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RESEARCH ARTICLE

The ground based geological assessment of an active landslide: A case study of Jharlang Landslide in Dhading district, Lesser Himalaya, Central Nepal

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ABSTRACT

Jharlang Landslide, also known as "Jharlang Pairo," is a large-scale, ongoing landslide that is situated in the northwest of the Dhading District. This article provides a detailed geological assessment and evaluates the causes, consequences and general mitigation plan of the landslide. The overall study of the landslide was carried out by desk study and field investigation. Field work was carried out to gather pertinent data and information about slope failures. The primary methods of evaluation are knowledge-driven approaches, kinematic analysis, visual inspection, satellite image interpretation, and topographic maps interpretation. The study facilitates comparative analysis through previous studies, satellite images and field observation. The study area is located in the Lesser Himalayan region in Central Nepal. The dominant lithological units in this area are Meta-sandstone, Ulleri Augen Gneiss and phyllite. The constant risk of the landslide to the local people and damage of farmed land and infrastructures is increasing. The area has been impacted by the "2015 Gorkha Earthquake," which has caused new tension cracks to emerge, slope failures to increase, and landslides to spread toward neighboring settlements. Slope failures in different dimensions are caused by the area's brittle, high density soil masses that lay on top of the weathered Ulleri Augen Gneiss, phyllite, and meta-sandstone.

The Jharlang Landslide is a composite of debris flows, debris slides, and rotational slides. The potential and weak section are mostly located in NE and SW direction of the study area. The tension cracks are noticeable that extend towards the villages. The result of the study exhibits weak geological condition, lithological composition, tectonic activity, oversaturation of soil mass, high precipitation and anthropogenic factors are the major causes of the landslide. According to the field assessment and the type of slope failures, the landslide is unstable, particularly during the rainy season. General recommendation incorporates structural and non-structural techniques to minimize the risk and mitigate the landslide hazard.

Keywords: ***Lesser Himalaya, Slope failures, Rotational slide, Debris flows, Ulleri augen gneiss***

INTRODUCTION

Nepal Himalaya lies at the center of Himalayan Mountain range of 2400 km. The region is geodynamically active which witness frequent and widespread landslides every year during rainy seasons. Slope instabilities are common problem in hilly and mountainous regions. Physiography of slopes, poor geological condition and triggering factors such as excessive monsoon rainfall, cloudburst and earthquakes etc. contribute to the frequency of landslides in Nepal (Paudyal et al., 2021). Landslides are one of the major land degradation processes that occur frequently in the Himalaya (Nepal et al., 2019). According to the Ministry of Home Affairs, Nepal (MoHA), approximately 230, 315 and 340 major landslides occurred in 2021, 2022 and 2023 respectively with the significant loss of lives and casualties. Landslides continue to be a terrible occurrence that obliterate human life, property, and the natural world's beauty (KC et al., 2018). Accurate evaluation and identification of high-risk locations are necessary for landslide research and mitigation initiatives (Budha et al., 2016; KC et al., 2018; Timalsina and Paudyal, 2018). Neupane et al. (2023) identified rivers for generating landslides in terrain with soft lithology like Siwalik.

Jharlang Landslide is commonly called 'Jharlang Pairo' (Fig. 1), located in Dhading District in Central Nepal. The landslide is active since 1954 AD and has been threatening to human lives. It is reported that the households near the landslide area have been resettled in the Western part of Nepal. The present study is a field-based geological assessment of the active landslide through visual inspection and observation. In this study, the landslide has been evaluated through geology of the area, lithological composition, hydrogeological interactions, rock and soil conditions and observation of slope failures. By the geological field investigation, this paper presents and discusses the associated causes and consequences of the landslide.

Numerous studies have been conducted to understand landslides from geological and geotechnical perspectives in Dhading and the surrounding districts. Ghimire et al. (2007) investigated the Ramche landslide, while Pant (2010) carried out structural analysis and geological mapping along the Trishuli Valley in Central Nepal. Thapa et al. (2007) employed a geographical information system (GIS) to perform quantitative landslide hazard prediction modelling on natural hill slopes in the study area. Dahal et al. (2006) discussed slope failures along road corridors during episodes of intense rainfall, which included parts of the current study region.

In addition, several recent studies have addressed landslide hazards across the Nepal Himalaya, geographically similar train of the present area (Paudyal et al., 2024; Acharya et al., 2023; Neupane et al., 2023; Paudyal and Maharjan, 2023; Paudyal and Maharjan, 2022; Shahi et al., 2022; Paudyal et al., 2021; Budha et al., 2016 and 2020; KC et al., 2018). Among these, Paudyal and Maharjan (2023) mapped landslide susceptibility in the Main Boundary Thrust zone in Arghakhanchi and Palpa districts, emphasizing the influence of geological structures on slope stability. Similarly, Acharya et al., (2023) identified active faults—such as the Badi Gad Fault—as a significant triggering factor for landslides.

