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A scalable workflow for shallow landslide inventory construction based on multitemporal LiDAR data with the explicit inclusion of landslides in forests

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For the development of accurate shallow landslide (translational debris and earth slides with a depth < 2 m) susceptibility assessments and further hazard or risk analyses, it is essential that complete and accurate landslide inventory data is available. Various methods are applied for the construction of shallow landslide inventories. However, it is known that the most used methods underreport landslides in forests, e.g. with visual interpretation of satellite/aerial imagery and manual mapping of landslides during field visits. To address this issue, several studies have instead used topographic Light Detection and Ranging (LiDAR) data to create their landslide inventories. These studies showed that landslides under forest cover can be mapped using topographic LiDAR, as LiDAR can penetrate the vegetation cover. The methods used in these studies can be divided into (1) methods using raster data derived from filtered LiDAR point-cloud data and (2) methods working directly on point-cloud datasets. The benefit of the raster-based methods is their computational speed and scalability, while point-cloud based methods are difficult to apply to larger areas, due to their high computational requirements, but have a greater measurement accuracy (e.g., landslide depth). This difference in accuracy is especially important for the mapping of shallow landslides, which often leave only limited traces in the landscape.

This study investigates how both methods can be combined to derive a semi-automatic workflow for mapping shallow landslides using LiDAR data that is accurate and scalable. The investigation focusses on mapping shallow landslides under forest, and on how the derived workflow for mapping landslides needs to be adapted to forested and non-forested areas. In a first step, potential landslide-prone areas are identified using the difference of pre- and post-event digital terrain models, an after-event digital terrain model and their related topographic derivatives such as the roughness coefficient and slope. In the next step, the identified areas are segmented and man-made topographic changes are removed, before they are further analyzed with a more accurate mapping technique using point-cloud data from the multiscale model-to-model cloud comparison (M3C2) algorithm. In addition to the M3C2 distances, the point-cloud based mapping will also make use of 3D shape features describing point location and orientation to increase the accuracy and robustness of the topographic change detection and estimation. The scalability of

the workflow is tested by applying the workflow to several areas in the Tyrolean Alps (Austria).

First results, derived with a logistic regression model using the raster-based derivatives, show a distinct difference in the feature importance of the topographic derivatives when forested and non-forested areas are compared. In addition, the performance of the model also greatly benefits from a separate training in forested and non-forested areas, with an increase in the Area Under the Curve (AUC) value from 0.84 to 0.89 for, respectively, unseparated and separated training.