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Landslide hazard zonation along Phulmawi village and Tlungvel village road, Thingsulthliah Rural Development Block, Aizawl District, Mizoram, India

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ABSTRACT

Landslides are the most common hazard in the state of Mizoram. Rapid development and the uncontrolled interaction with the nature are the reason for l and slide in Mizoram. Landslide vulnerability of Mizoram is already high due to lithology, land use and land cover, geomorphology and slope factor. The extensive mining activities along the highways for road construction and building materials also cause one of major landslide along the highways in the state of Mizoram. The present study investigates the Landslide Hazard Zones along the national highway 54 between Phulmawi village and Tlungvel village. The National Highway Number 54 is the most important road connecting Aizawl city and Northern, Southern and Eastern part of the State of Mizoram. Thematic layers such as slope morphometry, geomorphology, Lithology and land use / land cover were created using Remote Sensing and Geographic Information System (GIS) techniques. On the different groups of thematic layers, a weight age rating system dependent on the relative importance of various causative factors is used. In the GIS setting, the classes were given the corresponding rating value as attribute information. An ordinal ranking of 0 to 10 was allocated to each class within a thematic layer. Landslide hazard zonation map generated could be utilized as a reliable database for mitigation measures and planning for secured growth of the village.

Keywords: *GIS, Landslide hazard zonation, Mitigation and remote sensing*

Introduction

Landslide is one of the major geo-environmental hazards in the Indian Himalayan Region including in the state of Mizoram. Landslides are directly related to the tectonically active Himalayan regions, and are one of the most frequent natural hazards in hilly terrains, causing damage to roads and residential areas (Gurugnanam, *et al*., 2012). Mizoram is made up of immature formations with North-South trending anticlinal ridges, steep cliffs, and synclinal valleys in between. Faulting has resulted in steep fault scarps in many regions (GSI, 2011). Therefore, the entire area is generally prone to landslides. Due to concentration of population and developmental activities in urban as well as rural areas, the vulnerability of human settlements to landslides is continuously increasing. Hence, when they occur in such human habitations, landslides become disasters (Chandel, *et al*., 2011). Moreover, the population can be highly vulnerable to natural disasters on account of concentration of high density population on hill slopes (Rawat, *et al*., 2010).

Several landslide disasters have been recorded from Aizawl district for the last two decades. Massive landslide in the stone-quarry at South Hlimen village in 1992 claimed the lives of 66 inhabitants and 17 houses were destroyed. Land subsidence occurred in 1994, in Aizawl Venglai locality, Ramthar locality and Armed veng locality which caused severe damage to 65 houses. In 1995, at Hunthar locality alongside Aizawl to Sairang road (National Highway 54), due to a longline crack about 17 houses were dismantled. The subsidence at Hunthar locality,which took place in 1995 and occurred again in 1999 endangering the structures of about 12 houses and 11 families within this area were evacuated. During the monsoon of 2011, Lengpui Airport road was blocked by landslide causing havoc to commuters and, within Aizawl city around 10 houses were dismantled and about 15 families were evacuated. In 2012, a massive landslide at the stone-quarry near Keifang locality (Saitual town) claimed the lives of 18 people which are one of the worst tragedies in terms of geo-environmental catastrophes in the state. The same year experienced a logline crack at Ramhlun Sport Complex in which 10 houses were dismantled and almost 60 families were shifted. During the month of May 2013, there was a massive landslide at Laipuitlang locality within Aizawl city claiming the lives of 17 persons. More than 10 persons were injured, about 12 houses and 16 vehicles were damaged. Due to the manifold miseries and problems it causes, attempts to study landslide within the state of Mizoram is one of the most important and challenging aspect in the field of geology.

Study Area

The study area lies under Thingsulthliah Rural development Block in the state of Mizoram between 92° 51.0′E to 92° 52.30"E and 23° 36.0′N to 23° 34.30′N in Aizawl district and falls under Survey of India topographical map No. 84A/14.