Fig. 1: Satellite image of Jharlang Landslide and proximity of landslide to nearby villages (Source: Google Earth Pro 2024)

MATERIALS AND METHODS

Study Area

Jharlang Landslide is located in Dhading district which is approximately 250 km North West from Kathmandu Valley (Fig. 2). The study area has latitude 28˚07'30"N and longitude of 85˚02'30"E. The elevation of the study area is approximately 2500 m from mean sea level whereas slope varies from 20˚ to 55˚. The study area has been drained by several streams flowing from northeast to southwest direction. Ankhu Khola is the major stream whereas other small tributaries form the drainage system of this area. Geo-morphologically, the area is rugged, slightly steep to gentle hill slopes. The crown section of the landslide is covered by trees and cultivated land and characterized by unconsolidated sediments and highly weathered rocks.

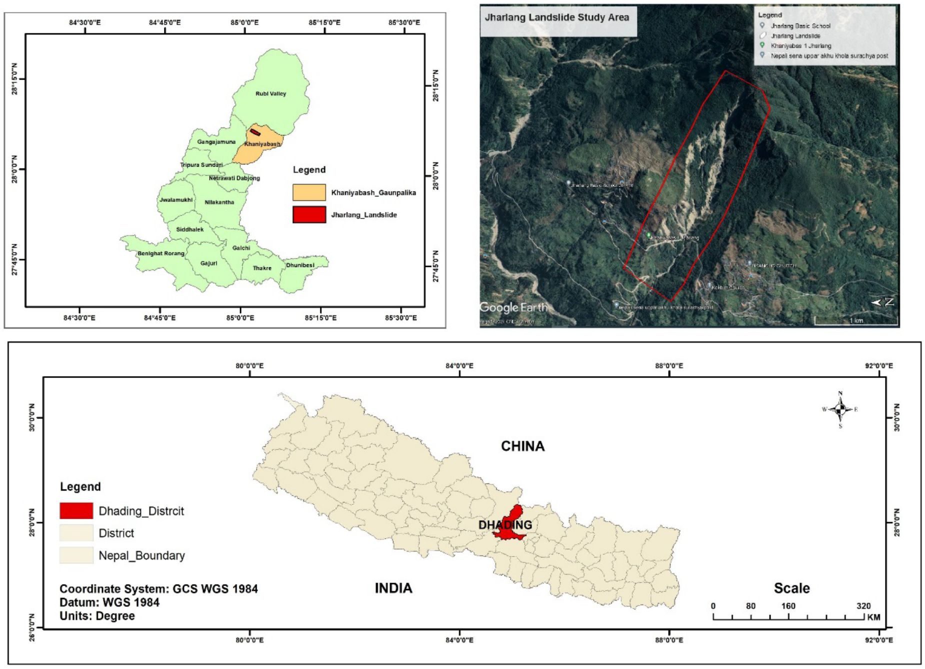


Fig. 2: Geological map showing the study area

According to Stöcklin and Bhattarai (1977), the research area is located in the Kuncha Formation, which is the oldest unit in the Lesser Himalaya. The Formation is composed with metasandstone, metaconglomerate, phyllite (psammatic and pellitic) and lesser proportion of quartzite (Fig. 3). One of the major lithological compositions in the study area is Ulleri Augen Gneiss. Highly crushed and deformed rocks and shear band of black clay (approximately 3-5 m width) were observed at the middle and toe sections of the landslide (Fig. 4 a). It indicates the area is affected by the seismic activities. Furthermore, alternating bedding sequences of metasandstone, phyllite and schist prevail slope failures in the study area (Fig. 4 b).

