

Application of Remote Sensing In Earthquake-Induced Landslide Mapping: Advances and Case Studies

Dr. Meera Joshi

Professor

Department of Geoinformatics

Himalayan Institute of Science and Technology, Dehradun, India

Email:*meera.joshi@hist.edu.in*

Arjun Desai

Research Scholar

Department of Earth Sciences

National Institute of Technology, Silchar, India

Email:*arjun.desai@nit.ac.in*

Abstract

Earthquake-induced landslides are among the most devastating secondary hazards triggered by seismic events, often resulting in widespread damage to infrastructure, loss of life, and long-term environmental impacts. Rapid, accurate, and large-scale mapping of such landslides is critical for effective disaster response and risk reduction. Remote sensing technologies—including optical imagery, Synthetic Aperture Radar (SAR), and LiDAR—have emerged as indispensable tools in post-earthquake landslide detection and analysis. This paper explores the principles, methodologies, and integration of these techniques, supported by case studies from recent major earthquakes such as the 2015 Nepal Gorkha earthquake and the 2008 Wenchuan earthquake in China. The study highlights the role of Geographic Information Systems (GIS) in combining multi-source data for susceptibility mapping, hazard assessment, and recovery planning. Furthermore, it evaluates the advantages and limitations of each

remote sensing method, underscoring the need for hybrid approaches and automated detection algorithms to meet the growing demands of disaster management in seismically active regions.

Keywords: *Earthquake-induced landslides, Remote sensing, SAR, LiDAR, Optical imagery, GIS mapping, Hazard assessment*

INTRODUCTION

Earthquake-induced landslides are a major geohazard in mountainous and seismically active regions. They occur when seismic shaking destabilizes slopes, causing mass movements of rock, soil, and debris. These events can block rivers, bury roads, damage settlements, and disrupt lifeline infrastructure. The rapid assessment of affected areas is essential for **disaster response, evacuation planning, and reconstruction efforts**.

Traditional field surveys, while accurate, are **time-consuming and resource-intensive**, especially in remote or inaccessible terrain. Remote sensing offers the ability to capture **synoptic, multi-temporal, and high-resolution imagery** over large regions, enabling efficient detection, monitoring, and analysis of landslides triggered by earthquakes.

REMOTE SENSING TECHNIQUES FOR LANDSLIDE MAPPING

Optical Remote Sensing

Optical satellite imagery, including medium-resolution sensors like Landsat and high-resolution platforms such as WorldView and PlanetScope, can identify changes in surface reflectance and texture associated with landslides. Pre- and post-event image differencing and object-based image analysis are common techniques.

Synthetic Aperture Radar (SAR)

SAR systems, such as Sentinel-1 and ALOS-PALSAR, can penetrate clouds and operate day or night. SAR coherence change detection effectively identifies disturbed surfaces after earthquakes. Interferometric SAR (InSAR) provides displacement measurements that reveal slope instability precursors.

Light Detection and Ranging (LiDAR)

LiDAR captures detailed 3D topography, enabling precise detection of slope failures, even under forest cover. Airborne LiDAR is particularly valuable for generating Digital Elevation Models (DEMs) before and after events to quantify volume changes.

CASE STUDIES

2015 Gorkha Earthquake, Nepal

The earthquake triggered more than 25,000 landslides across central Nepal. Landsat-8 and Sentinel-2 imagery, combined with UAV surveys, allowed rapid landslide inventory generation. SAR coherence change maps highlighted areas of severe slope disturbance, guiding relief operations.

2008 Wenchuan Earthquake, China

The magnitude 7.9 event caused over 56,000 landslides. High-resolution optical imagery from SPOT-5 and aerial photographs enabled precise mapping. LiDAR surveys revealed complex failure patterns in deeply incised valleys.

2011 Tohoku Earthquake, Japan

Post-event TerraSAR-X imagery captured slope displacements in mountainous coastal areas. Integration with hazard models in GIS supported the prioritization of slope stabilization works.

