THOMSON REUTERS ENDNOTE

[Laldintluanga*, 5(2): February, 2016] ISSN: 2277-9655

(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

LANDSLIDE HAZARD ZONATION ALONG STATE HIGHWAY BETWEEN AIZAWL CITY AND AIBAWK TOWN, MIZORAM, INDIA USING GEOSPATIAL TECHNIQUES

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ABSTRACT

Road transport network is one of the most common victim of landslide disaster which inturn affects the population. Landslide is one of the most common geo-environmental hazards in Mizoram due to its fragile geologic conditions and unplanned developmental activities. The present study investigates the Landslide Hazard Zones along State highway between Aizawl city and Aibawk town of Mizoram. This highway is the most important road connecting northern and southern parts of the state. 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, relative relief 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. The ground information on landslide occurences were also considered while classifying 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 state highway to ensure smooth flow of transportation between the state capital and other important district headquarters of the southern part of Mizoram. Landslide inventory was also conducted and remedial measures were suggested at several landslide locations.

KEYWORDS: GIS, Landslide Hazard Zonation, Remote Sensing, Aizawl city, Aibawk town.

INTRODUCTION

Landslide is a major natural geologic hazards causing loss of lives, damage to houses, roads and other infrastructures (Dai et al., 2002; Sarkar and Kanungo, 2004; Gurugnanam et al., 2012; Sujatha et al., 2012). Rapid increase of man-made stuctures, fast expansion of road networks and growth of 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). Geologically, 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, settlement areas along with roads in Mizoram are highly vulnerable to landslide disaster.

Several attempts were made to study landslide within the state of Mizoram. These include Geoenvironmental appraisal of Aizawl town and its surroundings (Jaggi, 1988), study of Vaivakawn landslide in Aizawl city with geotechnical laboratory testing of the slide materials (Choubey, 1992), critical study of the causes of South Hlimen landslide in 1992 which claimed the lives of almost 100 people (Tiwari and Kumar, 1997) and Geo-data based Total Estimated Landslide Hazard Zonation in the southern part of the state (Lalnuntluanga 1999). A comprehensive report on Landslide Hazard Zonation of southern part of Mizoram which includes Lunglei, Lawngtlai and Saiha districts (Raju et al., 1999), and Landslide Hazard Zonation Mapping of Serchhip town (Ghosh and Singh, 2001) were also carried out.

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). Landslide Hazard Zonation of Aizawl city, the state capital of Mizoram using satellite data like IRS LISS III and PAN data had also been done successfully (Lallianthanga and Laltanpuia, 2007).

Remote Sensing and GIS techniques have been proved to be of immense value in landslide hazard zonation, and this had been validated in the study conducted for Aizawl city (MIRSAC, 2007). Similar 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 Aibawk town which frequently suffered many landslide incidents. The study also suggest the methods for mitigation of landslide along this vibrant highway.

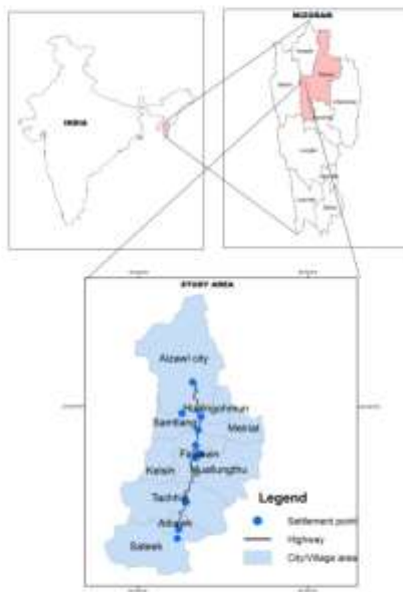


Figure 1: Location map of the study area

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

For the preparation of landslide hazard map, a detailed knowledge of the processes which influence the landslide activities in an area is required (Dutta and Sarma, 2013). There are several geo-environmental factors which are known to induce landslide (Bijukchhen *et al.*, 2009). Selection and preparation of these factors as thematic data layers are highly crucial for landslide hazard 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-

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

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.

