Influence of fold and foliation direction in the occurrence of large-scale landslides in the Nepal Himalayas

Large-scale Landslides, Fold, Foliation Direction

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1. Introduction

The intercontinental collision between Indian and Eurasian continent which continues today has caused the leading edge of Indian continent i.e. Nepal to fold and bend into various stages. As a result of which variety of mountain ranges from moderate hills to Higher Himalayas has been formed in Nepal as shown in Fig 1. Seismic activity with fragile topography and geology has caused the mountain slope of Nepal in incipient failure state condition. Relief ranging in kilometers caused the large scale valley creeping due to gravity prolonging from the early upliftment. In addition adverse climatic condition and haphazard development activities are playing vital role in making the unstable topography to fail in the form of landslides. Varieties of landslides do occur in Nepal every year but, in this paper deep-seated large-scale landslide are only considered as they are closely related to geological structures like bedding plane, foliation, joints and faults etc. Nevertheless, the relationship among the tectonic, geological structure and landslides are poorly known. In this paper, the distribution of large-scale landslide and their relationship with tectonically produced geological structures such as fold and foliation are investigated.

The purpose of this study is to determine the influence of the geological structure (fold geometry) along with topography on the large-scale landslides occurrence with the use of directional information (dip and strike) of rock and landslides.

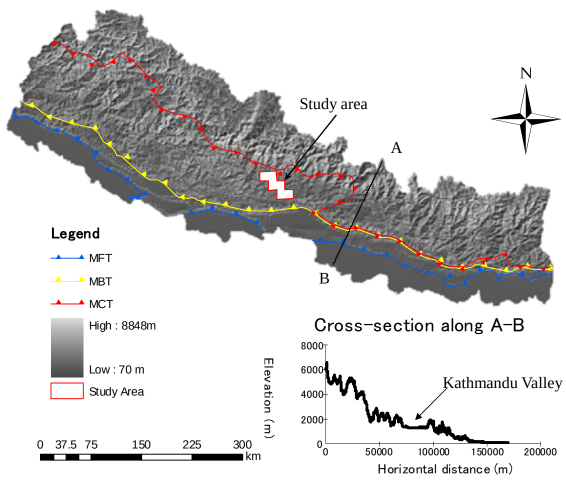

Fig.1 Topography of Nepal

2. Geology and geological structure of the study area

The study area lies in western development region of Nepal (Fig. 2). It accommodates some portion of Prithivi Highway which connects the capital city of Kathmandu to Pokhara, a famous tourist destination. Fig. 2 indicates phyllite quartzite, slate, dolomite, and alluvial deposits are the dominant rock types. The rocks in the study area; portion of the mega anticline Trisuli-Gorkha-Pokhara are folded into east west orientation (Uprety 1999). Numerous small folds are found inside the mega fold (Upreti 1999). Folding results many thrust fault and weak planes and can be seen in between the folds. Thrust fault and lineament also have east-west or N-W to S-E orientation. Landslides are found concentrated along these fault, thrust or weak plane lines.

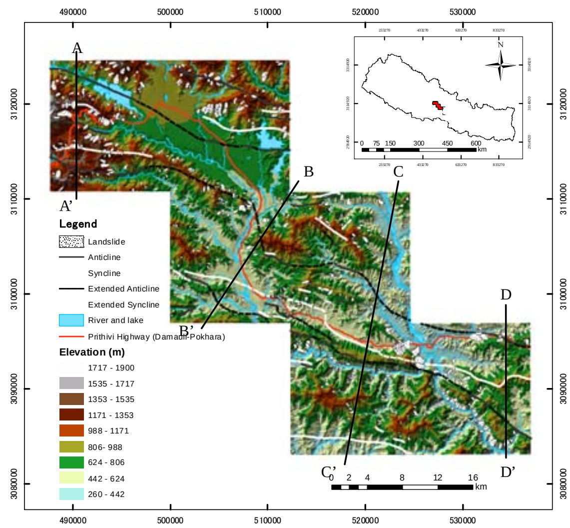

Fig: 2 Location of study area

3. Material and method

Folding structures are very old geological structure i.e. the initial process of mountain building and very difficult to analyze as they changed a lot with time. So, a simple method to determine the underlying rock orientation and comparing with the present topography was done. A fold map is prepared by digitizing the foliation axis present in the geological map as shown in Fig 2. Cross sections through four different points were made using GIS and approximation of present topography and underlying rock using the contour and foliation map was prepared. In addition landslide locations are also marked on the cross-section to determine the influence of topography and rock orientation (Fig. 3 and Fig. 4). These cross-sections at four points indicate rough information on how similar orientation of underlying rock and present topography are leading to the occurrence of most of landslides. Then, some geological analysis in the form of

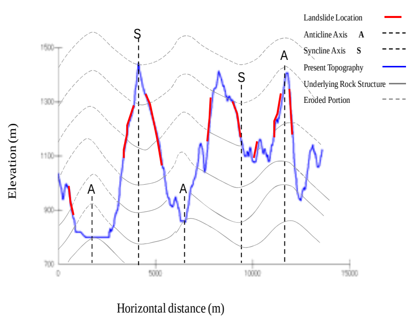

Fig.3 Section A-A'

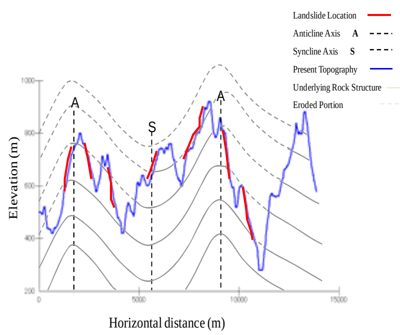

Fig. 4 Section B-B'

stereographic projection and rose diagram of rock and landslides orientation was done to understand the influence of folding and foliation direction in detail. In order to accomplish this task a database of dip and strike of the rock formations and landslides were prepared and compared. For this, most frequent rock type of rock in the study area, i.e. phyllite and quartzite zone were selected, and dip and strike information are collected from the rock map of the study area. In case of landslide, length direction was considered as the dipping direction and average slope of landslide as dipping angle. Similarly, the breadth direction of the landslides was considered to represent the strike of landslides. After calculating the dip and strike of landslides and Phyllite-Quartzite zone, stereographic projection (Schmidt Net of equal area), rose diagram and density plot of stereographic projection were prepared using a geological software 'Molestereo' and compared.

