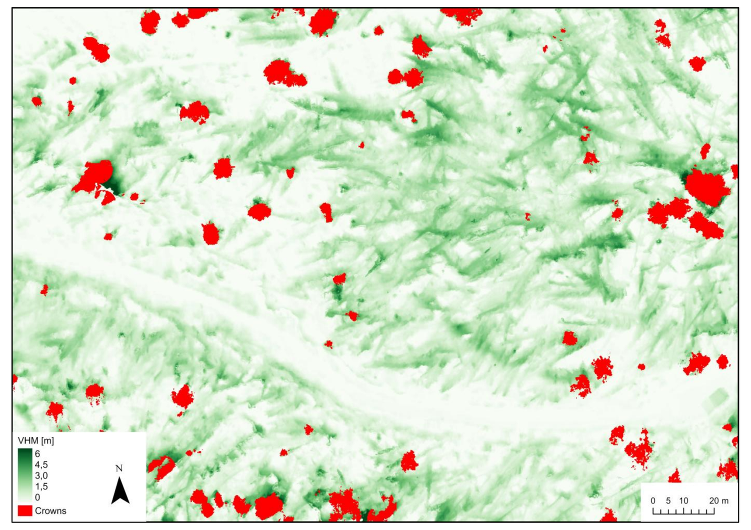
1. Conducting high-resolution photogrammetric surveys with low-cost (<€5,000) drones during snow-free conditions



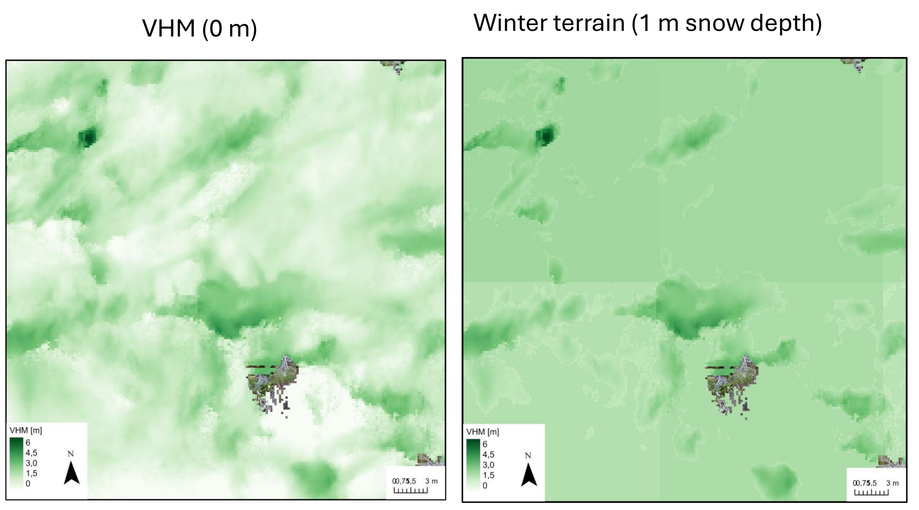
2. Processing drone images into point cloud and deriving a Vegetation Height Model (VHM) (drone-DSM minus ALS-DTM) representing remaining standing trees and deadwood



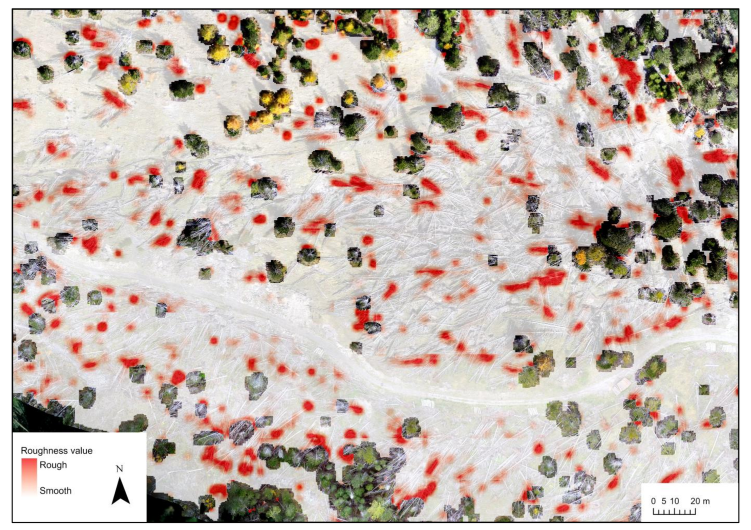
3. Automatic detection and masking of remaining standing trees and their crowns



