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RESEARCH ARTICLE

Palaeo-Landslide Identification and their Role in Triggering Recent Mass Movement Activities: A Case Study from the Batote-Baglihar Region, NW Himalaya

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ABSTRACT

In recent times, the Batote-Baglihar area of Jammu and Kashmir, NW Himalaya, has witnessed increased landslide activity, damaging houses along the western slope of Chakwa *Nala,* located on the footwall of the Main Boundary Thrust (MBT). The mass movement activation is reflected in the form of slumps, creeps, and cracks in land, roads, and buildings of the affected area. The area has a gentle to moderate slope, moderate relative relief, and moderate to high Stream Power Index (SPI). The field-based mapping of intrinsic factors revealed the dominance of unconsolidated overburden material (81%). The frequency ratio (FR) reveals the highest positive correlation with old debris material (2.01), followed by mudstone-sandstone lithology (1.3), gentle slope (1.3), and moderate slope (1.2). The Google terrain and contour maps reveal the presence of indistinct morphological markers of palaeo-landslide activity such as rolling topography, slope-top benches, smoothened steep crest slopes with elliptical to amphitheatre shape, and reversal of contours. The field-based palaeo-landslide markers include thick (2-20m) debris material, the presence of rock boulders within the debris, and deflection of drainage around relict palaeo-landslide accumulation zones. The disposition of recent landslide features shows 92.5% of failures are witnessed over palaeo-landslides, indicating their strong reactivation. Thus, the identification and mapping of such palaeo-landslides, along with engineering geological and landslide activity maps, will be beneficial for development purposes and landslide risk reduction.

Keywords: Palaeo-landslides, Stream Power Index, Chakwa *Nala*, Main Boundary Thrust, NW Himalaya

INTRODUCTION

Mountains and their accompanying slopes are complex physiographic structures, formed by diverse processes and materials (Ollier and Pain, 2000). In high relief mountains, landsliding is one of the important mechanisms of landform evolution originating through landscape denudation and sediment transfer (Hovius et al., 1997; Nadim et al., 2013; Hu et al., 2020). The resulting landforms and deposits may act as evidence of the prehistoric or palaeo-landslides, which have been reported globally from Pleistocene to Holocene (Shoaei and Ghayoumian, 1998; Philip and Ritz, 1999; Mather et al., 2003; Strasser and Schlunegger, 2005). However, records of palaeo-landslides are very rare and most of them probably remain unrecognised (Clague, 2015; Grunert and Busche, 1980; Schultz and Harper, 1996). Many of these palaeo-landslides continue to reactivate every year during rainy seasons or an earthquake, thereby resulting in loss of life and property (Burns 2002; Jibson 2005; Reichard 2011; Mahmood et al., 2015). Therefore, it becomes imperative to identify and map such palaeo-landslides for identifying potential future failures, and thereby minimising the associated risks (Kehew, 2006; Burns, 2013; Clague, 2015).

Areas of potential slope instability, i.e., active landslides, are easily demarcated by the tell-tale signs of mass wasting (Mohan et al., 2020). However, palaeo-landslides are quite challenging to identify from the ground as well as from aerial and satellite imagery, due to the loss of their distinctive landslide morphology through subaerial aggradation processes with time (Mather et al., 2003; Garriss, 2019). In such zones, vegetation reclaims the landslide deposit and obscures its surface morphology. Therefore, for recognition of palaeo-landslides, evidences from morphological, topographical, and landform characteristics need to be identified.

The Kashmir Himalaya, forming part of the NW Himalayan fold-thrust-belt, is under constant landslide threat attributed to its inherent high relief, steep gradient, highly deformed terrain, and fast approximately 4.5mm year^{-1} upliftment (Jehan and Ahmad, 2006; Sana et al., 2024). The area also experiences frequent moderate to major earthquakes, heavy rainfall, and snowfall, acting as triggering factors for most of the landslide occurrences (Nanda et al., 2021, Mir et al., 2024). During the last two decades, developmental activities have tremendously increased in the Himalayan states, often at the expense of the region's delicate geo-environmental conditions.

The present study deals with the reactivation of palaeo-landslides in the Batote-Baglihar area adjacent to the regional Main Boundary