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LANDSLIDE HAZARD ZONATION ALONG NATIONAL HIGHWAY BETWEEN AIZAWL CITY AND LENGPUI AIRPORT, MIZORAM, INDIA USING GEOSPATIAL TECHNIQUES

Laltlankima*, F. Lalbiakmawia
* Astt. Professor, Department of Geology, Govt. Zirtiri Residential Science College, Mizoram, India
Asst. Hydrogeologist, PHE Department Mizoram, India

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ABSTRACT

One of the most common victim of landslide is road transport network. This is inturn affects the economy and population. Due complex tectonic set up and unplanned developmental activities in Mizoram, the most common geo-environmental hazard in the state is landslide. The present study investigates the Landslide Hazard Zones along the highway between Aizawl city and Lengpui airport of Mizoram. This highway is the most important road connecting Aizawl city and other parts of the country. The study utilized Remote Sensing and Geographic Information System (GIS) techniques. The road was buffered 50m on both side to delineate the study area. Important factors which induced landslide were identified and accordingly, five thematic layers viz., slope morphometry, geological structures like faults and lineaments, lithology, geomorphology and land use / land cover were generated. These thematic layers were ranked and weighted based on their relative importance in causing landslide. Each class within a thematic layer was assigned an ordinal rating from 1 to 10 as attribute information in the GIS environment. These attribute values were then multiplied by the corresponding rank values to yield the different zones of landslide hazard. Landslide inventory map is also considered while classifying the the different zones of landslide hazard. The resulting Landslide Hazard Zonation map classified the area into five relative hazard classes like very high, high, moderate, low, and very low. The final map generated will, therefore, be used by engineers and administrators for maintenance and monitoring of this highway to ensure smooth flow of transportation between the state capital and Lengpui airport, which the only airport in Mizoram. Remedial measures for landslide were also suggested at several landslide locations.

KEYWORDS: GIS, Landslide Hazard Zonation, Remote Sensing, Aizawl city, Lengpui Airport.

INTRODUCTION

Landslide is one of the most common natural hazards which causes loss of lives, damage to houses and roads (Dai et al., 2002; Sarkar and Kanungo, 2004; Gurugnanam et al., 2012; Sujatha et al., 2012). Increasing artificial stuctures, rapid expansion of road networks and growth of human population lead to high vulnerability of human lives and properties. Landslide therefore, become a disaster when it occurs in such human habitations (Chandel et al., 2011). The geology of Mizoram comprises N-S trending ridges with steep slopes, narrow intervening synclinal valleys, dissected ridges with deep gorges, and faulting in many areas has produced steep fault scarps (GSI, 2011). Therefore, road transport networks in Mizoram are highly vulnerable to landslide disaster.

Remote Sensing and GIS have wide-range applications in the field of geo-sciences (Jeganathan and Chauniyal, 2002). Therefore, many researchers have utilised these techniques for landslide hazard studies (Vahidnia et al., 2009; Dinachandra Singh et al., 2010). The same techniques had been used to carry out Landslide Hazard Zonation of Uttaranchal and Himachal Pradesh States by National Remote Sensing Agency (NRSA, 2001). Remote Sensing and GIS techniques had also been successfully applied in Landslide Hazard Zonation studies for Serchhip town (Lallianthanga and Lalbiakmawia, 2013), Mamit town (Lallianthanga *et al.*, 2013), Kolasib town (Lallianthanga and Lalbiakmawia, 2013), Saitual town (Lallianthanga and Lalbiakmawia, 2013), entire Aizawl district (Lallianthanga and

Lalbiakmawia, 2013) and for Aizawl City (Lallianthanga and Lalbiakmawia, 2013). The present study utilizes Quickbird, IRS(P-6) LISS-III and IRS(P-5) Cartosat-I data to map the different landslide hazard zones and to create database for mitigation measures of landslides along the highway between Aizawl city and Lengpui airport which frequently suffered many landslide incidents. The study also suggest the methods for mitigation of landslide along this vibrant highway.