Materials and Methods

Data used

The key data were stereo-paired Cartosat-I data with a spatial resolution of 2.5 m from the Indian Remote Sensing Satellite (IRS-P5) and quick bird data with a spatial resolution of 0.8 m from the Indian Remote Sensing Satellite (IRS-P5). SOI topographical maps and various ancillary data were also referred to.

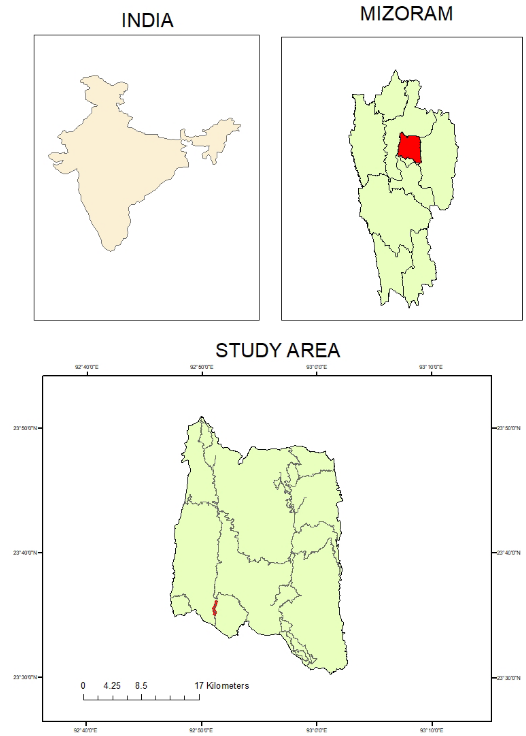

Fig. 1. Location map of the study area

Thematic layers

Several factors contributed to the landslide's occurrence (Bijukchhen *et al.*, 2009). Landslide susceptibility mapping relies heavily on the selection of these variables and the preparation of thematic data layers (Sarkar and Kanungo, 2004). Integration of multiple sources of data is a significant step forward (Kausik, 2013). Five essential thematic layers were created using satellite data and field work in this research. Landslide Hazard Zonation was applied to these layers. The following are the various layers:

Slope

Landslides are more common on steep slopes than they are on moderate and low slopes (Sharma *et al.*, 2011). This is because the shear stress in soil or other unconsolidated material increases as the slope angle rises. As a consequence, when considering stability, slope is one of the most important factors to consider (Lee *et al.*, 2004; Nithya and Prasanna, 2010). In a GIS setting, a slope map was created using IRS-P5 stereo-paired Cartosat-I data and a Digital Elevation Model (DEM). The area's slopes are measure in degrees and conveniently divided into eight slope facets: 30-35, 35-40 and40-45 degrees. Weightage values are assigned in accordance with the steepness of the slope. The slope map of the study area is shown in Fig 2.