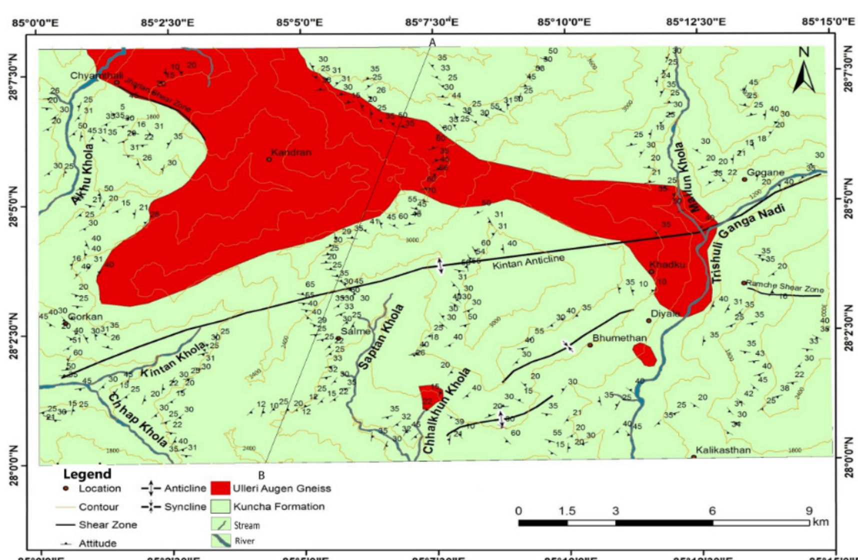


Fig. 3: Geological map of the study area and the landslide area is shown by the yellow enclosed boundary (KC et al., 2019)

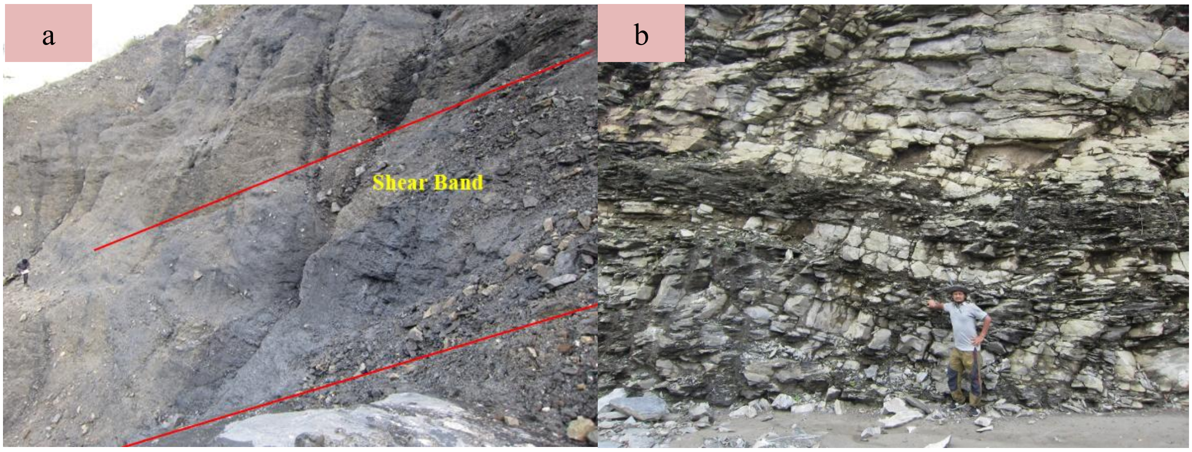


Fig. 4: Outcrop view of (a) Shear band interlayered with highly weathered rocks at the middle of the landslide and (b) metasandstone alternately bedded with schist and phyllite near the study area

Methods

Present study of the Jharlang Landslide focuses on geological implications, dimension and current status of the landslide, slope failure condition, propagating trend and the consequences that local people are facing. Two phases of the study were conducted: a desk study and a field inquiry.

Desk Study

During desk study, the landslide, erosional features, tectonic structures, land use pattern and lithological units were reviewed through aerial photographs, topo maps (issued by Survey Department) and google maps etc. Along with aerial photos, a 1: 25,000 scale topographical map served as the foundation map for gathering field data. Reports and maps pertaining to geology were also examined.

Field Investigation

Several traverses and walkover surveys were carried out in several landslide sections as part of the field study to assess the slope instability and its geological relationship. During the field investigation, along with the geological study, morphology of the landslide was examined. Additionally, hydrogeological phenomena, landslide dimension, newly formed cracks and subsidence, condition of rock and soil etc. were also determined. Similarly, the nature of the slide was classified based on the nature of flow, types and properties of materials present in the study area. To understand more about the landslide's nature, anthropogenic causes and its consequences interviews were conducted with the local people. The field investigation was concentrated mainly in three sections of the landslide i.e. crown, body and the toe. To evaluate the rock slope stability condition, kinematic analysis was performed by the discontinuity data from the rock outcrop positioned at the body of the landslide.

Moreover, field studies facilitate the actual scenarios of the area. It helps to identify the different attributes of landslide origination, its current status and activeness, propagating trend etc. Similarly, various consequences and damages that is incurred by the landslide were noted and tried to identify the mitigation measures and adaptation system for the local inhabitants. Field study was one of the crucial periods to collect different data and information of slopes, discontinuities, orientation of beds, slope gradient, types of failures, and structural relationship with the slope failures. It also supports to verify the collected data, reviewed materials with the actual condition of the landslide.

