GIS-based analysis of landslide distribution pattern in most vulnerable geological formation in central Nepal

Key words: GIS, landslides, Nepal

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1. Introduction

Nepal is moderately threatened by various natural hazards among which landslides have considerable economic impact and ecological consequences. The conventional trend of hazard mapping shows preparing landslide hazard map for specified site and using it for landslide monitoring as well as delineating area requiring mitigation measures. Nepal is hit by more than 1200 small and large-scale landslides and slope failures every year (Bhattarai et al., 2002). Only a few studies have been done to understand the Nepal Himalayan landslide mechanisms and processes and it is due to lack of sufficient data. In this study, a certain geological area is separated from the rest. By using available geological and geomorphological parameters, an attempt is made to find out the most influencing parameters so that it will be easier to predict hazard condition with the most influencing parameters in other belts of central Nepal. Previous researches on landslides in Nepal have shown that most of the slope failures and slides are found to occur in weak metamorphic rocks such as Phyllites, Shell, Slate, Gneiss, etc and Phyllite is the most vulnerable geological formation among all according to Pantha et al. 2008. GIS is chosen as tool for this particular study since it facilitates more efficiently and reduces duration in hazard mapping process.

2. The study area

The study area lies in Lesser Himalayan zone and Siwalik zone of central Nepal (Figure 1) and encompasses sections of Prithvi Highway, Narayanghat-Mugling Highway, and Tribhuvan Highway and measures about 1190 km^2 area. It comprises 4 sections namely, Damauli-Pokhara, Narayanghat-Mugling, Devighat-Sunaula Bazaar and Kathmandu Hetauda section, among which Kathmandu-Hetauda section lies on South whereas Damauli-Pokhara, Narayanghat-Mugling and Devighat-Sunaula Bazaar lie on N-W from the capital Kathmandu. The study area is geologically characterized by rugged topography, steep slopes, deep and eroding rivers. It consists of more than 14 types of geological formations (Figure 2) of which Phyllite is the major rock types as shown in Figure 3. Because of dynamic geology and steep slopes, large scale landslides are very common in lesser and higher Himalayan zones of central Nepal (Hasegawa et al. 2008) and the landslides dealt here are all deep seated landslides. The area also consists of closely passing Main Central Thrust (MCT) and Main Boundary Thrust (MBT) along with numerous local faults. Combination of high-grade metamorphic rock to low weathered and fractured grades are found in the study area.

