Extended Abstract DOI: https://doi.org/10.64862/ajeg.2025.2s4p.74.199 Open Access

Integration of Geological Survey and Digital Mapping Tools for Geological Modeling to Investigate the Relationship Between Geological Structures and Landslide Distribution

Pai-Chiao Lo[1*], Yong-Zhi Huang[1], Tai-Tien Wang[1], Wei Lo[2] and Yu-Chung Hsieh[3]

[1]National Taiwan University, Taipei, Taiwan
[2]National Taipei University of Technology, Taipei, Taiwan
[3]Geological Survey and Mining Management Agency, MOEA, New Taipei, Taiwan

(*Corresponding E-mail: lopaichiao@gmail.com)

Received: August 18, 2025, Accepted: October 29, 2025

Abstract: Geological structures are crucial in determining rock mass characteristics and slope stability, directly influencing the occurrence and distribution of landslides. Traditional geological surveys are often limited by terrain, vegetation, and resolution constraints. With the rapid advancement of remote sensing technologies, such as LiDAR and UAV-based photogrammetry, the ability to investigate terrain, geomorphology, and rock discontinuities has significantly improved. These tools improve spatial resolution and data quality, making it easier to interpret geological features, rock engineering parameters, and terrain variability. This study investigates a structurally complex area along the Southern Cross-Island Highway in Taiwan, near the boundary between slate and schist belts. A combination of surface geological surveys, remote sensing analysis, and UAV-based digital mapping was used to create a geological model. The findings highlight the importance of combining geological modeling with remote sensing data to analyze landslide-prone areas. The developed model not only reveals the structural controls on landslide occurrence but also provides a practical foundation for hazard assessment and highway maintenance planning.

Keywords: ***Landslide, Remote sensing, UAV, Geological model.***

Introduction

Geological factors play a critical role in determining the engineering properties of rock masses and, consequently, in influencing slope stability, landslide types, and their spatial distribution. Stead and Wolter (2015) reviewed how geological structures control rock slope failure mechanisms, highlighting the importance of structural geology in slope stability assessment. Traditional geological surveys are constrained by topography, manpower, and accessibility. Surface investigations are often limited in resolution due to terrain and vegetation cover. However, with the advancement of digital mapping tools such as LiDAR and UAVs, it has become possible to identify surface structural features more effectively. Progress in remote sensing and geospatial technologies has enhanced the study of geomorphic features and terrain changes associated with landslide processes. These advancements also facilitate the analysis of correlations among landslide activity, susceptibility, topography, geological structures, and rock mass properties (Langridge et al., 2014; Lo et al., 2021; Pánek et al., 2024). They significantly improve the resolution and accuracy of surface structural information, providing new tools for analyzing the spatial relationship between landslides and geological structures.

This study integrates surface geological surveys with UAV imagery and digital mapping techniques to construct a geological model of the study area, aiming to investigate the spatial relationship between geological structures and landslide distribution.

Study area

The study area is located along the southern section of the Central Mountain Range in southeastern Taiwan, specifically between Wulu and Lidao along No. 20 Highway (Southern Cross-Island Highway) in Taitung County. Xinwulü River, which flows west to east through the study area, passes beneath the Wulu Bridge at an elevation of approximately 700 meters. The surrounding slopes rise to about 1,500 meters on both the northern and southern sides. Figure 1 shows the topographic map and regional geological map of the study area. The exposed formations consist primarily of Late Paleozoic to Miocene metamorphic rocks, including the Kaoling Schist and the Eocene Pilushan Formation. The Kaoling Schist is dominated by quartz-mica schist, interbedded with quartzite and chlorite schist. The Pilushan Formation mainly comprises slate intercalated with metamorphosed sandstone.

Route geological mapping and supplementary investigations

Figure 2 shows the results of the geological mapping route. Quartz-mica schist is exposed in the southeastern part of the study area and extends northwestward to roughly 300 meters west of Wulu Bridge along the Xinwulü River. The schist demonstrates well-developed foliation, striking northeast–southwest and dipping to the north. Based on this mapping, additional field investigations were carried out at selected outcrops to support later applications of digital geological mapping and landslide analysis.

