MANTECH Publications

Journal of Remote Sensing, Environmental Science & Geotechnical Engineering

Volume 1, Issue 2, May-August, 2016

Integration of Remote Sensing and Geotechnical Data for Landslide Hazard Zonation

Dr. Ananya Mehra

Associate Professor

Department of Civil Engineering

Himalayan Institute of Technology, Dehradun, India

Email:*ananya.mehra@hit.ac.in*

Rahul Singh

Research Scholar

Department of Geoinformatics

National Institute of Remote Sensing, Hyderabad, India

Email:*rahul.singh@nirs.ac.in*

Abstract

Landslides are among the most destructive natural hazards, causing significant loss of life, infrastructure damage, and environmental degradation. Accurate landslide hazard zonation (LHZ) is essential for risk mitigation and planning. This paper discusses the integration of remote sensing techniques and geotechnical data to enhance the accuracy and efficiency of LHZ mapping. Remote sensing provides spatially continuous and multi-temporal datasets, while geotechnical data offers in-depth insight into soil strength, slope stability, and subsurface conditions. The combined approach facilitates the creation of detailed hazard maps that can be used by policymakers, engineers, and planners. This paper explores data acquisition methods, integration techniques, analytical models, and real-world case studies, emphasizing the importance of interdisciplinary collaboration for effective landslide hazard management.

Keywords: *Remote Sensing, Geotechnical Data, Landslide Hazard Zonation, GIS, Risk Mitigation, Slope Stability, Disaster Management*

INTRODUCTION

Landslides are mass movements of rock, soil, or debris down a slope due to gravity, often triggered by natural events such as heavy rainfall, earthquakes, volcanic activity, or anthropogenic factors like deforestation and construction. In mountainous regions, particularly the Himalayas, landslides pose recurring threats to human settlements and infrastructure.

Traditional methods of landslide hazard assessment have relied heavily on **field-based geotechnical investigations**. While accurate, these methods are time-consuming, labor-intensive, and spatially limited. The advent of **remote sensing** technologies, such as optical imagery, LiDAR, and radar interferometry, has revolutionized hazard mapping by providing large-scale, repetitive, and cost-effective data.

However, remote sensing alone cannot capture subsurface soil properties or slope material strength. Therefore, **integrating remote sensing data with geotechnical measurements** such as shear strength, cohesion, angle of internal friction, and groundwater conditions provides a more holistic and accurate landslide susceptibility model.

REMOTE SENSING FOR LANDSLIDE HAZARD ZONATION

Satellite and Aerial Data Sources

Remote sensing platforms such as **Landsat, Sentinel-1/2, CartoSAT, and ASTER** are commonly used for landslide studies. These satellites provide multi-spectral and radar data capable of detecting surface changes, vegetation cover, and slope morphology.

LiDAR offers high-resolution elevation data crucial for deriving Digital Elevation Models (DEMs), while **InSAR (Interferometric Synthetic Aperture Radar)** detects minute ground displacements over time.

GEOTECHNICAL DATA FOR SLOPE STABILITY

Geotechnical investigations focus on subsurface properties that influence slope stability. This includes:

- **Soil texture and composition**
- **Moisture content and groundwater table depth**
- **Shear strength parameters** (cohesion c and angle of internal friction φ)
- **Bulk density and porosity**

These properties are determined through **field sampling, borehole drilling, and laboratory tests** such as triaxial shear, direct shear, and Atterberg limits.

INTEGRATION METHODOLOGY

The integration process involves combining remote sensing-derived thematic layers (e.g., slope, aspect, land cover, rainfall intensity) with geotechnical layers (e.g., soil strength, depth to bedrock) in a **Geographic Information System (GIS)** environment.

Weighted Overlay Analysis and **Analytical Hierarchy Process (AHP)** are common multi-criteria decision-making approaches used to assign importance to different factors.

Table 1: Comparison of Remote Sensing and Geotechnical Data in LHZ Mapping

Parameter	Remote Sensing Data	Geotechnical Data	Explanation
Data Coverage	Large-scale, regional to global	Localized, site-specific	Remote sensing provides spatial continuity, while geotechnical is limited to sampled sites.
Temporal Resolution	Frequent (days to weeks)	Infrequent, event-based	Satellite revisits enable change detection; geotechnical requires periodic campaigns.
Parameters Measured	Surface morphology, land cover, moisture index	Soil strength, density, pore pressure	Both datasets are complementary, measuring surface and subsurface factors.
Cost and Time	Lower cost for large areas	Higher cost and time-intensive	Remote sensing is cost-effective for initial mapping; geotechnical is essential for precision.