JHARLANG LANDSLIDE

Jharlang Landslide is one of the large and active landslides which is situated in the upper region of the Dhading District in Nepal. The landslide affected area is about 4 sq. km. It is regularly propagating in NE-SW direction. It is one of the renowned landslides in south Asia and has long history of its origination. The mostly affected villages are Chhyamthali, Kalmarn and Jharlang Gaon. Human settlements of these areas are at high risk of the landslide. More than 100 houses in the periphery of this landslide are at high risk. It is being propagating sharply towards the Chhyamthali Village. Most of the slope failures occurred due to intense precipitation and ground water flow during monsoon season, weak rock–mass and lack of bed rock support (Fig. 5). The average annual precipitation around the study area in 2023 published by Department of Hydrology and Meteorology is ranges from 1500-2000 mm (Fig. 6). Main features of the landslide are presented in Table 1.

Fig. 5: Wide view of multiple scarps of the Jharlang Landslide

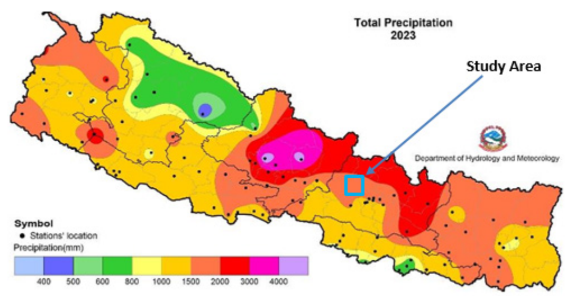


Fig. 6: Total annual precipitation (published by the Department of Hydrology and Meteorology in 2023)

Table 1: Main features of Jharlang Landslide

length	2.0 Km (approximate)
Width	1.5 Km (approximate)
Area	4.0 Sq. Km (approximate)
Slope angle	30°-50°
Type of failures	Rotational slide, debris slide and debris flow
Depth of failure	0.2-2.5 m
Mechanism of failure	Shear failure
Activity	Active
Rock Type	Ullleri Augen Gneiss, meta-sandstone and phyllite
Soil Type	Colluvial soil
land cover/use	Bare rocks, cobbles, pebbles, sand, cultivated land and sparse vegetation

Triggering causes	High precipitation and high degree of loose unconsolidated sediments.
Impact	Damage of settlements, declination of cultivated lands, destruction of foot trails and vegetation
Direction of propagation	North east and north west
Geometry of slope	Concave and nail scratching type

Consequences of Jharlang Landslide

On the basis of field study, the overall consequences of the landslide were drawn which are continuous weakening of the landmass, washing out the fertile and residential areas, damage of houses, water sources, vegetation, roads and foot trails. Unconsolidated materials and over saturation enhance the slope failures.

Symptoms of the landslide propagation

Landslide propagation towards residential areas is one of the main concern depicted by this study. Several prominent tension cracks, sliding and subsidence at crown and middle of the landslide were reported during field observation (Fig. 7). Additionally, tilting of trees, sliding and detachment of soil mass due to percolation of rainwater indicate active movement of the landslide.

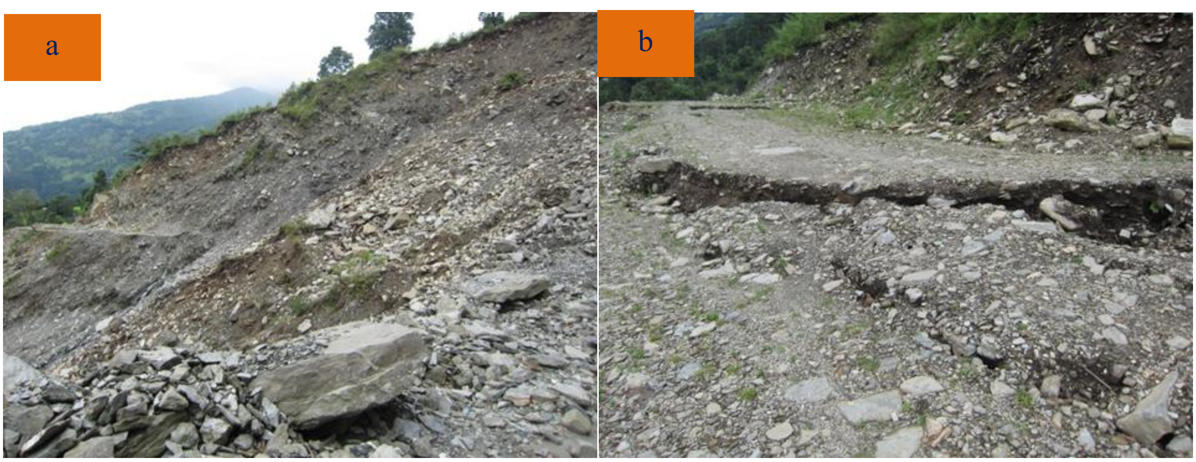


Fig. 7: (a) Slope failures blocking the foot-trail and (b) land subsidence (approximately 20 cm) near the landslide area