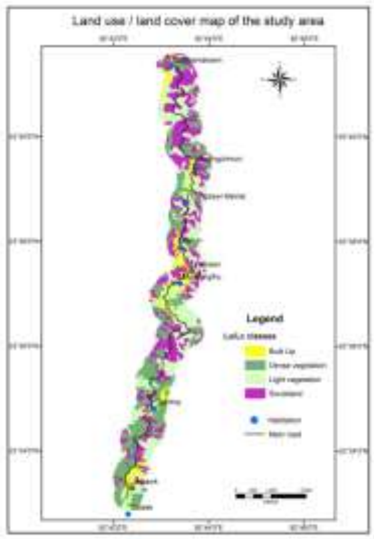


Figure 2: LU/LC map of the study area

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 six slope classes, viz., 0-10, 10-20, 20-30, 30-40, 40-50, and above 50 degrees. Weightage values are assigned in accordance with the steepness of the slope. Slope map is shown in Figure 3.

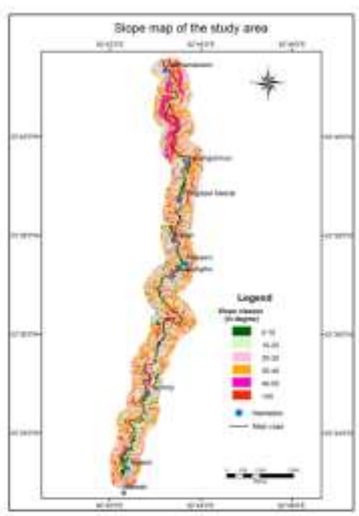


Figure 3: Slope map of the study area

Relative relief

Relative relief plays a 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 into High and Moderate classes with elevation ranging from more than 1000m and 500-1000m from msl respectively. 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 relative relief classes. The relative relief map of the study area is shown in Fig. 4.

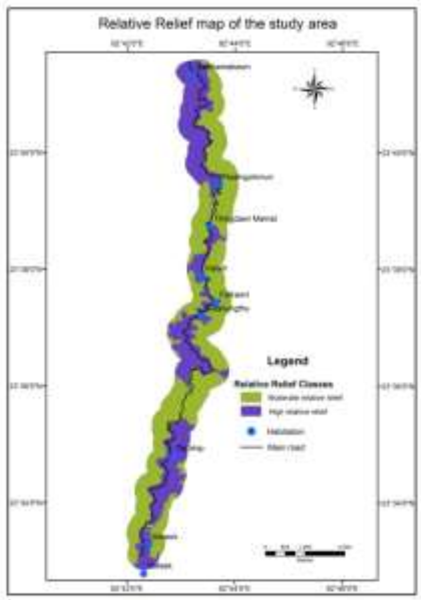


Figure 4: Relative relief map of the study area

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 lies over Middle Bhuban, Upper Bhuban and Bokabil formations of Surma Group of Tertiary age (GSI, 2011). Middle Bhuban and Bokabil formations 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 Structure

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.

[Laldintluanga*, 5(2): February, 2016] ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

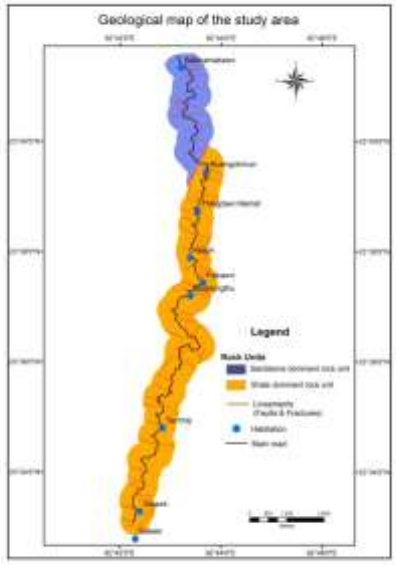


Figure 5: Geological map of the study area

DATA ANALYSIS

The main road connecting Aizawl city and Aibawk was buffered 500m 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, relative relief, 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 Table 5.

Parameter	Rank (%)	Category	Weight
Lithology	25	Sandstone unit	5
		Shale unit	8
Land Use / Land Cover	15	Dense Vegetation	3
		Sparse Vegetation	5
		Scrubland	6
		Built-up	8
		Barren land	5
Slope in degrees	35	0 – 10	2
		10-20	4

		20-30	5
		30-40	6
		40-50	7
		>50	8
Structure: Faults and Fractures	15	Distance Buffered	8
Relative relief	10	High	5
		Medium	4
		Low	3

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, [about 45 degrees or more] 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.

