Landslide susceptibility mapping on major earthquake in Nepal based on weights of evidence model

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1. INTRODUCTION

On 25 April 2015, at 11:56AM local time, Nepal (Fig. 1) was hit by a major earthquake (locally known as Gorkha Earthquake) measuring 7.8 in moment magnitude with its epicenter at Barpak town of Gorkha District. Several aftershocks were also recorded including the biggest one of M_w7.3 on 12 May, 2015. This earthquake was the worst natural disaster since the 1934 Nepal-Bihar Earthquake. It killed around 9,000 people, injured around 22,000 people, and destroyed hundreds of thousand homes and UNESCO world heritages. The earthquake also triggered numerous slope failures and an avalanche on Mount Everest and Langtang valley. Likewise, huge amount of landslides and slope failures were triggered on the northern part of Nepal. In order to mitigate these slope failures in future and to predict the highly susceptible areas of landslides, GIS analysis using weights of evidence method is applied in this study.

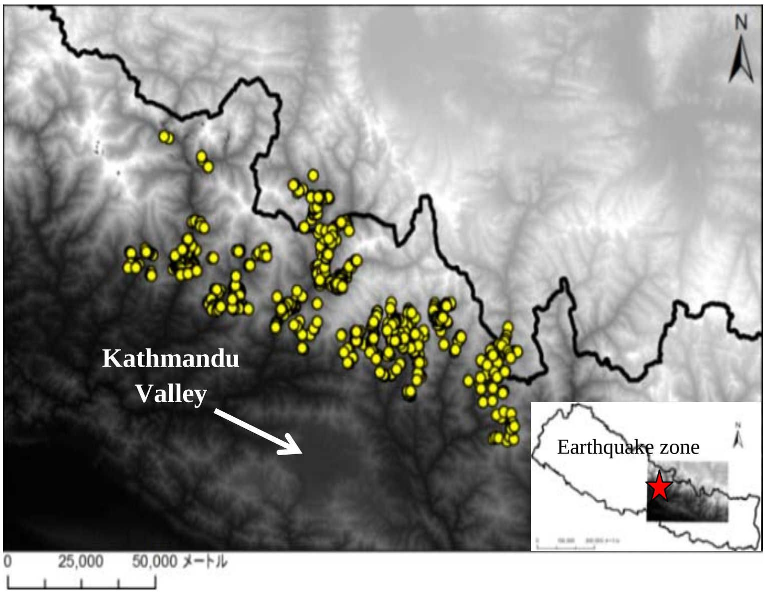

Figure 1: Study area and landslide location map

2. MATERIAL AND METHOD

The main assumption made in this study is past is the key to future. Based on this assumption, landslide inventory map was prepared with the help of google earth by mapping the slope failures on northern part of Nepal where slope failure and landslide occurred in a large number (Fig. 1). A total of 1,335 slope failures were identified, out of which 24 were triggered by the aftershocks. Five landslide triggering factors, i.e. slope, aspect, curvature, geology and distance from river were considered as influencing parameters, where slope, aspect and curvature are calculated from DEM. After detecting the landslides and constructing the spatial database, using weight index method as a statistical index (Wi), landslide susceptibility mapping was performed. By using weight index method, the weight of each parameter was analyzed. Wi values are calculated by dividing the dense class by dense map, taking the natural log with the help of raster calculator tool. Furthermore, representing the map of the sum of each values of Wi for each parameter was obtained as the final weight. The weight of the factor for each parameter can be calculated using the following equation of Wi.

$$Wi = ln\frac{DenseClass}{DenseMap} = ln\frac{\frac{Npix(S_i)}{Npix(N_i)}}{\sum_{i=1}^{n}\frac{Npi(S_i)}{\sum_{i=1}^{n}Npix(N_i)}}$$

Where Wi is statistical index; DenseClass is distribution density of seismic slip in the parameter class; DenseMap is distribution density of slope failure by earthquake map in while target region; Npix (Si) is number of pixel of slope failure during earthquake, which accounts for each parameter; Npix (Ni) is number of pixels of each parameter.

3. RESULTS AND DISCUSSION

Figure 2 shows the distribution of the area and Figure 3 shows the relationship between the slope length (L) and surface width (W). The relationship of slope length and slope width were found to be in the range of L = 0.2W ~ 7.3W.

Figure 4 shows the distribution of the altitude, which indicates that the slope failures are concentrated in the areas of high altitude. The study area lies in the higher

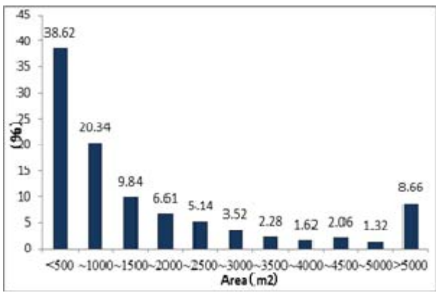

Figure 2: Distribution of area

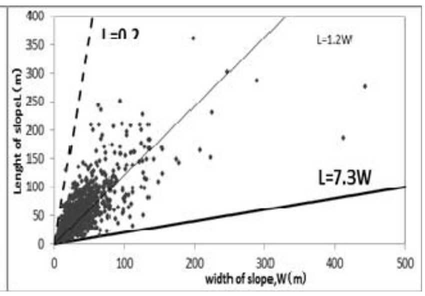

Figure 3: Relation between length and width of slope

Himalaya, which tends to undergo more shaking causing more slope failures.

Figure 5 shows the distribution of aspect. Mainly slope failures were focused on south direction (especially the southeast). Likewise, Figure 6 shows the distribution of the slope gradient, where the number of occurrences of landslides on 35°~55° slopes accounts for 63.6% out of the total area. This shows the characteristics of general seismic slope failures.