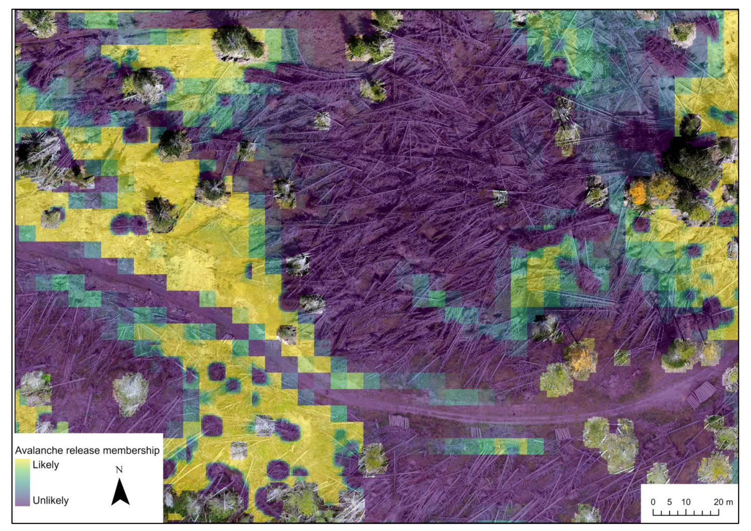
4. Modeling of the winter terrain by assigning increasing snow depths
- Snow accumulating on protruding logs is progressively redistributed into the gaps between fallen logs, resulting in an increasingly smoothed terrain surface.



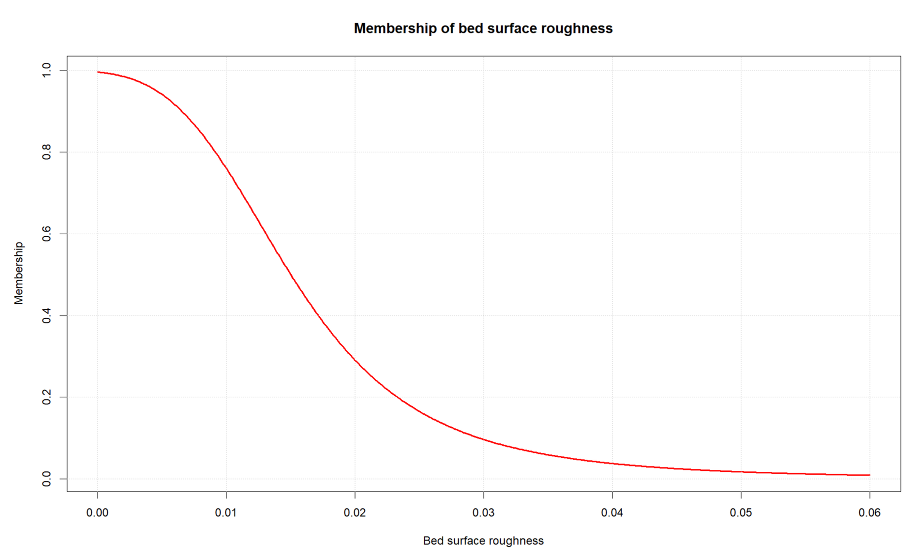
5. Calculation of winter terrain bed surface roughness using Vector Ruggedness Measure 7x7 algorithm (Sappington et al., 2007)

