

Machine-learning segmentation of ERT and DEM-of-Difference analysis for quantitative landslide activity modelling: a case study from the Dynów Foothills (southern Poland)

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This study presents an integrated, multi-sensor workflow for quantitative landslide activity modelling that combines photogrammetric topography reconstruction, airborne laser scanning (ALS) and electrical resistivity tomography (ERT) with machine-learning-assisted interpretation. The analysis is based on three input terrain models: a digital terrain model derived from archival black-and-white aerial photographs acquired in 2002 (scale 1:10,000) and two ALS LiDAR-based terrain models from 2013 and 2022. DEMs of Difference (DoD) were computed for 2002–2013 and 2002–2022 to quantify spatial patterns of elevation change, vertical displacements and volumetric mass redistribution. The DoD results indicate a total mobilized colluvial volume exceeding 30,000 m³ and reveal distinct depletion and accumulation zones consistent with landslide kinematics. Subsurface conditions were characterized using an ERT profile extending from the main scarp across the entire landslide body. The resistivity model delineates the geometry of the shear zone to depths of ~10 m and highlights lithological and hydrogeological contrasts, calibrated against four archival boreholes. To reduce interpreter subjectivity and enable reproducible zoning of resistivity domains, ERT data were classified using unsupervised k-means clustering and supervised Random Forest modelling trained on borehole-derived reference information. The supervised approach further provides probabilistic class assignments that help identify ambiguous zones and support robust integration with geomorphic evidence. Finally, the reconstructed activity phases were compared with rainfall records, linking observed deformation patterns with hydro-meteorological forcing. The proposed methodology offers a transferable template for landslide mapping and long-term monitoring in flysch terrains by coupling surface-change quantification with ML-supported subsurface segmentation.