GEOLOGICAL INVESTIGATION AND SLOPE STABILITY RISK EVALUATION

Geologically, the Jharlang Landslide is located in the soft soil over the Ulleri Augen Gneiss, meta-sandstone and Phyllite (K C et al., 2018). Ulleri Augen Gneiss and phyllite are highly weathered whereas meta-sandstone is comparatively intact in the area. The landslide characterizes with rupture curved concavely upward indicates rotational slide (Fig. 8a) as defined by Varnes classification (1978). Field observation clearly shows that the landslide has unsorted and unconsolidated soil materials with limited bedrock support at the lower section of the landslide triggering for the debris flow during oversaturation. Debris deposit consist of unsorted materials of clay, silt, pebbles, cobbles and boulders of which cobbles and boulders are made up of the Augen Gneiss and meta-sandstone with rock fragments. Sliding soil mass with multiple newly generated tension cracks is profoundly distributed. Some boulders are up to 5-10 m in diameter.

During intensive monsoon rainfall in combination with surface runoff and water drain through cracks of slopes oversaturate the soil mass leads to slope failures. It has several slope failures occurred along with sliding blocks of soil mass and accumulation of boulders came at the toe from the upper portion of the landslide. Bedrock exposure is limited in the area. Highly deformed and weathered bed rock of phyllite, metasandstone and Ulleri Augen Gneiss are exposing at the body (center) of the landslide (Fig. 8b). Initially, the slope failures triggered in the uppermost part then seepage, tectonic movements, unplanned cultivation and deforestation give rise to debris flow and slide of the whole soil mass around the area.

Fig. 8: (a) Typical morphology of the landslide illustrating origination of new landslide, reactivation of old landslide and new cracks around the area and (b) Rock exposure at middle section of the landslide.

RESULTS AND DISCUSSION

Jharlang Landslide is a large and well distributed in the region. The trend of its propagation, regularly developed tension cracks and slope failures register great threats to the villages like Chhyamthali Village, Jharlang Gaon and Kalmarn Village. Based on the study and site investigation, it is clear that the landslide is supposed to be one of the great threats to the local inhabitants. Basically, the study was made based on various facts and information collected by various means such as documents, geological maps, news articles, satellite images and field investigation. Field study was major part of this study where geological assessment was conducted to find out the causes and consequences of the active landslide.

Causes of landslide

The geology of the area has remarkable cause of the landslide. Geological assessment deals with the study of the lithology, structural features, rock and soil mass condition, orientation of beds, weathering pattern etc. According to According to Dahal (2012) analysis, fine-grained soil mass, low internal friction angle, abundance of clay minerals, and bedrock hydrogeology are the prominent geological causes of the landslide. Geologically, the landslide area lies in the Kunchha Formation where phyllite, meta-sandstone and Ulleri Augen Gneiss are the major rock types (Fig. 9). Highly deformed and weathered Ulleri Augen Gneiss and phyllite prevails greater susceptibility for the slope failures (Fig. 10). Additionally, the unconsolidated soil materials with limited rock exposure around the area also aid to the slope failures.