DATA INTEGRATION WITH GIS

Remote sensing data becomes most powerful when combined with GIS analysis. Landslide inventory layers can be overlaid with seismic intensity maps, geological formations, slope gradients, land use, and rainfall data to produce **landslide susceptibility and hazard maps**. This integration aids in **risk zoning, early-warning systems, and post-disaster planning**.

ADVANTAGES AND LIMITATIONS

Technique	Application	Advantages
Optical Imagery	Detecting landslide scars and vegetation loss	High spatial resolution, visual interpretation
SAR/InSAR	Detecting surface disturbance and slope	All-weather, day-night capability

Technique	Application	Advantages
	deformation	
LiDAR	Mapping detailed topography and landslide volumes	Penetrates vegetation, high accuracy

Advantages:

- Rapid assessment over large areas
- Repeat coverage for monitoring changes
- Non-intrusive and accessible in remote areas

Limitations:

- Optical sensors limited by cloud cover
- SAR data processing complexity
- LiDAR surveys are costly and require specialized equipment

RESEARCH METHODOLOGY FOR LANDSLIDE MAPPING

The workflow for earthquake-induced landslide mapping typically involves:

1. **Pre-event Data Collection** – Acquiring baseline imagery or DEMs.
2. **Post-event Data Acquisition** – Using satellite, airborne, or UAV sensors.
3. **Pre-processing** – Atmospheric correction, orthorectification, radiometric calibration.
4. **Change Detection** – Image differencing, spectral index analysis, or coherence change mapping.
5. **Classification and Mapping** – Manual digitization or automated segmentation.
6. **Validation** – Comparing results with field observations and GPS measurements.
7. **GIS Integration** – Generating hazard maps and reports for decision-makers.

FUTURE PROSPECTS

Emerging developments include **machine learning and deep learning algorithms** for automated landslide detection, the use of **CubeSats for daily high-resolution imagery**, and **UAV-LiDAR integration** for rapid 3D modeling. Cloud-based processing platforms such as **Google Earth Engine** enable near-real-time analysis of massive datasets, supporting faster disaster response.

CONCLUSION

Remote sensing plays an indispensable role in earthquake-induced landslide mapping by providing rapid, accurate, and large-scale data that is critical for **risk assessment and disaster management**. Combining optical, SAR, and LiDAR data within GIS frameworks enhances hazard mapping accuracy and enables targeted mitigation strategies. The continued integration of emerging technologies, AI-based detection, and open-data initiatives will further improve our capacity to respond to these devastating natural hazards.

REFERENCES

1. Martha, T.R., et al. (2017). Post-earthquake landslide mapping using satellite imagery. *Remote Sensing of Environment*, 188, 168-182.
2. Robinson, T.R., & Davies, T.R.H. (2013). Review of landslides triggered by the 2011 Tohoku earthquake. *Landslides*, 10(1), 1-13.
3. Xu, C., et al. (2014). Landslides triggered by the 2008 Wenchuan earthquake. *Engineering Geology*, 182, 109-120.
4. Mondini, A.C., et al. (2011). Semi-automatic recognition of landslides triggered by earthquakes using remote sensing. *Natural Hazards*, 58(2), 331-347.
5. Yamagishi, H., & Yamazaki, F. (2018). Use of SAR for landslide monitoring after earthquakes. *Earthquake Engineering and Structural Dynamics*, 47(3), 633-648.
6. Qi, S., et al. (2012). LiDAR applications in landslide detection. *Journal of Applied Remote Sensing*, 6(1), 063590.
7. Parker, R.N., et al. (2011). Spatial distribution of earthquake-induced landslides. *Geomorphology*, 125(1), 386-397.
8. Wang, F., et al. (2020). Machine learning approaches for rapid landslide mapping. *Remote Sensing*, 12(3), 444.