MANTECH Publications
Journal of Remote Sensing, Environmental Science & Geotechnical Engineering
Volume 6, Issue 2, May-August 2021

Impact of Land Use Change on Slope Stability Assessed Via Remote Sensing and Gis

Dr. Meera Kulkarni
Assistant Professor
Department of Civil Engineering
Institute of Technology, Pune
Email: *meera.kulkarni@itpune.edu.in*

Mr. Arjun Patil
Research Scholar
Department of Geoinformatics
Institute of Technology, Pune
Email: *arjun.patil@itpune.edu.in*

Abstract

Slope stability is crucial for ensuring safety and sustainability in hilly and mountainous regions. Land use changes, including urbanization, deforestation, and agriculture expansion, significantly affect slope stability by altering natural hydrological regimes, vegetation cover, and soil structure. This paper evaluates the impact of land use change on slope stability through remote sensing and Geographic Information System (GIS) techniques. Multitemporal satellite images and digital elevation models (DEMs) were analyzed to assess land use variations and their correlation with slope failures. Vegetation cover reduction and increased impervious surfaces were found to exacerbate slope instability. GIS-based slope stability models integrated with land use maps helped delineate vulnerable zones. A detailed table summarizes key land use types and their associated slope failure risk. Limitations such as spatial resolution and temporal frequency of data are discussed. This study demonstrates that remote sensing and GIS are effective tools for monitoring land use changes and predicting slope

Page 48-51 © MANTECH PUBLICATIONS 2021. All Rights Reserved

failure risk, thus aiding planners and policymakers in sustainable land management.

***Keywords**: Slope Stability, Land Use Change, Remote Sensing, GIS, Landslide Susceptibility, Vegetation Cover, Digital Elevation Model*

INTRODUCTION

Slope stability is a critical aspect in geomorphology and civil engineering, influencing infrastructure safety and environmental sustainability. Land use change, driven by human activities like urban expansion, deforestation, and agriculture, can destabilize slopes by disrupting soil properties, surface water flow, and vegetation that anchors soil. Accurate assessment of these impacts is essential for hazard mitigation.

Remote sensing offers spatially continuous and time-efficient data on land use, while GIS facilitates integration of multiple datasets such as topography, geology, and hydrology to model slope stability. This study explores how land use changes impact slope stability and demonstrates the use of remote sensing and GIS for assessment and monitoring.

LAND USE CHANGE AND SLOPE STABILITY

Changes in land cover and land use have profound effects on slope dynamics:

- **Deforestation** reduces root reinforcement and soil cohesion, increasing susceptibility to landslides.
- **Urbanization** increases impervious surfaces, altering runoff patterns and increasing slope saturation.
- **Agriculture** can cause soil erosion and compaction, weakening slope integrity.

Understanding these influences requires spatial-temporal monitoring of land use changes, achievable through remote sensing technologies.

REMOTE SENSING AND GIS TECHNIQUES FOR ASSESSMENT

- **Satellite Imagery**: Multi-temporal Landsat and Sentinel images are utilized to classify land use categories over time, detecting transitions like forest to agriculture or agriculture to built-up areas.
- **Digital Elevation Models (DEMs)**: DEMs provide slope, aspect, and elevation data essential for identifying physically vulnerable areas.
- **GIS-based Modelling**: Layers including land use, slope, soil type, and rainfall are integrated using weighted overlay and statistical methods to delineate landslide-prone zones.

TABLE 1: Land Use Types And Associated Slope Failure Risk

Page 48-51 © MANTECH PUBLICATIONS 2021. All Rights Reserved

Land Use Type	Description	Impact on Slope Stability	Risk Level
Dense Forest	Undisturbed, high canopy cover	High soil cohesion, water retention	Low
Agricultural Land	Crops with periodic soil disturbance	Reduced root anchorage, erosion prone	Medium
Urban/Built-Up	Impervious surfaces, construction	Increased runoff, slope saturation	High
Grassland	Moderate vegetation cover	Moderate soil stability	Low to Medium
Bare Soil	Exposed earth without vegetation	High erosion and instability	Very High

Table 1: Overview of land use types and their effects on slope stability.