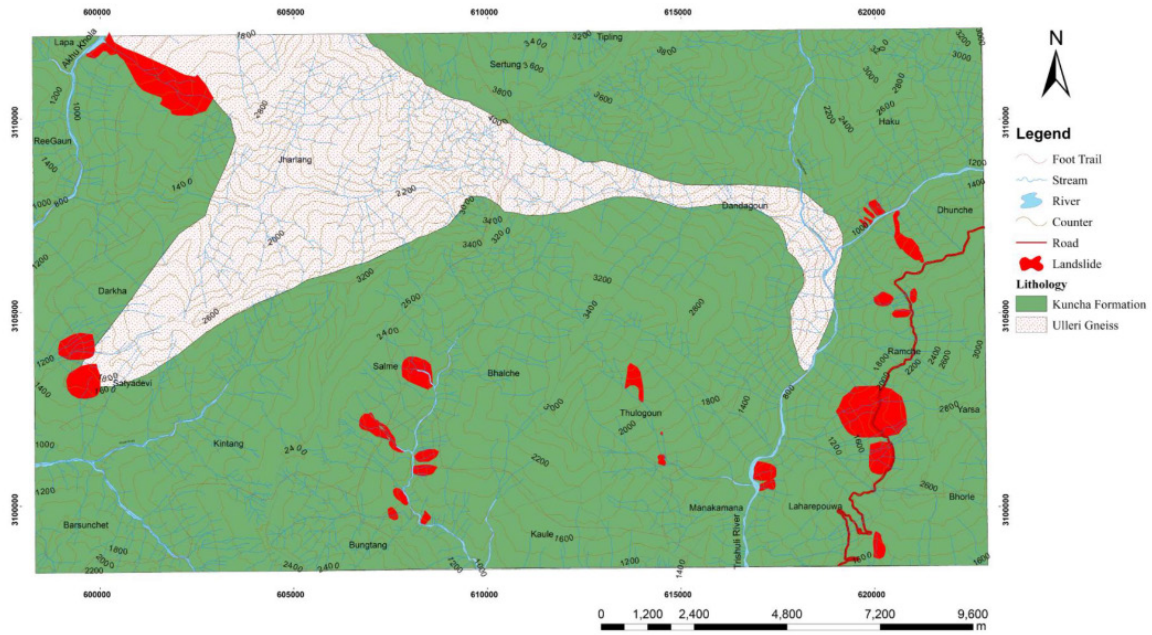


Fig. 9: Landslide inventory map of Ramche-Jharlang area indicating the Jharlang landslide by yellow boundary (KC et al., 2018)

Fig. 10: Outcrop view of weathered Ulleri Augen Gneiss and phyllite near the landslide area

Kinematic analysis was executed for identifying the mode of slope failures and slope stability analysis. Representative orientation of bedding and discontinuities were measured from the proximity of the landslide and were plotted in stereographic projection (Fig. 11). In the stereographic projection, three joint sets are formed including foliation plane i.e. F/J1, J2 and J3. There are two critical wedges are formed by the intersection of J1 and J2 and J1 and J3 which are in day light condition. From the kinematic analysis, it can be analyzed that the landslide area is prone to wedge failures.

