DISCRIMINANT ANALYSIS OF EARTHQUAKE- INDUCED LANDSLIDES HAZARD IN NEPAL

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Seismicity of the Nepal Himalayan region is considered to be high based on the frequency and strength of the past earthquakes. During the past ~100 years, three great earthquakes were occurred along the Himalayan front. From east to west, the sequence includes the 1905 Kangra earthquake (Mw ~7.8), the 1934 Bihar-Nepal earthquake (Mw = 8.1), and the 1950 Assam earthquake (Mw ~8.6). After 1934 Bihar-Nepal earthquake in Nepal, seven major earthquakes hit Nepal. The last earthquake was Sikkim/Nepal border of September 18, 2011. In this earthquake, 14,544 houses damaged (6,435 completely destroyed), 6 people died and 30 people were injured in Nepal. During this earthquake, USGS and Department of Mines and Geology of Nepal measured the peak ground accelerations between 38 gal and 90 gal in the Koshi Highway region and 90 gal to 177 gal in the Mechi Highway region. As a result, there were many roadside slope damages along the Mechi Highway in comparison with the Koshi Highway (Figure 1). The main objective of this paper is to evaluate the earthquake-induced slope failure hazard mapping in Nepal. For this purpose, recently damaged area due to Sikkim/Nepal border Earthquake of September 18, 2011 of eastern Nepal along the Mechi Highway is selected for the study and hazard zonation map was prepared.

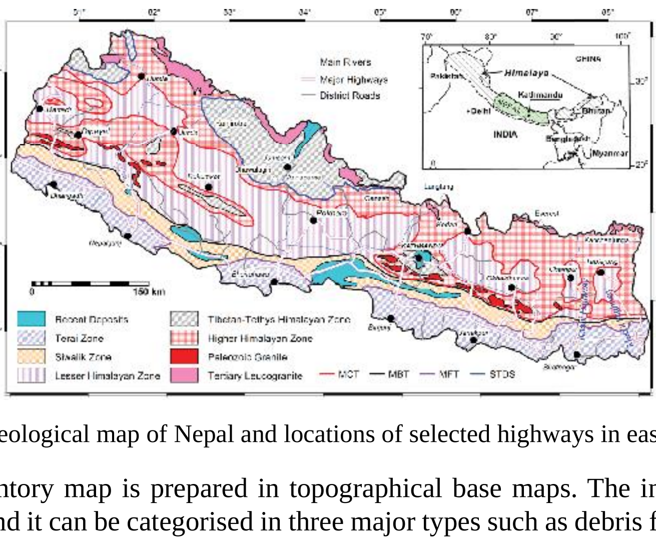

Figure 1. Geological map of Nepal and locations of selected highways in eastern Nepal

First of all, a landslide inventory map is prepared in topographical base maps. The inventory shows 35 earthquake-induced failures slope failures and it can be categorised in three major types such as debris falls, debris slides and rock falls and most of the slope failures had failure depths of less than 2 m, and mostly translational to semi-rotational movement was evident on the failure plain. The area of the slope failures ranged from 93 sq m to 10,987 sq m. The various investigations showed that topographic features are basically responsible for dissipation of seismic energy and extremely high accelerations are usually observed at sites located on topographic ridges. To evaluate topographic effect in the study area, the topographic curvature was calculated from DEM of 20 m pixel size for the Mechi Highway area and cross checked with the landslide inventory. In total 75% of earthquake-induced slope failures are found on ridge slope pixel and 25% were found on valley slope pixel. This simple evaluation clearly supports that in the Himalayan slopes also, frequency of earthquake-induced slope failure is much higher on or near the crests of hills. The method proposed by Uchida et al. (2004) was used in this study to perform an earthquake-induced slope failure susceptibility analysis within the GIS platform. Taro Uchida and his team extensively studied landslide damage in the Rokko mountain region (granitic terrain) after the Hanshin-Awaji Earthquake (Kobe earthquake) of 1995. They derived a landslide probability function based on discriminant analysis using slope, average curvature and maximum ground acceleration (Uchida et al., 2004) without considering geology and other intrinsic factors as given in Equation 1.

$$F = 0.075[\theta] - 8.9[\varepsilon] + 0.0056[a_{\max}] - 3.2 \quad (1)$$

Where, F is the landslide probability function or discriminant score, θ is the slope angle in degrees, ε is the average curvature, and slope failure is the maximum ground acceleration in gal (1 gal = 0.01 m/s^2). Pixels having positive F-value always have the potential to fail during an earthquake, and negative F-values suggest the slope will not fail during an earthquake. To check the predictive power of F for slope failure occurrence, the F-values were qualitatively examined with the help of success rate curves. In this study, the area under the success rate curve is 0.8344, indicating that the prediction rate was 83.44% (Figure 2a) and the analysis is valid. For the earthquake-induced slope failure after September 18 2011 Sikkim/Nepal border earthquake, the success rate reveals that in 20% of the study area, F-values had a high rank and could explain 64% of total landslides. Likewise, 40% of higher slope failure hazard index (LHI) values could explain 95% of all existing landslides. Finally, four slope susceptibility classes are established as Stable Zone (less than 40%), Moderately Stable Zone (40-60%), Quasi Stable Zone (60-80%), and Unstable Zone (80-100%).

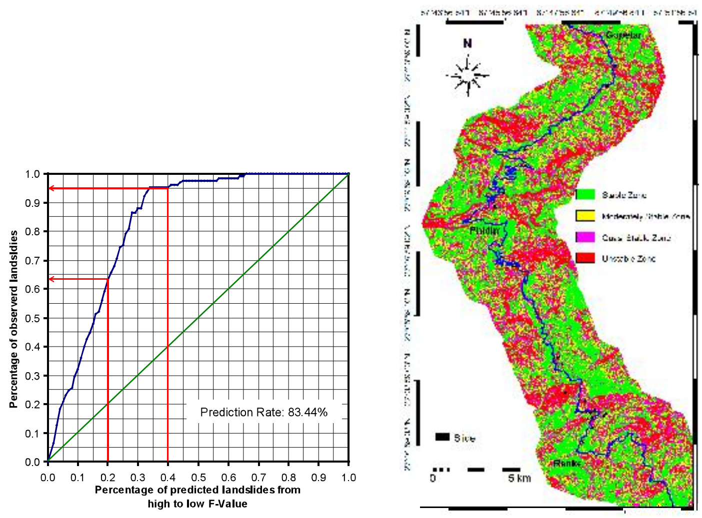

Figure 2. Left: Success curve for predeciting capacity of earthquake induced landslide susceptibility zonation, Right: landslide susceptibility zonation map of Mechi Highway

REFERENCES

Uchida T, Kataoka S, Iwao T, Matsuo O, Terada H, Nakano Y, Sugiura N and Osanai N (2004) A study on methodology for assessing the potential of slope failures during earthquakes, Technical note of National Institute for Land and Infrastructure Management, p 91 (in Japanese with English summary)