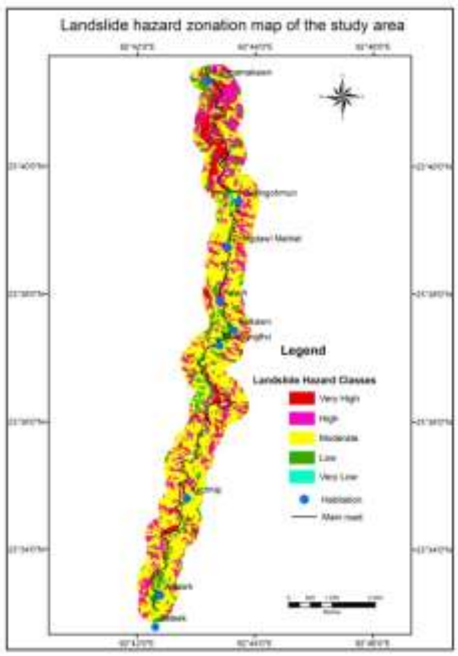
Moderate Hazard Zone

This zone comprises the areas that have moderately dense vegetation, moderate slope angle and relatively compact and hard rocks. It 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 may be noted that as seismic activity and continuous heavy rainfall can reduce the slope stability. 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.



REMEDIAL MEASURES

Landslide inventory survey was conducted along the state highway between Aizawl city and Aibawk town. The active landslide locations were marked identified using GPS and photographs were also taken which were correlated using alpha-numeric code. Remdial measures were also suggested as follows:

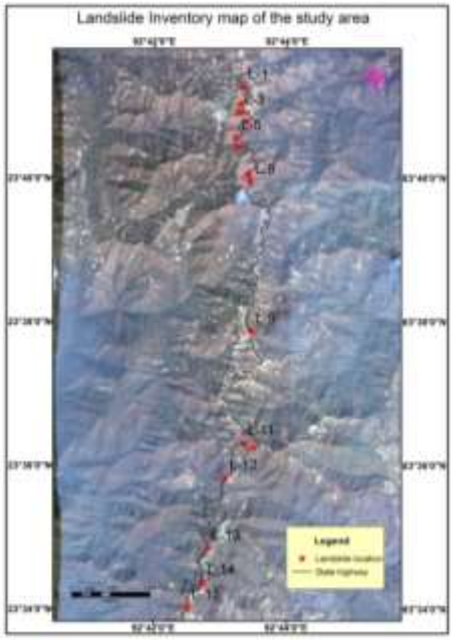


Figure 7: Landslideinventory map of the study area

Landslide location code: L-2

Landslide location code: L-3

For landslide location code L-1, L-2 and L-3, excessive use of heavy machinery and excessive blasting should be avoided in these stone quarries. Extraction of building stones should be done with exreme care and in systematic ways.

Landslide location code: L-4

Landslide location code: L-11

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

For landslide location code L-4, L-9 and L-11; 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.

Landslide location code:L-12

Landslide location code:L-15

Control of surface water using catch water or interceptor drains L-12 and L-15 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 and shall be given a gradient of 1 in 50 to 1 in 33 to avoid high water velocity and possible wash out.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Landslide location code: L-6

Landslide location code: L-11

Highly weathered fractured rock was found at L-6, L-10. 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. Rock falls can be contained by providing gabion wall to withstand the pressure at least a height of 4m. Gabion walls acts as retaining walls. Geo grid netting up to top and well anchored on all the sides of the rock fall zone may also be utilized.

Landslide location code: L-5

Benching of slopes may be provided at L-5, L-7 and L-8. 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. The width of bench shall not be less than 4 m to enable the slope segments to act independently. 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.

In High and Moderate hazard zones, forestation scheme should be implemented. It is also 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.

CONCLUSION

The present study has proven that terrain factors like land use/ land cover, lithology, slope, geological structure and relative relief are directly associated with the occurrence of landslides. The study further indicates that landslide occurrences are mostly confined at the newly constructed or widened roads. This shows that proper planning with landslide mitigation measures is required for expansion of settlement and construction of road communications.

Different methods of remedial measures should be utilized depedening upon the types of landslides for implementing suitable mitigation measures.

ACKOWLEDGEMENTS

The authors are thankful to their colleagues of Mizoram University and PHE Department of Mizoram for their co-operation and support during the course of study.

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