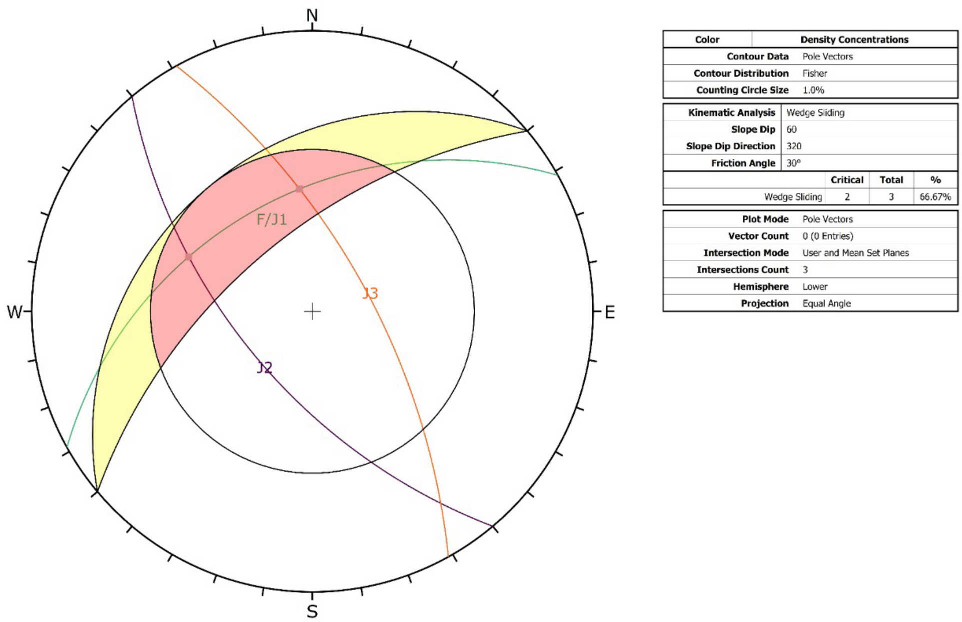


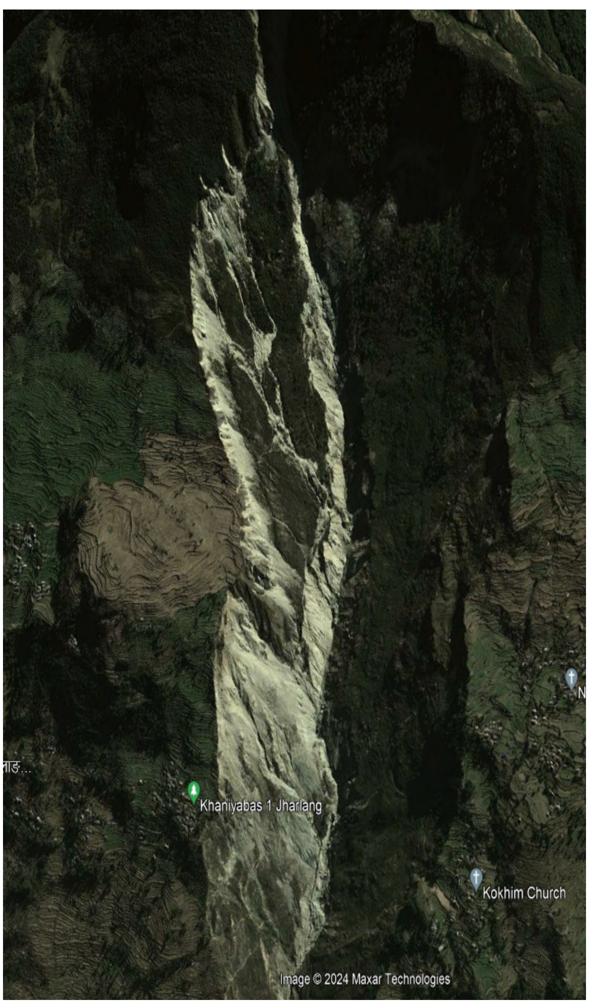
Fig. 11: Representative stereographic projection of discontinuities in rock-mass exposed at the main body of the landslide

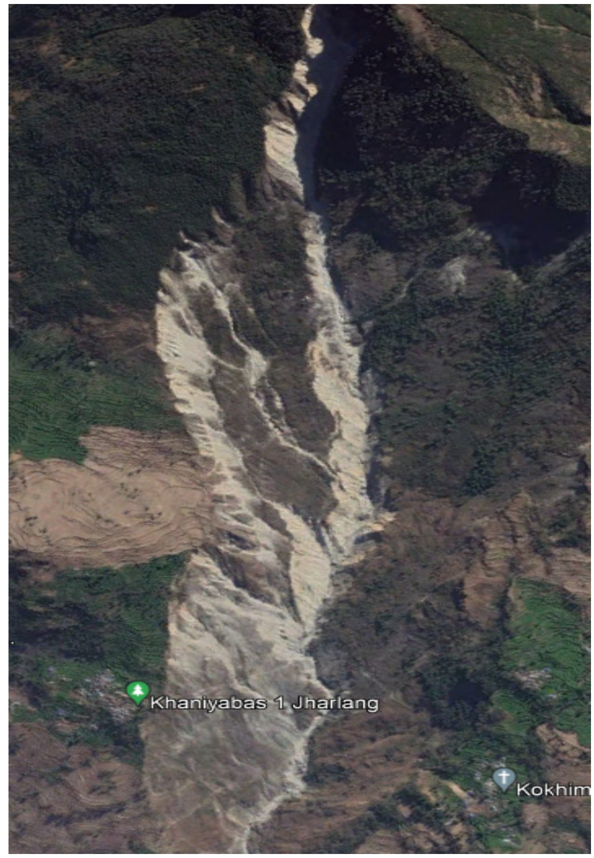
In the landslide area, slope failures are concentrated at NE and SW directions. Core information of the landslide based on field observation are tabulated in Table 2.

Table 2: Core information of the landslide based on the field observation

Observation	North-East	South-West
Number of slopes failures	10	15
Distance to proximity of villages	100 m	200 m
Type of slope failures	Debris Slide and Debris flows	Rotational slide with debris flow
Length of tension cracks	1-10 m	1-15 m
Depth of tension cracks	3-15 cm	5-30 cm
Displacement of cracks	1-2 m	1-3 m
Water content	damp to wet	damp to wet
Landslide susceptibility rating	moderate to high	moderate to high

Overall study shows that Jharlang Landslide is a combination of rotational slide, debris slide and debris flow and shows perceptible movement during rainy season. Debris flows are considered to occur more commonly in coarse-grained soil and on steeper slopes while the debris slides are more likely to occur in medium textured soil with a mixture of sand and mud in steep to gentle slopes. Slope failures have been exacerbated by human action, such as haphazard settlement, haphazard farming practices, deforestation etc. Comparative study of the landslide can be observed from 2011 to 2015 (Fig. 12). It shows gradual rise of the slope failures with the development of new tension cracks in northern portion and gaining natural stability in southern portion.