Study area

The study area is located in the northern part of Mizoram which is in north-east India. Aizawl city is the capital of Mizoram and the distict headquarters of Aizawl distict. Lengpui airport is the only airport in Mizoram connected by daily flights with Kolkata and Guwahati.

This specific road starts at the coordinates of 92º 37′ 32.15"E & 23º 50′ 18.62" E and ends at 92º 42′ 44.82" & 23º 44′ 30.34" N. The distance between Aizawl city and the airport is 32 km. It falls under Survey of India topo sheet No. 84A/9 and 84A/10. Location map of the study area is shown in Fig. 1. The climate of the study area ranges from moist tropical to moist sub-tropical. The average annual rainfall is 2688.50 mm (Lalzarliana, 2015).

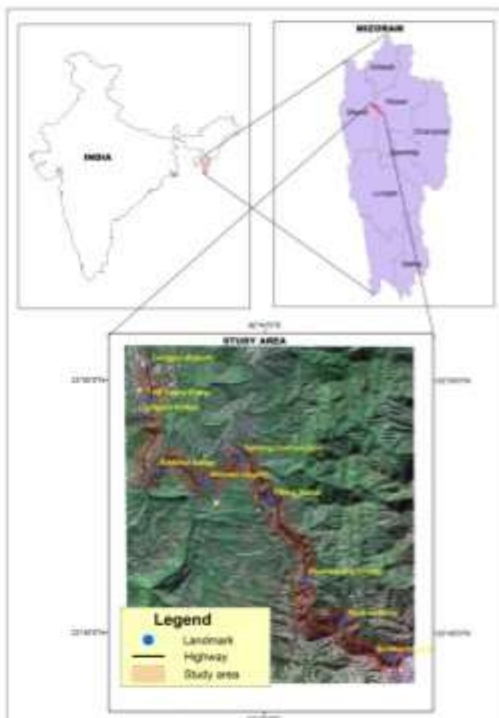

Figure 1: Location map of the study area

MATERIALS AND METHODS

Data used

Indian Remote Sensing Satellite Quickbird, (IRS-P6) LISS III data having spatial resolution of 23.5m and Cartosat-I stereo-paired data having spatial resolution of 2.5m were used as the main data. SOI topographical maps and various ancillary data were also referred in the study.

Thematic layers

Detailed knowledge of geo-environmental factors which are inducing landslide activities in an area is required for preparing landslide hazard map (Dutta and Sarma, 2013; Bijukchhen *et al.*, 2009). Selection and preparation of these factors as thematic data layers are highly crucial for landslide hazard zonation mapping (Sarkar and Kanungo, 2004). Integration of multi-sources of information is a major goal to attain more reasonable results in the assessment of many environmental issues (Archana and Kausik, 2013). The present study utilised five thematic layers for Landslide Hazard Zonation which were prepared from satellite data and field work. The different layers are as follows-

Land use / Land cover: Land use / land cover pattern is one of the most important parameters governing slope stability as it controls the rate of weathering and erosion (Anbalagan *et al.,* 2008). The study area was divided into four classes, viz., Dense Vegetation, Light Vegetation, Scrubland and Built-up areas. Built-up areas were more prone to landslide than all the other classes (Pandey *et al.,* 2008) while Dense vegetation vegetation were considered less prone to the occurrence of landslides (Mohammad Onargh *et al.,* 2012). The different land use / land cover classes in the study area are shown in Figure 2.