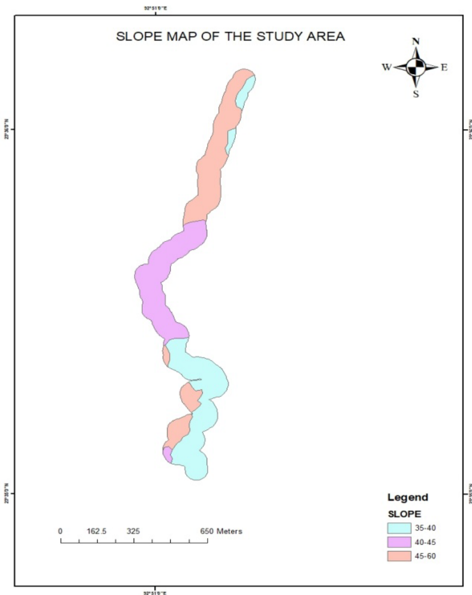

Fig. 2. Slope map

Land use / Land cover

The landslides are found commonly in and out around the areas where there are excessive land use along the highways and human settlements. Land use and landslides may be helpful in understanding the role of land use that induces landslides. Abandoned land in the form of old jhum with sparse vegetation cover are basically potential site of landslide. One of the most significant factors in Landslide Hazard Zonation is land use/land cover, which influences the rate of weathering and erosion. Heavy Vegetation, Light Vegetation, Scrubland, Built-up, and Barren Land were the five groups used to divide the study area. Heavy Vegetation class was given a low weightage value because areas with thick vegetation cover were thought to be less vulnerable to landslides (Mohammad Onargh *et al.*, 2012). Built-up areas were found to be more susceptible to landslides than all other groups (Pandey *et al.*, 2008) and were assigned a higher weighting. Figure 3 depicts land use and land cover.

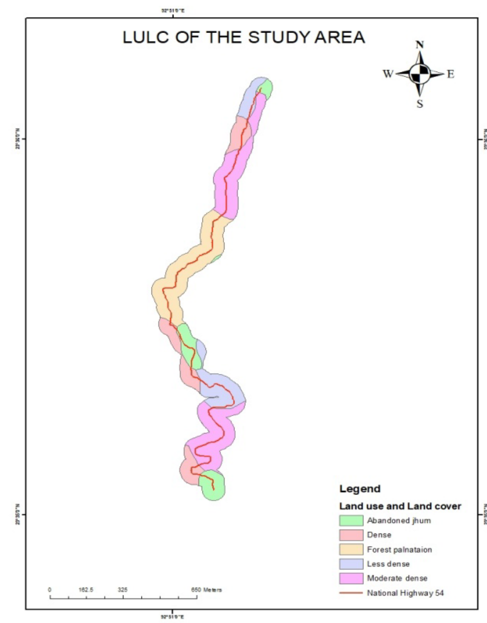

Fig. 3. Land use and Land cover map

Lithology

One of the factors in landslide hazard zonation is lithology (Sharma *et al.*, 2011). Mizoram's geology consisted of large flysch facies rocks with monotonous shale and sandstone sequences (La Touche, 1891). The study area is located within the Surma Group of Tertiary age's Bhuban formation, which has been subdivided into Lower, Middle, and Upper formations (GSI, 2011). Middle Bhuban which consist of mainly argillaceous rocks exposed and the Upper Bhuban rocks of Arenaceous nature is also exposed within the study area.The area is made up of three different types of sedimentary rocks viz; sandstone,shale and silty shale. Sandstone occupied the major portion of the formation which are highly compact with fine to medium grained having two distinct colors. The weathered sandstone horizons are brownish in colour while the less weathered sandstones are grayish in color.The study area has been divided into three litho-units based solely on the exposed rock forms. Shale-sandstone, Silty shale, and Sandstone-shale are the names of the litho - units. These shale and siltstone lithological units are more prone to landslides than hard and compact sandstone - shale units. Among the rock types in the region, silty shale is the most prone to landslides.

Geomorphology

The vulnerability of settlements and transportation networks is largely determined by geomorphic units. As a result, it plays a significant role in land-

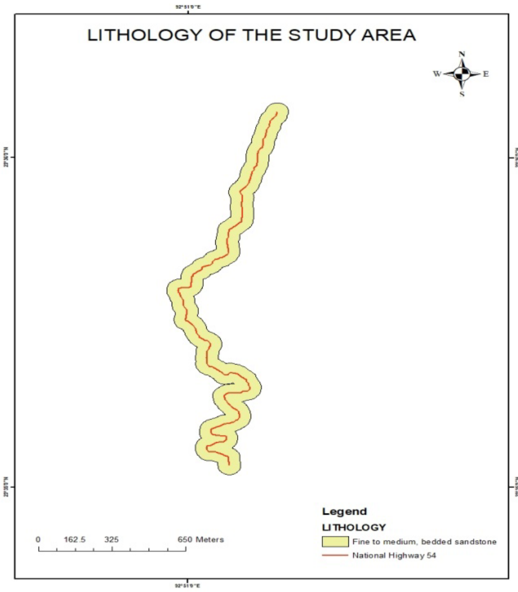

Fig. 4. Lithology map

slide hazard classification (Chandel *et al.*, 2011). The study area is graded as highly dissected and less structural hills due to its high relative or local relief. Since higher elevations are more prone to landslides than lower elevations (Lee *et al.*, 2004), weightage values were assigned to each of the geomorphic groups in accordance with this trend.