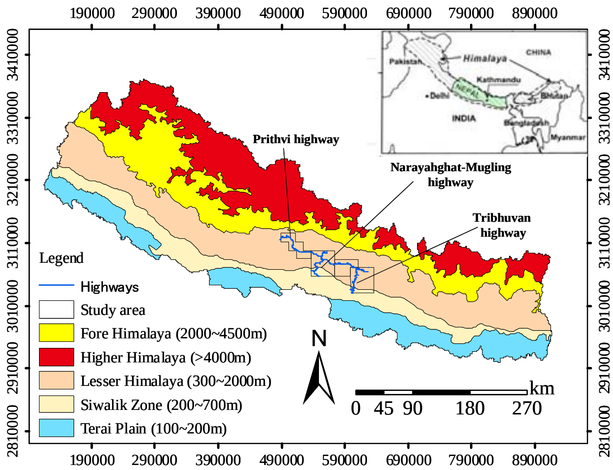

Figure 1: The study area

3. Methodology

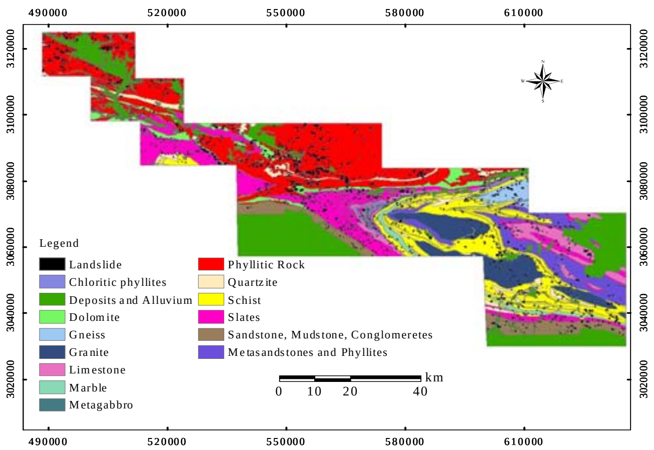

Figure 2: The geological map of study area

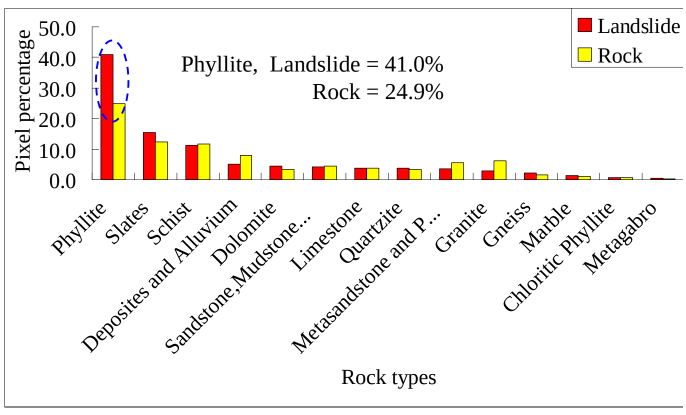

Figure 3: Landslide and rock type distribution in study area

ArcGIS 9.0 was used to produce different layer maps which assist in the preparation of landslide hazard map. The influencing parameters selected for hazard mapping in this particular study include slope, aspect, relief energy and distance to thrust-faults with 50m resolution whereas rock formation was kept constant. The selected Phyllite area (Figure 4) is the part of 5075 km^2 study area. Phyllite and Phyllite related geological formations with similar mineral contents (Kunchha formation, Dadagaun Phyllite, Nourpool formation) were grouped under Phyllite. Blocks of 1km × 1km (USKB) size were constructed covering the Phyllite area (Figure 5). The total numbers of blocks were 1190. The shape file of unit square blocks was crossed with landslide raster employing zonal statistics function of Spatial Analyst Tool in ArcGIS. It gave the number of pixels of landslides occurring in each block. Thus landslide density of each block was calculated which varied from 0.0025 to 0.6775 km^2/ km^2. The resultant landslide density map was classified into four landslide density zones (Figure 6) by defined interval method of statistics with their density ranges namely none (0 km^2/km^2), low (<0.1 km^2/km^2), medium (0.1-0.3 km^2/km^2), and high (>0.3 km^2/km^2). High, medium, low, and none landslide density zones occupied 4.20%, 17.05%, 32.94%, and 45.81% Phyllite area respectively. Huge portion of Phyllite was extracted as landslide free zone from this method of unit square kilometer block (USKB).