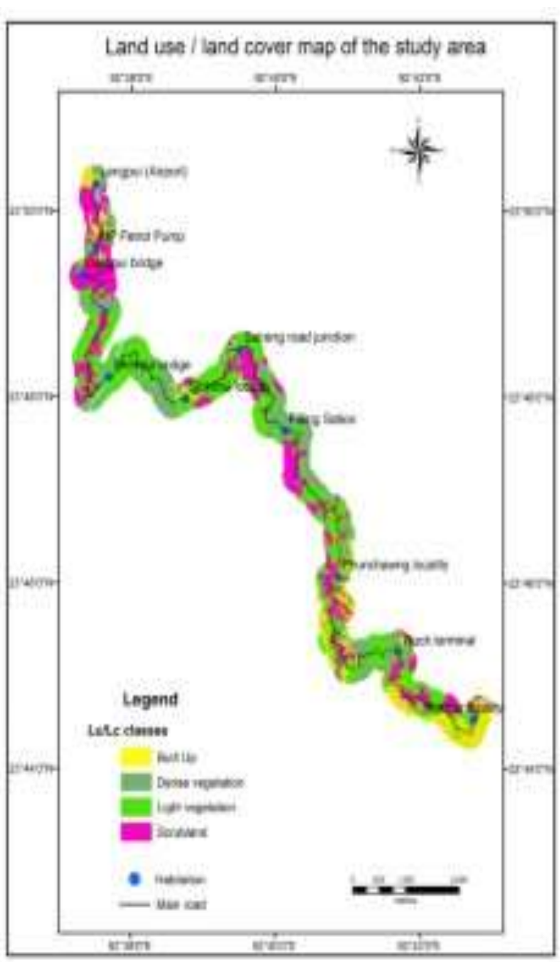

Figure 2: LU/LC map of the study area

Slope

Landslides are more prevalent in the steep slope areas than in moderate and gentle slope areas (Sharma *et al.,* 2011; Das *et al.,* 2011). This is due to the fact that the shear stress in soil or other unconsolidated material increases as the slope angle increases. Therefore, slope is one of the most important parameter for stability consideration (Lee *et al.,* 2004; Nithya and Prasanna, 2010). Slope map was generated from Digital Elevation Model (DEM) in a GIS environment. The slopes of the area are represented in terms of degrees, and are divided into nine slope classes, viz., 0-15, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, 40-45, and above 45 degrees. Weightage values are assigned in accordance with the steepness of the slope. Slope map is shown in Figure 3.

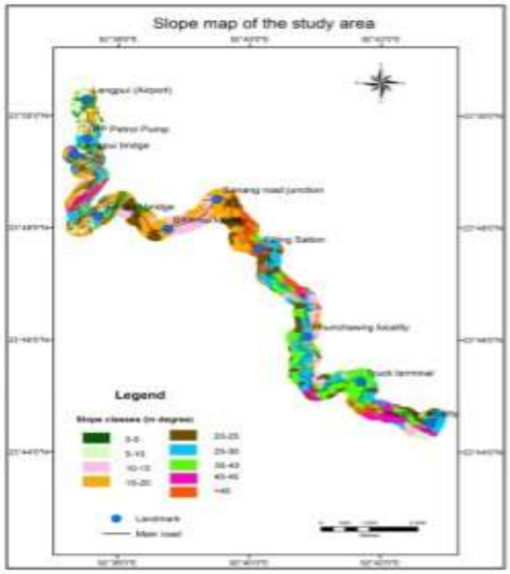

Figure 3: Slope map of the study area

Geomorphology

Geomorphic units play crucial role in the vulnerability of settlements and transport network. Hence, it is an important factor in landslide hazard zonation (Chandel et al., 2011). The study area possesses high relative or local relief and was divided Highly dissected, Moderately dissected and Less structural hills. Other geomorphic units include Alluvial plain and Intermontane valley. High elevated areas are more susceptible to landslide than areas with lower elevation (Lee et al., 2004) and following this pattern, weightage values were given to each of the geomorphic classes. The geomorphological map of the study area is shown in Fig. 4.