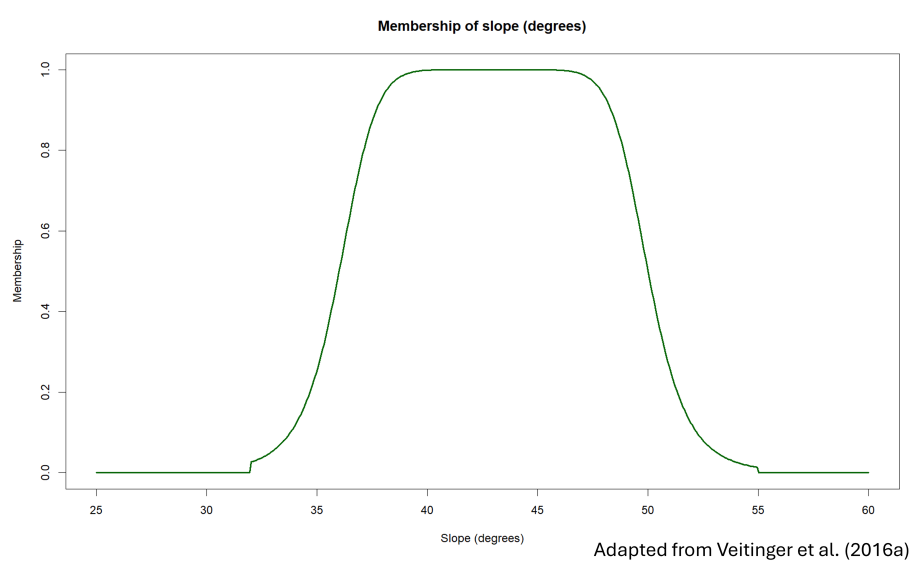


6. Determination of avalanche release membership for different snow depths using fuzzy logic modelling intersecting
- Membership of bed surface roughness (0.5 m resolution)
- Membership of slope (5 m resolution)



- Membership functions for slope and bed surface roughness were based on Veitinger et al. (2016).
- The lower minimum threshold of the slope membership function for avalanche release was adjusted from 27° to 32° steepness.
- The bed surface roughness membership function was adapted from the snow surface roughness membership function, based on measured bed surface roughness values as presented in Veitinger et al. (2016b).

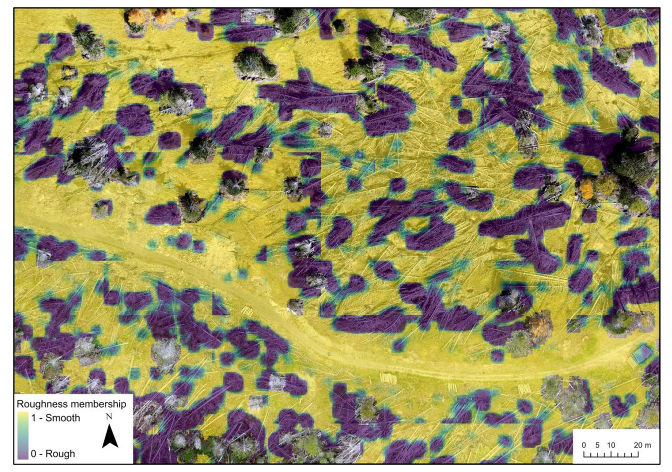


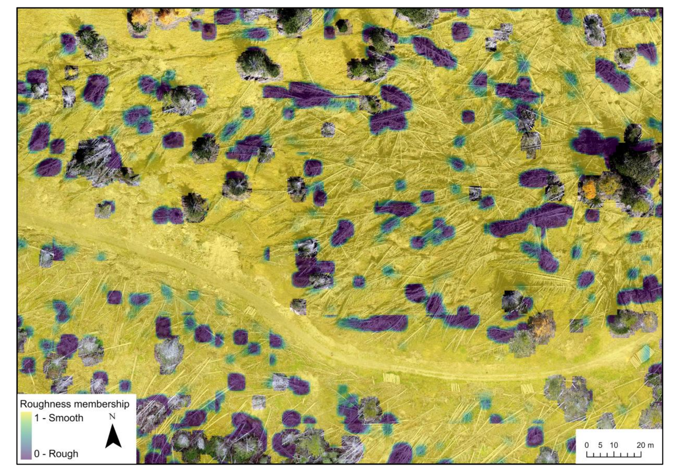


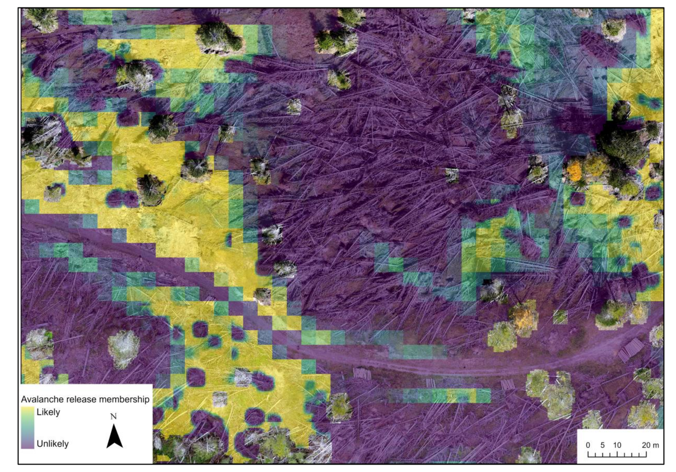
Adapted from Veitinger et al. (2016a)

Results

Case study Franza (Veneto) 2019 - 1 year after the windthrow event
- Initial forest structure was heterogeneous, featuring a mix of dense spruce-dominated forest