Data Analysis

The road along Phulmawi village and Tlungvel village was buffered 100 m on both side to delineate

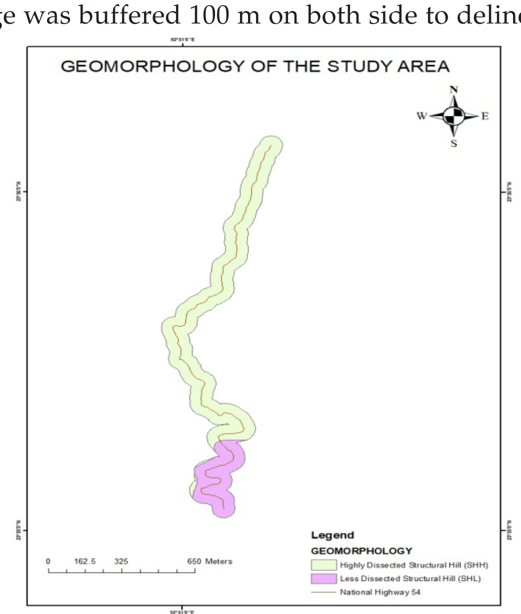

Fig. 5. Geomorphological map

the studyarea keeping in mind that any landside incident within that vicinity may damage the road and disrupt transportation activities. Recent and dormant landslides were detected, analyzed, and plotted in a GIS environment as part of a landside inventory along the route.

Landslides are caused by geo-environmental factors such as slope morphometry, land use/land cover, lithology, and geomorphology in the study area. These four themes are the main hazard zonation parameters, and each is divided into relevant groups. Individual groups in each parameter are examined in detail in order to determine their relationship to landslide susceptibility. Each class is given a weighting value based on their vulnerability to landslides, with lower weightage representing the least impact on landslide incidence and higher weightage representing the high impact. The weighting of the various groups within a parameter is determined by their presumed or predicted significance in causing a landslide, as determined by the experts' prior knowledge. To create a Landslide Hazard Zonation map, all the thematic layers were combined and analyzed in a GIS environment using ARCINFO (10.4 version). The National Remote Sensing Agency's (NRSA, 2001) weighting scheme and Joyce and Evans' (Joyce and Evans, 1976) stability rating were used in the analysis, as shown in the Table 1.

Results and Discussion

Very High Hazard Zone

This zone is highly unstable due to wedge failure of slope. The area is steep slopes with rock fall prone area due to illegal quarrying. Tlungvel old quarry lies in the area. The unscientific extraction of boulders for construction materials and due to high angle cutting which resulted the upper rock to fall.

High Hazard Zone

It mostly involves areas where there is a high risk of falling debris. It is a region with steep slopes that is vulnerable to landslides when disturbed. Furthermore, this zone includes areas where the rocks' dip and the area's slope, which is typically very steep, are in the same direction. This region also includes human settlements. Landslip has caused road subsidence in the city. Because of the soft nature of the lithology and the loose unconsolidated rubble, rainfall may also cause landslides.

Table 1. Ratings for Parameters on a scale of 1-10

Parameter	Rank in percent	Category/Unit	Weight
Lithology	30	Shale-sandstone	8
		Sandstone-shale	4
		Silty-shale	6
Slope in degree	40	1-5	1
		5-15	1
		15-25	2
		25-30	4
		30-35	4
		35-40	6
		40-45	7
		>45	8
Geomorphology	20	Highly dissected structural hill	7
		Less dissected structural hill	4
Land Use / Land Cover	10	Heavy vegetation	2
		Light vegetation	7
		Scrub land	7
		Built up	6
Total	**100%**		

Moderate Hazard Zone

This zone is considered stable and although steep slopes may include in this area, less overlying debris and absence of anthropogenic activity make the zone less hazardous. It is best not to disturb the natural drainage, and at the same time, slope modification should be avoided as far as possible.