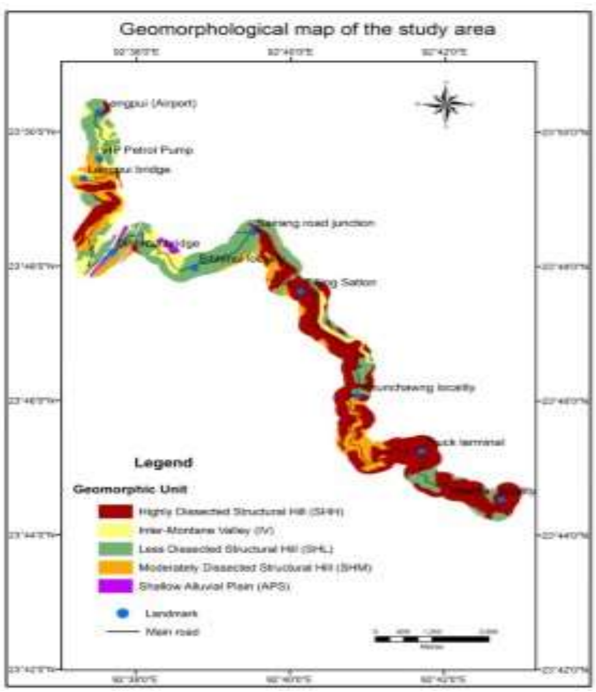

Figure 4: Geomorphological map of the study

Figure 4: Geomorphological map of the study

Figure 5: Geological map of the study area

Lithology

Lithology is one of the major parameters for landslide hazard zonation (Sharma et al., 2011). The geology of Mizoram consists of great flysch facies of rocks comprising monotonous sequences of shale and sandstone (La Touche, 1891). The study area is underlain by Middle Bhuban and Upper Bhuban formations of Surma Group of Tertiary age (GSI, 2011). Middle Bhuban consist mainly of argillaceous rocks while Upper Bhuban formation compirses mainly of arenaceous rocks. Two litho-units have been established for the study area purely based on the exposed rock types. These are named as Sandstone dominant unit and Shale dominant unit. Soft rock units comprising of shale erode faster and are easily weathered (Anbalagan et al., 2008), and are therefore considered more susceptible to landslide than the hard and compact sandstone units. In accordance with this, weightage values are assigned for analysis.

Geological Structur*e*

Remote sensing data can be utilised to delineate and analyse the geological structures like faults, fractures, joints, etc. (Kanungo *et al.*, 1995). These geological structures are among the most important parameters for Landslide Hazard Zonation (Saha *et al.*, 2002). It was observed that the rocks exposed within the study area were traversed by several faults and fractures of varying magnitude and length (MIRSAC, 2006). Areas located within the vicinity of faults zones and other geological structures are considered more vulnerable to landslides. For analysis, areas with 50 m on both sides of all the lineaments including faults were buffered. The geological map of the study area is given in Fig. 5.

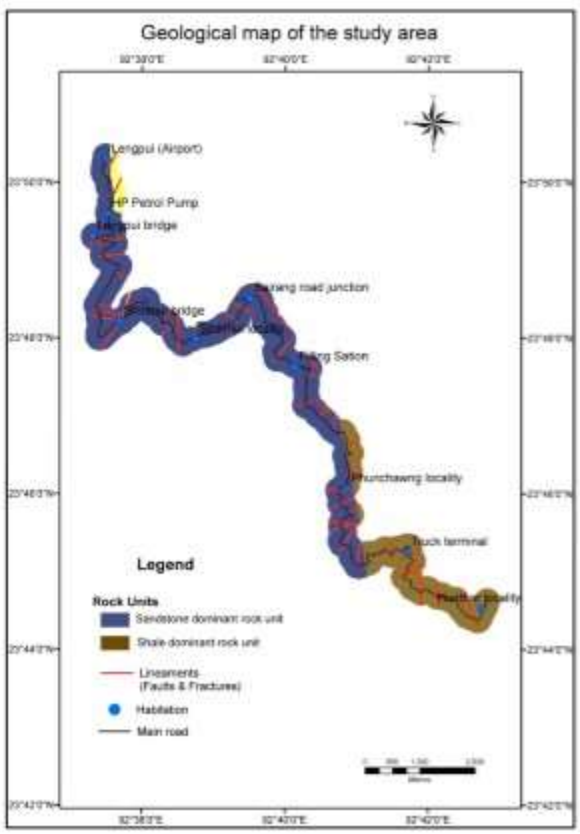

Figure 5: Geological map of the study area

DATA ANALYSIS

The main road connecting Aizawl city and Lengpui airport was buffered 300m on both side to delineate the study area keeping in mind that any landside incident within that vicinity may damage the road and disrupt any kind of transportation activities. Landside inventory was done along the the road in which recent and dormant landslide were identified, anaylse and plotted in a GIS environment.