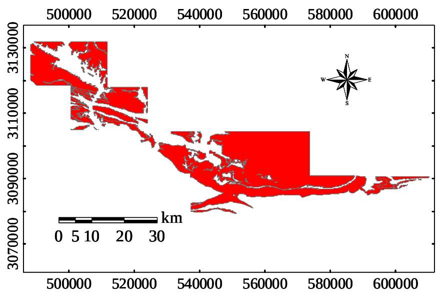

Figure 4: Delineation of Phyllite

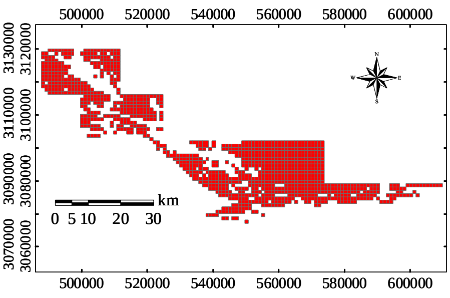

Figure 5: Rasterization of USKB

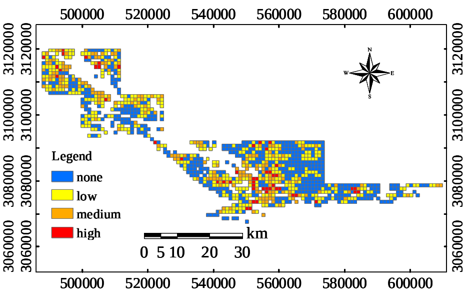

Figure 6: Landslide density map

4. Results and discussion

Figure 7 shows the maximum percentage of 20-40 slope, but its percentage is almost same in all landslide density zones. However, 10-20 slope was found to be varying and increases from low to high & governs the variation in landside occurrence when 20-40 slope class is constant. N aspect shows increasing trend from lower to higher zones. However, the increment of north (N) pixel percentage in consecutive zones is not considerable. These indicate that there may be the role of other parameters for non-uniform distribution of landslide in Phyllite. Distance to thrust-faults parameter is found as one of the major influencing parameter to cause non-uniform distribution of landslide in Phyllite. The distinct increasing trend of 0-0.5 km distance to thrust-faults from none to high zone and at the same time the distribution of 0-0.5 km distance to thrust-faults, thrust-faults density and landslide density show similar increasing trend (Figure 8). Relief energy is found as other major influencing topographical parameter. The increasing trend of medium (400-600m) and higher (>600 m) relief energy from low to high zones indicate medium and higher relief are also responsible for non uniform distribution of landslide.

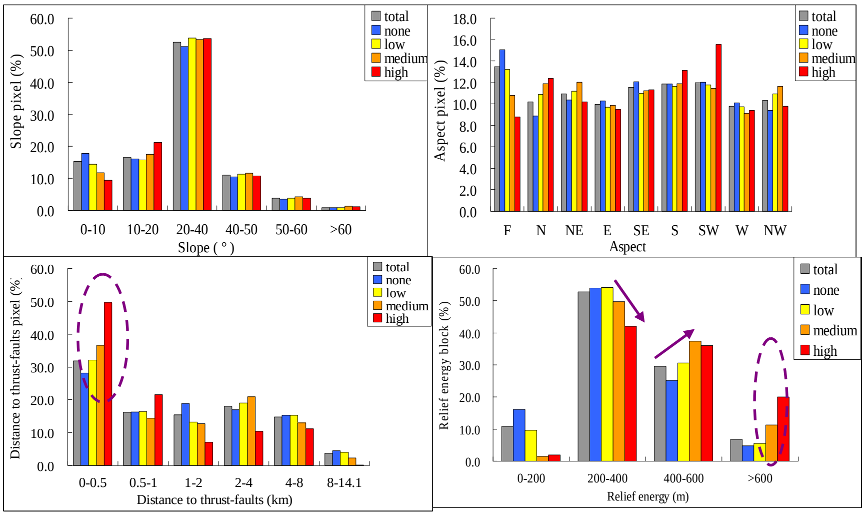

Figure 7: Results of Phyllite analysis

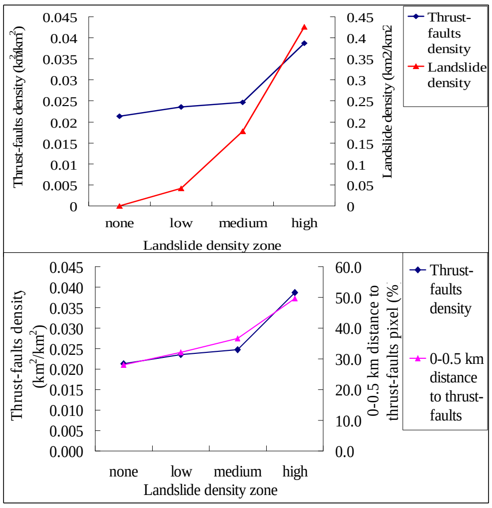

Figure 8: 0-0.5 km distance to thrust-faults, landslide and thrust-faults density distribution

5. Conclusions

The non-uniform distribution of landslide within the most vulnerable geological formation draws considerable attention. The identification and localized mapping of the existing landslides is prerequisite to mitigation of landslide disaster. Several GIS-based qualitative and quantitative technologies are useful in analyzing relationship between landslides and landslide causative factors. In this study, a very new research was done by constructing unit square kilometer blocks in geological formation. Phyllite was attempted to analyze by constructing the unit square blocks. Relief energy and distance to thrust-faults were found as the most influencing parameter to cause non-uniform distribution of landslide. There are still some issues that need further study. The availability of few geological and topographical parameters is limitation to this study. The effect of dip and strike are still to be observed.

References

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