Remote sensing in landslide and geological surveys

This study uses advanced surveying and mapping technologies to investigate landslides along the slopes of the Southern Cross-Island Highway in Taiwan. The results show that using DSMs created from UAV-based and close-range photogrammetry, along with point cloud models from ground-based LiDAR, provides multiple benefits for landslide assessment (Figure 3). The findings also show that single- or multi-temporal satellite and aerial photogrammetry imagery enables broad-scale observation of surface topographic features. When combined with digital surface models (DSMs) from UAV-based and close-range photogrammetry, as well as terrestrial LiDAR point cloud models, these data provide multiple benefits for landslide assessment. Finally, a geological model was created by combining surface geological surveys, remote sensing analysis, and UAV-based digital mapping techniques to study the connection between landslides and geological structures.

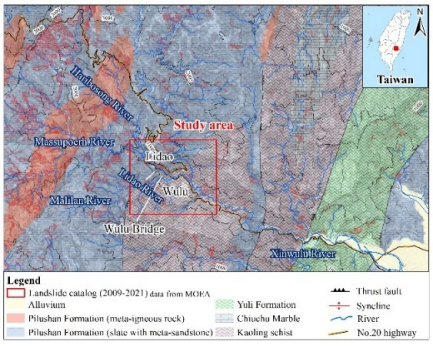

Figure 1, Geological map of the study area.

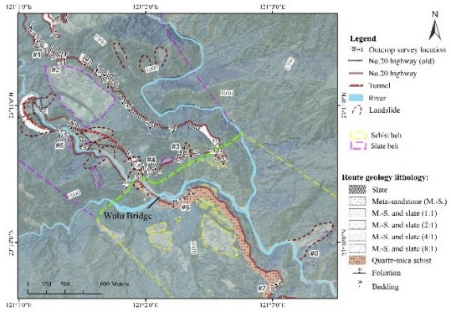

Figure 2, Route geological map of the study area.

Constructing a geological model

A geological model was developed by integrating surface geological surveys, remote sensing analysis, and UAV-based digital mapping techniques to investigate the relationship between landslides and geological structures. Based on a synthesis of the slate–schist contact zone, major fold exposures, and landslide distributions within the study area, the results show a strong spatial link between frequently occurring landslides and the hinge zones of multi-scale polyharmonic folds, especially those with wavelengths from tens to hundreds of meters and in areas where tight folds are exposed.

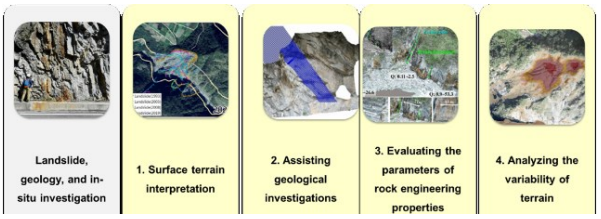

Figure 3, Remote sensing in landslide and geological surveys.

Conclusion

Multiple factors influence landslides in highly metamorphosed and structurally complex regions. This study integrates remote sensing and field investigations to clarify the engineering characteristics and controlling factors of landslides along the slate–schist contact zone, highlighting that a multidisciplinary, well-scaled geological model is essential for landslide assessment and slope management.

References

Langridge, R. M., Ries, W. F., Farrier, T., Barth, N. C., Khajavi, N., and De Pascale, G. P. (2014). Developing sub 5-m LiDAR DEMs for forested sections of the Alpine and Hope faults, South Island, New Zealand: Implications for structural interpretations. Journal of Structural Geology, 64, 53–66. https://doi.org/10.1016/j.jsg.2013.11.007

Lo, P. C., Lo, W., Wang, T. T., and Hsieh, Y. C. (2021). Application of geological mapping using airborne-based LiDAR DEM to tunnel engineering: Example of Dongao Tunnel in north-eastern Taiwan. Applied Sciences, 11(10), 1-19. https://doi.org/10.3390/app11104404

Pánek, T., Březný, M., Havenith, H. B., and Tibaldi, A. (2024). Landslides and growing folds: A lesson from the Kura fold-and-thrust belt (Azerbaijan, Georgia). Geomorphology, 449, 109059. https://doi.org/10.1016/j.geomorph.2024.109059

Stead, D., and Wolter, A. (2015). A critical review of rock slope failure mechanisms: The importance of structural geology. Journal of Structural Geology, 74, 1–23.https://doi.org/10.1016/j.jsg.2015.02.002