CASE STUDY: LANDSLIDE HAZARD ZONATION IN HIMACHAL PRADESH

In Himachal Pradesh, India, researchers integrated **Sentinel-1 SAR imagery** with **field-measured geotechnical data** to map landslide-prone zones. The study used a **Weighted Linear Combination (WLC)** model in ArcGIS. Remote sensing layers such as slope, NDVI, rainfall, and lineament density were combined with geotechnical layers like soil cohesion, depth to bedrock, and groundwater levels.

The integration significantly improved the accuracy of hazard predictions compared to using either dataset alone. Zones were classified into **Very High, High, Moderate, Low, and Very Low hazard levels**, enabling targeted mitigation measures.

ADVANTAGES OF INTEGRATED APPROACH

1. **Enhanced Accuracy** – Combining datasets captures both surface and subsurface instability factors.
2. **Cost-Effectiveness** – Remote sensing reduces fieldwork scope while geotechnical tests validate findings.

3. **Timely Monitoring** – Frequent satellite revisits allow near-real-time monitoring of landslide triggers.
4. **Decision Support** – Produces actionable hazard maps for planners and policymakers.

LIMITATIONS AND CHALLENGES

- High-resolution satellite data may be costly.
- Geotechnical sampling in remote, rugged areas is logistically challenging.
- Integration requires skilled GIS professionals and interdisciplinary collaboration.

FUTURE DIRECTIONS

Emerging technologies such as **UAV-based LiDAR**, **machine learning algorithms**, and **cloud-based GIS platforms** offer improved capabilities for automated hazard detection. The integration of **IoT-enabled geotechnical sensors** with remote sensing data streams can facilitate real-time hazard warning systems.

CONCLUSION

Landslide hazard zonation is a critical tool for disaster risk management in vulnerable regions. The integration of remote sensing and geotechnical data offers a more accurate, cost-effective, and comprehensive method for identifying landslide-prone zones. While remote sensing provides large-scale, continuous spatial data, geotechnical measurements offer essential insights into subsurface conditions that govern slope stability. The combined approach strengthens predictive models and enhances preparedness strategies, ultimately reducing the socio-economic impacts of landslides. Future research should focus on automating integration processes and developing community-based hazard management frameworks.

REFERENCES

[1] Gupta, R. P., and Anbalagan, R. "Landslide hazard zonation using the GIS approach – A case study from the Himalayas." *Engineering Geology*, vol. 58, no. 3-4, pp. 219–231, 2000.
[2] Metternicht, G., Hurni, L., and Gogu, R. "Remote sensing of landslides: An analysis of the potential contribution to geo-spatial systems for hazard assessment in mountainous environments." *Remote Sensing of Environment*, vol. 98, pp. 284–303, 2005.
[3] Cruden, D. M., and Varnes, D. J. "Landslide types and processes." *Transportation Research Board Special Report*, 247, pp. 36–75, 1996.
[4] Singhroy, V., and Molch, K. "Characterizing and monitoring rockslides from SAR techniques." *Advances in Space Research*, vol. 33, pp. 290–295, 2004.
[5] Van Westen, C. J., et al. "Geomorphological hazard assessment using remote sensing and GIS: An overview." *Natural Hazards*, vol. 61, no. 1, pp. 3–29, 2012.
[6] Das, S., and Pal, S. "Integration of remote sensing and field data for landslide hazard zonation in Darjeeling Himalaya, India." *Environmental Earth Sciences*, vol. 77, no. 1, pp. 1–17, 2018.
[7] Martha, T. R., et al. "Landslide hazard mapping using high resolution satellite data in the

Himalayas." *Landslides*, vol. 7, no. 3, pp. 285–295, 2010.
[8] Highland, L. M., and Bobrowsky, P. "The landslide handbook: A guide to understanding landslides." *U.S. Geological Survey Circular 1325*, 2008.