Low Hazard Zone

This region contains areas where a variety of controlling parameters are unlikely to have a negative impact on slope stability. The vegetation is thick, and the slope angles are usually mild, about 30 degrees or less. A large portion of this region is made up of consolidated debris and rough, compressed rock. This region is often restricted to areas where human activity is minimal or non-existent.

Very Low Zone

This zone generally includes valley fill and other flatlands. Playgrounds are prominent features within this zone. As such, it is assumed to be free from present and future landslide hazard. The dip and slope angles of the rocks are fairly low. Although the lithology may comprise of soft rocks and overlying soil debris in some areas, the chance of slope failure is minimized by low slope angle.

The present study area proved that physical factors like slope, geomorphology, land use/land cover and lithology are directly linked with landslide hazard. The study area has been categorized into four different hazard zones, i.e. Very high hazard ,High hazard zone, Moderate hazard zone , Low hazard zone and Very low. Majority of the study area falls in the Moderate hazard and Low high hazard zones.

Mitigation Measures

Complete prevention of landslide is a very difficult task. However, the effects of landslides especially the smaller ones and those provoked by human activities, can be minimized. So the study revealed the following:-

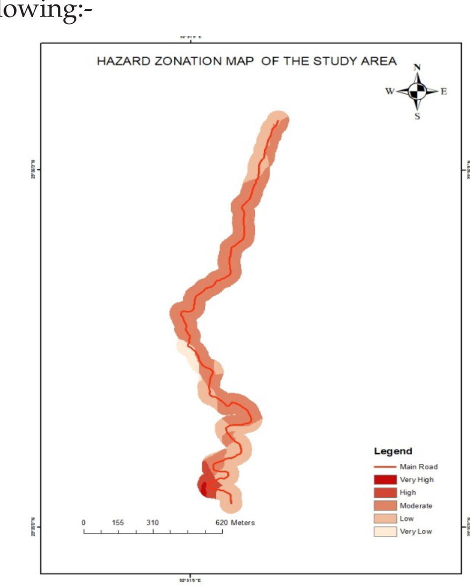

Fig. 6. Hazard zonation map

i) The study areas fall under Tertiary sediments composed mostly of Arenaceous and Argillaceous sand and shale interbedded.

ii) Illegal quarry and unscientific blasting also causes destabilization of rock particularly along the joint planes. Illegal quarry operation should be stopped.

iii) The identified slip surfaces are to be treated for conservation measures in order to avoid triggering of new slides in the area.

iv) Area required to prevent soil erosion and extensive gully erosion.

v) Rock excavation and extraction have been done primarily from bottom of the rock formation, i.e. toe cutting. This type of excavation and extraction triggered and exacerbated the rock fall. So, this kind of excavation and extraction of rock must be banned.

vi) Develop good and effective drainage system so that slope materials do not become water logged and trigger the slide.

Conclusion

The present study area proved that physical factors like slope, geomorphology,land use/land cover and lithology are directly linked with landslide hazard. The study area has been categorized into five different hazard zones i.e. Very high hazard ,High hazard zone, Moderate hazard zone , Low hazard, zone and Very low hazard zone, Majority of the study area falls in the Moderate hazard and Low hazard zones. As a result, the landslide threat map created through this analysis can be used to identify critical areas for implementing appropriate mitigation measures as well as selecting sites for future village expansion. It's also worth remembering that while the very high and high danger zones are limited to small areas, major parts of the study area fall under the moderate hazard zone could become extremely unstable if unplanned anthropogenic activities are carriedout without regard for the geo-environmental situation.

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