The geo-environmental factors like slope morphometry, land use/land cover, geomorphology, lithology and geological structure are found to be playing significant roles in causing landslides in the study area. These five themes form the major parameters for landslide hazard zonation and are individually divided into appropriate classes. Individual classes in each parameter are carefully analysed so as to establish their relation to landslide hazard. Weightage value is assigned for each class based on their hazard to landslide in such a manner that less weightage represents the least influence towards landslide occurrence, and more weightage, the highest. The assignment of weightage value for the different categories within a parameter is done in accordance to their assumed or expected importance in inducing landslide based on the apriori knowledge of the experts. In addition, ground information regarding landslide occurences within the study area were also considered. All the thematic layers were integrated and analysed in a GIS environment to derive a Landslide Hazard Zonation map. The scheme of giving weightages by National Remote Sensing Agency (NRSA, 2001) and stability rating as devised by Joyce and Evans (Joyce and Evans1976) were adopted in the study as shown in the table.

Parameter	Rank	Category	Weight
Lithology	25	Sandstone unit	5
		Shale unit	8
Land Use / Land Cover	15	Dense Vegetation	3
		Light Vegetation	5
		Scrubland	6
		Built-up	8
Slope in in degree	35	0 – 5	1
		5-10	1
		10-15	2
		15-20	3
		20-25	4
		25-30	5
		30-35	5
		35-40	8
		40-45	9
		>45	6
Structure: Faults and Fractures	15	Distance Buffered	8
Geomoprhology	10	High	5
		Medium	4
		Low	3
		Alluvial plain/Valley	1

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

RESULTS AND DISCUSSION

Very High Hazard Zone

This zone is highly unstable and is at a constant threat from landslides. The area forms steep slopes with loose and unconsolidated materials, and include areas where evidence of active or past landslips were observed. Besides, it also includes those areas which are located near faults and tectonically weak zones. It further includes areas where road cutting and other human activities are actively undertaken.

High Hazard Zone

It mainly includes areas where the probability of sliding debris is at a high risk. It covers an area of steep slopes which when disturbed are prone to landslides. Most of the pre-existing landslides fall within this category. Besides, this zone comprises areas where the dip of the rocks and slope of the area, which are usually very steep, are in the same direction. This rendered them susceptible to slide along the slope. Several lineaments, fractured zones and fault planes also traverse the high susceptible zone. Areas which experience constant erosion by streams because of the soft nature of the lithology and loose overlying burden, fall under this class.

Moderate Hazard Zone

This zone is generally considered stable, as long as its present status is maintained. Although this zone may include areas that have steep slopes, the orientation of the rock bed and absence of overlying loose debris and human activity make them less hazardous. The Moderate Hazard Zone is well distributed within the study area. Several parts of the human settlement also come under this zone. It is recomended not to disturb the natural drainage, and at the same time, slope modification should be avoided as far as possible. Further, future land use activity has to be properly planned so as to maintain its present status.

Low Hazard Zone

This zone includes areas where the combination of various controlling parameters is generally unlikely to adversely influence the slope stability. Vegetation is relatively dense, the slope angles are generally low, about 30 degrees or below. Large part of this zone prominantly lies over hard and compact rock type. This zone is mainly confined to areas where anthropogenic activities are less or absent. No evidence of instability is observed within this zone, and mass movement is not expected unless major site changes occur.

Very Low Hazard Zone

This zone generally includes the area where the slope angles of the rocks are fairly low. As such, it is assumed to be free from present and future landslide hazard. Although the lithology may comprises of soft rocks and overlying soil debris in some areas, the chance of slope failure is minimized by low slope angle.
The Landslide Hazard Zonation map is shown in Fig. 6.

