Automated Multi-Metric Change Detection for Landslide Monitoring Using Satellite Time Series and Landscape Metrics

Ionuț ȘANDRIC[(1)], Viorel ILINCA[(1,2)], Teona DAIA-CREINICEAN[(1)], Radu IRIMIA[(1)], Alexandru TAMBUR[(3)], Igor NICOARĂ[(3)] Nicolas ALEXANDRU[(1)], Victor JELEAPOV[(3)], Cristina SPIAN[(3)], Ion FRANCOVSCHI[(3)]

[(1)]University of Bucharest, Faculty of Geography, Bucharest, Romania
[(2)]Geological Institute of Romania, Bucharest, Romania
[(3)] Moldova State University, Institute of Geology and Seismology, Chișinău, Republic of Moldova

* Corresponding author: e-mail: ionut.sandric@geo.unibuc.ro

Abstract

Accurate and timely detection of surface changes associated with landslide activity remains one of the major challenges in Earth Observation-based hazard monitoring. Traditional visual or threshold-based methods often fail to capture the subtle pre-failure dynamics or post-event recovery processes that occur over heterogeneous terrains. To address these limitations, this study presents an automated, data-driven framework for identifying significant geomorphic changes in landslide-affected areas using multi-temporal imagery and derived landscape metrics. A fully Python-based processing chain was developed to compute and integrate multiple categories of variables sensitive to surface changes. These include vegetation indices (NDVI, MSAVI, SAVI, NDWI), texture features based on the Grey Level Co-occurrence Matrix (GLCM) such as contrast, dissimilarity, and homogeneity, as well as landscape structure metrics including the number of patches, patch density, edge density, and Shannon diversity. Masks were systematically employed to remove clouds, shadows, and snow contamination, ensuring reliable pixel-level filtering and temporal consistency across the entire observation period. The change detection procedure systematically evaluates all potential temporal splits in each time series to automatically identify statistically significant shifts in surface characteristics. For each split, pre- and post-event values are compared using a set of sensitivity metrics including Hedges' g, Cohen's d, Mann–Whitney U test, and Cliff's delta, which are subsequently aggregated into a composite sensitivity score. This ranking-based approach allows for the objective identification of transition dates corresponding to geomorphic disturbances, vegetation loss, or recovery.The proposed framework was tested on several representative landslides across Romania and the Republic of Moldova, which are known for recurrent reactivation episodes. Results demonstrate that the number of vegetation-indices-derived patches, derived from NDVI segmentation, serves as a highly sensitive indicator of slope instability, often exhibiting abrupt changes immediately before or after field-documented landslide events. Texture metrics derived from red and SWIR bands were found to complement vegetation-based indicators, improving the ability to detect both disturbed and stabilized areas.Overall, the approach demonstrates high transferability and computational efficiency, relying entirely on open-access Sentinel-2 and Landsat data. It provides a scalable, sensor-agnostic solution for near-real-time monitoring of landslides and other surface disturbances, supporting the development of operational early warning systems and quantitative risk assessment tools for infrastructure and natural hazard management.