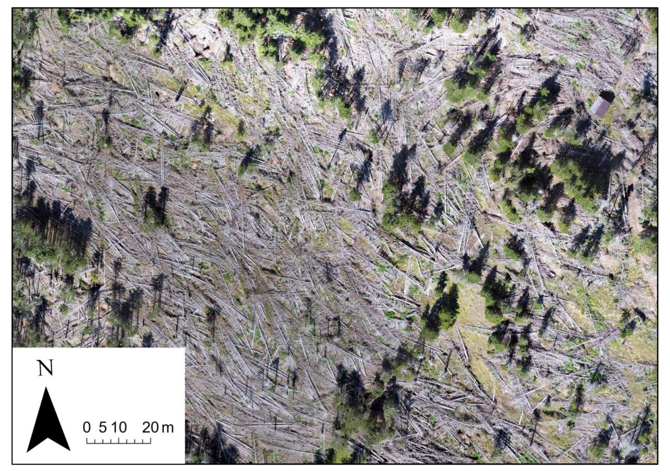


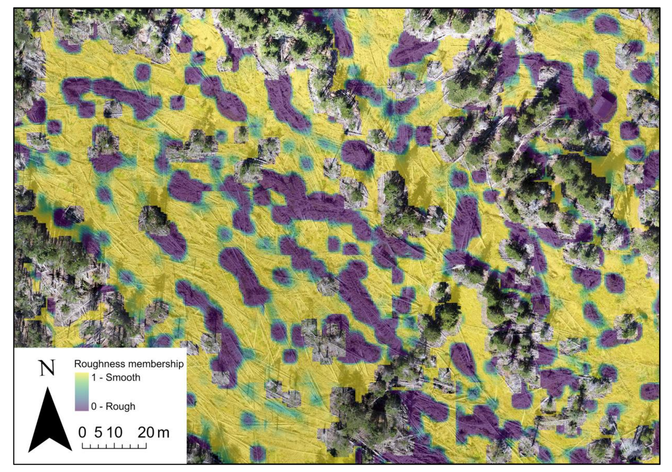
Orthophoto

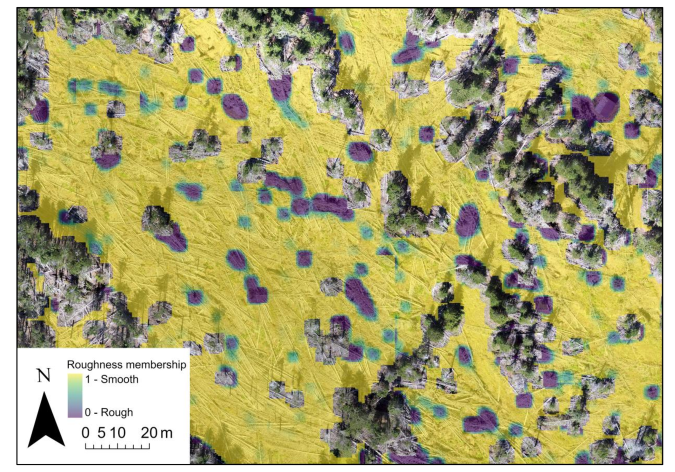
Bed surface roughness membership with 1 m snow (2y return period, 30y return period with 1m additional snowpack)

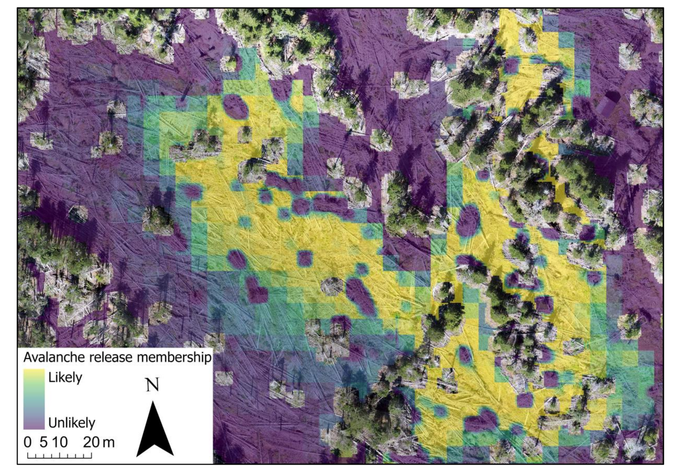
Bed surface roughness membership with 1.5 m snow (10y return period, 70y return period with 1m additional snowpack)

