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Integrated Geomorphological and Remote Sensing-Based Recognition of Deep-Seated Gravitational Slope Deformations Around the Budhigandaki Hydropower Reservoir, Central Nepal Himalaya

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Abstract: Deep-Seated Gravitational Slope Deformations (DGSDs) are slow-moving, large-scale slope failures that pose significant hazards in mountainous terrains, particularly along reservoir rims. This study integrates geomorphological mapping, Sentinel-1 InSAR time-series, and field verification to identify and characterize DGSDs around the Budhigandaki Hydropower Reservoir in the Central Nepal Himalaya. High-resolution (5 m) DEM derivatives enabled identification of morphological indicators such as antiscarps, double ridges, sagging slopes, and bulging toes. InSAR analysis quantified line-of-sight displacements, revealing active or potentially reactivating DGSD zones. Field surveys provided lithological and structural context. DGSDs are concentrated along steep slopes (>30°), where lithological contrasts and structural discontinuities (foliation, joints, shear zones, faults) guide deep-seated movements. InSAR measurements show slow deformation rates (3–5 mm/year). This integrated approach provides a robust framework for DGSD recognition, slope-hazard assessment, and reservoir rim monitoring, supporting long-term stability of hydropower infrastructure.

Keywords: ***Deep-seated gravitational slope deformation (DGSD); Budhigandaki hydropower reservoir; Central Nepal himalaya; Geomorphological mapping; InSAR; Reservoir rim stability.***

Introduction

DGSDs represent pervasive, slow-moving slope failures along deep-seated shear zones in mountainous terrains. They influence long-term landscape evolution and pose hazards for infrastructure such as dams and reservoir rims. The Budhigandaki River Basin, characterized by steep slopes, complex lithology, and high seismicity, provides an ideal setting for DGSD investigation (Prajapati et al., 2018). Accurate recognition and mapping of DGSDs are essential for hazard assessment and slope management (Gori et al., 2013).

Materials and methods

The study integrates multi-source remote sensing and field-based approaches. High-resolution (5 m) DEM, ALOS PALSAR DEM, and SRTM DEM were utilized for terrain analysis and geomorphological interpretation. Optical imagery from Google Earth, PlanetScope, and Sentinel-2 supported lithological and structural mapping. Sentinel-1 SAR datasets were processed for interferometric (InSAR) analysis to assess ground deformation. Field investigations employed GPS for spatial data acquisition, a Brunton compass for structural measurements, and a geological hammer for sampling and outcrop examination.

Results

Over 40 major and 70 minor DGSDs mapped along reservoir rim and valley flanks, out of which some are presented in Table 1. DGSDs concentrated on slopes >30° where lithological contrasts intersect structural discontinuities. Morphologies include antiscarps, double ridges, sagging slopes, bulging toes, and trench-like depressions. InSAR-derived LOS displacement rates: 3–5 mm/year. Field surveys confirmed geomorphic interpretations and structural controls.

Discussion

DGSD evolution is influenced by slope gradient, lithological heterogeneity, and structural discontinuities (Pazzi et al., 2018). Some DGSDs are potentially active and susceptible to reservoir-induced hydrological fluctuations, posing retrogressive failure risks. Integrated geomorphology and InSAR provide a robust framework for hazard assessment, monitoring, and mitigation planning.

Conclusion

DGSDs are widespread along steep slopes in the Budhigandaki Basin, controlled by lithology and structural orientation. InSAR confirms ongoing slow movement along key slopes. The integrated approach supports slope-hazard assessment and reservoir rim monitoring. Findings provide essential guidance for long-term stability of hydropower infrastructure in tectonically active mountainous terrain.

Table 1, Major DGSD features around Budhigandaki reservoir.

DGSD ID	Slope Grad. (°)	Lithology Rock Formation	Structural Pattern	Geomorphic Features Observed at the site	Displacement (mm/year)
DGSD-1	38	Dandagaon Phyllite	Foliation/ Joint planes	Antiscarp, Sagging slope	4
DGSD-2	42	Fagfog Quartzite	Faults intersect	Double ridge, Bulging toe	3
DGSD-3	35	Nourpul Formation	Bedding plane	Sagging slope, Trench	5
DGSD-4	40	Benighat Slate	Foliation/Joint	Bulging toe, Displaced drainage	4
DGSD-5	33	Dhading Dolomite	Fault/joint	Antiscarp, Sagging slope	3

References

Gori, S., Falcucci, E., Dramis, F., Galadini, F., Galli, P., Giaccio, B., Messina, P., Pizzi, A., Sposato, A., and Cosentino, D. (2013). Deep-seated gravitational slope deformation, large-scale rock failure, and active normal faulting along Mt. Morrone (Sulmona Basin, Central Italy): Geomorphological and paleoseismological analyses. Geomorphology, 208, 88–101. https://doi.org/10.1016/j.geomorph.2013.11.017

Pazzi, V., Morelli, S., Frodella, W., and Fanti, R. (2018). Analysis of LiDAR derived DEM geomorphometric parameters to assess the kinematic behaviour of a DSGSD. Geophysical Research Abstracts, 20, EGU2018–5228. Available at: https://www.researchgate.net/publication/324747375_Analysis_of_LiDAR_derived_DEM_geomorphometric_parameters_to_assess_the_kinematic_behaviour_of_a_DSGSD

Prajapati, R. N., Miya, A. H., Raut, B., Aryal, A. R., and Shrestha, B. (2018). A study of reservoir volume and its inundated RMs of Budhi Gandaki Hydropower Project with respect to dam height variation. SCITECH Nepal, 13(1), 48–54. https://doi.org/10.3126/scitech.v13i1.23501