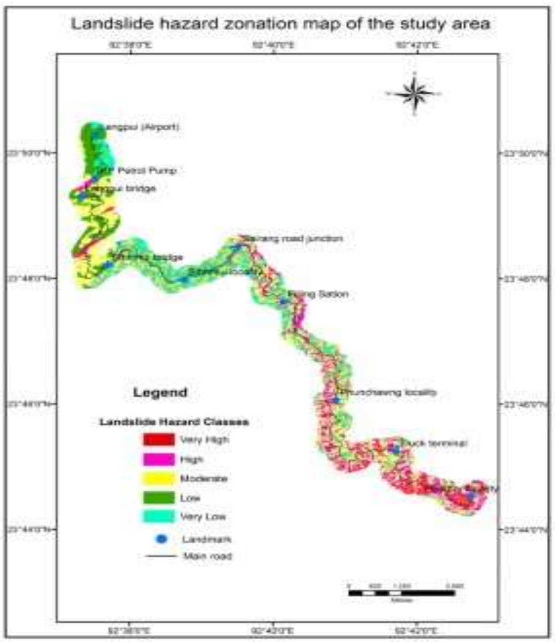

Figure 6: Landslide hazard zonation map of the study area

REMEDIAL MEASURES

There are three massive and severe active landslide along the national highway connecting Lengpui airport and Aizawl city. Remedial measures were suggested as follows:

Landslide location code:L-1

For landslide at Hunthar locality (L-1)Control of surface water using catch water or interceptor drains on the landslide area of chainage is suggested as loose soil may continue to slide during rainy season.

The collection of run-off at the uphill of unstable area may be done using catch water or interceptor drains, in order to intercept and divert the water from the hill slope, catch water drains shall be located, after the topography of the ground is studied in detail. Catch water drains shall be lined and properly maintained to avoid high water velocity and possible wash out. A number of inter-connecting lined catch water drains may need to be reconstructed on the slope to collect the surface run-off depending upon the area of slide. Water from the catch water drains shall be diverted a natural hill-side drain or diverted by sloping drains and lead into culverts at a lower level finally to be lead through chutes into the nearest natural watercourse.

Landslide location code:L-2

For landslide near vaivakawn locality (L-2) two methods may be considered viz., Forestation or Preserving vegetation and Rock fall protection. Removal of vegetation from a landslide-prone slope initiates a landslide. Trees, grasses, and vegetation can minimize the amount of water infiltrating into the soil, slow the erosion caused by surface-water flow, and remove water from the soil. Although vegetation alone cannot prevent or stop a landslide. Vegetation is an important slope stabilizer. Planting the slope with thick native vegetation serves to strengthen the shallow soils with root systems, prevents erosion, and deters infiltration and increasing seepage pressures.

Since, the area comprises highly weathered fractured rock rock fall protection using geogrid netting is suggested at this site as rock fall cause danger to the life of the pedestrian and passenger of the vehicle.

Landslide location code:L-3

Benching of slopes may be provided at the massive landslide of Rangvamual locality (L-3). Benching involves straight slopes separated by near horizontal bench. Benching increases stability of slopes by dividing the long slope into segments or smaller slopes connected by benches, the proper width of bench shall be estimated by analysis of stability of slopes for a given soil. In Benching of slopes, construction becomes easier since steeper slopes are feasible with benches. The benches shall be constructed with a V-shaped or gutter section with a longitudinal drainage grade and with suitable catch basins to carry the water down the slopes. The ditch shall be lined or paved to reduce erosion or to prevent percolation of water into pervious areas on the benches.

It is also recommended that the landslide awareness program should be arranged for the local people. Therefore, people should be aware of the do's and don'ts. They should not use the slopes as dump yard for the garbage. It should be ensured that the adjoining slopes of landslide should not be used for any activities such as agriculture. The people may be educated to aware the possible consequences of having cultivation on adjoining the roads.

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