CASE STUDIES

1. **Hilly Region of Western Ghats, India**

Land use analysis using Landsat imagery from 2000 and 2020 showed extensive deforestation and urban sprawl. GIS slope stability modeling indicated increased landslide susceptibility in deforested and urbanized zones. Field data corroborated increased incidence of slope failures near road cuttings and settlements.

2. **Nepalese Himalayas**

Remote sensing detected agricultural terracing and forest degradation patterns over a decade. Combining this with rainfall data in GIS highlighted critical areas where land use changes aggravated slope instability, triggering landslides during monsoon seasons.

DISCUSSION

Remote sensing and GIS provide an effective approach for mapping and monitoring land use changes impacting slope stability. However, some challenges persist:

- **Data Resolution**: Moderate resolution satellites may miss fine-scale land use changes.
- **Temporal Gaps**: Satellite revisit periods limit detection of rapid changes.
- **Ground Truthing**: Validation with field data remains necessary to improve model accuracy.
- **Complex Terrain**: Diverse slope conditions and microclimates require region-specific models.

Despite limitations, these tools enable proactive identification of hazard zones, crucial for land management and planning.

Page 48-51 © MANTECH PUBLICATIONS 2021. All Rights Reserved

FUTURE DIRECTIONS

Integrating higher resolution satellite data, UAV imagery, and machine learning classification methods can enhance detection accuracy. Combining hydro-meteorological data with land use change models will improve predictive capacity for slope failure risk. Collaboration between remote sensing specialists, geotechnical engineers, and urban planners is vital for sustainable development in sensitive terrains.

CONCLUSION

This study underscores the significant impact of land use change on slope stability and demonstrates that remote sensing combined with GIS offers a powerful methodology to assess and monitor this effect. Deforestation, urban expansion, and agricultural practices notably increase slope failure risk. GIS-based landslide susceptibility mapping integrating land use data supports targeted mitigation strategies. Continued advancements in remote sensing technologies and analytical methods will improve slope hazard assessments, helping policymakers promote sustainable land use and infrastructure safety.

REFERENCES

[1] Sidle, R.C., Ochiai, H., *"Landslides: Processes, Prediction, and Land Use,"* American Geophysical Union, 2006.
[2] Gupta, R.P., et al., "Remote Sensing and GIS for Landslide Hazard Zonation," *International Journal of Remote Sensing*, vol. 20, no. 9, pp. 1877-1896, 1999.
[3] Shrestha, A.B., et al., "Impact of Land Use Change on Slope Stability in the Nepal Himalayas," *Geomorphology*, vol. 261, pp. 15-27, 2016.
[4] Roy, P.S., et al., "Mapping Land Use/Land Cover Change Using Remote Sensing Data," *Journal of the Indian Society of Remote Sensing*, vol. 37, pp. 213-225, 2009.
[5] Lee, S., et al., "GIS-Based Landslide Susceptibility Mapping Using Statistical Approaches," *Environmental Geology*, vol. 45, pp. 665-674, 2004.
[6] Das, S., et al., "Application of Remote Sensing and GIS for Landslide Susceptibility Mapping in India," *International Journal of Geomatics and Geosciences*, vol. 4, no. 3, pp. 331-339, 2013.
[7] Dai, F.C., Lee, C.F., "Landslide Characteristics and Slope Stability Modeling Using GIS in Hong Kong," *Engineering Geology*, vol. 54, pp. 171-188, 1999.
[8] Saha, S., et al., "Multi-Temporal Analysis of Land Use Change and Its Impact on Slope Stability," *Remote Sensing Applications: Society and Environment*, vol. 5, pp. 117-125, 2017.

Page 48-51 © MANTECH PUBLICATIONS 2021. All Rights Reserved