4. Results and Discussion

Four cross sections as shown in Fig. 3, and Fig. 4, respectively indicates that about 60 % of total landslides are found where the rock and the topography are dipping in the same direction. Whereas landslides are found in anti-dipping direction also but most of them are smaller in size comparing to the landslide occurring in similar dipping direction. Comparison of rose diagrams (Fig. 5) between the landslides and the rock formation indicates that most of landslides show similar orientation as posed by the rock-formation. Similarly, comparison of stereographic projection (Fig. 6) and density plot (Fig. 7) also indicate that landslide possess similar trend as posed by the rock type. This similar orientation of landslides clearly indicates the relation between the rock orientation i.e. the fold geometry (direction and inclination). However, this study does not clearly explain about why the landslide are having similar direction and dipping trend as posed by the rock type. It needs further detail data to explain the reasons behind the similar trend of landslides and rock type. Similarly, an analysis on the landslide that is occurring in the dipping topography was done and found out that they are mostly found in the relief of range 500-1000. As the relief increases, percentage of large area landslide is increased as shown in Fig 8. Landslides possess similar orientation and dipping angle as posed by rock indicates the clear influence of folding and foliation direction of rocks in the landslides occurrence. Thus, this study provides some additional information on geological structures (fold geometry) and indicates that orientations of landslides are governed by the rock formation orientation in the considered area.

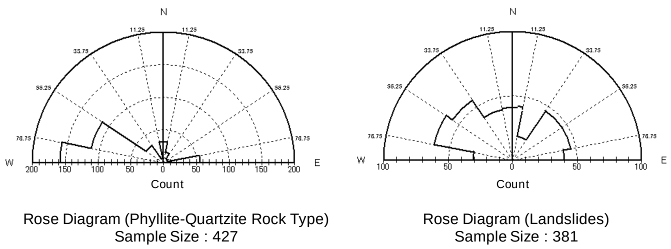

Fig.5 Comparison of rose diagram

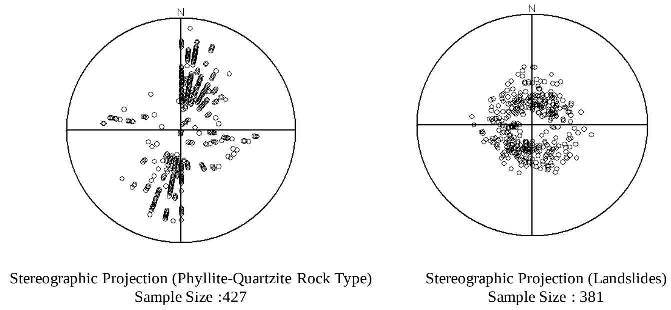

Fig. 6 Comparison of stereographic projection

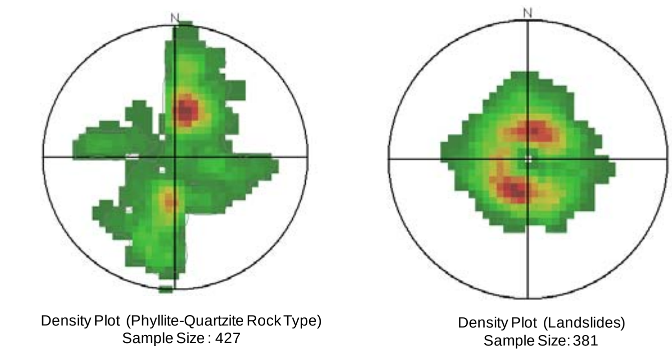

Fig. 7 Comparison of density plot

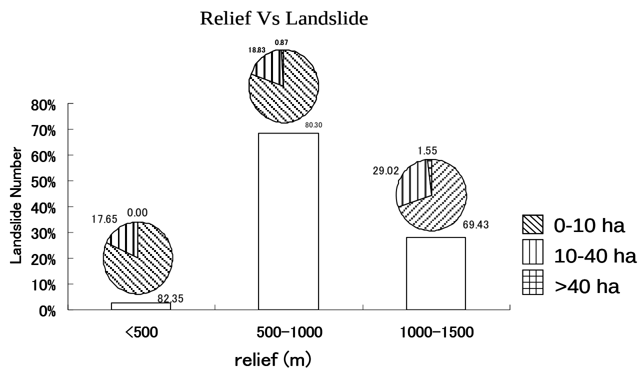

Fig. 8 Relief Vs landslide occurring in dipping direction and area of landslide

5. Conclusions

Landslides possess similar orientation and dipping angle as posed by rock indicates the clear influence of folding and foliation direction of rocks in the landslides occurrence. Similarly, the landslides occurring in dipping direction are found mostly in 500-1000 m relief range and landslide area increase with increase in relief. Thus, this study provides some additional information on geological structures (fold geometry) using the orientation data of rock in the form of dip and strike and indicates its influence in the occurrences of landslides.

References

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