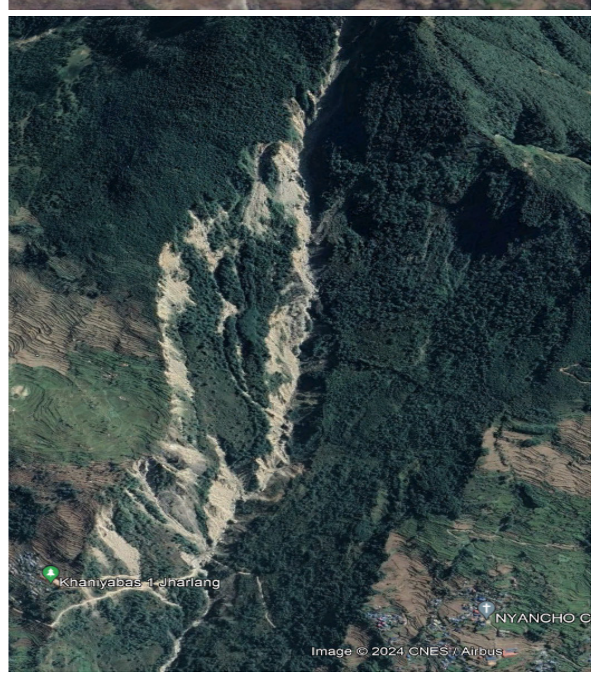


Fig. 12: Illustration of changing of the landslide from 2011 to 2024 (Source: Google Earth)

GENERAL RECOMMENDATION OF THE LANDSLIDE MITIGATION

A thorough understanding of the unique physical traits and mechanisms causing landslides in each location is essential to assessing the risk of landslides (Paudyal et al., 2024). Considering the slope failures and ruptures, generation of tension cracks and propagating trend, damages etc. landslide prevention and controlling works should be implemented. In other words, with the vulnerabilities and risk of the landslide there need to be mitigation measures should be formulated to save lives and properties. Based on the detailed geological studies and relevant findings of Jharlang Landslide, various reliable mitigation measures can be adopted.

In order to reduce future risk of the landslides, both structural and non-structural measures are recommended. Shallow and deep drainage wells would be the most effective measures to control surface and sub-surface flow of water. Surface runoff is captured by shallow drainage, which guides it away from potentially unstable locations. Bio-engineering could be done at upper and middle parts of the landslide. It will help to stabilize the agricultural lands. Similarly, to protect the cultivated lands, terrace farming is suggested. Other geotechnical in-situ testing, drilling and laboratory investigation of rocks and soil is important for in depth remedy for slope instability. In addition to structural mitigation measures, it is equally important to educate people regarding landslide, conducting public awareness and disseminating experiences to the communities. These are some of the non-structural counter measures to fight against the challenges of the hazard.

CONCLUSION

Landslide is one of the common natural disasters that Nepal is facing each year with loss of lives, properties and natural beauty. Jharlang is one of the active, large scale and catastrophic landslide in the Lesser Himalaya. Geological field assessment, knowledge based approach, kinematic analysis, visual observation, satellite image and topographic maps analysis are the primary methods of evaluation. It has been studied that the landslide occurred due to weak geological condition, high topographical relief, unconsolidated sediments, active hydrogeology, unscientific cultivation and anthropogenic causes. Kinematic analysis at the middle section of the landslide exhibit critical wedge failures that also contribute for the landslide. The area possesses thin to medium foliated, highly deformed, moderate to highly weathered phyllite, metasandstone and Augen Gneiss. Additionally, the evidences of shear bands encountered at the bottom of the landslide prevails the area has been affected by the historical seismic activities. Overall study shows the landslide is combination of rotational slide, debris flow and debris slide.

The activeness of the landslide can be observed by the newly formed tension cracks and land subsidence around the study area. The landslide propagation towards the adjacent villages registered great threats among the locals. To stabilize and control the mass movement, various prevention and general mitigation measures are suggested. Drainage ditches, drainage wells and support structures seems necessary. Likewise bioengineering technique can be adopted to stabilize the landslide and cultivated lands lying nearby. Geotechnical in-situ testing, drilling, laboratory investigation and continuous monitoring are essential attributes for long term slope stability. Similarly, public awareness and more detail study are some of the non-structural countermeasures to mitigate the hazard in future.

Present study is focused on the causes, consequences and general mitigation measures of the landslide. We wish this study will be helpful to understand the root cause of the landslide and to formulate effective management plan to mitigate the landslide at present and in future.

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AUTHORS CONTRIBUTION

All the authors have made remarkable contribution to preparing this research article. JKC has prepared the study concepts and design of the research. JKC, DG, PN, SD have the role for field observation, data acquisition and data analysis. Dr. Kabi Raj Paudyal contributed in the verification of data and review of the article. The first draft of the manuscript was written by Mr. Jharendra K.C. and all the authors supported to making the draft form of the manuscript into the final version.

CONFLICT OF INTEREST

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon a reasonable request.

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