Paleo landslide reactivation and threat to the people in the Nepal Himalaya

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Abstract: Landslides are significant natural hazards influenced by factors such as rainfall, earthquakes, and human activities, posing severe risks to communities, particularly in the Nepal Himalaya. This study focuses on the reactivation of ancient landslides in Sindhupalchwok, Nuwakot, and Rasuwa Districts, where 114 distinct landslide deposits were reactivated during the monsoon season between 2019 and 2023. Field surveys identified and analyzed the geological and socio-economic factors contributing to this phenomenon. Laboratory tests on disturbed soil samples revealed low cohesion values (3 to 10.5 kPa) and a plasticity index of 3 to 7, indicating the soil's vulnerability to deformation under saturated conditions. Additionally, increased rainfall (ranging from 2300 mm to 3200 mm) and seismic activity, particularly the 2015 Gorkha earthquake, have exacerbated instability. The study highlights the threat to 287 houses and 792 individuals residing on these landslide deposits, underscoring the urgent need for effective risk mitigation strategies to enhance community resilience against future landslide events.

Keywords: ***Landslide reactivation, settlement threat, Nepal Himalaya, soil investigation*.**

Introduction

Landslides are natural hazards that occur when soil, rock, or debris flows downhill under the influence of gravity (Varnes 1978). Various factors contribute to their occurrence, including rainfall, earthquakes, and human activities such as deforestation and construction. The monsoon season in Nepal typically brings heavy rains, leading to saturated soil conditions that can destabilize slopes (Dahal 2012).

The reactivation of old landslides has increasingly become a pressing issue in the Nepal Himalaya, particularly in regions like Sindhupalchwok, Nuwakot, and Rasuwa Districts. Many communities have long inhabited areas atop historical landslide debris, unknowingly exposing themselves to the persistent threat of reactivation. This study investigates the deformation mechanisms of reactivated landslides and the consequent risks faced by residents in these districts, particularly between 2019 and 2023.

During this period, an alarming number of one hundred and fourteen distinct ancient landslide deposits were reactivated during the monsoon season. The increasing frequency and intensity of monsoon rains, combined with geological and human factors, have led to a heightened risk of landslides. This research not only emphasizes the geological parameters influencing these reactivations but also underscores the socio-economic vulnerabilities of the communities affected.

Study Area and Methodology

The study area encompasses Sindhupalchwok, Nuwakot, and Rasuwa Districts, which are characterized by a complex interplay of geological and climatic factors conducive to landslides. Both remote sensing and extensive field surveys were conducted to identify and analyze reactivated landslides. A community survey and focus group discussion were conducted to ascertain the occurrence dates of certain unreported landslides.

Data Collection

The data collection involved, field survey, soil sampling and strength test. Landslide deposits and areas affected by reactivation of landslide were identified. Disturbed soil samples from twenty major reactivated landslides were collected for laboratory analysis. Multistage direct shear tests were conducted on unsaturated soil samples to determine shear strength parameters. Casagrande plasticity chart was used to classify the soil after doing liquid limit and plastic limit test. Seismic and precipitation data from 2010 to 2023 were collected to determine an association with reactivated landslide data.

Analysis and Result

The shear strength tests revealed important characteristics of the soil samples obtained from reactivated landslides:

Cohesion Values: Ranging from 3 to 10.5 kPa, indicating low cohesion.

Internal Friction Angle: Varies between 19 and 29 degrees, further indicating instability.

Plasticity Index: Ranged from 3 to 7, suggesting that the soils are not highly plastic.

Soil Composition: The gradation study classified the soils primarily as clayey sands (SC) with low plasticity and low cohesion.

There is no significant peak in the shear stress versus horizontal displacement curve which revealed that the soils are loose in nature (Fig.1). Similarly, the shear strength of the sampled soils is below 40 kPa.

These properties suggest that the soils are prone to deformation, particularly under saturated conditions during heavy rainfall.