Avalanche release membership with 1.5 m snow





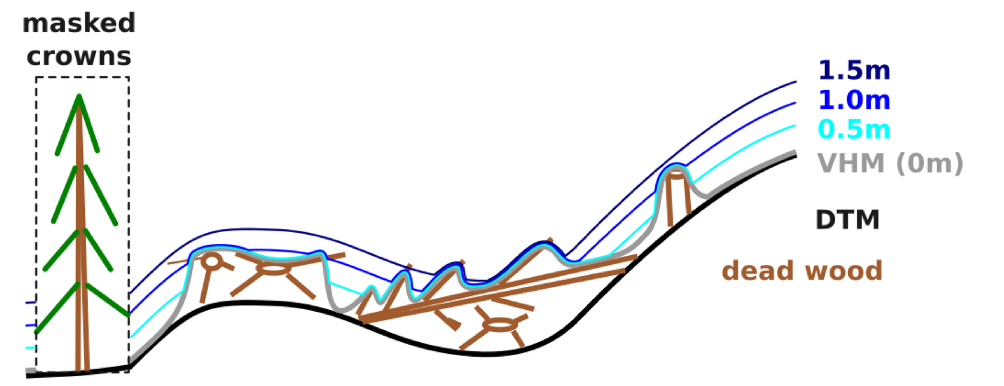




Case study Col di Lana (Veneto) 2020 – 2 years after the windthrow event
- Initial forest stand was extremely dense spruce-dominated forest

Conclusion

- Low-cost drone photogrammetry provides high-resolution data on deadwood structure, enabling an assessment of its protective effect.
- Approximately 1.5 meters of snow (corresponding to a 10-year return period) is required to smooth connected areas that may exceed the minimum size necessary for avalanche release.
- By adding a 1-m snowpack which could lead to relevant avalanche release, the corresponding return period increases to 70 years.
- The initial forest structure is not crucial for the protective effect of lying deadwood; rather, the arrangement and stacking of the deadwood itself are key factors in enhancing its protective effect.



Next steps and open questions

Next steps:

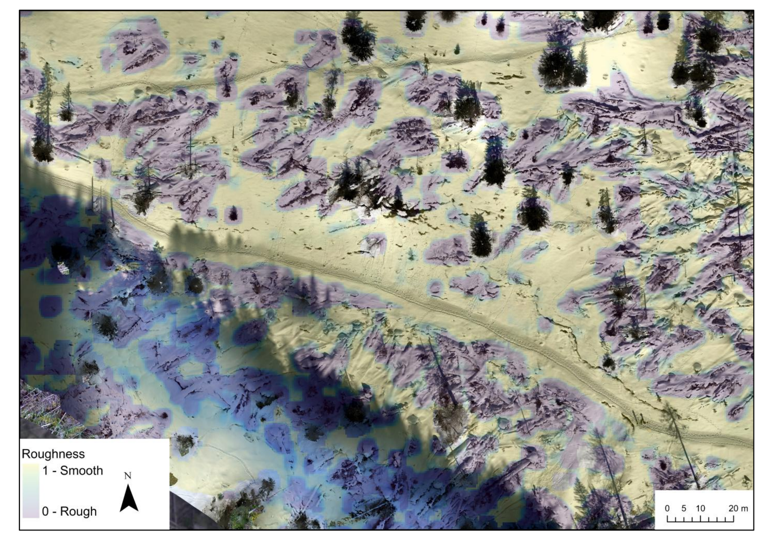
- **Robustness analysis** of photogrammetry-derived indices by comparing them to high-precision LiDAR drone-based indices.
- **Assessment of potential avalanche release areas** based on release probability membership functions across varying snow depths and associated return periods.
- **Plausibility checks and refinement of winter terrain modeling** through integration of snow-on drone survey data to improve terrain representation under snow cover.
- **Upscaling the methodology** using Airborne Laser Scanning (ALS) data to assess the protective effect of windthrow areas at broader spatial scales.

Open questions:

? Data availability: Do you have drone survey data from windthrow areas that could be used for testing and validation?

? Methodology clarity: Is the proposed approach clearly understandable, and are there key elements missing or requiring further elaboration?

? Roughness representation: Given the lack of direct bed surface roughness measurements after avalanche release, would it be more appropriate to use the snow surface roughness membership?



Plausibility check: Bed surface roughness membership with 0.8 m snow compared with an orthophoto acquired during snow-on conditions with approximately 0.8 m of snow

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