Figure 7 shows the distribution of curvature. No significant effect was observed between positive and negative curvature. Likewise, Figure 8 shows the distribution of distance from the river. The slope failures are concentrated on short~ medium range distance from the river.

Figure 9 shows the distribution of geology. The slope failures were mainly concentrated on Himal group and Ranimatta formation. Likewise, some slope failures were also seen in Ghanapokhara and Ulleri formation. These formations mainly consist of soft rock such as phyllite, sandstone, shale. Thus, these formations have fragile geological structure.

Figure 10 is the prepared hazard map. From the high Himalaya to the transition of lesser Himalaya, there is high degree of failure risk. In some places, however, slope failures have been seen in low risk area. Through this study, it is understood that the geological parameter is a major factor for the evaluation of hazard analysis. Figure 11 shows the ROC curve. The result shows AUC= 0.718 which shows the little bit less accuracy in ROC curve. The possible reason for the less accuracy of ROC curve could be the large study area rather than choosing the area where most slope failure are concentrated.

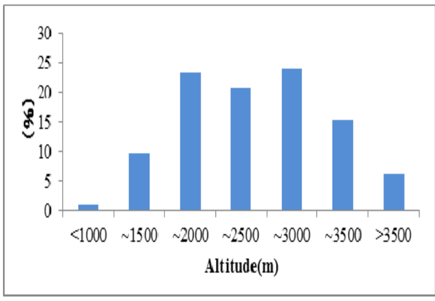

Figure 4: Distribution of altitude

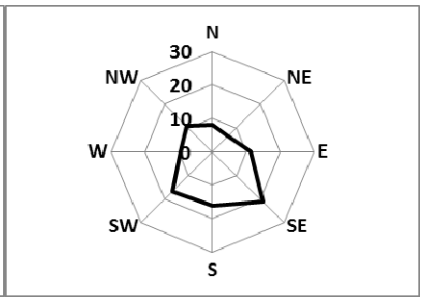

Figure 5: Distribution of aspect

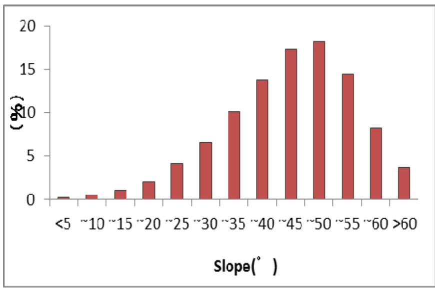

Figure 6: Distribution of slope gradient

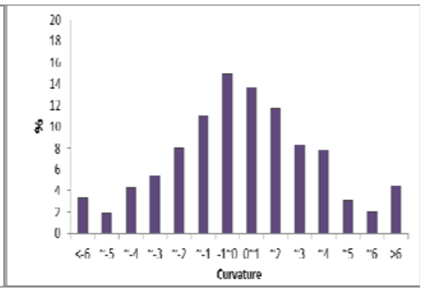

Figure 7: Distribution of curvature gradient

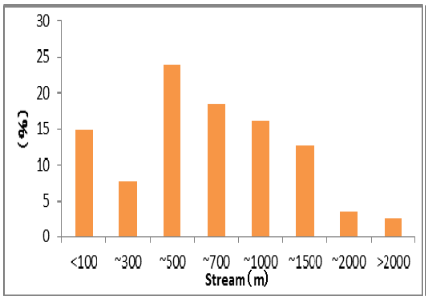

Fig 8. Distance from river

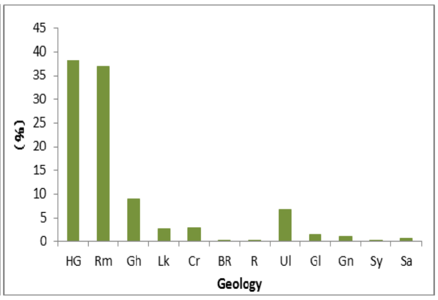

Fig 9. Distribution of geology

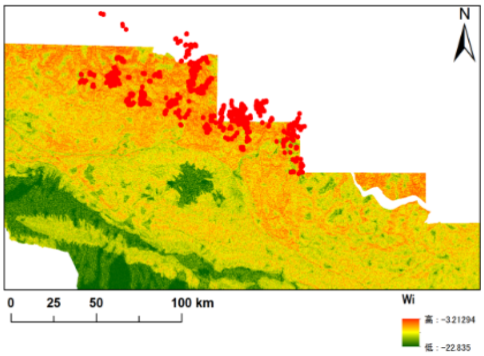

Fig 10. Hazard map

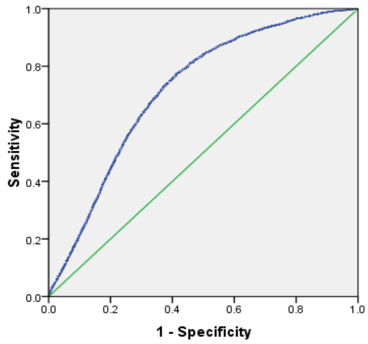

Fig 11. ROC curve

4. CONCLUSIONS

The weights of evidence method using GIS is used to make a hazard map and landslide susceptibility mapping showing the relationship between landslide and landslide triggering factors. Similar to other natural disasters, landslides are also hard to predict but landslide risk can be systematically assessed and managed. Among five parameters, slope, aspect and geology show better correlation with the failure. The study area lies in the lesser Himalaya and higher Himalaya zone where seismic slope landslide and slope failure in all mountainous areas had occurred along its distribution. The geology of the study area consists of the soft rock, such as sandstone, phyllite and shale that causes more slope failure and landslide in this region. Hazard map also tends to show the high risk in areas where slope failures have frequently occurred.

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