The average rainfall during the monsoon season from 2010 to 2023 ranged from 2300 mm to 2800 mm, with a notable increase in early monsoon rainfall observed since 2019. The total rainfall during the monsoon period experienced a significant increase, reaching up to 3200 mm in Sindhupalchwok district, while Nuwakot district saw its rainfall peak at 3050 mm in 2023. The extreme rainfall events, particularly those occurring during the pre-monsoon period after an extended dry season, have contributed significantly to surface deformation in the study area.

The 2015 Gorkha Earthquake of 7.8 magnitude, along with its aftershocks, exacerbated the situation by loosening rock formations and destabilizing slopes. The combination of seismic activity and heavy rainfall has created a precarious situation for residents living atop these ancient landslide deposits. The number of reactivated landslides rose from 2015 to 2017; however, there was a notable increase in landslide reactivation from 2020, despite the absence of significant seismic events, attributed to a rapid increase in rainfall during the monsoon period (Figure 2 and Figure 3).

The socio-economic implications of landslide reactivation are profound. The study identified that a total of 287 houses and approximately 792 individuals are currently under threat from potential paleo-landslide reactivation in the affected districts.

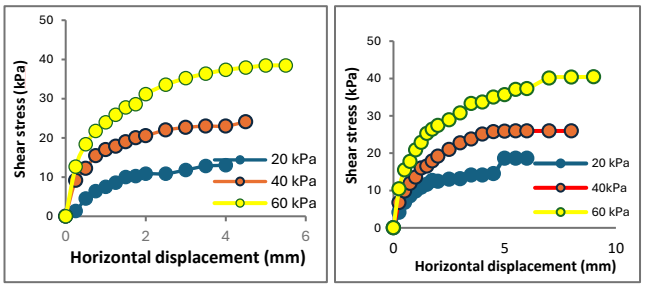

Figure 1: Shear stress versus horizontal displacement curve of two representative soil samples.

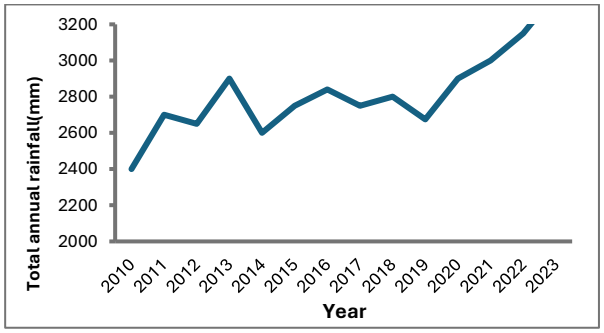

Figure 2: Year wise distribution of earthquake magnitude and reactivation events

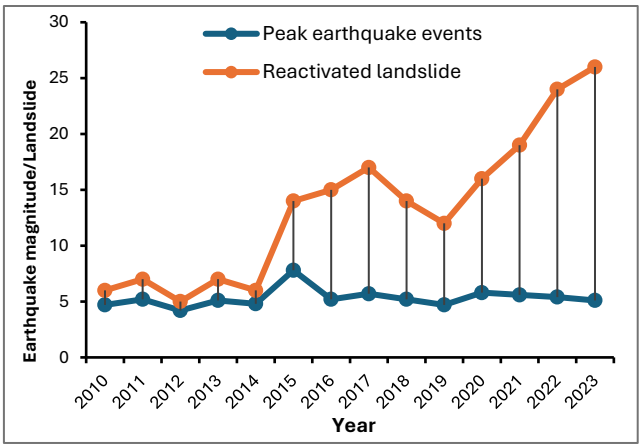

Figure 3: Average of total annual rainfall distribution in three districts

Conclusion

The reactivation of old landslides in the Sindhupalchwok, Nuwakot, and Rasuwa Districts poses a significant threat to local communities, exacerbated by increasing rainfall and seismic activity. The analysis of soil characteristics and rainfall patterns underscores the vulnerability of these areas and highlights the need for targeted interventions.

As many residents continue to live atop ancient landslide deposits, it is imperative to implement comprehensive risk mitigation strategies that include community education, monitoring systems, and effective land-use planning. Addressing these challenges will not only protect lives and property but also enhance the resilience of communities against future landslide events in this geologically complex region.

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