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Geographic Object-Based Image Analysis (GEOBIA) for inventory mapping of forest-covered landslides: a case study in Jena, Germany

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For assessing landslide susceptibility and hazard reliable landslide inventories are essential. Historic landslides might indicate periods of increased landslide activity compared to more recent decades. However, landslide features might have diminished over time especially due to human impact. Often features of historic landslides are well preserved under forest providing a valuable source for preparing or completing landslide inventories, but mapping them is challenging.

Analyzing Light Detection and Ranging (LiDAR) and its derivatives have become powerful tools in landslide research, particularly in the identification and mapping of landslides. In contrast to the expert-based analysis of LiDAR derivatives, there is a limited number of studies employing object-based approaches to (semi)automatically mapping landslides from LiDAR data. This study focuses on the use of Geographic Object-Based Image Analysis (GEOBIA) based solely on LiDAR derivatives (1 m resolution) to conduct inventory mapping of forest-covered landslides within a middle mountainous region in Germany.

The study centers on Jena and its surrounding areas in Germany, covering an approximate area of 150 km^2. As part of the Thuringia basin, the study area is dominated by two major geological formations. The Muschelkalk (limestone) covers the majority of the upper parts of the slopes and the plateau areas. It is underlain by the Buntsandstein (marls, claystone and sandstone). Large landslides are historic and covered by forest. The methodology incorporates an inventory map for the purposes of module training and validation. LiDAR derivatives, encompassing slope, plan curvature, Terrain Roughness Index (TRI), Terrain Position Index (TPI), and differential openness, are systematically applied across diverse scales to identify landslide scarps and bodies within distinct window sizes. This systematic approach is further complemented by multi-resolution segmentation at multiple levels, support vector machine (SVM), rule-based classification, GEOBIA-based refinements, and a rigorous accuracy assessment. Collectively, these components establish a comprehensive framework for the progression of landslide detection and mapping methodologies.

The results reveal that the proposed approach achieved an 80% detection rate compared to the expert-based inventory. Nevertheless, continuous efforts are being made to reduce the occurrence of false positive detections. While the module demonstrates proficiency in identifying and mapping historical forest-covered landslides, its current functionality is limited to recognizing and mapping large and medium-sized landslides [area > 0,5 ha]. The transferability of this module should be evaluated in other regions. We anticipate that globally landslides with clear geomorphological signatures in high-resolution Digital Terrain Models (DTMs) can be identified using this approach.